The Impact of Space Debris on Launches

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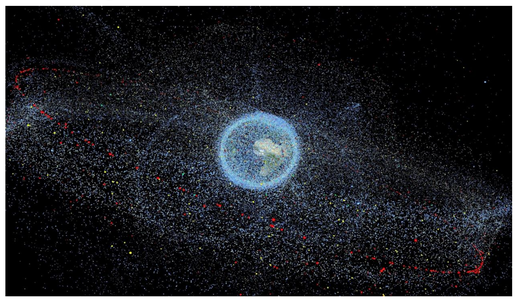
Research Questions

- What effect, if any, does space debris have on launches?
- What are the potential economic impacts related to space debris?

Background

Hundreds of millions of space debris objects are orbiting Earth.

Fig. 1. Space Debris Belt



(European Space Agency, 2017)

Table 1. Debris Estimates

Object Size	Count
10+ cm	34,000
1-10 cm	900,000
1 mm - 1 cm	128,000,000

(European Space Agency, 2016)

Space debris left in orbit not only remains but proliferates in a belt around the Earth (Kessler and Cour-Palais, 1978). Scientists hypothesize, in what is known as the Kessler Effect, that this belt may become dense enough to limit extra-atmospheric activity and could inadvertently trap humanity on Earth. Some estimates suggest that Earth could reach the Kessler Effect's threshold as early as 2100 (Nozawa et al., 2023). Satellites largely operate in Low Earth Orbit, where the limited area and threat of space debris is especially prominent and potentially costly.

Methodology

Preliminary Model: *Log* Launches = β0 + *Log* β1Space Debris Count + β2Payload/Launch + β3Average Cost Function

A regression analysis was performed using data from 1957 to 2024 on space debris and the number of launches from Spacetrack.org. The cost variable was calculated by averaging cost per kilogram per launch over time.

Limitations

Data is annual and includes Low Earth Orbit(LEO) and beyond.

Preliminary Results

Fig. 2. Launches vs. Debris

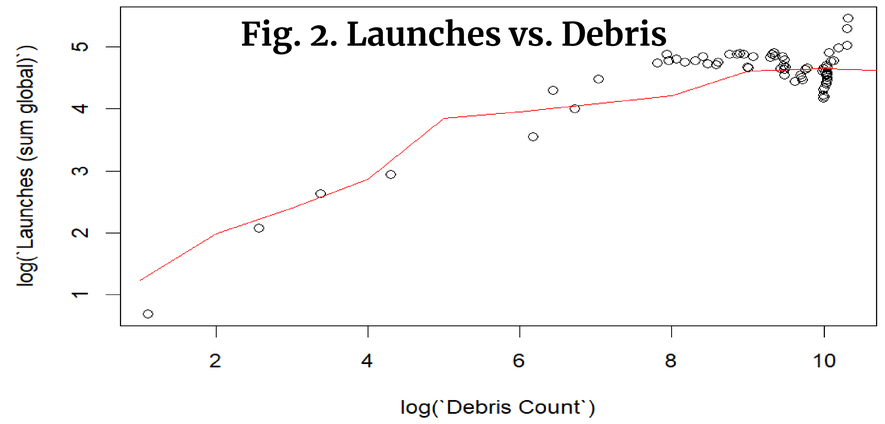


Table 2. Preliminary Regression Results

Variable	Estimate	Std. Error
β1 Log of Debris Count	5.36e-01***	0.2328
β2 Payloads per Launch	9.739e-02***	.01169
β3 Cost per kg per Launch	5.965e-05***	.000004750
# of Observations (N)	67	

*** P < .001.

Preliminary regression results are based on public and private launches from 1957 to today.

The relationship between the percentage change of debris and change of launches begins with a strong positive correlation.

As debris increases, the graph flattens indicating a marginally diminishing impact of debris on launches.

Policy Implication and Future Research

The satellite industry alone makes up ¾ of the $384 billion space economy. We rely on satellites for communication, navigation and more, and the industry is expected to grow 20% over the next ten years (Christensen, 2023).

Debris mitigation efforts are already estimated to cost 5-10% of total mission costs, which can be upwards of millions of dollars (Limiting Future Collision Risk to Spacecraft, 2011). While governments face a collective action/free rider problem in regulating their space industries to produce less debris, private firms have stepped in and may continue to offer unique solutions to this challenge (Chronopoulos, 2023).

Future research will include more precise private sector data, to capture exacter cost metrics related to launches. In terms of methodology, future research will employ a Monte Carlo simulation to develop a future-looking model of the observed relationship and will incorporate economic data about the space and LEO economies to make economic predictions.

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References