Commercial SSA

Data Analysis: Monitoring and Cataloguing Software

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SSA solutions overview

- **SSA Software Suite**
  - Software product line for SSA operations
  - Automated processing system that generates/maintains a space catalog, and performs SSA operations functions

- **Commercial Space Operations Center (ComSpOC)**
  - Leverages SSA Software Suite to fuse observations from a global network of commercial sensors
  - Delivers commercial SSA services via SpaceBook™

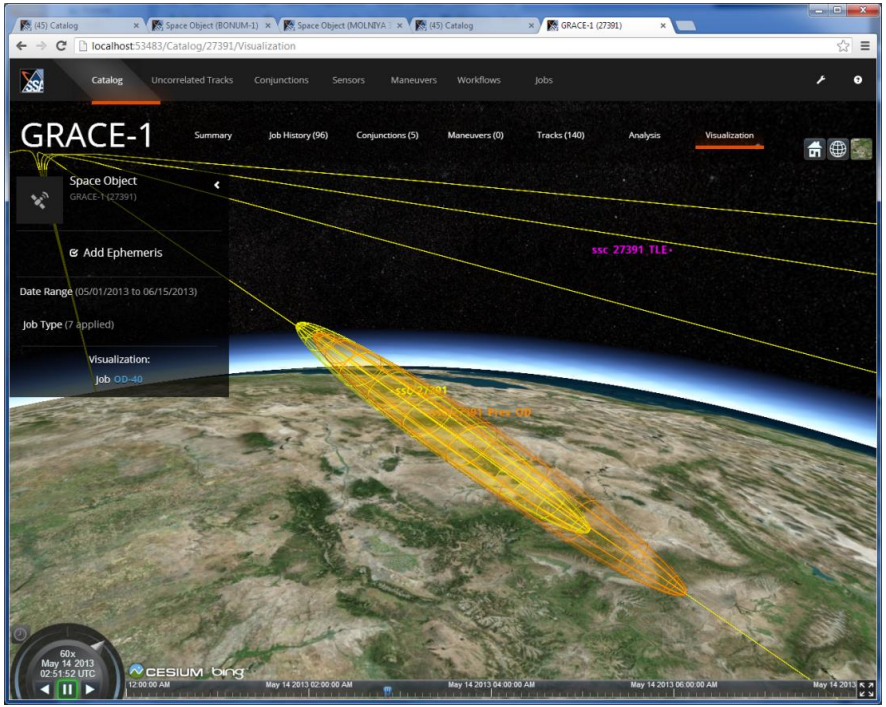
- **Space Object Threat Assessment (SOTA)**
  - Assess a space object's vulnerability to another object's actions or events
  - Decreases risk to satellite missions and increases survivability against threats
  - Performs assessments and rank orders potential threats

SSA Software Suite (SSS)

Capabilities description

SSA Software Suite capability overview

Universal measurement data processing for SSA /Space Intel Operations



- **Catalog Maintenance and Observation Processing** – Process sensor observations and perform observation association and orbit determination to generate precision state vectors and produce a High Definition Ephemeris (HiDEph) catalog.
- **Maneuver Detection, Processing, Trending & Prediction, Visualization** – Monitor observation data to identify deviations from anticipated trajectories, evaluate potential maneuver profiles, trend behaviors for future maneuver predictions, and analyze to understand implications and intent.
- **Look Angle Generation** – Provides overflight warning and sensor collect opportunities.
- **Conjunction Assessment** – Use all sources of ephemeris data to determine potential conjunctions.
- **Mission Analysis Application** – Integrate SSA and space defense capabilities in a web-based, network centric infrastructure with integrated visualization.

Sensor agnostic data processing & fusion

Sensor Sources

Traditional
- SSN, SBSS
- Fylingdales
- Vardo
- Sapphire
- GRAVES
- TIRA
- ESTRACK (ESA)
- ISTRAC (ISRO)
- EISCAT
- Chibolton
- Other

Non-traditional
- Missile warning
- Missile defense
- Mission data
- Hosted payloads
- OPIR
- Owner / operator
- Telescopes

Sensor Measurements

Ground
- 2-way range
- Bistatic range
- Doppler
- Az / El angles
- RA / Dec angles
- X / Y angles
- Direction cosines
- Phased array
- Deep Space Network (DSN)
- TDOA, FDOA
- TDRS
- GPS ground rcvr.

Space based
- RA / DEC angles
- Az / El angles
- Range
- GNSS (GPS, QZSS, Galileo)
- TDOA, FDOA
- TDRS
- Doppler
- Ephemeris

Sensor Tracking Formats
- SSN, B3
- SLR (laser ranging)
- RINEX (GPS)
- NASA UTDF and GEOS-C
- DSN TRK-2-34
- CCSDS Tracking Data Message (TDM)
- AFSCN
- Tracking data reader
- User defined / custom

Commercial SSA Data processing and Validation

Summary

- Validation is an ongoing process
  - Initial calibration to determine sensor performance
  - Detailed calibration across multiple known satellites
  - Ongoing validation and curation to ensure optimal performance
- Very diverse commercial sensor networks and Optimal Sequential Filter processing affords high confidence results

Basic validation steps

- Sensor location
- Coordinate reference frame
- Time tag reference
- Light time delay and other corrections
- Units

Determine measurement accuracy

- Obtain metric observations on objects with “truth” ephemeris
  - PNT: GPS, GLONASS, QZSS, Galileo and Beidou
  - Satellite Laser Ranging (SLR) targets
  - Space Based Augmentation System (SBAS)
- Compare measurements to truth – residuals vs reference process
  - Establish typical “noise” level of sensor
  - Identify potential biases
- Use Optimal Sequential to estimate sensor biases
  - Solve for biases based on truth data
  - Characterize how fast the biases are drifting
- Additional details in 2015 AMOS paper: http://www.amostech.com/TechnicalPapers/2015/Poster/JohnsonT.pdf

Commercial SSA Data Curation

Calibration and consistency

- ComSpOC sensors are frequently calibrated against known truth sources including:
  - Global Navigation Satellite System (GNSS) satellites
  - Satellite Laser Ranging (SLR)
  - Space Based Augmentation System (SBAS)
  - GPS derived O/O ephemeris

- ComSpOC-derived ephemerides are compared daily to the ephemerides of these truth sources

- ComSpOC-predict ephemerides are compared against ComSpOC-actual ephemerides after every orbit determination (OD)

Comparisons to other data sources

- ComSpOC frequently compares its ephemerides against other sources
  - Two Line Element (TLE) sets
  - Special Perturbations (SP) ephemeris
    - Dependent on access to SP data
  - Satellite Owner/operator ephemeris
- In cases where comparison data is available, SSA Software Suite processing has demonstrated the following:
  - Ability to provide significant accuracy improvements over public TLEs
  - Ability to provide equivalent accuracy of SP ephemeris when compared to an independent truth source while requiring less tracking data
    - Particularly evident with maneuvering GEO and LEO satellites

Dynamic data rejection

- **High fidelity calibration enables automated rejection of bad data**
  - Detailed understanding of measurement uncertainty
  - Detailed model for dynamic forces acting on the satellite
  - Solve for corrections to those forces with every measurement
    - Drag
    - Solar Radiation Pressure
    - Atmospheric Density
    - Planned maneuvers
    - Others

- **If measurements deviate from the predicted location PLUS uncertainty they are automatically rejected**
  - Bad measurements (mis-tags)
  - A maneuver or other force inducing anomaly (out-gassing)
  - Potential data corruption

AGI's Optimal Sequential Filter Implementation = SSA "Lie Detector"

Multi-phenomenology Verification

- Collect and process with as many phenomenologies as possible
  - Radar
  - Optical
  - Passive RF
  - Laser

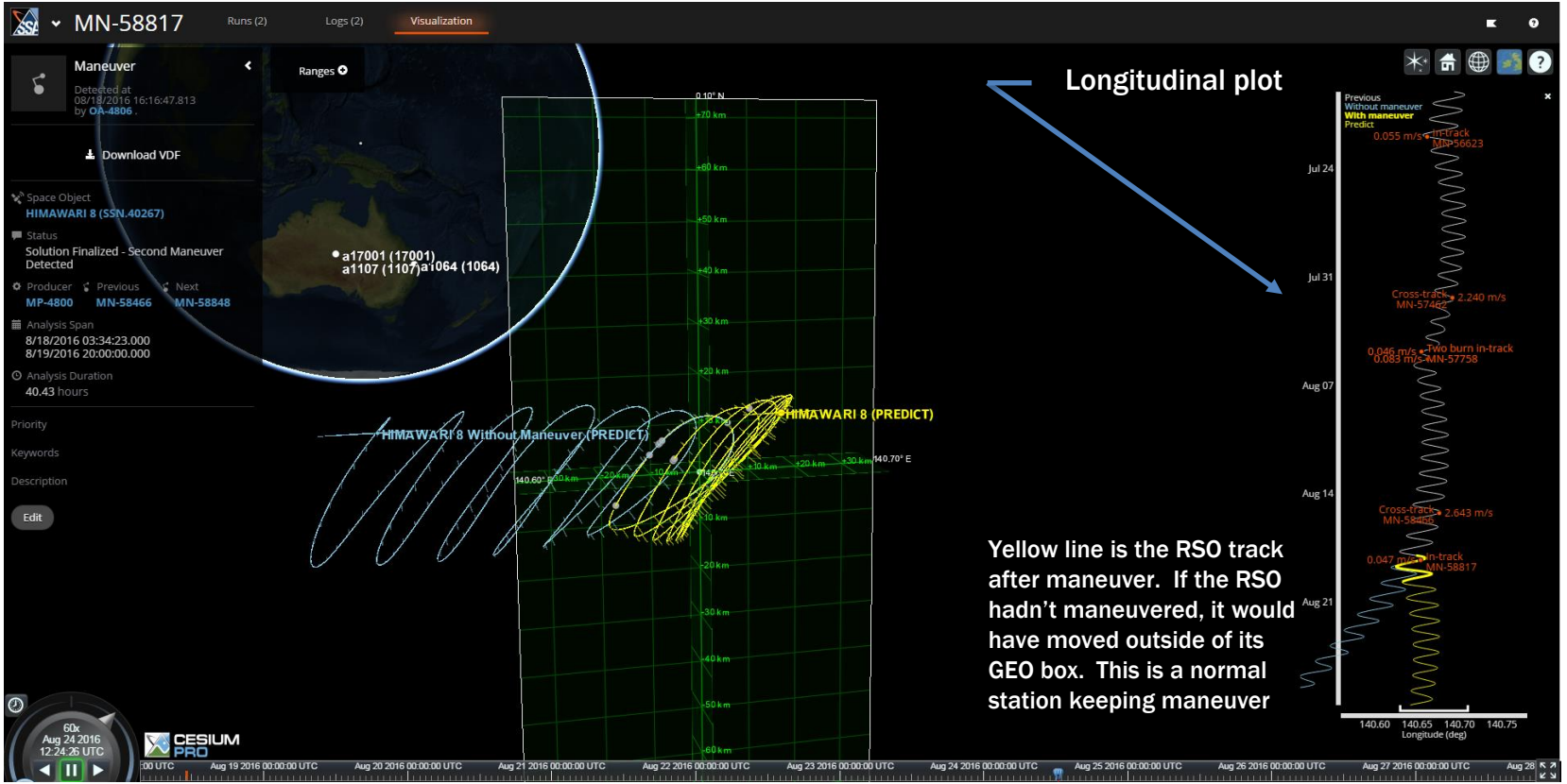
- View from as many independent sites as possible
  - ComSpOC leverages sensors on five continents

Comparisons against reference orbits

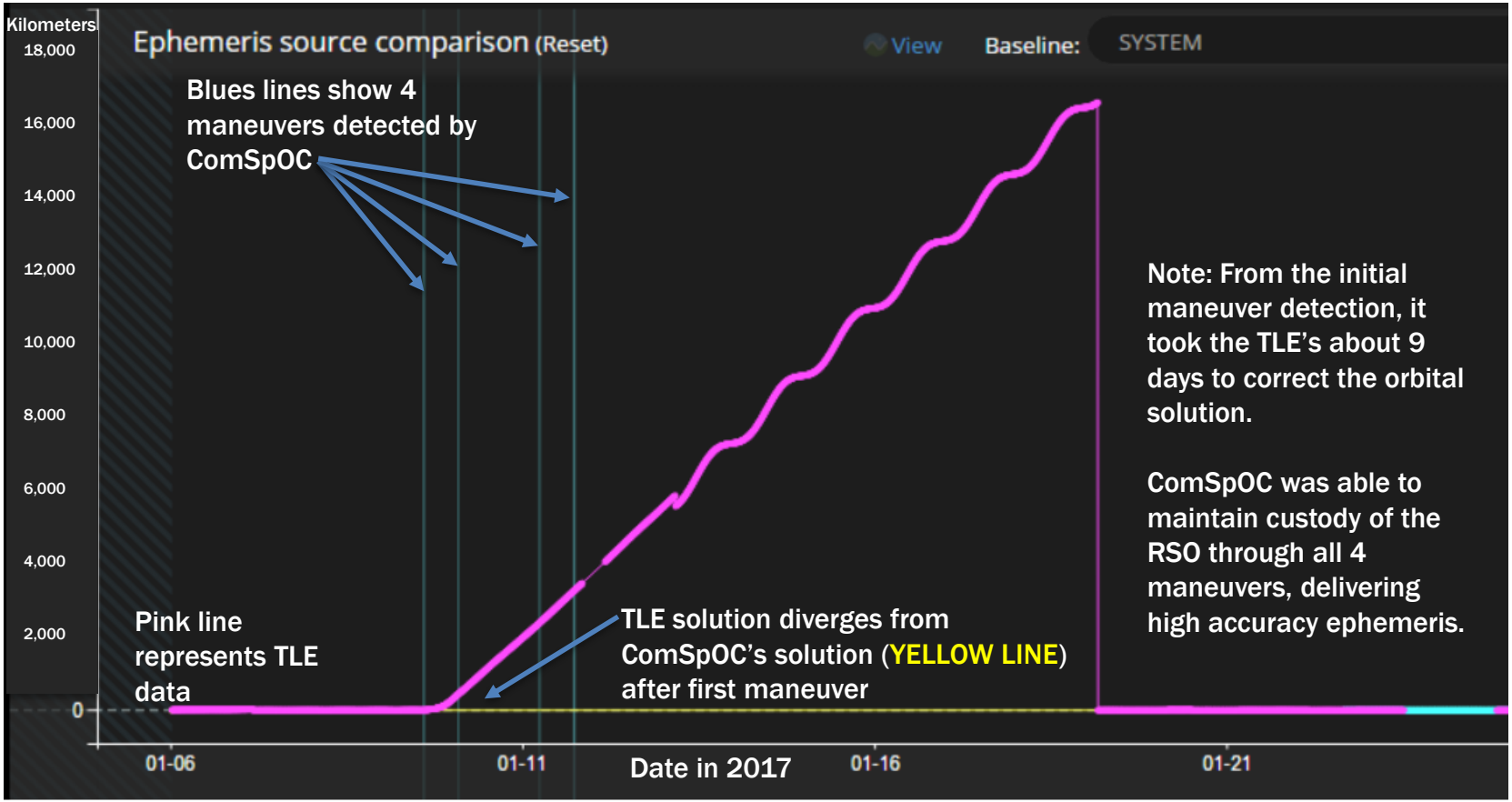
- **For maneuvering GEOs:**
  - Typical AGI SSA Software processing difference: 40-200 m
  - Typical TLE: 10-30 km
    - Can improve to 1-2 km when significant deep space radar tracking available
- **For LEO:**
  - Typical AGI SSA Software processing difference: 25-75 m
    - Required significantly less tracking data to derive this result
  - Typical TLE difference: 5-10 km

Real-world events

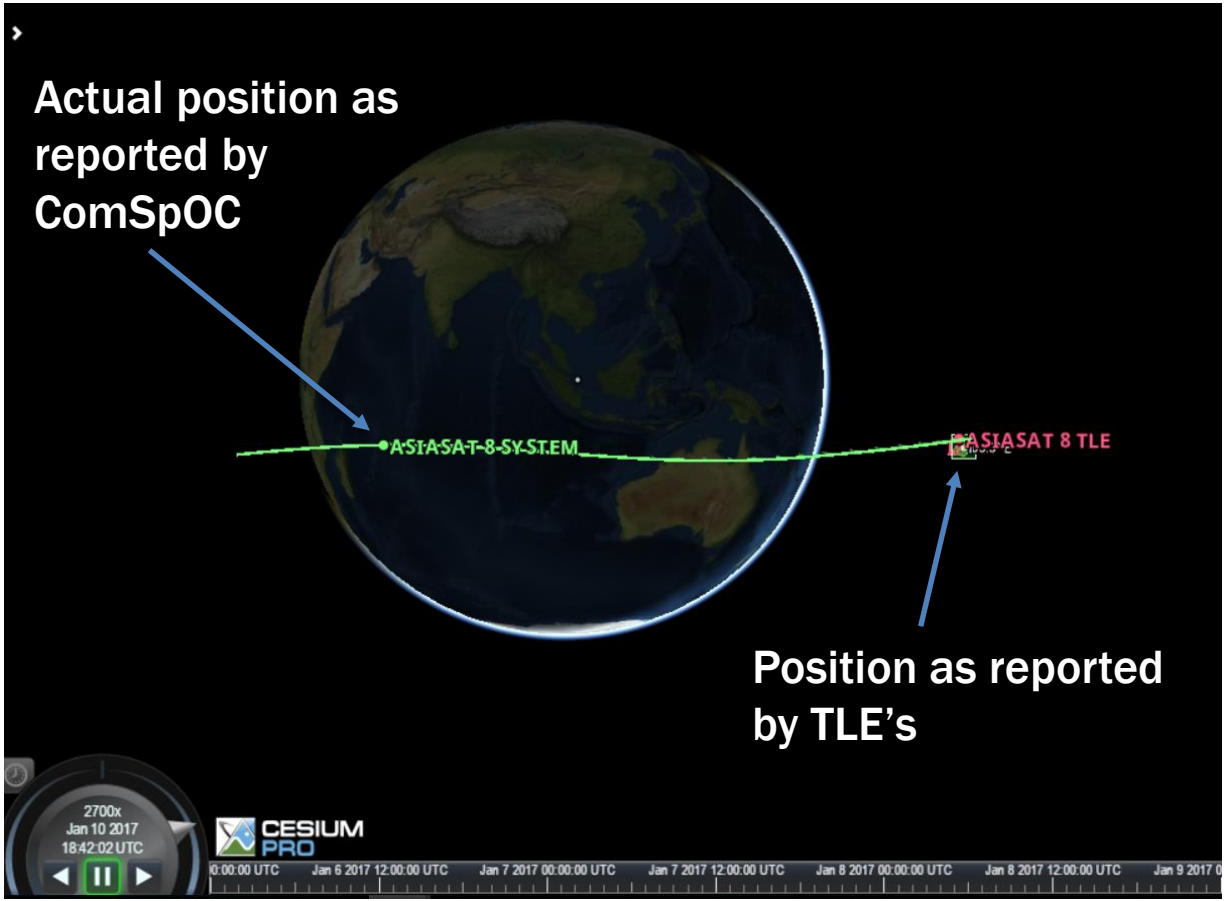
SpaceBook™ maneuver visualization



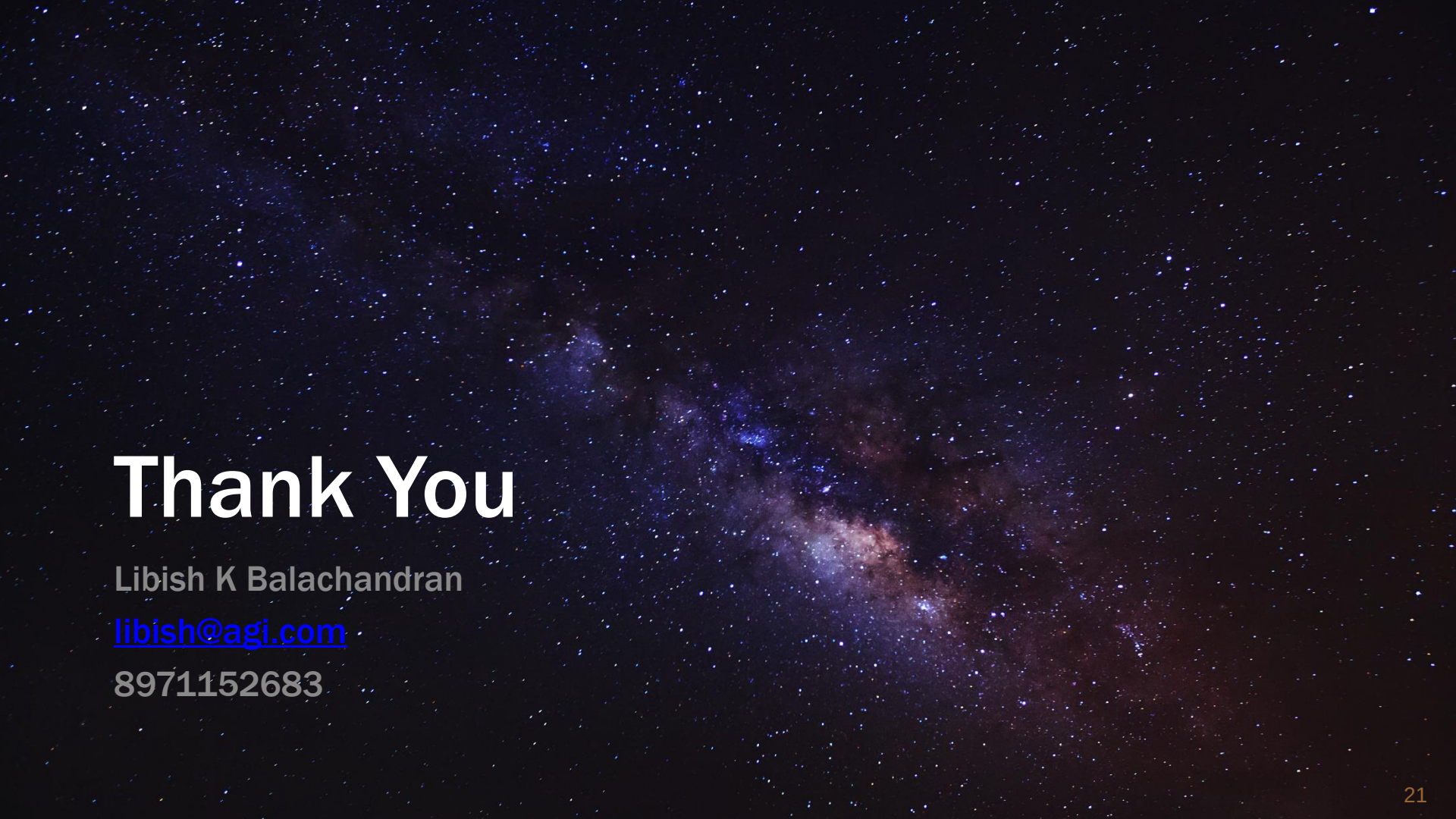
ASIASAT 8 Maneuver Responsiveness



ASIASAT 8 maneuver responsiveness




SRI International: Radar and RF Facilities


Thank You
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