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LEO-BEaNS: a phased-array Ka-band CubeSat constellation PNT solution with the goal of increased reliability

Photo by Stefan Els

The Team

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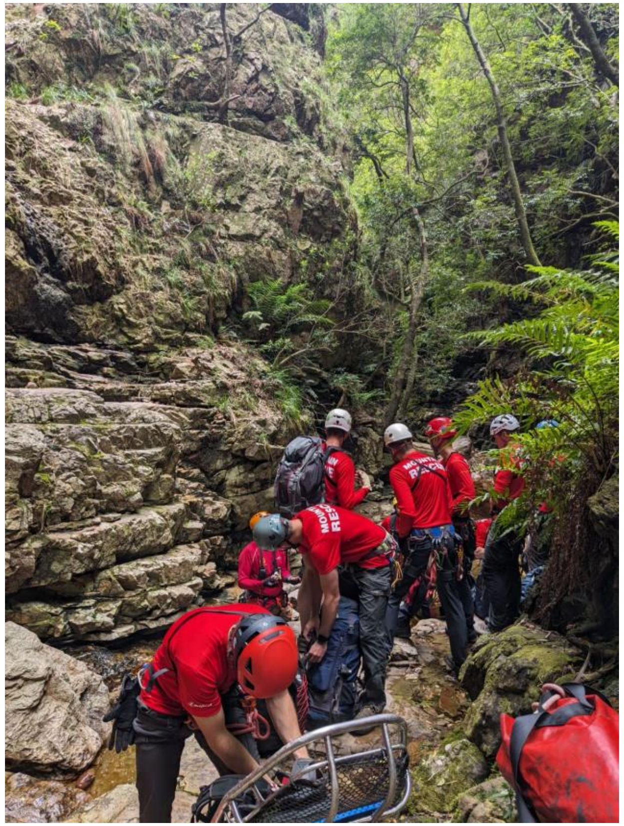
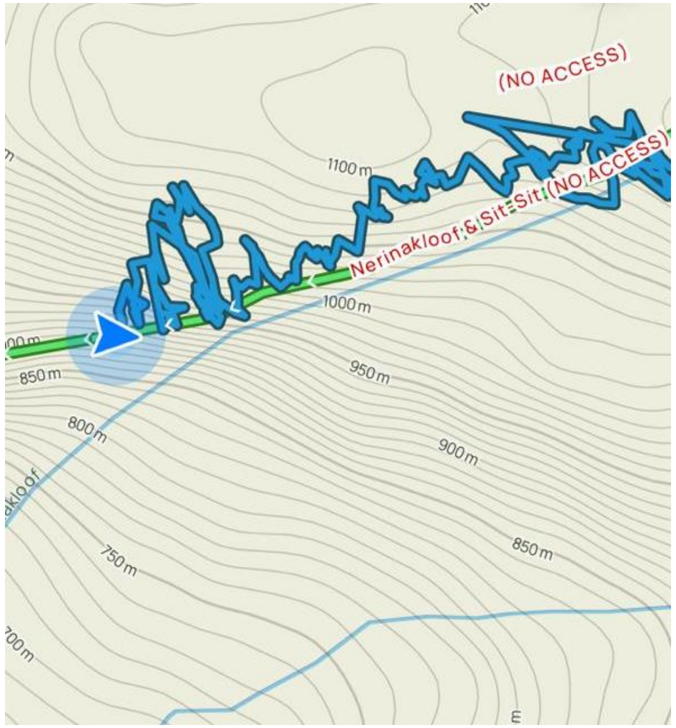
ESL
Electronic Systems Laboratory

Problems with GNSS

- Low amount of satellites
- Multipath error
- Foliage cover
- Atmospheric interference





Mission Objectives and Performance Parameters

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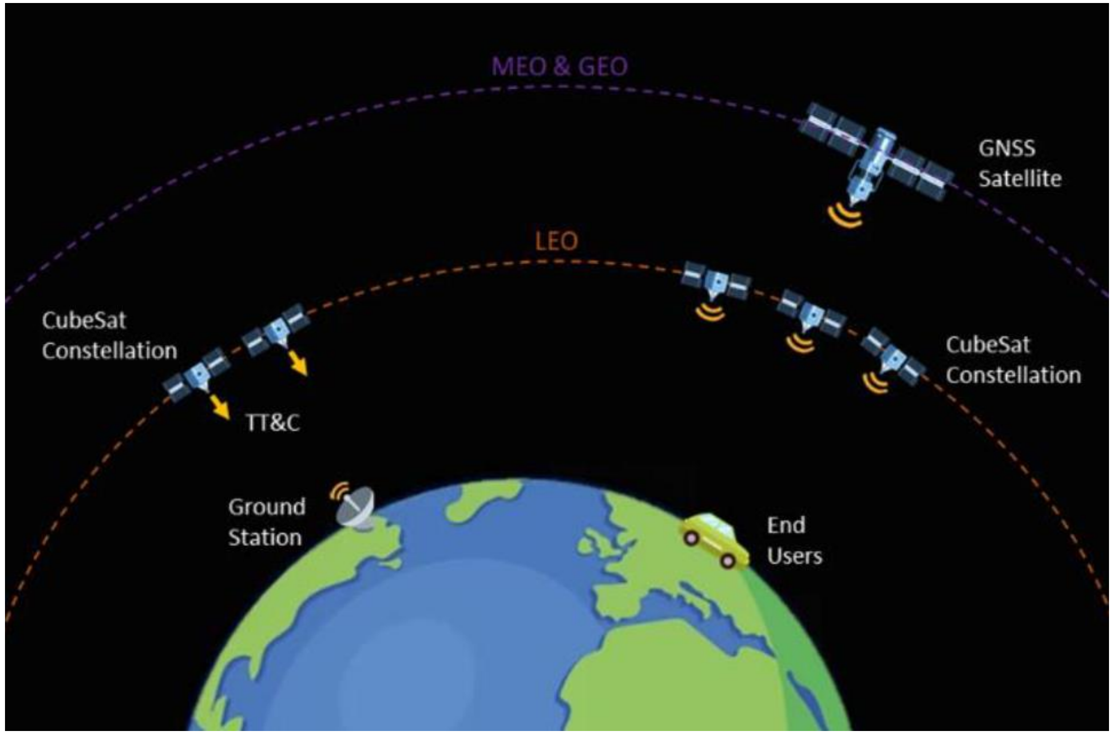
- Transmit a novel positioning, navigation and timing (PNT) signal from mission satellites
- Do this in a frequency band less susceptible to ionospheric scintillation and multi-path error
- Increase the number of satellites visible from any point
- Achieve sufficient signal-to-noise ratio (SNR) for reception
- Reduce the cost per satellite when compared to traditional GNSS solutions

Concept of Operations

- Constellation of 6U CubeSats in LEO receives data from existing GNSS satellites in L-band
  - Used to calculate position and clock drift
- LEO constellation transmits a custom Ka-band PNT signal
  - Done via a phased-array antenna to reduce power requirements



Satellite System Overview

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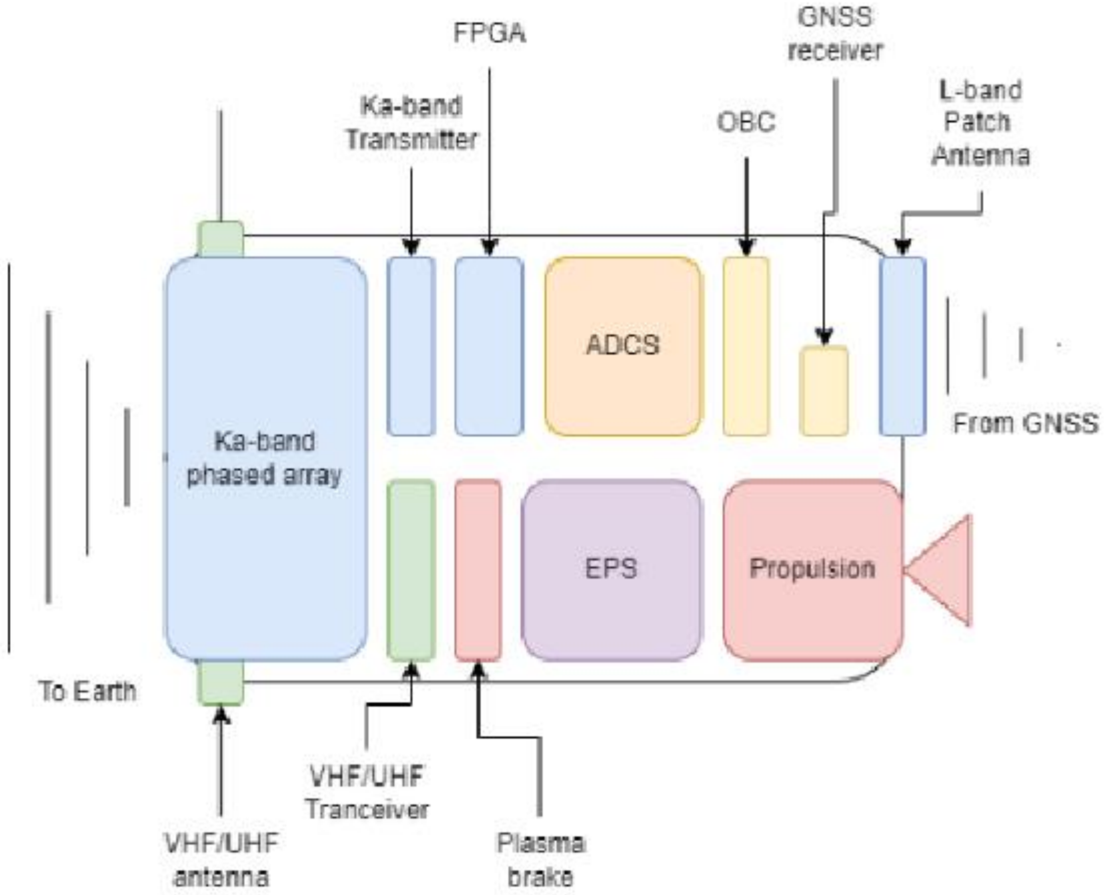

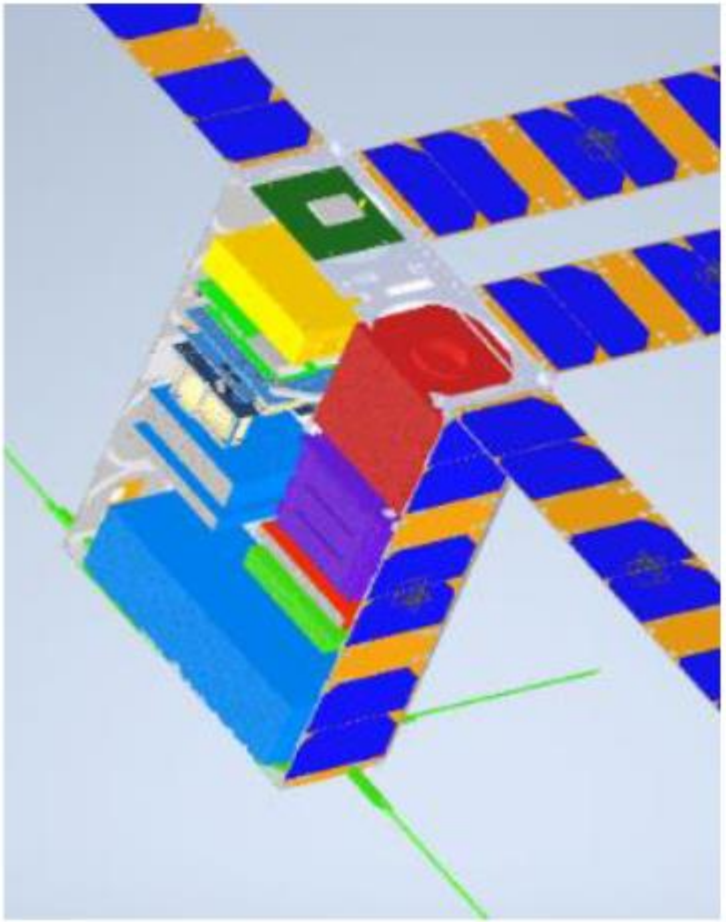

Phased Array Antenna

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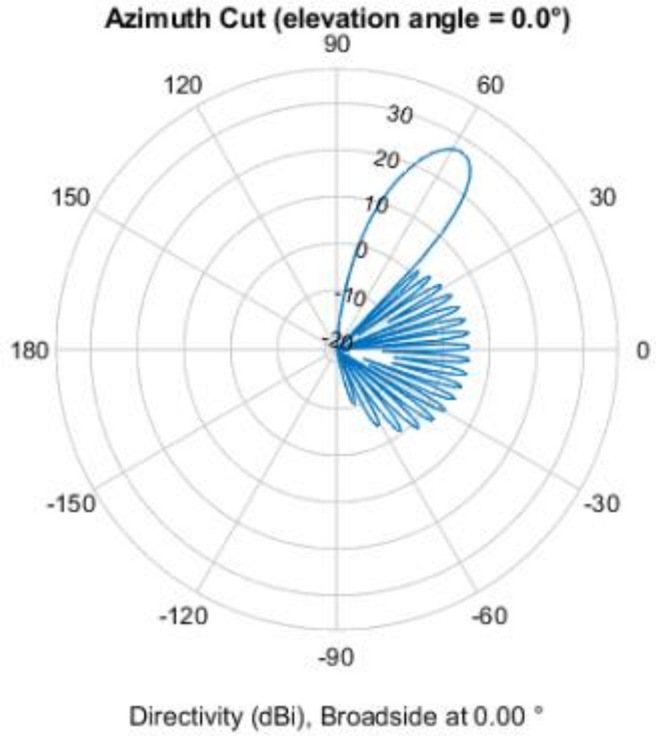
- Custom part proposed
- Electronically steered and swept over service area
- 24 by 24 grid of elements with 30 dB Chebyshev tapering
- Integrated with TDMA
- Allows for higher directivity and reduced power consumption
- Allows for selectively allocated availability



Other Components

- ISISpace 90 Wh EPS and OBC
- CubeSpace CubeADCS
- CludeSpace GNSS receiver and UHF/VHF transceiver
- Enpulsion Nano FEEP Thruster
- ISISpace Deployable Solar Panels
- Aurora Propulsion Systems plasma brake
- See full paper for power and link budgets

Orbit Design

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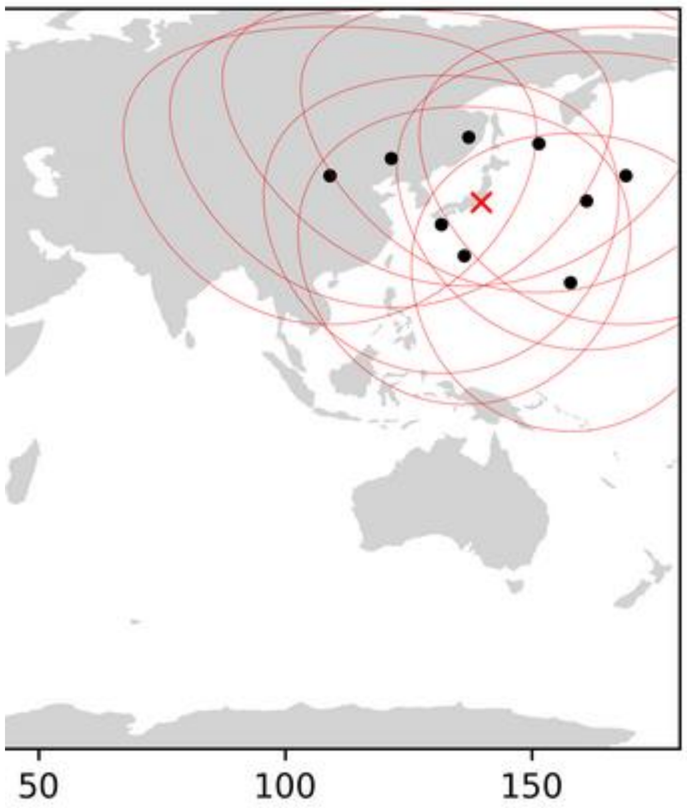
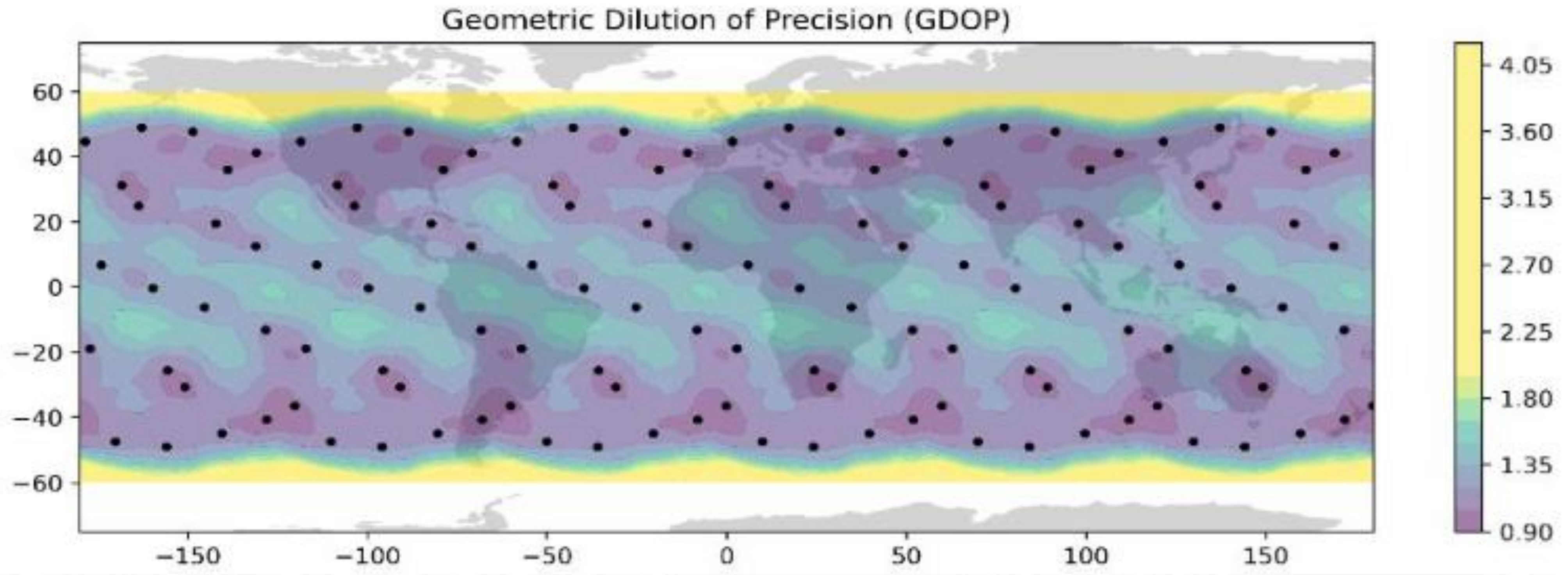
- Altitude of 1000 km chosen as trade-off between radiation, delta-V requirement and service area
- Walker-Delta layout, 18 planes, 7 satellites per plane for a total of 126
- Inclination of 49.1 degrees
- Ensures between 5 and 13 satellites visible for locations within +-60 degrees latitude
- Monte-Carlo simulation done to estimate GDOP: <4 for chosen latitudes



Geometric Dilution of Precision



In-Orbit Operations

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- Launch to 300 km by 1000 km orbit to passively deorbit failing satellites
- Use Enpulsion Nano system to raise perigee and phase RAAN over roughly a year
- Use this system for collision avoidance over lifespan of satellite
- Drop perigee back down for reentry at end-of-life
- Total delta-V of 570 m/s divided between 370 m/s for orbit raise/lower and 200 m/s for collision avoidance

Implementation Plan

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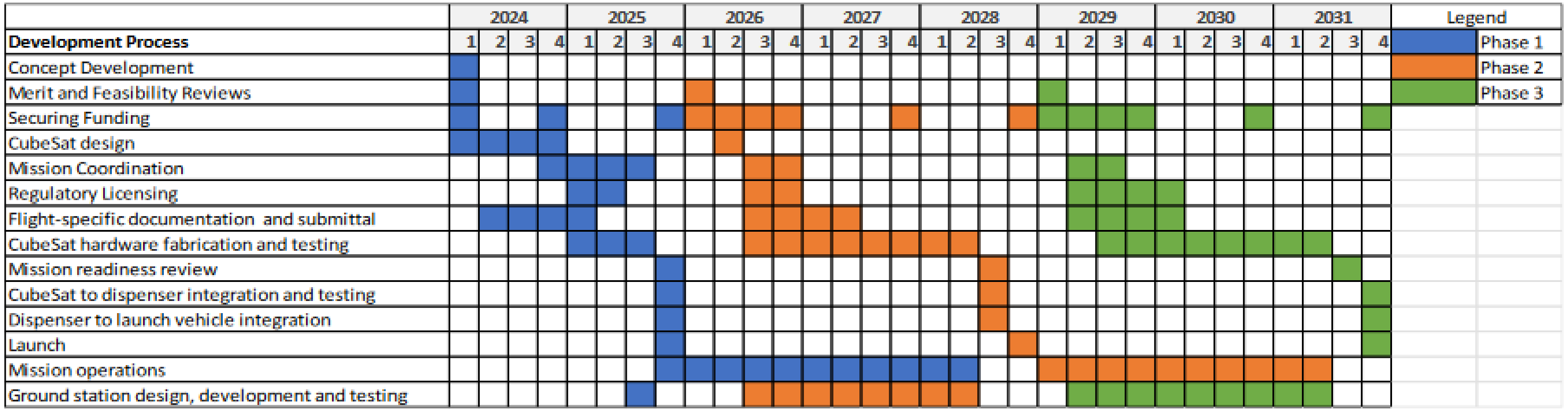
- Proposed to execute mission in three phases
  - Develop a single satellite in a university context as proof of concept
  - Build and launch a small number of satellites to confirm functionality
  - Continue to launch new satellites to maintain and grow constellation



Mission Risks

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- Regulatory hurdles
- Funding difficulty
- Technical problems related to extreme timing precision required
- In-orbit failure of satellites
- Operational problems

Summary

- Novel solution proposed for enhancing GNSS reliability
- Ka-band transmissions should be more resistant to ionospheric scintillations and obstruction
- Phased array allows for broad coverage angles and low power use
- This allows the solution to be scaled down to CubeSat size and significantly decreases deployment cost
- Offers a forward-looking strategy to address PNT demands of modern technology, urbanization, and rapid humanitarian response

Photo by Stefan Els