~~SECRET//TK//REL TO USA, FVEY~~

NATIONAL RECONNAISSANCE OFFICE

(U) Rocket Science 101

CL BY: [redacted] (b)(3)
DECL ON: 25X1, 20660412
DRV FROM: INCG 1.0, 13 February 2012

SUPRA ET ULTRA

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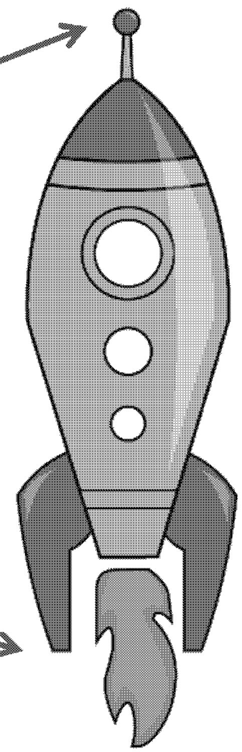
(U) The Basics of Rocket Science

(U) Pointy end up



(U) Any Questions?

(U) Fire comes out the bottom

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(U) Objectives

- (U) Describe the advantages of overhead reconnaissance
- (U) Explain the physics of launch using terminology of simple rocketry and science
- (U) Describe low earth, geosynchronous, and highly elliptical orbits and their advantages and disadvantages in gathering intelligence data
- (U) Identify key launch site factors

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(U) Why Space?

- (U) The ultimate high ground
- (U) Limitless geographical access
- (U) No political constraints
- (U) Information superiority
- (U) Constant reconnaissance capability
- (U) No risk of loss of life

(U) So how do you get there?

(U) Let's Start at the Beginning…

- (U) Since about 200 AD, scientists believed:
  - Earth was the center of the universe and
  - The sun and planets revolved around the Earth
  - Able to predict eclipses of sun and moon and future positions of planets, even though the theory was wrong

- (U) In 1530s, Nicolaus Copernicus proposed that the Sun was the center of the universe and all planets revolved in circles around the sun
  - Unable to prove this theory before his death in 1543
  - Some questions about certain planetary movement
- (U) In 1602, Johannes Kepler mathematically proved Copernicus' theory
  - Used observations of Danish astronomer Tycho Brahe

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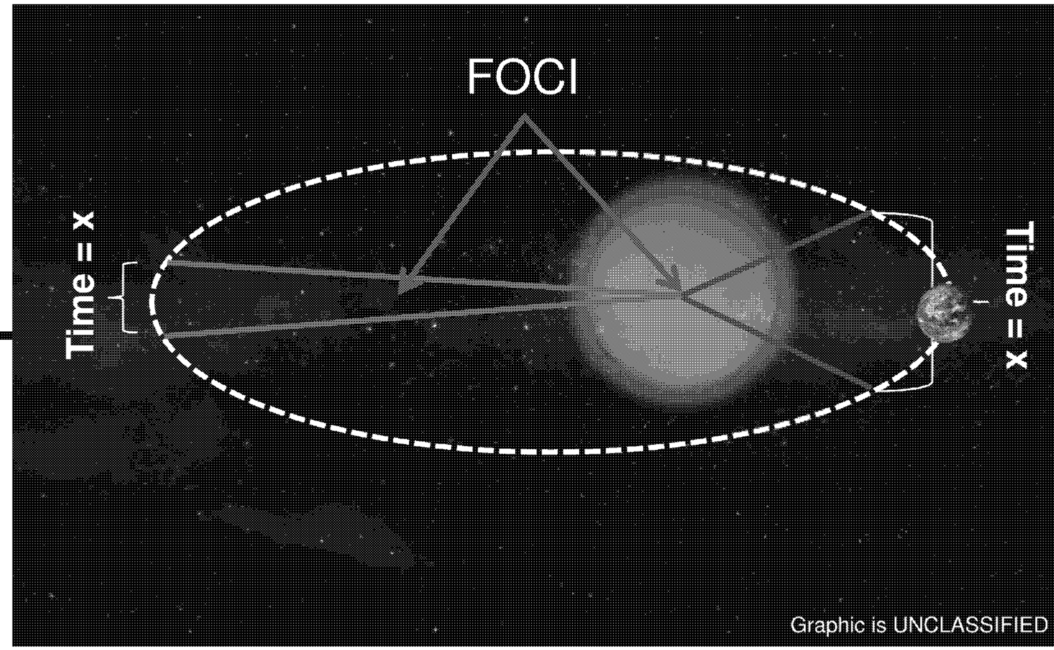
(U) Kepler's Laws of Planetary Motion

(U) Kepler's First Law:

- Planets move in ellipses with the Sun at one focus



(U) Kepler's Second Law:

- A line segment joining a planet and the Sun sweeps out equal areas during equal intervals of time

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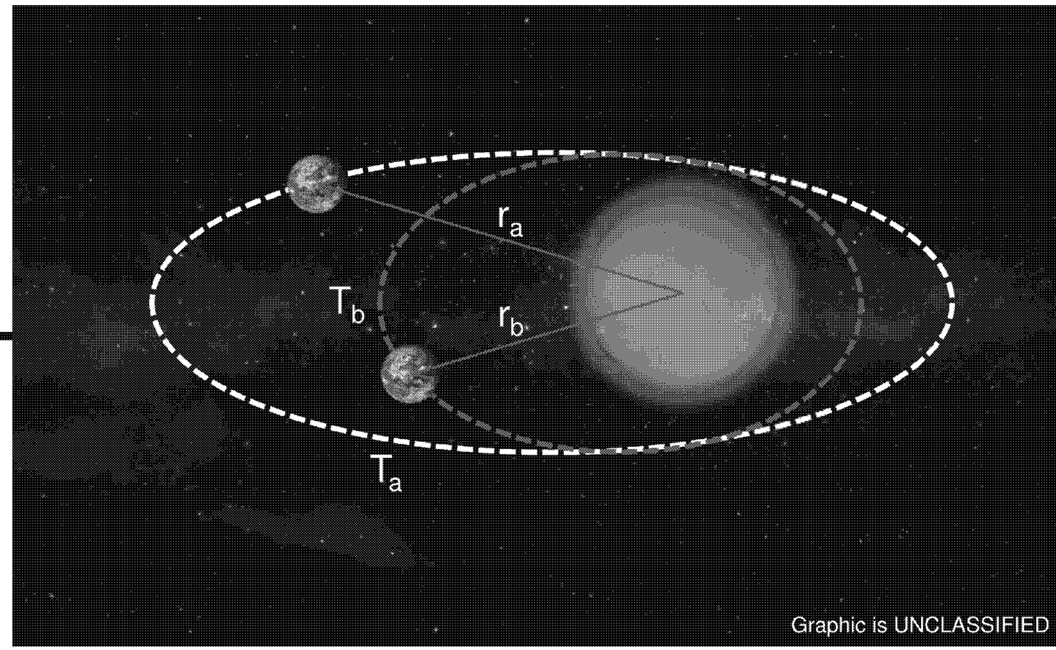
(U) Kepler's Laws of Planetary Motion

(U) Kepler's Third Law:

- The square of the orbital period is directly proportional to the cube of the semi-major axis of its orbit

$$\frac{T_a^2}{R_a^3} = \frac{T_b^2}{R_b^3} = \text{CONSTANT}$$



But Kepler could not explain why…

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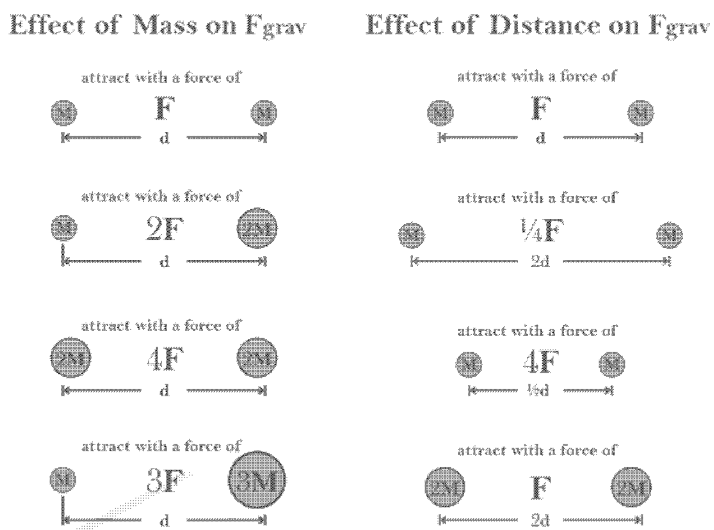
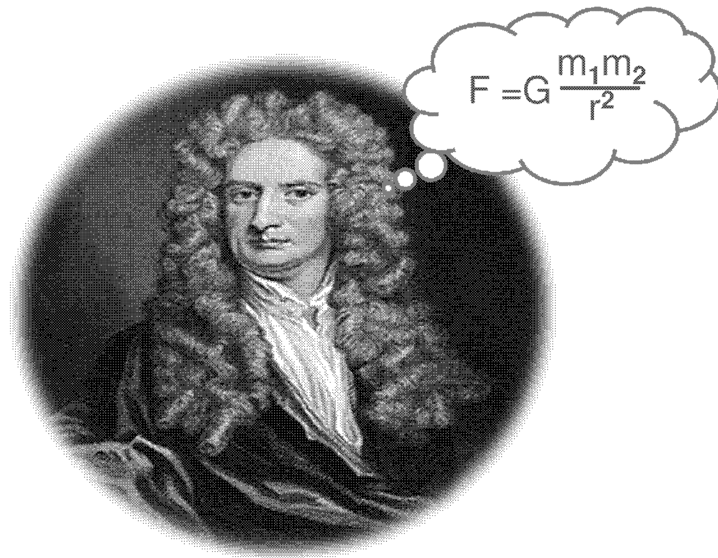
(U) Sir Isaac Newton to the Rescue

(U) Newton's Law of Universal Gravitation

- Every object in the Universe attracts every other object with a force directed along the line of centers for the two objects that is proportional to the product of their masses and inversely proportional to the square of the separation between the two objects.





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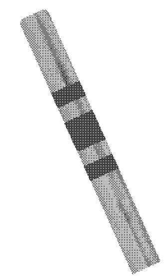
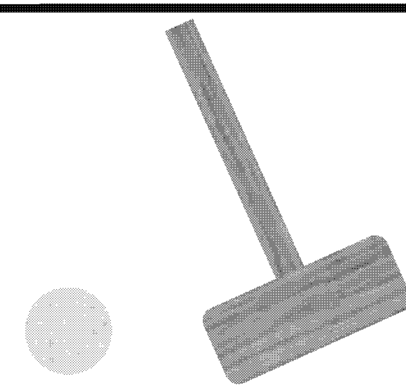
(U) Newton's First Law of Motion

(U) A body continues at rest or specific linear velocity unless acted upon by a force.



(U) A force applied to a body at rest or specific linear velocity results in a change in velocity.



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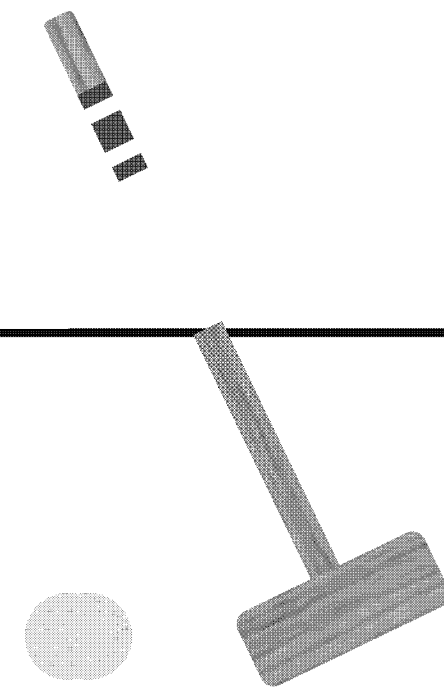
(U) Newton's Second Law of Motion

(U) A force applied to a body results in the product of its mass and acceleration

$$F = ma$$

(U) Increased force = increased acceleration with same mass



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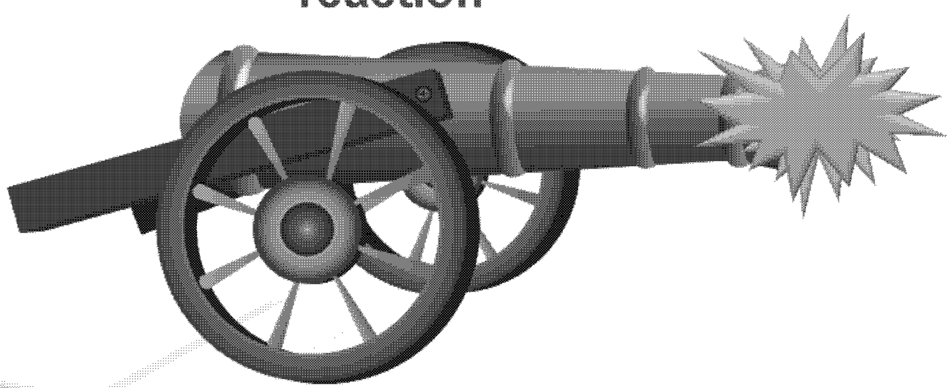
(U) Newton's Third Law of Motion

(U) A force exerted by object x to object y results in an equal force exerted by y to x

OR

(U) For every action, there is an equal and opposite reaction

reaction **action**



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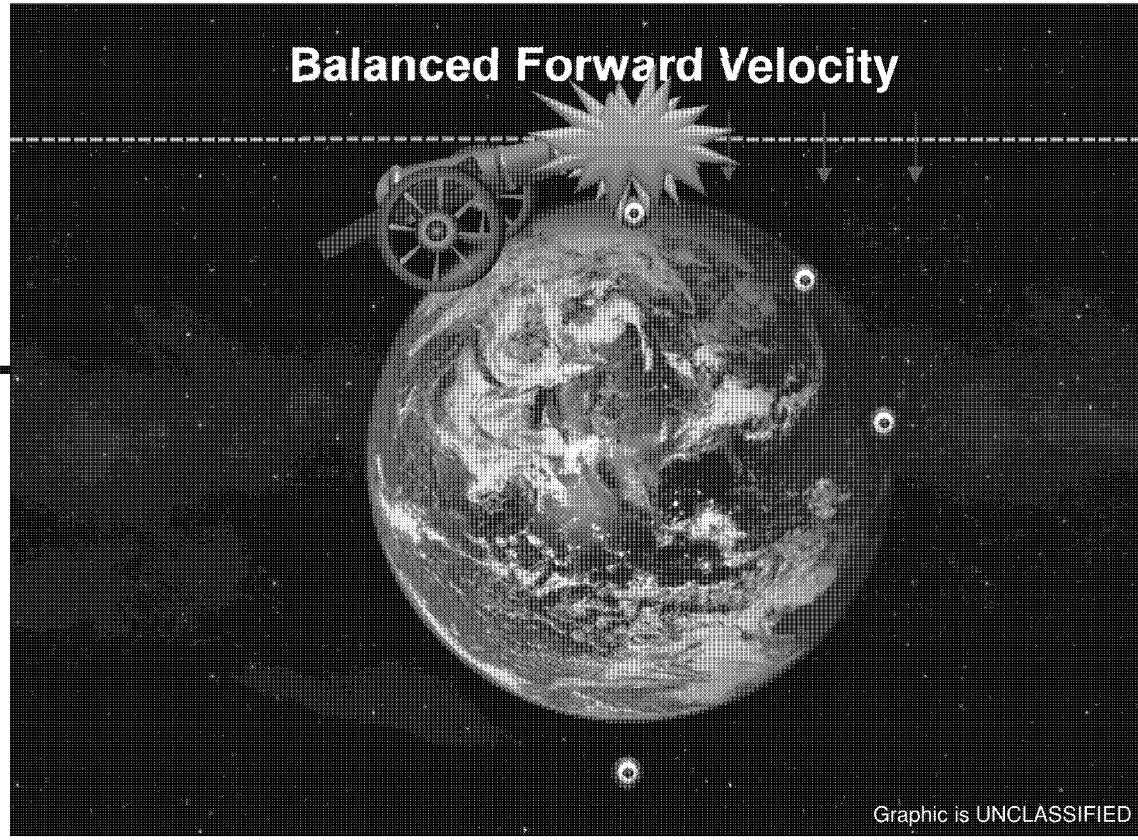
(U) Effect of Forward Velocity - Newton's Cannon

(U) Remember Newton's First Law of Motion – A body continues at rest or specific linear velocity unless acted upon by a force

(U) Newton's Law of Universal Gravitation – The Earth exerts a force on the cannonball and cannonball exerts a force on the Earth

(U) Newton's Second Law of Motion – F = MA
Mass is constant so greater force produces faster acceleration



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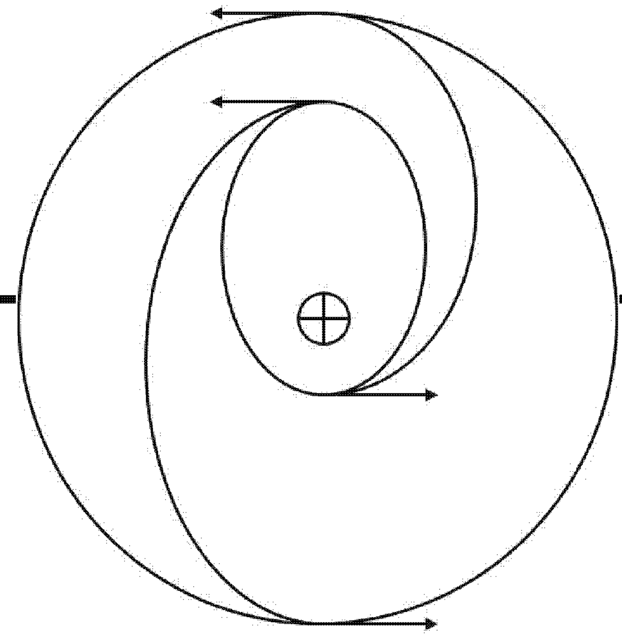
(U) Terminology

- (U) Orbits and Orbital Plane
- (U) Trajectory
- (U) Azimuth and Inclination
- (U) Ellipses and Circles
- (U) Altitude and Orbital Velocity/Period
- (U) Apogee and Perigee
- (U) Eccentricity and Dwell Time
- (U) Footprint and Ground Trace/Track



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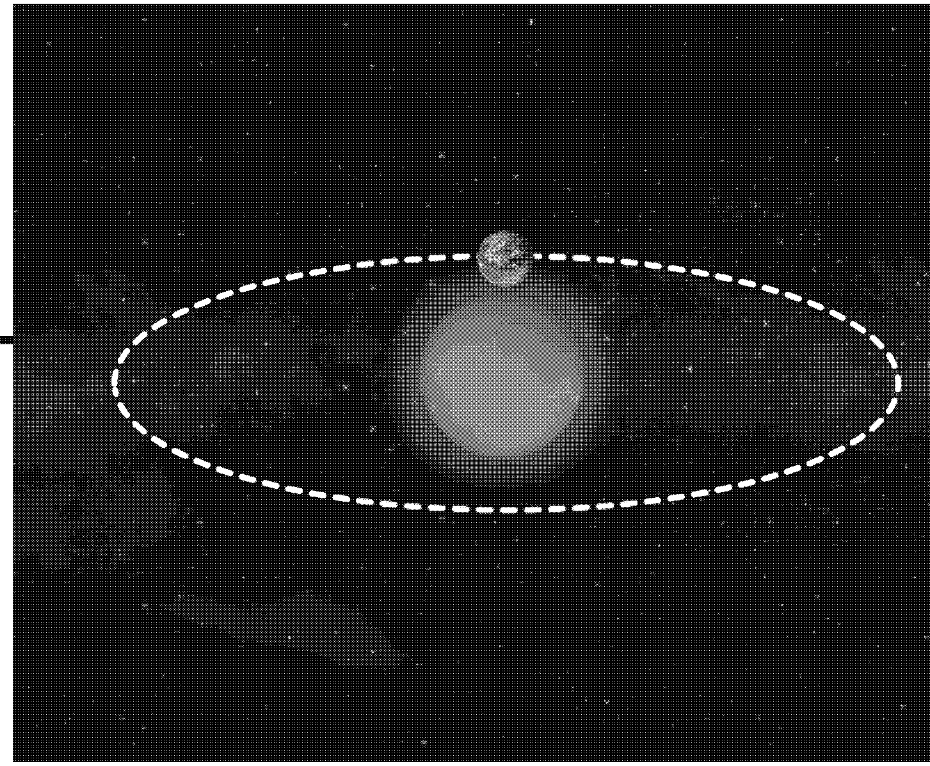
(U) Orbits

- (U) An orbit is the natural path of an object in mutual gravitational attraction to another object, usually with an extended or repetitive path



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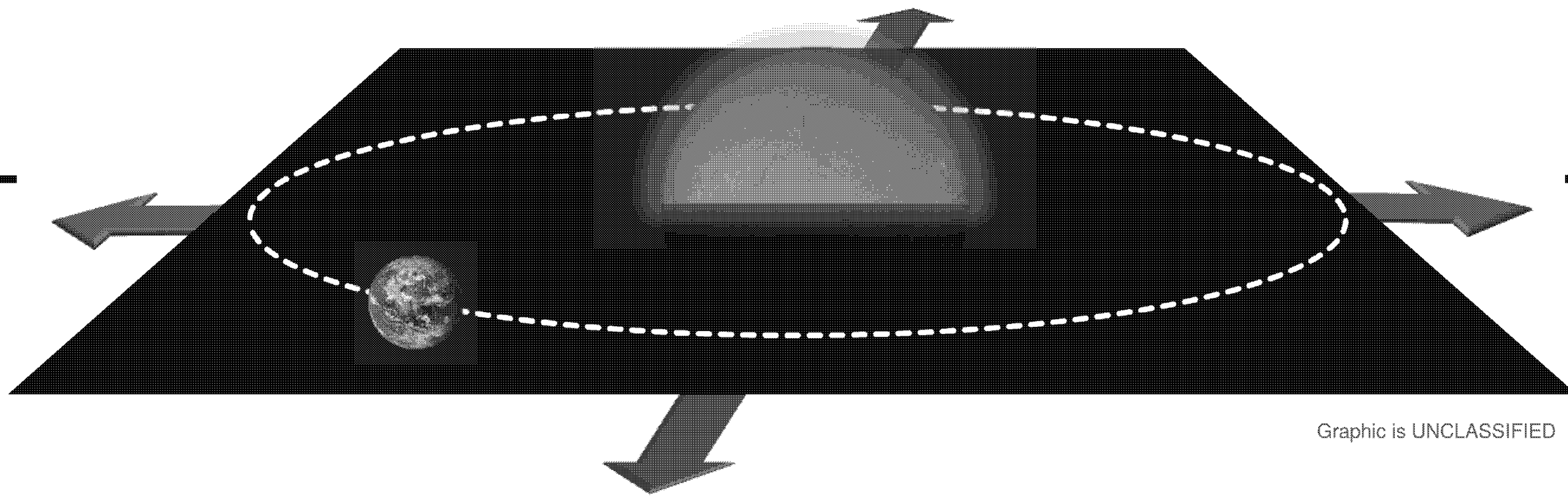
(U) Orbital Plane



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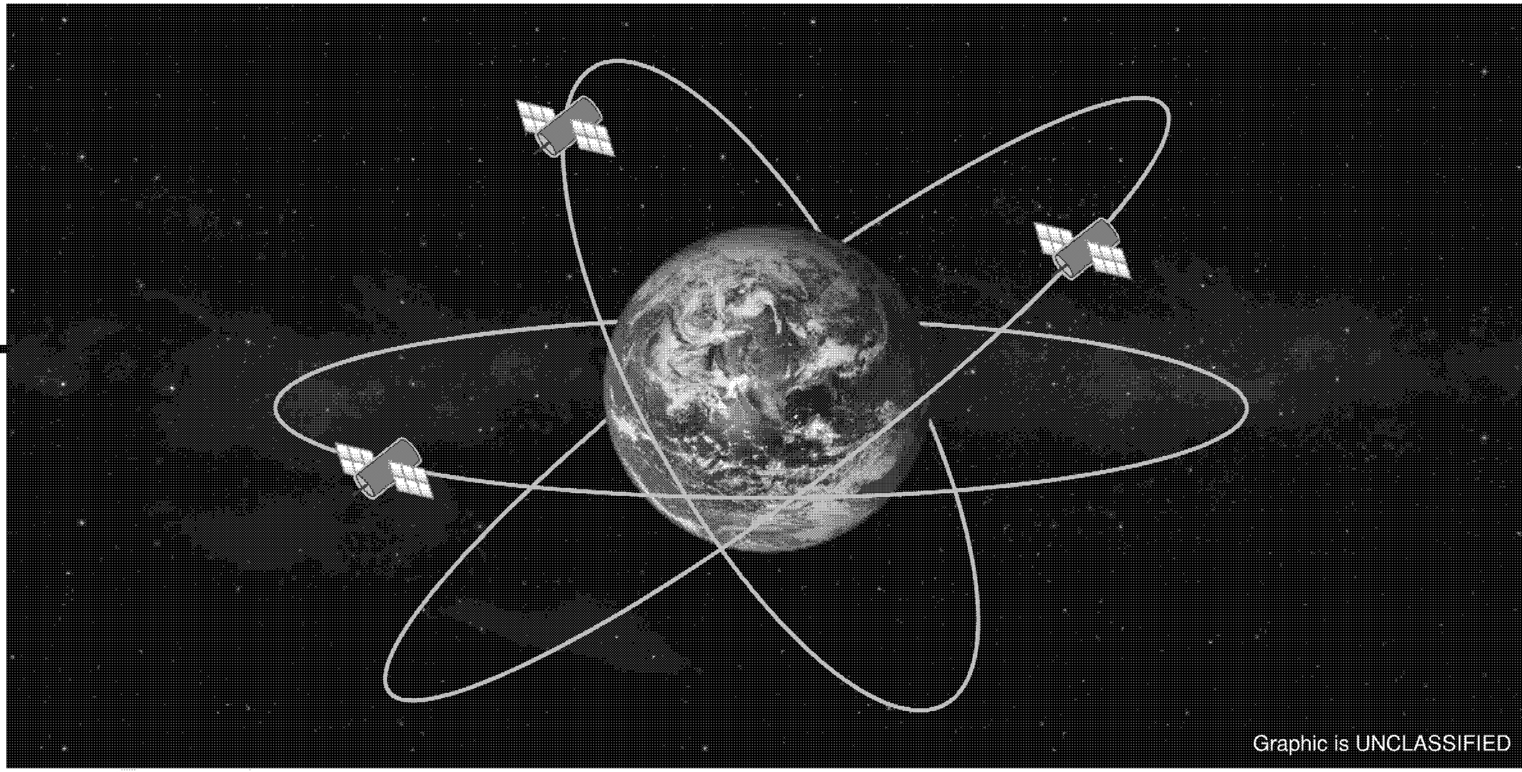
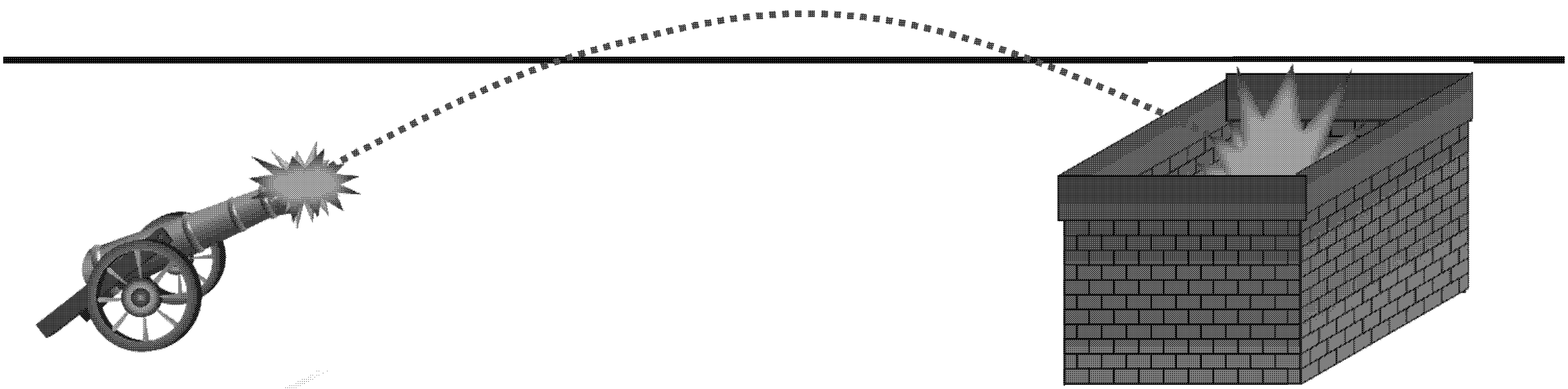
(U) Orbital Plane



(U) Trajectory

- (U) A trajectory is the path of an object through space, with identifiable start and end points, which may or may not be affected by external forces (such as gravity)



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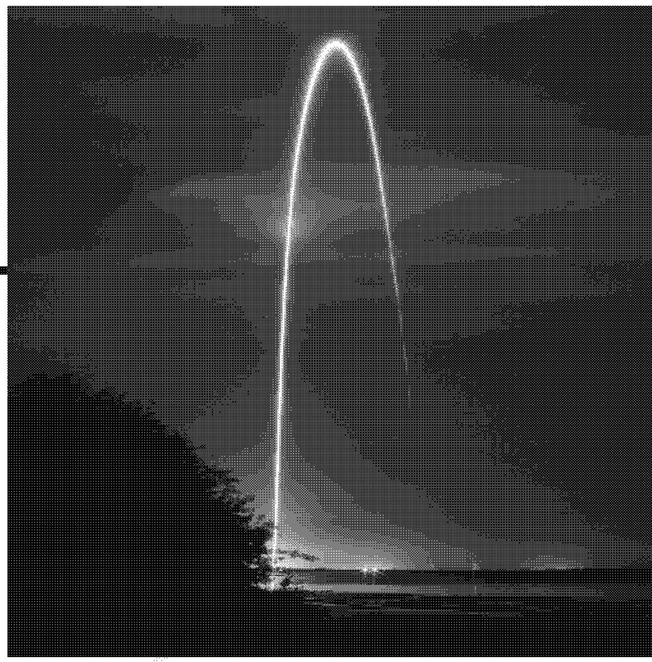
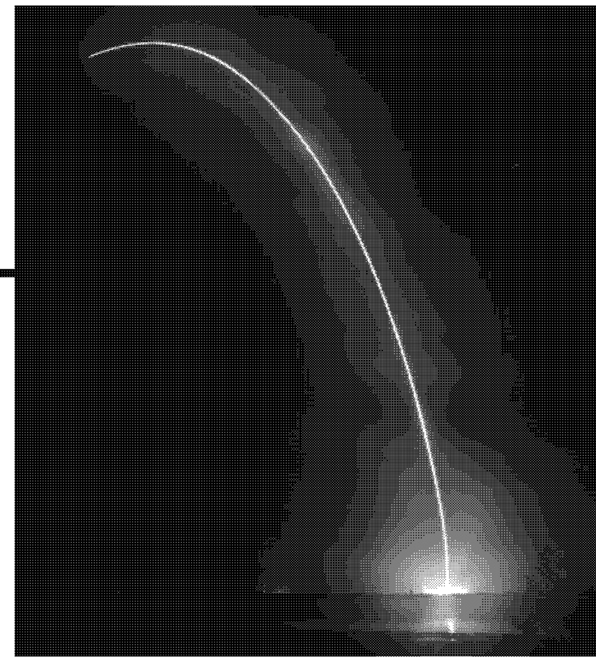
(U) Trajectories





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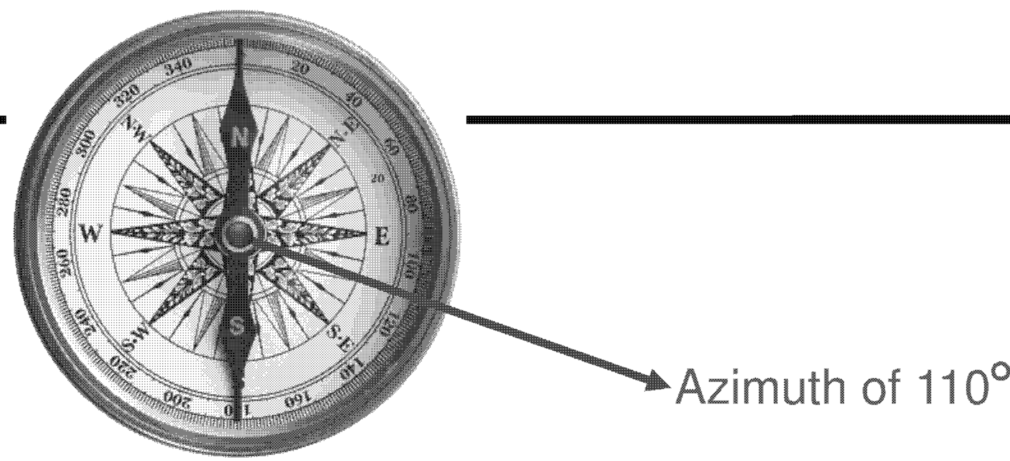
(U) Azimuth and Inclination

- (U) Azimuth is the direction of an object in motion measured in degrees from true or magnetic north.



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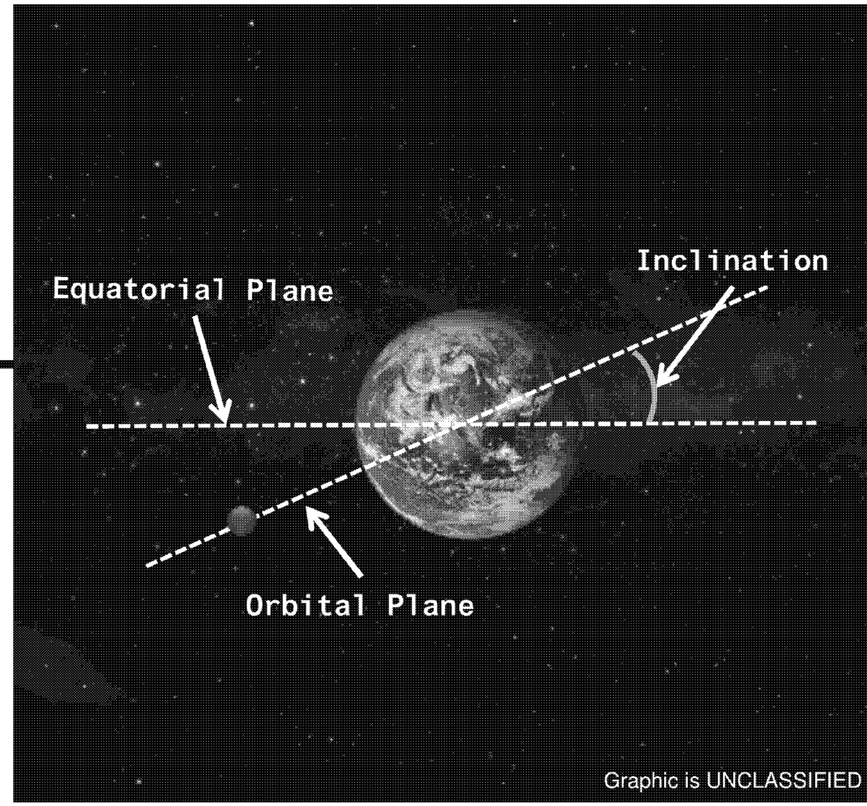
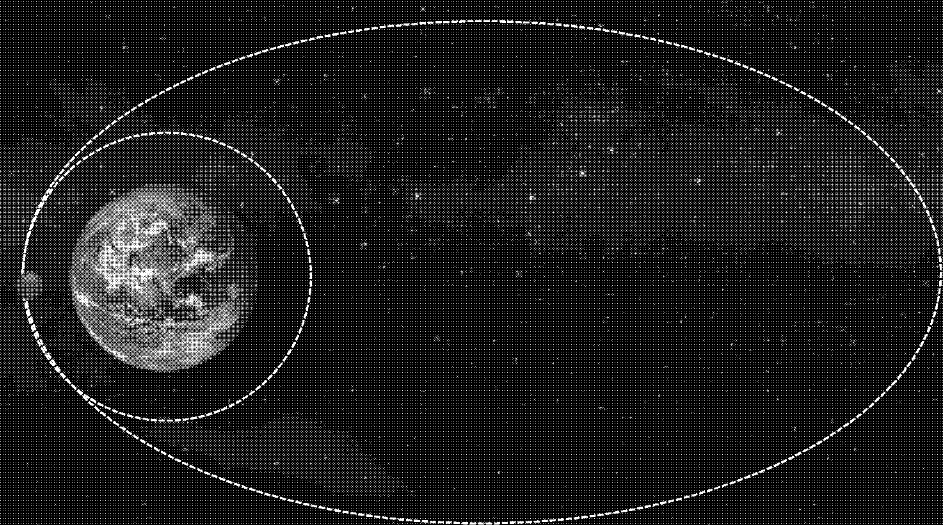
(U) Azimuth and Inclination

- (U) Inclination is the angle of the orbital plane relative to the equatorial plane.
- (U) Inclination is also the angle between the ground trace and the equator as the satellite crosses the equator.
- (U) The term inclination is usually applied to objects in orbit, while the term azimuth is usually applied to objects at launch.



(U) Orbits Follow a Predictable Path

(U) All orbits follow an ellipse, which may be circular, but not necessarily so.



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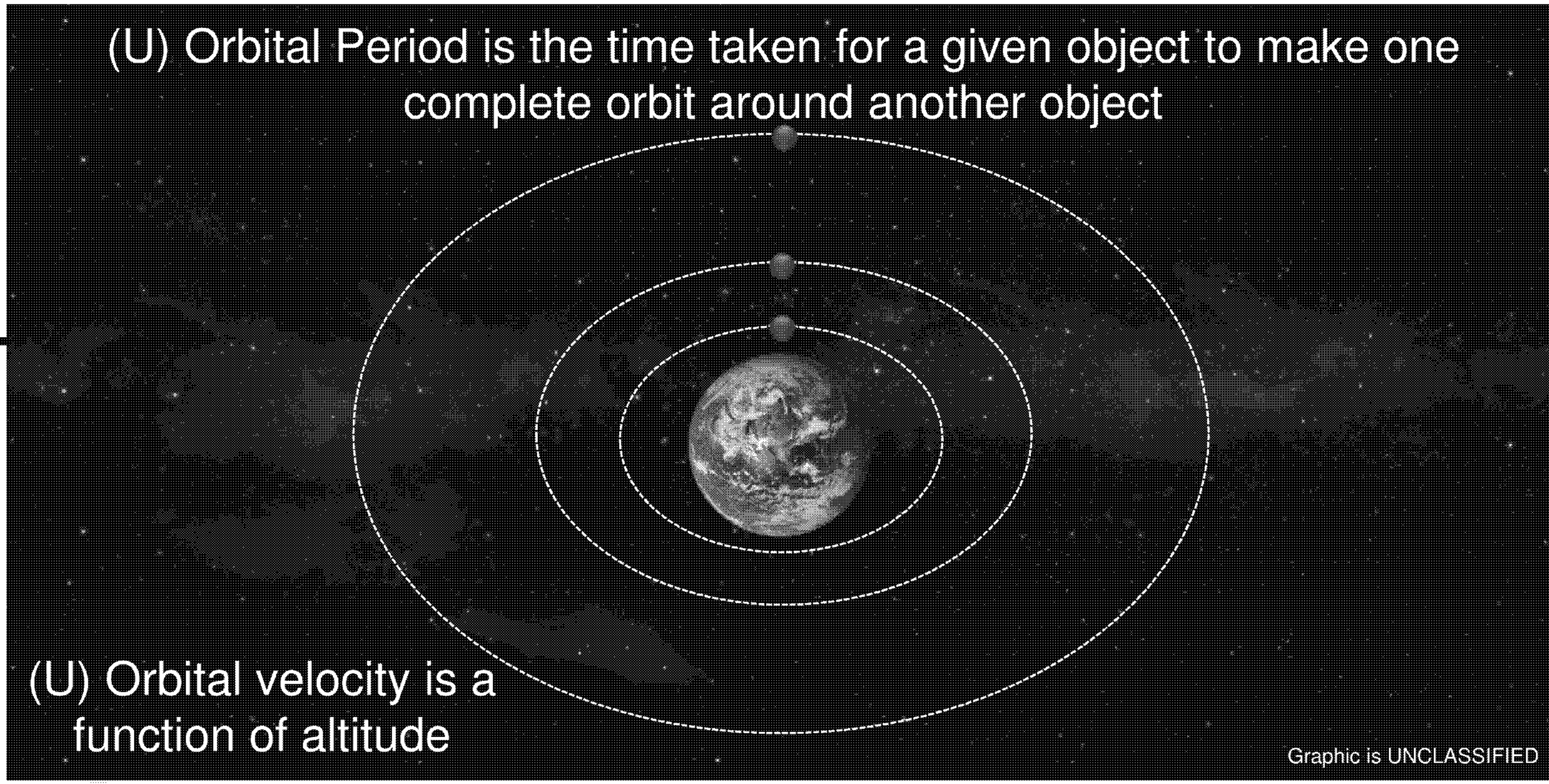
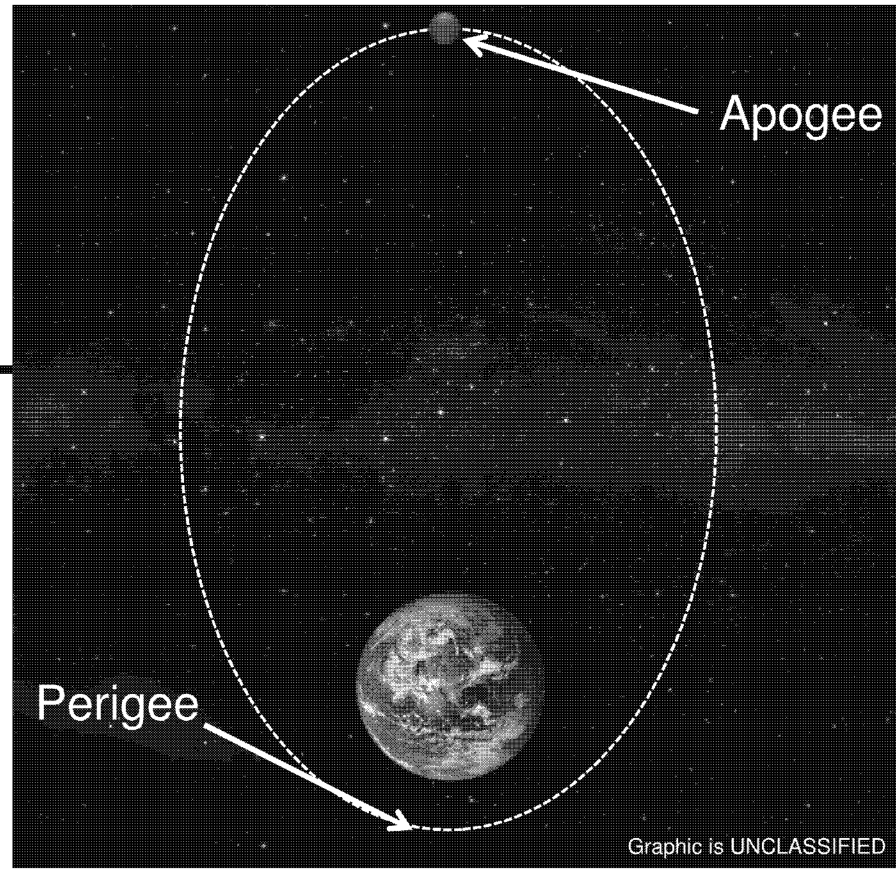
(U) Orbital Period/Velocity



(U) Apogee and Perigee

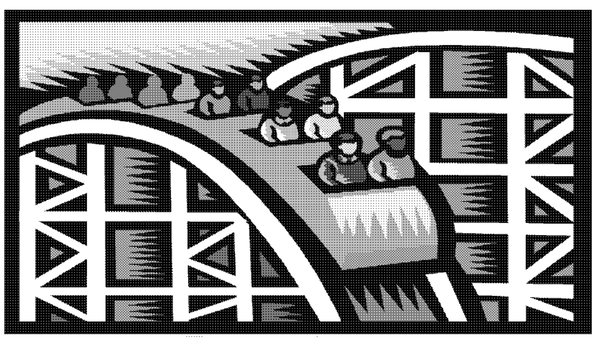
- (U) Apogee = Point in Orbit Highest in Altitude
- (U) Perigee = Point in Orbit Lowest in Altitude

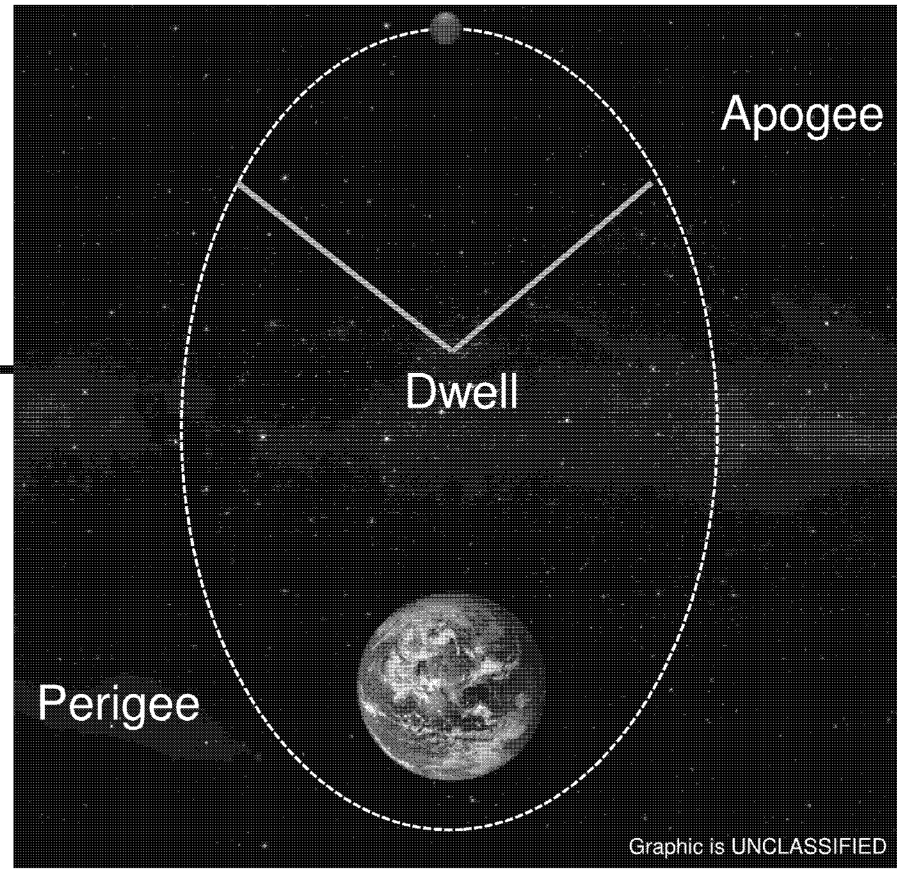


(U) Eccentricity And Dwell Time

Orbital Eccentricity is a parameter that determines the amount by which an orbit around another body deviates from a perfect circle

- Circular Orbit – e=0
- Elliptical Orbit – 0<e<1





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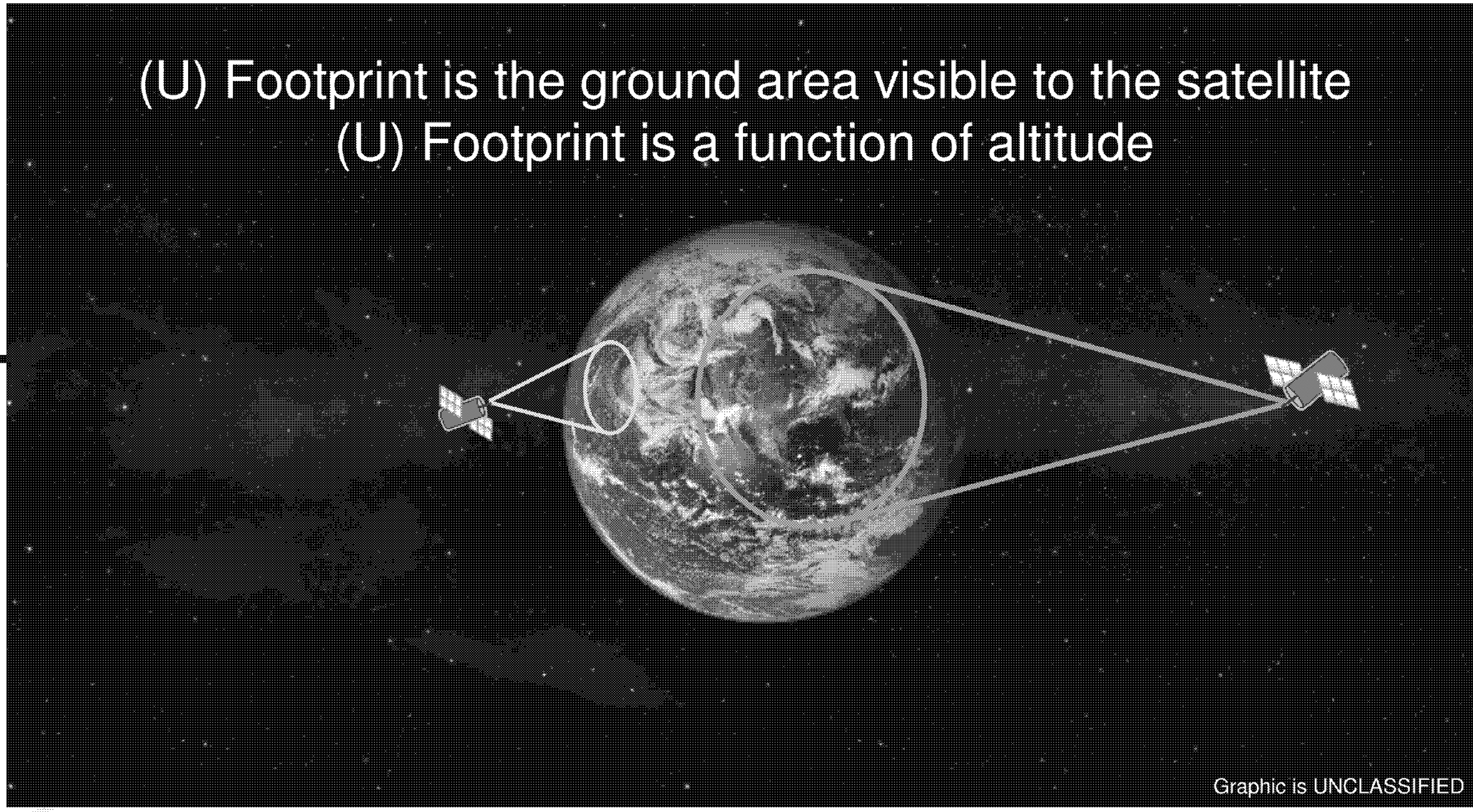
(U) Footprint


(U) Footprint is the ground area visible to the satellite
(U) Footprint is a function of altitude
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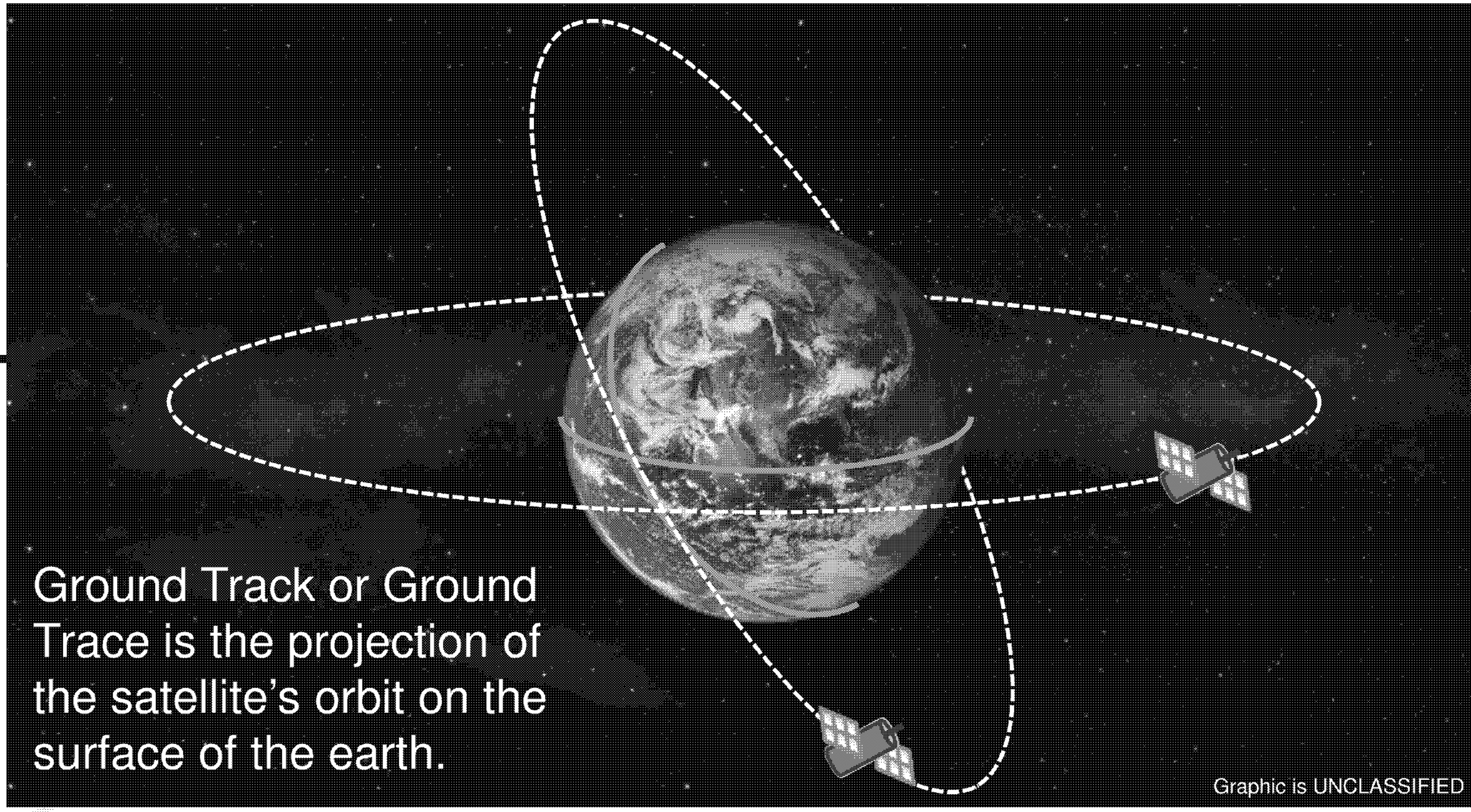
(U) Ground Track



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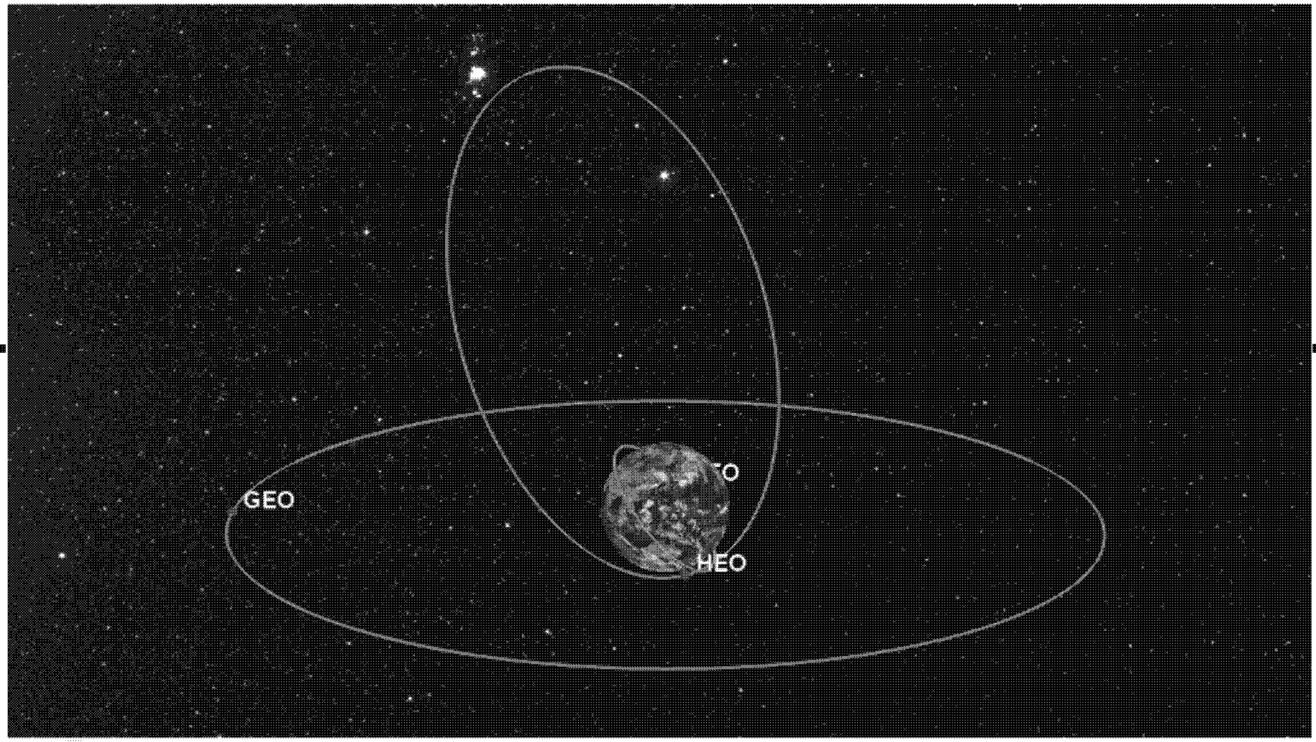
(U) Orbits



HEO_GEO_LEO.wmv

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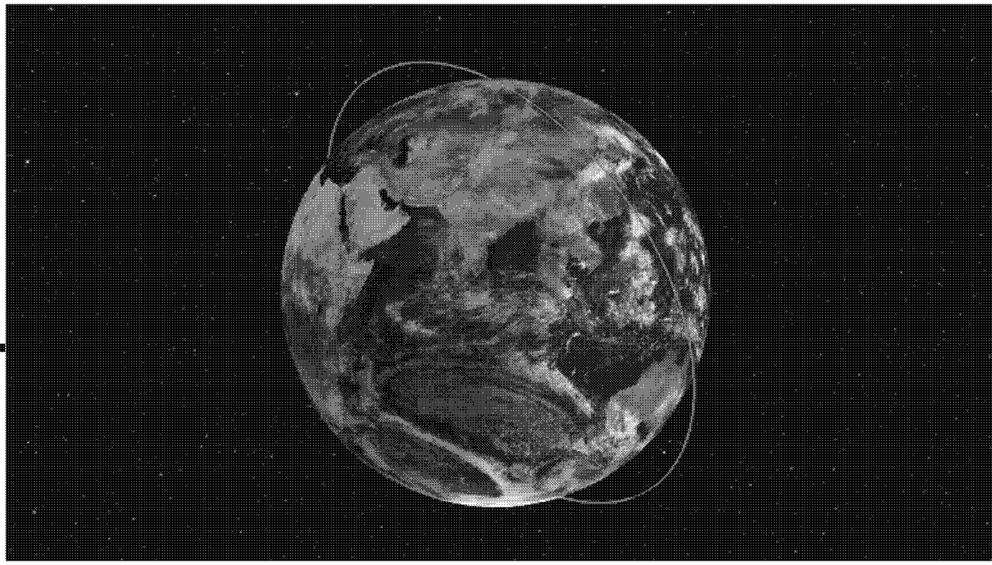
(U) LEO



LEO.wmv

Video is UNCLASSIFIED

- (U) Altitude: 150-600 miles
- (U) Velocity: 17,000 mph
- (U) Orbital Period: 90 minutes
- (U) Inclination: Varies
- (U) Launch Site: [redacted] depending on inclination (b)(3)
- (U) Types: Polar, Sun-Synchronous
- (U) NRO uses: [redacted] (b)(1) (b)(3)

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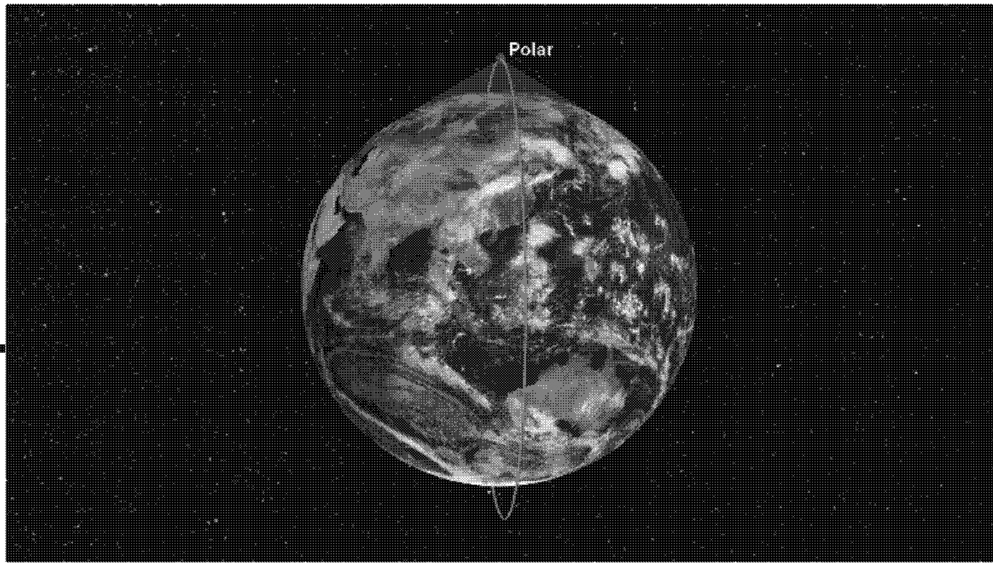
(U) LEO



Polar.wmv Video is UNCLASSIFIED

(U) POLAR ORBIT:

(U) Inclination: 90˚

(U) Typical Use: Magnetic field study, [redacted] (b)(3)

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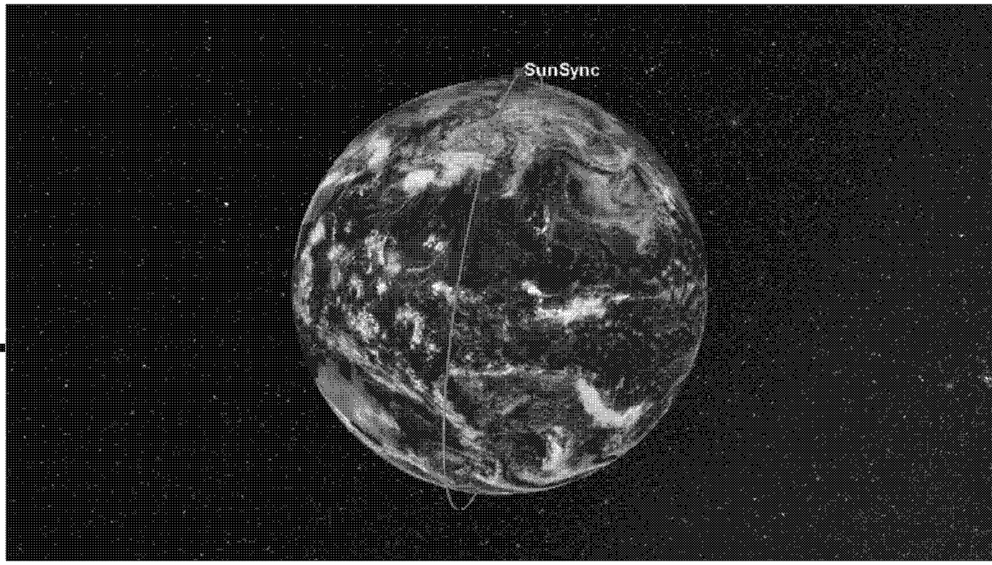
(U) LEO



SunSync.wmv

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(U) SUN SYNCHRONOUS ORBIT:

(U) Inclination: Approximately 98˚ but depends on altitude

(U) Typical Use: [redacted]

(b)(1)
(b)(3)

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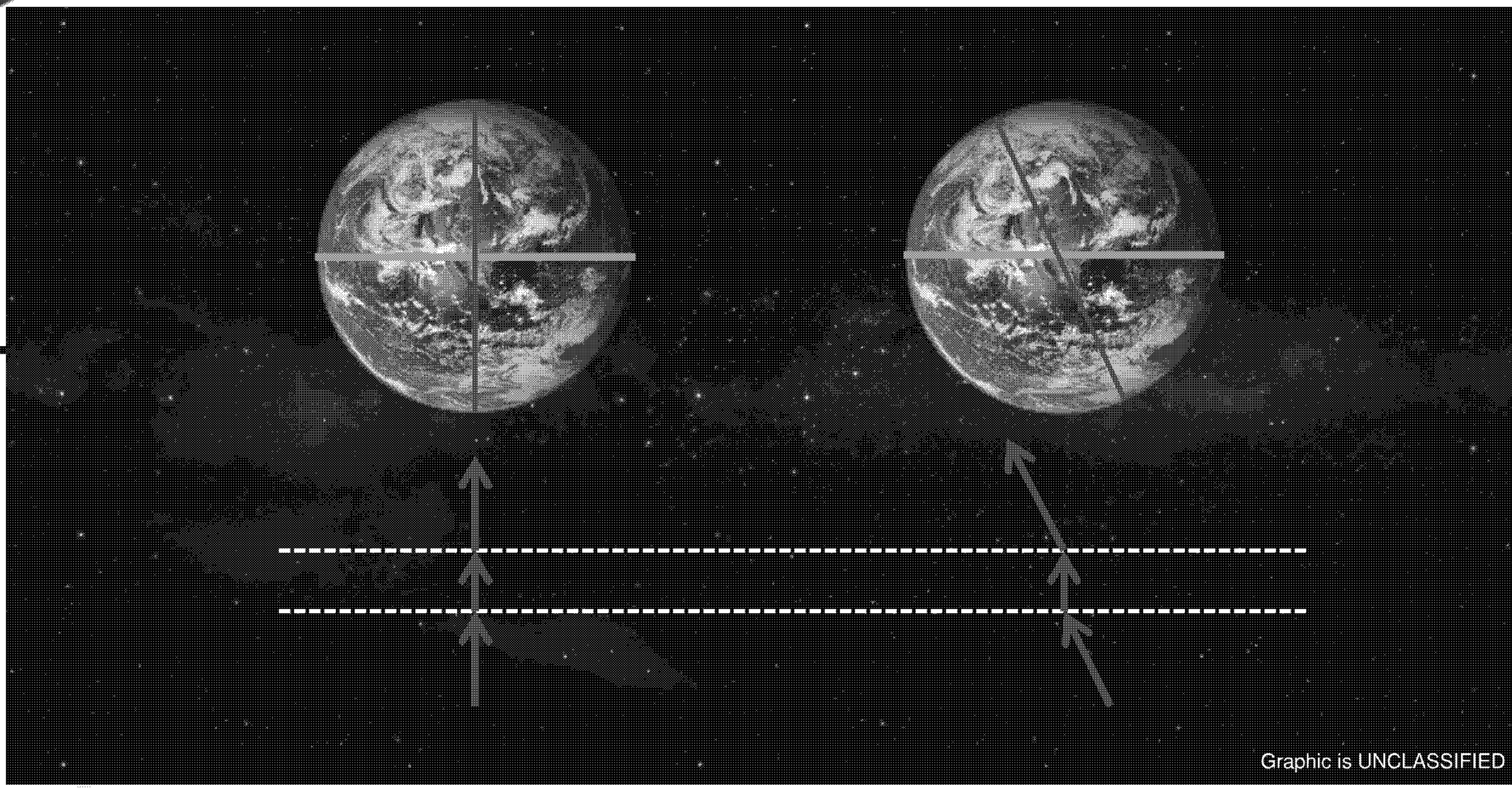
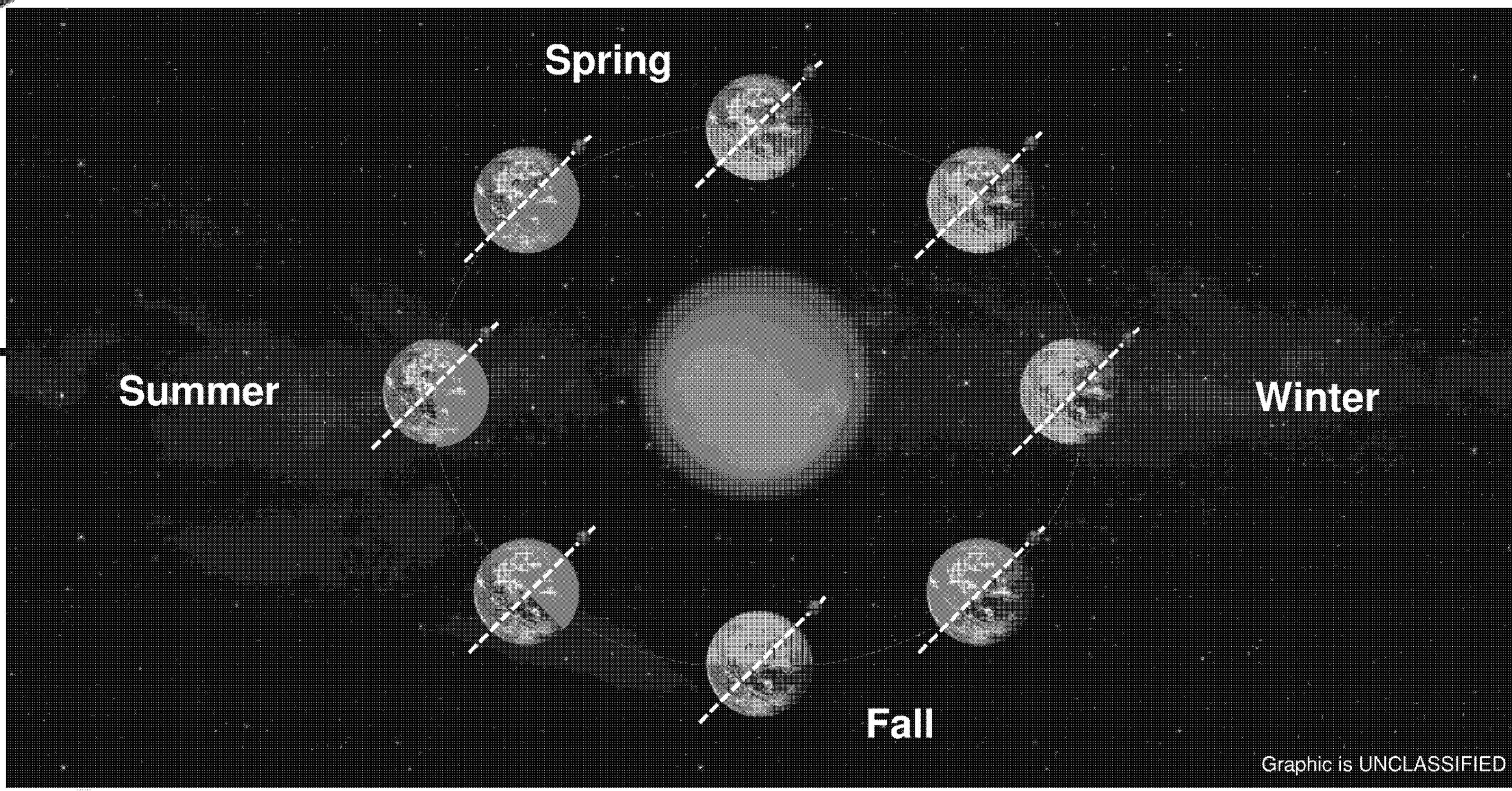
(U) Sun-Synchronous Orbit



(U) Polar Orbit



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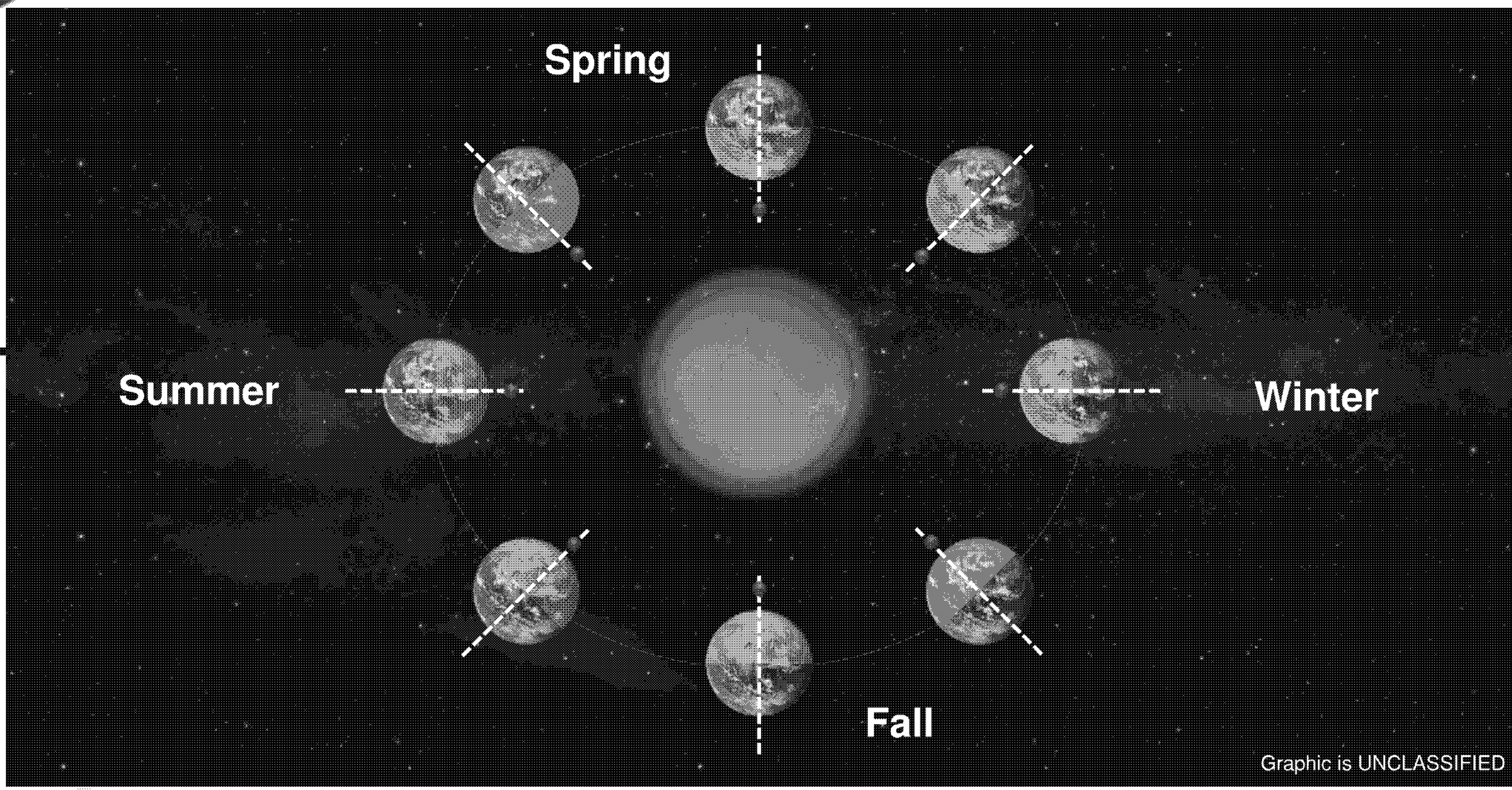
(U) Sun-Synchronous Orbit



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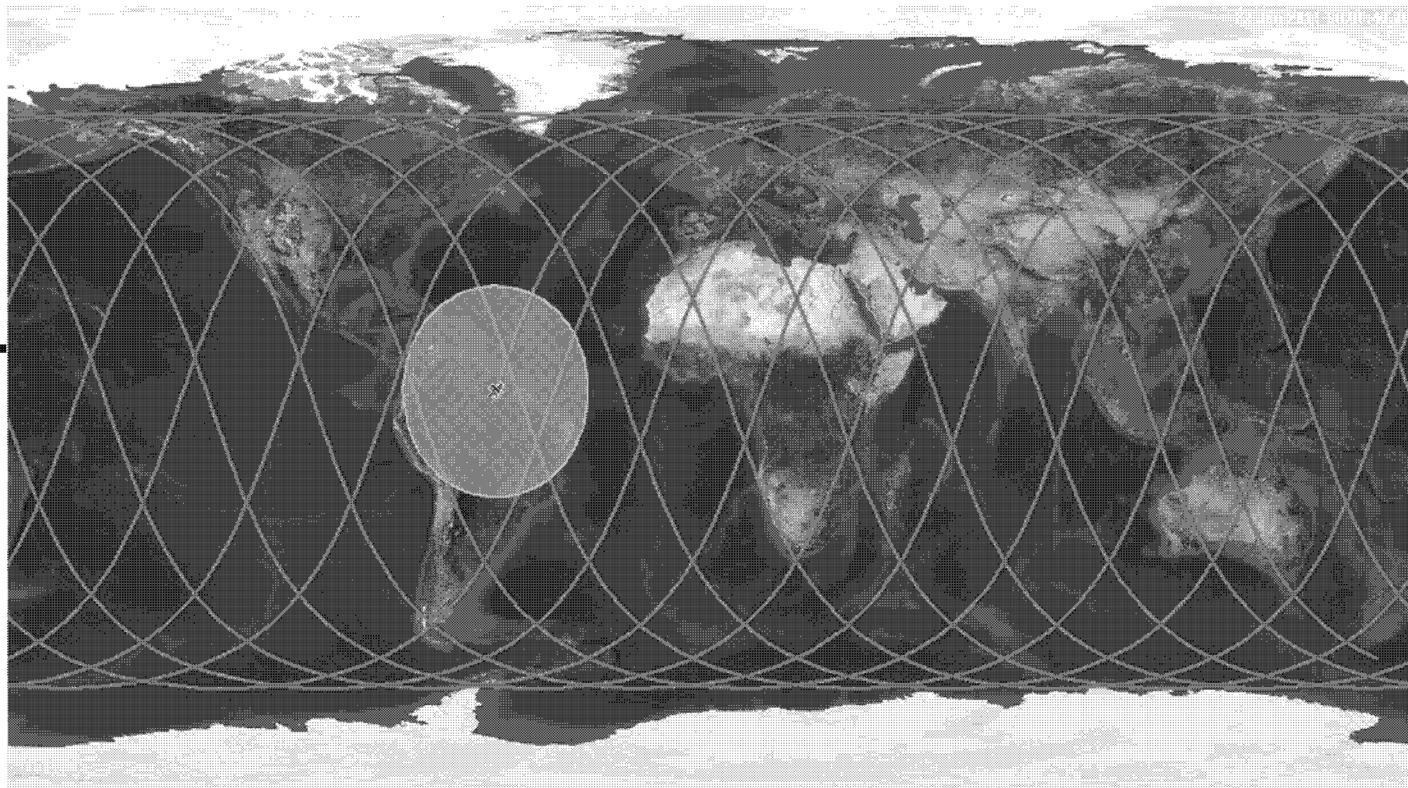
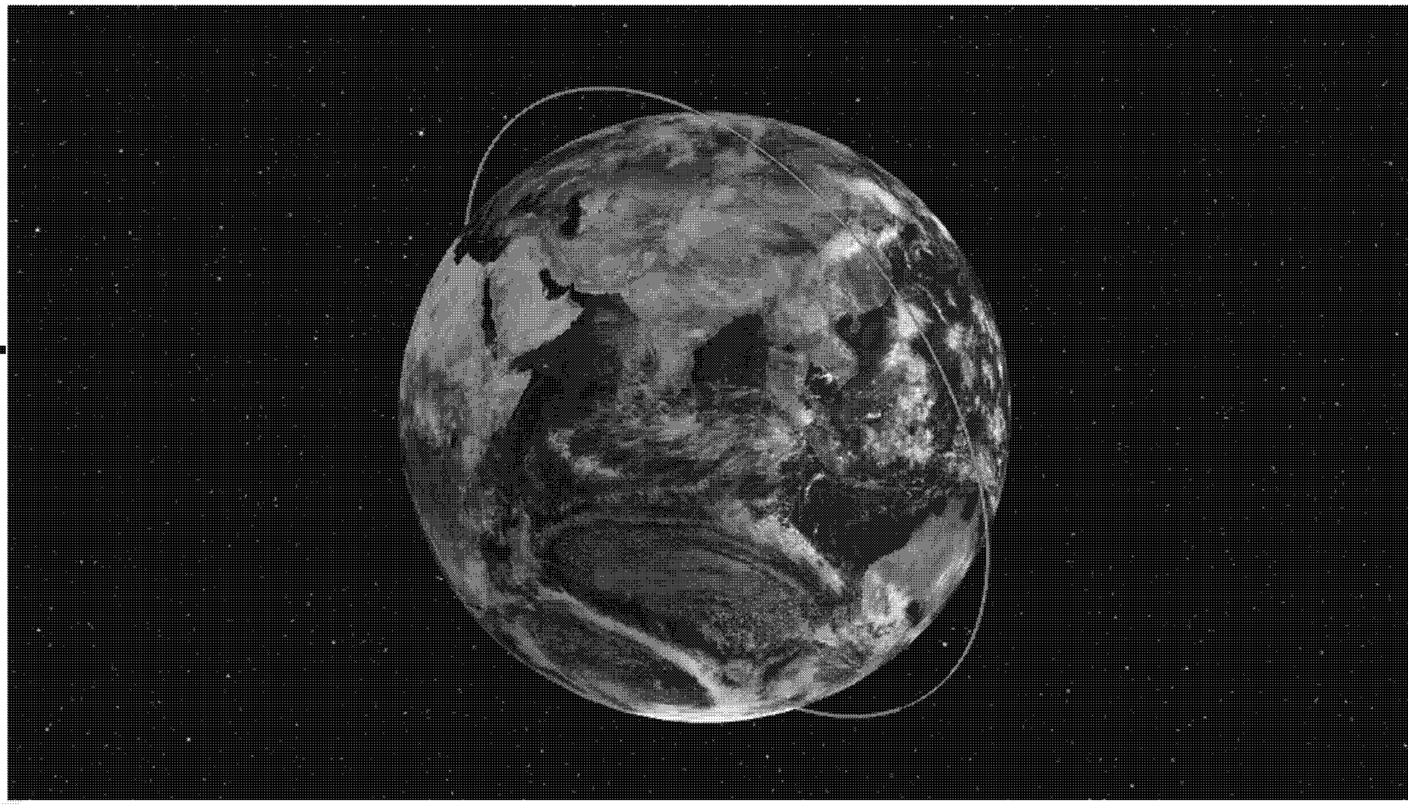
(U) LEO – Ground Trace



LEO_Trace.wmv Graphic is UNCLASSIFIED

(U) LEO Capabilities



LEO_Footprint.wmv Graphic is UNCLASSIFIED

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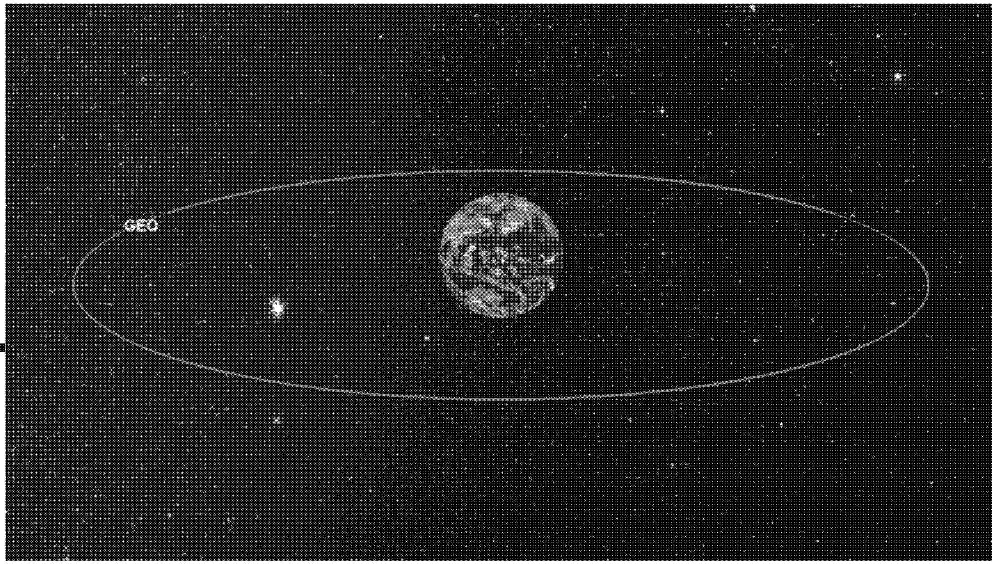
(U) GEO



GEO.wmv

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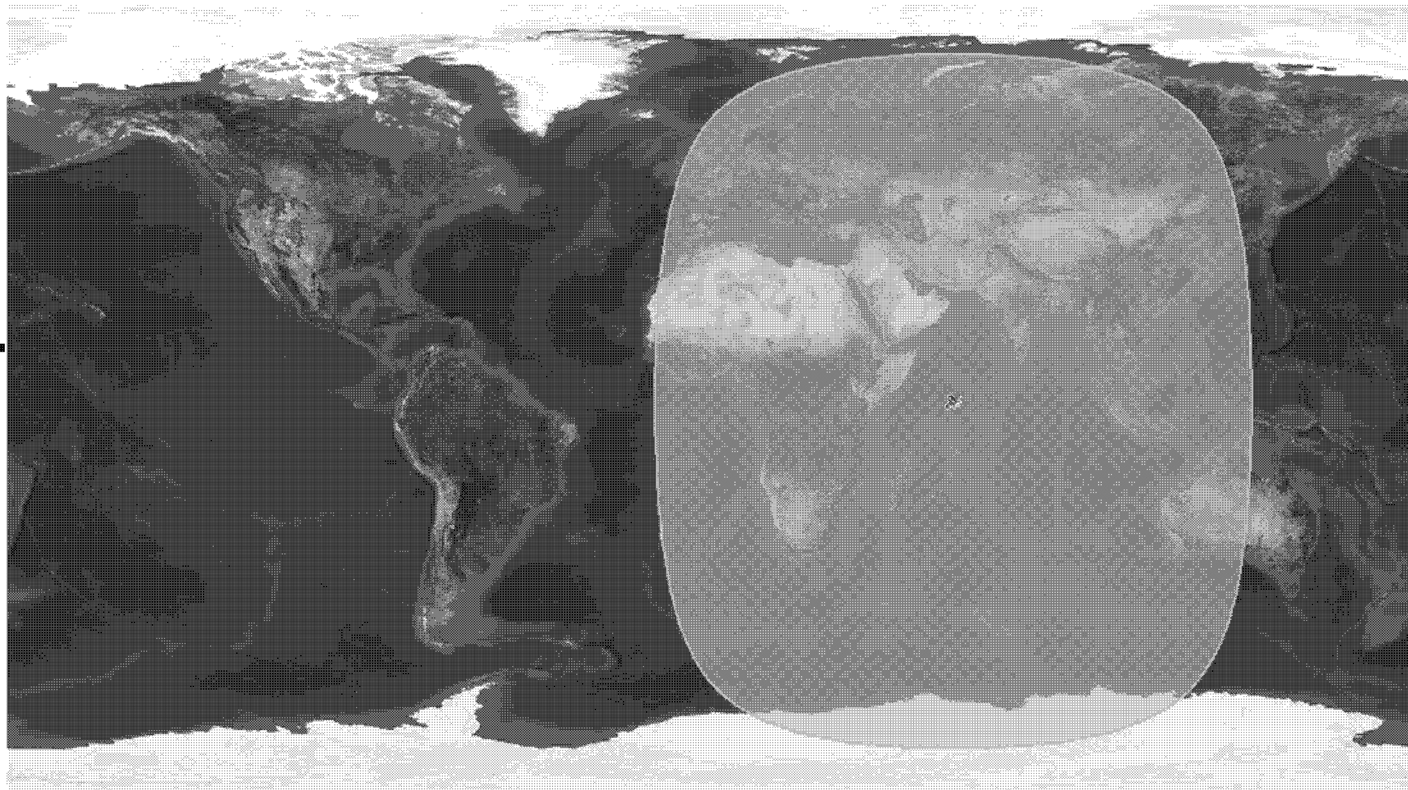
- (U) Altitude: 22,236 mi
- (U) Velocity: 6,875 mph
- (U) Orbital Period: 24 hours
- (U) Inclination: 0~3˚
- (U) Launch Site: [redacted] (b)(3)
- (U//FOUO) NRO uses:

[redacted] (b)(1) (b)(3)

(U) GEO – Ground Trace



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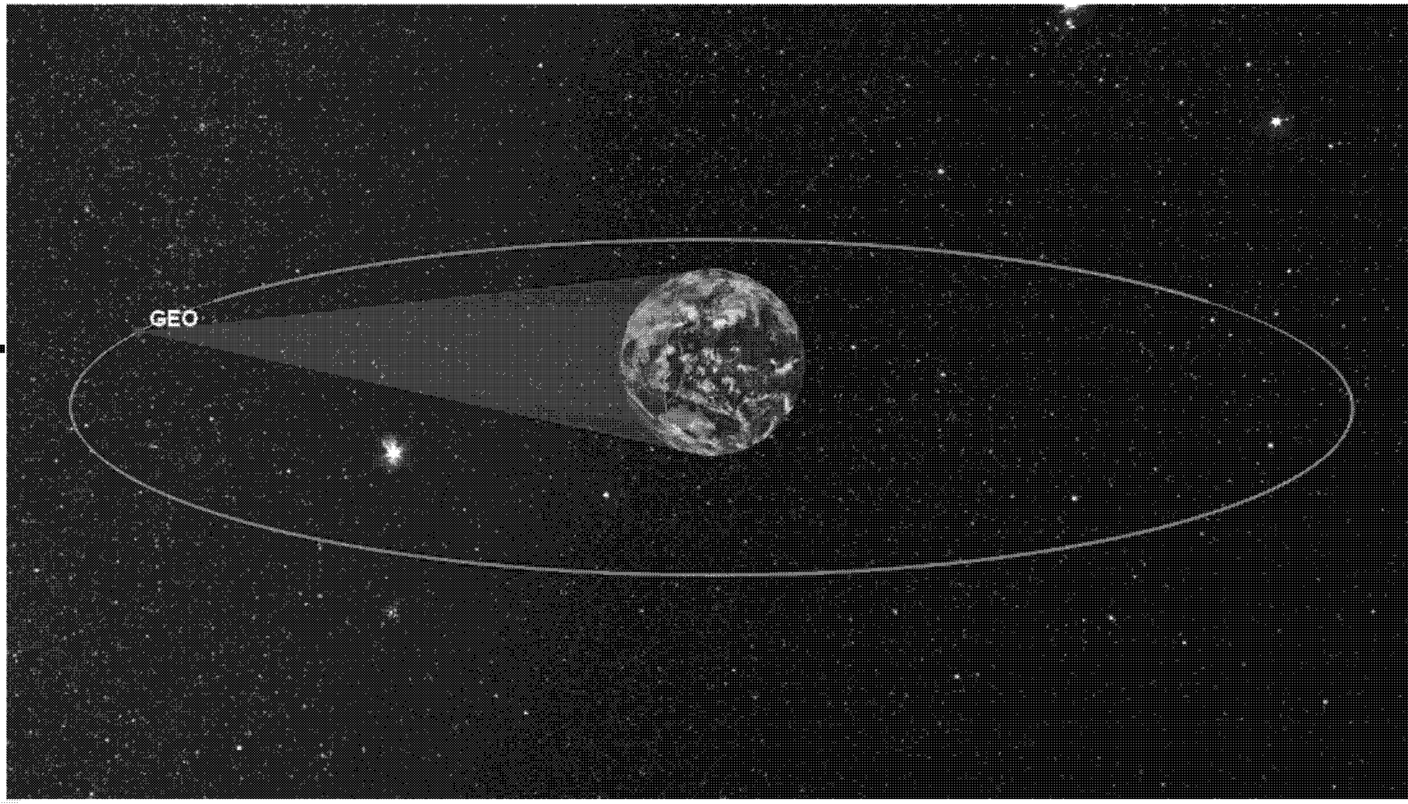
(U) GEO Capabilities



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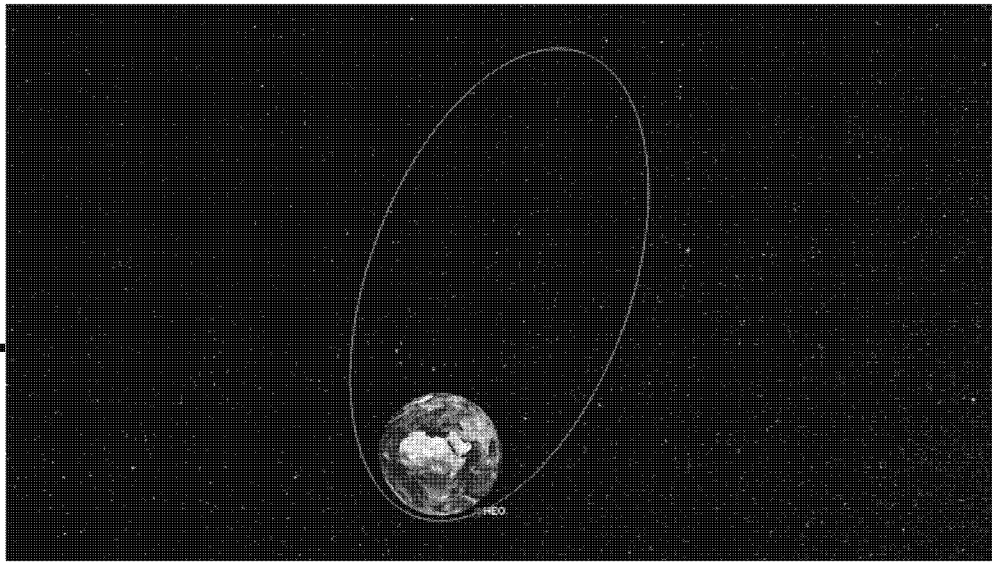
(U) HEO



HEO.wmv

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- (U) Altitude: 200-24,000 miles
- (U) Velocity: Varies
- (U) Orbital Period: 12 hours
- (U) Inclination: Usually 63.4°
- (U) Launch sites: [redacted] (b)(3)
- (U//~~FOUO~~) NRO Uses:

[redacted] (b)(1) (b)(3)

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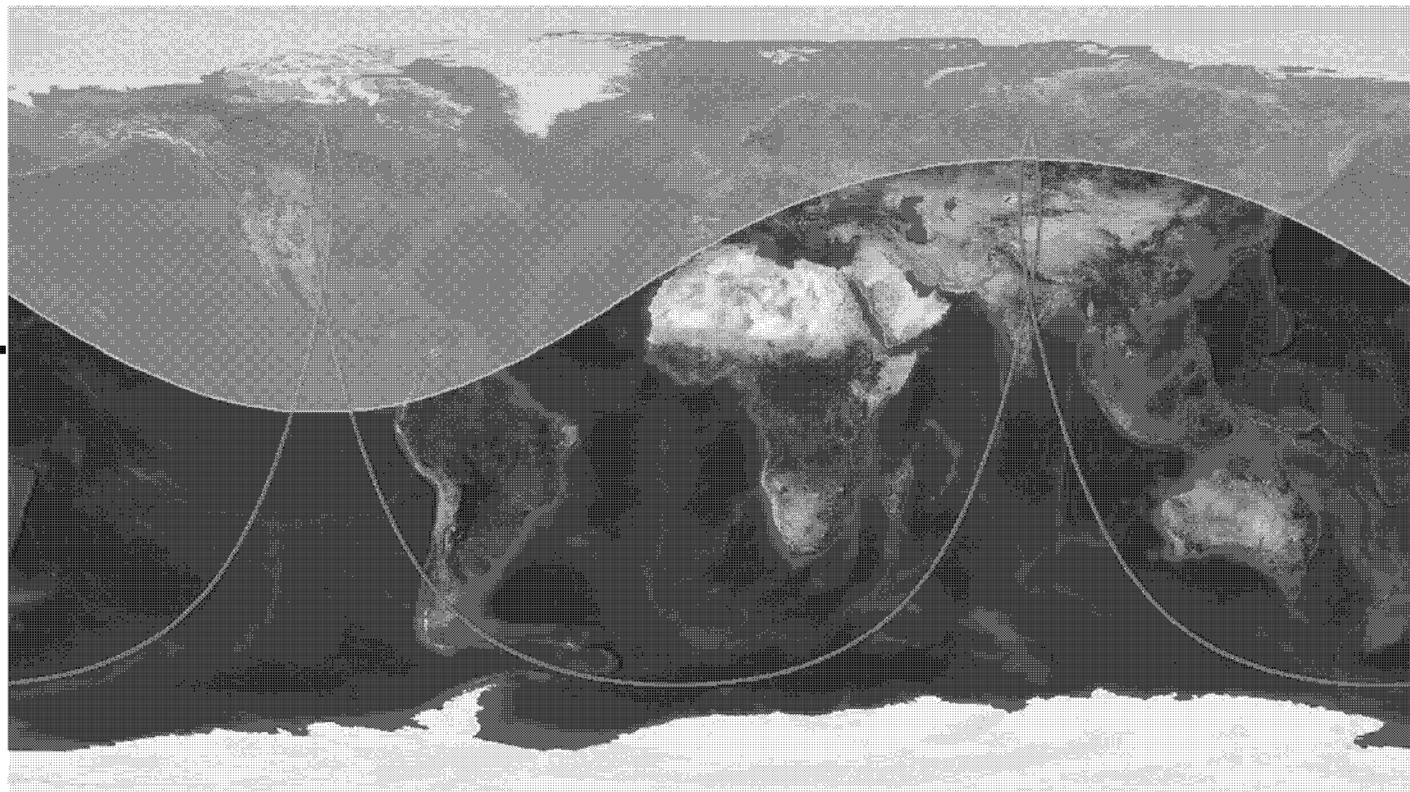
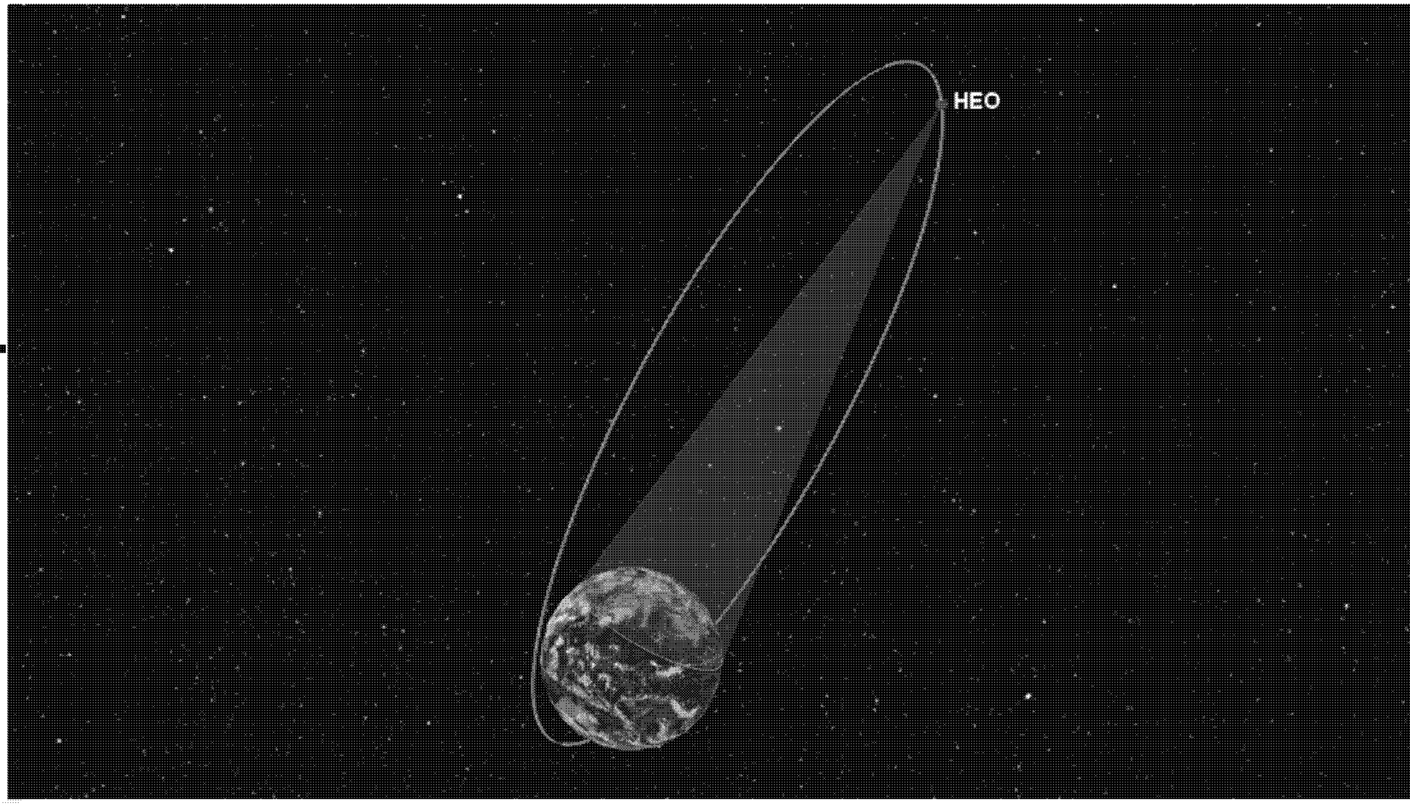
(U) HEO – Ground Trace



GEO_Trace.wmv Graphic is UNCLASSIFIED

(U) HEO Capabilities



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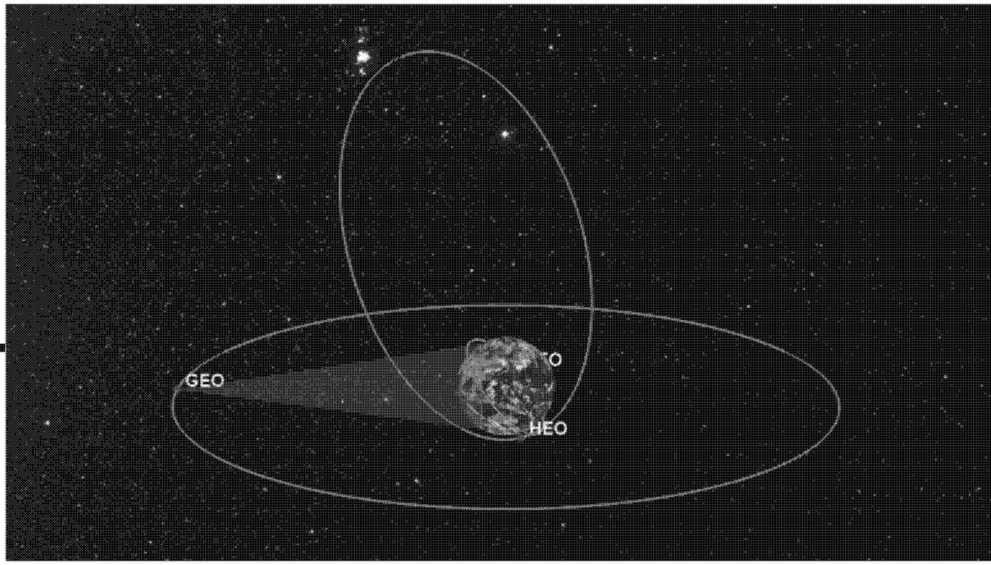
(U) Orbit Capabilities



HEO_GEO_LEO_Footprint.wmv Video is UNCLASSIFIED

(U) LEO: [redacted]

(U//~~FOUO~~) GEO: [redacted]

(U//~~FOUO~~) HEO: [redacted]

(b)(1)
(b)(3)

(U) The Satellite in Orbit

(U) Characteristics	(U) LEO	(U) GEO	(U) HEO
(U) Altitude (mile)	(U) 90-600	(U) 22,236	(U) 300 - 24,000
(U) Inclination	(U) varies	(U) 0~3˚	(U) 63.4˚
(U) Orbital Period	(U) 90 minutes	(U) 24 hours	(U) 12 hours
(U) Launch Site	[redacted]		
(U) Uses			

(b)(3)

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(U) NRO Constellation

(b)(1)
(b)(3)

NRO_Constellation.wmv Graphic is SECRET//TK//REL

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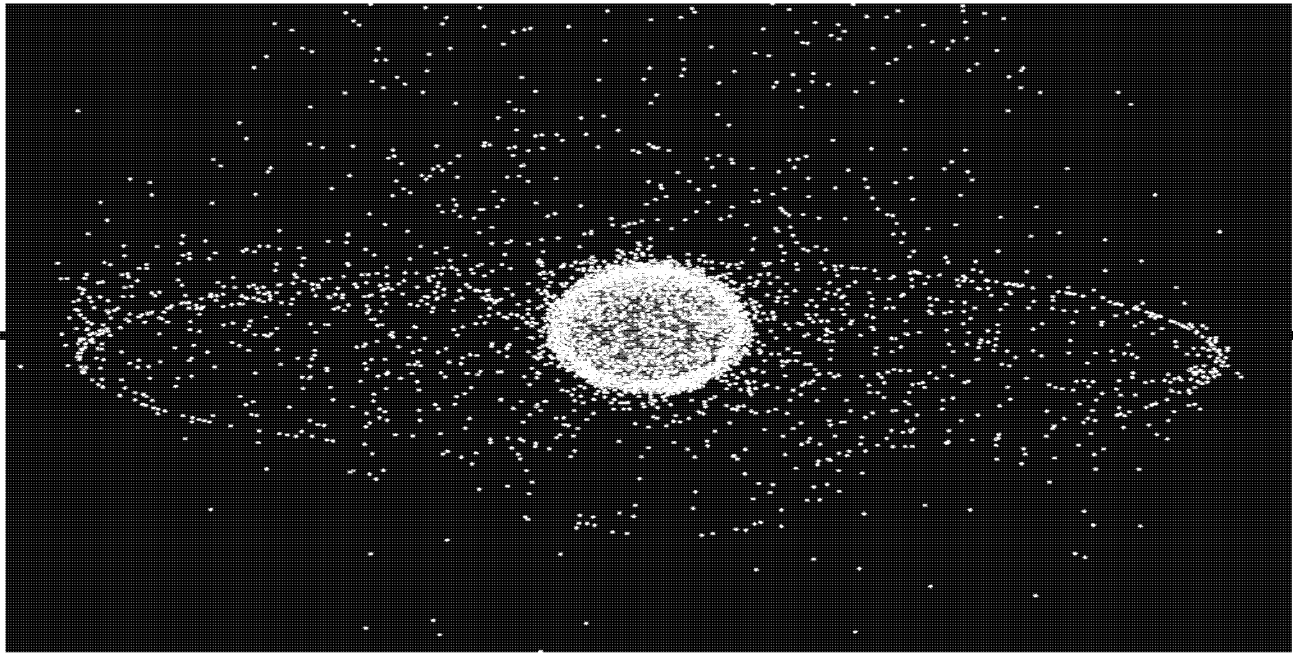
(U) The Neighborhood



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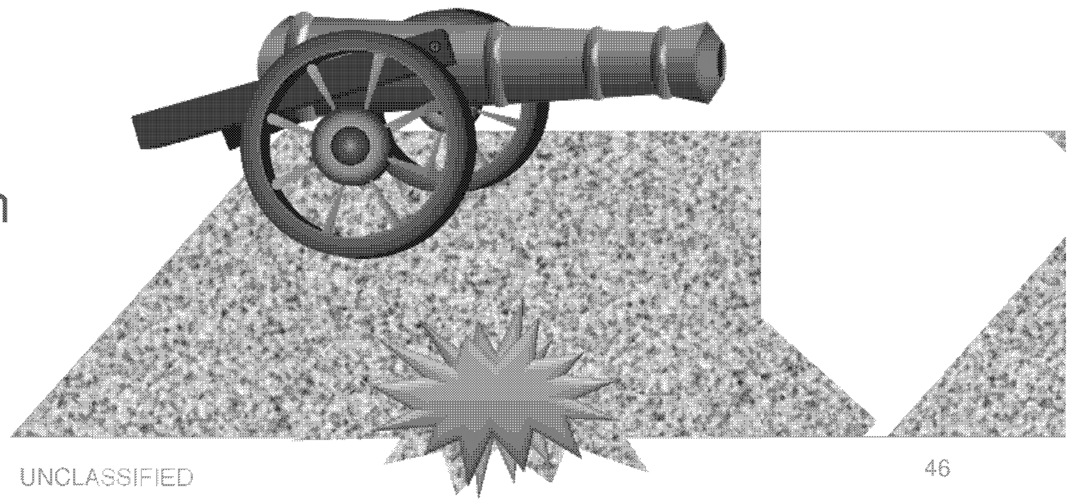
(U) Rocket Theory

(U) Remember Newton's Third Law of Motion…

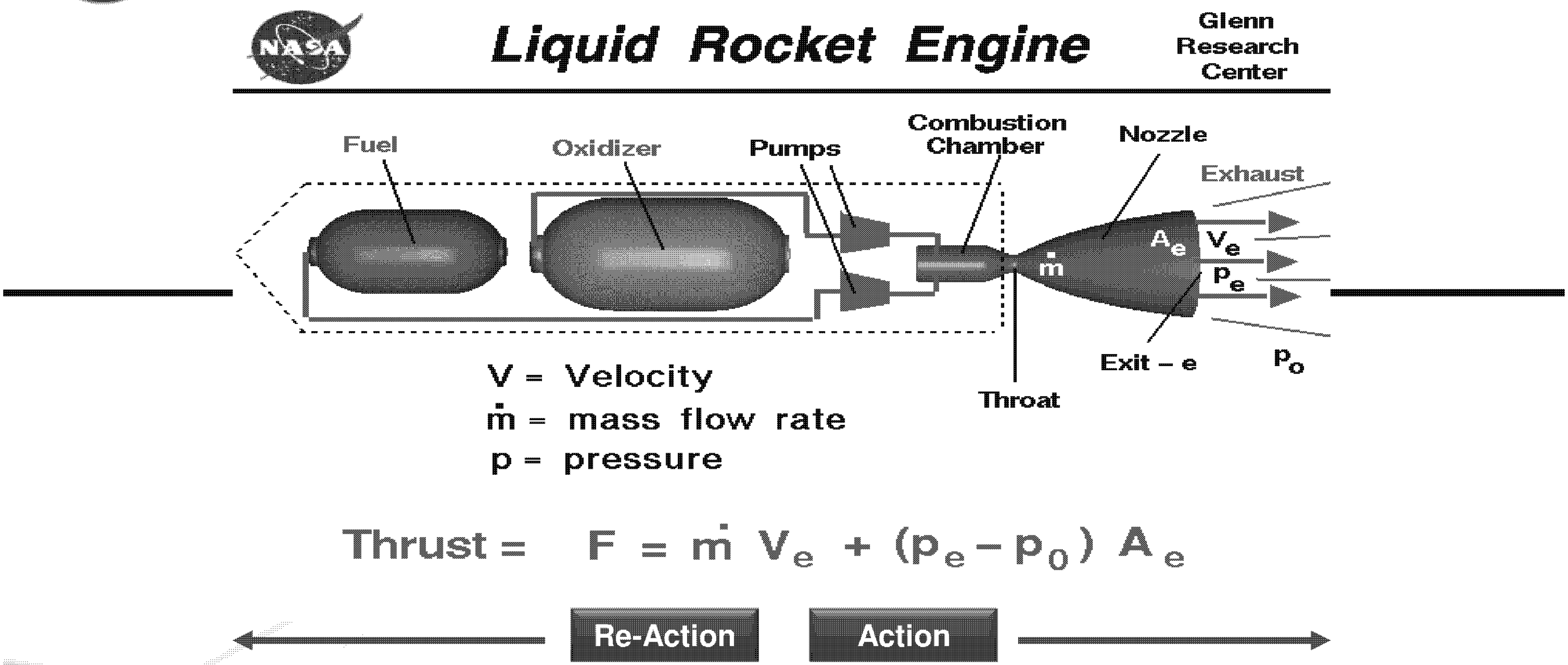
(U) A force exerted by object x to object y results in an equal force exerted by y to x

OR…

(U) For every action, there is an equal and opposite reaction



(U) Rocket Engine



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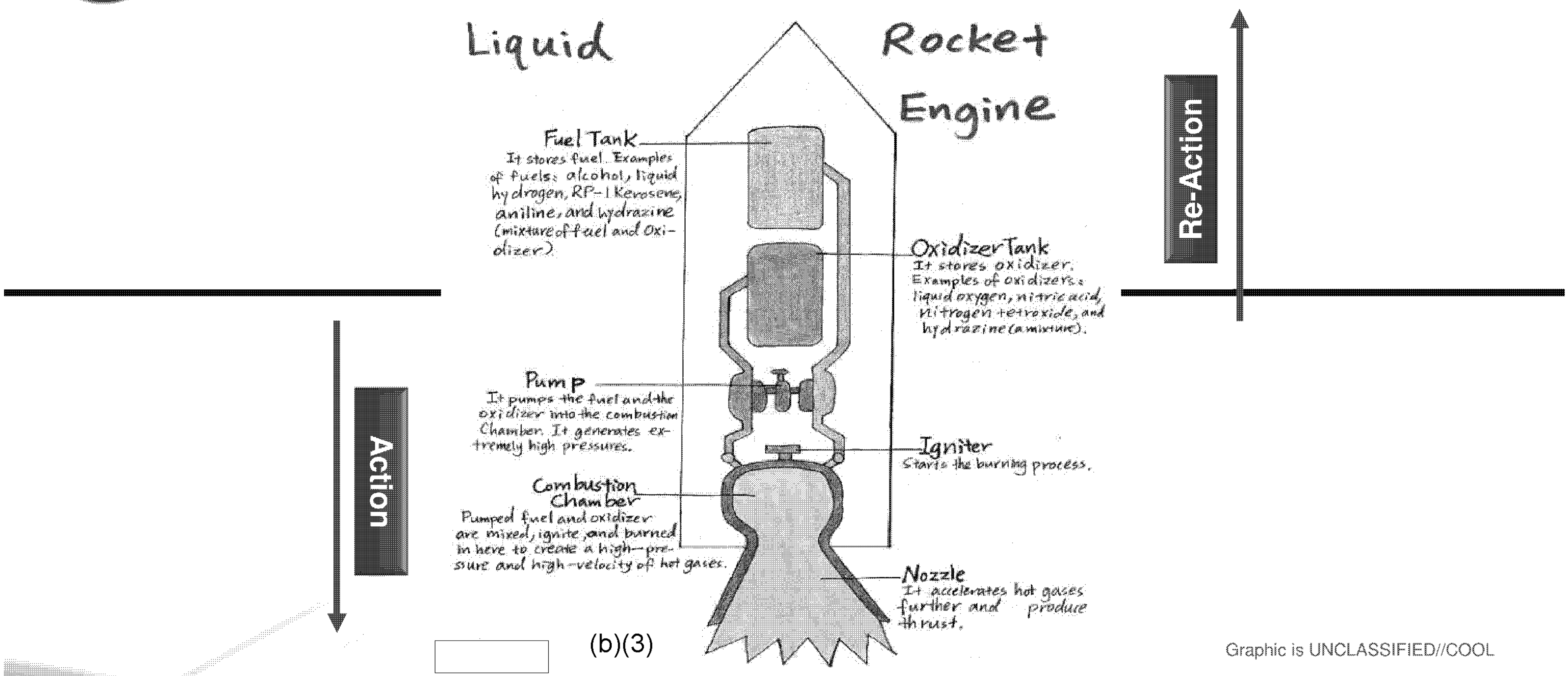
(U) Rocket Engine



(b)(3)

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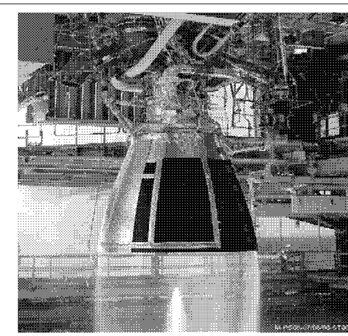
(U) Liquid Fuels Rockets

- (U) Types of Liquid-Fueled Rockets

[redacted] (b)(3)

- (U) Advantages of Liquid Fuel
  - Higher specific impulse than solids
  - Capable of being throttled, shut down, and restarted
- (U) Disadvantages of Liquid Fuel
  - Fuels are difficult to handle and toxic
  - Stresses on pumps, seals, valves, etc. make them more expensive



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(U) Solid-Fueled Rockets

- (U) Solid rocket fuel is an Ammonium Perchlorate Composite Propellant

[redacted] (b)(3)

- (U) Advantages of Solid Fuel
  - Easy to store and handle
  - Simplicity of operation and low cost
- (U) Disadvantages of Solid Fuel
  - Lower specific impulse than liquid
  - Cannot be throttled in real time

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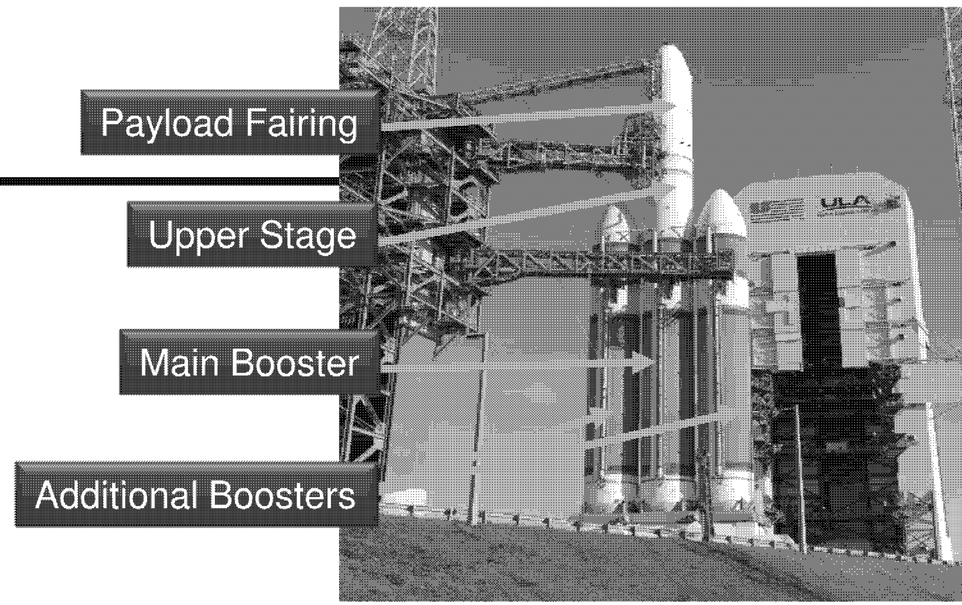
(U) Staging

(U) Staging is the process of discarding a portion of the launch vehicle in order to lighten the weight

- (U) **Serial Staging** – smaller upper stage on top of the main booster
- (U) **Parallel Staging** – several small first stages are strapped onto a central sustainer rocket
- (U) Most launch vehicles use a combination of serial and parallel staging



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(U) The Launch

(b)(1)
(b)(3)

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(U) Launch Site Factors

(U) Earth Rotation – Slingshot East

[redacted] (b)(3)

(U) Inclination

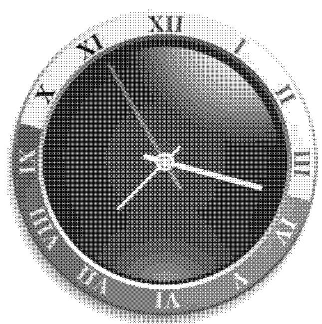
- Based on launch azimuth and trajectory
- Orbital inclinations of 0-65 degrees launch from [redacted] (b)(3)
- Orbital inclinations of 55-180 degrees launch from [redacted]
- Orbital inclination of 55-65 degrees can launch from [redacted]
- Primary consideration is safety

(U) Collision Avoidance (COLA)

- Creates periods during launch window when the launch cannot occur

(U) Rocket Science 101

(U) Time to check your knowledge on rocket science.



Time: 10 minutes

(U) Knowledge Check

1. The __***apogee***___ is the point in the orbit that is highest in altitude.

2. __***Orbit***___ describes the natural path of an object in mutual gravitational attraction to another object, usually with an extended or repetitive path.

3. [redacted]

(b)(3)
(b)(1)

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(U) Knowledge Check

4. In which orbit do altitude and velocity widely change? ___***HEO***___ .

5. ___***Inclination***___ is the angle of the orbital plane in relation to the equatorial plane.

6. Satellites in ___***geosynchronous***___ orbit appear to hover over the same location on the earth.

(U) Knowledge Check

7. The point in the orbit at which the satellite is lowest in altitude is called ___***perigee***___.
8. Apogee equals perigee in ___***circular***___ orbits.
9. ___***Ellipse***___ describes all orbital shapes.
10. The ___***Earth's***___ ___***rotation***___ provides slingshot effect for eastward launches.

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(U) Knowledge Check

11. The path of an object through space, usually with identifiable beginning and end points, which may or may not be affected by external forces, is called ***trajectory***.

12. Of the three most commonly-used liquid rocket fuels, the most hazardous spill would be caused by ***hydrazine***.

(U) Knowledge Check

13. ***Dwell time*** is the long slow time that a satellite spends approaching and passing apogee.

14. ***Gravitational attraction*** and ***velocity*** are required for an object to achieve orbit.

15. ___[redacted]___ is commonly used when launching polar satellites, but ___[redacted]___ is used when launching GEO satellites. (b)(3) (b)(3)

(U) Knowledge Check

Very Good!

You get an….

A + + + + + +

(U) Summary

- (U) Space is the ultimate high ground
- (U) Factors such as inclination, trajectory, orbit, and rocket configuration can not only affect a launch, but be indicators of the mission
- (U) LEO, GEO and HEO offer advantages that are maximized to provide the best possible intelligence data
- (U) Security professionals should consider orbits and launch site factors when constructing their security plan

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