Grand Challenge
UNIVERSITY OF COLORADO **BOULDER**
SPACE WEATHER CENTER

SWx TREC

Observing and Forecasting the LEO Satellite Drag Environment

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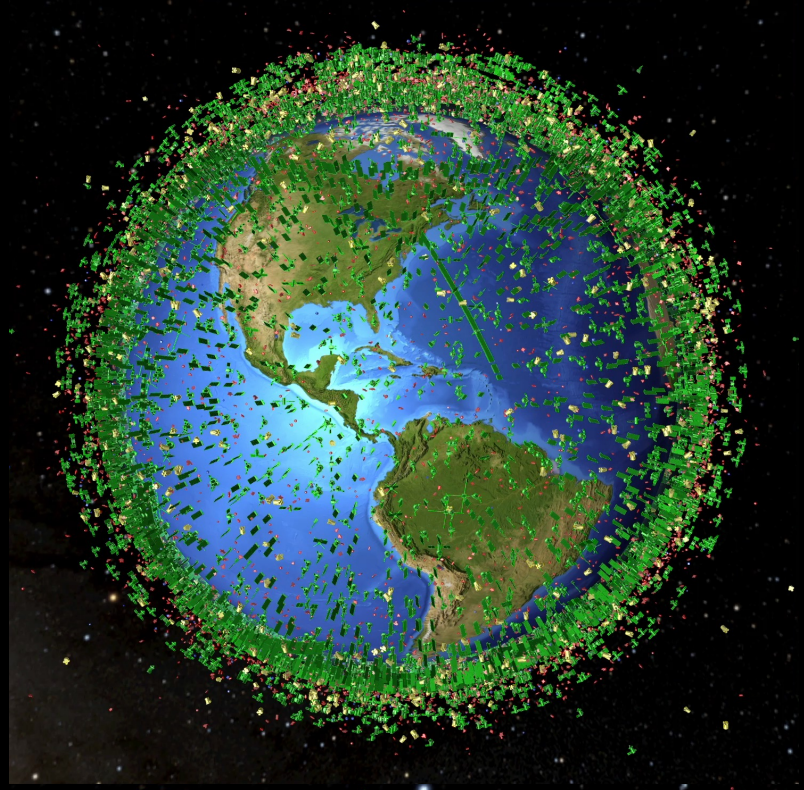
STM Concerns in LEO:

Crowding

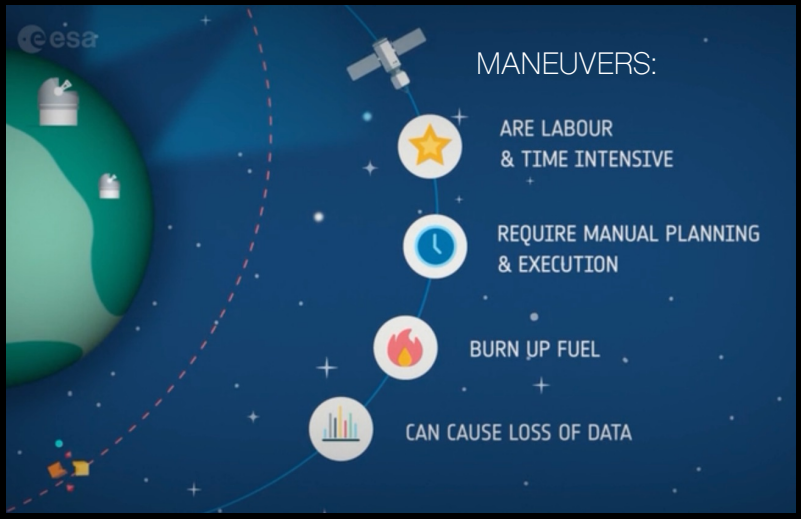
FEBRUARY 8, 2022

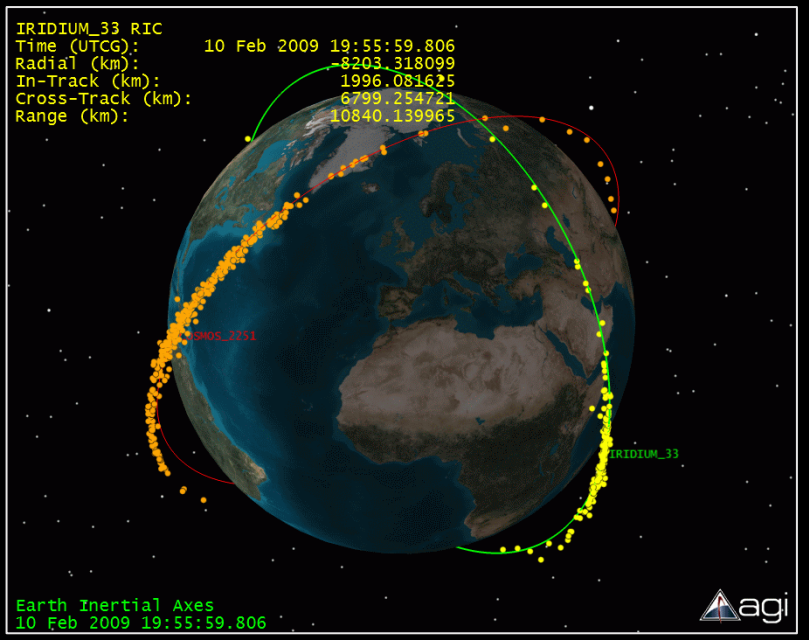
GEOMAGNETIC STORM AND RECENTLY DEPLOYED STARLINK SATELLITES

Loss of VLEO Assets



Day-to-Day CA





Collisions

Sustainable LEO Orbits

The Atmosphere naturally clears out the orbiting population:

- A collision at 500 km is much more manageable than one at 1,200 km

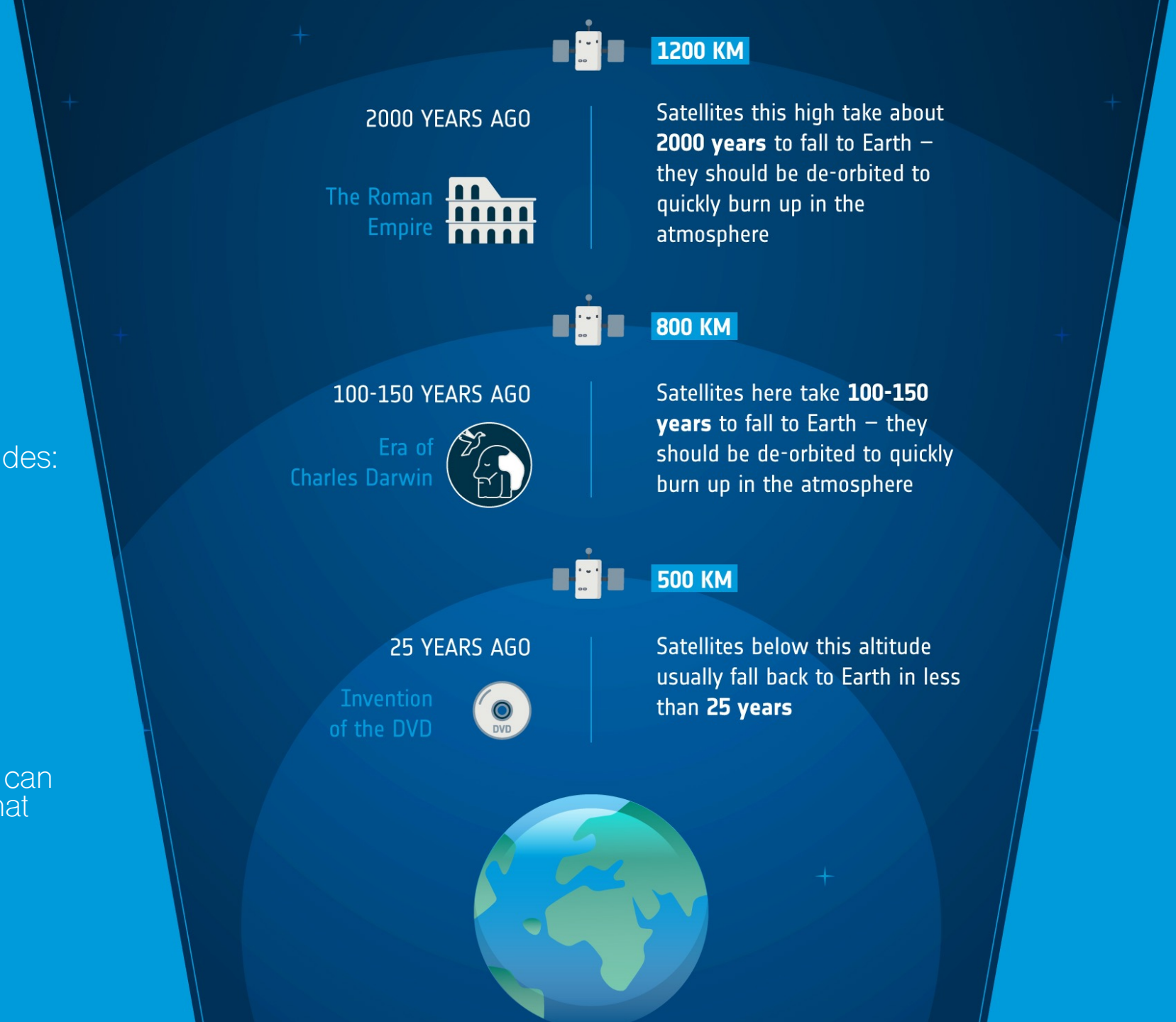
Incentives to operate at lower altitudes:

- Low-latency communications
- Lower launch fuel consumption
- Atmosphere provides a natural fail-safe to clean up debris

Disincentives to operate at lower altitudes:

- Limited ability to forecast neutral environment and predict orbits

**The Space Weather community can provide solutions to help ensure that the lowest orbits can be effectively used

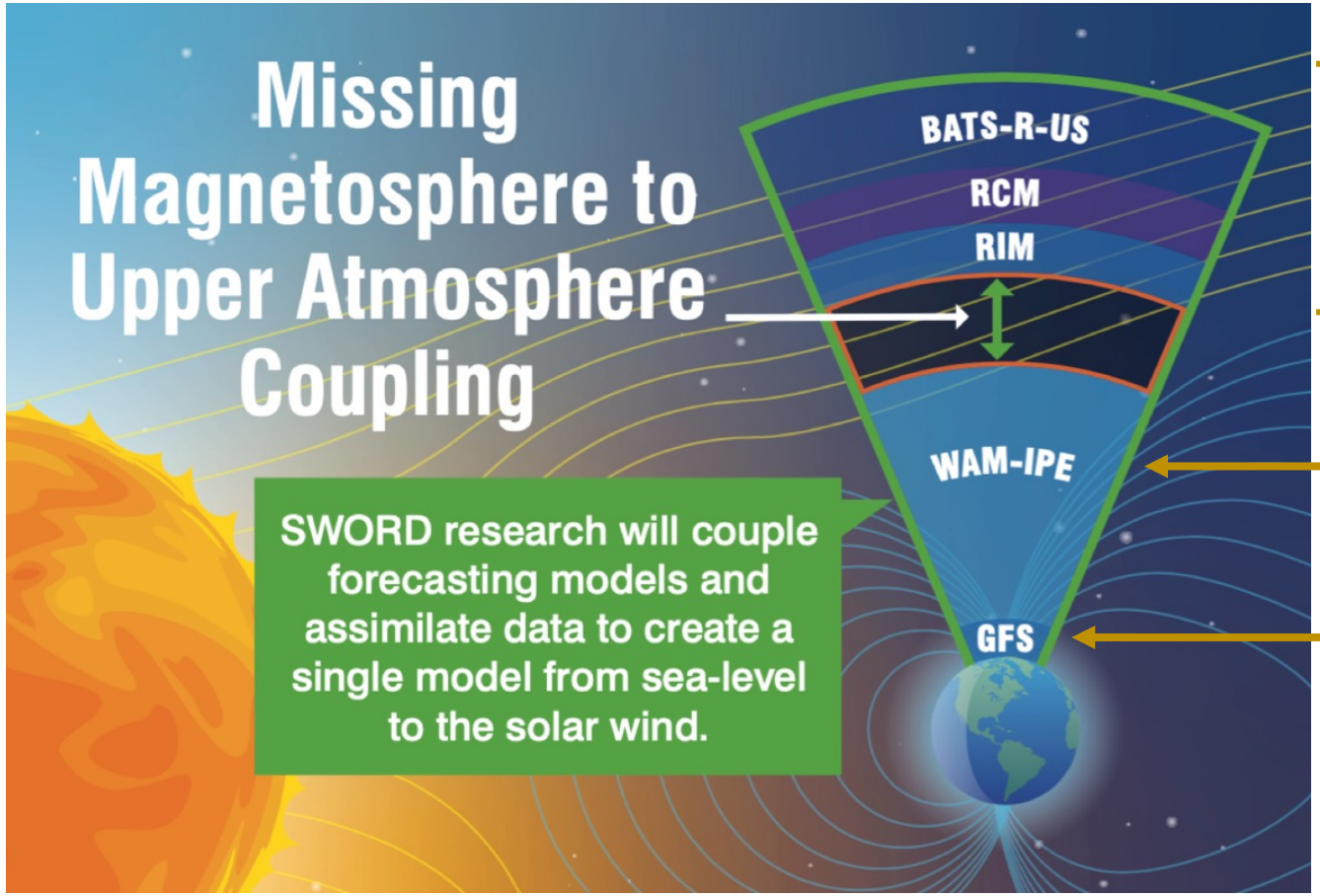


esa

UNITED NATIONS
Office for Outer Space Affairs

SWORD: Space Weather Operational Readiness and Development Center of Excellence

A **NASA Space Weather Center of Excellence** five-year project to create an *accurate and reliable* geospace forecasting model



U Mich. Space Weather Modeling Framework SWMF/Geospace
NOAA Magnetosphere model

CU Whole Atmosphere Model – Ionosphere Plasma Electrodynamics
NOAA ITM model

Global Forecasting System
NOAA Tropospheric weather model

NASA · SWx TREC · Climate and Space Sciences and Engineering · NCAR · The University of Iowa · University of Alaska Fairbanks · NOAA

Two Tracks of SWORD research

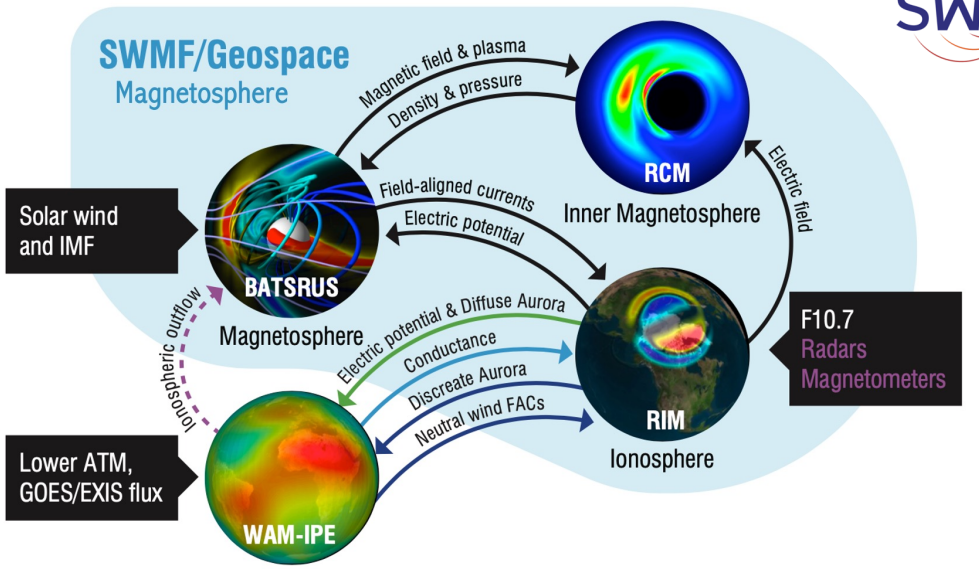
Machine Learning/Data Sciences

Track 1: Coupled Model Development

- Integrate operational WAM-IPE model into SWMF
- Couple SWMF/Geospace to SWMF/WAM-IPE

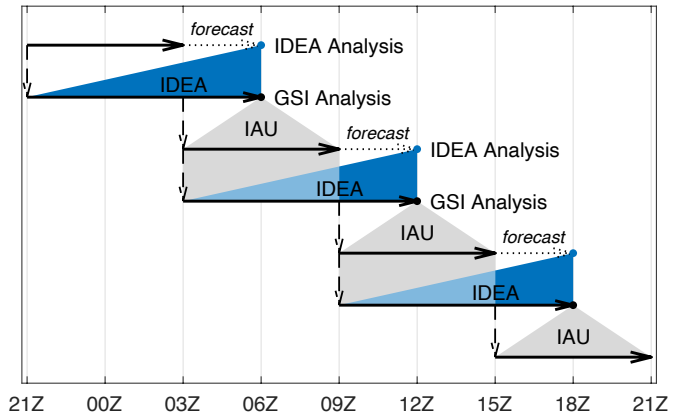
Track 2: Data Assimilation Research

- Integrate IDEA data assimilation into coupled model
- Develop FISM solar irradiance model based on GOES/EXIS data
- Develop advanced data assimilation in JEDI framework using WACCM-X



Ionosphere-Thermosphere-Mesosphere (ITM) System

Proposed WAM-IPE Data Assimilation Scheme





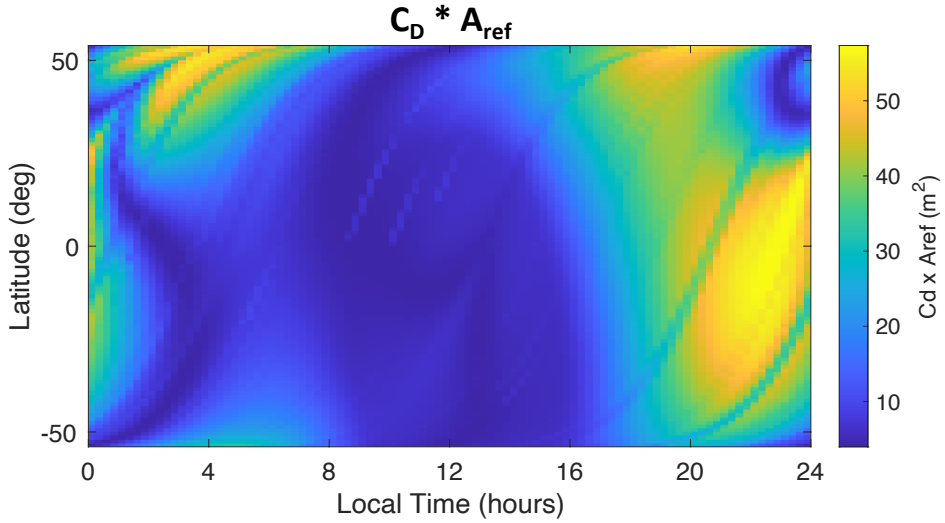


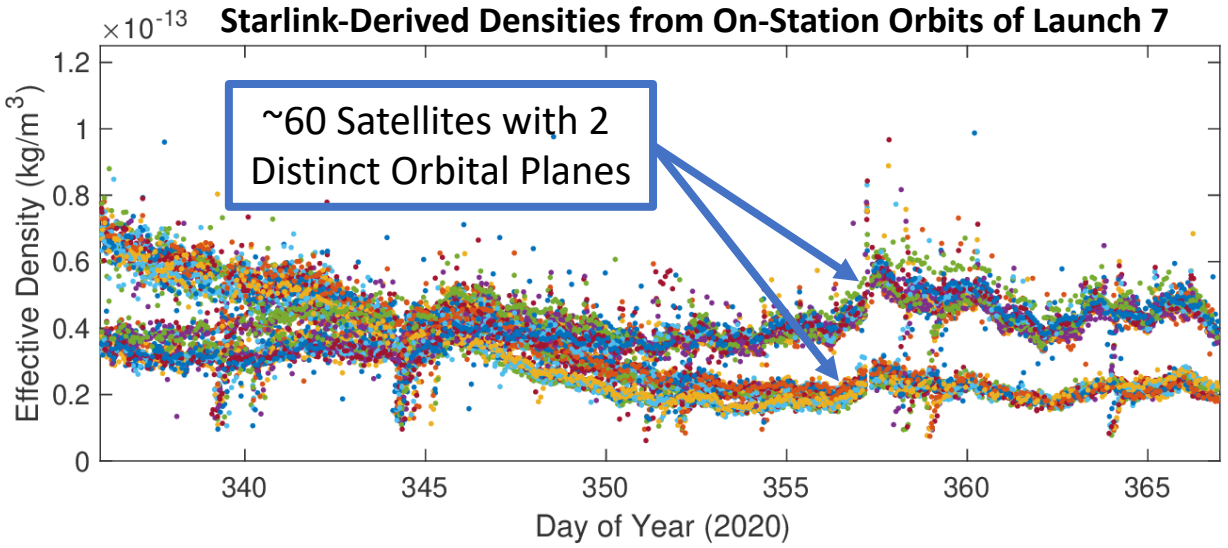

GNSS-Accelerometry Methods & Constraints:

Receiver Quality:	Single Frequency	Dual Frequency
Data Available:	Onboard Nav.	Commercial OD/POD	Raw GNSS (pseudorange/phase)
Processing Method:	Density Estimation Integrated into the POD Solution	Monitor Orbital Energy from Ephemeris
Altitude:	~400 km ←	→ 600+ km
Solar Activity:	Solar Min. ←	→ Solar Max.

Monitoring Neutral Densities from Commercial Constellations

- NOAA/NESDIS Joint Ventures sponsoring data pilot and DA with Starlink neutral densities
- Commercial satellites are non-compact, with frequent maneuvers
- Low-fidelity force models are typically used by operators and tracking agencies / companies
- Extracting information that can be generalized to another satellite or object requires high-fidelity modeling
- **We are currently processing orbit-effective neutral densities from Starlink and Spire constellations**
- A subset of these data will be used to drive a data assimilation engine with SWPC's WAM





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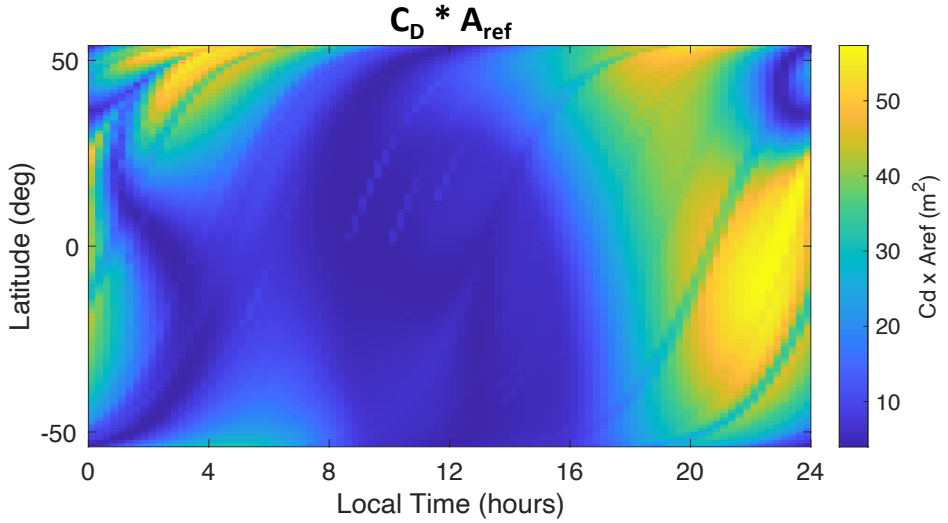

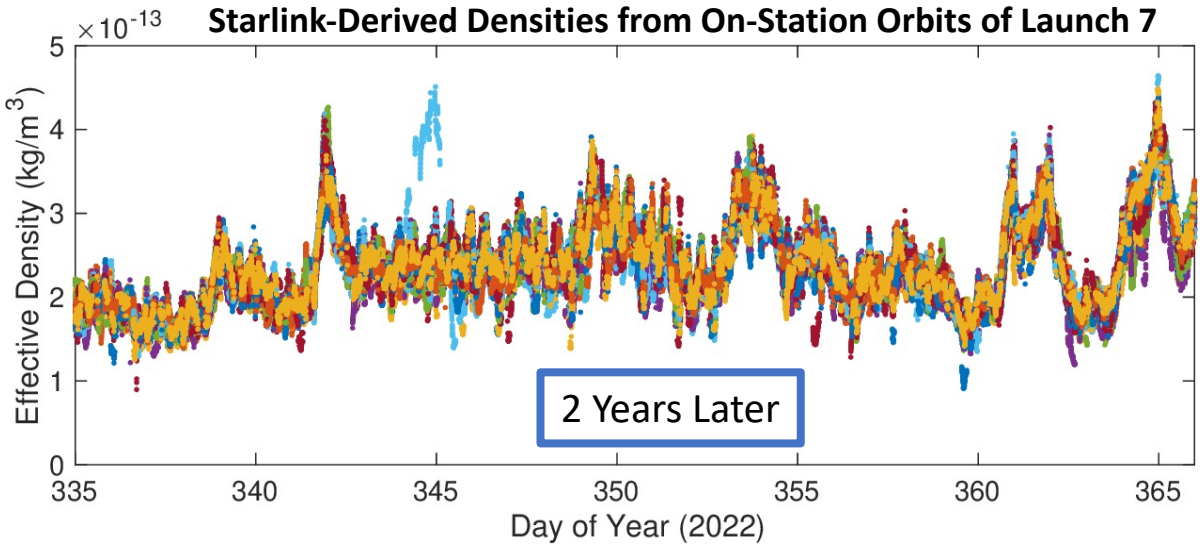

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Thank you

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We gratefully acknowledge our sponsors:

NSF AGS Program

NASA

NOAA National Environmental Satellite Data and Information Service
DEPARTMENT OF COMMERCE