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 Spacecraft I
Cosmos 2251

- 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 (*Ionosfernaya*, 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>bus</td>
<td>KAUR-1</td>
<td>LM700A</td>
</tr>
<tr>
<td>dry mass [kg]</td>
<td>900 (estimated)</td>
<td>556</td>
</tr>
<tr>
<td>Shape</td>
<td>Cylinder with boom</td>
<td>Triangular prism with panels</td>
</tr>
<tr>
<td>Stabilization</td>
<td>Gravity gradient</td>
<td>3 axis</td>
</tr>
<tr>
<td>Size</td>
<td>2 m x 2 m (body)</td>
<td>3.6 m long</td>
</tr>
<tr>
<td>onboard energy</td>
<td>Core cylinder may have been</td>
<td>Hydrazine tanks for</td>
</tr>
<tr>
<td>sources</td>
<td>pressurized</td>
<td>thrusters; NiH$_2$ battery</td>
</tr>
<tr>
<td>Initial orbit</td>
<td>800x776 km, 74° inclination</td>
<td>779x776 km, 86.4° inclination</td>
</tr>
<tr>
<td>status</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
Masses estimated using median A/m and characteristic lengths; power law slope is -1.2, considerably steeper than standard breakup model.
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

Number

Log$_{10}$(A/M m$^2$/kg)

-3 -2.5 -2 -1.5 -1 -0.5 0 0.5 1 1.5 2

0 10 20 30 40 50 60 70 80 90 100 110 120

NASA Breakup Model Prediction

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

A/M Distribution of Cosmos 2251 Fragments

-3 -2.5 -2 -1.5 -1 -0.5 0 0.5 1 1.5 2

Number (Normalized)

Log$_{10}$(A/M m$^2$/kg)

NASA Breakup Model Prediction
TLE Data (17 May 2010)
Comparison of the Two Fragment Clouds

Iridium 33 Fragments

Cosmos 2251 Fragments
• **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

- % 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**