NATIONAL RECONNAISSANCE OFFICE

Orbital Mechanics

THE OVERALL CLASSIFICATION FOR THIS BRIEFING IS UNCLASSIFIED

Approved for Release: 2018/05/09 C05108585

(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

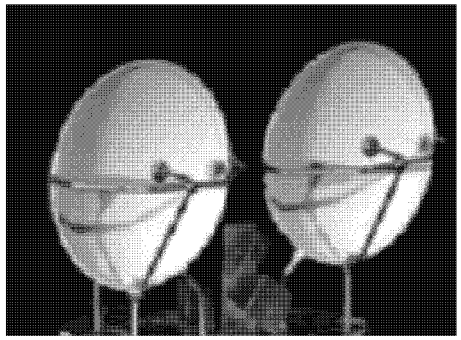
- Define LEO, HEO and GEO
- Describe given spacecraft and orbital mechanics terminology
- Describe the altitudes of HEO, LEO and GEO
- Describe the benefits of HEO, LEO and GEO
- Define the four types of inclination
- Recognize satellite ground tracks and map projections
- Identify impacts of solar activity 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

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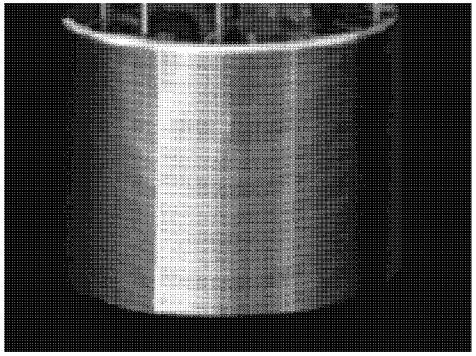
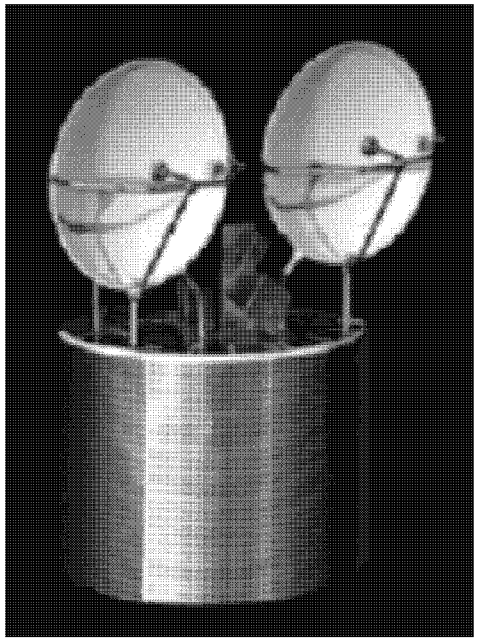


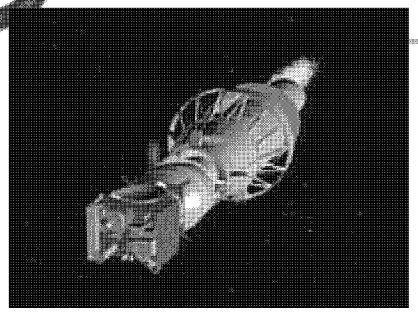
Vehicle or "Bus"

=

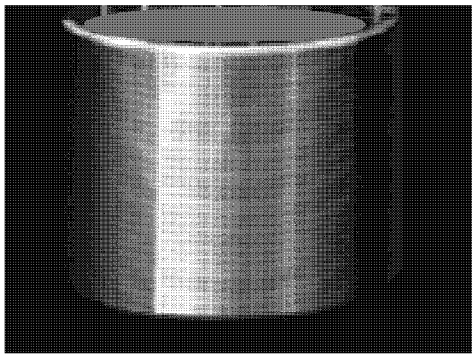


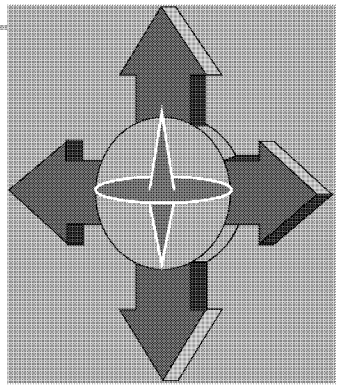
Satellite

(U) Vehicle Subsystems

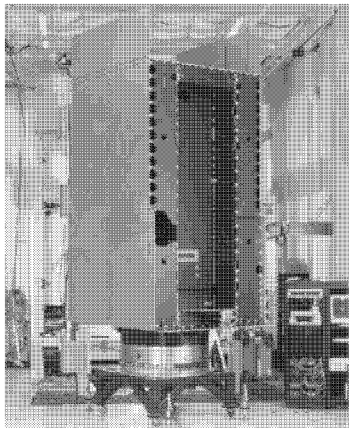


Navigation, Guidance and Control

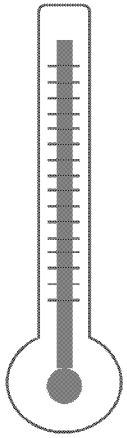




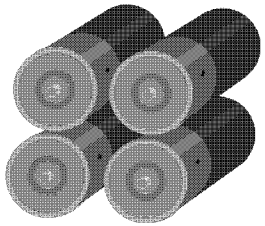
Attitude Determination and Control



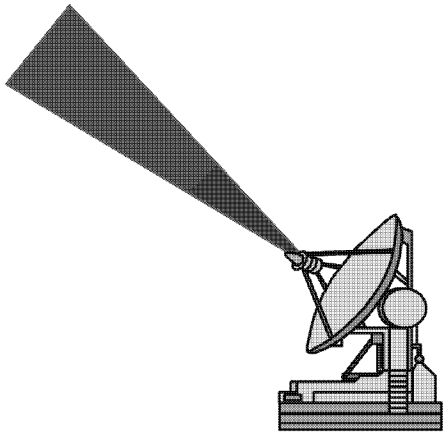
Structural



Thermal
(Life support for manned missions)



Power



Communications and Data Handling

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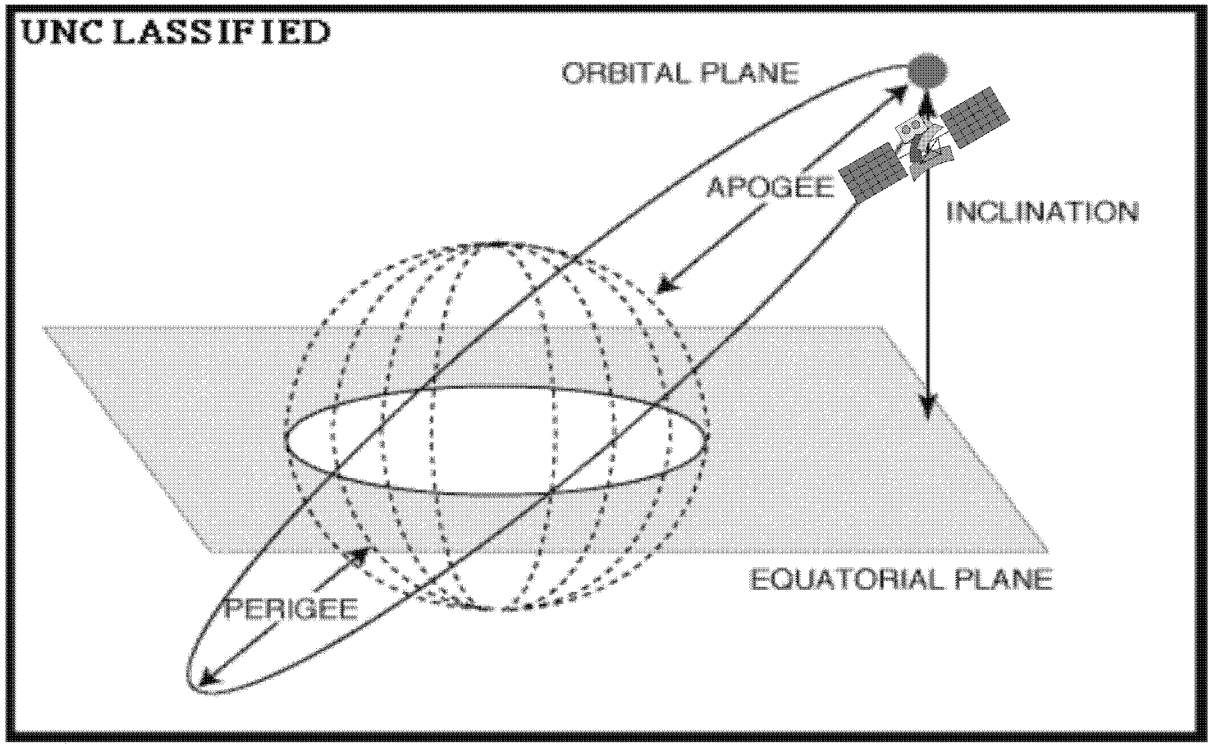
(U) Apogee & Perigee

- (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

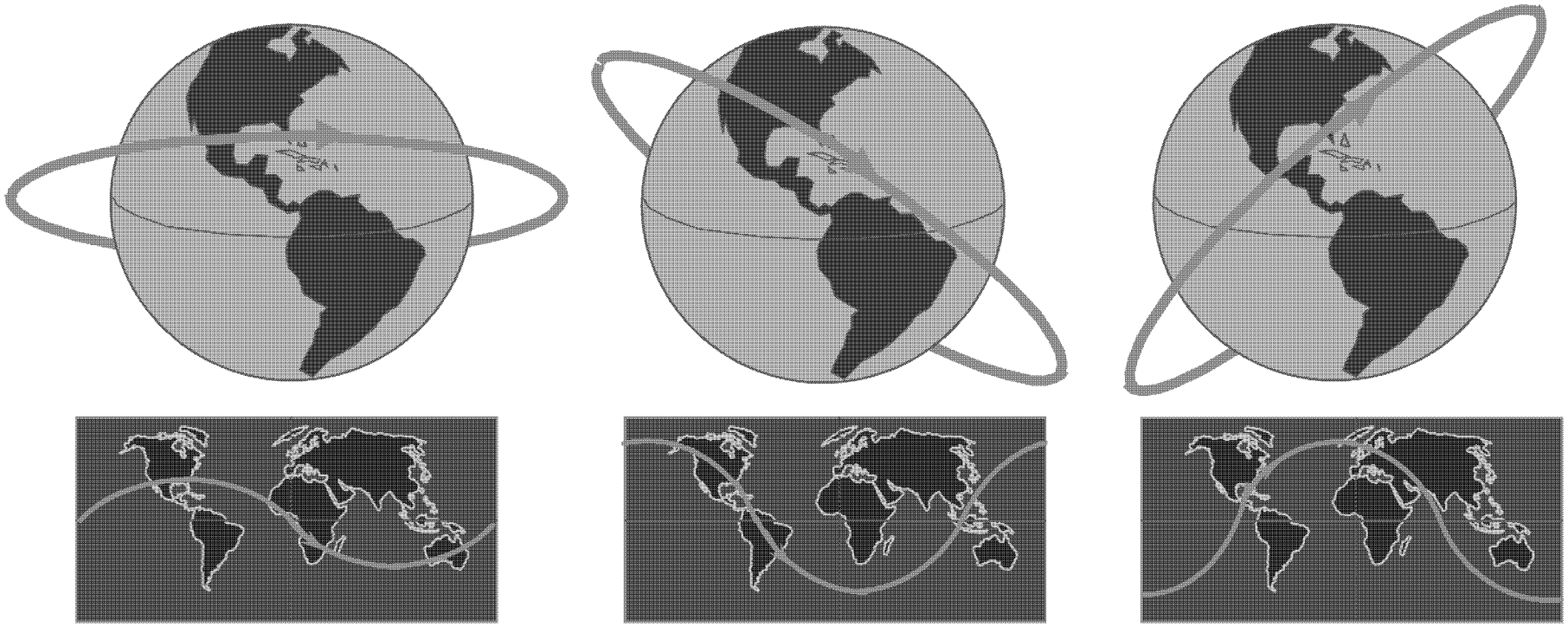
(U) Inclination (i)

- (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



Launch Due East | **Launch Southeast** | **Launch Northeast**

(U) For launches from Kennedy Space Center, we must do a plane change maneuver to get to the equatorial plane!

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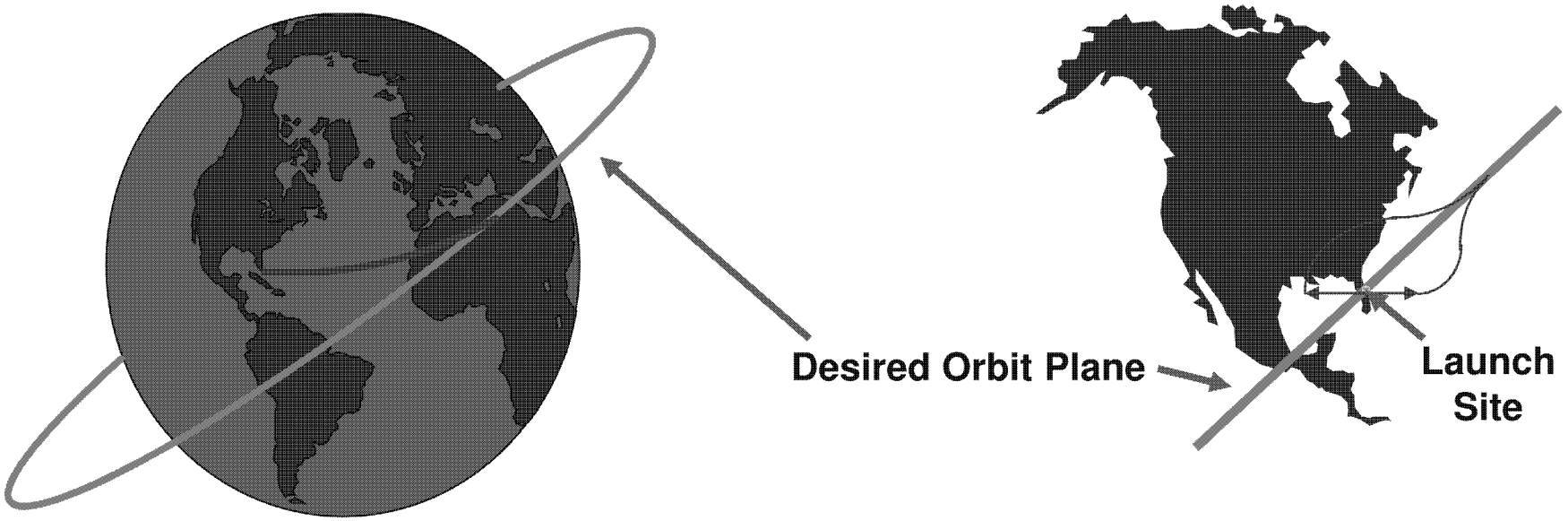
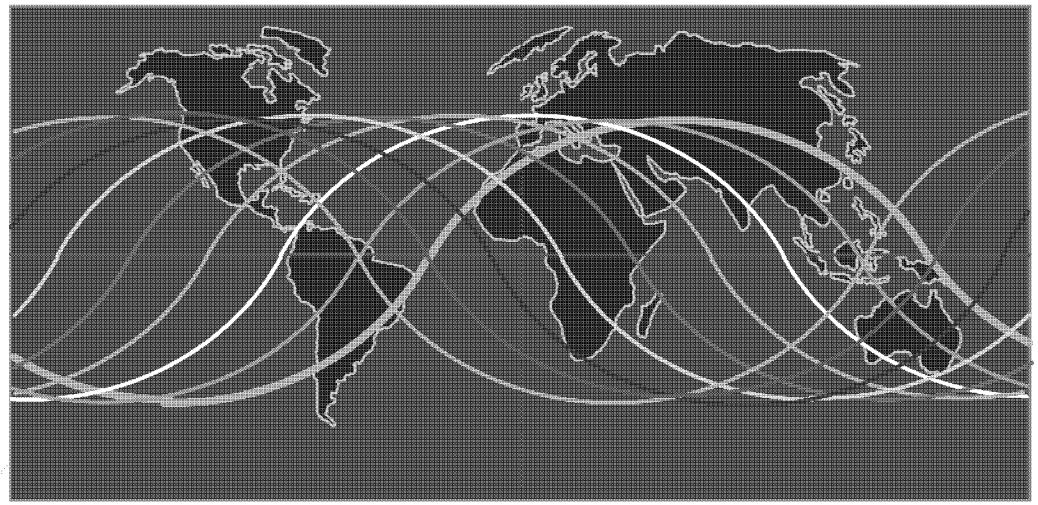
(U) Launch Windows



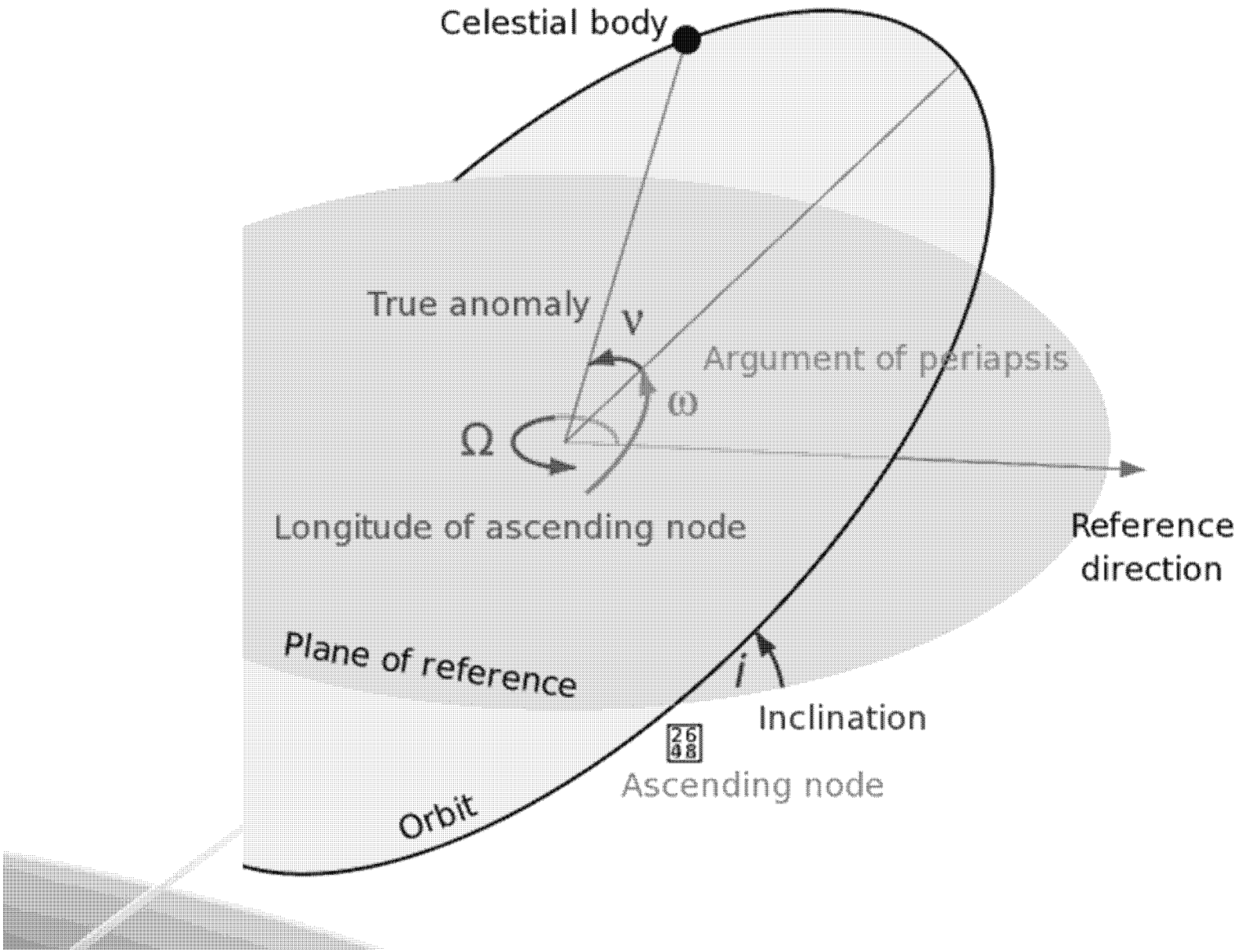


(U) Parts of an orbit

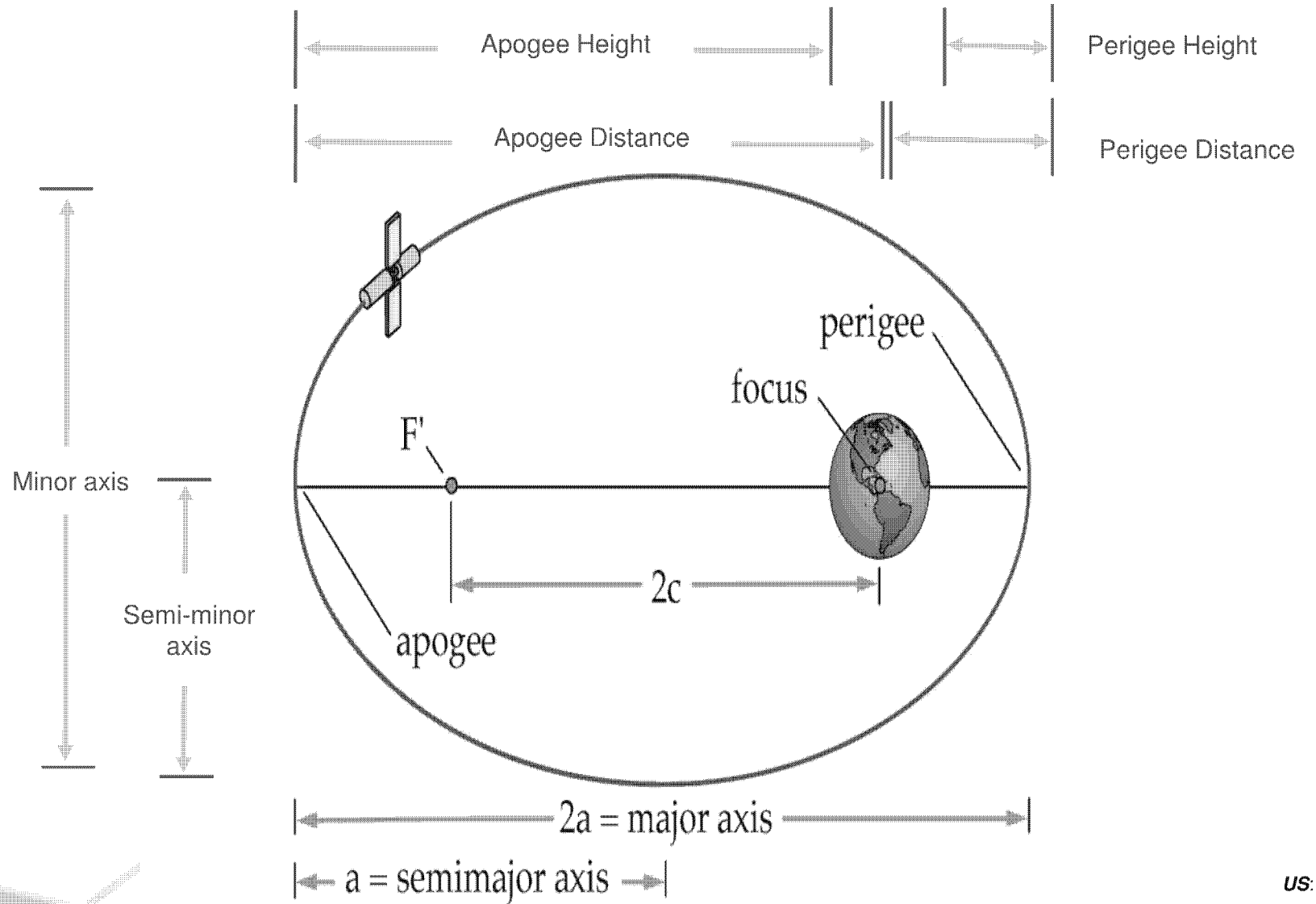
- (U) Classical Elements
  - Inclination
  - Right Ascension of the ascending node
  - Eccentricity
  - Argument of perigee
  - Semi-minor axis
  - Mean anomaly

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

Orbital Elements



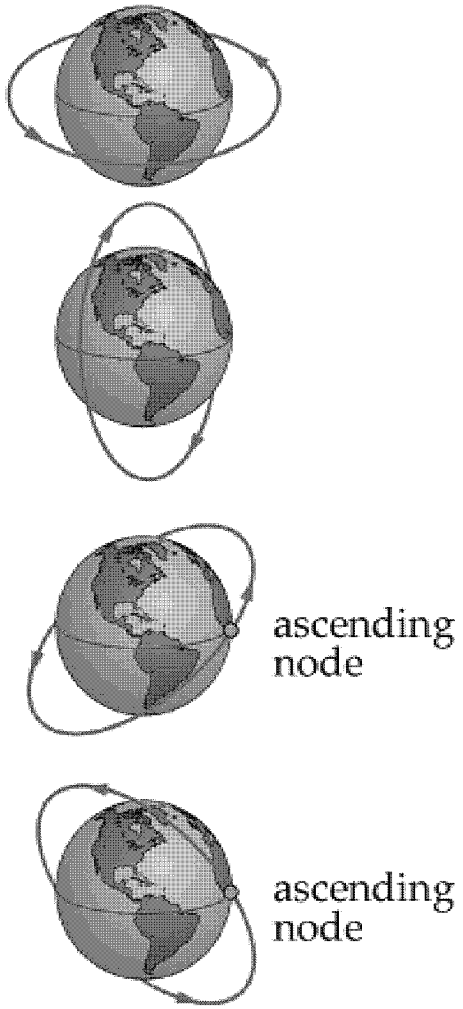
(U) Orbital Elements



US: Fig. 5-2

(U) Tilt: Inclination (i)

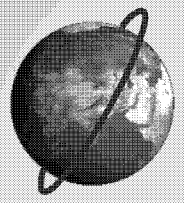
Inclination, i	Orbit Type
0^o or 180^0	Equatorial
90^o	Polar
$0^o \leq i \leq 90^0$	Direct or prograde (satellite moves in direction of Earth's rotation)
$90^o \leq i \leq 180^0$	Indirect or retrograde (satellite moves in opposite direction of Earth's rotation)



US: Table 5-2

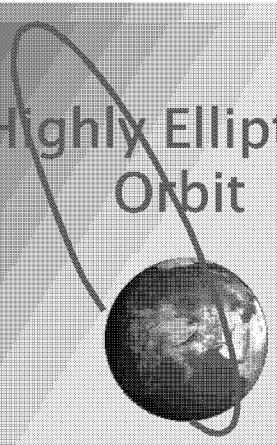
(U) Orbital Applications

Low Earth Orbit



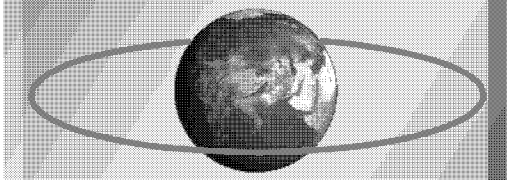
- (U) Worldwide coverage
- (U) Short time over target (10-20 minutes per visit)

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



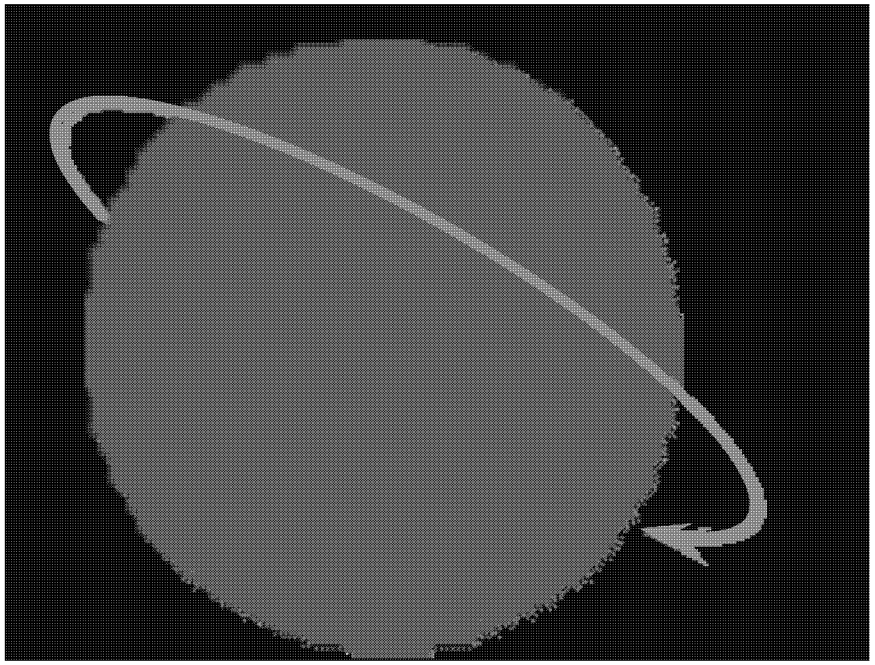
- (U) Stationary, wide-area access
- (U) Continuous focused dwell (24 hours over fixed areas)
- (U) Focus on 1/3 of world

(b)(3)

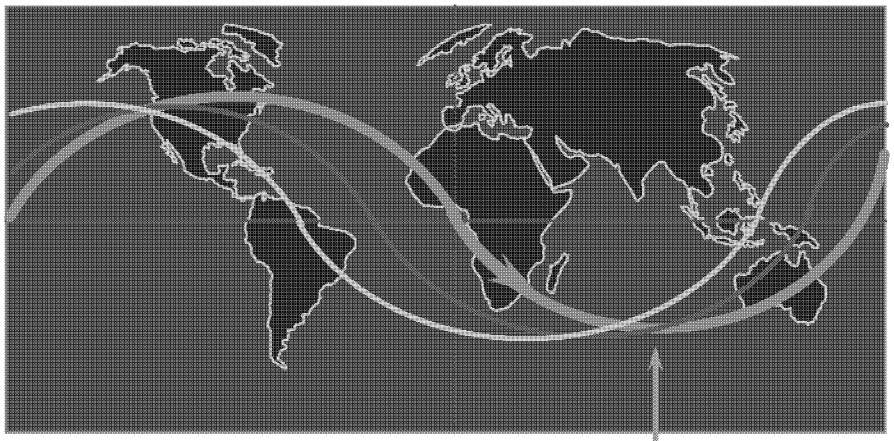
(b)(3)

(U) Map Projection

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



~ 15° per hour



Ground Track

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

(U) Low Earth Orbit (LEO)

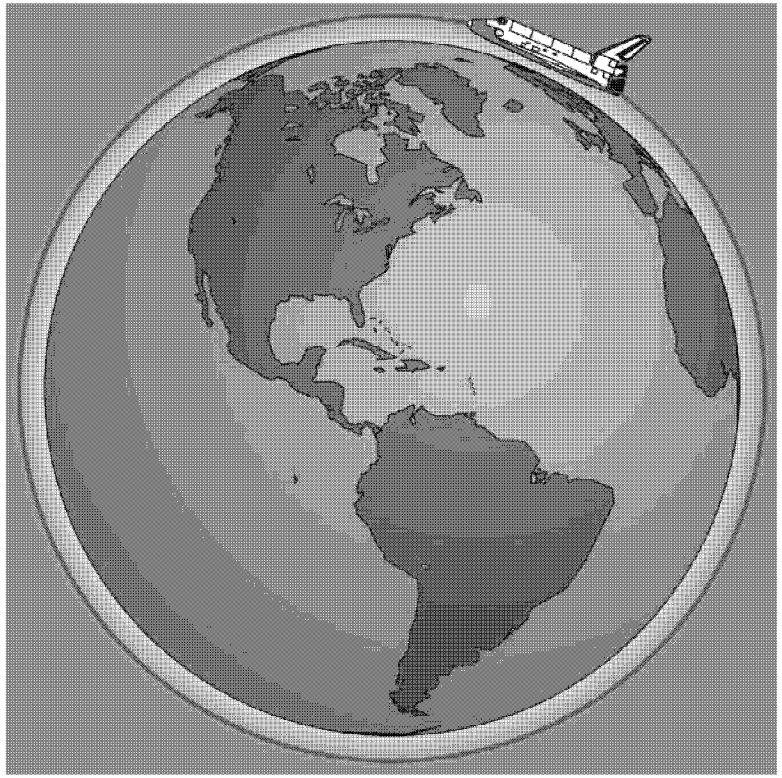
- (U) Altitude: Up to about 1500 km
- (U) Period: 90 – 120 min
- (U) Limited coverage
- (U) Small sensor field of view
- (U) Short dwell time over target
- (U) Missions:
  - Manned (Shuttle)

(b)(3)

  - Observation
    - Weather
    - Earth sensing

(b)(3)

    - Astronomy



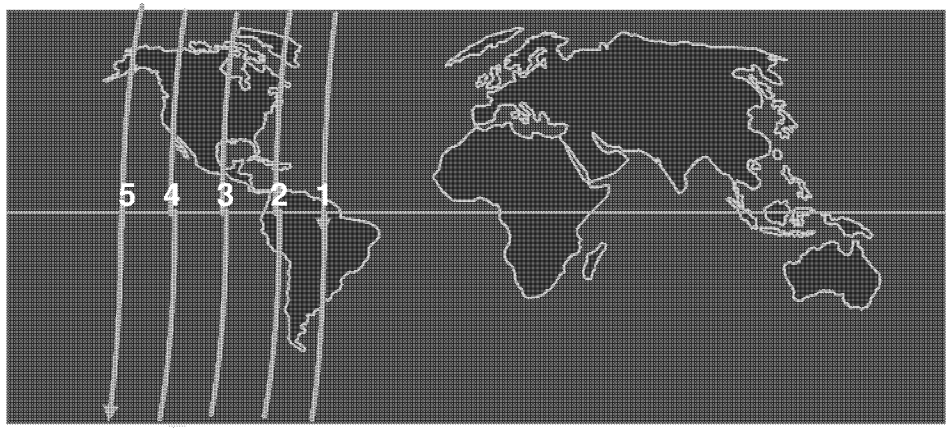
US: Fig. 3-3

(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:

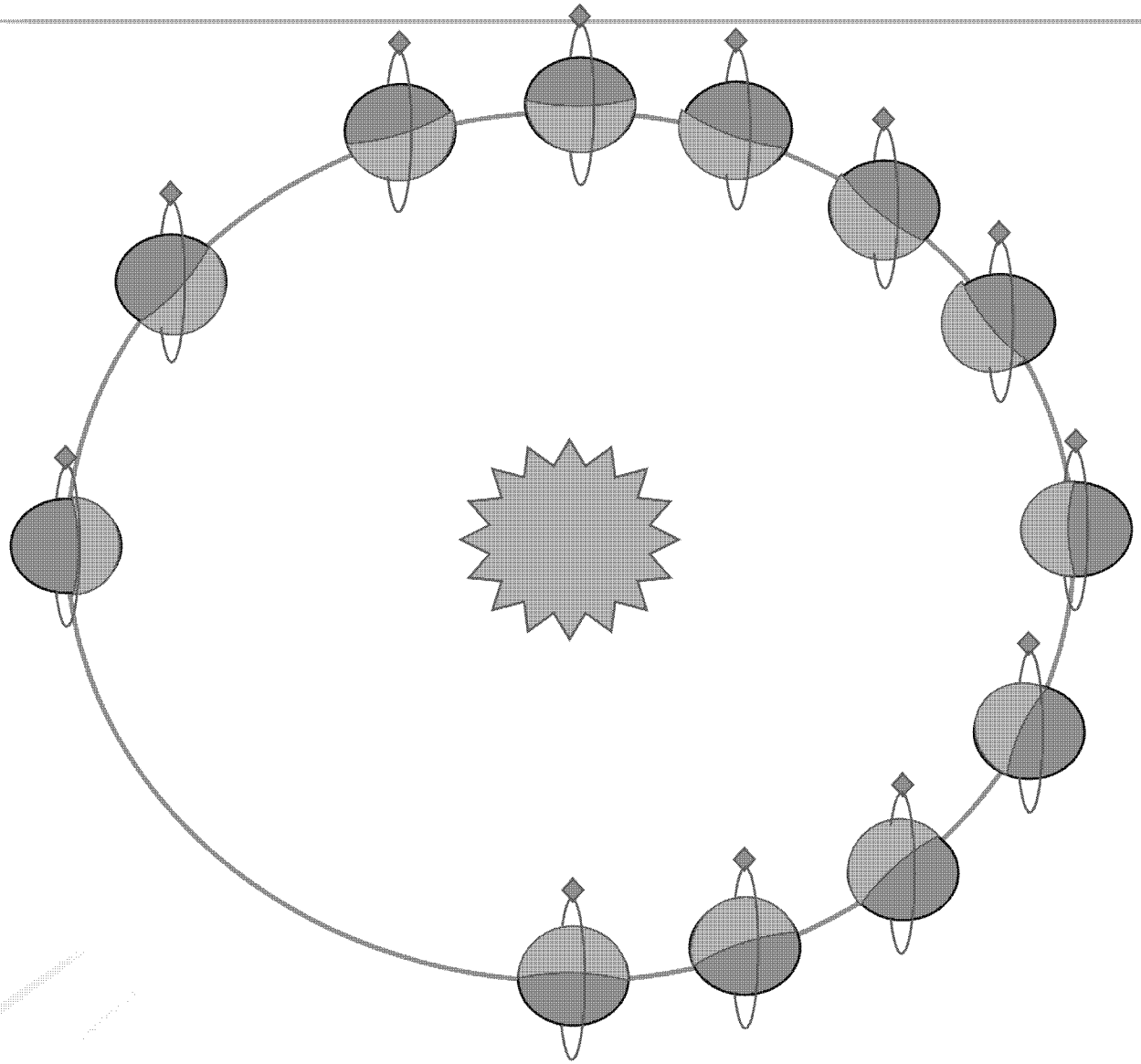
  [redacted] (b)(3)

  - Weather (DMSP/TIROS)
  - Earth sensing (LANDSAT)



SSO Ground Track

(U) Polar Orbit



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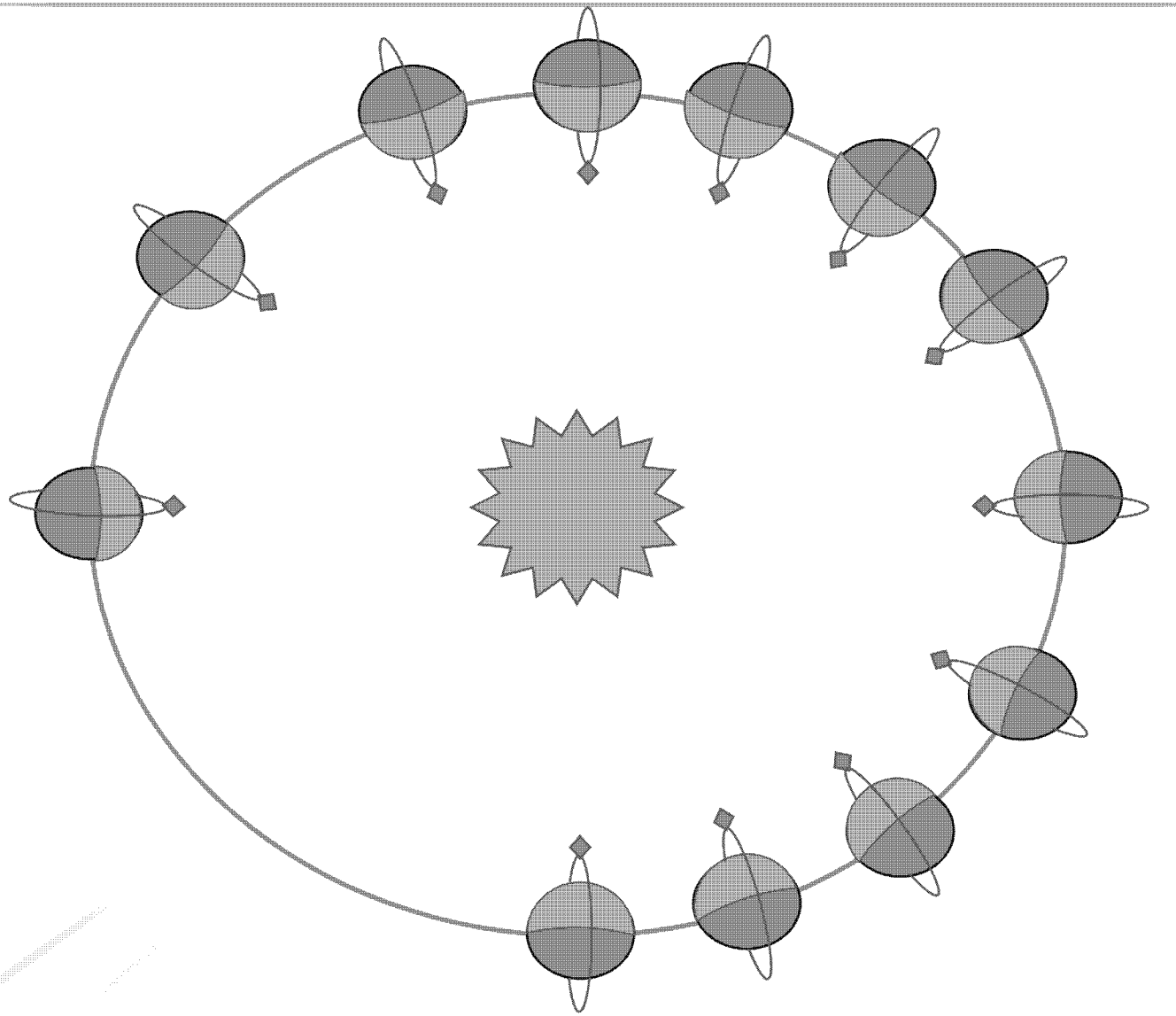
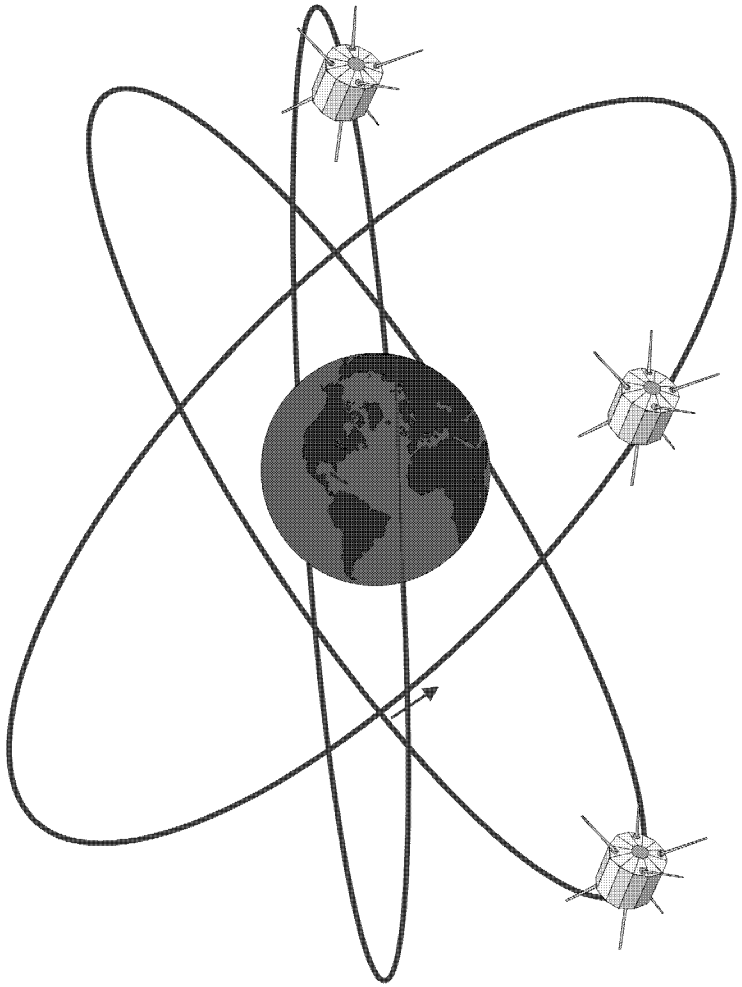
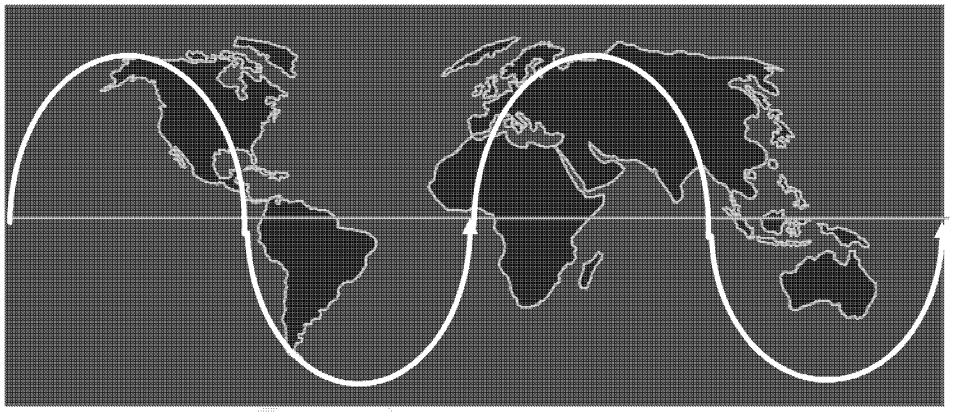
(U) Sun Synchronous Orbit



(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)





Semi-Synchronous Ground Track

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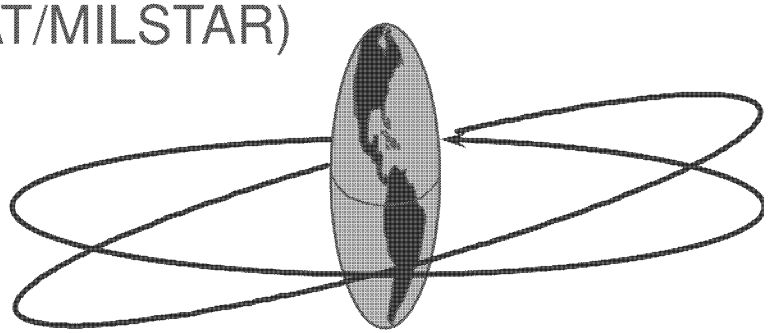
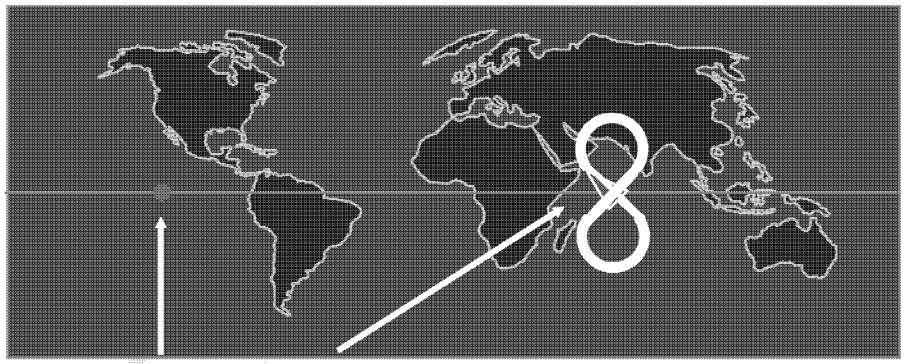
(U) Geosynchronous Orbit (GEO)

- (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)

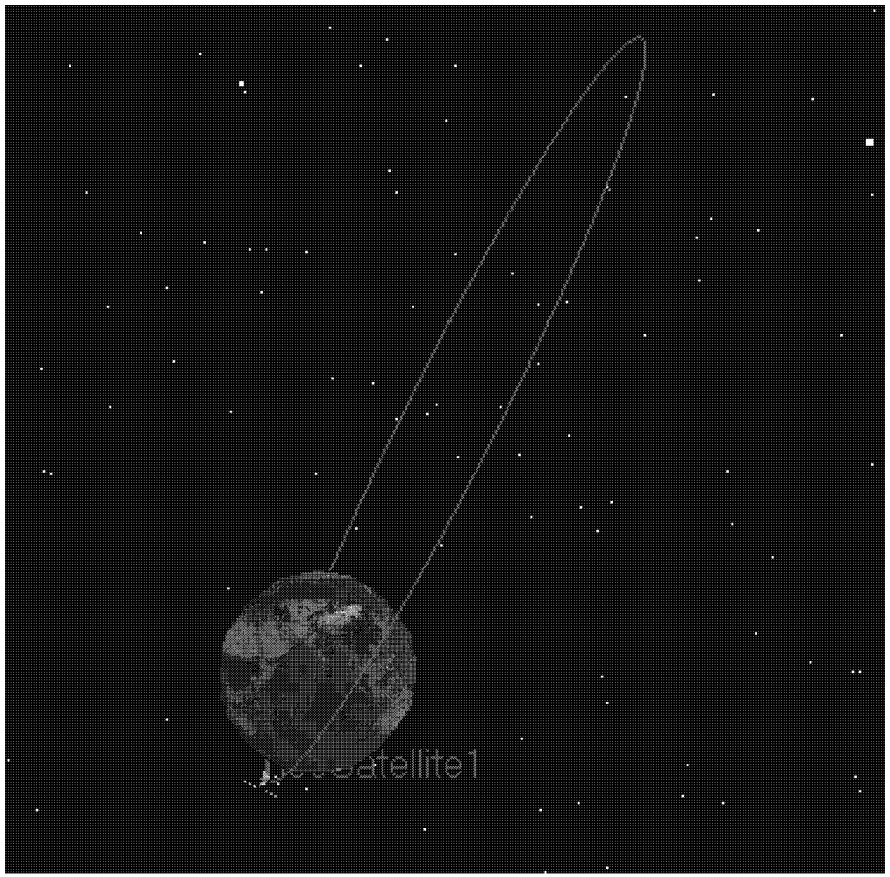




GROUND TRACK

(U) Highly Elliptical Orbit (HEO)

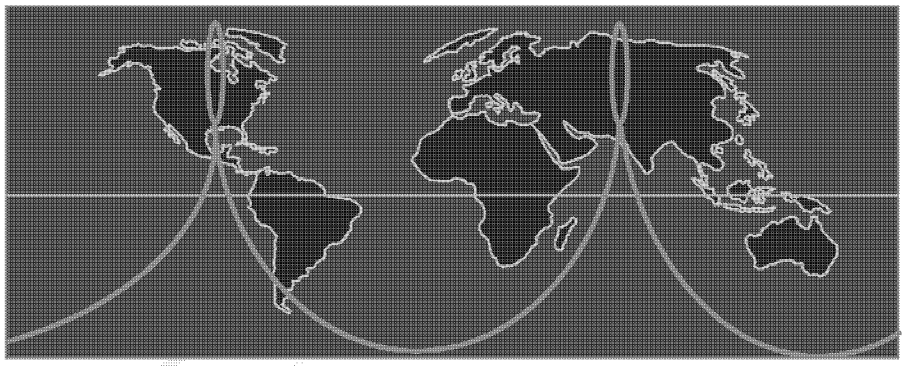
- (U) Nav and comms
- (U) Period is 12 hours (Semi-synchronous)
- (U) Inclinations between 50 to 70 degrees



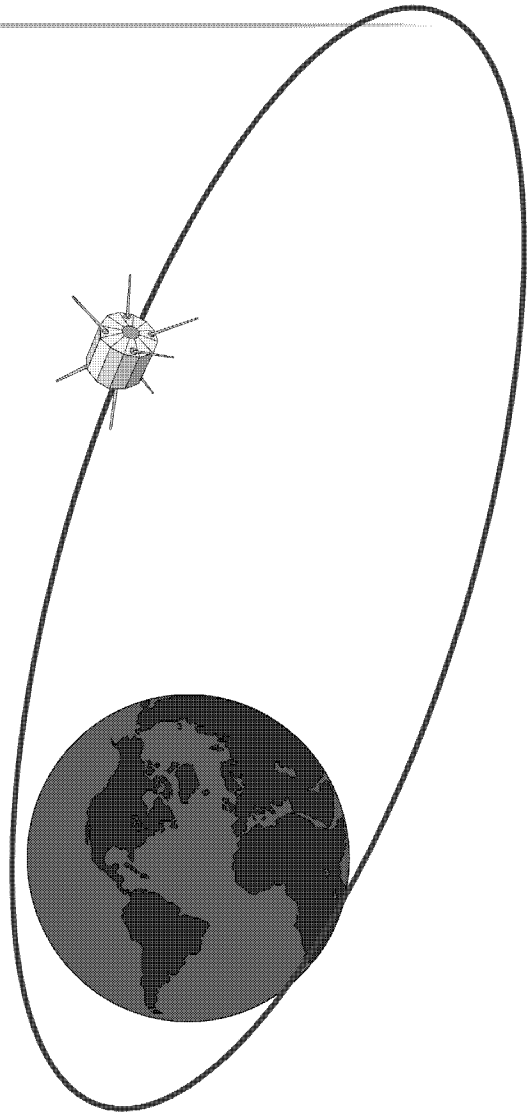
(U) Molniya Orbit

- (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:

(b)(3)



Molniya Ground Track



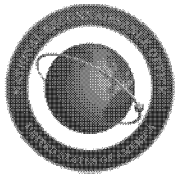
(U) Orbit Types Summary

- (U) LEO (Low Earth Orbit) – altitudes up to 1500 km, orbit periods between 90 and120 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