**Geography 403**
**Lecture 5**
**Satellite Basics and Systems**

*Needs*: Lect_403_5.ppt, globe, LANDSAT large images

*Key Terms and Concepts*
**General Characteristics of Circular Orbits**
**Geostationary Orbit Characteristics**
**Sun Synchronous Orbit Characteristics**
**Public: LANDSAT Satellites and Sensors**
**Private: SPOT, IKONOS, QUICKBIRD, WORDVIEW Satellites and Sensors**

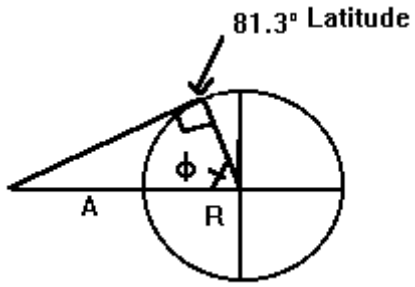
A. Basic characteristics of orbits
PP1-2 1. Circular orbit--most useful for remote sensing purposes
a. Speed is determined by altitude

$v = SQRT(GMe / r)$ in m/s, where:

$G = 6.67 \times 10^{-11}$ $Nm^2kg^{-2}$ ($N = kgms^{-2}$) together = $3.99 \times 10^{14} m^3s^{-2}$
$Me = 5.98 \times 10^{24}$ kg
$r = A + R$, where A=altitude, and R= earth's radius of $6.357 \times 10^6$ m

---->Example for 100 km (100,000 m) orbit
$v = SQRT (GMe / 100{,}000 + 6.357 \times 10^6) = 7860$ m/s
b. (p) period of orbit = $2\pi r / v$ in s (/ by 3600 for h)

---->Example for 100 km as above
$p = 6.457 \times 10^6 (2\pi) / 7860$ m/s = 5162 s = 1.43 h
c. Calculate orbit radius (from center of earth) for a known period:
radius = $(p\ SQRT\ (GMe)\ /\ 2\pi)^{2/3}$
Note: HIGHLY sensitive to rounding error
d. Escape velocity = SQRT(2GMe/R) = 11,186 m/s (from Earth's surface)
PP3-4 2. Geostationary orbit--special circular orbit over equator where the period is the same as the earth's rotational period, which is equal to 23.94 hours (86184 s)
a. Satellite "hovers" over the same spot in relation to the earth's surface, and can be used for communications or continuous weather observation
b. What height? , use radius formula for p = 86184 s after subtracting out earth's radius ≈ 36,000 km




c. Limitations--poor for viewing polar regions as view is perpendicular to equator by definition-- what is the limit of view (the tangent) from trig...
$\cos \varphi = R / A+R \approx .15$ or $81.3^{\circ}$

PP5 3. Sun synchronous orbit--spacecraft always passes over a given patch of earth at the same local solar time
a. An attempt to eliminate obs. time as a variable in multi-temporal observations
b. Polar type orbital--passes over equator at same solar time with each orbit
c. LANDSAT and other satellites attempt to do this, still some N-S variations in observation time

PP6 4. Elliptical orbit--dips in close to area under study
a. "spy" satellites commonly use this, move fast when close
b. Problem--resolution changes with orbit radius changes

B. Coverage and nadir trace

PP7 1. Nadir trace or ground track of the satellite is generated from orbital motion and the rotation of the earth
2. Sensor view area determined by nadir trace, and the field of view (fov) and pointing (angle of view relative to nadir) characteristics of the sensor package
3. Both together determine "coverage" of the satellite-sensor
a. Higher orbits cover larger areas at lower resolution

C. Additional considerations affecting orbits:
1. Precessional movements--rotation of the orbital plane around the earth's axis
2. Planned orbital changes using thrusters (sometimes to correct problems)
3. Solar and lunar gravity perturbation
4. Atmospheric drag (“deorbits”, e.g. Skylab, science satellite in Jan. 2008)
5. Space junk

D. LANDSAT MSS and Thematic Mapper *(show examples at Earthshots, RS tutorial, and NASA sites)*

**Talk about public-private considerations of satellite administration and maintenance**

PP8 1. First satellite for systematic study of Earth's land surface resources
2. Early satellites carried MSS sensor with bands very similar to
PP9-10 traditional CIR film (Landsat 1-3) (also Discuss RBV system)

a. Orbital characteristics were a compromise
18 day repetitive cycle at an altitude of ≈ 900 km,
crossing equator at ≈ 0930 to 1000 local solar time
≈ 80 m resolution (now resampled to 60), except Band 8 (thermal) 240m

4. Thematic Mappers (Landsat 4-5)
a. Orbital characteristics were modified
16 day repetitive cycle at an altitude of ≈ 700 km,
crossing equator at ≈ 0945 local solar time
≈ 30 m ground resolution, except Band 6 (thermal) 120m (now resampled to 30 m)

PP11-12 b. Coverage traces different from previous LANDSATs

PP13 c. More and narrower bands than MSS, more selectivity

PP14 5. LANDSAT 7 "public" (orbit similar to Thematic Mapper and earlier LANDSATs)
a. Band 6 (thermal) resolution is now resampled to 30 m
b. Includes a panchromatic band (.52-.90μm) at 15 m

6. LANDSAT 8 "public" (orbit similar to earlier LANDSATs)
a. Includes an "Ultra Blue" band (.435-.451μm) for coastal and aerosol study
b. Other bands similar to LANDSAT 7

| | **LANDSAT 1-3** | **LANDSAT 4-5** | **LANDSAT 7** | **LANDSAT 8** |
|---|---|---|---|---|
| **BAND 1 (4)** | .5-.6μm (60m*) | .45-.52μm (30m) | .45-.52μm (30m) | .435-.451 μm (30m) |
| **BAND 2 (5)** | .6-.7μm (60m*) | .52-.60μm (30m) | .52-.60μm (30m) | .452-.512 μm (30m) |
| **BAND 3 (6)** | .7-.8μm (60m*) | .63-.69μm (30m) | .63-.69μm (30m) | .533-.590 μm (30m) |
| **BAND 4 (7)** | .8-1.1μm (60m*) | .76-.90μm (30m) | .77-.90μm (30m) | .636-.673 μm (30m) |
| **BAND 5** | | 1.55-1.75μm (30m) | 1.55-1.75μm (30m) | .851-.879 μm (30m) |
| **BAND 6** | | 10.4-12.5 μm (30m*) | 10.4-12.5 μm (30m*) | 1.566-1.651μm (30m) |
| **BAND 7** | | 2.08-2.35μm (30m) | 2.09-2.35μm (30m) | 2.107-2.294μm (30m) |
| **BAND 8** | | | .52-.90μm (15m) | .503-.676μm (15m) |
| **BAND 9** | | | | 1.363-1.384μm (30m) |
| **BAND 10** | | | | 10.6-11.19 μm (30m*) |
| **BAND 11** | | | | 11.5-12.51 μm (30m*) |

*resampled

7. General interpretation guidelines
    a. Cloud cover obliterates an average 60% of scenes
    b. Even slight sun elevation changes will change reflectance and overall brightness of images (multi-temporal problems)
    c. Considerable geometric correction required to georegister images
    d. Seasonal changes can be a problem (or an opportunity)

PP15 e. LANDSAT satellite band comparisons at: https://landsat.usgs.gov/what-are-band-designations-landsat-satellites

E. SPOT 1-3—early "private sector" satellite *(show Milwaukee scenes)*

PP16 1. Orbital characteristics
    26 day repetitive cycle at an altitude of 822 km, sun synchronous crossing 40°N at ≈ 1000 local solar time
    ≈ 10-20 m ground resolution
2. Imaging capabilities
    a. Panchromatic image (.51-.73 μm) 10 m resolution
    b. CIR-like images (green, .50-.59μm; red, .62-.68μm; and NIR, .79-.89μm bands) 20 m resolution
    c. Off-nadir viewing capability can increase coverage, but at a decreased resolution, can also be used to produce stereo pairs
    d. Lacks the spectral resolution of the thematic mapper, and is **much** more expensive to obtain
3. SPOT 4
    a. HRVIR sensor (similar to earlier SPOTs)
    b. Vegetation sensor (similar to NOAA AVHRR, 1.15km resolution)

F. Other "private sector" satellites (IKONOS, OrbView-3, Quickbird, Worldview)

PP17 See comparisons at https://www.geoimage.com.au/satellites/satellite-overview

1. IKONOS *(Show Milwaukee scene)*
    a. Blue, Green, Red, and NIR bands similar to SPOT, but at 4m resolution
    b. Panchromatic band similar to SPOT, but at 1m resolution
    c. Orbital characteristics
        3 day or less repetitive cycle at an altitude of 681 km, sun-synchronous crossing equator at ≈ 1000 1100 local solar time
2. QUICKBIRD *(Show Milwaukee scene)*
    a. Blue, Green, Red, and NIR bands similar to SPOT/IKONOS, but at 2.5m resolution
    b. Panchromatic band similar to SPOT/IKONOS, but at 0.6m resolution
    c. Orbital characteristics
        1-5 day repetitive cycle (depending on latitude) at an altitude of 600 km NOT sun-synchronous (equatorial crossing time variable)

3. WORLDVIEW (2-3)
    a. Blue, Green, Red, and NIR similar to QUICKBIRD, plus additional bands, and at 2m (2) or 1.2m (3) resolution
    b. Panchormatic band similar to QUICKBIRD, but at 0.5m (2) or 0.3m (3) resolution

| | **SPOT 1-4** | **SPOT 5** | **QUICKBIRD** | **WORLDVIEW 2** |
|---|---|---|---|---|
| **BAND 1** | .5-.59µm (20m) | .5-.59µm (10m) | .45-.52µm (2.5m) | .4-.45µm (2m) |
| **BAND 2** | .61-.68µm (20m) | .61-.68µm (10m) | .52-.6µm (2.5m) | .45-.51µm (2m) |
| **BAND 3** | .79-.89µm (20m) | .79-.89µm (10m) | .63-.69µm (2.5m) | .51-.58µm (2m) |
| **BAND 4** | .51-.73µm (10m) .61-.68 µm (Spot 4) | .48-.71µm (2.5m) | .76-.9µm (2.5m) | .585-.625µm (2m) |
| **BAND 5** | 1.58-1.75 µm (20m, Spot 4) | 1.58-1.75 µm (20m) | .45-.9µm (0.6m) | .63-.69µm (2m) |
| **BAND 6** | | | | .705-.745µm (2m) |
| **BAND 7** | | | | .77-.895µm (2m) |
| **BAND 8** | | | | .86-1.04µm (2m) |
| **WV Pan** | | | | .45-.80µm (0.5m) |

G. Other “public” satellites (GOES-***show online viewer***, NOAA-series, MODIS: Terra [EOS-AM] and Aqua [EOS-PM], ASTER)
PP18