How China “Wins” a Space War

Brian Weeden

In his recent article “How China Loses the Coming Space War” Dr. Geoffrey Forden presents a scenario with a hypothetical attack by China on American space power as a prelude to a conflict over Taiwan.¹ In this attack, China assaults U.S. space assets using the direct ascent ASAT weapon that was tested last January. Forden concludes that this weapon system alone would not be sufficient for China to degrade U.S. space power in a conventional conflict over Taiwan. His analysis is squarely aimed at hawks in the U.S. government who might use the perceived Chinese space threat as justification for America to weaponize space. Within the scenario he defines, Forden’s analysis is mostly correct, but there are a number of tactical subtleties that could very well change the outcome.

Those subtleties are examined here as well as the additional weapons in China’s counterspace arsenal, all of which ultimately lead to a different set of parameters for a likely conflict scenario in space between China and the United

Brian Weeden is a consultant with the Secure World Foundation developing the technical feasibility and architecture for Space Traffic Management.

2008 World Security Institute
How China “Wins” a Space War

States. In fact, with these additional capabilities, it is feasible for China to “win” a hypothetical space war with the United States by severely degrading American space power and, consequently, U.S. military power. This analysis ends with a discussion of why the worst possible reaction to this likely scenario is for the United States to weaponize space.

Direct Ascent ASATs

On the issue of a U.S. response to an ASAT attack, Dr. Forden writes:

It is highly unlikely...that the United States would simply roll over while these attacks took place. Even today, with no formal satellite defenses, we could be fairly effective at stopping the destruction of our satellites.

The United States would most definitely like to try and prevent attacks, but the reality is that there is currently no way to do so. As stated in congressional testimony by the former commander of the U.S. Strategic Command, Gen. James Cartwright, currently the only tactic the United States has to counter China’s kinetic ASATs is by using submarine-launched Trident ballistic missiles or future “prompt global strike” systems. And even that is a specious tactic given the mobile nature of the SC-19 booster that was used to loft the ASAT into space and our inability to find SCUDs within a much smaller area over which we had complete air superiority during the 1991 Gulf War. Finding the ASAT launchers in China is made doubly hard given that the launchers would target the very satellites that would be used to find them.

NORAD

NORAD no longer tracks satellites for the U.S. military. That mission was passed to the U.S. Strategic Command (USSTRATCOM) several years ago. In fact, the operators and the location (the Cheyenne Mountain facility in Colorado Springs) stayed the same, thus it was merely a “patch change” for their sleeves and walls. NORAD is still one of the key users of space surveillance data for its aerospace defense mission. Just recently there was another change as the operators, equipment and mission were moved from Colorado and now reside at Vandenberg AFB in California as part of the Joint Operations Space Center (JSpOC).
Brian Weeden

Maneuvering Satellites

As a tactic for countering the direct ascent ASAT threat, Forden asserts:

[T]he United States could effectively stop China’s attack simply by chang-
ing the remaining satellites' orbital speeds by as little as 200 mph (they are
typically moving at over 16,500 mph). This very small change will have a large
effect in the position of the satellite the next time it crosses over China; effec-
tively putting the satellite out of range of the pre-positioned ASAT launcher.

While there are some elements of truth to this statement, the real tactical situ-
ation is much more complex. There are two broad categories of satellite maneu-
vers that could be done: a reactive maneuver to avoid an incoming kill vehicle and
a pre-emptive maneuver to change the satellite’s orbit prior to launch. Currently,
neither of these are very effective tactics.

Reactive Satellite Maneuvers

In order to conduct a reactive maneuver there are several things that need to
be calculated: the amount of fuel available to the satellite, the amount of velocity
change a satellite can impart over a short period of time, the velocity of the kill
vehicle, the velocity change that the kill vehicle can impart to correct its inter-
cept trajectory, and the ability of the seeker head to track the satellite.

This is a scenario where the kill chain of events for the attacker moves much,
much faster than the protection chain for the defender. The time it would take
for an ASAT traveling at upwards of 9 kilometers per second to get from launch
to a satellite at an approximate 1,000 km distance is measured in a handful of
minutes.6 Satellites cannot maneuver on their own – human operators must de-
terminate the need for a maneuver, calculate the correct timing and direction of the
engine thrust, and then command the burn. This is a process that usually takes
days to weeks since the consequences of commanding a bad maneuver can be
disastrous in terms of both wasted fuel and if the satellite is maneuvered into the
path of another object. Detecting the ASAT launch, calculating its trajectory and
speed, determining which satellite(s) are in range, alerting the operators who
command the satellite, planning the maneuver burn, and commanding the burn
would take far too long.
Even if one assumes that the entire decision chain for detecting, calculating, deciding and commanding the maneuver can be shrunk to zero, there is still the problem of getting those instructions to the satellite. Controllers utilize ground stations consisting of large antennas which transmit instructions up from the ground to the satellite and which allow for data to flow from the satellite. Generally, each satellite constellation has a dedicated ground station or set of ground stations from which it can receive commands, although some action to change this limitation with future generations of satellites is underway. An example of a ground station network can be seen above, which shows the network of GPS ground stations which transmit commands from controllers in Colorado Springs.

Until a satellite flies over one of the ground stations with which it can communicate, it cannot receive any new orders from the controllers on the ground. So not only would the warning of an ASAT attack have to be disseminated to different command centers depending on which satellite(s) were threatened, there could be additional delays of many minutes to hours before the threatened satellite flies over one of the correct ground stations and the maneuver command can be sent. By then it would be a cloud of dust.

Pre-emptive Satellite Maneuvers

Intelligence gathering satellites will have to orbit China in order to be useful. If the United States starts maneuvering those assets pre-emptively, then China
has already achieved its goal without needing to destroy the satellites. Such maneuvers will indeed throw off the satellite’s ground track far enough to put it out of range of pre-positioned ASATs. However, that same maneuver will also throw the satellite off the ground track needed to collect the imagery and intelligence information. If the United States cannot use these satellites to collect intelligence on China they are effectively removed from the battle-space to China’s advantage.

Almost all electro-optical (EO) intelligence gathering low Earth orbit satellites operate in what are known as sun-synchronous orbits (SSO). These orbits utilize the variations in the shape of the earth to keep the angle between the sun, the satellite and the earth constant. More specifically, they operate in SSOs with repeating ground tracks – the satellites will overfly the same point on the earth after a set number of orbits. The end result of these two factors is that every time a SSO satellite overflies the same point on the ground it will be with the same sun angle and thus the same shadow length (correcting for seasonal effects).

This is a very important feature for trying to collect information on how a ground scene changes over time and requires a very precise orbit with a specific inclination and altitude. Changing either one of those parameters to avoid flying over an ASAT means either more maneuvers to get back on the original ground track, and more fuel wasted, or a complete disruption of the data set.

Satellites that image the ground using radar do not rely on the sun for lighting conditions, are not restricted to SSOs and thus could have more freedom to maneuver. But they do rely on the sun for solar power, and if they fly in a non-SSO the amount of time sunlight falls on their solar panels will vary and it could adversely affect the duty cycle on their radar. Flying the same SSO ground tracks as EO satellites also makes it much easier to combine imagery from the two. All of the current unclassified radar satellites (RADARSAT, SAR-LUPE, TERRASAR-X) fly in SSO according to the public orbital data found on Space Track.

All sun-sync satellites eventually fly over the entire surface of the earth (excluding minute portions of the poles). There would be no way to prevent these
How China “Wins” a Space War

satellites from flying over China and thus the ASAT launchers. The repeat time between flights over a specific point on the ground is impossible to calculate without knowing the precise orbits of these classified satellites, but it can range between one day (12 to 15 revolutions) to 50 days and higher. One could guess that these spy satellites probably fly orbits that repeat over a location in single-digit days, but the same effect could also be accomplished by having multiple satellites flying staggered multi-day repeat SSOs.

Pre-emptive maneuvering would work to U.S. advantage by introducing the problem of tracking the satellites for an adversary looking to destroy them with ASATs. Currently, China only has a few radar and optical tracking facilities and they are almost all located within Chinese territory. China does possess ships that are deployed to broaden its tracking capability for domestic space launches, but we can assume that such ships would be easy targets for the U.S. Navy or Air Force. If the U.S. satellites were to conduct pre-emptive maneuvers, Chinese tracking stations would need to observe at least a couple of passes over China before being able to calculate an accurate enough position to use as targeting. How accurate this position needs to be depends on the capabilities of the kill vehicle seeker head. So as long as the spy satellites continue to maneuver and change their orbit often, say at least once a day, it would be very difficult for the Chinese to target them. But it would also make it very difficult for the U.S. intelligence agencies to use the satellites and greatly reduce their lifetime. Given that these satellites are estimated to cost billions of dollars and have acquisition times measured in several years to a decade, the United States would be hard-pressed to replace them. Therefore such pre-emptive maneuvering still meets the Chinese strategic goals of eliminating that piece of U.S. space power.

Kill Vehicle Targeting

Forden’s article also highlights the problem of targeting satellites:

Even though the site from which the interceptor was launched was cloaked in darkness, the target satellite was high enough to be brightly illuminated by the sun. Until China does develop better sensors, this imposes a very severe constraint on how and when it could attack other satellites: it must wait to
attacking low Earth orbit satellites when they are in bright sunshine.

Forden is completely correct that optical tracking on the kill vehicle does have major drawbacks and that the Chinese are probably some time away from developing sensors that can work accurately enough in other electromagnetic bands. However, most power-intensive satellites, such as radar imagers, usually align their orbits so that their solar panels are always in direct sunlight. This is done by aligning the orbit close to the day/night terminator. This means that radar imagers would probably have a much higher probability of being over China with the proper lighting conditions than EO imagers and signals intelligence (SIGINT) payloads.

Of course, precise kill vehicle targeting is only necessary if you need to directly hit the target satellite to achieve a kinetic kill. There are other methods, such as “clouds of pellets” or a high-power microwave blast, which could potentially be used to disable satellites without the need for precise targeting at high velocity.

Global Positioning System

The NAVSTAR GPS is tactically the hardest target to crack. This is mainly a function of the relatively large number of GPS satellites (as opposed to the handful of imagery satellites) and their distance from the earth. However, the system does have its weaknesses.

The primary weakness of GPS is its susceptibility to jamming. As outlined in a series of articles published on GPS Anti-Jam in the Weapons Systems Technology Information Analysis Center Newsletter, the actual amount of the Coarse/Acquisition (C/A) signal from a GPS satellite to a receiver on the ground is extremely
low. Military receivers use the stronger Precise (P) signal but still rely on the C/A for acquisition. This means that jamming can be an effective tactic and jammers are very much available on the commercial market.

The newsletter series also point out another weakness in GPS: you don’t need to destroy all the GPS satellites, just enough so that only three are in coverage over a spot on the earth. This is because while theoretically only three are needed for a position fix this requires a perfect clock (i.e. an atomic clock) in the receiver. Virtually all receivers do not have the space or power needed to host atomic clocks and thus use the fourth satellite to alleviate any local timing problems.

The ASATs used to take out any GPS satellites do not have to be launched all at the same time in a mass wave. Instead of the direct ascent method demonstrated last January, a co-orbital ASAT could be used. Co-orbital ASATs are actually placed into orbit and then maneuver to rendezvous with their targets. The kill vehicles can be pre-positioned months or years ahead of time in orbit and then, when commanded, maneuver towards their targets. One way to do this would be for the Chinese to hide the kill vehicles as pieces of debris (or as part of the rocket body) when launching their own semi-synchronous satellite navigation system. It would be extremely difficult for the United States to verify that such weapons are there until they are activated and start maneuvering.

A full analysis would likely show that the elimination of some GPS satellites, reducing their numbers over Taiwan at any given time to three, coupled with intense jamming of the Taiwan Strait, would impart a severe degradation to the GPS signal and the effectiveness of precision guided munitions and other GPS-derived combat benefits.

All-Out Space Warfare

There is no reason to think that China would rely solely on its demonstrated direct ascent ASAT as the only weapon in its counterspace arsenal. Indeed, it is only logical that China would employ a full spectrum of capabilities – and it has shown hints at what some of those are.
The same concept of jamming for GPS can be applied to communication satellites as demonstrated by the jamming of a Thuraya satellite in 2006 and the (likely) unintentional recent jamming of satellite TV over Lebanon.\textsuperscript{14} Lasing satellites to either blind optics or overload the satellite’s thermal control system are also feasible. There is also the alleged 2006 dazzling of a U.S. spy satellite by China.\textsuperscript{15}

But the real doomsday weapon in counterspace warfare is the electro-magnetic pulse (EMP) – a side effect of certain nuclear detonations. The effects of EMP were first widely noticed following the STARFISH PRIME high-altitude nuclear detonation (NUDET) over a Pacific island.\textsuperscript{16} Simply put, a nuclear detonation can generate a pulse which can damage, and in some cases destroy, sensitive satellite electronics. While these electronic components can be hardened against EMP, it requires significant additional costs and added weight.

If China really wanted to remove the U.S. communication ability in a conflict over Taiwan, a relatively small nuclear weapon lofted into geosynchronous orbit, maneuvered to position over Asia and then detonated would have devastating consequences. The only known geosynchronous communications satellites designed with survivability in a nuclear environment are the U.S. Milstar satellites. Theoretically, they could withstand such a blast but would be of little benefit. Six Milstar satellites were designed and built but one failed to achieve orbit.\textsuperscript{17} As they are intended to provide global secure satellite coverage, it can be assumed that the five remaining satellites are spread out along the equator, meaning that at most only two or three are positioned in the area of Asia. With maximum data rates of 2,400 bps (satellites 1 and 2) or 4.8 kbps (satellites 4 thru 6) there is no way for these to possibly handle the gigabits of bandwidth needed.\textsuperscript{18}

The Aftermath

The concept of “winning” in the above hypothetical scenario should be understood only in the most Pyrrhic sense. We have already seen the damage done by the destruction of just one SSO satellite (Chinese test). If that were repeated a half dozen times or more over a short period the effects would be disas-
trous, to say nothing of what the space environment would look like if a NUDET were to occur in populated orbits.

This counterproductive maxim holds true for any destructive counterspace activity by any nation, including the United States. It is a fact of physics that the permanent disabling of a satellite’s ability to maneuver, or the ability of controllers on the ground to command maneuvers, by any means, transforms that satellite into a piece of debris and increases its chances of a collision in space. Collisions generate more pieces of debris, which in turn increases the probability of additional collisions, creating a feedback loop that we currently do not know how to stop.

While it is true that space power is an important foundation of overall U.S. military power, it is also true that U.S. prowess in power is closely linked to America’s economic power and, in turn, the world’s economy as a whole. Any permanent degradation or damage to critical space systems, such as GPS or commercial communications satellites, would have a devastating impact on the American economy, the global economy, and thus the economy of the very nation that brought conflict to outer space.

China does possess the ability to significantly affect U.S. space power. But this conclusion does not mean that the United States should respond to the Chinese space threat by further weaponizing space; in fact precisely the opposite should be done. It can be argued that one of the factors driving the dichotomy between the Chinese rhetoric banning weaponization of space and their pursuit of counterspace capabilities is current U.S. space policy, which states:

The United States considers space capabilities – including the ground and space segments and supporting links – vital to its national interests. Consistent with this policy, the United States will: preserve its rights, capabilities, and freedom of action in space; dissuade or deter others from either impeding those rights or developing capabilities intended to do so; take those actions necessary to protect its space capabilities; respond to interference; and deny, if necessary, adversaries the use of space capabilities hostile to U.S. national interests.19

Here, the United States declares the right to act in space without granting
others the same privilege. It does this by reserving the prerogative to develop counterspace capabilities in order to prevent other nations from interfering with U.S. freedom of action in space. This runs counter to the spirit of the Outer Space Treaty as summarized in Article I:

The exploration and use of outer space, including the moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind.20

The U.S. space policy is an attempt to solve a sticky strategic dilemma. As America, and indeed much of the world, is so reliant on space, how can they guarantee its security? Does America protect its space assets through military force and weaponization? Or does it simply entrust its well-being in the belief that all the world’s nations will act in space only for the betterment of all humankind?

One possible answer to this quandary, instituting an outright ban on the development of all counterspace weapons, is a non-starter. The dual-use nature of almost every key space technology means that implementing such a ban would either impose impractical verification requirements or significantly neuter all space development. Weaponization of and destructive combat in space, as shown above, is equally unfeasible. Any solution designed to solve this dilemma needs to bring a diversity of approaches to the situation somewhere between these two extremes.

A good starting point would be the same Moral Code of Conduct for space that Forden highlights.21 The world community also needs to move forward toward a more complete space security effort, an acceptable and reciprocal mechanism involving such factors as international space situational awareness and the coordination of space traffic. The goal is to not only increase the safety of space operations, but also to provide a degree of transparency and cooperation with the aim of reducing tensions in space. These measures could have the same stabilizing effect on space security as National Technical Means had on arms control verification during the Cold War.

It would also be advisable to implement such a solution in stages with a stag-
gered process of engagement building upon shared goals. The key element in the process is that no nation should be forced to resort to the threat or use of counterspace as a primary piece of its national policy. There needs to be greater coordination and engagement on key issues which reflect the desire for all actors to preserve the free use of space, motivated by fundamental self-interest.

“How About a Nice Game of Chess?”

In the end, a space war can be “won” only in a purely tactical sense. At a strategic and global level these tactical gains are hugely offset by the long term degradation of the space environment, perhaps even leading to the complete denial of the use of space by any party. The consequences of conflict in space can also be illustrated through another military scenario – nuclear warfare. Parallels can be drawn between the thousands of nuclear intercontinental ballistic missiles poised on a hair trigger alert and the deployment of fully developed counterspace capabilities by paranoid nations. The most serious of these parallels is the potential for escalation and heightened tension leading to undesired actions. And while it can be argued that nuclear weapons actually prevented large-scale conventional war, they did so at an enormous economic cost and they created many side effects that will continue to cause problems long into the future.

This Cold War analogy only goes so far since the current international relations environment is fundamentally different than anything seen since World War II. There is no longer a simple zero-sum situation with two great powers espousing two opposite philosophies backed by massive conventional and nuclear armies. The modern world is a highly dynamic one where nations are interlinked through complex economic ties and where the main prize is international soft power and influence rather than physical territory. Thus, this system inherently already has a form of economic deterrence damping major military action among major powers. There is no need to develop a “space deterrence” similar to nuclear deterrence that was used in the Cold War.

Hopefully, we can learn from our history and avoid making the same mistakes in the emerging domain of space. As stated at the end of the movie “War Games,”
“the only winning move is not to play the game.” Space warfare and weaponization is a game that no nation can afford to play.

Notes

3. “Cheyenne Mountain Directorate,” NORAD, see www.norad.mil/about/CMOC_2.html.
7. Graphic reprinted with permission, see http://www.palowireless.com/gps/tutorial2.asp.
12. Special thanks to Analytical Graphics, Inc. for use of their Satellite Toolkit software for use in this article.
How China “Wins” a Space War

glasstone.blogspot.com/2006/03/emp-radiation-from-nuclear-space.html.
18 Ibid.