



CENTER FOR SPACE
STANDARDS & INNOVATION

Improved Conjunction Analysis via Collaborative Space Situational Awareness

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Overview

- Motivation
- Background
- Proposed Solution
- Analysis of Orbital Data Sources
 - Supplemental TLEs
 - GPS, GLONASS, Intelsat
- Application: SOCRATES-GEO
- Summary & Conclusions

Motivation

- Recent events emphasize need for improved SSA for conjunction analysis
 - Chinese ASAT test (2007 Jan 11)
 - USA 193 intercept (2008 Feb 21)
 - ISS maneuver to avoid Cosmos 2421 debris (2008 Aug)
- Geostationary orbit (GEO) is a limited resource
 - More satellites = more conjunctions
 - Implications of a collision are significant
 - Potential loss of colliding satellites and associated revenues
 - Increase in debris, putting other satellites at risk

Background

- Conjunction analysis needs full-catalog orbital data
 - TLEs are currently the only such source
 - Low accuracy results in high false-alarm rate
- More accurate orbital data could
 - Reduce false alarms
 - Improve use of limited tracking resources

Background

- Current system limited to non-cooperative tracking
 - SSN uses combination of radar and optical resources
- Operational satellites most difficult to track due to maneuvers
 - Maneuvers typically not known ahead of time
 - Delay in detecting maneuvers can result in poor accuracy or even 'lost' satellites
 - Requires more SSN resources to maintain orbits

Proposed Solution

- Satellite operators already maintain orbits
 - Active ranging, GPS can be very accurate
- Develop Data Center to collect operator data
 - Use operator data to improve conjunction analysis
 - Provide analysis/data to all contributors
- Current Data Center participation
 - Intelsat, Inmarsat, EchoStar, SES (Astra, New Skies, Americom), NOAA, Star One, Telesat
 - 117 satellites—32% of all active GEO satellites
 - 24 satellites pending

Analysis of Orbital Data Sources

- Many sources of operator orbital data
 - Direct from satellite operator (Data Center)
 - Public sources
 - GPS (almanacs, precise ephemerides)
 - GLONASS (precise ephemerides)
 - Intelsat (11-parameter data, ephemerides)
 - NOAA, EUMETSAT (state vectors)
- Challenges
 - User-defined data formats
 - Variety of coordinate frames & time systems used

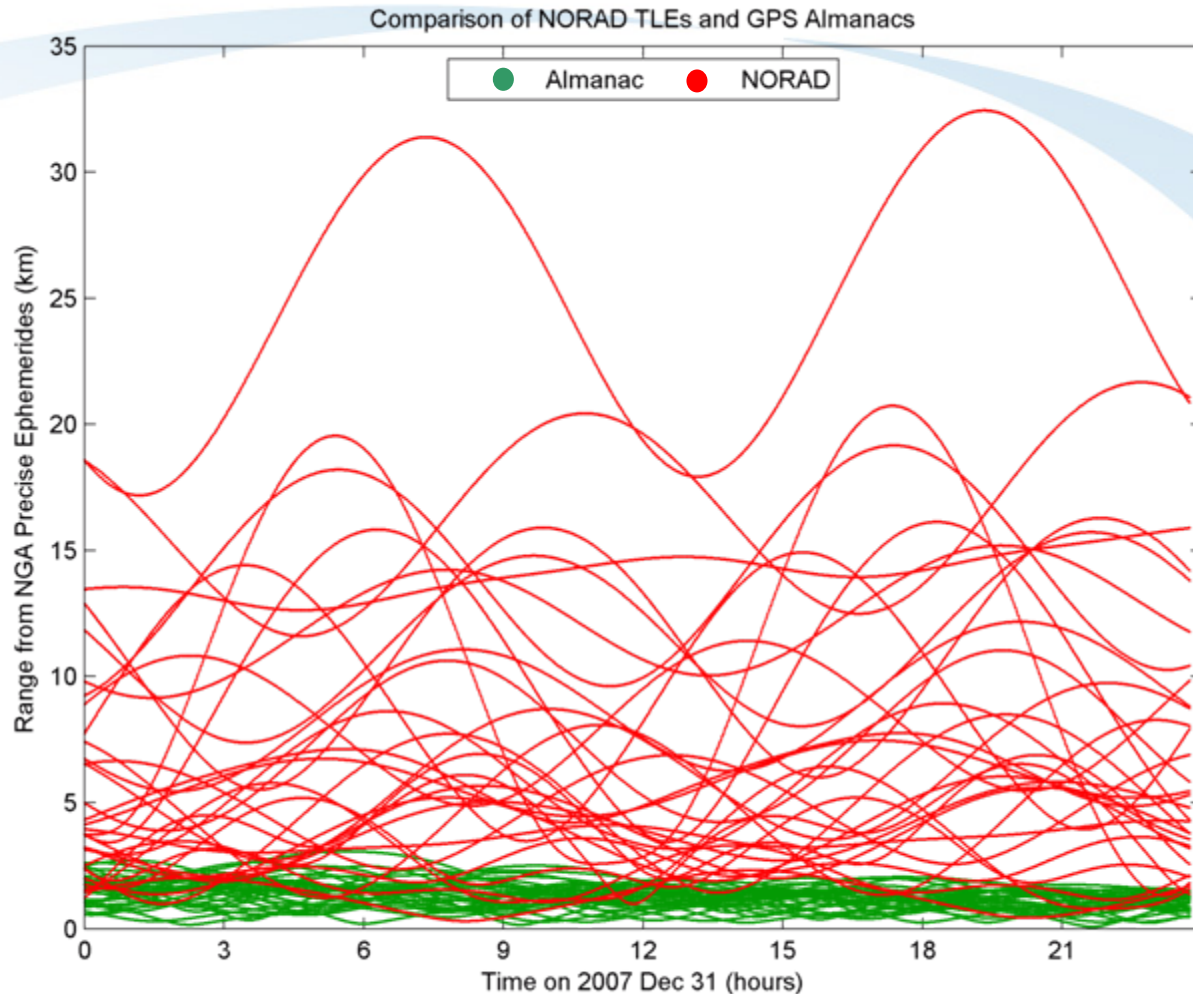
Supplemental TLEs

- Use public orbital data
 - GPS almanacs
 - GLONASS precise ephemerides
 - Intelsat 11-parameter data
- Import data into STK to generate ephemerides
- Generate TLE from ephemerides
 - <http://celestrak.com/NORAD/elements/supplemental/>
 - Allows users to see benefit
 - Test cases with supporting data
 - Overcomes limitations in most orbital software
 - Most applications can handle TLEs/SGP4

GPS Almanacs vs. TLEs

Mean: 7.544 km

Max: 32.449 km

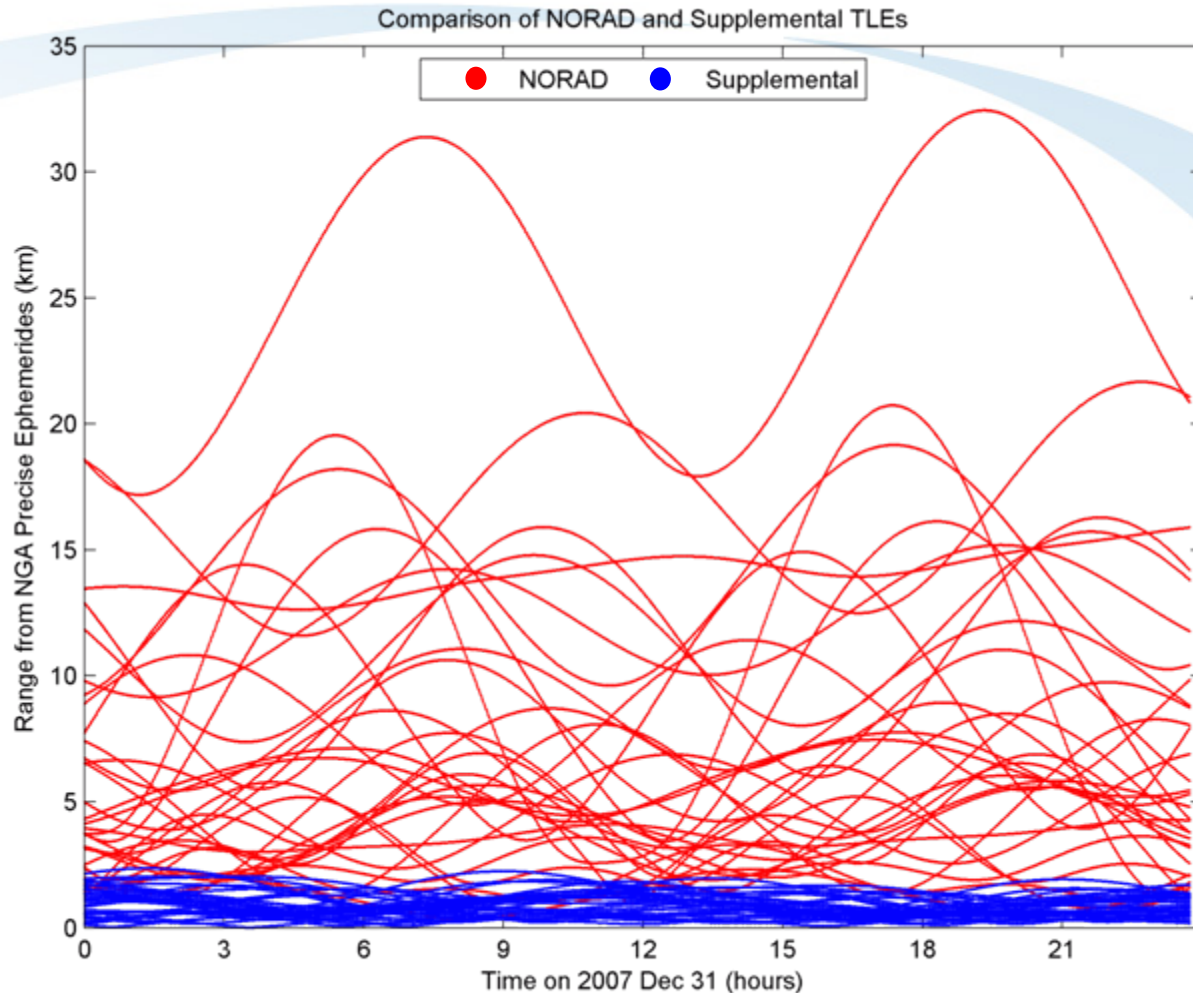


Mean: 1.292 km

Max: 3.073 km

GPS Supplemental TLEs

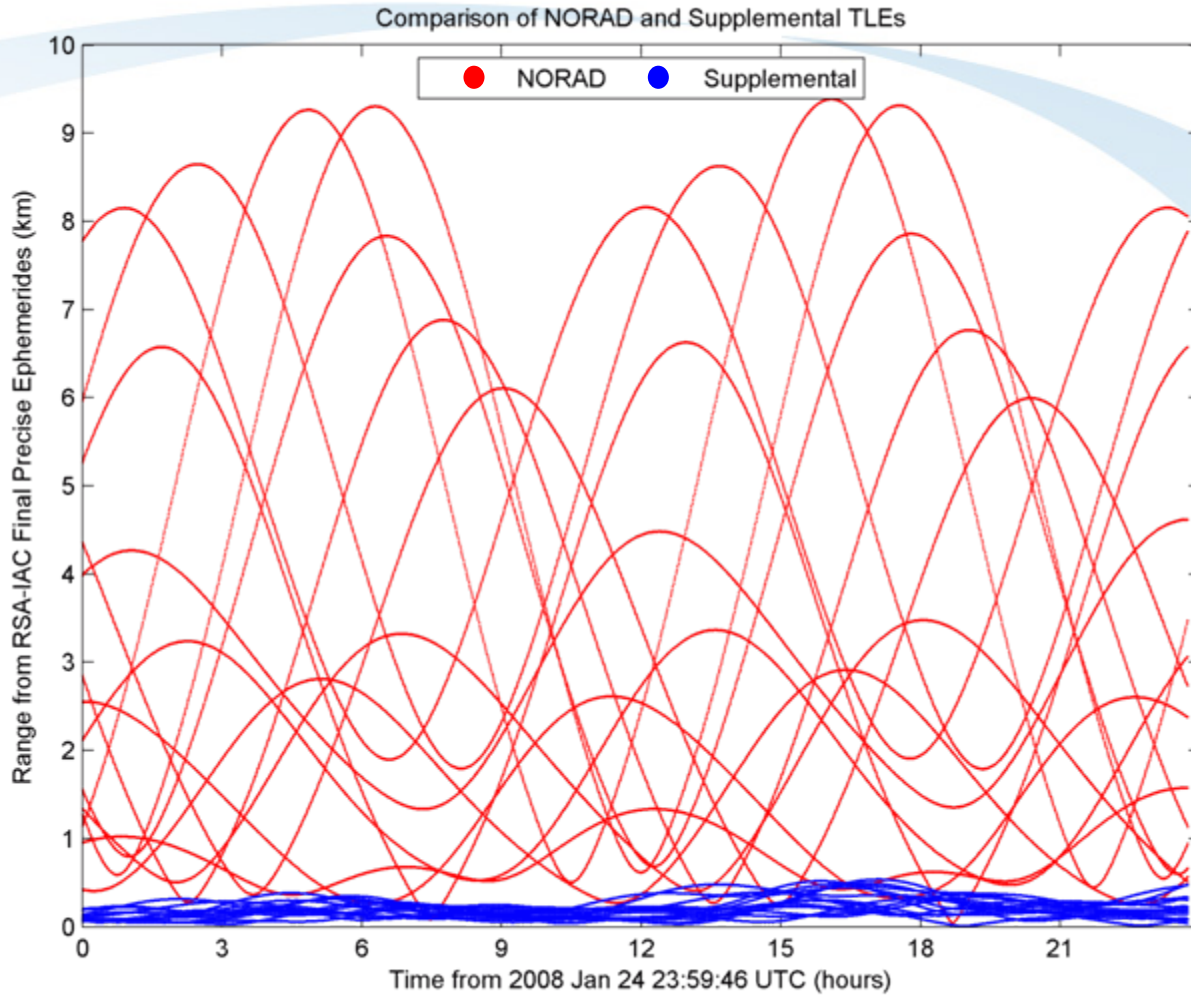
Mean: 7.544 km
 Max: 32.449 km



Mean: 0.872 km
 Max: 2.366 km

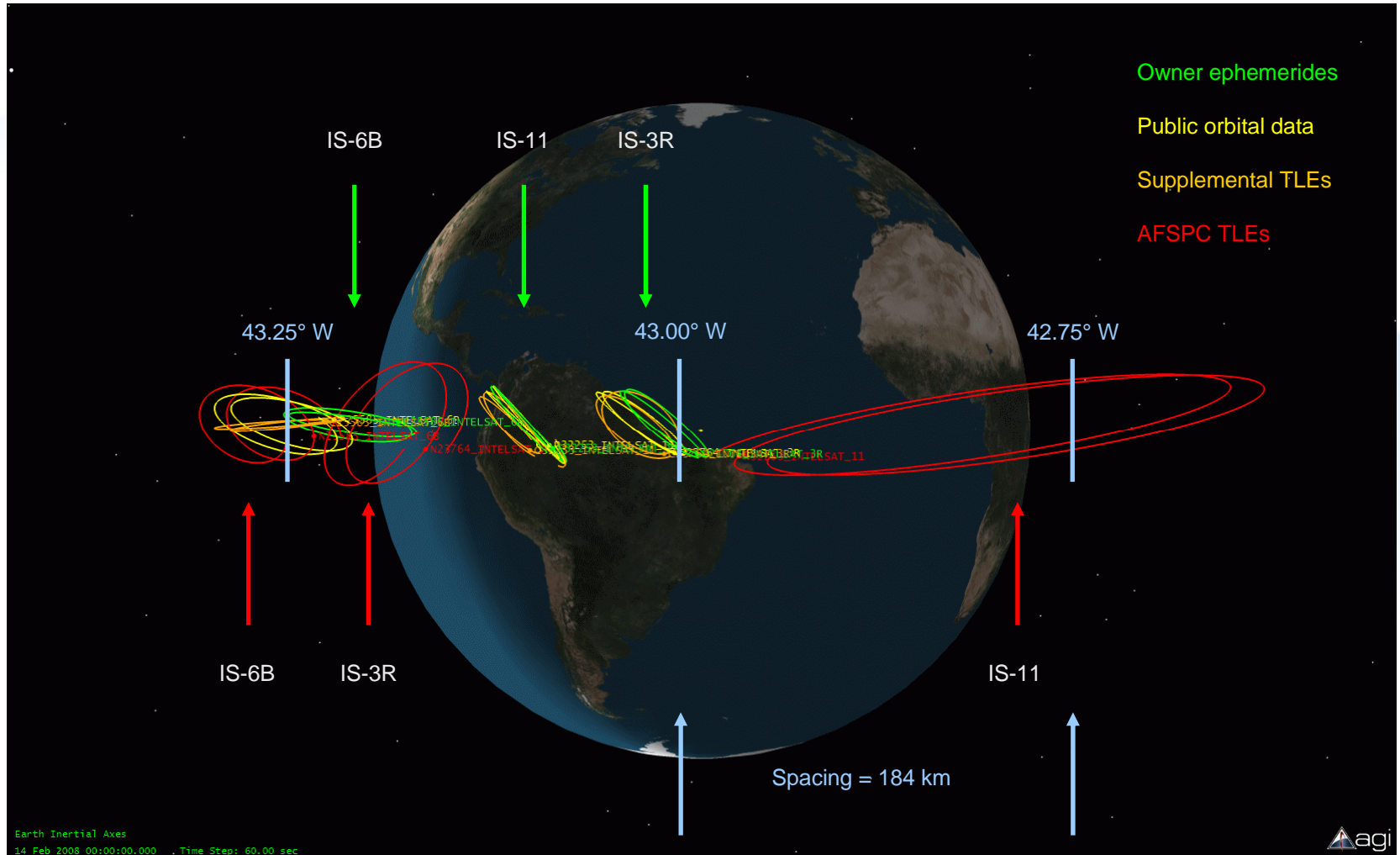
GLONASS Supplemental TLEs

Mean: 3.301 km
 Max: 9.388 km



Mean: 0.201 km
 Max: 0.539 km

Intelsat Comparison

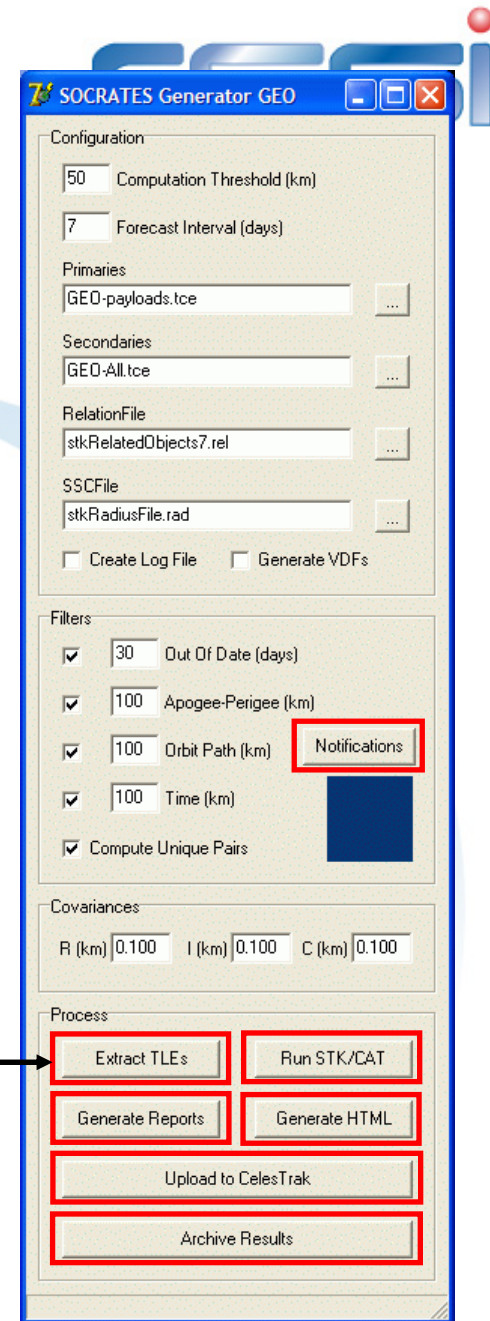
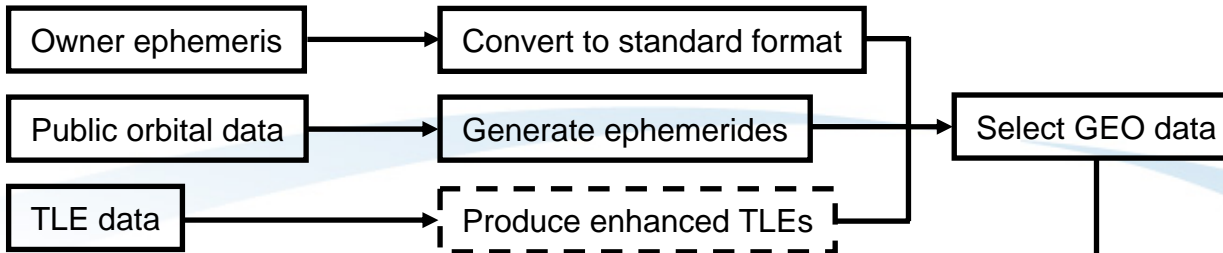


Application: SOCRATES-GEO

- New system on CelesTrak
 - Looks for all objects which pass within 250 km of GEO
 - Uses improved data sources, when available
 - Generates standard reports, including orbital data
 - Allows user-defined notification criteria
 - Automatically sends notification
 - Web access via secure system

Data sources

Data preparation



SOCRATES-GEO Reports Updated - Thunderbird

File Edit View Go Message Tools Help

Get Mail Write Address Book Reply Reply All Forward Tag Delete Junk Print Back Forward Previous Next File

Subject: SOCRATES-GEO Reports Updated
From: Dr. T.S. Kelso
Reply-To: TS.Kelso@celestrak.com
Date: 15:41
To: Joe Chan, Bjorn Burkwalter
Cc: T.S. Kelso

The latest SOCRATES-GEO analysis is complete at 2008 Sep 05 21:41:06 UTC and results are now available at <https://celestrak.com/SOCRATES-GEO>.

Min range threshold violation for GALAXY 11 (G-11) and GALAXY 26 (G-26):
 Min range at TCA (2008 Sep 10 23:11:44.702) = 4.135 km
<https://celestrak.com/SOCRATES-GEO/searchSOCRATESGEO.pl?IDENT=CATNR&CATNR TEXT1=26038&CATNR TEXT2=25626&ORDER=MINRANGE&MAX=25>

Min range threshold violation for INTELSAT 709 (IS-709):
 Min range at TCA (2008 Sep 07 18:51:57.183) = 4.564 km
<https://celestrak.com/SOCRATES-GEO/searchSOCRATESGEO.pl?IDENT=CATNR&CATNR TEXT1=11440&CATNR TEXT2=23915&ORDER=MINRANGE&MAX=25>

Min range threshold violation for INTELSAT 3R (IS-3R) and INTELSAT 11 (IS-11):
 Min range at TCA (2008 Sep 11 17:39:42.891) = 5.144 km
<https://celestrak.com/SOCRATES-GEO/searchSOCRATESGEO.pl?IDENT=CATNR&CATNR TEXT1=23764&CATNR TEXT2=32253&ORDER=MINRANGE&MAX=25>

Min range threshold violation for INSAT-2E (APR-1):
 Min range at TCA (2008 Sep 10 21:47:17.459) = 8.001 km
<https://celestrak.com/SOCRATES-GEO/searchSOCRATESGEO.pl?IDENT=CATNR&CATNR TEXT1=21016&CATNR TEXT2=25666&ORDER=MINRANGE&MAX=25>

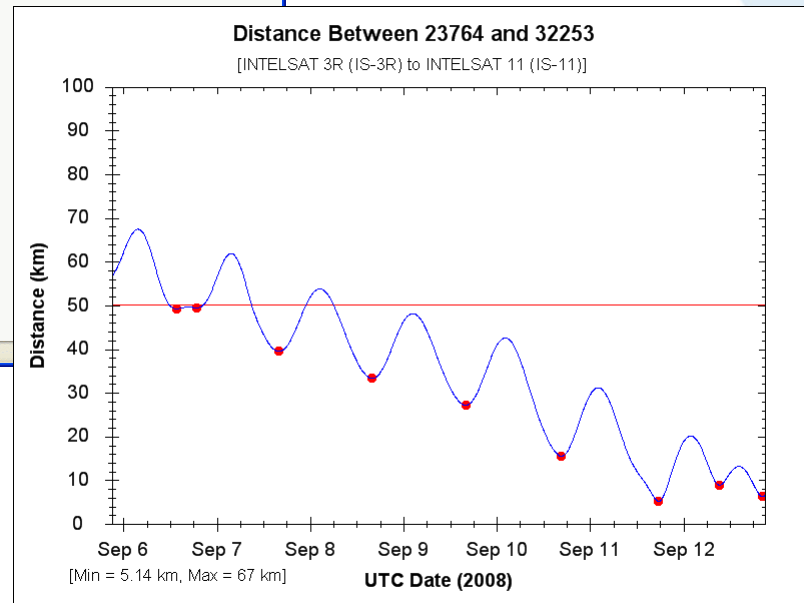
Min range threshold violation for GALAXY 15 (G-15):
 Min range at TCA (2008 Sep 05 22:56:19.090) = 8.406 km
<https://celestrak.com/SOCRATES-GEO/searchSOCRATESGEO.pl?IDENT=CATNR&CATNR TEXT1=28884&CATNR TEXT2=19913&ORDER=MINRANGE&MAX=25>

Min range threshold violation for GALAXY 23 (G-23):
 Min range at TCA (2008 Sep 11 08:01:35.968) = 9.662 km
<https://celestrak.com/SOCRATES-GEO/searchSOCRATESGEO.pl?IDENT=CATNR&CATNR TEXT1=08366&CATNR TEXT2=27854&ORDER=MINRANGE&MAX=25>

Neighborhood Watch Results
<https://celestrak.com/SOCRATES-GEO/NW/27513-28628.png>
<https://celestrak.com/SOCRATES-GEO/NW/26038-31307.png>
<https://celestrak.com/SOCRATES-GEO/NW/25937-26402.png>
<https://celestrak.com/SOCRATES-GEO/NW/23764-32253.png>

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<https://celestrak.com/SOCRATES-GEO/NW/23764-32253.png>



Summary & Conclusions

- Collaborative effort addresses current limitations
 - Improves orbital accuracy
 - Reduces search volumes
 - Reduces false-alarm rate
 - Supplements full-catalog orbital data source
- Reduces SSA tracking requirements
 - Trust but verify



Questions?