Space Surveillance and Situational Awareness

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Overview

- Catalog Maintenance Loop
- From Surveillance to Situational Awareness
- US Space Surveillance Network
- Global SSA Resources

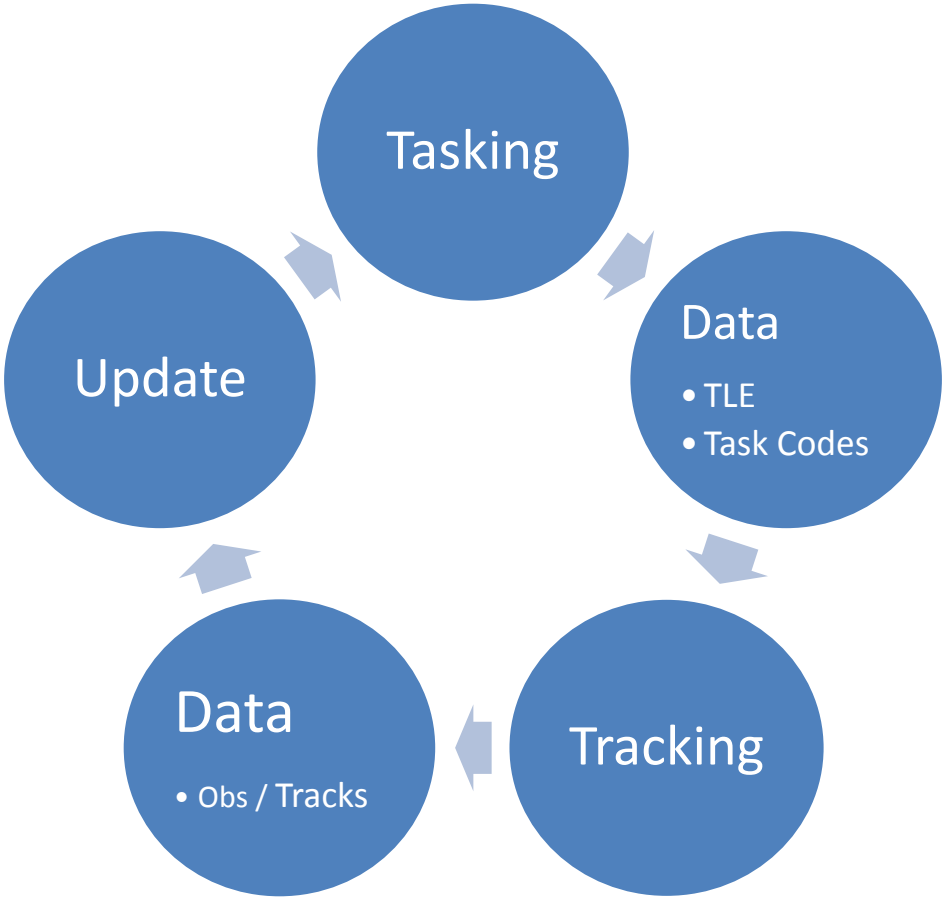
THE CATALOG MAINTENANCE LOOP

Comparing Space Domain to Air/Land/Sea

- Three "unique" properties of space
  - Space is really big (~10^{14} cubic kilometers volume out to GEO)
  - Objects move very fast and cannot easily change speed/direction
  - Very few slowing forces

- Effects of these properties
  - Objects stay in orbit for a long time (depending on altitude)
  - Unfeasible to track everything in Earth orbit all the time
  - Generally easy to predict an object's future position
  - Almost always using instruments (IFR) instead of human senses (VFR) to provide information

The Catalog Maintenance Loop



Obs vs Tracks

- An ***observation*** is the position of a satellite at a specific moment in time, as detected by a sensor
  - Gives satellite position in reference to the sensor which can then be converted to Earth-centric coordinates
    - In-track (time)
    - Cross-track (beta)
    - Height

- A ***track*** is made of multiple observations taken sequentially as a satellite passes overhead a sensor
  - Number of obs in a track depends on how much data is needed and the workload of the sensor

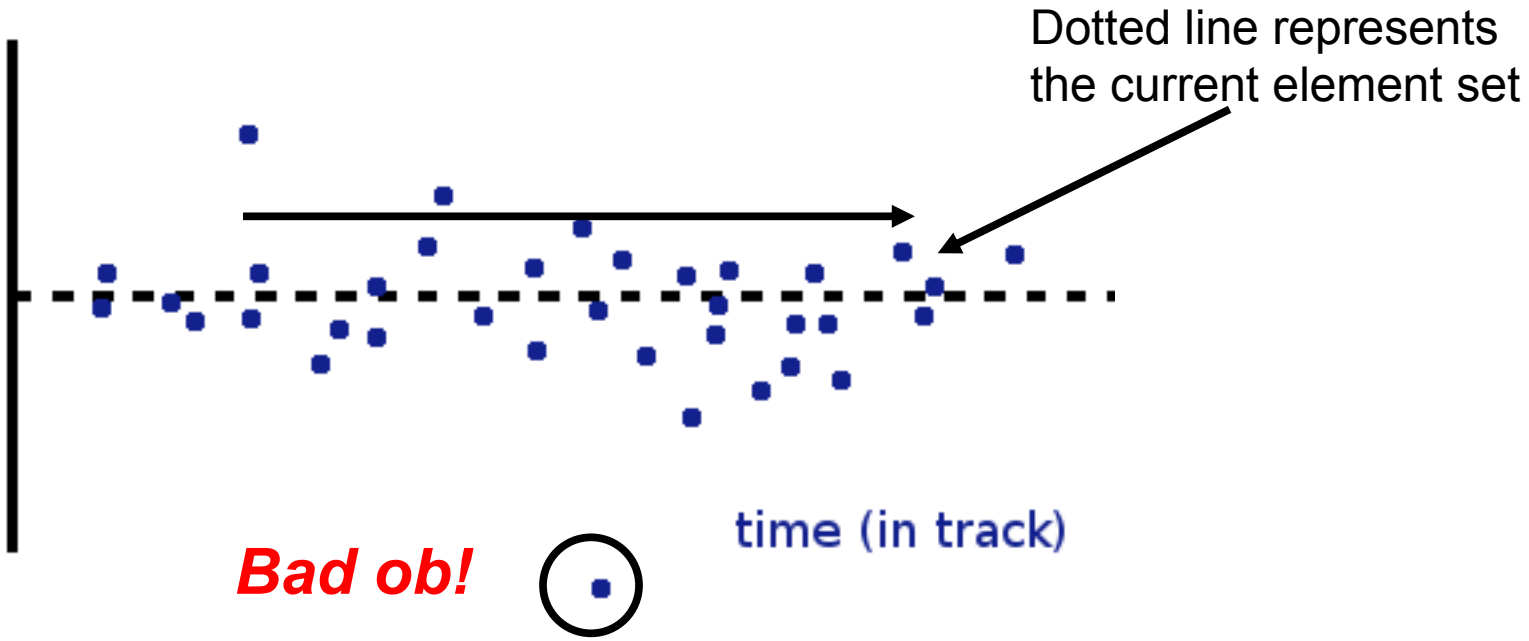
Element Set

- An ***element set*** (elset) gives an equation for the location of a satellite at a fixed point in time

- Standard Keplerian Elset
  - Epoch Time: point in time when all the other values were
  - Inclination: angle between the equator and the orbit
  - Eccentricity: shape of an orbit (how close to a circle it is)
  - Right Ascension of the Ascending Node (RAAN): angle between a distant star and were the satellite crosses the equator heading from south to north
  - Argument of Perigee: position of perigee as measured from ascending node
  - Mean Anomaly: position of the satellite as measured from perigee
- State Space Vector
  - X, Y, Z position of satellite as referenced to the center of the Earth
  - Xdot, Ydot, Zdot velocities of the satellite in all 3-axes

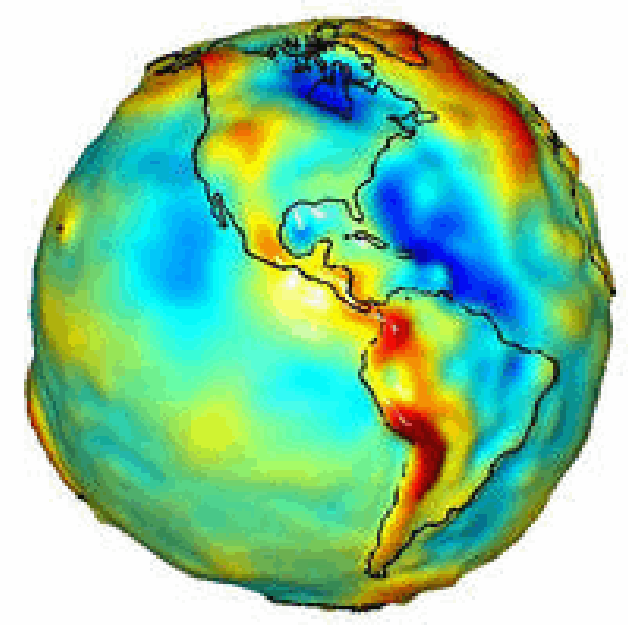
Creating Elsets from Obs

- If we draw a curve through all the observations for a satellite, we can create an element set



Perturbations

- A ***perturbation*** is a change in the orbit due to a natural force
  - Mass Asymmetry (J effects)
  - Drag (all satellites out to 2000 km)
  - Radiation Pressure (force from sunlight)
  - Third-body effects (Sun and Moon)
- Because of perturbations, a satellite's orbit is changing all the time



Gravity Map of the Earth from the GRACE satellite

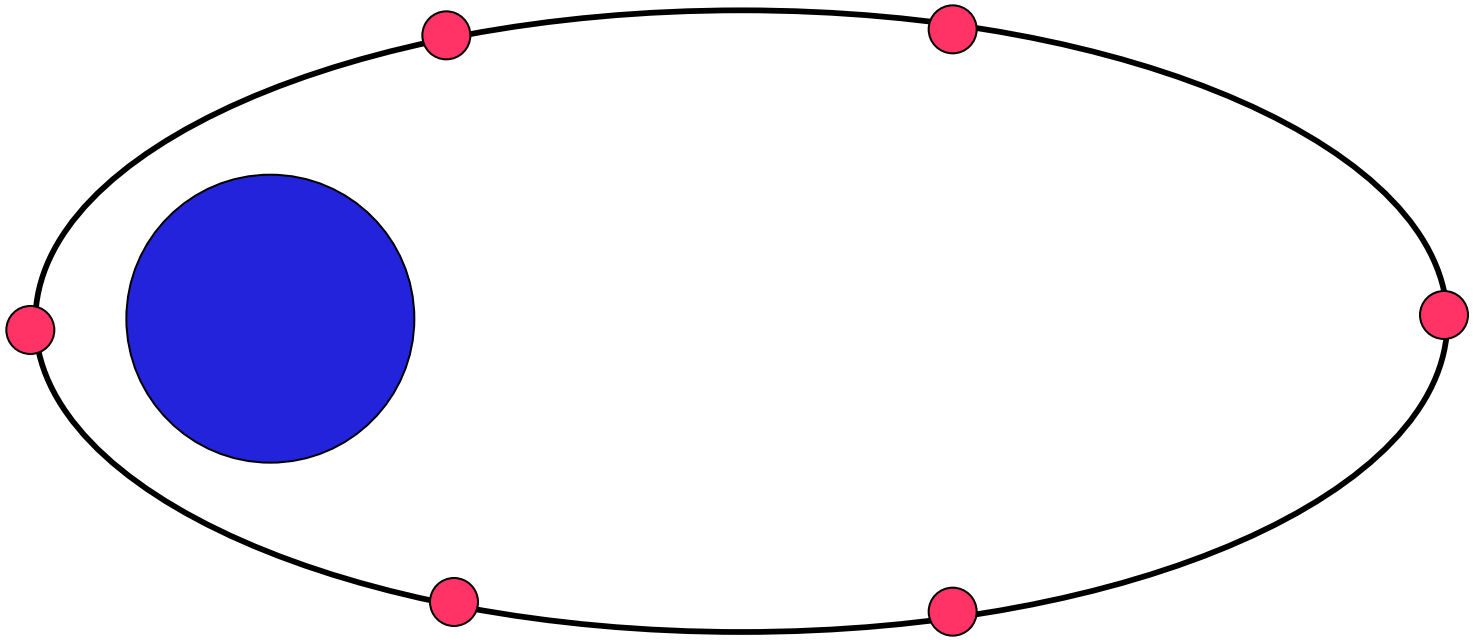
Types of Perturbation Theory

- General Perturbations (GP, SGP, SGP4)
  - Takes average of all perturbations over the entire orbit and lumps it together into one variable
  - Produces smooth curve over time
  - Quick to calculate but not very accurate over time
  - Publicly available through Space Track website

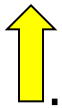
- Special Perturbation (SP)
  - Does numerical calculation of all the perturbations acting on a satellite at each point in the orbit
  - Produces a "jagged" orbit
  - Requires more processing power but much more accurate for prediction
  - Not released by US military

Argument of Latitude Coverage

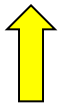
- To accurately measure the perturbations, you need to track a satellite at all parts of its orbit and observe at least one full revolution
- The amount of the orbit tracked is known as the ***argument of latitude coverage***



element set + perturbations = future position



current position



change over time

- If we know the element set and perturbations, we can predict the satellite's position forward or backwards in time (***propagation***)

Tasking

- The central coordinator creates a daily tasking for the entire sensor network
- For each object in the database the following is determined
  - Rate of change in the orbit (energy dissipation rate)
  - Object type and mission priority
- Determine number and capacity of sensors available for the next day

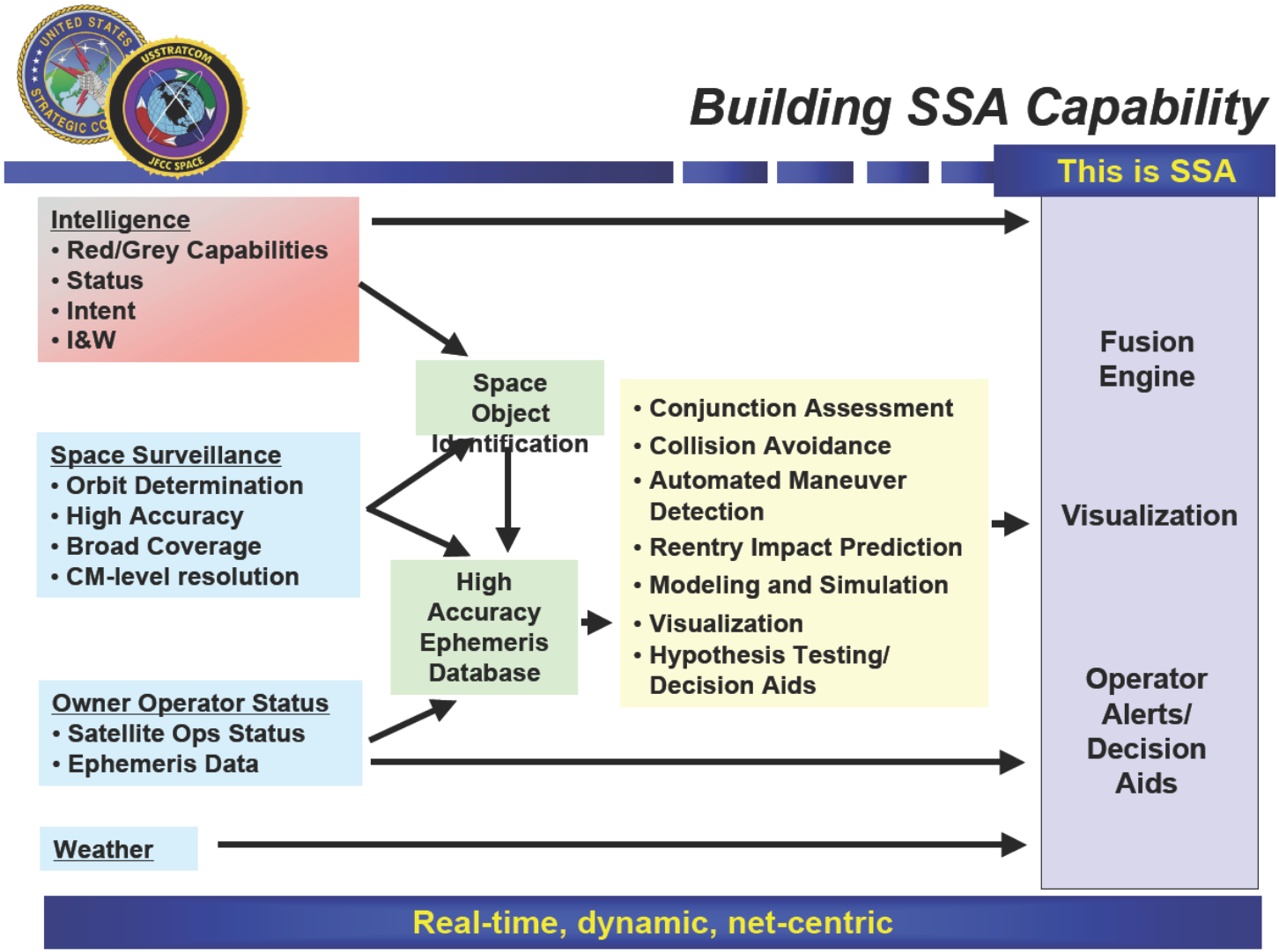
- A tasking algorithm goes through the above and generates a tasking list for each sensor
  - Uses both geometric look angles and probability of detection based on RCS or Vis Mag
  - Specifies ***which satellites*** and ***how many obs*** but not ***when***

FROM SURVEILLANCE TO SITUATIONAL AWARENESS

Definitions

- Space surveillance is knowing positional data
  - Just a dot on the screen
  - Need more data types!

- Space Situational Awareness fuses multiple data types and sources
  - Transforms raw data into information that you can base decisions on


Building SSA Capability
This is SSA
Intelligence
• Red/Grey Capabilities
• Status
• Intent
• I&W
Space Object Identification
Space Surveillance
• Orbit Determination
• High Accuracy
• Broad Coverage
• CM-level resolution
High Accuracy Ephemeris Database
• Conjunction Assessment
• Collision Avoidance
• Automated Maneuver Detection
• Reentry Impact Prediction
• Modeling and Simulation
• Visualization
• Hypothesis Testing/ Decision Aids
Owner Operator Status
• Satellite Ops Status
• Ephemeris Data
Weather
Fusion Engine
Visualization
Operator Alerts/ Decision Aids
Real-time, dynamic, net-centric

Space Object Identification (SOI)

- Narrowband
  - Can be done by any radar
  - RCS over time
  - Allows for determination of object type (payload, R/B, debris)

- Wideband
  - Provided by imaging radars with very low wavelengths
  - Produces a 3-D “image” of the object

- Optical Imaging
  - Closest thing to a photograph of a satellite

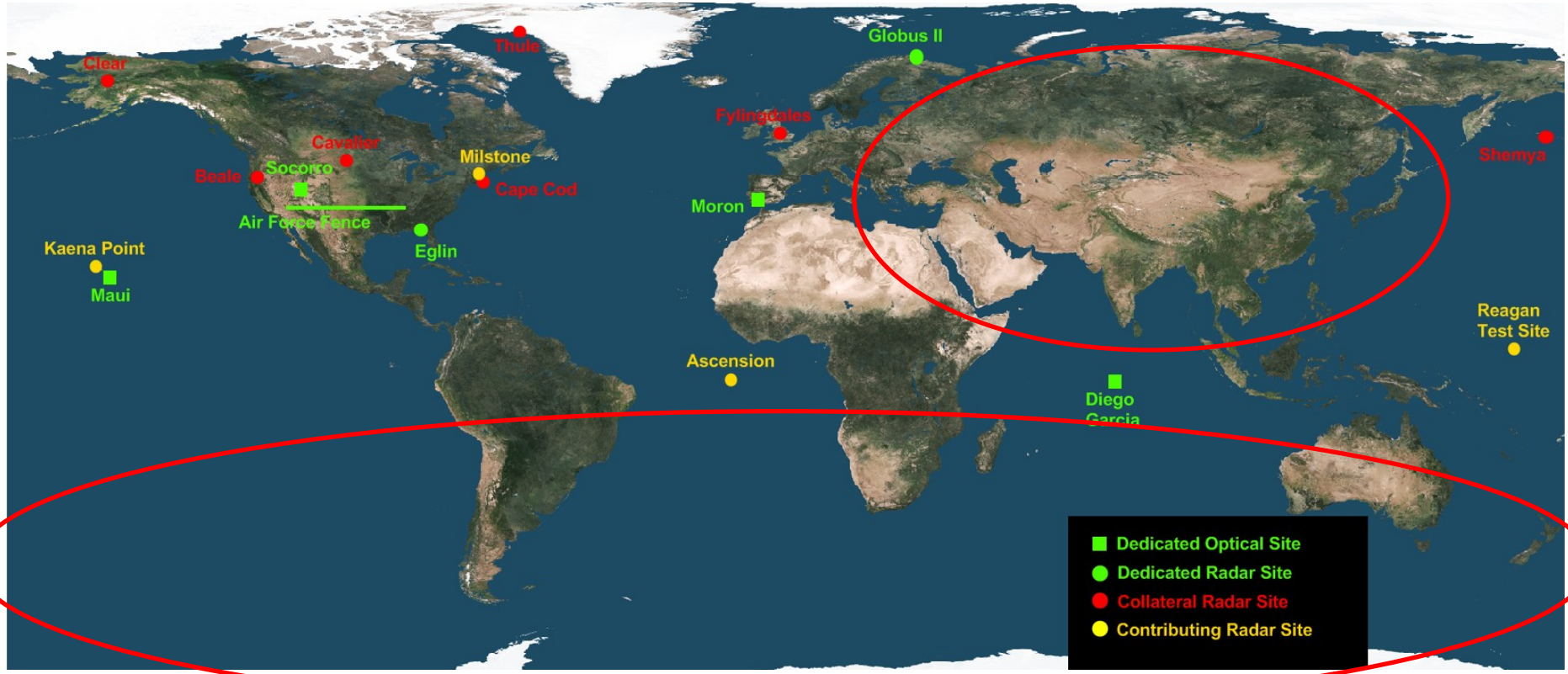
GEMINI Optical Imager

Promoting Cooperative Solutions for Space Security

THE US SPACE SURVEILLANCE NETWORK (SSN)

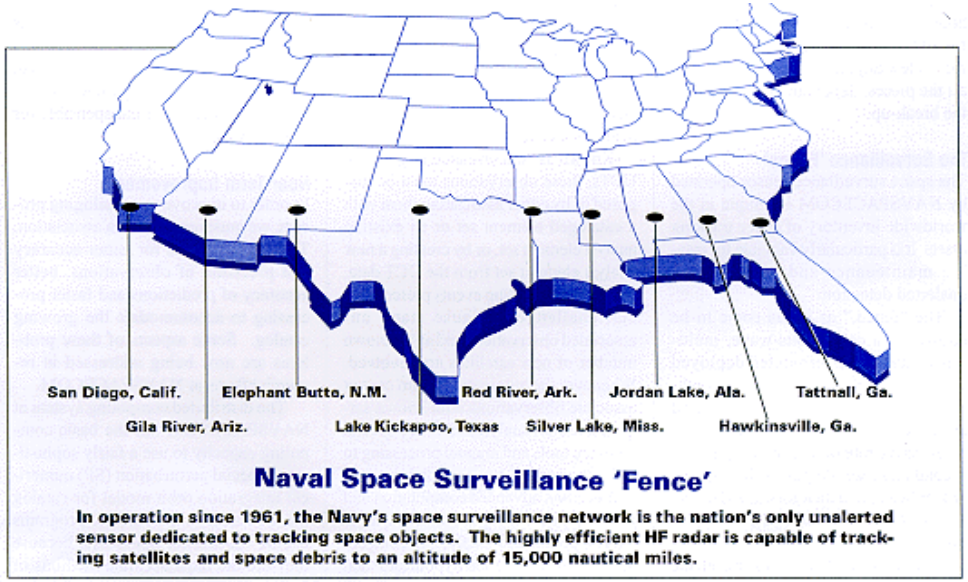
US Space Surveillance Network

Promoting Cooperative Solutions for Space Security



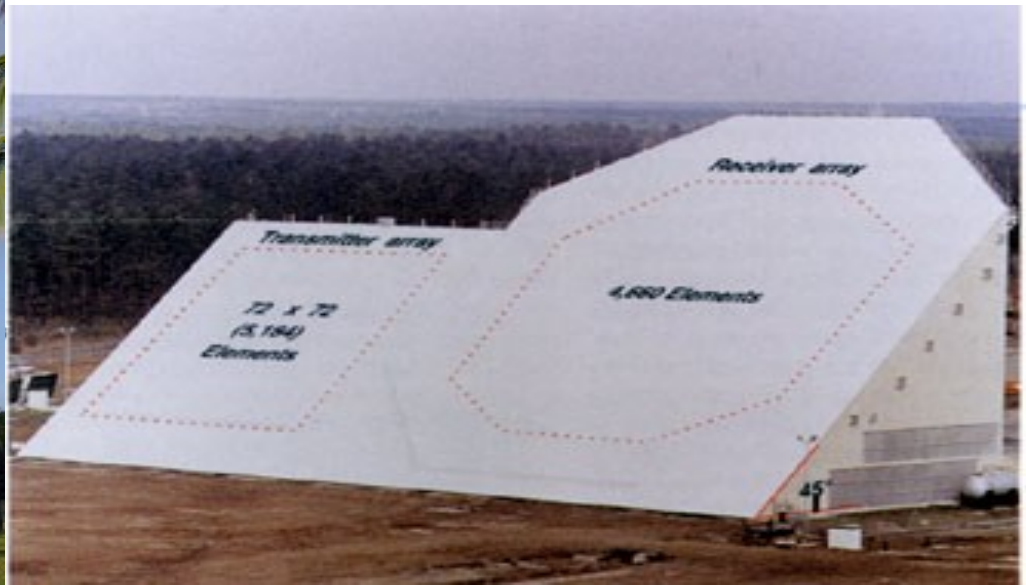
What's missing from this picture?

Examples of Radars



Naval Space Surveillance 'Fence'

In operation since 1961, the Navy's space surveillance network is the nation's only unalerted sensor dedicated to tracking space objects. The highly efficient HF radar is capable of tracking satellites and space debris to an altitude of 15,000 nautical miles.



Examples of telescopes

Public Data from US SSN

- A ***Two Line Element Set (TLE)*** is the specific format used by the US Military to publish element sets since the 1960's

- Space Track website
  - **http://www.space-track.org**
  - Contains the entire public Satellite Catalog (SATCAT)
  - Need to fill out NORAD Form 1 for access (.doc file found on the website)

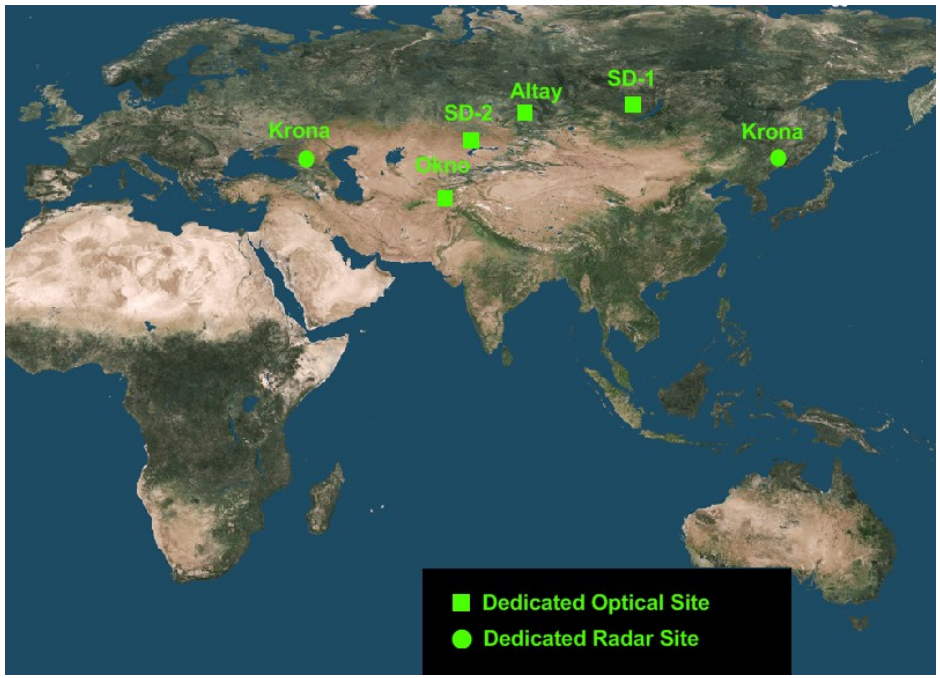
```
25544U  98067A   04236.56031392   .00020137   0000-0   16538-3   0    5135
25544    51.6335  341.7760  0007976  126.2523  325.9359  15.70406856  32890
```

```
satno   intl designator   epoch        ndot/2    ndotdot/6  bstar       elset #
satno   inclination RAAN   ecc         arg per   m anom  m motion   revno
```

GLOBAL SSA RESOURCES

Russia

- Maintains network of radars and some optical sensors
  - Good LEO catalog, average to poor deep space catalog (no global GEO coverage)
  - Some imaging capability
  - Data not made public (except in some instances to NASA)



Okno ("Window")

Okno Electro-optical tracking facility

Krona Radar tracking and imaging facility

Altay

Altay optical tracking and imaging facility

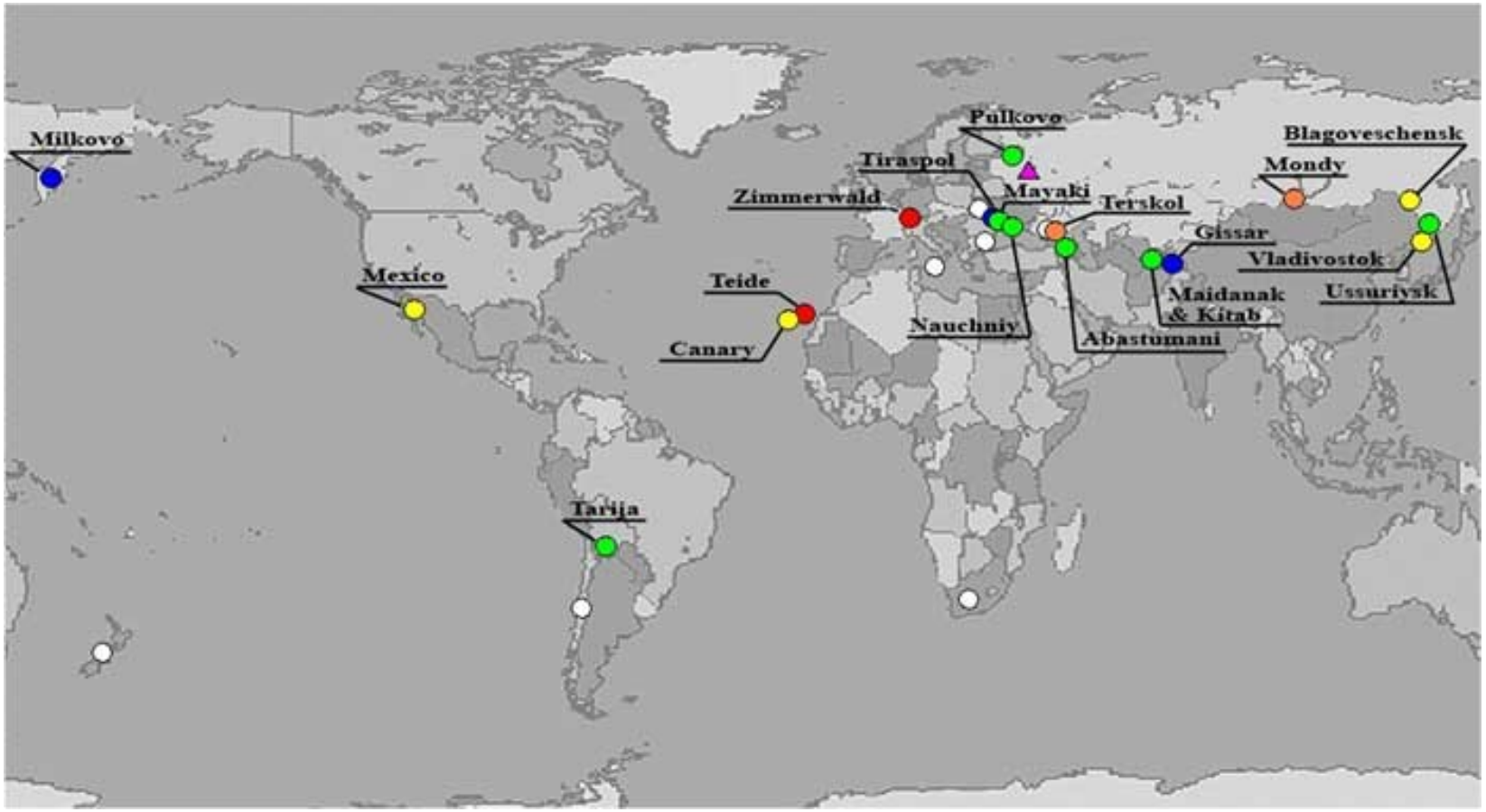
Other States

- EU
  - Germany FGAN radar
  - French GRAVES radar
  - A few scattered optical telescopes
- China
  - Purple Mountain Observatory (space debris research)
  - 4 tracking ships
  - Planned to build network of optical telescopes

- ROW (Rest of World)
  - Scattered optical telescopes and a few radars
- ISON (network of scientific telescopes)

International Space Observation Network (ISON)

Promoting Cooperative Solutions for Space Security

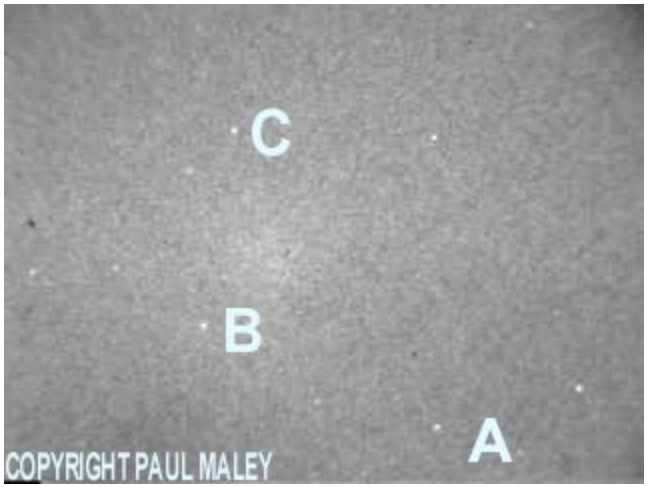


- Works with Rudi Jehn at ESA to publish a supplement to the GEO Space Track catalog **"ESOC Classification of Geosynchronous Objects"**

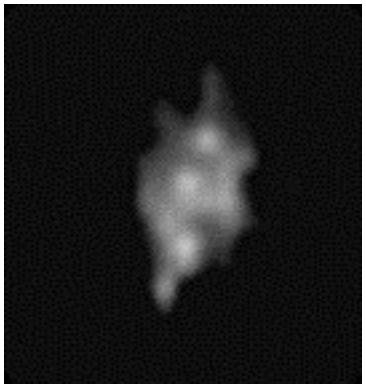
Amateur Satellite Observers

- See-Sat Mailing List
  - **http://www.satobs.org**
  - Amateur observers from all over the world
  - Discussion on best methods to track, software for propagating orbits, and posting of observations

- Couple hundred members
  - A few dozen active observers routinely post observations and element sets
  - Tend to focus on large classified payloads that aren't otherwise in the public catalog (easy to track)



NOSS triplet



USA 193

Iridium Flare

Satellites that don't exist

"The last Titan rocket, 4B-26, was launched on Oct 19. It deployed USA 186, a classified NRO satellite, into polar orbit. ***Hobbyists have observed the satellite and determined its orbit to be 264 x 1050 km x 97.9 deg. This confirms that the satellite is one of the improved CRYSTAL series (KH-11 derived) imaging reconnaissance satellites****, replacing a satellite launched in 1996."* – Jonathan's Space Report, Nov 2005

28888 05 042A 2701 G 2008081602075269O 17 25 0218065+573443 18 S
28888 05 042A 2701 G 2008081602081195O 17 25 0329816+593344 28 S
28888 05 042A 2701 G 2008081602094057O 17 25 0611645+523739 18 S

1 28888U 05042A 08229.08029740 .00005163 00000-0 48953-4 0 07
2 28888 97.9296 290.4131 0543547 73.9612 292.0741 14.75806181 00

SL-12 Aux Motor Breakup

International Civil SSA

- Allows for safer and more efficient use of space
- Provides foundation for International Space Traffic Management
- Potential to reduce likelihood of space conflict
  - Transparency
  - Paranoia Reduction
  - Basis for Cooperation

- Technical paper session and panel discussion at 3rd IAASS Space Safety Conference (20-22 Oct in Rome)
- Future projects in 2009/2010

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Questions?

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