SPACE DATA
ASSOCIATION

www.space-data.org

SDA Users Meeting: General Forum

12 March 2012

Early Afternoon Agenda:
SDA General Forum (15:00-17:00)

- Welcome
- What is the SDA and SDC, and Why Do You Need It? (Sanders)
- How SDA protects your data and you (D'Uva)
- SDA 2012 Key Initiatives (Sanders)
- Technical SDC Aspects (Oltrogge/Vallado/Chan/Kelso)
- General Q & A (Sanders)

SDA Users Meeting: SDA General Forum

WHAT IS THE SDA, SDC, AND WHY DO YOU NEED IT?

SANDERS/CHAN/KELSO

What is the Space Data Association?

- The Space Data Association (SDA) is a not-for-profit association formed by and for satellite operators to provide reliable and efficient data-sharing critical to the safety and integrity of the space environment and the RF spectrum.

- The SDA was founded by **Inmarsat**, **Intelsat** and **SES** — three of the leading global satellite communications companies. These three companies, plus **Eutelsat**, now form the Executive Board of the SDA.

SDA Charter

- Seek and facilitate improvements in the safety and integrity of satellite operations through wider and improved coordination between satellite operators

- Seek and facilitate improved management of the shared resources of the Space Environment and the RF Spectrum

Why was the SDA created?

- **Enhance "Safety of flight"**
  - Maintain the long-term viability of satellites and their orbit regimes
- **To improve the accuracy of collision avoidance predictions**
  - Expand satellite operator participation
  - Adopt best practices across industry
  - Provide necessary framework for full operations (legal, technical)
  - Address ops. issues with current cross-industry conjunction coord.
    - Reduce false alarms, missed events
    - Minimize member time and resources devoted to CA
- **To take advantage of opportunities for other data sharing**
  - RFI mitigation, including data for RFI geolocation
  - Company contacts
  - General operations data sharing

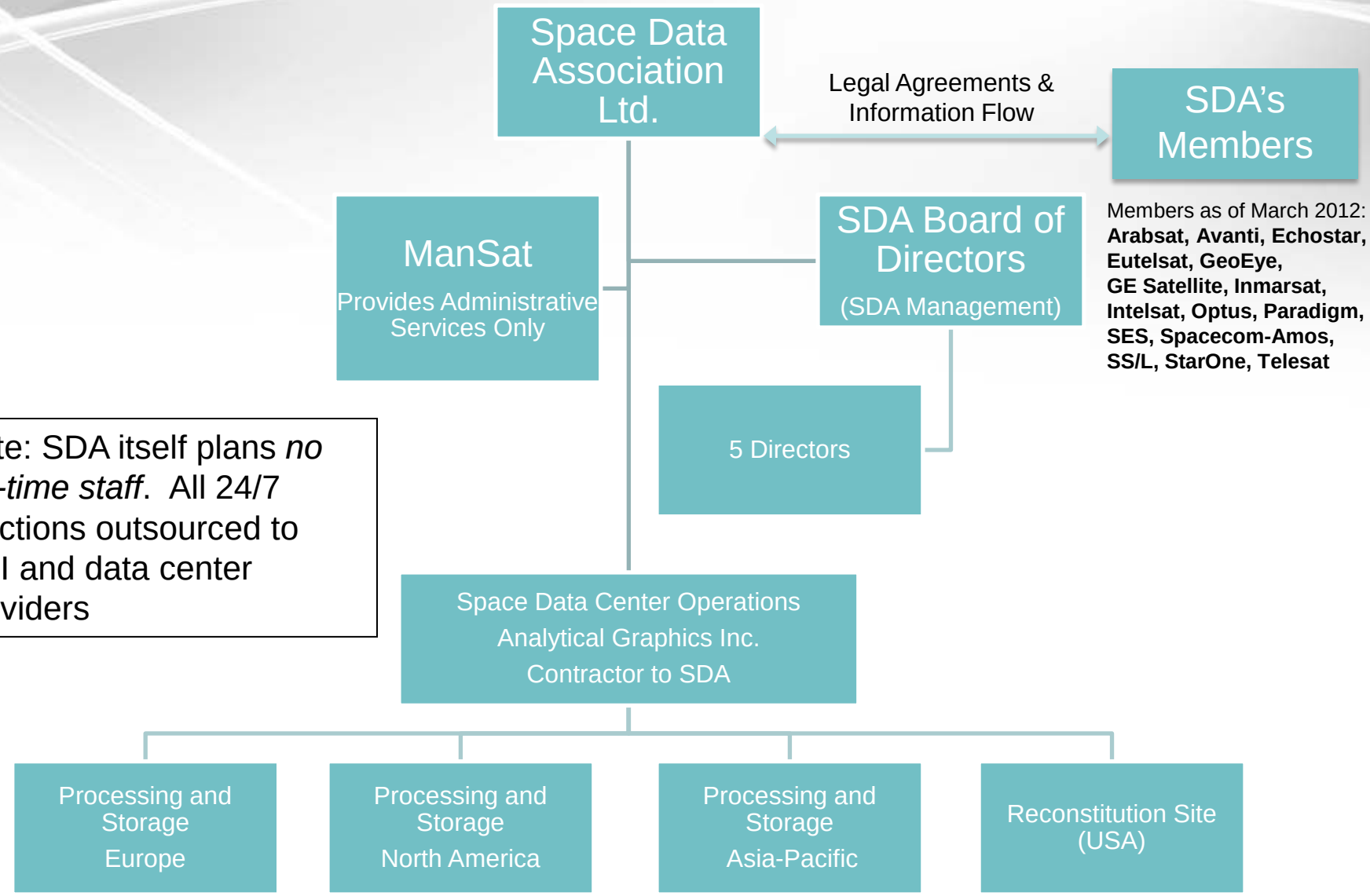
Conclusion: SDA Enhances its Members' Satellite Operations

SDA Status

- **SDA established as a legal entity in the Isle of Man**
  - Provides necessary legal framework for sharing and protection of data
- **Space Data Center (SDC) system built by Analytical Graphics, Inc. (AGI)**
  - System has now achieved Full Operations Capability, providing Conjunction Assessment service to its members
- **Growing membership**
  - Currently fifteen satellite operators from Geosynchronous and LEO orbital regimes
  - As of February 2012, CA Processing for approximately 237 GEO satellites (more than 65% of all GEO satellites) and 110 LEO/other orbit satellites

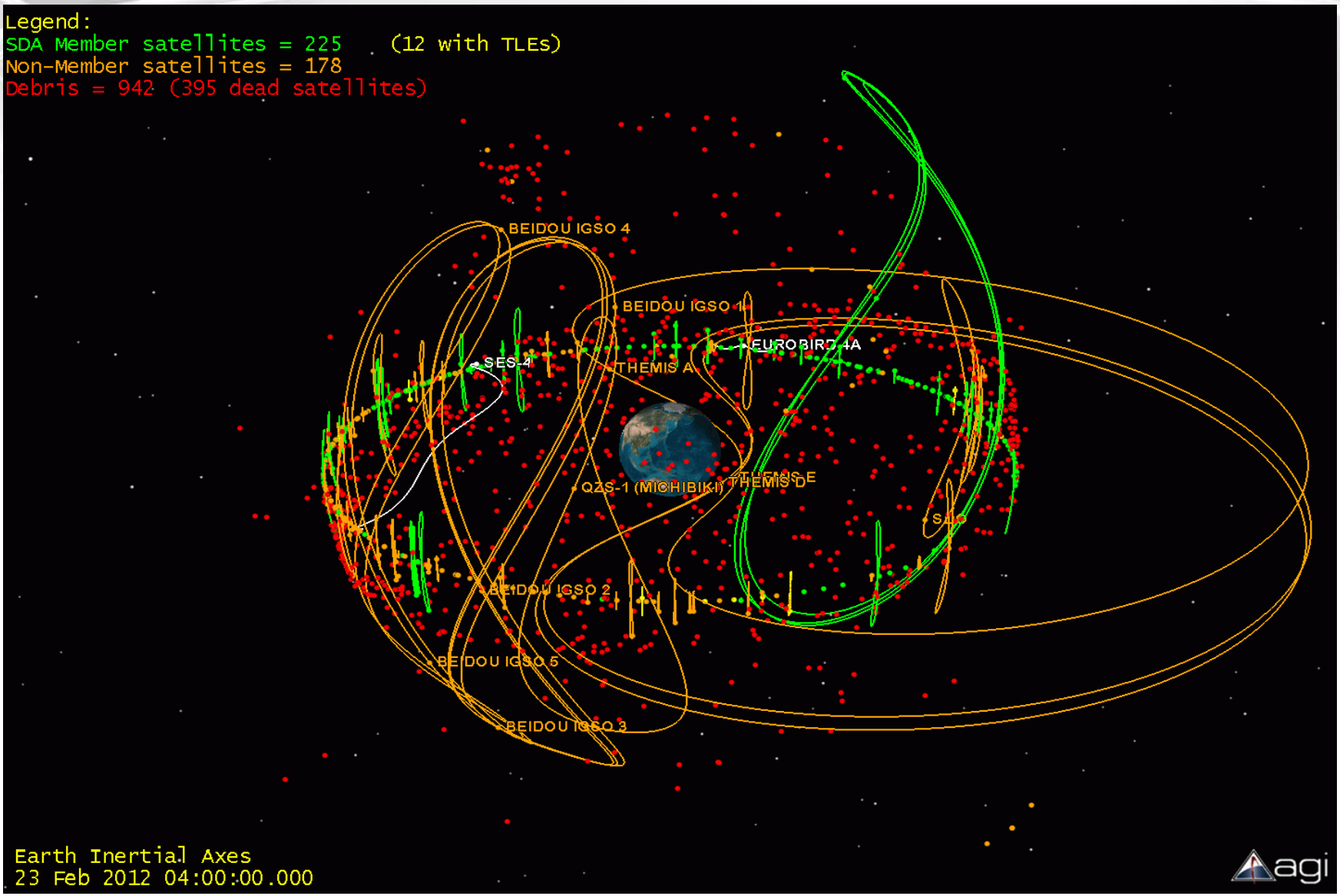
Multinational, open to all space operators

SDA Organization



Note: SDA itself plans *no full-time staff*. All 24/7 functions outsourced to AGI and data center providers

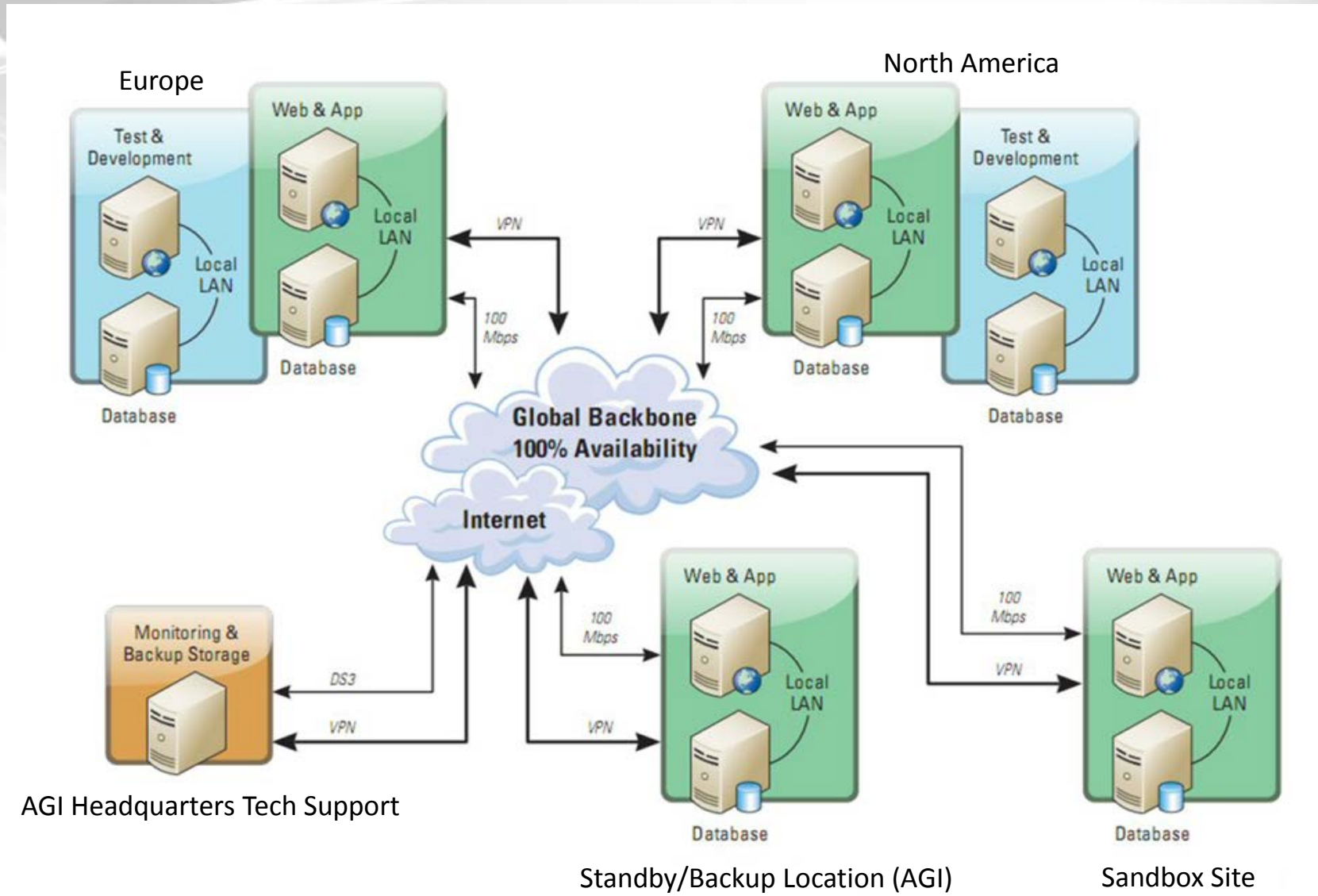
In-Orbit objects as of March 2012



Space Data Center (SDC)

- **The SDC is the processing system of the SDA**
- **SDC – Three Key Mission Areas:**
  - Collision avoidance monitoring (Conjunction Assessment)/ Manoeuvre Planning Validation / Flight Safety
  - Radio Frequency Interference mitigation / Geolocation support
  - Contact information (operations center) for SDA Member objects
- **SDC reliable and secure operation:**
  - Tertiary, geographically separated redundancy
  - High level data security and encryption
  - Best practice Information Assurance (IA) based on standards for high level computing systems

Current SDC Network Architecture



What data will be shared?

- **Data sharing will be defined by the type of service:**
  - **Points of Contact**: Operations points of contact
  - **Conjunction Assessment (CA)**: Orbital data and manoeuvre plans
  - **RF Data Sharing**: RF data including sat. config., ref. carriers, etc.
  - **RFI Alert**: RFI event reports
  - **Enhanced Services**: All of above plus agreement to share data with approved 3rd parties in return for access to enhanced services (geolocations, other data sources)
- **Third party access to data (Enhanced Services only) will be strictly controlled as agreed by SDA Members**
- **All members must participate in Points of Contact and Conjunction Assessment but can choose whether to participate in other services**
- **Participation in a service requires Member to provide associated data**

Why is data sharing through the SDA important?

- **Data from other sources has proven to be unreliable**
  - TLEs for conjunction assessment are insufficient
  - Conjunction Summary Messages (CSMs) for active satellites are not accurate, and do not incorporate maneuvers
- **Operators' own data is one of the best sources**
  - Facilitate operator-to-operator sharing
- **SDC can ensure common data formats/data is current**
  - Automated conversion of ephemerides to common format
- **SDA can help operators validate data**
  - Periodic calibration of data
- **Data automatically available**
  - Checks on data validity
  - Available on system, no manual intervention

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HOW SDA PROTECTS YOUR DATA AND YOU

D'UVA

Participating in the SDA

- Meet the membership criteria & apply
- Obtain SDA approval
- Agree to Space Data Centre Terms & Conditions Comply with Isle of Man & business formalities
- Complete SDC data acceptance and validation process for your satellite data
- Receive SDA services

Legal Liability Objectives

- **SDA legal arrangements intended to:**
  - Encourage data contribution & use
  - Protect data from deliberate misuse
  - Allow contribution and use of data on “as is” basis

Data Use Control / Legal

- **How does SDA obtain & protect member data?**
  - Legal agreements between subscribers and SDA
    - Permitted Uses for SDC data/products
    - Prohibited Uses for SDC data/products
    - Retransmission to third parties prohibited
    - Obligations for member data contribution
    - Legal liability issues are addressed by enforceable contract
      - Isle of Man law allows the members to enforce the terms of the agreement directly against other members
  - Multiple technical / security controls within SDC

Permitted & Prohibited Uses

- **SDC - Permitted Uses:**
  - Operational support, including Safety of Flight
  - EMI/RFI resolution of actual harmful interference, including at ITU
  - Support for insurance underwriting
  - As legally required by national regulatory authorities
- **SDC - Prohibited Uses:**
  - Any commercial purposes (sales, planning, marketing, etc.)
  - Securing orbital-spectrum rights
  - Transmittal to 3rd parties (except for Safety of Flight)
  - **Any other use that is not a Permitted Use**

SDC Data Sources (As of 12 Mar 12)

Data and Source	Purpose
GP Two-Line Elements (space-track.org)	Conjunction Assessment (CA) for objects not in SDC (e.g., debris)
SDA Member Ephemerides and planned maneuvers (SDA Members) *Measured by operators (ranging, etc.)*	Populate SDC with current Member object information for CA and EMI/RFI support
SDA Member satellite and operations center / POC details	EMI/RFI resolution & Geolocation support Populate “phone book”

Member Data Contributed

SDC Mission Area	Data Contributed by Member for Its Fleet	Other Member Direct Data Access?
CA & Maneuver Planning Safety of Flight	Measured Ephemerides Planned Maneuvers	Only for identified conjunctions Analysis products provided
EMI/RFI Resolution RFI Alerts Service	Satellite communications payload configuration Reference Emitters / Calibrators Satellite beam configuration & patterns Local Oscillator / Translation Frequencies Nominal Satellite Longitude Stationkeeping box size per satellite RFI event alerts	Some, but primarily analysis products provided
Operational Contact Information	Satellite bus and payload Control Center Information for each satellite	Yes

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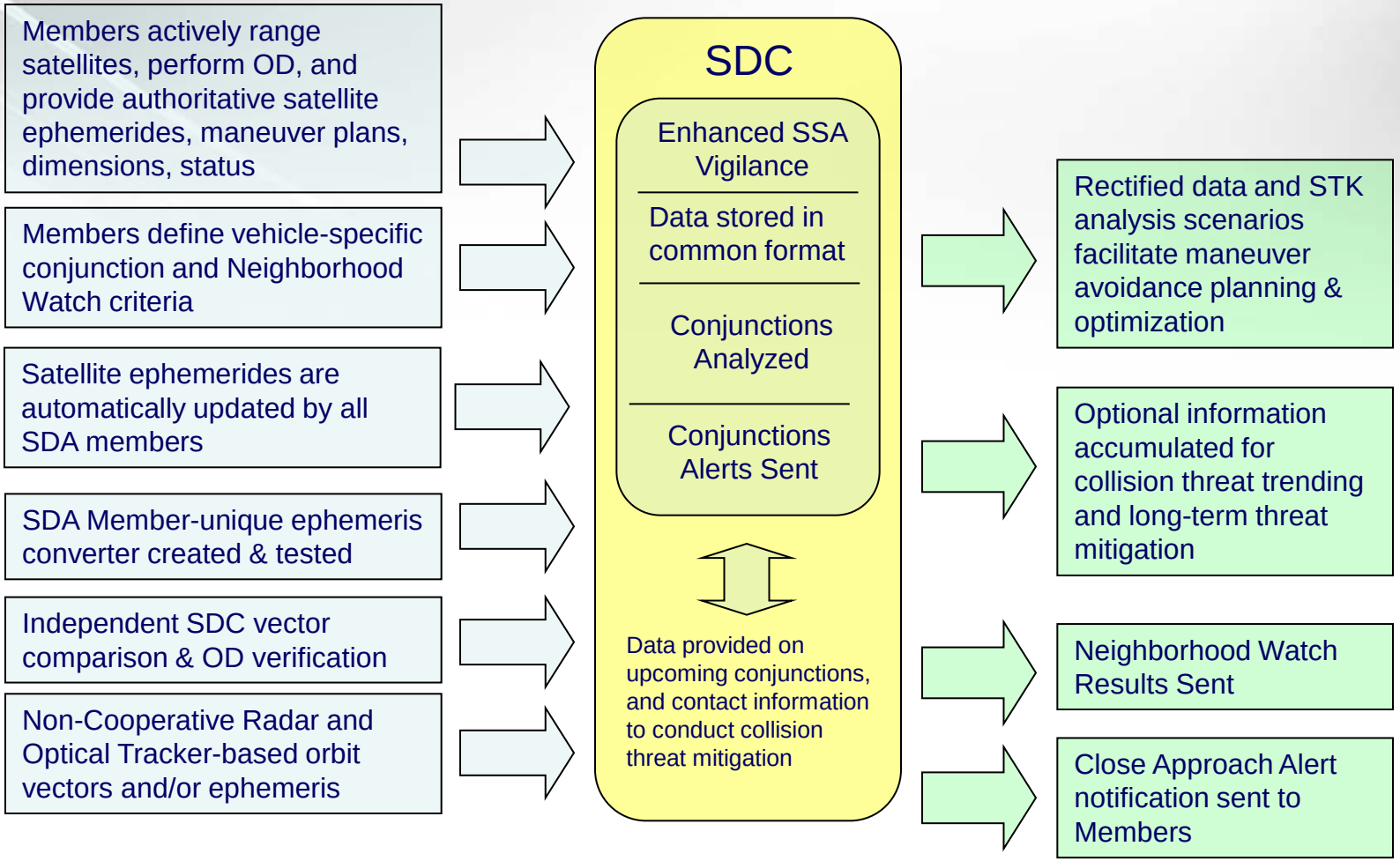
SDA 2012 KEY INITIATIVES

SANDERS

Key Initiatives

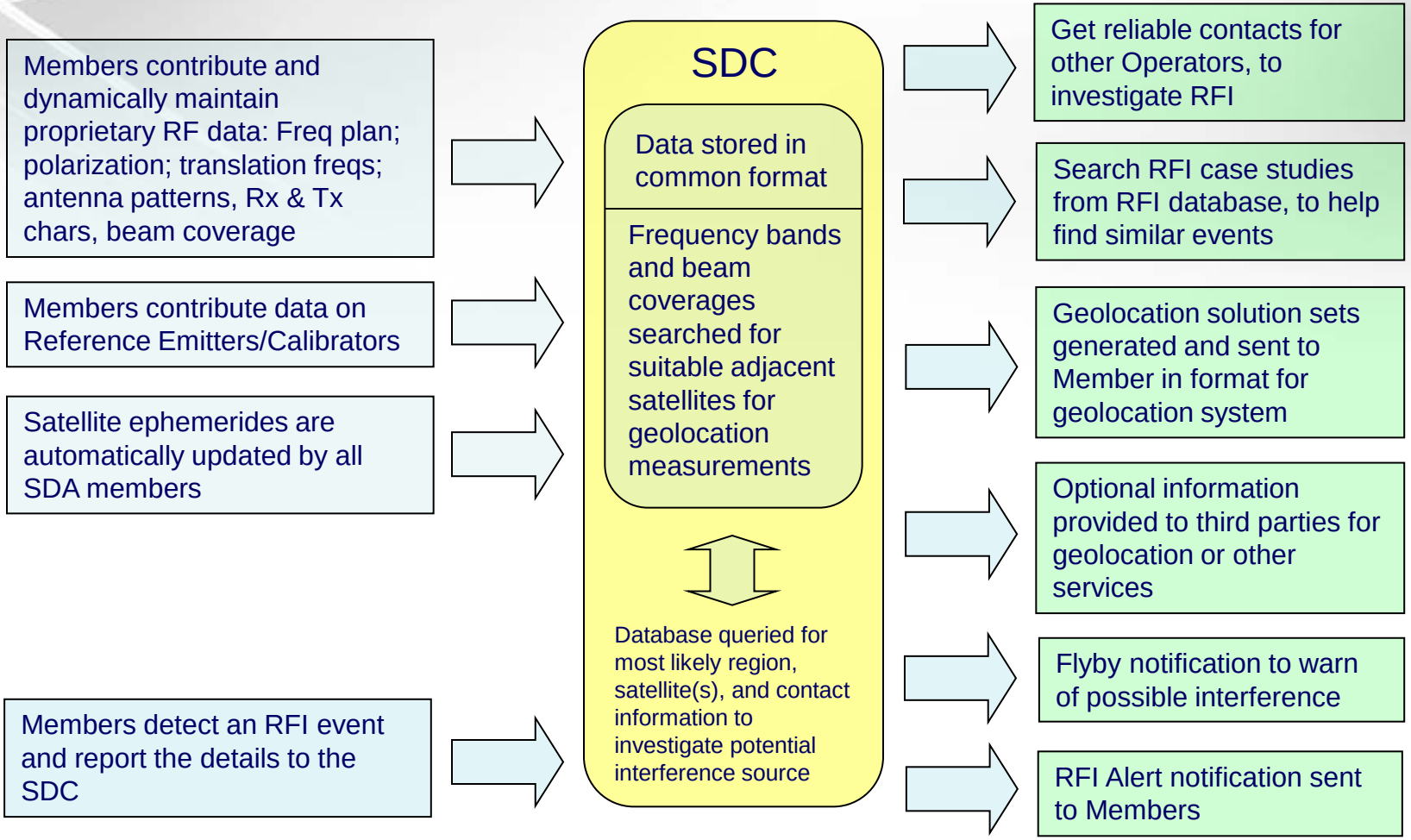
- **Grow membership**
  - Goal is for 100% membership of all operators in all regimes
- **Develop Government and industry relationships**
  - Seek cooperation with US and other Governments
  - Data sharing and improve best practices for all parties
- **Secure access to additional data sources**
  - Improve accuracy of data, particularly for non-active objects and debris
- **Develop space insurance relationships**
  - Aim to secure preferred terms for SDA members since we are better managing risk
- **Implement data sharing for RFI mitigation**

SDC CA Process Flow



System allows faster investigation of CA events, enabling responsive and accurate threat mitigation

SDA RFI Planned Process Flow

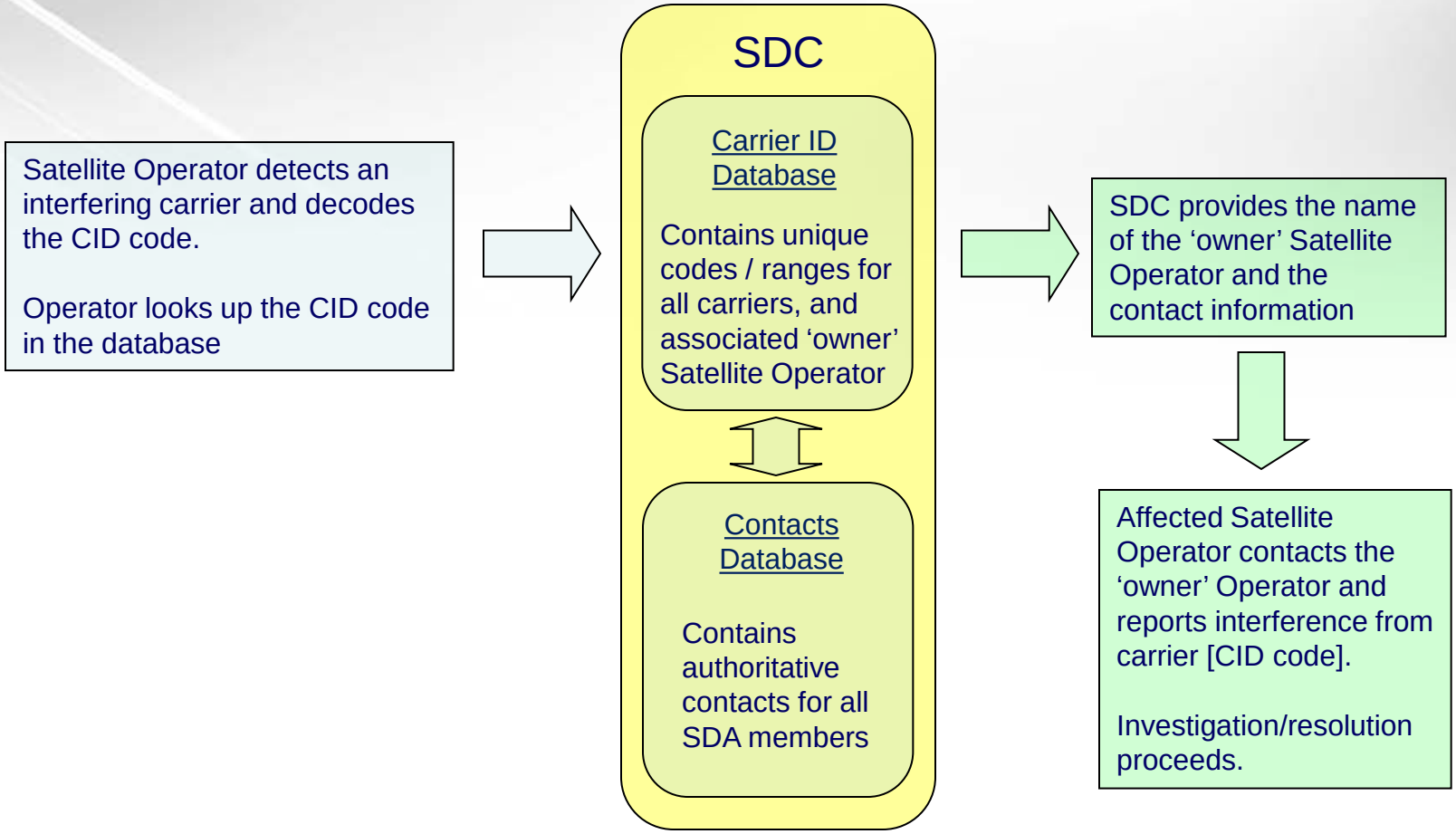


System allows faster investigation of RFI events, improving service quality and creating more efficient operations

Carrier ID and Data Sharing

- What is Carrier ID (CID)?
  - A unique code on every carrier (broadcast, data, VSAT)
  - A Satellite Operator receiving an interfering carrier, will decode the CID and obtain information on the 'owner' of the carrier, which may be another Satellite Operator. Contact can then be made to speed-up investigation and resolution
  - Currently, broadcast carriers supported by DVB embedded (NIT) CID information
  - Innovative solutions for future broadcast and data carriers (e.g. robust Comtech spread spectrum)
  - Still defining potential VSAT CID solutions
- Implementation plan
  - Target Olympics 2012 for Broadcasters to demo CID
  - Target 2014/2015 for global implementation
  - Led by sIRG organization, supported by industry groups and Satellite Operators
- Data sharing
  - SDA will host common industry database required for CID codes.

SDA Planned CID Database Process Flow

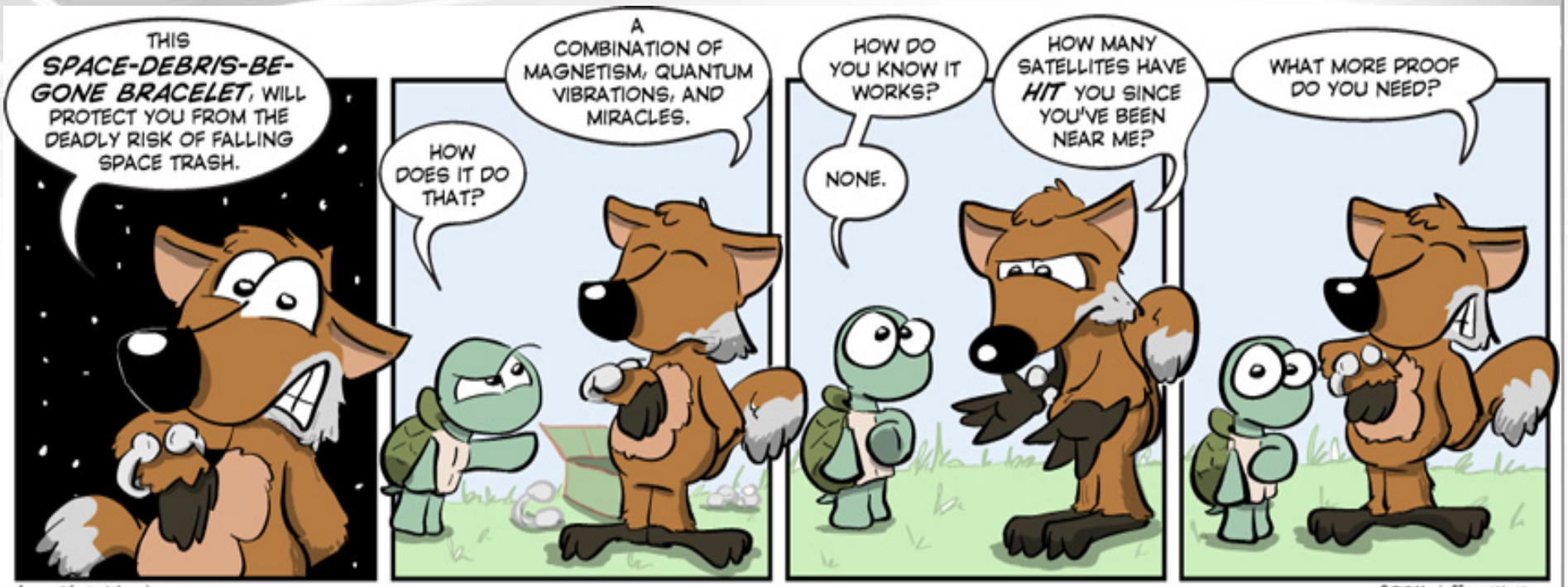


System allows faster investigation of RFI events, improving service quality and creating more efficient operations

SDA RFI/CID Functions

Benefits to speed RFI mitigation

- **Operations contacts database for members and non-members** → Obtain quick and accurate contact information
- **RFI Alert messages** → Alerts sent to focused distribution
  - Seek help, advice, and provide updates
- **RFI database with records of RFI events** → Find previous events with similar characteristics
- **Payload configuration data for members satellites** → Accurate data for geolocation
  - Focus search area
  - Automatic generation of geolocation solution sets
- **Fly-by notification** → Warning of potential interference
- **Carrier ID database** → Speed-up contact with uplinker



* Used by permission, Jeffrey Weston, ApeNotMonkey.com

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TECHNICAL SDC ASPECTS

OLTROGGE/VALLADO/KELSO

Terminology For Our Discussion:

- **Space Situational Awareness (SSA) is:**
  - Space situational awareness (SSA) is the assessment of one's space environment and its implications on one's activities in space. SSA combines satellite positional information (obtained from optical telescopes, radars and transponder ranging) with space weather and "satellite-as-a-sensor" information.
  - Relevant attributes:

Complete and robust, timely and efficient, standardized and maintainable, accurate, and importantly, trusted

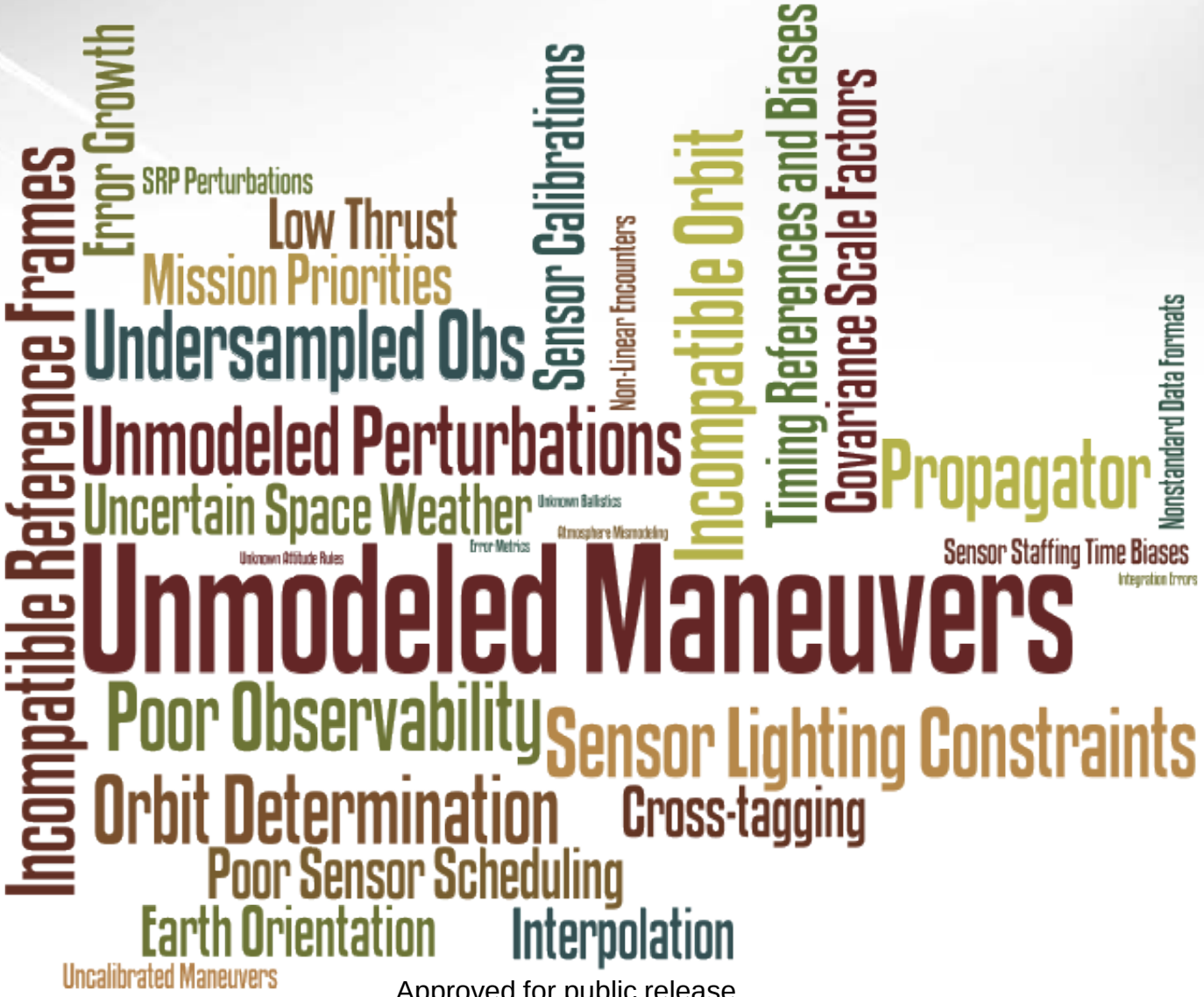
Additional Terminology :

- **A Few Types of SSA:**
  - "CA" (conjunction assessment OR collision avoidance)
  - Radio Frequency Interference (RFI) mitigation
- **Other Terms:**
  - Non-Cooperative Tracking (NCT)
  - U.S. Joint Space Operations Center (JSpOC)
  - General Perturbations (GP); Two-Line Element (TLE)
  - Special Perturbations (SP) = Numerical Orbit Theory
  - Time of Closest Approach (TCA)

Imagine, If You Will …

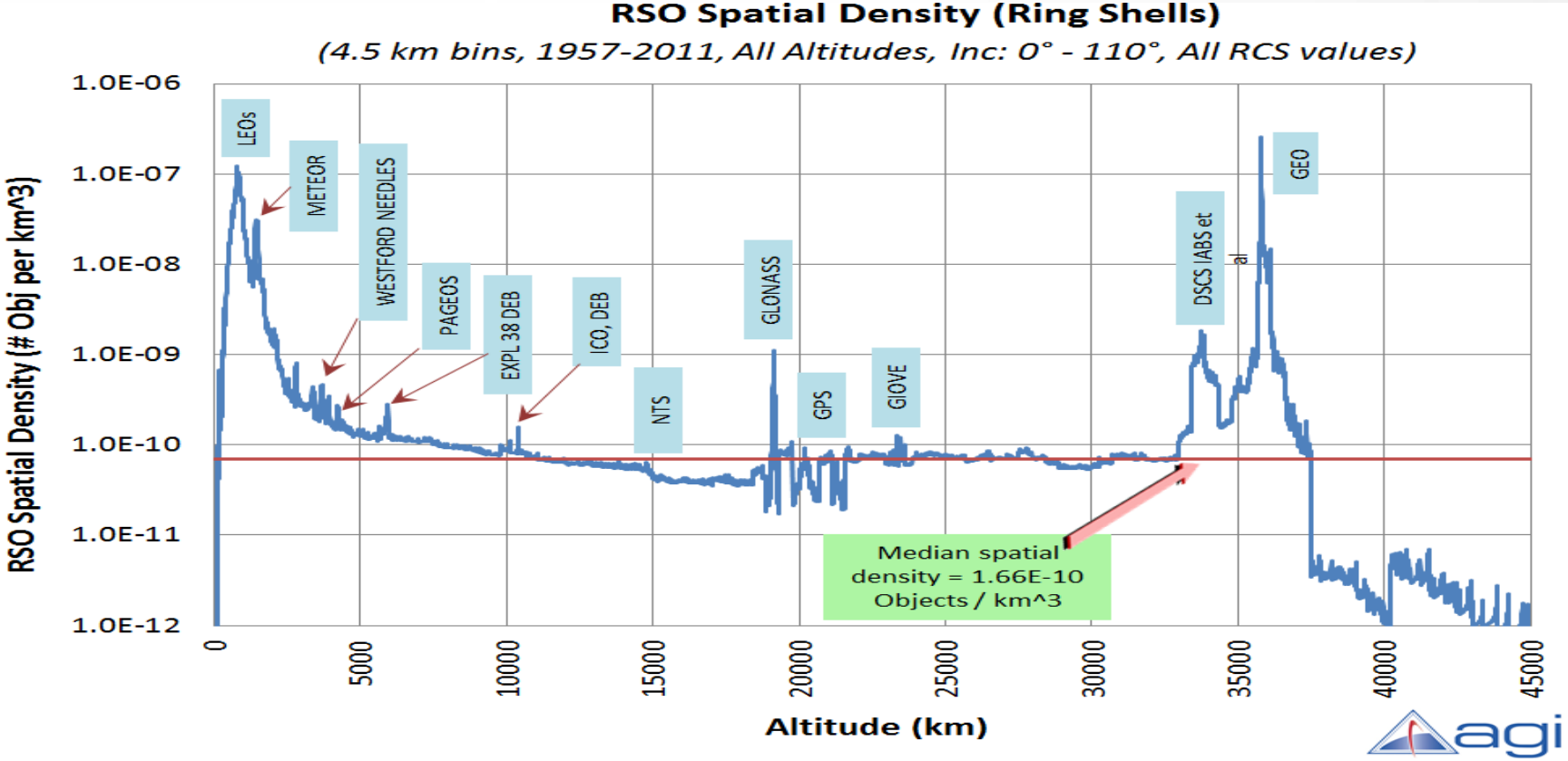
- **You are the operations decision authority for a space operator. A collision warning is issued by the SDA, or by USG, but not both**
  - How would you reconcile the disparity?
  - What metric(s) would you use for determining action?
  - What are <u>your</u> SSA decision thresholds?
    - What data qualities required to support your thresholds for CA? For RFI? Are such data qualities even feasible?
  - What challenges do you face using various data sources? How would those affect your decision?
  - Turns out to be bewildering SSA landscape…

What Degrades CA & RFI SSA ??



Fun Fact: Did You Know …?

- GEO actually as crowded as LEO !!
- A collision at GEO presents a greater threat to our economy, global communications



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UNMODELED PRIOR MANEUVERS AND UNANTICIPATED FUTURE MANEUVERS

OLTROGGE

SSA & Unmodeled Maneuvers

- **ANY unmodeled perturbations degrade SSA**
- **Ways to reduce/mitigate impact of such unmodeled/intervening phenomena (atmospherics, unmodeled maneuvers)**
  - More frequent and collaborative observations
  - Higher-fidelity orbit determination, prediction and better space weather forecasts

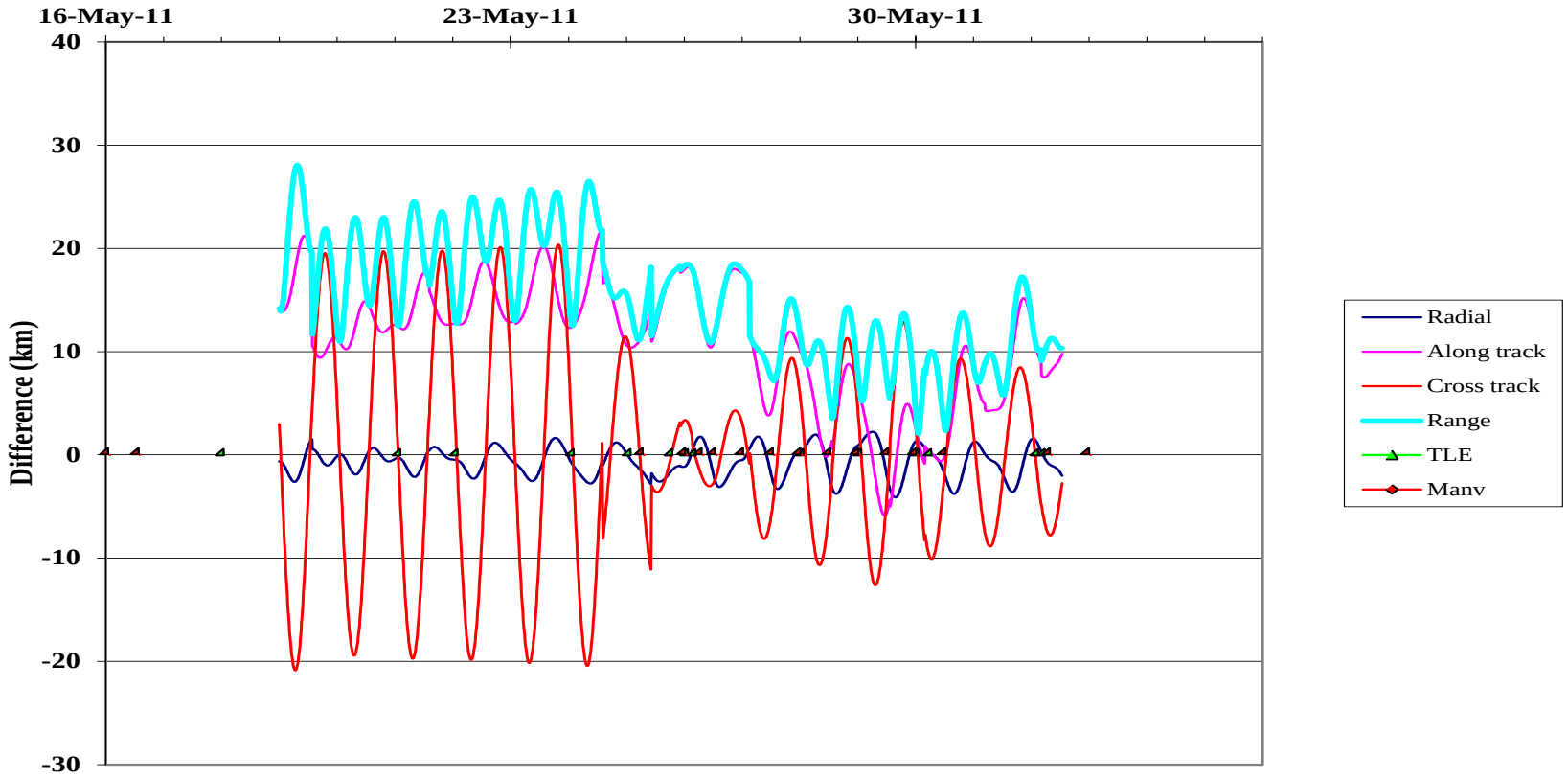
  →Data fusion of complementary, authoritative data
- **Now examine unmodeled maneuvers in 2 areas:**
  - Quarterly Orbit Determination Independent Verifications
  - 5 months of AMC-3 data…

SDA Satellite Characterization

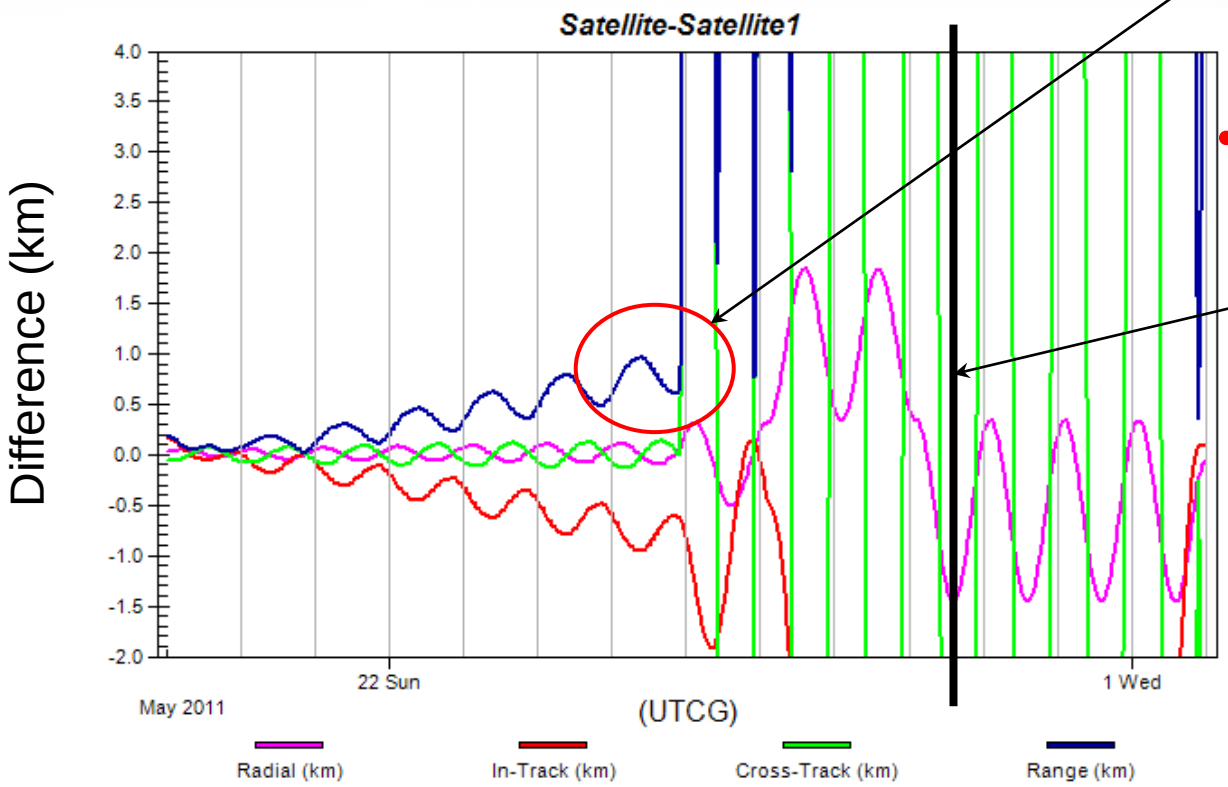
- **Variety of active (tone and spread-spectrum) ranging of each satellite 6X to 48X/day, 24/7**
  - Frequent tracking sessions ≈ spaced ***hourly***.
  - Intensive ranging close to maneuvers
- **Dynamic maneuvering**
  - Xenon-Ion (XIPs) plasma thrusters maneuver daily
  - Others every few days to few weeks
- **≈4 CA alerts per satellite per year, most false alarms**

How Do Operator & NCT Datasets Compare?

- Numerous TLEs and numerous maneuvers
- Reasonably well tracked; “Baseline” 10-20 km error



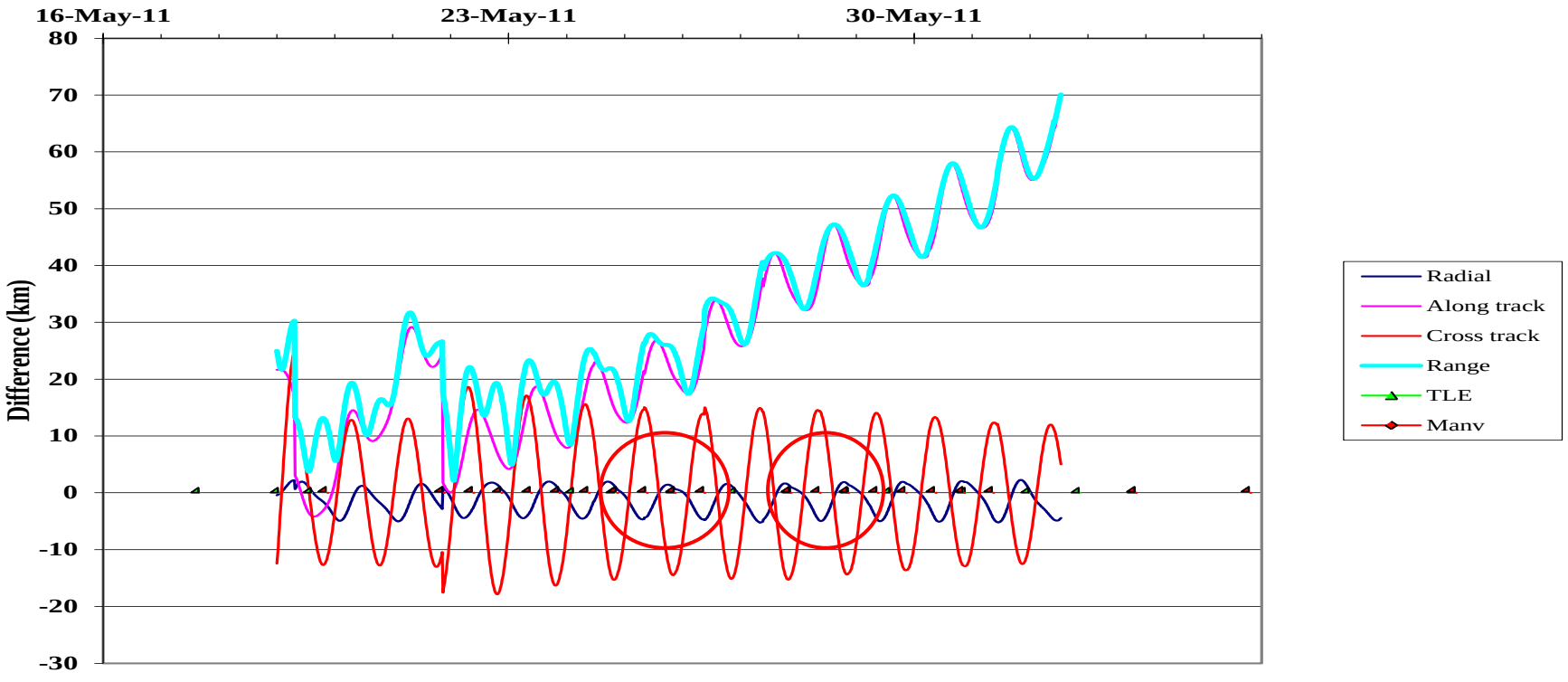
Single Unmodeled Maneuver



- Unmodeled maneuver not included in one prediction
  - Differences to 40-60 km!
- Consider the effect on a predicted CA…

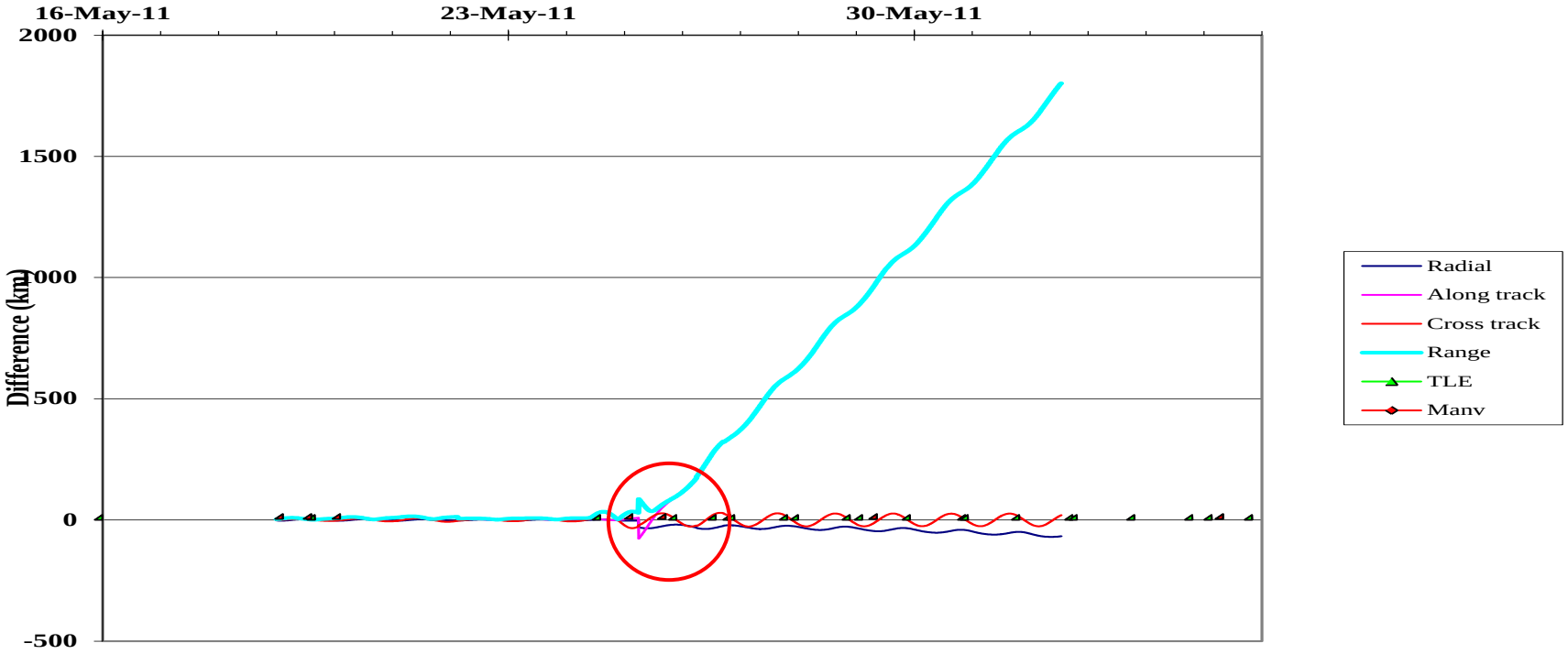
Several Missed Maneuvers…

- Reasonably well tracked with a few maneuvers
  - Several missed; cumulatively getting worse



Missed Maneuver, Becoming “Lost”

- Reasonably well tracked with a few maneuvers
  - One missed; satellite probably lost from that moment onward
  - CSM (SP) and TLE would both be affected



SDA Users Meeting: SDC Overview &Training

OPERATOR EXPERIENCES FROM RECENT COLLISION THREATS

JOE CHAN, INTELSAT

Recent Close Conjunction Between G28 and Galaxy 2

G28 ephemeris vs. TLE

- Collision risk between at 2012/01/27 23:50:20.000 DT =14.33 km, DN = 1.65 km, DR = 0.44 km, TLE Age = 2.367
- Normally NOT flagged as potential close approach
- Flagged using Intelsat CA detection algorithm – equivalent miss distances

SP vs. SP

- Using SP versus SP analysis, JSpOC identified no conjunctions within 3 days and less than 5Km.
- G28 maneuver one day earlier and loaded a week of SPT (electrical propulsion) maneuvers onboard (twice daily)

G28 ephemeris vs. SP

- TCA: 27 JAN 2012 23:40 UTC => Overall miss distance: 601 meters (R = -382 m, T = 462 m, N = 54 m)

Cancelled G28 SPT maneuvers

- TCA: 27 JAN 2012 23:40 UTC => Overall miss distance: 3935 meters (R = -59 m, T = 3909 m, N = 449 m)
- SP vs. SP TCA: 27 JAN 2012 23:40 UTC => Overall miss distance: 3500 meters

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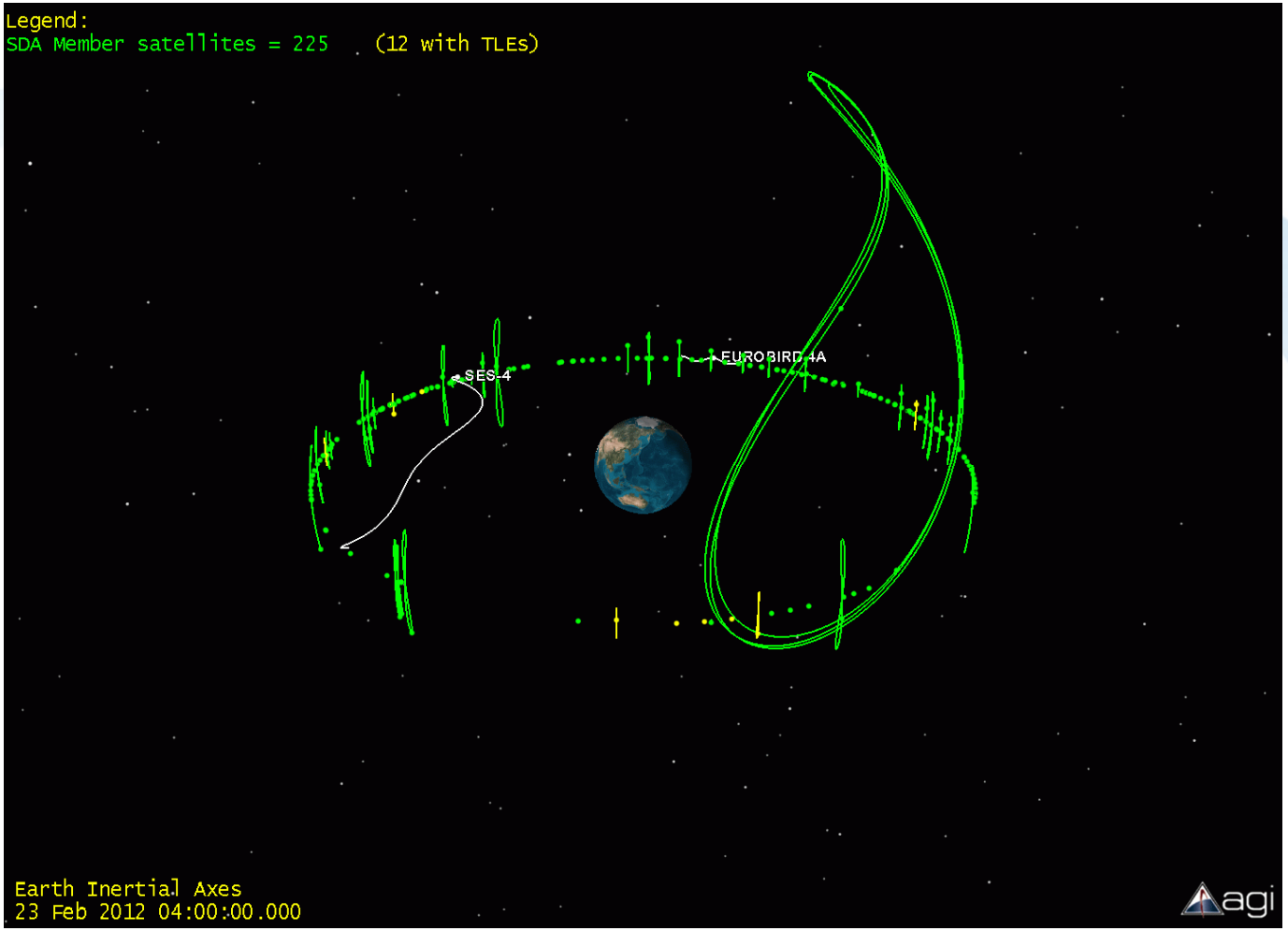
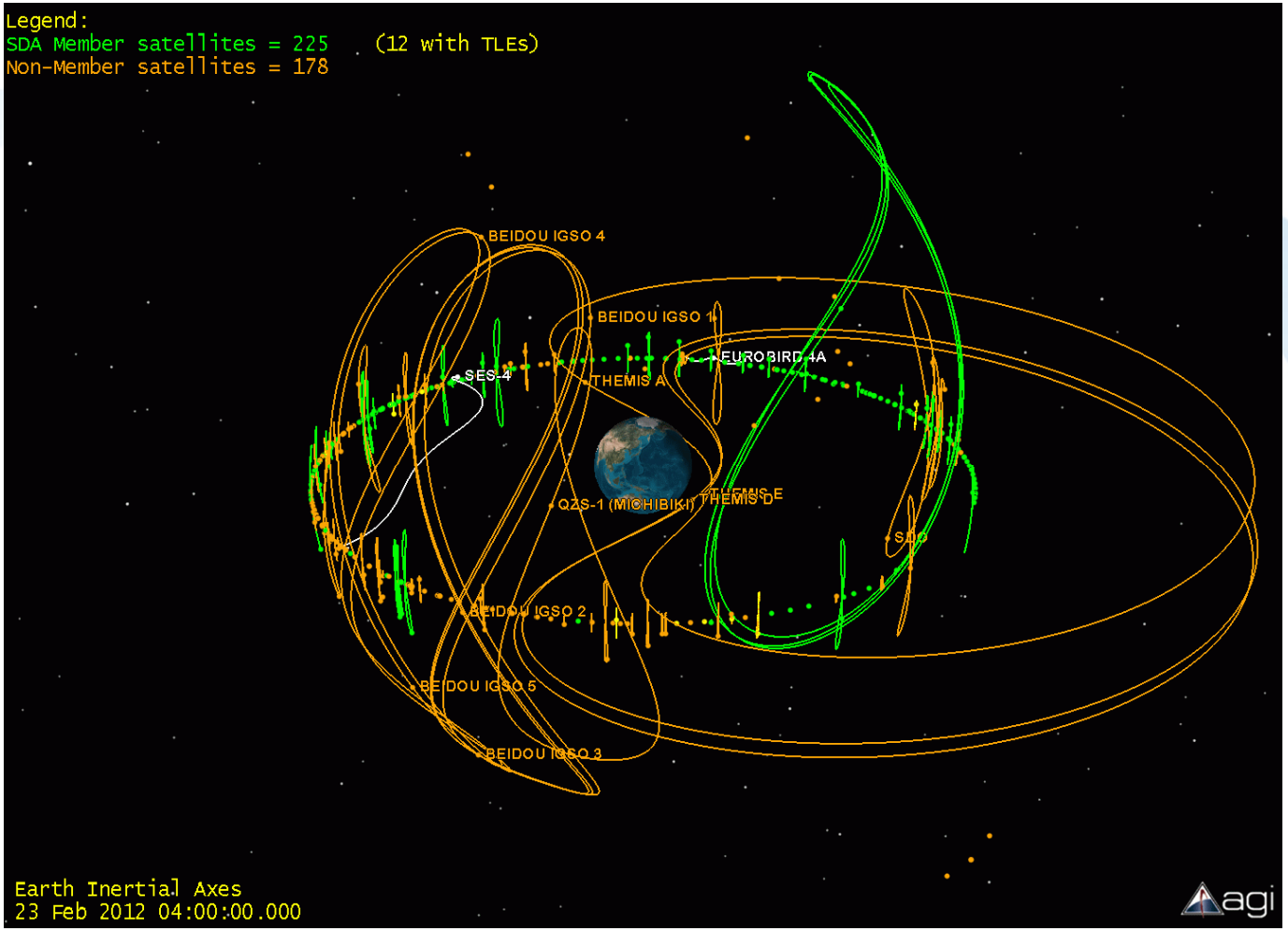
OPERATOR EXPERIENCES FROM CSM DATA COMPARISONS

T.S. KELSO, SDC OPERATIONS MANAGER

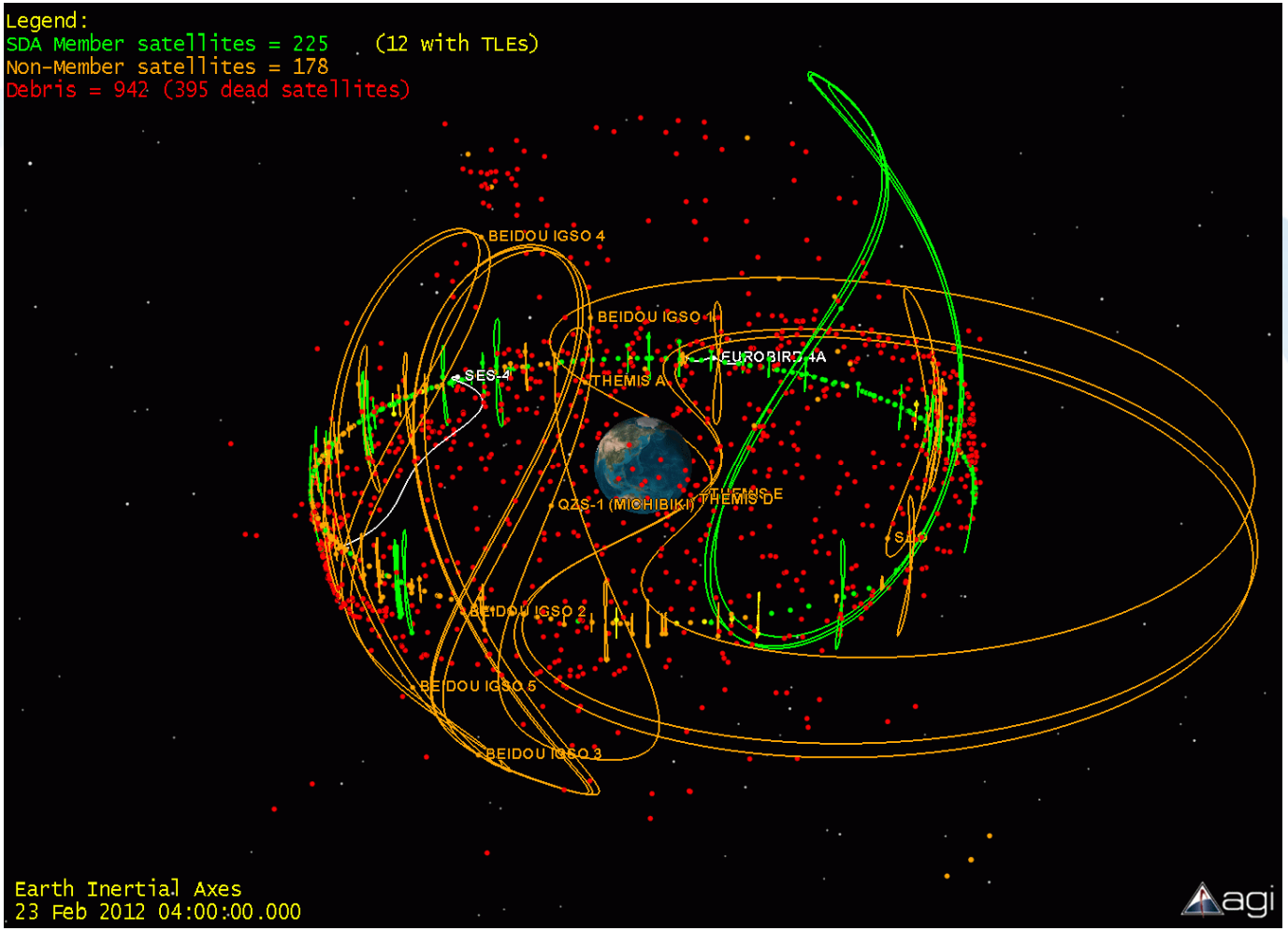
SDC Participation



Active GEO


Legend:
SDA Member satellites = 225
Non-Member satellites = 178
(12 with TLEs)
BEIDOU IGSO 4
BEIDOU IGSO 1
EUROBIRD 1A
SES-4
THEMIS A
QZS-1 (MICHIBIKI)
THEMIS D
BEIDOU IGSO 2
BEIDOU IGSO 5
BEIDOU IGSO 3
Earth Inertial Axes
23 Feb 2012 04:00:00.000
agi

All GEO


Legend:
SDA Member satellites = 225 (12 with TLEs)
Non-Member satellites = 178
Debris = 942 (395 dead satellites)
BEIDOU IGSO 4
BEIDOU IGSO 1
EUROBIRD 1A
SES-4
THEMIS A
QZS-1 (MICHIBIKI)
THEMIS D
BEIDOU IGSO 2
BEIDOU IGSO 5
BEIDOU IGSO 3
Earth Inertial Axes
23 Feb 2012 04:00:00.000
agi

Sample Report

JSpOC Unique ID 201206240401

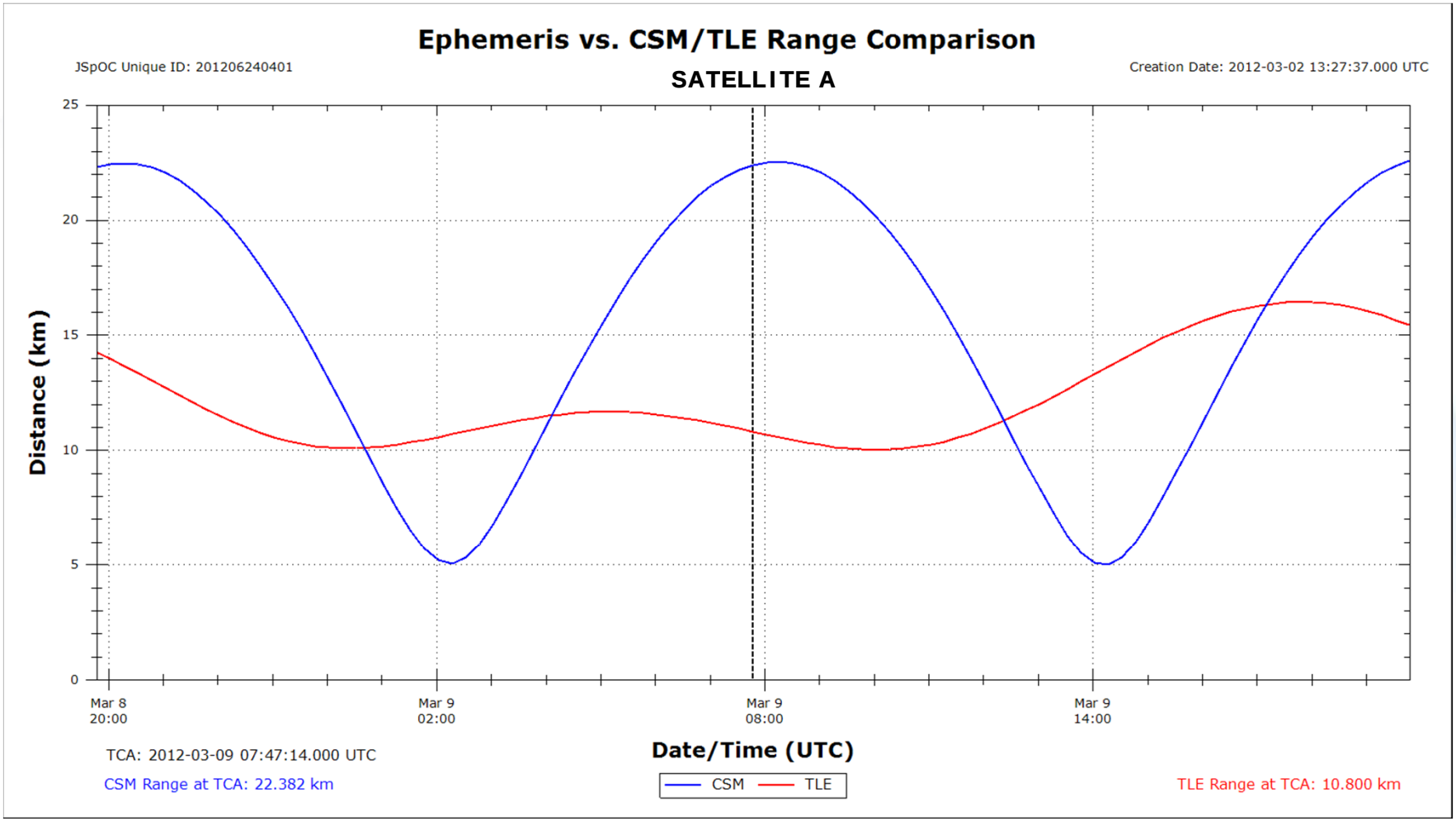
Creation Date: 2012-03-02 13:27:37 UTC (5.3 hours ago)

Upload Time: 2012-03-02 18:13:45 UTC (0.5 hours ago)

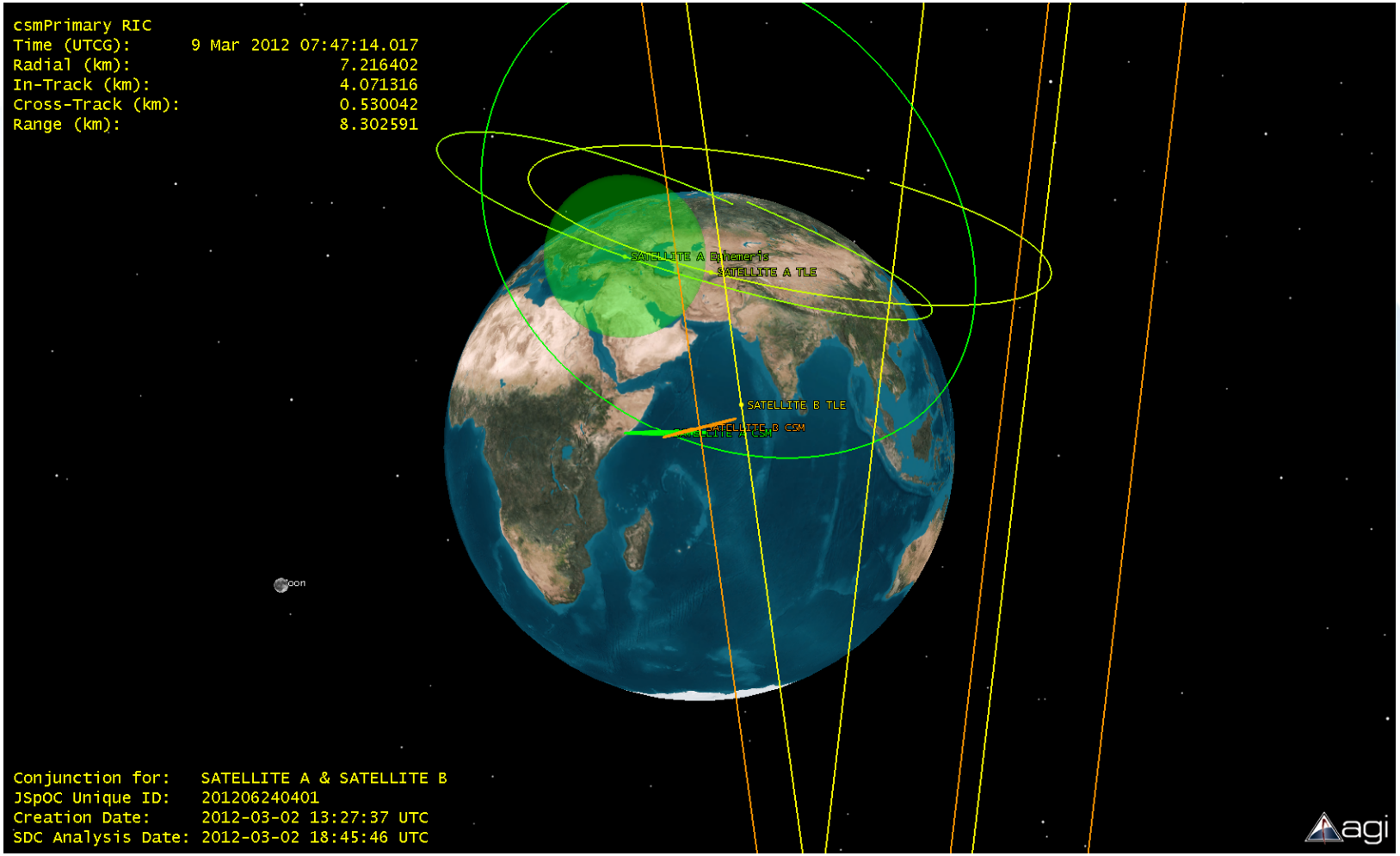
Conjunction for 12345/SATELLITE A [+] and 23456/SATELLITE B [?]		
CSM min range at TCA (2012-03-09 07:47:14.017 UTC) = 8.302 km		
Ephemeris vs. CSM/TLE Comparison		
Primary	CSM Range at TCA: 22.382 km	TLE Range at TCA: 10.800 km
Primary ephemeris epoch: 2012-03-01 00:00:00.000 UTC (1.78 days old)		

CSM Conjunction Comparisons	
CSM vs. CSM	TCA: 2012-03-09 07:47:14.017 UTC, 8.303 km
Ephemeris vs. CSM	TCA: 2012-03-09 07:47:42.716 UTC, 9.541 km
Ephemeris vs. TLE	TCA: 2012-03-09 07:47:40.094 UTC, 15.927 km
Ephemeris vs. Ephemeris	N/A
Latest SDC Search Results for 12345 and 23456	
Complete AGI Viewer Scenario	

Primary Comparison



AGI Viewer File



Sample Report

JSpOC Unique ID 201206240386

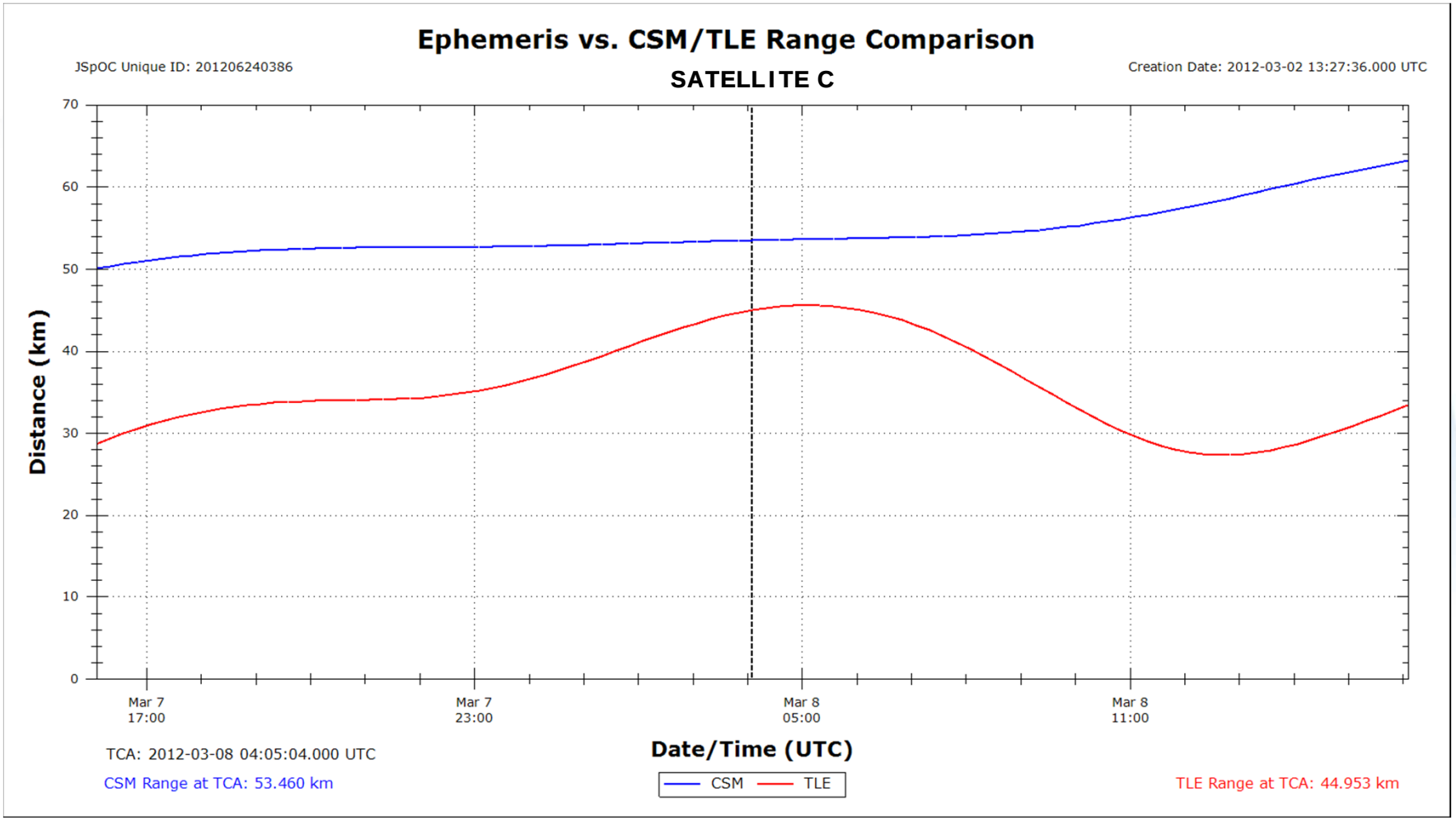
Creation Date: 2012-03-02 13:27:36 UTC (5.3 hours ago)

Upload Time: 2012-03-02 18:13:45 UTC (0.5 hours ago)

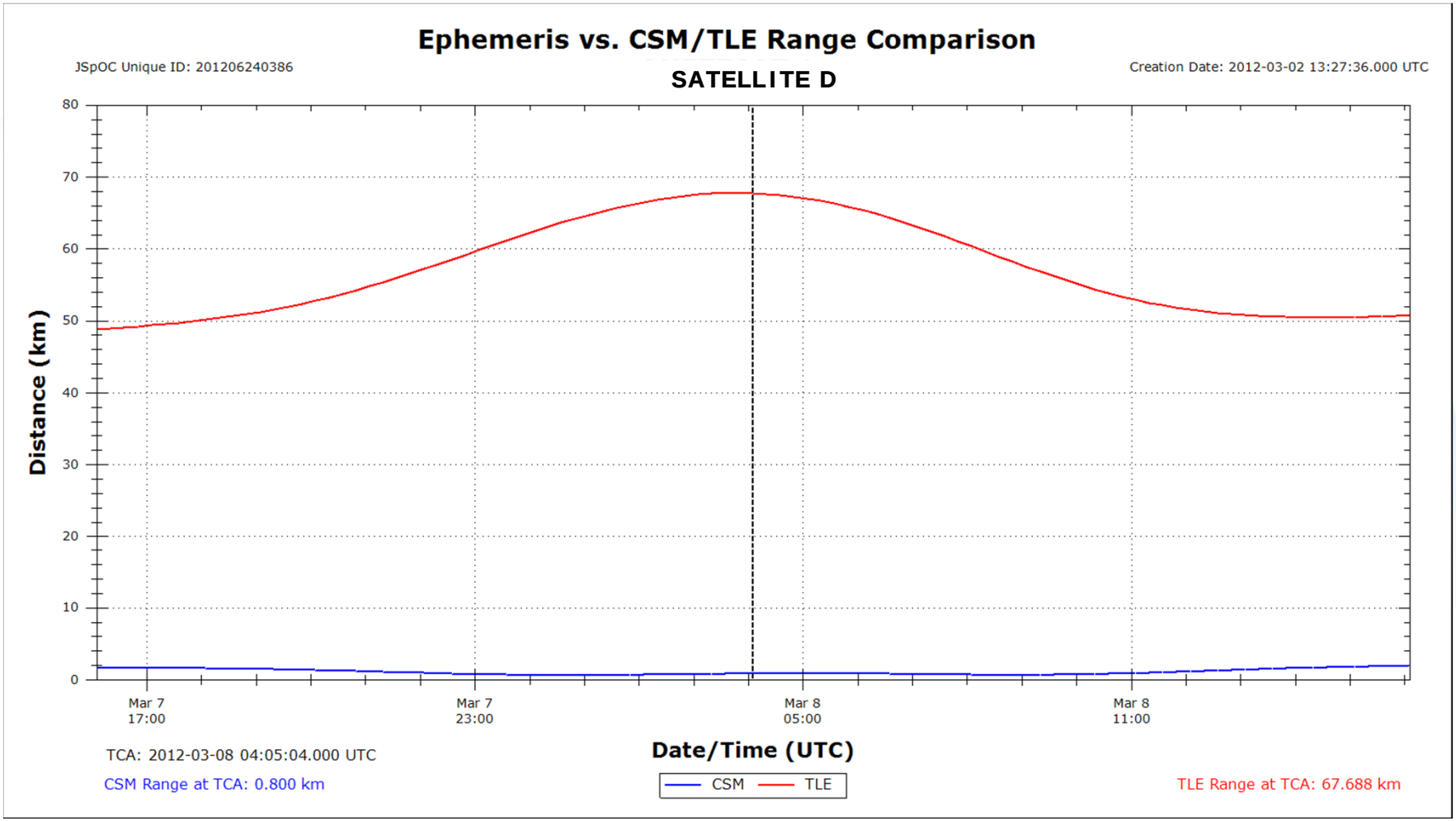
Conjunction for 02468/SATELLITE C [+] and 13579/SATELLITE D [+]		
CSM min range at TCA (2012-03-08 04:05:04.691 UTC) = 3.779 km		
Ephemeris vs. CSM/TLE Comparison		
Primary	CSM Range at TCA: 53.460 km	TLE Range at TCA: 44.953 km
Primary ephemeris epoch: 2012-03-02 10:30:00.000 UTC (0.34 days old)		
Secondary	CSM Range at TCA: 0.800 km	TLE Range at TCA: 67.688 km
Secondary ephemeris epoch: 2012-03-02 10:30:00.000 UTC (0.34 days old)		

CSM Conjunction Comparisons	
CSM vs. CSM	TCA: 2012-03-08 04:05:04.693 UTC, 3.779 km
Ephemeris vs. CSM	TCA: 2012-03-08 03:50:03.926 UTC, 55.594 km
Ephemeris vs. TLE	TCA: 2012-03-08 00:31:43.519 UTC, 122.506 km
Ephemeris vs. Ephemeris	TCA: 2012-03-08 03:42:54.626 UTC, 56.339 km
Latest SDC Search Results for 02468 and 13579	
Complete AGI Viewer Scenario	

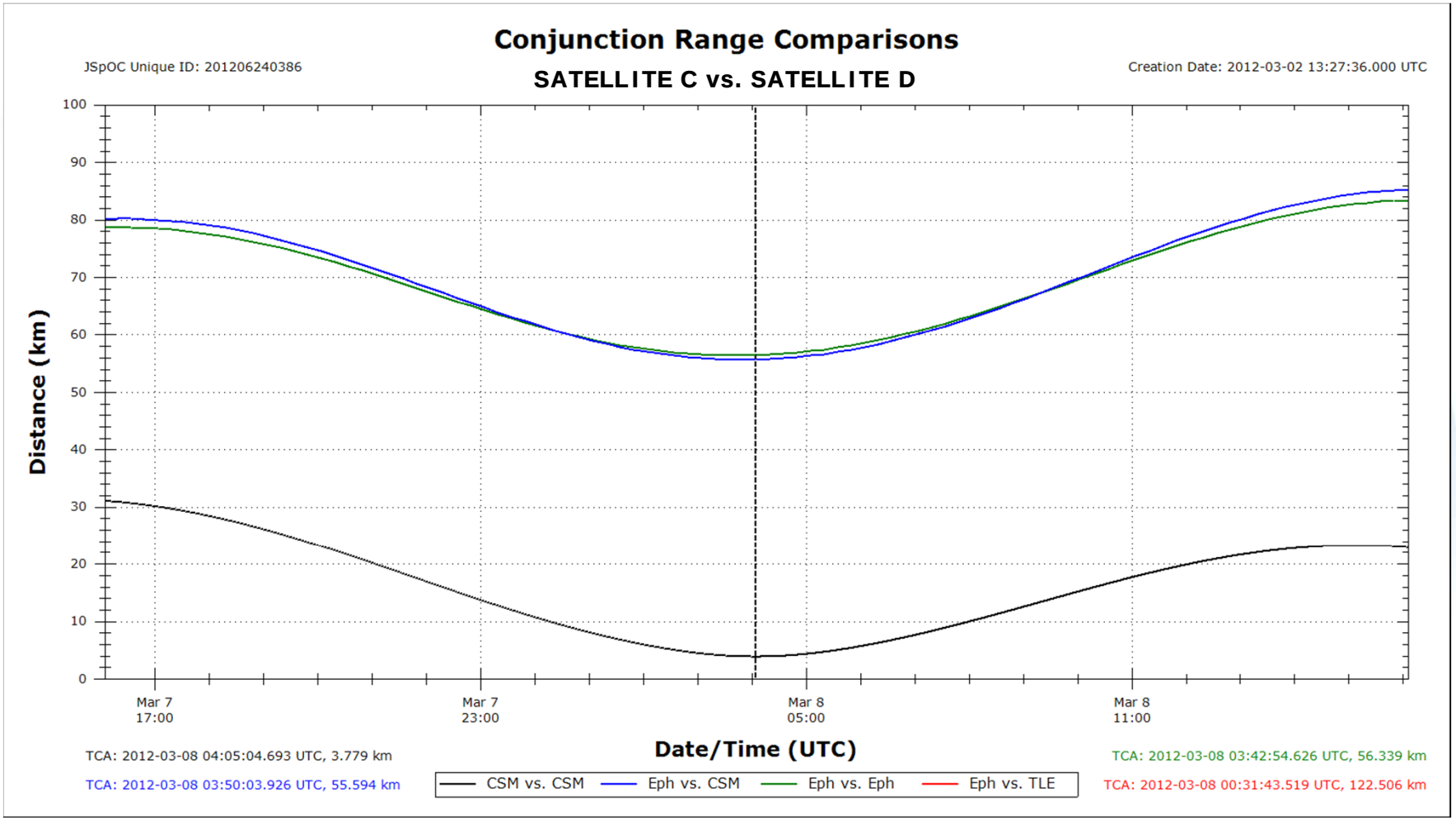
Primary Comparison



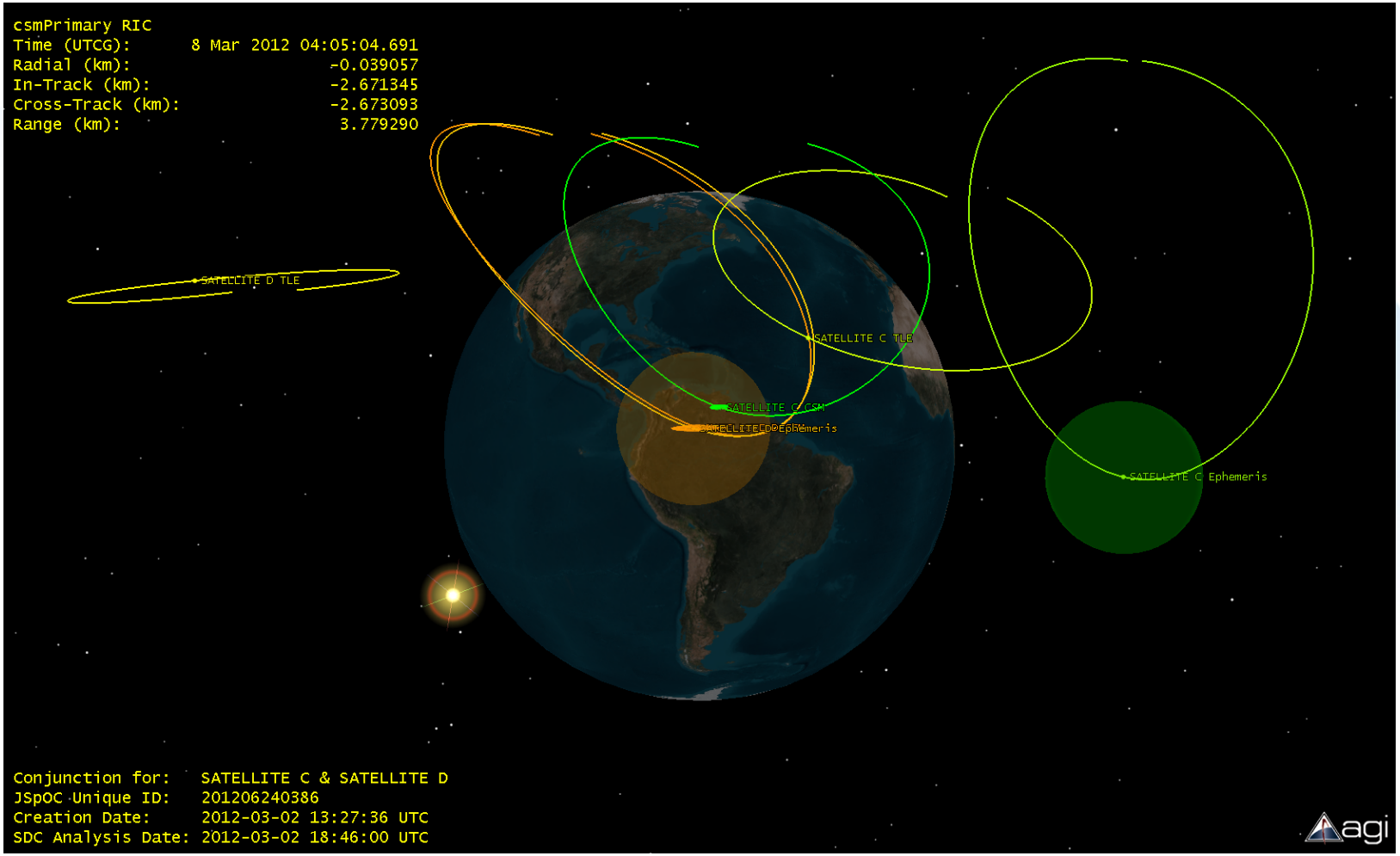
Secondary Comparison



Conjunction Comparison



AGI Viewer File



Unnecessary Maneuver

JSpOC Unique ID 201200635887

Creation Date: 2012-01-06 19:08:31 UTC (4.3 hours ago)

Upload Time: 2012-01-06 21:07:39 UTC (2.3 hours ago)

Conjunction for 11111/SATELLITE E [+] and 22222/SATELLITE F [+]		
CSM min range at TCA (2012-01-09 20:42:59.242 UTC) = 1.600 km		
Ephemeris vs. CSM/TLE Comparison		
Primary	CSM Range at TCA: 1.295 km	TLE Range at TCA: 25.003 km
Primary ephemeris epoch: 2012-01-05 00:00:00.000 UTC (1.98 days old)		
Secondary	N/A	N/A
N/A		

CSM Conjunction Comparisons	
CSM vs. CSM	TCA: 2012-01-09 20:42:59.242 UTC, 1.600 km
Ephemeris vs. CSM	TCA: 2012-01-09 20:41:23.432 UTC, 1.061 km
Ephemeris vs. TLE	TCA: 2012-01-09 15:40:23.187 UTC, 57.896 km
Ephemeris vs. Ephemeris	N/A
Latest SDC Search Results for 11111 and 22222	
Complete AGI Viewer Scenario	

Unnecessary Maneuver

JSpOC Unique ID 201200635887

Creation Date: 2012-01-06 19:08:31 UTC (4.3 hours ago)

Upload Time: 2012-01-06 21:07:39 UTC (2.3 hours ago)

Conjunction for 11111/SATELLITE E [+] and 22222/SATELLITE F [+]		
CSM min range at TCA (2012-01-09 20:42:59.242 UTC) = 1.600 km		
Ephemeris vs. CSM/TLE Comparison		
Primary	CSM Range at TCA: 1.295 km	TLE Range at TCA: 25.003 km
Primary ephemeris epoch: 2012-01-05 00:00:00.000 UTC (1.98 days old)		
Secondary	CSM Range at TCA: 70.722 km	TLE Range at TCA: 7.771 km
Secondary ephemeris epoch: 2012-01-03 19:15:44.000 UTC (3.18 days old)		

CSM Conjunction Comparisons	
CSM vs. CSM	TCA: 2012-01-09 20:42:59.242 UTC, 1.600 km
Ephemeris vs. CSM	TCA: 2012-01-09 20:41:23.432 UTC, 1.061 km
Ephemeris vs. TLE	TCA: 2012-01-09 15:40:23.187 UTC, 57.896 km
Ephemeris vs. Ephemeris	TCA: 2012-01-09 15:58:46.889 UTC, 65.415 km
Latest SDC Search Results for 11111 and 22222	
Complete AGI Viewer Scenario	

Missed Maneuver Requirement

JSpOC Unique ID 201203438032

Creation Date: 2012-02-03 08:24:19 UTC (5.4 hours ago)

Upload Time: 2012-02-03 13:31:49 UTC (0.2 hours ago)

Conjunction for 33333/SATELLITE G [+] and 44444/SATELLITE H [+]		
CSM min range at TCA (2012-02-08 11:02:18.612 UTC) = 8.415 km		
Ephemeris vs. CSM/TLE Comparison		
Primary	CSM Range at TCA: 46.511 km	TLE Range at TCA: 27.146 km
Primary ephemeris epoch: 2012-02-01 00:00:00.000 UTC (2.57 days old)		
Secondary	N/A	N/A
N/A		

CSM Conjunction Comparisons	
CSM vs. CSM	TCA: 2012-02-08 11:02:18.600 UTC, 8.416 km
Ephemeris vs. CSM	TCA: 2012-02-08 17:16:11.014 UTC, 27.044 km
Ephemeris vs. TLE	TCA: 2012-02-08 11:35:19.577 UTC, 49.272 km
Ephemeris vs. Ephemeris	N/A
Latest SDC Search Results for 33333 and 44444	
Complete AGI Viewer Scenario	

Missed Maneuver Requirement

JSpOC Unique ID 201203438032

Creation Date: 2012-02-03 08:24:19 UTC (5.4 hours ago)

Upload Time: 2012-02-03 13:31:49 UTC (0.2 hours ago)

Conjunction for 33333/SATELLITE G [+] and 44444/SATELLITE H [+]		
CSM min range at TCA (2012-02-08 11:02:18.612 UTC) = 8.415 km		
Ephemeris vs. CSM/TLE Comparison		
Primary	CSM Range at TCA: 46.511 km	TLE Range at TCA: 27.146 km
Primary ephemeris epoch: 2012-02-01 00:00:00.000 UTC (2.57 days old)		
Secondary	CSM Range at TCA: 36.666 km	TLE Range at TCA: 45.759 km
Secondary ephemeris epoch: 2012-02-01 00:00:00.000 UTC (2.57 days old)		

CSM Conjunction Comparisons	
CSM vs. CSM	TCA: 2012-02-08 11:02:18.600 UTC, 8.416 km
Ephemeris vs. CSM	TCA: 2012-02-08 17:16:11.014 UTC, 27.044 km
Ephemeris vs. TLE	TCA: 2012-02-08 11:35:19.577 UTC, 49.272 km
Ephemeris vs. Ephemeris	TCA: 2012-02-08 15:47:23.111 UTC, 4.676 km
Latest SDC Search Results for 33333 and 44444	
Complete AGI Viewer Scenario	

SPACE DATA ASSOCIATION

SDA Users Meeting: SDC Overview &Training

OPERATOR EXPERIENCES FROM LONG-DURATION COMPARISONS

DAN OLTROGGE, SDC PROGRAM MANAGER

Impact of Missed Maneuvers

- **Sample case:**
  - Recent AMC-3 relocation
  - AMC-3 replaced by SES-2
  - AMC-3 20° easterly 2-wk drift
- **Compare SES ephemeris with public TLEs**
  - SES does transponder ranging of AMC-3 hourly from geometrically-diverse MD & CA
  - Reduced slightly during spacecraft transits to prevent RFI

SPACE MART

SES Relocates AMC-3 Satellite To 67 Degrees West To Serve Latin American Growth Markets

by Staff Writers
Luxembourg (SPX) Feb 17, 2012

SES S.A. reports that the AMC-3 satellite is being relocated from its former location of 87 degrees West to 67 degrees West to optimize coverage of Mexico, Central America and the Caribbean.

File image of an An A2100 satellite bus in orbit.

The 67 degrees West orbital position offers an extensive Ku-band satellite frequency range and excellent viewing angles for coverage of the Americas and the Caribbean.

The drift was initiated in January and the satellite is scheduled to arrive at its new orbital location on February 24th.

AMC-3 was launched in 1997 into the orbital location of 87 degrees West. Built by Lockheed Martin, the spacecraft carries Ku- as well as C-band transponders.

The AMC-3 spacecraft was replaced at the 87 degrees West slot by the SES-2 satellite launched on board an Ariane 5 vehicle on September 22, 2011. AMC-3 has enough fuel to operate in geostationary orbit until 2017.

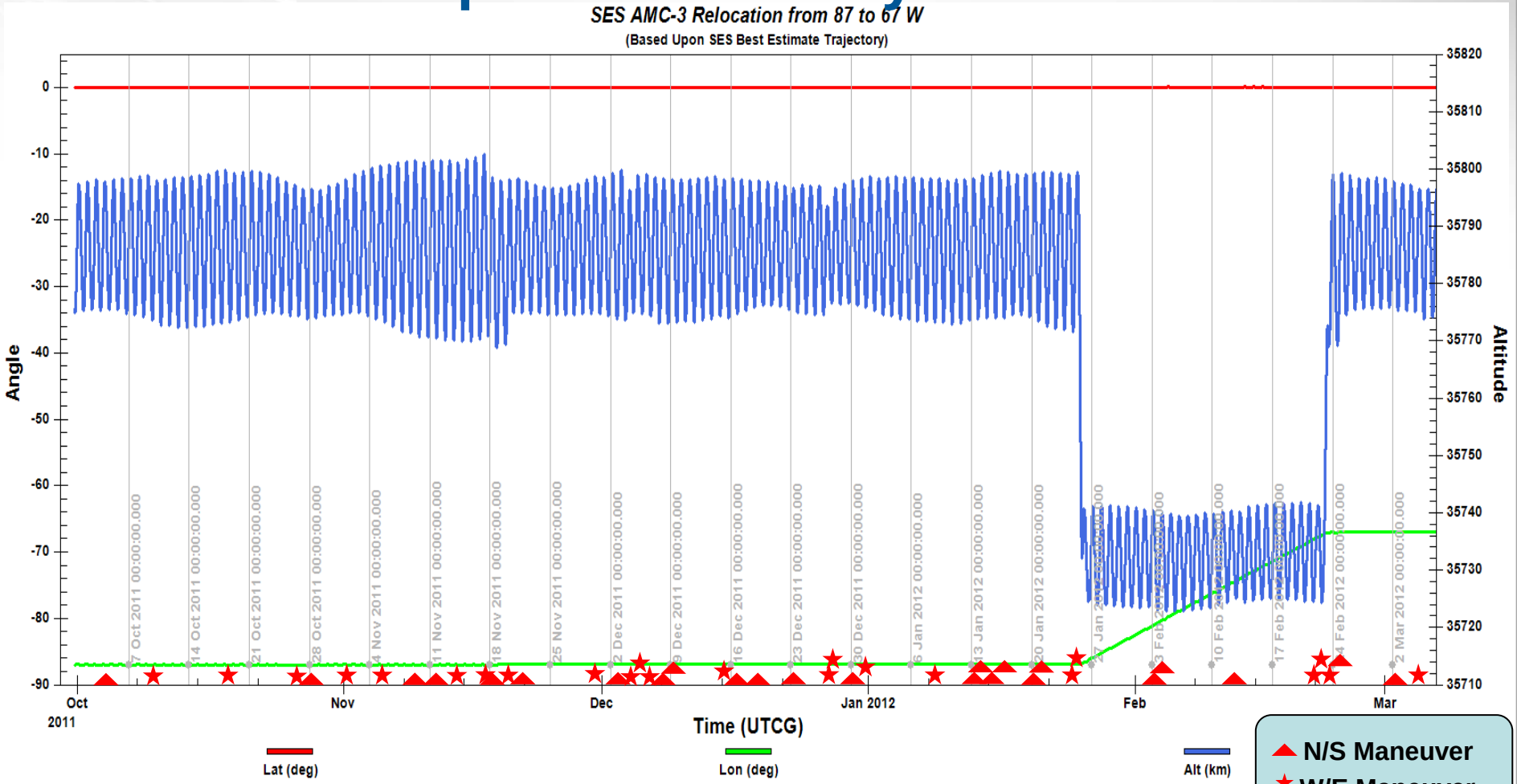
At 67 degrees West, AMC-3 will be co-located with the AMC-4 satellite, which has been providing services over Latin America and the Caribbean since its deployment at this position in 2010. Together, AMC-3 and AMC-4 will be able to offer 28 commercially available Ku-band transponders (36 MHz equivalents) at 67 degrees West.

Romain Bausch, President and CEO of SES stated: "The relocation of the AMC-3 satellite once again demonstrates the operational flexibility provided by a 50 spacecraft strong global fleet.

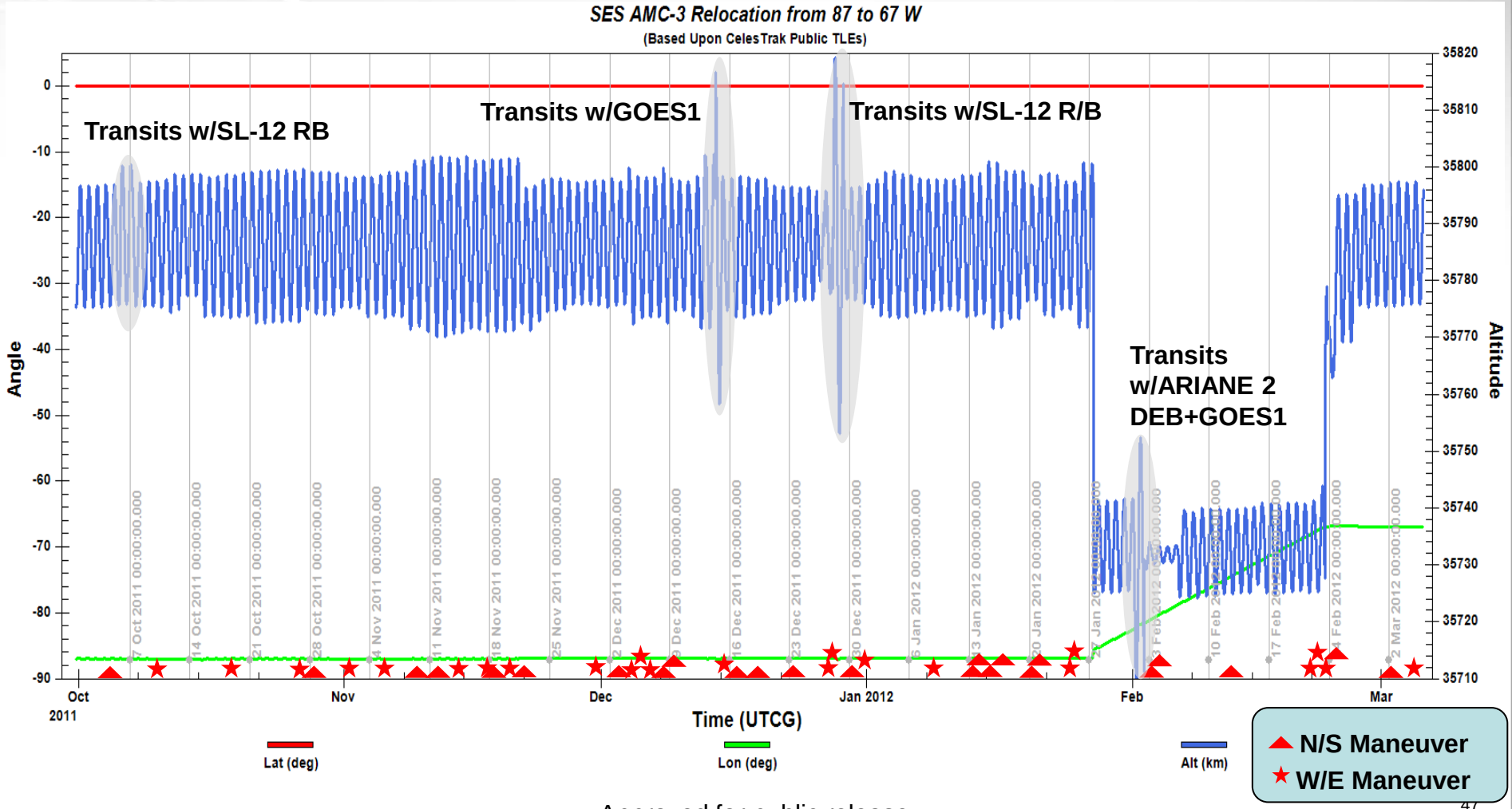
"The orbital slot of 67 degrees West offers an additional growth opportunity to SES to efficiently serve Mexico, Central America and the Caribbean with satellite solutions for television distribution, broadband connectivity and government services."

Owner/Operator Data Says…

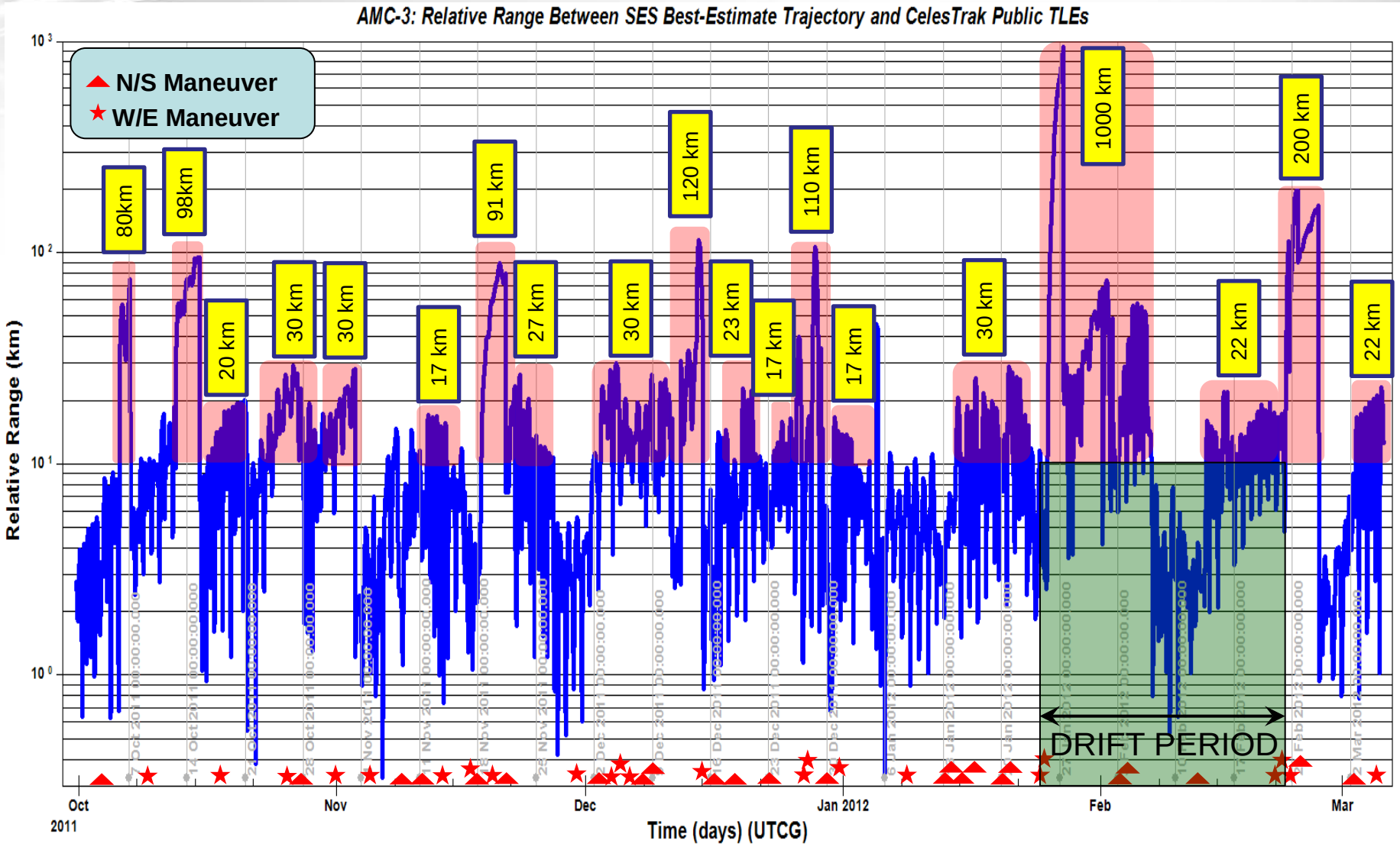
- **Latitude/Longitude/Altitude profile shows altitude drop w/20° Easterly drift**



Radar/Optical Network Data Says…



But the Two Sources Differ By…



AMC-3 Relocation Conclusions

- **Public data lags authoritative operator data by up to one week**
  - Errors of more than 1000 km typify optical response to maneuvers
  - May have identified cross-tagging as well
- **Unmodeled maneuvers and cross-tags degrade TLEs AND Special Perturations data**
  - ∴ CSMs suffer from these same effects
- **Also see daily positional errors, likely due to observational undersampling**
  - Errors of up to 12 km observed during daylight hours

SDA Users Meeting: SDA General Forum

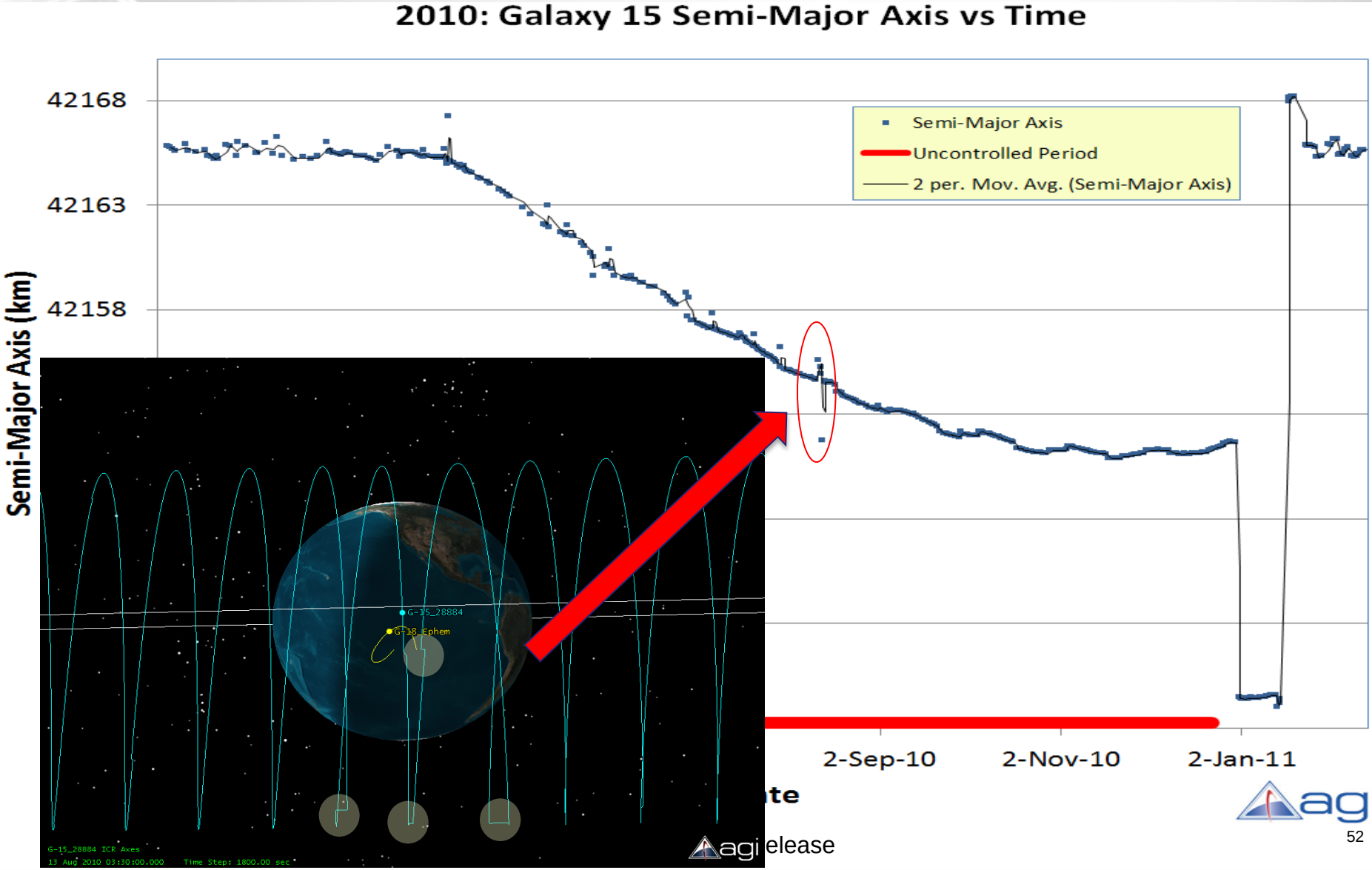
TRACK MISASSOCIATION & CROSS-TAGGING

OLTROGGE

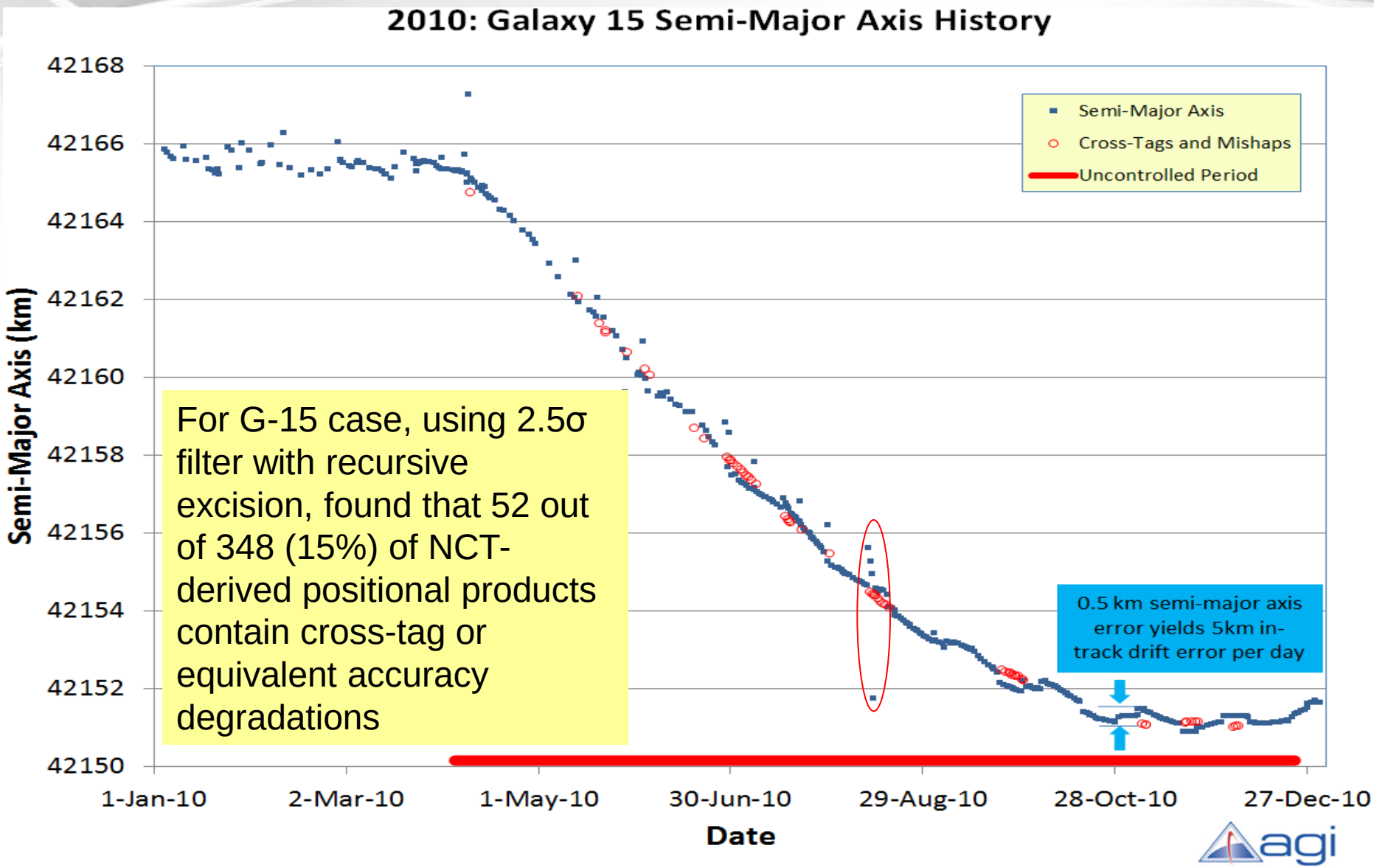
Cross-tagging and System Errors

- **Galaxy-15 anomaly caused westward drift *with no maneuvers* from April – December 2010**
  - G15 WAAS intact; orbital position well understood by operator but not in public catalog
  - Great opportunity to study public data-derived performance
- **Large cross-tag discontinuity observed 13 Aug**
  - Readily identified as G15/G18 conjunction
- **Many other such discontinuities observed**
- **Collision risk was never an issue because SDA Members were sharing ephemerides with the SDC**

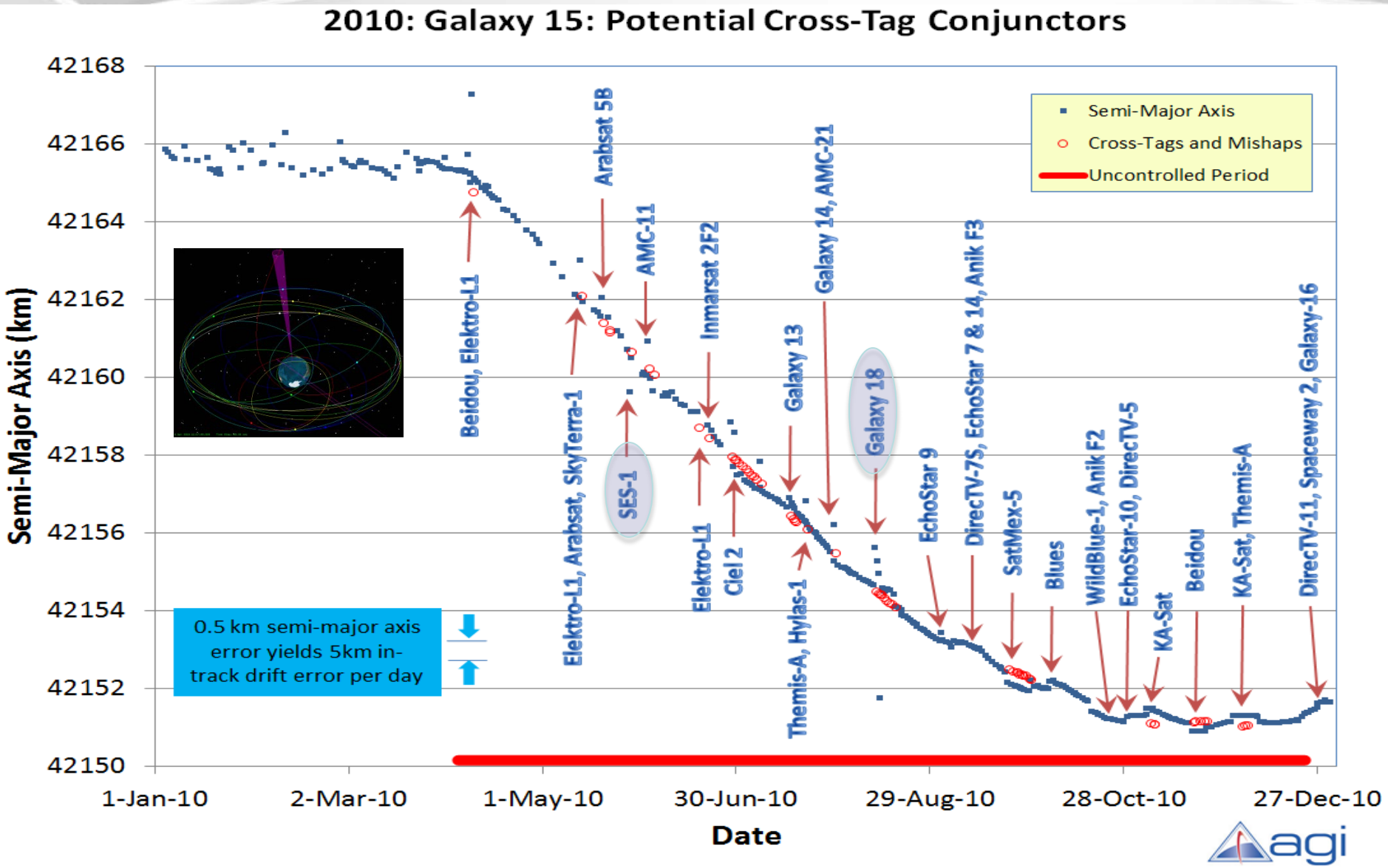
Semi-Major Axis Reveals NCT Discontinuities…



“Orbit Detective” Identifies Cross-tags

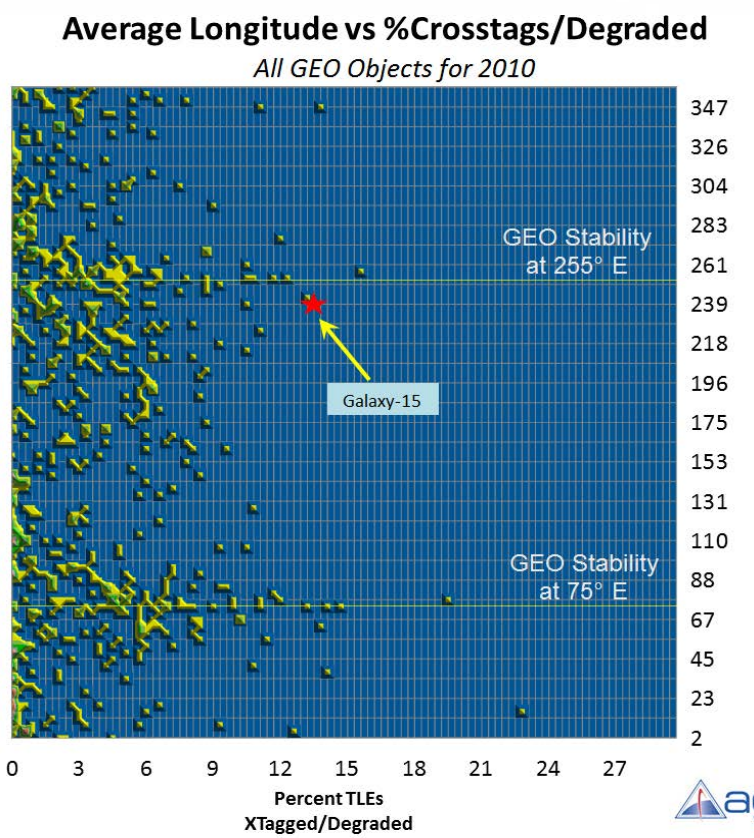


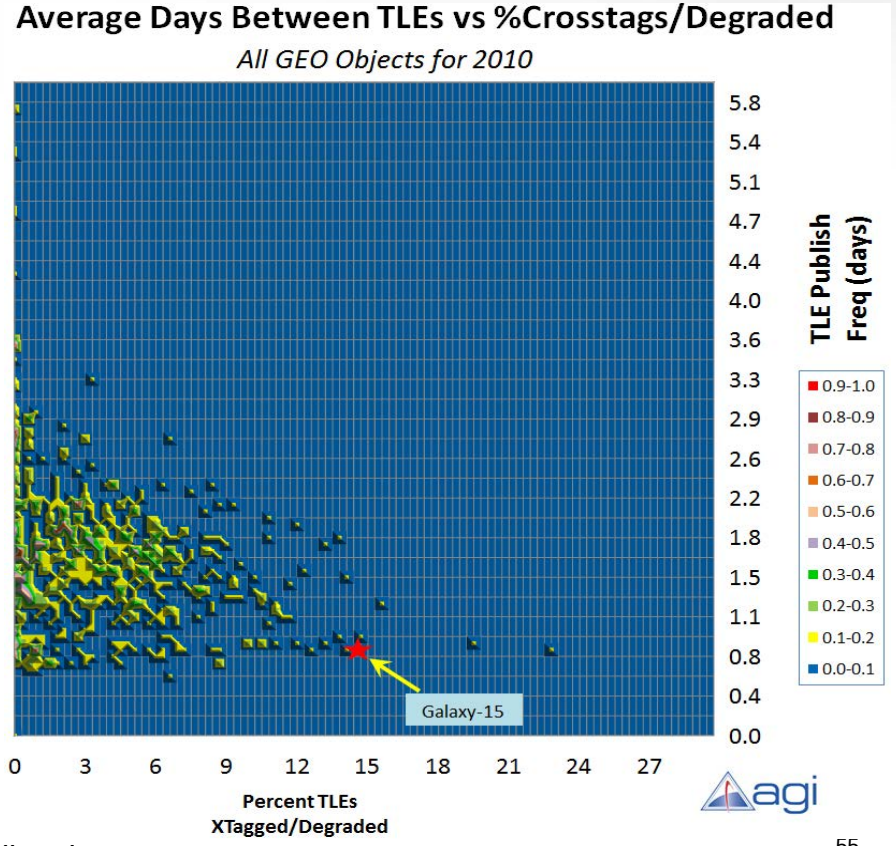
Discontinuities Match Conjunctions…



Crosstags by GEO Longitude, Time

- % Crosstags/Degradations =f(GEO longitude)
- More-frequent orbit updates don't reduce %Crosstags/Degradations





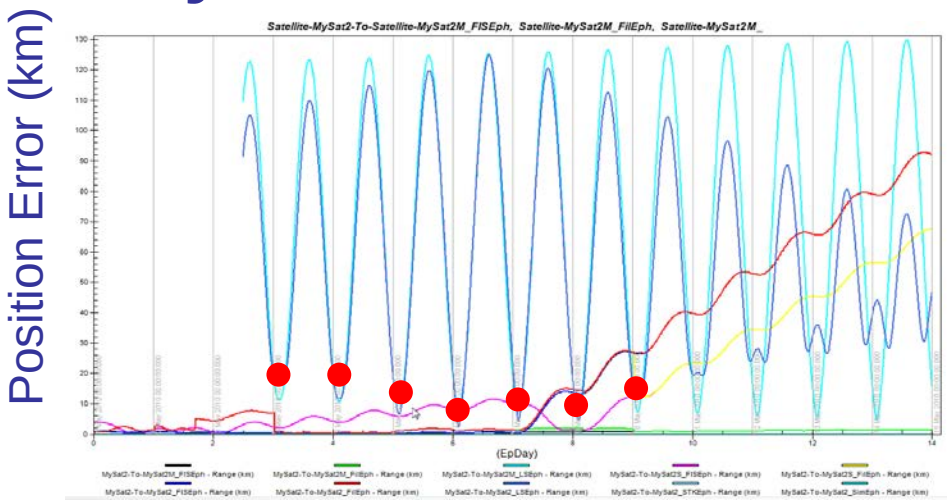
SDA Users Meeting: SDA General Forum

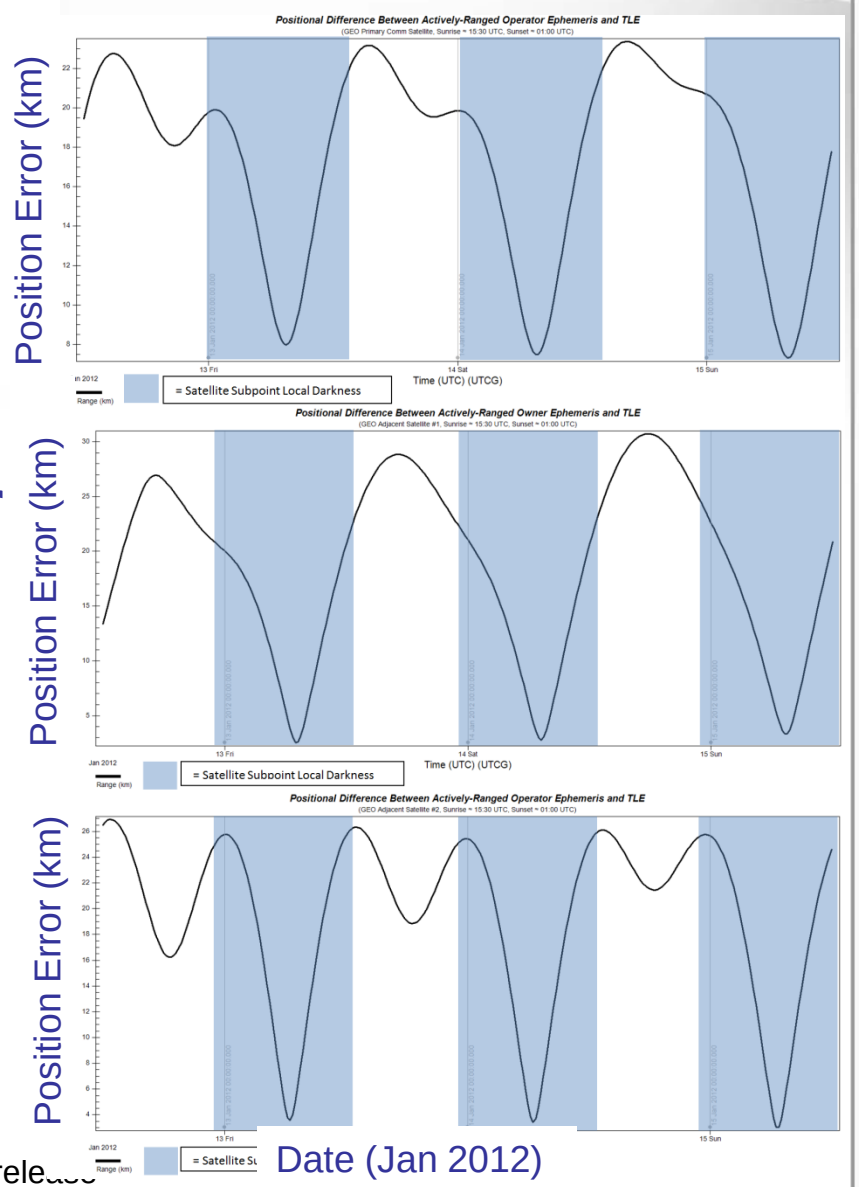
UNDERSAMPLED AND NON-OPTIMAL SENSOR TASKING ARTIFACTS

OLTROGGE

NCT Limitations Affect CA & RFI

- **Analyses of 3 satellites reveale distinct TLE night-favoring accuracy trend**
  - Test confirmed owner data better
  - Optical systemic obs undersampling
- **No reason to assume SP better**
- **Only solution: data fusion**





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SSA PRECISION, ACCURACY AND ACTIONABILITY

DAN OLTROGGE, AGI

SSA Precision & Accuracy

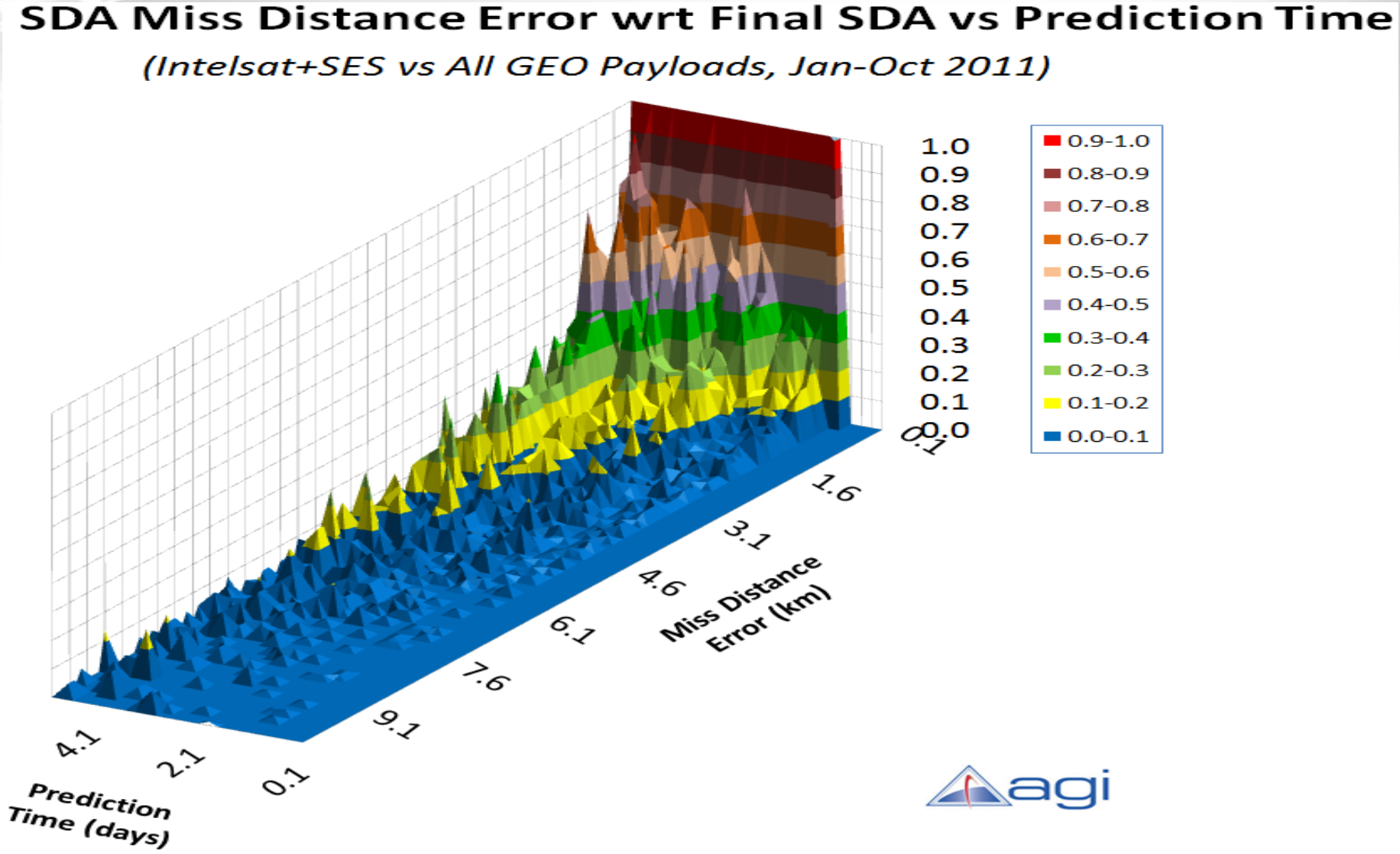
- **"Actionable" SSA is timely, accurate, precise**
  - Available inputs may be unsuitable for action
  - User requirements may exceed SSN rqmts or capabilities
- **Depends on entire SSA inputs+analysis chain**
  - Can't be more actionable than weakest link
  - Accuracy requires notion of "truth", which we often lack
  - Space Data Association (SDA) compared w/other sources
    - SDA data very good quality (typically)

SSA Precision & Accuracy (cont)

- **Actionable SSA = precision AND accuracy**
  - ***"Accuracy is degree of veracity; precision is degree of reproducibility"****
  - Can't have reliable accuracy without precision, but can have precision without accuracy
  - Precision (reproducibility) of SSA products is necessary, but not sufficient, condition for actionable Miss-Distance-based SSA

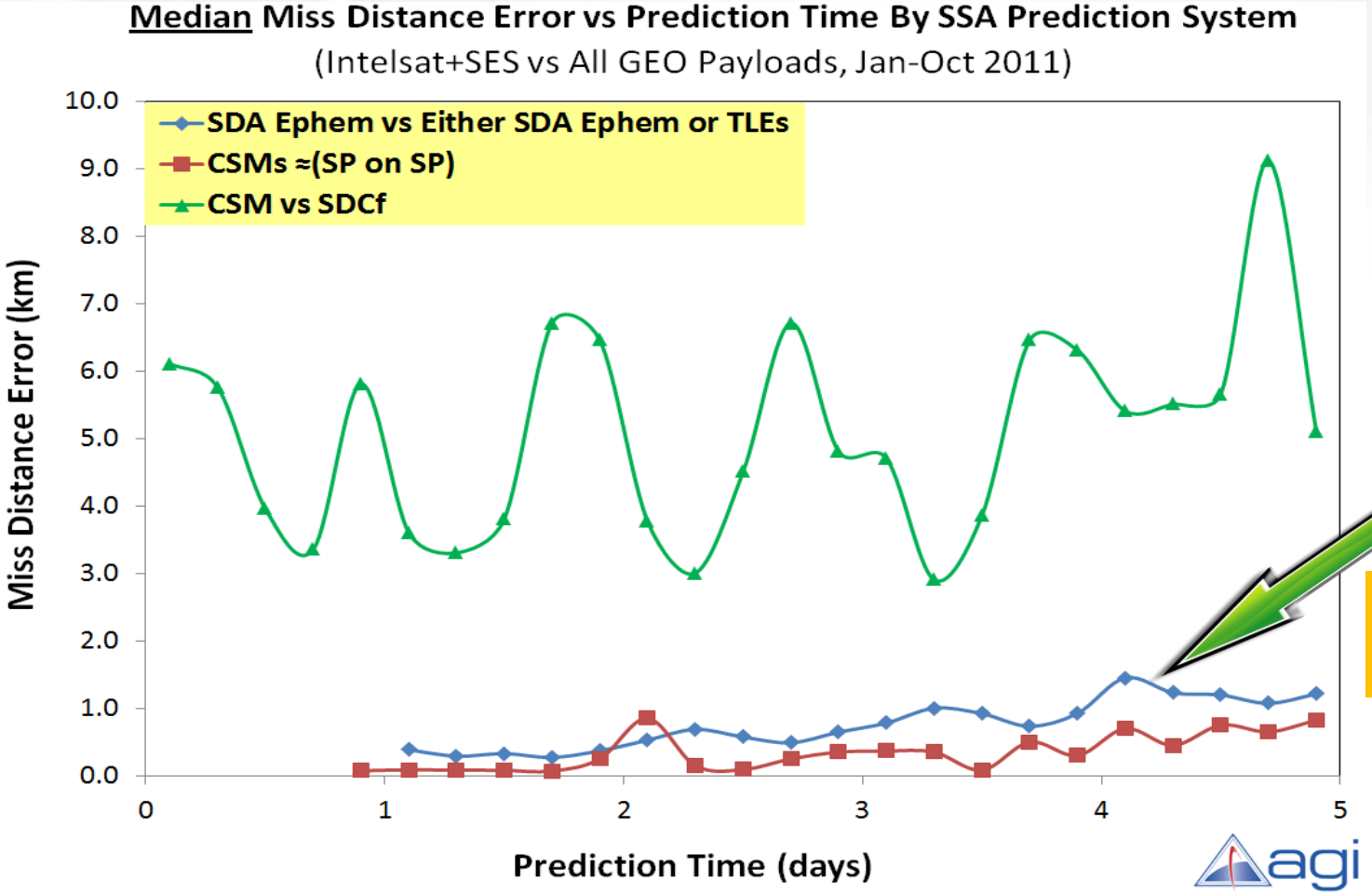
- **Examined 2011 convergence of time-ordered SSA products from SDC & SP-based CSMs**
  - ≈4000 SDA & ≈325 CSM conjunctions (162 common)
  - What's TRUTH? Adopted last SDA & CSM estimates

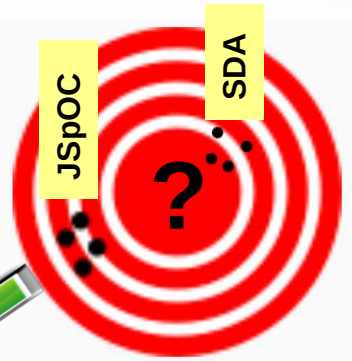
SSA Precision & Accuracy (cont)



SSA Precision & Accuracy (cont)

- **SDA & JSpOC similarly precise w/different accuracy**





Where's dead-center?

Conclusions on Precision and Accuracy of SDA and JSpOC CA

- Typical precision (reproducibility) of both the SDA and JSpOC warnings supports convergent predictions of up to four days
- Yet, SDA and JSpOC warnings do not agree
- Combined with impacts of unmodeled maneuvers and cross-tagging, suggests that JSpOC warnings (CSMs) are equally precise but less accurate for GEO active satellites
- Data fusion is the key to removing these inaccuracies & biases

SPACE DATA ASSOCIATION

SDA Users Meeting: SDA General Forum

SENSITIVITY OF RFI GEOLOCATION TO DATA QUALITY

OLTROGGE

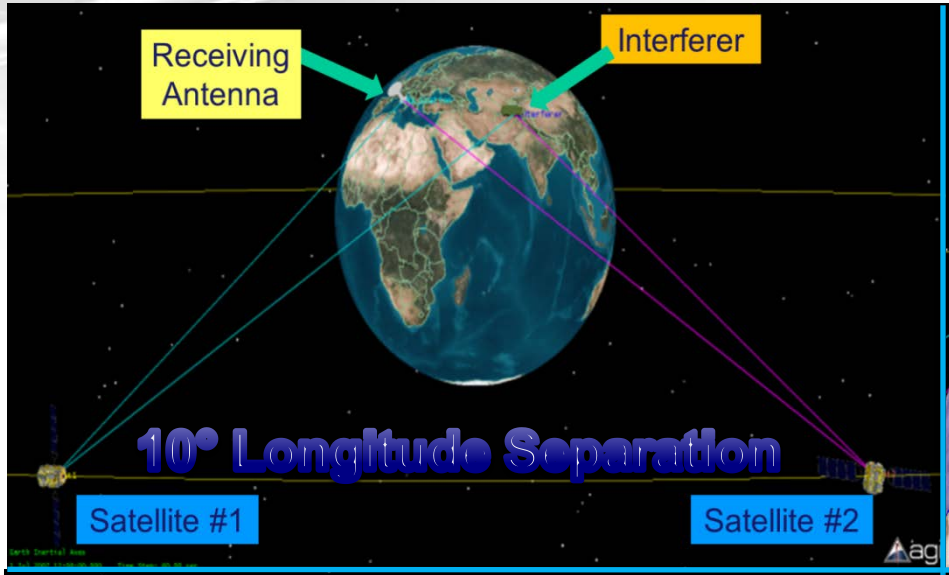
SDC As Geolocation Tool

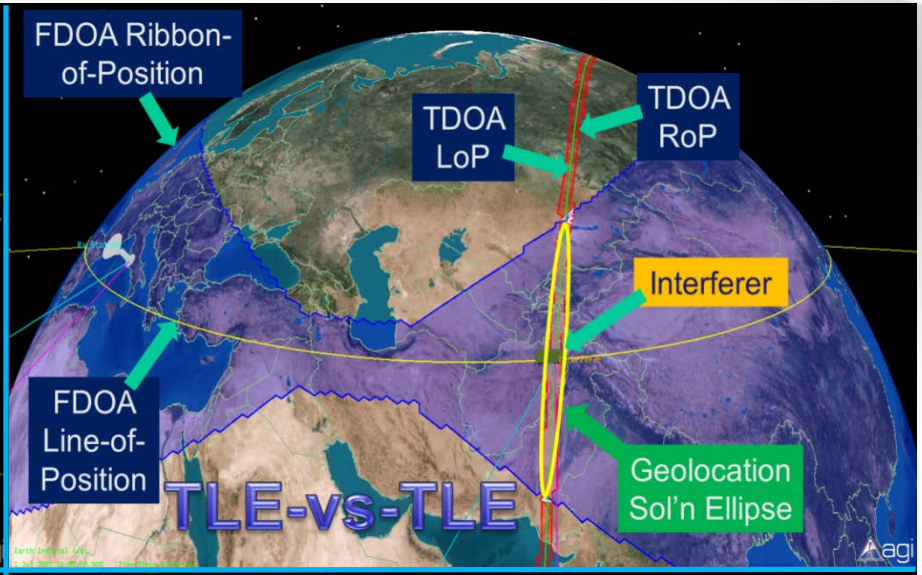
- **Without SDC**
  - Multiple phone calls required to adjacent Operators
  - Hours/days required to locate viable solution sets and data
  - Data formats = anyone's guess
  - Satellite positional data of degraded quality
- **With SDC**
  - Solution sets immediately available
  - All necessary data centralized and in consistent format
  - Better data = more accurate results

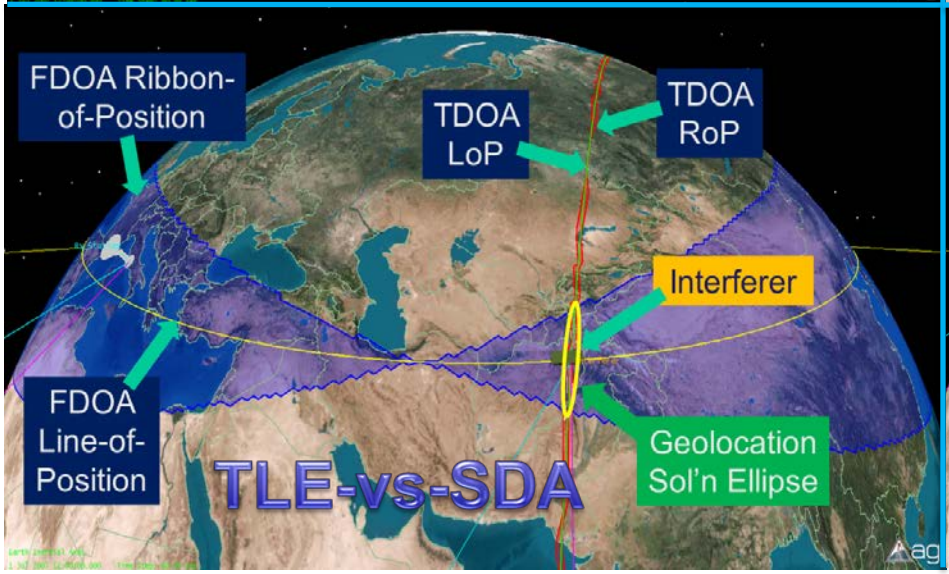
- **RFI geolocation error reduced by two orders of magnitude using SDA-on-SDA quality ephemeris**

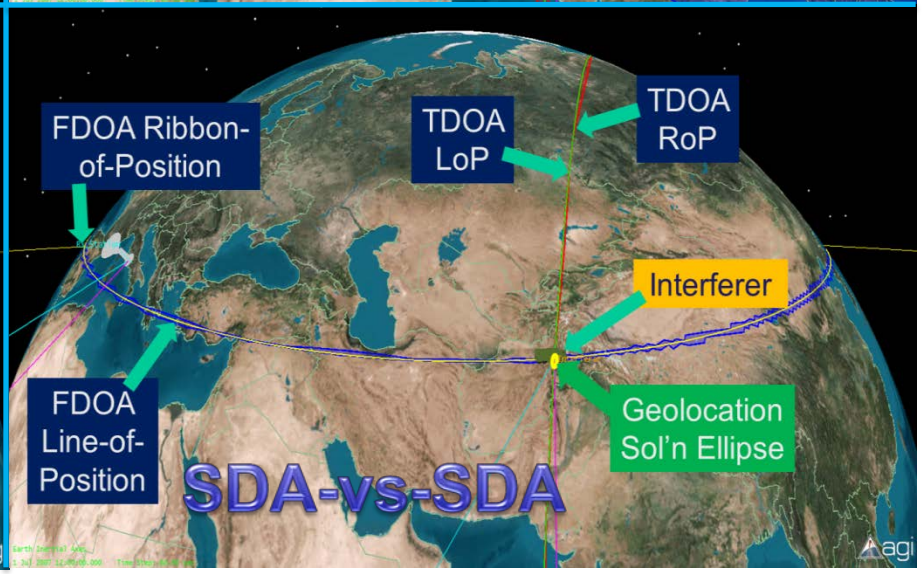
SDC enables faster, more accurate geolocation results

RFI Geolocation Sensitivity to Ephemeris Accuracy









* "Out-of-the-box" accuracy estimate w/o incorporation of reference emitters

SPACE DATA ASSOCIATION

SDA Users Meeting: SDA General Forum

ASSEMBLING ALL THE PIECES: WHAT DOES IT ALL MEAN?

OLTROGGE

Conclusions

- **Analyses reveal SDA member data are of highest quality**
  - Owners are best source of their satellites' positional data
  - Owners are only source of planned maneuver information
- **Maneuvers are critically important**
  - Past: Increases uncertainty of epoch vector
  - Future: CA without predicted maneuvers invalid after 1st maneuver
- **From this, conclude that no data source can "do it all"**
  - SDA (Owner/Operator) for actives
  - NCT data products for all debris

Obs/Sensor Type	Debris	Live Satellite
Radar		
Optical		
Active Ranging		

Solution IS Collaborative SDA & Radar/Optical Data Fusion

SDA & Data Fusion Are THE Answers…

- No single source (SDA or NCTs) has all the data
- NCTs unable to anticipate maneuvers, detect them, recover from them in a timely manner, or maintain actionable SSA for maneuvering objects. Plain and simple.
- SDC created to ingest “best-available” data
- SDA committed to fuse authoritative data from available sources to support operator decisions

Again points to data fusion and the need to collaborate.

SPACE DATA ASSOCIATION

SDA Users Meeting: SDA General Forum

GENERAL Q & A

SANDERS/NASSIF

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