Enhanced orbit prediction for comprehensive SSA in LEO

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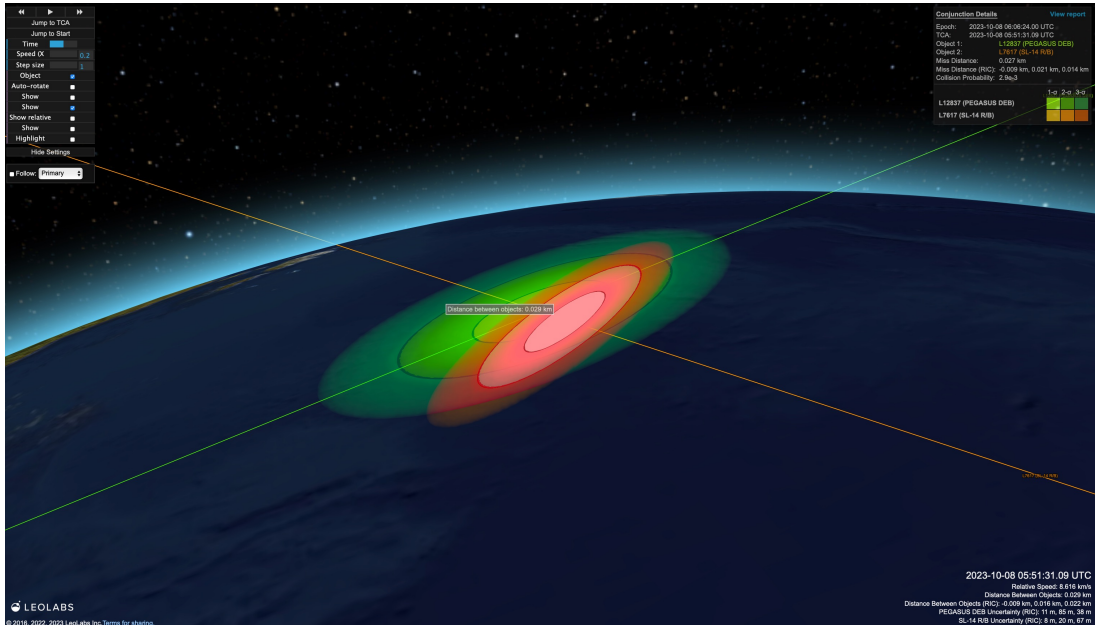
Why enhanced orbit prediction is important?

Operational requirements and associated constraints in LEO environment

- Atmospheric drag is second most significant perturbation in LEO
- Variation in upper atmospheric temperature & density, during solar cycle, impacts orbit prediction capabilities

$$a_{drag} = \frac{1}{2}\rho C_D \frac{A_{ram}}{m} v_r^2$$

- Modeling of neutral density & localized structures is important
- Poor modeling can lead to -:
  - unrealistic covariance estimation,
  - inaccurate conjunction assessment,
  - operational limitations,
  - loss of spacecraft, and/or
  - debris generation



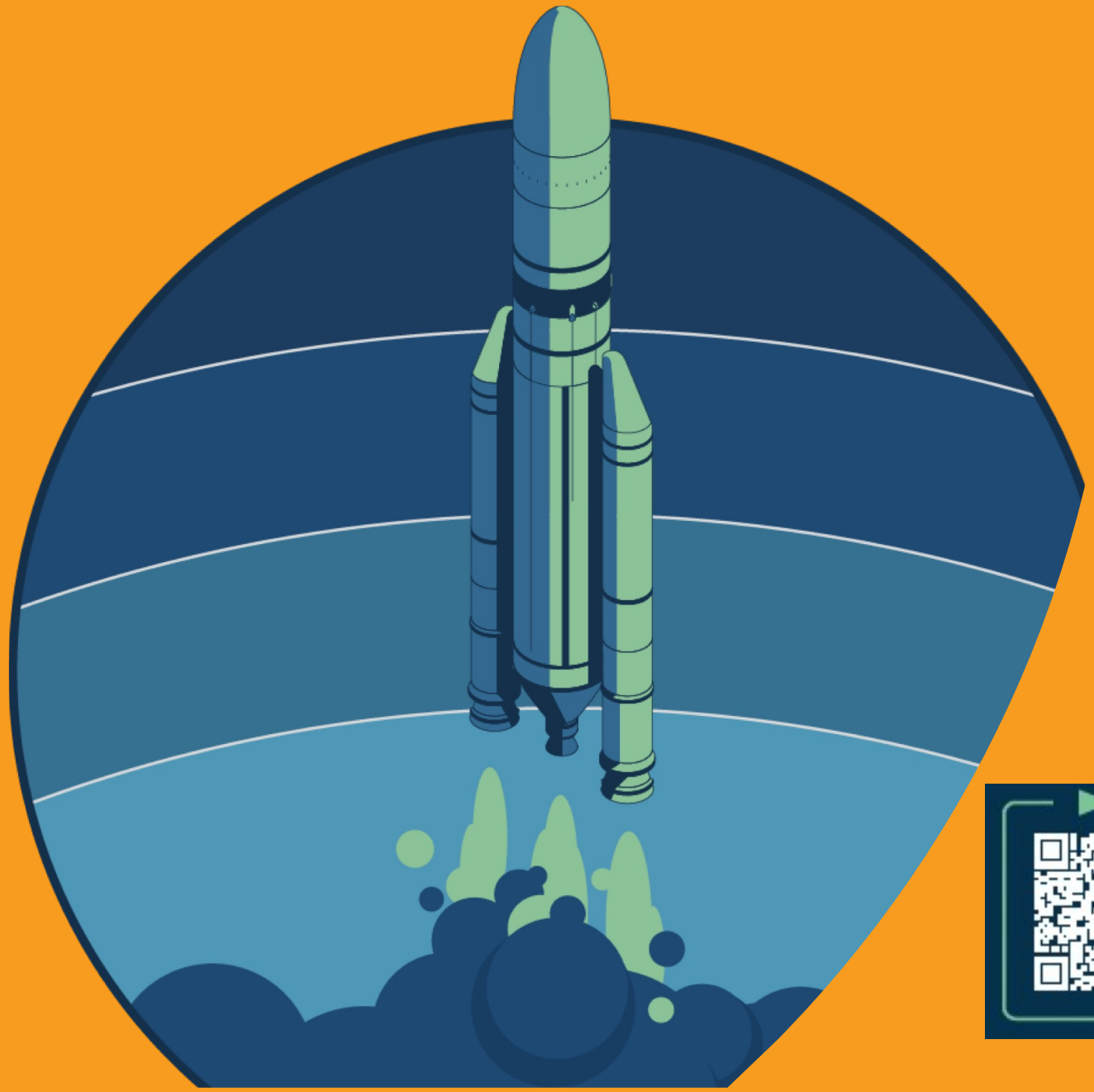
Steps taken for enhanced orbit prediction

On-going research & future opportunities

- ✓ Continuous calibration for biases, residuals, and ionospheric error using ILRS satellites
- ✓ Frequent ingestion of solar weather data files
- ✓ Realistic estimates for area to mass ratio
- ✓ Enhanced sequential filtering and process noise handling
- ❑ Move from covariance realism to uncertainty realism
- ❑ Improved drag modeling – incorporation of semi-analytical methods and better physics-based model, including WAM-IPE
- ❑ Integration of operational ephemerides for accurate modeling

Summary

- **Accurate orbit prediction requires improved modeling of atmospheric drag**
- **Knowledge sharing by NOAA-SWPC & other community members is helpful**
- **More effort is needed in following areas -:**
  - ❑ Early warning systems to enable nowcasts and forecasts
  - ❑ Effective models which are easy to integrate
  - ❑ Standardized models and best practices
  - ❑ Operationally relevant products with incorporated uncertainty estimates



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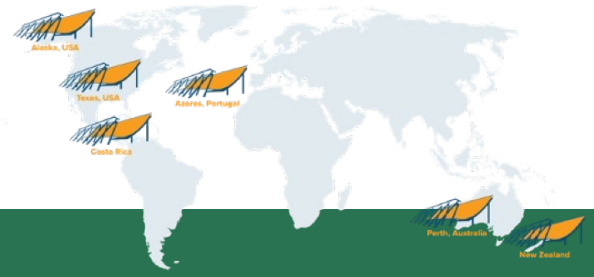
What does Comprehensive SSA mean?

A life cycle of space safety services

- ✓Vertically integrated space operations stack powered by cloud data platform
- ✓Continuous, reliable, and **accurate tracking and realistic uncertainty modeling** to enable consistent surveillance
- ✓A suite of holistic risk assessment tools provide traceable & transparent solutions
- ✓Near-real time alerts with actionable & operationally-relevant insights



LeoLabs System Metrics

Full transparency on LeoLabs system speed, accuracy, and quantity of data

Key Performance Indicators
9/24/2023 - 10/24/2023

LATENCY	ACCURACY VS TRUTH DATA	PRECISION OF STATE VECTORS
TIME - RADAR PASS TO STATE VECTOR	DIFFERENCE BETWEEN LEOLABS & TRUTH DATA	RMS UNCERTAINTY
11 MIN	41 METERS	20 METERS
RADAR PASSES	**MEASUREMENTS**	**OBJECTS**
2,545,198	42,361,595	21,099
STATE VECTORS	**OPERATIONAL EPHEMERIS SCREENINGS**	
2,417,423	948,619	

Livestream Counter
All time

MEASUREMENTS	STATE VECTORS
1,141,299,328	47,877,234

Latency

Time from when an object passes over a LeoLabs radar to when its state vector is available on the platform. Median value taken from the past 30 days.