Analysis and Consequences of the Iridium 33-Cosmos 2251 Collision

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Outline

• The spacecraft
• Circumstances of the collision event
• Physical characterization of the debris clouds
  – Characteristic size, mass, and area-to-mass (A/m)
  – Directionality and ∆v distributions
  – Momentum transfer
• Comparisons with the NASA Standard Breakup Model
• Long-term evolution of the debris clouds
• Conclusions
The Strela-2M series utilized the versatile NPO-PM KAUR-1 standard bus (Kosmicheskiy Apparat Universalnogo Ryada-1, (Космический Аппарат Универсального Ряда), which can be translated as Spacecraft Bus from the Standardized Line (Group)-1). In addition to the LEO communication constellation Strela-2/-2M, the KAUR-1 bus has served as the basis for navigation (Tsiklon/Parus military series and Tsikada civil series and Nadezhda civil COSPAS/SARSAT subseries), geodesy (Sfera and GEO-IK/Musson), and science (Iionosfernaya, Cosmos 381 ionospheric topside sounder) spacecraft.

- **Background:** family album of spacecraft using the KAUR-1 bus; **middle inset:** cross section of a Nadezhda spacecraft*; **top inset:** a Strela-2M spacecraft**

** FROM: http://www.astronautix.com/craft/strela2m.htm
The Iridium first-generation constellation utilized the Lockheed-Martin LM700A bus, shown in exploded view (left) and with Iridium nadir payload module (above).

From: Rudiger et al., Application of Existing Satellites to Space and Earth Science Missions, 1997.
# The Spacecraft III

## Physical & Operational Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Cosmos 2251</th>
<th>Iridium 33</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>bus</strong></td>
<td>KAUR-1</td>
<td>LM700A</td>
</tr>
<tr>
<td><strong>dry mass [kg]</strong></td>
<td>900 (estimated)</td>
<td>556</td>
</tr>
<tr>
<td><strong>Shape</strong></td>
<td>Cylinder with boom</td>
<td>Triangular prism with panels</td>
</tr>
<tr>
<td><strong>Stabilization</strong></td>
<td>Gravity gradient</td>
<td>3 axis</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>2 m x 2 m (body)</td>
<td>3.6 m long</td>
</tr>
<tr>
<td><strong>onboard energy sources</strong></td>
<td>Core cylinder may have been pressurized</td>
<td>Hydrazine tanks for thrusters; NiH₂ battery</td>
</tr>
<tr>
<td><strong>Initial orbit</strong></td>
<td>800x776 km, 74° inclination</td>
<td>779x776 km, 86.4° inclination</td>
</tr>
<tr>
<td><strong>status</strong></td>
<td>derelict</td>
<td>operational</td>
</tr>
</tbody>
</table>
The collision event

Estimated collision parameters:

Event time: 10 February 2009, 16h 55m 59.8s GMT
Location: 72.50° N latitude
         97.86° E longitude
         778.6 km altitude
Relative velocity: 11.647 km/s
Directionality: from the viewpoint of the Iridium 33 spacecraft, Cosmos 2251 approached at an elevation of -2.6° and an azimuth (measured from North) of 231°
Orbital distribution: see Gabbard charts on next 2 pp.
Cosmos 2251 Gabbard diagram

- C2251 apogee series, June 2010
- C2251 perigee series, June 2010
- C2251 apogee srs, June 2009
- C2251 perigee srs, June 2009
Iridium 33 Gabbard diagram

- Iri33 apogee srs, June 2010
- Iri33 perigee srs, June 2010
- Iri33 apogee srs, June 2009
- Iri33 perigee srs, June 2009
Size Distributions of Iridium 33, Cosmos 2251, and FY-1C Fragments

Diameter (m)

Cumulative Number

FY-1C
Iridium 33
Cosmos 2251
Masses estimated using median A/m and characteristic lengths; power law slope is -1.2, considerably steeper than standard breakup model.

“step” indicative of objects with no size (RCS) data.
A/M Distribution of Iridium 33 Fragments (1/2)

A/M Distribution of Iridium 33 Fragments

- Blue line: NASA Breakup Model Prediction
- Red line: TLE Data (17 May 2010)
A/M Distribution of Iridium 33 Fragments

NASA Breakup Model Prediction

TLE Data, A/M/3 (17 May 2010)
A/M Distribution of Cosmos 2251 Fragments

![Graph showing the A/M distribution of Cosmos 2251 Fragments. The graph includes two lines: one for the NASA Breakup Model Prediction and another for the TLE Data (17 May 2010). The x-axis represents Log$_{10}$(A/M m$^2$/kg), and the y-axis represents the Number (Normalized).]
Comparison of the Two Fragment Clouds
• SSN Catalog data analysis
  - $\Delta v$ and directionality distributions have been estimated for both clouds, but are currently under review
  - Little or no momentum transfer observed in cataloged clouds

• Haystack/HAX data analysis
  - Both clouds were observed by the Haystack and Haystack Auxiliary (HAX) radars shortly after the event
  - Analysis ongoing
Long-term evolution of the debris clouds

Percent of Cosmos 2251/Iridium 33 Collision Fragments
Still in Earth Orbit as a Function of Calendar Year

Year
2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075 2080 2085 2090 2095 2100 2105 2110

Percent of Objects Still in Orbit
0 10 20 30 40 50 60 70 80 90 100

- % of Cosmos 2251 fragments
- % of Iridium 33 fragments
Conclusions

• A very large, very energetic event:
  – C2251: 1267 fragments cataloged; 1212 on orbit as of 10 June 2010 SSN catalog
  – Iri33: 521 fragments cataloged, of which 498 are on orbit
  – History indicates that cataloging may continue for some time
  – Impact velocity highest of known intentional & accidental collisions

• These debris clouds will influence the LEO environment for decades to come

• Significant work remains to be done to understand origin of A/m distribution (Iri33), mass and size distributions in context of the NASA standard breakup model