Primer on On-orbit Collision & Debris Generation

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Outline of Presentation

ISSUE 1

WHAT HAPPENS WHEN TWO THINGS GO BOOM IN SPACE?

ISSUE 2

HOW "PROBABLE" IS IT FOR TWO THINGS TO GO BOOM IN SPACE?

ISSUE 3

ARE THE CALCULATED "PROBABILIES" USEFUL?

On-orbit collisions
(Accidental, Hypervelocity/Catastrophic, and Recorded)

Impact date: 23 December 1991 Object 1: Cosmos 1934 Object 2: Cataloged debris 13475 Altitude: 980km **New cataloged debris generated: 2**	Impact date:24 July 1996 Object 1: Cerise (spacecraft) Object 2: Cataloged debris 18208 Altitude: 685km **New cataloged debris generated: 1**	Impact date: 17 January 2005 Object 1: Thor Burner 2A Object 2: Cataloged debris 26207 Altitude: 885km **New cataloged debris generated: 6**	Impact date: 10 February 2009 Object 1: Cosmos 2251 Object 2: Iridium 33 Altitude: 789km **New cataloged debris generated: 2199**
Impact velocity: 14.3km/s Energy-to-mass ratio: 7.66104 J/kg	Impact velocity: 14.8km/s Energy-to-mass ratio: 8.30106 J/kg	Impact velocity: 5.7km/s Energy-to-mass ratio: 6.28105 J/kg	Impact velocity: 11.6km/s Energy-to-mass ratio: 1.59107 J/kg

Inferences

- Debris-Intact collisions are more probable

- All collisions are not created equal
  - We don't know why

- **How objects** collide may be as important as **which objects** collide
  - We are "good" at answering **which objects** will collide. But, we are "not so good" at answering **how objects** collide. How objects collide has a direct bearing on debris produced.

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Assumptions in the Estimate

Empirical Systemic Collision Probability in LEO

- Number of unclassified and classified objects in LEO space

- Orbital density of objects in 10 altitude shells each 200 km wide (up to 2,000 km). Average fluxes in each altitude shell is determined

- Average Collision Rate of three possible combinations in each altitude shell is determined. Total collision rates is obtained by summing up all the shell contributions
  - Debris-Debris, Debris-Intact, and Intact-Intact collisions

- Probability of "*k*" collisions in a given time period (in 2,000 km orbital region)

Probability of *k* collisions in LEO

(Debris-Debris, Debris-Intact, and Intact-Intact collisions)

Number of collisions k	Probability (%) up to 2030 (next 16.5 years)	Probability (%) up to 2040 (next 26.5 years)
0	1.0	0.0
1	4.6	0.2
2	10.5	0.9
3	16.2	2.4
4	18.7	4.9
5	17.3	8.1
6	13.3	11.3
7	8.8	13.4
8	5.1	13.9
9	2.6	12.8
10	1.2	10.6
11	0.5	8.0
12	0.2	5.6
13	0.1	3.6
14	0.0	2.1
15	0.0	1.2
16	0.0	0.6
17	0.0	0.3
18	0.0	0.1

All collision probabilities are calculated beginning mid-2013.

Probability of exactly 4 collision by 2030 = 18.7%

Probability of 1 to 4 collision by 2030 = 50%

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ARE THE <u>“PROBABILIES”</u> USEFUL?

Are the "probabilities" useful?

- The probabilities determined in the previous slides are a "bird's eye" view. They are purely empirical and not based on computationally intensive orbital modeling and simulation

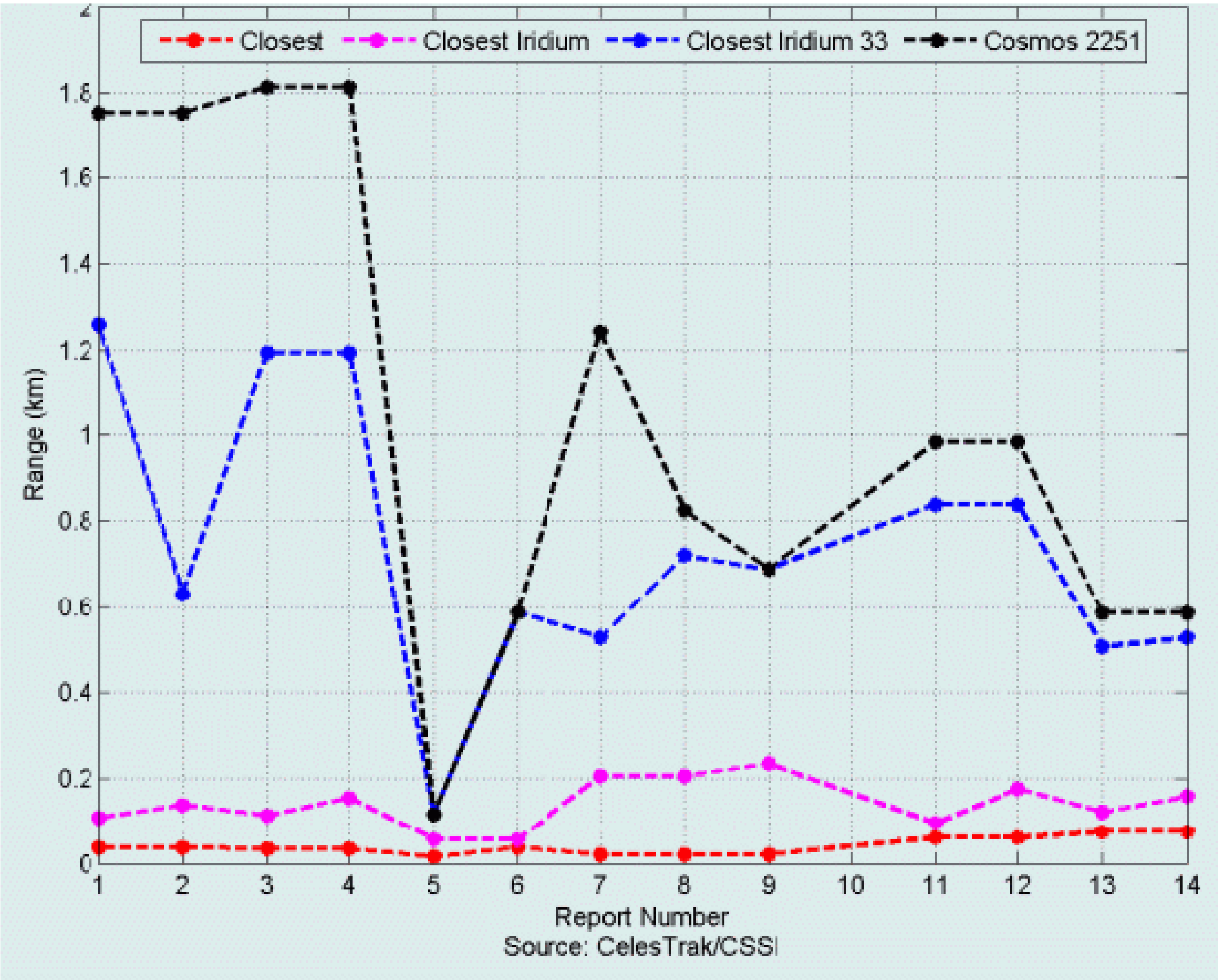
- They provide one probability number to describe the chance that any randomly selected object (debris or intact) that lies within 2,000 km from earth will collide with any other object in the same region of space

- While providing a broad picture of the nature of the existing orbital pollution, the number has limitations

- They are not very helpful for satellite operators worrying about a particular satellite in a specific orbit

10 February 2009: Iridium 33-Cosmos 2251 Collision

Too Many Collision Warnings?



10 February 2009: Iridium 33-Cosmos 2251 Collision

IRIDIUM 33

COSMOS 2251

Inferences

- System level probabilities provide very little guidance for individual satellite operators
- Conjunction Analysis determines collision probabilities of a specific orbital object. More accurate but computationally time consuming
- Conjunction Analysis suffers limitations
  - Improvements have been slow and evolutionary

Thank you.