Contents

1 Space Systems

1.1 Oberg

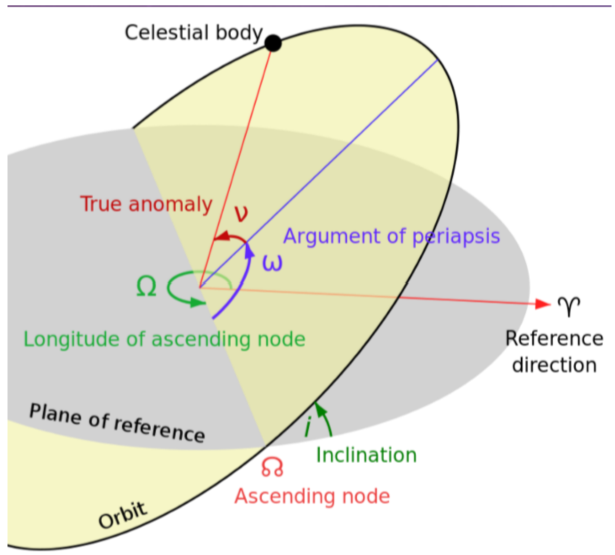
Notes that space is

1. Really Big - isolation, time delay
2. Nearby - only 100km away
3. Provides a vantage point for intelligence and communications
4. Mostly Empty - no limit on speed, but nothing to absorb radiation
5. Full of energy - uninterrupted sunlight, UV rays

There is a lack of a coherent Space Power Threory, hindered by bureaucracy, Cold War, etc.

1.2 Weapons in Space

1. Most effects from space weapons could be attained through conventional weapons
2. Getting kinetic weapons to space is costly
3. Directed-Energy Weapons are currently impractical
4. US might be comdemned for militarization
5. Invites political rivals to target US space assets

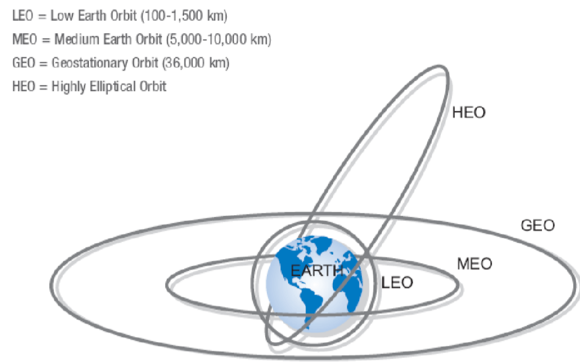


1.3 Orbital Elements

- Eccentricity(e): shape of the ellipse, describing how much it is elongated compared to a circle
- Semimajor Axis (a): the sum of the periapsis and apoapsis distances divided by 2
- Inclination(i): the angle between the satellite's orbital plane and the reference plane—i.e., the earth's equatorial plane
- Longitude of the ascending node(Ω): horizontally orients the ascending node of the ellipse (where the orbit passes upward through the reference plane, symbolized by ascending node) wrt the reference frame's vernal point
- Argument of periapsis (ω): an angle measured from the ascending node to the periapsis
- True anomaly (ν,θ, or f): the position of the satellite at a specific time

1.4 Orbits

In elliptical orbits, velocity is slowest at Apogee, fastest at Perigee



1.5 Satellite Structure

- Bus
  - Structure
  - Thermal Control
  - Electrical Power
  - Attitude Control
  - Telemetry
- Mission Payload

1.6 Fuels

Liquids are more vesatile than solids, can be turned on/off. Solids common in strap-on boosters.

- Liquid Oxygen (LOX) – Saturn V, Atlas V, Falcon 1, Falcon 9
- LOX & Liquid Hydrogen – Saturn V, Atlas V, Delta IV
- Nitrogen Tetroxide & Hydrazine – deep space rockets
- APCP – solid fuel for boosters/ballistic missiles

Monopropellants such as hydrogen peroxide, hydrazine, and nitrous oxide are used in spacecraft maneuver and station-keeping

1.7 Satellite Maintenance

Mission control center (typically, NASA) operates the system until the satellite is in stable orbit then hands control over to the Air Force Satellite Control Network (AFSCN) several hours after launch AFSCN maneuvers satellite to its operational position, jettisons tank and shroud, activates systems (extends solar panels, sensors, and antennas, etc.), achieves attitude, and does full system checkout (weeks to months)

Orbit	Height	Period
LEO	100-1500 km (60-1000 mi)	90 min
MEO	1600-20100 km (1000-12500 mi)	12 Hrs
GEO	36000 km (22300 mi)	24 hrs
HEO	500-40000 km (300 - 25000 mi)	varies

Special Orbits:

- Polar Sun Synchronous: circular LEO (98°)
- Polar Non-Sun-Synchronous: LEO (80-94°)
- Geostationary: circular GEO (0°)
- Molniya: HEO, 12 hour period, (63.4°)

1.8 Launch Sites

Cape Canaveral used for prograde orbits VAFB used for polar orbits (launched South) Latitude determines inclination – close to the equator is easier for GEO Inclination will be at least as high as launch latitude

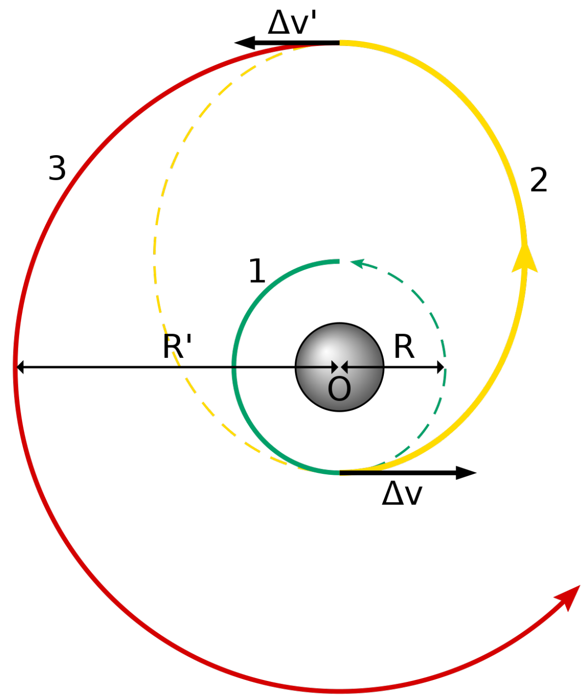
1.9 Station Keeping

Earth's oblongation, atmospheric drag, third body effects, solar wind, electromagnetic drag

1.10 Sun-Synchronous Orbit

Mean rate of precession of 360° will be synchoronized with the earth's orbit Benefits:

- Satellite is always in sunlight
- Orbit near day-night terminator(shadows)
- Passes over the same places at the same times every day



1.11 Hohmann Transfer

An apogee kick motor is used to change from a circular LEO orbit to an elliptical one, and then again at apogee in elliptical orbit to regain a larger circular orbit.

1.12 Ground Traces

A project of a satellite's orbit onto the earth's surface, which shifts with each revolution.

2 Missions

Orbit	Missions		
LEO	Manned	Recon/Weather	Comms
MEO	Navigation(GPS)		
Molniya	Comms	Surveillance	
Sun-Synchronous	Recon	Weather	

2.1 ISR

Intelligence – the end product of data collection, processing, and interpretation
Surveillance – data collection from continuous observation
Reconnaissance – data collection that is event driven

- IMINT - imagery
  - Passive: visible, IR, multispectral
  - Active: radar, synthetic aperture radar (SAR)
- SIGINT - signals
  - ELINT - electronic (frequencies, bandwidths, emitter locations)
  - COMINT - communications (intercepted signals)
  - FISINT - foreign instrumentation signals (signals from noncommunication systems like command, telemetry, tracking)
  - MASINT - measurement and signitures (electromagnetic spectrum)

2.2 Missile Marning and NUDET

Defense Support Program (DSP) and Space-Based Infrared System (SBIRS) use MASINT to assess ballistic missile launches and nuclear detonations. Ground stations operate the satellites and perform strategic warning missions. Joint Tactical Ground Systems receive, process, and disseminate missile warning data to fielded forces.

2.3 Weather

Defense Meteorological Satellite Program (DMSP) runs 2 sun-Synchronous orbits. Currently NOAA operates Polar Operational Enivornmental Satellites (POES), Geostationary Operational Environmental Satellites (GOES), and day-to-day control of DMSP.

2.4 Communications

GEO COMSAT provides hemispheric coverage except for poles. HEO COMSATS provide coverage over northern polar region. LEO COMSATS provide tactical communications. Military operations rely both on government and commericial satellite systems.

2.5 Position, Navigation, and Time

NAVSTAR GPS provides

- highly accurate, all-weather position and velocity calculations
- timing signals accurate to within 20ns
- NUDET Detection

There are 24 satellites in 6 orbital planes, 55° inclination in MEO orbits. This means there are always 4 satellites in view of any given location. They provide both Standard Positioning Service (public, 3-5m accuracy) and Precise Positioning Service (military and government, 2-4m accuracy, encrypted)

3 20th Century Space Power

3.1 US Early Rocketry

A team of German scientists and engineers who had specialized in rocketry and the development of missiles, surrendered to the US during WWII. They eventually worked with the US Army's Space Program.

The Air Force helped develop RAND in order to keep academics invested in defense research, instead of having them all return to academia after WWII.

US wanted space power to gather intelligence on the Soviet Union as they were developing nuclear capabilities, however they needed to secure space as an international commons.

They chose to develop the plan of an "International Geophysical Year" to use science to form the precedent of freedom of passage in space.

The Navy Vanguard project had several failed launches, and after the successes of the first 3 Sputniks, Von Braun's team with the Army launched Explorer I.

Initial attempts at reconnaissance included the U2 project, which used high-altitude planes to fly out of the reach of Soviet Anti-Aircraft weapons. However, in 1960, one was shot down, ending all subsequent U2 flights. However, later that year, the US put its first, primitive reconnaissance satellites up. Project Corona shot photos on film, and then dropped cannisters of the film out of the sky to be collected by aircraft.

3.2 Cold War

In 1962, Moscow berated the US for flying ISR satellites as a violation to the "peaceful purposes" of the freedom of space, until they developed their on ISR satellites in 1963. However, they threatened to develop a fractional orbital bombardment system (FOBS).

This prompted the US to develop 2 anti-satellite (ASAT) systems. The Army had Project MUDFLAP was a solid fuel Nike-Zeus SAM. The Air Force developed liquid fueled Thor IRBMs. The Army had a quicker response time, but had a shorter range and a less powerful warhead.

3.3 Treaties on the Militarization of Space

In 1958, the UN declared that freedom of space only existed for peaceful missions. In response, the US stated that all missions that it flew were peaceful, concealing any military space-based projects. This resulted in the formation of NASA for highly public, peaceful space programs, and the NRO for secret military and intelligence operations.

In 1962, high-altitude nuclear tests showed that such explosions generated an EMP, leading to talks about stricter space treaties. In 1963, the UN passed Resolution 1884, banning putting weapons of mass destruction in orbit. Some states also signed the Nuclear Test Ban Treaty, banning testing nuclear weapons in the atmosphere, ocean, or space.

In 1967, the US, UK, and USSR signed the Outer Space Treaty (OST), which:

- Banned WMD in orbit, celestial bodies, or elsewhere in space
- Bans military installations on the moon or other celestial bodies
- Makes states liable for damage caused by their space objects
- Prohibits states from making claims of sovereignty on the moon or other celestial bodies

However, the treaty does not bar states from putting conventional weapons in space, or firing them from or to space.

In 1971/1972, the US and USSR established SALT, limiting ICBMs, SLBMs, SLBM-equipped submarines. They also made the Anti-Ballistic Missile Treaty, which limited each state to an ABM site near its capital, and one near its ICBM fields.

3.4 ASAT Weapons

Ford directed DoD to develop ASAT system. Carter continued this development, but also wanted to pursue an ASAT treaty. However, they had trouble logistically defining what ASATs would be banned.

Negotiations around ASATs failed, as there were arguments over whether ASAT attacks on other nations would be allowed, and what would be classified as an ASAT (ex would the US kamikaze a Space Shuttle).

Reagan pushed for continuted ASAT development, believing it would deter Soviet Aggression. In 1985, there was a successful ASAT test, using a modified SRAM missile launched from an F-15, destroying a satellite in LEO.

3.5 Military Space Operations

Reagan announced the Strategic Defense Initiative (Star Wars) in 1983. It was a program to defeat ballistic missile attacks against the US. Bush scaled down SDI into the Global Protection Against Limited Strikes (GPALS) to defend against up to 200 nuclear missiles launched at the continental US.

In the early to mid 80s, each service branch also developed their own independent space commands.

The Air Force Space Operations Doctrine identified 4 main military space mission areas:

- Space Support: capabilities that provide critical launch and satellite control infrastructure, capabilities, and technologies that enable the other mission areas
- Space Force Enhancement: capabilities contribute to maximizing the effectiveness of terrestrial military operations (recon, surveillance, comms, weather, GPS)
- Space Control: capabilities to attain and maintain a desired degree of space superiority by allowing friendly forces to exploit space capabilities while denying an adversary's ability to do the same
- Space Force Application: ICBMs

For the most past, the Air Force has only performed the first 2 mission areas

3.6 Space Support

Space was used in the 1991 Gulf War to supply imagery and intelligence for operations planning. This allowed US forces to navigate through a otherwise innavicable desert, defeating Iraqi forces.

However, even with this support, space was poorly integrated, with field commanders unprepared to handle new information, improvised arrangements to get space recon to the field, and space liaison officers who were ineffective.

After this, the space community overhauled their systems to better support warfighters and improve the space literacy of the forces.

With the advent of GPS and precision guided weapons, we were able to adopt "Network Centric .Warfare." Sensors, weapons, operators, and command centers networked together on a space comms backbone allows for more agile and lethal forces.

3.7 Presidential Administrations

Reagan - SDI
HW Bush - GPALS
Clinton - Cancelled space-based weapons portions
W Bush - Withdrew from ABM treaty and continued missile defense efforts
Obama - Continued programs from previous admins, neither adding noe detracting
Trump - Implemented the "Space Force"

Overall, administrations have been more open with making space more overtly militaristic.

4 Modern Space and Nat'l Security

4.1 American Civilian Dependence on Space

We use satellites for many things, but are not dependent on them, as the loss would have little impact on most Americans, and we have terrestrial backups for many functions. Most of our satellite constellations are fairly robust, and it is likely that large quantities of these satellites could be destroyed.

4.1.1 GPS

GPS is fairly robust - 30 satellites, while we can operate with fewer. We have terrestrial backups for timing, and navigation, but they are less precise and slower. Would make ships and aircraft more suceptible to bad weather.

4.1.2 Weather (LEO and GEO)

We can track hurricanes, anticipate floods, avoid frost damage, manage electrical power and natural gas production. We would reduce the quality of weather forecasting by 25% in the northern hemisphere and %60 in the southern hemisphere. West Coast would be the most affected, however we could rely on other country's weather satellites. It is unlikely that adversaries would target weather satellites.

4.1.3 Communications (GEO)

Cable TV is the largest user of these satellites. Attacks on GEO satellites in the Western hemisphere is unlikely since we fight in the Eastern Hemisphere. COMSAT is fairly resilient, so attacks on a few satellites would only result in some economic costs.

4.1.4 Communications (LEO)

Emergency services are the main users of LEO COMSATs for when cellular service can't be used. Since they support military users, they have a greater likelihood of LEO COMSATs being attacked then GEO COMSATs in the western hemisphere. However civilians would not be affected much.

4.1.5 Remote Sensing

These satellites support cartography, environmental monitoring, disaster response, agriculture and mining, and commericial, government, and military intelligence collection. Loss of these satellites would cause small economic costs, and could impact national security. These satellites are likely at the greatest risk of being attacked.

4.1.6 Science, Research, Exploration

Loss of these satellites would slow down research, but would not likely effect society in general. It is unlikely a hostile state would attack these assets, since there is little gain and an attack would likely carry political costs.

4.2 Military Dependence on Space

Loss of space support would disrupt our ability to conduct high-speed, network-centric warfare. Space assets provide syngergistic effects, that could lead to higher casualties and costs in war.

4.2.1 Communications

Communications between fixed installations can rely on terrestrial souces, but mobile elements need mobile connectivity. Military communications operate in the following bandwidths.

Name	Bandwidth	Function
Ultrahigh (UHF)	300MHz-3GHz	highly-manueverable tactical units
Superhigh (SHF)	3GHz-30GHz	the backbone of long-haul DoD comms
Extremely high (EHF)	30GHz-300GHz	supports high-level command and control

4.2.2 Surveillance and Reconnaissance

S&R are essential for finding, tracking, and targeting assets. They can also be used defensively, like for ballistic missile defense. Due to our space capabilites, US forces have better situational awareness than any other fighting force in the world.

4.2.3 Position, Navigation, and Timing

GPS gives precise location and navigation information, allowing for precision guided munitions (leading to less collateral damage). Blue Force Tracking gives command centers the location data of US forces

4.2.4 Meteorology

Lets forces see what weather is incoming to lead to better informed plans. Losing weather satellites would hinder mission planning/execution, but they are unlikely to be targeted due to the redundancy with NOAA, Global Weather Service, friendly nations

4.3 Attacks

Adversaries can attack any of the 3 space segments:

- Orbital: satellites
- Ground: satellite ground stations, any space-related bases
- Communications Link: communications between ground and orbital segments

They can also choose between reversible and non-reversible effects.

Some reversible effects are:

- Jamming radio receivers on satellites or ground stations
- Temporarily blind optical sensors on a satellite

Some non-reversible effects are:

- Kinetic strikes on satellites or ground stations
- Permanently damaging sensors on satellites

4.4 Modern Chinese and Russian Space Assets

China launched its first satellite in 1970 under Mao Zedong. However, when Xiaoping came to power, space efforts were sidelined until 1986 under Plan 863. In 1993, after the first Gulf War, the PLA concluded that space would become a vital asset, changing its doctrine to reflect the notion that the quality of weapons, in addition to quality mattered, a greater emphasis on joint operations, and the critical role of command, control, communications, and intelligence.

China deployed its first satellites in 90s (weather), and has been expanding the range of operations that their satellites perform. In 2007, China conducted a successful ASAT test, and currently, China is developing radio-frequency jammers, low and high power ground-based lasers, airborne/spaceborne lasers, and high-power microwave weapons.

Recently, the US brought up concerns over Russia's development of anti-satellite weapons.

The "Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects" focuses on the risks entailed in weaponizing space, playing up the sanctuary doctrine. It outlines that weapons or military installations should not be put in space, and asks states to not resort to the threat or use of force against outer space objects.

4.5 Space as a Sanctuary

4.5.1 Astropolitik

Described by Everett Dolman, it is an extension of 19th century geopolitics into space. Believes that if a state colonizes space, they can use the resulting power as a "normative justification for dominating or oppressing others"

Believes that there are certain "choke points" that are key to maintaining "space dominance", and that highest altitude presents a strategic advantage (gravity is working in ones advantage)

Dolman also argues that the Outer Space Treaty, as a free domainn, has taken away economic incentive for developing space. Wants to privatize space to avoid a "Tragedy of the Commons."

Argues that the US could seize space dominance by:

1. Withdrawing from current space Treaties
2. Seizing near-Earth space and putting laser or kinetic weapons there
3. Establishing an agency to coordinate commercial, civil, and military space projects

4.5.2 Sanctuary

Promising weapons can sometimes prove incompatible with the nation's higher policy objectives (example: the nueutron bomb).

The past 40-50 years have shown that space as a sanctuary has served US interests well.

David Zeigler argues the US is better served by preserving the present equilibrium in space weapons. It is possible to move dependence away from space, and as long as we have better and faster ISR, competing nations will still be at a disadvantage.

Overall, space weapons are provocative, destabilizing, and expensive

4.6 Space Wars

There are several types of weapons:

- Directed-energy
- Kinetic-energy against missile targets
- Kinetic-energy against surface targets
- Space-based conventional weapons against surface targets

Weapons in space have good reach, responsiveness, may be less destabilizing, and are difficult to defend against, however, they operate in fixed orbits, are expensive, require large numbers to be effective, and have potential legal consequences.

Terresltrial forces can produce all the effects that space-based weapons potentially could, but could make some assets more vulnerable (like aircraft carriers). There is currently no reason to invest in space weaponry until potential adversaries do.

4.6.1 Directed-Energy Weapons

Directed-energy weapons include jammers, high-power microwaves, particle-beams, etc. They travel at very high speed, and their effectiveness, $E\alpha\frac{P}{R^2}$, where P is power and R is distance. It is an easily accessible technology, but is difficult to incur non-reversibe effects.

Orbital Lasers are theoretically good for shooting ballistic missiles. However, they would only have about 300 seconds of firing capacity, moreover, the effect is not instant, as the laser needs to be focused on the target to ignite its fuel. Therefore, they would provide a limited defense against ballistic missile attacks, as each satellite mmust focus on a single target. The enemy could overwhelm the system by firing missiles simultaneously, or by ensuring the missile doesn't overheat due to the laser. Plus, these satellites are on fixed, predictable orbits and the cost of putting them in space is expensive.

4.6.2 Kinetic-Energy Weapons

By putting kinetic weapons in space, you incur both a cost for putting them in orbit, any another cost to decelerate the weapons for reentry. They could potentially intercept ballistic missiles during late boost or later. In order to have a sufficient response time, they would need to be placed in LEO, but that drastically increases the number of weapons needed to cover the earth. Opponents could design around this by making faster burn missiles, or by overwhelming the system

If firing against terrestrial targets, your weapon must be large enough to survive reentry and inflict damage on their targets. Due to their speed, they could be useful for firing against highly-defended targets. A cylindrical weapon would need active cooling to survive reentry, and would need to be dropped at a near vertical, in order to avoid any gliding or aerodynamic behavior that could steer it away from its target. They would be useful for attacks on tall structures, or ships, but much less useful against buried bunkers, short buildings, or runways.

4.6.3 Conventional Weapons

Generally consists of putting precision-guided munitions in pods that would deorbit over targets. Overall, they would be best utilized against fixed targets, and could maneuver to evade defenses, but not necessarily follow moving targets. This is roughly equivalent to long-range ballistic missiles, but more complicated and expensive.

4.7 Contemporary Issues

According to "Coyote" Smith, spacepower is ideally suited for war prevention. ISR provides insight into other countries where we couldn't necessarily gather intelligence from, while partnerships with other states promotes collaboration. Direct methods include assurances of not using weapons against states who do not pursue space weapons, or by promising protection to states who do not have space capabilities. We are also able to dissuade states not to develop space capabilities if they are too far behind technologically. Lastly, we can deter war by presenting a threat of retaliation.

War will likely eventually extend into space, and it will be critical to preserve their space systems, while denying opponents access to theirs. Current satellites are few, if existant at all. However, we are developing smaller satellites which can remain in orbit undetected. Additionally, war is the art of deception, and getting the enemy to overestimate inconsequential systems, while underestimating critical systems. Lastly, there is strength in numbers, as getting a weapon to space is difficult and expensive, it is good to have redundant systems. However, the best defense is having a system that is broadly used by many international partners.

Attacks now take place on a spectrum:

1. Deception - manipulation, distortion, or falsification of information
2. Disruption - temporary impairment of some or all of a space system capability
3. Denial - temporary elimination of some or all of a space system capability
4. Degradation - permanent impairment of some or all of a space system capability
5. Destruction - permanent elimination of some or all of a space system capability

And the severity of the effects will align with the severity of the conflict. Non-destructive will be difficult to deter. If an enemy is willing to commit to a terrestrial war, deterrence in space will likely fail. Many states see that space assets have enabled US dominance in conventional warfare, and the US has more to lose than other state in terms of space assets. We can try to deter destructive attacks. If we condemn the use of force to, from, or in space and declare we will punish states that do so. We want to deter a first strike, so we need to be willing to engage in brinksmanship, so that avoiding escalation is on the opponent's shoulders.