# THE CURRENT STATE OF RUSSIAN SPACE SURVEILLANCE SYSTEM AND ITS CAPABILITY IN SURVEYING SPACE DEBRIS

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ABSTRACT

A review is made on the stages of creation and the current state of Russian Space Surveillance System (RSSS), its information sources and information processing technology. The percentage of space debris in the trackable space objects (SO) catalogue is determined. Classification of RSSS-tracked SO is made and analysed. The RSSS capability for enlarging the trackable SO set in the area of small and weakly-contrasting SO is estimated.

## 1. INTRODUCTION

The idea of creating the SSS in the USSR arose in 1961 and first real space surveillance was put into practice in 1962 by the information from optical facilities of the Academy of Sciences and of the Department of Defence.

In 1969 the Space Surveillance Center (SSC) was created for performing these functions. In 1970 the SSC was keeping close track of 200-250 SO (10-15% of the total amount of SO in orbit) by information of optical stations and of the first specimens of radar sensors of the Ballistic Missile Early Warning System (BMEWS) and the Anti-Ballistic Missile Defence (ABMD). By 1975 the number of trackable SO had already exceeded 1000, for 80% of them the SO position determination temporal error along the track having been less than 2 s.

During the subsequent years building up the sensors net continued (first of all of the radar ones) and the data processing methods had been improved.

## 2. RSSS'S CAPABILITIES

So at the present time the primary data acquisition system of the RSSS includes the net of radars (Table 1) and the net of optical sensors (Table 2). And also some other sensors may be enlisted occasionally.

| Location | Operating system | Coordinates of site | Azimuth coverage | Observing band |
|---|---|---|---|---|
| Irkutsk Russia | BMEWS | 103 E<br>53 N | 30-300 | VHF |
| Balkhash Kazakhstan | BMEWS | 74 E<br>45 N | 30-330 | VHF |
| Murmansk Russia | BMEW | 40 E<br>68 N | 295-355 | VHF |
| Riga Latvia | BMEWS | 22 E<br>57 N | 220-310 | VHF |
| Sevastopol Ukrain | BMEWS | 33 E<br>44 N | 140-260 | VHF |
| Uzhgorod Ukrain | BMEWS | 23 E<br>48 N | 165-285 | VHF |
| Petchora Russia | BMEWS | 57 E<br>65 N | 300-0-55 | VHF |
| Mingechaur Azerbijan | BMEWS | 48 E<br>41 N | 105-215 | VHF |
| Moscow Russia | ABMD | 37 E<br>55 N | 255-305<br>65-120 | UHF |

Table 1. RSSS radar sensors

Unlike the SSN of the USA all the sensors of the RSSS are located only at the former USSR territory. Hence, relatively great interruptions in observation and some "invisibility" zones are peculiar to the RSSS. Figs. 1 and 2 represent the simulated SO observability breaks distribution depending on orbit inclination and altitude for the both SSS - Russian and American. One can see the difference in favour of the last one.

To provide the high quality of performing space

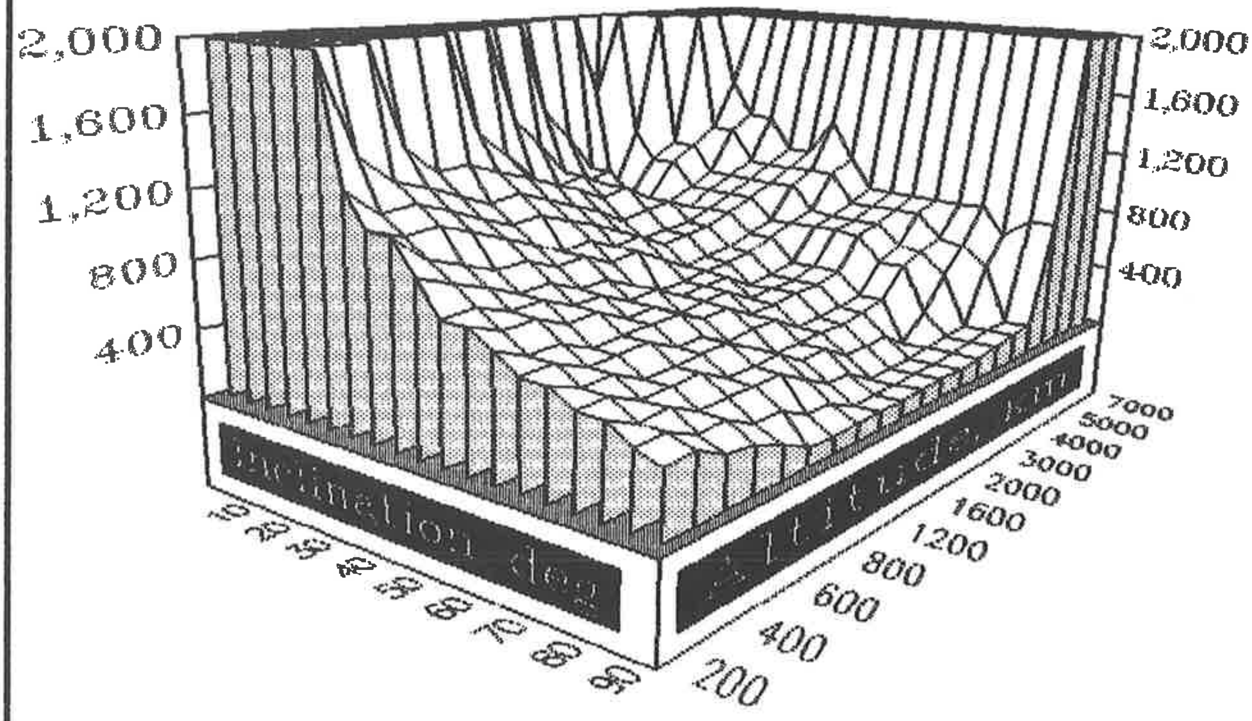



**Fig. 1. Observability breaks, min (Russia)**

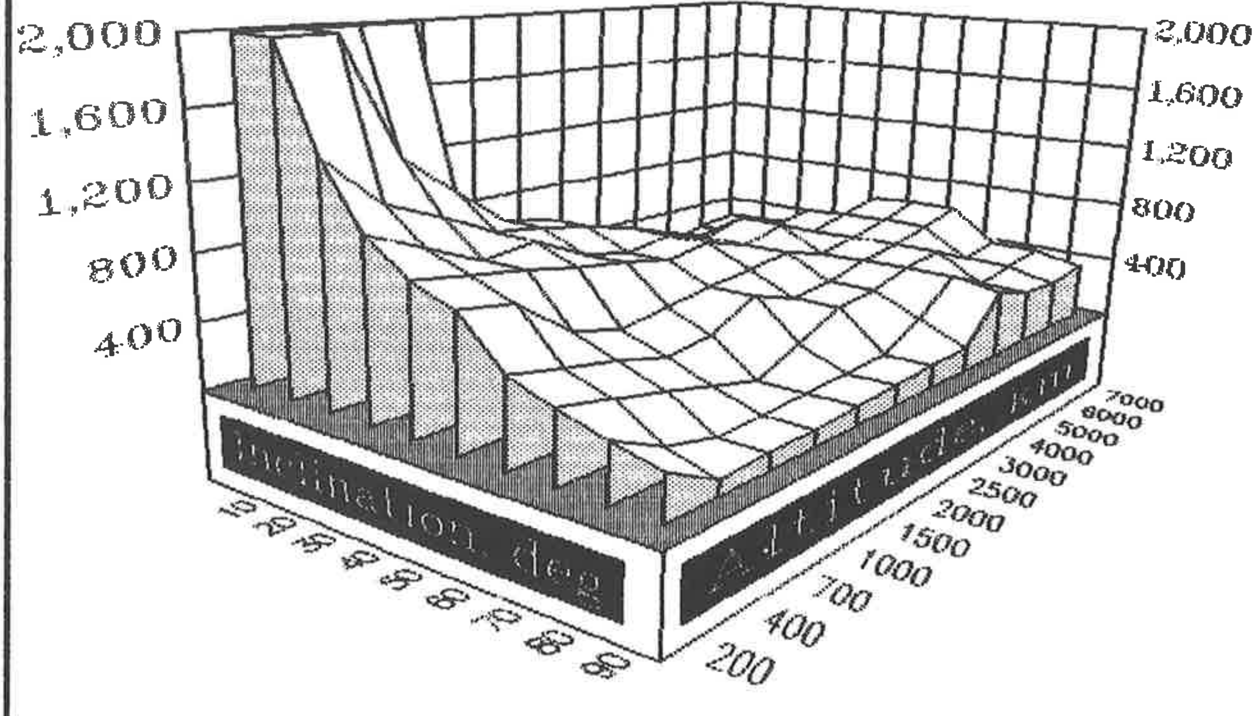



**Fig. 2. Observability breaks, min (US)**

surveillance functions in such circumstances we have been forced to give particular attention to the development of measurement processing theory, methods and technique.

| Location | Coordi-nates of site | Azimuth coverage | Type |
|---|---|---|---|
| Irkutsk (Russia) | 100 E 52 N | 0-360 | Electro-optical |
| Kiev (Ukrain) | 30 E 50 N | 0-360 | Optical |
| Uzhgorod (Ukrain) | 22 E 49 N | 0-360 | Optical |
| Dushanbe (Tadjikistan) | 69 E 39 N | 0-360 | Optical |
| Alma-Ata (Kazakhstan) | 77 E 43 N | 0-360 | Optical |
| Abastumani (Georgia) | 37 E 56 N | 0-360 | Electro-optical |
| Burokan (Armenia) | 44 E 40 N | 0-360 | Electro-optical |
| Zvenigorod (Russia) | 37 E 56 N | 0-360 | Optical |
| Simeiz (Ukrain ) | 34 E 44 N | 0-360 | Electro-optical |
| Uzhno-Sakhalinsk (Russia) | 143 E 47 N | 0-360 | Optical |
| Ashgabad (Turkmenia) | 58 E 38 N | 0-360 | Electro-optical |
| Kourovka (Russia) | 60 E 57 N | 0-360 | Optical |

Table 2. RSSS optical sensors

As a result a good space ballistic school was originated. One can judge about its scientific level by the results of well known emergency works on the reentry stage of flight of the satellites "Cosmos-954"(1978), "Skylab"(1979), "Cosmos- 1402" (1983), on informational provision of docking the transportation spacecraft "Soyuz-T-13" and the orbital station "Salyut-7"(1985) and, finally, monitoring the last stage of flight of the orbital complex "Salyut-7"-"Cosmos-1686"(1991).

The information from all the sensors mentioned is transmitted to the SSC. The measurements are identified there, then they are used for updating the cataloged SO orbital parameters. Measurements not related to any cataloged SO are being collected and then are used for detecting new SO orbits or for recovering the "lost" SO orbits.

On the base of the SO catalog there are performed planning the observations, calculation of the initial data for subsequent SO observations, calculation of SO orbit life-time and the area of its reentry, and preparing and delivery of information to the consumers. The structure of information processing in the SSC is presented in Fig. 3. Some characteristics of the RSSS on March 1993 are shown in Table 3.

| | |
|---|---|
| Total number of cataloged SO | 7500 |
| Number of breakup SO fragments | 2450 |
| Number of payloads | 2000 |
| Daily number of measurements | 40000 |
| Percentage of identified measurements | 99% |
| Number of orbit updates per day | 10000 |
| Daily number of new orbits | 7 - 10 |
| SO position determination mean square error at the time of the last measurement: | |
| along track | 4.5 Km |
| radial component | 1.5 Km |
| binormal component | 0.8 Km |
| SO decay time determination error when the time to decay is less than 1 day | < 4.5% |
| 2 day | < 8% |
| 30 days | < 10% |

Table 3. Characteristics of SSS on March, 1993

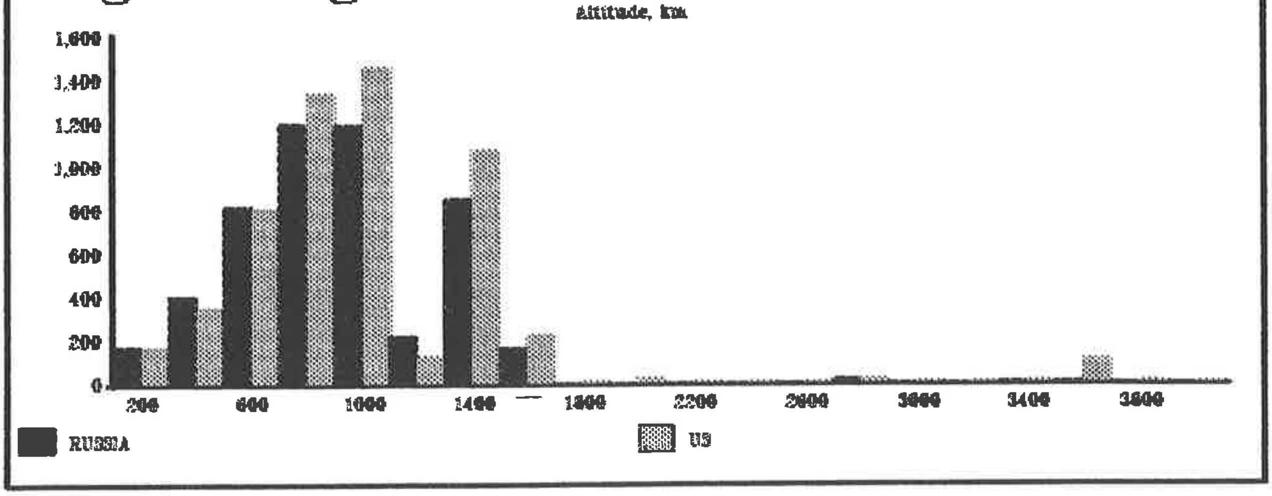
Figs. 4 and 5 display the cataloged SO distribution at the RSSS and the American SSN depending on perigee hight (for altitudes less than 4000 Km) and inclination. It can be seen that for inclinations from 60 to 100 degrees the American catalog contains by 850 objects more than the Russian one, but for inclinations less than 25 - by 160 SO less than the Russian catalog. This divergence is conditioned first of all by different technical characteristics of tracking facilities used, their locations and also by different criteria of putting SO orbit data into the catalog and taking them out of it.

The RSSS catalog comprises about 7500 SO, some 2000 of them being payloads (operating or dead).

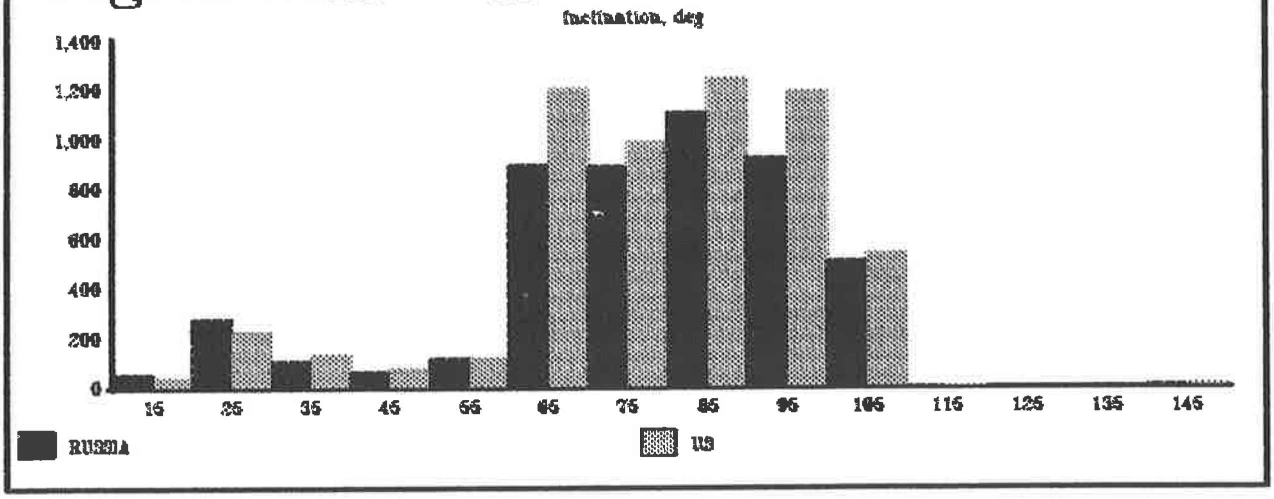
Fig. 6 illustrates the RSSS capability of detecting SO breakup fractions, taking an example by "Cosmos-2227" upper stage breakup on Dec. 26, 1992. There is shown fragments catalogation dynamics after the SO breakup in integral and differential forms.

The RSSS as well as the American one was not designed

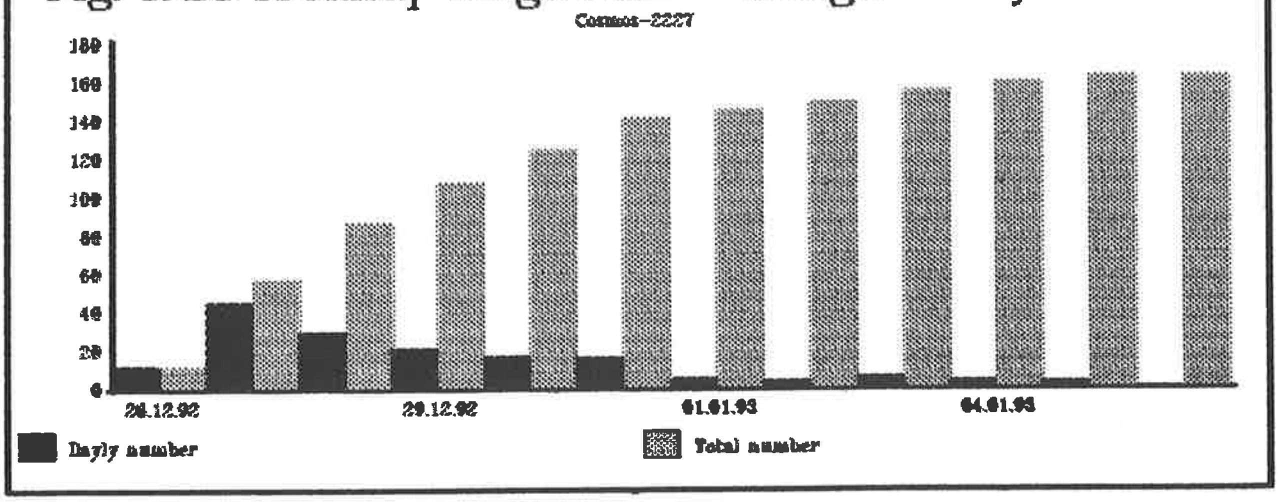
## Fig. 4 Perigee altitude distribution of SO




## Fig. 5. Inclination distribution of SO




## Fig. 6. SO breakup fragments catalogation dynamics



for observing small objects. And that is the sore spot, susceptibilities of the both SSS while concerning their capabilities in surveillance of space debris.

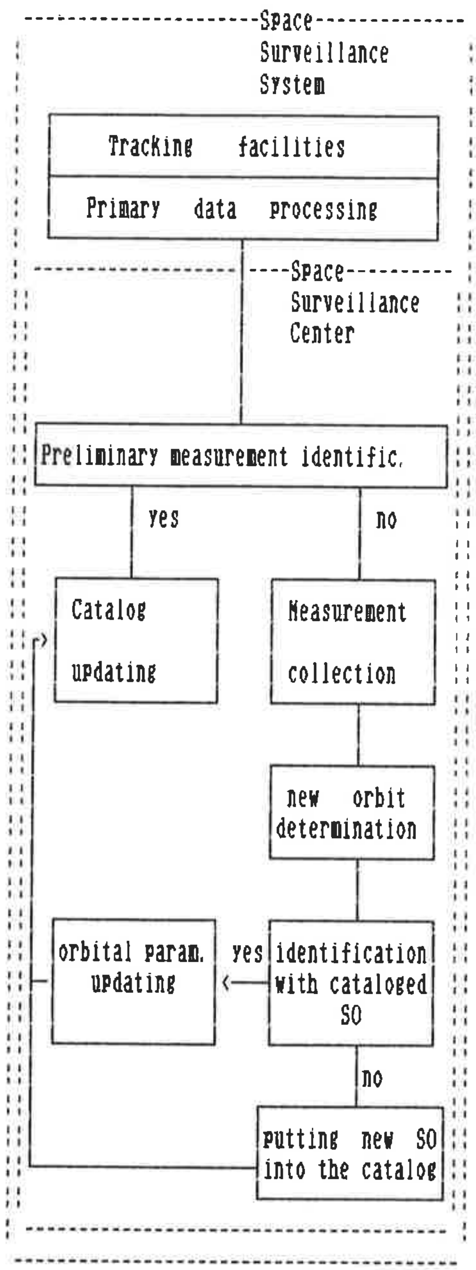



Fig. 3. Automatic data processing in the SSS

With the aim of overcoming this obstacle in the RSSS investigations are being carried out in the following areas:

lowering the radar's operational sensitivity thresholds;

creating the special ground based facilities for detection of small SO;

development of special methods for acquisition of a weak useful signal, using a-priori information on the SO motion, with the help of narrow-angle and narrow-beam sensors.

As to the first direction, 5 experiments with a radar in UHF-band were conducted, duration of each being up to an hour. The following preliminary results were obtained. When lowering the sensitivity threshold by 2.5 dB and taking some measures for mitigation of interferences, the measurement flux increased by 2.7 times and the total number of detected 10 cm particles increased by several times. The experiments will continue.

The second direction is being assimilated by for example Dr.Tolkatchev from SRI of Radiophysics in Moscow.

As to the third direction, a special report is dedicated to it here later.

### 3. OFFERS FOR COOPERATION

Sharing the concern of international scientific community about increasing contamination of space, Russia in the person of the SRC "Kosmos" is ready to cooperate in the following areas:

1. Informational support of space programs and experiments of concerned countries.
2. Coordinated operations in contingencies and notification of the concerned countries about dangerous situations in space and out of space.
3. Control of international agreements related to legal issues of using the near Earth space.
4. Informational provision for research on the upper atmosphere density variations.
5. Ecological monitoring of the near Earth space (space contamination control and analysis of its consequences).
6. Scientific provision of business cooperation mentioned above.