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Arms Control in Space

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INTRODUCTION

While the policies related to arms control should be based primarily on their significance for military security, it is also necessary to take into account their effects on other activities, including those of commerce, and of government for matters not related to military security. Many of the international treaties for control of arms are complicated by the dual nature of the use to which both military and civilian equipment or systems can be put. Also, some of the purposes for which weapons can be employed can be considered as desirable in terms of international stability. And, to complicate matters still further, if the objective is to negotiate a treaty to protect assets of a particular type, the weapons which threaten these assets may have other roles threatening other assets not being considered in this treaty.
This problem of dual or multipurpose use presents itself in many aspects when the design of useful practical measures of arms control in space is being considered.

Firstly, many of the applications of satellite technology have both civilian and military uses. The civilian uses may be too indispensable for any restrictions to be acceptable. And if the civilian applications are permitted, it will probably be possible for the military to use them.

Secondly, many of the military applications of satellite technology can be employed for some purposes which can be described as offensive and destabilizing for security, but also for some other purposes which are defensive and supportive of international stability.

Thirdly, if it is desired to negotiate measures to protect satellites against threats to their safety, it must be recognized that many of the military systems which could be employed to destroy satellites have a dual-purpose nature themselves, such as the attack of ballistic missiles or of surface targets, or the launching of unarmed satellites.

This paper describes some of these problems which must be taken into account in any serious attempt to design a program for arms control an space.

THE MANY APPLICATIONS OF SATELLITES FOR THE SUPPORT OF PEACEFUL CIVILIAN ACTIVITIES

One of the principal reasons for the establishment of arms control in space is to protect the many satellites which perform invaluable services for civilian purposes. The main examples are communications, navigation, environmental monitoring, and control of civil air traffic. These and other functions are listed in Table I. The appearance of one, two, or three stars in the central column (headed "CIVILIAN") are an indication of the relative importance of these services. Any impediment to these activities would be regrettable.

THE MANY APPLICATIONS OF SATELLITES FOR THE SUPPORT OF MILITARY ACTIVITIES

TABLE I
SATELLITE FUNCTIONS

TYPE	CIVILIAN	MILITARY
MMUNICATIONS		
-LONG DISTANCE RELAY	***	***
-REAL TIME IMAGERY	*	***
NAVIGATION		
-GPS	**	***
OVERHEAD IMAGERY OF THE EARTH'S SURFACE		
-MAPPING	*	**
-ENVIRONMENTAL MONITORING		
-POLLUTION	**	
-FLOODS, FIRES, EARTHQUAKES, ERUPTIONS	**	
-AGRICULTURE, FORESTS, MINERAL PROSPECTING	**	
-INTELLIGENCE	*	***
-SURVEILLANCE	*	***
-RECONNAISSANCE	*	***
-ARMS CONTROL MONITORING		***
DETECTION & TRACKING OF MOVING OBJECTS		
-COOPERATING AIRCRAFT	**	*
-NON-COOPERATING AIRCRAFT		(**)
-BALLISTIC MISSILES		
-LAUNCH		***
-TRACKING		**
-SURFACE SHIPS AT SEA	*	**
-MOVING LAND VEHICLES		(**)
DETECTION OF NUCLEAR EXPLOSIONS		
-IN PEACE, FOR INTELLIGENCE, ARMS CONTROL, & ACCIDENTS	*	**
-IN WAR, FOR RETARGETING		*
ATMOSPHERIC MONITORING		
-WEATHER FORECASTING	**	**
-HURRICANE WARNING	**	
-ENVIRONMENTAL MONITORING		
-POLLUTION, POISON AEROSOLS	**	*
SCIENTIFIC RESEARCH		
-ATMOSPHERE, CLIMATOLOGY, GEODESY, ASTRONOMY	**	*

The initial development of the techniques necessary for the launching and operation of earth satellites was pursued in the 1950s and 1960s for military purposes. Applications to civilian uses came later, but was able to profit from the technology acquired in the military programs.

Today the most important military applications include communications; collection, rapid processing, and dissemination of overhead imagery, with vital consequences for the effectiveness of surveillance and reconnaissance, monitoring of arms control agreements, and the general support of intelligence; navigation, including the guidance of missiles and unmanned aerial vehicles; and warning of the launching of large rockets. In the future, it is likely that satellites will become able to detect and track moving objects on the earth's surface or in the air, which would give them a vital role in defence against aircraft and missiles, and for observation of enemy movements in a theatre of war.

These and other functions are listed in the right-hand column of Table I, with the number of stars indicating their relative importance. Note the large number of times that both civilian and military functions appear on the same line. While military and civilian organizations may prefer to operate their own satellites only for their own purposes, there are an increasing number of opportunities for one satellite to serve both types of user. For example, defence organizations often rent channels on civilian satellites, or buy imagery collected by civilian satellites. The Global Positioning System, created for military purposes, has many civilian users

The entries in Table I represent functions which are well established today, except for the military functions of detection and tracking of non-cooperating aircraft, missiles in flight, and moving land vehicles (for which the stars are enclosed in parentheses). But there are reasons to expect that these capabilities will soon be available, and will prove to be very important for air and missile defence.

THE ROLES FOR SATELLITES IN THE DELIVERY OF WEAPONS

While satellites are now being employed for a host of very significant military functions, at present none are in service as orbiting platforms for weapons. In the 1970s the USSR deployed an anti-satellite (ASAT) system which used a ground-based SS-9 Intercontinental Ballistic Missile (ICBM) booster rocket to inject an ASAT vehicle into the same orbit as a target satellite. The ASAT vehicle then slowly manoeuvred close enough to be able to destroy its target by detonation of high explosive which drove fragments into the target. This "co-orbital" ASAT system is believed to be no longer operational.

Since there are no weapons in space today, an evident objective for arms control could be to prohibit all space-based weapons.[1] However, satellites are assuming an ever-growing role in the application of weapons based on the earth, which will increase once the techniques are mastered for the tracking from space of moving objects on the earth. The prohibition of weapons based in space would not prevent the use of space for the employment of many weapon systems not based in space.

[1] The precedent is sometimes cited of the Antarctic Treaty of 1959, which bans all weapons from that continent.

Today, satellites provide warning of the launching of ballistic missiles, tracking of ships at sea, and identification and location of fixed targets on land. This is the type of information needed before surface-based weapons can be used to attack these targets. But once it becomes possible to detect and track missiles and aircraft in flight, and vehicles moving on land, cueing and guidance can be provided to the sites, ships, and aircraft controlling the weapons, and perhaps even directly to the weapons themselves. This list is illustrated on Table II. The roles that are already being played today are underlined.

Only two of these roles depend on weapons based in the satellites. These are for the attack of other satellites, and of ballistic missiles in flight. The satellite-borne weapon could be a rocket-propelled ASAT or Anti Ballistic Missile (ABM) missile, a laser, or a nuclear device for the generation of an electromagnetic pulse.

Prohibition of satellite-borne weapons could reduce the threats to satellites and ballistic missiles that could be posed by future space-to-space weapons, but would do nothing to reduce the role of satellites for the support of surface-based weapons.

TABLE II
PROBABLE FUTURE ROLES FOR SATELLITES IN WEAPON DELIVERY

TARGET	WARNING	CUEING AND GUIDANCE FOR SURFACE-BASED WEAPONS	WEAPON LAUNCHING
SATELLITE			ASAT MISSILE, LASER OF E.M.P.
BALLISTIC MISSILE	LAUNCH DETECTION	MISSILE TRACKING	ABM MISSILE OR LASER
AIRCRAFT	DETECTION	TRACKING	
CRUISE MISSILE	DETECTION	TRACKING	
SHIP UNDER WAY	DETECTION	TRACKING	
MOVING LAND TARGET	DETECTION	TRACKING	
FIXED SURFACE TARGET	IDENTIFICATION	LOCATION	

THE NON-NUCLEAR THREATS TO SATELLITES IN LOW EARTH ORBIT (LEO)

Most of the satellites whose functions could be considered to be destabilizing operate in LEO (as well as many that are stabilizing). Example include the identification and precise location of targets, support for terrestrial operations of war, and missile guidance, the functions which opponents would have the greatest incentives to prevent.

Satellites in LEO could be attacked by surface-based weapons using components already designed for use in ballistic missiles, ABM systems, and space launching, but with the guidance and warheads designed for an ASAT role.

Kill by Kinetic Energy

In order to maintain a circular orbit at altitudes below 1000 km, a satellite must move at a speed of more than 7.4 km/sec. The kinetic energy associated with this enormous velocity makes a lightly constructed satellite extremely vulnerable to destruction by collision with any small mass, whether stationary or moving at a much lower velocity. To use this situation to achieve a "kinetic kill" an ASAT warhead need only disperse a pattern of small objects into the path of the satellite, so that it collides with one of them. The satellite provides the kinetic energy for its own destruction, and there is no need for a heavy explosive charge in the ASAT payload. The key capability needed in the ASAT missile is guidance accurate enough to place the small objects in the satellite's easily predictable path.

Kill by Fused Fragmenting Warhead

An alternative ASAT kill mechanism, somewhat less demanding of precise guidance (but depending on precise timing of a fusing device), and long developed for anti-missile and antiaircraft defence, is to use a high explosive warhead to drive fragments into the target at the instant when the warhead is in the best position relative to the satellite. In either case, the ASAT system relies on a guided missile completing a long trajectory in a very short time, to deliver an ASAT warhead very close to the fast-moving satellite. While this is a most demanding operation, it should be easier to incapacitate a delicately built satellite mounting vulnerable sensors, antennas, and solar panels, and approaching along a known path at a predicted time, than to intercept and destroy a toughly built ballistic missile with a thick heat shield for atmospheric reentry, launched at an unpredictable time along a trajectory that cannot be forecast with precision.

Conversion of Ballistic Missiles to an ASAT Role

To reach a terrestrial target at a range of 1000 km, a Short-Range surface-to-surface Ballistic Missile (SRBM) must be launched with a burnout velocity of 3 km/sec. If fired straight up, its SRBM payload would attain an altitude of 500 km, well into the orbital heights of LEO satellites. A payload specially designed for the ASAT role would probably be considerably lighter than the one optimized for the SRBM role, so that the SRBM booster rockets could propel it to altitudes well above 500 km.

Conversion of ABM Missiles to an ASAT Role

If it is to provide effective defence of targets over a considerable area against ballistic missiles, an ABM interceptor rocket needs to have a burnout velocity not very much less than that of the attacking missile. While the "lower tier" or endoatmospheric

Anti-Theatre Ballistic Missile (ATBM) systems such as the American Patriot may not be adaptable for an ASAT role, the American "upper tier" ATBM projects such as THAAD and Navy Area Defence will need booster rockets which could put payloads up into the orbits of Theatre Ballistic Missiles (TBMs). And a system using rockets able to intercept ICBMs could certainly put payloads up to altitudes of nearly all Low Earth Orbits.

Conversion of Space Launchers to an ASAT Role

Finally, and obviously, any Space Launch Vehicle able to propel a satellite payload into orbit can also put an ASAT payload (of no greater mass) into the satellite's orbit.

Laser Weapons

Apart from weapon systems which depend on a rocket-propelled guided missile to transport an ASAT (or an ABM) warhead up to the path of the satellite (or ballistic missile) target, research and development has been devoted to the transmission of destructive energy directly from the defensive site to the target. The most promising method appears to be the use of electromagnetic radiation. While the primary objective of the R&D has been for anti-missile defence, it is clear that the same technology could be applied against satellites.

Generation by a laser of coherent electromagnetic radiation in the optical band permits the focusing of the transmission into an extremely narrow beam, allowing the energy to be deposited, with the speed of light, onto a small area of a very distant target.

Application of this technology is constrained by the scattering or absorption of the laser beam in the lower parts of the atmosphere, by clouds, fog, rain, and water vapour. Another problem is posed by the need for a heavy installation for a powerful laser transmitter. Two solutions being pursued are to locate the transmitter at the top of a high mountain, or in a large aircraft. Provision of adequate electrical power should not be a problem on the ground, but in the airborne version the power would probably be generated by a chemical laser.

The Many Possible ASAT Weapons

It can be concluded that satellites in LEO are vulnerable to attack by surface-based systems using warheads designed for ASAT, boosted up to LEO altitude by rocket propulsion of the type already deployed for surface-to-surface missiles, ABM interceptors, and space launches. In the near future they are also likely to be threatened by laser weapons, probably deployed with the primary role of ABM defence, but with an ASAT capability, either based on high ground or in large aircraft.

THE NON-NUCLEAR THREATS TO SATELLITES IN GEOSYNCHRONOUS EARTH ORBIT (GEO)

Almost all of the functions provided by satellites in GEO are of a stabilizing nature. Examples are launch warning, detection of nuclear explosions, and rapid worldwide communications.

To reach the 36,000 km altitude of GEO in a vertical launch requires a burnout velocity of more than 10 km/sec (nearly enough to escape from the earth forever), which is far beyond the launch velocities necessary for ICBMs, or AICBM interceptors.

The most likely means of attacking satellites in GEO appear to be by other satellites orbiting at high altitudes and armed with ASAT laser weapons.

THE NUCLEAR THREAT TO SATELLITES

While physical structures are vulnerable to blast and heat, electronic devices are also vulnerable to electromagnetic radiation. A nuclear explosion detonated on or near the surface of the earth transmits most of its immediately destructive energy in the form of blast and heat. But if detonated at a high altitude, above the air in the lower atmosphere and some of the layers of the ionosphere, there is no blast, and much of the energy is transmitted in the form of a powerful pulse of radiation (the Electromagnetic Pulse, EMP) which is extremely destructive to sensitive electronic devices such as computer chips, sensors, circuitry, and solar panels. Serious damage would be caused to installations on the surface and in aircraft, and especially to satellites, even those situated at great distances from the explosion.

During the decade beginning in 1964 the USA had ASAT batteries on two islands in the Pacific Ocean, using Nike Zeus rockets designed for the AICBM role, armed with nuclear warheads.

The American "Starfish" experiments, conducted in 1962, prior to the signing of the Outer Space Treaty, disabled several satellites, and also electrical equipment on islands in the Pacific, and first alerted scientists to the dangers of the Electromagnetic Pulse.

The effects of an EMP would be essentially indiscriminate, inflicting damage on electronic devices over a wide part of the earth and the space above it, including not only satellites but also the installations on the ground necessary to communicate with them and control them. Use of such a weapon would be in contravention of several of the international treaties on arms control.

EXISTING TREATIES INVOLVING WEAPONS IN SPACE

The Outer Space Treaty

The multilateral Outer Space Treaty, first signed in 1967, and now involving 120 participating states, prohibited the placing in orbit around the earth of any objects carrying nuclear weapons or any other weapons of mass destruction. The treaty contained no provision for verification.

The ABM Treaty

The ABM Treaty, signed in 1972, included the prohibition of the development, testing, or deployment of sea-based, air-based, or space-based systems designed for the interception of ballistic missiles of intercontinental range, and of components of such systems. It was agreed that in the event of future ABM systems employing "other physical principles", limitations on their use would be discussed between the parties. The only concession to a need for verification was an agreement to not interfere with National Technical Means (NTMs) or use deliberate measures of concealment. This provision has significant implications for space, since the primary form of NTM used for verification has been, and still is, space surveillance.

Much has changed since 1972, including the dissolution of the USSR, one of the two original signatories, but its obligations have been assumed by the four successor states which possessed ICBMs. A factor of major importance is the development of weapons for defence against theatre ballistic missiles (TBMs). As the ranges of TBMs increase, systems able to intercept them will require capabilities which will begin to approach those needed for defence against ICBMs. While the ABM Treaty makes no mention of a capability to attack satellites, it must be realized that a system able to intercept an ICBM also possesses most of the performance characteristics that would enable it to intercept a satellite in Low Earth Orbit. Another recent development is the laser weapon, potentially capable of destroying ballistic missiles in flight, which qualifies as "an other physical principle" as compared to the rocket weapons of the 1970s.

Nuclear Test Ban Treaties

Some other international treaties have some applicability to space. For example, the 1963 Limited Test-Ban Treaty and the 1996 Comprehensive Test-Ban Treaty prohibited nuclear test explosions in space. In 1979, SALT II banned the development, testing, and deployment of systems for placing into earth orbit nuclear weapons or any other kind of weapons of mass destruction, including fractional orbital missiles.

The Undefined Boundary Between the Atmosphere and Outer Space

An unresolved matter in space law is the boundary demarcating the atmosphere from outer space, and aircraft from space vehicles. Vehicles are being developed which fly part of their trajectories within the atmosphere, using aerodynamic lift and air for combustion, but part far above the altitudes at which air can be used for lift, control, or propulsion.

PROBLEMS OF VERIFYING COMPLIANCE WITH TREATY UNDERTAKINGS

Objectives of most important arms control treaties are to reduce international tensions and the fears which motivate increased spending on weapons, and to build confidence that the capabilities and intentions of potential adversaries are not being directed towards aggression. In most cases, especially when relations in the recent past have provided reasonable cause to suspect the intentions of some of the signatories of the treaty, an important requirement is to include in the treaty adequate provisions for verification that all participants are in fact carrying out the obligations which they have undertaken.

The Outer Space Treaty contains no provision for verification, and the ABM Treaty simply forbids interference with such verification as can be exercised by NTMs. The Limited Test-Ban Treaty prohibited nuclear tests in the atmosphere, outer space, and under water, and assumed that such tests could be verified by existing systems.[2]

[2] After much agonizing over inability to verify its non-occurrence, the eventual LTBT permitted underground testing. The CTBT extended the prohibition to underground testing, and introduced an international monitoring system for verification. However, all of the focus on verification was directed towards detection of underground testing.

Verification of the Roles and Capabilities of Satellites

Verification of treaties concerning arms control of satellites would have three main areas of application. One would concentrate on activities and equipment on the ground, of the type needed for preparation of the launching of satellites. It could hardly accomplish much unless some form of inspection of the satellites were permitted shortly prior to their launching. Parties to the treaty would have to agree to a considerable degree of intrusion.

A second type of verification would be the monitoring of the trajectory of the satellite subsequent to its launching. Cooperation would not be essential, and this monitoring could be conducted by systems existing in NTMs today.

The third type would be any possible examination of the satellite in orbit, together with monitoring of any communications made between it and control posts on the ground or of other radiations or activities which could be observed. Cooperation would not be essential, but confidence would be built if the owners of the satellite were prepared to volunteer explanations regarding its activities.

Verification of Measures to Protect Satellites

The most serious threats to satellites described in earlier sections of this paper are essentially by-products of the multipurpose capabilities of surface-based systems designed (and in many cases already deployed) for their primary roles, such as attack of surface targets, defence against missiles, and space launchings. Conversion to ASAT from their primary role would likely involve replacement of payloads and guidance and control programs, which are not changes easily detected by remote sensing.

Clearly, any treaty intended to protect satellites would have to focus on control over the use of these surface-based systems for the ASAT role. This would require intrusive inspection of closely-guarded and sensitive installations whose main purpose was not ASAT but other functions considered to be greater importance for national security. It seems most improbable that the owners would be prepared to compromise the security of their ballistic missile, ABM, or space launch facilities for the sake of verifying an agreement to protect satellites.

The conclusion would be that for states depending on ballistic missiles, ABM defence, or domestic space launchings, (which are the very ones able to pose a threat to satellites), willingness to participate in a treaty for the protection of satellites would probably not extend to the agreement for intrusive verification, including the right to inspect on demand all of their relevant installations. Most of them might, however, agree to undertakings to abstain from development, testing, deployment, or use of ASAT weapons, perhaps with certain caveats.

POSSIBLE ADVANCES IN ARMS CONTROL

There are two categories of arms control which could be considered for application to space. One is to limit the capabilities of satellites for offensive purposes. The other is to protect satellites from the things which can be used to destroy them. Both objectives face formidable complications, and under present circumstances there is no practical possibility of attaining far-reaching measures of control. It may, however, be worthwhile to seek modest steps which would have some chance of widespread acceptance.

Prohibition of Weapons in Space

Most of the useful services which satellites perform (as well as some that could be described as harmful) depend on their sensors and communications. Today, there are no weapons based in space, or immediate prospects of their use. The most likely uses would be against other satellites, and possibly ballistic missiles. The weapons would probably be homing missiles or lasers. In the following text it will be assumed that to be chosen for the ASAT role an armed satellite would have to be able to destroy several targets within a fairly short time.

Unless an ASAT satellite armed with space-to-space missiles were orbiting in close proximity to its targets prior to the attacks, it would need sufficient manoeuvrability to move close to each target, or else have missiles able to home on their target from long range. This implies fairly large missiles, and hence a large satellite, whose structure might be observable by remote sensing devices and might well indicate its purpose.

In view of their long range reach in empty space, their virtually instant time of flight, and the ability to fire as many bursts as permitted by their power supply, lasers offer advantages as space-to-space weapons. The main limitation for basing in a satellite would probably be supply of energy sufficient to deliver a number of very powerful bursts. It seems unlikely that the usual method of supplying electrical power by solar panels would be adequate. The American design of an airborne laser weapon suggests that a chemical laser would be the system of choice. However, another even more ambitious solution, which would provide virtually unlimited "ammunition" for the laser, would be to employ a small nuclear reactor.[3]

Prohibition of the placing of nuclear power sources in satellites would have implications other than prevention of very powerful laser weapons. The USSR required nuclear power to operate the radar for its "RORSAT" ocean surveillance satellite,[4] and the placing of very long-range radars or other electrically powered sensors in other satellites (perhaps in High Earth Orbit) could depend on a large continuous supply of electrical energy. Nuclear power is sometimes employed in scientific satellites, especially when their trajectories take them too far from the sun to make collection of solar power sufficient. But considerations in favour of abolition of reactors in space are that radioactivity in low earth orbit can interfere with scientific observations, and that an accident during the launching of a satellite containing a nuclear reactor could cause a disaster on the earth.

Verification of the presence of ASAT weaponry or of a nuclear reactor in a satellite would probably be possible, either during inspection prior to launch or by remote

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[3] Whether this would be considered to be a nuclear weapon, which would be a violation of the Outer Space treaty, or its use to be a nuclear explosion, which would breach the LTBT, would be a matter for space lawyers to decide.

[4] A RORSAT designated as COSMOS 954 fell in Northern Canada in 1978, spreading radioactive debris over large (fortunately sparsely inhabited) area.

sensing while in orbit. And if the treaty included the prohibition of full scale testing in space, this would very likely be observed by NTM if not by an international verification agency.

A treaty prohibiting laser weapons would need to distinguish the weapons, which must have high power, from lasers used for legitimate purposes such as remote sensing, communications, and scientific research. It would not be acceptable to ban all lasers, and it would be necessary to be able to verify that the lasers that were in a satellite, ship, aircraft, or ground installation were not capable of being used as weapons.

Measures to Protect Satellites

The prohibition of the stationing of weapons in space, just discussed, would provide protection of satellites against space-to-space attack, by weapons which do not yet exist. However, as described earlier, the main threats to satellites are from surface-to-space attack by weapons which could easily be made from other systems which do exist today. Compliance with undertakings to refrain from making these modifications could not be verified without acceptance of intrusive inspection of sensitive defence installations.

A partial solution to this dilemma could be the prohibition of testing, rather than development or deployment of ASAT weapons. The testing of surface-to-space weapons should be amenable to detection by several monitoring systems.

Another partial measure of protection of satellites would be to single out those in Geosynchronous Earth Orbit (GEO) and perhaps High Earth Orbit (HEO). There are two main reasons for selecting this subset of all the orbits (although it does not include the majority). They encompass some of the most widely used civilian and military functions (communications and weather forecasting), and of the most stabilizing and defensive military functions (warning of missile launch and detection of nuclear explosions). And they are not accessible to surface-based ASAT weapons constructed from modifications to ballistic and ABM missiles. Their natural enemies are weapons projected by Space Launch Vehicles or ASAT satellites. A surface launched ASAT missile would be large and expensive, and would take several hours to reach GEO. Tests would be observable. An ASAT satellite would be prohibited by a ban on weapons in space.

An agreement to prohibit ASAT in GEO would do little to protect the large number of satellites in LEO, but it might be acceptable to the space powers who are not ready to forego their dependence on ballistic missiles and ABM systems, and perhaps also their future power to destroy satellites in LEO.