Global Surveillance
The Advantages of New Vantages for Earth Science:

Earth Observing Strategies:
Options and Analysis

Gordon Johnston
NASA Headquarters
Office of Earth Science
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**

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 Constant 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

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<td>Potential Gap: ESSE Orbits?</td>
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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

9/2 Orbit

Constant Sunlight

5/1 Orbit
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.