Orbit and Constellation Design for Safety

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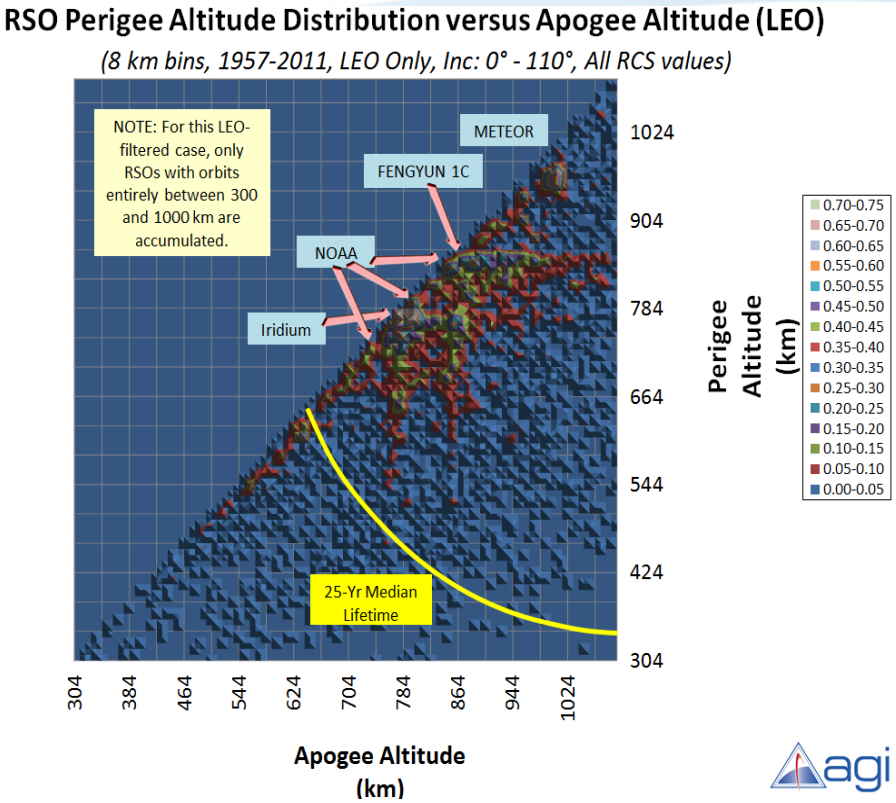
Outline

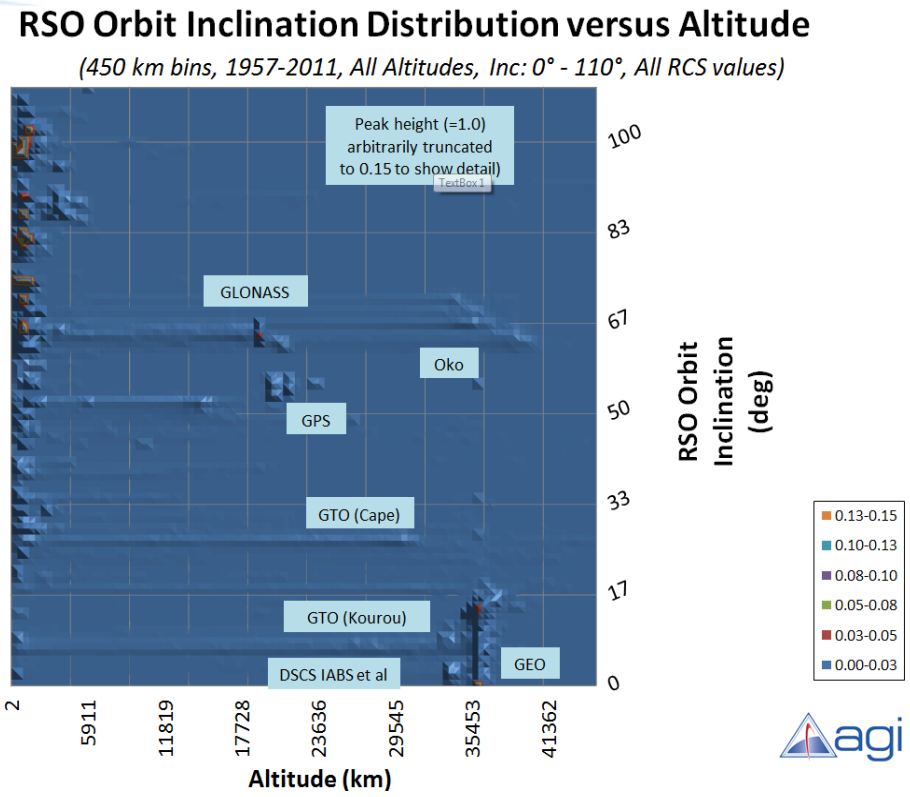
- Distribution of Objects in Earth Orbit
- Rules of the Road
- Passive Alternatives for Safe Operation
- Characteristics of Unsafe Orbits
- Safe Alternatives for Surveillance
- Conclusion

The Earth Orbit Environment

- Satellites are concentrated in a few very useful and relatively easily achieved orbit regimes
  - Geosynchronous
  - Sun Synchronous
  - Semi-synchronous
  - Launch site latitude bands

The Earth Orbit Environment
(From Oltrogge and Kelso)





Consequences of Concentrations

- Thousands of close approaches daily
  - Very few have notable probability of actual physical contact or pervasive consequence
  - Close approach is not a sufficient measure of risk
- Owner/operators should no longer function as though they were the only presence unaffected by or not affecting others

Rules of the Road

- Mutually beneficial, well understood courteous behaviors on the land, at sea, and in the air are marginally feasible in space.
  - Precipitous moves consume great amounts of energy
- Advance planning beginning with orbit assignments, such as those in GEO, is most efficient
  - GEO assignments are not based on physical proximity
  - The most desirable orbits are contested

Passive Approaches to Orbital Safety

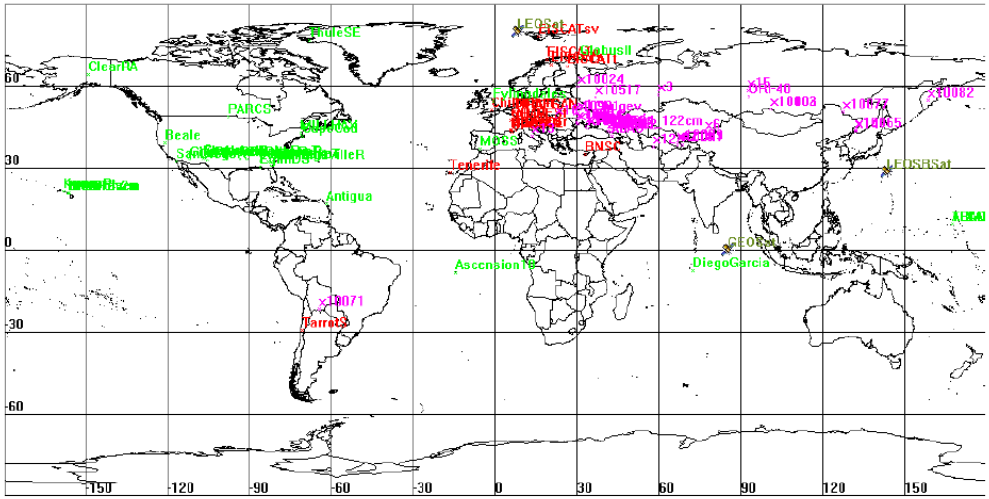
- Ubiquitous Observability
  - Satellites are more controllable the better we know their state at all times
- Judicious Sensor Distribution
  - We can never see everything, everywhere
  - The more sensors, the less the contribution of each additional sensor

–Deploy sensors for greatest orbit determination advantage

–Make observability a prominent architectural consideration

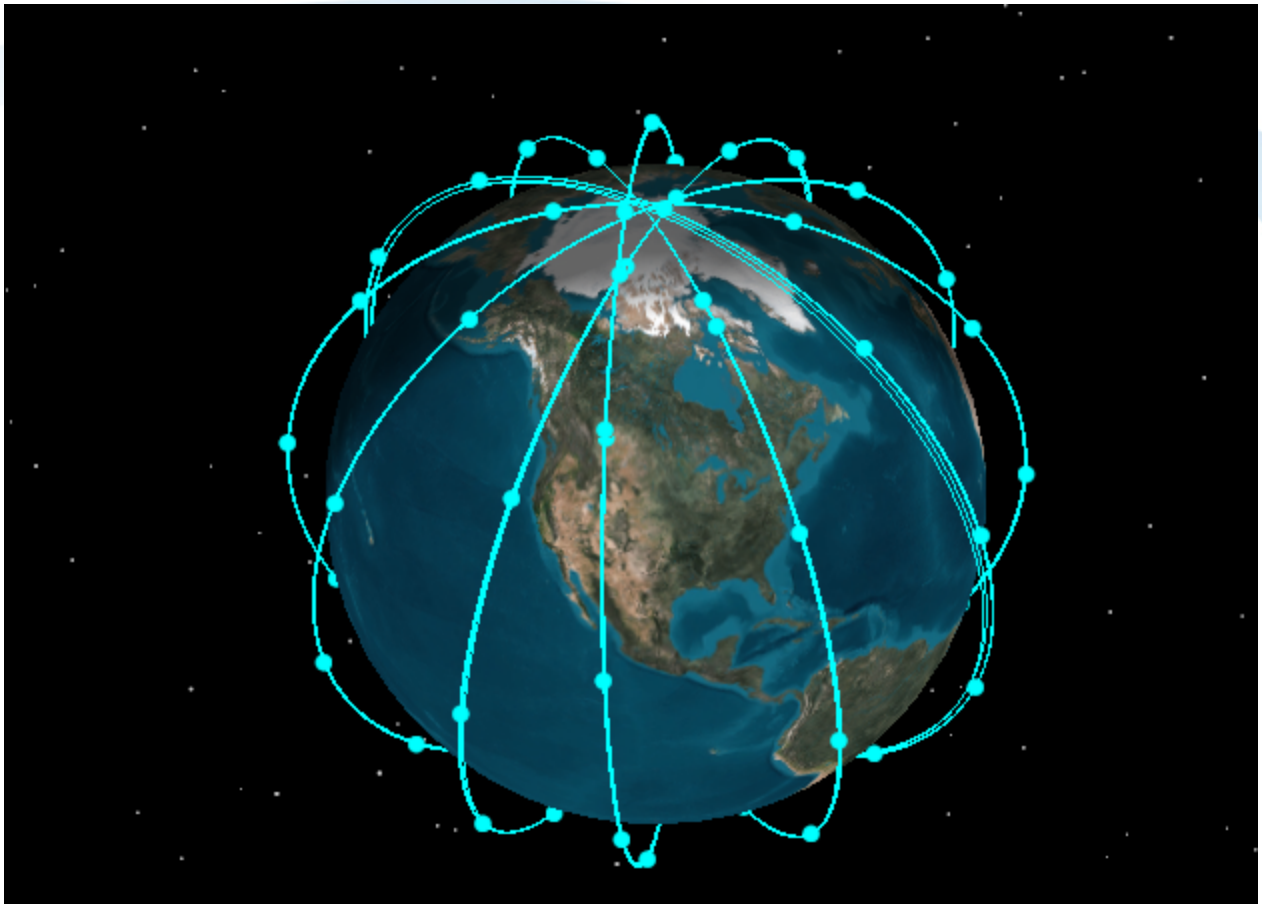
Sensor Deployment Considerations

- Line of sight contact is not sufficient
  - Confident orbit determination is the goal
  - This requires coordination of observation quality, distribution, and orbit determination architecture

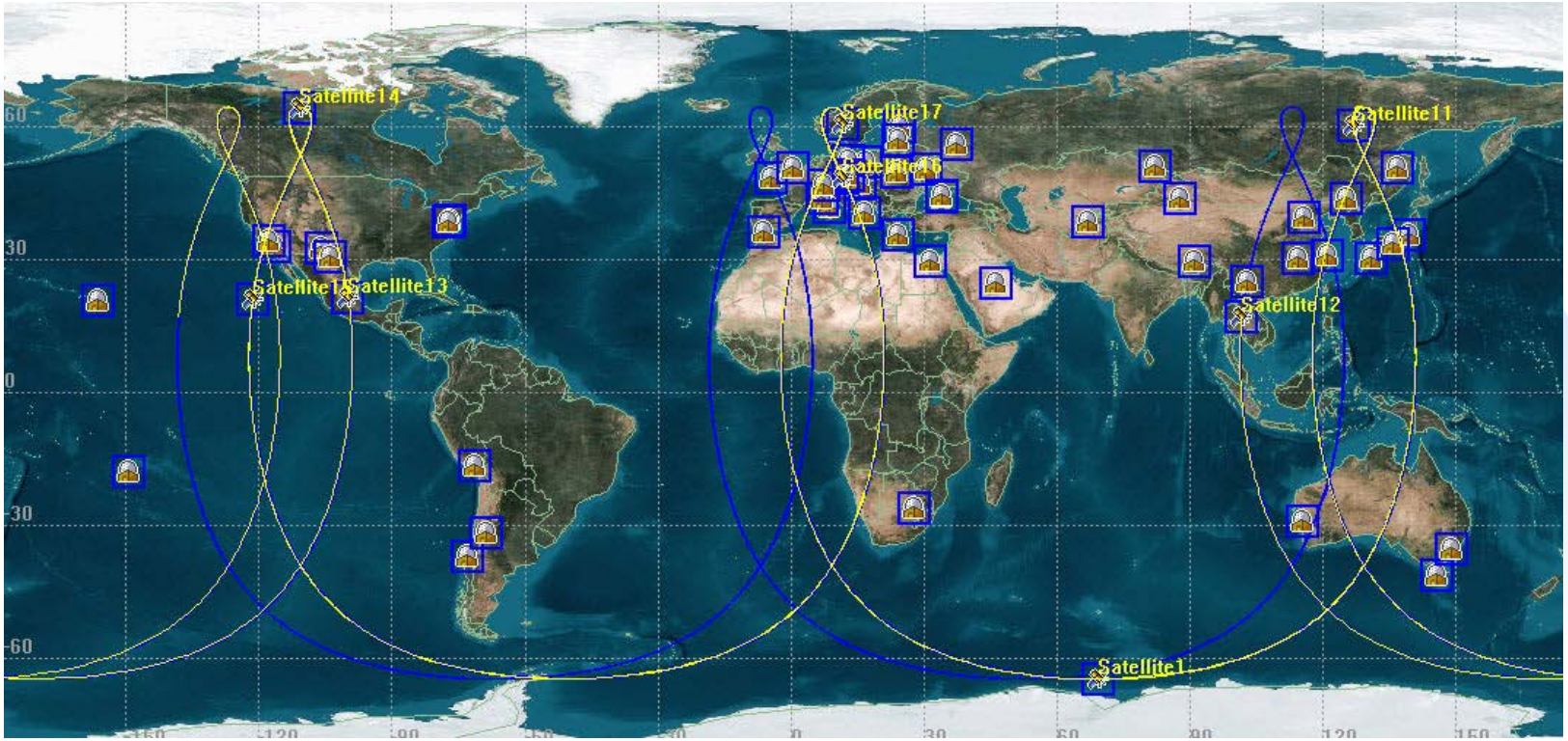


Sensors documented and characterized by Vallado and Griesbach

A High Risk Constellation

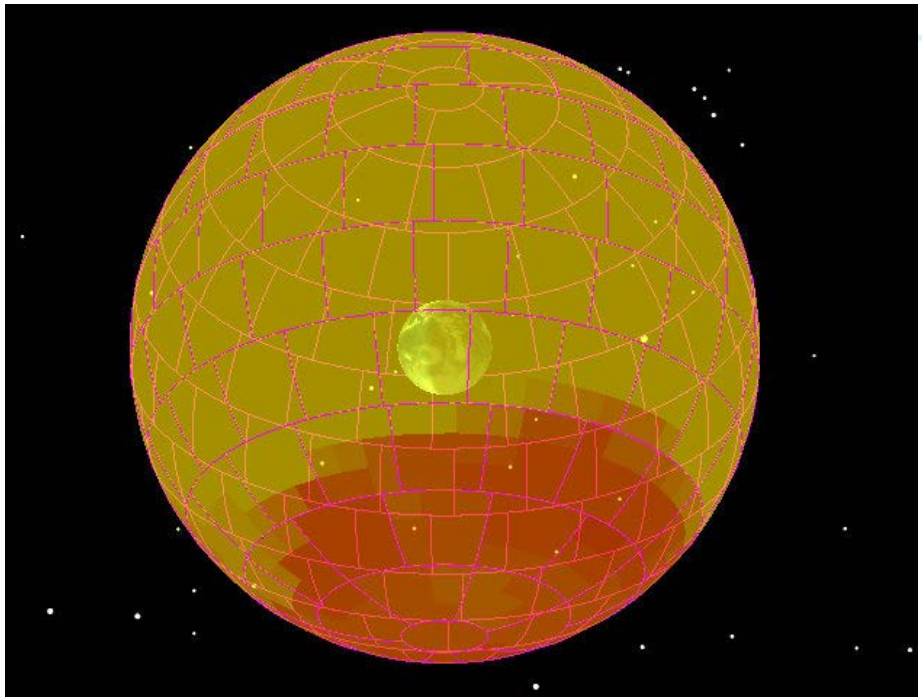


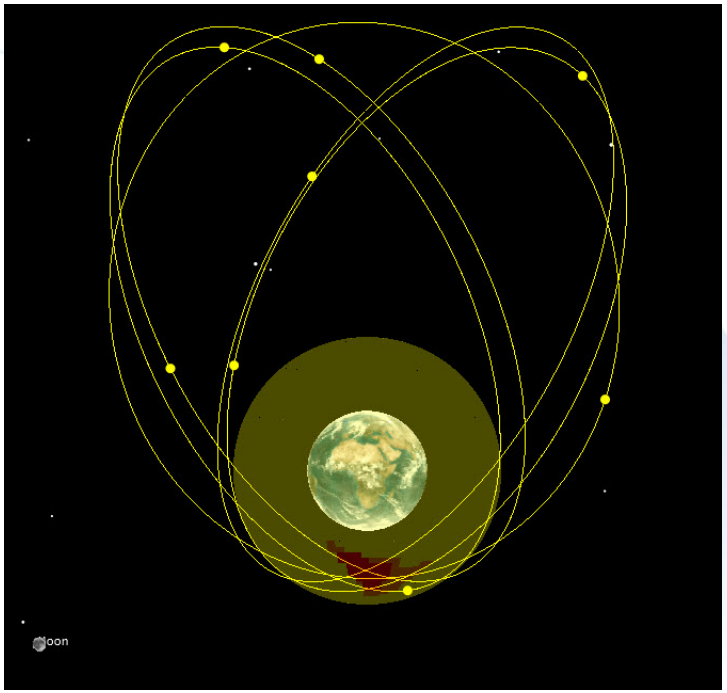
A Low Risk Constellation



Draim 8 satellite, 16 hour orbit Droplet Constellation for continuous whole Earth coverage

Continuous Observability
(Satellite Laser Ranging Network)





Apogee

Perigee

Red = Single Coverage
Yellow = Triple Coverage or more

Conclusion

- Orbital safety can be achieved through innovative design
  - Without compromising missions
  - Without additional energy requirements
  - Without little or no additional cost
- Numerical constellation optimization breaks the boundaries of commonly used and more readily analyzable architectures
- Draim constellations exemplify safe and efficient mission architectures.