Space Concepts for a Strategist

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Resumé

Artikeln behandlar det strategiska perspektivet på den militära rymdarenan. Naturlagar och mänskliga lagar, utvunna från erfarenhet av land-, sjö-, och luftstrid, har framkallat dagens operationella rymdmiljö. Manöver och verksamheter i rymden karakteriseras av hög hastighet, till sin karaktär både begränsade och obegränsade på ett sätt som är främmande för många strateger. Rymden som en militär skådeplats är ett högteknologiskt, globalt gemenskapsområde med snabb global tillgång. Militär rymdverksamhet är relativt outvecklad, med tämligen få men med ett stigande antal aktörer. Rymden lockar militärt av olika skäll, inte minst för global åtkomst utan kränkande av suveränitet, samt, åtminstone hittills, av relativ osårbarhet. De tämligen höga entrékostnaderna och den globala karaktären skapar naturliga förutsättningar för samarbete mellan mindre stater, och möjligheter för stater med gynnsam geografi och resurser som Sverige.

The heavens have captured the imagination of humankind for millennia, though our understanding of it is rather recent, and exploration and use of it is confined to living memory. Whereas land and sea have been a part of the human experience since before Homers Odyssey, our venture into the air is barely a century old, and space only half that. Consequently, we are only beginning (particularly with respect to space) to understand how these media play a role in human interaction. On the scale of human activity, one unfortunately finds conflict, and it is there I intend to focus, fully aware that conflict has always its roots in other forms of human interaction. I write for the strategist who intends to weigh alternatives to address the effects space and its operational environment shape modern warfare. This is not intended as a technical instructional text, but rather an introduction of how the laws of science and man conspire to provide opportunities and challenges to the strategist.

What is Space?

Unlike the divisions between land, sea, and air, there is no bright line bounding space. It is quite easy to determine whether one is swimming, walking, or flying, only one of those being a natural condition of mankind. Ships, cars, and airplanes have little in common, rarely travel the others' media and when they do, they do it poorly. Such is not the case with the transition from air to space. Space travel begins either on the ground or at sea, transitions the air, and then spends most of its time in space, though often only temporarily. The debate about the boundary between space and air is long and complicated, and has the additional entertainment value of pitting scientists, lawyers, statesmen and soldiers against one another. If you enjoy kicking back with popcorn and a coke to watch such dramas, I regret that you won't get that here. We'll leave that discussion for future articles and just focus on the area far enough from the earth that the effects of atmospheric drag are small enough to allow unpropelled free flight for longer than a few minutes to hours. That limit is about 100 kilometers. Below that altitude, the effects of the atmosphere have a significant effect on the motion, maneuver, and propulsion of the satellite as well as having thermodynamic heating and communication consequences. Few if any practical vehicles are currently found between this altitude and the upper reaches of flying altitude (about 20 kilometers), though research is underway.

The laws of nature

Humans first occupied terrain, then the seas, then long after air and space. This was determined by the laws of nature. As one progresses from land to sea to air, the environment becomes increasingly foreign and hostile. Presence of food, water, and shelter abates, and the ability to maneuver and energy required to operate change dramatically.

By far the most foreign medium is Space. No food, water, or shelter, and enormous amounts of energy required to get there (though paradoxically, little is required to stay there). Movement is extremely fast and unconstrained by obstacles, but as we will discuss, is highly constrained by the laws of nature. Unlike land, sea, and air, space vehicles cannot and do not remain in a particular area to exert their influence. Their motion is highly predictable, repetitive, and at times appears static, but in a way very unfamiliar to terrestrial experiences.

In an idealized universe in which the Earth did not rotate, was perfectly round and homogeneous, and no other heavenly bodies exerted their gravity, space objects would retrace their path over the ground over and over again on lines that perfectly divide the globe in two halves, in any orientation you choose. Their speed is dictated by the laws of nature, relating only to their distance from the center of the earth (though that speed is not a constant unless the orbit is perfectly round). The object is in a continuous state of free fall in which gravitational attraction is balanced by the resulting centrifugal force of its curved path. As mentioned earlier, this results in an idealized path that requires no energy to sustain. Since the objects are travelling at very high speeds (nearly 8 km per second for a satellite near the earth), and started essentially from rest at the surface of the earth, tremendous energy is required to get it to that state, hence the enormous rockets for even small objects.

Because the earth does rotate (the largest of the non-idealized effects), these ground tracks vary with time depending on the tilt of the orbit relative to the earth's axis of rotation, the altitude (speed) of the satellite, and the circularity of its orbit. Some may be familiar with a geostationary satellite concept that baits one into believing the satellite doesn't move. In reality it travels around the earth at the same rate the earth rotates (which happens at a height above the ground of 35000 km, 10 % of the distance to the moon), is a nearly perfectly round orbit, and shares the same plane as the equator.

All of you who have satellite TV service at home have fixed dishes that point at a satellite of this type. Notice that these dish antennas don't point up, but rather near the horizon, generally south. This is because these satellites are over the equator, and Sweden is at 60 degrees north latitude. All other satellites move relative to the earth, creating opportunities and challenges very different than previous domains. For a strategist, the key points are that satellites are in constant motion, are highly technological, and require significant investment. On the positive side, they provide unprecedented perspective, speed, and access to the entire planet.

Laws of mankind

On land, competition for limited or coveted space resulted in the defense of these gifts becoming relevant nearly at the same time as they emerged, and the ability to do so extended to, in practice, everyone. The prospect of perpetual conflict and savage violence being the norm motivated human beings to organize themselves territorially and develop international norms based on territory. Defense of territory is the foundation of military thinking, and is the starting place for tactics, strategies and laws. However, as Ukraine is the latest to rediscover, international laws, generally found in treaties, are only as credible as their signatories, and violent means of achieving objectives can never be dismissed.

At sea, in practice, to defend ones position required energy and investment, reducing the capability to do so to those with ships and cannons, though such machines can readily travel the globe and exert force for a sustained period anywhere. This capability developed almost immediately with commerce. Whereas on land the organization was territorial, at sea the concept evolved to one of a global commons, with only those waters near enough to land to be controlled from land being treated as sovereign. Even there one finds exceptions, as in choke points like Öresund. Those nations who have the proximity to such choke points could exercise control over them technologically, but they risk perpetual conflict or conquest in so doing.

Defending the air medium and exerting force on the previous two media from the air is possible, and often advantageous, though it requires complex machinery and is fleeting in its nature, both in time and range. A hybrid of the land and sea concepts emerged. There is a territorial aspect embodied in current laws and practices in the use and defense of airspace. It developed from the ability to credibly control the space, and the threat of having hostile actors gaining influence over the ground. Like at sea, the air over the seas and the chokepoints, are generally considered global commons. Recent Chinese declarations of air sovereignty and the American responses to that show that the distance from shore where these principles apply are somewhat in dispute.

Defending the medium of Space, and exerting influence over the activities of mankind is a new science and far less mature than other media. As a consequence of this, the laws of mankind are different and less developed for space. In 1903 man's first powered, piloted venture into the air occurred in North Carolina, in 1911 the first wartime powered flight reconnaissance occurred, and the first bomb dropped in Libya, in 1915 the first aerial combat in France, and in 1921 the first battleship sunk, all within the first 20 years of flight. Space has developed much more slowly, 50 years after the first manned space flight, military activities from space are largely limited by both choice and technology to observation, communication, and navigation.

The foregoing realities of satellite's movement, and technical challenges of control have contributed to space remaining a global commons by international law and practice. There has been very little success in asserting sovereign territorial control, including in 1976, when some equatorial states claimed valuable geosynchronous orbits over their territory. For the most part, it is electromagnetic spectrum regulation that dominates "ownership" discussion as opposed to a satellites location. The two merge as positions in the geosynchronous orbits are limited, primarily by radio interference concerns. These are therefore managed by the International Telecommunications Union (ITU), a United Nations Agency.

To what end?

Serious strategists have an end in mind. They use ways (methods) and means (resources) to achieve that end. Partly because it lacks a sovereign identity, operating in space is generally not an end, but a way, and it is often only one of several ways to achieve a desired end. Sometimes it is the most effective way, sometimes it is the cheapest. The end objective of a space capability is a wide open field, and the domain of visionaries, imaginative entrepreneurs. Space attracts military interest for a variety of reasons, among them providing world access without violating sovereignty, and for the time being relative invulnerability.

The range of possibilities is broad and growing as technology develops. Communications, observation, and navigation, and global strike are among the military applications that benefit from these features of space. Key technologies like low power communications, advanced signal processing, cross-linking (satellite to satellite communications), advanced sensor design, and miniaturization have revolutionized the possibilities.

The potential motivations for developing a space capability are so numerous and diverse it is impossible to adequately do them justice in a short article. Common features of space solutions to problems are: Worldwide access, non-territorial, low threat vulnerability, and responsiveness (once on-orbit). These advantages are not exclusive to space, and technology developments at time shift the advantage. Let's explore some examples. In the decades of the 70's and 90's, space was a very attractive alternative for long range communications. Satellites were the bridge between and across continents and island groups. Compared to laying subterranean or sub ocean copper wire, for high capacity communication, satellites were cheaper and better. Along came high capacity fiber optics and much of that changed for fixed communications between more developed infrastructures. But the military more often than not requires (and is willing to pay for) highly reliable mobile communication, and terrestrial infrastructure is frequently nonexistent or suppressed in conflict.

Whereas terrestrial mobile services abound, they require significant infrastructure, and are hardly resilient in crisis—anyone experiencing 9/11, tsunamis, or earthquakes can attest to mobile phones being flooded with traffic or inoperative due to the crisis. Non-military space-based mobile communications have been developed, but they have historically struggled a bit, due to the cost relative to terrestrial solutions in high demand markets. Smaller, cheaper, high performance satellites may be changing this.

A similar dynamic exists in the world of imagery (a subset of surveillance or observation). Many of the images creating the mosaic of Google Earth are taken from airplanes, not satellites. For the desired resolution in developed areas, it was simply more effective to do it that way. This is not the case in remote areas where few airplanes go. There it is satellite imagery that dominates. This balance too may be shifting, as higher quality imagery becomes available from simpler and cheaper satellites. For the military application, the advantage of remaining relatively untouchable in space remains.

In terms of responsiveness, imagine this. When you turn on your GPS (intentionally left as an acronym to drive home the point that the system is so ubiquitous it is part of everyday language), at least four satellites are in view to help you determine where you are. That means four satellites can potentially see you, all the time, anywhere. That is with only about 30 satellites. Some applications require lower orbits for a closer view, but they don't often need four at once, nor do they always need continuous coverage. Suffice it to say, a modest constellation of satellites can provide observation of any point on the earth within minutes.

Costs of entry

One seemingly inescapable barrier to access to space is the initial energy required to achieve even the lowest orbit. The cost per kilogram of payload (a complex metric, but currently and crudely estimated at about 10K USD per kilo to a low orbit) has diminished moderately over time, primarily due to more effective operational and business models, less so due to revolutionary technological breakthroughs. What does promise to revolutionize some parts of the industry is the required weight of a satellite necessary to attain a given level of performance. Like telephones and computers, satellites the size of briefcases now perform like 1000kg satellites of a few decades ago. This has significantly lowered barriers to entry, and enabled a growing number of creative services from space.

Geography as an advantage

A bit of foundational, but necessary physics follows. As mentioned earlier, the minimum orbital speed of a low satellite is about 8 km/second. At the equator, the surface of the earth is moving at 0,5 km/sec due to the earth's rotation, or about 6 percent of orbital velocity. This diminishes with latitude to about 0,2 km/sec in Sweden to zero at the poles. This is both an advantage and disadvantage, depending on desired orbit. For geosynchronous orbits this is speed gained for free and reduces launch vehicle requirements. For polar orbits (the majority of low orbiting satellites) this speed is a liability that must be compensated for with launch vehicle performance. Another important launch and satellite design factor is on orbit maneuver physics.

An orbit generally exists on a flat planar surface that is tilted at various angles with respect to the earth's equator and orientation to a fixed point in outer space. This is called the orbital plane and remains fairly constant, at least in the short term. If one plans properly, and is patient, maneuvering within the original launched orbital plane can be done with small velocity changes and need not require much fuel. However, large changes in plane require a large velocity change and therefore a great deal of energy, and are generally to be avoided. For this reason it is most efficient to launch directly into the desired plane. Realizing that without an inefficient plane change as described above, it is impossible to launch directly into a plane whose inclination is less than the launch pad's terrestrial latitude, a launcher at the North Pole can only launch a polar orbit, in Sweden one can only launch directly to 60 degrees or higher, while a launch from the equator can achieve any plane. Another not insignificant factor for responsible launching nations, is that the downrange danger zone for planned and unplanned launch debris can be hundreds of kilometers, demanding unpopulated or ocean areas adjacent the launch site in the direction of launch.

Another important factor in addition to launch is ground station location. High latitude ground stations can easily observe many satellites several times a day, though often for only short periods. Equatorial ground stations have optimal continuous viewing conditions for geosynchronous satellites, can see virtually all satellites eventually, but see low flying satellites only infrequently and briefly.

The consequences to strategists are these: The geography of a space faring nation influences its space capabilities. A natural partnership arises between near polar and near equatorial nations if one has an ambition to offer a complete range of efficient satellite launch and ground contact functions. Alternatives exist (more capable launchers, networking grounds stations, and crosslinking, satellite to satellite communications) but the underlying physics and inherent efficiencies remain. Beyond security implications a nation's geography is clearly a valuable national economic resource.

Big, wealthy, or allied.

Since the only satellites in a relative fixed geographic position are equatorial, and a long distance away, many of the potentially useful military tasks require lower satellites that eventually cover the entire earth. This is particularly true of satellites that need to visit extreme latitudes, like here in Sweden. So a satellite, intended to view Sweden, will also view most of the rest of the planet eventually. For a country to invest in such a capability, they must either have global interests, have sufficient fiscal resources to accept the inefficiencies, or cooperate with others to share the resource. The need for continuous or persistent coverage amplifies this phenomenon. At high latitudes, and if desired performance dictates low flying satellites, continuity requires many satellites. Sweden's challenge is further complicated by policy intentions that include interest in much of the world, but not all of it, all the time. The previously mentioned trend toward smaller, cheaper, well-performing satellite relieves the costs of these inefficiencies, but the savings afforded by cooperation remain. A strategist therefore is left with the choice if the desire to be self-sufficient outweighs these costs.

Space Weapons

The more reliant a nation becomes on space capabilities, the greater the need to defend ones presence, and potentially deny others access to these global commons. This is a taboo subject for many, optimistically clinging to the hope that weaponizing space can be avoided. Unfortunately this train left the Niceville train station a long time ago, and it is never coming back. It is though, travelling slowly and it is still possible to catch up, climb aboard, and influence its speed and direction. The simple fact is that space is a weaponized medium already. Ballistic missiles, even short range models, are considered by some to be space weapons. They travel *through* space on an orbital path intersecting the earth's surface and the preponderance of their path is managed as space flight. Although once synonymous with nuclear weapons, improvements in accuracy have allowed ballistic missiles to be fielded effectively with conventional warheads, reducing the threshold for their use. Systems to combat these missiles, particularly in mid-course, are also space weapons. Weapons operating *from* space are less developed and prolific, though not non-existent. No operational system to engage land, sea, or air systems for destruction from space has yet been acknowledged by any country capable of doing so, though many have been considered. Limited ground based and space based anti-satellite systems have been tested and fielded.

From an international legal perspective, restrictions to militarization of space are few. Treaties are in place prohibiting deployment of weapons of mass destruction in space, though other weapons are not restricted in any meaningful way.

The foundation of any battle is awareness of the various influencing factors, including enemy order of battle, movements, and environmental conditions. Battlefield awareness of all domains from space is well developed, but not completely developed. Space situational awareness capabilities have been under development from the very beginning of space exploration with tracking interferometers, radars and telescopes dating back to the first space launches. It is now possible, though not trivial, to track, identify, catalog and predict movement of nearly everything larger than a milk carton, which by the way, is literally tens of thousands of objects. As impressive as that may be, many, many more inert objects of that size or smaller exist, and at 8 km/sec they carry with them devastating destructive risks to other satellites.

Miniaturization even today allows milk carton size satellites to have significant military capability, forcing any serious space faring nation to seek to maintain awareness of these objects. Again physics works against a geographically small nation acting alone, as this capability generally requires networked sensors over multiple continents and in space, especially if the targets are uncooperative (as are nearly all military satellites, when they choose not to be). Large investment, or cooperation, or both are essential.

Use of space weapons, like the use of all other weapons, is subject to international norms to the extent their operators respect those norms. Proportionality is among those norms. Article 8(2)(b)(iv) of the Rome statute criminalizes "Intentionally launching an attack in the knowledge that such attack will cause incidental loss of life or injury to civilians or damage to civilian objects or widespread, long-term and severe damage to the natural environment which would be clearly excessive in relation to the concrete and direct overall military advantage anticipated." A relatively simple attack against a single satellite by another with the force of collision alone can have lasting effects, the resulting debris widespread, indiscriminate, and remaining a catastrophic hazard to other satellites potentially indefinitely. The Chinese conducted such a collision in 2007 and the debris remains a concern today (note that the US has twice done the same in 1985 and 2008, though the action was planned to and apparently succeeded in minimizing debris). Setting aside the moral aspects of limiting space weapons, the strategic dimensions are easier to evaluate.

Currently the US is diplomatically isolated as one of the few countries who opposes limiting space weapons. This stands to reason in as much as the US military is highly dependent on space, enjoys a clear lead in space technology, and stands to lose the most by such an agreement. Considering also the proven differences between a functioning democracy and authoritarian regimes like China's and Russia's propensity to disregard international agreements, the US reluctance is understandable.

For the time being, there appears not to be a mad race for military dominance in space, largely because the only power currently capable of doing so has shown some restraint despite opposing international norms against it. A strategist would be wise to study this debate and compare it to other international norms of sanctuary like, for example, Antarctica.

A few takeaway thoughts and final words

Unlike war on land and sea, air and space warfare are barely about 100 and 50 years old respectively. Airmen might claim that soldiers and sailors still do not understand air power, but few serious strategists contemplate conflict without accounting for air power. Space power is at that level in only a handful of nations. Technology is gradually lowering the barriers to access, though space remains a global media, with natural opportunities for cooperation, and nearly inescapable global consequences.

We are only beginning to understand and exploit space for the benefit of mankind. As we do, it becomes more valuable, and that naturally leads to a desire to both preserve it for ourselves and potentially deny it to others. We have really only scratched the surface of what space means to a strategist, but as food for thought, allow me to plant a few questions to ponder for future discussion.

Thinking in strategic terms, how have the elements of surprise, maneuver, unity and concentration of effort, and unity of command been influenced by space capabilities?

How has the global mobile instantaneous military communication afforded by space influenced wartime decision-making?

It is my firm belief that such musing leads to the inevitable conclusion that space operations will only grow as a decisive element in warfare, and that understanding its dynamics will become an inescapable part of a strategist's toolkit.

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