Current and Future Military Uses of Space[a]

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The civilian space program is a cultural activity, designed to express people's sense of adventure, the progress of technology, and national prowess. Economic or scientific utility is not the standard applied in designing the civilian space program, despite some hopeful talk about growing crystals and performing electrophoretic separations at zero *g*. The military space program is completely different. In our military program, the benchmark of success is not technological advance or novelty, but military capability and related national security.

It is unfortunate that we sometimes tend to carry over to the military space program the mystique that underlies the civilian program. This mystique—reflected equally in urgings that we "must seize the high ground" and that we "must avoid militarizing space"—is not very helpful in perceiving what kind of military space program we need or in managing it.

This talk begins with the premise that however special or dramatic space might appear, it should be regarded merely as another medium for national security activities. We should apply to military missions conducted from space the same standards of cost-effectiveness, survivability, and trade-offs with alternatives that we apply to our other military decisions. The drama can be taken into account after we have gotten our bearings in a more hard-headed military sense. I will not in this paper emphasize arms control as a solution to security problems in space, to the neglect of unilateral military initiatives and acts of self-restraint.

CURRENT MILITARY USES OF SPACE

For the first three decades of the Space Age, the superpowers have found it technically and economically attractive to use space only for the five so-called traditional missions of reconnaissance and surveillance, communications, navigation, meteorology, and geodesy. Let me review these missions very

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briefly before passing on to the host of new technologies that might in the future greatly lengthen this list of military space missions.

Reconnaissance and Surveillance

Electromagnetic radiation emitted or reflected from terrestrial objects can be detected from space in any of the three wavelength bands to which the intervening atmosphere is transparent, namely, the visible band, certain infrared bands, and the microwave radio band. It follows that these are the bands used for military surveillance.

In peacetime, these remote sensing techniques are used to characterize foreign weapons for U.S. force planning and treaty monitoring and to contribute to strategic warning. Collection of peacetime intelligence is characterized by a leisurely time scale and a benign environment. Naturally one would also like to use these remote sensing techniques for wartime purposes, such as tracking fleet movements, locating rear area targets, sorting out enemy lines of supply and command, monitoring activities at airbases, intercepting field communications, and warning of enemy advances. Though many of the same remote sensing technologies apply to both tactical and strategic intelligence, there are three crucial differences between these two missions. First, battlefield intelligence must be processed and disseminated rapidly if it is to be useful. Second, it is to be expected that tactical sensors of genuine military value will come under attack, whereas peacetime intelligence collection is not directly impeded. Third, space-based sensors, a necessarily global capability, must compete in cost-effectiveness and survivability with other collectors such as aircraft and remotely piloted vehicles that can be brought rapidly to bear in a theater of conflict. These factors make the notion of an "electronic battlefield" orchestrated from space somewhat less compelling than a first thought might suggest.

In the realm of nuclear operations, space is used to detect missile launches and nuclear detonations. Missile warning data permit the safe escape of bombers, tankers, cruise missile carriers, airborne command posts, and, for launch-under-attack (LUA), intercontinental ballistic missiles (ICBMs). Confirmation of detonations on U.S. soil might also serve as a last check on an LUA decision. But the most important use of missile launch and nuclear detonation data would probably be to give decision-makers a clear assessment of what happened, information crucial to responsible action and, under the chaotic circumstances, hard to come by otherwise.

Imagery

The resolution of a given spaceborne optical camera is proportional to its altitude. Thus a photoreconnaissance satellite orbiting at an altitude of 200 km and yielding imagery with one-foot resolution (about the view the human eye gets from the top of a skyscraper) would at 5000 km yield Landsat-like imagery useful for forestry and for *National Geographic*, but useless for most intelligence purposes. Photoreconnaissance satellites are therefore confined to low-earth orbit. Coverage at all latitudes requires polar orbits for these satellites.

Infrared cameras would collect information about the surface temperature of objects on the earth, potentially revealing features obscured at visible wavelengths. Radar images can be formed by illuminating the earth with microwaves and collecting the reflected signals. Radar satellites would provide nighttime and all-weather imagery, since they would supply their own illumination, and microwaves penetrate easily through clouds.

Signal Detection

Satellites can also detect discrete signals in the three atmospheric bands, including microwave pulses from the air defense radar on the ship, telemetry from a cruise missile test vehicle, the visible flash of a nuclear detonation, or the infrared plume of an ICBM launch. If the signal is sharply structured in time, like the flash of a nuclear burst or the pulses of a radar, the emitter's location can be deduced from the differences among the signal's arrival times at several well-separated satellites.

Orbits for signal detection should be chosen to provide continuous coverage of target areas, preventing the opponent from performing tests, sending messages, moving mobile radars, or launching missiles during coverage gaps. Geosynchronous orbits (GEO) offer continuous dwell over mid-latitudes; the U.S. acknowledges stationing warning satellites there. Long dwell times (and coverage of northern latitudes) are also possible from Molniya orbits; the Soviet Union deploys warning satellites in this way. Continuous coverage by several widely separated satellites, permitting emitter location by the time-difference-of-arrival technique, requires a "birdcage" constellation; the U.S. Nuclear Detection System (NDS) aboard the Navstar GPS satellite is in this kind of orbit. (FIGURES 1 and 2 illustrate these orbit types.)

Communications

There are only two ways to communicate information over long distances within seconds: by landline (including transoceanic cable) and by radio. Because the earth is round, line-of-sight radio contact between widely separated points on the earth's surface is impossible. One way to propagate radio waves over the horizon is to bounce them off the ionosphere; shortwave (HF, high frequency) radio propagation in this manner was until recently the U.S. Navy's chief means of communicating with its far-flung ships. But ionospheric reflection is unreliable and cannot support large rates of message traffic. Long-distance communication companies have long placed microwave radio relays on towers and mountaintops for over-the-horizon relay. The communcations satellite is just an extension of the relay principle to higher altitudes and consequently longer relay distances.

Most operational communications satellites (COMSATs) today use ultra-

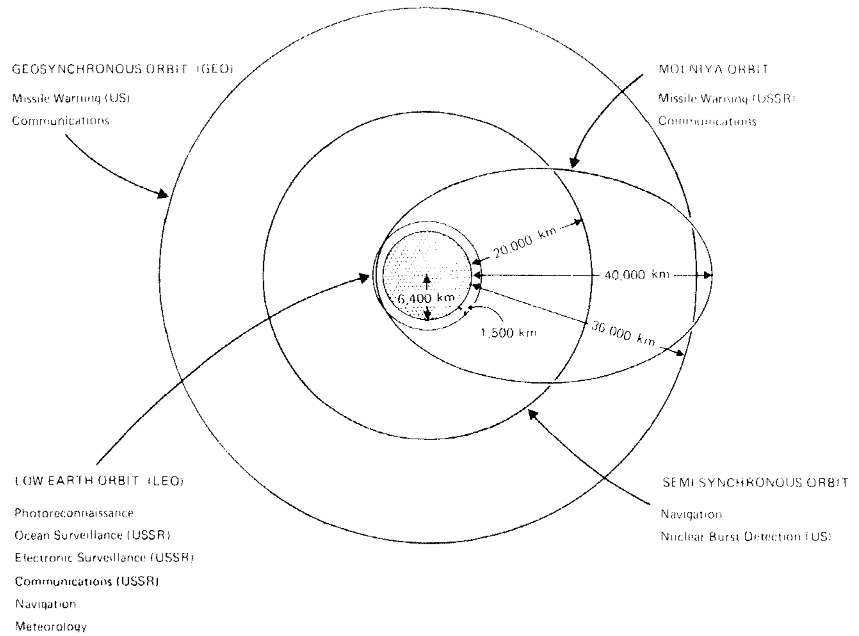

FIGURE 1. The four major orbit types, drawn here to scale, contain almost all military satellites. The LEO region, represented here by a 1500 km (930 mile) circular orbit, is subject to attack by both the U.S. and Soviet ASATs. The U.S. ASAT also has the propulsive capability to attack Molniya orbit, though it will not in fact have that capability in its proposed operational deployment; the Soviet ASAT cannot attack Molniya orbit. Neither ASAT can climb to semisynchronous orbit or GEO. The nature and orbits of U.S. reconnaissance satellites are classified. The supersynchronous region above GEO is little populated today, but its vast reaches offer opportunities for satellite survivability that are likely to be exploited in the future.

high frequencies (UHF) and super-high frequencies (SHF), but extremely high frequency (EHF) systems are under development. The move to higher frequencies for military satellite communication (SATCOM) is motivated by five factors. First, higher-frequency radio waves have a higher limit to their data-carrying capacity than lower-frequency waves. Second, transmitting antennas for higher frequencies can be made smaller without sacrificing performance, since the effectiveness of a transmitter dish is determined by the ratio of its size to the wavelength of the radio waves it is transmitting. Three additional advantages of high frequencies (accompanied by wide bandwidths) for the peculiar needs of military SATCOM are: it is easier to protect higher-frequency links against hostile jamming; covert ("low-probability-of-intercept," or LPI) communication, which does not betray the location of the transmitting ground terminal, is easier with wide bandwidths; and higher frequencies suffer less distortion in passing through an ionosphere disturbed by nuclear detonations.

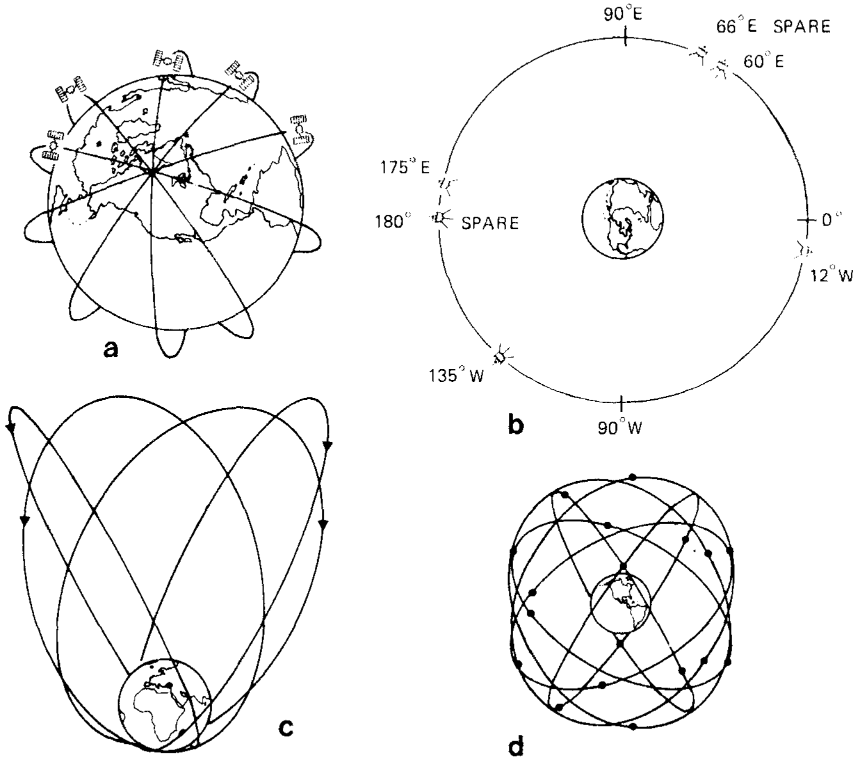

FIGURE 2. Military satellite constellations illustrate the four orbit categories. (**a**) Five U.S. TRANSIT navigation satellites in polar LEO, arranged in five separate orbital planes. (**b**) Four U.S. DSCS communications satellites in GEO equatorial orbit. (**c**) Four Soviet Molniya communications satellites in inclined Molniya orbits, arranged in four planes. (**d**) Eighteen U.S. Navstar GPS navigation and nuclear burst detection satellites in inclined semisynchronous orbits, arranged in six planes.

Laser communication is also coming into use for satellite-to-satellite links and for satellite-to-aircraft links. Ground-to-space laser communication links could obviously be frustrated by clouds.

Military COMSATs are deployed in a variety of orbits. GEO is high enough to allow widely separated ground stations to communicate through a single satellite, and a stationary satellite makes it easy for users to point their antennas. But the polar regions are invisible from geosynchronous equatorial orbit. The Soviets, with many military installations at high latitudes, deploy COMSATs in Molniya orbits. A communications satellite in low earth orbit (LEO) is only visible at any given time from a relatively small patch of earth below. Two terminals within the patch can communicate directly, but widely separated users must store messages on board the satellite when it is overhead, ordering the satellite to "dump" the message when it passes over the recipient. The Soviets deploy large numbers of such store-and-dump satellites in LEO.

Transmitting a message from one hemisphere to another requires an intermediate ground station in view of two satellites, the satellites in turn being in view of the originator and recipient. Likewise, a low earth orbiting satellite that collects its data out of sight of its processing station must have either a local earth station connected by landline or satellite relay to the processing station, or tape recorders to store the data until the satellite passes over the processing station and can "dump" it. Control of complex spacecraft requiring frequent ground commands depends on a worldwide network of earth stations. Suitably located earth stations, in politically stable areas that would also be unaffected by military conflict, are hard to provide. Direct satellite-to-satellite relay links avoid all these problems. NASA's Tracking and Data Relay Satellite System (TDRSS), consisting of a pair of spacecraft in synchronous orbit, will provide essentially uninterrupted relay between satellites at all altitudes and a ground station at White Sands, New Mexico. Satellite cross-links and relay COMSATs are crucial for freeing satellites of their dependence on overseas ground stations.

Navigation

Navigation is not a glamorous mission, but is is essential for supporting reconnaissance, weapon delivery (including submarine-launched ballistic missiles, SLBMs), precision emplacement of sensors and mines, and rendezvous. Terrestrial navigation systems have either restricted coverage (*e.g.*, LORAN) or poor accuracy (*e.g.*, OMEGA). In one satellite navigation method, used by the U.S. Navy's TRANSIT system and its Soviet equivalent, the user listens to how the received frequency of a radio signal changes as the transmitting satellite passes from horizon to horizon, like the wail of an ambulance siren as it first approaches and then recedes. Knowing the satellite's orbit and the pattern of frequency change allows the receiver to deduce its location on the earth's surface. Global coverage points to polar orbits for these satellites; frequent revisits of all locations indicate a number of orbital planes.

Meteorology

Military operations, special operations, and reconnaissance planning all require knowledge of the weather patterns in distant parts of the globe.

Geodesy

This peacetime function has little importance for the ASAT problem, since it would be accomplished by the time hostilities began.

Though they are located in space, these satellites perform the rather mundane functions of a host of other military equipment (reconnaissance aircraft and ships, microwave communications towers, and terrestrial navigation beacons like LORAN). Though these satellites do not carry weapons and do not shoot at anything, some of them can directly support military operations. It therefore seems oddly inconsistent to seek to create a sanctuary in space for this "threatening" military equipment. Why shouldn't satellites be subject to attack like all the other instruments of warfare?

No single answer to this question applies to all satellites. What one can say is that next to these threatening satellites is a class of what I will call "benign" satellites that should *not* be subject to attack. Missle warning satellites exemplify this class most clearly. The much discussed RORSAT, a Soviet radar ocean reconnaissance satellite that tracks multibillion-dollar American carrier battle groups at sea and could direct air attack on them, is supposed to exemplify the threatening category most clearly, though in view of the limitations of the current version we should perhaps say that a future version of RORSAT would make the case more clearly.

In the case of other space missions, it is harder to decide whether they belong in the threatening or benign category, and many fall in between. It is vital to recognize that the designations "benign" and "threatening" inhere not in the spacecraft's mission only, but in the circumstances of its use as well. A benign U.S. photo reconnaissance satellite monitoring a crisis abruptly turns threatening to the Soviet Union when war begins and its daily imagery becomes the basis for air strikes on Soviet supply lines entering the theater. At this point the Soviets will wish to have an antisatellite weapon (ASAT).

If today's military uses of space include a substantial fraction of benign missions, in the future this fraction seems destined to decrease. Many of the potential future military uses of space are clearly threatening. It is natural to want to be able to threaten these satellites in return. Thus arises the basic paradox of antisatellite arms control: to the extent that ASAT development is suppressed and the vulnerability of spacecraft masked, the superpowers will be more and more tempted to deploy threatening spacecraft. And to the extent they do so, pressures will in turn build to set aside the treaty and deploy ASATs.

POSSIBLE FUTURE MILITARY USES OF SPACE

A host of hypothetical future space missions vie for attention and funding. Which of these concepts will actually reach the deployment stage depends not only on technical feasibility (not demonstrated in many cases) and on the value of mission they serve, but most importantly on their prospects for surviving antisatellite attack. Missions that would never be taken seriously if they had to face an unconstrained antisatellite threat will be much more tempting if the threat is constrained. Since some of these missions fall decidedly in the "threatening" category, giving them sanctuary in space could well prove intolerable over time.

Adjuncts to Current Missions

The advance of technology will permit support functions performed from space today to be performed better. For instance, introduction of SATCOM at extremely high frequencies in the U.S. MILSTAR system will allow improved resistance to jamming, low-probability-of-intercept transmission that does not betray the communicator's location or even existence, and better emergency communication through ionospheric regions disturbed by nuclear bursts. Missions performed by terrestrial equipment today might by augmented or backed up by spacecraft. For instance, blue-green laser communications are proposed as a backup to terrestrial and airborne VLF radio for communicating with missile submarines. Space-based infrared sensors could perform the vital job of continuously surveying all orbiting objects, replacing the current network of ground-based radars. Relay satellites like the shuttle-launched TRDSS continue the process of freeing U.S. satellites from dependence on overseas ground stations.

Elaborations to the Nuclear Offense

Four different possibilities can be envisioned in this category. First, space-based sensors might be used to seek out and direct attack on relocatable or mobile targets such as air defense radars, mobile missiles, and mobile (even airborne) command posts. A second elaboration would be a means by which to assess the damage to an opponent from an initial nuclear strike and re-strike whatever targets survived. One such scheme would use data from the Nuclear Detection System aboard Navstar GPS to observe detonations of U.S. weapons over the Soviet Union and to "fill in the blanks" where expected detonations failed to occur because of the imperfect reliability of U.S. missiles. Two-on-one targeting of silos and other hardened targets would then be unnecessary. Damage assessment would also support a "shoot-look-shoot" tactic designed to penetrate preferential ballistic missile defenses.

A third offensive elaboration would use satellite navigation to reduce missile guidance errors to tens of feet rather than hundreds of feet, ushering in "usable" low-yield strategic nuclear weapons and even nonnuclear strategic weapons. Satellite navigation could also reduce the cost of Midgetman missiles which must otherwise each carry an expensive guidance system to have silo-killing accuracy. The fourth type of hypothetical elaboration to the nuclear offense comprises the space-based components of all the countermeasurers the offense will need to compete with "Star Wars" defenses. Though these elaborations cannot be specified without specifying the type of defense system deployed, they would be akin to the short-range attack missiles (SRAMs), cruise missiles, stealth and other electronic countermeasures (ECMs), and ICBMs that were the elaborations made to U.S. offense of the 1950s, based upon the high-flying bomber, when the Soviet Union improved its air defenses. In the "Star Wars" case the space-based components of penetration systems might include orbiting jammers, shields, decoy dispensers, and antisatellite weapons.

Nuclear Defense

This includes all the beam and kinetic energy weapons, together with their sensors, discussed in the Strategic Defense Initiative. Orbiting radars or infrared sensors for tracking aircraft, and laser battle stations to attack them, might be components of a future air defense against intercontinental bombers. Lastly, this category includes still-hypothetical sensors for locating and tracking strategic missile submarines through their hydrodynamic, thermal, or other signatures.

Support for Conventional Forces

This is a vast category that ranges from the monitoring of rear areas (akin to peacetime strategic intelligence) to detailed participation in battlefield operations, for example, locating targets, guiding "smart" weapons to them, and relaying voice and data traffic.

Antisatellite Weapons (ASATs) and Satellite Defense (DSATs)

ASATs and DSATs comprise all the paraphernalia of a military competition in space: (1) mines, directed-energy weapons, kinetic energy weapons, jammers, and ECM pods to destroy or fool enemy satellites; (2) defensive escorts for friendly satellites, carrying jammers, decoys, shields, or weapons to fight off ASATs; and (3) space-tracking and identification sensors for ASAT, DSAT, and treaty monitoring.

Space-to-Earth Weapons

Space-to-earth weapons discussed from time to time include beam weapons, orbiting nuclear-armed and conventionally armed reentry vehicles (RVs), and electromagnetic pulse (EMP) generators. Space-to-earth beam weapons have to contend with atmospheric attenuation, which rules out many types, and with the abundant shielding available to terrestrial targets. Nuclear-armed RVs stored in space have never competed in terms of cost, accuracy, or command and control with RVs stored in the noses of ICBMs.

Human Presence in Space

The perennial question of the military utility of staffed spacecraft really should be divided into two questions. First, are there military space missions that can either only be done or be done much better by human beings? Second, do such missions require a continually staffed space station or just a space shuttle capable of periodic visits? A third question is whether the military will find uses for a space station if it is justified, built, and paid for by the civilian space program. This third question is easily answered in the affirmative and is sometimes confused with the first two questions, even though it does not address itself to the true military requirements for staffed spacecraft.

Human beings can perform varied, innovative, and subtle functions that cannot yet be mechanized. It also appears that humans can operate efficiently in space for at least six months without physical harm. But humans require life support, safety, and reentry systems that are expensive and heavy, and they need a habitat spacious enough to keep them physically and mentally healthy. Motions caused by humans moving about in the cabin can impair certain kinds of surveillance. Radiation is also a serious limitation: humans are about 100 times more susceptible to harm than ordinary space equipment and about 10,000 times more susceptible than hardened electronics. Operation in the radiation belts for more than a short period is impossible, and in the polar orbits most useful for earth surveillance, protons from solar flares would expose even shielded humans to radiation doses far in excess of those permitted for terrestrial workers. Staffed military spacecraft would also be very vulnerable to radiation from nearby nuclear bursts and to radiation from distant detonations that were trapped in space by the earth's magnetic field.

Continuous coverage and redundancy are usually more important than complexity for military spacecraft anyway, so many unstaffed satellites would obviously be preferable to a few staffed spacecraft. Satellite repair, replenishment, and assembly, identified by NASA as available from a space station, can also be accomplished from the shuttle. If necessary, the shuttle can be equipped with supplies to allow it to remain in orbit for longer periods than it now can. Since the space station would be in inclined LEO and most military satellites are in GEO or polar LEO, fetching the satellites to be repaired requires orbit transfer vehicles that need themselves to be refurbished on orbit. Repair will not pay for itself unless the number of candidate space systems to be repaired is large. GEO staellites have lifetimes of 7–10 years, after which users usually wish to launch improved models rather than repair old ones.

Photoreconnaissance satellites could profit from periodic refueling, since they use propellant to compensate for atmospheric drag experienced in their low orbits and to adjust their ground tracks for timely viewing of important reconnaissance targets. Assembly of large space structures from many small units transported separately to space has some theoretical attractiveness, but there is as yet no identified military need for it. Assembly, like repair, might be better accomplished from a shuttle than from a space station. For all these reasons, the Department of Defense and the intelligence community greeted the NASA space station rather coolly. Once NASA has made the investment, however, military users are certain to find the station convenient for some purposes.

PRINCIPLES FOR U.S. MILITARY EXPLOITATION OF SPACE

Some of the future military uses of space described above are technically fanciful, and some address military problems of peripheral concern, but an important reason that some of them have not gained popularity or been deployed already is that they have been judged too vulnerable to destruction by ASATs. ASAT limitations might encourage rather than discourage some of these deployments.

ASAT arms control faces two basic problems. First, ASAT attack on some space missions is both tempting and relatively easy. Complex satellites in low earth orbit will probably remain fairly cheap to attack in relation to their cost, and if they are engaged in threatening military activities they will present an irresistible temptation for ASATs. Other arms control regimes have sought to limit activities that were less easy and less tempting. The ABM Treaty conformed to the prevailing technical facts that effective missile defense could not be built. Militarizing the Antarctic and stationing nuclear weapons in space were not tempting enough to stimulate concerns over "breakout" of the treaties that forbade them. Limiting ASATs might mean swimming against the tide of technological advance and short-term military opportunity in a way that limiting these other activities by treaty did not.

The second problem for ASAT arms control is that not all uses of space are benign and deserve protection. Paradoxically, any possibility of sanctuary from attack will probably encourage the superpowers to place more and more threatening satellites in space.

Skirting these two problems will be a challenge for negotiators, and the resulting treaty, if one ever emerges, could be quite complex. It is therefore worthwhile to plot a clear course of actions the United States should take *with or without* ASAT arms control.

Let me close by stating six principles that I think should guide U.S. use of space for its national security:

1. Take advantage of the many means available to improve satellite survivability. The survivability features of satellites in orbit today are not a good indication of what is possible at relatively modest cost. No arms control provisions can protect a satellite whose designer has left it open to "cheap shots." Adequate satellite survivability programs are not an alternative to, but a *necessary precondition* for, effective arms control. Only to the extent that satellites can be made immune to all but elaborate, verifiable threats will ASAT limitations be meaningful.
2. Improve spacetracking and surveillance. In order to alert U.S. satellites to attack, to support attack upon Soviet satellites, and to monitor ASAT treaties, the U.S. will require much better space surveillance than it has today. Much more can be done with available technology.
3. Avoid dependence on vulnerable spacecraft. Space systems assigned wartime roles should have to prove themselves in terms of cost-effectiveness and survivability or not be assigned such roles. Deploying threatening satellites in a way that makes them inherently vulnerable to attack (*e.g.*, in low orbits) reflects bad military judgement. Satellites cannot be protected absolutely by any treaty, and no treaty can survive if such temptations to break out of it are ever-present.
4. Employ survivable backups to satellites. Almost all of the missions performed by satellites can be performed (not as well perhaps, but some-

times adequately and sometimes even better) by terrestrial systems. Thus data relay, reconnaissance, and navigation in the NATO theater can be performed from aircraft (in the nature of some current U.S. programs), remotely piloted vehicles, aerostats, and sounding rockets. Even if backups are not quite as capable as the satellite systems they replace, their existence might have the effect of reducing Soviet incentives to attack satellites in the first place.

5. To the extent possible, segregate on different satellites "benign" from "threatening" missions and nuclear-war-related missions from conventional-war-fighting missions. This will give the Soviet Union the opportunity to respect these distinctions and to exercise restraint in the kinds of threats it poses to "benign" missions like missile warning.
6. Plan to attack Soviet satellites to the extent dictated by U.S. security interests. No ASAT treaty will ban all methods of disrupting all types of satellites. The United States therefore cannot avoid the responsibility to develop a serious and reasonable policy towards attack on Soviet satellites. The U.S. should not forbear to possess ASATs if they are of a type not clearly forbidden by treaty, if using them would have an effect on Soviet military capability worth its cost (and not just fulfill someone's idea of symbolic strength), and if they are tailored to avoid posing a threat to "benign" Soviet satellites to the extent possible. In my mind, these criteria do not justify development of a high-altitude ASAT by the United States at this time, and they also raise questions about the high cost of the current F-15-launched ASAT. On the other hand, the U.S. should demonstrate the ability to give threatening Soviet satellites such as a future generation of ocean reconnaissance satellites and "Star Wars" battle stations a rough time in low earth orbit.

DISCUSSION OF THE PAPER

R. Garwin (*IBM Thomas J. Watson Research Center, Yorktown Heights, N.Y.*): I think the idea of theater backup capabilities for space-derived functions is very important. It is not always true that these are less capable because they are required to be only local. So, we can do a better job, with higher capacity communication systems and more timely surveillance if we are forced into doing it in the European theater by aircraft, rocket, etc., and if we emphasize that and fund it it can have a very stabilizing effect on the evolution and use of antisatellite capabilities on the other side.

A. B. Carter (*Harvard University, Cambridge, Mass.*): I completely agree and I overstated it if I said that backups are always less capable. A satellite gives you necessarily, whether you like it or not, a global capability. If you are fighting a theater war that might not be the best way to focus.

We have some programs like the Joint Tactical Information Distribution