

# **The Cost of Future Collisions in LEO**

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# Insurance Perspective

## Insurance Against Untracked Debris and Meteoroids in LEO

- Not sold separately at this time

Can these events happen?

- Yes

Can they be detected?

- Yes



BLITS satellite hit  
on January 22, 2013

# The Risk

## **Existing risk**

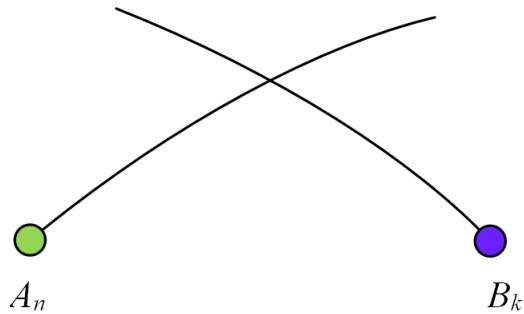
- Untracked debris and meteoroids in the current LEO environment
- Use ORDEM, MASTER, or similar models to estimate risk

## **Future risk**

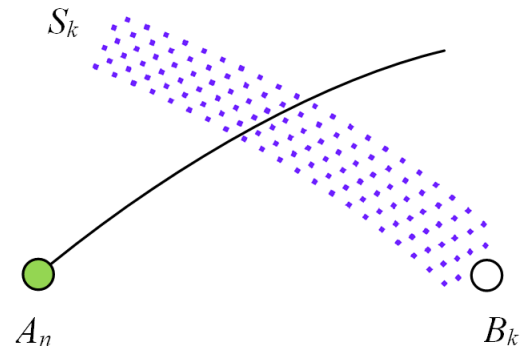
- What if another collision like Cosmos-Iridium injects hundreds of thousands of fragments into LEO?
- Many unknowns, very few precedents
- Would like to have a parametric model to analyze risk and quantify uncertainty

# Possible Realities

**With some probability, each intact object could be fragmented in a future collision**



Present

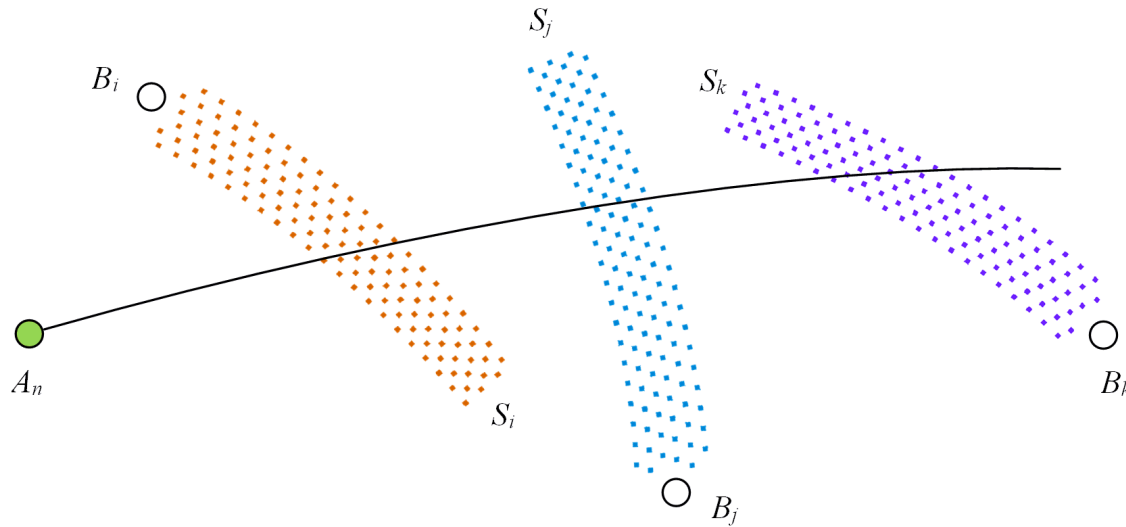


Possible future

Full mathematical model: <http://electrodynamictكنولوجий.com/PDF/WhitePaper-2012.pdf>

# Superimposed States

**Superimposed probability-weighted virtual streams of future collision fragments**

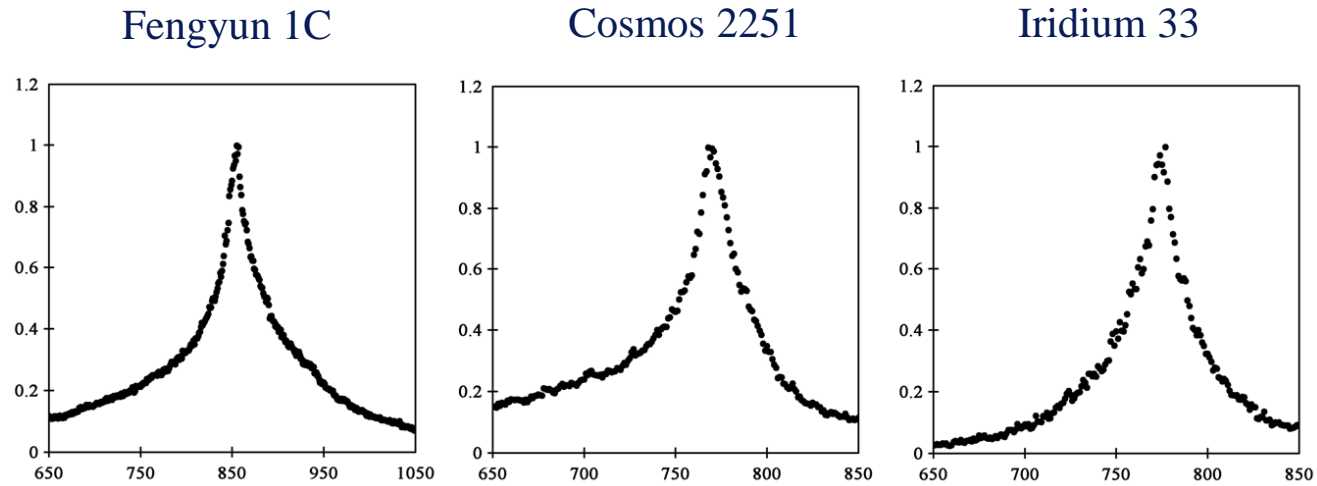


Total virtual flux of fragments encountered by asset  $A_n$ :

$$\Phi_n \approx \frac{k_n}{P_c} \sum_{k,i} \beta_{nk} P_{ki} F_{ki}(m) g_{ki}(H_n)$$

# Altitude Distribution

## Known altitude distributions of collision fragments

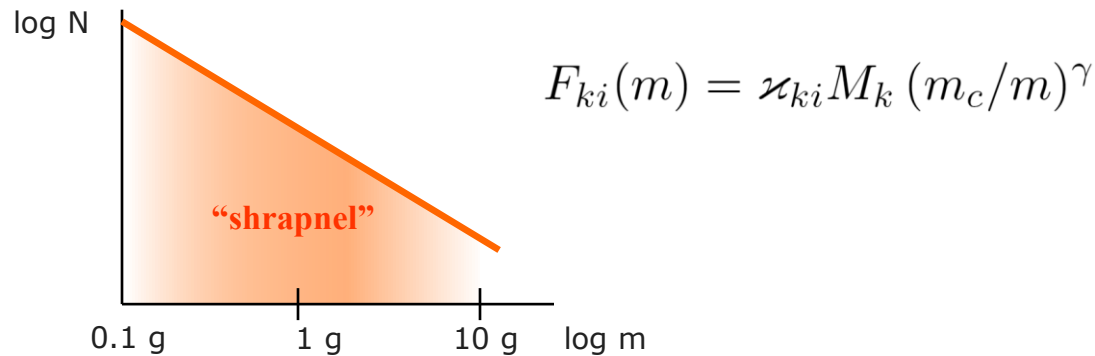


Approximation:

$$n(h, h_0) = \frac{k_0}{h_s} \left( 1 + \frac{|h - h_0|}{h_s} \right)^{-b}$$

# Mass Distribution

## Power law in the range of interest



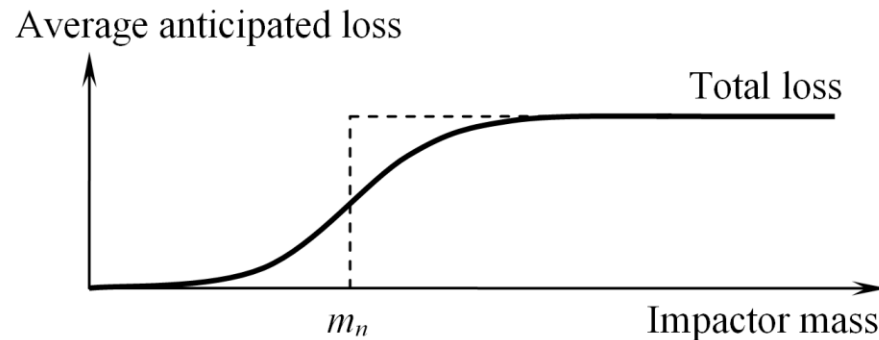
Average anticipated yield of fragments over 1 g

- Estimated based on currently available data:  $\sim 24/\text{kg}$
- $\gamma \approx 0.8$

# Lethal Impactors

## Sub-gram impactors (“shrapnel”) can disable large spacecraft

- They are produced in huge numbers in collisions, but remain untracked



- Conservatively assumed  $m_n \sim 1$  g in this study
- But could be as low as 0.1 g



# The Losses

## Immediate loss

- Asset(s) destroyed in the collision

Iridium 33



## Long-term delayed losses

- Asset(s) disabled or degraded by impacts of the collision fragments
- Statistically expected total delayed loss:

$$D_c = \sum_n L_n T_n q_n \sigma_n \Phi_n$$

# The Cost

## **The average cost of a collision between intact objects in LEO**

### **Immediate loss**

- Statistically expected ~ \$30M
- Most collisions will not involve operational spacecraft

### **Long-term delayed losses from impacts of the collision fragments**

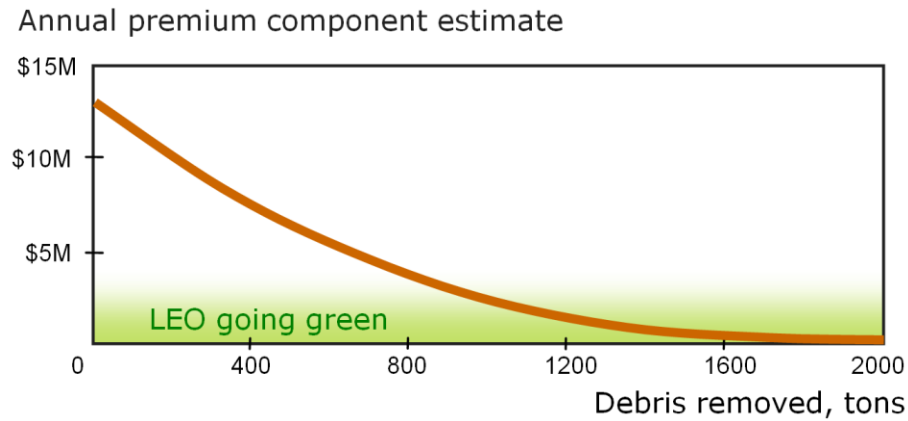
- Statistically expected ~ \$200M (conservative estimate)
- Mostly from impacts on high-value assets

### **Annual premium component**

- To insure all LEO assets against future fragment impacts ~ \$13M (could be more, depending on the lethality threshold)

# The Effect of Debris Removal

## Annual premium component due to future collision fragments



- Small-scale debris removal will not reduce the premium much
- Wholesale removal of large debris will remediate this risk

# The Challenge

- Primary losses from the fragments produced in future collisions will result from their impacts on high-value assets
- High-value assets are typically owned by governments
- Governments are mostly self-insured
- Anticipated annual loss (long-term average) is relatively low
- To appeal to the governments economically, debris removal campaigns should substantially reduce the anticipated annual loss at a comparable cost
- **If you can make insurance against future collision fragments unnecessary, your debris removal proposal is very good!**