Toward Loosely Coupled Orchestration for the LEO Satellite Edge

Vaibhav Bhosale

Ketan Bhardwaj

Ada Gavrilovska

LEO Satellites

SpaceX Launches 60 Starlink Satellites, Nails Rocket Landing in Record-Breaking Flight

By Amy Thompson January 07, 2020

SpaceX now operates more satellites than any other company. Thousands more will follow.

SpaceX launches 58 more Starlink satellites in Saturday ride-share mission

For its third launch in two weeks, Elon Musk's rocket company sends more Starlink satellites and three Planet Labs satellites to orbit.

Image Credits: Space.com, Cnet.com, SpaceX

Why LEO Satellite Edge?

- Intuitive edge advantages over bent-pipe
  - Bent-pipe incurs two RTTs for each request
- Easily be extended to many current satellite applications
- LEO edge can help with economic feasibility and broaden the use

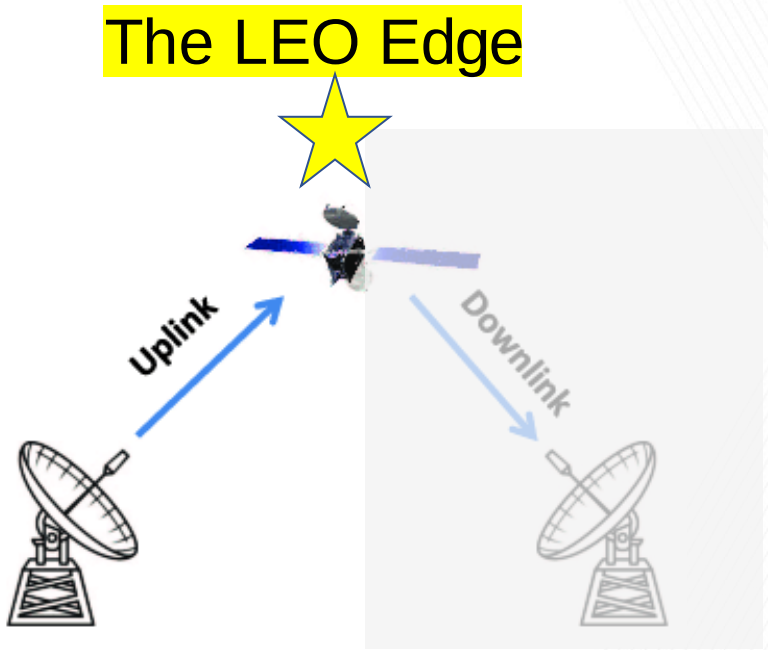


Image Credits:Abdel-Rahman, Mohammad & Krunz, Marwan & Erwin, Richard. (2012). Out-of-band sensing scheme for dynamic frequency hopping in satellite communications. 10.1109/ICC.2012.6363682.

Need for a New Orchestration Stack for LEO Edge

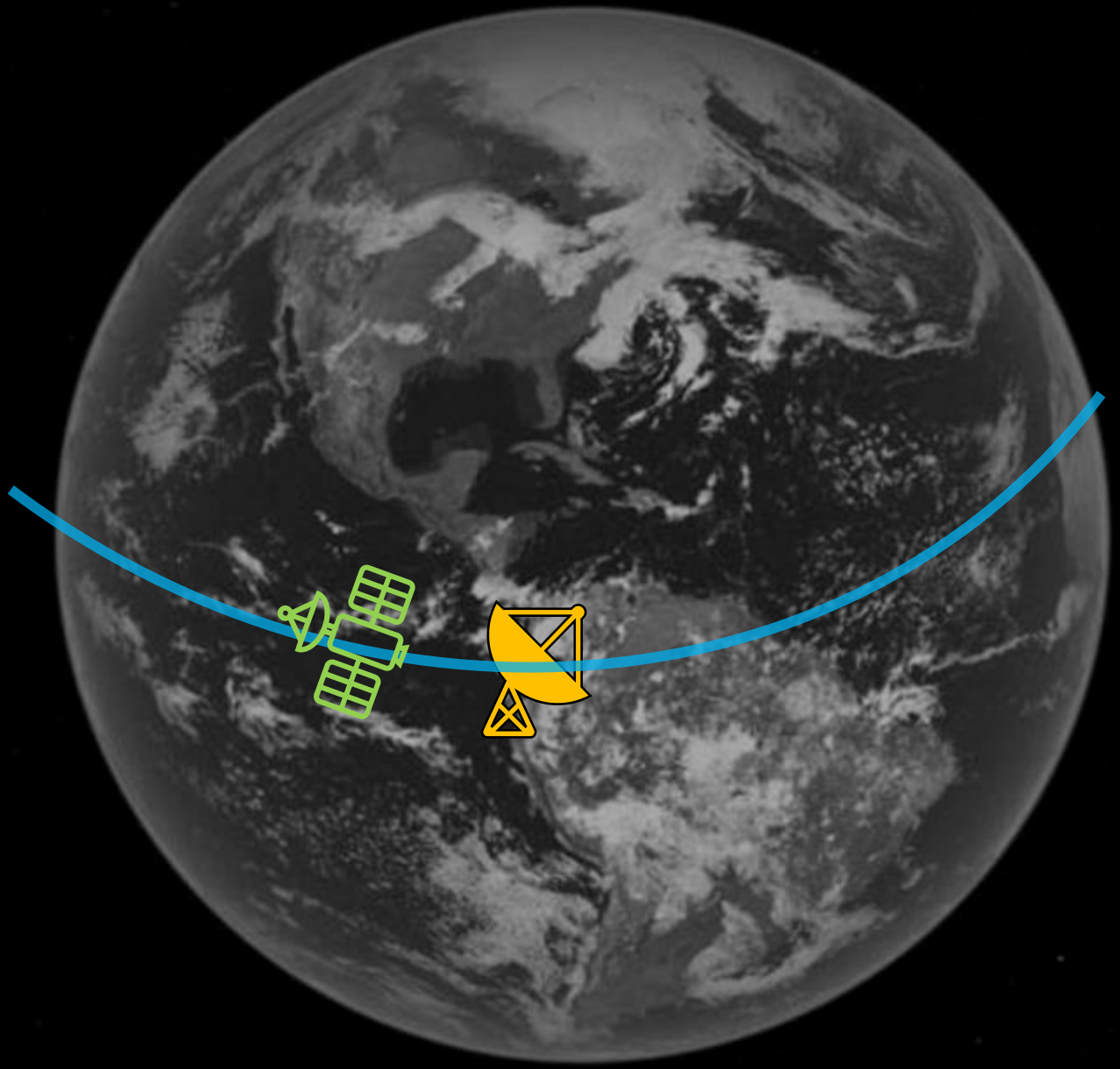
- Most of the currently commissioned satellites serve a single mission

- Availability of the LEO Satellites is tied to its economic feasibility
  - Support on-demand, multi-tenant workloads at LEO Edge
  - Dynamic configuration & deployment at LEO Edge
  - Same usage model & inter-operation as terrestrial edge

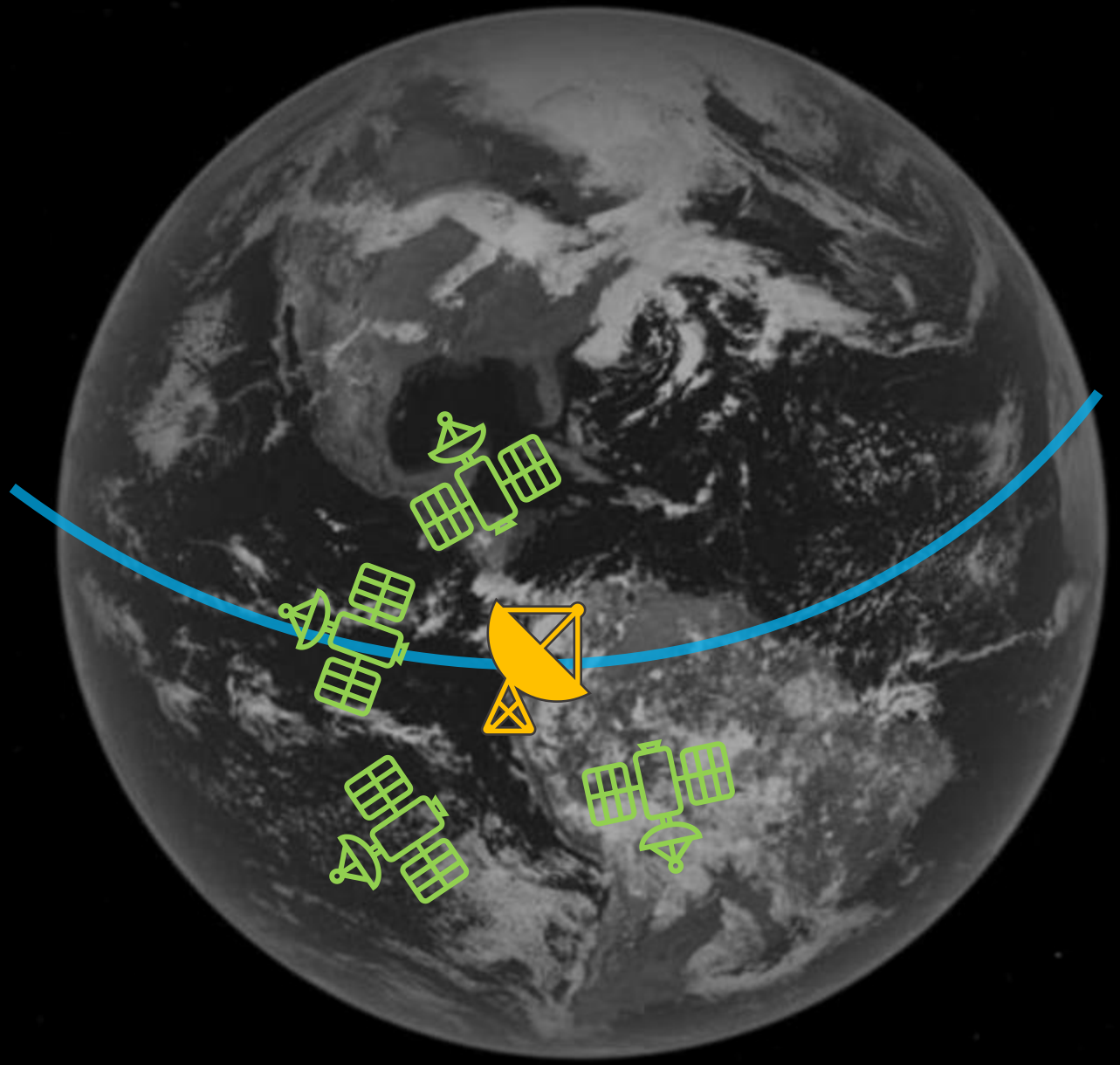
MESOSPHERE

Georgia Tech
CREATING THE NEXT

Current LEO Satellite Ecosystem



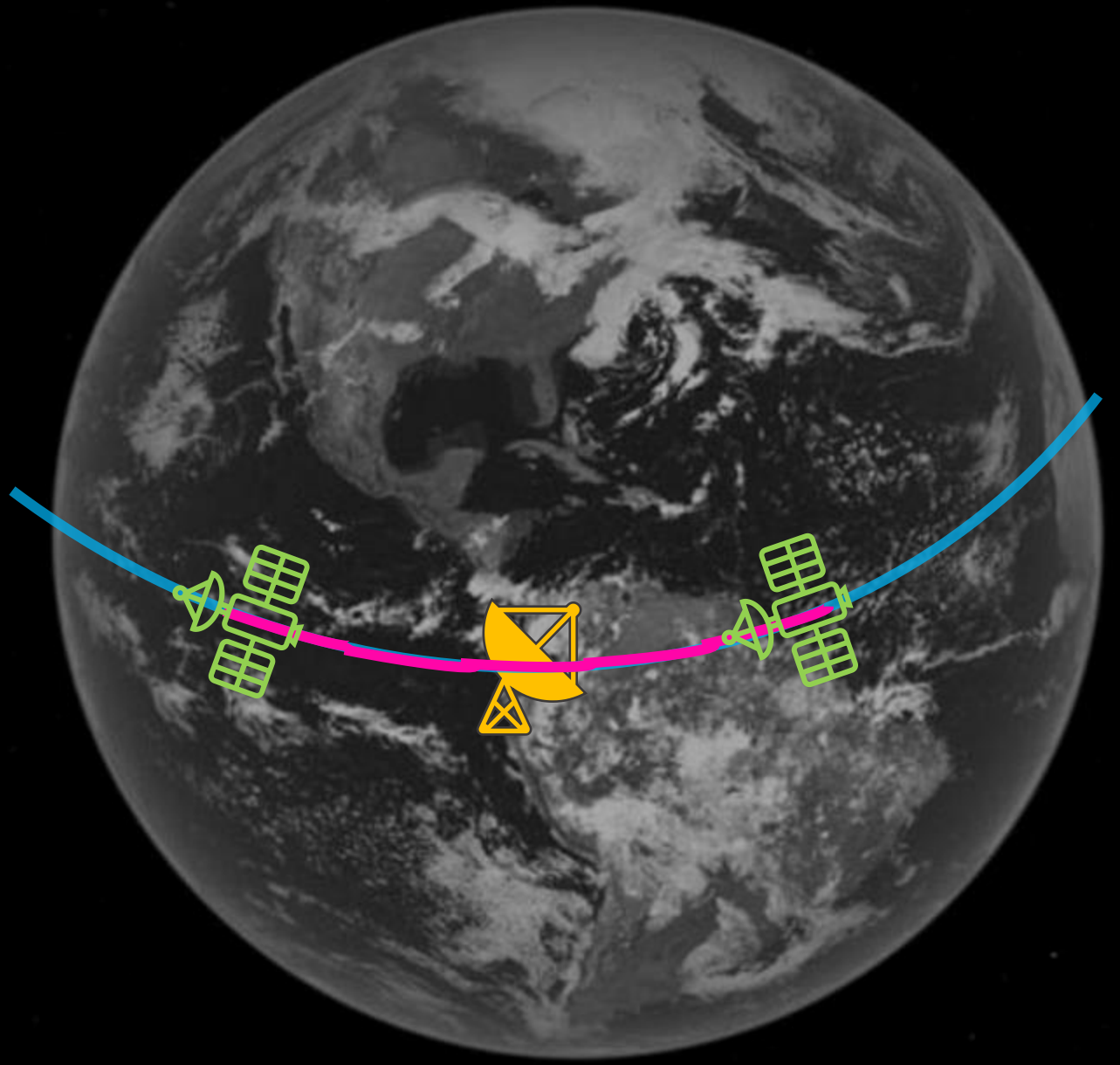
Current LEO Satellite Ecosystem



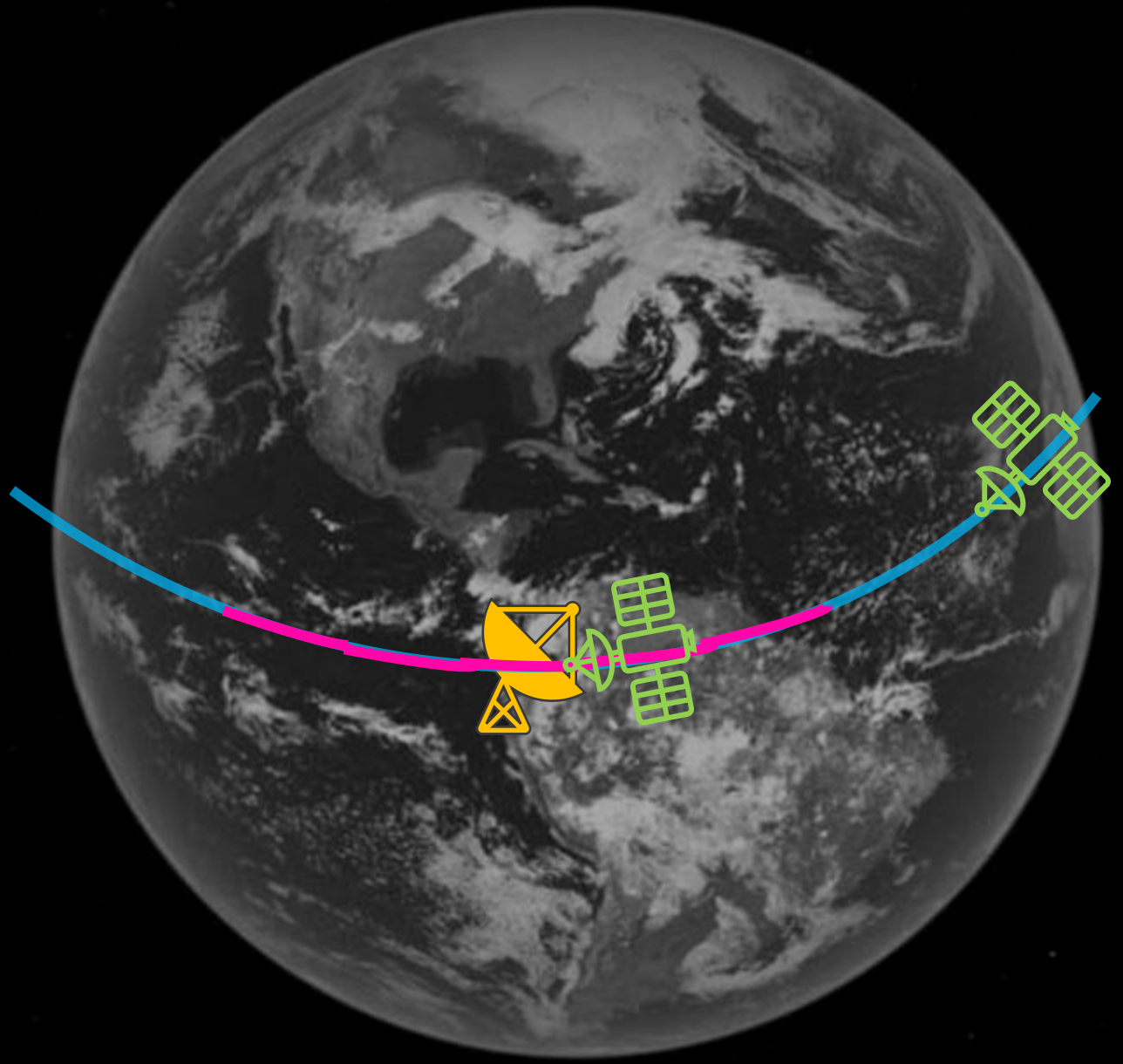
Design Goals of a LEO Edge Orchestrator

- Incorporating mobility of the LEO edge

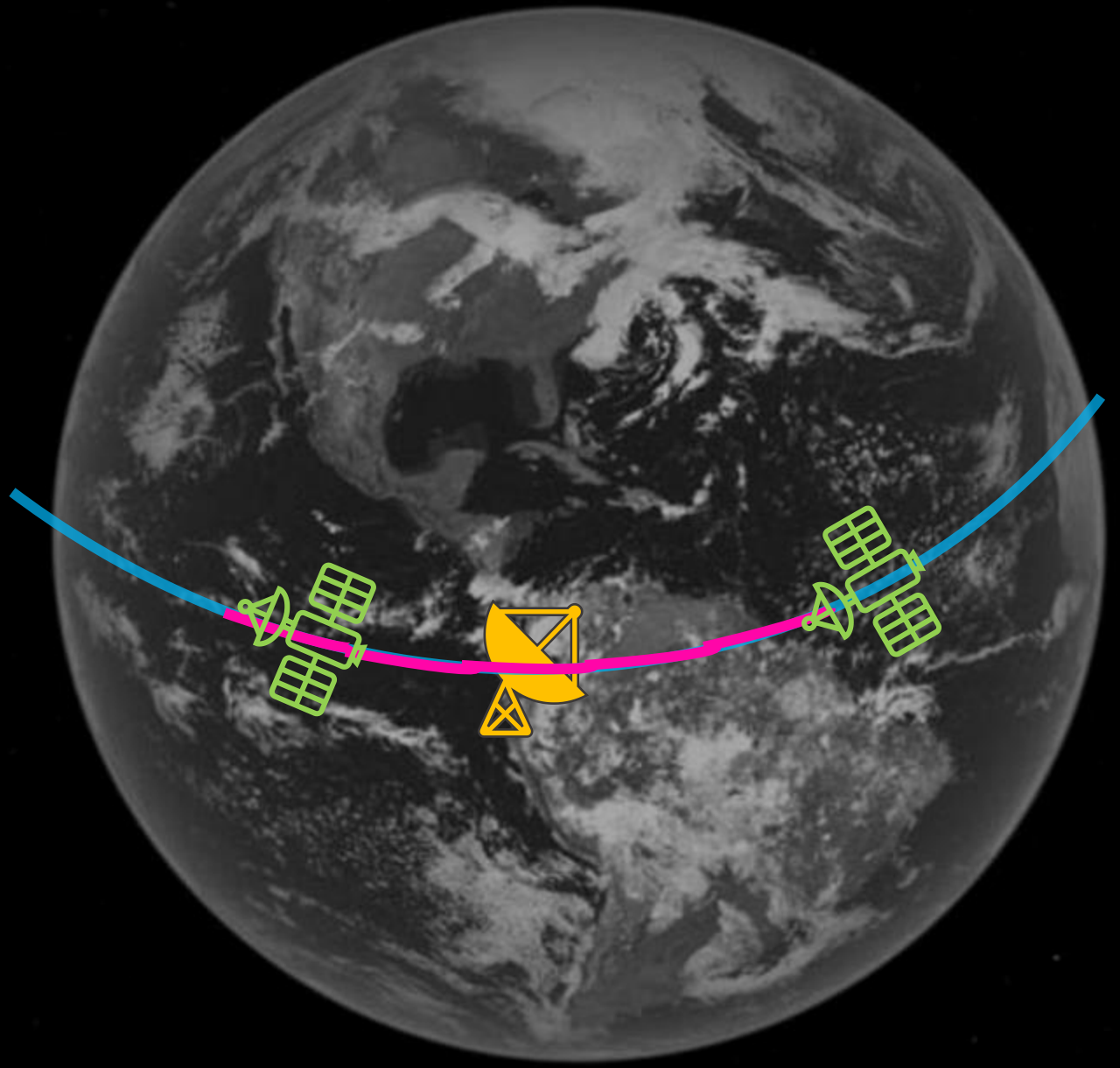
Using the terrestrial orchestration stack



Using the terrestrial orchestration stack



Just-in-time Orchestration

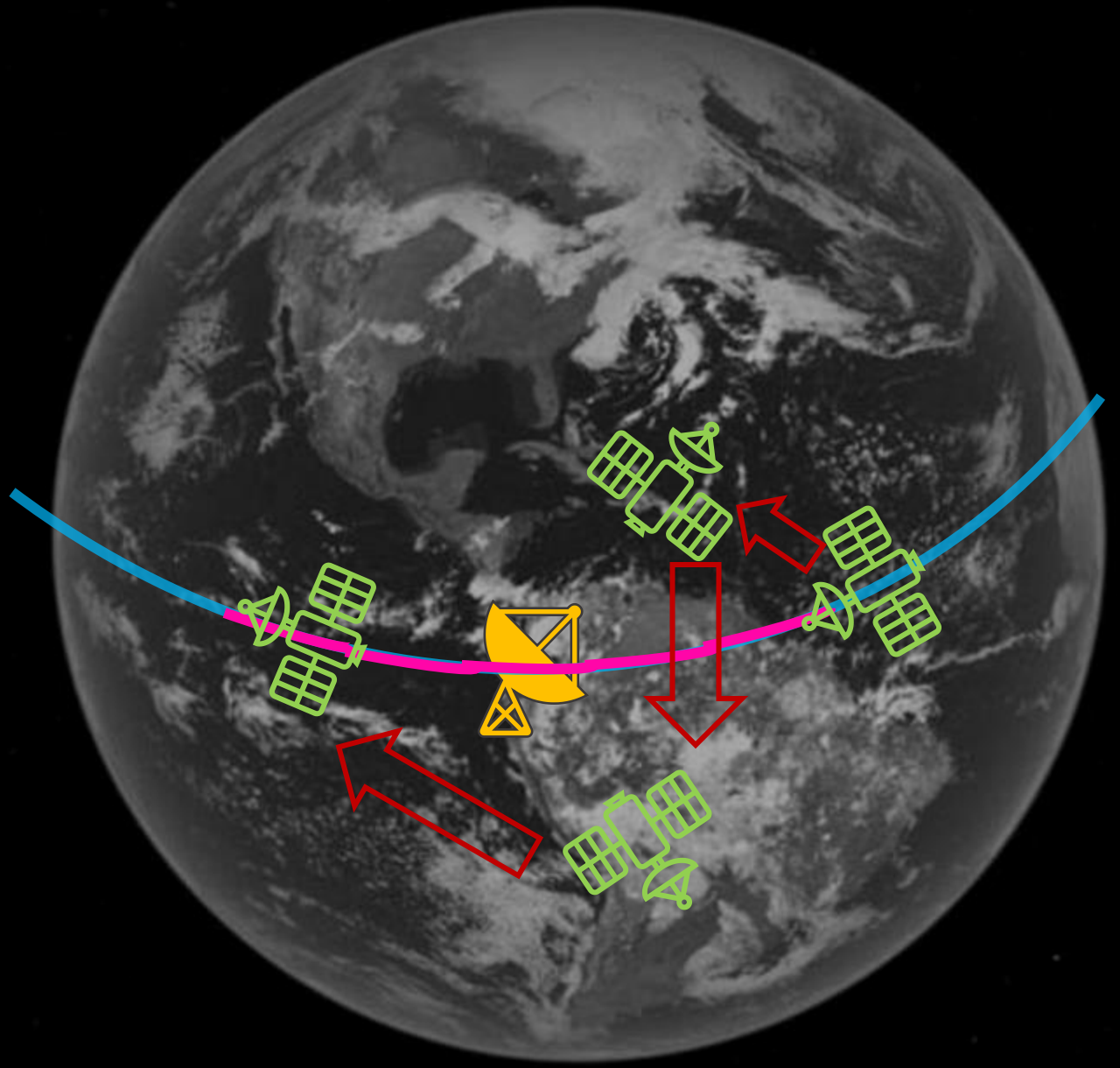


Design Goals of a LEO Edge Orchestrator

✓Incorporating mobility of the LEO edge

- Leveraging periodicity in LEO edge mobility

Sub-optimal handoffs

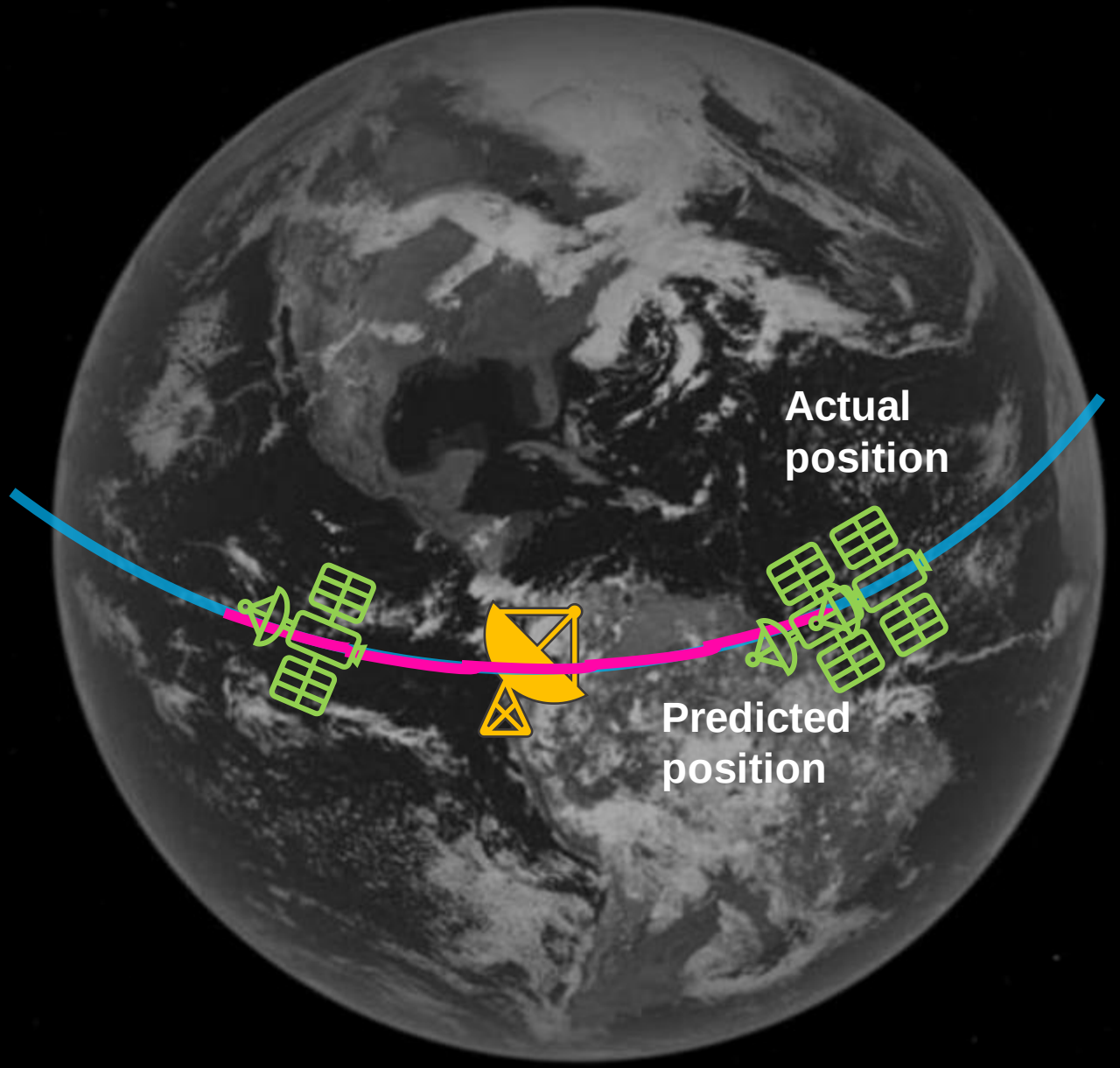


Design Goals of a LEO Edge Orchestrator

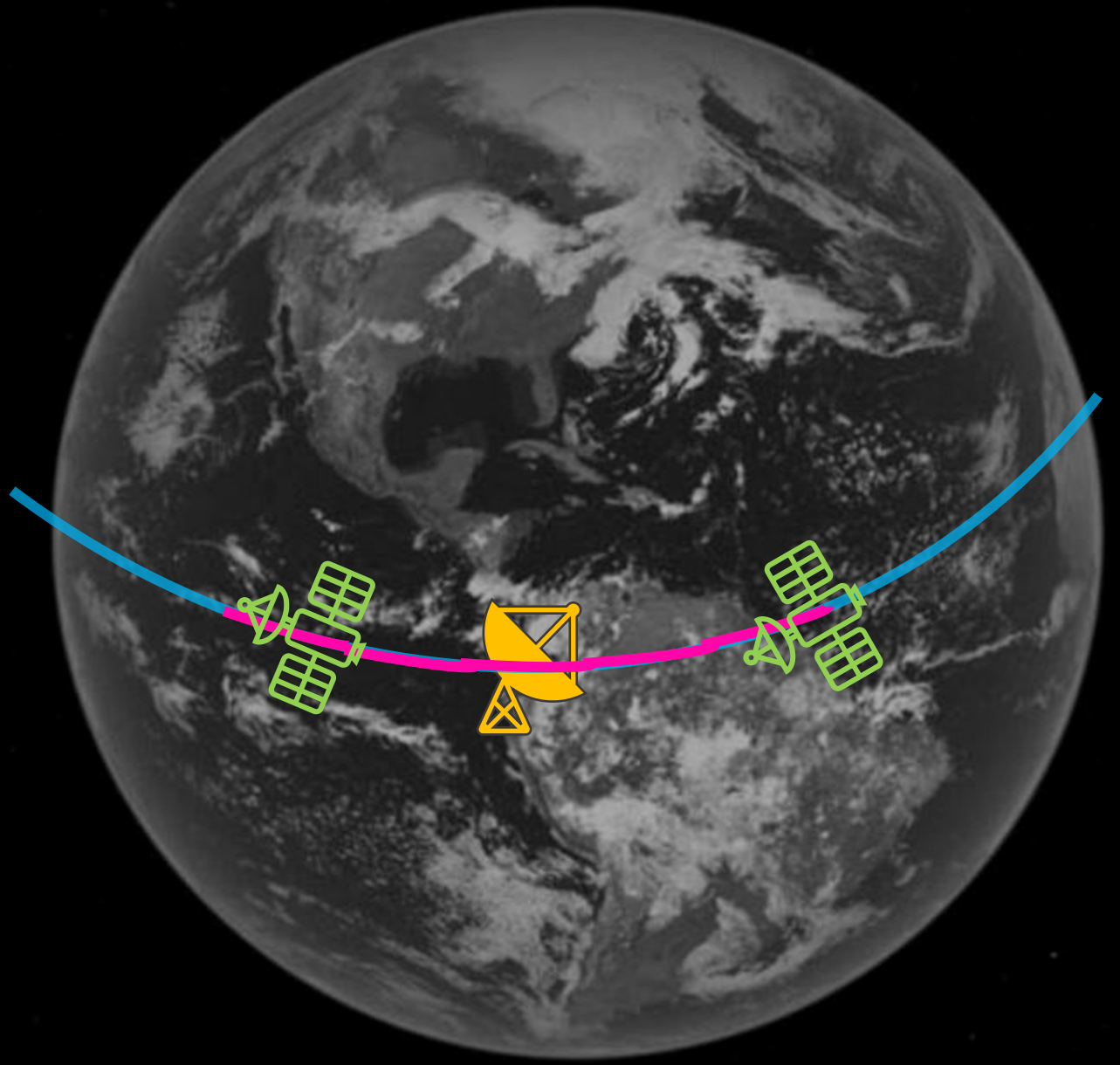
✓Incorporating mobility of the LEO edge

✓Leveraging periodicity in LEO edge mobility

- Compensating for error in mobility prediction of LEO satellites


Actual
position
Predicted
position

Just-ahead-of-time orchestration



Design Goals of a LEO Edge Orchestrator

- ✓Incorporating mobility of the LEO edge
- ✓Leveraging periodicity in LEO edge mobility
- ✓Compensating for error in mobility prediction of LEO satellites
- ✓Compensating app initialization overhead in terrestrial orchestration

Unique LEO Edge Orchestration Challenges

- Mobility of the LEO edge
- Inaccurate position prediction

Further amplified due to the tight coupling between existing orchestrators & the underlying infrastructure

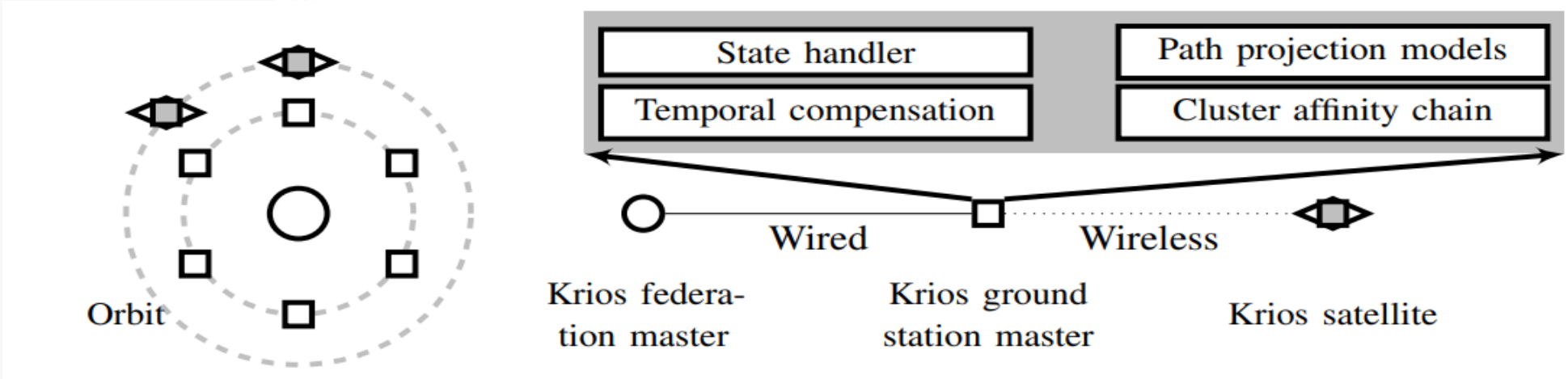
Holds true for any other non-stationary edge infrastructure as well

Krios: Loosely Coupled Orchestrator for LEO Edge

Key Idea: Make orchestration decisions "just ahead of time"

Thus, loosen coupling b/w orchestration & LEO infrastructure using

- Path projection models, cluster affinity chains and temporal compensation



Preliminary Evaluation

Experimental Setup:

- Emulated LEO edge
- SGP4 path model used

Evaluation Goal: How does loose coupling help in LEO edge?

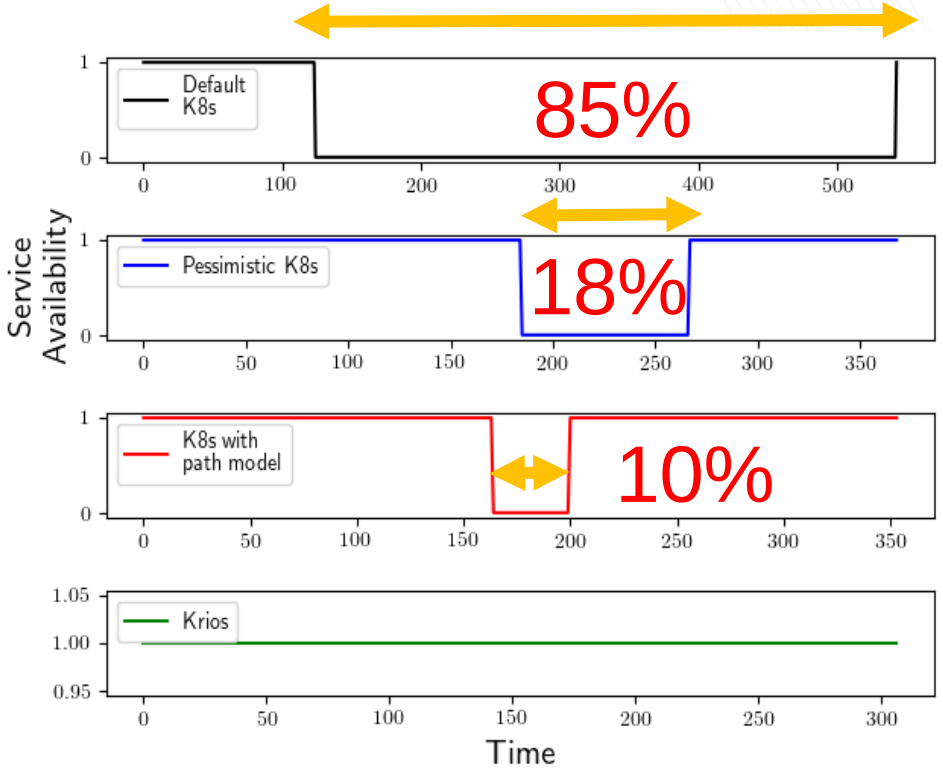
- Impact on expected downtime (availability)
- Benefits of state handling and state transfer

Two kinds of workloads at LEO edge

- Stateless: Nginx service
- Stateful: Full Wikipedia web cache

Downtime during Application Handoff

- Krios can completely eliminate downtime
- Works with no changes to Kubernetes
  - Developers use it for LEO Edge as well



Other results showing benefit for stateful edge functions in the paper

A clear signal for "new research" for & at LEO Edge

Next Steps: Comprehensive evaluation & extension of current Krios for larger constellations with high fidelity experimental setup

- Need help / Want collaboration
  - Actual details / access to LEO satellite(s): hardware, software, platforms
  - Details / access to ground stations for experiments & testing

THANK YOU

For any follow-up questions, you can reach us at:

vbhosale6@gatech.edu

ketanbj@gatech.edu

ada@cc.gatech.edu