Global Surveillance
The Advantages of New Vantages for Earth Science:

Earth Observing Strategies: Options and Analysis

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Outline

I. Aspects of Orbit Value
II. Range
III. Lighting/ Time of Day
IV. Geocoverage/ Geolocation
V. Correlation Between Range and Geolocation
VI. Space Mission Vantage Types
VII. New Technologies May Add Options

I. Aspects of Orbit Value

- Often Use Classifications Based On How Individual Missions Observe
  - Region of Electromagnetic Spectrum (e.g., Vis vs. IR, lidar vs. radar)
  - Spectral & Spatial Coverage & Accuracy (e.g., Imagers, Spectrometers, Radiometers)
  - Physics of Observation (e.g., In Situ vs. Passive Remote vs. Active Remote Sensing)
- This Paper Focuses on 3 Main Aspects of Orbits that Users Find Valuable
  - Range/ Continuity of Coverage
  - Lighting/ Time of Day
  - Ground-track Geolocation

II. Range

- Close Range for Resolution & Active Sensing
- Distant Range for Coverage/ Synoptic View
- Constant Range Can Simplify Instrument Design & Operation
  - Correlated to Rate of Spacecraft Motion
  - Affects Scanning Rates, etc.

Close Range for Resolution & Active Sensing

- Diffraction Limit
  - For Given Wavelength, Passive Resolution Driven By Range and Telescope Aperture
- Range Strongly Affects Power Required for Active Sensing

Image courtesy of DigitalGlobe, www.digitalglobe.com

Distant Range for Coverage/ Synoptic View

Common Approaches for Constant or Near Constant Range

- Circular (or Near Circular) Orbits:
  - Distant Circular Orbits to Achieve Synoptic Coverage
    - Geostationary (24 Hour Orbit Period)
  - LEO (Close) Orbits for High Resolution or to Reduce Active Sensing (Lidar/Radar) Power
  - Higher LEO and MEO Orbits to Balance Coverage and Power Requirements
- Highly Eccentric Orbits
  - Most of Orbit Spent Near Apogee
    - Molniya Orbits
- Earth/Moon and Earth/Sun Lagrange Points
  - Stable (but Distant) Locations

III. Lighting/Local Time of Day

- Similar vs. Different Lighting/ Time of Day
  - Ease of Comparison vs. Diurnal Sampling
  - Dependent Upon Goals of Specific Missions
- Generalized Rule For Optical Instruments
  - Spatial Resolution Instruments Prefer Sun Angles That Enhance Shadows for Feature Contrast
  - Spectral Resolution Instruments Prefer Sun Angles That Reduce Shadowing and Enhance Spectral Contrast
- Time of Day Effects on Subject Area
  - Correlations With Cloud/Fog Cover For the Areas of Interest

Common Approaches for <u>Constant</u> Lighting/Time of Day

- Close Circular Sun-Synchronous Orbits
  - Orbit Crosses Equator at Same Relative Time of Day
    - Secular Variation in Right Ascension of Ascending Node Matches Earth's Rate Around the Sun
    - Requires Highly Inclined, Retrograde Orbit
  - Very Common
    - Weather Satellites, Landsat, IKONOS, etc.
- Earth/Sun Lagrange Points
  - Constant Lighting, but at Astronomical Distances
- Others Appear Possible

Common Approaches for Variable Lighting/Time of Day

- Distant Circular Orbits:
  - Geostationary (24 Hour Orbit Period)
    - Views Constant Geolocation At All Local Times of Day
    - 12 Hours of Daylight, 12 Hours of Night Coverage
- LEO Orbits Designed to Provide Variable Lighting
  - Example: TIMED Mission
    - Uses Same Effect As Sun-Synchronous Orbits, But With Opposite Sign
    - Secular Variation Adds to Effect of Earth's Motion Around The Sun
    - Dawn to Dusk Four Times Per Year

Operational Value of Lighting/ Local Time of Day

- Constant Lighting Can Simplify Instrument Design & Operation
  - Exposure/Gain States
  - Aperture/Time Required to Collect Adequate Signal
- Spacecraft Solar Panel Illumination
  - Design Consideration for High Power (Radar, Lidar) Missions
    - Sun-synchronous Polar Orbits with 6 AM/6 PM Equatorial Crossing Provide Constant Solar Power (Except For Brief Period Near One Solstice per Year)

IV. Geocoverage/Geolocation

- Orbits Are Often Designed For Repeat Ground-Track
  - Subject Benefits
    - Spatially Correlated Observations
    - Direct Comparison of Time-Dependent Phenomena
  - More Predictable Operations
    - Instrument State Changes (Land/Sea Boundaries, etc.)
    - Ground-Station Passes, etc.
  - Examples: Exact Ground Track Repeat Every x Days
    - 1 Orbit per Day for Geostationary (Constant Geolocation)
    - Half-Day Orbits for GPS and Molniya Satellites
      - Nearly Same Geolocation for 11 Hours Per Day
    - 16 Day Repeats (233 Orbits) for Terra, Aqua, etc.

V. Correlation Between Distant Range and Constant Geolocation

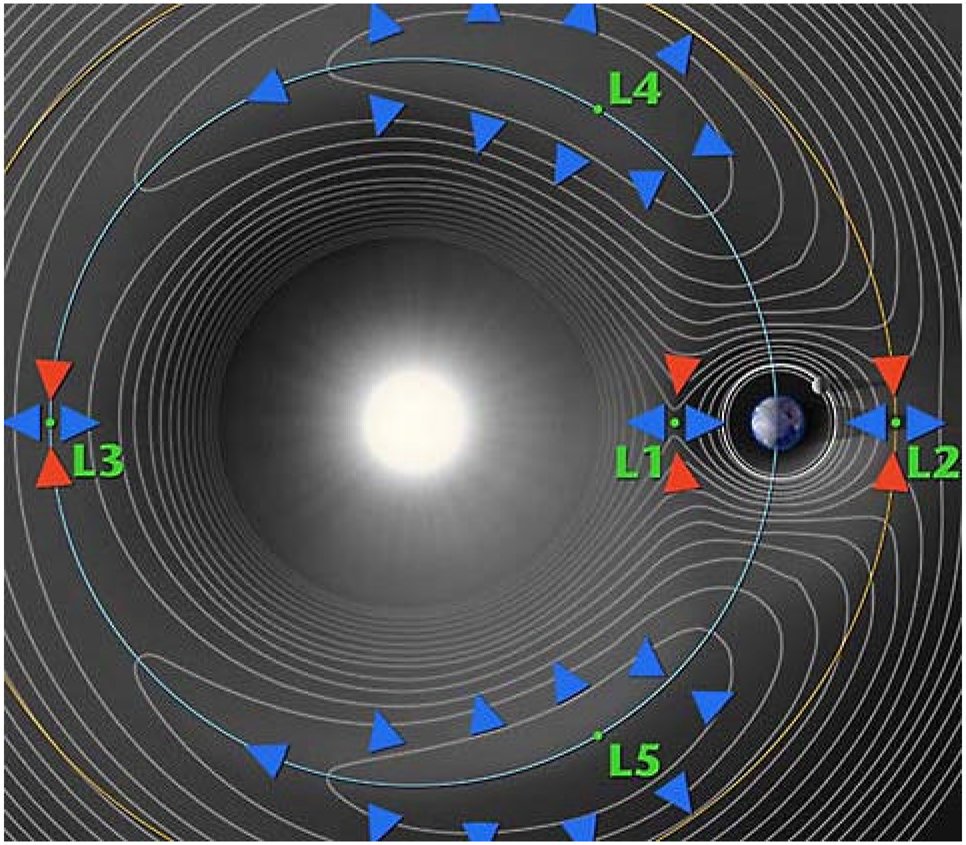
- Distant Range Orbits Can Match or Nearly Match Earth Rotation Rate
  - Enables Constant or Near-Constant Geolocation
    - Geostationary: Constant Geolocation
    - Molniya: Near-constant Geolocation for 11 Out of 12 Hour Orbit (Alternate Sides of Earth)
- Move Away to See Finer Time Scales!

VI. Space Mission Vantage Types

Range	Lighting/ TOD	Geo-Location	Example Orbit Types	Mission Examples
Close	Variable	Non-Repeat	Non-Repeating Non-Synchronous Orbits	ISS
Close	Variable	Repeating	Repeat Groundtrack Non-Synchronous Orbits	
Close	Similar	Non-Repeat	Non-Repeating Sun-Synchronous (Retrograde Polar) Orbits	
Close	Similar	Repeating	Repeat Groundtrack Sun-Synchronous Orbits	Landsat, Terra
Distant	Variable	Non-Repeat	GEO Transfer Orbits, MEO, HEO, Earth-Moon Lagrange	GOES
Distant	Variable	Repeating	Geosynchronous Orbits, Molniya Orbits	
Distant	Similar	Non-Repeat	Sun-Earth Lagrange Points, Gap?	DSCO
Distant	Similar	Repeating	Potential Gap: ESSE Orbits?	

VII. New Technologies May Add Options

- Constant Thrust
  - Shift Orbit/Maintain Lighting Alignment
    - “Bias” Geostationary Orbits Towards Polar Latitudes
    - “Bias” Lagrange Points Towards Earth:
  - Candidate Technologies
    - Solar Sails
    - Nuclear Electric

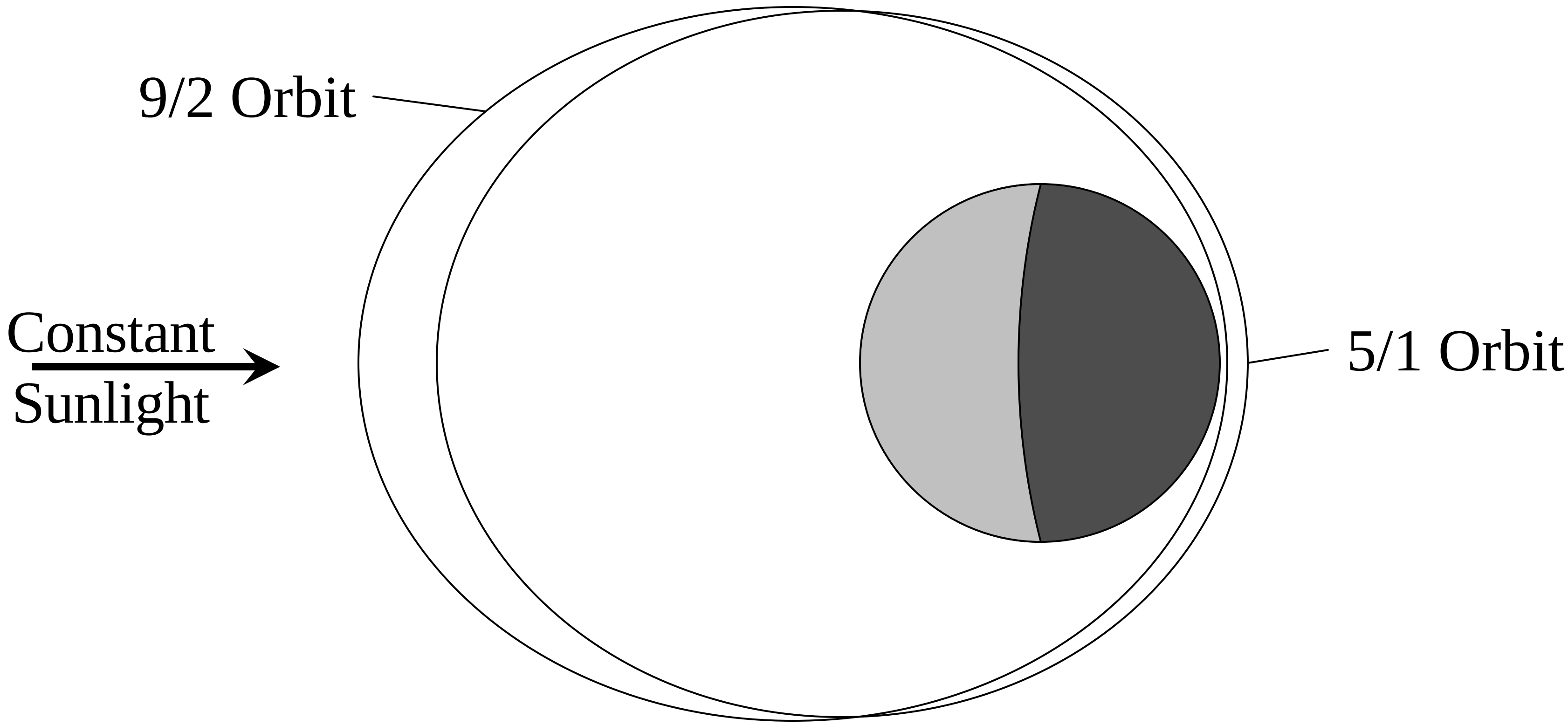


- Technology Push vs. Science Pull
  - Will Scientists Find New Orbits Useful?

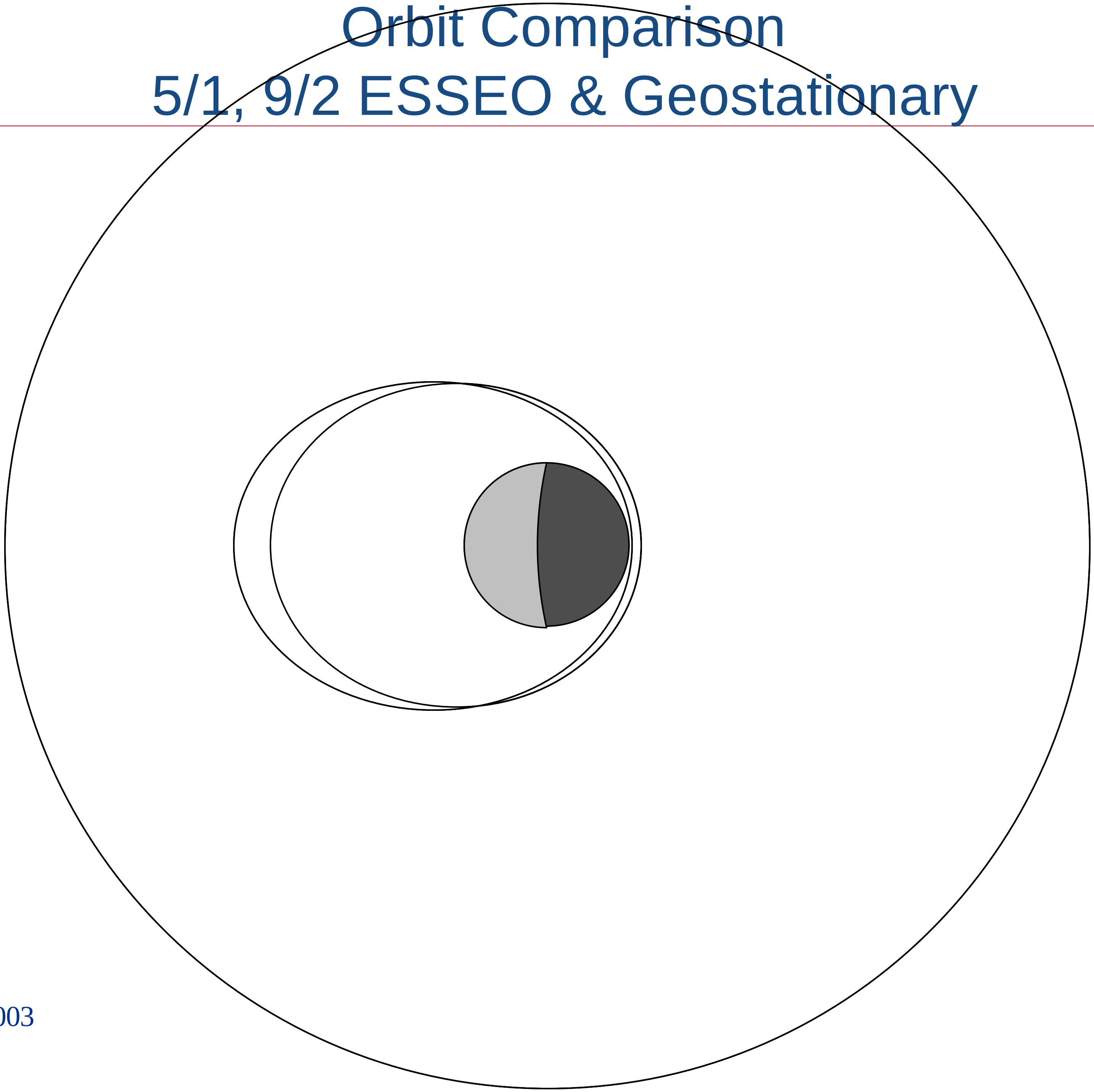
Figure source: URL http://down.dsg.cs.tcd.ie/ipn/background/ob_techorbit1.html

Backup Slides

ESSE Orbit Comparison
9 Orbits/2 Days and 5 Orbits/Day



Orbit Comparison
5/1, 9/2 ESSEO & Geostationary



ESSE Orbit

- Orbit That Precesses So That Apogee Remains Over Local Noon
  - Allows Two Satellites to Provide Continuous Daytime Coverage
  - Modeled Using Satellite Took Kit (Version 4.2.1)
    - J_4 Propagation
    - Full Year to Confirm Rotation of Apogee
    - Modeled Two Cases:
      - 9 Orbits Per 2 Days
        - » Two Satellite Effective Daily Repeat Ground-track by Alternating Tracks Every Other Day
        - » Maximum Apogee, Low Perigee (273 km.)
      - 4 Orbits Per Day
        - » Daily Repeat Ground Track
        - » Lower Apogee, Higher Perigee

ESSE Orbit

- 9 Orbits/2 Days
  - Two Satellite Effective Daily Repeat Ground-track by Alternating Tracks Every Other Day
  - Orbit Properties
    - Period: 5 hr. 20 min. 10 sec.
    - Eccentricity: 0.57
    - Altitude of Perigee: 273 km.
    - Altitude of Apogee: 17,976 km.
- 5 Orbits/Day
  - Orbit Properties
    - Period: 4 hr. 48 min. 8 sec.
    - Eccentricity: 0.49
    - Altitude of Perigee: 1,025 km.
    - Altitude of Apogee: 15,120 km.