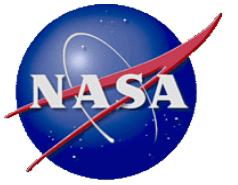
National Aeronautics and Space Administration



Analysis and Consequences of the Iridium 33-Cosmos 2251 Collision

Phillip Anz-Meador[1] and J.-C. Liou[2]

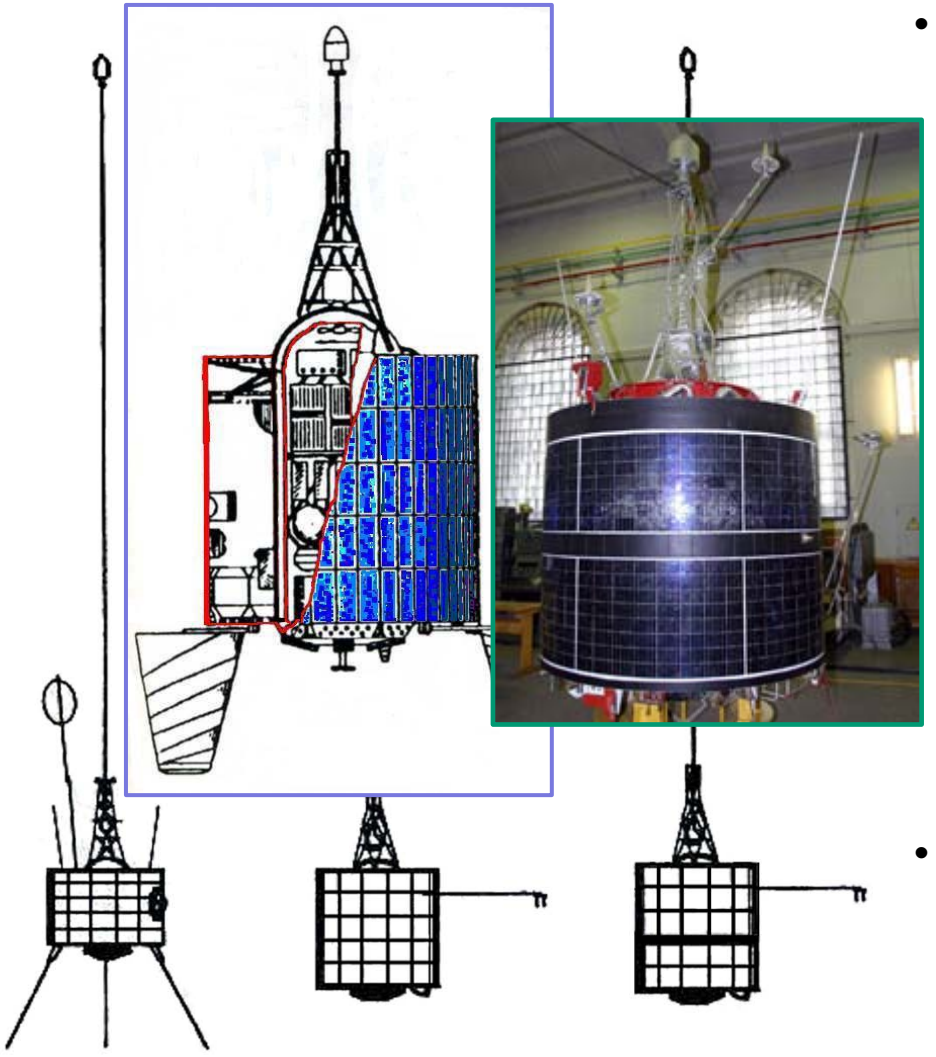
[1] ESCG Jacobs, Houston, Texas, USA

[2] NASA Johnson Space Center, Houston, Texas, USA

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 Δv distributions
  - Momentum transfer
- **Comparisons with the NASA Standard Breakup Model**
- **Long-term evolution of the debris clouds**
- **Conclusions**

The Spacecraft I
Cosmos 2251

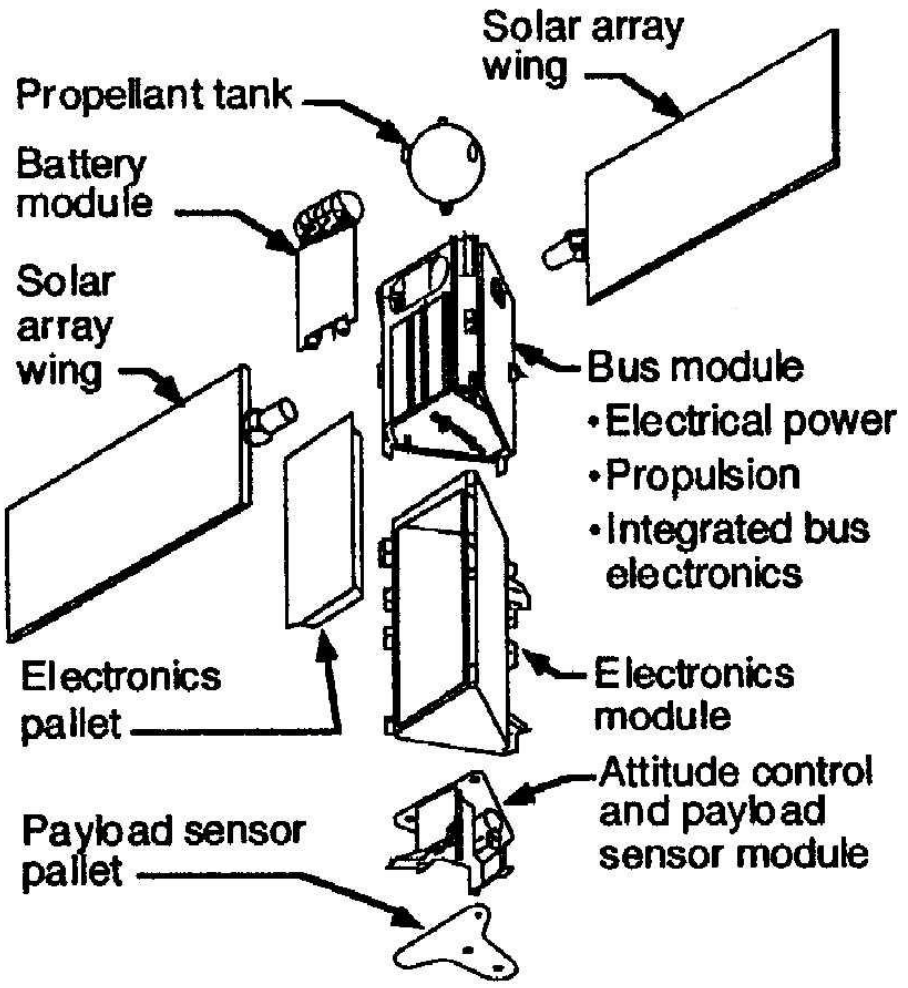


- **The *Strela-2M* series utilized the versatile NPO-PM KAUR-1 standard bus (Kosmicheskiy Apparat Unversalnogo Ryada-1, (Космический Аппарат Универсального Ряда), which can be translated as Spacecraft Bus from the Standardized Line (Group)-1). In addition to the LEO communication constellation *Strela-2/-2M*, 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****

*** after Russian Space News, issue 24 (1994), p. 24**

**** FROM: http://www.astronautix.com/craft/strela2m.htm**

The Spacecraft II
Iridium 33



From: Rudiger *et al*., Application of Existing Satellites to Space and Earth Science Missions, 1997.

•The Iridium first-generation constellation utilized the Lockheed-Martin LM700A bus, shown in exploded view (left) and with *Iridium* nadir payload module (above)

The Spacecraft III
physical & operational characteristics

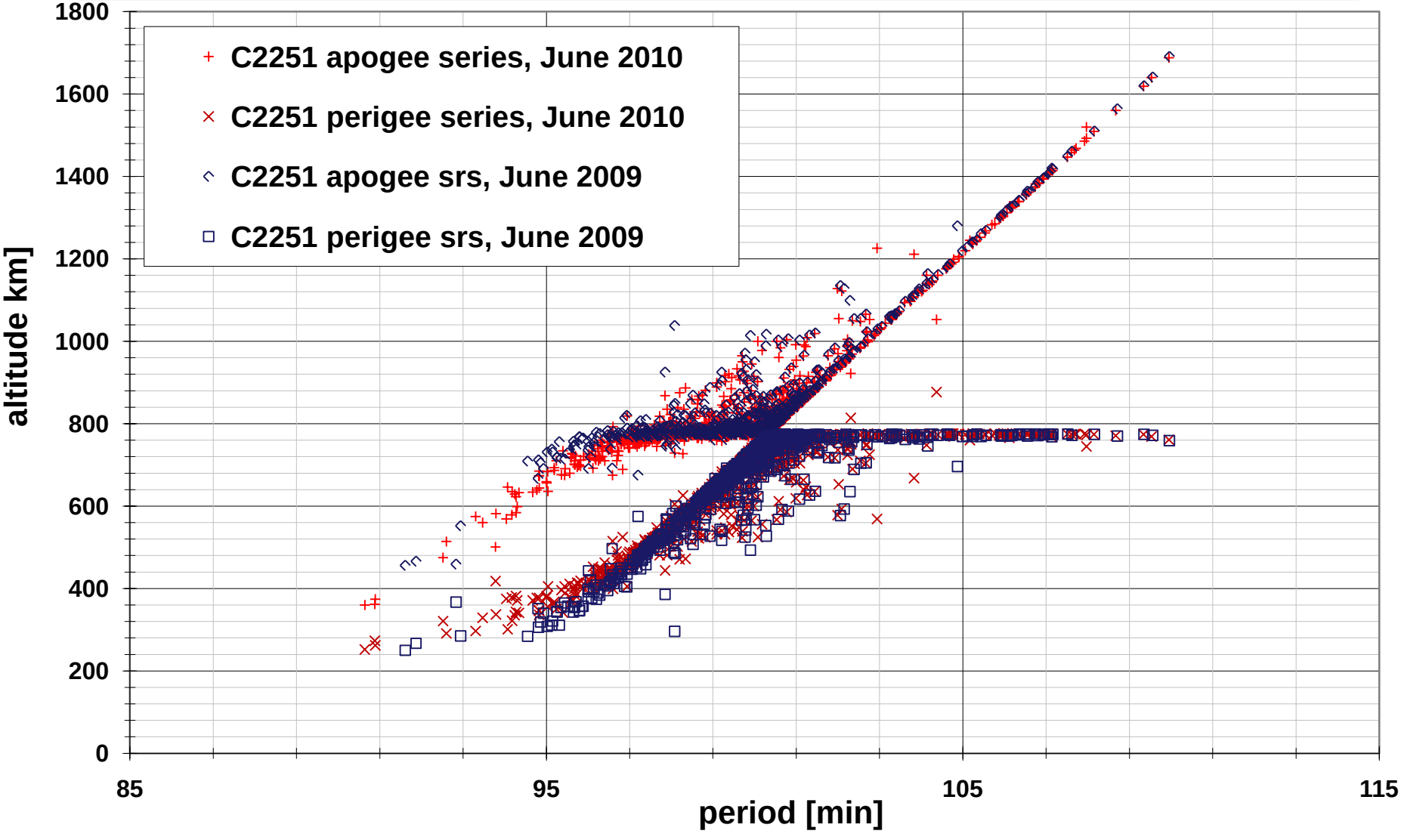
	Cosmos 2251	Iridium 33
bus	KAUR-1	LM700A
dry mass [kg]	900 (estimated)	556
Shape	Cylinder with boom	Triangular prism with panels
Stabilization	Gravity gradient	3 axis
Size	2 m x 2 m (body)	3.6 m long
onboard energy sources	Core cylinder may have been pressurized	Hydrazine tanks for thrusters; NiH_2 battery
Initial orbit	800x776 km, 74° inclination	779x776 km, 86.4° inclination
status	derelict	operational

The collision event

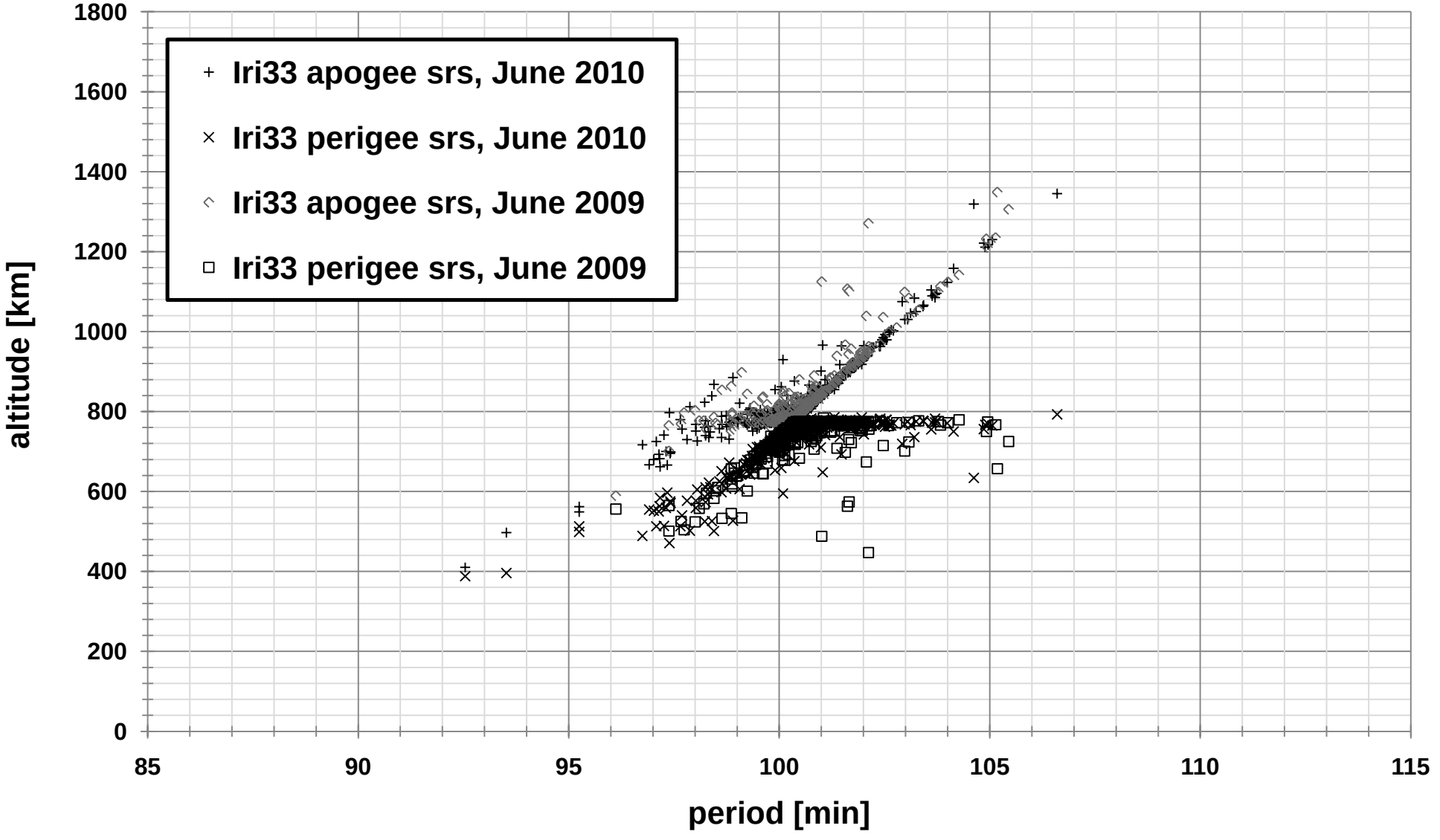
Estimated collision parameters:

Event time: 10 February 2009, 16^h 55^m 59.8^s 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.

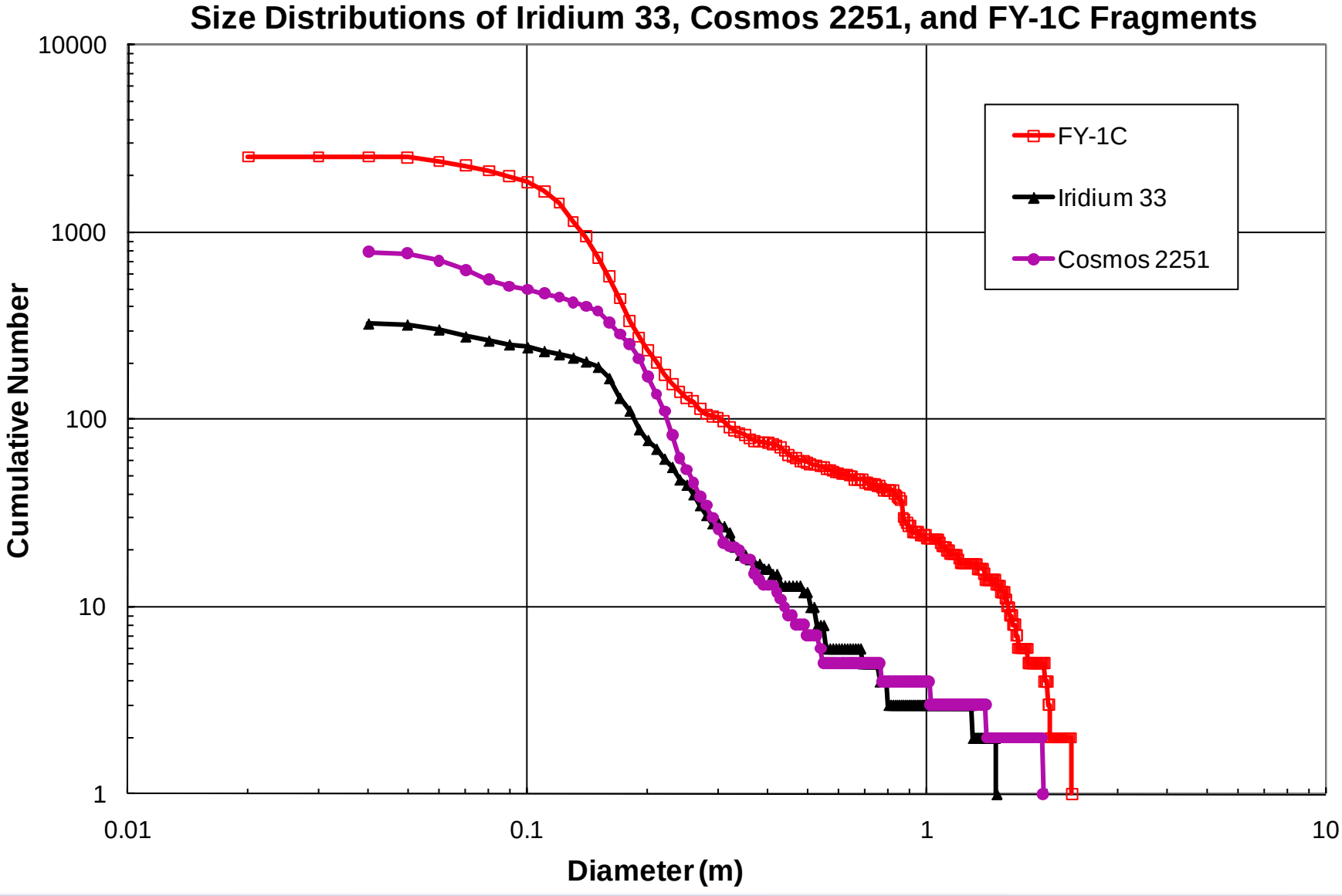
Cosmos 2251 Gabbard diagram



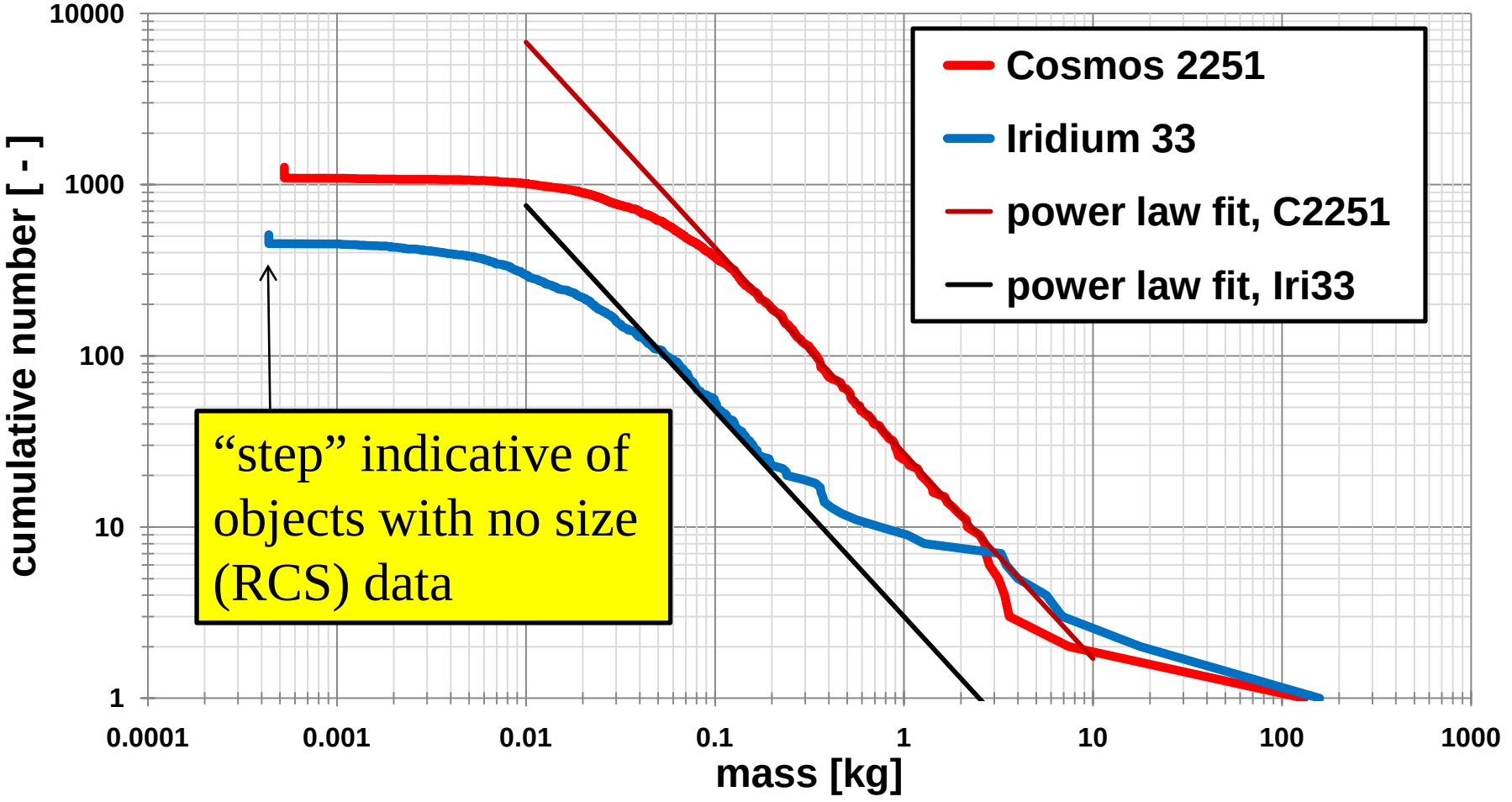
Iridium 33 Gabbard diagram



Physical characterization of the debris clouds I
characteristic size distribution

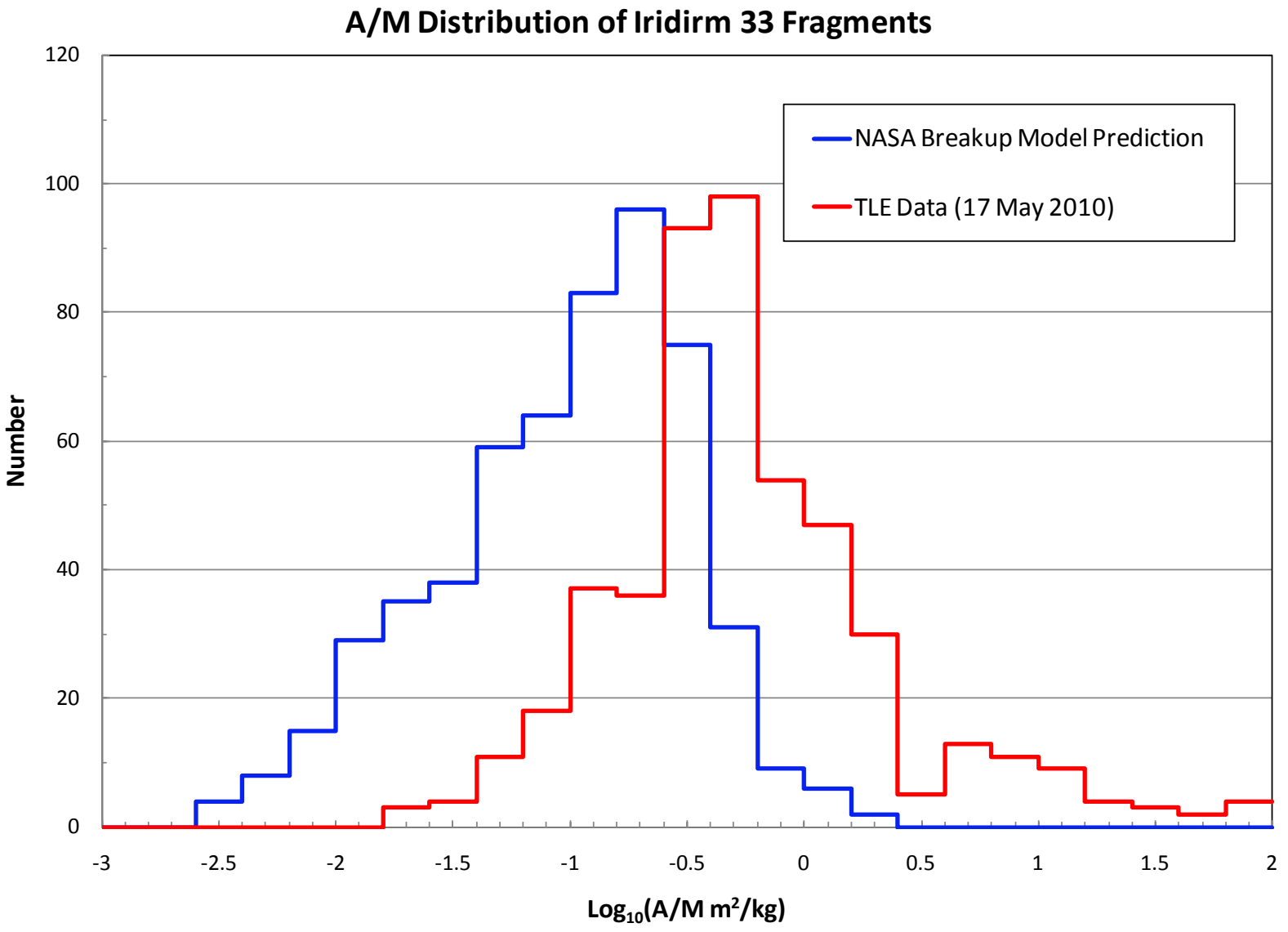


Physical characterization of the debris clouds II
mass distribution

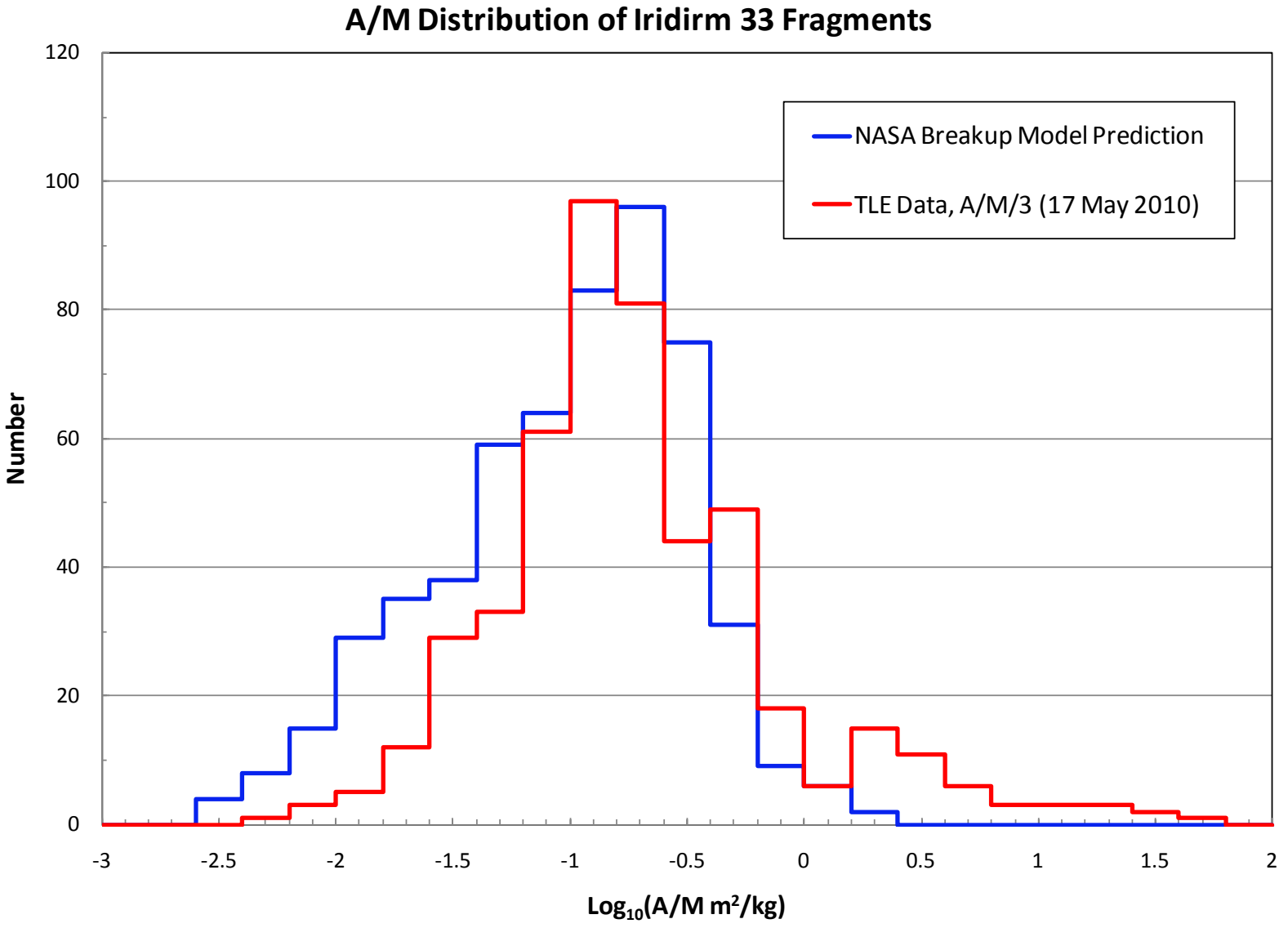


Masses estimated using median A/m and characteristic lengths; power law slope is -1.2, considerably steeper than standard breakup model.

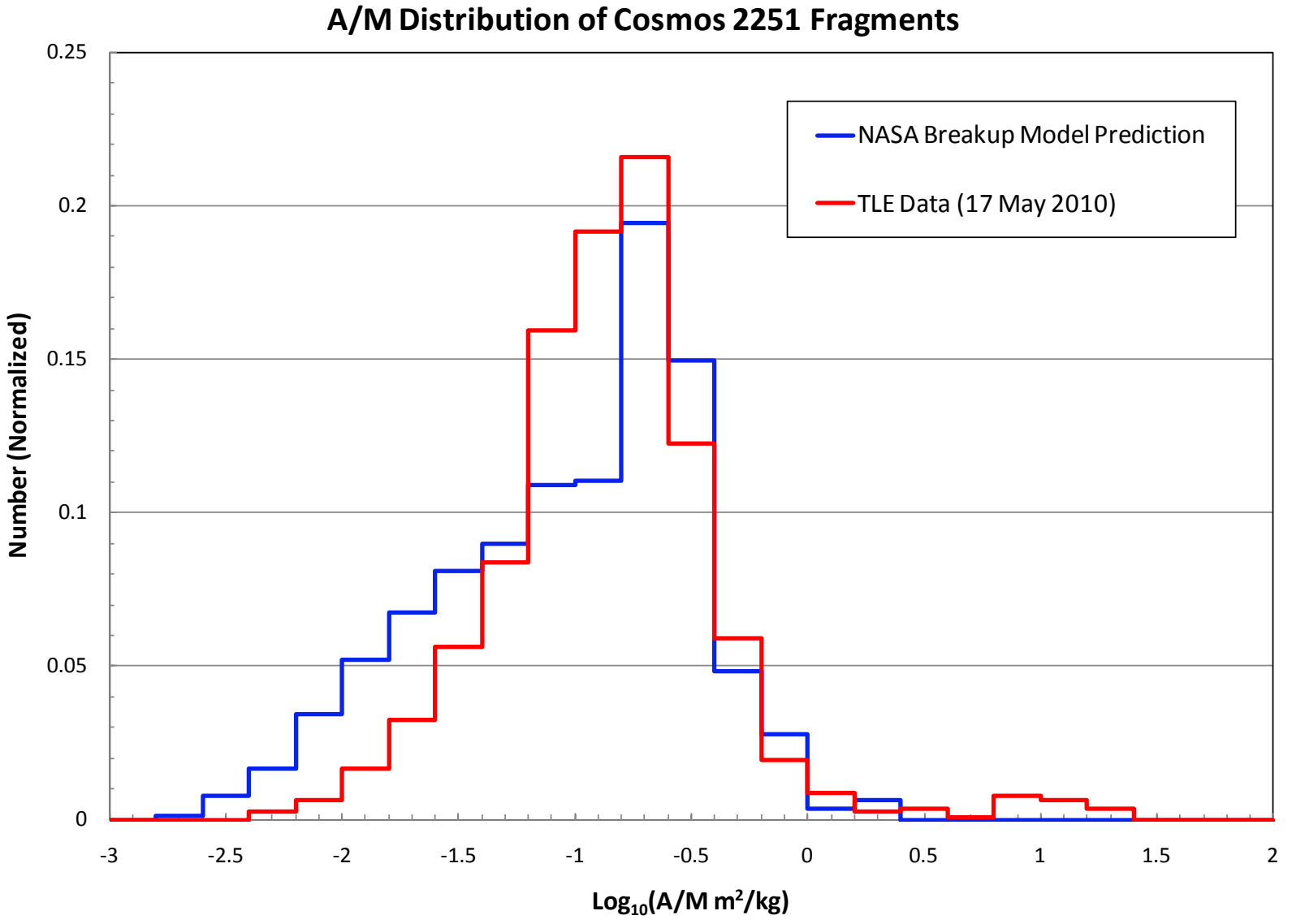
A/M Distribution of Iridium 33 Fragments (1/2)



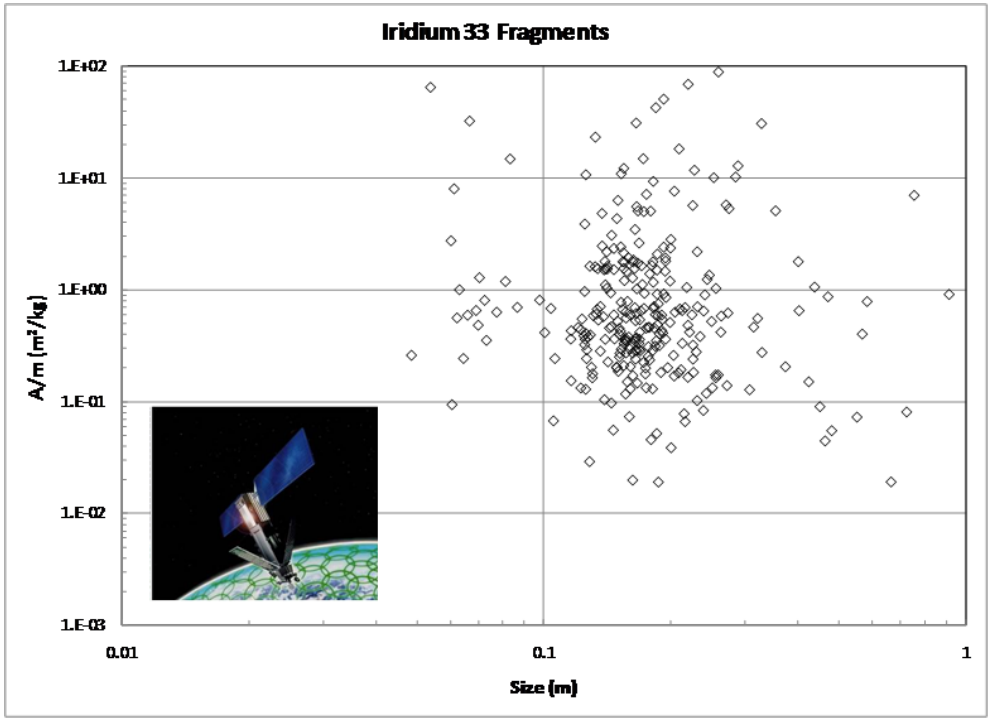
A/M Distribution of Iridium 33 Fragments (2/2)

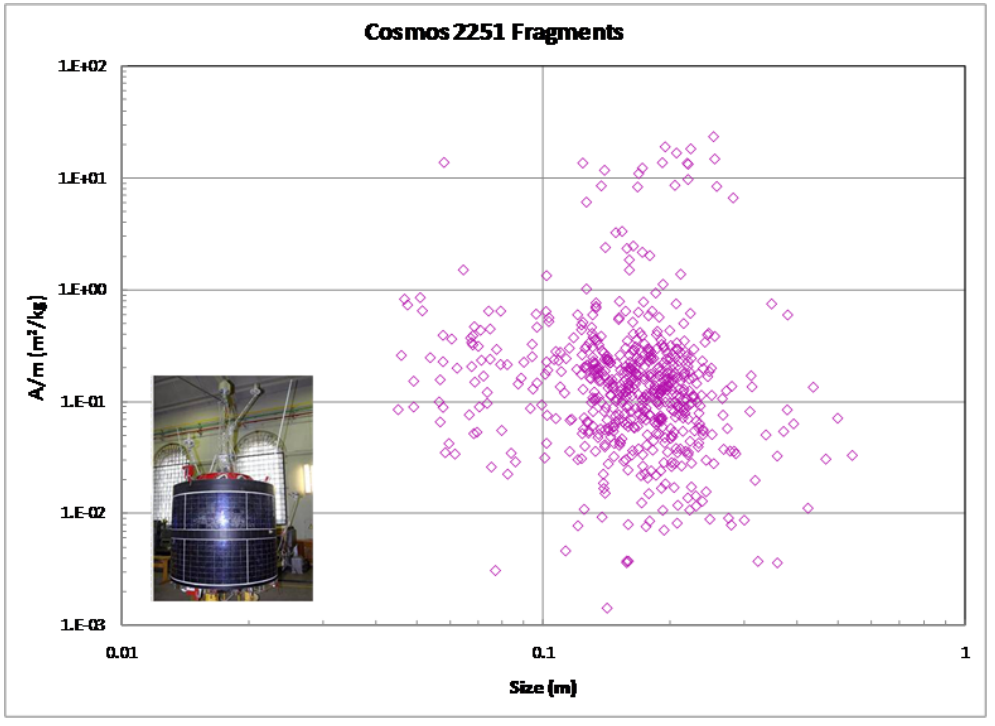


A/M Distribution of Cosmos 2251 Fragments



Comparison of the Two Fragment Clouds

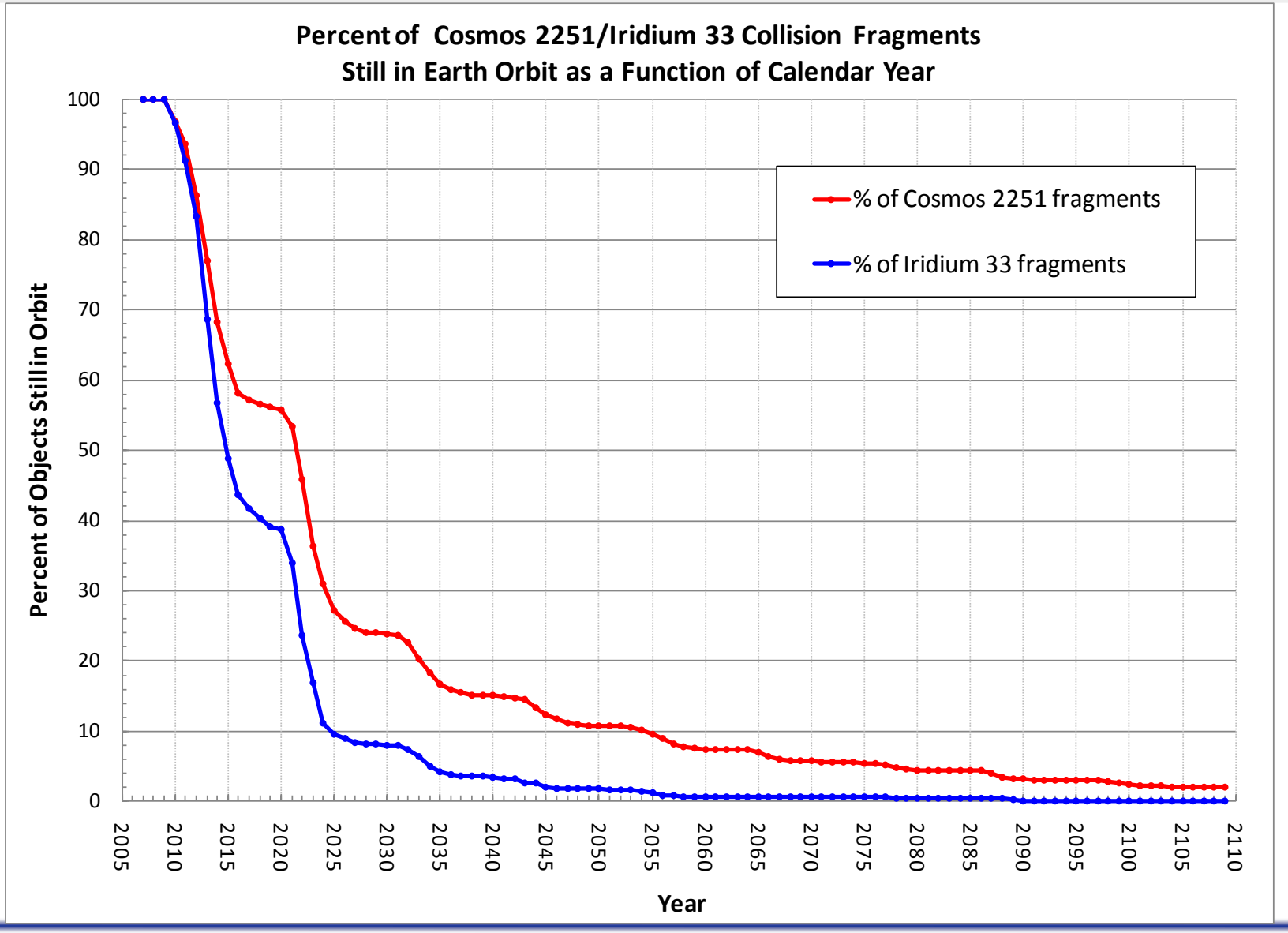




Physical characterization of the debris clouds IV

- **SSN Catalog data analysis**
  - Δv 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



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**