**Strategic Defense Initiative**

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| **Strategic Defense Initiative Organization** |
| **SDIO** |
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| **Agency overview** |
| **Formed** | 1984 |
| **Dissolved** | 1993 (renamed) |
| **Superseding agency** | Ballistic Missile Defense OrganizationMissile Defense Agency |
| **Jurisdiction** | Federal government of the United States |

The **Strategic Defense Initiative** (**SDI**) was proposed by U.S. President Ronald Reagan on March 23, 1983, to use ground and space-based systems to protect the United States from attack by strategic nuclear ballistic missiles. The initiative focused on strategic defense rather than the prior strategic offense doctrine of mutual assured destruction (MAD). The **Strategic Defense Initiative Organization** (SDIO) was set up in 1984 within the United States Department of Defense to oversee the Strategic Defense Initiative.

The ambitious initiative was widely criticized as being unrealistic, even unscientific as well as for threatening to destabilize MAD and re-ignite "an offensive arms race". In light of Reagan's vocal criticism of the MAD doctrine (Mutually Assured Destruction) the SDI (Strategic Defense Initiative) was an important part of his defense policy intended to offset MAD bias. It was soon derided, largely in the mainstream media, as "Star Wars," after the popular 1977 film by George Lucas. In 1987, the American Physical Society concluded that a global shield such as "Star Wars" was not only impossible with existing technology, but that ten more years of research was needed to learn whether it might *ever* be feasible.

Under the administration of President Bill Clinton in 1993, its name was changed to the Ballistic Missile Defense Organization (BMDO) and its emphasis was shifted from national missile defense to theater missile defense; and its scope from global to more regional coverage. It was never truly developed or deployed, though certain aspects of SDI research and technologies paved the way for some anti-ballistic missile systems of today. BMDO was renamed to the Missile Defense Agency in 2002. This article covers defense efforts under the SDIO.

Under the SDIO's Innovative Sciences and Technology Office, headed by physicist and engineer Dr. James Ionson, the investment was predominantly made in basic research at national laboratories, universities, and in industry, and these programs have continued to be key sources of funding for top research scientists in the fields of high-energy physics, supercomputing/computation, advanced materials, and many other critical science and engineering disciplines: funding which indirectly supports other research work by top scientists, and which would be politically impossible to fund outside of the defense budget environment.

**History**

**Bombers to ICBMs**

Although the Germans put considerable effort into the first surface-to-air missiles (SAMs) after 1943, they did not have enough time to develop operational-level weapons before the war ended.

Their research proved valuable to teams in the US and USSR, where missile programs slowly developed in the immediate post-war era. As the cold war started, the Soviets found themselves facing massive USAF and RAF bomber fleets they could not hope to counter in the air. In response they dramatically increased their efforts in SAM development, deploying the SA-1 Guild system around Moscow as early as 1955. This was followed by the dramatically improved and semi-mobile SA-2 Guideline, a weapon that remains in service in the 2000s (decade). Similar US and UK weapons soon followed. By the late 1950s, as missiles developed both in quality and number, the ability for the US air fleet to penetrate Soviet airspace was increasingly at risk.

In response, both sides increased their efforts to develop long-range missiles. The Soviets, with no effective bomber force of their own, put considerable effort into their program and quickly brought their basic R-7 Semyorka system into operation in 1959. The US's SM-65 Atlas followed almost immediately thereafter. These early examples were useful only for attacking large targets like cities or ports, but their relative invulnerability and low cost provided both sides with a credible force in an era of stiffening air defenses.

**ABMs**

At first it appeared that the ICBM could be countered by systems similar to the ever-evolving SAMs already in operation. The ICBM's high trajectory meant they became visible to defensive radars not long after being launched, which meant that defensive systems would have time to prepare. Although they moved quickly in flight, early re-entry systems slowed dramatically once they reached the lower atmosphere, which gave time for a fast missile to attack it. By the early 1960s both nations were working on their first anti-ballistic missile (ABM) systems.

As ABMs were being developed, countermeasures were also being studied. As the systems generally used long-range radars to find and track the incoming warheads, the simplest solution was to add radar reflectors and other decoys to the launch. These took up little room or weight, but would make a radar return that looked like an additional warhead. This would force the defender to use more ABMs to ensure the "right" object was hit, or wait until they started to re-enter, when the lighter objects would slow down faster and leave the warhead racing ahead. Neither option was particularly attractive in cost terms, generally requiring more and faster missiles.

A better understanding of electromagnetic pulse (EMP) presented new problems; a warhead set off at high altitudes and long ranges from the defensive missiles could blind the radars, making the incoming warheads only become visible at lower altitudes. This would further reduce the amount of time the ABM system had to react. Systems using non-obvious approaches might be able to blind the radars in a sneak attack; the Soviets developed the R-36 with a system called Fractional Orbital Bombardment System to allow attacks on US missile fields from low altitudes and/or from the south, while the US relied on manned bombers for the same role.

Making matters worse was the continual increase in ICBM numbers. Even before the systems were ready for use, the number of interceptor missiles needed to effectively deter an attack kept increasing. As the ABM systems were expensive, it appeared the simplest way to defeat them was to simply make more ICBMs and deliberately start an arms race the defender could not win. The introduction of MIRV systems dramatically upset this in the favor of the attack; missiles now carried several warheads that would be dispersed over wide areas, so now every new ICBM built would require a small fleet of ABMs to counter it. Both the US and USSR rushed to introduce new weapons with MIRV systems, and the number of warheads in the world rapidly proliferated.

Whether or not deploying an ABM system was worthwhile was a highly contentious issue. The US scaled back their plans significantly and their Sentinel Program aimed only to counter the small Chinese ICBM force, a limited Soviet attack or an accidental launch. By the late 1960s, widespread efforts were underway to solve the problem diplomatically instead of with more missiles. The Anti-Ballistic Missile Treaty, signed in 1972, placed limits on the number of ABM systems, later followed by limits on the number of warheads. Both countries continued to deploy a single ABM site; the US briefly deployed a single site under their Safeguard Program, while the Soviets deployed A35/A135 missile defense system around Moscow.

**Attack from above**

Throughout the development of the ABM, another possibility existed that avoided most of these problems. If the interceptors were placed in orbit, some of them could be positioned over the Soviet Union at all times. These would fly "downhill" to attack the missiles, so they could be considerably smaller and cheaper than an interceptor that needed to launch up from the ground. It was also much easier to track the ICBMs during launch, due to their huge infrared signatures, and disguising these signatures would require the construction of large rockets instead of small radar decoys. Moreover, each interceptor could kill one ICBM; MIRV had no effect. As long as the interceptor missile was inexpensive, the advantage was on the side of the defense.

The US Air Force had studied these concepts under "Project Defender" as early as 1958, which included work on the "Ballistic Missile Boost Interceptor", or BAMBI. BAMBI interceptors would be deployed on a series of satellites, and would be launched towards ICBMs as they climbed. As they approached the ICBM, they would open a large metal net, which would destroy the missile on impact. Depending on assumptions about the accuracy of the system and the number of missiles it would have to face, between 400 and 3,600 such satellites would be needed in order to keep enough above the USSR at any one time. The Air Force concluded that there was simply no way to launch the required number of satellites, let alone have any way to service them. As their space logistical abilities improved through the 1960s, they continued to study the problem, but in each case the problem of increasing ICBM numbers meant the numbers of interceptors needed grew to overwhelm any possible launch capability.

However, the introduction of the laser in the 1960s appeared to offer the possibility of a way out of the problem. The amount of time needed to attack any one missile was known as the "dwell time", and if a powerful laser had a short dwell time, say 10 seconds, it would be able to attack multiple missiles during the minutes while the ICBM was launching. Given current laser energies this was impractical, but the concept was studied throughout the 1960s and later.

**X-ray laser**

In 1979 Edward Teller contributed to a Hoover Institution publication where he claimed that the US would be facing an emboldened USSR due to their work on civil defense. Two years later at a conference in Italy, he made the same claims about their ambitions, but with a subtle change; now he claimed that the reason for their boldness was their development of new space-based weapons. In fact, there was no evidence at all that such research was being carried out, what had really changed was that Teller was now selling his latest nuclear weapon, the x-ray laser. Finding limited success in his efforts to get funding for the project, his speech in Italy was a new attempt to create a missile gap.

The new weapon was the result of a 1977 development by George Chapline, Jr. of Lawrence Livermore's "O-Group". Livermore had been working on x-ray lasers for some time, but Chapline found a new solution that used the massive release of x-rays from a nuclear warhead as the source of light for a small baseball-bat sized lasing crystal in the form of a metal rod. The concept was first tried out in 1978s underground nuclear test "Diabolo Hawk" but had failed. Peter Hagelstein, new to O Group, set about creating computer simulations of the system in order to understand why. At first, he demonstrated that Chapline's original calculations were simply wrong and the Diabolo Hawk system could not possibly work. But as he continued his efforts, he found, to his dismay, that using heavier metals appeared to make a machine that would work. Through 1979 a new test was planned to take advantage of his work. The follow-up test in November 1980s "Dauphin" appeared to be a success, and plans were made for a major series of experiments in the early 1980s under "Excalibur".

Since the lasing medium was fairly small, a single bomb could host a number of them and attack multiple ICBMs in a single burst. The Soviet ICBM fleet had tens of thousands of *warheads*, but only about 1,400 *missiles*. If each satellite had two dozen lasers, two dozen satellites on-station would significantly blunt any attack. In Molniya orbits, where the satellites would spend much of their time over the USSR, only a few dozen satellites would be needed, in total. An article in *Aviation Week and Space Technology* described how the devices "... are so small that a single payload bay on the space shuttle could carry to orbit a number sufficient to stop a Soviet nuclear weapons attack". Some time later Teller used similar language in a letter to Paul Nitze, who was preparing a new round of strategic limitations talks, stating that "A single x-ray laser module the size of an executive desk... could potentially shoot down the entire Soviet land-based missile force..."

Livermore is just one of several major US weapons labs. Other labs had been working on ideas of their own, from new space or ground-based missiles, to chemical lasers, to particle beam weapons. Angelo Codevilla argued for similar funding for powerful chemical lasers as well. None of these efforts were taken very seriously by members of the Carter administration. In a meeting with Teller and Lowell Wood, a critic noted that the Soviets could easily defeat the system by attacking the satellite, whose only defense was to destroy itself. They also pointed out that the US public would be unlikely to accept nuclear bombs in space, regardless of the potential benefits. At the time Teller was stymied by these arguments; the concept was later adapted to be popped-up from submarines based off the Russian coast.

**Initial impetus**

In 1979 Ronald Reagan visited the NORAD command base under Cheyenne Mountain where he was first introduced to the extensive tracking and detection systems extending throughout the world and into space. However, he was struck by their comments that while they could track the attack down to the individual targets, there was nothing one could do to stop it. Reagan felt that in the event of an attack this would place the president in a terrible position between immediate counterattack or attempting to absorb the attack and maintain an upper hand in the post-attack era. In the fall of 1979, at Reagan's request, Lieutenant General Daniel O. Graham conceived a concept he called the High Frontier, an idea of strategic defense using ground- and space-based weapons theoretically possible because of emerging technologies. It was designed to replace the doctrine of Mutual Assured Destruction, a doctrine that Reagan and his aides described as a suicide pact.

The initial focus of the strategic defense initiative was a nuclear explosion-powered X-ray laser designed at Lawrence Livermore National Laboratory by a scientist named Peter L. Hagelstein who worked with a team called 'O Group', doing much of the work in the late 1970s and early 1980s. O Group was headed by physicist Lowell Wood, a protégé and friend of Edward Teller, the "father of the hydrogen bomb".

Ronald Reagan was told of Hagelstein's breakthrough by Teller in 1983, which prompted Reagan's March 23, 1983, "Star Wars" speech. Reagan announced, "I call upon the scientific community who gave us nuclear weapons to turn their great talents to the cause of mankind and world peace: to give us the means of rendering these nuclear weapons impotent and obsolete." This speech, along with Reagan's Evil Empire speech on March 8, 1983, in Florida, ushered in the final major escalation in rhetoric of the Cold War prior to a thawing of relations in the mid-to-late-1980s.

The concept for the space-based portion was to use lasers to shoot down incoming Soviet intercontinental ballistic missiles (ICBMs) armed with nuclear warheads. Nobel Prize-winning physicist Hans Bethe went to Livermore in February 1983 for a two-day briefing on the X-ray laser, and "Although impressed with its scientific novelty, Bethe went away highly skeptical it would contribute anything to the nation's defense."

**Project and proposals**



President Reagan delivering the March 23, 1983 speech initiating SDI

In 1984, the Strategic Defense Initiative Organization (SDIO) was established to oversee the program, which was headed by Lt. General James Alan Abrahamson USAF, a past Director of the NASA Space Shuttle program. Research and development initiated by the SDIO created significant technological advances in computer systems, component miniaturization, sensors and missile systems that form the basis for current systems.

Initially, the program focused on large scale systems designed to defeat a Soviet offensive strike. However, as the threat diminished, the program shifted towards smaller systems designed to defeat limited or accidental launches.

By 1987, the SDIO had developed a national missile defense concept called the Strategic Defense System Phase I Architecture. This concept consisted of ground and space based sensors and weapons, as well as a central battle management system. The ground-based systems operational today trace their roots back to this concept.

In his 1991 State of the Union Address George H. W. Bush shifted the focus of SDI from defense of North America against large scale strikes to a system focusing on theater missile defense called Global Protection Against Limited Strikes (GPALS).

In 1993, the Clinton administration further shifted the focus to ground-based interceptor missiles and theater scale systems, forming the Ballistic Missile Defense Organization (BMDO) and closing the SDIO. Ballistic missile defense was revived by the George W. Bush administration as the National Missile Defense (since renamed "Ground-Based Midcourse Defense").

**Ground-based programs**



Extended Range Interceptor (ERINT) launch from White Sands Missile Range

**Extended Range Interceptor (ERINT)**

The Extended Range Interceptor (ERINT) program was part of SDI's Theater Missile Defense Program and was an extension of the Flexible Lightweight Agile Guided Experiment (FLAGE), which included developing hit-to-kill technology and demonstrating the guidance accuracy of a small, agile, radar-homing vehicle.

FLAGE scored a direct hit against a MGM-52 Lance missile in flight, at White Sands Missile Range in 1987. ERINT was a prototype missile similar to the FLAGE, but it used a new solid-propellant rocket motor that allowed it to fly faster and higher than FLAGE.

Under BMDO, ERINT was later chosen as the Patriot Advanced Capability-3 (PAC-3) missile.

**Homing Overlay Experiment (HOE)**



4 m (13 ft) diameter web deployed by Homing Overlay Experiment

Given concerns about the previous programs using nuclear-tipped interceptors, in the 1980s the U.S. Army began studies about the feasibility of hit-to-kill vehicles, i.e. interceptor missiles that would destroy incoming ballistic missiles just by colliding with them head-on.

The Homing Overlay Experiment (HOE) was the first hit-to-kill system tested by the US Army, and also the first successful hit-to-kill intercept of a mock ballistic missile warhead outside the Earth’s atmosphere.

The HOE used a Kinetic Kill Vehicle (KKV) to destroy a ballistic missile. The KKV was equipped with an infrared seeker, guidance electronics and a propulsion system. Once in space, the KKV could extend a folded structure similar to an umbrella skeleton of 4 m (13 ft) diameter to enhance its effective cross section. This device would destroy the ICBM reentry vehicle on collision.

Four test launches were conducted in 1983 and 1984 at Kwajalein Missile Range in the Republic of the Marshall Islands. For each test a Minuteman missile was launched from Vandenberg Air Force Base in California carrying a single mock re-entry vehicle targeted for Kwajalein lagoon more than 4,000 miles (6,400 km) away.

After test failures with the first three flight tests because of guidance and sensor problems, the fourth and final test on June 10, 1984 was successful, intercepting the Minuteman RV with a closing speed of about 6.1 km/s at an altitude of more than 160 km.

Although the fourth test succeeded, the New York Times charged in August 1993 that the test had been rigged. Investigations into this charge by the Department of Defense, headed John Deutch for Secretary of Defense Les Aspin, and the General Accounting Office concluded that the test was a valid, successful test.

This technology was later used by the SDI and expanded into the Exoatmospheric Reentry-vehicle Interception System (ERIS) program.

**Exoatmospheric Reentry-vehicle Interception System (ERIS)**

Developed by Lockheed as part of the ground-based interceptor portion of SDI, the Exoatmospheric Reentry-vehicle Interception System (ERIS) began in 1985, with at least two tests occurring in the early 1990s. This system was never deployed, but the technology of the system was used in the Terminal High Altitude Area Defense (THAAD) system and the Ground Based Interceptor currently deployed as part of the Ground-Based Midcourse Defense (GMD) system.

**Directed-energy weapon (DEW) programs**

See also: Directed-energy weapon

**X-ray laser**



1984 artist's concept of a generic laser-equipped satellite firing on another

An early focus of the project was a curtain of X-ray lasers powered by nuclear explosions. The curtain was to be deployed using a series of missiles launched from submarines or, later on, satellites, during the critical seconds following a Soviet attack. The satellites would be powered by built-in nuclear warheads – in theory, the energy from the warhead detonation would be used to pump a series of laser emitters in the missiles or satellites, allowing each satellite to shoot down many incoming warheads simultaneously. The attraction of this approach was that it was thought to be faster than an optical laser, which could only shoot down warheads one at a time, limiting the number of warheads each laser could destroy in the short time 'window' of an attack.

However, on March 26, 1983, the first test, known as the Cabra event, was performed in an underground shaft and resulted in marginally positive readings that could be dismissed as being caused by a faulty detector. Since a nuclear explosion was used as the power source, the detector was destroyed during the experiment and the results therefore could not be confirmed. Technical criticism based upon unclassified calculations suggested that the X-ray laser would be of at best marginal use for missile defense. Such critics often cite the X-ray laser system as being the primary focus of SDI, with its apparent failure being a main reason to oppose the program. However, the laser was never more than one of the many systems being researched for ballistic missile defense.

Despite the apparent failure of the Cabra test, the long term legacy of the X-ray laser program is the knowledge gained while conducting the research. A parallel developmental program advanced laboratory X-ray lasers for biological imaging and the creation of 3D holograms of living organisms. Other spin-offs include research on advanced materials like SEAgel and Aerogel, the Electron-Beam Ion Trap facility for physics research, and enhanced techniques for early detection of breast cancer.

**Chemical laser**



SeaLite Beam Director, commonly used as the output for the MIRACL

See also: Chemical laser

Beginning in 1985, the Air Force tested an SDIO-funded deuterium fluoride laser known as Mid-Infrared Advanced Chemical Laser (MIRACL) at White Sands Missile Range. During a simulation, the laser successfully destroyed a Titan missile booster in 1985, however the test setup had the booster shell pressurized and under considerable compression loads.[*citation needed*] These test conditions were used to simulate the loads a booster would be under during launch. The system was later tested on target drones simulating cruise missiles for the US Navy, with some success. After the SDIO closed, the MIRACL was tested on an old Air Force satellite for potential use as an Anti-satellite weapon, with mixed results. The technology was also used to develop the Tactical High Energy Laser, (THEL) which is being tested to shoot down artillery shells.

During the mid-to-late 1980s a number of panel discussions on lasers and SDI took place at various laser conferences. Proceedings of these conferences include papers on the status of chemical and other high power lasers at the time.

The Missile Defense Agency's Airborne Laser program uses a chemical laser which has successfully intercepted a missile taking off, so an offshoot of SDI could be said to have successfully implemented one of the key goals of the program.

**Neutral Particle Beam**

In July 1989, the Beam Experiments Aboard a Rocket (BEAR) program launched a sounding rocket containing a neutral particle beam (NPB) accelerator. The experiment successfully demonstrated that a particle beam would operate and propagate as predicted outside the atmosphere and that there are no unexpected side-effects when firing the beam in space. After the rocket was recovered, the particle beam was still operational. According to the BMDO, the research on neutral particle beam accelerators, which was originally funded by the SDIO, could eventually be used to reduce the half-life of nuclear waste products using accelerator-driven transmutation technology.

**Laser and mirror experiments**



Technicians at the Naval Research Laboratory (NRL), work on the Low-powered Atmosphere Compensation Experiment (LACE) satellite.

The High Precision Tracking Experiment (HPTE), launched with the Space Shuttle Discovery on STS-51-G, was tested June 21, 1985 when a Hawaii-based low-power laser successfully tracked the experiment and bounced the laser off of the HPTE mirror.

The Relay mirror experiment (RME), launched in February 1990, demonstrated critical technologies for space-based relay mirrors that would be used with an SDI directed-energy weapon system. The experiment validated stabilization, tracking, and pointing concepts and proved that a laser could be relayed from the ground to a 60 cm mirror on an orbiting satellite and back to another ground station with a high degree of accuracy and for extended durations.

Launched on the same rocket as the RME, the Low-power Atmospheric Compensation Experiment (LACE) satellite was built by the United States Naval Research Laboratory (NRL) to explore atmospheric distortion of lasers and real-time adaptive compensation for that distortion. The LACE satellite also included several other experiments to help develop and improve SDI sensors, including target discrimination using background radiation and tracking ballistic missiles using Ultra-Violet Plume Imaging (UVPI). LACE was also used to evaluate ground-based adaptive optics, a technique now used in civilian telescopes to remove atmospheric distortions.

**Hypervelocity Rail Gun (CHECMATE)**

Research out of hypervelocity railgun technology was done to build an information base about rail guns so that SDI planners would know how to apply the technology to the proposed defense system. The SDI rail gun investigation, called the Compact High Energy Capacitor Module Advanced Technology Experiment (CHECMATE), had been able to fire two projectiles per day during the initiative. This represented a significant improvement over previous efforts, which were only able to achieve about one shot per month. Hypervelocity rail guns are, at least conceptually, an attractive alternative to a space-based defense system because of their envisioned ability to quickly shoot at many targets. Also, since only the projectile leaves the gun, a railgun system can potentially fire many times before needing to be resupplied.

A hypervelocity railgun works very much like a particle accelerator insofar as it converts electrical potential energy into kinetic energy imparted to the projectile. A conductive pellet (the projectile) is attracted down the rails by electric current flowing through a rail. Through the magnetic forces that this system achieves, a force is exerted on the projectile moving it down the rail. Railguns can generate muzzle-velocities in excess of 24 miles per second. At this velocity, even a rifle-bullet sized projectile will penetrate the front armor of a main battle tank, let alone a thinly protected missile guidance system.

Rail guns face a host of technical challenges before they will be ready for battlefield deployment. First, the rails guiding the projectile must carry very high power. Each firing of the railgun produces tremendous current flow (almost half a million amperes) through the rails, causing rapid erosion of the rail's surfaces (through ohmic heating, and even vaporization of the rail-surface.) Early prototypes were essentially single-use weapons, requiring complete replacement of the rails after each firing. Another challenge with the rail gun system is projectile survivability. The projectiles experience acceleration force in excess of 100,000 g. In order to be effective, the fired projectile must first survive the mechanical stress of firing, the thermal effects of a trip through the atmosphere at many times the speed of sound, and then the subsequent impact with the target. In-flight guidance, if implemented, would require the onboard guidance system to be built to the same standard of sturdiness as the main mass of the projectile.

In addition to being considered for destroying ballistic missile threats, rail guns were also being planned for service in space platform (sensor and battle station) defense. This potential role reflected defense planner expectations that the rail guns of the future would be capable of not only rapid fire, but also of multiple firings (on the order of tens to hundreds of shots).

**Space-based programs**

**Space-Based Interceptor (SBI)**

Groups of interceptors were to be housed in orbital modules. Hover testing was completed in 1988 and demonstrated integration of the sensor and propulsion systems in the prototype SBI. It also demonstrated the ability of the seeker to shift its aiming point from a rocket's hot plume to its cool body, a first for infrared ABM seekers. Final hover testing occurred in 1992 using miniaturized components similar to what would have actually been used in an operational interceptor. These prototypes eventually evolved into the Brilliant Pebbles program.

**Brilliant Pebbles**



Brilliant Pebbles concept artwork

Brilliant Pebbles was a non-nuclear system of satellite-based interceptors designed to use high-velocity; watermelon-sized, teardrop-shaped projectiles made of tungsten as kinetic warheads. It was designed to operate in conjunction with the Brilliant Eyes sensor system and would have detected and destroyed missiles without any external guidance. The project was conceived in November 1986.

John H. Nuckolls, director of Lawrence Livermore National Laboratory from 1988 to 1994, described the system as “The crowning achievement of the Strategic Defense Initiative”. Some of the technologies developed for SDI were used in numerous later projects. For example, the sensors and cameras that were developed for Brilliant Pebbles became components of the Clementine mission and SDI technologies may also have a role in future missile defense efforts.

Though regarded as one of the most capable SDI systems, the Brilliant Pebbles program was canceled in 1994 by the BMDO.

**Sensor programs**



Delta 183 launch vehicle lifts off, carrying the SDI sensor experiment "Delta Star", on March 24, 1989.

SDIO sensor research encompassed visible light, ultraviolet, infrared, and radar technologies, and eventually led to the Clementine mission though that mission occurred just after the program transitioned to the BMDO. Like other parts of SDI, the sensor system initially was very large-scale, but after the Soviet threat diminished it was cut back.

**Boost Surveillance and Tracking System (BSTS)**

BSTS was part of the SDIO in the late 1980s, and was designed to assist detection of missile launches, especially during the boost phase. However, once the SDI program shifted toward theater missile defense in the early 1990s, the system left SDIO control and was transferred to the Air Force.

**Space Surveillance and Tracking System (SSTS)**

SSTS was a system originally designed for tracking ballistic missiles during their mid-course phase. It was designed to work in conjunction with BSTS, but was later scaled down in favor of the Brilliant Eyes program.

**Brilliant Eyes**

Brilliant Eyes was a simpler derivative of the SSTS that focused on theater ballistic missiles rather than ICBMs and was meant to operate in conjunction with the Brilliant Pebbles system.

Brilliant Eyes was renamed Space and Missile Tracking System (SMTS) and scaled back further under BMDO, and in the late 1990s it became the low earth orbit component of the Air Force's Space Based Infrared System (SBIRS).

**Other sensor experiments**

The Delta 183 program used a satellite known as *Delta Star* to test several sensor related technologies. Delta Star carried an infrared imager, a long-wave infrared imager, an ensemble of imagers and photometers covering several visible and ultraviolet bands as well as a laser detector and ranging device. The satellite observed several ballistic missile launches including some releasing liquid propellant as a countermeasure to detection. Data from the experiments led to advances in sensor technologies.

**Countermeasures**



An artist's concept of a ground / space-based hybrid laser weapon, 1984

In war-fighting, countermeasures can have a variety of meanings:

1. The immediate tactical action to reduce vulnerability, such as chaff, decoys, and maneuvering.
2. Counter strategies which exploit a weakness of an opposing system, such as adding more MIRV warheads which are less expensive than the interceptors fired against them.
3. Defense suppression. That is, attacking elements of the defensive system.

Countermeasures of various types have long been a key part of warfighting strategy. However, with SDI they attained a special prominence due to the system cost, scenario of a massive sophisticated attack, strategic consequences of a less-than-perfect defense, outer space basing of many proposed weapons systems, and political debate.

Whereas the current U.S. NMD system is designed around a relatively limited and unsophisticated attack, SDI planned for a massive attack by a sophisticated opponent. This raised significant issues about economic and technical costs associated with defending against anti-ballistic missile defense countermeasures used by the attacking side.

For example, if it had been much cheaper to add attacking warheads than to add defenses, an attacker of similar economic power could have simply outproduced the defender. This requirement of being "cost effective at the margin" was first formulated by Paul Nitze in November 1985.

In addition, SDI envisioned many space-based systems in fixed orbits, ground-based sensors, command, control and communications facilities, etc. In theory, an advanced opponent could have targeted those, in turn requiring self-defense capability or increased numbers to compensate for attrition.

A sophisticated attacker having the technology to use decoys, shielding, maneuvering warheads, defense suppression, or other countermeasures would have multiplied the difficulty and cost of intercepting the real warheads. SDI design and operational planning had to factor in these countermeasures and the associated cost.

**Controversy and criticism**



SDI was not just lasers; in this Kinetic Energy Weapon test, a seven gram Lexan projectile was fired from a light gas gun at a velocity of 23,000 feet per second (7,000 meters per second or 15,682 miles per hour) at a cast aluminum block.

SDI may have been first dubbed "Star Wars" by opponent Dr. Carol Rosin, a consultant and former spokeswoman for Werner von Braun. However, Missile Defense Agency historians attribute the term to a *Washington Post* article published March 24, 1983, the day after the Star Wars speech, which quoted Democratic Senator Ted Kennedy describing the proposal as "reckless Star Wars schemes." Some critics used that term derisively, implying it was an impractical science fiction fantasy. In addition, the American media's liberal use of the moniker (despite President Reagan's request that they use the program's official name) did much to damage the program's credibility. In comments to the media on March 7, 1986, Acting Deputy Director of SDIO, Dr. Gerold Yonas, described the name "Star Wars" as an important tool for Soviet disinformation and asserted that the nickname gave an entirely wrong impression of SDI.[60] However, supporters have adopted the usage as well on the grounds that yesterday's science fiction is often tomorrow's engineering.

Jessica Savitch reported on the technology in episode No.111 of Frontline, "Space: The Race for High Ground" on PBS on 4/11/1983. The opening sequence shows Jessica Savitch seated next to a laser that she used to destroy a model of a communication satellite. The demonstration was perhaps the first televised use of a weapons grade laser. No theatrical effects were used. The model was actually destroyed by the heat from the laser. The model and the laser were realized by Marc Palumbo, a High Tech Romantic artist from the Center for Advanced Visual Studies at MIT.

Ashton Carter, a board member at MIT, assessed SDI for Congress in 1984, saying there were a number of difficulties in creating an adequate missile defense shield, with or without lasers. Carter said X-rays have a limited scope because they become diffused through the atmosphere, much like the beam of a flashlight spreading outward in all directions. This means the X-rays needed to be close to the Soviet Union, especially during the critical few minutes of the booster phase, in order for the Soviet missiles to be both detectable to radar and targeted by the lasers themselves. Opponents disagreed, saying advances in technology, such as using very strong laser beams, and by "bleaching" the column of air surrounding the laser beam, could increase the distance that the X-ray would reach to successfully hit its target.

Physicist Hans Bethe, who worked with Edward Teller on both the nuclear bomb and the hydrogen bomb at Los Alamos, claimed a laser defense shield was unfeasible. He said that a defensive system was costly and difficult to build yet simple to destroy, and claimed that the Soviets could easily use thousands of decoys to overwhelm it during a nuclear attack. He believed that the only way to stop the threat of nuclear war was through diplomacy and dismissed the idea of a *technical solution* to the Cold War, saying that a defense shield could be viewed as threatening because it would limit or destroy Soviet offensive capabilities while leaving the American offense intact. In March 1984, Bethe coauthored a 106-page report for the Union of Concerned Scientists that concluded "the X-ray laser offers no prospect of being a useful component in a system for ballistic missile defense."

In response to this when Teller testified before Congress, he stated that "instead of [Bethe] objecting on scientific and technical grounds, which he thoroughly understands, he now objects on the grounds of politics, on grounds of military feasibility of military deployment, on other grounds of difficult issues which are quite outside the range of his professional cognizance or mine."

On June 28, 1985, David Lorge Parnas resigned from SDIO's Panel on Computing in Support of Battle Management, arguing in 8 short papers that the software required by the Strategic Defense Initiative could never be made to be trustworthy and that such a system would inevitably be unreliable and constitute a menace to humanity in its own right. Parnas said he joined the panel with the desire to make nuclear weapons "impotent and obsolete" but soon concluded that the concept was "a fraud".



SDI drew criticism from abroad as well. This 1986 Socialist German Workers Youth graffiti in Kassel, West Germany says "Keinen Krieg der Sterne! Stop SDI! SDAJ" or (No star wars! Stop SDI! SDAJ).

**Treaty obligations**

Another criticism of SDI was that it would require the United States to modify, withdraw from, or violate previously ratified treaties. The Outer Space Treaty of 1967, which requires "States Parties to the Treaty undertake not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner" and would forbid the US from pre-positioning in Earth orbit any devices powered by nuclear weapons and any devices capable of "mass destruction". Only the nuclear-pumped X-ray laser would have violated this treaty since other SDI systems would not utilize nuclear warheads.

The Anti-Ballistic Missile Treaty and its subsequent protocol, which limited missile defenses to one location per country at 100 missiles each (which the USSR had and the US did not), would have been violated by SDI ground-based interceptors. The Nuclear Non-Proliferation Treaty requires "Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control." Many viewed favoring deployment of ABM systems as an escalation rather than cessation of the nuclear arms race, and therefore a violation of this clause. On the other hand, many othersdid not view SDI as an escalation.

**SDI and MAD**

SDI was criticized for potentially disrupting the strategic doctrine of Mutual Assured Destruction. MAD postulated that intentional nuclear attack was inhibited by the certainty of ensuing mutual destruction. Even if a nuclear first strike destroyed many of the opponent's weapons, sufficient nuclear missiles would survive to render a devastating counter-strike against the attacker. The criticism was that SDI could have potentially allowed an attacker to survive the lighter counter-strike, thus encouraging a first strike by the side having SDI. Another destabilizing scenario was countries being tempted to strike first before SDI was deployed, thereby avoiding a disadvantaged nuclear posture. Proponents of SDI argued that SDI development might instead cause the side that did not have the resources to develop SDI, to, rather than launching a suicidal nuclear first strike attack before the SDI system was deployed, instead come to the bargaining table with the country that did have those resources, and, hopefully, agree to a real, sincere disarmament pact that would drastically decrease all forces, both nuclear and conventional. Furthermore, the MAD argument was criticized on the grounds that MAD only covered intentional, full-scale nuclear attacks by a rational, non-suicidal opponent with similar values. It did not take into account limited launches, accidental launches, rogue launches, or launches by non-state entities or covert proxies.

During the Reykjavik talks with Gorbachev in 1986, Ronald Reagan addressed Gorbachev's concerns about imbalance by stating that SDI would be given to the Soviet Union to prevent the imbalance from occurring. Gorbachev answered that he could not take this claim seriously.

**Non-ICBM delivery**

Another criticism of SDI was that it would not be effective against non-spacefaring weapons, namely cruise missiles, bombers, and non-conventional delivery methods. It was never intended to act as a defense against non-space faring weapons.

**Soviet view of SDI**



SDI was high on Gorbachev's agenda at the Geneva Summit, November 1985.

The Soviet response to the SDI during the period March 1983 through November 1985 provided indications of their view of the program both as a threat and as an opportunity to weaken NATO. The SDI was seen not only as a threat to the physical security of the Soviet Union but as part of an effort by the United States to seize the strategic initiative by neutralizing the military component of Soviet strategy. A major objective of that strategy was the political separation of Western Europe from the United States which the Soviets sought to facilitate by aggravating allied concern over the SDI's potential implications for European security and economic interests. The Soviet predisposition to see deception behind the SDI was reinforced by their assessment of US intentions and capabilities and the utility of military deception in furthering the achievement of political goals.

**Timeline**

