05 MAY 1997
Ref: 97-F-0084

Mr. Skipper Jones
Department of Politics and Contemporary History
Room 404, Crescent House
University of Salford
Salford, M5 4WT
ENGLAND

Dear Mr. Jones:

This letter responds to your January 3, 1997, Freedom of Information Act (FOIA) request.

Your request was processed by the Office of the Deputy Assistant Secretary of Defense (Counterproliferation Policy) (DASD(CPP)), which has provided the enclosed document as responsive to your request. However, Mr. Gerald M. Fitzgibbon, Acting Director, Special Advisory Staff, DASD(CPP), an Initial Denial Authority, has determined that release of portions of the document must be denied pursuant to 5 USC 552(b)(1). The denied information is currently and properly classified pursuant to Executive Order 12958, Sec 1.5 (a), (b), and (c), which pertains to military plans and operations; foreign government information; and intelligence sources and methods.

You have the right to appeal Mr. Fitzgibbon's decision to deny this information. Any such appeal should offer justification to support reversal of the initial denial and should be forwarded within 60 calendar days of the date of this letter, to this office.

There are no chargeable costs for processing your request in this instance.

Sincerely,

"Signed"

A. H. Passarella
Director
Freedom of Information
and Security Review

#869

Enclosure:
As stated

IDA DOCUMENT D-1411

THE OPERATIONAL IMPLICATIONS OF PROLIFERATION (U)

Gordon Boezer, *Editor*

August 1993

Prepared for
Office of the Secretary of Defense
(International Security Affairs/Nonproliferation Policy)

WARNING NOTICE
INTELLIGENCE SOURCES OR METHODS INVOLVED

#869

IDA
INSTITUTE FOR DEFENSE ANALYSES
1801 N. Beauregard Street, Alexandria, Virginia 22311-1772

Proliferation of Precision Navigation Technologies and Security Implications for the United States (U)

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
August 1993

3. REPORT TYPE AND DATES COVERED
Final--July 1991-August 1993

4. TITLE AND SUBTITLE
The Operational Implications of Proliferation

5. FUNDING NUMBERS
C - MDA 903 89 C 0003
T- T-K2-943

6. AUTHOR(S)
Gordon L. Boezer, Matthew O'Brien, John Metzko,
John P. McHale, Steve Wooley

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Institute for Defense Analyses
1801 N. Beauregard St.
Alexandria, VA 22311-1772

8. PERFORMING ORGANIZATION REPORT NUMBER
IDA Document D-1411

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
OSD/ISA/NPP
The Pentagon, Room 2D453
Washington, DC 20301

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Warning Notice: Intelligence Sources or Methods Involved

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The studies and briefings in this document examine the operational implications of the proliferation of militarily critical and dual-use technologies related to the use of ballistic missiles. These technologies offer critical operational improvements in weapons capabilities, presenting the United States and its allies with new military realities and threats. The purpose of these studies and briefings is to identify some of these new and emerging threats to U.S. national security for the policy official and military commander so that appropriate countermeasures can be devised and employed.

14. SUBJECT TERMS
ballistic missiles; C3I upgrades; navigation and guidance technologies; proliferation; space technology

15. NUMBER OF PAGES
179

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
SECRET/NOFORN	UNCLASSIFIED	UNCLASSIFIED	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

SECRET
NOT RELEASABLE TO FOREIGN NATIONALS

IDA DOCUMENT D-1411

THE OPERATIONAL IMPLICATIONS OF PROLIFERATION (U)

Gordon Boezer, *Editor*

August 1993

Classified by:	**DD Form 254 dtd 1 Oct 88**
	MDA 903 89 C 0003
	OUSD(A) (FFRDC Programs)
Declassify on:	**OADR**
Derived from:	**Multiple Sources**

IDA
INSTITUTE FOR DEFENSE ANALYSES
Contract MDA 903 89 C 0003
Task T-K2-943

SECRET

(BLANK)

PREFACE

This document was prepared for the Director, Office of Non-Proliferation Policy (OSD/ISA/NPP) by the Technology Identification and Analyses Center (TIAC) of the Science and Technology (STD) Division of the Institute for Defense Analyses (IDA). The studies and briefings contained in this document fulfill the requirements of the task order, Countering the Operational Implications of Proliferation.

Various authors and analyst teams worked closely with senior officials in the Office of Non-Proliferation Policy to understand the implications of advanced technologies and to frame various concerns for increases in military capabilities. Special recognition for authorship and creativity has been earned by IDA employees Tom Morgan, Matt O'Brien, John McHale, and Steve Wooley [now with the Office of Technology Assessment (OTA)] and by Mike Fitzgibbon of the Department of Defense (DoD). There are others. Matt O'Brien deserves special recognition for coordinating the assembly of this document.

(BLANK)

ABSTRACT

The studies and briefings in this document examine the operational implications of the proliferation of militarily critical and dual-use technologies related to the use of ballistic missiles. These technologies offer critical operational improvements in weapons capabilities, presenting the United States and its allies with new military realities and threats. The purpose of these studies and briefings is to identify some of these new and emerging threats to U.S. national security for the policy official and military commander so that appropriate countermeasures can be devised and employed.

(BLANK)

CONTENTS

I. THE OPERATIONAL IMPLICATIONS OF PROLIFERATION

Many of the technologies that heretofore have only been available to the North Atlantic Treaty Organization (NATO) and the former Warsaw Pact are widely available to other countries. Moreover, advances in technology are enabling proliferant countries to leapfrog generations of military operational capability. These new technologies can be combined in military systems for synergistic effect or coupled with weapons of mass destruction to achieve strategic results. Further compounding such threats is the likelihood of a lag between the time when the proliferant country develops or acquires a technology and the time when the United States or its allies can deploy effective countermeasures.

During the Cold War, U.S. perceptions of the Soviet threat led to specific levels of sophistication and particular applications of advances in technology. However, the U.S. approach to technology application for military systems yields few clues about the likely actions of a proliferant nation. For example, during the Vietnam War, the North Vietnamese made novel and effective use of technology to frustrate a technologically superior U.S. military. Consequently, since proliferant nations often apply technology in unpredictable ways to fit their method of warfare, U.S. analysts and military officials must be cautious to avoid thinking that the U.S. approach to technology application is likely or favorable.

The technologies selected for analysis meet one or both of the following criteria, which are found in the Department of Defense (DoD) 1992 Militarily Critical Technologies List (MCTL):

- Significantly negate or impair a major military capability of the United States
- Significantly advance a critical mission area of a potential adversary.

These technologies also have a significant impact on the development, production, and use of missile systems; biological, chemical, or nuclear weapons; and weapons delivery systems.

In this document, the study entitled "Implications of the Proliferation of Navigation and Guidance Technologies" discusses the current state of militarily significant positioning and navigation technologies, their potential for military application, and the possibility that countries may seek to upgrade less sophisticated weapon systems by integrating these technologies. The navigation technologies that are considered include equipment that is capable of accurate position and time updates from external references (satellites, stars/planets, or ground radio aids) or internal sensors (inertial) that provide data on vehicle motion and position.

The briefing entitled "Proliferation of Precision Navigation Technologies and Security Implications for the United States" examines the evolution of selected navigation technologies and highlights some major policy implications. The Global Positioning System (GPS), Differential GPS (DGPS), and Global Navigation Satellite System (GLONASS) are three major navigation technologies analyzed for their security implications. Access to these technologies is widespread, and this access creates multiple, affordable weapons combinations for proliferant countries. A number of U.S. countermeasures are recommended to meet this emerging threat.

The briefing entitled "Space Technology Assessment: Annotated Briefing" shows that the near exclusive control of space technology and its constituent hardware has slipped away from the United States. At least 18 other countries manufacture, design, or test space components. Of these, seven countries can assemble whole satellite systems and launch them into near earth orbit without any assistance from U.S. industry. Moreover, the technological sophistication of these systems meets or surpasses that of the United States in many critical areas. In the next decade, the military use of imaging satellites (i.e., for the detection of large-scale military maneuvers like those of Desert Storm) will be available to many satellites not under U.S. control.

The briefing entitled "C^3I Upgrades for Developing Nations' Missile Operations" identifies and analyzes the operational military implications of the proliferation of Command, Control, Communications and Intelligence (C^3I) technologies. The paper concludes that C^3I upgrades will enable developing nations to:

- Locate and attack high-value targets that are time sensitive
- Execute mass attacks that can defeat active missile defenses
- Take advantage of accuracy improvements to substantially increase the effectiveness of accurate missile attacks.

Moreover, these C^3I upgrades are currently underway, and the technology is widely available commercially.

The final study, "The Military Implications of Ballistic Missile Proliferation," examines the military effectiveness of ballistic missiles in the context of technology proliferation. This study notes that missiles have been militarily ineffective in regional wars up to the present time. The principal reasons for this ineffectiveness have been a lack of coordination in missile strikes, a lack of knowledge about target vulnerabilities, a lack of the means to gather intelligence about the target, and a lack of post-attack damage assessments. Actively using missiles to attack military targets will require that a military commander develop and integrate these capabilities into a coherent fighting strategy. This study surveys strategies for fighting missile wars by examining the doctrine and logistics needed to make them practical.

These analyses strongly affirm the need for a U.S. capability to defend against ballistic missile attack. The Ballistic Missile Defense Organization (BMDO), with its emphasis on theater defense and a ground-based territorial defense of the United States, is an important step in this direction. It is hoped that this reinvigorated organization will help to bring the visibility, focus, and resources that are necessary to address this critical defense need. Active countermeasures will also be a critical component of any strategy to defend against this emerging threat.

II. STUDIES AND BRIEFINGS

The studies and briefings in Section II examine the operational implications of the proliferation of militarily critical and dual-use technologies related to the use of ballistic missiles. These technologies offer critical operational improvements in weapons capabilities, presenting the United States and its allies with new military realities and threats. The purpose of these studies and briefings is to identify some of these new and emerging threats to U.S. national security for the policy official and military commander so that appropriate countermeasures can be devised and employed.

(BLANK)

II-2

Implications of the Proliferation of Navigation Guidance and Technologies (U)

(BLANK)

II-4

IMPLICATIONS OF THE PROLIFERATION OF NAVIGATION AND GUIDANCE TECHNOLOGIES

Steve Wooley

John McHale

15 June 1993

(BLANK)

INTRODUCTION

This study was undertaken on behalf of OSD/ISA/NPP to evaluate navigation and guidance technologies that may be of use militarily to proliferant countries.[1] A virtual technology explosion has revolutionized navigation and guidance equipment. Both inertial and radio-based systems are now less costly and more accurate, reliable, and widespread. By combining accurate navigation and guidance to existing weapons or those in development, proliferant countries will be able to drastically improve selected military actions. In the near-term future, it will be impossible to control access to highly accurate aircraft, unmanned aerial vehicles, ballistic missiles/launch systems, cruise missiles, ships, submersibles, and even space vehicles.

This paper discusses the current state of militarily significant positioning and navigation technology, their potential for military application, and the possibility that countries may seek to upgrade less sophisticated weapon systems by integrating these technologies. The navigation technologies that are considered include equipment capable of accurate position and time updates from an external reference (satellites, stars/planets, or ground radio aids) or internal sensors (inertial) that provide data about vehicle motion and position. In addition to sparking a revolution in the commercial navigation industry, these technologies constitute a major segment of the brains of modern, accurate weapon platforms.

BACKGROUND

Throughout the history of weapons development, the key determinant in selecting ballistic missile guidance has been system autonomy. A major principle of deterrence has been a credible threat—ballistic missiles must reach their target after being fired, even if the launch site is subsequently destroyed. Since inertial systems provide internal guidance to a vehicle that is impervious to outside factors, they were the logical choice for use in the early ballistic missiles, even though radio navigation systems could provide better accuracy (as

---

[1] There is no representative profile for a "proliferant country". There is a huge variation in technical capabilities of those countries that develop and/or sell large numbers of weapons. The purpose in this paper is to summarize the navigation technologies that will be available and indicate which of these technologies are candidates for use in the military systems of some of the more prolific weapons producers and consumers during the next 10 years.

measured in circular error probable).[2] This remained true until the early 1970s, when the accuracy and reliability of inertial systems increased and inertial systems gained wider application in both military and commercial aircraft. Inertial navigation systems remain essential to manned and unmanned vehicles.

Before World War II, essential tools for navigation on the earth's surface and in the air consisted of visual triangulation, dead reckoning, and the hand-held sextant. Technology improvements included nondirectional low frequency radio beacons, amplitude modulated radio range "legs" that provided a Morse code letter A or N if one deviated significantly from course, and strings of colored lights placed at close intervals across the country along frequently traveled routes. Pilots flew from light to light, visually.[3] Technology such as radio detection and ranging (RADAR), short-range navigation (SHORAN), long-range navigation (LORAN), and a long-range radio aid to navigation (Consol) followed, with RADAR one of the important developments of the World War II era. Concurrently, displays which allowed the visualization of data from radar, such as the "A" scope (a cathode ray tube with two axis display), became the primary tool for resolving position relative to a graph of intersecting hyperbolas or turning "blips" into angle and distance.

New technologies gave rise to new methods of navigation.[4] Technology continued to evolve. The Very-High-Frequency (VHF) Omnidirectional Range (VOR) provided horizontal angle information relative to a ground station. Distance measuring equipment (DME) was added to VOR at an offset frequency and provided distance information. The combination of VOR and DME became the Tactical Air Navigation (TACAN) system and VHF Omnirange TACAN (VORTAC). These technologies provided the means to arrive reasonably close to a desired destination but were inadequate for precision bombing of fixed targets or careful mining of primary approach lanes within a nautical channel.

---

[2] Radio navigation systems provide a vehicle with position updates generated at that time by ground stations. For example, an aircraft would fly over a series of stations en route from point to point, providing position information to the navigator. Subsequent systems have been located on airborne and spaceborne platforms. Circular error probable (when referring to missiles) is a measure of the radius of the circle around the target into which at least 50 percent of the missiles fired at the target will land.

[3] A number of these routes still survive within "Amber Six", but all are non-functioning remnants of a past era.

[4] For example, one could hold a stopwatch and count beeps until they were no longer audible in a headset and resolve that count into a line of position. Radar triangulation was found useful at sea in station keeping or in approaching a harbor.

As radio navigation methods matured, inertial systems were developed and deployed, and these systems slowly replaced gyrocompass technology as "stable platforms." Early models used strain gauges that sensed the forces that were imposed on a small mass by vehicle acceleration. Analog processors kept track of force magnitudes as they varied with time and generated a vector correction that could be added to the primary motion vector maintained in memory. An "accelerometer" for each axis (X, Y, Z) could define motion within a three-dimensional (3-D) gyroscopically stabilized inertial frame of reference. Large numbers of these early Inertial Navigation Systems (INSs) remain in active service today in aircraft, ships, and underwater systems. The INS inertial reference frame is coupled to a geodetic frame by initializing the INS with a latitude/longitude when power is applied, and the system is aligned to true North by sensing the earth's rotation. The C-5B and C-141B fleets both use early versions of INS technology. For some of these systems, the Z-axis accelerometers have never been installed so the systems disregard vertical motion over the 8 miles of altitude these aircraft transit. These INS processors are programmed in octal and use arrays of ferrite cores for memory. Dual systems were installed so that the more accurate system can be chosen for use. Drift, the difference between actual and computed Latitude/Longitude with respect to time, is the major error of concern in inertial navigation.

NEW TECHNOLOGIES FOR NAVIGATION AND GUIDANCE

The accuracy and reliability of both inertial and radio-based navigation systems have improved dramatically in recent years. Accurate INSs are now more widespread and less costly. Inertial systems with navigation accuracies that would have prevented their export from the United States several years ago are now being manufactured in, among other places, China and North Korea. However, the most revolutionary technology is the Global Positioning System (GPS), which is a series of navigation satellites (NAVSTAR GPS) developed and launched by the Air Force to provide position information to receivers on the ground or in the air. A GPS receiver will calculate its position in latitude, longitude, and altitude based on the information received from at least three GPS satellites on several broadcast channels.[5]

---

[5]The (former) USSR was developing a GLONASS with slightly poorer performance than GPS. Its future is uncertain, although a new GLONASS satellite was launched after the attempted coup in 1991. Currently, 9 of 24 GLONASS satellites are functioning. The system will likely find its "market niche" as a back-up or redundant system to GPS. If the network is completed, there is a potential market for receivers to increase (differentially) the accuracy of GPS.

GPS signal strength of the satellites is modest. Aircraft flying low-level missions will experience diminished accuracy because of signal attenuation from some satellites by hills or mountains. Each satellite continuously transmits data that defines its orbit and position in that orbit. A full data set is repeated every 30 seconds. Orbital data is updated once each hour from data stored onboard the satellite. GPS receivers can sequence slow or fast or multiplex, or these receivers can simultaneously monitor multiple channels by using an array of parallel receivers. Generally, they provide position and velocity data in 1-second increments. A very fine GPS "engine", built on a 2 1/2" by 6" printed circuit board and consuming a bit over 2.5 watts, can be purchased for under $600. An antenna to accompany the electronics costs an additional $200 or $300.

An operational GPS can enhance relatively inexpensive INSs so that they have performance characteristics previously associated with high-cost systems built only in the U.S., France, United Kingdom, or possibly one or two other countries. Less costly and less accurate inertial systems whose errors can be bounded by the accuracy of GPS are increasingly becoming available, and the operational implications are severe for the U.S. military and domestic security agencies. A commercial inertial system has an accuracy of about 1 nautical mile per hour while the gyros have drift rates of about 0.01 degrees per hour. With the introduction of ring laser and hemispherical resonator technology into the commercial inertial marketplace, the surplus market for older systems will easily exceed several thousand systems. This does not include systems built in China and North Korea. When these older "standard" systems are integrated with a GPS receiver, the result is a guidance package suitable for a unmanned aerial vehicle (UAV) or other aircraft on a suicide mission. When GPS updates are used to bound these commercial inertial systems, the accuracy is much better and can approach a target area on the order of a football field. The options for a country, organization, or individual bent on destruction or on conveying a political message multiply. Ballistic missiles are no longer necessary because less costly, more accurate systems with a reduced payload may produce better results. Even when the GPS signal is jammed, the inertial system provides greatly improved calibrated information.

DoD has undertaken concerted efforts to control access to both precise global position system data and highly accurate INSs. The highly accurate position information from the GPS system is preserved for military systems by encryption of selected data bits. Civilian users of GPS receive slightly degraded position information—accurate enough to find one's way to the next town but not good enough to line up and land on a dark runway. The process of degrading the GPS signal is known as selective availability (SA). With SA turned on, civilian users can obtain accuracies of +/- 90 m. Military users can obtain accuracies of better than 20 m with encrypted, or precise-code, signals. Although efforts to control access to GPS data have been somewhat effective, proliferant countries have, and will continue to have, access to accurate navigation aids.

In some instances, these degraded accuracies are adequate for carrying out a military mission. There are a number of methods to overcome the accuracy degradation that results from SA. A popular technique is differentiating, or correcting, the GPS signal. One can isolate the error introduced by SA to the GPS signal by comparing readings to known locations at geodetically surveyed ground sites. These corrections can then be broadcast from ground-based stations to specially equipped GPS receivers within a certain radius, usually up to 1000 km. This technique, Differential GPS (DGPS),[6] can provide users with accuracies of 1 to 5 m. The coverage area is dependent on the range of the ground transmitter, and the accuracy degrades proportional to the range. Because a DGPS station is not primarily a military system, anybody can purchase a one for between $35,000 and $100,000. Such systems provide navigation accuracies of 1-10 m over a range of 1000 km. Test results have demonstrated that DGPS can meet and generally improve on the accuracy requirements of 10m 2dRMS for buoy positioning. However, occasional short period transient errors are observed in the DGPS line of position solution where the positioning error exceeds the 10-m requirement. These occurrences are infrequent, and will decrease as the GPS satellite network is completed.[7]

Other test results are even more impressive. Testing of the United States Coast Guard (USCG) DGPS from Montauk Point in New York has shown that 97 percent of the position information was accurate within 10m on the worst day of the tests and over 99 percent of the position information was accurate to within 10m on the best day of the tests. Thus, even with selective availability, differential systems will correct the signal to

---

[6]A DGPS station is a receiver/broadcast station positioned at a geodetically defined position (a site surveyed to precise longitude, latitude, and altitude), which receives the GPS C/A signal, calculates a correction to the satellite transmission, and then rebroadcasts those corrections to modified GPS receivers within a given radius. The effective radius is dependent upon the broadcast range of the transmitter and the difference in GPS error at transmitter and mobile receiver locations.

[7]"Differential GPS Autonomous Failure Detection," Allison Brown and Janet King, NAVSYS Corporation, Monument Colorado, and Jay Spalding, U.S. Coast Guard. Paper presented at the Fourth International Technical Meeting of the Satellite Division of the Institute for Navigation, September 11-13, 1991.

such a degree that accurate buoy positioning (for harbor navigation and harbor approaches) will be possible.[8]

Recently, a market for satellite-fed DGPS corrections has evolved. It is now possible to obtain a differential correction from a private satellite (similar to a cable television broadcast) on a contract basis. In addition, a U.S. company is now offering GPS corrections nationwide via FM radio links. For about $1,000 per year, the company offers access to DGPS corrections (accurate to within 1-2 m).[9]

USES OF GPS

GPS and DGPS provide potential adversaries or proliferants with low cost and easily obtainable solutions for a number of navigation and guidance problems. The effects of SA are minimal when the 90-m accuracy is compared to technology that existed before GPS. If a proliferant is concerned about the degradation of the GPS signal, there are solutions to this problem as well, as the burgeoning DGPS industry indicates.

The outstanding potential of GPS can be exploited best in nonballistic applications.[10] For example, two representative methods of decreasing the 90-m error of SA that would work exceptionally well in a drone aircraft or other UAV are as follows:

1. Combine commercial GPS with a ground station for terminal approach. It is certainly possible to link an UAV or a ground vehicle to a ground station that can provide terminal guidance to a target. This approach could have applications in a terrorist strike or first-strike scenario.
2. Use digitized maps or satellite images to improve DGPS data for use as a guidance system. Spatial data is available from a number of sources including civilian remote sensing satellites. It is most likely that the data from these satellites [e.g., Satellite Positioning and Tracking (SPOT) or Land Satellite (LANDSAT)] will be used in targeting systems, but data with better resolution may be applicable. This would require several good computer workstations or

---

[8]"Status of Prototype USCG DGPS Broadcasts," Joseph Spalding, Scott Krammes, USCG, and David Pietraszewski, USCG Research and Development Center. Also presented at ION-GPS, 1991.

[9]*Space News*, 8 March 1993.

[10]GPS could bring only marginal improvement to the accuracy of ballistic flight. Most error in ballistic targeting can be attributed to the reentry buffet due to current missile design. GPS could only be used to re-initialize a missile in the post-boost phase, making re-entry occur at a position closer to that predicted in its flight path. Commercial GPS receivers will not function in conditions that subject them to forces of acceleration greater than 4 times the force of gravity (4 g's).

486-based personal computers to run an AutoCAD-type program for combining the GPS data with the map or image data. This digital record could then be used to guide a UAV with an image-matching flight software program or more crudely using only GPS or DGPS data to match a flight plan. Such a system could be combined with a radar altimeter for terminal guidance as well. See Appendix A for more information about linking GPS and mapping technologies.

In addition to making the use of UAVs a more realistic possibility for proliferant countries, DGPS and even SA GPS data can have other important military applications. GPS can play a role in the initialization of mobile ballistic missiles. Mobile ballistic missiles must be fired from precisely surveyed sites to guarantee the accuracy of flight. This initialization process can be complicated and time consuming. DGPS could make the process much easier because any number of potential launch sites can be pre-surveyed,[11] giving the missile crew seemingly unlimited options for launch and numerous hiding places. Access to these sites will also decrease the time required to prepare a missile for launch.

GPS can also be used to increase the accuracy and speed with which mines are positioned, increasing the efficacy of mine warfare. As events during the 1991 Gulf War indicate, GPS technology provides huge cost and time savings when used effectively in logistics management. GPS can also improve reconnaissance, increase the accuracy of artillery, and reduce the amount of radio traffic[12] between ground units relaying position information to one another.

ADDRESSING THE POTENTIAL THREAT

The advent of greater navigation and guidance technologies may change countries' views about the political and military utility of weapon platforms. For example, the War of the Cities between Iran and Iraq and the Scud attacks on Israel by Iraq indicate that striking the cities of an enemy has great political value even if the military implications are currently limited. Countries (such as Iran and Iraq) that have shown a willingness to target population centers and use chemical and biological weapons will have increasing access to highly accurate weapon systems including ballistic missiles, nonballistic missiles, aircraft,

[11] This eliminates the need to have a DGPS network functioning during battlefield conditions, where it could be jammed or destroyed.

[12] Radio traffic is an important source of electronic intelligence with application for targeting, avoidance, etc.

UAVs, and cruise missiles. Proliferants may also wish to maximize their investment in weapons of mass destruction by integrating chemical, biological, and nuclear materials with platforms that have a reasonable chance of striking highly valued targets. This evolution in technology will generate international concern for years to come. The United States should be prepared to counter these more accurate weapon systems that will soon become commonplace. More accurate weapons in the hands of proliferant countries may never be so effective as to threaten the defeat of U.S. military forces, but they will certainly pose a more serious challenge if appropriate countermeasures are not considered.

Creative use of GPS and DGPS can potentially provide proliferants with the ability to strike fixed targets with much better accuracy. Decreasing the accuracy of the GPS signal is not a viable solution to this problem. However, there are a number of ways that the United States can prepare to respond to the potential military use of the GPS system against our own interests:

- Track the worldwide distribution of advanced photogrammetric equipment to known proliferants and countries with ongoing UAV programs.
- Track the distribution of DGPS equipment sold commercially and be prepared to search for, jam, and/or destroy DGPS broadcast facilities. This will become increasingly difficult as DGPS information is downlinked from satellites to receivers.
- Be prepared to increase anti-terrorist defenses around important targets as terrorists increase their strike capabilities. The lethality of systems such as UAVs may increase as GPS is integrated into the systems. Ideally, U.S. installations will be forewarned of a planned attack by intelligence sources using a precise system. In the absence of such forewarning, point defense should be trained to destroy incoming UAVs or other vehicles.

With the breakup of the Soviet Union, some of the engineering and production personnel with experience in navigation systems have become available to the highest bidder. The proliferant countries will employ these people to obtain the knowledge that they possess. The United States should pre-empt this situation by providing employment to those former Soviet personnel with critical skills in navigation. Although the information on inertial systems technology of the Soviet Union is limited, there were Soviet attempts to copy and emulate U.S. designs. Personnel involved with these projects could possibly recommend significant design changes to improve the production and reliability of U.S. systems. Under the guidance of DoD and the Department of Commerce, a plan should be formulated and implemented to provide funding similar to that appropriated for nuclear proliferation control.

APPENDIX A

GPS AND THE USE OF MAPS AND CHARTS

Positioning technology that allows one to navigate to within 5 m of a destination anywhere on earth would seem adequate for most military and civil purposes. The limiting factor for determining position shifts to cartography is the accuracy of maps and charts. Maps have nowhere near the accuracy inherent in current navigation systems. Ground combat is usually conducted using one or more maps of 1:50000 scale. Commanders take great care to ensure that all battle participants are furnished maps of identical series and edition. The universal transverse mercator (UTM) grid overlay on the combat map functions as a relative reference frame shared by all, even though this grid system is part of a worldwide reference system. The grid effectively washes out map error as a variable within the small area depicted. Error, when noticed, tends to be attributed to other factors such as inadequate propellant in an artillery shell. The effect is analogous to a platoon of soldiers, each with perfect vision, being furnished with corrective lenses ground with an identical set of optical aberrations. The platoon would share a common visual experience of reality. Positioning data provided by coupled GPS/INS function as an absolute reference frame and quickly expose cartographic error. Topography and features turn out to be at different locations than those derived from the map's coordinates. When taken to the extreme, it can be truthfully said that no map in the world is totally accurate and the only "known" position is Greenwich, England. The inverse, of course, occurs when a weapon is fired at a target defined by map coordinates. The weapon impacts precisely on the desired coordinates but "misses" the target.

Civilian users can reduce the errors in the course-acquisition code, however. Since the GPS signal is generated by a number of satellites, the introduced error can be filtered out by a two-step process. There are large numbers of precisely surveyed or geodetically surveyed sites around the world. The position information obtained from GPS can be compared to the geodetically surveyed site, and a correction can be derived. If this correction is automated and continually updated and broadcast to hand-held units, it can provide accuracies of greater than 5 m, depending on satellite configurations.

Widespread access to highly accurate position information is critical to production of accurate maps. Such data are integrated with remotely sensed images in Geographic Information Systems (GISs). Ground-truthed data make the data more useful for any number of applications (e.g., digital cartography, mineral exploration) since objects in the image can be accurately located.

GISs are becoming a more useful tool as accurate GPS position information is used to augment information collected from aircraft, satellites, or remotely piloted vehicles (RPVs). GPS has made it possible to obtain accurate position information for the entire world that previously had not been possible to obtain. This information is helping to expand the coverage of accurate, usable maps. In addition, as the amount of remotely sensed data from satellites or aircraft increases, GISs have become more comprehensive. Data obtained from GPS and remote sensors are often integrated in a computer-automated design environment as well. Such a computer-driven integration can produce digital maps or automated guidance systems for automobiles, aircraft, or other vehicles. An anticipated increase in the amount and nature of remotely sensed data could change the nature of GIS. The GIS and GPS value-added industries will continue to grow rapidly.

Frustration over the differential accuracy of the two technologies (positioning and mapping) will continue for years. Given a requirement to destroy a high value, nonmobile target, a user could order a "point" map of the target and receive a Latitude/Longitude definition of that selected geographic point with an accuracy of the same order as a GPS receiver would generate if it was placed upon the point. However, production of point maps is labor intensive, takes a few days to produce, and results in data that are not extensible, i.e., accuracy is defined at the cross-hair point, only. Mathematically, there are an infinite number of "points" on the surface of the earth; therefore, producing lots of them would not resolve map errors in a generic fashion. From where do these errors come? Most maps are produced by a process of photogrammetry, a mixture of analog and digital technology. Some are made from "cartographic source materials," i.e., maps made by reference to other maps. The process is as much art as science, and error is induced by personal technique and day-to-day variation in the operator's depth perception. Vertical error is commonly of the order of +/- 300 feet. Features (buildings, roads, railway tracks, forests, marshy areas) are resolved by the cartographer's best judgment. Contour lines are produced by a mathematical process. Horizontal error is deliberately spread across the surface of a map using a least squares algorithm. Symbols are displaced from their precise locations to avoid visual clutter. A building or topographic point near the edge of a map may appear at slightly different coordinates on an adjacent map. Information concerning the maximum vertical and horizontal error of a map and the coordinates at which they occur are not routinely included in the map's legend nor always known. Placement of a precise grid over a map does not diminish the magnitude of the errors embedded within the map. In short, the maps that are used in combat are symbolic representations of terrain and features. Rapid increase in production precision is unlikely. The coefficients defining the shape of the earth, the geoid, were last updated in 1984. That update resulted in considerable change to "plates" in the Far East. Maps are not updated often. Ten- to 12-year intervals between recompilations are not infrequent. Some areas of the world remain unmapped today. Gathering the required source materials and compiling, printing, and distributing a map takes approximately 18 months.

The military applications for hybrid GPS/INS/LORAN/GLONASS are manifold and include establishing positions for mobile missiles, establishing "roadmaps" for targeting purposes, laying mines, and guiding aircraft or UAVs. There are a variety of theoretical and practical articles that provide detail design specifications for several different types of differential networks.[13] A proliferating country could develop its own differential GPS or differential LORAN simply by establishing a transmitter and rebroadcasting the correction through its own equipment. Such a system would be highly valuable in creating maps and adding targeting information to commercially provided satellite photos. Because a DGPS would be susceptible to jamming, it would be of limited use under battlefield conditions; however, it would be quite effective in relaying position information to a UAV or cruise missile in a first strike.

Commercial GPS units proved their value to military operations in Operation Desert Storm. Commercial GPS units provide highly accurate latitude, longitude, and altitude readings to users and provide access to some of the world's most accurate atomic clocks. Precise time information is critical to determine distance as a function of speed (rate). GPS in Operation Desert Storm was clearly advantageous, and it is highly likely that a number of countries will incorporate GPS into their systems and tactics. Commercial GPS will be used ubiquitously in the future. Other navigation aids such as astronautical (ASTRO)-aided or magnetic maps could be developed by proliferant countries. However, it is unlikely that these navigation aids will be usable within 10 years.

---

[13]"Differential GPS Network Design," Peter Loomis, Len Sheynblatt, Jim Robbins, and Tysen Mueller, Trimble Navigation, Ltd., Sunnyvale CA. Paper presented at the Fourth International Technical Meeting of the Satellite Division of the Institute for Navigation, September 11-13, 1991.

(BLANK)

Proliferation of Precision Navigation Technologies and Security Implications for the United States (U)

(BLANK)

PROLIFERATION OF PRECISION NAVIGATION TECHNOLOGIES AND SECURITY IMPLICATIONS FOR THE UNITED STATES

Presentation for the Proliferation Countermeasures Working Group

9 December 1991

(BLANK)

THE PROBLEM

Autonomous Third World weapon systems have not had the required accuracy to strike military targets and achieve operationally significant results without resorting to warheads of mass destruction.

This is changing.

A technology explosion has occurred in navigation and guidance. By using technologies now widely available, proliferants can dramatically improve their delivery systems and strike capability.

This briefing will review selected technical evolution and highlight major policy ramifications of these rapidly growing capabilities.

POLICY IMPLICATIONS

Accurate weapons a reality for proliferants:

- **Further export restrictions are not practical; U.S. policy reactive**
- **Effects of selective availability can be overcome, and further GPS restrictions are not likely**
- **Impractical to control differential GPS**
- **U.S. policy for countries that use CA-Code for military purposes is evolving**
- **GLONASS may have some missile applications; some controls worth investigating**
- **U.S. intelligence requirements will be driven by technology growth**
- **Effective countermeasures are mandatory**

GPS

CA-GPS:

Worldwide coverage

- position accuracy under 100 m
- time accuracy=10^{-8} sec

Accuracy can be further degraded

Can be corrected (differential)

Affordable $500-$60,000

Reliable

Passive

Integrated easily into existing platforms

Numerous applications

MTCR Limitations: Cannot exceed 60,000 ft., 1000 nmph, or designed or modified for use with unmanned air vehicles.

DIFFERENTIAL GPS

- Ground station with receiver and broadcast capability positioned at geodetically surveyed site
- Correction to CA-code is determined and applied by users
- Range varies depending on equipment, usually 750-2000 km
- Affordable: $30-70K
- Becoming widely available (commercial and government)
- Commercial, pay as you go, satellite-based systems are growing
- World-wide differential service is plausible in 5-10 years

MANUFACTURERS OF GPS CONSUMER PRODUCTS

Adroit Systems (U.S.)
Ashtech (U.S.)
Ball Communications (U.S.)
Garmin (U.S.)
Interstate Electronics (U.S.)
John E. Chance (U.S.)
Litton (U.S.)
M/A Com Adams-Russel (U.S.)
Magellan Systems Corp. (U.S.)
Magnavox (U.S.)
Motorolla (U.S.)
Navstar (U.S.)
Piezo Crystal Company (U.S.)
Stanford Telecom (U.S.)
Rockwell Collins (U.S.)
SI-TEX (U.S.)
3S Navigation (U.S.)
Trak Systems (U.S.)
Wellnavigate (U.S.)

GEC-Plessey (UK)
Inmos-Columbus (UK)
Inmarsat (UK)
Racal (UK)
STC-Norther Telecom (U.K)
Trimble Navigation Ltd. (UK, U.S.)
NovAtel (Canada)
Sercel (France)
Sagem (France)
Japan Radio Company (Japan)
Topcon (Japan)
Toshiba (Japan)
Sony (Japan)
SEL (Germany)
terraSat (Germany)
Leica, plc. (U.S. and Swiss merger)
Geotronics (Sweden)
Rokar International, Ltd. (Israel)

GLONASS

- **Funding a limitation**
- **Uncertain future**
- **Projected accuracy similar to GPS**
- **No apparent accuracy degradation like selective availability or performance limits**
- **If completed, will provide redundancy to GPS coverage**

GLONASS (CONTD.)

24 total satellites (3 spares)

8 of 24 satellites launched, completion by 1994—maybe

3 orbital planes, 8 satellites will travel in each

Synchronize every 8 days (17 orbits)

Coordinate system slightly different than GPS

GPS+GLONASS integrated receivers already developed (Honeywell and Northwest Airlines have tested system)

Accurate time transfer between GPS, GLONASS and other radio navigation aids

OTHER RADIO/SATELLITE NAVIGATION SYSTEMS

OMEGA, LORAN, TACAN, Commercial satellite systems

- **Not as accurate or complete as GPS or GLONASS, but reliable backup systems**
- **Not likely to be major competitors with GPS, but offer supplemental refinements to navigation accuracy**

INERTIAL NAVIGATION SYSTEMS

Expensive ($150,000) stand-alone inertial systems widespread in Western commercial and military aircraft

Cheaper systems ($50,000) widely available, can be updated by satellite data (GPS, GLONASS)

Integration complexity varies by platform

Bottom line: Proliferants leapfrog 15 years of navigation development by purchasing available inertial systems linked to GPS

THE PROGRESSION

1981

Proliferants had marginal navigation systems

- Attitude heading reference system for aircraft (MiG-21, MiG-23, MiG-25)
- Inertial guidance in ballistic missiles

Overall assessment: Poor, easily confused, limited performance; few missiles

1991

Easy access to improved navigation and guidance

- GPS, DGPS, better inertial systems

Unmanned air vehicles with GPS capability becoming common (SCARAB, Helstar, Skyeye, HAVE SLICK, Seawolf, Hunter)

Hybrids (inertial plus imbedded GPS) now available

Overall assessment: Quantum leap in capabilities, access

THE FUTURE

1991

Proliferants

GPS used in aircraft navigation

U.S., France, Germany exporting inertial systems with GPS update

DGPS used to initialize mobile missiles, artillery in proliferant countries

GPS used to produce highly accurate (80m over unlimited range) drones and UAVs (SCARAB)

GPS used to locate targets

GPS in small aircraft, automobiles, ships (combined with digital maps) standard

DGPS used to develop maps and guidance systems

United States and Allies

Fly-off, Seawolf and Hunter UAVs

DGPS used for harbor navigation, mineral exploration

GPS complete after 24th satellite is deployed

Commercial GPS receivers reach $500

GPS becomes standard with commercial and military INS

GPS integrated into weapon platforms and targeting (SLAM)

1996

Dual GPS and GLONASS receivers available commercially

DGPS incorporated into air traffic control– precision approach

2001

Multiple options for terminal guidance available

Overall Assessment: Countermeasures are Mandatory

RECENT ACTIVITIES

Seeking DGPS to develop photogrammetric techniques:

Pakistan	Indonesia
China	Thailand
India	
Arab Int'l Optoelectronic	

Actively trying to integrate GPS into missiles, UAVs:

Pakistan	Iran
China	USSR
Burma	France
Israel	Germany

AVAILABILITY

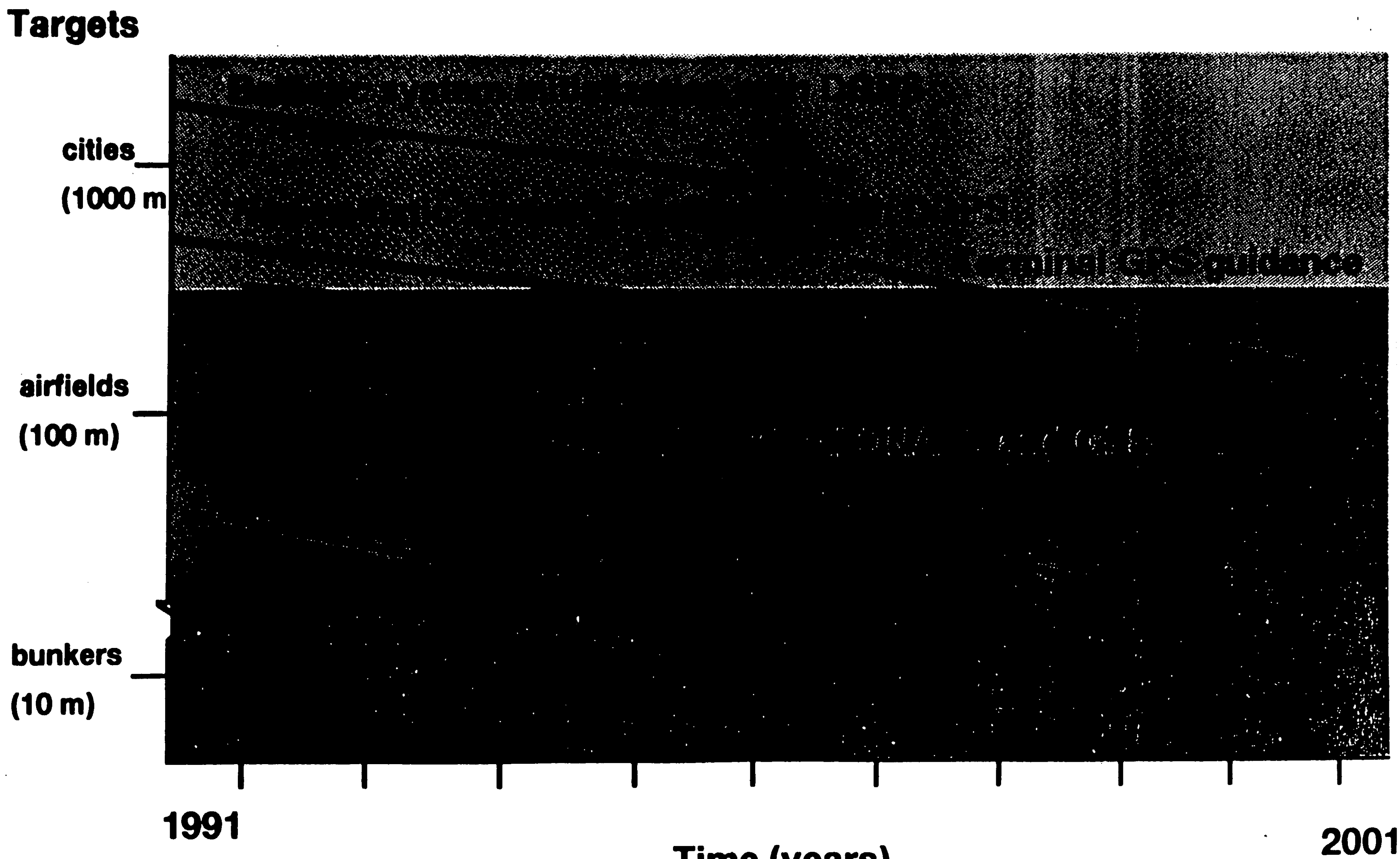
Technologies

Inertial (Military and Commercial systems)	Satellite/radio based (CA-GPS, DGPS, LORAN, OMEGA TACAN)	Other (Astro-aided, magnetic mapping)

Availability

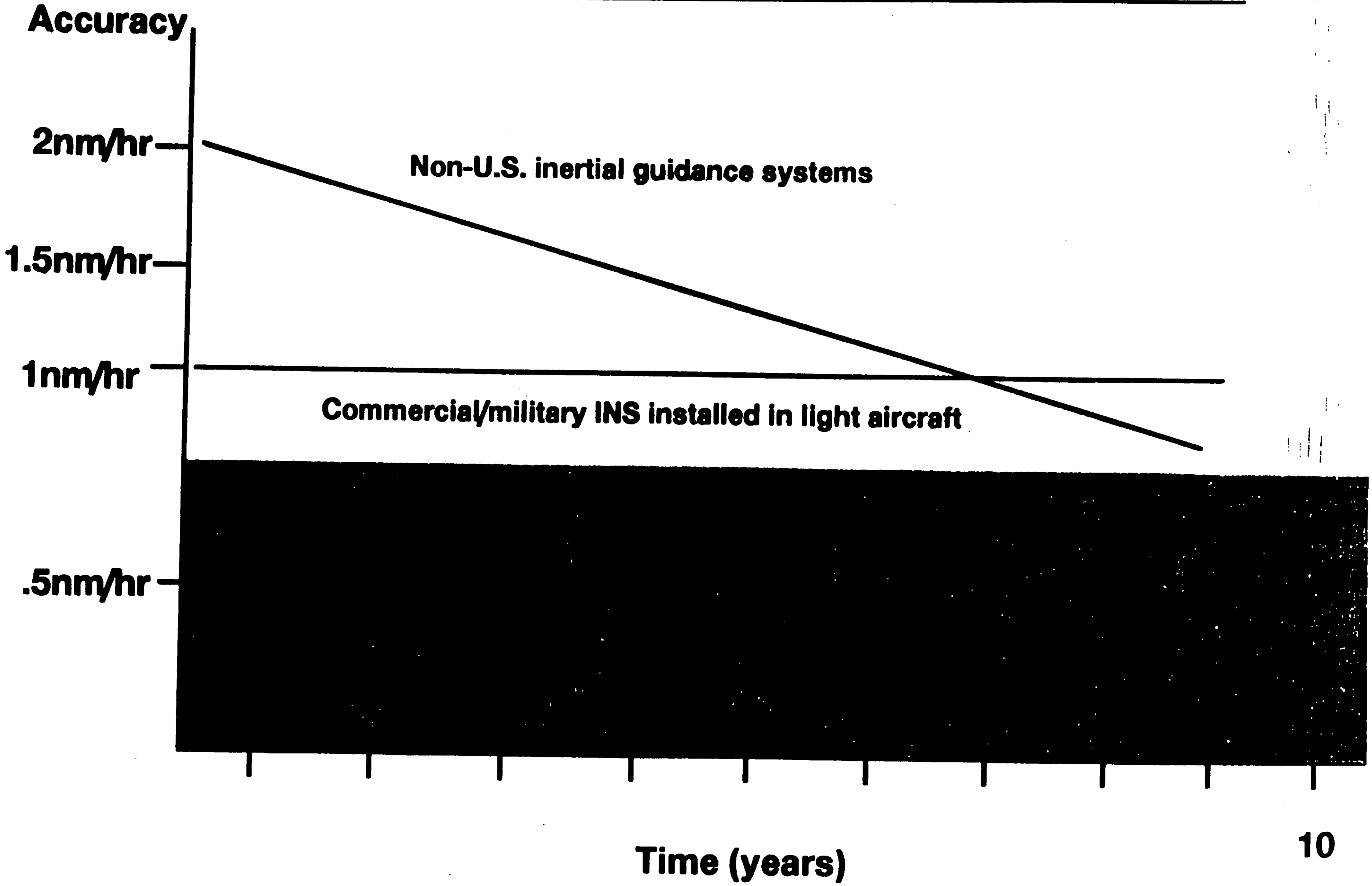
Some commercially available Several organized and active theft rings Spares and maintenance/3d country diversion	CA-GPS, DGPS, OMEGA, LORAN commercially unrestricted Private systems will be increasingly available	Beyond ten years

SYSTEM ACCURACIES WITH SATELLITE NAVIGATION



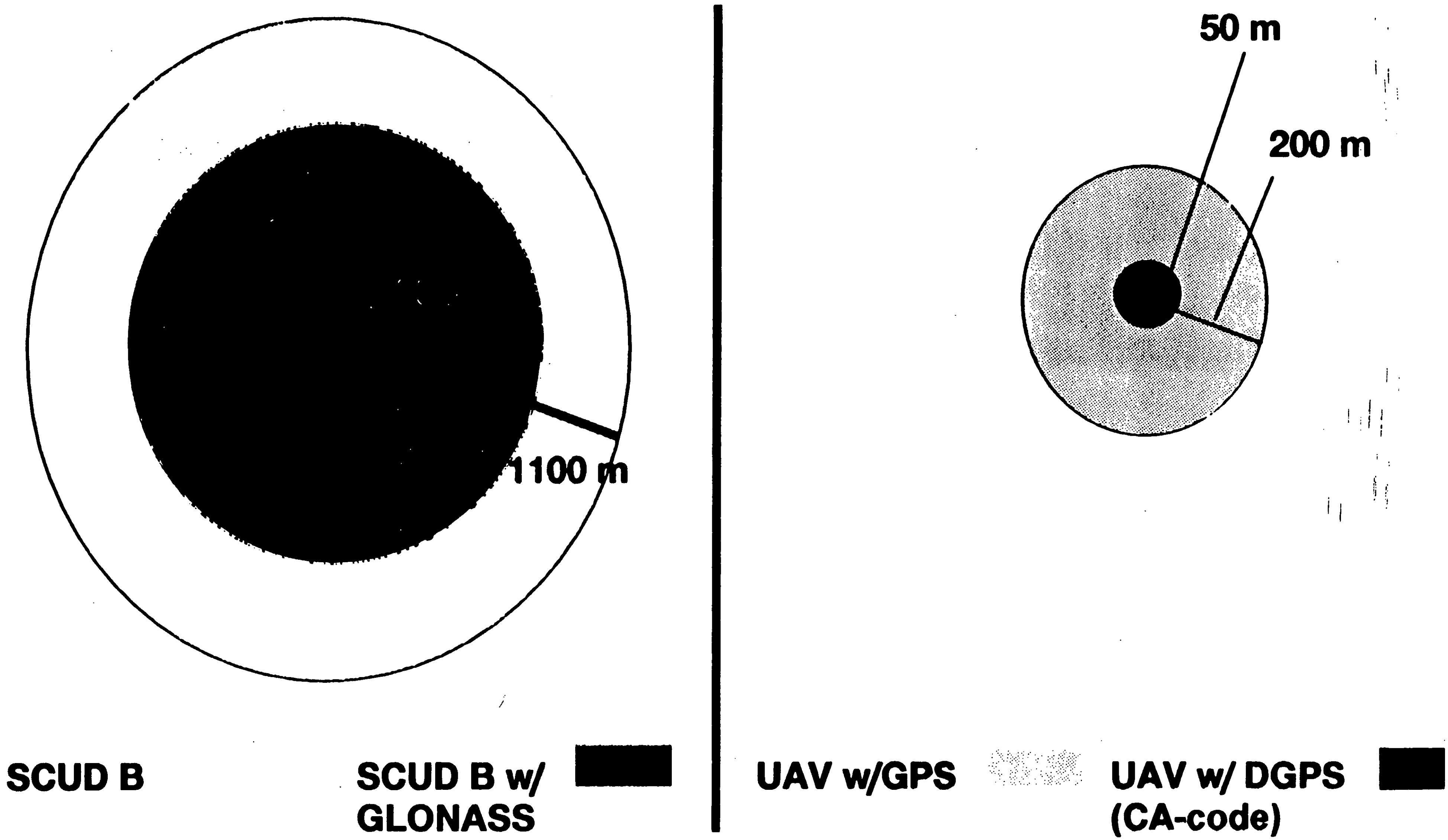
[redacted]

NOMINAL ACCURACIES OF INERTIAL SYSTEMS



UNCLASSIFIED

SYSTEM CEP WITH DGPS



UNCLASSIFIED

ANOTHER GUIDANCE OPTION FOR PROLIFERANTS

Purpose:

Develop accurate targeting system for UAVs

Method:

Digitize satellite image generated by LANDSAT or SPOT, add position information from differential GPS, use radar altimeter for intermediate and terminal guidance.

Accuracy:

<50mCEP

Range:

Theoretically unlimited

Cost:

$100,000 total, $60,000 recurring

Limitation:

Must have access to en route navigation points

ACCURATE INITIALIZATION AND TARGETING

Satellite systems can improve the initialization for ballistic missiles, and speed the firing of mobile missiles

Satellite systems will enable more effective targeting of non-ballistic missiles

COUNTERMEASURES

Accurate intelligence can dictate necessary countermeasures

Counters will likely include:

- Electronic Warfare, especially ability to detect, jam GPS, DGPS
- Optimized target location/selection
- Ability to strike mobile missile sites
- Missile/UAV point defense
- Radar optimized for detecting mobile missiles, UAVs

CONCLUSIONS

Radio and satellite navigation aids complicate countermeasures:

- **Systems more autonomous**
- **Mobility**
- **Rapid rate of fire**
- **Highly accurate range information**
- **Fewer munitions required**
- **Inexpensive; large numbers of accurate systems**

SUMMARY

Navigation technology will change targeting, strategies of proliferants

- **Technology has exploded; access widespread**
- **Multiple and affordable weapons combinations**
- **Existing systems more accurate**
- **Broader range of targets**

(BLANK)
II-44

Space Technology Assessment: Annotated Briefing (U)

(BLANK)

~~SECRET/NOFORN~~

BERNER
LANPHIER AND
ASSOCIATES
INC.

SPACE TECHNOLOGY ASSESSMENT: ANNOTATED BRIEFING

PRESENTED TO: DEPUTY FOR NON-PROLIFERATION POLICY
INTERNATIONAL SECURITY AFFAIRS
OFFICE OF THE SECRETARY OF DEFENSE
JULY 12, 1991

CONTRACT NO. MDA903-90-C-0127
CONTRACT EXPIRATION DATE AND OTAL DOLLAR VALUE: 23 SEPTEMBER 1991, $169,754.00
CONTRACTOR'S PROJECT DIRECTOR AND PHONE NUMBER: VERN LANPHIER, (301) 654-8111
GOVERNMENT SPONSOR: DOD/OSD

~~SECRET/NOFORN~~

THE PROLIFERATION OF SPACE CAPABILITIES WILL POSE AN INCREASING PROBLEM FOR POLICY MAKERS

Despite the high cost of gaining access to space, and the even higher cost of maintaining this access, many nations have embarked on ambitious space programs. This assessment addresses the specific content, pace, and direction of these programs. It does so with the objective of identifying current and future civil space and dual use developments that will pose problems for U.S. strategic and tactical forces, and complicate U.S. planning for future military engagements. While final conclusions are still being formulated, preliminary observation suggest that:

- The number and availability of launch vehicles, and the competition between providers of launch services, means that virtually any payload owner can place his payload in orbit.

- Current and planned civil remote sensing systems exceed in number and cost even the most optimistic scenarios for growth of the market; several of these systems look like budding NTM.

- Indigenous, non-U.S. communications satellite systems are under construction or planned in at least 14 countries; U.S. manufacturers can expect serious competition in future construction contracts

- The surest indication of long range interest is investment in infrastructure; the Europeans and the Japanese are putting in place all the facilities necessary for fully autonomous space operations.

THE PROLIFERATION OF SPACE CAPABILITIES WILL POSE AN INCREASING PROBLEM FOR POLICY MAKERS

✓ DENOTES PROJECT IN STUDY PHASE	LAUNCHERS	REMOTE SENSING	SATELLITE COMMUNICATION	INFRASTRUCTURE
SOVIET UNION	• PROTON • ZENIT • ENERGIA • VOSTOK • BURAN • SOYUZ • TSYKLON • MOLNIYA	• SOYUZ • MIR • COSMOS	• MOLNIYA • STATSIONAR • GORIZANT	• MIR • PHOTON • TYURATAM • KAPUSTINYAR • PLESETSK
CHINA	• LONG MARCH I • LONG MARCH II • LONG MARCH III • LONG MARCH IV	• CHINASAT 1,2 • INSCOM	• STW • DFH	• FSW - 1,2 • JIOUAN • XICHANG • TAIYUAN
ESA (80-89 $10.6B) (90-2000 $20.1B)	• ARIANE 1,2,3,4,5 • HERMES	• ERS	• ECS • OLYMPUS • DRS	• COLUMBUS • EURECA • SPACELAB • SPAS • KOUROU ✓ AMICA
FRANCE (80-89 $4.4B) (90-93 $4.8B)	• ARIANE 1,2,3,4,5 • HERMES	• SPOT • HELIOS	• TELECOM • SPACEBUS • TDF • SYMPHONIE • LOCSTAR • ARABSAT • HISPASAT	✓ MATRA SPACE PLATFORM • CNES PARABOLIC PLANE • KOUROU
JAPAN (80-89 $6.4B) (90-2000 $39B)	• H-I • H-II ✓ HOPE	• MOS • JERS • ADEOS • GMS SERIES	• CS SERIES • BS SERIES • ETS SERIES • SUPERBIRD • JCSAT	• JEM • SFU • KAGOSHIMA • TANEGASHIMA
GERMANY (80-89 $2.0B)	✓ SANGER	• MOMS	• DFS • TV-SAT • SPACEBUS • DRS	• SPACE COURIER • TEXUS • MAXUS ✓ AMICA
U.K. (80-89 $0.36B)	✓ HOTOL		• SKYNET • OTS • MARECS • EUROSTAR • OLYMPUS • INMARSAT • NATO IV	
ITALY (80-89 $1.3B)	• SCOUT II		• ITALSAT	• TOPAS • SAN MARCOS
CANADA		• RADARSAT	• ANIK SERIES • M-SAT	• SPACE ROBOTICS

THE PROLIFERATION OF SPACE CAPABILITIES WILL POSE AN INCREASING PROBLEM FOR POLICY MAKERS (CONTD.)

√ DENOTES PROJECT IN STUDY PHASE	LAUNCHERS	REMOTE SENSING	SATELLITE COMMUNICATION	INFRASTRUCTURE
INDIA	• SLV • PSLV • ASLV • SOUNDING ROCKETS • GSLV	• IRS SERIES	• INSAT II SERIES	• SHAR • TERLS • BALASORE
BRAZIL	• VLS • SONDA 1,2,3 • INSCOM (CHINA) • TALKS W/SOVIETS	• MEBE • CHINA/BRAZIL EARTH RESOUCES SATELLITE		
ISRAEL	• SHAVIT • TRANSFER ORBIT STAGE	• OFAQ 1,2 • ASTRONOMY	• AMOS	
AUSTRALIA				√ CAPE YORK • WOOMERA RANGE
IRAQ	• LAUNCH VEHICLE	• ATTEMPTS TO BUY FROM BRAZIL, FRANCE		
KOREA	• 1993 SOUNDING ROCKET	• KITSAT	√ KOREASAT	
PAKISTAN		• BADR-A,B	• BADR-A	
SOUTH AFRICA			• SATELLITE PLANNED	• HARTEBEESHOCK TRACKING STATION
TAIWAN	50B NT DOLLARS FOR 5 YEAR PLAN TO DEVELOP LAUNCHERS, SATELLITES			

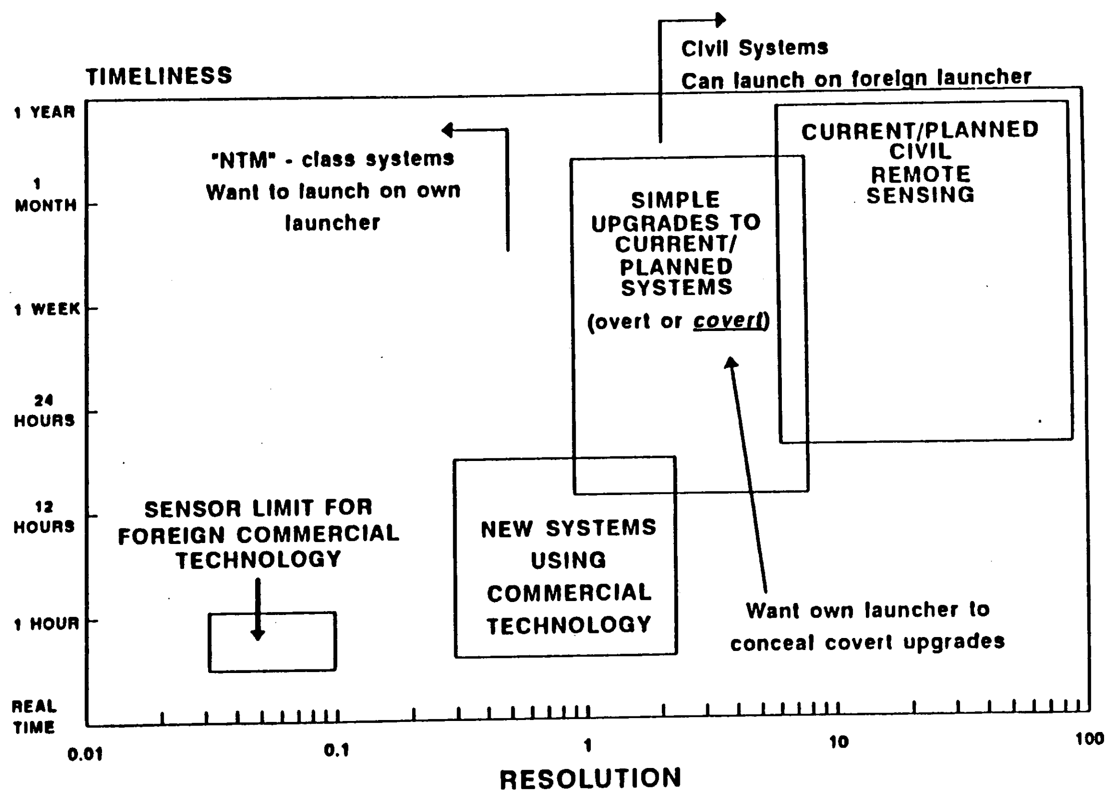
(BLANK)

AS THE MILITARY UTILITY OF SATELLITES INCREASES, SO DOES THE DESIRE TO LAUNCH AN INDIGENOUS LAUNCHER

Countries don't need to develop indigenous launchers for civil/commercial satellites; they can launch on currently available commercial launchers. Still, as will be demonstrated, civil/commercial satellites can provide significant levels of military capability.

Indigenous launch capabilities become more important when countries wish to covertly upgrade ostensibly civil/commercial satellites or add covert "piggyback" payloads. Indigenous launchers are also more important when system capabilities approach those of "National Technical Means". It avoids the prospect of revealing design features either by physical inspection or through data that must be provided to the launch provider as part of the payload integration process.

AS THE MILITARY UTILITY OF SATELLITES INCREASES, SO DOES THE DESIRE TO LAUNCH AN INDIGENOUS LAUNCHER



UNILATERAL CONTROL BY THE UNITED STATES OF KEY SYSTEMS AND COMPONENTS IS NOT A VIABLE POLICY OPTION

Starting in the Early-to-mid 70's both Europe and Japan began to develop internally, and purchase externally, the capability to build key subsystems and components for space systems. Now, that process is virtually complete; the Europeans and the Japanese are currently marketing state-of-the-art satellite componentry. Thus, any hope the U.S. might have had of imposing unilateral control over foreign space programs by limiting the export of key components is virtually gone. If such controls are to work in the future they must include the active participation of Europe and Japan in the control regime.

UNILATERAL CONTROL BY THE UNITED STATES OF KEY SYSTEMS AND COMPONENTS IS NOT A VIABLE POLICY OPTION (U)

	FRANCE	GERMANY	UNITED KINGDOM	OTHER EUROPEAN COUNTRIES	JAPAN
EO SENSORS	MATRA-1	MBB-1	ZEV-2	PHILLIPS	NEC-1 FUJITSU-2
OPTICS	REOSC-1 ANGENIEUX-2 BERTIN ET CIE MATRA SODERN	ZEISS-1 SCHOTT-1*** MAREUS-2	CRANFIELD		OHARA GLASS-1 TOKYO OPTO-ELECTRONICS-2
VISIBLE DETECTORS	THOMSON-1	VALVO-2	EEV-2	IMEC-1 CATHOLIC UNIV-1 PHILLIPS	MELCO-1 NEC-1 HITACHI-1 TOSHIBA-1 FUJITSU-1 OKI-1
IR DETECTORS	SAT-2* THOMSON-2* SOFRADIR CEA	VALVO-2* AEG 1* TELEFUNKEN	ROYAL SIGNALS-3 MULLARD-3	PHILLIPS-1 IMEC	FUJITSU-2 NEC-2 MELCO-2 TOSHIBA-2
SAR SENSORS	ALCATEL DASSAULT	DORNIER-2 DLR (AIR)	MARCONI-2	TECH. UNIV. OF DENMARK (AIR) SELENIA SPAZIO (X-SAR)	MELCO-2
ANTENNA	ALCATEL-1	DORNIER-1	MARCONI-1		MELCO-1
TWTA	THOMSON-2	AEG-2 TELEFUNKEN SIEMENS	MARCONI FERRANTI THORN		TOSHIBA-2 NEC-2
T/R MODULES	ALCATEL-2 THOMSON-2		PLESSEY/ MARCONI-2	AME SPACE-1 (CHIRP MODULATORS) (NORWAY)	FUJITSU-2 TOSHIBA-2 NEC-2 MELCO-2
ATTITUDE SENSORS	SODERN-1 SAGEM	MBB (STAR)-1	FERRANTI-1 (GYRO) SIRA-1 (STAR) MARCONI		TOSHIBA NEC MELCO
ACTUATORS	AEROSPATIALE-1	TELDIX-1	MARCONI BAe		MELCO IHI
ACS	MATRA-1 SODERN (?)	DORNIER-1 MBB-1	BAe		MELCO TOSHIBA
EPS	SAFT AEROSPATIALE	TELEFUNKEN MBB	BAe		TOSHIBA SHARP
PROCESSORS		DLR	FERRANTI (ASARS) MARCONI	MDD SPAR NORSK	FUJITSU NEC
WIDEBAND TAPE RECORDERS	ENERTEC-2				

* SWIR
** LWIR
*** SUPPLY GLASS BLANKS

PROLIFERATION OF DUAL-USE TECHNOLOGIES IS ENABLING MORE COUNTRIES TO FIELD SPACE SYSTEMS (U)

(BLANK)

ISRAEL AND KOREA HAVE THE INDUSTRIAL BASE TO BEST ABSORB THESE TECHNOLOGIES

Both Israel and Korea have in-place the high-technology industries that will allow them to efficiently absorb space technologies initially acquired from overseas sources. Israel has an existing aeronautics and defense-electronics industry with capabilities for tactical weapons and sensors. These same companies will form the core of the emerging Israeli space industry. IAI is the leading system-level house, but second-tier sources exist in such key areas as guidance and attitude control, sensors, detectors, and optics.

While Israel's defense industry provides the core for absorbing and developing space technologies, Korea's strong commercial electronics industry provides the underpinning of its drive to develop space capabilities. Japan has already demonstrated that a strong commercial electronics base can serve as the springboard for developing space systems.

Other countries with emerging space programs generally lack the level of indigenous high-technology industry of the Israelis and Koreans. Thus, they will internalize technologies at a slower pace, and will remain dependent on foreign, but not necessarily U.S., sources for a longer time interval. They are thus more susceptible to control if a multi-national regime can be developed and enforced.

ISRAEL AND KOREA HAVE THE INDUSTRIAL BASE TO BEST ABSORB THESE TECHNOLOGIES

ISRAEL	ROK	BRAZIL	PAKISTAN	INDIA
• ISRAEL SPACE AGENCY • IAI (SYSTEMS, SENSORS, ACS) • El Op (SENSORS, OPTICS, IR DETECTORS) • RAFAEL (DETECTORS) • REHOVOT (SENSORS, DETECTORS) • TADIRAN (SENSORS, DETECTORS) • ELBIT (PROCESSORS) • MTC (ACS) • TECHNION (SENSORS) • HEBREW UNIVERSITY (OPTICS)	• KOREAN AEROSPACE RESEARCH INSTITUTE • KOREA ADVANCED INSTITUTE FOR SCIENCE AND TECHNOLOGY • INSTITUTE FOR SPACE SCIENCE AND ASTRONOMY • SAMSUNG AEROSPACE (SYSTEMS, SENSORS, ACS) • SAMSUNG ELECTRONICS (SYSTEMS, SENSORS) • GOLDSTAR (SYSTEMS, SENSORS) • ORIENTAL ELECTRONICS (SENSORS, DETECTORS) • R&J ELECTRONICS (IR DETECTORS) • KUKJAE (SENSORS, DETECTORS) • BARXON ELECTRO-OPTICS (SENSORS) • HAP DONG ELECTRONICS (IR SENSORS) • JUNGPOONG PRODUCTS (IR SENSORS) • HIGH GAIN ANTENNA (EARTH TERMINALS)	• INPE • AVIBRAS • ELEBRA	• SUPARCO	• ISRO • NATIONAL REMOTE SENSING AGENCY • ELECTRONICS CORPORATION OF INDIA • BHARAT ELECTRONICS

SUBSYSTEMS AND TECHNOLOGIES FOR CIVIL AND MILITARY IMAGING SYSTEMS ARE INCREASINGLY OVERLAPPING

This Exhibit compares civil/commercial component parameters with military parameters for the same components. It is intended to answer the question, "Are there significant differences between figures of merit for the major segments of civil vs. military remote sensing systems?" The answer is that the differences are not significant. The figures of merit typical for such systems and components of civil and military imaging systems are virtually identical. The two types are distinguishable primarily by their configurations and orbits, or in some cases, by there being no overlap in componentry.

For example, civil imaging systems are not required to slew rapidly from target to target to meet military tasking requirements. They therefore would not normally make use of control moment gyros (CMGs) whereas military imagers would. Fuel loads for attitude control and orbital maneuvers would also be larger for military systems than for their civil variants, and for some military systems (Soviet RORSATs, for example) power is supplied by nuclear generators rather than solar panels.

The only military subsystem for which there is no comparable civil requirement is the wide band sensor data recorder found on some electro-optical and synthetic aperture radar imagers. We have found no Japanese supplier of such space-qualified recorders, and only one potential European source, Enertec, which has a wide band tape recorder under development. This difference would be significant were it not for the fact that both the Japanese and the Europeans are developing and will soon deploy relay satellites which will allow imagery gathered over a remote site to be transmitted in real time to a ground station instead of being recorded for later transmission.

SUBSYSTEMS AND TECHNOLOGIES FOR CIVIL AND MILITARY IMAGING SYSTEMS ARE INCREASINGLY OVERLAPPING

	COMPONENT	TYPICAL CIVIL/ COMMERCIAL PARAMETER	TYPICAL MILITARY PARAMETER
	BUS		
	ACS		
	• ACCURACY	1 - 5 SEC	1 - 5 SEC
	• MOMENTUM WHEELS	0.1 - 0.3 NM	0.1 - 0.3 NM
Indicator →	• CMG's	NA	200 - 700 NM
	• SLEWING	LIMITED	EXTENSIVE
	EPS		
	• SOLAR	< 7 KW	< 7 KW
Indicator →	• NUCLEAR	NA	> 7 KW
	AUX. PROP		
Indicator →	• LBS PROPELLANT	300 KG (SPOT 4)	9000 KG
	• ORBIT CHANGE	LIMITED	EXTENSIVE
	EO SENSOR		
	OPTICS	{ 1 - 5 M (SCIENCE, GROUND) 0.3 - 1 M (SPACE)	1 - 3 M
	DETECTORS		
	• VIS	< 10 um, SI CCD	< 10 um SI CCD
	• IR	10 um	10 um
	SAR SENSOR		
	• ANT	10 X 2 M	5 X 2 M
	• TWTA	3 - 5 KW	3 - 5 KW
	• T/R	4 - 10 W	4 - 10 W
	SENSOR SUPPORT		
Gap →	• RECORDER	50 Mbps	1 Gbps (U.S. only)
	• DATA COMP	2X	2X
	• TRANSMIT RATE	{ 1 Gbps (LOCAL) 300 - 600 Mbps (GLOBAL	{ 1 Gbps (LOCAL) 300-600 Mbps (GLOBAL)
	TASKING	3 - 8 HOURS (SPOT)	< 3 - 8 HRS

JAPANESE AND EUROPEAN CCDs DEVELOPED FOR COMMERCIAL APPLICATIONS CAN ALSO BE USED IN THE FOCAL PLANE OF SPACE-BASED SENSORS

The Hubble Space Telescope is an example of a high performance, space-based imaging system using late 1970's U.S. technology. If it were pointed at the earth it could achieve a ground sample distance (resolution) of .05 meters (about 2") from an altitude of 200 km (about 132 miles). Using the best currently available European and Japanese charge coupled devices in the focal plane of a space-based remote sensing system, our notional design shown in the right column could achieve almost the same resolution. Fabricating the optical system for this sensor would be a challenge, but within the range of capabilities of both the Japanese and Europeans. Similarly, both have, or are rapidly acquiring, the necessary capability to design, assemble, and operate such large space systems. The European Ariane V and the Japanese H-2 launchers could place the required mass and volume in orbit, and planned relay satellites would allow transmission of the imagery directly to national users. The United States could not, through technology export controls alone, prevent the development or launch of such a system.

JAPANESE AND EUROPEAN CCDs DEVELOPED FOR COMMERCIAL APPLICATIONS CAN ALSO BE USED IN THE FOCAL PLANE OF SPACE-BASED SENSORS

	HUBBLE TELESCOPE (13 MICRON PIXELS)	SYSTEM DESIGNED WITH CURRENT EUROPEAN OR JAPANESE DETECTORS
GSD (FROM 200 KM)	0.05 M	0.06 M
PRIMARY MIRROR	2.4 M F/3	2 M F/1.9
SYSTEM FOCAL LENGTH	57 M	16.67 M
S/C LENGTH	13.16 M	8 M
DRY WEIGHT	11,000 KG	6,500 KG

CIVIL SYSTEMS ARE MOVING TOWARD HIGHER RESOLUTION AND MORE TIMELY DATA DELIVERY

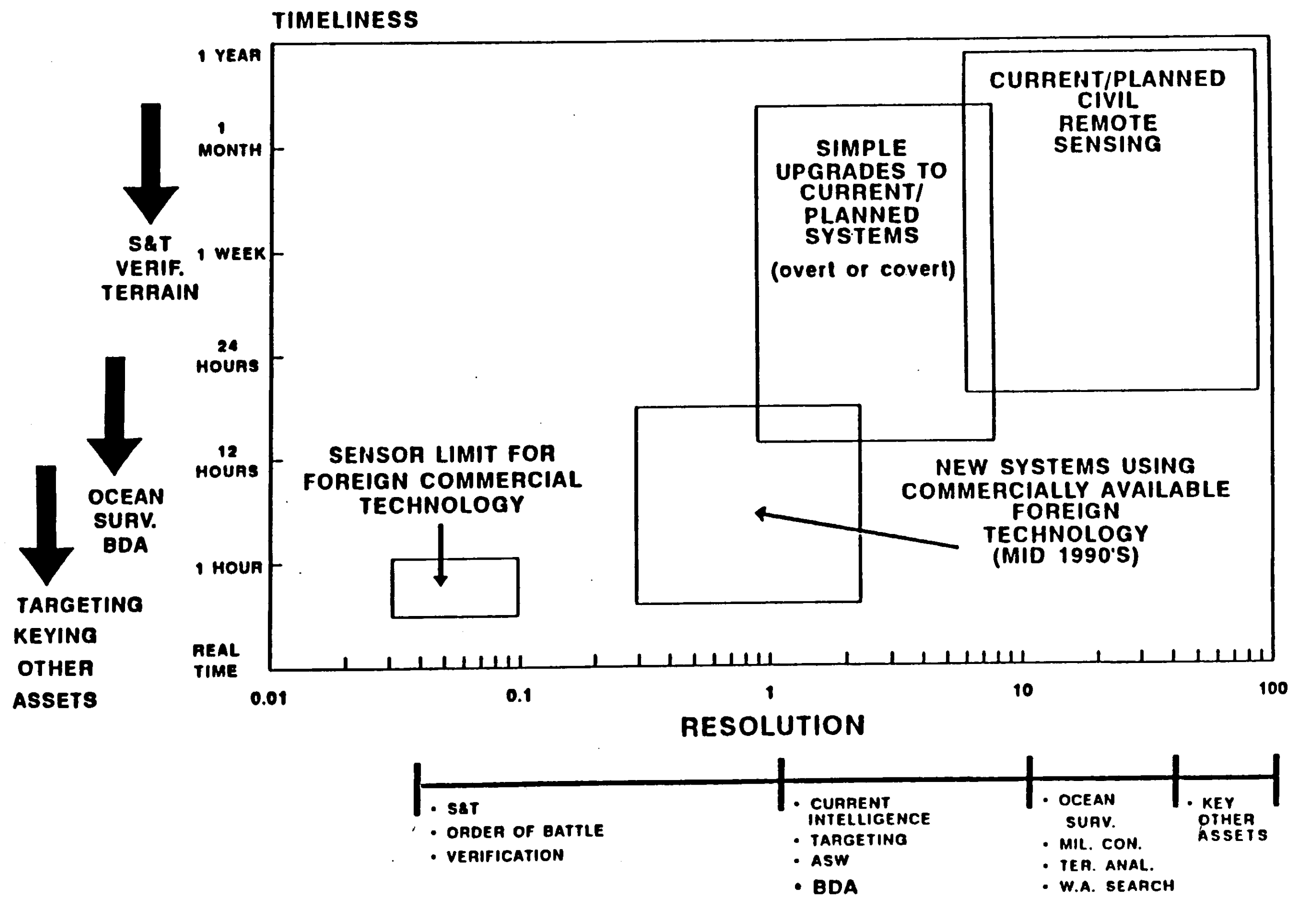
There is a natural tendency to define the national security sensitivity of a civil remote sensing system in terms of its resolution. Those characteristics of system that allow for high resolution are technically demanding. They include large optical trains, precise attitude control and stabilization of the spacecraft, and high data rate transmission from the spacecraft to the ground. These technical characteristics easily distinguish highly capable spacecraft and sensors from ones that are less capable.

But resolution is only one measure of military utility. Another equally important measure is the timeliness with which data from the spacecraft can be delivered to users. For current civil systems this delay extends from days to a week or more. It is a consequence of relatively long revisit time, relatively limited capabilities to look off to the side of the satellite's ground track, and relatively low through-put for civil image processing systems at the ground. As the operators of U.S. NTM know only too well, overcoming these limitations is expensive both in equipment cost and personnel hours.

By 1995, civil space based remote sensing systems will be operating with a combination of relatively high ground resolution and relatively rapid data delivery times. This will be due in part to an increase in satellite and sensor capabilities, and in part to expanding infrastructures, including relay satellites enabling satellites transmit data in real time to virtually any point on the earth's surface, and more capable image processing and data transmission systems.

The combination of these improvements means that the next generation of civil remote sensing satellites will be capable of performing increasingly sensitive military functions.

CIVIL SPACE SYSTEMS ARE MOVING TOWARD HIGHER RESOLUTION AND MORE TIMELY DATA DELIVERY



DEFINITION OF TERMS FROM PREVIOUS CHART

Definition of Terms from Previous Chart

Resolution less than 1 meter

- **S&T** (Science and Technology): With sufficiently high resolution, a trained image interpreter can perform analyses of military equipment otherwise limited to close-up inspection. Such so-called "S&T" analyses include measuring the dimensions of antennas, determining vehicle weight from wheel and track impressions, and estimating equipment performance from maintenance and service patterns.
- **Order of Battle**: A primary task of the military intelligence analyst is to determine the location and size of opposing forces. With sufficient detail available, an analyst can also determine the type and even the identity of those forces. The combination of all these factors, the "order of battle", reveals virtually all that a commander must know before planning an engagement.
- **Verification**: Arms agreements place severe requirements on analysis. The use of NTM to monitor such changes as the dimensions of an ICBM silo entailed achieving ground resolution on the order of inches.

Resolution from 1 to 10 meters

- **Current Intelligence**: Distinguishing between general types of aircraft on the ground, identifying tanks in a column of vehicles, and determining whether silo doors are open or closed are all examples of current intelligence functions that can be performed at resolutions of no greater than one meter (about 3 feet).
- **Targeting**: The availability of smart weapons means that a commander need not know the precise location of a target, only that it is out from cover and within the range of the assigned weapon's seeker. Civil space systems can provide this information.
- **ASW** (Anti-Submarine Warfare): A classic example of the use of remote sensing data by the Navy is to search for wakes and wave trains, surface disturbances left by periscopes or antennas, and thermal boundaries of ocean currents. This information can be derived from civil sources.
- **BDA**: While the term gained widespread usage in Operation Desert Storm, the mission has driven the development of many military surveillance and reconnaissance systems. It refers to the need to determine whether a target has been damaged and, if so, to what degree. Desert Storm saw the first use of civil space systems in this role. Most BDA can be performed at no finer than 1 meter resolution.

Resolution from 10 to 30 meters

- **Ocean Surveillance**: Locating ships at sea or large battle groups in the open ocean is a task well within the capability of current remote sensing systems.
- **Military Construction**: Roads, revetments, runways and other large-scale earth moving projects leave large areas of scarred or displaced earth. Such features are among the clearest indications of military construction activities, and are easily observed with civil remote sensing systems.
- **Terrain Analysis**: Combining spectral data with panchromatic imagery enables an analyst to locate swamps, and bogs, distinguish heavily forested areas from lightly forested areas, and locate barriers such as canyons and steep hillsides. Such information is vital for planning engagements and positioning forces.
- **Wide Area Search**: Civil systems are deliberately designed to provide "synoptic coverage" or large scene sizes. The military analogue of this feature is "wide area search".

Resolution greater than 30 meters

- **Key Other Assets**: Included in this category of activities are such things as the use of civil remote sensing data to guide other, higher-resolution systems to specific points of interest, and the use of meteorological satellite data to determine the likelihood and direction of a chemical weapon attack. The use of civil space based sensors can also be extended to cuing ground based sensors and aircraft.

(BLANK)

SOME USES OF CIVIL SPACE SYSTEMS DURING DESERT STORM

Desert Storm illustrated some of the military utility of civil space systems. Coarse-resolution imagery from European weather satellites (similar to the NOAA GOES satellite) proved useful in assessing the likelihood of chemical attacks by the Iraqis. Landsat and SPOT data, with resolution of from 10 meters to 30 meters, proved useful for such applications as generating updated maps, bomb damage assessment, and simulating approaches for pilots. Data from both systems was used to prepare for the allied attack on the Mina al Ahmadi oil complex.

SOME USES OF CIVIL SPACE SYSTEMS DURING DESERT STORM

- European Meteosat weather satellites used to assess wind patterns, evaluate likelihood of chemical attacks

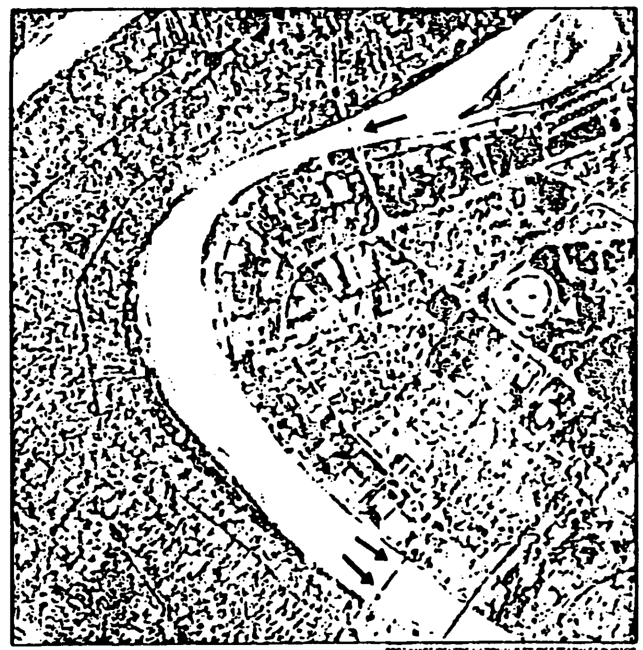
- Landsat, SPOT imagery used to support:
  - Flight-path simulations and strike planning
  - Plotting tank treks
  - Bomb damage assessment
  - Preparation of special maps (33 Landsat image maps, 46 SPOT image maps)

SPOT IMAGERY OF BAGHDAD BEFORE AND AFTER DESERT STORM AIR RAIDS ON TIGRIS RIVER BRIDGES

Civil systems can support Bomb Damage Assessment (BDA) missions. The photographs of Baghdad on the facing page were taken by the French SPOT system with 10 meter resolution. The left image, taken before Allied attacks, shows three intact bridges. The right image, taken after an Allied air raid, shows that two of the three bridges have been cut. Similar imagery is available from Landsat (U.S.), Almaz (U.S.S.R.), and IRS (India), and will soon be available from ERS (ESA), JERS (Japan), ADEOS (Japan), CBERS (China and Brazil), and Radarsat (Canada).

SPOT IMAGERY OF BAGHDAD BEFORE AND AFTER DESERT STORM AIR RAIDS ON TIGRIS RIVER BRIDGES

BEFORE: 19 FEB 91 IMAGERY FROM SPOT 2 (10 METER RESOLUTION) SHOWING THREE INTACT BRIDGES OVER THE TIGRIS RIVER IN DOWNTOWN BAGHDAD



AFTER: 10 MAR 91 IMAGERY AFTER ALLIED AIR RAIDS SHOWING THE TWO NORTHERN BRIDGES WITH DROPPED SPANS

CIVIL-TYPE IMAGERY CAN BE OF HIGH LEVERAGE WHEN TARGETS ARE HEAVILY DEFENDED

When targets are deep in heavily defended airspace, satellite-derived BDA data like that on the previous chart can drastically reduce sortie requirements and aircraft attrition. Attacking aircraft are most vulnerable when they must approach a target closely. air Force planning factors predict that a certain number of planes will be lost to defending fire in each pass over a defended site. The availability of satellite-derived BDA obviates the need for aircraft to perform this function. The accompanying chart illustrates the leverage such data provides when attacking rear-area bridges in Europe; with sorties and losses both reduced by more than 1/2. The European scenario was used because of the ready availability of standard planning factors. Similar leverage would be expected for such targets as the Yalu River bridges along the Sino-Korean border.

CIVIL-TYPE IMAGERY CAN BE OF HIGH LEVERAGE WHEN TARGETS ARE HEAVILY DEFENDED (U)

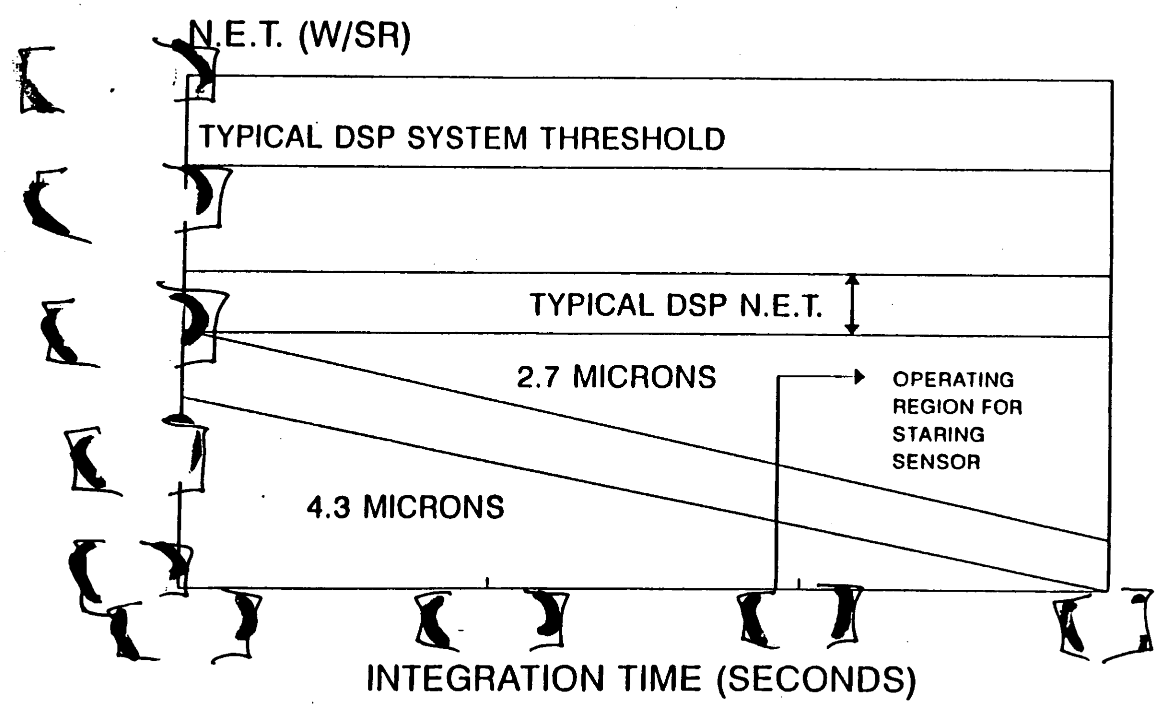
Requirements for 2 Week Campaign Against Rear-Area Bridges

	Sorties	Aircraft Lost
No Rear-Area BDA Satellite-Provided BDA	[ ]	[ ]

CIVIL SPACE TECHNOLOGIES CAN PROVIDE TACTICAL WARNING SYSTEMS AGAINST BALLISTIC MISSILES

Recent experience in Desert Storm demonstrated the utility of tactical-warning data of ballistic missile launchers. Data from the DSP system was used to cue Patriot batteries against incoming SCUDs. The accompanying chart illustrates that foreign civil space technologies can be used to build tactical warning systems with performance even better than that of DSP. Indeed, Israeli efforts to develop geosynchronous spacecraft technologies and a geosynchronous launch capability probably make more sense in the context of fielding a tactical warning system than they do for developing commercial communications satellites.

CIVIL SPACE TECHNOLOGIES CAN PROVIDE TACTICAL WARNING SYSTEMS AGAINST BALLISTIC MISSILES (U)



THERE IS ALREADY A HIGH DEGREE OF CROSSOVER BETWEEN COMMERCIAL AND MILITARY COMSATS

Many foreign civil space communication systems are being used for military purposes, or will have the capability to support military missions. In some cases civil commercial satellites are used as hosts for piggyback military systems, in other cases the systems are openly dedicated to a military role. We are not aware of any capability the U.S. has to control access to or operation of such systems in the hands of non-allies in time of war or heightened tension.

THERE IS ALREADY A HIGH DEGREE OF CROSSOVER BETWEEN COMMERCIAL AND MILITARY COMSATS

- FRANCE'S TELECOM SATELLITES ALSO HOST SYRACUSE MILSATCOM PAYLOAD
  - SUPPORT LAND, SEA, AIR FORCES WITH SECURE PHONE, DATA, TELEGRAPH, FAX
- JAPAN'S SUPERBIRD COMMERCIAL COMSATS HOST X-BAND MILSATCOM PAYLOAD
- BRITISH AEROSPACE ECS SATELLITE DEVELOPED FOR ESA ALSO USED FOR SKYNET, NATO-IV MILITARY COMSATS
- ITALY PLANS THE SICRAL MILITARY COMSAT USING TECHNOLOGIES DEVELOPED FOR ITALSAT

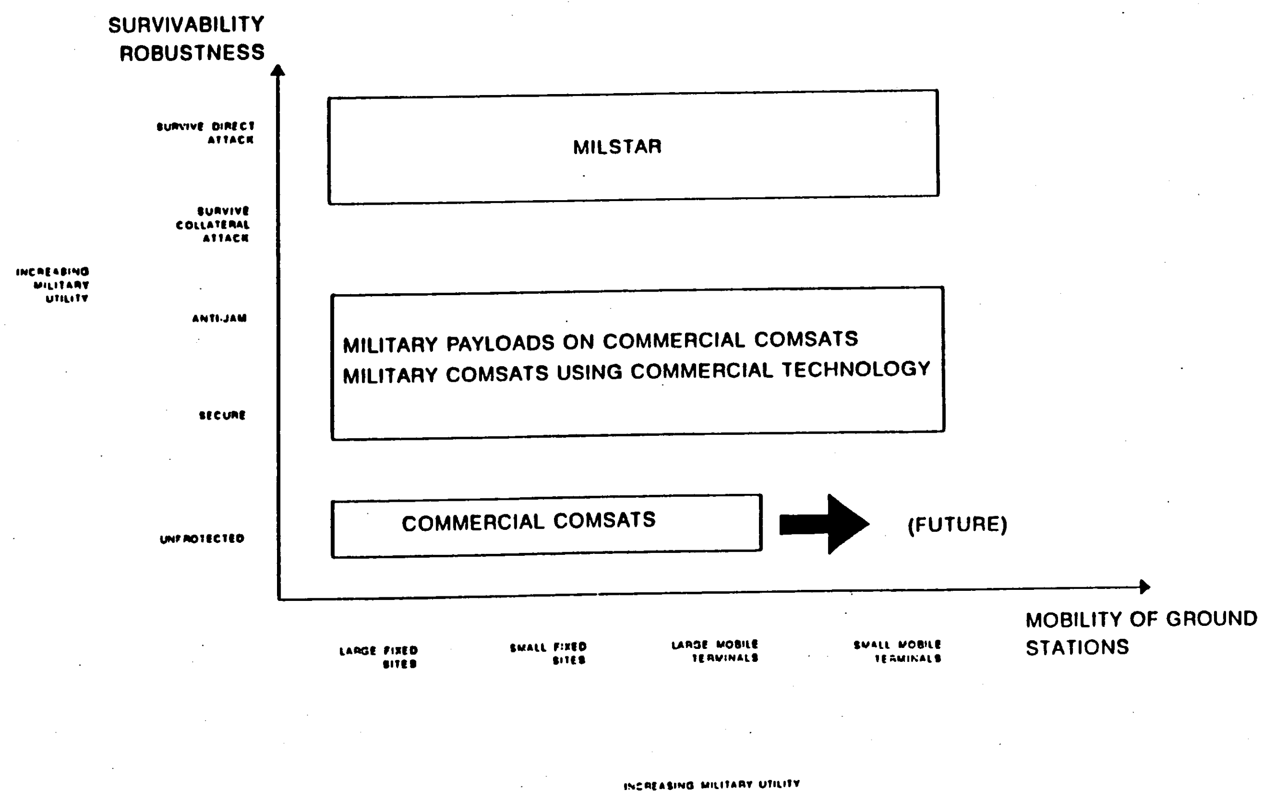
COMMERCIAL COMMUNICATIONS SATELLITES HAVE SOME INHERENT MILITARY UTILITY

Commercial satellites now provide communications with large mobile terminals, and will support small mobile terminals in the near future. While standard commercial links are not secure, users can provide security with encryption devices at the transmitting and receiving terminal. Foreign military comsats that use commercial technologies combine the support of small mobile terminals with secure links and at least partial jam resistance. These characteristics provide some degree of survivable C^3 for regional conflicts.

- Small mobile terminals are difficult to destroy
- Combination of mobility, some anti-jam capability complicates jamming ground stations
- Scenarios exist where denying mobile, jam resistent C^3 is important
- Need further assessment of U.S. jamming capabilities

No commercial satellites or military derivatives, however, are designed to provide the survivability of Milstar.

COMMERCIAL COMMUNICATIONS SATELLITES HAVE SOME INHERENT MILITARY UTILITY



COMPONENTS EXPORTED FOR COMSATS CAN ALSO BE USED ON IMAGERY SATELLITES

There is a general tendency to be more concerned about foreign capabilities for reconnaissance satellites than communications satellites. Thus export of technologies for comsats may not be subject to the same scrutiny as are technologies earmarked for imagery systems. However, a number of components exported for comsats can also be used to build imagery satellites.

The accompanying chart, for example illustrates the characteristics of momentum wheels commercially available from European sources. The German firm Teldex is exporting its DR50 momentum wheel to China for use on the DFH-3 communications satellite. That same component, however, is used by the Japanese for the attitude control of their MOS-1 imagery satellite. And more capable systems are also commercially available.

Thus, foreign communications satellite programs can serve as a vehicle for acquiring technologies that can be diverted to more worrisome reconnaissance applications. If an effective control regime is to be developed, policy makers must be aware of the potential applications of key systems and components as well as the overtly announced uses.

COMPONENTS EXPORTED FOR COMSATS CAN ALSO BE USED ON IMAGERY SATELLITES

EUROPEAN MOMENTUM WHEELS

TECHNICAL PARAMETER	AERCSPATIALE (FRANCE)			TELDIX (GERMANY)					
MODEL NUMBER	RCPM-15	RCPM-50	RCPM-150	DR50*	DR68	RDR3	DR4	RSR14	DR16
NOMINAL AVERAGE MOMENTUM (N-M-S)	15	50	150	50	68	3	3.6	14	16
CONTROL TORQUE (N-M)	0.2	0.1	0.1	0.07	0.085	0.09	0.07	0.2	0.1
MASS (KG)	8.5	10.5	13.5	7.6	7.9	3.35	3.3	6.5	5.5
DIAMETER (MM)	350	350	350	347	347	224	224	347	347
HEIGHT (MM)	150	190	190	119	119	85	85	119	119
NOMINAL POWER (W)	3	6	10	9-16	9-16	2.4-5	9-16	4.0	17
MAXIMUM POWER (W)	63	110	150	53	90	16.3	53	60	75

*USED ON MOS-1, DFH-3

COMMERCIALLY PLANNED RADIO DETERMINATION SATELLITE SYSTEMS WILL PROVIDE ACCURATE, TIMELY POSITION DATA

Several planned commercial systems will be providing services that include accurate position-location data. The European LOCSTAR system, for example, is based on technology licensed from the U.S. firm Geostar. The performance is illustrated on the accompanying chart.

As configured, a LOCSTAR-type system would be a moderate threat. An adversary who was a subscriber to the system would be able to obtain accurate position data, but at the cost of the making that same data available to the system operator. The threat increases significantly, however, if a turn-key system is re-exported to a potentially hostile nation. With direct control of the system, an adversary can provide accurate location data to military forces without involving third parties. Similar position-location data may be available from several of the commercial low-earth-orbit communications networks, such as Iridium, that are now under study.

Thus, the terms under which these technologies are exported need to be carefully considered. Even when exported to friendly nations, operating procedures regarding use of the system by adversaries in a crisis must be developed.

COMMERCIALLY PLANNED RADIO DETERMINATION SATELLITE SYSTEMS WILL PROVIDE ACCURATE, TIMELY POSITION DATA

SYSTEM	FULLY PROTECTED SERVICE	COVERAGE	POSITIONING (ACCURACY)	TIMELINESS
1.0	World Class	Global	Doppler (5 Mile Avg)	Hours
2.0	National	North America (Including Caribbean)	Loran C (<1 Mile)	Minutes
3.0	Dedicated	North America and Europe	Satellite Ranging (5-10 Meters)	Seconds
4.0	Global	Worldwide by Regional System Interconnection	Satellite Ranging (5-10 Meters)	

CIVIL SPACE PROGRAMS ARE PROVIDING FOREIGNERS WITH EXPERIENCE IN GROUND SEGMENT ARCHITECTURES FOR SYSTEM MANAGEMENT AND DATA EXPLOITATION (U)

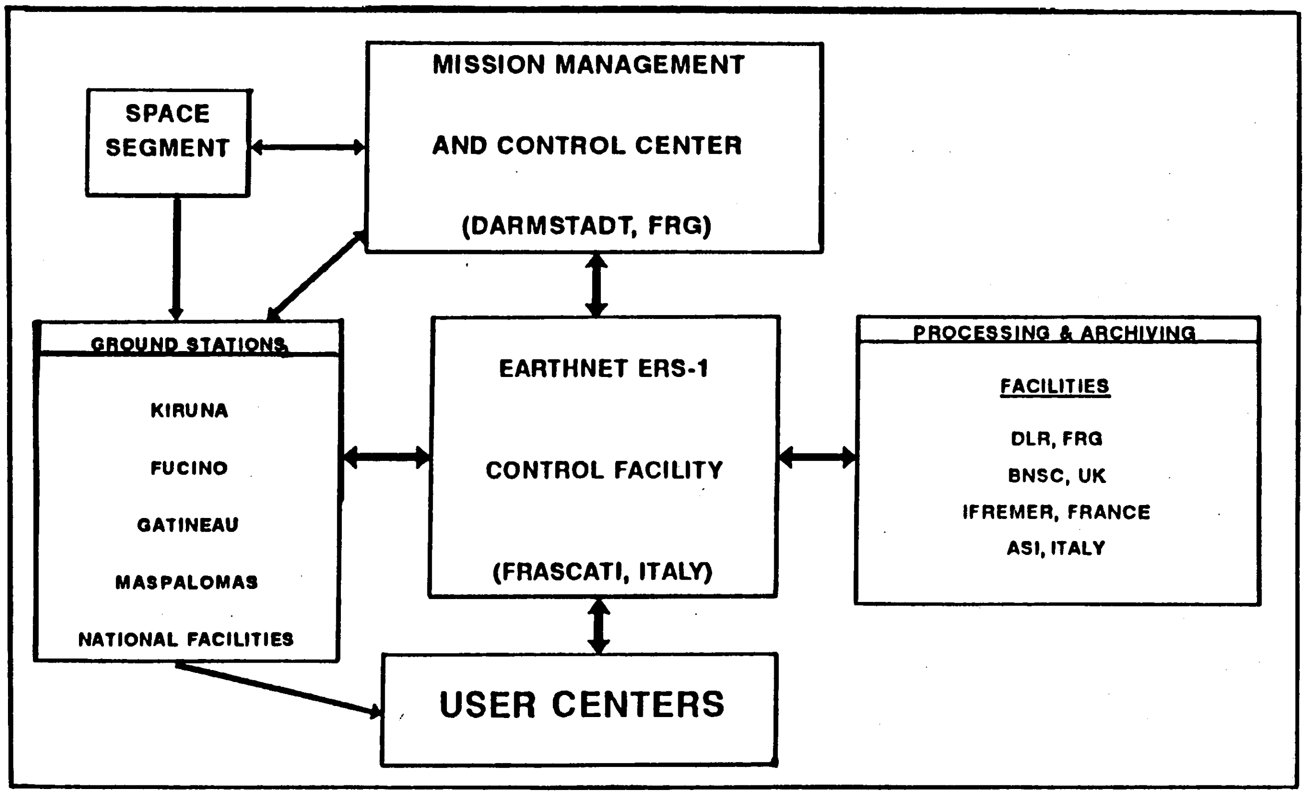
(U) Civil space programs also provide a mechanism for training personnel in the control, management, and exploitation of space systems. The accompanying chart, for example, illustrates the ground segment that the Europeans have put in place for their ERS-1 radar-imagery satellite. The General structure of the earth segment and the flow of tasking requests, control data, and mission data is similar to what would be anticipated for the control of a military reconnaissance system.

(S) In a similar vein, countries are using civil remote sensing systems to train military/intelligence imagery analysts.

[ ]

CIVIL SPACE PROGRAMS ARE PROVIDING FOREIGNERS WITH EXPERIENCE IN GROUND SEGMENT ARCHITECTURES FOR SYSTEM MANAGEMENT AND DATA EXPLOITATION

SAMPLE OF EUROPEAN GROUND SEGMENT: ERS-1



SOUNDING ROCKETS AND "COMMERCIAL" LAUNCH VEHICLES ALSO PROVIDE IRBM AND ICBM CAPABILITIES

Brazil's space launch vehicle development program is being undertaken ostensibly to develop the country's technology base, to create an indigenous capability for space operations, and to support an ambitious program of resource exploitation. At the same time, Brazil has unresolved border disputes with each of its South American neighbors and a regionally powerful military force with ambitious development plans. The launchers being developed for the country's space program respond to both sets of requirements.

This Exhibit shows the result of some simple calculations connecting space launch vehicle payload figures to throw weight and range figures. The figures show what Brazil's neighbors probably know only to well; that Brazil's civil space launch vehicle development program carries obvious military significance.

(BLANK)

FINDINGS TO DATE (U)

- EUROPEANS, JAPANESE CAN BUILD HIGH PERFORMANCE MILITARY SATELLITE SYSTEMS WITHOUT ACCESS TO U.S. TECHNOLOGY USING INDIGENOUS COMMERCIALLY AVAILABLE COMPONENTS
- CIVIL/COMMERCIAL/SCIENTIFIC SPACE PROGRAMS SERVE AS A VEHICLE FOR FOREIGN ACQUISITION F SPACE TECHNOLOGY AND TRAINING OF SYSTEM OPERATORS AND USERS
- EUROPEAN, JAPANESE, SOVIET AND CHINESE WILLINGNESS TO EXPORT SPACE TECHNOLOGIES IS HELPING THE EMERGENCE OF THIRD-WORLD SPACE POWER. SECONDARY TRANSFER FROM THESE RECIPIENTS COMPOUNDS THE PROBLEM
- TECHNOLOGIES ACQUIRED OR DEVELOPED FOR SPACE PROGRAMS PROVIDE CAPABILITIES FOR ADVANCED BALLISTIC AND GUIDED WEAPON-DELIVERY SYSTEMS
- WITH QUALIFIED, NON-U.S. SOURCES FOR MOST TECHNOLOGIES THE ONLY PROSPECT FOR CONTROL OF PROLIFERATION IS A MULTILTERAL REGIME

(BLANK)

C^3I Upgrades for Developing Nations' Missile Operations (U)

(BLANK)

SE[redacted]CAN/AUS

C3I UPGRADES FOR DEVELOPING NATIONS' MISSILE OPERATIONS (U)

July 1993

WARNING NOTICE: INTELLIGENCE SOURCES OR METHODS INVOLVED

Classified by:	DD Form 254, 1 Oct. 88
	MDA 903 89 C 0003
	OUSD(A) FFRDC Programs
Declassify on:	OADR
Derived from:	Multiple Sources

IDA
Institute for Defense Analyses
1801 N. Beauregard Street
Alexandria, VA 22311

SE[redacted]T

(BLANK)

II-94

WHY DO WE NEED TO FOCUS ON C3I UPGRADES FOR DEVELOPING NATIONS' MISSILE OPERATIONS? (U)

(U) C3I upgrades will enable developing nations to

- (U) Locate and attack high-value targets that are time sensitive;
- (U) Execute mass attacks that can defeat active missile defenses;
- (U) Take advantage of accuracy improvements to substantially increase the effectiveness of accurate missile attacks.

(U) The synergistic combination of accuracy improvements and C3I upgrades will enable developing nations to execute missile attacks ten times more effective than those of Iraq in the Gulf War.

(U) C3I upgrades are underway and the technology is widely available commercially.

(U) The threat that these upgrades pose to U.S. interests will depend upon our response.

WHAT QUESTIONS WILL THIS BRIEFING ANSWER? (U)

(U) What factors affect the level of C3I needed for missile operations?

(U) What level of C3I did Iraq need for its Gulf War missile operations?

(U) What are the elements of a C3I system for missile operations?

(U) What are the operational military implications of the C3I upgrades that developing nations' are now acquiring?

What factors affect the level of C3I needed for missile operations? (U)

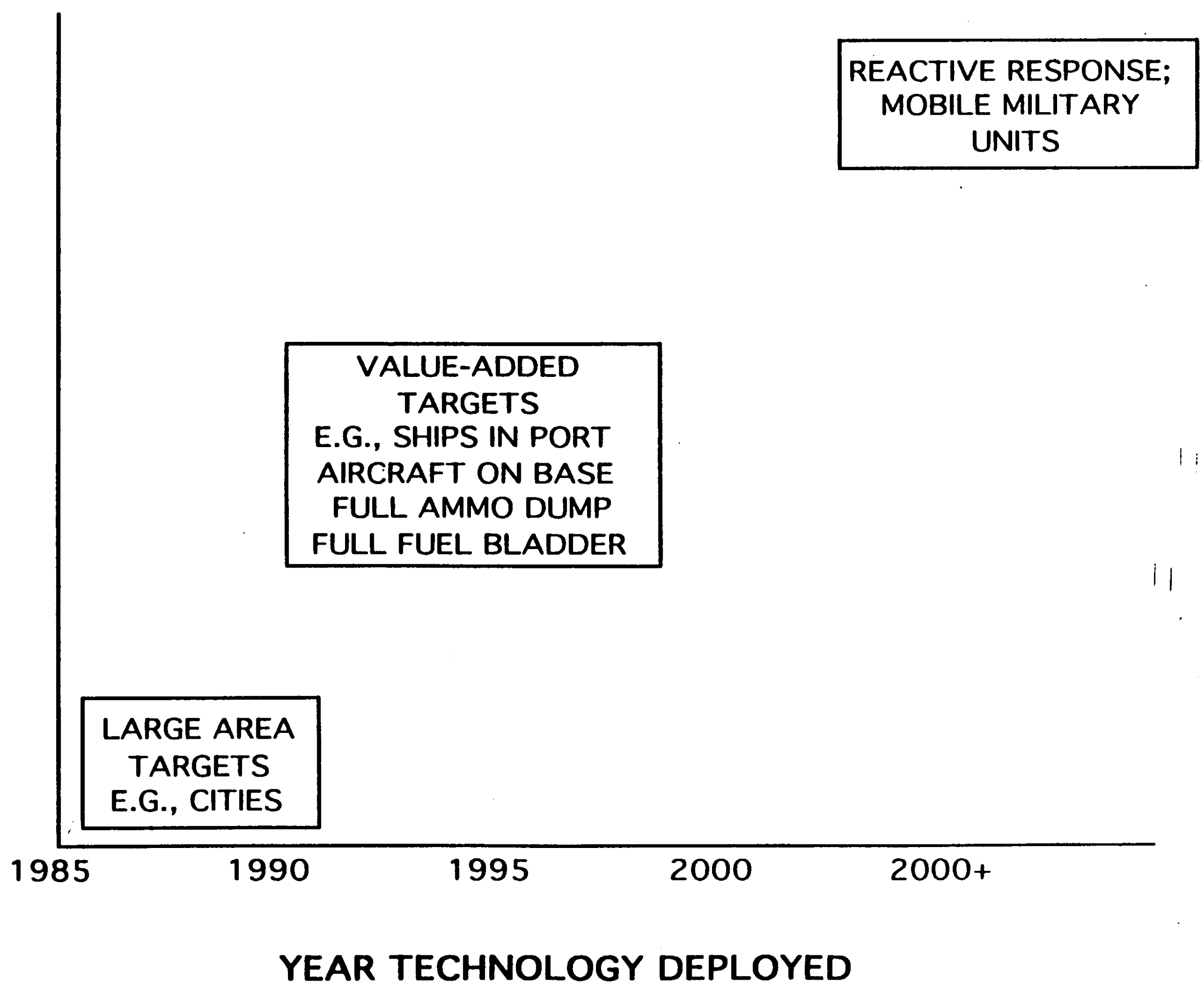
DEVELOPING NATIONS CAN EXECUTE NEW MISSILE OPERATIONS WITH C3I UPGRADES (U)

TARGET CHARACTERISTICS DRIVING C3I REQUIREMENTS

<u>Level III</u>
Very time sensitive mobile targets requiring immediate strikes (in minutes to hours)

<u>Level II</u>
Time sensitive fixed targets allowing strike planning (in hours to days)

<u>Level I</u>
Time insensitive fixed targets allowing strike planning (in days to months)



THE CHARACTERISTICS OF THE TARGET DETERMINE THE LEVEL OF C3I NEEDED FOR MISSILE OPERATIONS (U)

Level	Target Characteristics	Mission Requirements	Example
I	Time insensitive fixed targets allowing strike planning (in days to months)	Missile launch time can be set in advance. Target will not change location.	City, power stations, bridges, C3I nodes, supply depots
II	Time sensitive fixed targets allowing strike planning (in hours to days)	Presence of value-added targets decides missile launch times in fixed location. Target location known in advance.	Ships in port Aircraft at base Full ammo dump Full fuel bladder
III	Very time sensitive mobile targets requiring immediate strikes (in minutes to hours)	Missile launch time dependent upon identification of mobile targets. Target can change location.	Mobile military units: Tank column Air defense or artillery units

What level of C3I did Iraq need for its Gulf War missile operations? (U)

C3I WAS A SIGNIFICANT LIMITATION ON IRAQI MISSILE OPERATIONS (U)

(U) The execution and impact of missile operations were limited by

- (U) Lack of intelligence: The Iraqis were blind to the location and movement of coalition forces

C3I WAS ONE OF MANY LIMITATIONS ON IRAQI MISSILE OPERATIONS (U)

(U) Non-C3I factors also severely limited Iraqi missile operations

- (U) Inflexible launch range: Targets and launch sites were selected to accommodate maximum-range launches.
- (U) Liquid propellant: Use of a liquid propellant requires a high degree of maintenance.
- (U) In-flight breakup: Many Iraqi missiles broke-up in flight.
- (U) Inaccuracy: The 1000 m CEP of conventionally armed SCUDs precluded their being a significant threat to tactical targets.

HOW DID IRAQI C3I LIMIT MISSILE OPERATIONS? (U)

(U) There is no evidence Iraq had an intelligence gathering system for the identification of missile targets.

(U) The Iraqis did not execute mass attacks.

(U) C3I and other limitations prevented the execution of more sophisticated missile operations.

- (U) Value-added targets: e.g., ships in port

IRAQ ACCOMPLISHED SOME OF ITS OBJECTIVES DESPITE C3I LIMITATIONS (U)

(U) Iraqi missile operations

- (U) Penetrated U.S. defenses;
- (U) Hit Saudi and Israeli cities;
- (U) Killed U.S. military personnel; and
- (U) Threatened cohesion of coalition by seeking to provoke Israeli entry into war.

WHAT ARE THE C3I LESSONS FOR DEVELOPING NATIONS FROM IRAQI MISSILE OPERATIONS? (U)

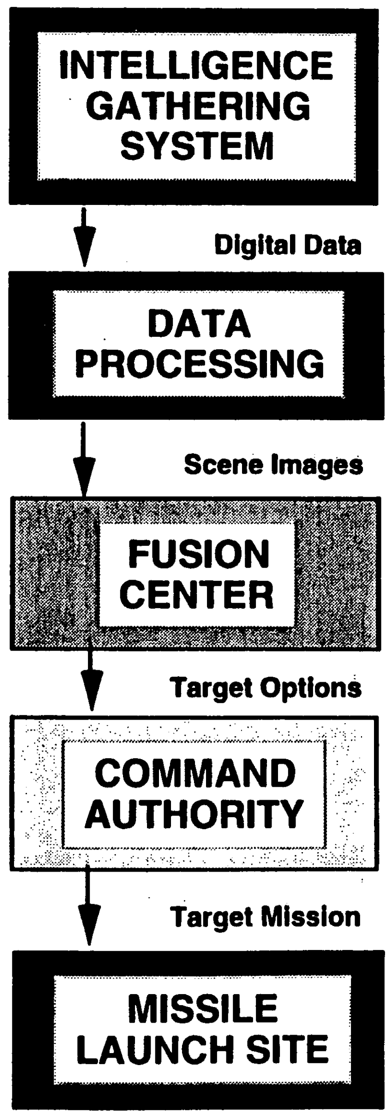
(U) Only very basic C3I is required for simple missile operations like those of Iraq.

(U) More difficult missile operations, such as mass attacks, will require higher levels of C3I than the Iraqis used.

(U) Further C3I upgrades will enable execution of new missile operations made possible by more accurate missiles.

What are the elements of a C3I system for missile operations? (U)

WHAT ARE THE ELEMENTS OF A C3I SYSTEM FOR DEVELOPING NATIONS' MISSILE OPERATIONS? (U)



Provides data from reconnaissance means

Forms imagery

Interprets imagery and integrates information from all sources

Makes target decisions

Executes mission

SATELLITE IMAGERY REPRESENTS AN EXTRAORDINARY CAPABILITY FOR DEVELOPING NATIONS' MISSILE OPERATIONS (U)

INTELLIGENCE GATHERING SYSTEM

Imaging Satellite

(U) 2-30 m resolution imagery is now commercially available.

(U) Imagery in <u>digital</u> form can be acquired in peacetime to create computer databases for

- (U) Target identification
- (U) Change detection

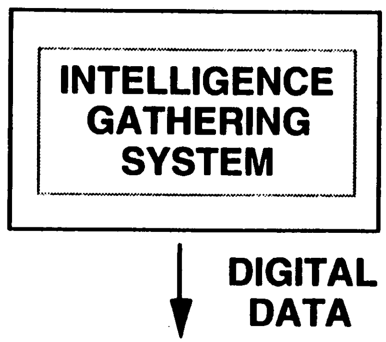
(U) Enemy use of satellites and satellite services in wartime is vulnerable to countermeasures: turnoff, jamming or attack.

(U) Real-time use of such imagery would be made difficult.

OTHER RECONNAISSANCE MEANS CAN ALSO BE USED FOR AN INTELLIGENCE GATHERING SYSTEM (U)

INTELLIGENCE GATHERING SYSTEM	
Aircraft	(U) Aircraft are readily available for reconnaissance missions in peacetime, but survivability becomes a major concern against superior air power and air defenses.
RPV	(U) RPVs are difficult to find and shoot down. Vehicles and sensors are commercially available; cost is low. RPVs also have great flexibility and short revisit intervals. Range and payload are limiting factors.
HUMINT	(U) Agents are difficult to detect. They can identify high-value targets and communicate information quickly. Agents have a limited area of effectiveness.

SOPHISTICATED MISSILE OPERATIONS WILL REQUIRE DIGITAL DATA COMMUNICATION (U)



(U) Digital communication is necessary to transmit large amounts of data (millions of bits [Mbits] of data per image).

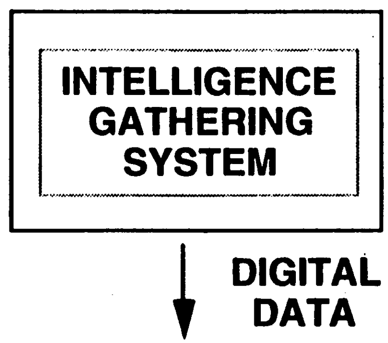
(U) Digital data can be downlinked from airborne reconnaissance means at a rate of 85 Mbits/sec (commercially available phone line: 19,200 bits/sec).

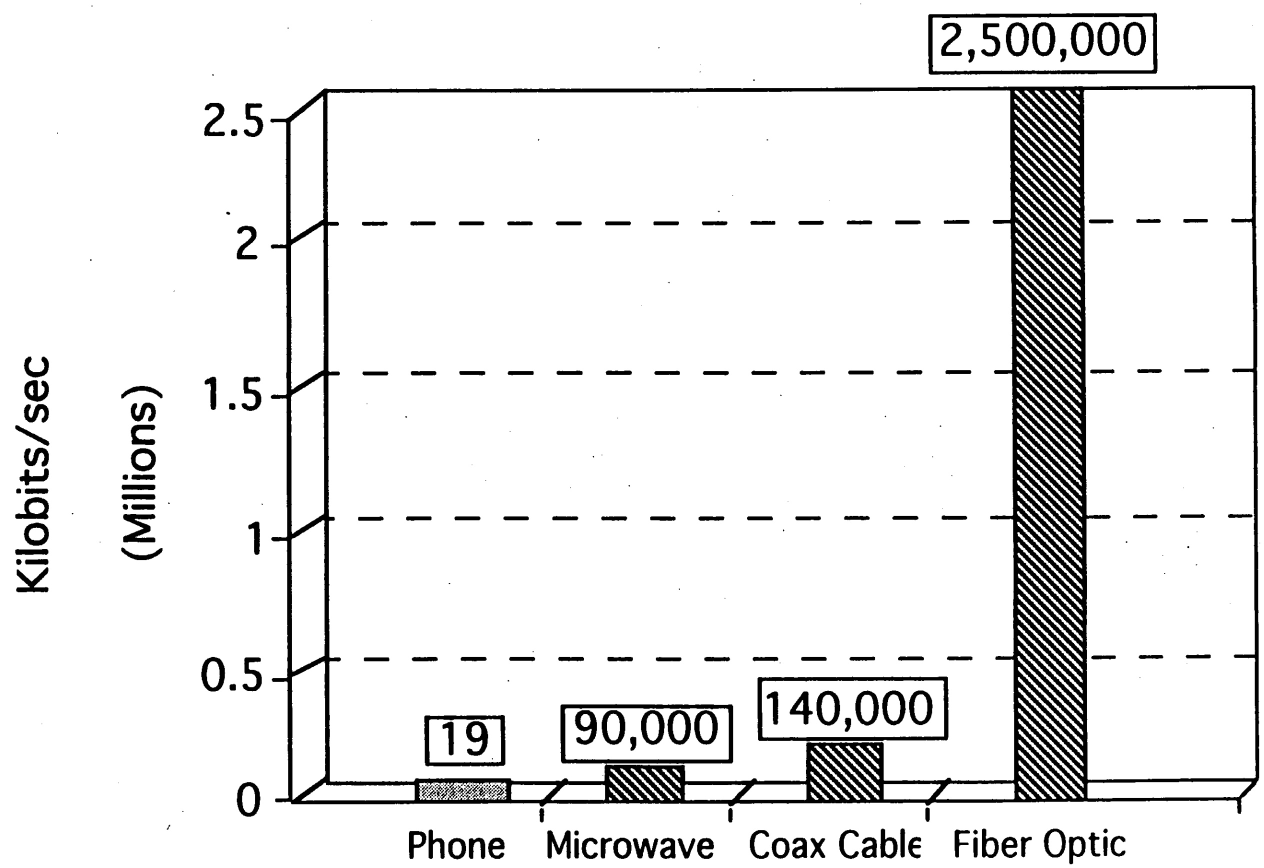
(U) Digital satellite, aircraft or RPV data can be downlinked in seconds to minutes.

(U) Digital data communication has the additional benefits of lower error-rates and improved security compared to analogue data communication.

UNCLASSIFIED

DIGITAL COMMUNICATION ALLOWS LARGE AMOUNTS OF DATA TO BE TRANSMITTED QUICKLY (U)

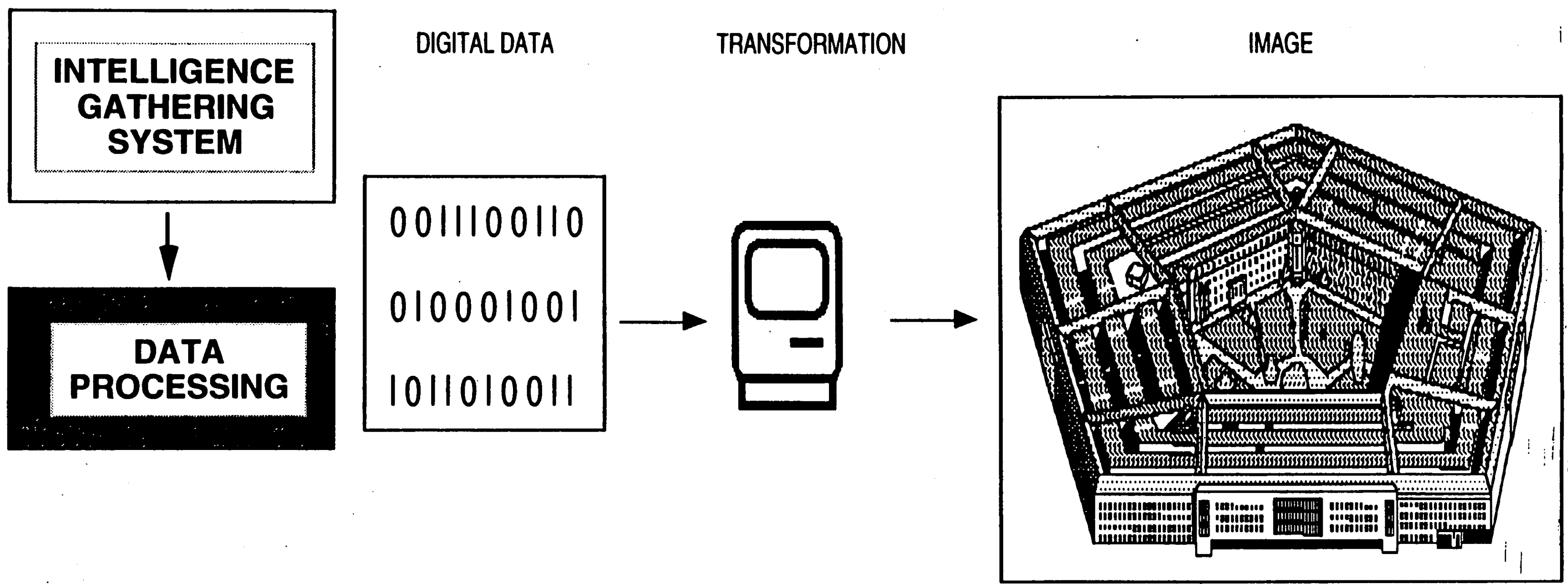




Capacity to transmit information

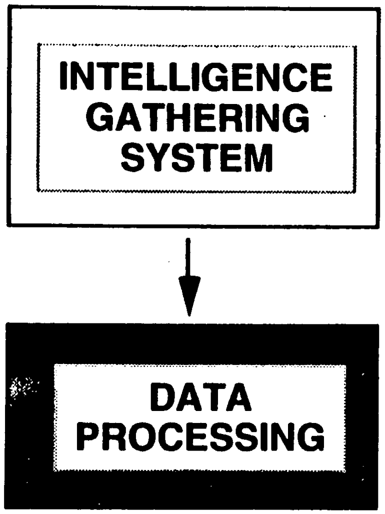
UNCLASSIFIED

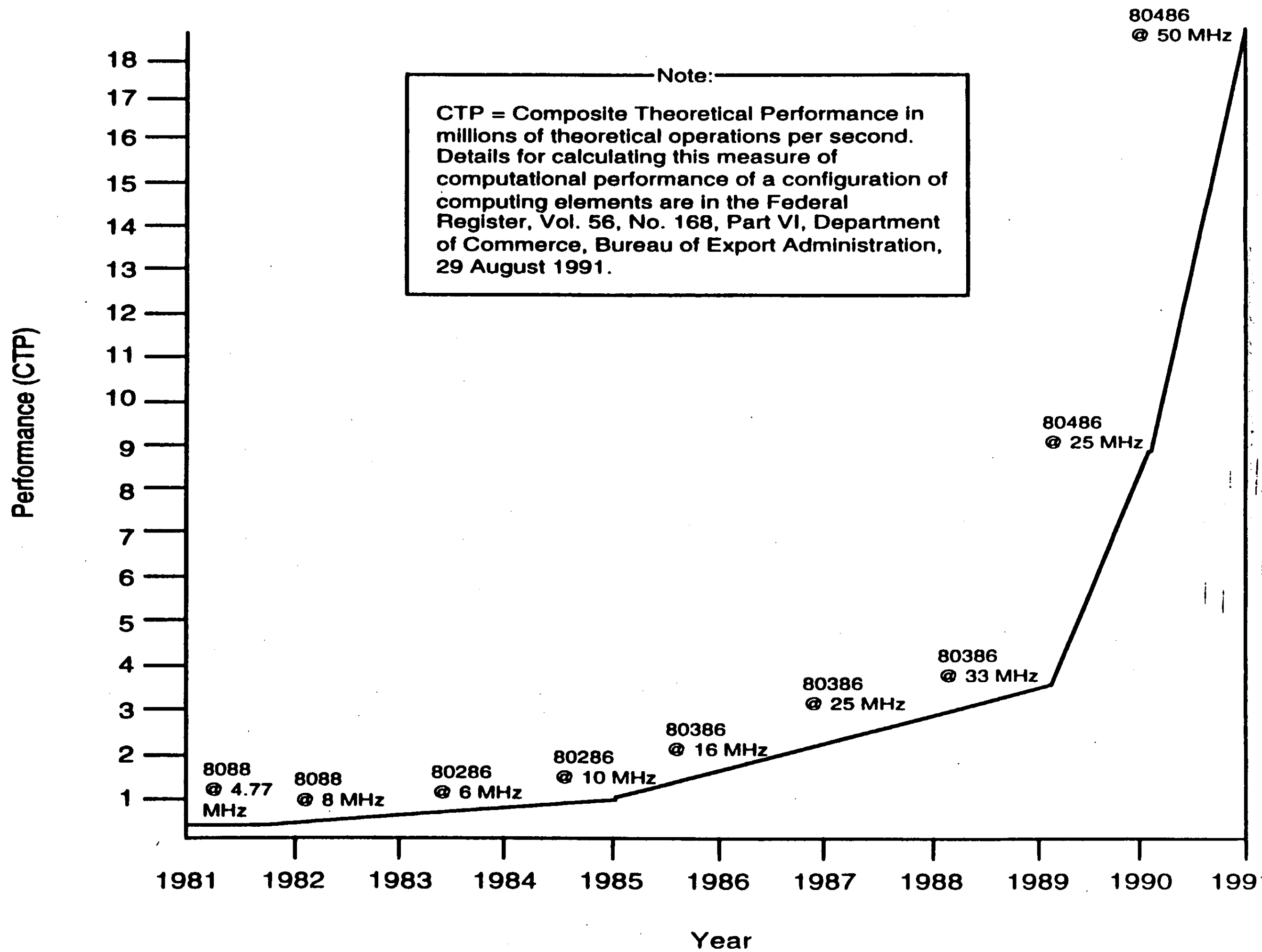
COMPUTER DATA PROCESSING TRANSFORMS DIGITAL DATA INTO IMAGERY (U)



(U) Processing of satellite, aircraft, or RPV data can take from a half hour to several hours.

COMPUTER DATA PROCESSING HAS BECOME QUICKER AND MORE POWERFUL OVER TIME (U)



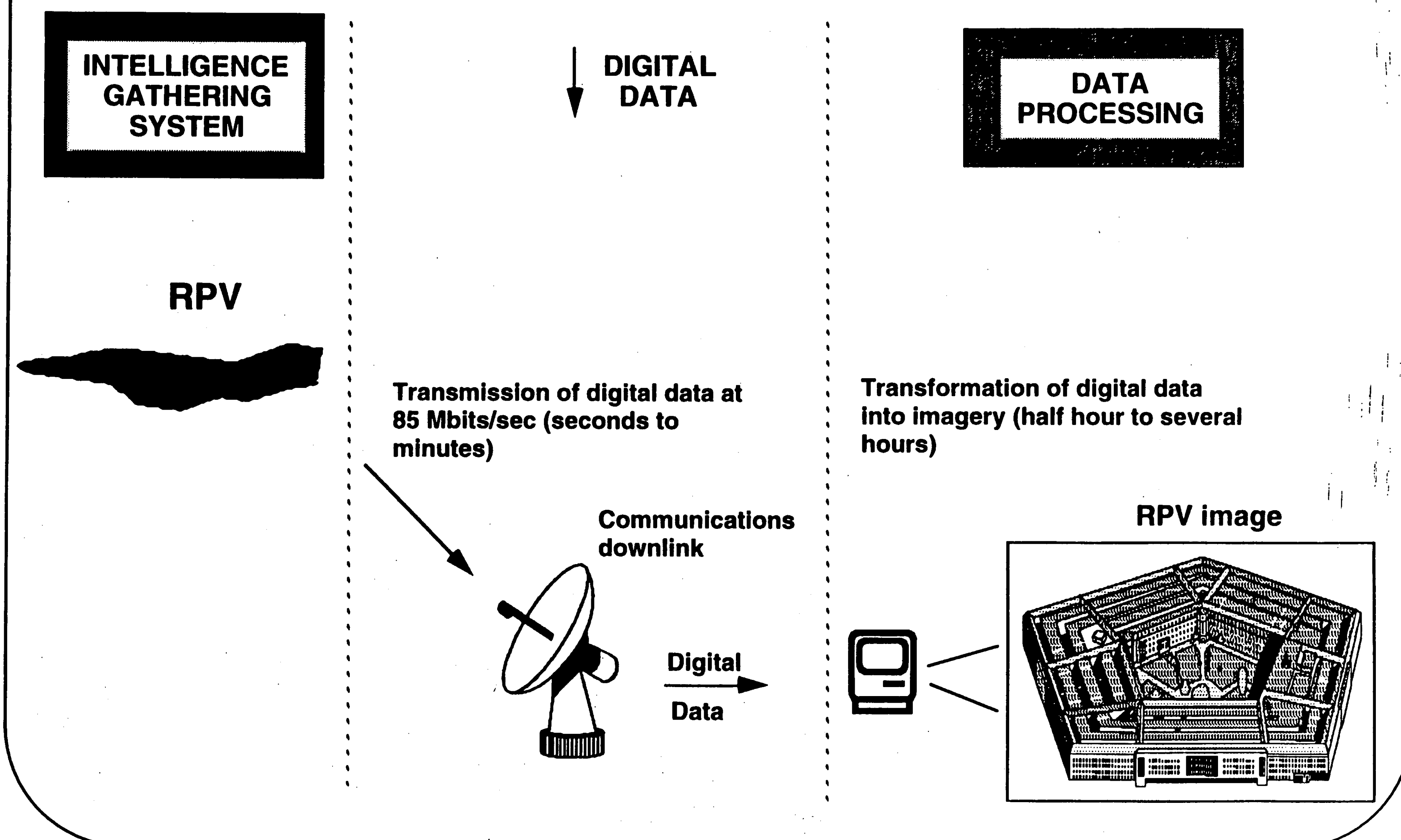


Note:

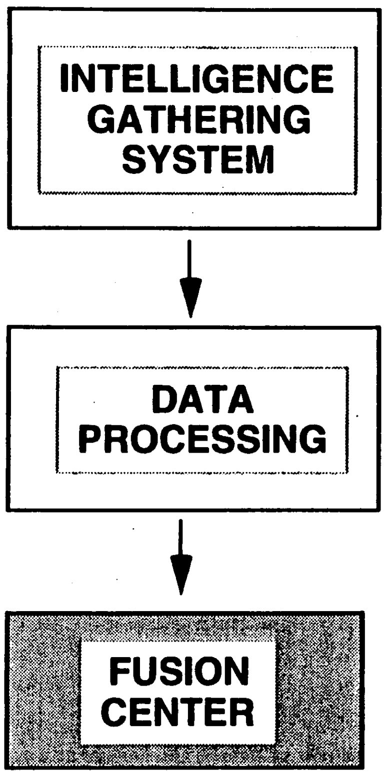
CTP = Composite Theoretical Performance in millions of theoretical operations per second. Details for calculating this measure of computational performance of a configuration of computing elements are in the Federal Register, Vol. 56, No. 168, Part VI, Department of Commerce, Bureau of Export Administration, 29 August 1991.

Computational Performance Growth

HOW DOES A C3I SYSTEM FORM IMAGERY FOR MISSILE OPERATIONS? (U)



THE FUSION CENTER INTERPRETS IMAGERY AND INTEGRATES INFORMATION FOR MISSILE OPERATIONS (U)



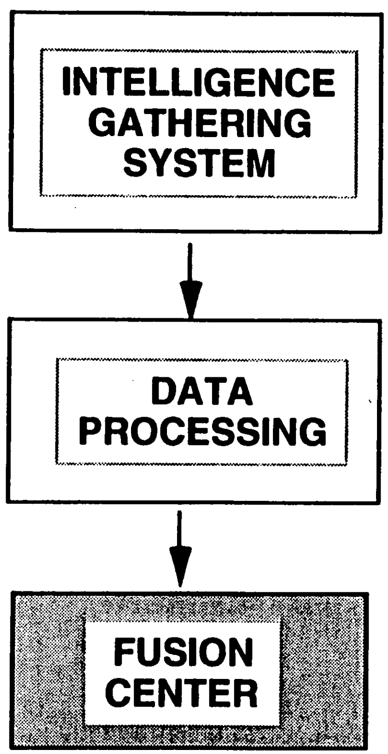
(U) Human and computer analysis of imagery is performed at the fusion center.

(U) Imagery analysis is the most time-consuming task performed at the fusion center.

(U) The fusion center also integrates information from other sources for missile operations.

- (U) Computer databases
- (U) Status reporting

ANALYSES PERFORMED AT THE FUSION CENTER CAN IDENTIFY HIGH-VALUE TARGETS (U)



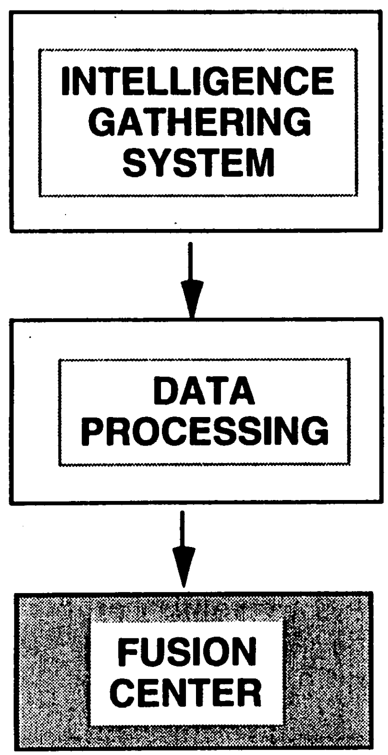
(U) Example:

(U) U.S. and coalition forces must establish numerous bulk fuel sites and ammunition sites in the field to support military operations.

(U) RPV imagery analyzed at the fusion center could be used to identify bulk fuel sites and ammunition sites.

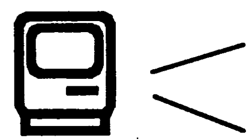
(U) Missile attacks against these critical targets could seriously disrupt U.S. and coalition military operations.

ANALYSES PERFORMED AT THE FUSION CENTER CAN IDENTIFY HIGH-VALUE TARGETS (cont'd) (U)



(U) Objective: Identify targets from RPV imagery (e.g., bulk fuel sites and ammunition sites).

RPV Imagery Scene



400 km^2 area
(1/7400 of Saudi Arabia)

(U) 1 scene = 4×10^4 frames

(U) 1 frame takes 10 sec to analyze (manually)

(U) Total analysis time ≅ 112 hrs.

(U) Note: Analysis time can be reduced in two ways

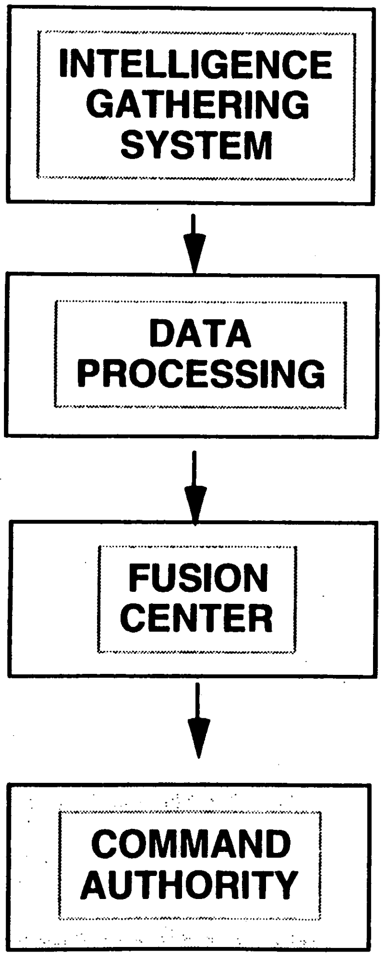
- (U) Multiple interpreters
- (U) Computer-aided analysis

THE FUSION CENTER INTEGRATES INFORMATION FROM COMPUTER DATABASES AND ON-LINE COMMUNICATIONS (U)

- (U) Target file
- (U) Targets of opportunity
- (U) Missiles and launchers
- (U) Natural factors
- (U) Threat data

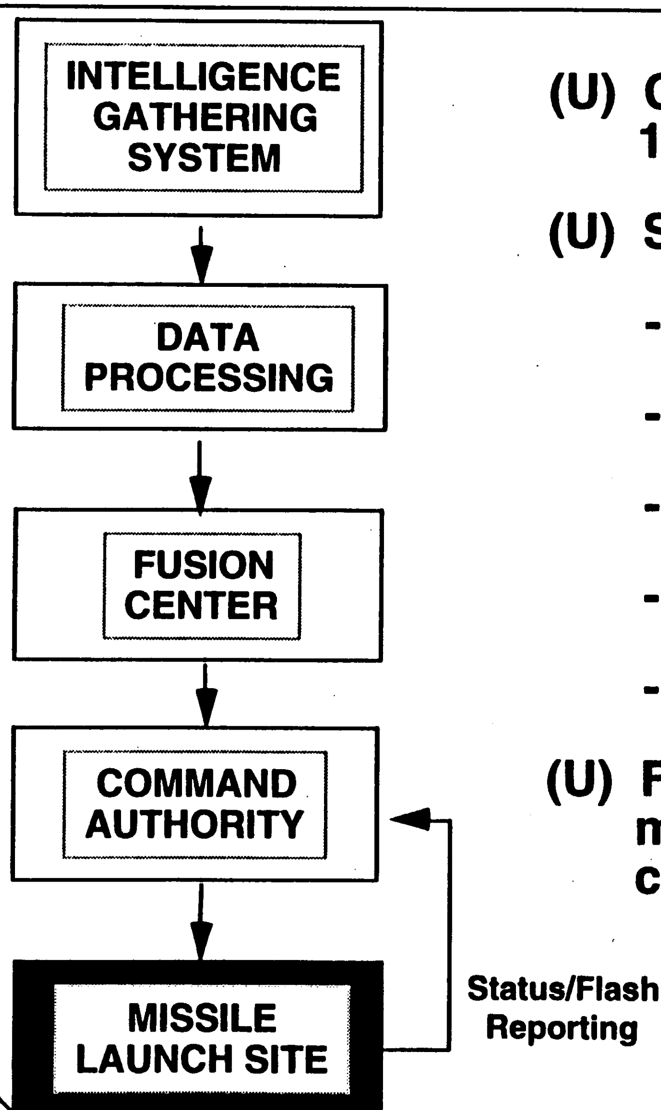
(U) Computers (2nd and 3rd generation [mid-to-late 1980s] PCs) allow for timely and accurate storage, retrieval and manipulation of this information.

THE COMMAND AUTHORITY MAKES DECISIONS ABOUT THE EXECUTION OF A MISSILE ATTACK (U)



- (U) Command authority decisions:
  - (U) Target location
  - (U) Warhead selection
  - (U) Launcher positioning
  - (U) Launch time (or time on target)
  - (U) Maintenance and repair logistics
  - (U) Personnel support
- (U) These decisions are communicated as short and infrequent messages.
- (U) The speed with which these decisions are communicated can determine the kind of missile attack that can be executed.

MISSILE UNITS EXECUTE MISSIONS AND PROVIDE STATUS INFORMATION TO THE COMMAND AUTHORITY (U)



(U) Current SCUD missiles can be launched in 15-30 minutes upon command.

(U) Status reporting is required (usually daily)

- (U) Launcher status
- (U) Missile status
- (U) Location & local conditions
- (U) Personnel status
- (U) Parts & supply needs

(U) Flash (or emergency) reporting allows missile unit to communicate quickly with the command authority.

WHAT ARE THE PERFORMANCE MEASURES OF A C3 SYSTEM FOR DEVELOPING NATIONS' MISSILE OPERATIONS? (U)

(U) Performance measures have been developed to measure the short, infrequent messages of a C3 system.

(U) C3 EVAL, a computer program that models real world C3 operations, measures several aspects of C3 system effectiveness.

- (U) Capacity: Volume of message traffic
- (U) Reliability: Absence of incorrect or lost messages
- (U) Security: Resistance to intrusion
- (U) Survivability: Robustness to attack and disruption
- (U) Time Delays: Results in commander's perceptions being different from ground truth at subordinate units

WHAT ARE THE PERFORMANCE MEASURES OF A C3 SYSTEM FOR DEVELOPING NATIONS' MISSILE OPERATIONS? (cont'd) (U)

(U) With the exception of time delays, the attributes of developing nations' C3 systems are sufficient for all levels of missile operations.

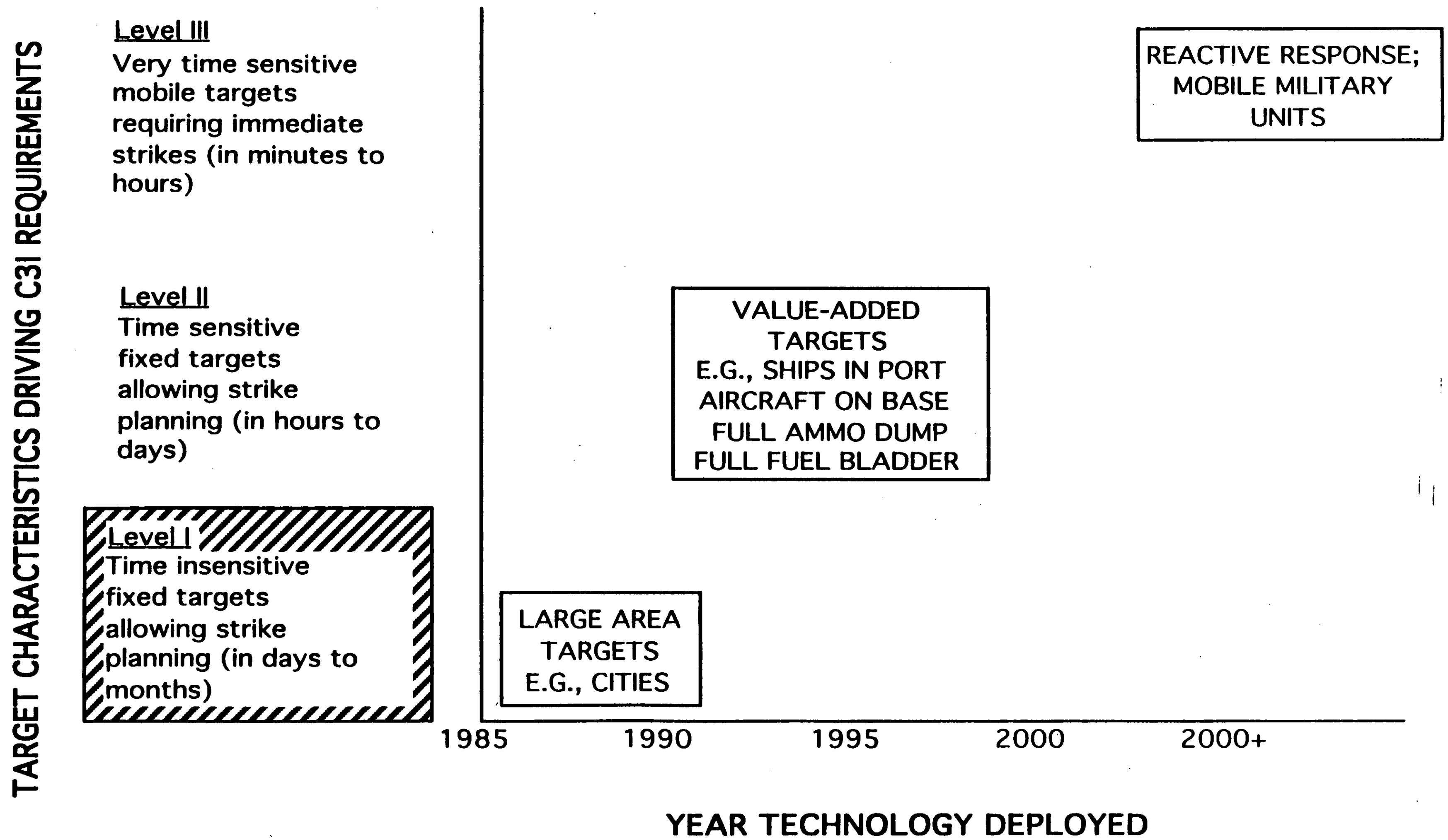
(U) The time delays imposed by using a courier can prevent the execution of time-sensitive (levels 2 and 3) missile operations.

(U) Use of a courier can also limit the effectiveness of time-insensitive (level 1) missile operations.

Communication Means	Attribute: Time Delays	Missile Operations (Levels)
COURIER	1 - 2 hours	1
PHONE LINE	seconds	1 - 3
COAX CABLE	seconds	1 - 3
DIGITAL MICROWAVE	seconds	1 - 3
FIBER OPTIC	seconds	1 - 3

What are the operational military implications of the C3I upgrades that developing nations are now acquiring?

DEVELOPING NATIONS CAN EXECUTE LEVEL I MISSILE OPERATIONS WITH EXISTING C3I (U)



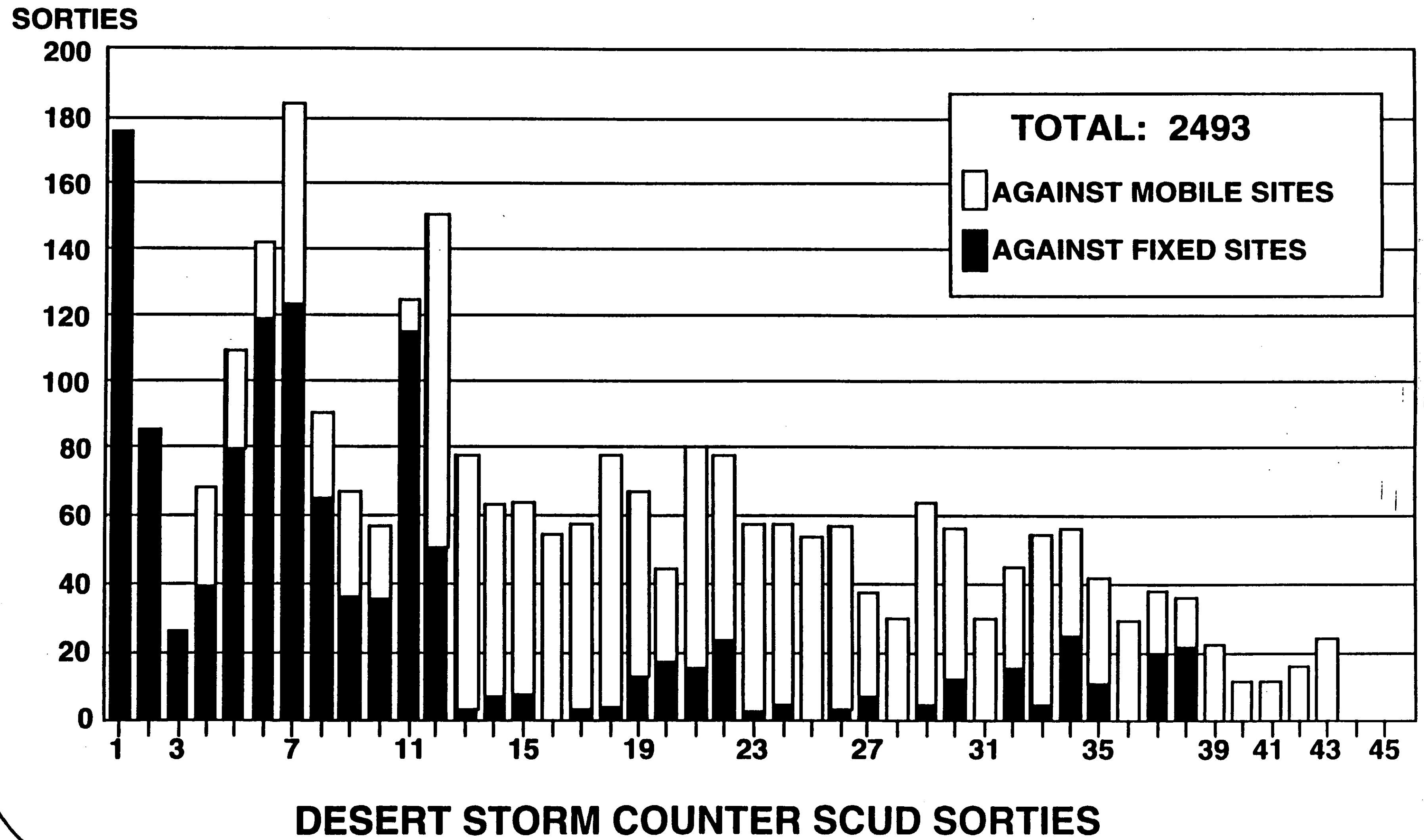
WHAT ARE THE TARGET CHARACTERISTICS AND MISSION REQUIREMENTS FOR LEVEL 1 MISSILE OPERATIONS? (U)

Level	Target Characteristics	Mission Requirements	Example
I	Time insensitive fixed targets allowing strike planning (in days to months)	Missile launch time can be set in advance. Target will not change location.	City, power stations, bridges, C3I nodes, supply depots, etc.

HISTORICALLY LEVEL I MISSILE OPERATIONS HAVE HAD SIGNIFICANT POLITICAL/MILITARY IMPLICATIONS (U)

WAR	WEAPON	TARGET	RESULT
WW II (1944-45)	V.1 (UAV) V.2	CITIES	Missile attacks were used to instill terror into civilian population and lower their morale to wage war. Allies' response: Long-range weapon targets took precedence over everything except urgent requirements of battle in Normandy.
IRAN-IRAQ WAR OF THE CITIES (1988)	SCUD	CITIES	Missile attacks led to mass exodus and forced evacuations from the cities; disrupted major industrial centers.
PERSIAN GULF WAR (1991)	SCUD	CITIES PORTS	Missile attacks threatened the cohesion of the coalition: Israeli entry into war. 2493 sorties were devoted to SCUD hunt; they represented 15% air campaign.

LEVEL I MISSILE OPERATIONS IN DESERT STORM DIVERTED SIGNIFICANT RESOURCES (U)



WHAT ARE THE C3I PARAMETERS FOR LEVEL I MISSILE OPERATIONS (U)

Operational Capability	Functional Capability	Performance Requirments		Technology Requirements	
		Minimal	Full	Minimal	Full
Level I Time insensitive fixed targets allowing strike planning (in days to months)	Communications	Manual transmission	300 bits/sec	Courier	Low-quality phone line (twisted pair)
	Processing/Fusion	Manual calculation	Precise pre-calculated data	Pen and paper	Ballistic tables, Geographic survey data

WHAT C3I IS NEEDED FOR LEVEL I MISSILE OPERATIONS? (U)

(U) C3I to execute Level I missile operations is readily available

- (U) Courier and manual processing of information are sufficient

(U) C3I upgrades will significantly improve Level I missile operations

- (U) Sophisticated means of reconnaissance: satellite imagery and RPVs
- (U) Improved means of communication: especially microwave and fiber optics

(U) C3I upgrades will <u>enhance</u> the already high survivability of missile forces through better communication with

- (U) Air defenses for early warning

(U) Most importantly, C3I upgrades will enable the execution of a mass attack

WHY ARE MASS ATTACKS DESIRABLE? (U)

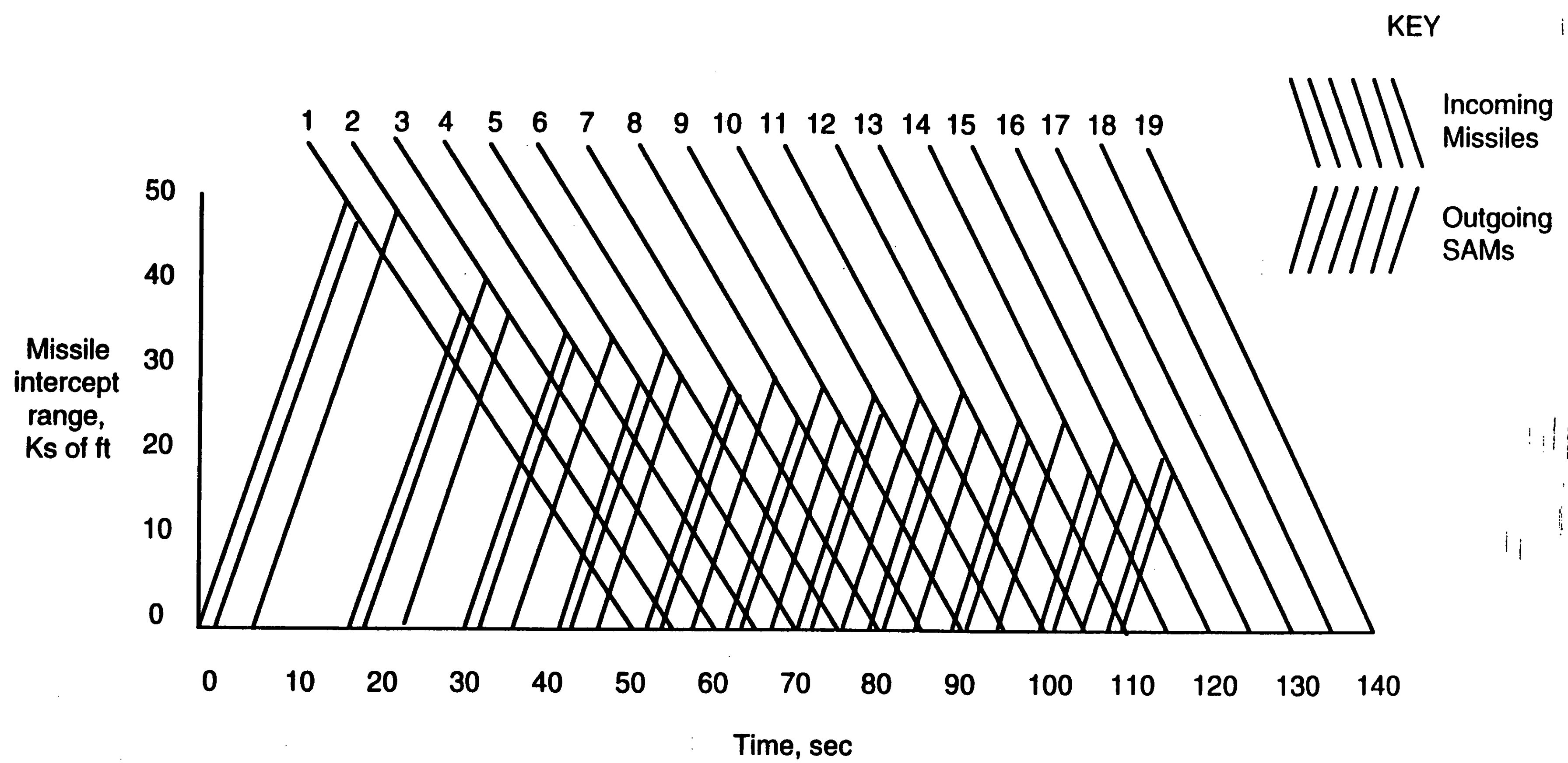
(U) A mass attack can overcome missile defenses through

- (U) Saturation (too many missiles to engage at once)
- (U) Exhaustion (missile defense has limited supply of interceptors)
- (U) Rollback (engagements occur at successively shorter ranges until range is too short for intercept)

(U) The ability to overcome air defenses makes missile operations

- (U) More efficient (less missiles needed to hit target)
- (U) More effective (more missiles will hit target)

A MASS ATTACK OVERCOMES AIR DEFENSE THROUGH EXHAUSTION (U)



(U) Note: Warhead arrival spacing = 5 sec

(U) The air defense is exhausted after engaging the 16th missile; the 17th missile and beyond penetrate.

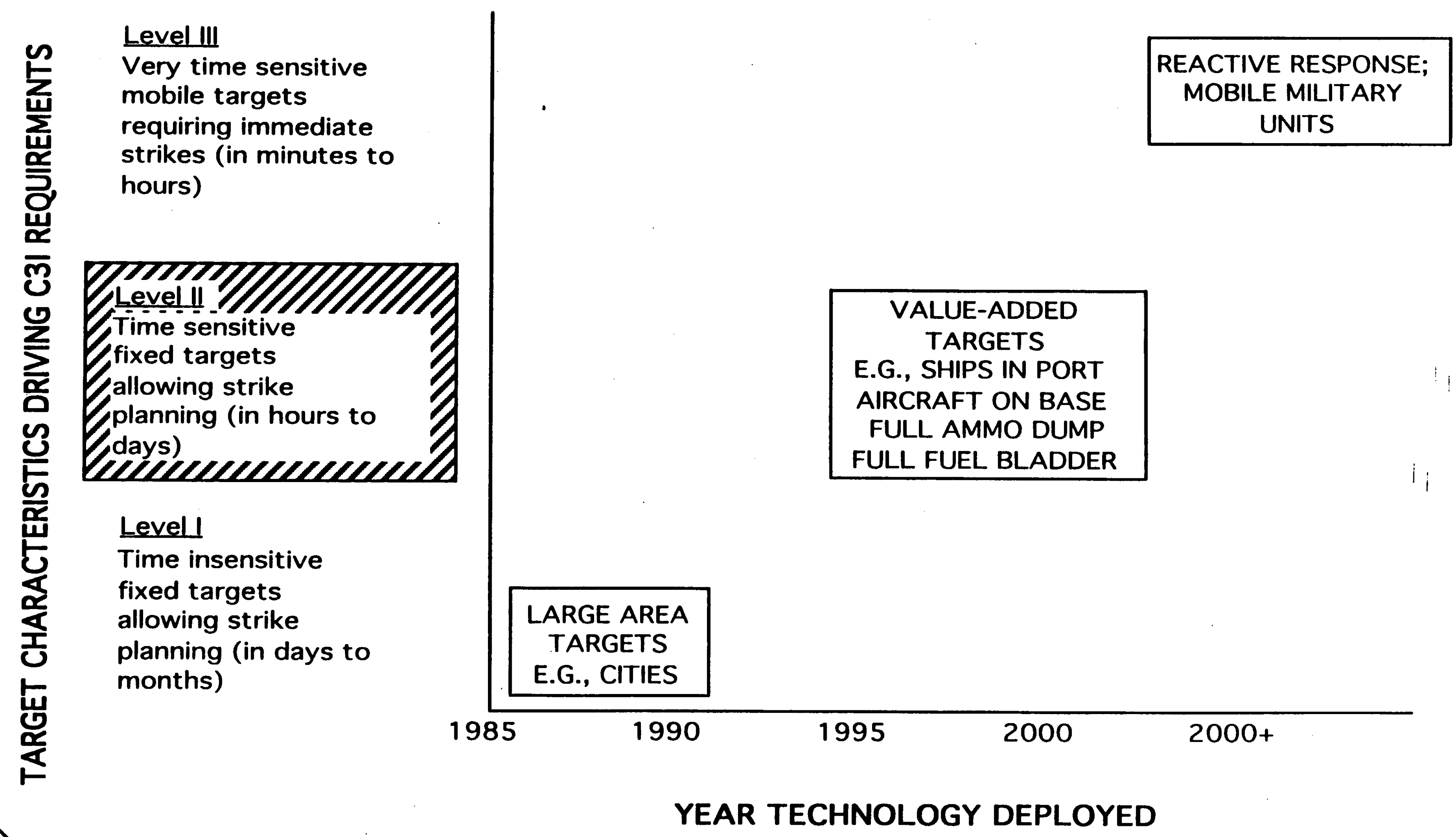
HOW WOULD C3I UPGRADES CONTRIBUTE TO EXECUTION OF A MASS ATTACK? (U)

(U) C3I upgrades (communications) allow high-speed two-way message traffic for

- (U) Mission assignments
- (U) Real-time updates of information
- (U) Launch command
- (U) Confirmation of command

(U) These communications enable the command authority to coordinate the launch and time on target of multiple missile strikes (mass attack).

DEVELOPING NATIONS CAN EXECUTE NEW MISSILE OPERATIONS WITH C3I UPGRADES (U)



WHAT ARE THE TARGET CHARACTERISTICS AND MISSION REQUIREMENTS FOR LEVEL II MISSILE OPERATIONS? (U)

Level	Target Characteristics	Mission Requirements	Example
II	Time sensitive fixed targets allowing strike planning (in hours to days)	Presence of value-added targets decides missile launch times in fixed location. Target location known in advance.	Ships in port Aircraft at base Full ammo dump Full fuel bladder

WHAT ARE THE C3I PARAMETERS FOR LEVEL II MISSILE OPERATIONS? (U)

Operational Capability	Functional Capability	Performance Requirments		Technology Requirements	
		Minimal	Full	Minimal	Full
Level II Time sensitive fixed targets allowing strike planning (in hours to days)	Communications	300 bits/sec	40 Mbits/sec	Low-quality phone line (twisted pair)	Narrow band microwave (w/data compression)
	Processing/Fusion	Manual Calculation (pre-planned)	3 Mtops	Pen and paper	2nd/3rd generation PCs: 8088 80286 80386

MOST DEVELOPING NATIONS HAVE A MINIMAL CAPABILITY TO EXECUTE LEVEL II MISSILE OPERATIONS (U)

(U) Use of commercially available, sophisticated reconnaissance means for target acquisition will provide a broader range of target options.

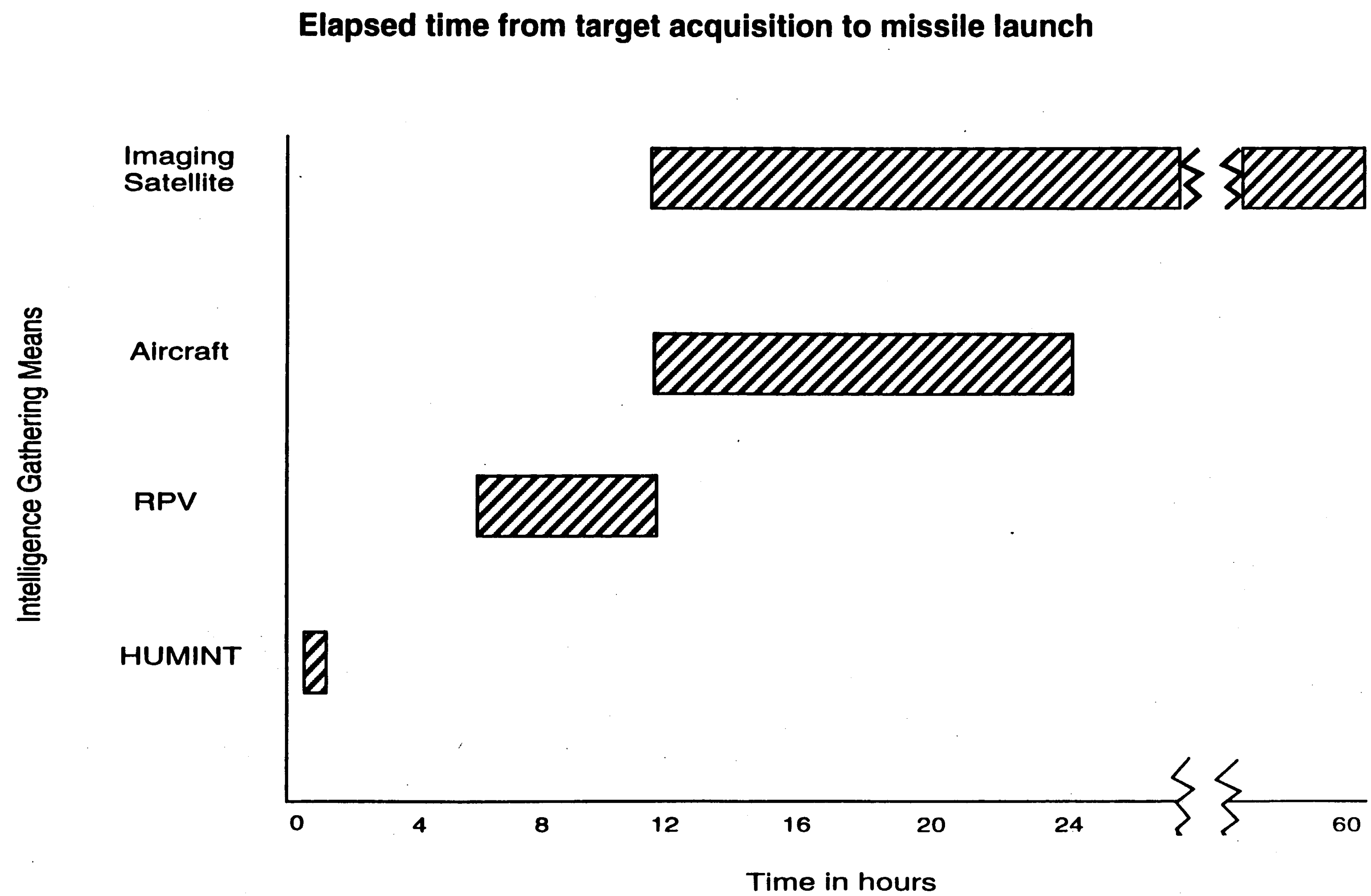
(U) Communications and computer processing/fusion upgrades will shorten the response time from target acquisition to missile launch.

(U) Shortened response time will enable developing nations to strike time sensitive, fixed location (Level II) targets.

(U) Combination of C3I upgrades and accuracy improvements will provide

- (U) A greater probability of hit on target

C3I UPGRADES WILL ENABLE THE EXECUTION OF LEVEL II MISSILE OPERATIONS (U)



ACCURACY IMPROVEMENTS AND C3I UPGRADES WILL INCREASE TARGETS VULNERABLE TO MISSILE ATTACK (U)

TARGETS	1991[a]	2000[b]
CITIES	RANDOM HITS AGAINST TARGETS W/IN CITIES	BUILDING, FACTORY, STORAGE SITE
PORTS	RANDOM HITS AGAINST TARGETS W/IN PORTS	SHIPS AT ANCHOR OR DOCKED; CARGO AREA
AIRFIELDS	RANDOM HITS AGAINST TARGETS ON AIRFIELD	AIRCRAFT, MAINTEN. HANGARS FUEL FARM
OIL FACILITIES	NO	WELLS, REFINERIES, DISTRIB. AND STORAGE
ELECTRICAL PROD. FACILITIES	NO	YES
WATER PROD. FACILITIES	NO	YES
ROADS, RAILROADS, AND BRIDGES	NO	YES
C3 NODES	NO	YES
MILITARY BULK FUEL SITES IN THE FIELD	NO	YES
MILITARY AMMUNIT. SITES IN THE FIELD	NO	YES

a 1000# WARHEAD MISSILE (SCUD) IN 1991 W/ 1000 M CEP

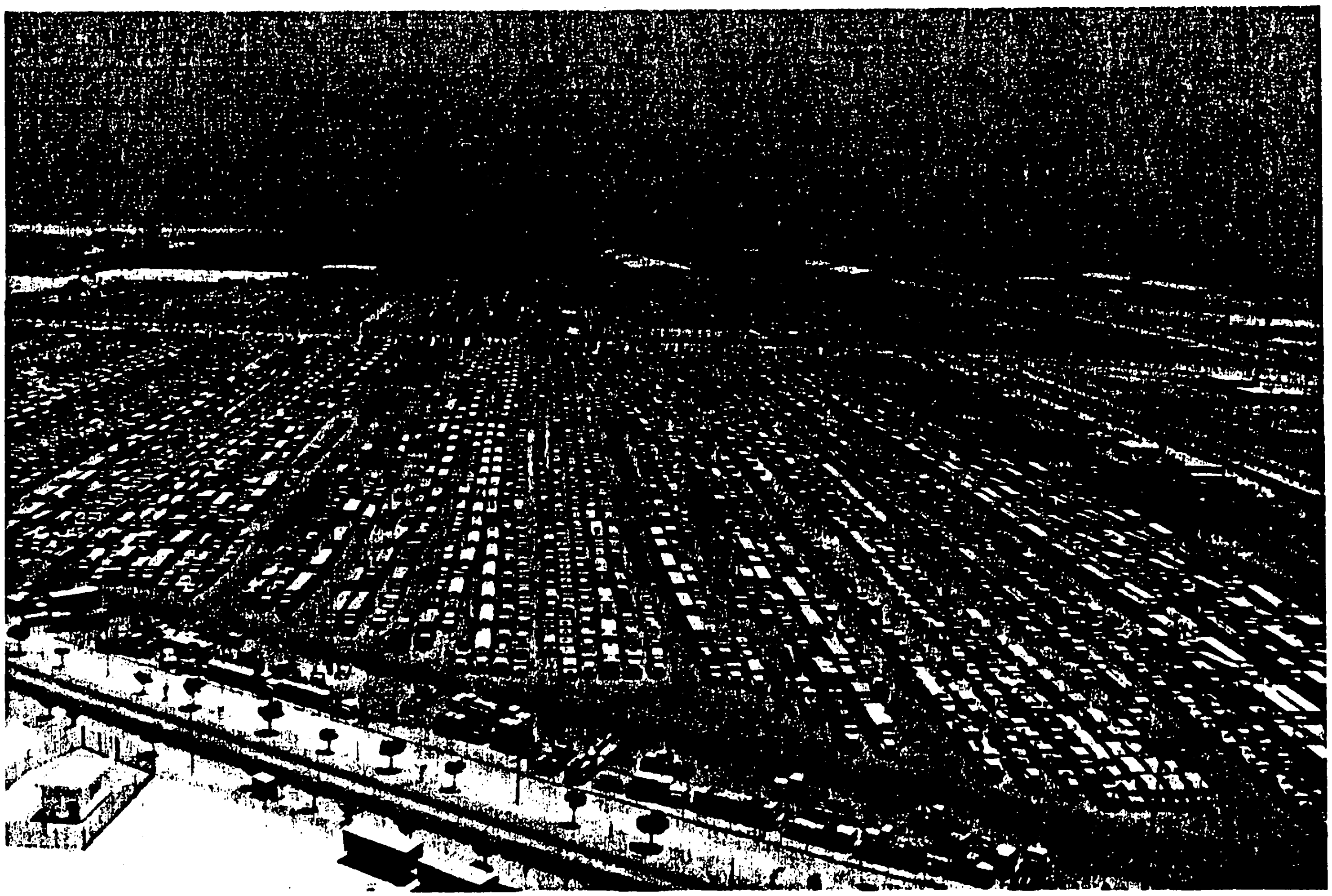
b 1000# WARHEAD MISSILE IN 2000 WITH 100 M CEP AND C3I UPGRADES

THE GULF WAR PRESENTED NUMEROUS HIGH-VALUE TARGETS FOR MISSILE ATTACK (U)

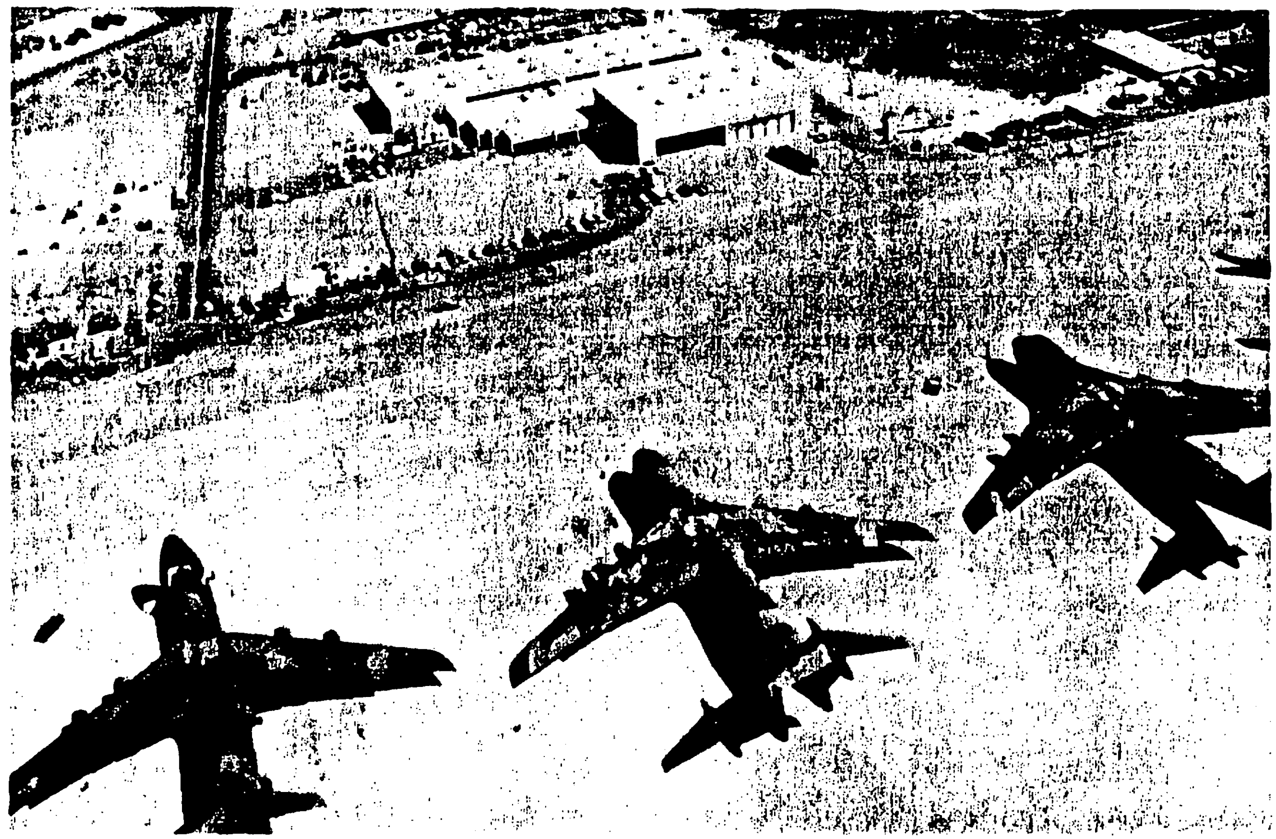
TARGET SET	NUMBER	SIZE	NOTES
	1	4.5 km^2	Numerous High Value Aim Points
	1	4.5 km^2	Numerous High Value Ai
	5		
	17		Most Aircraft Parked in Open or Open Revetments
	11		Most Aircraft Parked in Open or Open Revetments
	6		
	290	3 acres	
	45	1.75 acres	
	250	3 acres	
	1200	0.5 acre	

SHIPS IN PORT ARE A VALUE-ADDED TARGET (U)

PORT TARGETS PROVIDE NUMEROUS VALUE-ADDED TARGETS (U)



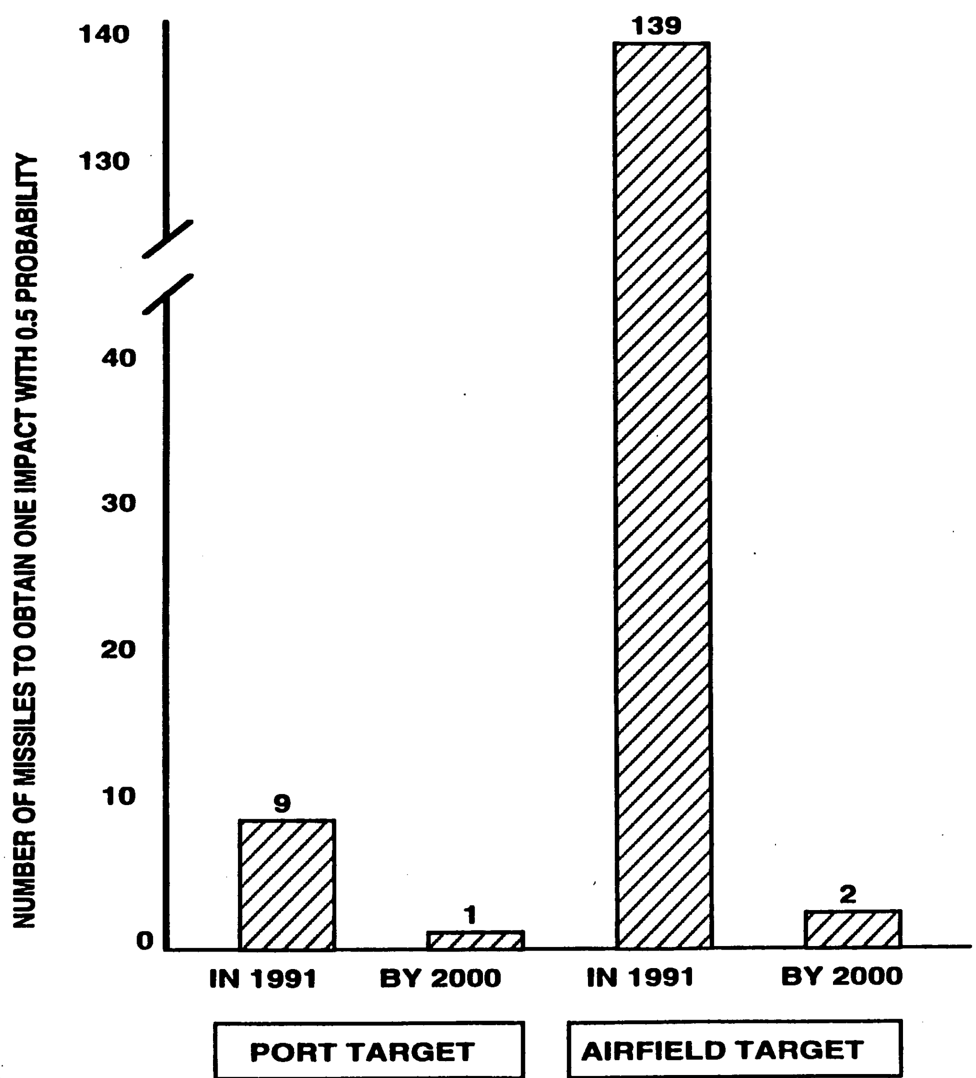
AIRCRAFT AT BASE ARE AN ATTRACTIVE VALUE-ADDED TARGET (U)



UNCLASSIFIED

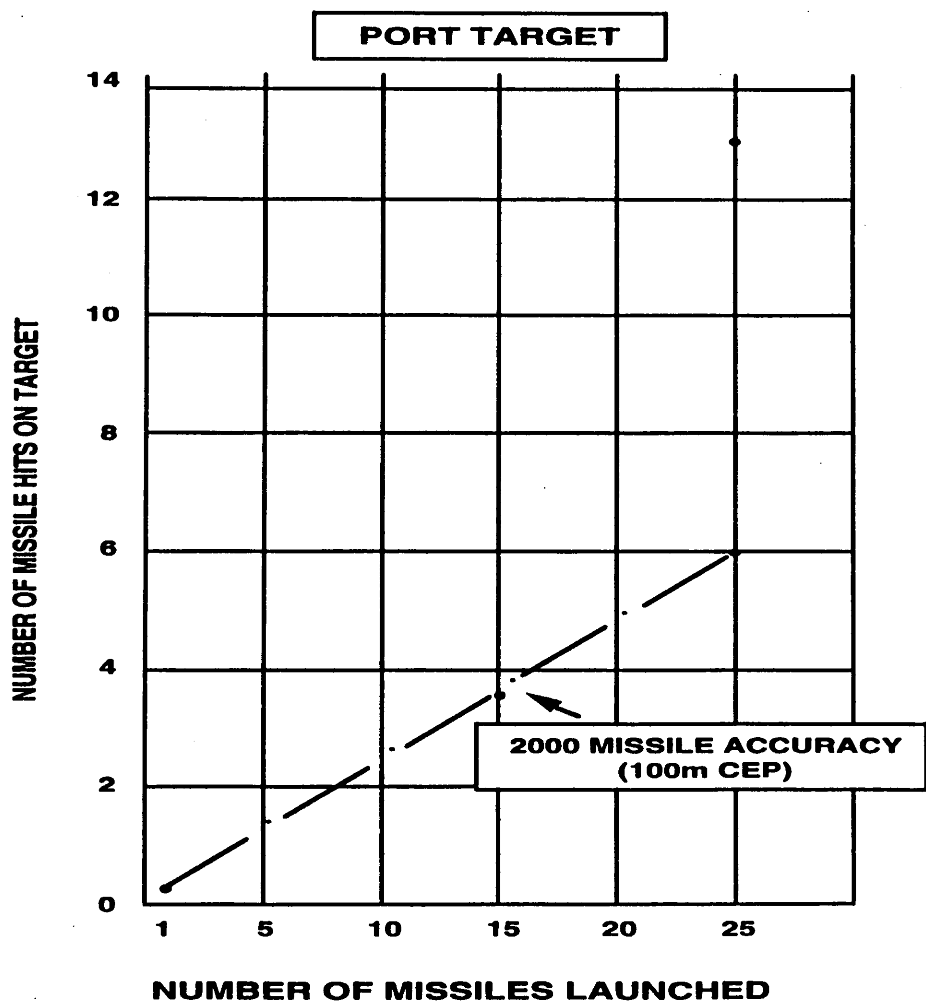
UNCLASSIFIED

ACCURACY IMPROVEMENTS WILL MAKE THESE TARGETS MORE SUSCEPTIBLE (U)

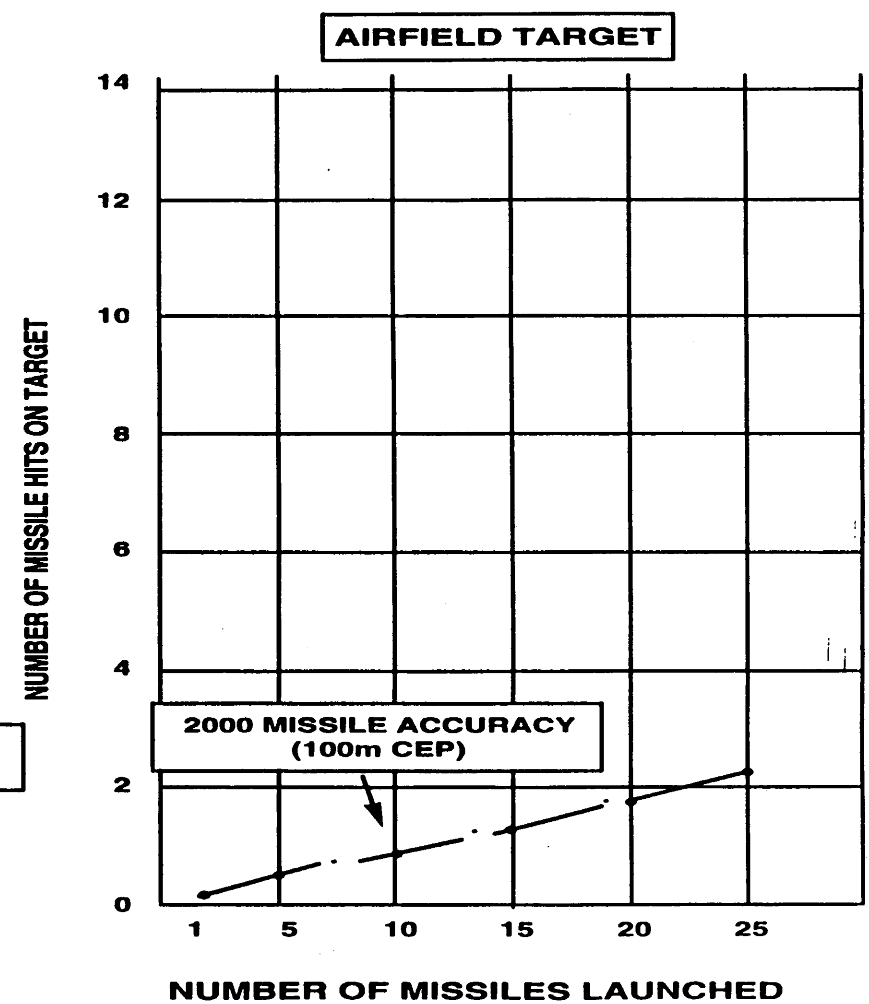


- (U) 1991 CEP 1000 m
- (U) 2000 CEP 100 m.
- (U) For a 92-acre marshalling area (port target), the probability of hit will improve from .08 to 1.00.
- (U) For a 5-acre cargo off-loading ramp area (airfield target), the probability of hit will improve from .005 to .37.

ACCURACY IMPROVEMENTS WILL MAKE MISSILE ATTACKS AGAINST DEFENDED TARGETS MORE EFFECTIVE (U)

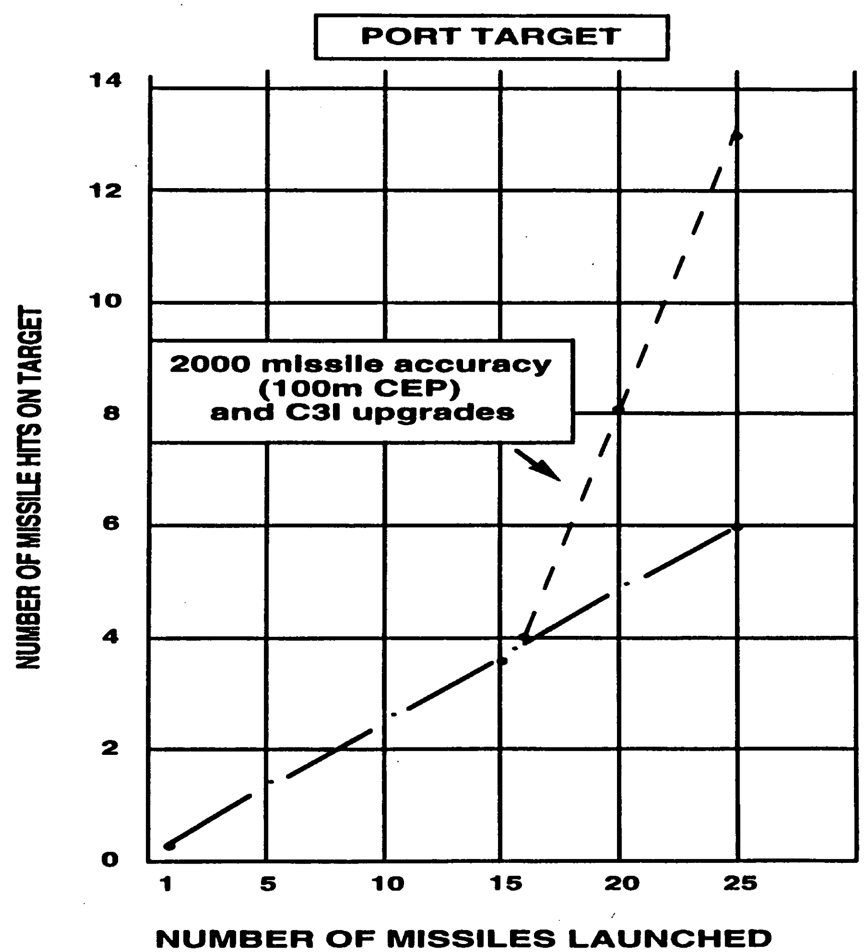


Probability that missile penetrates air defense = .25
Probability of hit on target = 1.00

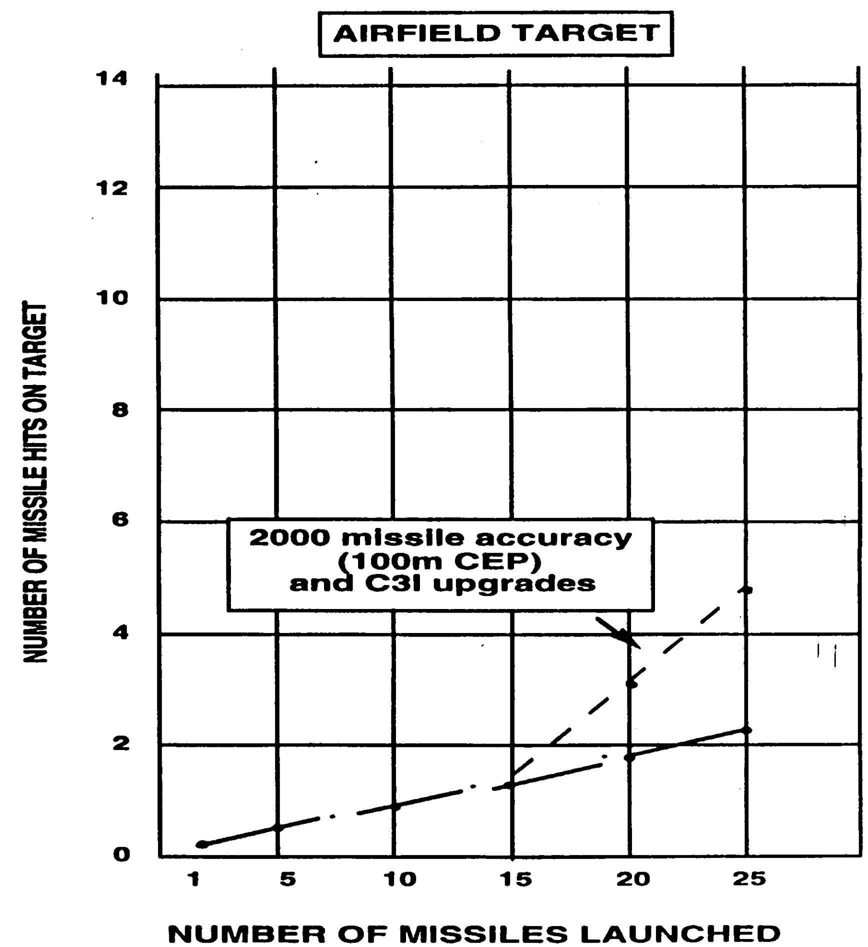


Probability that missile penetrates air defense = .25
Probability of hit on target = .37

C3I UPGRADES WITH IMPROVED ACCURACY WILL DOUBLE MISSILE EFFECTIVENESS IN A MASS ATTACK (U)



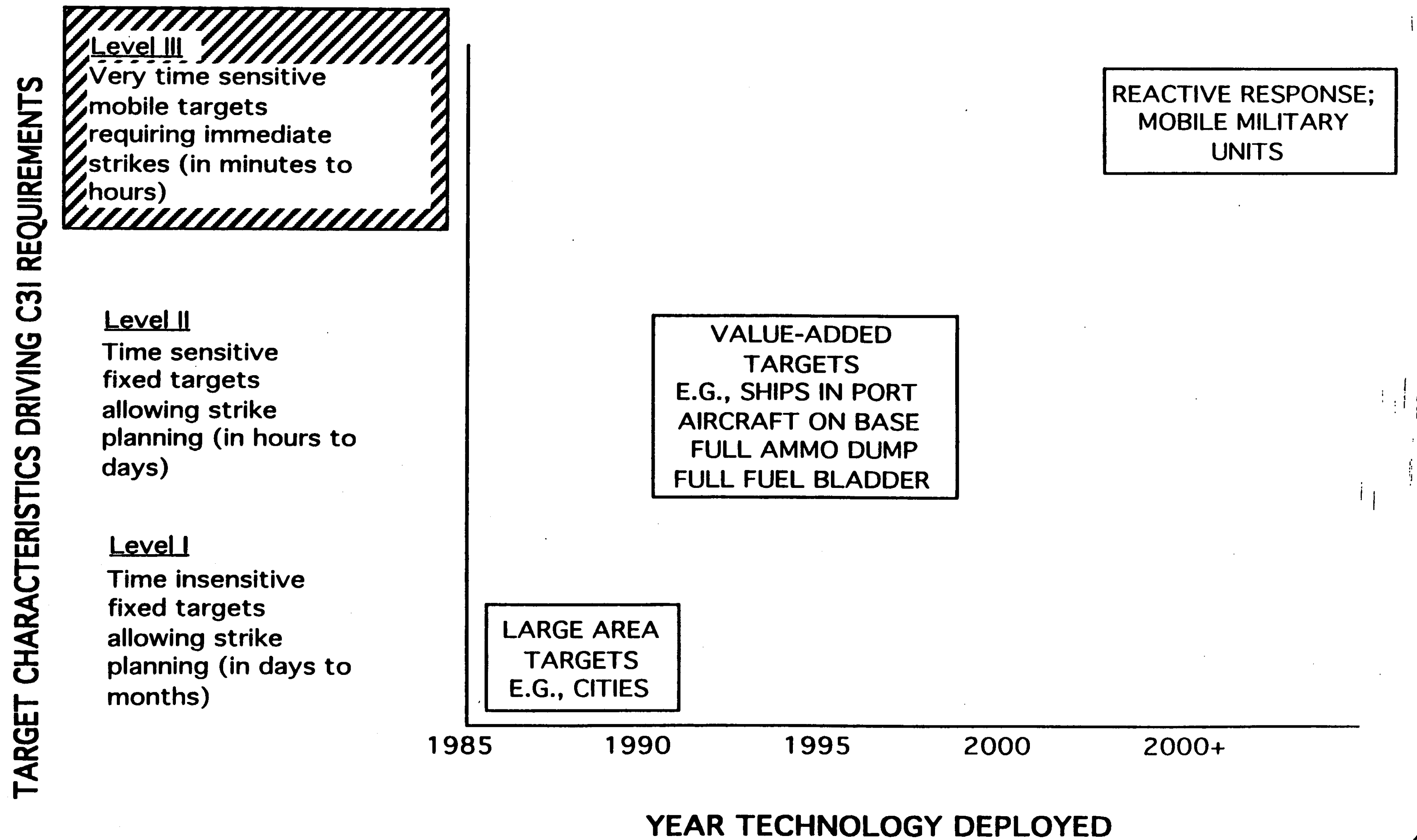
Probability that missile penetrates air defense = .25
Probability of hit on target = 1.00



Probability that missile penetrates air defense = .25
Probability of hit on target = .37

C3I upgrades increase missile effectiveness and lethality through exhaustion of air defense

LEVEL III MISSILE OPERATIONS ARE VERY DIFFICULT TO EXECUTE (U)



WHAT ARE THE TARGET CHARACTERISTICS AND MISSION REQUIREMENTS FOR LEVEL III MISSILE OPERATIONS? (U)

Level	Target Characteristics	Mission Requirements	Example
III	Very time sensitive mobile targets requiring immediate strikes (in minutes to hours)	Missile launch time dependent upon identification of mobile targets. Target can change location.	Mobile military units: Tank column Air defense or artillery units

WHAT ARE THE C3I PARAMETERS FOR LEVEL III MISSILE OPERATIONS? (U)

Operational Capability	Functional Capability	Performance Parameters		Technology Parameters	
		Minimal	Full	Minimal	Full
Level III Very time sensitive mobile targets requiring immediate strikes (in minutes to hours)	Communications	85 Mbits/sec	2+ Gbits/sec	Wideband microwave (w/data compression)	Single-mode fiber optic
	Processing	12-20 Mtops	1000+ Mtops	4th Generation PC: 80486	16-processor i860 array

LEVEL III MISSILE OPERATIONS ARE GREATEST TECHNOLOGICAL CHALLENGE (U)

- (U) U.S. has minimal capability to execute Level III missile operations.
- (U) The technology for Level III missile operations exists, but it is neither widely commercially available nor easily integrated into existing C3I systems.
- (U) Developing nations will not have much capability to execute Level III missile operations by 2000.
  - (U) HUMINT represents best option to operate at Level III because of short data processing/fusion time
  - (U) RPVs are next best option because of flexibility, short revisit intervals, and survivability

WHAT IS THE THREAT FROM C3I UPGRADES FOR DEVELOPING NATIONS' MISSILE OPERATIONS? (U)

- (U) Developing nations will be able to:
  - (U) Locate and attack high-value targets that are time sensitive;
  - (U) Execute mass attacks that can defeat active missile defenses;
  - (U) Take advantage of accuracy improvements that make missile attacks more effective.
- (U) The severity of the threat depends upon our response in areas such as:
  - (U) Logistics doctrine
  - (U) Strategic CCD
  - (U) Missile defenses
  - (U) Countermeasures

(BLANK)

The Military Implications of Ballistic Missile Proliferation (U)

BLANK

II-154

THE MILITARY IMPLICATIONS
of
BALLISTIC MISSILE PROLIFERATION

PREPARED FOR

THE INSTITUTE FOR DEFENSE ANALYSES

by

BERNER, LANPHIER and ASSOCIATES

UNDER SUBCONTRACT NO: 05625

(BLANK)

CONTENTS

(BLANK)

ABSTRACT

To date, ballistic missiles have been militarily ineffective in regional wars. The principal reasons for this ineffectualness are a lack of coordination in missile strikes, a knowledge of target vulnerabilities that can be capitalized on by the warhead, a means of gathering intelligence about the target, and post attack damage assessment. Actively using missiles to attack military targets requires that a military commander develop and integrate these capabilities into a coherent fighting strategy. This paper surveys strategies for fighting a missile war by examining the doctrine and logistics needed to make them practical.

(BLANK)

II-160

I) Introduction

In the wars in which it has been used since 1945, the ballistic missile has proven ineffectual as an instrument for advancing a military campaign. Many countries have wielded missiles decisively and convincingly to sow panic in civilian populations; none have used them as part of a coordinated military strategy. Without a doubt, the anxiety ensuing from a missile raid undoubtedly affects the will of non-combatants in the path of the attack to continue fighting. At least one scholar on the subject of Mideast wars, A.H.Cordesman, credits the terror associated with Scud strikes as the motive behind Iran's lack of resolve at the conclusion of the Iran-Iraq war. Nevertheless, outside of the realm of psychological warfare these terror bombings, however temporarily disruptive and demoralizing, have neither reversed nor arrested the course of a war or major conflict.

Iraq, Nazi Germany, Afghanistan, and Iran have all launched missiles against cities or native populations during wars, more or less at random, either as an act of desperation or as a conscious attempt to sue for peace on more favorable terms. Egypt, in the Yom Kippur War, departed from this pattern by launching Scud-A missiles against an Israeli army in the field. The attack marked the first use of guided ballistic missiles as an integrated part of a military campaign. Israel, however, did not discover its part in this historical footnote until several weeks after the war had ended. Clean up crews stumbled upon the missile debris on one of the battlefields.

More to the point, though, Egypt demonstrated that some regional powers had started to define the missile by the terms for which it was invented, as an extension of long range artillery and as another instrument to be brought to bear in the course of battle. A decade later, Iraq noted this lesson and embarked on a program to extend the range of its missiles for the specific purpose of shelling Iranian cities.

Adopting the notion that a missile can be used to advance a military aim, this paper explores the methods for planning such attacks, the supporting infrastructure that is required to make the attack viable, and the likelihood of its success. To date, Superpowers have studied missile attacks only in the abstract - that is, as an adjunct to a policy of deterring their use. Paradoxically, some nations now arming themselves with ballistic missiles display no such dilettantism. Iran, Iraq, Syria, and Afghanistan have shown no particular hesitation about using ballistic missiles during a conflict, nor do they flaunt any intellectual proclivity for debating the strategies of deterrence and counter-deterrence.

There is no proof that missiles will be any more militarily effective in the future than they have been in the past. Yet, even in the face of this fact, smaller nations are aggressively purchasing or seeking to manufacture missile stockpiles. Despite the unclear impetus for these actions, the West nonetheless faces the real possibility of being embroiled in combat with any *one of the countries now cultivating missile arsenals. As the potential for encountering a hostile missile attack grows, western military planners must consider the possibility, however remote, that missile attacks will be one element of a larger, more coordinated strike to achieve a military objective. Failing to study this possibility fully, and plan accordingly, makes western military operations vulnerable to the surprises that complacency creates.*

II) Motivations

Outside of the Superpowers, there is no published body of literature presenting a coherent strategy for one country attacking another one with missiles. The instances of strikes to date show every indication of being uncoordinated, unplanned and episodic. Hitler, for instance, used the V-2 as a last desperate act in his war with the British. His selection of the name "vengeance" weapons for his rocket fleet verifies the true motivation for his arsenal. Saddam Hussein, to pick another example, launched Scuds during the Gulf War with the express purpose of widening the conflict and breaking up the Gulf Coalition. Hussein's attack against Israel only furthered the strategy he employed during the Iran-Iraq war, where Iraq fired Scuds at Iran in deliberate retaliation for the Iranian Scud raids against Baghdad.

In some case these tactics are meaningful, in others they are superfluous. The Afghan attacks on mujaheddin bazaars during the 1980's generated the highest death tolls ever reported for rocket attacks. These attacks forced the mujaheddin even deeper into hiding and prevented settled rebel camps from coalescing. If the German V-2 attacks against London had occurred earlier in World War II, a population already made jittery by the fall of France and the evacuation of Dunkirk might have felt especially vulnerable to a rocket assault and sought peace on unfavorable terms. On the other hand, the Egyptian Scud salvo against the Israelis, taking place far from a population center remained obscure until long after the Yom Kippur War was over.

Uncoordinated, unplanned, and unanticipated missile attacks arise from circumstances that are only clear to the military commander ordering the action or the civilian authority sponsoring it. This paper will not weigh the repercussions of such stunts. Military missile raids, on the other hand, are much less lackadaisical. They are characterized by a specified set of objectives which in turn defines a rational target list. If a nation expects to undergo a ballistic missile attack, it must compare the hardness of these likely targets to the potency of the rocket arsenal to determine if additional hardening is prescribed or other defensive moves seem justified.

This logic leads naturally to two types of tactics that will in turn determine the targets. An attacker can launch a raid against a civilian site that supports or a war effort or one that by consequence of its destruction can cause further damage through a leveraging effect. Alternately the attacker can strike directly at a military target. In the first case targets might coincidentally coincide with cities and the collateral civilian damage can be quite high. Some *examples of these targets might be dams that serve agricultural regions or large hydroelectric generating facilities, or nuclear power plants if the warhead is sufficiently large to breach a containment vessel and spread a radiological hazard. Within cities an attack might be aimed at key transportation arteries or large industrial parks associated with military production. To accomplish a military objective the missile must possess a combination of accuracy and lethality that supports the purpose of the attack. A great body of literature exists proving that this combination very rarely exists during declared hostilities. Still, many lucrative targets are overlooked. A Patriot radar, for instance, ceases to function after a 1.5 psi blast wave passes over it. A missile carrying 1000 kgs. of high explosive specially designed to produce a long duration pulse can easily generate this kind of blast up to seventy meters from the point of detonation.*

Regardless of the purpose, in order to work as a military tool against an assigned target, several conditions must be present. First, the missile must have sufficient range to hit an intended target. Libya overlooked this elementary point in its Scud attack of the island of Lampedusa in 1986. The feat seemed almost laughably inept when the missile fell far short of its target. Secondly, if the missile carries a warhead it must detonate near enough to the target to inflict the required damage. Hitting an aim point is not always a principal function of the accuracy of a missile. Instead, it is a rather complex mix of the warhead lethality, the target vulnerability and the reconstitution rate of the target. The first two elements of this mix define a concept known as the "lethal radius" which will be dealt with in more detail in the body of this paper. Targets, particularly military targets, have a value and a vulnerability that vary dramatically with time. What determines warhead accuracy and lethality in one instance, almost certainly does not under different circumstances.

Target value must be enumerated <u>as well as</u> be anticipated since a missile launch is a lengthy process consisting not only of the ballistic flight time, but the set-up time, the time required to initialize the guidance system, and in the case of liquid rockets the time to fuel the rocket. Throughout this whole process the target cannot move nor can its value change. Assuming any target is either mobile or has a value that varies with time, the volatility of this target cannot be greater that the preparation time or alternately some communication and intelligence network is needed to evaluate the position and value of the target and direct fire against it. The time cycle may be further lengthened if missiles are located at remote sites for either defensive or logistic reasons and the launch commands must be communicated to field crews from a central command.

Some targets are ideal candidates to be assessed in advance and certain assumptions can be made about their volatility that supports a targeting doctrine. A attacker could attempt to hit a weapons ship in a port for instance in the hopes that a sympathetic detonation would ignite stockpiles of ammunition. The size and distribution of these stockpiles obviously changes with time as the material is stacked for disbursement. This distribution changes more quickly than most missiles can *be targeted. But, by understanding the unloading operation and the point when the stockpiled material will be most vulnerable a launch crew can prepare a launch to coincide with this moment. If such information is not available nor can it be refreshed with field intelligence in a timely manner an attacker may choose to launch a salvo attack against the port in advance, in the hopes that enough damage can be inflicted to prevent the ship form ever unloading in the first place. Since the port is immobile the launch crew is under no obligation to attack in a period shorter than it can prepare. A good deal of this information can be determined or measured in advance of a conflict. The exact location of airfields, ports, or civilian infrastructure facilities does not change with time, and so a determined missile power can accumulate and archive much of its required targeting information. On the other hand, even if the exact location of a logical target such as a port is known, the status of shipping traffic into and out of it as well as its character is generally not. Furthermore, the vulnerability of these targets, whether defensive batteries, or hardened shelters have been built as an example must be evaluated as the war proceeds.*

After a missile attack has been executed, subsequent attacks can be planned more efficiently if an assessment of the damage created by the initial attack can be accomplished. It is by no means a requirement to do bomb damage assessment in order to achieve a militarily useful goal. Absolute, overwhelming, force in the first strike can assure the attacker that the target has been destroyed. Such massive damage, however, generally results from a warhead of enormous destructive capability such as a nuclear weapon or a prohibitively large number of smaller missiles. Bomb damage assessment introduces the possibility that a smaller arsenal of missiles can be used, firing at rate that just matches the adversary's capability to reconstitute the target.

If any of these circumstances are not met it does not mean that a missile power will forego an attack. Effective attacks, however, generally exhibit the following characteristics: a lethal radius that is large enough so that only one missile or a small fraction of an arsenal is required to destroy the target, a method to determine the position and value of the target that matches the timeliness of the launch operation, a means of communicating this information to commanders in the field if the launch operation is remote from a central command, and a technique for bomb damage assessment when the arsenal is limited or the target is hardened and the outcome of the attack may be unknown.

In the paragraphs that follow each of these criteria will be examined in more detail.

1) Targeting Doctrine

Targeting war-supporting civilian enterprises, as opposed to targeting military targets directly, calls for different strategies, and different basing methods for a missile force. If the missile is mobile, some military assets, such as troops or logistics nodes, can be targeted from the vicinity of a front. In their favor, though, fixed missile launch sites are more robust, can *be defended as point targets with heavy air defense batteries, and can generally support longer range missiles. When a military strategy calls for attacking fixed, rear echelon, points such as ports, dams or other fixed positions behind front lines, a fixed launch site offers the further advantage of better accuracy and secure communications, as well as less hurried or otherwise inadequate launch preparations. These merits come at the cost of heightened susceptibility to counterattack, capture or destruction of the facility.*

In general, fixed launch sites will also dictate that a missile have greater range than mobile launch sites. This is partly compensated for by the fact that larger missiles can be launched from fixed sites and more equipment is available for their preparation. Targeting strategy and the purpose of the targeting influences to a great degree the range required from a missile.

To assess the potential for achieving a military objective in the face of these considerations, a representative target list must be assembled for each of the two purposes for an attack.

i) Civilian enterprises

Beyond stark terror, the purpose for striking a civilian target is to either disrupt the normal course of affairs in a rival capital or major city, or to destroy a target that provides destructive leverage beyond the damage the warhead itself creates. For instance, destroying a dam with a missile or a few missiles could possibly unleash subsequent flooding capable of destroying a city or agricultural area, far more effectively than any direct missile attack. Saddam Hussein employed this logic in another sense during the Gulf War by opening up sea terminal stopcocks and flooding the Persian Gulf with oil in an attempt to pollute desalinization plants in Saudi Arabia. Many example targets exist that are not generally discussed in the literature fall into this class of targets. The are attractive targets only if the lethal radius is properly matched to the hoped for outcome of the attack. The first attack postulates a warhead with a lethal radius of 100 meters and the second a warhead of twenty meters CEP. The statistics of the attack indicated that in both cases four of the missiles fell within the footprint of the CEP. But with the 100 meter lethal radius at least two of the missiles encompassed the target, whereas with the ten meter CEP none of the missiles hit the target. This example serves to illustrate the point that accuracy is not a necessary condition if the warhead is sufficient.

Some examples of soft civilian targets, that could be vulnerable in a typical regional war are:

1) Petroleum refineries. All of the petroleum products used in the Gulf were supplied by the Saudis. This lessened the Coalition's burden for supplying the fuel to support our operations. The Saudis provided fuel from three refineries one each at al Jubayal, *Rastanur, and Jedda. The output from all three refineries was required during certain times in the war to keep the air operation adequately supplied. Two of the three refineries are within Scud range of Iraq's fixed missile launch sites, and the third is nearly within range.*

The weakest link at these petroleum facilities are the above ground piping, supply regulators, high pressure bypass standpipes, and status monitoring equipment. Certainly, a direct hit with a Scud-sized warhead could breach an un-reinforced petroleum storage tank, and a tank farm covering some considerable acreage might make an attractive target, even if most of the missiles launched at the farm would miss any exposed point. Storage tanks within a tank farm are designed with sufficient safety margins to prevent the detonation of one from igniting the others. But a major fire presents such a hazard that the entire tank farm might be rendered unusable until the fire is extinguished.

Ruptured flow lines present a similar danger. The flow is controlled and is rerouted away from a burst pipe, but refining operations oftentimes cease until repairs are made to damaged equipment. For the major pipe ruptures that have occurred in petroleum facilities not experiencing wartime conditions, repair and refurbishment times of twenty four to forty eight hours are often required before normal operations are restored. The ground offensive in the Gulf War would have been delayed as much as three days if a missile salvo had successfully disrupted an entire facility, or the total offensive might have begun under diminished circumstances. As the outcome of the war showed, a one or two day delay is not generally significant. On the other hand, operational and mission planning rests on meeting certain timetables. The Gulf is a case in point. The major reasons Schwartzkopf select the date for the ground offensive were to avoid unfavorable meteorological conditions that occur in the region later in the month, to land on the beaches under the cover of darkness at a new moon, and to have the conflict completed before the beginning of Ramadan. Delaying the war by even a day or two shortens the window of opportunity for planning, and forces deadlines into shorter spans of time.

2) Desalination Plants. During the Gulf War, three desalination plants located in Saudi Arabia on the Persian Gulf supplied fifty percent of the total water consumption of the country. Sufficient storage capacity existed within the country to last for about ten days without water rationing and about two months with restrictive water rationing. The demands the war placed on the country's water supply cannot be adequately calculated since the U.S. military brought with it a significant supply of water and did not place an undue burden on the existing stocks or production capacity within the country.

In future conflicts, when the U.S. supply lines might not be so well fortified, a crippling attack on a desert country's water stores might prove trying. The Saudi desalination plants are unprotected from missile attacks and are within the extended range of the Scud missile. There are at least three vulnerable points associated with the plants and destruction *at any one of these points renders the plant inoperable until repairs are made. The three vulnerabilities are the power substation, the seawater intake pipes, and the water grid delivery pipes.*

Of these three weak points, the least vulnerable to a crippling high explosive attack is the seawater intake pipes. As a rule, the intake pipes are shielded from a direct blast by the sea itself, except where the pipes rise out of the water and cross open ground to an entrance in the plant. It would take an explosive warhead of incredible accuracy to hit these pipes. Given a capability for producing chemical or biological warheads, however, an attacking nation has the incentive to try to contaminate the water supply by introducing the chemical or biological agent upstream of the intake. If the desalination plant uses conventional electrolysis to purify the water, most chemical agents will be destroyed. Biological agents, though, could pass through the plant undiminished in lethality.

The most vulnerable point to attack is the electric substation supplying power to the plant. The substation is usually extensive in size, making it an easier target to hit, and more difficult to repair. Repair work on substations takes four to five days, under non-crisis conditions when the repairs involve replacing transformers, and as much as a week when the entire electrical grid needs modification.

The ten days of excess water in storage in Saudi Arabia would likely vanish quickly during a major break in desalination operations, particularly if news of a missile attack caused panic hoarding.

3) Ports. In any conflict a port becomes a particularly attractive target. When a port is disrupted all of the civilian and military traffic into and out of the port is affected and scheduling becomes highly uncertain. The Coalition used seven ports, but 80 percent of all material went through just two ports - Damman and al Jubayal. Both are within Scud range of Iraq. The two ports each cover an area of about 100 acres or about 4 square kilometers. Within each target area are a number of highly lucrative targets, including ships, port facilities, unloading equipment, cargo and personnel. At any given time the target mix shifts but approximately one tenth to one eighth of the total surface area might be covered by a high value target.

During a war, dangerous procedures such as unloading powder charges for artillery shells from ships are a necessity and while these operations progress the port is most susceptible to a devastating attack. During the war the U.S. frequently violated military protocols for the close spacing of powder bags as well as the duration with which powder bags could be left in one place. Powder bags for 155 millimeter shells sympathetically detonate if 1000 kgs of HE explodes within 100 meters or so. Civilian cargoes sensitive to ignition or detonation in the vicinity of a missile attack include liquified natural gas, liquid petroleum products, or even some high nitrogen content fertilizers.

The concussion associated with these sympathetic detonations have the force to destroy ships, either in port or waiting to be unloaded. On average it takes two days to unload a fully laden ship under wartime conditions and potentially twice as long during non crisis times. During the Gulf War each dock within a port area handled seven or eight ships. At any one time, 30 ships may be within the confines of a port area or entering and exiting the vicinity. Most ports are not incapacitated by one sunken ship, but the overall capacity of the port is diminished and all processes slowed by a crippled ship.

Further leverage can be gained by directly attacking a port when automatic loading equipment such as cranes and containerized ship-handling machinery is present. Regardless of whether the activity is associated with military or civilian concerns the loss of capital and labor intensive equipment generally halts the functioning of a port.

An often overlooked target at a port is the human infrastructure. Personnel providing labor for loading and unloading operations are exposed to attacks by chemical weapons or anti-personnel weapons such as fleschettes, napalm, and shrapnel. Approximately 2000 personnel within the immediate area of the port participated in some capacity in unloading operations during the Gulf War. About ten percent of these people had specialized skills associated with handling heavy machinery and cargo manifesting. Replacing them, particularly at a time of crisis, is extraordinarily difficult.

4) Concentrated heavy industry. Most emerging industrial nations, as well as established manufacturing societies, tend to aggregate their industries in one location. There are historical, and cultural reasons for this, in addition to the need to concentrate industry near shipping terminals and other related industries. Often zoning restrictions concentrate industry further into industrial parks. These industrial parks make attractive targets for ballistic missiles. Inaccurate missiles can strike anywhere within an industrial zone and probably still accomplish some degree of destruction. If by happenstance, the attack releases a chemical or toxin that is associated with the manufacturing process then further damage will occur within the industrial zone. A missile strike against Bopal in India, for instance, using just ten missiles has an 80 percent chance probability of creating the same toxic cloud over the area that the accident caused in 1984. Over a thousand people died in that accident which is nearly ten times the kill probability for using the same ten missiles against a conventional civilian target such as Tel Aviv.

The epitome of this targeting logic is an attack against a nuclear power plant. The release of radioactive material from a nuclear power plant multiplies many times the severity of a conventional missile attack. Once again, Saddam Hussein may have been following this prescription during the Gulf War. Many sources indicate Hussein intended to attack the Israeli nuclear facility at Dimona. Only the limited selection of ranges available with his modified missiles prevented him from attacking this facility in the Negev desert south of Jerusalem. On the other hand, even if Hussein scored a direct hit on Dimona the victory *would be a Pyrrhic one. Nuclear facilities by their nature are hardened to withstand most conventional weapons detonations.*

ii) Military enterprises

To be militarily important a missile target must have some direct role in the prosecution of the war. It does little good to knock out one oil refinery if the production is not being used to provide for the immediate needs of the troops, or if all of the oil refineries in the country are not fully subscribed. Similarly, destroying a desalinization plant has no purpose if other sources of fresh water are available to meet short term shortages. While attacking these targets without a specific objective may have some latent terror potential, a direct attack on a city serves that purpose much better and completely obviates the need for selecting a military target. The list of potential military targets that follow was selected specifically to illustrate the characteristics of likely military targets for a ballistic missile attack.

Candidate military targets share a number of features. Foremost, they are prone to extensive damage from a selective or highly specialized warhead in the attack. This situation imposes a dilemma on the attacker as well. Missiles must be designed to accommodate a wide variety of warheads capable of installation during the preparation phase of a launch. Selecting warheads in a timely fashion for a changing target has long been a bete noire for combat planners. One of the principal reasons the Japanese lost the Battle of Midway was that they equipped their planes with the wrong ordnance for combat, not once but four times in sequence as U.S. strategy unfolded.

Of nearly equal importance is the geographic extent of the target. Some military targets have the same attraction that cities do: a broad extent with many dispersed, but very high value point targets. An attacker choosing to target a city cares little if his crude missile strikes one neighborhood or another in a metropolitan area, just as the exact point where a warhead hits a large bivouac area makes little difference.

Finally, the attacker has the option of looking for a very high value target that has leverage beyond normal expectations. Accumulations of unique military hardware or personnel which cannot be easily replaced under combat conditions, especially satisfy this goal. The high command of a military operation for obvious reasons tend to congregate at one or more known points during a conflict. Historically, they headquarter far from the front lines or from active combat. But the unique aspect of the ballistic missile as Kennedy discovered during the Cuban Missile Crisis is that it can project the fighting far forward of the front lines.

The list that follows is by no means an exhaustive compendium of all likely military targets. It is provided only to illustrate some potential military targets.

1) Housing and headquarters for the high command. In the opening days of Operation Desert Shield the top echelon of CentCom was housed in a single high rise hotel across the street from the Saudi Ministry of Defense and Aviation. The hotel was unprotected until late October of 1990 by even the simplest countermeasures. After that time traffic barricades were placed around the building to prevent a car bombing and Royal Saudi Air Force security personnel set up round-the-clock guard duty. But in contradiction to official strategy the U.S. did not protect other adjacent hotels similarly as a decoy or deception tactic to draw attention away from the primary housing. The heightened security patrols around CentCom headquarters were a perfect clue that high level personnel were indeed staying at the hotel.

Because of the press of Operation Desert Shield there was no time to barricade the hotel or to further fortify it. Masking tape was placed on the windows to prevent shards of glass from hurting people during an air raid, but other than that the building had no special hardening.

This hotel is constructed of masonry and mortar. Two types of warheads, fuel/ air explosives and fragmentation mines penetrate this type of construction quite effectively. One thousand kgs. of fuel/air explosive delivered to within 100 meters of the structure would severely damage it. Collapsing walls and shards of glass amplify the destruction and carnage created by the original blast. Ten missiles of Scud-like accuracy launched as a salve against such a resident hotel have an eighty five percent chance of including the target in at least one blast wave.

At any time about one third of command echelon personnel were in the hotel. Removing such a large contingent of commanders from active duty in a missile attack no doubt has an adverse affect on the course of the war as well as the morale of the military and civilian population supporting the war.

2) High value facilities. The evolution of the modern battlefield has brought with it a concentration of war fighting support infrastructure. Planning an air strike, for instance, requires that a strategist know precise meteorological information a prediction of future weather, an image of the battlefield and a an air traffic control network. After the battle this same strategist must have a rapid and precise assessment of the effect of the strike to plan the next attack. The air force component of this assault relies almost exclusively on satellite information to accomplish these tasks. Interrupting communication to and from satellites, therefore, retards the ability of strategists to plan and evaluate attacks. But satellite communications are frequently received only through one source, usually a portable dish antenna placed in the field.

In the Gulf War the principal down link station for receiving JSTARS and other information was the Tri-Astars system. An un-camouflaged Tri Astars dish was set up on the *outskirts of Riyadh during Desert Shield but prior to Desert Storm. It was located within the footprint of one of the Patriot Batteries in Saudi Arabia. The large concentration of both contractor and U.S. uniformed military personnel both entering and leaving the facility tipped off many civilian observers about the nature of the facility. The dish associated with the facility is approximately two meters in diameter, so its construction and installation should have been apparent to civilian imaging satellites.*

Radar dishes such as the Tri-Astars collapse when exposed to as little as one psi of blast overpressure. A one thousand kilogram charge of high explosive generates a pressure wave of this strength out to a distance of forty meters. If a J-Astars dish or a similar model used for receiving near-first generation quality satellite imagery perished in a missile attack CentCom becomes blinded until replacements arrive. Alternative and more secure methods of communicating the same information exist, but in most cases the rate at which data is handled suffers noticeably with these substitutions.

3) Defense suppression. Air defense systems meant for tracking and destroying either ballistic or air breathing threats within a theater of operations rely on radar detection. The radar, as a matter of course, can have no intervening revetment or blast wall in front of the main source of fluence. In other words it is impossible adequately protect a radar from the blast or shrapnel created by a missile warhead. Losing the radar blinds and incapacitates systems such as the Patriot theater missile defense system. In the case of the Patriot, the air blast wave generated by a detonation does not need to be the principal mechanism for destroying a radar facility. The warhead lethality is greatly enhanced by replacing some of the high explosive with dart like projectiles or pellets that impairs or destroys the elements that constitute the phased array modules. With the proper orientation on a shaped charge propelling a fragmentation warhead can strew lethal pellets preferentially as far as two hundred meters away. In this example a strategist employs the missile as part of an overall planned attack. The first missile or salvos of missiles uses shrapnel to eliminate the Patriot or its follow-ons as an active defense and then subsequent missiles use the warhead that create the greatest lethality for the target that the Patriot defended. Of course, some intelligence or bomb damage assessment method increases the effectiveness of this strategy, but any attacker with a surplus arsenal of missiles can overcome this problem by launching a sufficiently large salvo.

4) Airfields. Coalition pilots flew sorties from seventeen airfields in use during the Gulf War. Each airfield covered an average area of one half of a square kilometer or a bout the size of a suburban development. Vital point targets such as control towers and fuel depots accounted for less than one half of one percent of this acreage. These targets are impossible to individually aim for and hit even with highly accurate warheads, but the distribution of high value assets is sufficiently uniform that any warhead landing within the perimeter of an airfield has an expected chance of hitting an asset of some description.

The principal leverage in attacking an airfield arises when individual airplanes come under threat. Most modern combat aircraft cost in excess of thirty million dollars, so a one million dollar missile that destroys even one airplane has accomplished a considerable amount of damage relative to its cost. When the total damage that the airplane can cause if a sortie is successfully and repeatedly launched against the country using the missiles is factored into the equation the benefits of using a missile against an airfield become more apparent.

Ever since the Japanese attack on Pearl Harbor, the risks of parking airplanes wingtip to wingtip have been well known to defense thinkers. Under emergency conditions, though, and as massive air sorties are being prepared and begun airplanes are often in close proximity to one another. The ballistic missile with its short flight time relative to the duration of launching 200 aircraft spaced thirty seconds apart proves to be an ideal offensive weapon to catch part of this sortie train. Once again the only support needed is effective intelligence that the raid is under way which can be communicated to missile launch crews before the entire sortie is off the ground.

Saudi airfields exhibited many weak points. The layout of Coalition airfields limited the space over which the Air Force could disperse its planes. Furthermore, the original designers of these airfields did not envision the overwhelming volume of traffic so commonplace during the air campaign. Inadequate hangar space for all of the aircraft involved prompted many pilots to park their planes in relatively exposed locations. Traffic along limited apron spaces tied up the take-off, landing and refueling operations for these planes preventing many of the planes from being properly sheltered form an air attack. Finally, Saudi construction methods meant the hangars were not blast hardened in the same manner that similar hangars are constructed in the United States. Even small warheads armed with shrapnel bombs would easily penetrate the sheet metal sides of these hangars.

5) Bulk fuel and water sites. The U.S. military understands fully the consequences of outrunning its own supply lines and has planned accordingly by designing and manufacturing portable fuel and water depots. Theory and practice both hold that these reserves remain portable enough to move forward as fast the front advances, but nonetheless are maintained at a safe distance from the front. Ballistic missiles once again upend this theory by enabling the attacker to strike over the front and deep within the defended territory. Patriot batteries set up to defend each of the bulk fluid sites that must be built to equip a major assault force would cost more than these sites would be worth. The Gulf War is a case study in major conflicts requiring deployment of bulk fuel sites. The Army established 290 number of fuel storage sites in the Saudi desert to fuel the tank assault into central Iraq. The importance of these sites as a supply point for modern combat justifies the fuller description given in Appendix 1.

The sites are functionally bulldozed out of the desert in advance of a major military campaign and fuel is stored above ground in large polypropylene bags (similar to garbage *bags). The bags are highly susceptible to puncture from fragmenting warheads as well as by blast waves. The method for manufacturing these sites is contained in an unclassified construction document provided by the Army Corps of Engineers that would be available to virtually any potential adversary. As indicated in the appendix it takes a considerable amount of time to prepare one of these fuel sites and the construction has certain identifying characteristics that indicate the true nature of its intended purpose at almost any point during the construction cycle.*

While these emplacements are easy targets for a blast wave, another method of detonating a warhead over a target, namely an air burst triggered by some sort of altimeter is a particularly effective method of decimating the site. The pressure wave created at altitude spreads more evenly and further than a ground burst, thereby insuring a larger damage radius. Timing an air burst to occur at the right moment is not a simple problem, but nonetheless its results are so spectacular that a missile power expecting to use its missiles against military target would be foolish to overlook this possibility

6) Ammo dumps. There were 250 major ammo dumps of one quarter square kilometer in extent and 1200 minor ammo dumps of 1/20 square kilometer in size pressed into service at one time or another in the Gulf War. These were the battalion level ammo dumps. At the Corps level various munitions were collected in large open and undefended areas at two sites in the desert. These corps level ammo dumps exhibit all of the same characteristics that make the fuel bladders such lucrative targets, namely a large exposed surface area and a combustible or deflagratory material that augments the initial blast created by the missile warhead. An accuracy of two hundred meters allows a missile power to seriously consider attacking an ammo dump with some possibility of actually hitting the target.

2) Supporting technologies

Over the decades of the Cold War the United States spent approximately ten percent of it gross national product on defense and of this amount approximately ten percent was invested in our missile arsenal. The Soviet Union spent a far higher amount of it national treasure matching the arsenals of the West. These funds were spent not only for the purchase of ballistic missiles themselves, but for an array of supporting hardware and increasingly more advanced warheads to make the missiles increasingly more potent.

Missile expenditures have been earmarked for technologies both on board the missile and external to it, but nonetheless needed to keep the missile functioning as its role in overall strategic planning has been defined. Such things as improved guidance systems for advanced ICBM's constitute examples of the internal supporting hardware. At the beginning of the Cold War, the Atlas missile could deliver a nuclear warhead no closer that about ten kilometers to a target. Three decades later the AIRS class guidance system on the MX delivers a warhead to less than three hundred meters of its target. External technologies are exemplified by *communication networks that allow a national command structure to direct fire from secure bunkers during a war, and by tracking and data relay satellites that warn of impending missiles attacks.*

In microcosm, a newly emerging missile power needs some form of these same supporting structures if the missile force is expected to be used effectively in combat. In the paragraphs that follow some of the major supporting equipment has been identified and described.

i) Warheads

The warheads a commander selects to achieve a tactical military objective are different from those selected to disrupt civilian operations, and if ballistic missiles are used in conjunction with military campaigns then a suite of warheads is a requisite foundation of an arsenal. In some cases it doesn't matter if the intended target is a military one or a civilian one, the proper warhead will be the same in either case. Chemical warheads undoubtedly disrupt military operations and slow troops in the field, but these same weapons launched against a city will have provide just as much devastation upon impact. On the other hand, a chemical warhead has little or no chance of ravaging a dam or a petroleum refinery. So a panoply of devices is required and these devices must be universal and interchangeable enough to be quickly fitted onto a missile in the field.

When a country has available to it a host of different warhead types, the planning and execution of an attack must take into account the most effective way to use the proper warhead. A survey of the major warheads shows that there is a virtually limitless set of options available for planning military targeting.

1) Nuclear warheads. While the U.S. and the Soviet Union have introduced thermonuclear warheads into their arsenals in the past thirty years, a device as sophisticated as this is not required for any purpose. Most missiles covered by the MTCR can carry simple fission devices without any modifications. Following historical trends a rough upper boundary of 40 kilotons on these devices can be expected. A forty kiloton nuclear device has the power to destroy any structure hardened to one hundred psi at a radius of one kilometer. This is a threshold of sorts in that it is roughly equal to the CEP of most missiles in developing nations. When the Cep is equal to the damage radius then no further gains in accuracy are required to achieve a strategic objective.

Possession of a nuclear weapon among smaller nations almost insures that any adversary's target can be destroyed. If a country uses the nuclear weapon in a counter force mode there are very few targets hardened sufficiently to withstand the blast. Those few targets, maybe hidden deep underground, in tunnels and in caves which call for a more accurate nuclear warhead, are probably better attacked by some other means.

Used to target any war supporting civilian enterprise the consequences of a nuclear attack are equally grave. Dams, canals, ports, and other such elements of the civilian infrastructure can sustain a ten psi blast. Therefore a nuclear warhead can be used in the same way that a conventional high energy warhead might be, namely, to achieve a leveraging effect.

Thus a nuclear warhead demands no further improvement from the missile in order to be an effective weapon. The only other specification incumbent upon the missile might be a great enough range to reach the selected target.

2) Conventional high energy warheads. In the purest sense high energy warheads, those made up of nitrocellulose, nitroglycerin compounds or TNT, create damage in the same way as nuclear warheads, by creating a blast of air that bursts upon the target. Conventional high explosives however have a longer pulse duration and few or none of the radiological effects such as prompt X-rays, which might induce a combustible target to burst into flames.

A conventional high explosive warhead can only generate about one fifty- thousandth of the blast pressure of a first generation nuclear warhead and consequently to manifest any damage at all at a target, the missile must impact extraordinarily nearby. In some cases a conventional warhead still creates more damage than simple physics would predict, particularly when its shock couples with the structural characteristics of a building, or when shrapnel from the detonation carries away and directs the blast energy at specific weak points. Shrapnel and blast debris heavily damages such things as radar antenna, air fields with planes parked in close proximity and other lightly fortified, high value targets. Clever design and shaping of the warhead's blast pattern focuses the energy and creates an even higher level of damage.

In most cases the blast created by a conventional high explosive warhead, is more effective if the detonation occurs in the air at between fifty to one hundred meters over the target. To support this level of precision in the detonation a sophisticated arming and triggering device must be used in the warhead to initiate the warhead. It is possible to trigger the explosion with a radar altimeter or other active sensing device that determines the exact height of the missile's trajectory above the ground. Usually contrivances that rely on barometric pressure, sensed acceleration, or time of flight are too inaccurate to be truly effective.

3) Fuel/Air explosives. A fuel/air explosive magnifies the destructive power of a warhead by using oxidizer that is present at the site of the explosion, rather than carrying this oxidizer along during the missile's flight. If oxygen in the air can be exploited generally eight to nine times as much fuel reagent is carried by the warhead and the blast created is correspondingly larger. Fuel/air warheads deliver many times the energy of conventional high explosives such as TNT. In addition, they impart a shock to a structure in a lengthy pulse *rather than an instantaneous jolt and in general this does a larger amount of damage.*

Five hundred kilograms of fuel air explosive detonating within 50 meters of a bridge will damage the structure regardless of the orientation of the bridge to the axis of the blast. At 100 meters the level of damage will be more superficial. This same warhead must detonate within 50 meters of a dam to inflict a significant level of damage.

Fuel/air explosives are still in the prototype phase in the United States and it is unlikely they will be found in smaller nations in the near future. The potential they hold for use in ballistic missiles, though, no doubt makes them likely candidates for exploitation by newly emerging regional powers.

Fuel/air explosives do require a fairly sophisticated dispensing mechanism, one that atomizes the fuel into a fine vapor which then combines with oxygen in the air at a proper stoichiometric ratio to maintain combustion. Another device must be incorporated into the warhead to simultaneously ignite all of the explosive material at once. Otherwise the blast of one part of the detonation blows the rest of the vapor cloud out of the vicinity before it can ignite. The dispensing mechanism can be regarded as part of the warhead infrastructure that must be developed in conjunction with the warhead in order to make it a viable threat.

4) Anti-personnel weapons. If the military target of interest is a concentration of troops, military commanders might choose to use anti-personnel weapons such as fleschettes on ballistic missiles. Fleschettes require some form of propulsion, but this is provided by a conventional high explosive. With proper aerodynamic design fleschettes can be propelled to a distance of a hundred meters or more from the site of the original impact. Individual darts that compose a fleschette cloud are lethal at weights as small as 20 grams. Thus a one thousand kilogram warhead with 200 kilograms of propelling charge is capable of strewing as many as forty thousand fleschettes over an area of thirty thousand square meters. If only one tenth of one percent of these fleschettes were effective, four hundred troops in the field could die.

Another form of anti-personnel weapons includes incendiary or blistering agents. The principal example of this category of weapon is napalm or its derivatives. Agents such as napalm do not require the same degree of accuracy from a ballistic missile as detonating warheads. Despite the notion of circular probabilities contained in the figure "CEP", ballistic missiles are more likely to accumulate errors in the down range direction rather than the cross range direction. Hence, if a missile is launched with the proper orientation to a battle line, and napalm is dispensed in the terminal few seconds of the flight a considerable fraction of troops on the line could be exposed to its effects.

5) Chemical agents. If the ultimate purpose of a missile attack is to slow or arrest a troop advance chemical warheads provide a possible option to a commander. The *most likely agents compatible with ballistic missiles are Tabun and Sarin as well as their derivatives. These agents mix well with secondary binders such as poly-methyl-methacrylate and in general are stable enough to remain in the warhead for extended periods of time. One exposed to sunlight, however, the agents have a tendency to break down rapidly by photolysis. A persistency of six hours or less mean that the chemical must be frequently reintroduced into a theater if a battle takes longer than this amount of time. A further disadvantage to chemical warheads is the easy set of preventative countermeasures which can be used. Most chemical weapons suits isolate the wearer completely form the environment and are impervious to chemical agents. Admittedly, chemical suits slow operations in the field, but delays of a few hours can be accommodated in most military planning.*

Combining chemical warheads with ballistic missiles presents other problems that must be solved. The foremost problem is reentry velocity. Ballistic missile reenter the atmosphere at speeds of between one and six kilometers a second. These speeds make it difficult to properly dispense the chemicals without them interfering with the air stream in such a way as to completely destroy their lethality. A related problem is the cloud of the agent that is dispersed. As the missile dispenses chemical agent its forward velocity will be much greater than any side velocity, leaving it to form a highly elongated cloud. Unless this cloud can be oriented preferentially along the axis of a similarly shaped target most of the agent will be useless.

To date dispensing mechanisms have been simple, exploiting a pressure differential that naturally arise in the airflow around a warhead in flight to drive the chemical agent from it canister. In the future countries may develop smaller cartridges capable of independent flight that could circularize the shape of the dispensed cloud. These advances, however use up useful payload and thereby diminish the overall weight of the agent that can be delivered.

6) Biological weapons. Both wet and dry spores of various neurological viruses have been developed as biological weapons and could be used on ballistic missiles. Dry spores of anthrax are particularly threatening since they do not lose their potency when exposed to a supersonic airstream. These spores then infiltrate the body directly or through the food chain until they find a host.

Biological weapons do not hold the same potential as a military weapon and will probably be used only as terror weapons if at all. Most pathogens are slow to work their way through the body, and consequently may have a pronounced effect on troops only several hours or even days later. A delay of several days would not necessarily immediately affect military operations.

ii) Intelligence gathering

In order to adequately intelligently attack any targets and to select the correct warhead *for the purpose some form of intelligence gathering apparatus is mandatory. Time dynamic targets must be watched and the results must be relayed to commanders in the fields in a timely manner. But time dynamic targets create their own demands on the intelligence gathering capability.*

First, the intelligence must arrive within the time horizon of the launch operation and the time it takes to communicate the intelligence to a commander in the field. Failing this the field commander is still launching a blind attack which will be no more effective than if the support infrastructure did not exist in the first place.

Second, the intelligence must have sufficient detail to determine which warhead is required to accomplish the mission. Incendiary devices may be prescribed if ammunition is present, say, during a ship unloading procedure, but in other cases a high explosive warhead might be the best choice if the intention is to sink a ship. Powder bags that are stacked on a pier may be readily apparent to a person stationed near the dock, but would be invisible to overhead imagery.

There can be any number of ways for gathering the information required to support an attack. Four methods are reviewed in the paragraphs that follow each requiring a higher degree of technical sophistication.

1) Pre-surveying a target

If the target is not time dynamic or if its value varies in a predictable manner, the intelligence gathering function becomes much easier. These types of targets are represented by such facilities as dams and nuclear power generating stations. To support a missile raid, particularly one that is highly accurate and not simply a scatter shot salvo, the target coordinates must be known with a higher precision than can be determined from conventional maps. This can accomplished in a variety of ways.

One method to pre-survey a target is to use a commercial grade GPS receiver and simply visit the target with the receiver. This requires some preplanning and can probably only be accomplished in peace time, but nevertheless a substantial target base can be built up in this manner.

Another method is to use geographical information that has been gathered for other purposes. It is possible to simply purchase satellite data from a number of vendors, the principal one being the French government and their quasi-public agency, SPOT. SPOT images presently cost roughly two thousand dollars, and are available within about two weeks. These images have sufficient resolution to support virtually any targeting activity.

Higher resolution images can be obtained from other existing photogrammetric surveys that have been performed by various governments to inventory natural resources or *agricultural areas. Converting these images into targeting maps is a matter of simply applying existing software packages to the problem. Intergraph, Inc. sells both the computer hardware and software to convert photogrammetric surveys into conventional topographical maps.*

The coordinates gleaned from these sources require no further evaluation to plan an attack. If a military commander wishes to target a dam, for instance, the coordinates are simply loaded into the guidance system of the ballistic missile and the attack is launched at the most convenient time.

2) Humint

Confederates stationed in the vicinity of a target may easily observe any operations and relay firing instructions at the most propitious moments. Modern cellular communication equipment allow these field agents to communicate almost instantaneously with any second party. If the country that has fielded the agent is worried that he may betray his presence by calling directly on an unsecured line, it would only delay the information from arriving in the attacking country momentarily if the information had to be relayed through a third party in another country.

In the decade to come cellular communications will make virtually any person fully autonomous from conventional phone systems. Direct relay to satellites or microwave repeater stations do not lend themselves to the kind of tapping that has allowed these phone calls to be traced in the past. If secrecy is still a concern standard encryption logic already exists to quickly and easily create a virtually unbreakable code that can be transmitted digitally to the attacking country. It is not feasible, nor can it be expected that all of these communication devices or the paths of transmission to the attacking country can be destroyed at the onset of a war as it has been possible to do in the past.

If a missile arsenal is extensive and many targets must be followed to support a targeting doctrine, then naturally a number of agents must be placed in the field as forward spotters. Each field agent obviously heightens the risk of exposure for any such operation and an attacking country may not wish to mount such a labor intensive effort.

3) Air breathing photo reconnaissance

More elaborate methods of gathering intelligence include using unmanned aerial vehicles (UAVs). For a country technologically knowledgeable enough to build or acquire a UAV there are many advantages to doing so. UAV's have small radar cross section and are therefore difficult to detect using conventional defense radars. Given a proper guidance system the UAV can operate autonomously and therefore maintain radio silence so it is not detectable by extraneous transmissions. As long as it is radio quiet it is difficult to detect by conventional facilities located in the field. With the right design a UAV can also fly at *extremely high altitudes and remain aloft for a considerable period of time. Because air defense radar units paint large portions of the sky with low energy emissions only high profile targets usually appear. Since the UAV does not need to operate in theater to accomplish its mission, but instead can be at altitudes as high as sixty thousand feet, and since it can be made out of lightweight plastic or phenolic material with a low radar cross section the chances of detecting it are small. Air defense radars also use thematic images rather than actual data to present information to an operator. The thematic image is a result of sorting through a countless number of images and sorting them by their likely mission. Objects on aggressive trajectories are dealt with immediately and those more benign appearing objects are treated more routinely. If a UAV is detected the chances are that these sorting algorithms will mistake it for commercial air traffic and dismiss it are quite high. UAVs might even spoof the operations of commercial aviation traffic as they approach a defended region.*

By operating in total autonomy the information that a UAV provides does suffer some in its freshness. The total turnaround time for information depends on the distance from the gathering site and the interpretation site and the time span over which the information must be gathered. The minimum turnaround time is the round trip flight time from the target to the point where the intelligence will be analyzed. Any loitering at the target site adds to this period of time. Still, it is apparent the UAV's can deliver useful information in periods of much less than a day.

UAV's offer some further advantages. They don't risk a pilots life and they can be launched and recovered from a country other than the one where the information will be used. In some cases, a high altitude UAV might patrol along the border of a non-combatant state with perfect diplomatic immunity. Shooting the UAV down could if it is within the borders of a third party country risks the possibility of widening the conflict. In any event it is open to interpretation as a hostile act.

4) Satellite photo and radar reconnaissance

Satellite imaging systems also provide the opportunity for intelligence gathering. The ship traffic into and out of ports, large troop movements the marshalling of trucks, armored personnel carriers, or the construction of large logistics support installations are all visible to existing satellites.

Launching a satellite and retrieving information from it is a daunting technical task, and most newly emerging missile powers do not have the wherewithal to accomplish the job alone. However, a country is not obligated to launch its own satellite in order to exploit this technology. Most satellites directly broadcast their data streams to all ground stations in their footprint. A number of ground stations exist throughout the world, and there is evidence that some clandestine ground stations have even been constructed. In the decade to come, these ground stations will shrink in size and become mobile. Already companies have offered mobile *ground stations for sale, and they have been contacted by foreign purchasers. Any country equipped with such a ground station can exploit the information that is broadcast by a passing satellite.*

It may seem that the best preventative for this contingency is to shut off broadcast transmissions during a crisis. This is not always possible. The French SPOT system supposedly shut off its operations during the Gulf War. However, a closer examination of this claim reveals a more complicated situation. For reliability reasons satellites usually do not cycle frequently through an on-off command. The SPOT image information cannot be turned off for this reason. On the other hand, it is possible to shut off the ephemeris data, the information band that indicates where the satellite is in its orbit, the direction it is pointing and other vital information about its condition. This information is used to provide corrections to the information contained in the image data stream. These "geographic" corrections make a processed image clearer with a better geometric appearance. Of course, to simply determine if a ship is in port or if troops are moving through an area these refinements to the image are not required. Therefore, pirating an image allows a country at war to access some highly useful information and provides an incentive to build a ground station. Regardless of the content of the transmitted data stream some useful information will be contained in any picture.

A second correction is generally made to images transmitted from satellites. These are called the "radiographic" corrections, although they include all corrections to the image field to make it match ground truth. Radiographic corrections are made to an image as a computer post processor operation at the ground station. Presumably, rogue ground station would not have access to the pixel-by-pixel corrections that would be needed to make these processes. On the other hand, prior to a conflict it would be possible to build a data base of this information by sampling pirated images and then comparing them to images that had been purchased from the agency that collected the data. In this way a data base of sufficient accuracy could be built up to satisfy any needs for higher resolution during a war.

If this method is unacceptable because it might expose a ground station, a determined missile power could build its own data base by sampling scenes that are known to be photographically neutral such as broad areas of oceans or deserts and determining a most likely radiographic correction ensemble.

The problem with using satellite information occurs in the turnaround time that is associated with these operations. The primary problem with turnaround time is the ground revisit time. Since satellites assets are relatively sparse at the moment, a country must wait until the satellite passes over a battlefield or other point of interest by chance. Presently, the Landsat satellite has a maximum revisit time of seventeen days. At higher latitudes the expected revisit time may be shorter, but in any case it is much longer than the turnaround times associated with UAVs.

As more satellites are orbited in the years ahead the time between passes of some form of satellite whether it is radar, electro-optical or infrared will be reduced substantially. Of course, pirating countries will also be obligated to invest more time in studying the operations for each of these individual systems, but nonetheless the incentive to do this will be very high since the investment will not be for the much more expensive launch and satellite maintenance operations. Besides, if present launch schedules are maintained by the year 2005, there will be enough imaging systems in space that virtually every point on the globe will be visited once every two hours or so.

At present, operations which require a significant amount of time to complete such as unloading a ship, are more susceptible to detection than short duration phenomena. In the coming decade a country cannot expect to be able to completely mask an operation which takes significantly longer than a day.

After the operation has been detected it takes a certain amount of time to process the image and relay it to the cognizant parties. If the image is transmitted directly to a ground station properly equipped to process it, the full correction cycle requires about an hour at present rates. By the time LANDSAT 7 is launched, this process will consume less than 6 minutes. After the image is processed it must then be analyzed by a photo interpreter, trained in military operations. This process can consume an hour or more depending on the skill of the interpreter, and the quality of the image. If this capability is not immediately available and a country must wait for an allied country to process the data the total turnaround time can take significantly longer, perhaps as long as a day.

It seems realistic to believe, then, that satellite reconnaissance of a battlefield takes a substantial portion of a day to complete, with the possibility that this process can be reduced to an hour if the satellite is in position to capture the image, and the rest of the processing apparatus is in place.

Satellite imagery can be useful for surveying targets that cannot move in shorter than this one hour time frame. Such targets include ports with large stores of ammunition standing at a dock, troop concentrations, convoys of trucks where the destination is clear and the road determines the route that the convoy will follow, and airports with large fleets of planes that are either in transit or in storage.

3) Improving ballistic missiles

As they now stand, ballistic missiles are not an overwhelming threat to the U.S. or our allies' conventional war-fighting ability. There are some improvements that can be made to ballistic missiles that make them more threatening, however. These improvements are on the horizon or are already in production on some proliferant missiles.

i) Range

Numerous examples have been given to prove that one of the critical attributes of a missile is its range. Single stage missiles are optimized to reach about 300 kms and in some case 500 kms. Beyond this the rocket design itself becomes quite inefficient unless some staging mechanism is included. Certainly single stage missiles can be built that reach more than 300 kms. The CSS-2s that China sold Saudi Arabia are a prime example. The missiles have a range of over two thousand kilometers. On the other hand, their payload capability is about 500 kgs or only about half of the payload of the Scud. Moreover, the Saudis paid a reputed $50 million dollars per missile as opposed to the $1 million dollar plus price of the Scud. Consequently, the cost for delivering a kilogram of payload has become exponentially more expensive with these inefficient devises.

Staging a missiles allows it to reach greater range very efficiently. A perfectly optimized modern missile reaches 300 kms. with one stage, 650 kilometers with two stages, and about 1200 kilometers with three stages. Advanced missiles stretch these numbers somewhat, so the ten thousand kilometer MX is optimized with four stages.

It is important to note that when the Chinese first offered their M-11 missile for export in 1987, the device was displayed at the Peking air show as a two stage missile and its range was stated as 1000 kilometers. This falls exactly within the boundaries of an optimized modern solid propellant missile. Adding a second stage to the existing missile is not an onerous chore. Presumably, the fittings maintain the overall structural stiffness and factors of safety of the first stage in the original design and so the structure could easily accommodate a second stage on top. It is also doubtful whether the Chinese have changed the guidance system on the missile with one that is not capable of accomplishing the staging operation. Therefore, to create a longer range missile a proliferant country merely needs to buy from the two stages in separate packages from the Chinese.

Longer range missiles significantly increase the target base that a missile power can contemplate, but they have an even more important advantage. They give the missile power more latitude in selecting launching sites and therefore more native territory in which to hide the missile. During the Gulf War, the coalition neither found nor destroyed any Scud missiles while patrolling the mobile launch sites. With a one thousand kilometer range missile the Iraqis would have available to them nearly four times as much territory in which to hide the missiles, making the possibility of finding and destroying them nearly impossible.

ii) Accuracy

The CEP of the Scud missile encompasses an area that is roughly equivalent to forty of the fuel depot installations described in the appendix. Targeting such a facility with a Scud is impractical. (Approximately 400 Scuds would have to be launched to have a ninety *percent probability of destroying the entire target). Improving the accuracy of the Scud to one-quarter of its present value or roughly about the same accuracy as the Chinese M-11 missile, shrinks the ratio of CEP to target area to about five to one. Now a much more modest raid size can insure at least some damage occurs to the fuel depot.*

How can this accuracy be gained? The most elemental improvement to the Scud is to separate the warhead upon reentry. As it now stands the entire Scud reenters the atmosphere and the large projected area of this missile makes it easily displaced from its trajectory by atmospheric phenomena such as the jet streams or differences in the relative humidity. A modern warhead with an efficient aerodynamic design would allow better penetration and a much higher accuracy. Simply separating the warheads would cut the current Scud CEP roughly in half.

There are a number of more advanced techniques to further improve the accuracy. For one thing, the warhead could be reoriented in exo-atmospheric space so that its nose pointed along the path of its flight. This simple procedure would eliminate errors in the trajectory that crop up from oscillations as the warhead penetrates the atmosphere.

If a mechanism is included to realign the direction a warhead points as it reenters the atmosphere, this same mechanism can probably spin the RV for gyroscopic stability. Once an Rv is spun it has a tendency to quickly damp out all nodding motions that are created by perturbations created in the atmosphere.

These two improvements alone cost very little in absolute throwweight, but can improve the accuracy by fifty percent. More elaborate schemes are accomplished by using the bus as a post boost vehicle. The buss consists of an accurate guidance system such as GPS or a star tracker and a small rocket motor that is used to steer out any errors that accumulate during the boost and mid course phases of the trajectory. Bussing an RV reduces the expected error at the time of penetration of the atmosphere to about a third of the total error for an un-bussed system. There is however a significant throwweight penalty associated with using a bus. Generally a bus consumes half of the total throwweight for a missile. If the warhead uses a simple conventional munitions the additional accuracy may not compensate for the loss in payload. The loss in extra payload for a bussed chemical warhead surely erases any gains that are expected from improved accuracy.

In the future a complete guidance set will not be required and some of the lost throwweight can be reclaimed. A simple GPS receiver with a hand-over update for position will have sufficient accuracy to eliminate al flight errors.

With the implementation of GPS receivers, virtually all of the error associated with the launch and midcourse portions of the flight can be accounted for and corrected. Nonetheless a significant error will accumulate during the atmospheric portion of the flight even when *some of these new technologies are included with the missile. These errors will limit the accuracy of any missile to 250 meters regardless of the type of update scheme used. 250 meters CEP combined with a conventional high explosive warhead does not provide a sufficiently high damage expectancy to have a large lethal radius.*

Inaccurate missiles will therefore drive a non-nuclear nation to seek other avenues of attack including wither cruise missiles or terminally guided RVs. With terminal guidance the attacker can repeatedly hit a target within 50 meters. Terminal guidance comes at an enormous cost however. Even a simple missile such as the Scud might cost fifty million dollars when equipped with a terminal guidance package.

iii) Inventory

The development of defensive batteries as well as the inherent inaccuracies of the ballistic missile may lead a commander to plan large barrage attacks in which many missiles are launched simultaneously at a target. Defense planners know that salvos of missiles will allow at least a few to penetrate the defense. To sustain a salvo attack, multiple missiles must be available to a commander as well as similar multiples of all of the other equipment including launch pads, mobile launchers, fuel and oxidizer trucks and skilled launch crews. Each of these items drives up the cost in money and manpower of making a salvo raid.

To overcome this problem countries will undoubtedly seek ways to lessen the cost of missile operations as well as the cost of missiles themselves. There is little correlation between a missiles's range and its price particularly if the missile features advanced technology or an innovative design, but nonetheless it is clear that extended range comes at a great price. To support an extended range launch capability, particularly one that is mobile the cost burden becomes even more worrisome. Portable launchers for a device as simple as the Scud can be manufactured from flatbed trucks. Multi-stage missiles, on the other hand, require elaborate tracked vehicles and erection cranes capable of lifting the much larger missiles.

Countries with longer range missiles and the expectation that they can be used in salvo attacks will be looking for methods to reduce the price as much as practical. Costs can be reduced by first producing the missiles indigenously. A $1.5 million Scud can be manufactured for about $400,000 in a country with a standard of living about one third that of the United States. There are some high technology items that are difficult to manufacture, so the total annual production rate might run about fifty missiles.

In this regard solid missiles are easier to produce indigenously than liquid ones because less advanced machining processes are needed and there are fewer parts. Since solid missiles require less maintenance and less launch support hardware, there are supporting reasons as well to build solid missiles.

It would take a country like Iraq about five years for start up costs to amortize out the price of a missile and for native production to be cheaper than simply purchasing missiles abroad. When the cost of support hardware is included in this computation though, indigenous production looks much more attractive. A producing country such as Iraq could build a missile arsenal of 500 missiles in about a decades time.

iv) Defense penetration

A salvo launch is not the only method to achieve defense penetration. There is a direct correlation between range and reentry velocity and between reentry velocity and the ability of a defense interceptor to hit an incoming threat object. Missiles arriving at the end of a two thousand mile trajectory impact at nearly twice the velocity of those entering from five hundred kilometers. This greatly complicates the possibilities for missiles defense. It is impossible for the present Patriot to intercept the CSS-2. As missiles in the hands of smaller nations achieve greater range they will render obsolete most existing defenses as a matter of course.

Modifications made to a missile for other reasons also greatly assist a warhead in penetrating defenses. A separating warhead on the front end of a missile presents a much smaller radar cross section to the defense radar. If the missile has not been detected in launch, and tracked from that point, then the chances of detecting it in the terminal phases of its flight are much smaller.

Separating the warhead and giving it a higher ballistic coefficient also means it will arrive at the ground with a higher velocity. The higher velocity makes the warhead more difficult to hit with a conventional terminal interceptor.

Appendix 1 - Fuel Storage Facilities

Introduction

During the Gulf War the U.S. Army and Marine Corps stored petroleum products, principally JP-8, in above ground bladders at a total of 245 sites. The petroleum deposited at these facilities constituted an expected reserve sufficient to support Marine amphibious operations and Army maneuvers for approximately 90 days. These facilities were built from scratch during the five month period prior to the commencement of hostilities. Judged by the rate of consumption experienced for all Army and Marine maneuvers including tank operations, Army Air helicopter support flights, electrical power generation and troop movements during the four day ground war, the storage capacity, in place, in Saudi Arabia appears to correlate well with the anticipated requirements for a ninety day campaign.

A number of factors unique to the Gulf War made these facilities relatively inconsequential to Allied logistical concerns when compared to more likely and anticipated conflicts. The Coalition forces had the good fortune to fight a relatively brief engagement, to function from a country well supplied with petroleum refining capacity and an extensive delivery network, to have short and well protected supply lines and to enjoy a limited civilian urgency for petroleum products.

In the event any one of these buffering conditions had not been present the fuel storage bladders would have provided a primary, and lightly fortified, node that could have been vulnerable to ballistic or cruise missile attack. To explain the circumstances under which fuel bladders might present an attractive and high leverage target, the following paragraphs first describe the design, emplacement, and use of the bladders, then the vulnerability of the bladders to conventional missile attack and finally the possibilities of force reconstitution or the related consequences of operating at diminished capacity.

Facility Description

There are two types of facilities that must be described. The Army refers to its system as the Tactical Petroleum Terminal or TPT. Currently seventeen TPTs are in inventory. Ten of these seventeen were deployed to Saudi Arabia to support the Gulf War. Each TPT has a capacity to hold 3.6 million gallons of fuel distributed throughout a network of bladders which individually hold fuel in increments of ten, twenty, fifty, and one hundred and twenty thousand gallon units. The network is connected by extensive plastic or polyester tubing, and fuel is delivered by multiple spigots at dispensing stations. The entire unit can be filled or resupplied by sea or land tankers.

The Marine Corps maintains a similar capability referred to as the Amphibious Assault Fuel System or AAFS. Most AAFS systems have a more modest capacity of six hundred thousand to one million gallons of fuel. The smaller capacity is compensated for by the greater number of AAFSs available. During the Gulf War the Marines deployed two hundred and twenty five AAFS's which was "about two thirds of available quantity". Filling and dispensing operations for the AAFS'S is almost identical to the TPT.

Assembly and installation of one TPT or AAFS requires four to seven days under normal conditions, although the pressure regulators and piping has been designed to be installed in forty eight hours under emergency conditions. As operation Desert Shield progressed it took an average of about ten days to install one AAFS. It is unclear if this was due to a shortage of trained crews or because the tank farms were not considered a priority because of the widespread availability of refinery products in Saudi Arabia.

Besides assembly, fully fueling the bladders also consumes a considerable amount of time. The pumping system can supply fuel from ships at 600 gallons a minute or trucks at a rate of 150 gallons a minute so to fully fuel an AAFS from a ship takes a little over one day and from a truck it takes four and one half days.
A TTP fueling cycle requires sixteen days from trucks and four days from a ship. Since the pumps for dispensing the fuel are larger the entire network can be emptied in about half the time it takes to fill it.

Once in operation the pumps, bladders and piping network have a mean time between failure of forty five days. Generally, enough critical spare hardware is kept in the field to perform at least three complete replacements. On the other hand, the valves, pressure regulators, manifolds, filters and monitors are not off-the-shelf hardware, but rather are custom designed for this application. Major suppliers in America can produce the hardware for a full TPT in about ten or fifteen working days.

The bladders are constructed of nylon fabric impregnated with a chemical that resists reaction with fuel. They can withstand about 2 psi of blast overpressure when filled fully and about 1 psi when partially filled. There are about three and one half miles of hoses in a typical TPT installation. The hose is constructed of wire reinforced plastic. At least some of the hose and all of the pressure monitoring equipment lies above ground. The blast overpressure required to rupture this equipment is unknown but 2 psi of blast overpressure will surely impede or impair the operation.

In most instances the TPTs and AAFSs are meant to be assembled no more than three miles inland from a beach. In extreme cases fuel can be pumped as far away as a mile feet from the main pump at a greatly reduced flow rate. (Diesel can be pumped the shortest distance - maybe three thousand feet). A second pumping station is required if the situation requires a greater run. Alternately, fuel can be pumped uphill to an elevation of 300 feet.

Installing a second pumping station to overcome these limitations greatly complicates the operations and the supply of spare parts for repair.

To install a TPT, a site is first selected. It generally must meet the requirements of being level - to deliver earth moving equipment and the component hardware - have a deep ground water table, and be comprised of loosely compacted soil or gravel. After the site is selected a depression is carved out of the soil with the approximate dimensions of 100 ft. by 100 ft. for a 60,000 gallon bladder. Following the excavation a berm is constructed. The berm is eight feet high by eight feet wide. The bladder is then rolled out and the hoses are connected. After the fuel is pumped into the bladder a second earth moving operation partially fills sand back in around the perimeter of the area to remove some of the stress on the seams. These barricaded containment revetments must then be separated by about 200 feet to prevent sympathetic deflagration in the event a neighboring bladder should ignite. This spacing does not consider the contingency that debris from an explosion could also ignite the bladders in the vicinity.

A fully-fueled, one million gallon capacity, site covers approximately twenty acres. Its lineal extent is roughly 2000 feet on a side. Including tanker trucks, dispensing stations, manifolds, and other soft points in the system, ten percent of the surface area is covered by high value targets.

Target Vulnerability

The vulnerability of gas storage facilities to conventional missile attack first depends upon the ability to advantageously target them. Attacking them after they are installed and filled would seem to provide the best opportunity for success. This strategy offers the possibility of a sympathetic detonation or at least the chance of destroying a piece of critical hardware, which would in effect trap the fuel until the hardware could be replaced or repaired.

Even before TPT's are built it is possible to do some limited deductive reasoning about their potential locations. The figures cited above about pumping distances, maximum grades for the pressure regulators, and other detailed technical specifications, come from an unclassified U.S. government publication (U.S.GPO TM-11275-15/3A). Monitoring any possible locations for unusual truck or ship traffic could give the first indication that a TPT was being constructed.

The extensive acreage a fuel supply network such as the TPT covers would make it visible to space-borne assets. SPOT and Landsat can both easily resolve the excavations as well as the character and layout of the structure. Spot revisit times of seventeen days make it impossible to say with certainty that the site would be detected as it was being constructed, but since the facility stays in place for extended periods of time, it cannot go unnoticed for *long. Once again, by narrowing the field of candidate sites for possible locations, a determined party could greatly reduce the number of SPOT images that need to be inspected.*

Once the TPT is identified, targeting it with conventional missiles is the next step. Even relatively inaccurate missiles such as the Scud-B have some capability against such extensive targets. At 1 kilometer accuracy, fourteen Scuds loaded with a typical high explosive warhead such as HMX would be assured of falling somewhere within the fuel farm and puncturing at least one bladder. If one Scud hit certain high leverage areas within the facility such as the manifold or a pumping station the facility would be inoperative until replacement parts arrived. One TPT contains fuel for six days of ground war operations.

Missile Requirements

There are some simple improvements that could be made to the Scud to enhance its lethality against these targets. The Scud detonates with a contact fuse when it hits the ground. A simple barometric switch that would cause the warhead to detonate at 500 feet above the ground would extend the lethal radius of the warhead so that only six Scuds would be needed to hit at least one bladder and any Scud detonating within the fuel farm would probably burst two or more bladders. A conventional high explosive is probably not the most effective warhead for this type of targeting. Fragmenting warheads which carry high velocity shards of material in preferential directions would be ideally suited to puncturing a large number of the bladders. These warheads would not necessarily damage the pumping stations or pressure regulators but they could still cause sympathetic detonations in adjacent units. Another warhead which would cause widespread destruction is a simple incendiary device (not a fuel/air explosive) made of either magnesium or petroleum based viscoelastics. Such weapons have been widely available since the Second World War and one type, Napalm, was used extensively in Vietnam.

Going beyond the Scud, new missiles with better CEPs make the option of targeting fuel farms even more attractive. Only three missiles are required to insure some damage is inflicted when the CEP improves to 500 meters.