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Shooting Down a "Star"
Program 437, the US Nuclear ASAT System and Present-Day Copycat Killers

Chun

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Program 437, the US Nuclear ASAT System and Present-Day Copycat Killers

Clayton K. S. Chun

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About the cover:
The cover art depicts Thor, the Norse god of thunder, weather, and crops, as a defender against hostile, enemy satellites. The Air Force used its Thor ballistic missile as the launch vehicle for its experimental Program 437 antisatellite weapon system.

COLLEGE OF AEROSPACE DOCTRINE RESEARCH AND EDUCATION

AIR UNIVERSITY

Shooting Down a "Star"

Program 437, the US Nuclear ASAT System and Present-Day Copycat Killers

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Foreword

Space-based systems of various kinds had proven their worth well before the end of the cold war. But it was only during the Persian Gulf War that the enormous multiplier effect of space systems on combat operations became widely recognized. In the immediate aftermath of that conflict, then Air Force chief of staff Gen Merrill A. McPeak went so far as to describe Operation Desert Storm as America's "first space war." Military exploitation of space has markedly accelerated during the years since 1991. So has US reliance on the satellite systems that inhabit that immense realm.

Shooting Down a Star: Program 437, the US Nuclear ASAT System and Present-Day Copycat Killers, by Lt Col Clayton K. S. Chun, is a case study of an early US antisatellite (ASAT) weapon system. In this study, Colonel Chun shows how the US Air Force developed a rudimentary ASAT system from obsolete Thor intermediate ballistic missiles, an existing space tracking system, and nuclear warheads. Largely forgotten today, this system helped to defend the United States from 1964 until the demise of the program in the mid-1970s.

Since many of Program 437's components were from off-the-shelf weapons stocks and ready to field after a short development program, the Air Force's first ASAT system was relatively inexpensive to create, deploy, and operate. In tracing the evolution of this ASAT system based on 1950s technology, Colonel Chun notes that a growing number of nations today have access to technology of much more recent vintage. He then proceeds to address in some detail the vulnerability of space-based systems that have become essential to the security and operational prowess of the United States and its allies. Given growing US reliance on space systems for warning, employment of precision weapons, communications, navigation and positioning support, weather reporting, and surveillance and reconnaissance, Colonel Chun's study constitutes a timely reminder of the threat that even a rudimentary ASAT could pose.

The US Air Force Academy's Institute of National Security Studies (INSS) sponsored Colonel Chun's research. In cooperation with INSS, the College of Aerospace Doctrine Research and Education is pleased to publish this work and make it available to the wider community of war fighters, aerospace power strategists, and national security decision makers.

JAMES R. W. TITUS
Dean of Research
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About the Author

Lt Col Clayton K. S. Chun (BS, University of California, Berkeley; MA, University of California, Santa Barbara; MS, University of Southern California; and PhD, RAND Graduate School) is deputy commander of the 34th Education Group, United States Air Force Academy, Colorado. A distinguished graduate of the Air Force Reserve Officer Training Corps program, he was commissioned in June 1978. Colonel Chun has had assignments at the School of Advanced Airpower Studies at Maxwell AFB, Alabama, Air Staff, Office of the Secretary of the Air Force, Headquarters Pacific Air Forces, and several space organizations. Colonel Chun is a graduate of Squadron Officer School, Air Command and Staff College, Army Command and General Staff College, Naval War College, and Air War College. He is married to the former Cheryl Lyn Bastian. They have two children, Douglas and Raymond.

Preface

From 1963 to 1975, the United States Air Force (USAF) operated a working ASAT system, Program 437, in the Pacific. The Air Force was able to rapidly cobble together an operational system out of deactivated missile components, existing launch pads, and a space tracking system to create the capability to use nuclear antisatellite weapons in a direct ascent mode to destroy orbiting space vehicles. Many nations today have the ability to acquire the ballistic missiles and nuclear warheads to produce similar, if not superior, systems to what the United States was able to field using aging booster rockets. Given that the technology is more readily available today than during the 1960s and 1970s, several nations may be capable of threatening the space assets of the United States and its allies. Could a foreign country deny space superiority to US military forces and neutralize many of the space-based capabilities that are integral to present-day war-fighting plans of US and allied joint force commanders?

This question is intriguing. My reassignment from the faculty of the School of Advanced Aerospace Studies to the US Air Force Academy at Colorado Springs, Colorado, gave me access to many of the key research materials at the US Space Command at Peterson AFB, Colorado, to pursue an answer to this question. I first explore the history of the Air Force's efforts to deploy an operational ASAT system. This story provides an interesting case study of issues that are relevant today. The Air Force and the Department of Defense first pursued doctrinal questions about counterspace applications and the United States's desire to use antisatellite weapons in 1963. The debate about and study of the feasibility of employing such space defenses still swirls through the halls of the Pentagon. Second, I take an in-depth look at nations that have or are capable of producing or acquiring sufficient boosters, nuclear devices, and space launch support capabilities to put into operation an ASAT system at least comparable to Program 437. My research and analysis indicates that four nations—North Korea, India, China, and Iran—are capable of duplicating or exceeding the capabilities of Program 437.

I thank Dr. James Smith and his staff at the Institute for National Security Studies at the United States Air Force Academy for funding my research on this project. Drs. Dan Mortensen and James Titus provided helpful comments on the drafts and sponsored publication of this research paper through the auspices of the Air University's College of Aerospace Doctrine Research and Education (CADRE) as part of its CADRE Papers series. I also want to thank Lt Col Roy Houchin for the initial inspiration concerning Program 437. We spent many afternoons talking about space defenses while we were assigned to the Air Staff and at the School of Advanced Airpower Studies.

I am very grateful to Dr. Rick Sturdevant of Headquarters Air Force Space Command's Office of History for locating many photographs of Program 437 components and facilities for this publication. Tom Boyd of the National Air Intelligence Center came through in the clutch and provided photographs of several of the foreign missiles discussed here. Dr. Charles Krupnick, a colleague at the US Air Force Academy, gave me much encouragement. Perhaps one day we will visit Johnston Island. I want to give a "big" thanks to my editor, Thomas Lobenstein of Air University Press. He turned my "opus" into its final form with a lot of hard work. Lula Barnes, also of the Press served as the copy editor on the manuscript—her careful eye helped immeasurably in readying this manuscript for final publication.

Finally, and most importantly, I thank my wife, Cheryl, and sons, Douglas and Raymond. They sacrificed much during the many evenings and weekends I devoted to researching and writing this paper.

Program 437: The Beginnings

What were the motivating factors that influenced and eventually led the United States to develop a nuclear-armed antisatellite (ASAT) capability in 1963? Although the Air Force investigated space defense weapons systems in the early 1950s, little was done in this area until 1957. The Soviet Union's launch of the world's first artificial earth orbiting satellite, *Sputnik I*, on 4 October 1957 put an exclamation point on the space race. The greatest danger posed by the launch of *Sputnik I* was not the tiny satellite itself but the demonstration that the Union of Soviet Socialist Republics (USSR) had developed a powerful, operational intercontinental ballistic missile (ICBM) that could carry a nuclear weapon. The threat from a space weapon was not great in the eyes of the Eisenhower administration. President Dwight D. Eisenhower commented, on 9 October 1957, that "so far as the satellite itself is concerned, that does not raise my apprehensions, not one iota."[1] Before *Sputnik* rocketed onto the international scene, the Central Intelligence Agency (CIA) through its Office of National Estimates correctly predicted the Soviets would orbit an earth satellite by 1957 but concluded that such a space vehicle would have limited military value.[2] The CIA estimated that the main military threat from the Soviet space activities would be a reconnaissance capability that could not be put into operation until the 1963–65 time frame.

Given the CIA's assessment, the Eisenhower administration's emphasis remained fixed on Soviet ICBM development in 1957. The CIA and the Army's assistant chief of intelligence believed the Soviets were developing an ICBM with a range of at least 3,800 nautical miles (nm).[3] In 1959 the CIA thought the Soviets were attempting to gain worldwide military superiority. Its intelligence experts believed the Soviets might not gain this superiority by numeric advantage alone but through more innovative approaches. As early as 1962, Maj Gen Robert A. Breitweiser, the Air Force assistant chief of staff for intelligence, believed the Soviets might gain this superiority by developing an orbital nuclear bombardment system.[4] He hypothesized that the USSR could use an SS-8 booster to orbit a 30,000-pound payload capable of de-orbiting a "very high yield" nuclear weapon. CIA analysts doubted the USSR would have an "effective offensive capability" until the late 1960s.[5]

Unconvinced, the Air Force's Air Research and Development Command (ARDC) continued to pioneer efforts to defend the country from space threats. In 1958 not only the Air Force but also the Department of Defense (DOD) started serious investigations into future ASATs. The Defense Advanced Research Project Agency (DARPA) sponsored two feasibility studies of developing space defenses. As a result of these studies, Maj Gen Bernard A. Schriever, commander of the Air Force's Ballistic Missile Division (and later commander of ARDC), embarked on the development of a co-orbital satellite inspector for space defense (SAINT). Although cancelled due to cost, schedule, and technical reasons in December 1962, SAINT provided valuable program and technical experience for future ASAT efforts.

ASAT Weapons: An Accidental Discovery?

As the SAINT program faded from sight, other events occurred that changed the face of ASAT options. This new approach was a result of a series of high-altitude nuclear tests. The Air Force, under the direction of Joint Task Force-8 (JTF-8), used a "loaned" launch pad and other facilities on Johnston Island in the central Pacific to conduct the tests.[6] As a result of these experiments, the Air Force Systems Command (AFSC)—a reorganized ARDC—proposed a direct ascent ASAT option under Advanced Development Option 40, Anti-Satellite Program, to DOD on 9 February 1962. These tests, which were a part of the cold war space race between the United States and the USSR, provided the spark to develop the direct ascent option into an operational weapon.

During the late 1950s, the United States and the Soviets were exploring and pursuing satellite and space technology at a feverish pace. Although moving swiftly, many US scientists were unsure about vulnerabilities of space systems. Solar rays, cosmic radiation, and magnetic fields were riddles to be solved. One scientist, Nicholas Christofilos, a physicist working at the University of California's Livermore Radiation Laboratory, speculated that if a nation could create electrically charged particles in space, then these particles might be held in the earth's magnetic fields and potentially destroy a satellite.[7] Specifically, Christofilos believed a nuclear device exploded in space or at a high altitude might provide sufficient energy to produce electrical particles that could destroy or disable a satellite's electrical components, kill spacecraft crews, jam military communications links, and disrupt antiballistic missile systems.

In April 1958 DOD approved a series of three nuclear explosions in space.[8] These high-altitude tests, code-named Project Argus, would explore the scientific validity of Christofilos's ideas. The first test would examine the effect of electrically charged particles on *Explorer IV*. On 26 July 1958 the satellite was placed in orbit with a device to measure the test's radiation effects. The first Project Argus rocket was launched with a two-kiloton nuclear weapon from the USS *Norden Sound* on 27 August 1958.[9] Measurements by *Explorer IV*, several sounding rockets, and ground stations confirmed Christofilos's hypothesis that the earth's magnetic fields would capture the radiation from such explosions. Two additional nuclear tests followed.

A presidential scientific advisory commission headed by James Killian[10] studied the Argus test data. Killian reported to President Eisenhower that the test results were relevant to military space systems. The explosions created free electrons that produced X-rays capable of damaging electronic components and erasing computer memories.[11] The most intense radiation effects would occur in low earth orbit (LEO). If a nation detonated a nuclear device with sufficient strength at the appropriate altitude, then targeted, orbiting satellites could be rendered useless.

The Atomic Energy Commission (AEC) also wanted to study the effects of high-altitude nuclear detonations, but with larger nuclear devices. The AEC asked the Air Force for help. The Air Force planned to use its Thor[12] intermediate range ballistic missile (IRBM) to conduct the first Fishbowl test, Starfish Prime, above Johnston Island in the Pacific. The Starfish Prime test used a nuclear warhead several hundred times more powerful than the Project Argus nuclear device. Engineers detonated the Starfish Prime nuclear warhead at an altitude of 248 miles on 9 July 1962.[13]

The test produced a visual extravaganza as well as several unintended effects that reverberated in Washington. The nuclear blast knocked out electrical systems throughout Hawaii—715 miles away. More importantly, electromagnetic pulse (EMP) effects[14] from the blast seriously damaged the solar panels of three orbiting satellites even though they were not in the line-of-sight of the nuclear detonation.[15] The radiation effects lingered in the earth's magnetic fields and affected satellites that followed an orbital path through the detonation area. Electronic components were destroyed and continued exposure to radiation trapped in the earth's magnetic fields degraded the life of affected satellites. The damaged satellites included two classified Air Force satellites and *Ariel*, a joint British-US satellite.[16]

The Starfish Prime test results showed that a high dose of radiation could provide the basis for an ASAT system. The Thor-launched Starfish Prime experiment illustrated the deadly EMP effects on unprotected electrical components. Additionally, intense light or nuclear flash might damage optical sensors on imagery reconnaissance satellites or overload solar panels, thus limiting a satellite's electrical power. The increased radiation could alter the operation or cause a surge in electrical current that might burn out or "fry" primary and backup systems and leave the satellite dead or useless. The Fishbowl tests included two other high-altitude experiments. On 25 October 1962, the Air Force exploded another nuclear device, Bluegill Triple Prime, at a lower altitude of 62 miles.[17] In the last Fishbowl test, Kingfish, the Air Force detonated a nuclear device at a similar altitude of about 62 miles. These were the last high-altitude nuclear tests conducted by the United States.

ASAT Development: The Air Force Leads the Way

On 12 September 1962, in light of the Starfish Prime test, Schriever combined the direct ascent option—Advanced Development Option 40—and the Fishbowl test results to propose a new ASAT program to Secretary of the Air Force Eugene B. Zuckert. Schriever's proposal was to deploy nuclear-armed Thors on Johnston Island crewed by Air Defense Command (ADC) personnel. On 27 February 1962, Zuckert and Air Force chief of staff Gen Curtis E. LeMay had helped lay the foundation for congressional support at the Senate's hearing on DOD appropriations by stressing the need for active defenses against hostile space systems.[18] Zuckert estimated the total cost of the system would approach $25 million. After being briefed on this proposed ASAT option, Secretary of Defense Robert S. McNamara approved the program on 20 November 1962 and directed Zuckert to explore it further. AFSC assigned Col Quentin A. Riepe to form a five-person project office in Los Angeles to study the proposal.[19] Riepe selected missile engineers and ADC personnel for his team. Meanwhile, Zuckert directed LeMay to submit the findings as "early as practical" for a start in fiscal year (FY) 1963 and a full development plan by 31 December 1962.[20] For security reasons, Zuckert renamed the project Program 437.

On 28 March 1963, Program 437 got a big push from McNamara when he asked Zuckert to make the system operational after an appropriate series of tests. Zuckert directed LeMay to accelerate Program 437 as one the highest Air Force priorities for development and to establish "an emergency operational capability" with the hope of developing a capability to negate satellites.[21] Zuckert had confidence in Program 437 but thought a limiting factor was detecting and tracking a hostile satellite. The estimated reaction time for an ASAT mission was two to three days. This lead time was not acceptable to Zuckert or McNamara since they wanted a system with instant reaction. Lt Gen James L. Ferguson, Air Force deputy chief of staff for research and development, was ordered to use "all assets necessary" to ensure that the Air Force properly demonstrated Program 437's practical feasibility and its eventual operational capability.[22]

This tasking to undertake development of an operational ASAT system led to a significant change in the Air Defense Command's mission. ADC's operational experience was mostly limited to air defense warning and using jet interceptors and surface-to-air (SAM) missiles to counter threats from fixed-wing enemy aircraft with air-breathing engines. Space warning was under ADC control and ADC tracked and catalogued space objects. Its users or customers were Strategic Air Command (SAC), AFSC (which conducted Air Force space launch activities, development, and satellite control), intelligence agencies, and the National Aeronautics and Space Administration (NASA). Giving Program 437 to ADC would expand its mission to active space defense. Additionally, this tasking signaled a sea change for space activities from a research and development to an operational focus.

Program 437 was not only an important Air Force program but a national one. Brig Gen Richard D. Curtin, Ferguson's director of advanced engineering, reiterated Zuckert's guidance to AFSC that Program 437 had the nation's top defense priority.[23] Any problems regarding Program 437 were "to be brought to the Secretary's attention promptly." The Air Staff directed SAC to release available Thors to AFSC immediately. AFSC was to take all actions to establish an emergency ASAT for ADC.[24] The Air Force rocketed ahead with Program 437 even though not everyone in the national security community believed in its usefulness or feasibility. The CIA's position was the same in 1963 as it had been in 1957: No foreign country's satellites posed a major space threat. President John F. Kennedy did not share the CIA's opinion and directed McNamara to develop an ASAT system at the "earliest practicable time."[25]

Why ASAT Weapons?

What motivated the Kennedy administration to pursue such a contentious drive to militarize space given no apparent Soviet space threat? While the USSR had demonstrated its technical ability to launch a satellite into orbit and proved that it could put a payload, civilian or military, into space, US military analysts were concerned primarily about the threat deriving from the use of these launch boosters as ICBMs. Premier Nikita Khruschev's blustery claims of USSR space prowess and its ability to orbit nuclear weapons caused genuine unease within the US government.[26] While many top officials and intelligence experts undoubtedly considered these claims as idle boasting, others were equally convinced that the Soviets might well be close to fielding space-based systems that could threaten the United States.

The proposed use of a space-based strategic weapon system was not a new idea. During World War II, Dr. Eugen Sanger, director of the Luftwaffe's rocket research institute, proposed an antipodal bomber that would operate in the exoatmosphere and rely on a skip-glide reentry technique to strike America.[27] Sanger's "space bomber" had the capability to attack most areas on the earth's surface. He would continue his work after the war for the US government. Dr. Walter Dornberger, another key German scientist, proposed development of a two-staged, manned orbital space system called Bambi.[28] (Dornberger, the former director of the Wehrmacht's V-2 program, had gone to work for the Bell Aircraft Corporation at the war's end.) The Air Force used Sanger's concept to develop its hypersonic manned system, Dyna-Soar (X-20A).[29] The idea of building space weapons had been planted in the minds of government officials.

The United States also had studied an unmanned orbital nuclear bombardment satellite weapon system called the nuclear-armed bombardment satellite (NABS).[30] If the United States could develop an orbiting bombardment system, many high-ranking military leaders and national security policy makers presumed the Soviets could do the same. The USSR might develop and deploy its own version of NABS and loose a fusillade of nuclear bombs on US targets. Thus, the United States would need a defensive system to defeat a Soviet NABS. Indeed the Soviets were already contemplating such a system as early as 1957.[31] While it had extensive air defenses in place to counter attacks by Soviet bombers, the United States did not have a deployable system to defend against a Soviet NABS attack.

The US military frequently had attributed to the Soviets strategic motivations, objectives, and capabilities that were of concern within the walls of the Pentagon. Thus, military leaders often jumped to conclusions not supported by the facts.

For example, the development of a strategic nuclear bomber fleet by the United States was a result of the "bomber gap," which was only disproved after several U-2 reconnaissance flights over the Soviet Union. Similarly, the Kennedy administration's deployment of an ICBM force was based on a perceived "missile-gap." These events, fears, and Kennedy's unequivocal guidance clearly put pressure on AFSC to explore ways to rush an ASAT weapon into operation. Program 437 was at the proverbial right place at the right time. However, Program 437 was not the only ASAT program in development.

Nike-Zeus Becomes a Rival

The Army was adding an ASAT capability to its Nike-Zeus antiballistic missile (ABM) system. In November 1957 and again in January 1960, the Army proposed to DOD that Nike-Zeus could protect the nation from ICBMs and space threats.[32] An ABM system shares many characteristics with an ASAT weapon. Both systems require precise and timely target tracking and guidance systems and a quick reaction or launch capability. Under McNamara's guidance, the Army, after long debate within DOD and Congress, was given permission to develop Nike-Zeus into an ASAT system.[33] The project was code-named Program 505. The Army decided to base Program 505 at the Kwajalein Atoll in the Marshall Islands chain in the Pacific.

Nike-Zeus had a range of 250 miles with a ceiling of 174 miles.[34] This two-staged missile had solid-propellant motors that provided almost instantaneous launch capability. Though the Nike-Zeus B ASAT system carried a W-50, 400-kiloton nuclear weapon, it could not rival the Thor in range or payload.[35] The Army conducted several Program 505 test launches that provided evidence that Nike-Zeus could intercept a space vehicle. On 19 July 1962, Nike-Zeus successfully intercepted a reentry nose cone from an Atlas D launched from Vandenberg Air Force Base (AFB), California.[36] At the end of 1963, Nike-Zeus had intercepted 13 reentry vehicles. Nike-Zeus still required confirmation of its ability to hit an orbiting space vehicle. On 24 May 1963, a Nike-Zeus registered a close hit against a specially equipped Agena-D in orbit.[37] On 1 August 1963 the Army declared Program 505 operational.

Despite the success of these test launches and intercepts, Program 505 suffered from operational deficiencies. The most notable problem was its target tracking and missile guidance radar.[38] The Army used long-range, high-resolution radar systems in Program 505 to detect and track targets and guide the Nike-Zeus missile towards interception, but those radar systems could not track and discriminate among large numbers of potential targets. Thus, should an enemy attack the United States with a barrage of weapons or decoys, the Nike-Zeus's radar system would be overwhelmed. A second area of concern was the relatively small throw weight of the Army's Nike-Zeus. It could not carry as large a warhead as the Thor booster. Even though the Nike-Zeus could damage targets with a sizeable EMP burst without scoring a direct hit and thus did not need precise guidance, the Army could achieve only limited lethality with its ASAT system.

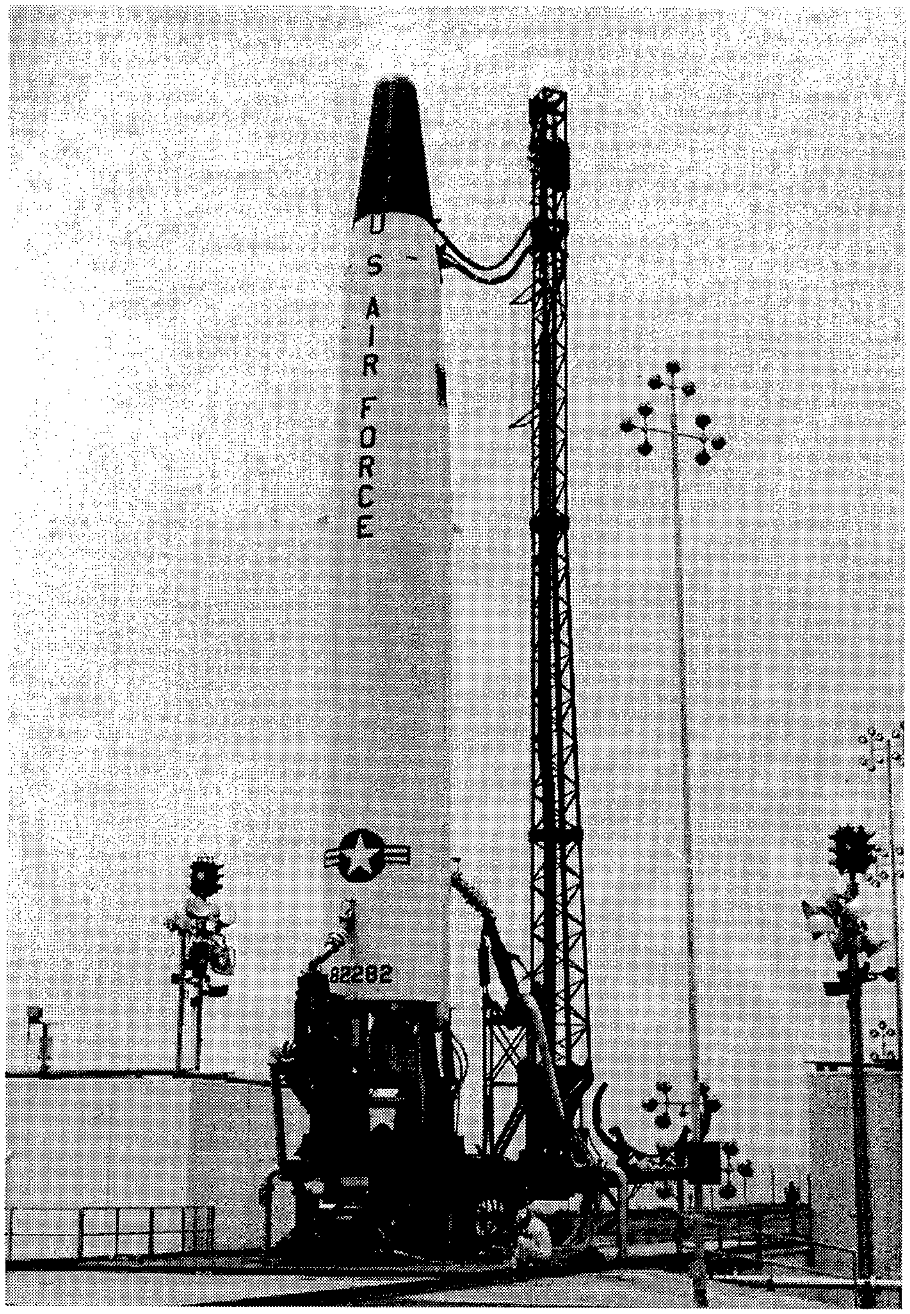
Despite these relative deficiencies, Secretary McNamara, on 27 June 1963, ordered a single Nike-Zeus missile to stand ready to intercept Soviet satellites.[39] McNamara believed a Nike-Zeus on alert allowed him to have a "capability to initiate destruction of [a] satellite by a phone call."[40] However, Program 505 was short-lived. In 1964 McNamara ordered that Nike-Zeus be deactivated in favor of Thor. His decision clearly made the Air Force predominant in the space defense mission.

McNamara's switch to Program 437 was likely based primarily on two factors: cost and duplication of roles and missions. Development and operation of two ASAT systems would duplicate efforts and would prove costly to maintain. Other cold war strategic systems and the Kennedy administration's eye on modernizing conventional forces required funding. The Army's Nike-Zeus ASAT system was more costly than the Air Force's Program 437. Program 505 needed development and production of new missiles whereas Program 437 could use spare Thors from SAC. Additionally, Program 505 was less effective than the Thor-based Program 437 because of the Nike-Zeus's limited range and ceiling. The latter's throw weight restricted it to lifting relatively small nuclear warheads with limited yields. Thor's reliance on existing space defense tracking systems did not require a costly program acquisition. Because of the complex nature of Nike-Zeus, personnel from Bell Telephone Laboratories and Western Electric Company acted as crews for the system. In contrast, the launch crews for Program 437 would be all "blue-suit" (Air Force). Finally, McNamara thought the Army was the wrong agency to control the space defense mission. Since the Air Force already had a growing role in space launch, tracking, and satellite systems, not only did the Army's involvement and/or control of the nation's ASAT capability seem awkward and an unnecessary duplication of the Air Force efforts but also somewhat contradictory. Thus, the secretary of defense decided that the ASAT mission rested with the Air Force and Program 437.[41]

Operational Concept and the Development of Program 437

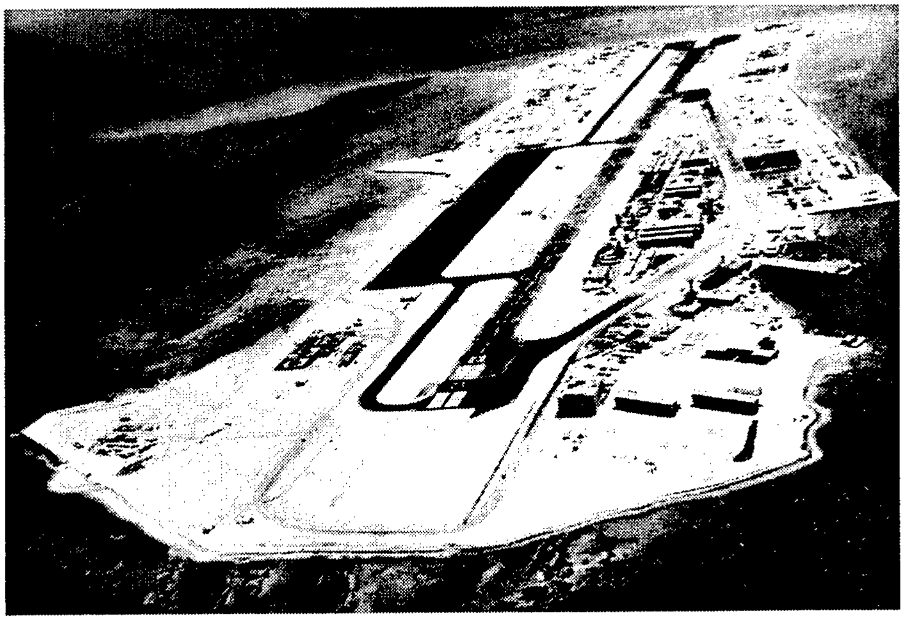
A significant advantage of Program 437 over Nike-Zeus was its use of existing technology and weapons systems. The Air Force's alternative melded the Thor booster, existing warheads and launch pads, and ADC's worldwide detection, tracking, communications, and command and control infrastructure into an operational ASAT system. McNamara's decision to make the Air Force the executive agent for the ASAT system energized Zuckert to move quickly to secure this role and make it an ADC mission.

Secretary Zuckert's operational concept for the program incorporated two bases, Johnston Island and Vandenberg AFB. The Johnston Island site provided launch pads for two Thor ASAT boosters on continuous alert. The Air Force would use Vandenberg AFB as the support and training facility for Johnston Island. The Air Force planned to airlift Thor boosters, crews, nuclear weapons, and support equipment to Johnston Island as needed. As envisioned by Zuckert and others, the location of Johnston Island, west southwest of Hawaii, would allow the Air Force to intercept a hostile satellite before it reached the continental United States. This defense against



(Courtesy of Air Force Space Command History Office)

Thor Ballistic Missile

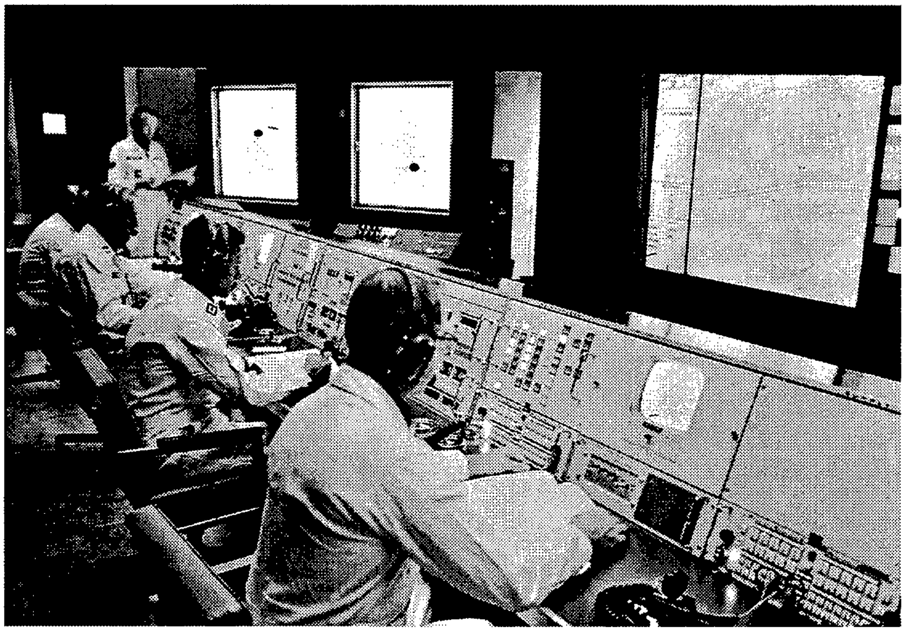


(Courtesy of Air Force Space Command History Office)

Aerial view of Johnston Island launch site

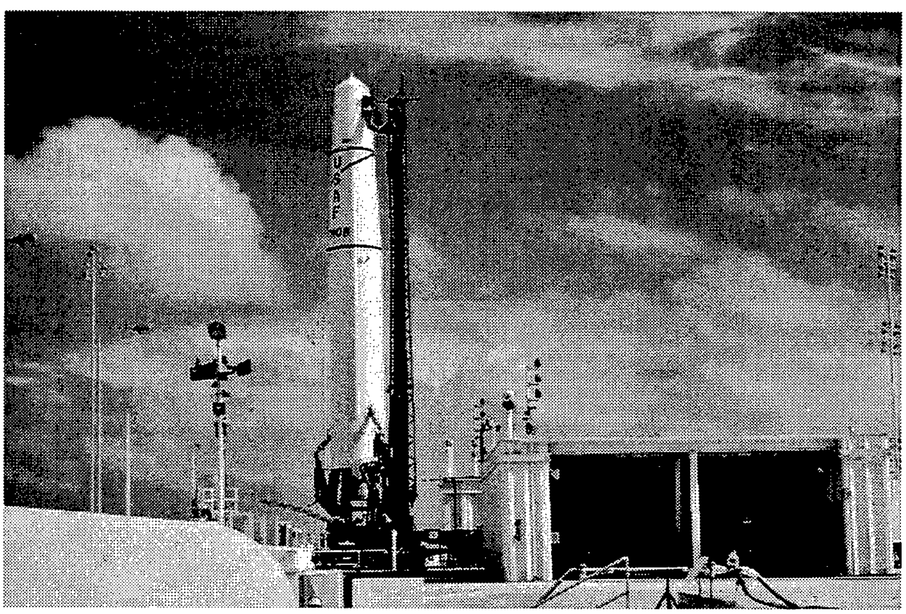
(Courtesy of Air Force Space Command History Office)

10th Aerospace Defense Squadron unit ADS patch



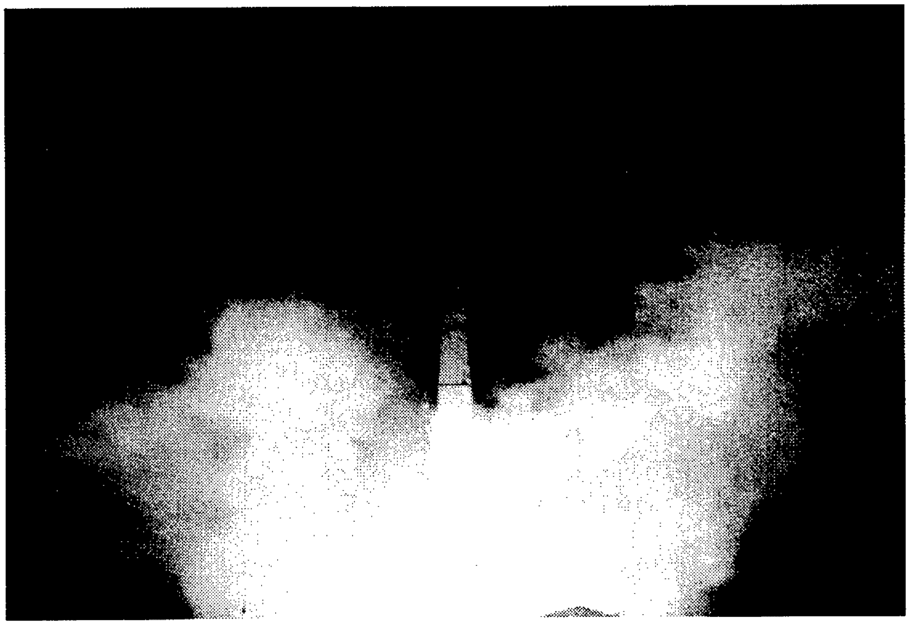
(Courtesy of Air Force Space Command History Office)

Johnston Island launch control center



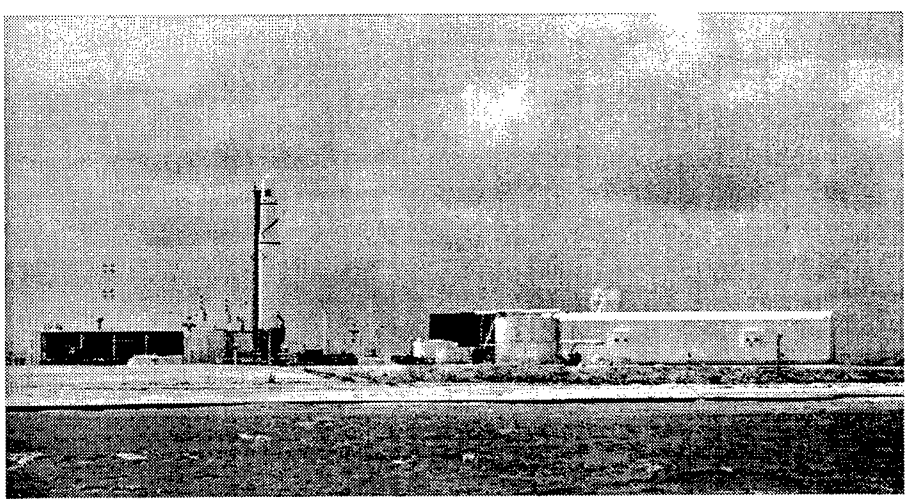
(Courtesy of Air Force Space Command History Office)

Thor missile on launch alert



(Courtesy of Air Force Space Command History Office)

Program 437 test launch



(Courtesy of Air Force Space Command History Office)

"Beach front" Thor launch pad

The close proximity of the Johnston Island launch facilities to the Pacific Ocean exposed the Thor booster and the launch equipment to severe damage by the harsh environment and strong Pacific Ocean storms.

attacks from space was especially important if the targets were carrying a nuclear bombardment system.

ADC formed the 10th Aerospace Defense Squadron (ADS) to operate the Johnston Island site. AFSC personnel from the 6595th Test Squadron at Vandenberg would assist in making the program operational. SAC training and maintenance personnel were recruited for their Thor experience to prepare crews and missiles. Additionally, ADC combed its Bomarc[42] SAM launch crews for personnel to operate Thor since they were familiar with the ADC mission. The original staffing concept called for 178 personnel. Three launch teams would rotate from Vandenberg to Johnston Island. A small, permanent Johnston Island detachment would maintain the launch pads.

Given an ADC order to launch, the detachment at Johnston Island would prepare the site and the missiles; additional crews from Vandenberg AFB would deploy if required. The detachment would have two missiles ready for launch. ADC would provide tracking and guidance information. The crews would countdown both missiles, in case of failure on the primary missile. ADC needed time to detect and compute tracking paths for Program 437. ADC required anywhere from 6–12 hours to determine an interception track for the Thor. Had the Army had to rely on this same data (as likely would have been the case), the launch time disparity between the two systems essentially would have become irrelevant. The immediate reaction or launch capability of Nike-Zeus would have become moot since the Air Force would have had the same window of time to prepare a Thor for launch and interception of the target.

Though Johnston Island needed a lead time of several hours to prepare the Thor's interception vehicle for launch, ADC combat crews had but a five-second window to launch the Thor ASAT weapon to attempt the intercept. Nonetheless, AFSC promised the system would deliver its payload with an accuracy of at least three nautical miles along a one-and-a half-mile-long track.[43] In comparison, Apollo moon launches had a time margin of error between four to five minutes.[44] Engineers ensured that Program 437's Mark 49 warhead had a five-mile kill radius against a satellite to compensate for errors in the launch time and in the intercept course.

AFSC engineers believed the Thor guidance system was better than advertised and would put warheads well within the nominal three nautical miles projected by others. AFSC's experts were confident that Program 437 would intercept a target within 40 meters.[45] Col Philip R. Jackson, a former targeting and guidance officer, estimated that on one test launch the interception did come within the forecasted 40 meter intercept range.[46]

AFSC's Space Systems Division (SSD) received the final "go-ahead" for Program 437 on 11 January 1963.[47] Several areas required SSD's attention to make the program operational. The existing Johnston Island facilities provided basic resources to launch the Thor. However, the AFSC engineering staff planned to improve the tracking radar and computer systems and modify the launch pads and blockhouse. SSD engineers believed it was necessary to modify the Thor booster, fabricate and improve the airborne guidance equipment, build an intercept vehicle, and integrate the Johnston Island operations into ADC's space detection and tracking system (SPADATS).

SPADATS was a part of the North American Air Defense Command's (NORAD) early warning system of worldwide radar and optical sensors. These systems allowed the Air Force to detect and calculate satellite orbits and potential interception guidance data. These capabilities required secure and timely communications, data analysis, and transmission of the flight data to Johnston Island. The main project concerns were the complex computer programming for the tracking radar relating to guidance and mission planning.[48] Ford Aerospace was responsible for developing the computer algorithms to determine the target's location at intercept. According to Maj Henry K. Kroft, a former ADC historical officer from the 1st Aerospace Control Squadron (ACS), this was the only "high tech" application developed for Program 437.[49] Program 437's software would guide the warhead to intercept the satellite at a cross trajectory. Once ADC crews determined the intercept location, they calculated the timing for the launch.

ADC faced serious obstacles in making the ASAT program operational. While ADC's activation of Program 437 was facilitated because it relied on existing boosters, facilities, and support systems, the command had only limited funding but had to meet an ambitious schedule to make the ASAT system operational. Research, development, facilities, support, test, and evaluation funding was restricted to $17 million for Phase I of the program with operations and maintenance funding of $3 to $5 million a year.[50] Contractor support used up $12 million of the total research funds. If all went well, ADC would have an initial operational capability by 1 May 1964. This schedule was released on 16 January 1963, giving AFSC a mere 17 months to develop and field the system. By 21 August 1963, the Air Force revised the initial program cost from $17 to $39.2 million. However, the schedule still reflected a 1 May 1964 initial operating capability. The major changes included buying additional Thor boosters. The Sandia National Laboratory, Albuquerque, New Mexico, was contracted to build an interception vehicle that included a warhead detonation system and telemetry receiving system.[51]

Although this project was an entirely new mission for the Air Force, many ADC, AFSC, and contractor personnel believed that Program 437 was viable. Col John R. Barnard, a former Program 437 combat crew commander and early project team member, recalled that developers had a "very positive feeling." "At no time did we feel that it couldn't be done or that we were spinning our wheels doing it."[52] Barnard attributed much of the success to the operational personnel from ADC's Bomarc program. These crews had few doubts about being able to implement the project.

The Program 437 development process provided few roadblocks towards operational deployment. The only slow up was caused by the shift of the nation's national security focus resulting from unfolding events in South Vietnam. Program 437's status as a DOD "top priority" was lost forever after the Tonkin Gulf incident. Money, manpower, and other resources were quickly shifted to fight the Vietnam War. Program 437 was but one among many projects that fell victim to this change in emphasis from preparing for hypothetical cold war nuclear conflict to fighting a "real" war.[53]

Undaunted, the SSD's engineers designed a series of four test launches to prove Program 437's operational capability. These tests were code-named Squanto Terror, a name perhaps more menacing than Program 437 was in reality. The first test launch was conducted by Douglas Aircraft Company engineers on 14 February 1964.[54] The target was a Transit 2A rocket body that was successfully intercepted within the prescribed kill radius. The Air Force launched the Squanto Terror tests over Johnston Island in sunlight to ensure that a Baker-Nunn camera on the island could photograph the intercept as proof of the mission's success.[55]

The second Squanto Terror test launch was conducted less than a month later on 1 March 1964. The primary Thor booster experienced mechanical problems, and the Douglas contractor crew recommended that SSD engineers switch to the backup Thor, which successfully intercepted its target. The third test shot, on 23 April 1964, differed from the previous launches. This time an all "blue-suit" crew from the 10th ADS conducted the launch and met the test objectives.

The last test launch was scheduled for 28 May 1964. Lt Gen Herbert B. Thatcher, ADC commander, went to Johnston Island to witness the test but the launch failed. The Thor's exhaust flames burned through the vernier engine actuator cable and caused a malfunction after liftoff. General Thatcher agreed with a postlaunch evaluation that the test's failure was not the fault of the 10th ADS crew or its procedures but the booster. As a result, Thatcher declared that Program 437 had met its initial operational capability. The Air Force finally had an operational military space force and weapon. On 10 June 1964, ADC transferred a second Thor to Johnston Island. The Air Force now maintained two nuclear-armed Thors on their launch pads on a 24-hour alert.

Limiting Factors

However, Program 437 had several limitations. ADC needed to ensure that launch crew proficiency remained high due to the nature of the 10th ADS mission but had limited resources (principally available Thors) for doing so. ADC planned to conduct three combat training launches (CTL) a year from Johnston Island to maintain the reliability of the program.[56] These CTLs provided a way to test the ADC crew readiness and test modifications to the ASAT systems. ADC policy was to have each of its three crews carry out a CTL mission. Each crew rotated to Johnston Island for a 90-day temporary duty. ADC conducted the first CTL on 16 November 1964.

Funding Shortfalls

However, an increasing funds shortfall in the Air Force budget did not allow the acquisition of sufficient components to sustain the recommended three CTLs per year. In December 1963 the Office of the Secretary of Defense allocated only enough funds to purchase eight Thor boosters for Program 437. The 10th ADS would maintain four vehicles—two on alert at Johnston Island and two at Vandenberg AFB in storage as spares. The CTL on 16 November left only three more opportunities for the ADC crews to test and sharpen their skills. The funding support for Program 437 was to last until 30 June 1967 (the end of FY 1967).

Despite the successful test launches from Johnston Island, Maj Gen John D. Lavelle, the Air Force's director of aerospace requirements, testified in congressional budget hearings that the system was not fully operational. General Lavelle's note of concern was to inform the Congress that Program 437 still required some developmental work before it was fully deployable. He stressed the point that Program 437 was "designed to prove a concept"[57] first, with the hope of providing a working weapon system once the test program proved the feasibility of an ASAT weapon. Lavelle's testimony led to congressional speculation that the Air Force was not doing enough in the space defense arena. Rep Daniel Flood (D-Pa.) in the same hearings chastised the Air Force as "a little timid" for not asking for more funding to expand the program.[58] Flood wanted a better space defense capability.

The second CTL occurred on 5 April 1965. This CTL mission was to intercept an inactive Transit 2A Navy navigational satellite, which had been in orbit since June 1960 and remained operational until August 1962.[59] The 10th ADS crew launched a Thor with a dummy warhead. The test was a total success: the warhead approached within 0.89 nautical miles of the Transit 2A. After this second training launch, few boosters were left—only two for CTLs.

Col Charles E. Minihan, the 10th ADS commander, pressed the Air Force for additional Thor boosters. Unless the Air Force could fund more boosters, the squadron's ability to maintain launch readiness was in question. Air Force efforts to sway McNamara to authorize more funding were successful. DOD authorized the purchase of 16 more boosters in September 1965 for Program 437 use from fiscal years 1966 through 1971. Despite the added funding, the 10th ADS did not schedule the next CTL until 31 March 1967.

Location, Location, Location

A second factor limiting Program 437's success was the limited coverage of its radar detection and guidance systems. First, if the Soviets launched offensive space weapons from the Tyuratam* complex on an orbital inclination between 65 to 80 or less than 57 degrees latitude, SPADATS would not detect the targets until they reached North American air space.[60] Second, because ADC needed 6–12 hours to track a target and calculate an intercept course, a Soviet barrage of fractional orbiting bombardment system (FOBS), multiple orbiting bombardment system (MOBS), or decoys would swamp the limited capabilities and resources of Johnston Island to counter the inbound space weapons. For example, a Soviet reconnaissance satellite might finish its mission over SAC bomber bases or, if it were a FOBS,[61] it could deliver its nuclear payloads before ADC could respond. Some US analysts speculated that the Soviets would launch a suborbital FOBS attack via the Southern Hemisphere to escape detection from the United States's northern missile warning radar system. The Soviets potentially could have launched a MOBS[62] that would have orbited the earth one or more times before releasing its weapons over a target. To defend against these multiple threats, the Air Force

*Tyuratam in Kazakhstan is more commonly known as the Baikonur Cosmodrome.

missiles and warheads to Johnston Island from the continental United States for the 10th ADS to undertake multiple intercepts. Once these Thors reached Johnston Island, the 10th ADS crews would have needed several hours, if not days, to prepare the missiles for launch and obtain the proper intercept guidance from the North American Air Defense Command. This process would have resulted in long delays before another ASAT launch could take place. Undoubtedly by the time the launch crew had the next Thor ready to launch, the Soviet missiles or warheads likely would have destroyed their targets.

Additionally, Johnston Island was relatively insecure. An enemy raid, by naval commandos, for example, could have destroyed the launch pads and Thors sitting on alert. Col Troy Alcorn, commander of Detachment 1, 10th ADS, during 1966, commented that Soviet submarines were only 10 miles off Johnston Island during test launches.[63] The Soviets were well within range to launch an attack. A more likely source of damage to Program 437 was from strong tropical storms that potentially could batter the island and reduce the site to rubble.

The Nuclear Specter

The Thor's nuclear warhead further constrained Program 437's viability. The use of an atomic weapon to kill an enemy satellite might inadvertently signal the start of a nuclear war. The US might launch such an attack suspecting that the Soviets were launching a surprise strategic attack from space. The USSR in turn might react by launching an all-out nuclear offensive thinking the United States was preparing for a nuclear first strike. Even if an ASAT mission were successful and did not start an all-out nuclear war, the residual radiation and EMP effects likely would have had unintended consequences. For example, such an ASAT attack might accidentally destroy friendly satellites as had happened during the Starfish Prime test.

Program 437 Unmasked

Details about Program 437 were completely unknown to the US public until the fall of 1964. On 17 September 1964, President Lyndon B. Johnson, during a reelection campaign trip to Sacramento, California, disclosed that the United States had developed an ASAT capability to intercept a satellite that might be carrying a weapon that threatened US national security.[64] The day after Johnson's revelation Secretary McNamara announced that the United States had conducted test launches of ASAT weapons that successfully had either intercepted orbiting satellites, or at least had passed within the weapon's effective kill radius. He noted that the ASAT system was a ground-based, direct-ascent system that relied on interception data from existing US radar systems.[65] McNamara did not mention the location, the number of weapons, or whether the ASAT weapons used nuclear or conventional warheads.[66]

Gen John P. McConnell, the new Air Force chief of staff, later admitted that Johnson had acknowledged the existence of Program 437 and its ASAT capabilities for several reasons. Chief among them was the need to defend the United States against a perceived "potential threat from space" and to counter "a psychological threat" to the nation.[67] Politics was also involved. Republican presidential contender Barry Goldwater earlier in the campaign had accused Johnson of being "soft" on defense. Whatever his reasons for revealing the existence of Program 437, President Johnson not only put the Soviets on warning that the United States had an operational ASAT system, but he also told the electorate that he was prepared to defend the country from any possible Soviet attack, even if it came from outer space.

This disclosure was not a complete surprise to many in the aerospace and defense industry. Kennedy had admitted to the nation that he had started development of an ASAT weapon in October 1963 to allay congressional fears about the vulnerability of the United States to Soviet FOBS and MOBS weapons.[68] Kennedy had declared the systems involved were the Nike-Zeus missiles on Kwajalein Island and Thor rockets. Still, some doubted the likelihood of a threat from a FOBS or MOBS attack. In earlier congressional hearings, Dr. Harold Brown, director of defense research and engineering and later secretary of the air force, tried to minimize the viability of a FOBS and MOBS weapon. He stated that the FOBS or MOBS needed a better guidance and stronger booster system than an ICBM.[69] The Air Force continued to develop Program 437 despite such doubts.

A New Mission for the 10th ADS

The 10th ADS's mission soon underwent a radical shift in direction. On 23 May 1963, AFSC directed the Space Systems Division to study the possibility of using Program 437 to act as a satellite inspection system. Program 437AP (advanced payload) would provide the ability to examine an orbiting satellite. This new program was vital if the president needed more information to determine whether an orbiting satellite constituted a threat to US national security and vital national interests and, thus, should be destroyed. Intelligence agencies, like the CIA, could look at a photograph to see if the space vehicle was an intelligence gathering, communications, or MOBS satellite.

AFSC and General Electric, the developer of the defunct SAINT system, urged ADC to take on Program 437AP and its satellite photographing mission. Program 437AP would incorporate a modified Mark 2 reentry vehicle using a camera from the National Reconnaissance Office's (NRO) successful Corona imagery satellite. On 9 December 1963, Under Secretary of the Air Force Brockway McMillan requested that LeMay complete a development plan for Program 437AP not later than 23 December. McMillan, who also served as the director of the NRO, may have had other reasons to develop Program 437AP. As the director of the NRO, he was responsible for much of the nation's space reconnaissance efforts, including imagery. The Corona satellite was an integral part of the NRO's assets.[70] The capability to gather imagery intelligence of an orbiting Soviet intelligence satellite would allow the NRO to examine these systems close up. Using the NRO's camera from the Corona satellite, hence the term "Corona camera," would reduce the cost and development time for the program. The Corona camera could take five to seven photographs in daylight at an altitude between 70 to 420 miles.[71] After the Program 437AP inspector satellite photographed a target, it would eject a film canister as its orbit passed near Hawaii. A specially modified

C-130 aircraft from Hickam AFB, Hawaii, would recover the film as it parachuted towards earth.

Although the added Program 437AP testing allowed combat crews to use these launches as CTLs, the 10th ADS feared that its ASAT capabilities would atrophy. While the launch and maintenance crews could change the photographic payload to a nuclear one, doing so would result in operational delays that would reduce the overall effectiveness of both programs. Thus, ADC decided to keep two separately configured missiles on alert—a Program 437AP Thor on the secondary launch pad and a nuclear-armed ASAT Thor on the primary launch pad. This change ended the practice of maintaining two ASAT vehicles ready for launch. This reduced ASAT capability was offset by AFSC's growing confidence in the overall reliability of Program 437. Douglas Aircraft Company engineers estimated that the system's overall interception reliability was about 70 percent for a single launch and more than 80 percent if a dual launch countdown was used.[72]

The Air Force was still convinced of Program 437's importance and continued to strive to improve the system. The Space Systems Division proposed to ADC that it should increase the ground-based guidance system capabilities on Johnston Island. The SSD plan involved the use of new computers and radars to correct a serious weakness in Program 437's guidance system, which had an inspection range of only 210 degrees. In addition to the changes in the Johnston Island support systems, SSD would construct a training facility at Vandenberg AFB. It would house radar and computer systems that duplicated those on Johnston Island. ADC would use this facility to train launch and support crews. These new radar and computer systems would have allowed a full 360-degree coverage for ground guidance capability. SSD planned completion of these upgrades by 1966.

Douglas Aircraft contractors and 10th ADS crews conducted several Program 437AP test launches from 7 December 1965 through 2 July 1966 to explore the capabilities of the primary panoramic and secondary index cameras. The tests required more precise guidance and interception data than an ASAT mission. Several early test launches failed. However, the feasibility of Program 437AP was proven, even though the film capsule was not recovered successfully, when, on 7 December 1965, a Thor-launched satellite photographed an expended Agena rocket body. The Thor's payload flew within 0.56 nautical miles and took only 8.18 minutes to intercept the target. A subsequent launch on 18 January 1966 was an unqualified success. The Thor booster put the photographic payload within range of another Agena rocket body. This time the AFSC-crewed C-130 recovered the film capsule. Another test launch on 12 March 1966 met with similar success. The Air Staff and AFSC decided to cancel the final test launch to save the Thor booster.

Program 437AP's concept of operations was simple. The Joint Chiefs of Staff (JCS) developed a satellite target list. ADC's mission was to photograph and analyze the targets and send the information to intelligence agencies for further review. The JCS priority target list allowed the 10th ADS to schedule Thor preparations and arrange C-130 recovery support on a routine basis. This new mission caused ADC to alter its operations.

The 10th ADS would keep both Thor boosters on ASAT alert for a dual launch capability. Countdown would proceed until T minus eight hours to launch. If it was to be a photographic inspection mission, the launch crew and support personnel would then remove and replace the nuclear warheads with a photographic payload on both Thors. Depending on the target, the Johnston Island or Vandenberg AFB ground guidance station would provide SPADATS, target intercept, and timing data along with other support to the launch crew. A reserve launch crew at Vandenberg would stand ready to go to Johnston Island for further assistance. If deployed, this backup crew would transport a Thor booster to Johnston Island. The 10th ADS kept two cameras ready for launch and had a backup on the island. The other two cameras remained in storage at Vandenberg AFB. The 10th ADS required at least 15 days to refurbish and prepare the site to launch either another photographic or an ASAT mission.

Meanwhile, NASA developed an interest in Program 437AP. As the Air Force was preparing to cancel the fourth test launch, NASA experienced problems with its Orbiting Astronomical Observatory I (OAO-I) satellite, which had been launched on 8 April 1966 in a 500-nm orbit.[73] The satellite had lost power and malfunctioned. The space agency asked the Air Force to photograph OAO-I so that NASA engineers could examine photographs to determine what had gone awry. On 2 July 1966 ADC launched a Program 437AP mission in search of OAO-I. The mission failed to find its target.

Several factors limited the feasibility of Program 437AP. First, the highest possible altitude possible using Thor boosters was 725 nautical miles. This ceiling let ADC inspect targets only in low earth orbit. Second, the recovery C-130 aircraft required time to calculate and find the recovery site. The Johnston Island location, ground guidance system, and intercept geometry restricted the Program 437AP's capability. Third, the panoramic camera onboard the Thor could operate effectively only within certain parameters. The target satellite had to be illuminated in direct sunlight and the Thor needed to put the camera at a 45-degree crossing angle. Fourth, the booster and payload would not separate until 160 seconds after liftoff, thus limiting the Program 437AP missions to a minimum intercept altitude of 100 nautical miles. ADC crews estimated the optimal intercept altitude was 400 nautical miles at a maximum range of 800 nautical miles.[74] Finally, accurate tracking of space vehicles in high-drag orbits, below 250 nautical miles, was unreliable and interceptions below that altitude were impractical.[75]

The possibility of photographing another nation's satellites was an interesting proposition for US intelligence agencies. The Program 437AP payloads provided the ability to uncloak "secret" Soviet space systems. Despite the technical restraints that had to be overcome on such launches, the Air Force scheduled a fourth test launch for 6 April 1966 to photograph a Soviet satellite.[76] The JCS and the United States Intelligence Board (USIB) vetoed the proposed mission because they thought the flight was too provocative. Even though this mission was vetoed, Harold Brown, now secretary of the air force, requested funding from McNamara to support at least 10 more Program 437AP missions. The USIB opposed Program 437AP launches from Johnston Island since the Soviets undoubtedly had identified that location as a hub for ASAT operations and might well regard any launch from Johnston Island as a nuclear attack on their space assets. The USIB suggested the Air Force build another base to launch Program 437AP missions. However, because the costs to replicate the launch facilities were too high, enthusiasm for Program 437AP among DOD and national security agencies waned. Consequently, the Air Staff decided not to build a separate Program 437AP launch facility and, on 30 November 1966, decided to cancel the satellite inspection program altogether.

A Third Life for Program 437

Despite increasing Soviet space activity in the 1960s, the Air Force's Program 437 did not target any specific space threats other than a hypothetical FOBS or MOBS deployment. The 10th ADS mission would soon get a surprising boost from the CIA. Its 1966 *National Intelligence Estimate* projected that the Soviets had conducted several test FOBS launches, but the CIA was not convinced the launches would lead to a MOBS capability.[77] The following year, the CIA revealed that the USSR had been experimenting with a FOBS capability as early as 1965. The agency's analysts concluded that the Soviets would likely deploy it.[78] The CIA thought the Soviet Union had the ability to launch a few FOBS attacks against the United States and that Program 437 might be able to handle the threat.

The Soviet Union's SS-9 ICBM was thought to be the FOBS booster. In the USSR's 1965 May Day celebration, its Strategic Rocket Forces proclaimed that the SS-9 had "an orbital weapons application."[79] As proof of this capability, the Soviets made no less than 15 test FOBS launches from 1965 through 1969. Most of the tests were conducted from January to October 1967. On 25 January 1967 an SS-9, *Cosmos 139*, was launched from the Baikonur Cosmodrome and its payload landed 90 minutes later near the Soviet military rocket range of Kapustin Yar.[80] Secretary McNamara revealed that *Cosmos 139*'s purpose was an orbital nuclear weapons test. If the Soviets used FOBS to attack the United States, then the nation would not have adequate warning time for an immediate nuclear response. What if the SS-9 put the MOBS payload into a higher, more permanent orbit? Although short warning times made Program 437 a questionable defense against suborbital FOBS, the Thor-based ASAT weapon system might be capable of intercepting an orbiting MOBS.

Not only was short warning time a problem against a FOBS, so was the location of the Thor launch site. Indeed, Johnston Island's location proved to be distinctly disadvantageous to the successful intercept of a FOBS threat. Since the FOBS was a suborbital weapon, its altitude would normally be below 250 nautical miles—not optimal for a Program 437 interception. Additionally, as noted above, Soviet launches from less than 57 degrees or between 65 and 80 degrees latitude would be outside the coverage areas of then existing US radar systems. Though the Thors could be launched to attack any target in any direction from Johnston Island, only those targets on a inclination between 57 and 65 degrees or above 80 degrees latitude would be detectable by US warning radar and thus susceptible to attack by the Thor. Incoming targets above 80 degrees latitude would likely be well out of range of Johnston Island. For example, if the Soviets used the Tyuratam space launch complex (or any other site) to launch a suborbital attack on a path between 49.5 to 50 degrees latitude, then the Thor could not intercept the incoming Soviet warhead(s).

The 10th ADS crews soldiered on despite these limitations. The squadron continued CTLs through 1967 until 21 November 1968 to prove the Thor's ability to hit targets in space orbit. On 30 March 1967, the Continental Air Defense Command (CONAD), a joint defense command that included ADC, conducted a simulated orbital bomb system attack on the United States. The 10th ADS's reaction was judged a success when a simulated ASAT payload intercepted a designated position in space within two nautical miles.

The possibility of Soviet FOBS and/or MOBS strikes provided a new reason to retain an ASAT capability. However, Program 437 was rapidly becoming obsolete. ADC still believed in an ASAT mission, but instead of a direct ascent system like Thor, the command requested that the Air Staff approve a replacement system based on a co-orbital interceptor like the original SAINT program. ADC issued a required operational capability (ROC) statement that defined this proposed system on 17 March 1967.[81] This ROC reflected ADC's desire to get the Air Staff to approve the development of a nonnuclear ASAT system. This system would intercept, inspect, negate, and conduct a postattack assessment of a space vehicle. The Air Staff disapproved the ROC and ADC continued to operate Program 437.

ADC tried other approaches to upgrade and develop new systems for Program 437. For example, the 10th ADS used a powerful second stage booster, the Burner II, to put defense meteorological support program (DMSP) satellites into polar orbit. Perhaps Burner II could extend Program 437's operational life. As a result of DMSP and Burner II testing, the 10th ADS became the 10th Aerospace Defense Group (ADG).

Despite the broadening of its mission and the change in its unit designation, the 10th ADG was barely hanging on to its operational life. The decreased numbers of Thors reduced the frequency of CTLs and degraded the 10th ADG's crew alert and readiness conditions. The ADC crews had only six Thor boosters to support the Burner II and DMSP programs. Four boosters were required to maintain the ASAT capability—two on alert at Johnston Island and two spares at Vandenberg AFB. The remaining two boosters were earmarked for the Burner II test program. This commitment of all available missiles eliminated future CTLs unless the Air Force acquired more Thors.

The Demise of Program 437

In addition to dwindling numbers and the age of available Thor boosters in the late 1960s, the vulnerability of the launch site to weather and other natural disasters helped to doom Program 437. The Thor boosters stood alert on open launch pads, unprotected from the harsh environment and strong Pacific storms or other natural disasters. Over time the rocket bodies and launch support equipment were susceptible to the corrosive effects of the heat, humidity, and salt-water spray. The 10th ADG began experiencing frequent failures of launch equipment. For example, on 22 March 1969, a Thor on alert was declared inoperable due to a failed turbopump.[82] Two weeks later a spare booster arrived from Vandenberg AFB, allowing the 10th ADG to regain full operational readiness. Additionally, ADC was concerned about the vulnerability of the Johnston Island launch site. Were a Soviet commando team to launch an attack from a submarine or surface ship, the island was hundreds of miles away from military support forces in Hawaii. Due to the cumulative impact of these negative factors, ADC proposed to move all operations to Vandenberg AFB.

The Air Staff initially rejected ADC's proposal. However, as the Vietnam conflict grew in size and intensity and as the United States committed more military resources to the Southeast Asia theater, the Air Staff soon decided to make drastic cutbacks in Program 437. In December 1969, the Air Staff's Directorate of Operations notified the 10th ADG, through ADC, that its manpower would be reduced by 124 guidance and security positions as of 1 October 1969. Because of these cutbacks, especially in security personnel, the Air Force directed the 10th ADG to remove the nuclear warheads from the Thor missiles on the launch pads and store them in shelters. Launch crews and support personnel would reinstall them if an ASAT launch were imminent. On 8 September 1969, the Air Staff decided to terminate Program 437 as of 30 June 1973.

The Air Staff timetable for terminating Program 437 was not fast enough for the Office of the Secretary of Defense. On 4 May 1970, Deputy Secretary of Defense David Packard directed Secretary of the Air Force Robert Seamans to shut down Program 437 by 30 June 1970.[83] On 14 May 1970 Seamans notified Secretary of Defense Melvin Laird that ADC would deactivate Johnston Island as of 2 October 1970. The launch reaction time to conduct an ASAT mission was relaxed to a 30-day period following a removal of all personnel from the launch site except for a caretaker staff.

The final nail in Program 437's coffin came on 19 August 1972 when Hurricane Celeste passed within 21 miles of Johnston Island. The storm's winds destroyed launch facilities and the guidance computer.[84] The lack of personnel and boosters, the 30-day reaction (or lead) time to ready a Thor and its payload for an ASAT launch, and the likelihood that such an ASAT mission would have limited or, at least, questionable effectiveness against FOBS or MOBS systems all worked to compound the impact of the damage inflicted by Celeste.

Once the decision had come to shut the program down, the Air Staff wanted the nuclear warheads retired immediately. ADC resisted this move and kept them as a marginal ASAT capability since it maintained that it had the ability to recreate Program 437 at Vandenberg AFB. The nuclear warheads were stored at Nellis AFB, Nevada.[85] Program 437 continued in name only until 1 April 1975 when its nuclear weapons were finally mothballed. Throughout its existence, Program 437's use of nuclear weapons had raised some eyebrows in the Pentagon.

During this "phase out" of Program 437, ADC had begun exploring the possibility of using conventional weapons on the Thor. One proposal considered was the use of a continuous rod warhead that used a pellet dispersal system.[86] Some in the 10th ADG viewed the Thor as a reliable delivery booster for a nuclear system because a direct hit or intercept was not required. The EMP resulting from detonation of a nuclear warhead would damage or destroy targets that passed within its effective kill radius. However, many of ADC's experts concluded that the Thor had limited potential as a launch vehicle for a conventional weapon system, which would have to score a direct hit to kill a target effectively. As Col John Barnard, a former Thor combat crew commander, put it, the booster was "not consistently accurate enough to use [to launch] conventional [ASAT] weapons."[87]

Program 437 was not a perfect ASAT system. However, it was the first operational weapon designed and deployed as a space defense system. Thus, it provided a glimpse into the future. Some critics might characterize the system as a crude weapon. However, by successfully transforming the Thor ASAT system from satellite interceptor to inspector, the crews of the 10th ADS proved the versatility of the system in many ways.

Program 437's cancellation and the Air Force's subsequent failure to replace it with a more advanced ASAT system has created a potentially critical hole—a modern Achilles' heel—in our nation's defenses. The debate over developing and testing an ASAT system has remained heated, though at times nearly unnoticed by the general public, since the end of Program 437. Some opponents argue forcefully that revival of an active ASAT program will rekindle an arms race of cold war proportions. Proponents of such a system see an urgent need for such a defense to protect the United States from such rogue states as North Korea and Iran and even the growing threat from Communist China. They also note that Russia has continued testing and improving its nuclear warheads. Whether such a system is vital to the nation's security depends on how critical our dependence on space has become in recent decades and how real the threat is from states other than Russia.

Space: A Critical Dimension

In the past two decades, the US military and civilian communities have become ever more dependent upon space-based reconnaissance, intelligence, surveillance, warning, communications, navigation, meteorological, and other systems. Although the US military is not solely reliant on space systems for fighting a war, winning a major theater conflict would prove more costly without them. The space systems used in the early 1960s were relatively crude and few in number. Had the United States lost a satellite then, its war-fighting capabilities would not have been seriously weakened because of the limited reliance on space systems. Today, the Air Force, other US services, and our allies would need to make major adjustments to their weapons and support systems and war-fighting plans to overcome the loss of vital space systems. The Air Force relies on several satellite systems and constellations of satellites for gathering and transmitting critical intelligence and battlefield information. These systems may be vulnerable to attack by ASAT weapons from several quarters, including Russia, North Korea, Iran, India, and China. The latter four have emerging missile and space programs that may give them the capability to attack and destroy some space-based defense systems.

Since many of the US intelligence-gathering and defense communications satellites fly in low earth orbits that range from 60–250 miles, they may well be vulnerable to rudimentary ASAT systems on the order of what the United States achieved with Program 437. As the United States becomes increasingly dependent on space systems, will its space systems become proportionately more vulnerable? Loss of one or more such space systems would affect our ability to observe a foe, target weapons, and fight a war. A potential adversary could develop several means to counter US space superiority. An opponent need not achieve space superiority or supremacy, only space denial for a limited time and/or region of space to seriously degrade US capabilities.

While Program 437 relied on 1950s technology possessed by only a small number of nations—particularly the USSR and the United States, equivalent, if not superior, technology is widely available today. Several nations likely have the ability to replicate Program 437. The EMP effects on unhardened satellites, illustrated by the Starfish Prime test, provide graphic testimony about the possible damage from the detonation of a nuclear-armed ASAT weapon in space, especially in low earth orbit. Not only are US space assets potentially at risk, but other nations' military, nonmilitary, and commercial space assets are potential targets too. Countries that do not rely extensively on space systems may believe an attack on a US space system will more than offset any collateral losses resulting from damage to what few satellites they use.

The United States conduct of military operations in Desert Shield and Desert Storm illustrates the growing dependence of its forces on space-based assets. The United States and coalition forces involved in the region did not have sufficient in-theater intelligence, communications, information, missile warning, and other support. Much of this crucial data was relayed by satellite links from sites in the United States to forces located in theater. The existing North Atlantic Treaty Organization (NATO) forward base defense doctrine, strategy, and force structure required military planners to redefine mobilization and other strategic moves. Thus the Air Force needed to transform itself into a more mobile force that required instantaneous information from space systems.

These space assets were major force multipliers that allowed the United States and its allies to win swiftly the conflict with Iraq. Air Force and other national space assets enabled the coalition forces to overcome many air- and surface-based communications, intelligence, navigation, weather, and early warning information gaps. Although the United States had several space assets available that provided coverage of southwest Asia, it had to reposition still other systems in space to provide additional support to the theater. For example, the Defense Communications Agency requested, through the Air Force Space Command, that the Joint Chiefs of Staff approve the repositioning of defense satellite communications system (DSCS) flight D-14 from the western Pacific to the Indian Ocean.[88] Those satellites that were in a low earth orbit (LEO) could have been vulnerable to attack by a system similar to a Program 437 clone and thus these systems might have been unavailable to US military forces.

Similarly, during Desert Shield, the NRO used KH-11 photoreconnaissance satellites and radar-imaging LaCrosse satellites.[89] Had these satellites been disabled, the coalition's military effectiveness would have been seriously impaired. These satellites were the eyes and ears for targeting by precision-guided munitions and for battle damage assessment. Had Iraq been able to damage these satellites, it may not have crippled the coalition forces but it could have hampered military operations and made the allied victory much more costly.

Many nonmilitary and commercial organizations and businesses rely heavily on US government and commercial satellites to conduct transactions and transmit information. Thus the reliance upon satellites is growing and will expand, perhaps geometrically, in the future. The United States Space Command (USSPACECOM) estimates that a tremendous explosion of commercial satellite use will take place within the next 10 years. The US Space Command believes 1,000 space launches will take place during this period.[90] Secretary of Defense William S. Cohen has predicted an even higher number in a recent report to the Congress. He expects that in the future 1,200 to 1,500 new satellites may be orbiting the earth.[91] Approximately 30 percent of these launches will come from US flag carriers. Regardless of the number, these new satellites and existing ones will provide many potential targets for a future space adversary, even those with only nascent capabilities. Thus the United States and other space-faring nations need to address the problem of how to defend their space assets.

Vulnerability of Space-Based Assets

How susceptible space systems are to attack depends on two primary factors: their orbit and the capabilities of individual nations or organizations to attack those systems. Satellites may be in low earth,[92] sun-synchronous,[93] geostationary,[94] geosynchronous,[95] or Molniya[96] orbits. Altitudes for these orbits vary significantly. The lower the orbital altitude the more vulnerable a space vehicle would be. Nations trying to establish an ASAT capability would need to select key targets and assess their ability to attack satellites given the orbit. Depending on its booster capability, a country might have a limited range of targets. Some countries may have the capacity only to launch ASAT weapons into low earth orbits. They potentially could put their ASAT weapons into co-orbits to intercept targets or use a nuclear warhead or other EMP device in a direct ascent mode to disable or destroy targets. Other countries may have the capacity to use multistage boosters to put an ASAT system into a low earth orbit and then transfer the warhead to a higher orbit.

Thus, the vulnerability of space assets of the United States and other countries varies according to the type of satellite and the capabilities of potential enemies. Most US military satellites and manned spacecraft are in LEO.[97] The United States puts many of its communications satellites in geostationary orbits. For example, only four satellites in a geostationary orbit provide global communications. A foe needs to understand these orbits and design weapons capable of disabling the appropriate systems. Which countries pose a potential threat to the space assets of the United States and its allies?

Potential Threats

In assessing the potential threat, we must examine which elements nations or groups will need to effect attacks on their enemies' space assets. They will need a means of delivery—they will, at a minimum, need a booster with a range and altitude at least similar to that of the Thor; and they will need a device capable of producing sufficiently strong EMP effect to disable or destroy the intended target. Unless such a nation merely wants to make a random attack on any orbiting satellite, it will need an accurate and timely detection, tracking, and targeting system. This capability requires the ability to support launch activities that include preparing the vehicle and launch pad; keeping a vehicle on alert or in a ready condition; effecting the launch; and possibly refurbishing the launch pad. How real is such a threat? The answer depends on access to space boosters and potential ASAT warheads.

Those nations capable of producing an ASAT system at least equivalent to Program 437 and its Thor-class booster include Russia, North Korea (the Democratic People's Republic of Korea or DPRK), Iran, India, the People's Republic of China (PRC), and Libya. Russia has the most mature development and production capability of the group and has produced ASAT weapons in the past. However, given that the space capabilities of Russia are more widely known, a focus on nations other than Russia is of more interest here. Several possible launch vehicles are available on the open market from one or more of the states listed above. Conversely, a nation may attempt to use its own technical resources and production capacity to build a booster. Some countries, notably North Korea, India, and China, have established domestic missile production capabilities.

North Korea and the PRC have exported and continue to export key ballistic missile technology, including ballistic missiles at least as capable as the Thor. Some of these boosters have been used as space launch vehicles. Both countries have sold components and complete missile systems to other nations, thus saving those countries the time and expense of developing their own missiles. For example, North Korea has sold its No Dong missiles abroad (notably to Iran) and may well begin exporting its Taepo Dong-1 and eventually the Taepo Dong-2.[98] The PRC has exported missile-related technology to Iran, Syria, and Pakistan,[99] thus giving these latter two countries the ability not only to field surface-to-surface ballistic missiles but rudimentary ASAT systems as well. Because neither Syria nor Pakistan has boosters capable of making space launches, this study examines only the potential of North Korean, Iran, India, and China to develop and deploy ASAT systems. Using the missiles and related technology that it has acquired primarily from the DPRK but also from Russia, Iran has the potential not only to develop and deploy an ASAT system but also to become a missile exporting nation. Thus, the United States not only faces a potential future ASAT threat from any of the four countries named above but as these nations begin producing ballistic missiles themselves then the threat of proliferation will increase significantly.

The likelihood that North Korea, Iran, India, or China can achieve an ASAT capability varies widely depending on the lift power and range possible with their ballistic missiles. The largest PRC ballistic missile, the CSS-4 has a range of about 7,000 nautical miles and clearly out performs the Thor by several orders of magnitude. The Chinese CSS-2 and CSS-3 have similar capabilities to the Thor's. North Korea's Taepo Dong-2 will surpass its previous ballistic missile systems. India has a budding ballistic missile capability. Not only could all three nations launch a future ASAT mission against US targets but they could launch missile attacks against neighboring states.

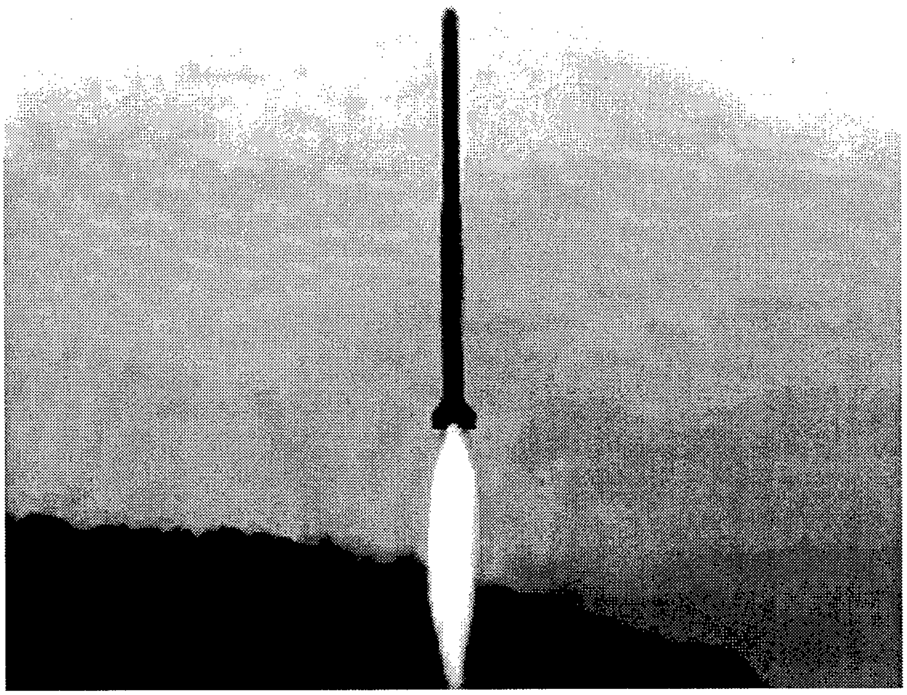
Having ballistic missiles with the power to serve as space launch vehicles does not necessarily give a country the capacity to field an ASAT system. A country would need to acquire or develop a warhead that can kill a target satellite. The most efficient and least costly device to produce is a nuclear weapon.[100] Many countries currently have or are close to developing nuclear warheads that could be used as ASAT weapons. Assuming the availability of a nuclear device and a willingness to use it in an ASAT role, the nation would need to build a large enough nuclear weapon to produce sufficient EMP energy to kill satellites, including those hardened to withstand these effects.

North Korea: Key Exporter of Technology

Some analysts believe the Democratic People's Republic of Korea poses the biggest threat to the United States because of its continuing efforts to expand its ballistic missile capabilities and acquire weapons of mass destruction.[101] North Korea has several medium range ballistic missiles that have operating capabilities close to or better than those of the Thor. The North Koreans not only produce these missiles and have them in their active military inventory but export them along with support equipment and technology. North Korea's need for financial resources has forced not only an increase in sales of existing missile-related materiel but has spurred the DPRK to improve further the capabilities of its ballistic missiles. Although based on the 1950s technology of the Soviet Scud, the North Koreans have applied advanced technology to significantly improve that 40-year-old missile.

The DPRK's Ballistic Missile Capabilities

The North Korean ballistic missile program includes five different models. The DPRK's first missile, based on the Soviet Scud B, is a product of reverse engineering on weapons acquired from Egypt.[102] These missiles became the foundation upon which the DPRK built its budding missile production and development program. North Korea has earned much hard currency from sales of its missiles. The North Koreans can produce from four to eight Scuds a month and they maintain an inventory of several hundred missiles.[103] The Scud B and C (also produced by the DPRK) have limited ranges—between 170 and 270 nautical miles respectively with a payload of between 700 and 1,000 kilograms. Intelligence experts do not believe these missiles have a nuclear or ASAT capability at this time. However, the production expertise and reverse engineering of the North Koreans have aided the expansion of

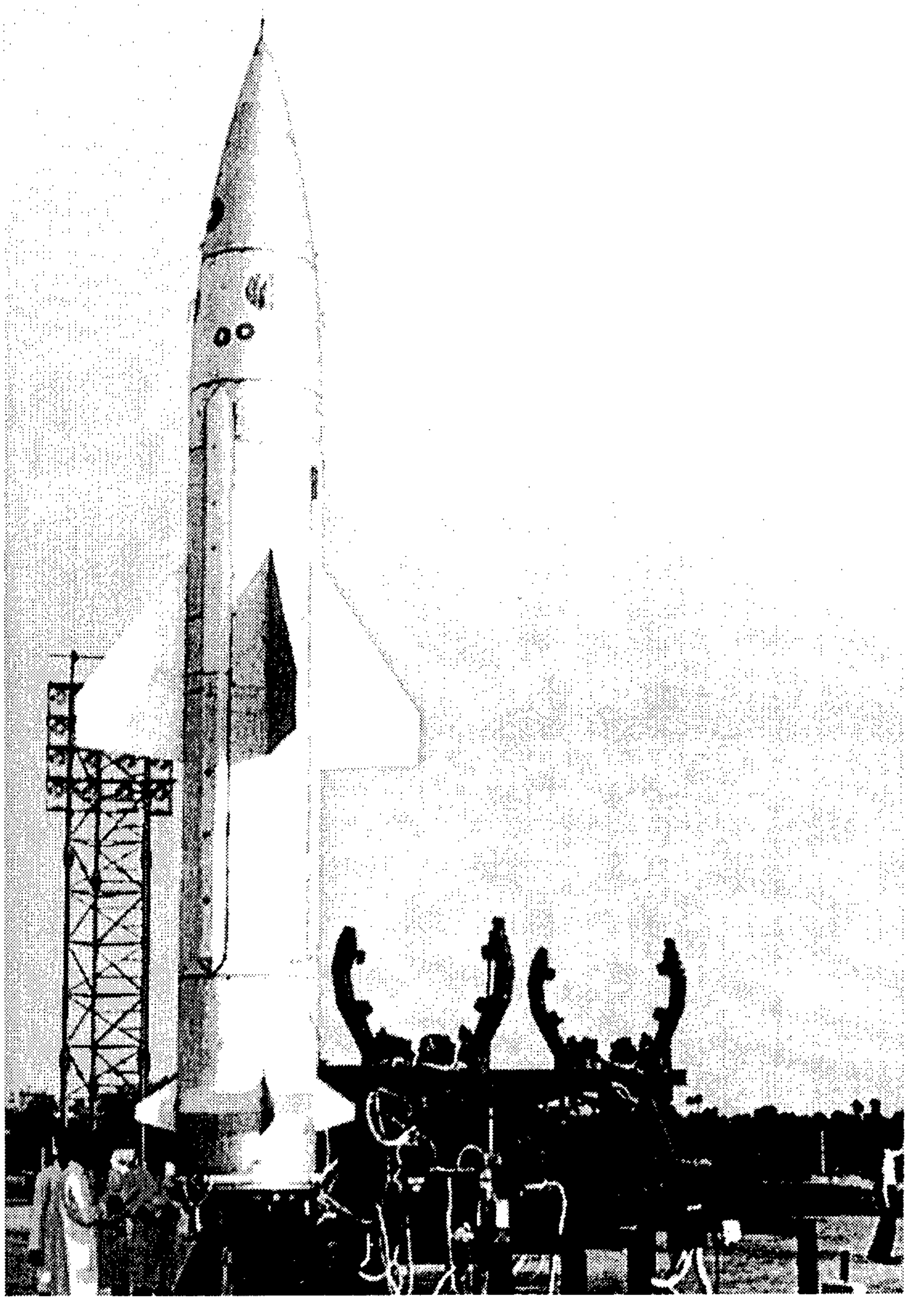


(Courtesy of NAIC)

North Korean Taepo Dong-1 ballistic missile

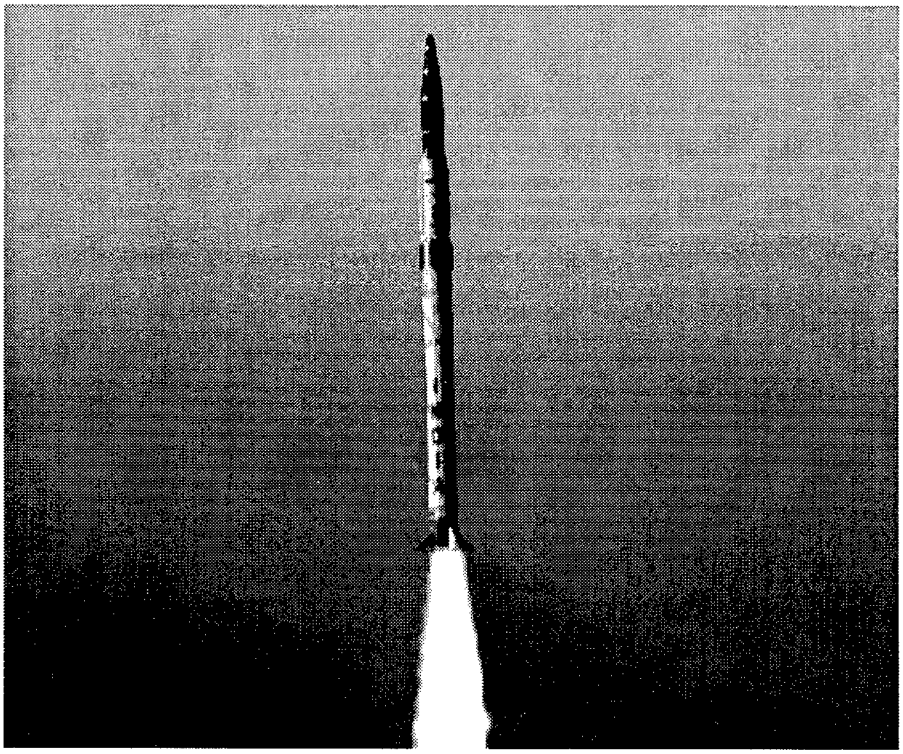
their missile industry. North Korea has reportedly sold Scud B and C missiles, infrastructure, missile assembly, and support equipment to Iran. They likely have provided much technical advice to other countries as well.

A logical step for the North Koreans was to extend the range of the new classes of missiles they developed. The North Koreans have tested the No Dong-1 and -2 ballistic missiles. Both are nuclear capable missiles and have ranges between 400 and 550 nautical miles. North Korea completed development of the No Dong-1 in 1994 and has deployed it.[104] The No Dong-2 is still in development. These missiles are mobile and can be launched from either a transporter-erector or fixed site. The Iranians have bought the No Dong-1 and are providing finan-



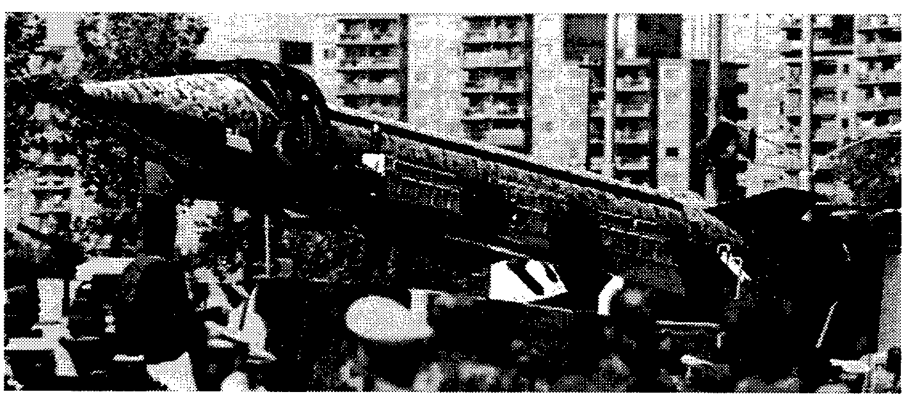
(Courtesy of NAIC)

Prithvi—Indian intermediate range ballistic missile



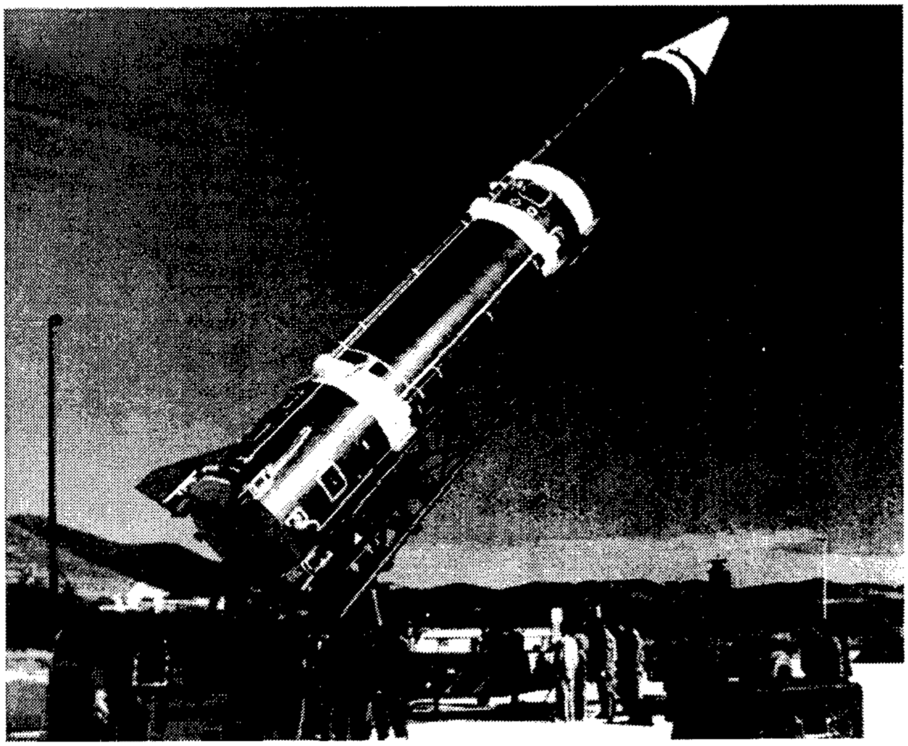
(Courtesy of NAIC)

Indian Agni ballistic missile



(Courtesy of NAIC)

Iranian Shabab-3 medium-range ballistic missile on display during Holy Defense Week parade on 25 September 1998

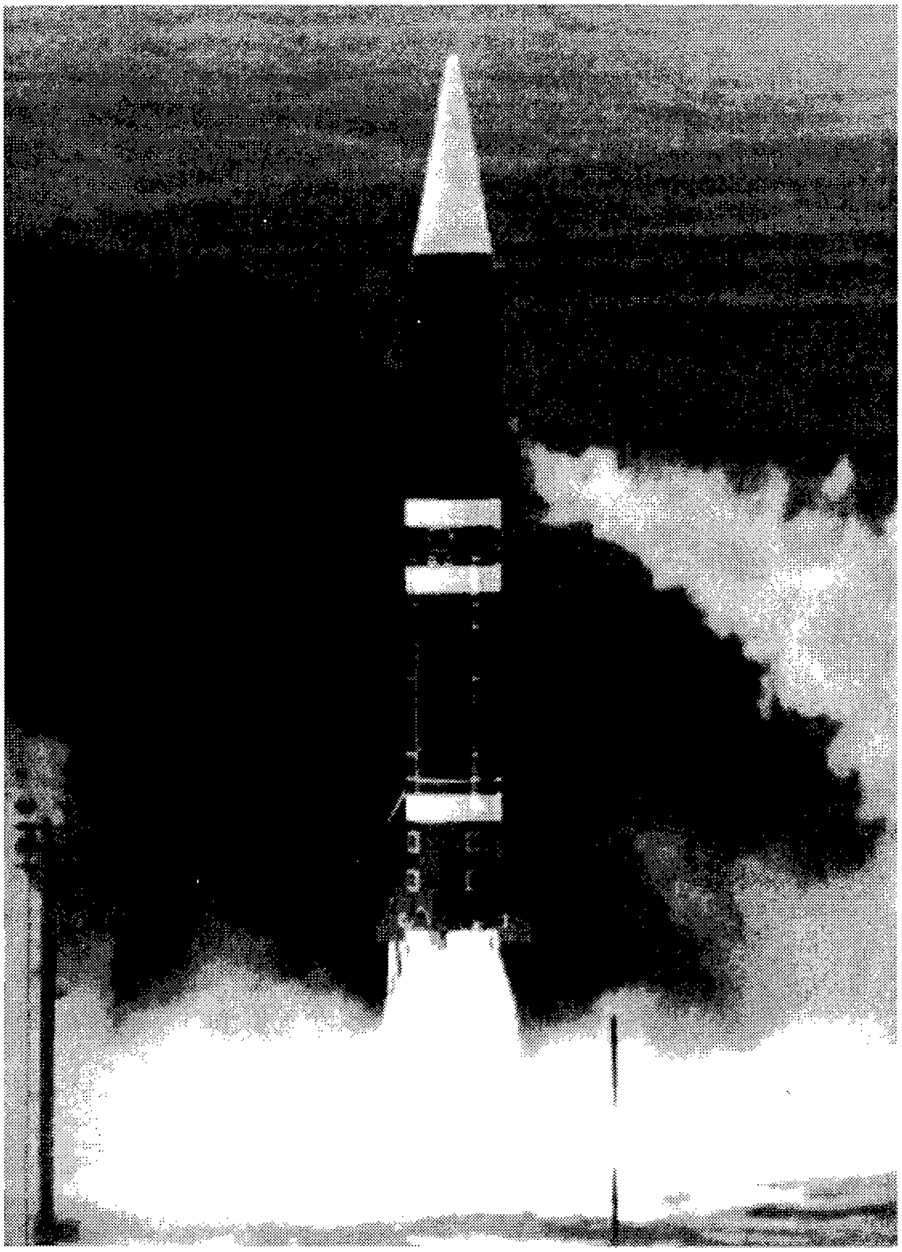


(Courtesy of NAIC)

Chinese liquid-fuelled CSS-2 ballistic missile

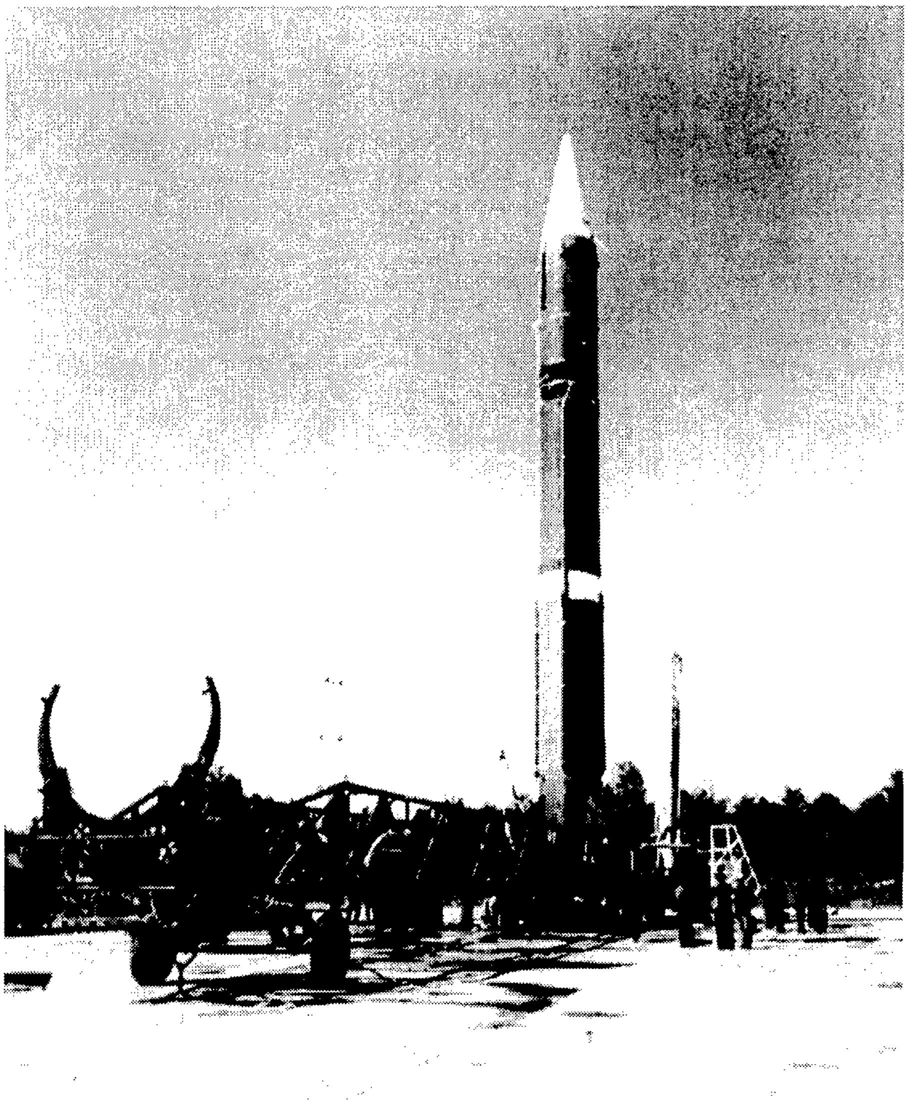
cial support to help develop the No Dong-2. These missile programs could serve as ASAT boosters.

The North Koreans recently have started work on the Taepo Dong-1 and -2. Both are three-staged missiles and are hybrids of the Scud and No Dongs. They have a superior operating capability to that of the Thor. The Taepo Dong-1 was test launched on 31 August 1998. This test took the missile over Japan. Some reports speculated that the flight path was an attempted, but failed, launch of a small satellite into orbit.[105] On 8 September 1998, based on data provided in a published North Korean launch announcement, the US Space Command concluded that the satellite had not achieved orbit.[106] This launch provides evidence of North Korea's potential ability to orbit a satellite. Though unsuccessful, that test indicates that



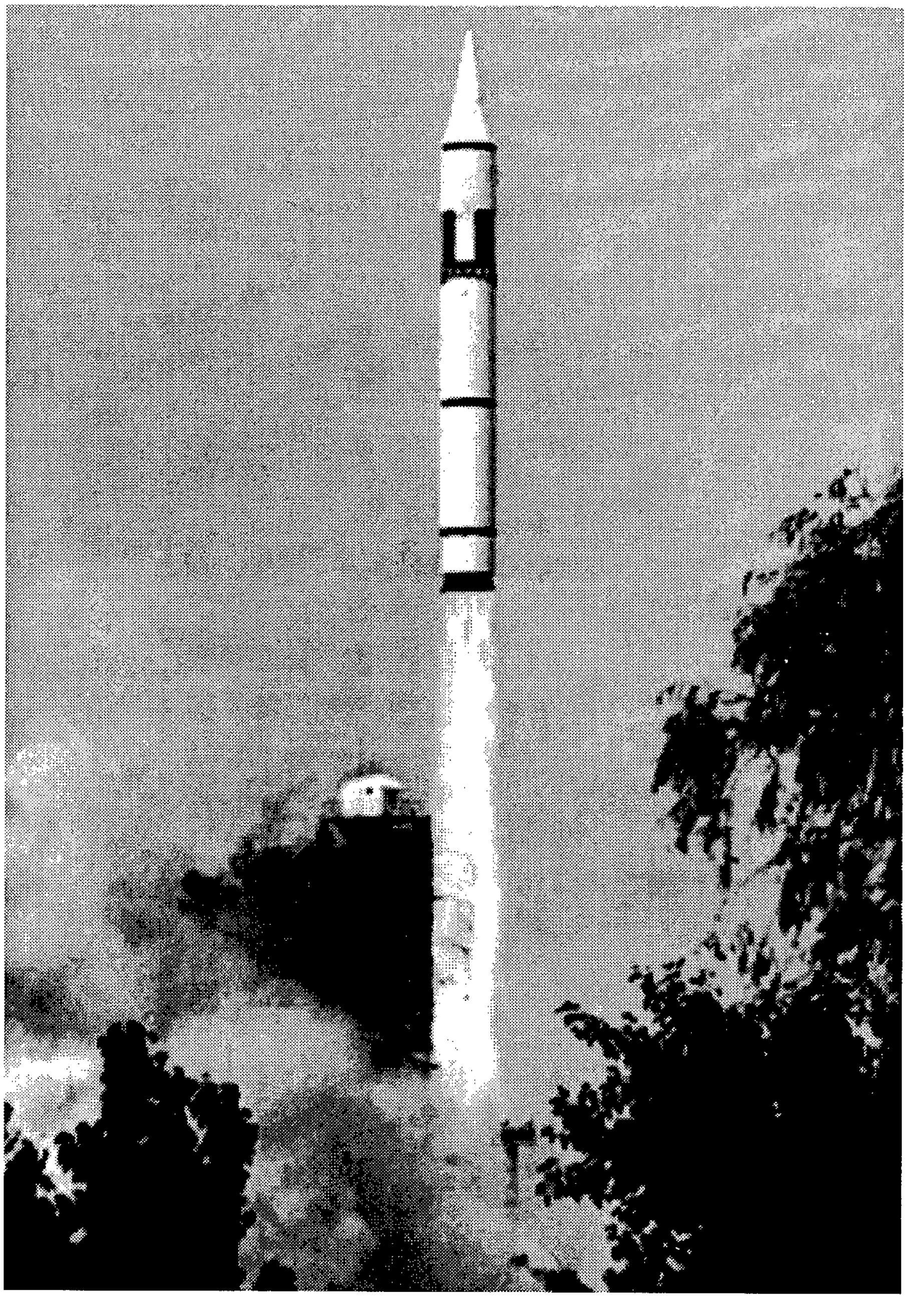
(Courtesy of NAIC)

Test launch of CSS-2



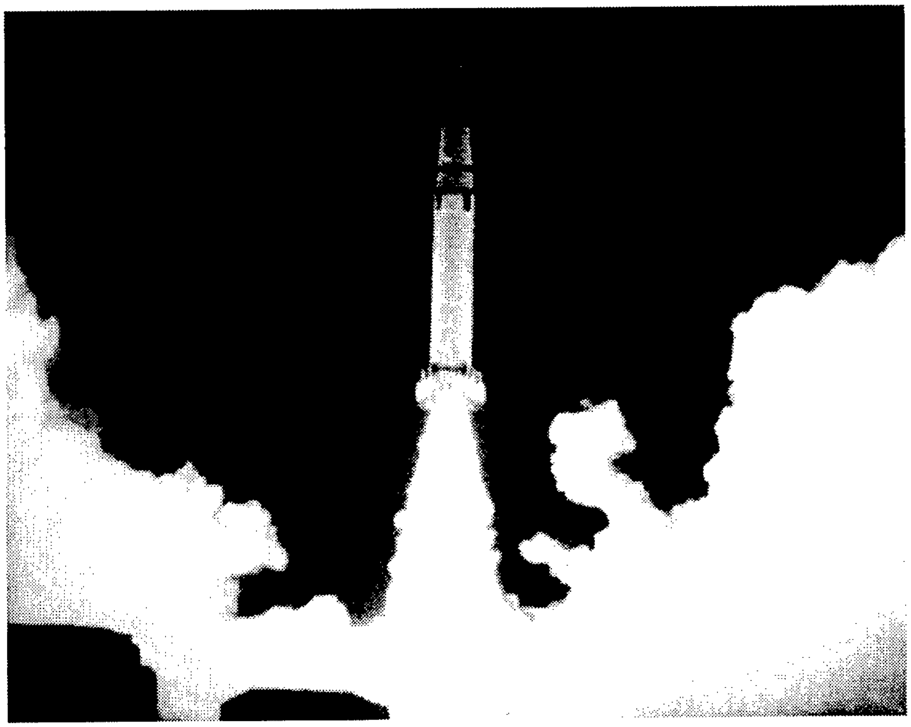
(Courtesy of NAIC)

PRC CSS-3 two-staged intercontinental ballistic missile and mobile erector



(Courtesy of NAIC)

Test launch of PRC CSS-4. This ICBM has a projected range of 8,000 miles



(Courtesy of NAIC)

Test launch of PRC CSS-6 short-range ballistic missile

the North Koreans (and Iran) may, in the near future, have boosters capable of launching an ASAT device against targets in low earth orbit. The Taepo Dong-2 has a range between 2,200 and 3,300 nautical miles.[107] These advanced missiles have an operational payload estimated at 1,000 kilograms. North Korea is expected to deploy this new class of missiles between 2001 and 2003.

North Korea: A Nuclear Sphinx

The existence and extent of North Korea's nuclear weapons program is the focus of much international debate. Although North Korea agreed in 1994* to stop all further production of nuclear weapons grade material at its Yongbyon Nuclear

*US-North Korea Agreed Framework

Research Center, the DPRK has retained sufficient weapons grade plutonium to build at least one nuclear weapon.[108] Under the terms of the agreement, North Korea was to freeze and eventually dismantle its nuclear weapons program. In exchange, the DPRK would receive financial aid and a light-water nuclear reactor. The North Koreans also have agreed to comply with the international nuclear nonproliferation treaty.* Even if North Korea fully abides by these treaties, it will still have the experience and technology to resume a nuclear weapons program in the future, whether openly or in a clandestine manner.

Although the nuclear programs in North Korea are under the eyes of International Atomic Energy Agency (IAEA) inspectors, the DPRK has attempted to circumvent inspections of its nuclear facilities. Before Pyongyang signed the 1994 agreement with Washington, the IAEA found numerous discrepancies regarding declared plutonium levels and nuclear production waste levels. If the North Koreans were to withdraw from the agreement, they could use their 0.5-megawatt, light-water reactor's nuclear rods and the spent fuel at their Yongbyon nuclear plant to develop nuclear weapons. Additionally, they might purchase nuclear material from other countries to expand their weapons programs. Potential secret stockpiles in undisclosed storage sites might provide more materials.[109]

This evidence seems to show that the North Koreans have a limited supply of nuclear materials from which to produce weapons for an ASAT device. They likely would develop a smaller yield weapon than the 1.44 megaton yield carried by Thor. While North Korea likely could build one, possibly two, nuclear weapons, it does not seem probable that the DPRK would loom large as potential ASAT threat. However, conditions may change swiftly. If the DPRK produces large numbers of long-range ballistic missiles in the future, it may decide to produce sufficient nuclear devices to arm these missiles. These weapons might be aimed at either surface or space targets. Perhaps a more realistic threat is the possibility that North Korea might export of its nuclear technology to coun-

*Treaty on the Non-Proliferation of Nuclear Weapons tries like Iran. The spread of nuclear systems, technology, and trained personnel raises the specter that Iran or some other country would manufacture nuclear weapons for itself and for sale or exchange to North Korea in return for receiving technological support and expertise, particularly as relates to ballistic missiles, from the DPRK.

India: A Growing Ballistic Missile Power

Another budding missile power is India. Unlike North Korea's reengineering of Soviet missile technology, India's ballistic missile programs are based almost exclusively on its domestic technology and industrial resources. Its missile program is grounded in its determination to defend itself against Pakistan (principally) and the PRC (secondarily).

India's Ballistic Missiles: An Overview

The Indian government relies on its indigenous resources to develop and produce its ballistic missiles. This strategy allows India to maintain the autonomy of its missile and space programs. Hence, India is in a better position to pursue future advances in both programs free from delays resulting from disruption of access to external sources of critical materials and technology or because of restraints imposed by international nonproliferation agreements. These nonproliferation agreements generally limit the missile and space technologies that nascent space and nuclear powers can acquire abroad. Were India a signatory nation, it would be subject to those international restraints on missile and space development programs.

India's first indigenously developed missile, the Prithvi, has provided the basic technology for further ballistic missile development. As a result of these efforts, the Indian government has several on-going ballistic missile systems in development that could launch an ASAT device. The Prithvi is a derivation from the Soviet SA-2 SAM. It is a short-range, surface-to-surface missile with a range of less than 100 nautical miles and a payload of 1,000 kilograms. The Indian Defence Research and Development Laboratory began design work on the Prithvi in 1983. India first launched the missile in 1988. It has been deployed as part of the Indian Army's weapons arsenal.

India next developed a second generation Prithvi, the SS-250—an Indian Air Force version of the missile. The SS-250 was first tested in early 1996. The range of this version of the missile was increased by about 50 percent but its payload was reduced by 50 percent. The Indian government expanded the Prithvi's test program in 1995 and conducted the last test launches of this missile on 27 January 1996 and 23 February 1997.[110] Although it is not capable of launching ASAT missions, the Prithvi led to the design of a more powerful missile, the Agni, which has allowed India to make further advances in its missile development program.

Given India's long history of nonalignment and support of disarmament, its pursuit of a ballistic missile capability has caused significant internal political turmoil. In 1994 Prime Minister P. V. Narasimha Rao cancelled further development of the Agni's infrastructure, missile assembly, and support equipment. In 1997, after much domestic and parliamentary debate during the governments of Prime Ministers Inder Kumar Gujaral and H. D. Deve Gowda, India resumed development of the Agni.[111]

The Agni is a three-staged vehicle with a solid-fuel SLV-3 first stage, solid-fuel second stage based on the Prithvi, and a third stage reentry vehicle. Despite Indian claims that the Agni will not be used militarily (New Delhi has asserted that the Agni is merely a test program), some analysts predict that the Indian armed forces will field the Agni by 2002.[112]

Despite its long history of advocating the nonproliferation of weapons of mass destruction and related technologies, India has recently shifted course and undertaken intensive efforts to improve its missiles. A. P. J. Abdul Kalem, scientific advisor to the Indian defense minister and chief architect of the military nuclear program, has stated that India is working "very hard" to bring a 1,250-mile range Agni II[113] with a nuclear capability into production.[114] The Agni II was tested on 11 April 1999. Development of this missile has led to speculation that India is attempting to field an ICBM.[115] This missile may become operational by 2010.[116]

The Indian military ballistic missile program has achieved not only the development of a surface-to-surface attack capability but also has led to a burgeoning space program.[117] India has been launching satellites using increasingly more powerful space boosters since 1979 from its Vikram Sarabhai Space Centre (VSSC) in the state of Kerala in southwest India.[118] The Indian military and space programs share common facilities at the VSSC. The Indians have successfully put payloads into orbit ranging in weight from 150 to 3,000 kilograms.[119]

India's augmented satellite launch vehicle (ASLV) served as the primary space booster for a seven-year period. The ASLV—a four-stage, solid-fuelled propellant vehicle—was capable of launching small payloads (about 150 kilograms) into low earth orbit.[120] The first ALSV was launched in 1987 and was used in four space missions. It was retired in 1994. India's polar satellite launch vehicle (PSLV)—designed by and developed at the VSSC—has been used as the successor to the ASLV. This booster can put a 1,000-kilogram (kg) payload into a sun-synchronous orbit of 500 nautical miles, a 450-kg vehicle into a geostationary transfer orbit, or a 3,000-kg object into a low earth orbit. India has used the PSLV three times since 1996. The Indian government is designing a replacement for the PSLV that involves adding strap-on liquid propellant motors. This proposed geostationary satellite launch vehicle (GSLV) would place a 2,500-kg satellite into a geostationary transfer orbit. The proposed GSLV and the PSLV provide a significant potential to launch satellites and could be used as an ASAT booster.

India's Nuclear Program

India has been determined to become self-sufficient on the nuclear front. The Indian government has maintained a nuclear weapons program for many years that culminated in the successful detonation of a nuclear device in 1998. India began its nuclear weapons program in 1964 following the PRC's detonation of an atomic device.[121] Pakistan's growing nuclear capability has provided an even stronger incentive for developing a nuclear deterrence. India's rising stature among Third World nations has intensified its drive towards fielding a nuclear weapon. The international and domestic prestige from these efforts has aided India in its quest to be seen as a world leader. That India now has the capability to deliver nuclear weapons in a surface-to-surface attack or a potential strike into space gives the Indians the capacity to deter other states from interfering in its affairs or dictating its actions in the world arena. India's achievements in the nuclear energy and weapons field and space give it the stature to be regarded by other nations as a significant global power.

The Indian government officially "proclaimed" its nuclear weapons capability when it exploded nuclear weapons on 11 and 13 May 1998.[122] India's nuclear capability is troubling in light of its previous public advocacy of the nonproliferation of nuclear weapons. Additionally, India's rapid transition from an emphasis on peaceful use of nuclear energy to a full-blown nuclear weapons program is alarming. The combination of ballistic missile and nuclear weapons programs provides India with many strategic options. India's success in developing missiles and space launch capabilities in the face of strong pressure from the international community—the United States in particular—may set an example that other nations might seek to follow.

According to one estimate, New Delhi has a growing nuclear weapons inventory. The Indians had approximately 65 nuclear weapons in 1995;[123] this number may rise to as many as 85 to 90 weapons by 2000. India's increasing reliance on nuclear power plants has led to an aggressive building program. From 1980 to 1995, India built six new nuclear plants. Ten more plants are either under construction or planned. These new plants and the existing nuclear facilities would give India the potential to manufacture significant amounts of plutonium for use in nuclear weapons for its growing nuclear arsenal and potential ASAT weapons systems. These power plants may enable India to double its nuclear weapons production. India is also pursuing research programs to create a domestic enrichment processing capability. If successful, India would likely be capable of producing a hydrogen bomb. India's nuclear weapons production is concentrated at three reprocessing plants. A large commercial processing plant now under construction may quadruple the capacity of the three existing plants. All evidence indicates that South Asia will be one of the most watched areas of the world by those who seek to limit the spread of nuclear weapons and ballistic missiles.

The pace of growth in India's ballistic missile program combined with its nuclear capabilities and Pakistan's development of nuclear weapons and acquisition of ballistic missiles elevate the South Asia subcontinent to an area of grave concern for the United States and the world community. India's potential to deploy ASAT weapons raises the possibility that India could attempt to damage or destroy the intelligence-gathering satellites of the United States and other countries to blind or severely limit the ability of those nations to monitor military activity and nuclear weapons tests in the region. India's potential to develop and deploy an ASAT system is alarming given the ongoing military confrontation between these two countries.

Iran: A Missile Exporter's Paradise

Experts concerned about proliferation also keep a watchful eye on the Middle East (or Southwest Asia). Secretary of Defense William S. Cohen has reported that the Middle East has one of the highest concentrations of new missile programs in the world.[124] Iran is heavily involved in developing missiles and has several active ballistic missile programs that may give the Iranians an ASAT capability.

Iran's Ballistic Missile Capabilities: An Overview

Iran first acquired Scud missiles from Libya and North Korea during its 1980–89 conflict with Iraq. Iran has since purchased or acquired technical assistance from several countries, notably North Korea. The Iranians have Scud B and Scud C missiles and have attempted to make arrangements to modify these missiles to improve their range and accuracy. Additionally, they have tried to develop their own domestic production capability. For example, they have begun work on the solid-fueled, Iran-700 missile. This missile has a limited range—about 400 nautical miles—and will not become operational until the year 2000.[125] Although the Iran-700 is not nuclear capable, Iran's domestic production capability is a giant step towards fielding powerful ballistic missiles.

Iran gets most of its missile systems, components, and technical assistance from North Korea, the PRC, and Russia through a series of cooperative agreements. The Russians have signed agreements to produce two medium range ballistic missiles, the Shabab-3 and Shabab-4.[126] More importantly, the North Koreans have negotiated to sell Iran their No Dong-1 missile.[127] This missile, which the Iranians have named Tondar-68, would allow Iran to increase its strategic surface-to-surface strike capability and allow them to have a potential ASAT capability. Using this missile, Iran could launch a 400- to 1,000-kg payload.[128] Iran is attempting to buy Taepo Dong-1 and Taepo Dong-2 missiles from the North Koreans.

While the Iranian ballistic missile industry is in its infancy, having its start in the early 1980s, Iran has swiftly assembled the proper elements to become self-sufficient in many key sectors to produce several Scud derivatives. The Iranian government has claimed that it could produce Scud B and C missiles domestically.[129] In the next few years, if left unchecked by international nonproliferation efforts or conflict resulting in damage to or destruction of its ballistic missile industry, Iran, like North Korea, may soon have the ability to produce and export missile systems and technology. Syria and Libya would be likely clients. If Iran is indeed capable of producing Scuds domestically, then this production capability would allow Iran to improve not only its technical skills and expertise but also its experiential base on which to base the design and manufacture of even more advanced ballistic missiles.

Iran Moves Closer to Nuclear Power

Iran initiated its nuclear electrical power generation programs with assistance from the West during the reign of Shah Mohammad Reza Pahlavi. Since the overthrow of the shah in the revolution led by the forces of the Ayatollah Ruholla Mussaui Khomeini, Iran has aggressively sought to acquire the necessary expertise and resources needed to develop a nuclear capability to deter Iraq and to extend its influence throughout the Persian Gulf. The nuclear power plants built under the shah, and in more recent times with foreign assistance, are a source of fissile material suitable for weapons production. However, since the Iranians do not now have the technological means to build them, they do not yet have operational nuclear weapons. In the wake of the Khomeini-led revolution, Iran has had to turn to other, non-Western sources for technical assistance in furthering the development of its nuclear programs. Given their current capabilities, the Iranians would need to import the technology and know-how to manufacture nuclear weapons grade materials through an enrichment process from the waste products of its nuclear energy plants. Perhaps, they would even need to buy the nuclear-grade fissionable materials from another country to produce a viable nuclear weapon.

In the post-revolution period, the PRC, Russia, and countries formerly in the USSR have been the primary source for much of Iran's nuclear technology. However, at a US-PRC summit in October 1997, the Chinese agreed to limit their transfer of nuclear technology and information to Iran. Likewise, Russia has scaled back its program of sharing certain nuclear technologies that would support Iran's uranium enrichment activities. However, Russia has assisted Tehran in the construction of a nuclear power plant at Bushehr.

Besides attempting to acquire the capability to produce nuclear weapons grade materials as a by-product of their nuclear electrical generation plants, the Iranians are actively pursuing efforts to acquire nuclear-weapons-grade fissile material through clandestine means from other nations. Evidence suggests that Iranian agents and officials have tried to acquire fissionable material from countries that split away from Russia after the collapse of the Soviet Union. For example, US and other intelligence agencies report that Iran has contacted nuclear facilities in Kazakhstan to buy and smuggle 500 kilograms of highly enriched uranium.[130]

Despite these efforts, the Iranians are several years away from having an effective nuclear weapons program. In March 1997, John Halem, the director of the Arms Control and Disarmament Agency, estimated the Iranians were 8–10 years away from developing a nuclear weapon.[131] The current international economic embargo and sanctions have denied many resources to Iran, thus hampering Iran's economic development. These trade restrictions, aimed at forestalling nuclear proliferation, have impaired Iran's ability to produce nuclear weapons. The increased vigilance of the Russian and US governments has diminished Iran's ability to purchase or steal nuclear materials and technology. However, the large quantities of nuclear materials stored in poorly secured facilities in the former Soviet Union are a cause of great alarm not only to the United States and Russia but to many other nations as well.

China's Reach for the Stars

The Peoples' Republic of China is a nuclear power aggressively pursuing the development of intermediate range and intercontinental ballistic missiles. China is simultaneously expanding its space program. The PRC not only pursues these programs to strengthen its own military forces and to pursue a national goal of becoming an international space power but also to assist other nations (friendly to the PRC) in these same quests. China has maintained and operated a space launch capability for years. The PRC has developed and deployed liquid- and solid-fuelled ballistic missiles and boosters that exceed the Thor's abilities. Some of these missiles have the range to reach the continental United States or boost a payload into orbit, thereby increasing the PRC's strategic power.

China's threat as a space power goes beyond its own capabilities. The Chinese export their technology, selling their ballistic missile assets and space launch capabilities abroad. And they continually seek to import foreign technology useful for their missile and space programs. For example, they have tried to acquire advanced missile technology—namely, the guidance system of the SS-18 ICBM—from the Ukraine.[132] This technology would enhance their ability to develop a multiple independent reentry vehicle. The PRC has strived to acquire US space and missile system technology through many channels. As widely reported in recent months, the Chinese have allegedly engaged in espionage to acquire technical information about highly classified US nuclear weapons technology.

PRC Ballistic Missiles: An Overview

The nuclear capable CSS-2 IRBM has been in China's inventory since 1971. The CSS-2 was developed from a Soviet SS-2 ballistic missile, which the USSR had derived from the German V-2. This liquid-fuelled, single-stage missile was the basis for the Long March satellite launch system used in the 1980s.[133] This missile is capable of delivering a one- to three-megaton payload. The PRC currently has 40 to 80 CSS-2 missiles deployed. The PRC's follow-on, CSS-3 ballistic missile—a two-staged improvement of the CSS-2—has an even greater range and payload. The CSS-3 led to the civilian three-staged Long March (LM)-1 satellite booster. The LM-1 was used to launch the PRC's first satellite in 1970. The PRC has between 10 and 25 LM-1 missiles deployed.

Further improvements to the CSS-3 led to the CSS-4 and the LM-2C.[134] The Chinese conducted at least 12 launches of the LM-2C from November 1975 through 1993. This booster and several later, improved models—the LM-2D, LM-2E, LM-3, and LM-4—have served as China's main space launch vehicles.[135] The CSS-4 can launch a five-megaton warhead with a curricular error probable (CEP) of 1,500 feet, a vast improvement over the CSS-2's CEP of 3,000 feet. The PRC has developed the CSS-5 mobile ballistic missile and three shorter-range ballistic missiles (CSS-6, CSS-7, and CSS-8). However, development has not stopped there. The PRC is attempting to develop an ICBM capability with its CSS-9 and CSS-10 solid propellant system missiles. The CSS-10 is a longer range CSS-4 and will carry a 250-kiloton warhead and reach deployment in 2002.

China's desire to establish a viable space program originated in its 1958 Twelve-Year Development Plan of Science and Technology. Since then the PRC has embarked on an extensive effort to put satellites into orbit. Its first successful orbital launch was from an LM-1 launch vehicle in April 1970. The current LM-2C vehicle can put a 750-kg payload into an orbit with an altitude of 500 nautical miles. Were the PRC to pursue development and deployment of an ASAT system, this capability would enable the PRC to pursue several orbital paths to launch an ASAT weapon against a target. The LM-2C's cousin, the LM-2E, can send an even larger payload (3,100-kilograms) into a geostationary transfer orbit. The PRC booster development has continued. The LM-3G can put a satellite into a geostationary orbit. The LM-4 provides another capability to the PRC. It has boosted a 1,500-kg payload into a polar orbit. The booster can put a 1,500-kg object into a sun-synchronous orbit or a 4,000-kg vehicle into LEO. This transition from a ballistic missile program to a space launch capability shows the seriousness of the PRC's drive to space access and to attain international recognition as world space power.

Chinese Nuclear Programs

In contrast to the three other countries examined here, China has a long-established nuclear weapons program. The PRC first tested a nuclear weapon in 1964. China's nuclear weapons capability has provided it with a deterrent against possible actions by the former Soviet Union (in essence Russia) or the United States. The PRC's nuclear arsenal has made it a credible major power in the eyes of Third World nations.

In 1996 China's government announced that it had concluded its nuclear weapons testing. The Office of the Secretary of Defense speculated that the end of nuclear weapons testing signaled an end to China's weapon design program.[136] However, even with their self-imposed moratorium on nuclear tests, the Chinese still have a considerable nuclear weapons inventory. China has about 450 nuclear weapons deployed on ICBMs and submarine-launched ballistic missiles.[137] These nuclear weapons make the Chinese military the third largest nuclear power—surpassing both the United Kingdom and France. China has sufficient nuclear weapons to employ them in several configurations. The PRC has armed approximately 100 ballistic missiles with nuclear warheads.[138] The Chinese CSS-2, CSS-3, and CSS-4 ballistic missiles have the sufficient payload and range to meet or exceed that of the Thor based US ASAT system. The CSS-2 and CSS-3 can carry a warhead with up to a 3.3-megaton yield, far more powerful than Thor's 1.44-megaton payload. The CSS-4 has an even more deadly yield of four to five megatons. The LM-2C and its variants have also shown that they can place systems in space. The fact that the LM-2 space launch vehicles are direct offshoots of the PRC's ballistic missile program gives credence to the claims of some analysts that China can convert its current military systems to include an ASAT system.

Although the Chinese have frozen their nuclear weapons testing, they still have the capability to produce advanced nuclear weapons. The PRC has an estimated four metric tons of plutonium and a further 23 metric tons of highly enriched uranium.[139] This stockpile would allow the Chinese to produce about 2,700 nuclear weapons and significantly increases the chance that PRC might develop ASAT weapons. Even though it has halted its nuclear tests, the PRC apparently has not altered its quest for foreign missile technology. Recent allegations of Chinese espionage at the US's top nuclear weapons technology laboratory are troubling. If true, this allegedly illicitly acquired knowledge may have replaced internal weapons design and significantly improved the PRC's ability to field advanced, miniaturized nuclear ASAT devices.

Space Launch Infrastructure

The third element needed for an operational ASAT system (in addition to adequate space boosters and deployable ASAT weapons, namely, nuclear warheads) is a space launch infrastructure: launch facilities and a tracking capability. Any nation attempting to deploy an ASAT system must have the ability to sustain prelaunch preparations of an ASAT booster, track the target, launch the vehicle, and observe the interception. Some countries may want to achieve a continuous 24-hour launch capability or be able to rapidly assemble a vehicle for launch against a single orbiting target. To conduct a satellite interception mission, a nation must have sufficient orbital data to calculate a proper path to destroy a satellite.

Neither North Korea nor Iran currently maintains an extensive space launch support capability. India has done better even though its space launch capability is still in its infancy. The PRC, in contrast, has an extensive space launch capability and has launched several commercial and military satellites, and the Chinese have sold space launch services to foreign companies. For example, the United States used Chinese space launch facilities to put Intelsat 708 into orbit. Although this attempt failed, several US firms believe the PRC can adequately launch and track satellites. The PRC has demonstrated its capacity to launch photoreconnaissance satellites and recover the intelligence data collected. The Chinese military recovered film capsules from this type of satellite, similar to the Program 437AP experience.[140] This evidence clearly shows that the PRC can track, monitor, control, and communicate with its reconnaissance satellites.

The PRC's Commission of Science, Technology, and Industry for National Defense operates the Chinese space program at three main sites. The first site in the Gobi Desert at Jinguan maintains two launch pads for LM-2 boosters. The second site, constructed in 1984, is at Xiachang and supports launches of their LM-3s for geostationary orbits. The last site, Taiyan, is designed for LM-4 sun-synchronous satellite orbits. These launch sites are supported by six fixed, three mobile, and two surface ship control stations. These stations allow the PRC to provide ample satellite command and control capabilities for commercial or potential ASAT operations.

Although the Iranians and North Koreans have not developed a space launch capability, this does not mean they cannot track space vehicles. The PRC has sold missile tracking technology and infrastructure elements to the Iranians. The Iranians' attempt to develop a domestic ballistic missile industry requires accurate tracking, telemetry, communications, and analysis functions to test these missiles. In 1988 the PRC's Great Wall Industries (China's ballistic missile and space launch vehicle manufacturer) sold Iran telemetry infrastructure to support tests of a medium range ballistic missile, the Shabab-3.[141] This sale included all radar, telemetry gathering, data processing, and analysis systems for a basic missile tracking system. If Iran has the ability to track ballistic missiles, space launch and tracking capabilities may not be far behind. Additionally, some Internet sites provide tracking information about the orbits of US intelligence and other satellites. This data is available to anyone with a personal computer, modem, and access to the Internet.[142]

Similarly, the North Koreans have attempted to sell the Taepo Dong-1 as a space launch booster to increase sales. The North Koreans claimed the test launch of a Taepo Dong-1 on 31 August 1998 was an attempt to orbit a Kwangmyongsong-1 (Bright Star) satellite.[143] Though this booster potentially gives them the ability to launch and orbit a satellite, they would need to develop or acquire a space tracking and control system. Even if it does not join the ranks of nations that can orbit satellites, the DPRK can sell this technology (the Taepo Dong-1) to other countries.

Likewise, the Indian government has shown its ability to launch and control space satellites for several years. India, like the PRC, wants to use geostationary communications, weather, and earth sensing satellites for domestic use. These satellite types require permanent launch and support facilities. India has shown that it wants to place satellites into polar orbit, which requires longer range and more extensive satellite control capabilities. In light of its switch from a staunch advocacy of nonproliferation to active development of nuclear weapons, India's space program may change course to a more military based system. Although still reliant on foreign space launch capabilities for many of its needs, this situation will change if the Indian government reaches its goal of launch autonomy by 2000.[144]

International ASAT Capabilities: How Real the Threat?

All four nations discussed above—North Korea, India, Iran, and the PRC—have the potential space boosters and have demonstrated the ability and willingness to develop nuclear devices. They realistically could, in the next few years, field a low-cost ASAT weapon system powerful enough to severely damage or destroy a target satellite. Such an ASAT device could be a conventional weapon. However, the proliferation of nuclear weapons increases the likelihood that many nations, especially the DPRK, India, the PRC, and Iran, will be capable of producing and supplying makes the latter technology the more likely choice for states seeking to deploy ASAT systems.

The nuclear weapons development by the four countries named above has been greatly aided by legal and illegal technology transfer.

That the Chinese and Indians have a space launch capability does not, by extension, give them an effective ASAT capability. Like other nations seeking to establish a military space force to conduct ASAT operations effectively, China and India will need accurate and timely weapons. Their space forces must be able to launch the booster at precisely the right moment, the guidance system must accurately track and plot a course to intercept the target, and the nuclear weapon or other warhead will have to detonate exactly on time to destroy the target. What chance does one of the above nations have of destroying a particular satellite? Determining this information may provide a rough order of magnitude of how many ASAT weapons a nation needs to ensure the destruction of a target.

A simple model to calculate the probability of a successful intercept by an ASAT device would include the compound probability of the booster launch, guidance, and warhead systems all functioning in proper sequence. There are several methods to determine the probability of a successful interception. One approach devised by Joshua Epstein provides a basis to investigate how many interceptions are needed to destroy a satellite.[145] An analyst, using Epstein's model, can compare the overall probability of kill (PK) for an ASAT system and compare it with the overall probability of a target surviving (OPS) a given number of ASAT attacks.[146] The following table illustrates how many ASAT weapons a nation might require to destroy a single satellite. Using this model, an analyst could assess whether a nation has an ASAT weapon system capable of adversely affecting our space resources and, therefore, poses a potential threat to our national security. If that nation has a questionable space booster or support infrastructure, then the prospect of it deploying and using its limited number of boosters or arsenal of nuclear weapons would make it less of threat than a nation with more sophisticated capabilities.

Matrix of number ASAT launches for given probability of kill and probability of survival

Probability of kill ⇨

Probability of survival ⇩

PK/ OPS	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
0.01	2	3	4	6	7	10	13	21	44
0.05	2	2	3	4	5	6	9	14	29
0.10	1	2	2	3	4	5	7	11	22
0.15	1	2	2	3	3	4	6	9	19
0.20	1	1	2	2	3	4	5	8	16
0.25	1	1	2	2	2	3	4	7	14
0.50	1	1	1	1	1	2	2	4	7

Number of launches ⇨

A nation may decide to fund an ASAT for a variety of reasons. The country may decide to acquire an ASAT as a political bargaining chip, as a deterrent, as a terrorist weapon, or as an offensive or defensive weapon; for prestige; or as a way to equalize its lack of a viable space capability relative to another nation. However, unless the military ASAT system is a credible weapon, it will become nothing but a curious footnote to that nation's arsenal. One method to evaluate the system's credibility and determine the viability of a program is to estimate the number of ASAT launchers necessary to destroy a satellite given the specifics of the ASAT system. A nation contemplating the acquisition of an ASAT system would likely want to weigh the cost of building a system with high probability of destroying a satellite against a lower capability. If the nation has tested and validated its PK of an ASAT launcher, it may explore what cost and level of effectiveness it desires to achieve.

The number of ASAT launchers is inversely related to the PK. Additionally, the OPS and PK are inversely related. As the system PK rises, the OPS falls as does the number of ASAT launchers. For example, assuming that the PK for Program 437 had been 0.7 and the United States had wanted to destroy a satellite with a 90 percent probability, then the 10th ADS would have had to use both Thors. Based on this hypothetical example, the United States likely would have posed a credible threat to Soviet satellites. Conversely, a space power may not regard as serious the potential threat posed by another country if the latter has a poorly designed and operated system that would require an extraordinary number of launchers to disable a target or targets. Based on Epstein's model, if that system has a PK of 0.1 and a desired OPS of 0.01, then that nation would need to conduct 44 ASAT launches (that is, it would need 44 boosters, a sufficient number of launch pads and support personnel, and 44 nuclear weapons).

As the above analysis shows, many nations have access to technology and systems that are much improved over what the United States used in the late 1950s and early 1960s. If these nations configured their ASAT weapons properly, they could pose a threat to US satellites. Nations that possessed such ASAT systems may not be able to strike US satellites in all of the possible orbital arrays, but they could at least use their ASAT system as a show of strength or to deny the United States local or regional space superiority. This ability to blind US or allied forces by knocking satellites out of commission may allow an unfriendly state to achieve a political or military objective without international monitoring, opposition, or interference, that is, to seize an opportunity and present the West with a fait accompli.

Conclusion

The space control and counterspace missions are hotly debated issues today within the US Space Command, DOD, and the Congress. Actions continue within the government to explore space control concepts. For example, the Joint Staff's Joint Requirements Oversight Council has approved a requirements document that outlines key performance parameters to consider in developing a space control capability.[147] As the

United States relies more on space systems as war-fighting assets, it will need to devote more resources to protecting those systems against an enemy ASAT system. Although it recognizes the threat of direct-ascent ASAT weapons, the discussion and analysis of this threat within the Air Force focuses almost exclusively on the Russian and Chinese efforts to develop and deploy such weapons.[148]

The successful test launches during Program 437 certainly show that a nation with less capable missile and nuclear programs might proceed in developing either a satellite interceptor or inspector. Additionally, Program 437 illustrates that an ASAT system does not need to have a sophisticated guidance system or warhead to become an effective space denial weapon. The boosters and nuclear warheads that were designed in the 1950s allowed the United States to produce a rudimentary ASAT system. Though it relied on space tracking systems that used first generation computing and information systems, the United States demonstrated that it could have delivered an effective nuclear punch against satellites in low earth orbit using its Thor-based ASAT system.

The Air Force has much to gain from its long experience with Program 437. It handicapped Program 437 by locating and keeping it on Johnston Island. In locating the program there, the Air Force limited Program 437's range and thus its capability to intercept certain satellites. This remote location also greatly diminished the ability of the Air Force to support Program 437, logistically and otherwise. The Air Force was virtually unable to defend Johnston Island from attack and the site was vulnerable to damage from tropical storms and the harsh environment. The location severely hampered the ability to defend the United States against potential MOBS and most importantly FOBS attacks. DOD never seriously considered the use of additional launch sites. Had the Air Force built at least one more site, the nation might still have an ASAT capability today. Had the Air Force decided to build multiple sites (or a mobile system), though costly, it would have reduced the impact of the destruction of the Johnston Island facilities that ultimately led to the program's demise. As a result of the loss of that launch site, the Air Force lacked available resources to pursue further development of a direct ascent system. If the Air Force had kept Program 437 operational, it could have maintained an active research and development program on ASAT and ABM systems. This may have led to its retention of the ground-based satellite defense mission instead of creating a debate with the Army and Navy about this mission.

Additionally, the Air Force was not prepared to maintain a long-lived program with limited resources. The financial and personnel resources necessary to sustain Program 437 were considerable. The estimate of the required CTL launchers was too low and contributed to a reduction in readiness that plagued Program 437 throughout its life. Although the Program 437AP test launch program was substituted as a proxy CTL experience, the Air Force's on-again, off-again commitment dogged the program until it was dismantled. The inclusion of experimental projects to test Program 437 further reduced the ability to maintain the ASAT primary mission. Instead, the Air Force should have transferred these research and development diversions to AFSC to properly test them.

Program 437 was not the most effective US weapon system developed in the cold war. However, the program serves as a model of US military and scientific ingenuity and determination to build an operational system in a short period with existing systems. For its day, the 10th ADS maintained a complex system on alert that had proven its capability to destroy or seriously disable a space vehicle. Ultimately, the cost, reliability, and eventual operational limitations caused Program 437 to fold. The Air Force, however, had displayed its keen interest in space and had developed appropriate space doctrine, strategy, and policy concerning ASAT operations during the 1960s. In the last few years the Air Force again has begun openly facing many of the same issues: What are the requirements and operational concepts necessary to field and sustain an effective ASAT system? During the intervening decades, these concerns have been buried in the reluctance to introduce weapons in space, arms control, and other pressing military problems just as they were in the late 1950s and early 1960s.

The Air Force did not provide a clear mission to the 10th ADS. Confusion among the operational crews and command staffs about its mission was prevalent throughout the program. The initial ASAT mission gave way to the photoreconnaissance objective of Program 437AP. The change in emphasis from an operational weapon system to an intelligence platform reduced the program's readiness and capability. If the United States decides to maintain a weapon like Program 437, it needs not only clear and relatively stable mission guidance, doctrine, and strategy but unequivocal support for the system. It should not use such a weapon system as a test bed for experimental systems.

The limited range, technology, increasing cost, threat, and change in weapon systems mission caused significant, practical challenges for Program 437. The Thor, although capable of reaching LEO altitudes, had a limited ability to intercept and destroy Soviet satellites. Additionally, the slow target detection and the calculation of the target intercept path took away vital hours to conduct ASAT operations. Improved detection and warning systems and computers could have alleviated this concern. However, other technical limitations, the remote location, and the lengthy prelaunch preparations required by the Air Force crews at Johnston Island made the Thor ineffective as an ASAT against FOBS—the major threat arising from Soviet space systems in the late 1960s. Even if the Thor could have intercepted a FOBS, the Soviets easily could have overwhelmed the two Thor launchers with multiple attacks.

The acquisition of advanced technology through legitimate and clandestine methods has increased the possibility of nations obtaining technology that either meets or, in most cases, exceeds the technology available to the United States in 1963. The missile, detection, tracking, and interception systems that allowed Thor to destroy a satellite are available through commercial space launch technology today. The availability of nuclear technology and the miniaturization of warhead size have increased in the last few years and provide access to nations willing to invest in this area for an ASAT weapon.

India, North Korea, Iran, and the PRC are all capable of producing an IRBM with a nuclear payload to conduct ASAT operations. The nation most likely to acquire a fully integrated ASAT capability needs to have the means to develop and sustain the required boosters, nuclear weapons, and space support infrastructure over a considerable period of time. If resources are limited, then the opportunity cost of deploying an ASAT system must be low relative to other potential uses of these same assets.

Only the PRC seems to have the requisite quantity and quality of launch and nuclear resources to produce an ASAT weapon in the near future. The Chinese have developed a series of space launch vehicles, have orbited space vehicles, and have tracked and controlled them. Additionally, their existing space program has become a valuable asset that they need to protect or, in some cases, use to deny space superiority to others. The PRC's potential to develop and employ ASAT capabilities provides an opportunity for the Chinese to enter another phase of space operations. They could dominate space activities against military and commercial space satellites that might interfere with a regional dispute on their borders. The development and visible operation of ASATs may serve as a source of national prestige to bolster the current government's position internationally and domestically. If it had an operational ASAT capability, the PRC might be able to force commercial and other countries, including the United States, not to place their satellites in harm's way, that is, near to or above Chinese air space (both within the earth's atmosphere and in outer space). Another benefit accruing to the PRC from building an ASAT system is the potential to sell operating systems, technology, and experience to third parties.

Assessing the PRC's intentions and current state of its space program is difficult at best; the challenge is equally hard for most other nations as well. Gen Richard B. Myers, former commander in chief, US Space Command, believed the US intelligence community currently has a gap in tracking the abilities of countries, especially developing ones, to create ASAT weapons.[149] This deficit has created some uncertainty about the threat facing our nation's space forces. The United

States' ability to observe the testing, launch, orbit, and use of satellite communications between surface and space is within the realm of today's capabilities. However, if foreign countries take steps to shield or disguise their space activities, then our intelligence-gathering agencies will face a difficult challenge in detecting and assessing those capabilities.

Determining the intentions of an enemy in any area is a difficult task for intelligence experts under even the most favorable circumstances. Unwritten doctrine, strategy, or policy may escape detection or notice by even the most technologically advanced intelligence gathering service. A nation may have the capability of conducting an ASAT attack, but whether it has the intention and desire to conduct such attacks is difficult to measure. Unlike the United States, which publicly announced the existence of Program 437, other countries may not be forthcoming about their programs. Sometimes intelligence services can determine another nation's intentions by the characteristics of its support facilities or from military actions such as exercises or training missions. However, a nation might use space launch pads for commercial or military purposes. Therefore, the determination of whether a military system like an ASAT weapon is being tested makes the analysis a challenge. If the PRC decides to put ASAT devices on ICBMs deployed in underground silos, then our ability to assess China's intentions becomes even more problematic.

If the PRC did build a rudimentary ASAT system, several US systems would be vulnerable. Not only would the nuclear explosion and resultant EMP effects directly affect the target satellite's electronic components, but they would also affect large areas on the ground. Transmissions between the earth's surface and satellites, such as the global positioning satellites (GPS), might be interrupted. Future military operations involving navigation for precision-guided munitions, aircraft flights, and surface operations that use GPS would be adversely affected since GPS is not hardened for operations in a nuclear environment. The Defense Special Weapons Agency (DSWA) studied the effect of a 50-kiloton nuclear explosion over New Delhi at altitudes of 150 and 250 kilometers. The detonation at 150 kilometers would seriously affect satellite communications with GPS for three hours at a range of up to 500 kilometers.[150] Such a high-altitude blast would affect the Air Force's ability to conduct precision strike and force location, primarily in South Asia. At 250 kilometers the damage would last about two hours. A nuclear explosion might also affect the ability to track infrared signatures because of background radiation. The loss of this capability would affect tracking of theater ballistic missiles and significantly degrade ballistic missile defense efforts. Finally, radiation trapped in an electronic belt can disable satellites up to 2,000 kilometers away in the same orbital plane (well in range of GPS) given a 50-kiloton nuclear explosion at a burst altitude of 250 kilometers.[151] These findings indicate that a high-altitude nuclear burst could damage or destroy a significant portion of our critical space assets without targeting a particular satellite or satellites in low earth orbit. If true, the DSWA study indicates nations would need a weapon not much more advanced than our Thor-based Program 437 system to threaten our space systems.

The United States' reliance upon space systems for numerous military force applications is a tempting target to many nations. The post-cold-war era has left the United States with a downsized military in terms of personnel, equipment, and bases. This situation has forced our military to rely on a number of force multipliers such as space-based systems to overcome force size, enemy geographic advantages, and distance concerns. For example, on 8 May 1998, the United States' National Reconnaissance Office launched an Orion signal intelligence spacecraft that allows the nation to eavesdrop on military communications from Pakistan, India, China, and North Korea.[152] The current drive towards using asymmetric strategies to defeat an enemy has, in one sense, opened the opportunity for a foe to attack our very strength through unconventional methods. The more capable the technology, the more our forces rely on it due to the reduced costs and improved capabilities provided to a joint force commander. Unless the United States, and the Air Force in particular, take precautions to defend vital space assets against such threats as ASATs, our forces likely will become more vulnerable to foreign threats despite our technological and military superiority.

A future enemy may not be able to achieve space superiority, but it may be able to deny this advantage to the United States. A nation with a few ASATs might use that capability as a deterrent, offensive weapon, or terrorist device. Such a nation may not want the United States to use its space resources over a particular area or during a certain time period. For example, because it might not want a US reconnaissance satellite to detect or watch an amphibious invasion of Taiwan, or support a US counterstrike against the PRC, China might use its ASATs to blind or disable a number of US military space satellites until the successful conclusion of the operation. Additionally, without space support, a US attempt to help Taiwanese forces recapture their territory would be more difficult. The destruction of US space satellites might also serve as a warning not to interfere in this situation. Any nation that wanted to warn the United States that it should not meddle in that state's affairs or intervene in a dispute could build and deploy a rudimentary ASAT system at least as capable as Program 437. By doing so it would gain the capability to inflict serious damage on US space systems.

Notes

1. David N. Spires, *Beyond Horizons* (Peterson AFB, Colo.: Air Force Space Command, 1997), 52.
2. *National Intelligence Estimate Number 11-5-57* (Washington, D.C.: Central Intelligence Agency [CIA], 1957), 62. Document is now declassified.
3. *National Intelligence Estimate Number 11-10-57* (Washington, D.C.: CIA, 1957), 63. Document is now declassified.
4. *National Intelligence Estimate Number 11-8-62* (Washington, D.C.: CIA, 1962), 189. Document is now declassified.
5. Ibid.
6. Lt Col Samuel G. Wilson, USAF, Retired, to Dr. Wayne Austerman, 23 January 1986. In the files of Air Force Space Command, Office of History, Peterson AFB, Colo.
7. Jack Manno, *Arming the Heavens: The Hidden Military Agenda for Space* (New York: Dodd, Mead, and Co., 1984), 55.
8. Ibid., 56.

9. Paul B. Stares, *The Militarization of Space U.S. Policy, 1945–1984* (Ithaca, N.Y.: Cornell University Press, 1985), 108.

10. James R. Killian Jr. was president of MIT (the Massachusetts Institute of Technology). He headed President Eisenhower's Scientific Advisory Commission (a cabinet-level position) and chaired the Technological Capabilities Panel, which studied issues relating to space. He was instrumental in the creation of the National Air and Space Administration during Eisenhower's second term. He served on foreign intelligence advisory boards under Presidents Eisenhower and Kennedy.

11. Manno, 58.

12. The Air Force's Thor was a great booster. The Douglas Aircraft Corporation manufactured the Thor as an interim strategic weapon that provided a nuclear capability in the late 1950s. The Thor missile was 65 feet long and eight feet in diameter, and used a liquid propellant engine. Its small size and 110,000-pound weight allowed the Air Force to fit it into a C-124 Globemaster transport for deployment. Thor required special handling because of its liquid fuel and oxidizer. This limited the launch reaction time and required extensive maintenance. Thor's effective range was 1,500 miles and its Mark 2 reentry vehicle carried a 1.44-megaton, W-49 nuclear weapon. See John C. Lonnquest and David F. Winkler, *To Defend and Deter* (Rock Island, Ill.: Defense Publishing Service, 1996), 268–9.

As the Atlas and other more advanced ICBMs were reaching maturity, the Thor was relegated to a secondary strategic importance. By 1 May 1962, McNamara had informed British minister of defence Peter Thorncroft that the United States would no longer support the Thor mission in the United Kingdom after 31 October 1964. The United States would have several Thor boosters, support equipment, and SAC training crews available for other uses like ASAT duties.

13. Stares, 108.

14. Electromagnetic pulse is a sharp, distinct pulse of long wavelength, radio-frequency electromagnetic radiation and is a by-product of a nuclear explosion. Defense Special Weapons Agency, *Weapons Of Mass Destruction Terms Handbook DSWA-AR-40H* (Alexandria, Va.: Defense Special Weapons Agency, 1998), 90.

15. Thomas Karas, *The New High Ground* (New York: Simon and Schuster, 1983), 148.

16. Manno, 84.

17. James N. Gibson, *Nuclear Weapons of the United States* (Afglen, Pa.: Schiffer Publishing, 1996), 38.

18. Senate, *Department of Defense Appropriations for 1963, Hearings on H.R. 11289 before the Subcommittee of the Committee on Appropriations*, 87th Cong., 2d sess., 27 February 1962, 182.

19. Wilson letter, ibid.

20. Secretary of the air force to chief of staff, Air Force, memorandum, Subj: "Proposed Early Satellite Intercept Capability," 31 December 1962. Document is now declassified.

21. Secretary of the air force to chief of staff, Air Force, memorandum, Subj: "Program 437," 20 March 1963. Document is now declassified.

22. Secretary of the air force to deputy chief of staff, research and development, memorandum, Subj: "Program 437," 28 March 1963. Document is now declassified.

23. Director of advanced engineering to AFSC, memorandum, Subj: "Program 437," 20 March 1963. Document is now declassified.

24. Director of advanced engineering to AFSC, memorandum, Subj: "Program 437 Operational Phase," 5 July 1963. Document is now declassified.

25. Wayne R. Austerman, *Program 437: The Air Force's First Antisatellite System* (Peterson AFB, Colo.: Air Force Space Command, 1991), 13.

26. John Lewis Gaddis, *We Now Know: Rethinking the Cold War History* (New York: Oxford University Press, 1997), 240–1.

27. Nicholas L. Johnson, *Soviet Military Strategy in Space* (London: Jane's Publishing Co., 1987), 28.

28. Ibid.

29. Stares, 129.

30. Johnson, 30.

31. Phillip J. Klass, "Value of Bombardment Satellites Debated," *Aviation Week and Space Technology*, 11 July 1960, 26.

32. Stares, 117.

33. Ibid., 118.

34. Gibson, 205.

35. Austerman, *Program 437*, ibid.

36. Gibson, ibid.

37. Stares, 119.

38. Lonnquest and Winkler, 110.

39. Gibson, 207.

40. Stares, ibid.

41. Stares, 120.

42. The Bomarc was the first supersonic, long-range antiaircraft missile. The Air Force authorized the program in 1947. The missile resulted from coordinated research between Boeing (Bo) and the University of Michigan Aeronautical Research Center (marc). "Bomarc, A Brief History," Boeing Company, http://www.boeing.com/companyoffices/history/ boeing/bomarc.html.

43. Austerman, *Program 437*, 23.

44. Notes from interview with Col Troy G. Alcorn, USAF, Retired, by Dr. Wayne Austerman, Peterson AFB, Colo., 26 August 1986. In the files of Air Force Space Command Office of History, Program 437.

45. Austerman, *Program 437*, 25.

46. Col Phillip R. Jackson, USAF, Retired, to Dr. Wayne R. Austerman, 5 January 1986. In the files of Air Force Space Command Office of History, Program 437, Peterson AFB, Colo.

47. Space Systems Division (SSD), *Program 437 Partial System Program Package* (Los Angeles, Calif.: Headquarters, Space Systems Division, 1963), 2-3. Document is now declassified.

48. Ibid., 2-2.
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50. SSD, 8-1.
51. SSD, 11-7.
52. Notes from interview with Col John R. Barnard, USAF, Retired, by Dr. Wayne Austerman, 17 September 1986, Peterson AFB, Colo. In the files of Air Force Space Command, Office of History, Program 437.
53. Austerman, *Program 437*, 33.
54. Curtis Peebles, *Battle for Space* (New York: Beaufort Books, 1983), 89.
55. Jackson to Austerman.
56. Stares, 124.
57. House, *Department of Defense Appropriations for 1966, Hearings before a Subcommittee of the Committee on Appropriations*, pt. 2, *Operations and Maintenance,* 89th Cong., 1st sess., 23 February 1965, 425.
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59. Peebles, 90.
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61. FOBS refers to space weapons systems developed by the Soviets in the early 1960s. These weapons would be launched into space and land on targets without having completed a full orbit of the earth, they would fly only a "fraction" of an orbit. See *Space Handbook*, vol. 1, AU-18 (Maxwell AFB, Ala.: Air University Press, 1995), 21–2. A FOBS would give a nation the capability to put a nuclear or other weapon of mass destruction into a low earth orbit that allowed it to attack another country from many directions. For example, instead of attacking the United States with missiles approaching from the North Pole, the Soviet Union could launch an initial attack via the South Pole. The FOBS system allowed the Soviets to gain strategic surprise since they could avoid early warning systems. However, these systems offered limited payloads, accuracy, and had a limited duration of less than one orbit.
62. A MOBS was a more advanced FOBS that allowed a vehicle to stay in orbit and on command from a ground station, dispense nuclear or other weapons from orbit to the surface.
63. Notes from Alcorn interview.
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70. Spires, 85.

71. Stares, 125.

72. Austerman, *Program 437*, 5.

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79. Austerman, *Program 437*, 40.

80. Johnson, 127.

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82. Ibid., 45.

83. Stares, 127.

84. Peebles, 94.

85. Notes from interview, Col John W. Yocum, USAF, Retired, by Dr. Wayne Austerman, 17 September 1986, Peterson AFB, Colo. In the files of Air Force Space Command, Office of History, Program 437.

86. Notes, Barnard interview.

87. Ibid.

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89. Ibid., 258.

90. *Long-Range Plan* (Peterson AFB, Colo.: Headquarters US Space Command, 1998), viii.

91. William S. Cohen, *Annual Report to the President and the Congress* (Washington, D.C.: Office of the Secretary of Defense, 1998), 68.

92. LEO is only one of several orbit types. Low earth orbits range in altitude between 60 and 250 nautical miles, below the Van Allen Radiation Belts. See John M. Collins, *Military Space Forces* (New York: Pergamon-Brassey's, 1989), 15. A satellite in LEO will not stay in orbit as long as one in a comparatively higher orbit because drag from the earth's gravity is stronger at lower altitudes. A satellite in low earth orbit would require more frequent engine or thruster use to maintain the orbit but would eventually exhaust its fuel supply and be pulled out of orbit and likely burn up in the earth's atmosphere upon reentry. Another drawback to LEO is that the closer the satellite's orbit is to the earth's surface, the more vulnerable it is to an ASAT attack and radiation in the Van Allen belts. A LEO orbital period (how long the vehicle in orbit takes to complete a revolution around the earth) is 90 minutes. Satellites in LEO orbits normally stay in aloft for about

a year. See Jerry Jon Sellers, *Understanding Space* (New York: McGraw-Hill, 1994), 150.

93. A sun-synchronous orbit is a LEO that is in an inclined orbit from the equator to maintain the same relative orientation to the sun. A nation might use this orbit for remote sensing satellites and to keep their photovoltaic cells constantly facing the sun to keep its electrical systems charged. For example, the United States uses the civilian LANDSAT remote sensing satellite imagery for mapping.

94. A nation could also use a geostationary orbit. An observer on the earth's surface viewing a satellite in a geostationary orbit might think it has a constant position. The satellite orbits at the same rate the earth spins on its axis. The satellite's inclination is zero degrees (0°) from the equator and is sometimes called an equatorial orbit. Several weather, communications, military early warning, and nuclear detection satellites use this circular orbit. These orbits have an altitude of about 22,300 nautical miles.

95. A variant of geostationary orbit is the geosynchronous orbit that has an inclined orbit. If an observer on the surface could trace the path of a satellite in this orbit, then it would appear as a figure eight. Nations put communications satellites in these orbits.

96. The last major orbital type is the Molniya, which has an elliptical path that has a 12-hour orbital period. Communications and intelligence satellites typically use this orbital type. These orbits keep satellites over the Northern Hemisphere for 8 of their 12-hour orbits. Satellites in Molnyia orbits are vulnerable to attacks over the Southern Hemisphere where they are at their lowest altitude. See Kurt Gottfried and Richard Ned Lebrow, "Anti-Satellite Weapons: Weighing the Risks," in *Weapons in Space*, ed. Ranklin A. Long, Donald Hafner, and Jeffrey Boutwell (New York: W.W. Norton and Co., 1986), 148.

97. Collins, 137.

98. Department of Defense, *Proliferation: Threat and Response* (Washington, D.C.: Office of the Secretary of Defense, 1997), 28.

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140. Phillip Clark, *Jane's Space Directory Thirteenth Edition 1997–1998* (Alexandria, Va.: Jane's Information Group, 1997), 11.

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146. **A Simple Model To Calculate ASAT Requirements**

Let: n = independent launchings against a satellite
PK = probability of kill (assumed constant)
OPK_n = Overall probability of kill with *n* launches
OPS_n = Overall probability of target surviving with *n* launches

Where $OPK_n + OPS_n = 1$ and $0 < PK < 1$

The value of PK is the compound probability of a successful launch, target interception, and the nuclear detonation from a single ASAT launch. For example, if the probability of a successful launch is 0.9, target interception equals 0.8, and the nuclear detonation is 0.9, then PK equals 0.648 (0.9 x 0.8 x 0.9). OPK_n then represents the PK for n launches. If the probability of defeating a satellite with *n* launches is represented by

(1) $OPK_n = 1 - (1 - PK)^n$, then

(2) $OPS_n = 1 - OPK_n$

(3) $OPS_n = (1 - PK)^n$

Using equation 3 one can find the level of OPS_n for a given satellite or constellation of space objects if attacked with several ASAT weapons. Given the PK and a desired level of OPS_n, one can then determine *n* (the number of required ASAT launches) from equation 3. If one took the natural logarithm (ln) from both sides of equation 3, one can easily calculate the value of *n* by using the following formula:

(4) $\ln(OPS_n) = n(\ln(1-PK))$

(5) $n = \dfrac{\ln(OPS_n)}{\ln(1 - PK)}$

Given the values of two unknowns, one can then find the missing third value. This equation allows one to find the number of launches to destroy a constellation of satellites or space vehicles. Suppose we use the Program 437's probability of kill (PK) of .07 (see Austerman, *Program 437*, 35) and assume the Air Force wanted to assure a high likelihood of a successful kill, namely, OPS=0.01. Using equation 5 to make the calculations

(6) $n = \dfrac{\ln(0.01)}{\ln(1-0.7)}$

(7) $n = \dfrac{\ln(0.01)}{\ln(0.3)}$

(8) n = 3.82 launches

Using a weapon system no more capable than the Thor-based Program 437 devices, the United States would need at least four launches to defeat a satellite to ensure a low probability (0.01) that an enemy satellite would survive a US ASAT attack.

Any nation evaluating how many ASAT launchers it would need to shape its space force might calculate its required number of launchers based on Epstein's calculations. Given equation 5, one determines the number of ASAT launchers given the known PK and a nation's desired OPS for a threatening satellite. For example, a simple matrix of calculations in table 1 above (the values of these ASAT launchers are rounded up to the nearest whole number) for the number of ASAT launchers given OPS provides a valuable observation.

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Shooting Down a "Star"
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