Orbital Mechanics

THE OVERALL CLASSIFICATION FOR THIS BRIEFING IS UNCLASSIFIED
(U) Overview

+ (U) What is a satellite?
+ (U) Breakdown of orbits
+ (U) Orbit Types
+ (U) Forces working against satellites
(U) Objectives

+ (U) Know Orbit Basics:
  • Inclination
  • Apogee
  • Perigee
  • Orbit Types
    + LEO, GEO, HEO
(U) Objectives

- Define LEO, HEO and GEO
- Describe given spacecraft and orbital mechanics terminology
- Describe the altitudes of HEO, LEO and GEO
- Describe the benefits of HEO, LEO and GEO
- Define the four types of inclination
- Recognize satellite ground tracks and map projections
- Identify impacts of solar activity on satellite operations
- Identify impacts of charged particles on satellite operations
- Identify impacts of geomagnetic effects on satellite operations
- Identify man-made operational concerns
(U) Satellites

+ (U) Intellipedia: A satellite is any object that orbits another object (which is known as its primary). Satellites can be man-made or may be naturally occurring such as moons, comets, asteroids, planets, stars, and even galaxies.

+ (U) Dictionary.com
  - Astronomy: A natural body that revolves around a planet; a moon
  - A device designed to be launched into orbit around the earth, another planet, the sun, etc
(U) Basic Elements of a Satellite

Payload + Vehicle or “Bus” = Satellite
(U) Vehicle Subsystems

- Navigation, Guidance and Control
- Attitude Determination and Control
- Structural
- Power
- Thermal (Life support for manned missions)
- Communications and Data Handling
(U) Apogee & Perigee

(U) Apogee
- Farthest distance the satellite reaches from the primary body
- Force of gravity is weakest at this point

(U) Perigee
- Closest distance the satellite passes from the primary body
- Force of gravity is strongest at this point
(U) Inclination (i)

(U) Describes the tilt of the orbit plane with respect to the equatorial plane
(U) Inclination and Launch Latitude

(U) Cannot launch directly into orbits with an inclination less than a launch site's latitude

(U) For launches from Kennedy Space Center, we must do a plane change maneuver to get to the equatorial plane!
(U) Launch Windows
(U) Parts of an orbit

+ (U) Classical Elements
  • Inclination
  • Right Ascension of the ascending node
  • Eccentricity
  • Argument of perigee
  • Semi-minor axis
  • Mean anomaly

+ (U) What we care about
  • Inclination
  • Apogee/Perigee – related to the semi-minor axis
Orbital Elements

- Celestial body
- True anomaly $\nu$
- Argument of periapsis $\omega$
- Longitude of ascending node $\Omega$
- Plane of reference $i$
- Inclination
- Orbit
- Ascending node
- Reference direction
(U) Orbital Elements

- Apogee Height
- Perigee Height
- Apogee Distance
- Perigee Distance
- Minor axis
- Semi-minor axis
- 2c
- 2a = major axis
- a = semimajor axis

**US.** Fig. 5-2
(U) Tilt: Inclination (i)

<table>
<thead>
<tr>
<th>Inclination, $i$</th>
<th>Orbit Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0^\circ$ or $180^\circ$</td>
<td>Equatorial</td>
</tr>
<tr>
<td>$90^\circ$</td>
<td>Polar</td>
</tr>
<tr>
<td>$0^\circ \leq i \leq 90^\circ$</td>
<td>Direct or prograde</td>
</tr>
<tr>
<td></td>
<td>(satellite moves in direction of Earth’s rotation)</td>
</tr>
<tr>
<td>$90^\circ \leq i \leq 180^\circ$</td>
<td>Indirect or retrograde</td>
</tr>
<tr>
<td></td>
<td>(satellite moves in opposite direction of Earth’s rotation)</td>
</tr>
</tbody>
</table>
(U) Orbital Applications

Low Earth Orbit
- (U) Worldwide coverage
- (U) Short time over target (10–20 minutes per visit)

Highly Elliptical Orbit
- (U) Dynamic, wide-area access
- (U) Moderate dwell per spacecraft (1–10 hours per visit)
- (U) Direct view Asia/North America

Geosynchronous Orbit
- (U) Stationary, wide-area access
- (U) Continuous focused dwell (24 hours over fixed areas)
- (U) Focus on 1/3 of world

(b)(3)
(b)(3)
(b)(3)
(U) Map Projection

(U) A ground track is the projection of a satellite’s orbit onto the Earth’s surface.

~ 15° per hour

(U) All orbits will have a westward shifting ground track due to the Earth's rotation.
(U) Low Earth Orbit (LEO)

- (U) Altitude: Up to about 1500 km
- (U) Period: 90 – 120 min
- (U) Limited coverage
- (U) Small sensor field of view
- (U) Short dwell time over target
- (U) Missions:
  - Manned (Shuttle)
  - Observation
    - Weather
    - Earth sensing
  - Astronomy

US: Fig. 3-3
(U) LEO Sun Synchronous Orbit (SSO)

- A special, near-polar inclination, low earth orbit with retrograde motion
- Passes over target same time of day (but doesn’t pass over the target everyday)
  - Same sun angle or shadow
- Inclination of 98°
- Missions:
  - Weather (DMSP/TIROS)
  - Earth sensing (LANDSAT)

SSO Ground Track
(U) Polar Orbit
(U) Sun Synchronous Orbit
(U) Semi-Synchronous

+ (U) Another “special” orbit that repeats its ground track every day
  + Period: 11 hours 58 min
  + Altitude: 20,184 km

+ (U) Mission:
  + Navigation (GPS, Glonass)
(U) Geosynchronous Orbit (GEO)

+ (U) Period – 23 hrs, 56 min, 4 sec
+ (U) Near circular - 37,160 km altitude (23,500 NM)
+ (U) Does not cover the polar regions (> 81 degrees latitude)

+ (U) Missions:
  + Communications Relay (DSCS/FLTSAT/MILSTAR)
  + Surveillance/Warning (DSP)

GROUND TRACK
(U) Highly Elliptical Orbit (HEO)

+ (U) Nav and comms
+ (U) Period is 12 hours (Semi-synchronous)
+ (U) Inclinations between 50 to 70 degrees
(U) Molniya Orbit

- (U) Orbit with long dwell times over high northern latitudes
- (U) Approximately 8 hours of a 12 hour orbit
- (U) Max coverage at higher latitudes
- (U) Covers the “hole” left by a GEO constellation
- (U) Missions:

Molniya Ground Track
(U) Orbit Types Summary

- (U) LEO (Low Earth Orbit) – altitudes up to 1500 km, orbit periods between 90 and 120 min periods

- (U) GEO (Geosynchronous/Geostationary Orbit) – a 35786 km altitude, 23 hr 56 min 4 sec orbit period

- (U) HEO (Highly Elliptical Orbit) – 400 x 40,000 km altitude, approximately 12 hr orbit period
(U) Summary

+ (U) What is a satellite?
+ (U) Breakdown of orbits
+ (U) Orbit Types
+ (U) Forces working against satellites
Questions?
(U) Perturbations Summary

- (U) Atmospheric Drag
- (U) Earth Oblateness
- (U) Solar Radiation Pressure
- (U) Third Body Affects
- (U) Electromagnetic drag