The Internet from Space, Reimagined: Leveraging Altitude for Efficient Global Coverage

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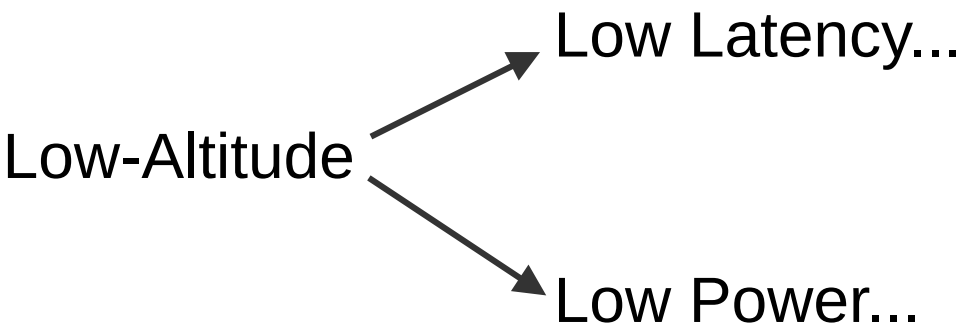
Why LEO?

Low-Altitude...

Why LEO?



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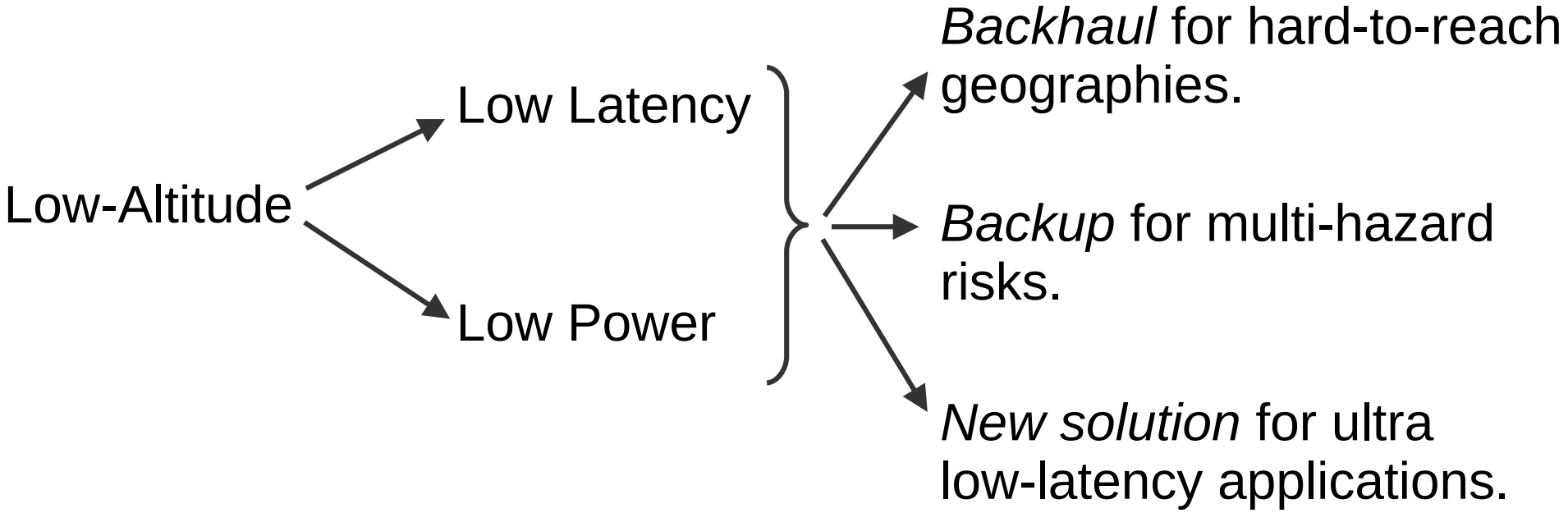

Low-Altitude
Low Latency
Low Power
Backhaul for hard-to-reach geographies.
Backup for multi-hazard risks.
New solution for ultra low-latency applications.

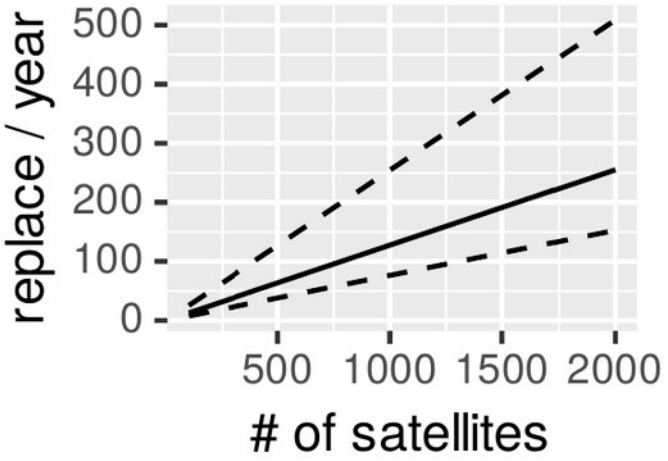
Why is LEO hard/dangerous?

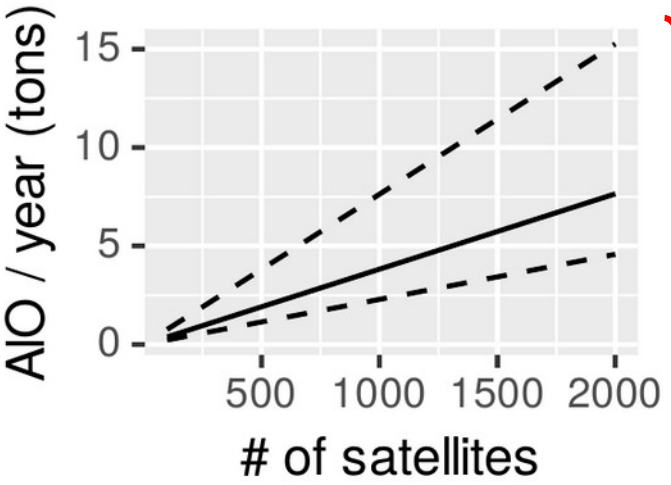
Pollution.

Orbital crowding.

High economic costs.

Why is LEO hard/dangerous?





Based on STELA simulations of orbit lifetimes.

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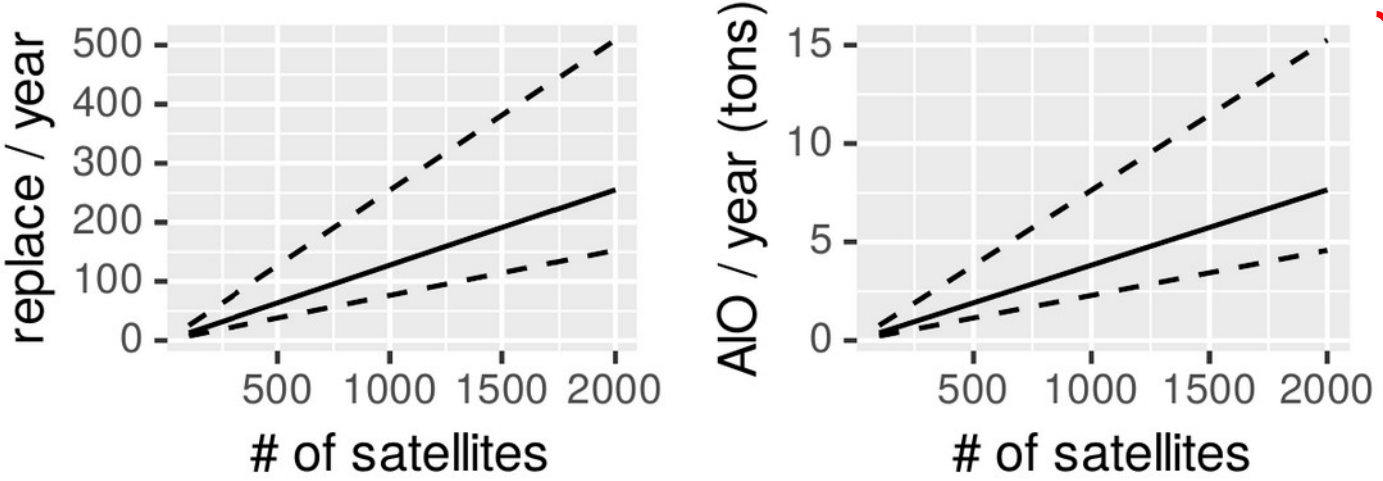

Based on STELA simulations of orbit lifetimes.

One StarLink shell (with 1584 sats.) requires:

- Disposing of **~202 satellites / year**
- **~6 tons AlO / year** (35% of total in 2022).

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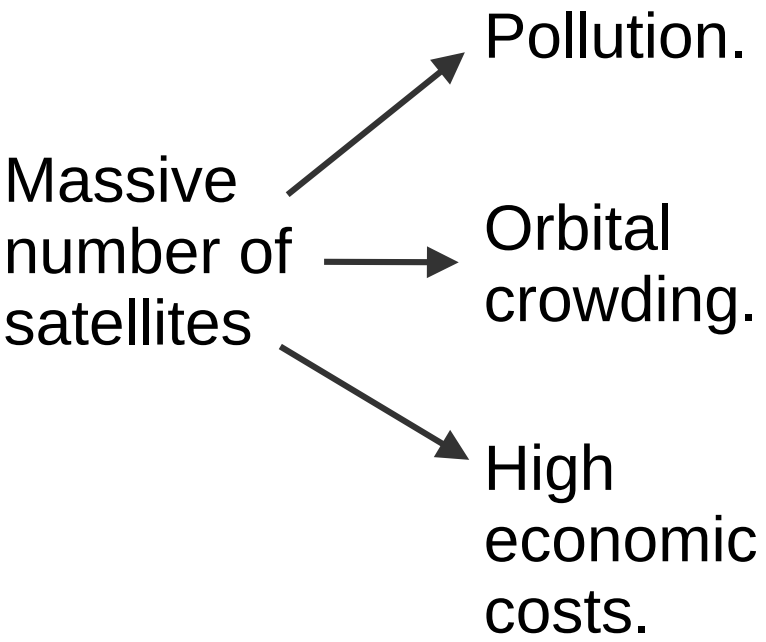
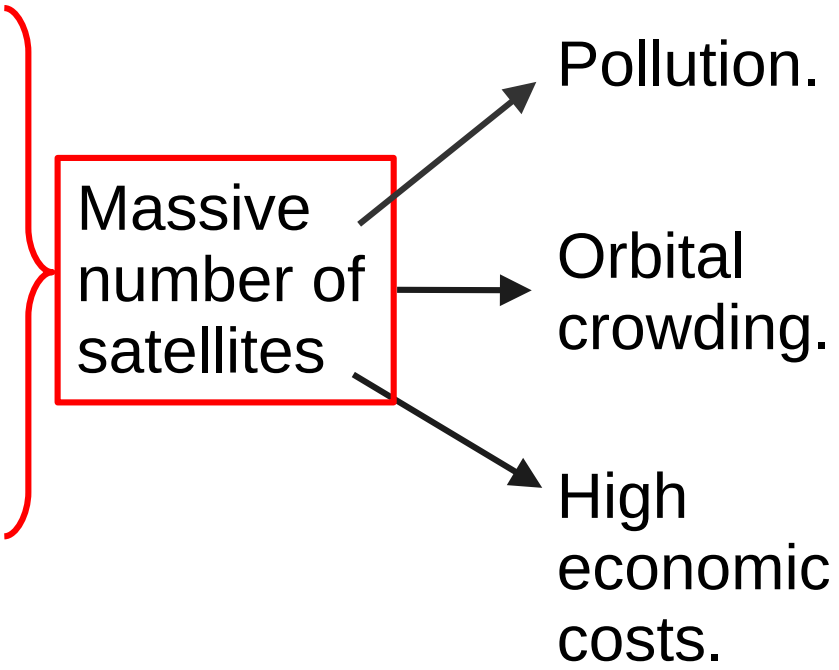


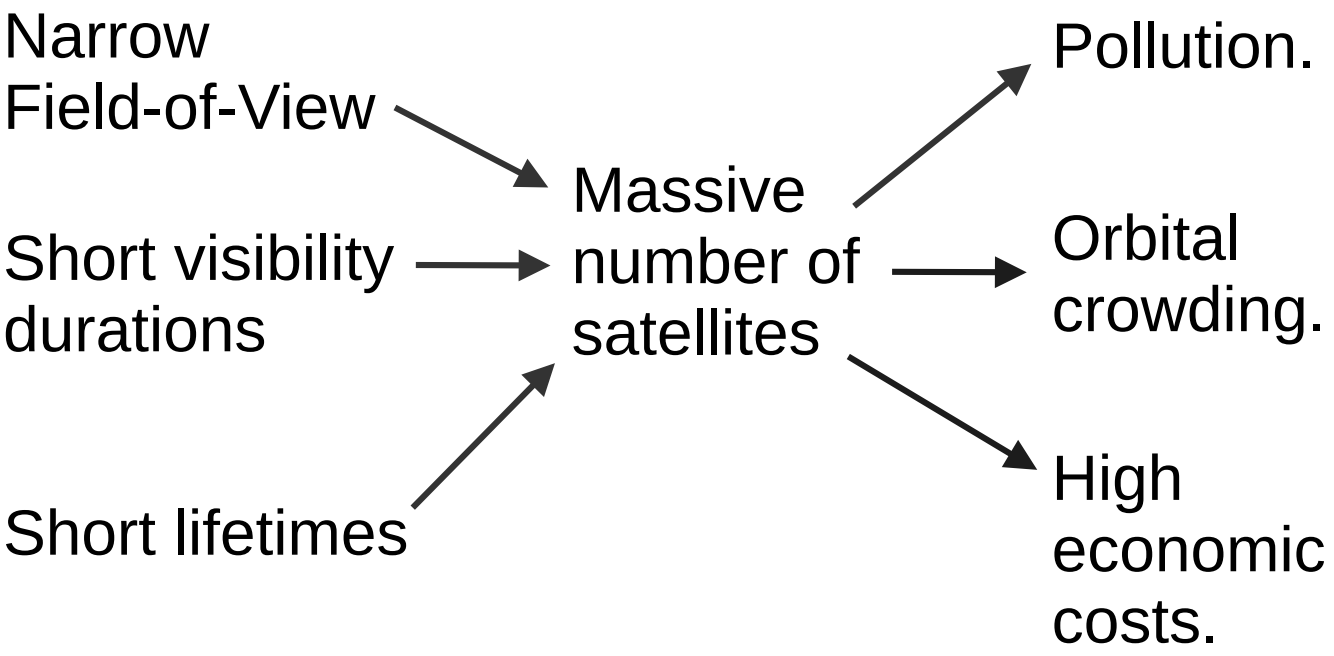
Recent Research Effort

Recent research[1] focuses on **minimizing** LEO constellations:

- *Leverage:* formulate as optimization problem.
- *Limitation:* hard to capture all 4-dimensions effectively.



1. TinyLEO (SIGCOMM'25), MegaReduce (INFOCOM'24)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Short visibility
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Massive
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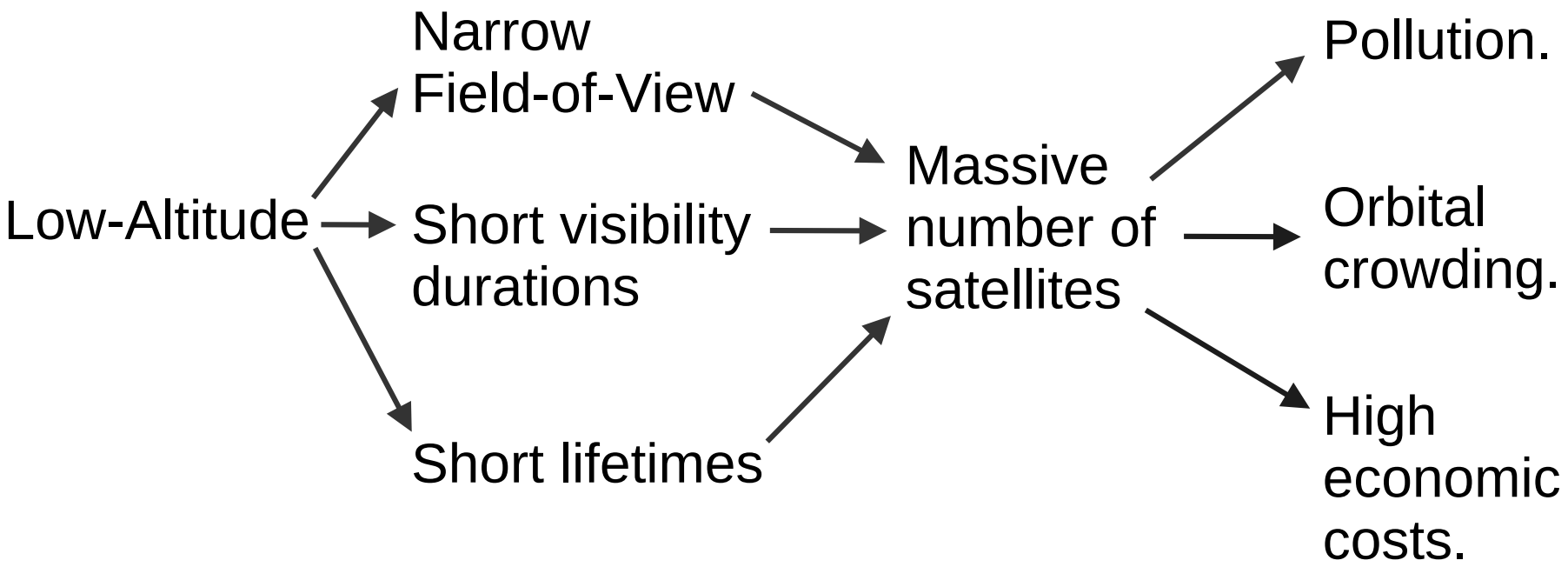
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Why *only* LEO?

Low-Altitude...

⋮

Medium-Altitude...

⋮

Geo-Altitude...

Why *only* LEO?

Low-Altitude...

⋮

Medium-Altitude...

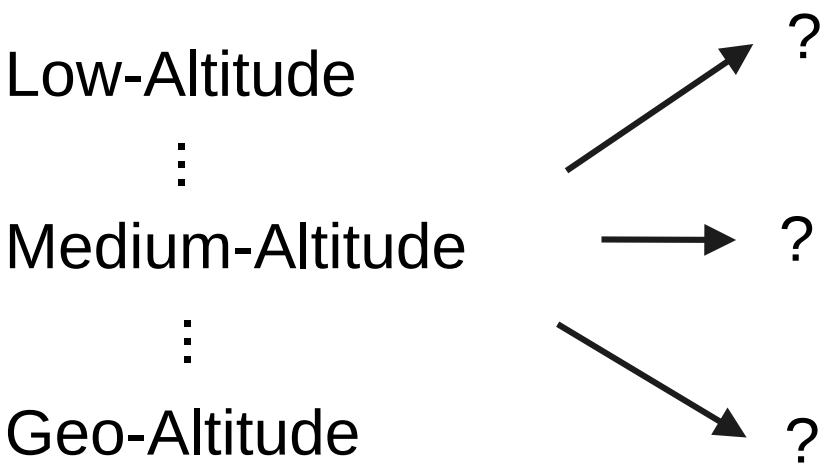
⋮

Geo-Altitude...

Orbital **altitude** is a *continuous* design variable.

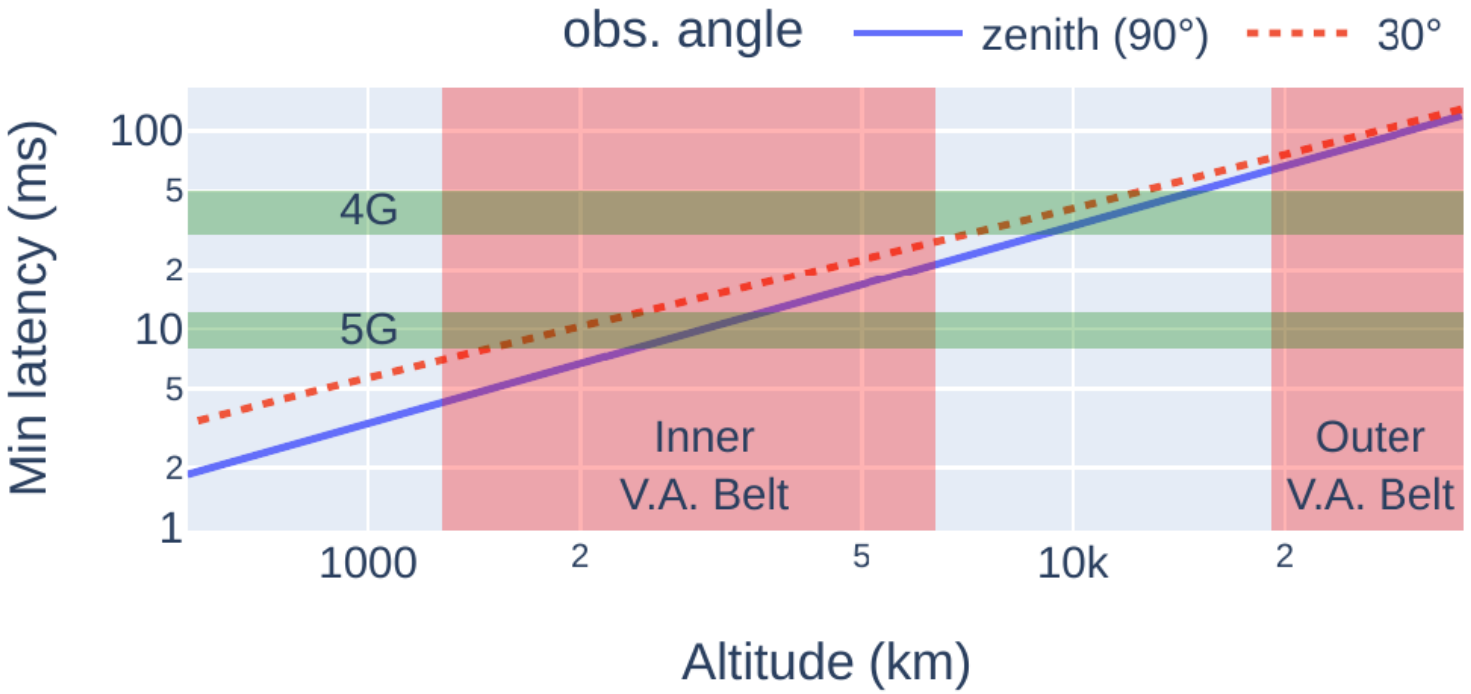
Hypothesis:
We can exploit orbital altitude to achieve **wide range of QoS** and **solve the minimization problem.**

Why *only* LEO?



...so we must first understand impact of *altitude.*

Impact of Altitude: Latency



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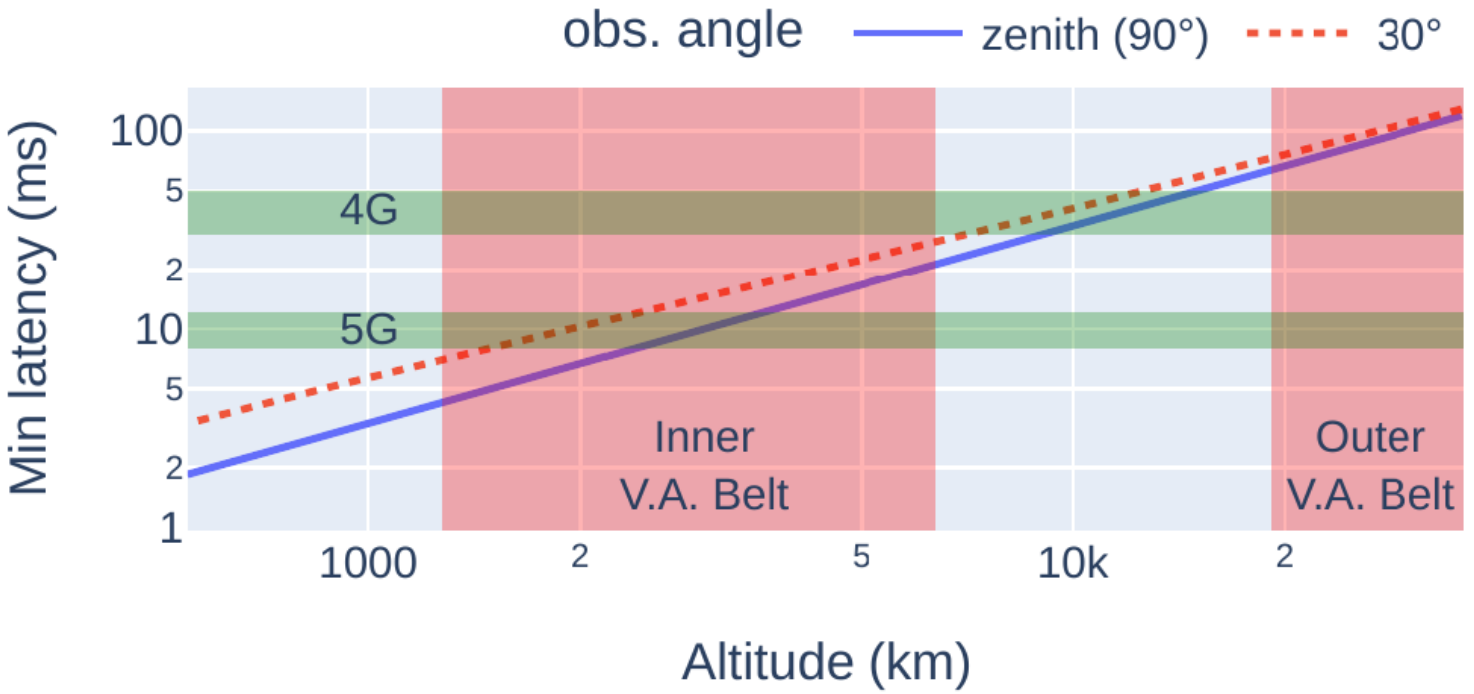

Wide range of intermediate altitude × latency combinations.

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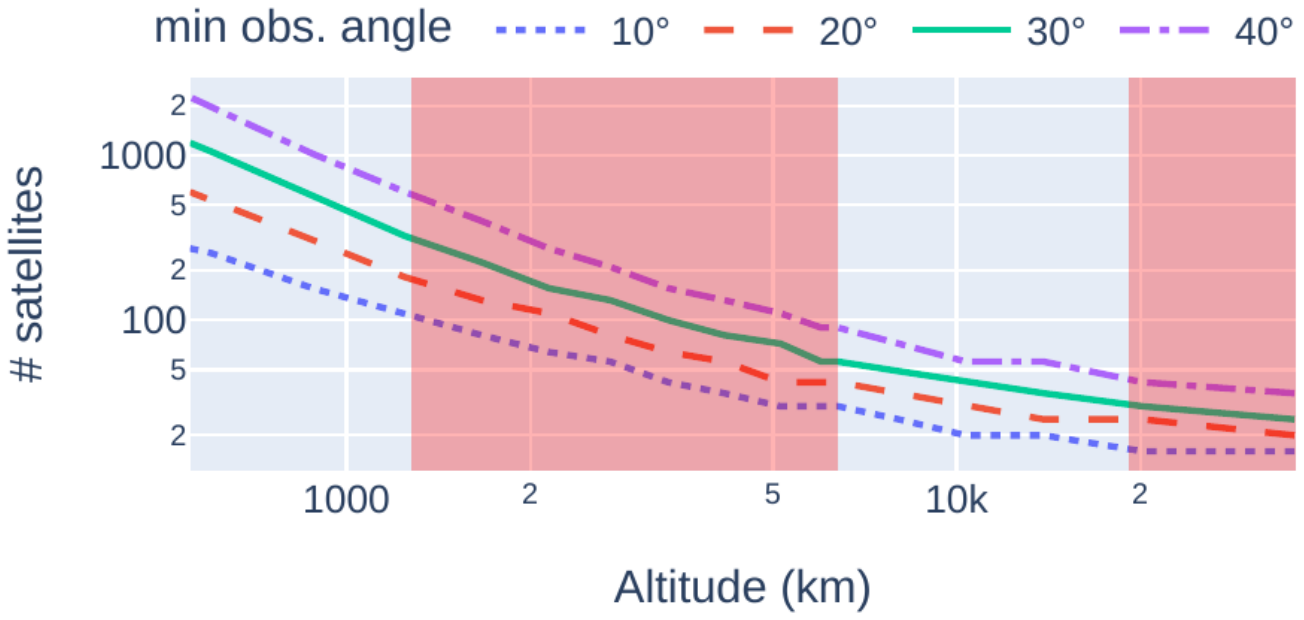
Impact of Altitude: # of Sats.



Assumptions:

- Walker-delta geom.
- Non-empty overlap.
- Coverage up to 65°.

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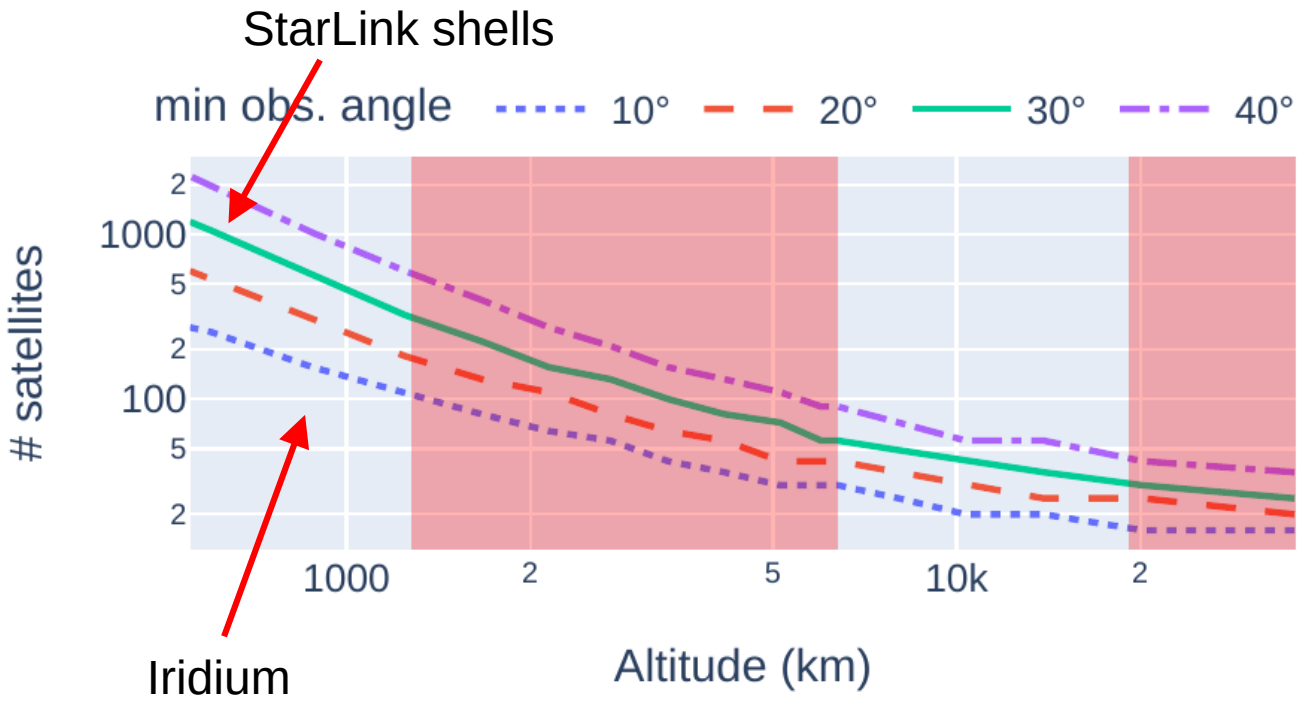

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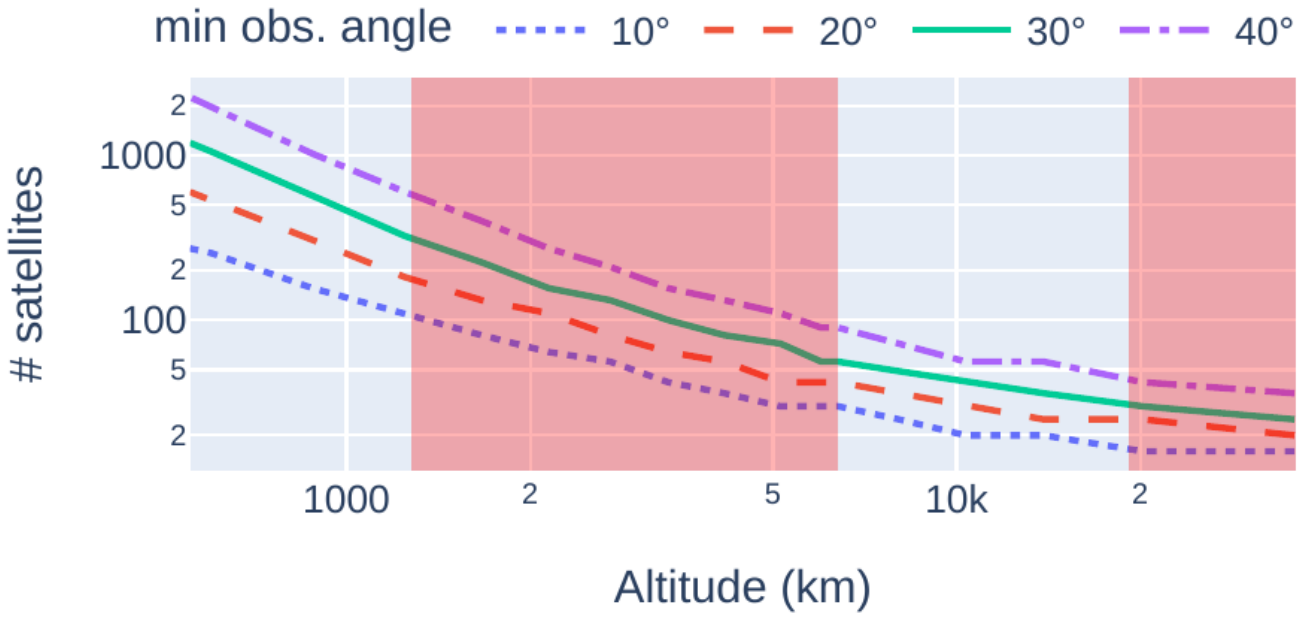

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Number of satellites required decreases *exponentially*.

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Impact of Altitude: Handovers

Data from fine-granularity simulation using SNS3.[1]

1. https://github.com/sns3/sns3-satellite

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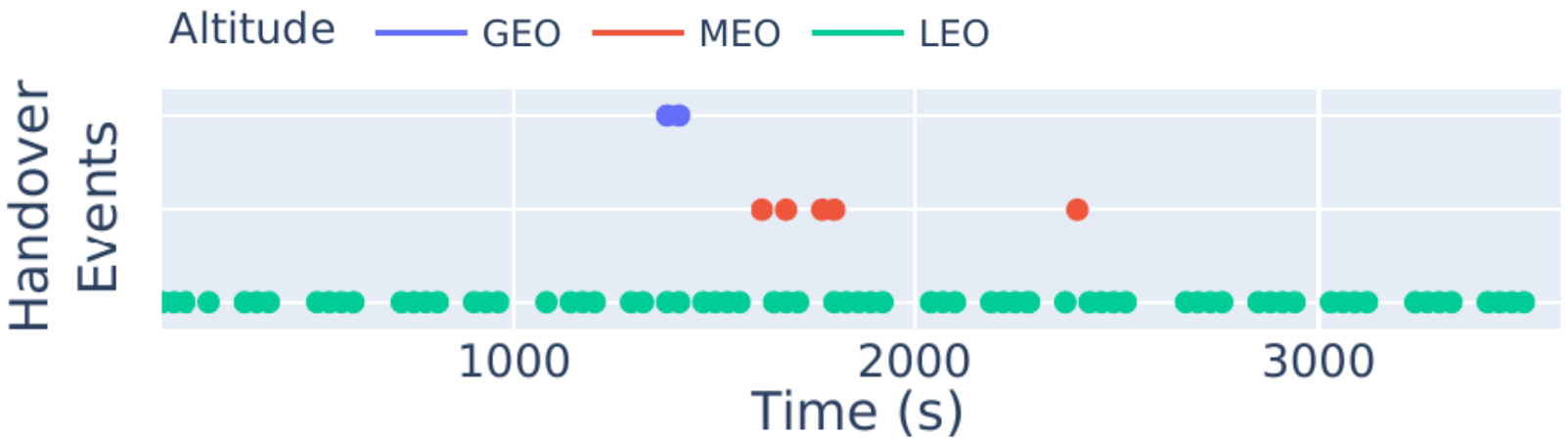
Impact of Altitude: Handovers

Higher altitude → **Slower movement** → ***Fewer handovers.***



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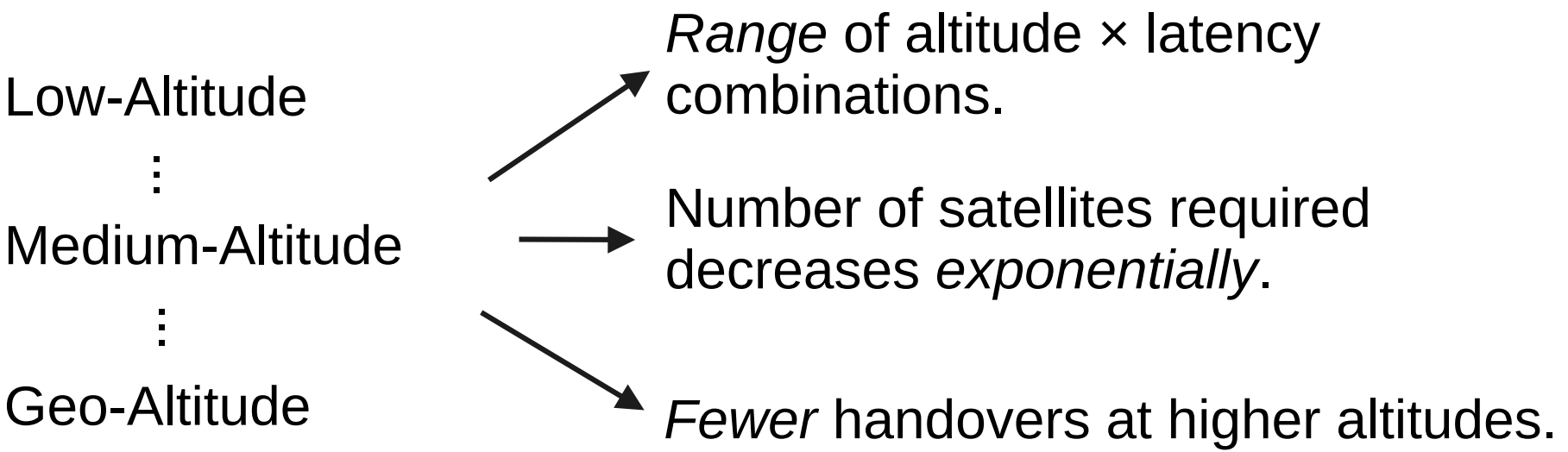
Impact of Altitude: Initial Summary



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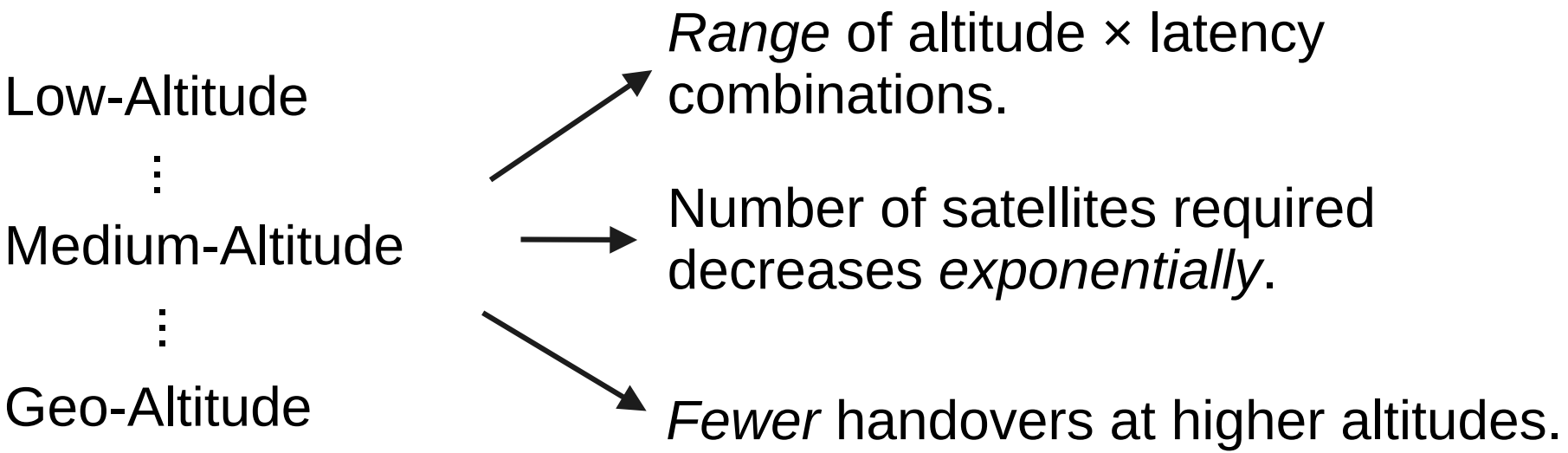

Not nearly comprehensive yet...

Future Challenges

- **Radiation:** Different altitudes have different radiation exposures.

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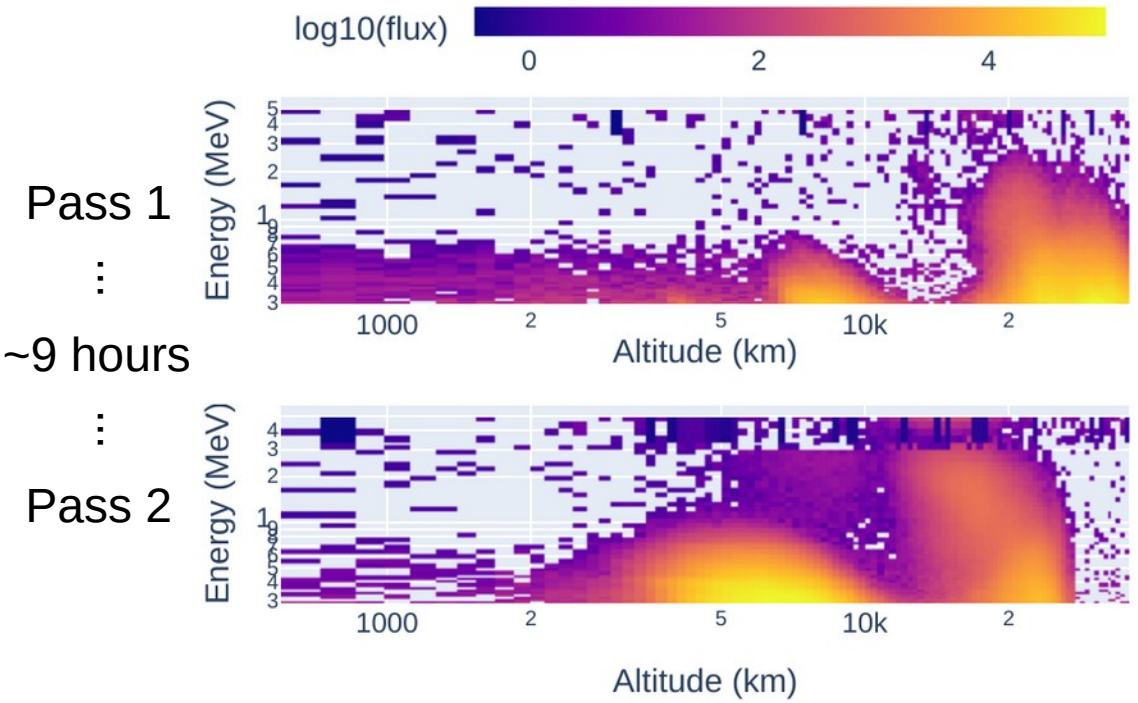

Radiation “belts” are not simple static structures...

Data from CIRBE.[1]

1. https://lasp.colorado.edu/cirbe/data-products/

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- **Joint optimization:** QoS-specific demand vs. altitude, topology, routing in 4-D.

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- **Radiation:** Different altitudes have different radiation exposures.
- **Joint optimization:** QoS-specific demand vs. altitude, topology, routing in 4-D.
- **Propagation latency:** Need to extend wireless architectures (e.g., 5G) for wide propagation latency ranges.

⋮

Thanks! Questions?

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