Comparative Analysis of the Russian and United States Space Object Catalogs

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Abstract: The space object catalogs maintained by Russia and the United States have been exchanged for many years. Comparisons of these catalogs have been performed previously. This paper summarizes characteristics of both catalogs on 30 June 2000 for low and geosynchronous altitude regimes. Overall, the catalogs compare favorably, although each catalog contains objects which are not in the other. These exchanges and comparisons have permitted the correction of errors in both catalogs. One issue which deserves further attention is the correlation of base international designators. Numerous examples exist in which the catalogs ascribe different launch origins to the same object. A resolution of these discrepancies would facilitate communications, particularly during collision avoidance assessments.
The main product of the Space Surveillance System (SSS) (either Russian or American) is the catalog of space objects (SOC), which is maintained and refined in real time. From its creation until now, the SOC is the one and only primary and comprehensive source of the current coordinate (metric) and non-coordinate (non-metric) information on the whole set of artificial space objects (SO) in the near Earth space.

It should be stated that the Russian and American catalogs do not simply duplicate each other. Their correlation is limited, and each of them contains some information different from the other. Since June 1992 regular (quarterly) exchanges of the catalogs has been beneficial for both sides – US and Russia. Originally, only the Reduced Set Catalog of Russia and the Satellite Situation Report of the US were exchanged. However, beginning in December, 1993, databases of two-line element (TLE) sets were added to the exchanges.

These data exchanges permit the correction of current and previous mistakes of catalog maintenance. They also allow the resolution of some doubts, which arise periodically, concerning the state and motion of some SOs.

The most valuable properties of SOC are its accuracy and the chronological “freshness” of the SO dynamic characteristics, calculated by the current measurements coming from the space surveillance sensors in real time.
The data contained in SOC comprise the trajectory parameters of SOs in different coordinate systems (Keplerian, Lagrange, Delaunay, TLE), non-metric data on SOs (including their mass/size characteristics and attitude dynamic parameters), their designation, state affiliation, time and place of launch, the expected reentry time and so on.

A special file of the catalog contains the archived data on SOs which are no longer in Earth orbit.

Of the most interest is the information on functional SOs, primarily being tracked by the US and Russian SSSs, which will be mainly considered here. On 30 June 2000 the US and Russian catalogs, respectively, contained information on SOs that could be classified as shown in Table 1.

Table 1. U.S. and Russian Space Object Catalog Contents, 30 June 2000

<table>
<thead>
<tr>
<th></th>
<th>US SOC</th>
<th>RUSSIAN SOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Officially cataloged non-GEO</td>
<td>7468</td>
<td>5719</td>
</tr>
<tr>
<td>Non-GEO “provisional set”</td>
<td>1217</td>
<td>907</td>
</tr>
<tr>
<td>GEO and close orbits(^a)</td>
<td>745</td>
<td>629</td>
</tr>
</tbody>
</table>

\(^a\)orbital periods between 1200 and 1600 minutes and eccentricities < 0.15
The “provisional set” of data represents objects which are tracked regularly or periodically by the respective surveillance systems but have not yet been officially cataloged.

Distributions of SOs by the key parameters built on the basis of data of Russian and US catalogs collected on 30 June 2000 are represented in the diagrams below in Figures 1 to 10. Figures 1-5 summarize selected parameters of the Russian catalog, and Figures 6-10 indicate the state of the US catalog for the same parameters. In some figures, e.g., Figures 5 and 10, the right column has a lighter shade, which means that this element of the histogram accounts for the parameter values to the right of it that do not match the main interval. The whole statistics volume, i.e., the total number of objects in the database for the figure, is given in round brackets at the title of histogram.

From Figure 11 featuring the distribution of the sum time error for the identified SO orbits of both catalogs, it can be seen that the time residual of orbits between the Russian and US catalogs is less than 2 seconds for nearly 90% of the absolutely identified SOs. At the top of this and the two following histograms, the following characteristics are given: minimum and maximum values, math. expectation ($M_x$), median ($X_{0.5}$), and root mean square error, as well as distribution quantiles by levels from 0.1 through 0.9 with the pace 0.1.
Figures 12 and 13 represent the distribution of sum residuals in orbit inclination and ascending node longitude, respectively. Since, as it can be seen from the figures, the estimates are unbiased, the conclusion can be made that the US and Russian SSSs do measure the orbit inclination and ascending node longitude practically without systematic errors. In 50% of all cases the modulus of sum error in each parameter does not exceed 20 arc seconds.

Now, a few words on some negative sides of SOC maintenance. Besides the characteristic of SOC phenomena of "twins" and "cross-tagging", there exist some differences in the identification of some SOs in both catalogs, i.e., some SOs have different base international designators in the two catalogs. Two examples are provided below, each with the Russian TLE first and the US TLE second.

1 728U 70025137 181.63994654 0.00000273 00000-0 11152-3 0 1109
1 00734U 64002B 00182.06058487 .00000296 00000-0 14076-3 0 06967
2 00734 99.1182 349.2743 0014310 251.0625 108.8986 14.27195684894938

1 1394U 74089017 180.43902397 0.00000000 00000-0 00000-0 0 1882
2 1394 101.8354 225.0131 0004367 128.3444 231.7997 12.53024503105938
1 06236U 72082B 00182.19552722 -.00000030 00000-0 10000-3 0 00225
2 06236 101.8425 226.7561 0003796 119.2978 240.8467 12.53022948267339
Each pair of TLEs represents a single SO which is being tracked by the SSS of Russia and the US SSS, but it is identified with different space missions. Since 1996 several identification differences of this type have been resolved. However, many similar discrepancies in the catalogs still exist. Correlating and synchronizing the base international designators of the two SOCs is essential for successful joint activities, in particular when handling close approach situations for the Mir Space Station and the International Space Station.

The exchange of additional SOC data, e.g., average radar cross-section values, would also be beneficial and could help to identify SOs more reliably.

In summary, the Russian and US SOCs compare very well, yet contain some unique data. The regular exchanges of SOCs have led to an improved mutual understanding of the respective space surveillance systems, benefiting both sides. Further correlation of the two catalogs would likewise be mutually beneficial.

References


Figure 1. Distribution of orbit inclination (Russian catalog of 30.06.2000)

Figure 2. Distribution of nodal period (Russian catalog of 30.06.2000)

Figure 3. Distribution of apogee and perigee heights (Russian catalog of 30.06.2000)

Figure 4. Distribution of eccentricity (Russian catalog of 30.06.2000)

Figure 5. Distribution of time intervals between orbit refinings (Russian catalog of 30.06.2000)

Figure 6. Distribution of inclination (US catalog of 30.06.2000)

Figure 7. Distribution of nodal period (US catalog of 30.06.2000)

Figure 8. Distribution of apogee and perigee heights (US catalog of 30.06.2000)

Figure 9. Distribution of eccentricity (US catalog of 30.06.2000)

Figure 10. Distribution of time intervals between orbit refinings (US catalog of 30.06.2000)

Figure 11. Distribution of time residuals between Russian and US catalogs (both of 30.06.2000)

Figure 12. Distribution of inclination residuals between Russian and US catalogs (both of 30.06.2000)

Figure 13. Distribution of ascending node residuals between Russian and US catalogs (both of 30.06.2000)