The Commercial Space Operations Center (ComSpOC)

ITU Satellite Communication Symposium 2017, Bariloche, Argentina

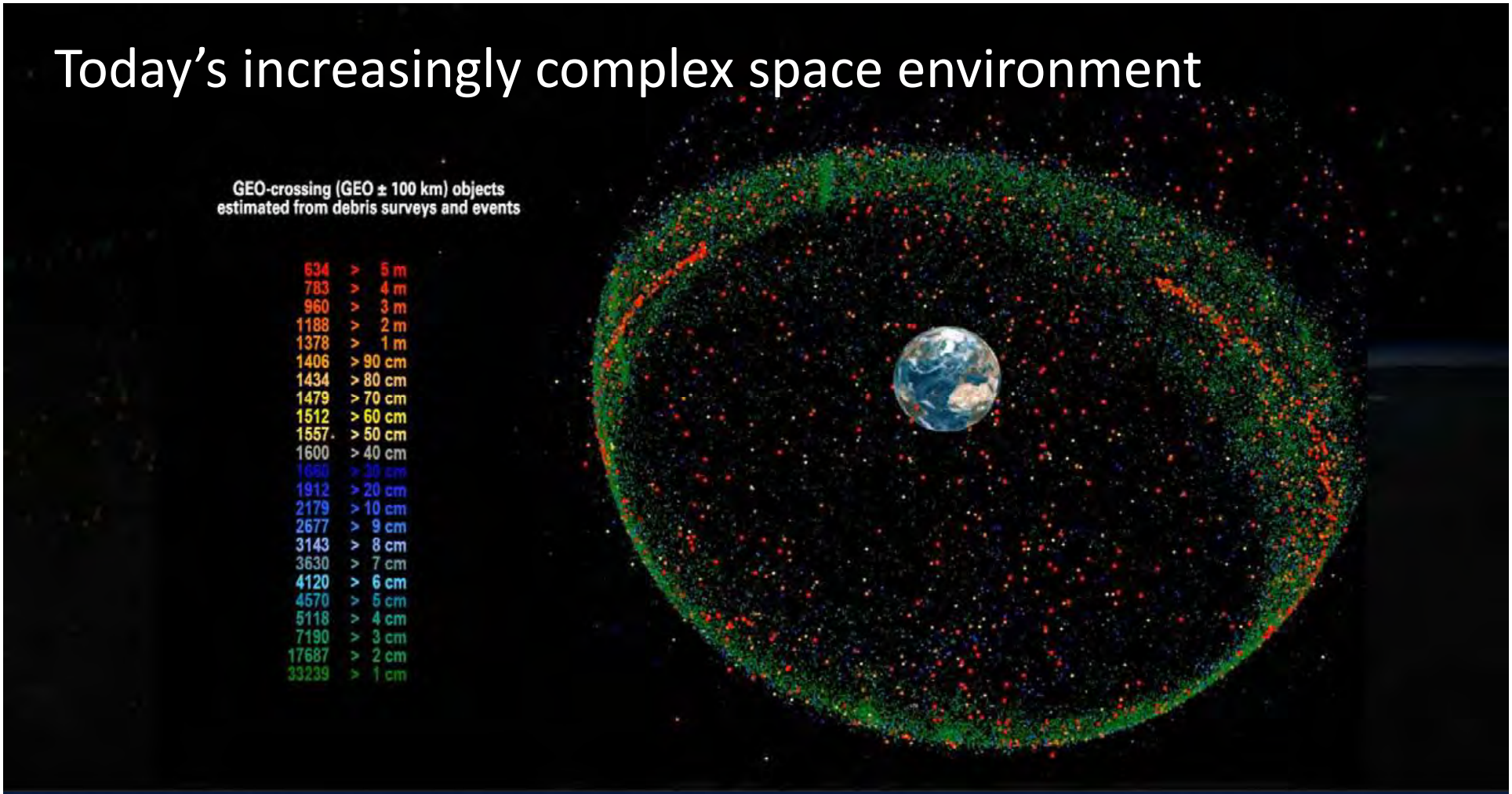
Dan Oltrogge

29-30 May 2017

Agenda

- Today's increasingly complex space environment
- The Commercial Space Operations Center (ComSpOC)
- ComSpOC sensor mix and data fusion
- Proven ComSpOC performance
- The Space Data Association (SDA) and new SDC 2.0

Today's increasingly complex space environment



Anticipated sharp increase in RF spectrum usage

- Many planned large constellations to be added

#	Operator	# S/C	Altitude (km)	Inclination (deg)	S/C Hardbody SIZE (full dimension in m)	Secondary's Hardbody SIZE (full dimension in m)	Combined Hardbody Radius (m)
1a	Boeing V-band	1120	1200	45°	3*	0.1	1.55
1b	Boeing V-band	828	1200	55°	3*	0.1	1.55
1c	Boeing V-band	1008	1000	88°	3*	0.1	1.55
2	CubeSat 380	100	380	98.5°	0.3	0.1	0.2
3	CubeSat 600 (≈Planet)	100	600	98.5°	0.3	0.1	0.2
4	CubeSat 800	100	800	98.5°	0.3	0.1	0.2
5	Globalstar	40	1400	52°	9.7	0.1	4.9
6a	Hawkeye 360	6	650	44°	0.4	0.1	0.25
6b	Hawkeye 360	6	650	63.5°	0.4	0.1	0.25
6c	Hawkeye 360	6	650	97°	0.4	0.1	0.25
7	Iridium	71	780	86.4°	4.27	0.1	2.19
8	LeoSat	140	1400	90°	2	0.1	1.05
9	OneWeb	648	1200	87°	2	0.1	1.05
10	Orbcomm	31	750	45°	10.5	0.1	5.3
11	Samsung	4600	900	?	3*	0.1	1.55
12	SpaceX	4000	1100	90°	2	0.1	1.05
13	Spire	100	651	97.95°	0.3	0.1	0.2
	Terra Bella	28	576	97.76°	1.5	0.1	0.8

On top of which …

- A proliferation of CubeSats projected
  - Modern 3D printing techniques, CNC machining and satellite "kits" make it easier to manufacture, mass produce and operate satellites of modest capability

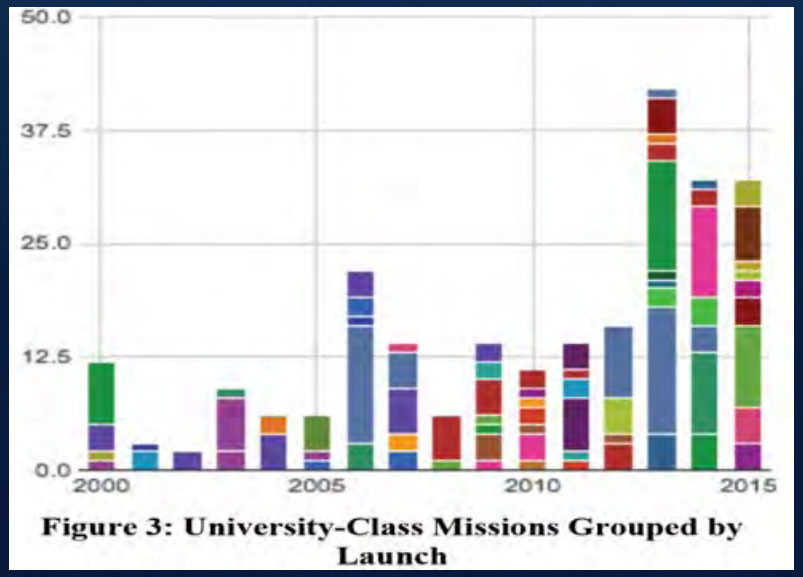
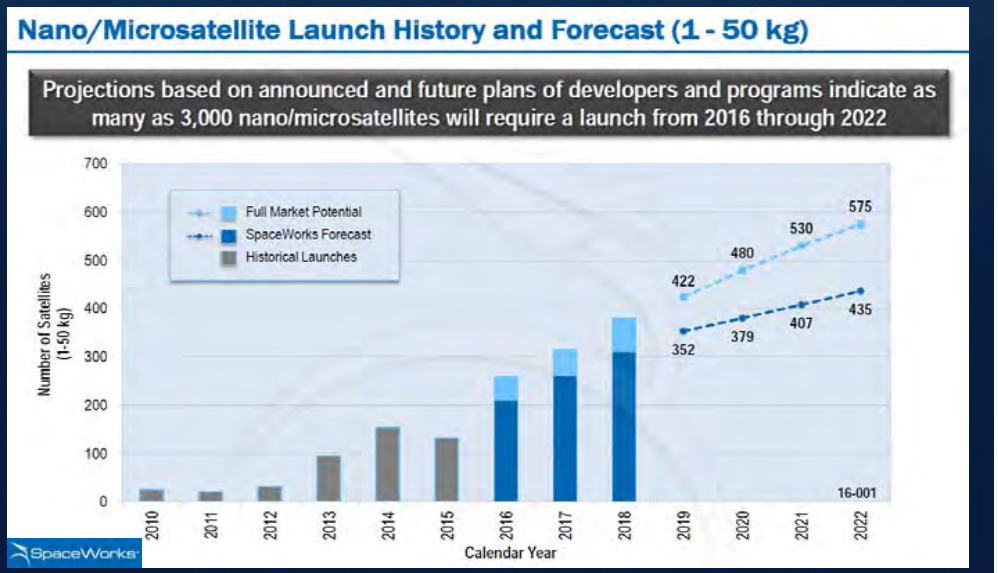


Figure 3: University-Class Missions Grouped by Launch



*Used by permission of author, Dr. Michael Swartwout, St. Louis University*Used by permission of author, Mr. Bill Doncaster of SpaceWorks

Further: Russian “Luch”/Olymp satellite (40258)

- Launched 28 Sept 2014
- Open-source web reports it is a Sigint mission
- High-interest object
- Several station changes since arriving at GEO
- Eventually designated Kosmos-2501

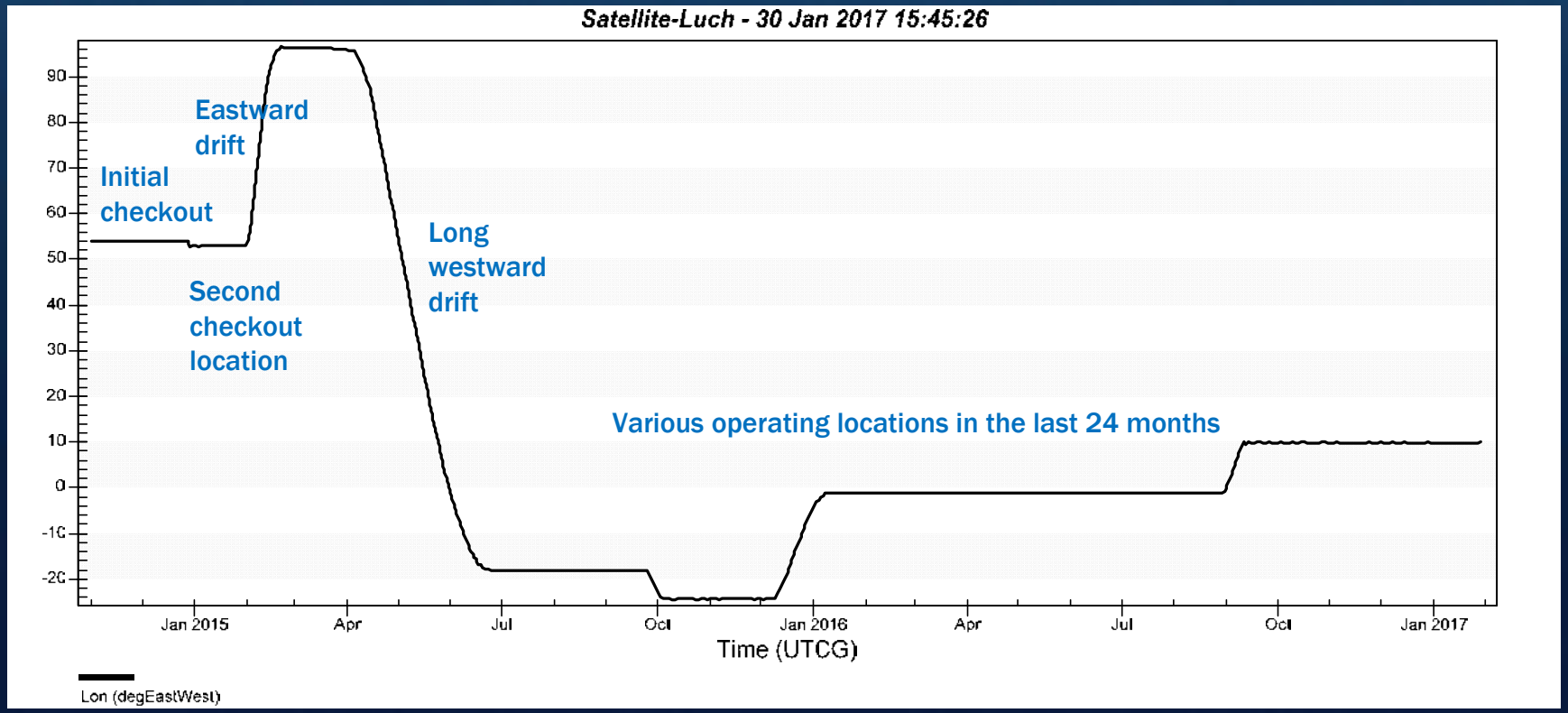
Proton successfully returns to flight delivering a secret Olymp satellite

For the first time since its failure on May 16, a Russian workhorse rocket delivered a payload into space, this time a hush-hush satellite apparently camouflaged as a civilian payload.

Previous Proton mission: Ekspress-AM4R

Above: *A Proton rocket lifts off in the early hours of Sept. 29, 2014, with the Olymp (a.k.a Luch or Kosmos-2501) satellite.*

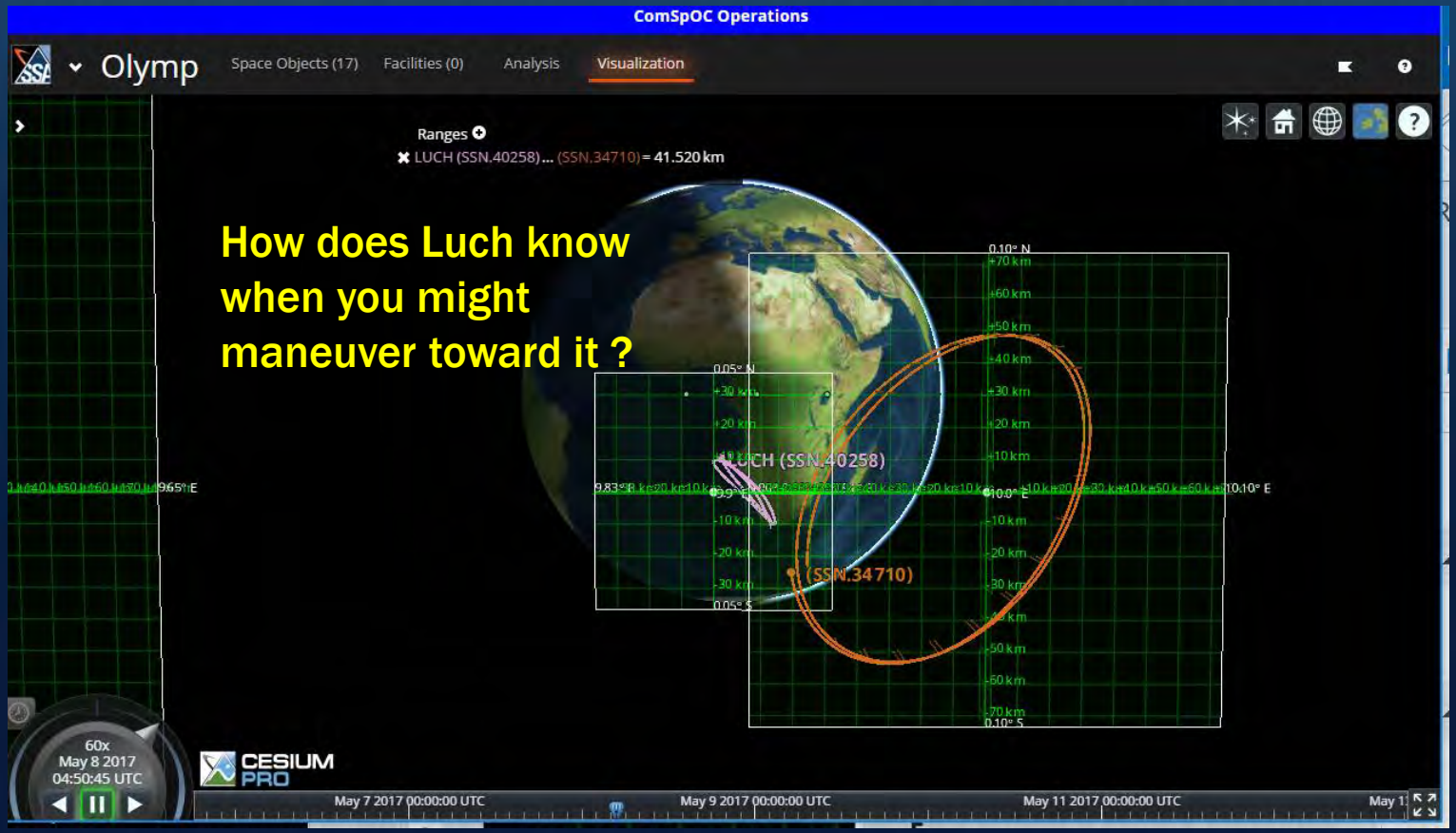
Luch location history



Luch post-checkout activity

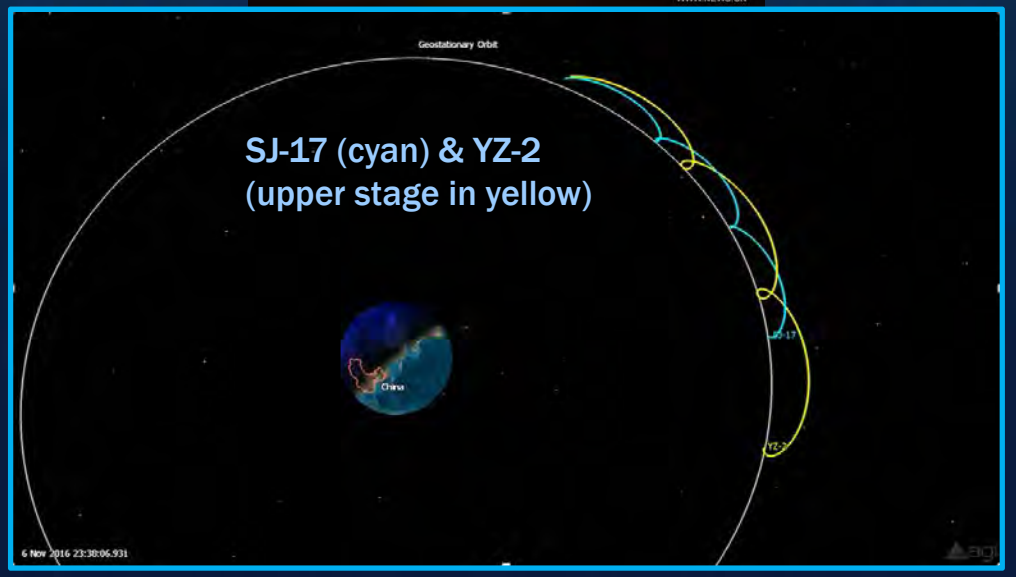
- Operational mission has included 4 proximity operations
  - Jun-Sep 2015
  - Oct-Dec 2015
  - Jan- Aug 2016
  - Sep 2016 – Present
- In each case, Luch parked within ~0.1 deg of its target
- Chemical & electrical thrusters used for station changes

Luch: current status

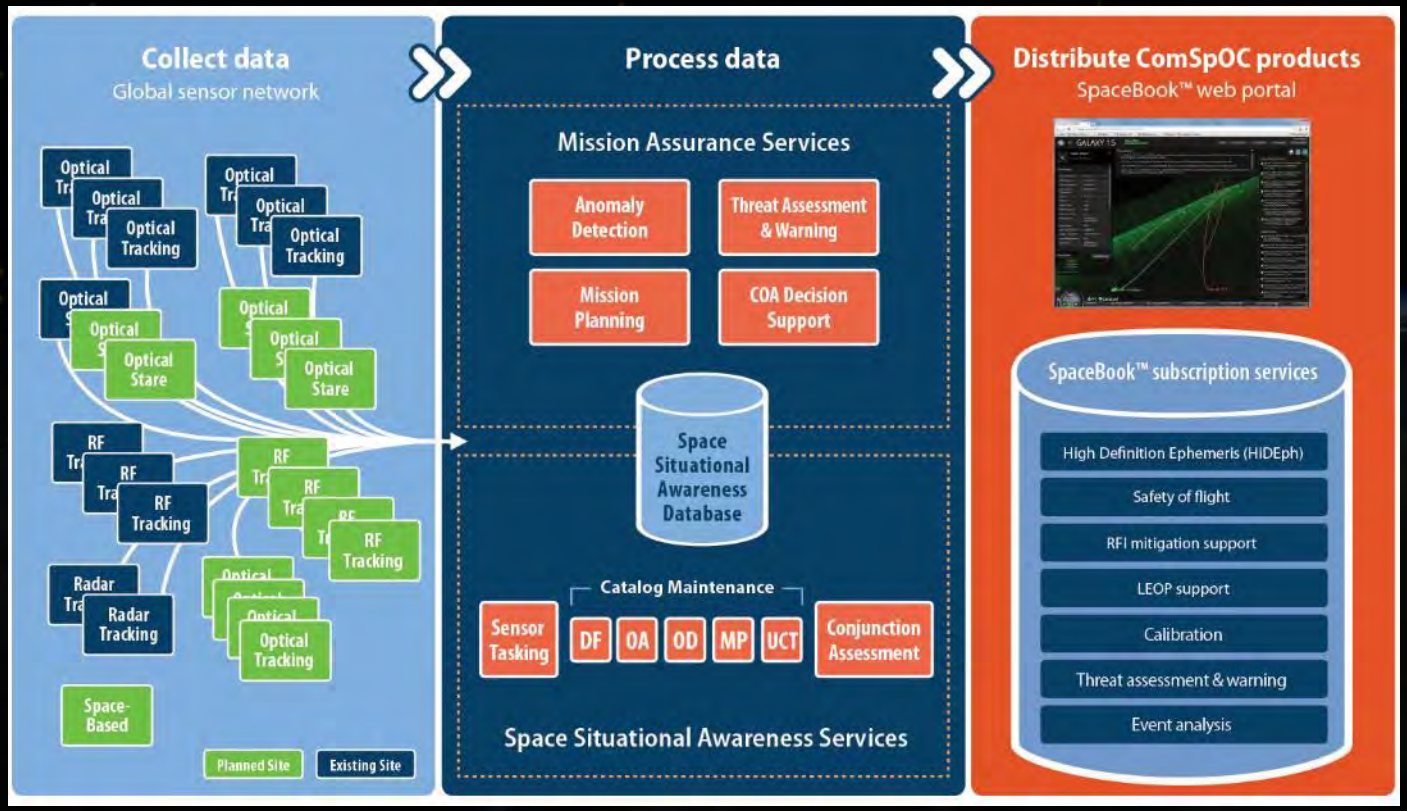


Shijian-17 initial drift to station (prior to 12 Nov)

- New Chinese technology demonstration satellite
  - Space debris observation
  - Including rendezvous and proximity operations
  - Low thrust technology
- Launched 3 Nov on Long March 5 inaugural flight
- ComSpOC has tracked and characterized SJ-17 since launch
  - Used open source info on LM-5 trajectory for initial acquisition



The Commercial Space Operations Center



AGI

ComSpOC

ComSpOC sensor data processing & fusion

Sensor Sources

Traditional

- SSN, SBSS
- Fylingdales
- Vardo
- Sapphire
- GRAVES
- TIRA
- ESTRACK (ESA)
- ISTRACK (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
- GPS
- 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

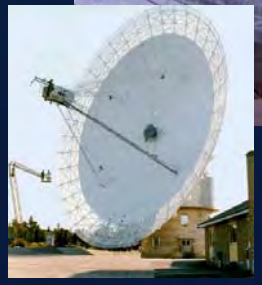
AGI

ComSpOC

ComSpOC's diversified sensor network

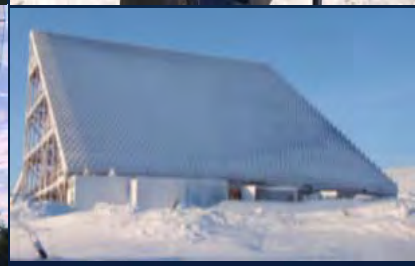
- Optical: Blend of low- and medium-cost, versatile with all-night stare at GEO and local stare, tip and cue of high res scopes at LEO
- Radio Frequency (RF): Long- and short-baseline interferometry provides constant custody of active GEOs
- Radar: Powerful phased-array radars for LEO and GEO
- Space-based: Comprehensive coverage of the GEO belt

Passive RF



GEO radar to 20 cm

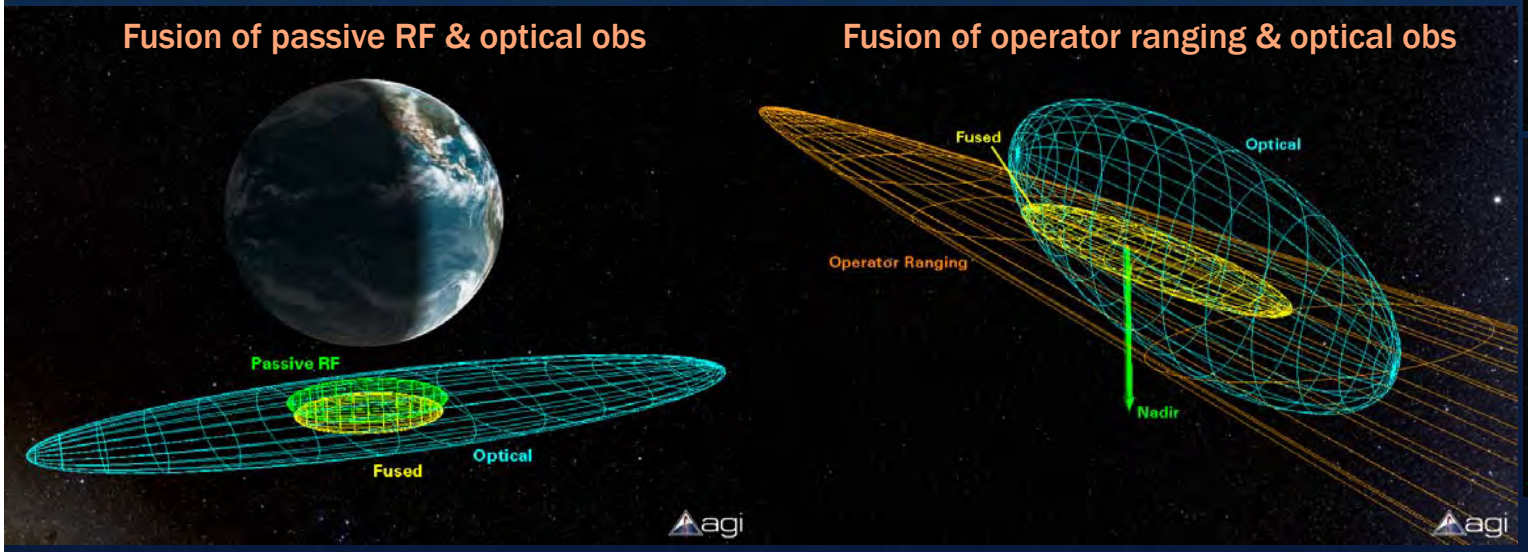
AGI Optical telescopes

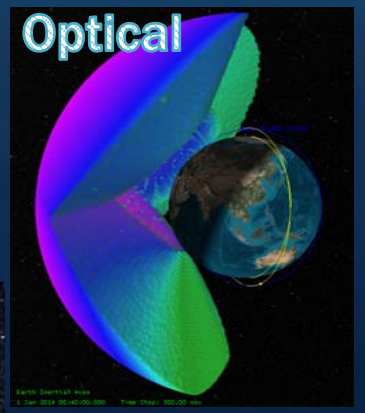


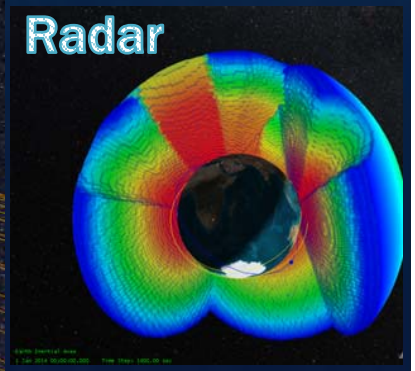
Phased Array Radar

ComSpOC & operator sensor data OD fusion

- Optical cheaper, does well at GEO
- Radar yields exquisite orbits in LEO
- Passive RF yields exquisite orbits in LEO - GEO
- Operator transponder ranging fused as well …







ComSpOC performance: 2016

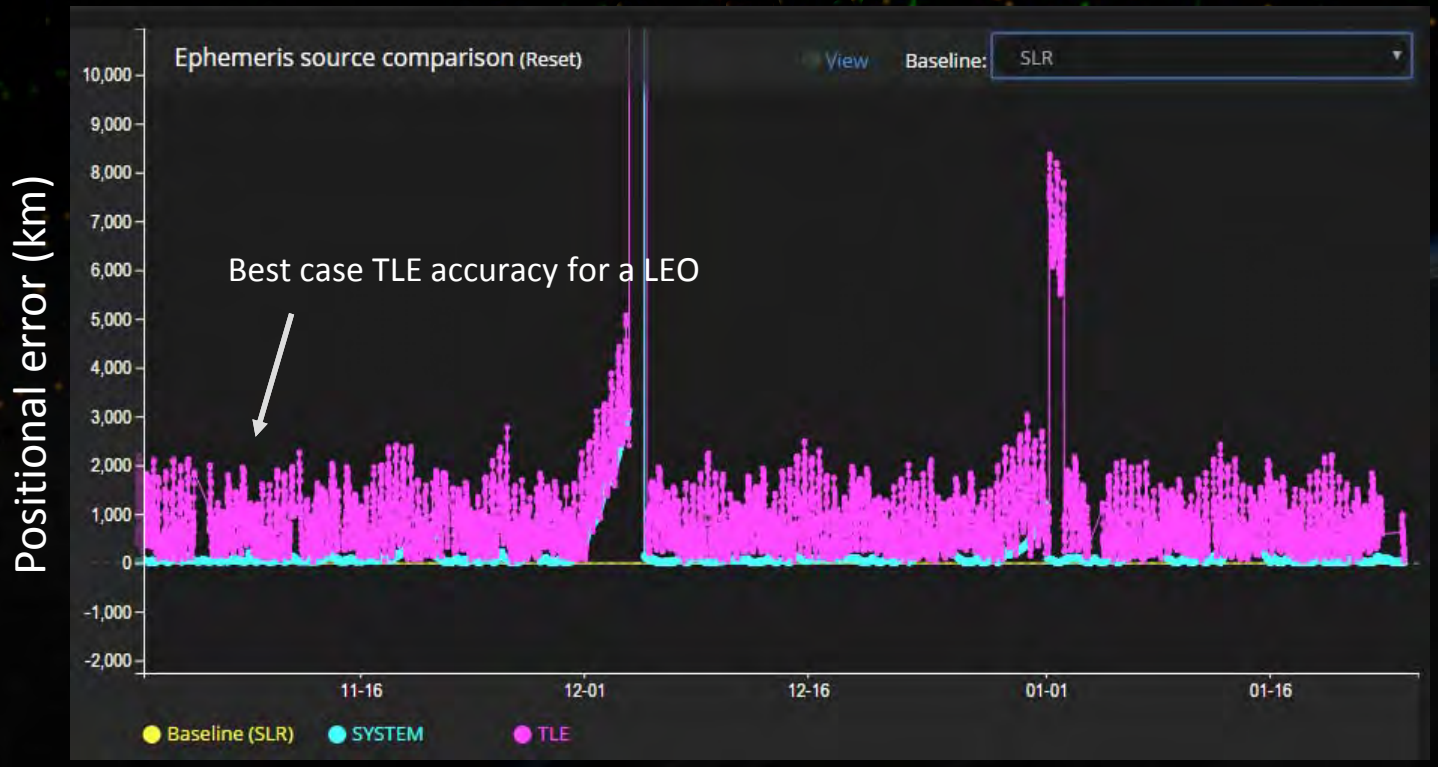
- Maintained a catalog of 9000+ objects
- Processed
  - 6.8 million tracks
  - 231 million measurements
- Found and characterized:
  - 18,800 maneuvers
  - 92% of these were in GEO

AGI

ComSpOC

Sample LEO accuracy: SWARM-B (SLR)

(Polar orbit, Alt ≤ 530 km)

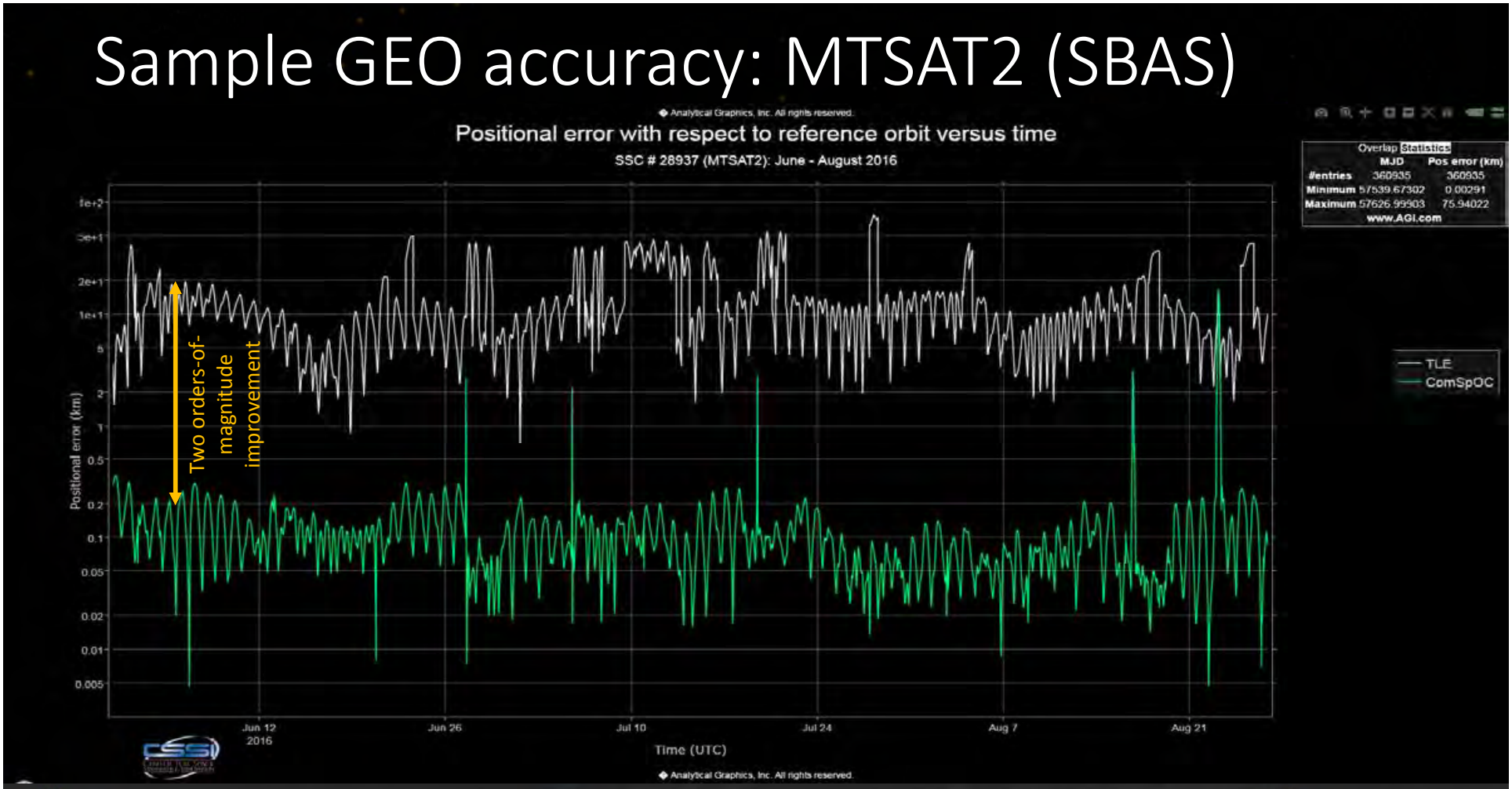


AGI

ComSpOC

Sample LEO accuracy: SWARM-B (SLR) (expanded scale)

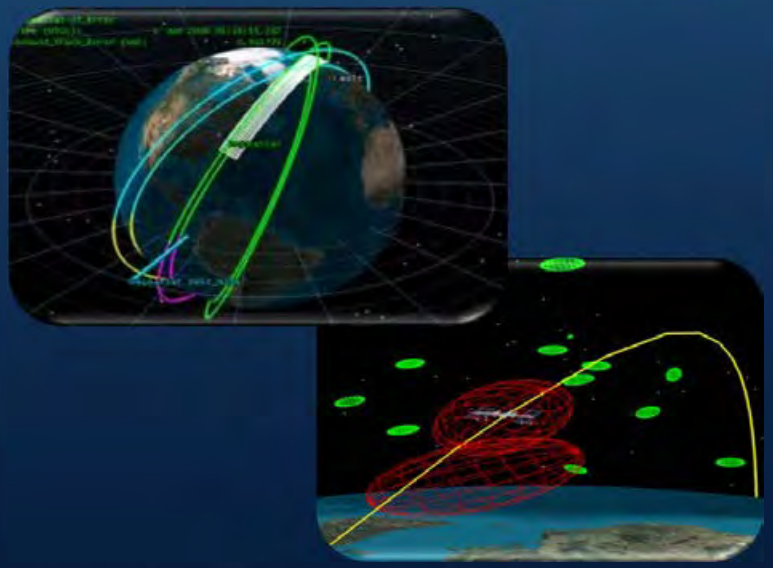
Sample GEO accuracy: MTSAT2 (SBAS)



AGI

ComSpOC

ComSpOC supports characterization



- Maneuver Characterization
  - Improved characterization of maneuvers for better track custody and collection planning
  - Trending to determine “out of family” maneuvers
  - Detect previously uncharacterized S/C maneuver modes
  - Maneuver profile info (e.g. magnitude, direction, duration)
- Conjunction Characterization
  - Determine if GEO S/C systematically approaching each other
  - Displays history of TCAs for each “conjunction event”
  - Perform conjunction trending
- RFI Characterization
  - Determine if RF interference likely
  - Display history of RFI “conjunction events”
  - Perform RFI event trending

Space Data Association: SDC 2.0

SPACE DATA ASSOCIATION

SDA: 34 participating operators, 615 satellites

The next generation of Space Traffic Management

www.space-data.org

FOR IMMEDIATE RELEASE

AGI SPACE DATA ASSOCIATION

SDA and AGI to launch next generation Space Traffic Management service

AGI's ComSpOC to power a major SDC upgrade to manage space traffic and mitigate the effects of Radio Frequency Interference in the geostationary orbit regime

Isle of Man and Exton, PA, USA (6th March 2017)— The Space Data Association (SDA) and Analytical Graphics, Inc. (AGI) have entered into a long term agreement to launch an upgraded Space Data Center (SDC) Space Traffic Management (STM) service, powered by ComSpOC.

SDC 2.0, which will be available to all members of the SDA, has a highly accurate, independently generated catalogue of space objects which will grow to include objects larger than 20cm in and traversing the GEO arc, and will allow for transparent and actionable collision warnings. The service also features functionality to combat Radio Frequency Interference (RFI), including the construction of geolocation scenarios and a Carrier ID database.

"As satellite operators, it is vitally important that we continually improve the Space Situational Environment to ensure safety of our own missions, continuity of services, and protection of the space environment for all operators. After considerable analysis we have determined that the collision risks are higher than previously understood. We underwent a comprehensive process to determine key requirements, conducted extensive market research and a competitive procurement process, and have concluded that AGI can offer the best STM service to adequately mitigate these risks. AGI clearly understands this critical mission and the SDC 2.0 service, using AGI capabilities, delivers the best value and is timely, validated and reliable," stated Mark Rawlins, SDA Chairman.

"We applaud the leadership of the SDA executive members Eutelsat, Inmarsat, Intelsat, and SES for continuing to set the standard for responsible space operations and traffic management," said Paul Graziani, AGI CEO and founder. "We look forward to extending our trusted working relationship with SDA as its Exclusive STM Services Provider and working in partnership with them to expand the boundaries of STM capability and space safety."

-ENDS-

SDC 2.0 recently announced

- Utilizes highly accurate, independently-generated space object catalog
- Powered by ComSpOC
- Catalog will grow to include objects larger than 20cm in and traversing the GEO arc
- Transparent, timely and actionable collision warnings
- Functionality to combat Radio Frequency Interference (RFI), including predictive RFI, optimal construction of geolocation scenarios and the Carrier ID database
- Positions SDA as the provider of the world's authoritative system

Why SDC 2.0?

- Collision risks much higher than previously understood
  - Need protection from all threats
  - Protect/preserve the geostationary environment for the future
- Will provide needed operations-oriented RF and RFI functionality
- SDC 1.0 limitations:
  - Inter-system biases in operator systems
  - Availability & accuracy limitations of debris data, particularly for < 1m objects
  - Lack of transparency and consistent availability of government-provided data

SDC 2.0 – a new level of flight safety

- High-accuracy, independently-generated ComSpOC catalogue
  - Catalogue will evolve to include all objects >20cm
  - More extensive than public space catalogues
- Advanced non-cooperative maneuver processing
  - Rapid recovery of orbits states after maneuvers
- Verification of maneuver plans
- Realistic covariance of catalogue objects
  - Yields actionable collision probability-based warnings
  - Enables realistic geolocation error ellipses
- Inter-system biases eliminated

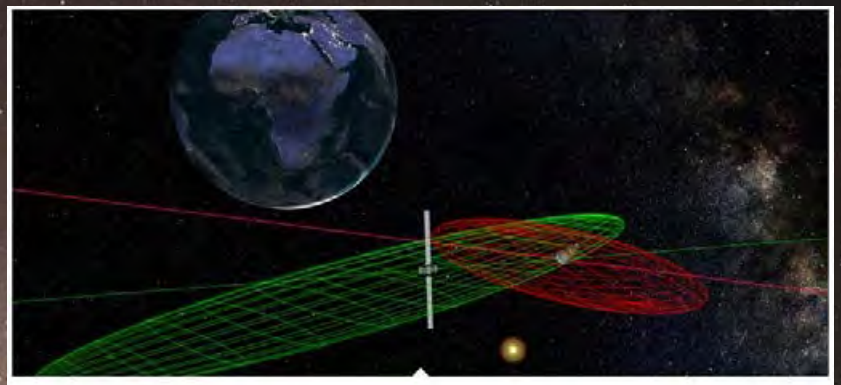
- Radio Frequency Interference mitigation functionality:
  - More accurate geolocation solutions in shorter times
  - Direct data download into geolocation systems
  - RFI predictions and alerts
- Carrier ID database:
  - Central management of Carrier ID reference numbers
- Validated algorithms and processing
- Commercial service agreement ensures:
  - Transparency
  - Reliability
  - Timeliness
  - Independence from government data sources

SDA will no longer rely on 3rd-party catalog data – it will independently derive its own catalogue and generate actionable collision warnings

Conclusions

- Collision risks in both LEO and GEO much higher than previously understood – need protection from all threats
- Increased RFI incidences very likely, given the developing large constellations and continued GEO growth
- Commercial SSA offers significant value for enhanced mission effectiveness
- High accuracy solutions and analyses improve the "signal-to-noise ratio" and allow customers to focus on their mission needs

- Dan Oltrogge (oltrogge@agi.com)
- For more information:
  - http://www.ComSpOC.com/
  - Phone: 1.610.981.8000



SDA – AGI SPACE DATA CENTER 2.0 INFO SESSION/WEBINAR, THURSDAY 1ST JUNE 2017

Thursday June 1st, 2017
9am CET/3am EDT or 4pm CET/10am EDT

On Thursday June 1st, we will be hosting a joint webinar in partnership with Analytical Graphics Inc. (AGI). The webinar is open to both existing and prospective members and will offer an overview of the current space environment plus more information about SDC 2.0 (Space Data Center).

(please contact me if interested !)

GPS: 20° 42' 26" N, 156° 15' 27" W 2015:07:17 20:24:19

Captured by T.S. Kelso