Global Studies/Physics 280: Session 21

Plan for This Session

Questions

News and discussion

Module 7: Efforts to Defend Against Nuclear Attacks

News:

Washington. President Trump has announced plans for a huge expansion of US missile defense with aim of destroying enemy missiles “anywhere, anytime, any place”

The Guardian

This article is more than **2 months old**

Trump announces huge expansion of US missile defense system

Arms control experts fear system review, unveiled at Pentagon, could fuel arms race with Russia and China

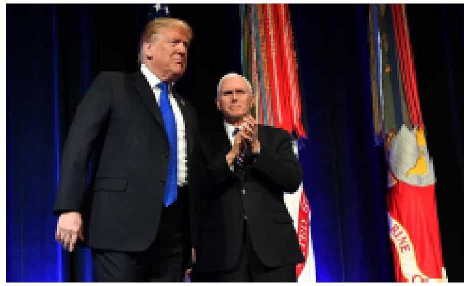
The missile defense review, which Trump unveiled on Thursday in a speech at the Pentagon, calls for a major upgrade in land- and sea-based missile interceptor systems, as well as the development of a layer of satellite sensors in low orbit that would help track new types of cruise missiles and hypersonic glide vehicles (HGVs) that countries like Russia and China are developing.
The review argues that nuclear deterrence is the main defense against major nuclear powers like Russia and China, which both own large and sophisticated arsenals. And it restates US policy that the primary aim of such defenses is to counter well-armed “rogue states”, North Korea and Iran.

The Pentagon review suggests that the system of sensors, radars and interceptors could eventually be used against a much broader range of adversaries, including defending US forces and allies in the Pacific and Europe against Russian and Chinese HGVs and cruise missiles. But Trump on Thursday went much further, presenting the plan as a potential panacea for future missile threats.

“Our goal is simple: to ensure that we can detect and destroy any missile launched against the United States – anywhere, anytime, any place,” Trump said.

News:

The Guardian



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Trump announces huge expansion of US missile defense system

Arms control experts fear system review, unveiled at Pentagon, could fuel arms race with Russia and China

"We are committed to establishing a missile defense program that can shield every city in the United States. And we will never negotiate away our right to do this."

Arms control experts expressed alarm at the review and Trump's presentation, warning that it would feed already substantial Russian and Chinese fears that US missile defense was aimed at blunting their deterrent. The review could drive those states to build more missiles with more capabilities to overcome US defenses, and trigger an arms race. "This is the action-reaction dynamic that we saw happened in the cold war and it's how we ended with 60,000 warheads," said Laura Grego, the senior scientist for the global security programme at the Union of Concerned Scientists.

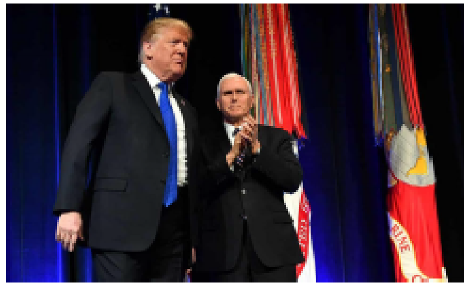
And there are also concerns over whether the very costly missile defense systems actually work. In tests that were tightly scripted, US interceptors hit their targets 50% of the time.

"Integrated, space-based capabilities are certainly worth exploring, but we don't have unlimited resources, so we must weigh investments among competing national security priorities," the Democratic senator Jack Reed said in a statement on the new review.

News:

The Guardian

It is unclear whether Congress will fund Trump's missile defense ambitions, especially with a Democratic majority in the House of Representatives. Congress crushed a similarly ambitious plan developed by the George W. Bush administration.



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Trump announces huge expansion of US missile defense system

Arms control experts fear system review, unveiled at Pentagon, could fuel arms race with Russia and China

The US has nonetheless spent nearly $300bn on missile defense since 1983, when Ronald Reagan launched his Strategic Defense Initiative (widely known as Star Wars), according to estimates by Stephen Schwartz, a senior fellow at the Bulletin of the Atomic Scientists.

Michael Griffin, an aerospace scientist who played a central role in Reagan's Star Wars scheme, is now under secretary of defence for research and engineering in the Trump administration, and has played a leading role in promoting the new missile defence plans.

He said that in view of recent technological progress, the new systems would be "affordable".
"It's not some outlandish number," Griffin said, but he would not give a cost estimate.
Melissa Hanham, an expert on weapons of mass destruction at the One Earth Future foundation, said that any idea that missile defence could limit the damage of a nuclear war was "fantasy".

If we invest as much money in lowering tensions and de-alerting missile systems, we would be safer by far," Hanham said.

Module 7: Efforts to Defend Against Attacks

- Introduction to Defending Against Nuclear Attacks
- History of Defending Against Ballistic Missiles
- Current and Proposed Missile Defense Programs

Introduction to Efforts to Defend Against Nuclear Attack

Types of Defenses Against Nuclear Attacks

Passive defenses (“civil defense”)

- Seeks to deter or mitigate rather than defeat an attack
- Requires sheltering and crisis relocation
- Has been embraced and discarded several times (1950s, 1960s, 1980s)

Active defenses (weapons to destroy weapons)

- Seeks to prevent nuclear weapons from detonating at their targets
- Requires destruction of delivery vehicles (aircraft, ICBMs, SLBMs, reentry vehicles, cruise missiles, etc.) before they reach their targets
- Must be nearly perfect to avoid enormous death and destruction (offensive weapons costing ~$10M can kill 1 million people and destroy $10B worth of property)

Passive Defenses Against Attacks

Sheltering (1950s,1960s,1980s) —

- Blast shelters (could withstand ~ 50–100 psi overpressures)
  - — Only a very small fraction of the land area of the US would be subjected to 50 psi, even in an all-out attack
  - — However, most people live in cities and hence would likely be subject to blast, fire, etc.
- Fallout shelters (could have protection factors of 100 against fall out)
  - — Radiation from fallout decays rapidly with time
  - — Cumulative exposure would still be serious
  - — Submarine attacks might continue for weeks or months
  - — Problems and costs of providing adequate sanitation, ventilation, food, and water are enormous
- Warning time could be very short (~ 10 minutes or less), so most people would not reach shelters

Passive Defenses Against Attacks

Crisis relocation (Reagan,1980s) —

- Plans developed by Federal Emergency Management Agency (FEMA)
- Plans called for evacuation of all urban and other “high risk” populations and quartering of evacuees in “host” communities
- There was confusion over whether many communities were high-risk or low-risk
- Feasibility of successful evacuation is doubtful
- Many urban areas and host regions refused to participate in planning, finding the concept unworkable and dangerous
- 1985, passive defense was again dropped

Current Direct Threats to the United States Posed by Nuclear-Armed Ballistic Missiles

Only two countries currently have nuclear-armed ballistic missiles that threaten the territory of the United States —

- *Russia*: currently has about 1,550 strategic warheads on delivery vehicles on high alert.
- *China*: has ~ 12 liquid-propellant long-range missiles; warheads are stored separately; has a solid-propellant program, DF-41 that has started deployment of two missile brigades with 12-24 missiles each (up to 10 warheads/missile, range of up to 15,000km)

The United States currently has about 1550 strategic warheads on delivery vehicles on high alert.

Country of concern —

- *North Korea*: has launched successfully two satellites, in principle such rockets should be able to reach Pacific Islands and the continental US. Payload unclear. Fissile material for perhaps 10 nuclear warheads. Possibly warheads have been miniaturized to fit on ballistic missiles. Short and medium range and long-range missiles have been tested.

Delivery Methods Other Than Long-Range Ballistic Missiles May Pose Greater Threats

Several countries are capable of developing mechanisms to launch SRBMs, MRBMs, or land-attack cruise missiles from forward-based ships or other platforms.

U.S. territory is more likely to be attacked with [nuclear weapons] using non-missile delivery means—most likely from terrorists—than by missiles, primarily because non-missile delivery means are —

- less costly
- easier to acquire
- more reliable and accurate

They also can be used without attribution.

Reducing the Threat of Long-Range Nuclear-Armed Ballistic Missiles

Different ways to reduce the threat of nuclear-armed missiles, such as —

- Developing friendly relations
- Use cooperative diplomacy, incentives, and disincentives to prevent the development and spread of nuclear and missile capabilities and to reduce and eliminate existing threats
- Plan to destroy threatening missiles on the ground (preemptive strike: “left of launch”).
- ***Attempt to destroy attacking missiles in flight***

Programs to Intercept Nuclear-Armed Ballistic Missiles Have Been Controversial. Why?

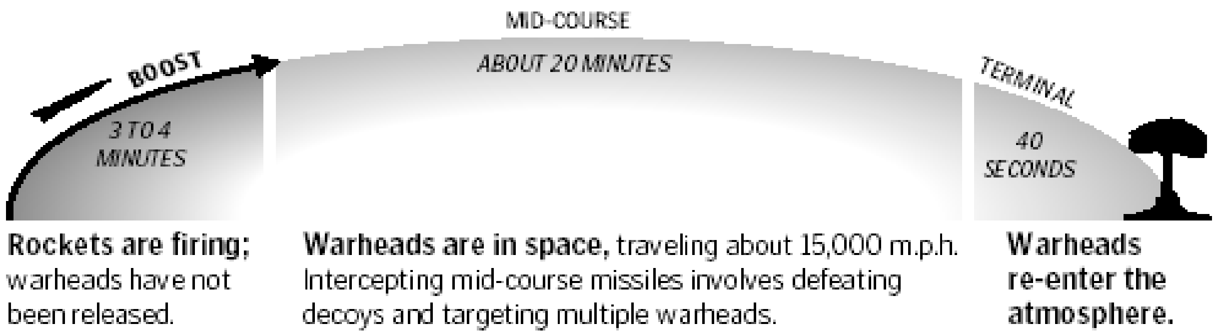
U.S. programs to intercept nuclear-armed long-range ballistic missiles have often been used for other purposes —

- As political bargaining chips
- To sidetrack or destroy arms control agreements
- To create a (false) sense of security
- To receive lucrative defense contracts

Programs to intercept nuclear-armed long-range ballistic missiles would *not* be controversial *if* —

- An effective defense was clearly possible using near-term technology
- Such a system could be built for an acceptable cost
- ABM programs would not cause other countries to do things that would end up decreasing our security
- ABM programs would not distract the U.S. from taking other steps that would be more effective in increasing our security

Phases of Flight of a Long-Range Ballistic Missile



Phases of flight —

- Boost phase (rocket motors burning) ~ 1 to 4 min
- Post-boost phase (MIRVed missiles) ~ 5–10 min
- Midcourse phase (ballistic flight) ~ 20 min
- Terminal phase (within atmosphere) ~ 30–40 sec

Types of re-entry vehicles —

- MRV = multiple RV (not independently targetable)
- MIRV = multiple, independently targetable RV
- MARV = maneuverable RV

Types of ABM Systems

'Terminal' defenses would attack RVs during re-entry —

- Traditional (radars & rockets armed with conventional or nuclear warheads)
- 'Simple/novel' systems (curtains of projectiles, 'dust defense' using buried bombs)

'Mid-course' defenses would attack RVs in space —

- Kinetic-kill vehicles or particle beams

'Boost-phase' defenses would attack missiles during powered flight, when their rocket motors are burning —

- IR sensors
- Kinetic-kill vehicles (KKVs), lasers, particle beams

ABM System Requirements

- Sensors
  - —Goal: detect, identify, and track targets
  - —Passive (optical, IR)
  - —Active (radar, particle beams)
- Weapons
  - —Goal: destroy missile boosters or warheads in flight
- Battle management capability
  - —Detection
  - —Identification
  - —Tracking
  - —Discrimination
  - —Targeting
  - —Damage assessment
  - —Retargeting

Consequences of a Single Warhead Penetrating a Missile Defense System Would Be Horrific

A large (100 kiloton – 1 Megaton) nuclear explosion in a major city would —

- kill millions of people
- reduce a hundred square miles to rubble

Very little can be done before or after a nuclear explosion to lessen the deaths, injuries, and destruction it causes.

Consequently, failure to intercept even a single nuclear warhead would have horrific consequences beyond anything in human history.

The Ongoing Dream of and Quest for a Technological Solution to the Threat of Nuclear-Armed Ballistic Missiles

- Over the last 50 years the U.S. has spent more than $300 billion in 2016 dollars on technologies intended to intercept nuclear-armed long-range ballistic missiles in flight.

- In recent years, the US is has been spending about $7-10 billion per year on missile defense.

- As of now, this enormous effort has not significantly enhanced the security of the United States.

Past and Current U.S. Missile Defense Programs

Eisenhower Nike-Zeus Program (1950s) → nuc. armed interceptors: small # of incoming missiles

Kennedy Nike-X Program (1960s) → nuclear armed interceptors inside atmosphere, protect cities

Johnson Sentinel Program (1966–68) → nuclear armed interceptors: protect against limited attack

Nixon Safeguard Program (1969–76) → nuclear armed interceptors: protect missile fields

Reagan Star Wars Program (1983–1990) → broad research program for new technologies for ABM

Patriot in the first Gulf War (1991) → defense against short and medium range missiles

Bush-I and Clinton Programs (1991–1997)

Clinton National Missile Defense Research Program (1997–2001)

Bush-II Missile Defense Program (2001–2009)

Obama Missile Defense Program (2009–present)

Total spent so far: > $300 billion in 2016 dollars.

Most of these systems were never deployed.

None were found to be effective.

The Nixon Safeguard Program

Based on Sentinel Defense System with reduced scope: defend missile sites and not the general population

Precision Approach Radar System (PAR) detects incoming RVs over artic sea and launches:

(1) Long range nuclear armed Spartan missiles to engage incoming RVs outside the atmosphere.
(2) Short range hypersonic Sprint missiles to engage RVs that have penetrated the Spartan defense.

Both Spartan and Sprint missiles carried nuclear warheads.

One Safeguard site in North Dakota went into operation on October 1st, 1975. The house voted to terminate the Safeguard program on October 2nd, 1975 and the North Dakota site was deactivated in February 1976.

Module 7: Efforts to Defend Against Attack

Reagan's 'Star Wars' Program (1980s),

R&D program broadly studying technologies for missile defense: historic example for the challenges related to missile defense

Reagan's ABM Weapon Program Motivated by Vision to Render Nuclear Weapons Impotent – Not Based on Evaluation of Current or Future Technological Capabilities

Began with a paragraph in Reagan's speech on March 23rd, 1983 expressing hope to render nuclear weapons impotent —

- Expressed a grand vision to make nuclear weapons "impotent and obsolete", replacing nuclear deterrence by a defensive weapons system
- Surprised experts in the US government and was a radical departure from previous US policy
- Contradicted the results of just-completed studies by the White House and the DoD
- Did not say success was assured, but implied it was highly likely and could be achieved soon
- Launched a major, long-term research and development program: the Strategic Defense Initiative (SDI)

Reagan's ABM Weapon Program Motivated by Vision to Render Nuclear Weapons Impotent – Not Based on Evaluation of Current or Future Technological Capabilities

Why was almost everyone surprised? —

- The President consulted with only a few advisors (not including his Secretary of Defense or his Science Advisor) before giving his speech.
- The U.S. already had a very large research program that was investigating ABM weapons.
- The White House Science Council had just completed a study which concluded that missile defense would be technologically infeasible for the foreseeable future.
- The Defense Department had just completed a series of detailed studies that concluded the prospects for success were very poor and recommended reducing the funding of the existing ABM research program - DDR&E (Defense Department Research & Engineering Enterprise) had testified about them earlier that same day).

Consequences of Reagan’s ABM Weapon Program

Some consequences of Reagan’s speech—

- Raised public hopes and expectations that could not be fulfilled (“protection of our population against nuclear attack is a practical possibility and might even be accomplished soon”)
- Led to doubling and tripling of expenditures on ABM weapon research and development, increasing budget deficits
- Closed off pursuit of alternative approaches to reducing the threat of nuclear weapons
- Accelerated the building of offensive weapons
- Started expensive programs to develop and deploy extensive missile defenses that continue unsuccessfully to this day

Reagan's ABM Weapon Program: Challenges

Sensors, computers, and weapons would have had to be integrated into an enormously complex system that—

- Would have had to attack ballistic missiles within seconds after having been dormant for years
- Would have had to work almost perfectly the first time it was used, even though it could not be tested under realistic conditions
- Would have had to work almost perfectly while being attacked by Soviet nuclear and in the future possibly space based weapons

Reagan's ABM Weapon Program: Challenges

Some technical realities of the time —

- A system that was 90% effective would have allowed a Soviet attack to kill 75% of the US population immediately, with millions of later deaths
- IR laser weapons would have required space-based mirrors 10 times larger than the largest ever built on the ground and lasers > 10^6 times brighter
- Midcourse intercept would have required detection, tracking, and discrimination of ~ 100,000 objects in space, at *existing* Soviet force levels
- Battle management computer programs would have required more than 100,000 man-years to write using the most advanced techniques then available and would have had to work almost flawlessly the first time they were used

Reagan's ABM Weapon Program: Challenges

For every SDI weapon concept that was proposed or imagined, including all space-based weapons, a counter-measure had already been identified.

Unlike the weapons themselves, these counter-measures were —

- Possible with existing technology
- Relatively cheap

The SDI program did not even attempt to address nuclear weapons carried by —

- Air-, sea-, or ground-launched cruise missiles
- Submarine-launched ballistic missiles
- Bombers
- Ships

Reagan's ABM Weapon Program: Public Perception and Response vs Expert Advise

Knowledgeable people inside and outside the government knew the goal of complete protection was impossible —

- Knowledgeable scientists and others outside the government spoke out strongly
  - Gave public speeches, talks, articles, etc.
  - Pledged not to participate
- Knowledgeable people inside government spoke out
  - Made cautious public comments
  - Some gave forceful secret advice
- Allies of Reagan tried to "move the goal posts" to —
  - Enhancing deterrence
  - Causing the Soviets to spend money on countermeasures
- However, all this had little impact on the public's perception

Reagan's ABM Weapon Program: Challenges Result in Shifting Focus on Different Technologies

As a result of its technological unreality, the emphasis of the SDI program moved from year to year —

- Space-based X-ray lasers
- Space-based particle-beam weapons
- Space- and ground-based optical and UV lasers
- Space-based kinetic energy weapons
- Brilliant pebbles (smart rocks)
- High- and low-altitude rocket interceptors

None of the resources spent on these exotic technologies contributed significantly to subsequent ABM programs.

Reagan's ABM Weapon Program: Costs and Demise

Some consequences of the SDI ABM weapon program —

- Spurred the race in offensive strategic weapons, until ~ 30,000 were deployed
- Spurred Soviet efforts to develop space weapons
- Complicated arms control efforts
- Large opportunity cost
  - —Diverted money, manpower, and other resources from education and internationally competitive civilian industries and products
  - —SDI ended up costing more than $150B in 2020 dollars, but accomplished very little that was useful

The SDI program was greatly reduced by Bush and terminated in 1994 by Clinton. However, Clinton felt compelled to restart a program to defend against long-range ballistic missiles in 1998. Missile defense programs have been pursued by the Bush-II and Obama administrations.

The ‘Nitze Criteria’ for Deploying an ABM System (Important)

In the early 1980s, Paul Nitze argued convincingly that to be considered for deployment, an ABM system must first meet the following three criteria —

1. The system must be effective
2. The system must be able to survive attack
3. The system must be cost-effective at the margin

These criteria were officially adopted ~ 1985 and have become known as the “Nitze criteria” for it to make sense to deploy a missile defense system.

Adoption of these criteria effectively ended any chance of deploying a missile defense system during the 1980’s and 1990’s, because no system then under development could come close to meeting them.

Bush-II departed from the Nitze Criteria in 2001 in order to deploy a missile defense system (see “capability-based development and deployment”).

Lessons from Reagan's ABM Program (Important)

- Missile defense technology is highly challenging
- Technology cannot be coerced by good intentions, ideology, or policy (engineering programs must be consistent with technical realities, because nature cannot be fooled)
- It is important to understand what technology can and cannot do in a given situation, because to be successful, policies must be consistent with the available technology
- An R&D program without clear goals will always waste time and money
- Frequent testing is critical and the budget for tests must therefore be large; if there is no commitment to such an effort, the program will fail
- An independent evaluation and review process is critical

Patriot in the 1991 Gulf War

Events that formed the US public's impression—

- TV videos of Patriot "engagements" and enthusiastic reports by military spokesmen and news reporters of the Patriot's successes.
- General Schwarzkopf: "The Patriot's success is 100%—so far, of 33 Scuds engaged, there have been 33 destroyed."
- President Bush, during a celebratory visit to Raytheon, said "Patriot is 41 for 42, 42 Scuds engaged, 41 intercepted... **Patriot is proof positive that missile defense works**."
- These statements also were aimed at the public in Israel to build trust towards US abilities to defend Israel from Iraqi aggression. Finally, they were aimed at Iraqi leadership to frustrate Iraqi efforts to widen conflict.

Patriot in the 1991 Gulf War

Later studies showed the Patriot's actual performance was *very* poor —

- The First Army study (February 1992) was found to have many serious flaws by the GAO (Government Accountability Office) and the CRS (Congressional Research Service).
- In April 1992, Pedatzur (Tel Aviv) reported only 1 Scud hit by a Patriot based in Israel; found that 4 Patriot warheads had fallen and exploded in populated areas.
- A corrected Army study (April 1992) reported a 'success rate' > 70% in Saudia Arabia and > 40% in Israel (success = incoming WH destroyed, dudded, or deflected) [this is still the official DoD claim].
- A September 1992 GAO study reviewed the corrected Army study and found only 4 engagements (9% of the total) in which there was strong evidence of a Patriot 'kill'.
- A detailed study by Postol & Lewis (MIT, 1991–92) found *evidence of 3 hits but no evidence of any 'kills'.* An independent study by the APS largely agreed.
- **In the end, there was not a single well-documented intercept but many well-documented complete misses**

Careful studies came late and had limited impact on the public's perception that Patriot had succeeded.

Israel: Iron Dome ➔ Short Range Rocket Defense System

- Sub-theater missile defense system for missiles with ranges up to 45 miles. One battery consists of 3 rocket launchers with 20 interceptors, controlled by a single battle control station.
- Developed and built by Israel Rafael Advanced Defense Systems with significant support from the United States. Israel has ordered 15 batteries at an estimated $1 billion.
- After visit to Israel in August 2012, Defense Secretary Leon Panetta reported that the Iron Dome interceptors had a rate of successful interceptions above 80%.
- Example (from news media reports): attack from Gaza on March 9th 2012 with over 300 rockets: 177 hit targets in Israel, Iron Dome identified 71 rockets and successfully intercepted 56.

Israel: Iron Dome ➔
Will the Early Reports of Success Hold?

MIT
Technology
Review

Interview with Ted Postol, MIT
Expert on ballistic missiles and defense

Why Israel's "Iron Dome" Missile-Defense System Actually Works

Successful intercepts show that missile defense can work against relatively slow-moving rockets.

By David Talbot on November 26, 2012

Intercept course: An Israeli battery launches a missile to intercept a Palestinian rocket.

Physics 280: Session 23

Plan for This Session

Questions

Module 7: Efforts to Defend Against Nuclear Attacks (cont’d)

Does this mean missile-defense systems may be more reliable than in the past?

Let's say you are batting .750 against a fastball pitcher. That's tremendously good. But a fastball pitcher can throw a pitch at only 160 kilometers per hour. So how well are you going to do against a pitcher who can pitch at 800 kilometers per hour? It's not a minor difference.

The actual speed of these Hamas rockets is in the range of 500 meters per second. Scuds that can travel 600 kilometers are traveling at 2,200 meters per second. An ICBM [intercontinental ballistic missile] is traveling at 7,000 meters per second, so 13 or 14 times as fast. With ICBMs, the main weakness of missile-defense systems is that they can be fooled by decoys that can be released in the near-vacuum of space and travel with the ICBM.

By David Talbot on November 26, 2012

Intercept course: An Israeli battery launches a missile to intercept a Palestinian rocket.

Delivery vehicle	Speed in [meters/second]
Mach-2 fighter	680
Hamas rocket	**500**
SCUD missile	2200
ICBM	7000

Short range rockets present a significantly smaller challenge to missile defense …

Module 7: Modern Efforts on Missile Defense

Boost-Phase Intercept System ?

Why is There Interest in Boost-Phase Intercept?

Boost-phase intercept has been described as easier than midcourse intercept, because

- ICBMs are slowly-moving targets during boost phase
- ICBMs have bright exhaust plumes that are easy to track
- An ICBM is a unitary target if it can be intercepted before it deploys its warheads and decoys
- It is usually assumed that there are few if any effective countermeasures to boost-phase intercept

It is also argued that boost-phase intercept . . .

. . . would reduce the challenge faced by the midcourse layer if it were the first layer of a layered defense

Requirements for a Successful Boost-Phase Intercept

- The interceptor rocket must reach the target missile before it has a velocity that will carry its warheads to the defended area.

- The interceptor's final stage ("kill vehicle") must be able to maneuver to hit the ICBM while it is in powered flight.

Reaching the ICBM in Time

- In many situations the interceptor rocket would have only ~ 2 min (solids) or ~ 3 min (liquids) to reach the target ICBM, even with a state-of-the-art space-based detection and tracking system

- In some situations, the defense would have only seconds to decide whether to fire, and even if its interceptors were fast and fired immediately, they could have difficulty reaching the ICBM in time

Difficulties for Boost-Phase Intercept

ICBM boost phases are short (4 min liquids, 3 min solids)

- The defense has little time to decide whether to fire
- Interceptors have little time to reach the ICBM

Geographical constraints require high interceptor speeds

- Intercept points for ICBMs from North Korea and Iran are 500 to 1,000 km from potential interceptor basing locations

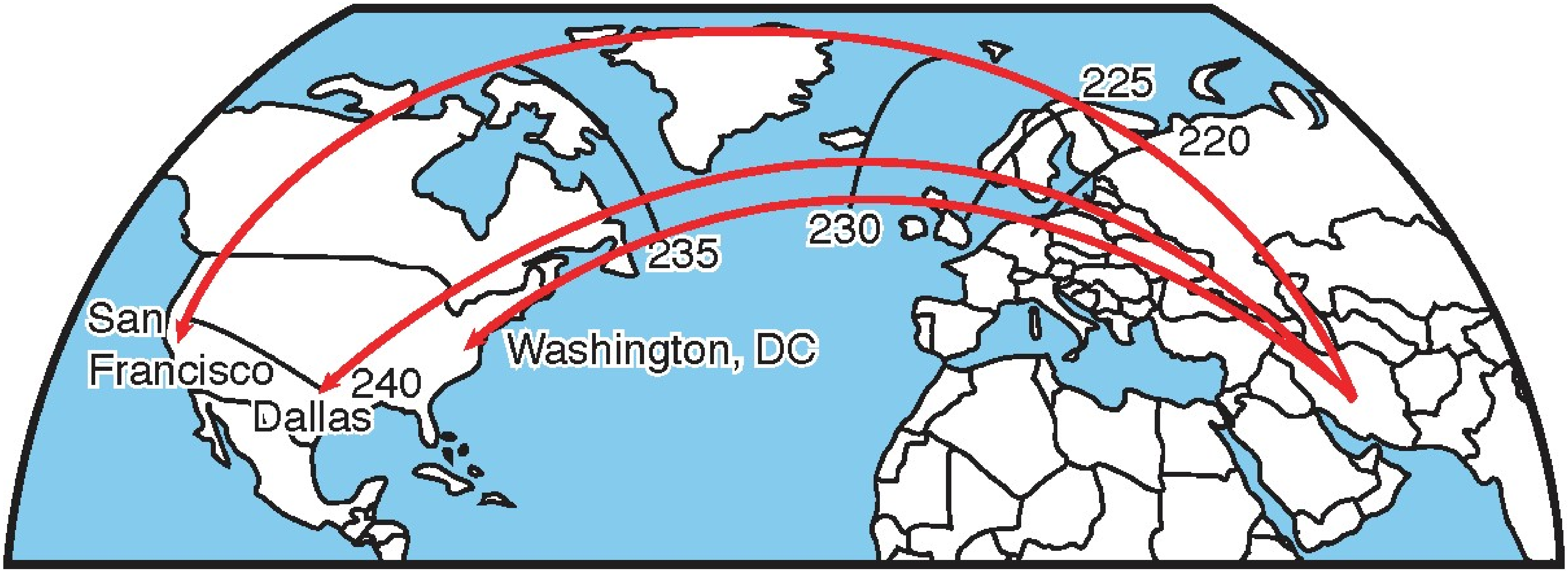
ICBMs in powered flight accelerate unpredictably

- Burn variations, energy management, programmed evasion
- Interceptors would have to be fast and agile

A successful intercept is unlikely to destroy warheads

- Live warheads could impact the territory of the United States or U.S. friends and allies (“shortfall management problem”)

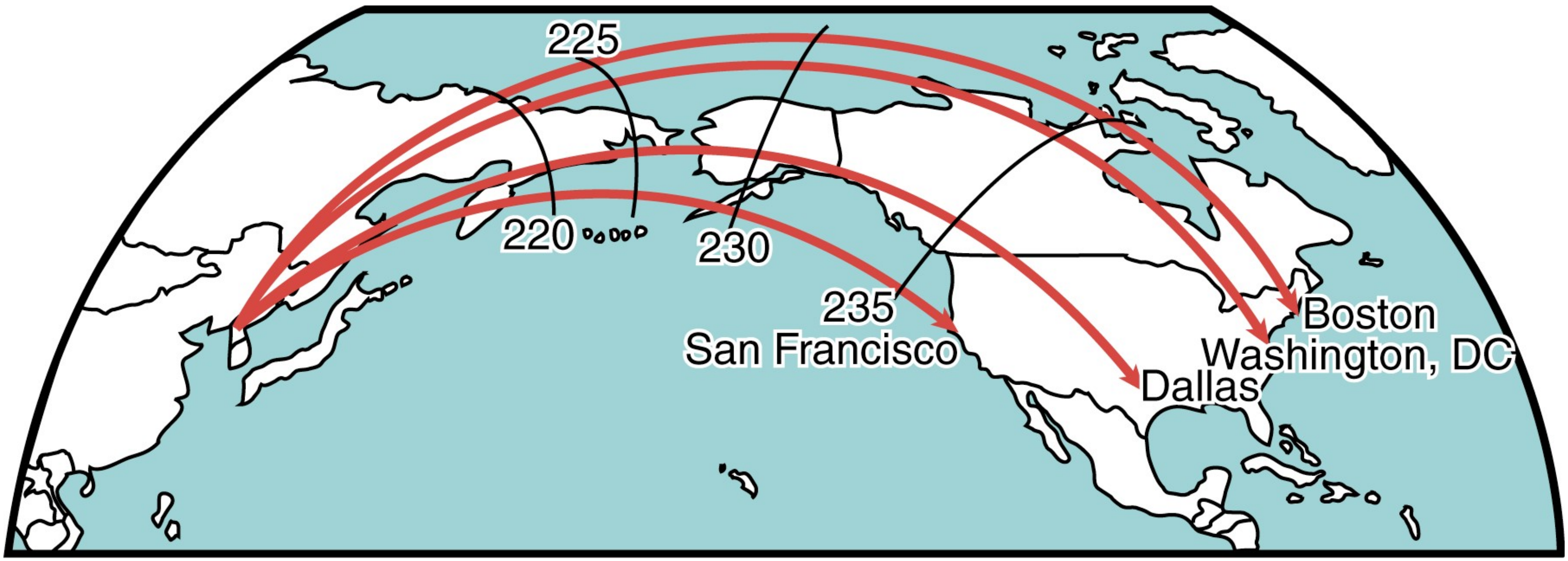
Munitions from Iranian Missiles Could Impact Western Europe or Canada



A successful boost phase intercept (after say 220 seconds of acceleration) may destroy the missile but leave the payload on course (intact or otherwise). The payload then continues in un-propelled ballistic flight with a range corresponding to the length of the shorter boost phase.

The black curves on the plot show the impact location of the payload depending on the length of boost phase before intercept in seconds.

Munitions from North Korean Missiles Could Impact Russia or Canada



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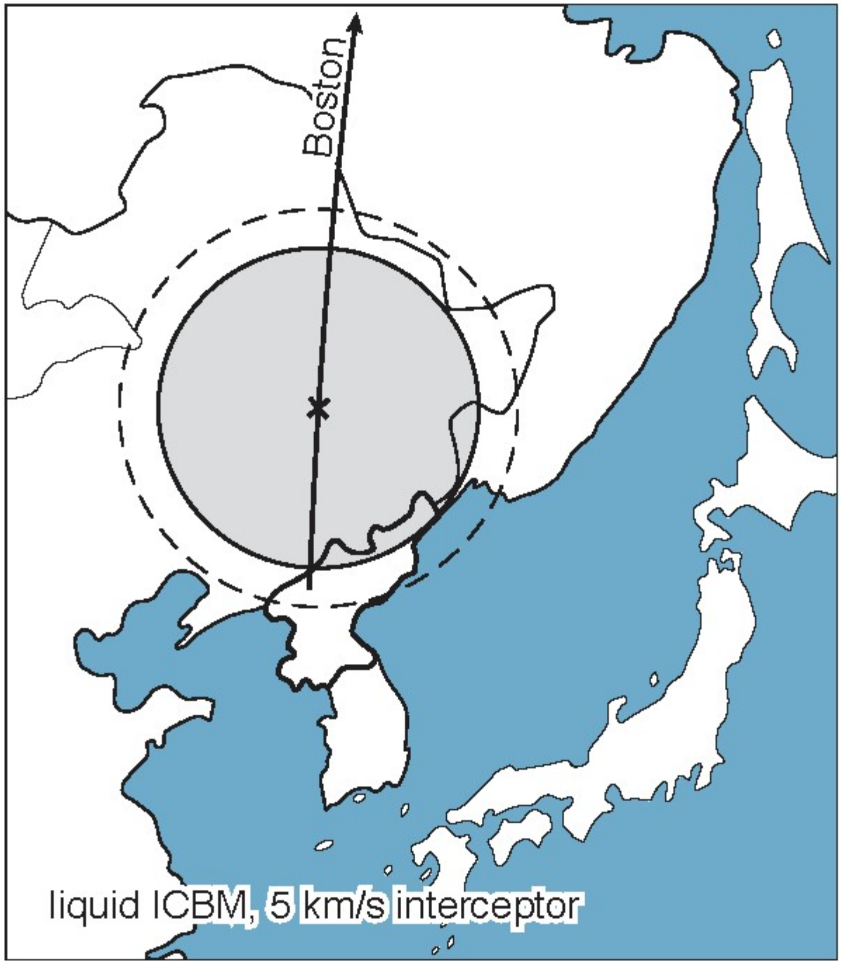
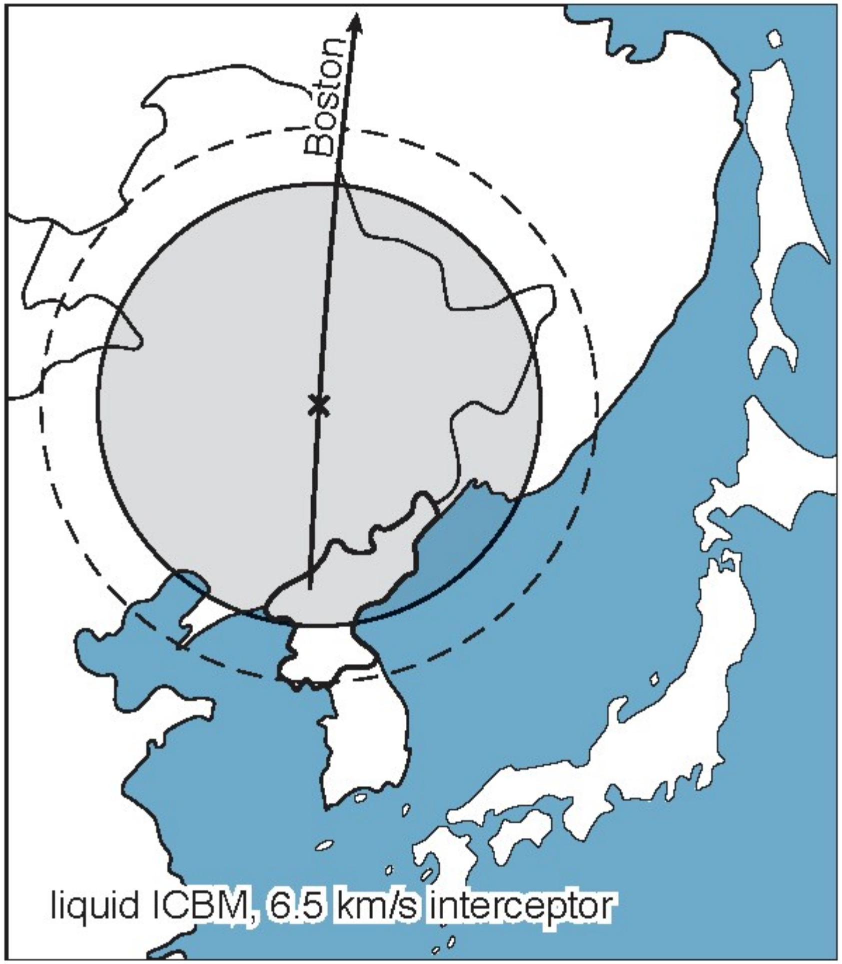
Regional Geography Constrains How Close Interceptors Could Be Based

Solid line: 30 sec. decision time

Dashed line: No decision time

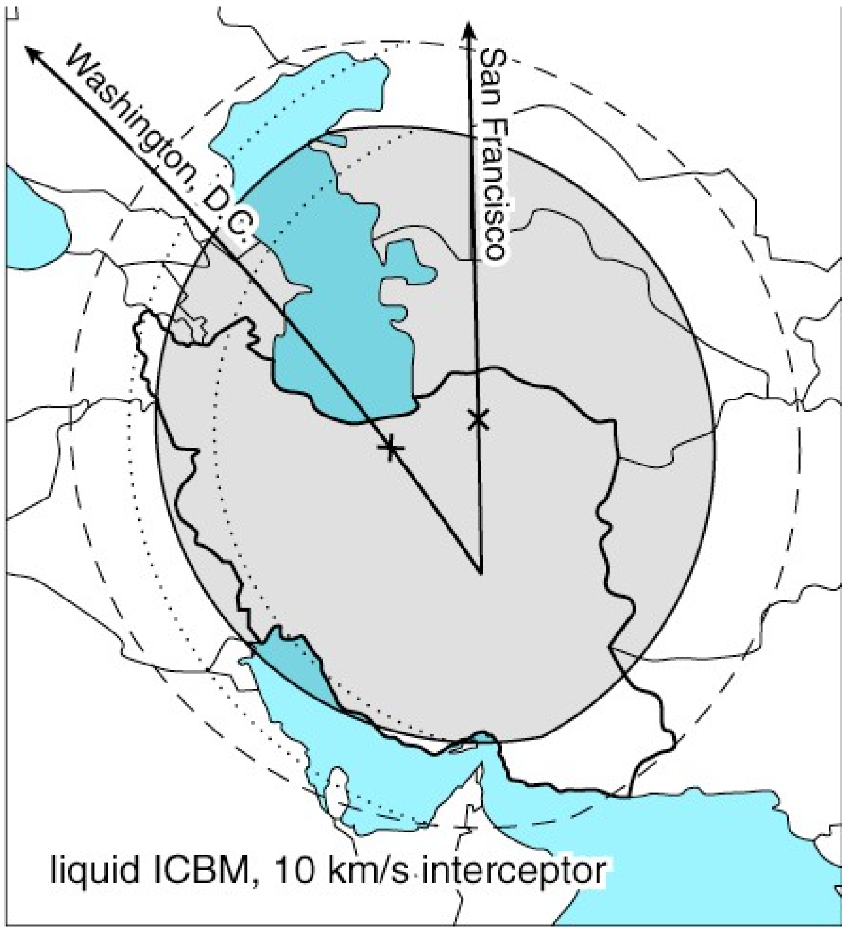


Basing areas for a 5 km/s interceptor to defend Boston against a liquid-propellant ICBM launched from North Korea

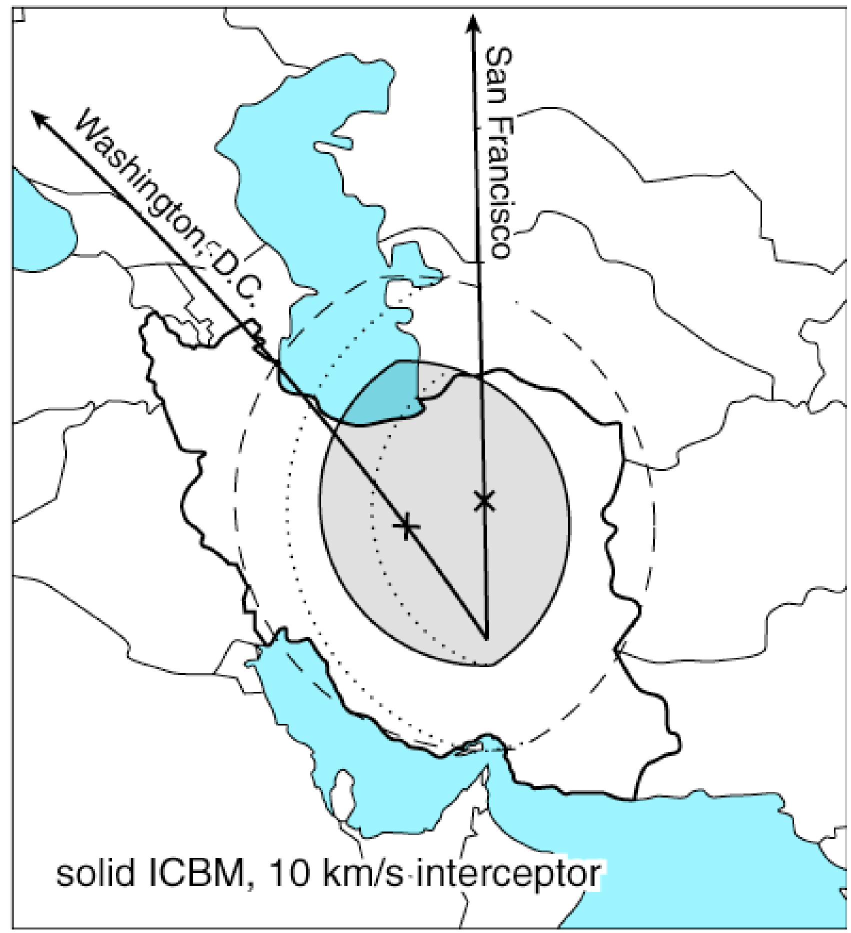


Basing areas for a 6.5 km/s interceptor to defend Boston against a liquid-propellant ICBM launched from North Korea

Regional Geography Constrains How Close Interceptors Could Be Based



Basing areas for intercepting a liquid-propellant ICBM from Iran to the Lower 48 States



Basing areas for intercepting a solid-propellant ICBM from Iran to the Lower 48 States

Implications of the Time Constraints

The very short time available to complete the intercept poses significant command-and-control issues —

- In some situations the decision whether to fire interceptors would have to be made within a few seconds after a firing solution was obtained
- There would generally be too little time to determine using the system's sensors whether the rocket is an attacking ICBM, a theater ballistic missile, or a rocket launching a satellite
- Consequently, interceptors would have to be fired whenever a large rocket in powered flight is detected, without waiting until the nature of the rocket or its trajectory is established
- Giving commanders the ability to divert or destroy interceptors in flight might extend the assessment time by about 100 seconds

A System of Space-Based Interceptors Would Require Many Large Satellites

Placing interceptors in space would avoid geographic restrictions on basing, but global geographic constraints would still determine when ICBM must be intercepted

To counter *solid-propellant ICBMs*, at least 1,600 interceptors would be required, each at 840 kg, for a minimum mass in orbit of 2,000 tonnes

- Would require a 5- to 10-fold increase in the annual U.S. space launch capability

To counter *liquid-propellant ICBMs*, roughly half as many interceptors and space launches would be required

- However, a space-based system designed to counter only liquid-propellant ICBMs could become obsolete quickly

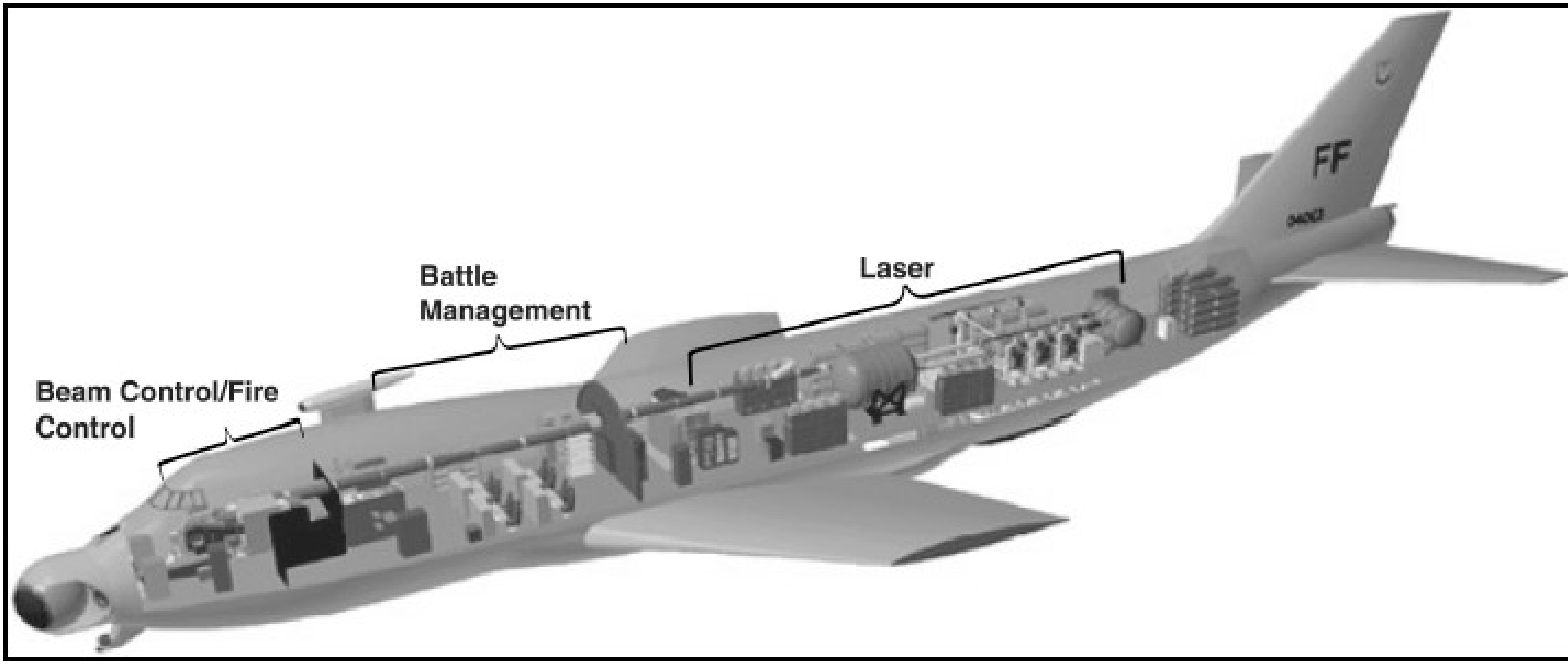
Airborne Laser Boost-Phase Intercept Program

U.S. Missile Defense Agency

The Airborne Laser Test Bed program's laser-armed aircraft takes off on February 14 from Edwards Air Force Base in California on its way to long-term storage at Davis-Monthan Air Force Base in Arizona.

The Airborne Laser Concept

Figure 1: Airborne Laser Aboard Boeing 747 Aircraft



Source: Airborne Laser Program Office.

The Airborne Laser Would Have Only Limited Capability Against ICBMs

The ABL's range would not be limited by time, but by the distance a focused beam could be propagated through the atmosphere

The ABL could in principle be used against ICBMs, if the laser worked as advertised

If it worked as advertised, the ABL would have a range up to 600 km against a liquid-propellant ICBM

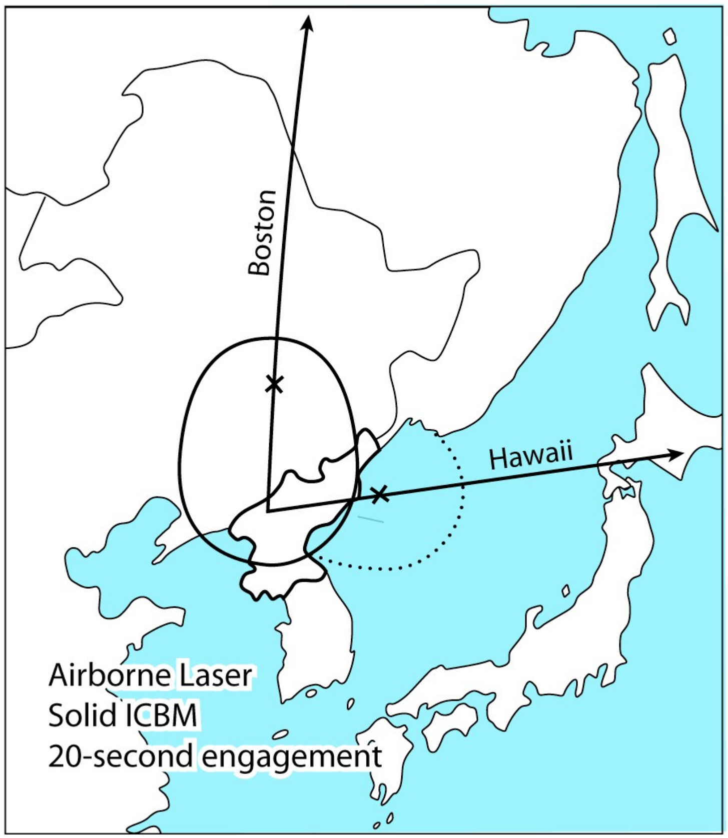
- Could be useful against ICBMs from North Korea, but not from Iran, unless ABL aircraft could fly over the lower Caspian Sea or Turkmenistan

The ABL would have a range of only 300 km against a solid-propellant ICBM (solid propellant ICBMs are more heat resistant)

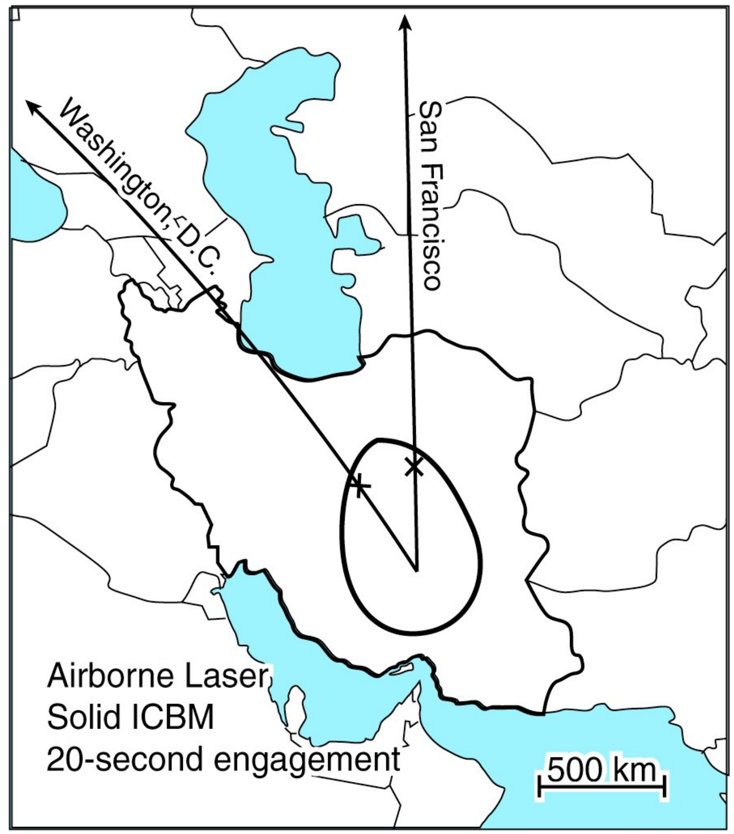
- Would not be effective in any of the scenarios examined by the APS

The Airborne Laser Would Have Only Limited Capability Against ICBMs

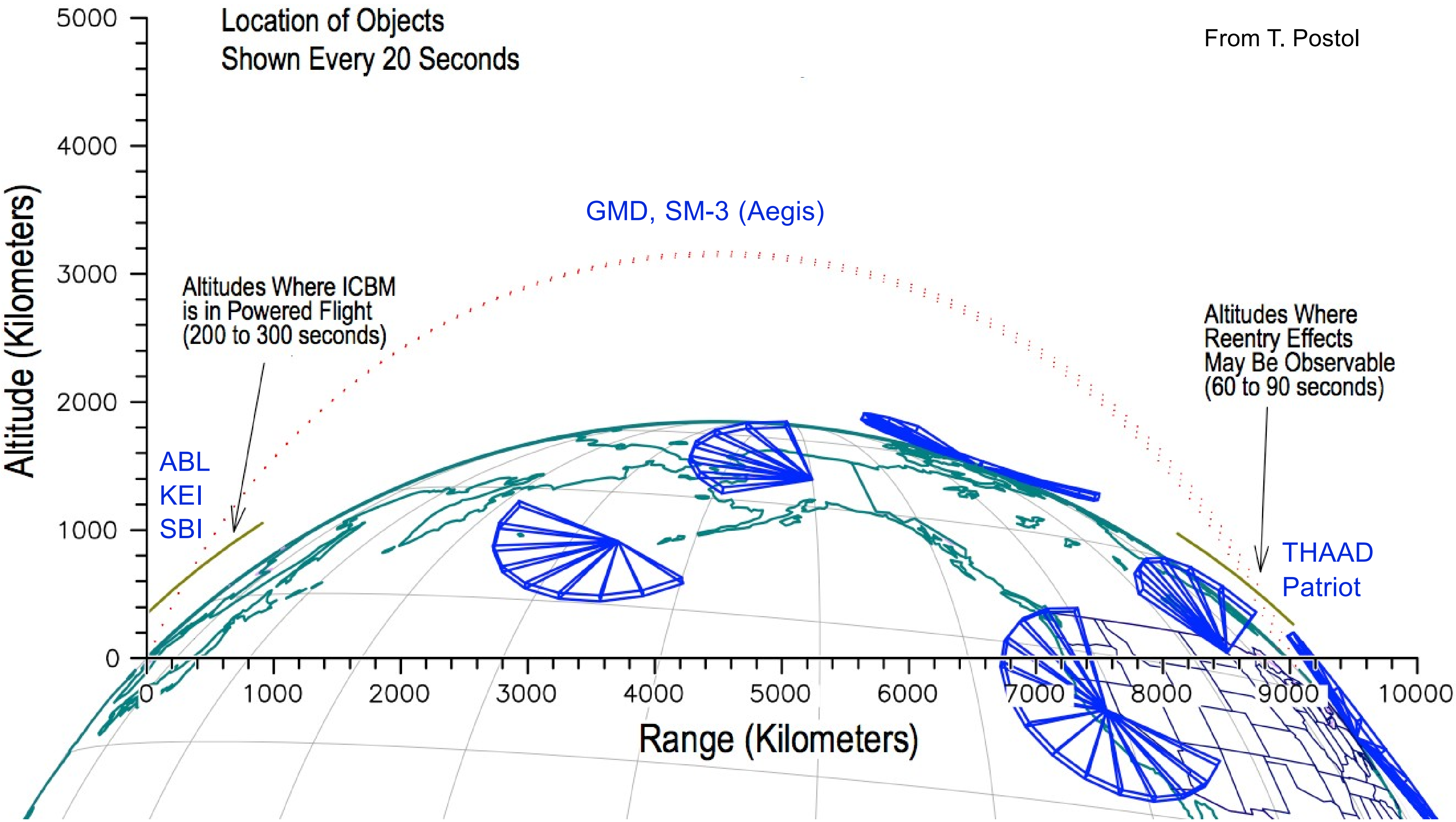
Basing areas for intercepting a solid-propellant ICBM from North Korea



Basing areas for intercepting a solid-propellant ICBM from Iran



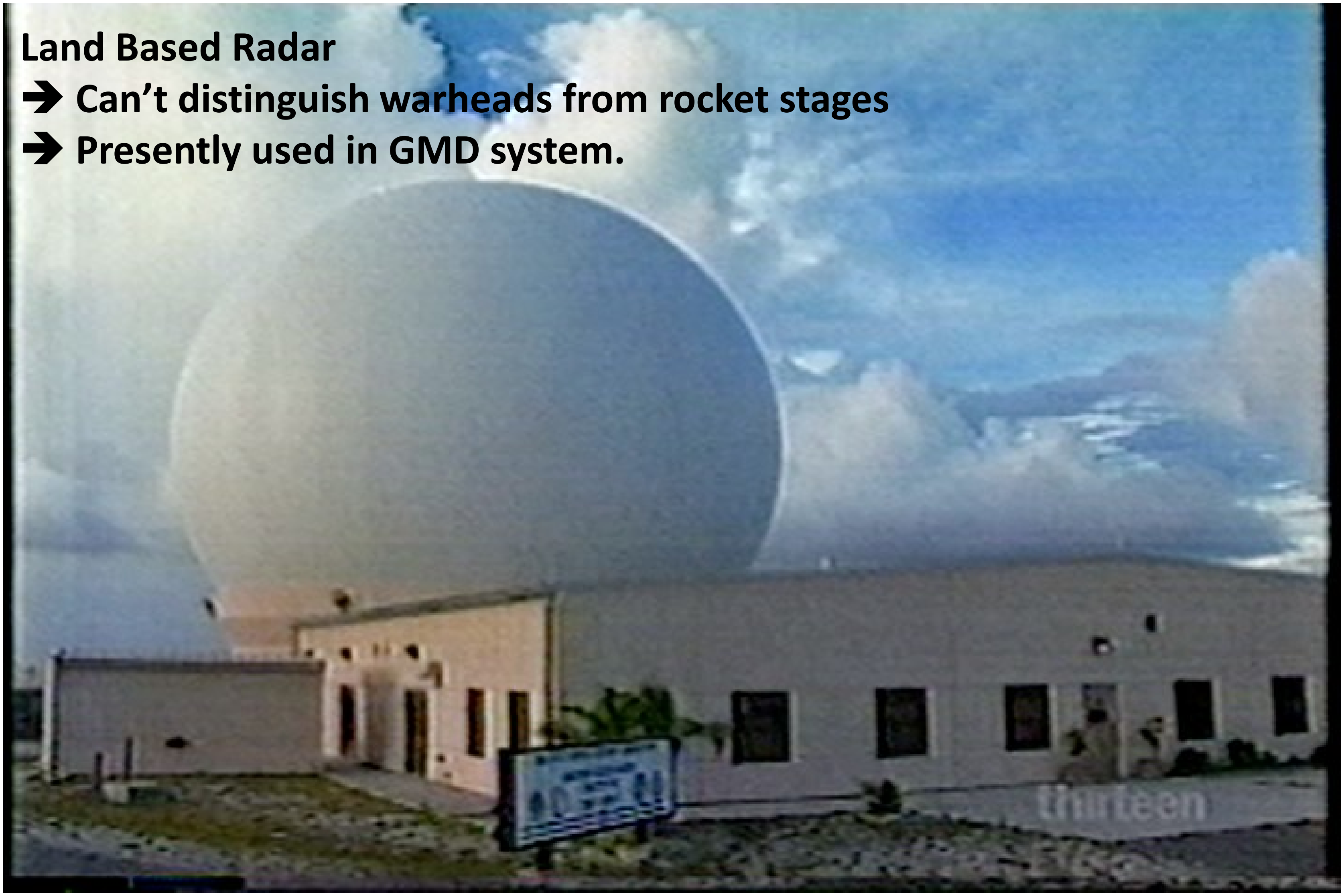
Bush II Defense Initiatives Against Nuclear-Armed Long-Range Ballistic Missiles



Several of the Bush II Missile Defense Programs have been Scaled Back or Cancelled

- Space-based Interceptor (SBI) — cancelled 2003.
- Airborne Laser (ABL) — reduced 2008, cancelled 2012.
- Kinetic-Energy Interceptor (KEI) — cancelled.
- Multiple Kill Vehicle (MKV) — cancelled 2005.
- Terminal High-Altitude Area Defense (THAAD) — scaled back, deployed in 2009 to Hawaii and in April 2013 in response to North Korean Missile Threat . Deployed in March 2018 to South Korea in response to heightened North Korean Missile Threat.

Radar Capabilities for Midcourse Intercept



Identification of Re-entry Vehicle Requires Bandwidth higher than 200 MHz

Bandwidth Requirements for TBM Length Discrimination

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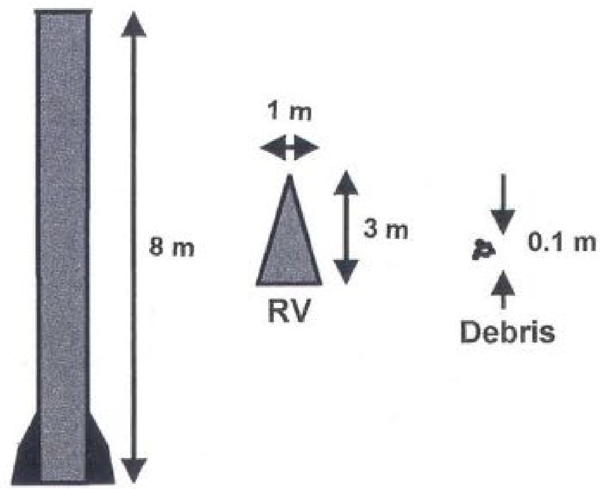
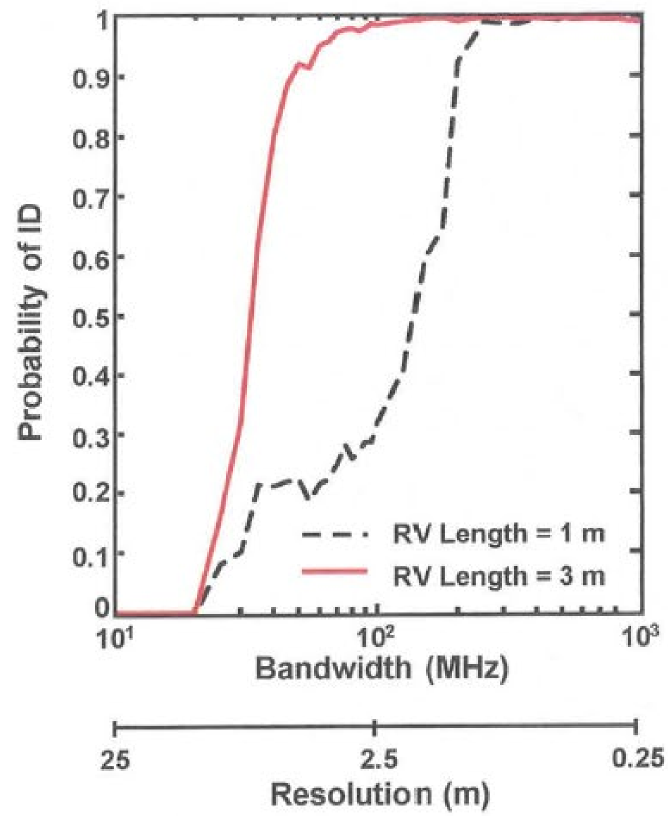




300 MHz Bandwidth (1 m resolution) Required Against Near-Term Threat

UNCLASSIFIED [Source: S. Wilson, 1996]

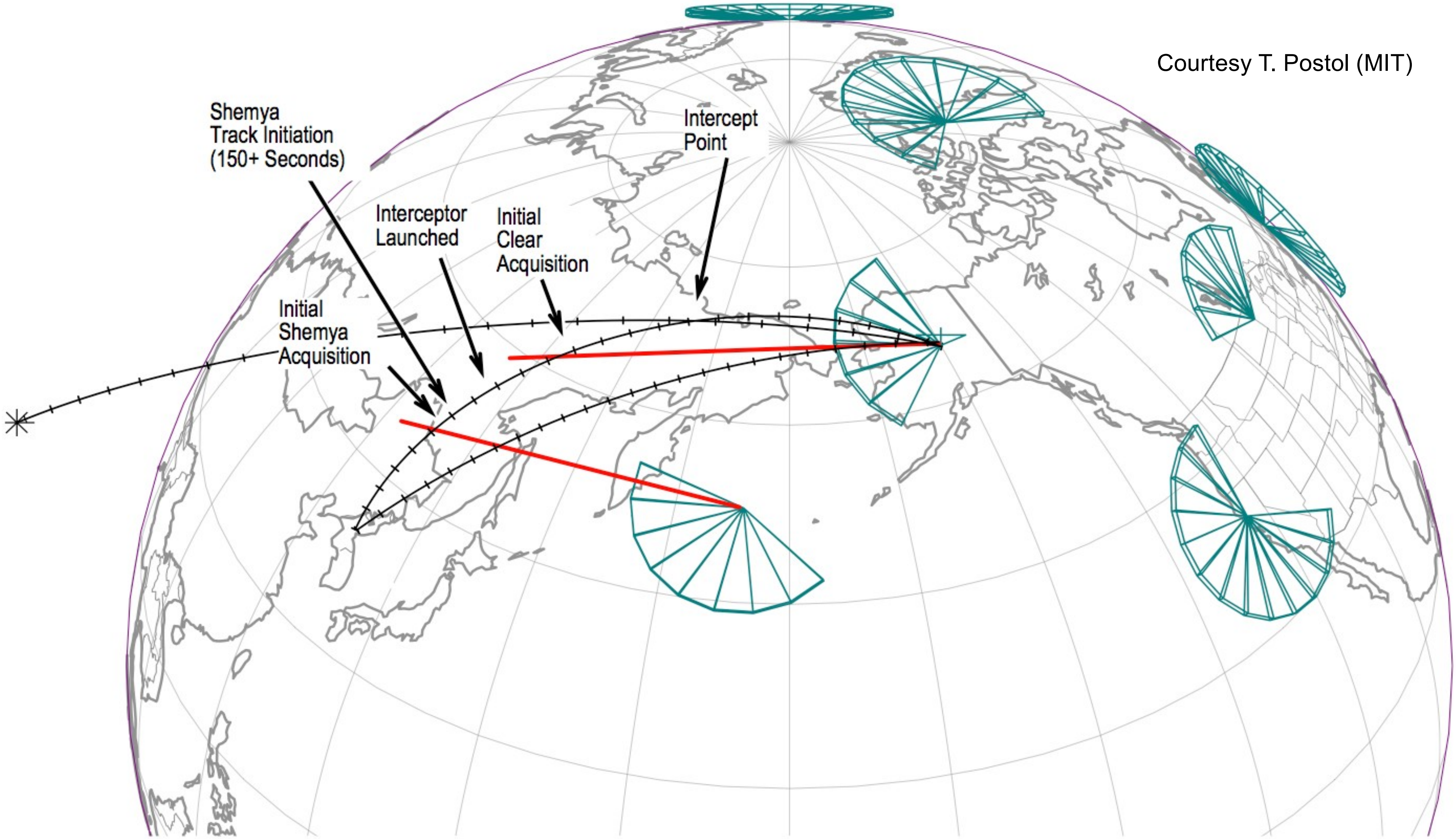
MIT Lincoln Laboratory

EDE-GR32-57
8/19/99

Sea Based X-Band Radar SBX-1

- ➔ **Sufficient resolution to distinguish warheads from rocket stages**
- ➔ **Used for tests, not active part of the GMD system – annual operating cost $160**

Operational Concept of the Ground-Base Midcourse Intercept (GMD) System



Courtesy T. Postol (MIT)

Challenges to Midcourse Intercept

- Each ICBM could launch —
  - Multiple warheads
  - Chemical or biological submunitions

  A large number of warheads would overwhelm the defense

- Each ICBM could launch —
  - Countermeasures and penetration aids, including large numbers of lightweight decoys

  Outside the atmosphere, these would be difficult to distinguish from warheads and would confuse the defense

DOT&E 2008 Annual Report on GMD System Evaluation

The January, 2008, DOT&E Annual Report stated:

- Flight testing of the GMD system “is not sufficient to provide a high level of statistical confidence in its limited capabilities.”
- “The addition of limited operational realism to BMDS testing against strategic threats has uncovered unanticipated deficiencies that will require additional development and testing.”

DOT&E
Office of the Director for Operational Testing & Evaluation

March 2009 Report on the Bush ABM Program by the Government Accountability Office

MDA spent $56 billion researching and deploying elements of the ground-based midcourse defense (GMD) system from 2002–2009.

MDA failed to achieve *any* of its 6 testing objectives for 2008. Two planned GMD tests were not carried out.

Nevertheless, system elements, including 24 modified GMD interceptors, were deployed before being fully tested.

The GAO recommended that MDA —

- Test its GMD interceptor against a complex scene with countermeasures.
- Ensure that items are not manufactured for fielding before their performance has been validated through testing.

Current Status of the GMD System

- The current GMD system:
  - 30 interceptors have been deployed initially in silos. Will increase to 64 by 2020.
  - Most are in Alaska, a few are in California
- Test results:
  - 9 hits in 17 scripted, simplified tests since 1999 (several launch failures— called “no tests” — are not counted)
  - The launch time and trajectory of the “attacking missile” were known and always the same, closing velocities were slow, no countermeasures were allowed
  - Only two tests involved the interceptor rocket intended for the system
- Stated capability of the current GMD system:
  - In 2010, the DOT&E stated that the current midcourse system provides only “emergency, low-confidence capability”.

Projected cost through FY2019: $41 Billion (source GAO, projection in 2013)

GMD Test Record (from MDA)

http://www.mda.mil/global/documents/pdf/testrecord.pdf

Date	Test Name	Hit
Ground-Based Interceptor (GBI)		
2-Oct-99	IFT-3	✓
19-Jan-00	IFT-4	x
8-Jul-00	IFT-5	x
14-Jul-01	IFT-6	✓
3-Dec-01	IFT-7	✓
15-Mar-02	IFT-8	✓
14-Oct-02	IFT-9	✓

Date	Test Name	Hit
Ground-Based Interceptor (GBI)		
11-Dec-02	IFT-10	x
15-Dec-04	IFT-13c*	x
14-Feb-05	IFT-14	x
1-Sep-06	FTG-02*	✓
25-May-07	FTG-03	N/A
28-Sep-07	FTG-03a	✓
5-Dec-08	FTG-05	✓

Date	Test Name	Hit
Ground-Based Interceptor (GBI)		
31-Jan-10	FTG-06	x
15-Dec-10	FTG-06a	x
05-Jul-13	FTG-07	x
22-Jun-14	FTG-06b	✓
30-May-17	FTG-15	✓

- 10 successful intercepts in 18 attempts since 1999
- Causes of Failures:
  - IFT-4 – Kill vehicle's infrared sensor cooling malfunctioned
  - IFT-5 – Kill vehicle and booster did not separate
  - IFT-10 – Kill vehicle and booster did not separate
  - IFT-13c* – Interceptor failed to launch due to problematic software configuration
  - IFT-14 – Interceptor failed to launch after a silo support arm did not retract, triggering an automatic abort
  - FTG-06 – Kill vehicle and system sensor performance issues
  - FTG-06a – Kill vehicle guidance error in final seconds of flight
  - FTG-07 - Kill vehicle and booster did not separate
- FTG-03 is characterized as a "no-test" – Target malfunctioned after launch, interceptor was not launched

Physics Today April-2018

Steve Fetter, Richard L. Garwin, and Frank von Hippel

NUCLEAR WEAPONS

Ballistic-missile defense (BMD) has been a contentious issue since the Soviet Union launched the *Sputnik 1* satellite in 1957. The two dimensions of the controversy concern the ability to neutralize BMD systems with relatively inexpensive countermeasures and the fear that BMD systems will prompt potential adversaries to increase their offensive strategic nuclear forces to ensure they can overwhelm the defense. All BMD systems deployed today to defend the continental US involve the intercept of incoming warheads in space. Many relatively simple countermeasures would be effective against such systems. Figure 4 shows one possibility: lightweight decoys. A 2012 National Research Council report, *Making Sense of Ballistic Missile Defense*, noted,

Discriminating between actual warheads and lightweight countermeasures has been a contentious issue for midcourse defense for more than 40 years. . . . Based on the information presented to it by the Missile Defense Agency (MDA), the committee learned very little that would help resolve the discrimination issue in the presence of sophisticated countermeasures. In fact, the committee had to seek out people who had put together experiments . . . and who had understood and analyzed the data gathered. Their funding was terminated several years ago, ostensibly for budget reasons, and their expertise was lost. (page 131)

Of course, counter-countermeasures exist, but after more than 50 years of analysis, the advantage remains decisively on the side of the offense.

Physics Today
April-2018

Steve Fetter,
Richard L. Garwin,
and Frank von Hippel

NUCLEAR WEAPONS

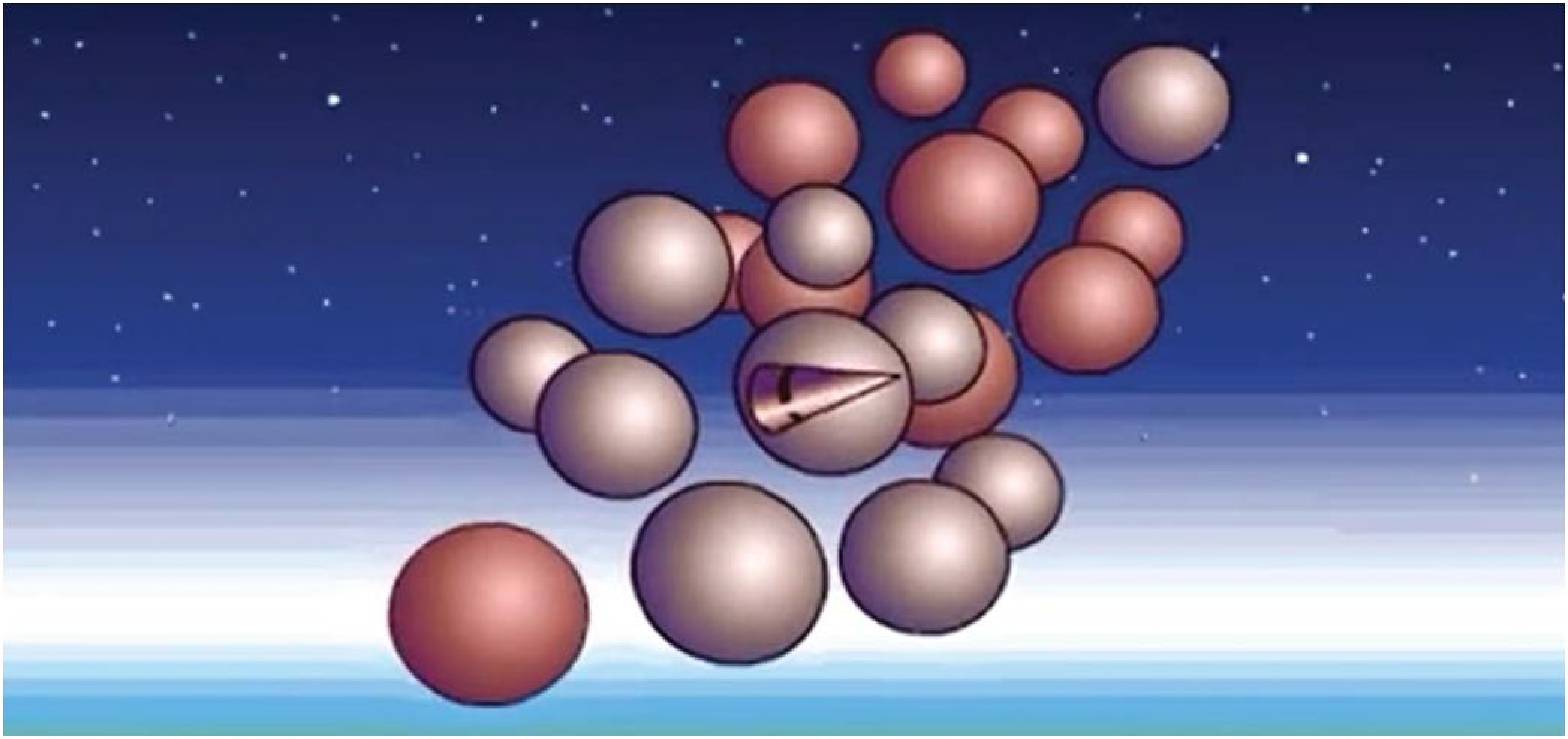
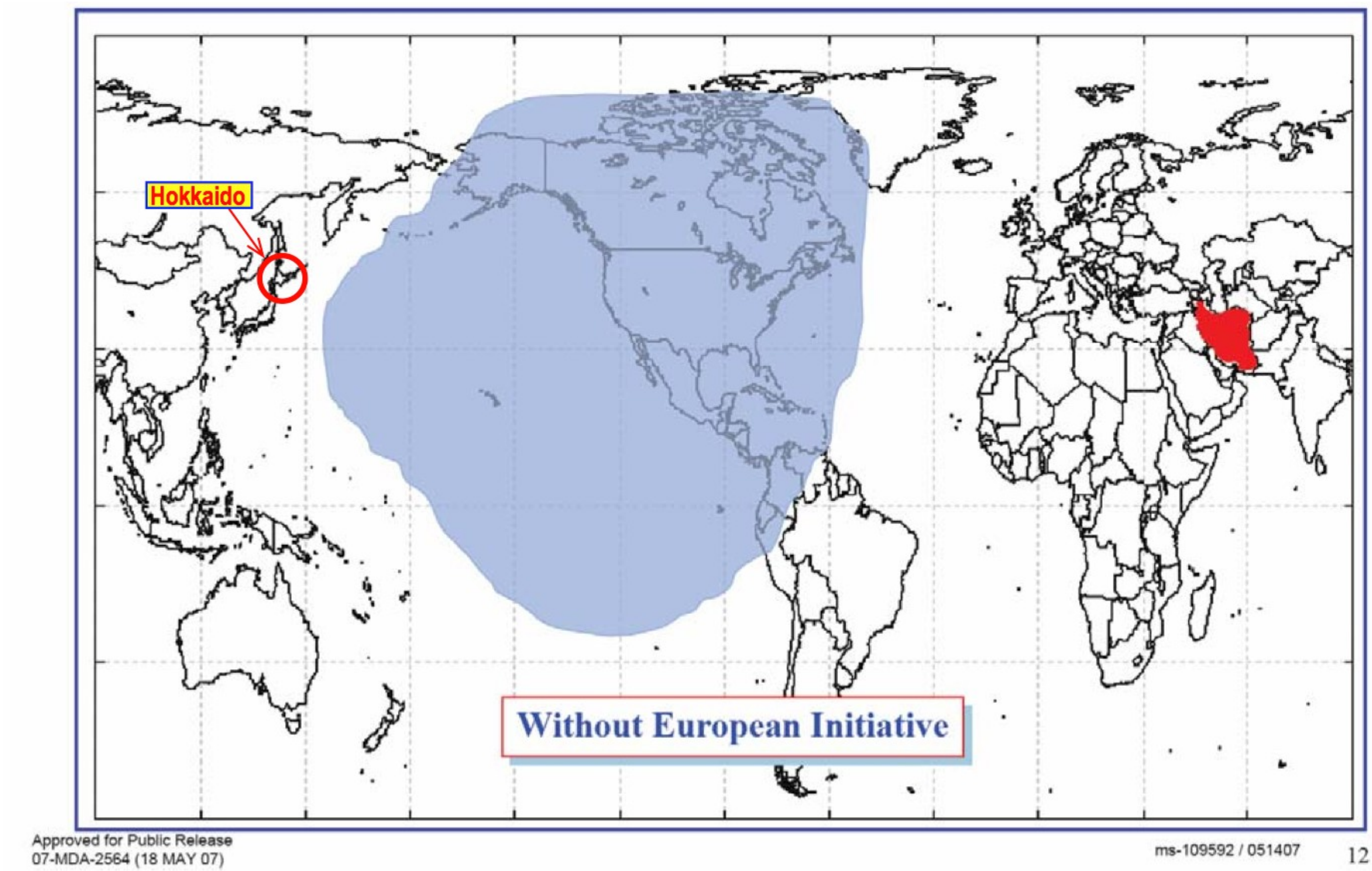


FIGURE 4. ONE POSSIBLE COUNTERMEASURE to the interception of ballistic-missile warheads in space. An aluminized balloon is inflated around a warhead to make it indistinguishable to radar from accompanying decoy balloons. Small, battery-powered heat sources introduced into the decoys make them indistinguishable to IR sensors. (Image from the Union of Concerned Scientists video *Missile Defense Countermeasures*, 2011; see also ref. 16.)

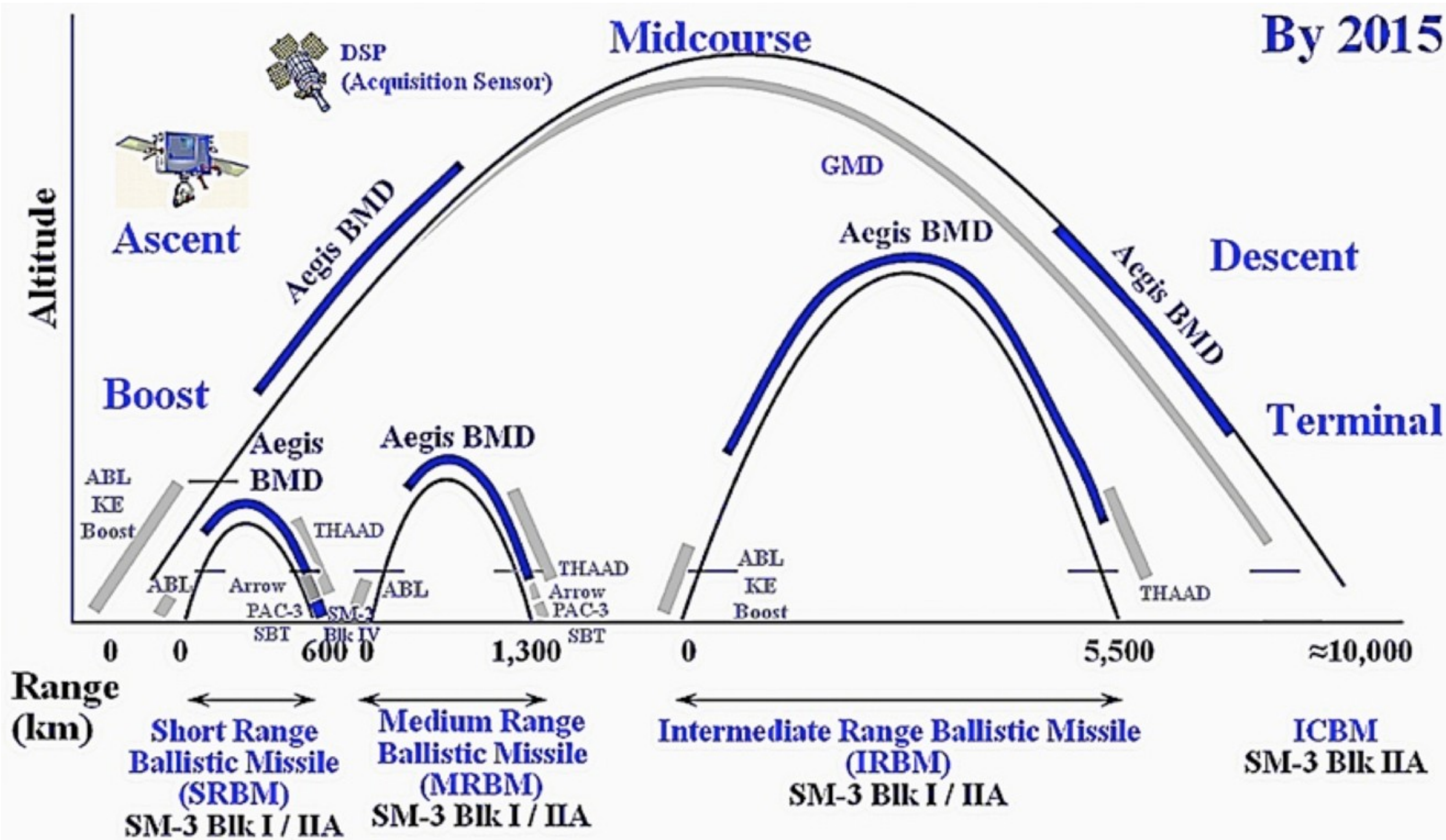
Claimed Theoretical Effectiveness of U.S. GMD Against Iranian Ballistic Missiles



European Missile Defense System

(as adapted by the Obama Administration giving up missile defense launch sites in Eastern Europe in favor of sea launched missiles)

Obama Administration: Phased Adaptive Approach to EMD



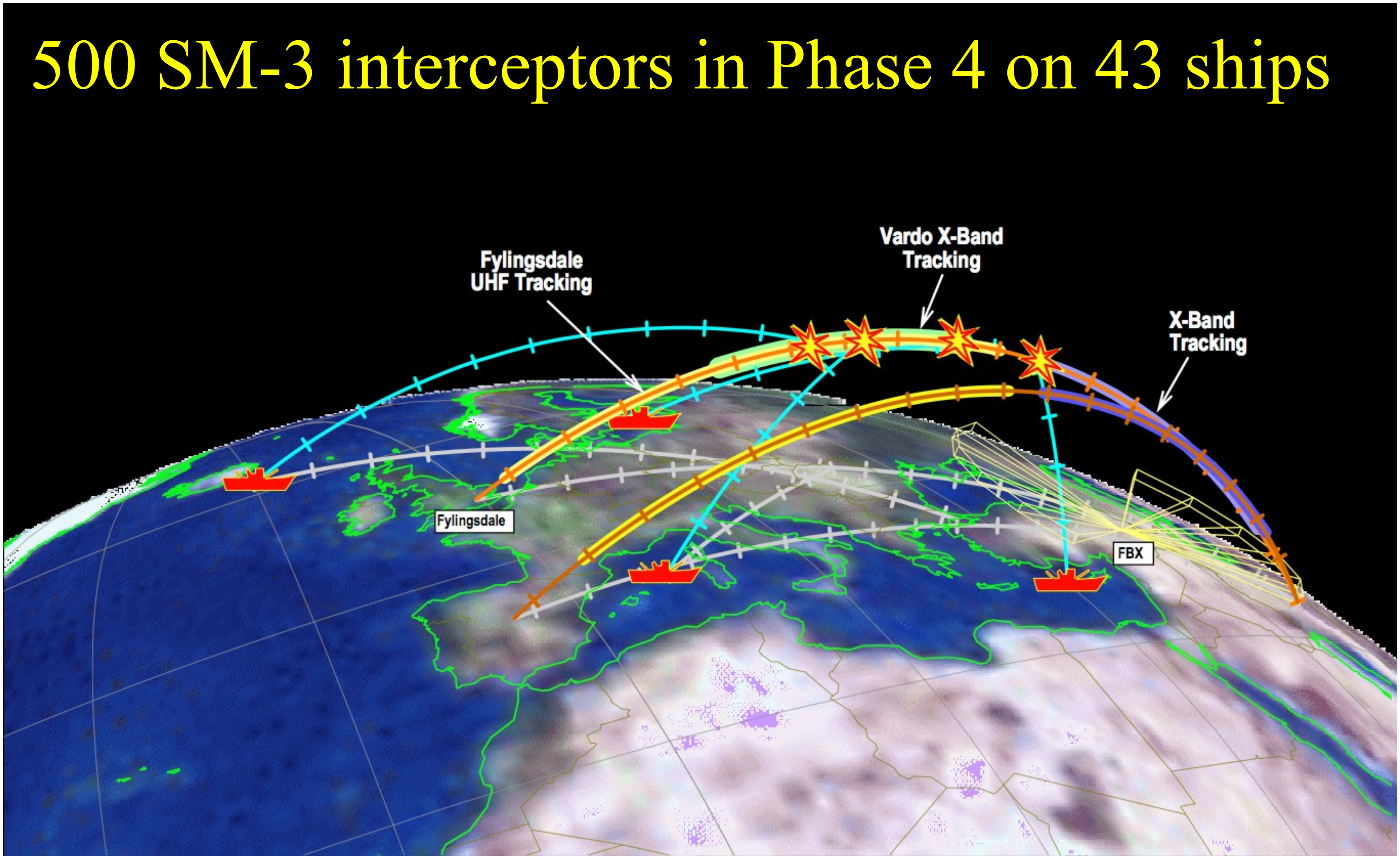
Phased Adaptive Approach to EMD

The European Phased Adaptive Approach (PAA) was presented as a more flexible alternative to Bush's proposed European-based GMD system.

It uses SM-3 interceptors, which are roughly 10X smaller than the 20-ton interceptors of the proposed European-based GMD system and will evolve continuously with increasing capability.

A system using these smaller and lighter interceptors would be incrementally tailored to the perceived threat over the coming decade.

Phased Adaptive Approach to EMD



Phased Adaptive Approach to EMD

U.S. Navy photo

A Standard Missile-3 is launched from the guided-missile destroyer USS *Paul Hamilton* in the Pacific Ocean on November 1, 2008.

Phased Adaptive Approach to EMD

- The PAA plan called for more than 500 SM-3 interceptors to be based on 43 ships by 2020.
- The PAA plan called for SM-3s with increasing capability to be stationed in Romania (in 2015) and in Poland (in 2020).
- The plan is to deploy SM-3 IIB interceptors by 2020. They are advertised as having some capability against longer-range missiles.
- In a study presented on January 29th , 2013 the GAO concludes that the final phase of PAA in its present configuration may be ineffective in defending the US from ICBMs from Iran. The Obama administration has canceled the final phase IV of PAA.

Navy/MDA Plans for Deployment of BMD-Capable Aegis Ships and SM-3 Interceptors

Table 1. Numbers of BMD-Capable Aegis Ships and SM-3 Missiles

	FY15	FY16	FY17 (req.)	FY18 (proj.)	FY19 (proj.)	FY20 proj.)	FY21 (proj.)
BMD-capable Aegis ships							
3.6 version	22	19	17	14	11	7	6
4.X version	8	10	10	12	15	19	20
5.0 CU version	3	4	7	11	9	4	2
5.1 version	0	0	0	0	5	13	21
Total	**33**	**33**	**34**	**37**	**40**	**43**	**49**
Aegis Ashore sites	**0**	**1**	**1**	**1**	**2**	**2**	**2**
SM-3 missile cumulative deliveries / inventory (including RDT&E purchases)							
Block I/IA	150/119	150/101	150/85	150/60	150/49	150/37	150/35
Block IB	59/49	107/92	146/128	185/166	221/202	256/236	295/271
Block IIA	0/0	0/0	0/0	4/2	15/11	17/12	20/14
Total	**209/168**	**257193**	**296/213**	**339/228**	**386/262**	**423/285**	**465/320**

Source: For numbers of BMD-capable Aegis ships and Aegis Ashore sites: Table prepared by CRS based on MDA briefing slide provided to CRS on March 25, 2016. For SM-3 cumulative deliveries/inventory: FY2017 MDA budget submission.

Current MDA Funding Request and Projections for Aegis BMD Program

Table 2. MDA Funding for Aegis BMD Efforts, FY2016-FY2021

(In millions of dollars, rounded to nearest tenth; totals may not add due to rounding)

	FY16	FY17 (req.)	FY18 (proj.)	FY19 (proj.)	FY20 (proj.)	FY21 (proj.)
Procurement funding						
Aegis BMD (line 24)	566.7	463.8	727.3	962.4	1,079.9	1,221.1
Aegis Ashore Phase III (line 28)	30.6	57.5	69.9	0	0	0
Aegis BMD hardware and software (line 30)	145.3	50.1	139.5	93.2	122.0	86.0
SUBTOTAL Procurement	**742.6**	**571.4**	**936.7**	**1,055.6**	**1,201.9**	**1,307.1**
Aegis BMD (PE 0603892C) (line 79)	830.6	959.1	841.7	700.6	592.9	528.7
Aegis BMD Test (PE 0604878C) (line 107)	78.5	95.0	127.7	91.5	88.2	98.5
Land-based SM-3 (PE 0604880C) (line 109)	35.0	43.3	29.0	19.3	21.3	21.6
Aegis SM-3 IIA (PE 0604881C) (line 110)	172.6	106.0	0	0	0	0
SUBTOTAL RDT&E	**1,116.7**	**1,203.4**	**998.4**	**811.4**	**702.4**	**648.8**
TOTAL	**1,859.3**	**1,774.8**	**1,935.1**	**1,867.0**	**1,904.3**	**1,955.9**

Source: Table prepared by CRS based on FY2017 MDA budget submission.

Recent Funding of Missile Defense Agency

Missile defense, budget —

In FY10, \$7.9 B. (before 9/11 about ~\$3.5B/year)

In FY11, \$8.5 B.

In FY12, \$8.4 B.

In FY13, \$8.3 B

In FY14, \$7.6 B

In FY15, \$7.8 B

In FY16, \$8.3 B

In FY17, \$8.1 B

http://www.mda.mil/global/documents/pdf/histfunds.pdf

Total MDA spending 1985 to 2017: 189.7 B

Possible Russian Concerns About the Phased Adaptive Approach to EMD

- The main concern of cautious Russian military planners would be the capability of missile defense interceptors to simply reach, or "engage", Russian strategic warheads, rather than whether any particular engagement results in an actual interception, or "kill."
- Interceptors with a kinematic capability to reach Russian ICBM warheads would be sufficient to raise concerns in Russian national security circles — regardless of the possibility that Russian decoys and other countermeasures might defeat the system in actual engagements.
- Hence even a missile defense system that could be rendered ineffective could still create serious concerns for cautious Russian military planners.

Possible Russian Concerns About the Phased Adaptive Approach to EMD

- The last two phases of the PAA – when the higher burnout velocity "Block II" SM-3 interceptors would come on-line in 2020 – could create legitimate concerns for Russian military analysts.
- These interceptors could in principle be used to create an integrated continental U.S. missile defense system that could engage Russian ICBM warheads, either in combination with, or independent of, the Ground-Based Midcourse (GMD) system now deployed in Alaska and California.
- This fact introduces the possibility that Russian ICBMs could face many hundreds, or eventually thousands, of SM-3 interceptors, in addition to the 30 or so GMD interceptors already deployed.
- Such large numbers of interceptors, which might in reality have little capability in combat, could be expected to create fears among Russian political and military leaders that the PAA could cause some attrition of Russian warheads.

Possible Russian Concerns About the Phased Adaptive Approach to EMD

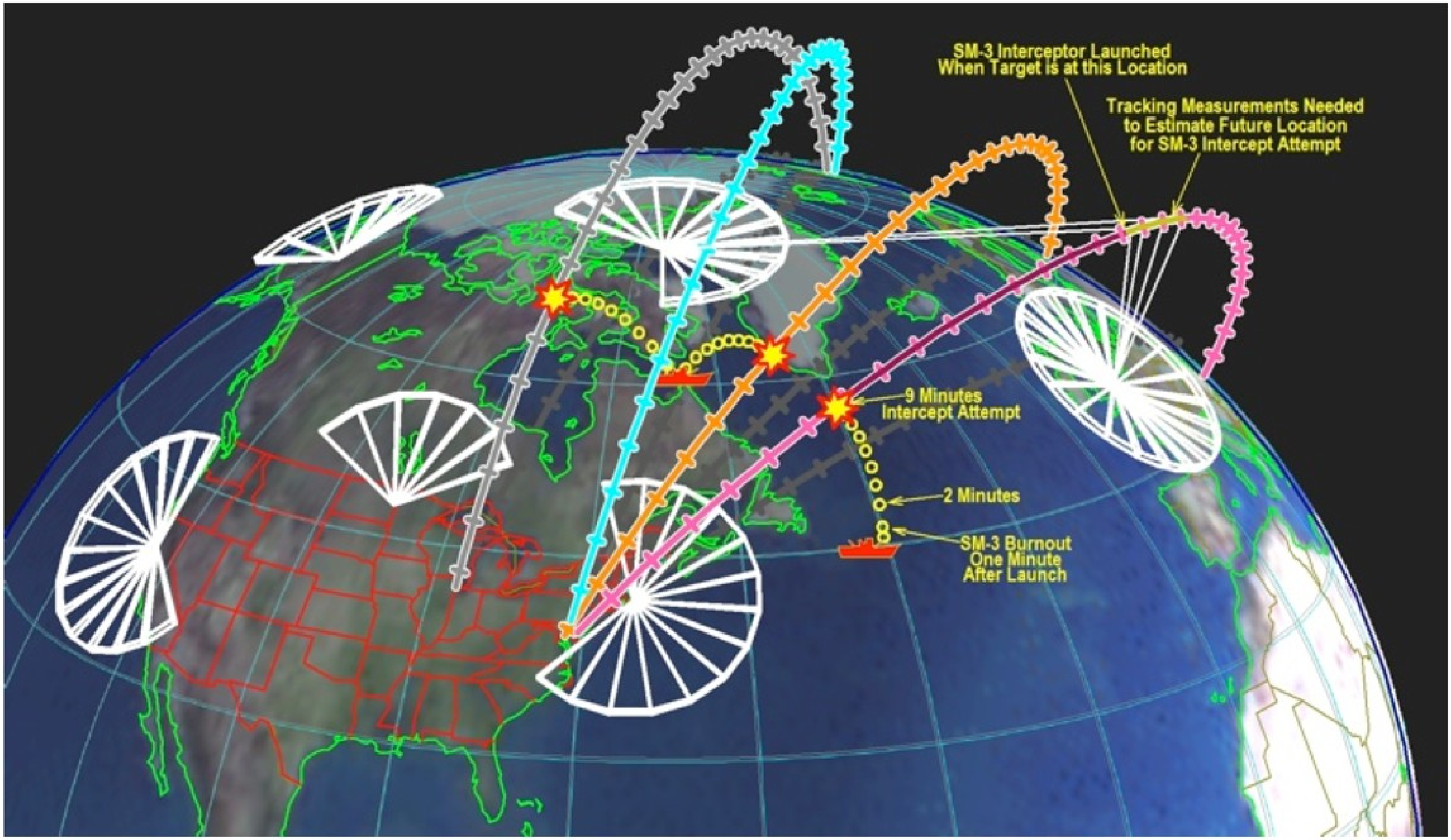
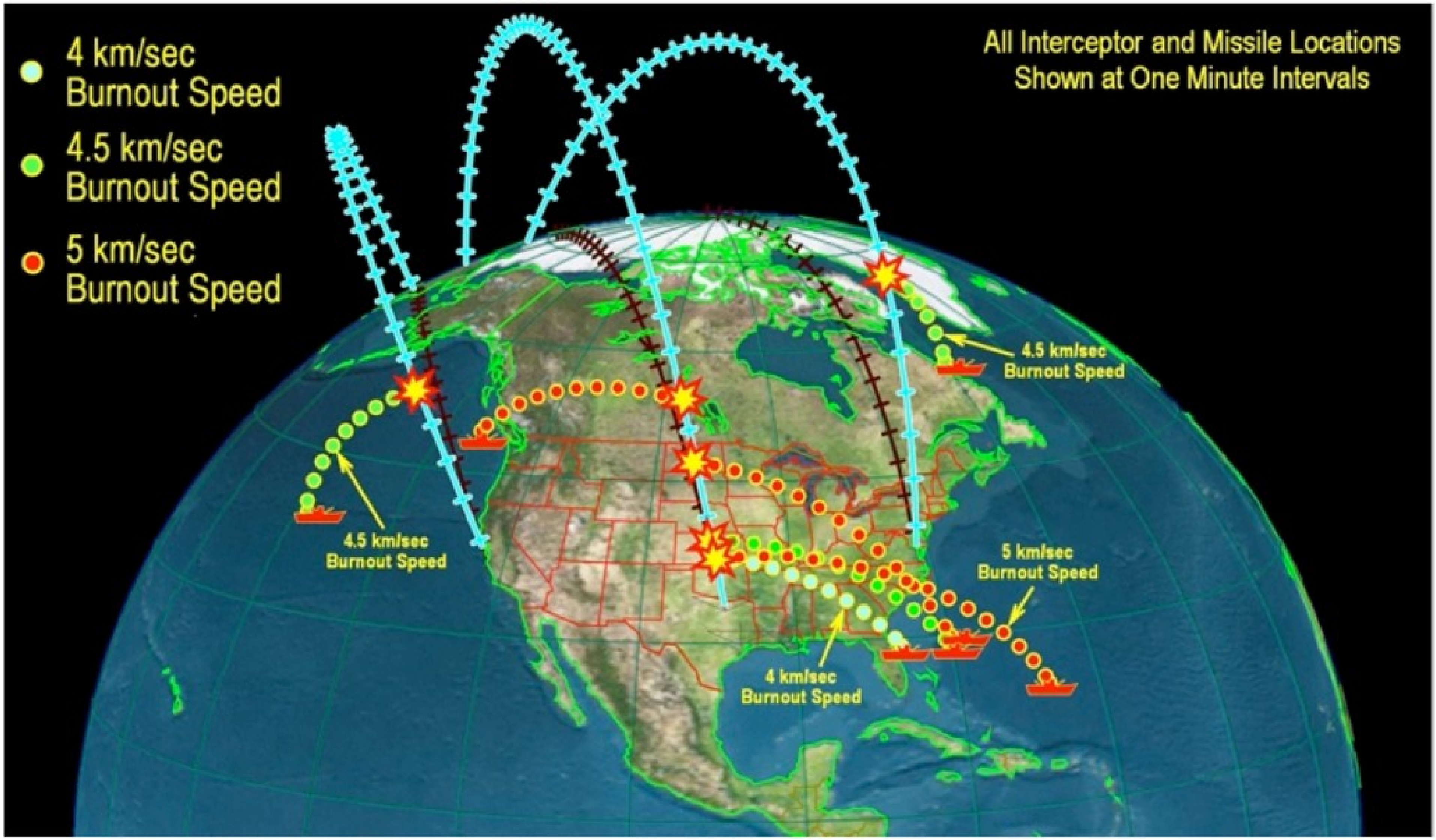


Figure 3: Northwest Atlantic-based SM3 Block II interceptors (with a conservative assumed burnout speed of 4 km/sec) engaging Russian ICBM warheads: each tick on the trajectories marks one minute.

Possible Russian Concerns About the Phased Adaptive Approach to EMD



Summary and Conclusions

Status of the U.S. Missile Defense Program

The technical performance of the current GMD ABM system is unclear due to insufficient testing under realistic conditions.

The Phased Adaptive Approach for European Missile Defense may not be effective in defending against ICBMs and requires review. The Obama administration has decided to cancel Phase IV.

Difficult to find solution that will create ABM effective against threats from the DPRK and from Iran and at the same time be not seen as threatening the nuclear deterrent of Russia and China.

Some Missile Defense Questions

The material presented in this module shows that the political actions in this area by the U.S. and Russia are not consistent with the scientific-technical realities. What is the reason for this failure?

- Is it insufficient scientific-technical advice reaching the highest levels of governments?
- Is it deliberate disregard of such advice by national leaders and the inherent conservatism of governments in their inability to change past erroneous decisions?
- Is it the skillful exploitation of valid public concerns for security by groups and institutions benefitting from large expenditure on missile defense?

Module 7: Defenses Against Nuclear Attack

Supplementary Slides

What Might a Successful Approach Look Like?

North Korea

Three no's —
No more bombs
No better bombs
No export

In return for one yes —
U.S. willingness to address North Korea's fundamental security concerns, including normalization of relations with the United States + energy and economic aid.

Iran

Two no's —
No bombs
No export

In return for one yes —
U.S. willingness to address Iran's fundamental security concerns. This would probably have to include normalization of relations with the United States

George W. Bush's Proposed European Midcourse Intercept System

Bush's Proposed European Missile Defense

(Missile Defense Agency Slide)

Courtesy: T. Postol (MIT)

- **Up to 10 silo-based long-range interceptors located in Eastern Europe (2011-2013)**

- **Re-location of a narrow-beam, midcourse tracking radar currently used in our Pacific test range to central Europe (2011)**

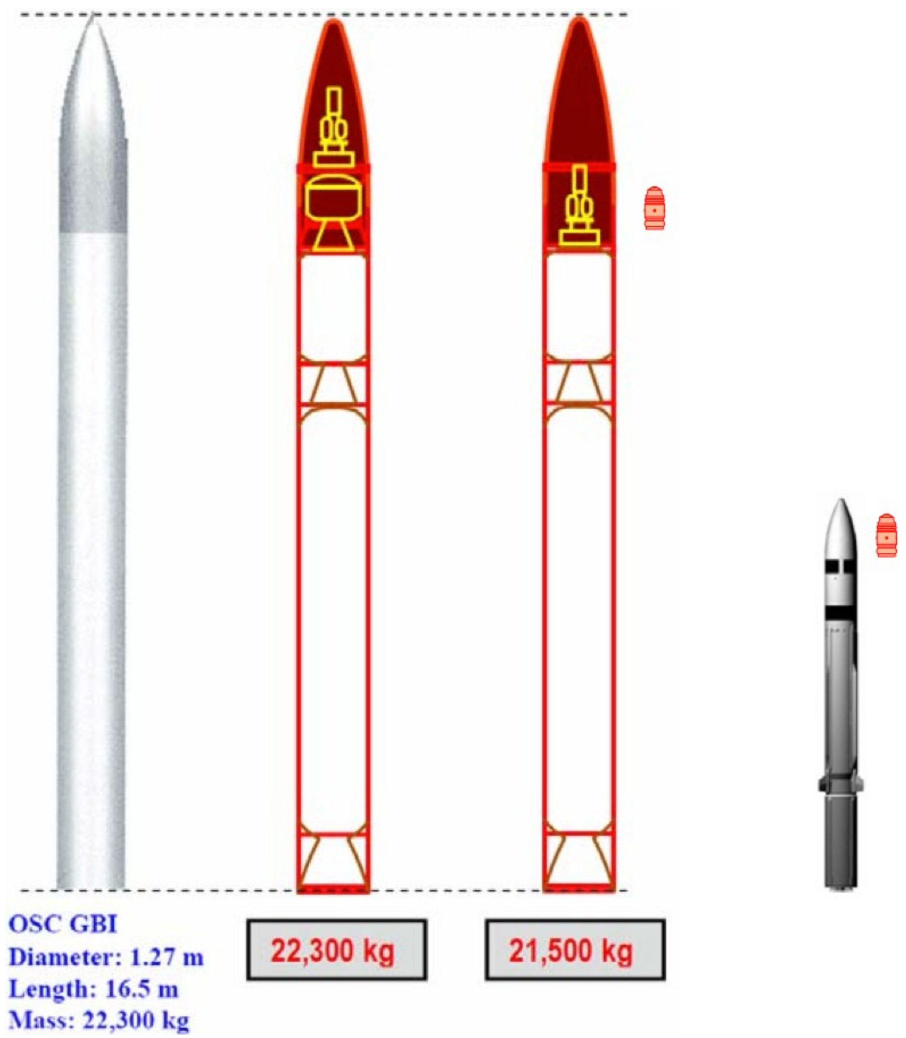
- **Field an acquisition radar focused on the Iranian threat from a forward position to provide detection, cueing, and tracking information (2010-2011)**

Approved for Public Release
07-MDA-2332 (9 MAR 07)

ms-109395A / 030707

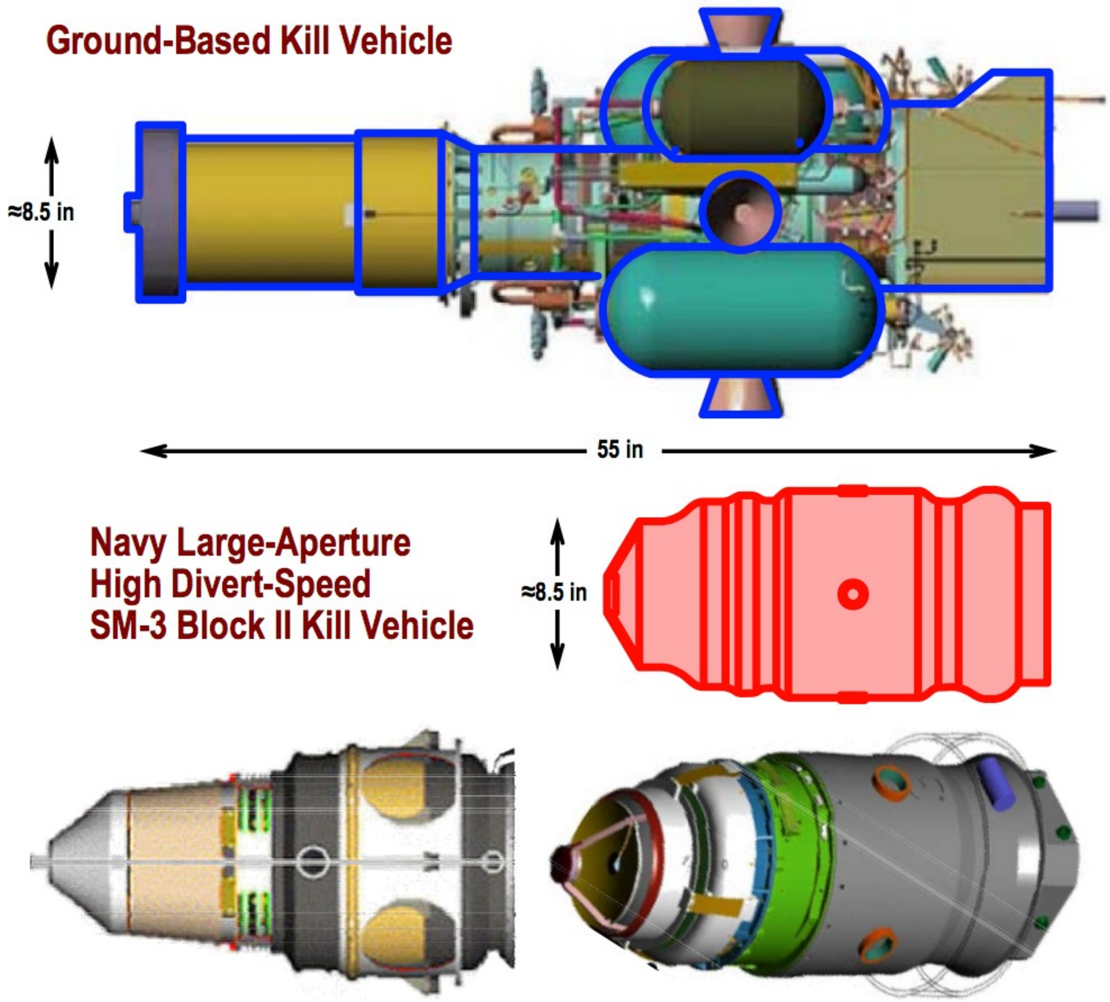
Planned Midcourse Intercept Rockets

Courtesy T. Postol (MIT)



Planned Midcourse Intercept Kill Vehicles

Courtesy T. Postol (MIT)



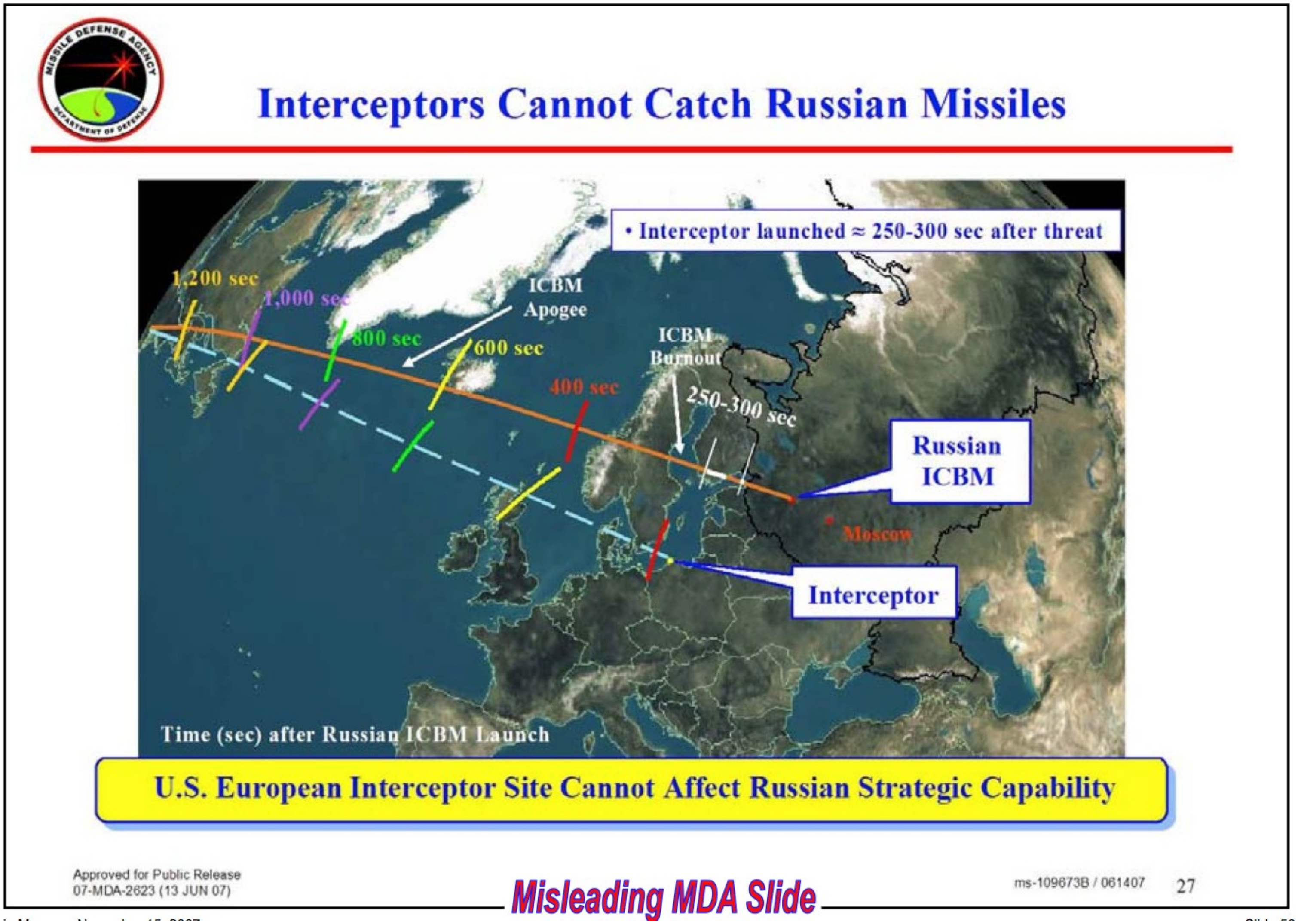
Proposed European Defense Against Ballistic Missiles

Courtesy T. Postol (MIT)

Proposed European Defense Against Ballistic Missiles

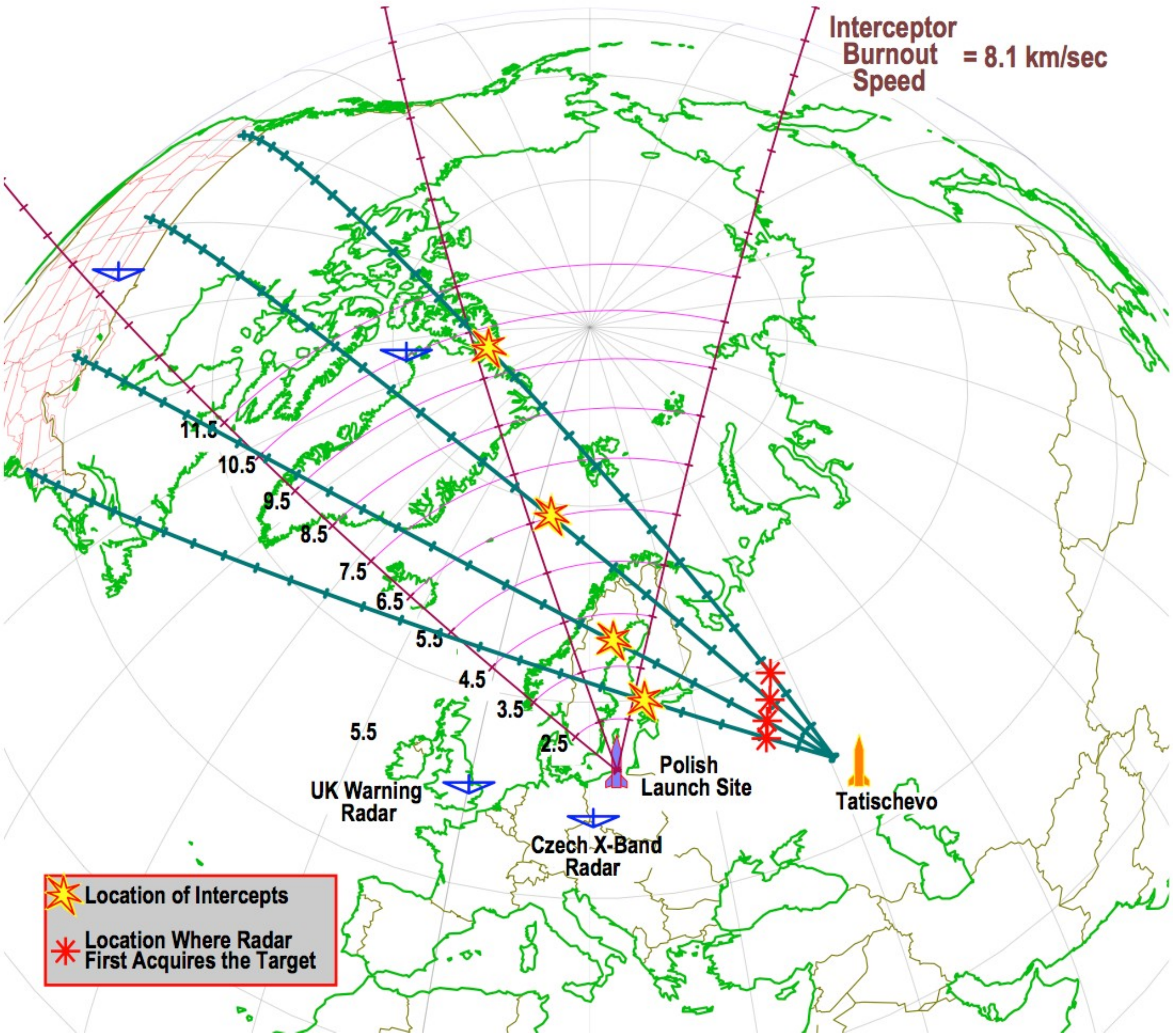
Courtesy T. Postol (MIT)

Proposed European Defense Against Ballistic Missiles



Courtesy T. Postol (MIT)

Proposed European Defense Against Ballistic Missiles



Courtesy T. Postol (MIT)

iClicker Question

The interceptor rockets for President Bush's European-based missile defense program:

A. Were tested about a dozen times

B. Were tested only 3 times

C. Were tested only once

D. Were never even built

iClicker Answer

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A. Were tested about a dozen times

B. Were tested only 3 times

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iClicker Question

Obama’s proposed European missile defense system will initially rely primarily on what type of interceptor?

A. Large ground-based interceptor rockets
B. Small ship-based interceptor rockets
C. Ship-based lasers
D. Airborne lasers
E. All of the above

iClicker Answer

Obama's proposed European missile defense system will initially rely primarily on what type of interceptor?

A. Large ground-based interceptor rockets

B. Small ship-based interceptor rockets

C. Ship-based lasers

D. Airborne lasers

E. All of the above

Defenses Against Nuclear Attack

Many aspects of this problem are counter-intuitive

Very important to distinguish—

- Technical issues (nature cannot be fooled)
- Policy issues (what is the goal)
- Arms race issues (effects on arms races)
- Costs vs. benefits, alternatives, opportunity costs
- Possible threats and threat evolution (number, characteristics, responsive vs. nonresponsive)

Crucial to avoid “the fallacy of the last move”

Consequences of a Nuclear Explosion

A single nuclear explosion can cause unimaginable death and destruction

A “small” (few kiloton) nuclear explosion in a major city would, within seconds to minutes —

- kill hundreds of thousands of people
- reduce many square miles to rubble

A large (100 kiloton – 1 Megaton) nuclear explosion in a major city would, within seconds to minutes —

- kill many millions of people
- reduce a hundred square miles to rubble

Very little can be done before or after a nuclear explosion to lessen the deaths, injuries, and destruction it will cause

Efforts to Defend the United States Against Attack by Nuclear-Armed Ballistic Missiles

Evolution of perceived threats

- Soviet long-range ballistic missiles (1950s – 1990s)
- Chinese long-range ballistic missiles (1960s – today)
- Accidental or unauthorized launch of ballistic missiles (early 1990s)
- *North Korean or Iranian long-range missiles (late 1990s – today)*

History of U.S. main anti-ballistic missile weapon programs

- Nike-Zeus (1950s)
- Nike-X (early 1960s)
- Sentinel (late 1960s)
- Safeguard (1970s)
- Star Wars (1980s)
- Global Protection Against Accidental Launches (GPALS, early 1990s)
- National Missile Defense (late 1990s)
- *Current Missile Defense Program (2001 to the present)*

Goals of U.S. ABM Programs

Some past announced or actual ABM program goals —

- Defend U.S. cities against a massive attack by Soviet ICBMs (1955–1962)
- Support the aerospace industry, defend the Johnson administration against attacks by Republicans, defend the United States against a limited attack by future Chinese missiles (1968)
- Defend some U.S. ICBM silos against a Soviet counter-force attack (1968–1975)
- Make nuclear weapons impotent and obsolete by creating an “impenetrable shield” that would completely protect the U.S. and all its friends and allies (Reagan, 1983–1988)
- Enhance deterrence, defend U.S. missile silos, achieve political advantage, etc. (everyone else, 1983–1988)

Goals of U.S. ABM Programs

ABM program goals (continued) —

- Defend the United States against accidental launches of Soviet ICBMs (1988–1990)
- Defend the United States against an unspecified, emerging Third-World ballistic missile threat (1990–1991)
- Counter the threat of theater ballistic missiles (1991–1998)
- Defend the Clinton administration against attacks by Republicans, defend the U.S. against missile attacks by emerging ballistic missile states with which the U.S. did not have friendly relations (1998–2001)
- Reward Bush supporters, defend U.S. against missile attacks by the “axis of evil” states (North Korea, Iran, and Iraq), or China, or an accidental launch from Russia, or … (2001–present)

The Patriot Weapon System

Originally an anti-aircraft system (IOC in 1985)

Given some ATBM capability in 1988 (PAC-1)

- Software upgrade
- Specifically designed to counter Soviet TBMs

Given improved ATBM capability in 1990 (PAC-2)

- Faster fuse
- Fragmenting warhead with larger pellets
- Some capability against Soviet Scud missiles
- No capability against Iraqi Al-Hussein missiles

Patriot in the 1991 Gulf War

The system—

- The US had only 3 PAC-2 interceptors in its inventory at the time the Iraqi's invaded Kuwait
- Changes in system software were made hastily after the invasion
- 600 PAC-2 interceptors were manufactured by January 1991
- PAC-2 interceptors were incorporated into all units deployed to the Gulf
- Critical software errors were discovered in the field, one may have caused major US fatalities
- No data was recorded in the field to evaluate the Patriot system's performance

What's Different About Current U.S. ABM Programs Compared to 'Star Wars'?

- Today's defined threat is numerically smaller, but nuclear and chemical or biological warheads still require that the defense meet very high performance standards
- Geographical factors and missile ranges are more diverse
- Defenses against shorter-range (theater or battlefield) missiles are technically easier because of these missiles have lower speeds
- Legacy technologies from the Star Wars program are occasionally helpful, but by-and-large the benefits from this enormous expenditure are small

Technological Challenges of Midcourse Intercept

The technological challenge is formidable, most difficult is "discrimination"

- The system has to confront an attacking missile that is designed to fool the interceptor into going after one of many decoys RVs
- The general performance characteristics of the EKV (com links, sensor suite, agility) will be known to the adversary
- The missile's payload could be one or more nuclear warheads, or dozens or hundreds of hardened chemical or biological munitions (bomblets)
- The system must identify and track RVs in the face of countermeasures, including decoys and anti-simulation devices

The Welch panel labeled the Bush II GMD program "Rush to Failure"

The system failed many tests. The DoD therefore exempted the system from any further testing until it was deployed.

GAO Report on Missile Defense

GAO
Accountability * Integrity * Reliability

GAO-11-555T

April 13, 2011

MISSILE DEFENSE

Actions Needed to Improve Transparency and Accountability

GAO does not make new recommendations in this testimony but emphasizes the importance of implementing past recommendations.

GAO Report on Missile Defense

I am pleased to be here today to discuss the transparency and accountability progress made by the Department of Defense's (DOD) Missile Defense Agency (MDA). MDA has been charged with developing and fielding the Ballistic Missile Defense System (BMDS), a system expected to be capable of defending the United States, deployed troops, friends, and allies against ballistic missiles of all ranges in all phases of flight. The BMDS is DOD's single largest acquisition program—spending between approximately $7 billion to $9.5 billion per year – to develop and field nine elements and supporting efforts. The system's architecture includes space-based and airborne sensors as well as ground- and sea-based radars; ground- and sea-based interceptor missiles; and a command and control, battle management, and communications system to provide the warfighter with the necessary communication links to the sensors and interceptor missiles.

GAO Report on Missile Defense

When MDA was established in 2002, it was granted exceptional flexibility in setting requirements and managing the acquisition, in order that its BMDS be developed as a single program, using a capabilities-based, spiral upgrade approach to quickly deliver a set of integrated defensive capabilities. This decision deferred application of DOD acquisition policy to BMDS until a mature capability is ready to be handed over to a military service for production and operation. Because the BMDS program has not formally entered the DOD acquisition cycle, application of laws that are designed to facilitate oversight and accountability of DOD acquisition programs and that are triggered by phases of this cycle, such as the engineering and manufacturing development phase, has also effectively been deferred. This gives MDA unique latitude to manage the BMDS and it enabled MDA to begin delivering an initial defensive capability in 2004. However, the flexibility also came at the expense of transparency and accountability.

GAO Report on Missile Defense

Specifically, a BMDS cost, schedule, and performance baseline does not have to be established or approved by anyone outside MDA. Recent laws have created some baseline-related requirements for parts of the BMDS.[8] In addition, while most major defense acquisition programs are required by statute to obtain an independent verification of cost estimates, MDA has only recently developed cost estimates for selected assets and plans t

Since its inception, MDA has employed at least three different strategies to acquire and deploy missile defense systems. Because these changes involved different structures for reporting cost, schedule, and performance data, they have exacerbated transparency and accountability challenges—each time a strategy changes, the connection between the old and new strategy planned scope and resources is obscured.

GAO Report on Missile Defense

As we concluded in a prior report, having less transparency and accountability than is normally present in a major weapon program has had consequences.[9] The lack of baselines for the BMDS along with high levels of uncertainty about requirements and program cost estimates effectively set the missile defense program on a path to an undefined destination at an unknown cost. Across the agency, these practices left programs with limited knowledge and few opportunities for crucial management oversight and decision making concerning the agency's investment and the warfighter's continuing needs. At the program level, these practices contributed to quality problems affecting targets acquisitions, which in turn, hampered MDA's ability to conduct tests as planned.

GAO Report on Missile Defense

MDA was still transitioning to this new capabilities-based block approach when the Director, MDA terminated it in June 2009. According to MDA, this was done in order to address congressional concerns regarding how to structure MDA's budget justification materials. This termination marked the third acquisition management strategy for the BMDS in the prior 3 years and effectively reduced transparency and accountability for the agency. The agency then began to manage BMDS as a single integrated program but planned to report on cost, schedule, and performance issues by each element within the program.

Changing the acquisition strategy is problematic because each time it is changed, the connection is obscured between the old strategies' scope and resources and the new strategy's rearranged scope and resources. This makes it difficult for decision makers to hold MDA accountable for expected outcomes and clouds transparency of the agency's efforts.

GAO Report on Missile Defense

In 2010, MDA made significant progress in addressing previously reported concerns about transparency and accountability. Specifically, MDA :

- Established resource, schedule, test, operational capacity, technical, and contract baselines for several missile defense systems. It reported these to Congress in its June 2010 BMDS Accountability Report.
- Identified three phases of development where baselines are approved—technology development, product development, and initial production phases—and specified the key knowledge that is needed at each phase.
- Established processes for reviewing baselines and approving product development and initial production jointly with the military services that will ultimately be responsible for those assets.

GAO Report on Missile Defense

GAO also reported last year that MDA extensively revised the test plan to increase its robustness and ability to inform models and simulations for assessing missile defense performance.

While it is clear that progress has been made in terms of implementing new acquisition reviews and reporting detailed baselines, there remain critical gaps in the material reported, particularly the quality of the underlying cost estimates needed to establish baselines. Moreover, GAO still has concerns about realism in test planning and acquisition risks associated with the rapid pace of fielding assets. These risks are particularly evident in MDA's efforts to develop systems to support a new approach for missile defense in Europe as well as the Ground-based Midcourse Defense system.

GAO Report on Missile Defense

Ground-based Midcourse Defense: GMD is a ground-based defense system designed to provide combatant commanders the capability to defend the homeland against a limited attack from intermediate, and intercontinental-range ballistic missiles during the midcourse phase of flight. The GMD consists of a ground-based interceptor—a booster with an Exoatmospheric Kill Vehicle on top—and a fire control system that receives target information from sensors in order to formulate a battle plan. GMD continues to deliver assets

GAO Report on Missile Defense

before testing has fully determined their capabilities and limitations. The Director, MDA testified on March 31, 2011 that he considers the GMD interceptors essentially prototypes. In the urgency to deploy assets to meet the Presidential directive to field an initial capability by 2004, assets were built and deployed before developmental testing was completed. During the ongoing developmental testing, issues were found that led to a need for retrofits. GMD intercept tests conducted to date have already led to major hardware or software changes to the interceptors—not all of which have been verified through flight testing. In addition, manufacturing of a new variant called the Capability Enhancement

GAO Report on Missile Defense

of which have been verified through flight testing. In addition, manufacturing of a new variant called the Capability Enhancement II is well underway and more than half of those variants have already been delivered although their capability has not been validated through developmental flight tests. To date, the two flight tests utilizing this variant have both failed to intercept the target. According to MDA, as a result of the most recent failure in December 2010, deliveries of this variant have been halted. Again, because of the urgency to deploy some capability, limited work was undertaken on long-term sustainment for the system which is critical to ensure the system remains effective through 2032. In September 2010, MDA finalized the GMD Stockpile Reliability Program Plan, a key step in developing the knowledge needed to determine the sustainment needs of the GMD system.

GAO Report on Missile Defense

<u>Aegis Ashore:</u> Aegis Ashore is MDA's future land-based variant of the ship-based Aegis BMD. It is expected to track and intercept ballistic missiles in their midcourse phase of flight using Standard Missile-3 (SM-3) interceptor variants as they become available. However, while Aegis BMD has demonstrated performance at sea, these demonstrations used the currently fielded 3.6.1 version of Aegis BMD with the SM-3 IA interceptor, not the newer variant of the Aegis operating system and new interceptor that Aegis Ashore will use. Aegis Ashore is dependent on next-generation versions of Aegis systems—Aegis 4.0.1 and Aegis 5.0—as well as the new SM-3 IB interceptor, all of which are currently under development. Moreover, a series of changes are required to further modify these new variants of Aegis BMD for use on land with Aegis Ashore.

GAO Report on Missile Defense

Changes to those existing Aegis BMD components that will be reused for Aegis Ashore may reduce their maturity in the context of the new Aegis Ashore program, and new features will require testing and assessment to demonstrate their performance. MDA plans to make production decisions for the first operational Aegis Ashore before conducting both ground and flight tests. We concluded in this year's report that it is a highly concurrent effort, with significant cost, schedule and performance risk.

Approach of the APS Boost Missile Defense Study Group

Relied on the threat assessments in unclassified summaries of recent National Intelligence Estimates and Congressional testimony by NIC staff

Considered a range of possible goals for the defense (defending all 50 states, only the largest cities, only one coast, only Hawaii, ...)

Made generally optimistic assumptions about the performance of boost- phase defense systems:

- Assumed the attacker would have only early-1960s technology
- Assumed the defense would be able to deploy the most advanced technology available ten years from now
- Set aside all battle management, communications, command, control, lethality, and reliability issues and countermeasures

Identified system architectures that could work in principle

Constructed computer models of missiles, missile tracking systems, interceptors, and kill vehicles and carried out simulations to determine the performance that would be required for these systems to work

Why the APS Study's Results Differ From Those of Some Other Studies

It considered liquid-propellant model ICBMs based on 40-year-old technology, but did not assume they would have very long (300+ second) boost phases

It considered solid-propellant model ICBMs based on 40-year-old technology

It did not assume the defense is "omniscient" —

- It *did* assume the ICBM's performance characteristics are known exactly (but they may not be)
- It *did not* assume knowledge of the attacker's intent
  - —Initial direction of flight and target unknown in advance
  - —ICBM's flight path not known in advance

It carefully analyzed kill-vehicle performance required to intercept an accelerating ICBM

It carefully examined the defense technologies likely to be in hand in 10 to 15 years and their implications for interceptor and kill-vehicle performance

Why Solid-Propellant ICBMs Need to Be Considered

The two fundamentally different types of ICBMs (liquid- and solid-propellant) present very different challenges

Although North Korea might initially deploy liquid-propellant ICBMs, recent NIE summaries point to significant transfer of solid-rocket technology among North Korea, Iran, Pakistan, China, and other countries of concern

On the basis of unclassified summaries of the most recent U.S National Intelligence Estimates and briefings, the Study Group concluded that countries of concern might deploy solid-propellant ICBMs within the next 10–15 years, if they were able to purchase or acquire solid-propellant missiles or technology and the U.S pursued a boost-phase missile defense

Because it would take at least a decade for the United States to field a boost-phase missile defense, a defense that is effective only against liquid-propellant ICBMs would risk being obsolete when deployed or soon afterward

Whether the Interceptor Rocket Could Reach the ICBM in Time Depends . . .

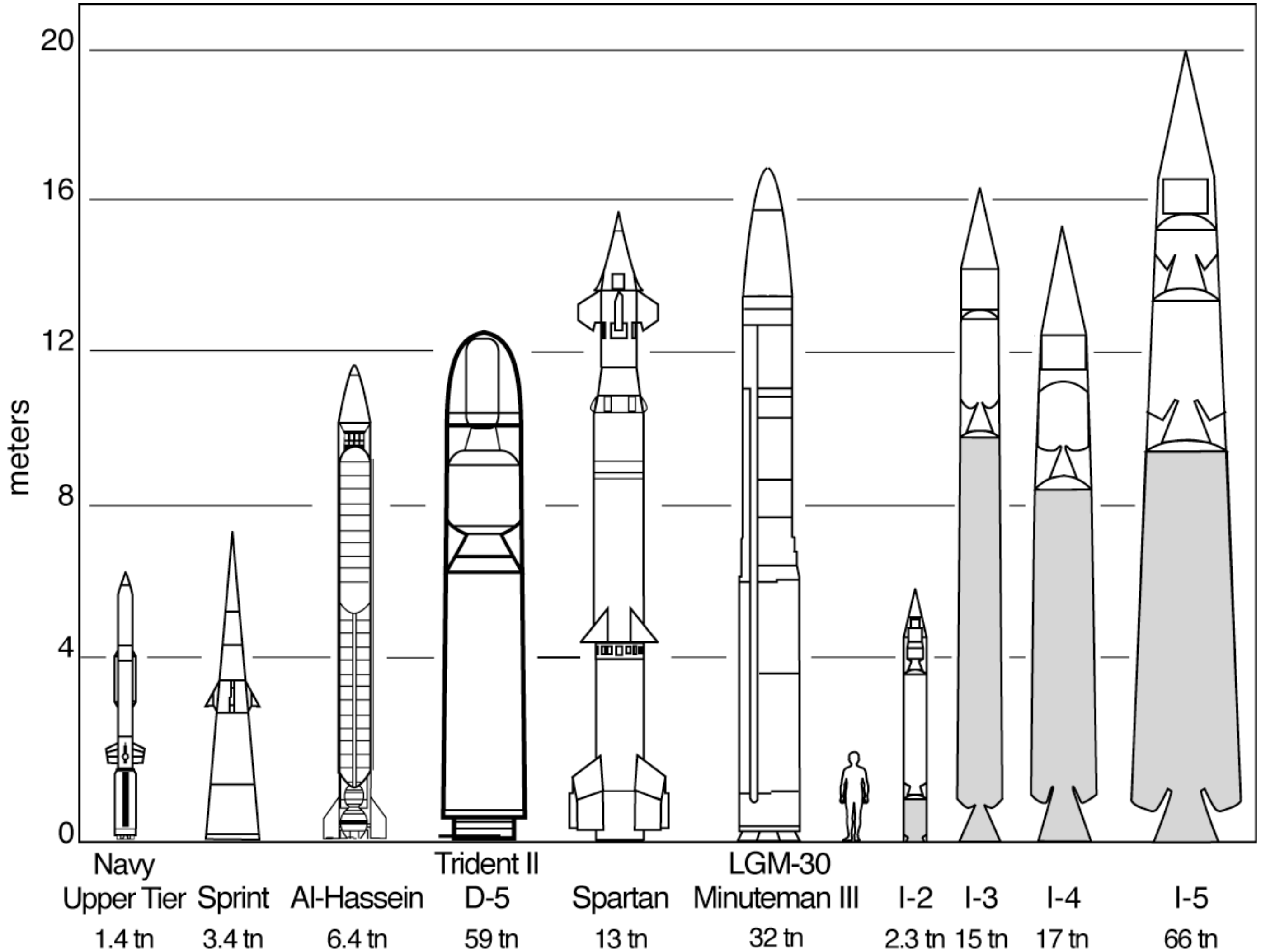
On whether the target ICBM is a liquid-or a solid-propellant missile

The global geography determines how early in its flight the target ICBM must be intercepted

Regional geography determines how close to the target ICBM's flight path interceptors could be based

Generally interceptors must be based far from the intercept point, must fly almost their maximum range (~ 500 km for solid ICBMs or ~ 1,000 km for liquid ICBMs), and must intercept the ICBM at the last possible moment

Reaching and Hitting the Target Would Require Large, Fast Booster Rockets



Hitting an ICBM in Powered Flight Requires a Highly Capable Kill Vehicle

The APS Study found no fundamental obstacle to developing adequate kill vehicles, but —

The kill vehicle must have sensors capable of tracking the cool missile body in the face of the bright exhaust plume, which is displaced from it

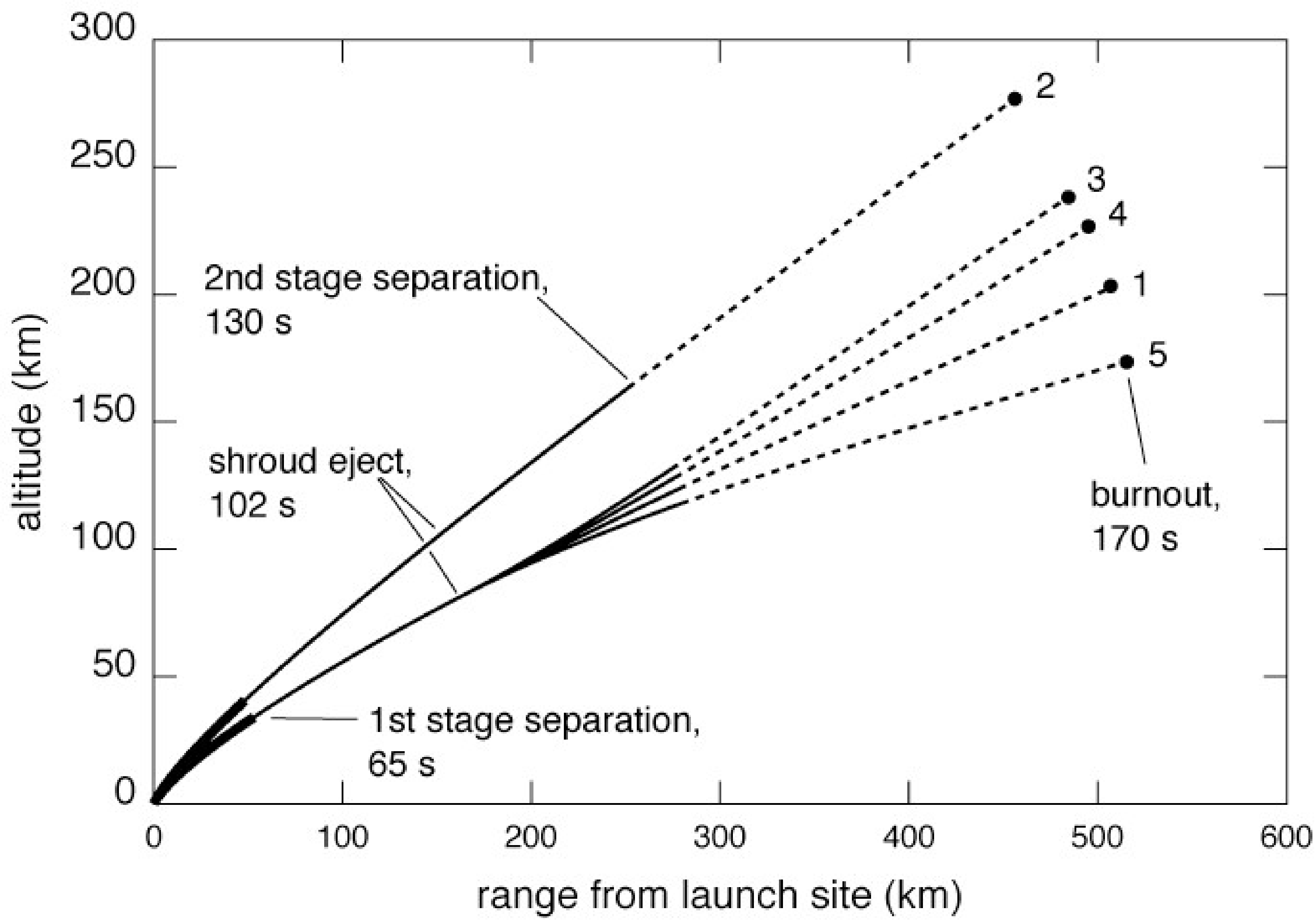
- Passive infrared, optical, and UV sensors
- Active sensors such as LIDAR

The kill vehicle must be able to compensate fully for changes in the flight of the target missile

- Must have adequate total divert capability (2.0 to 2.5 km/s)
- Must have sufficient acceleration for the endgame (15 g)
- Must have fast guidance and control and quick dynamic response (0.1 s or less total lag)

Kill vehicles with these capabilities would be relatively heavy (90–140 kg)

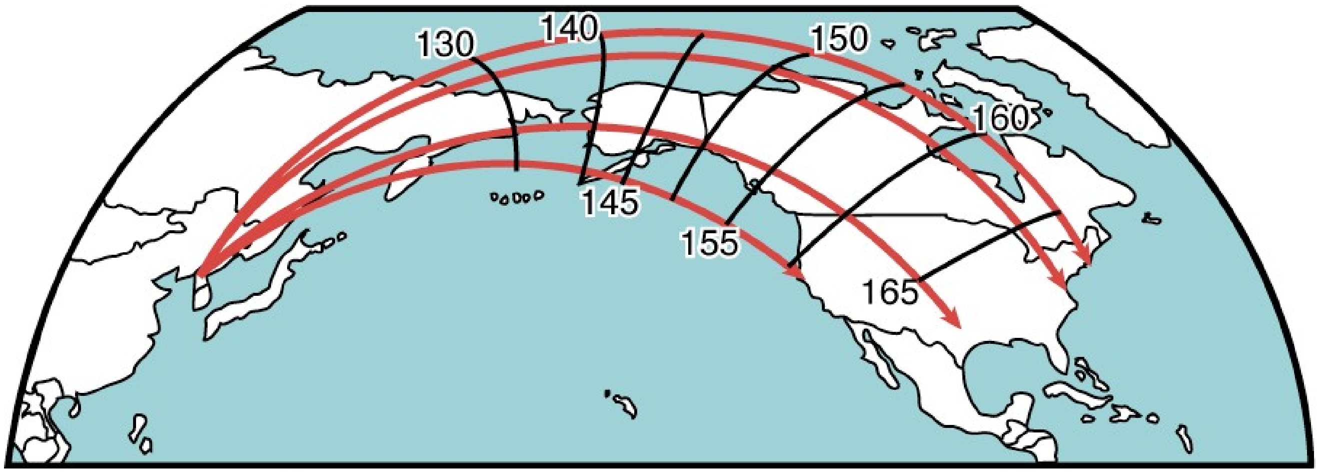
Hitting an ICBM in Powered Flight is Very Challenging



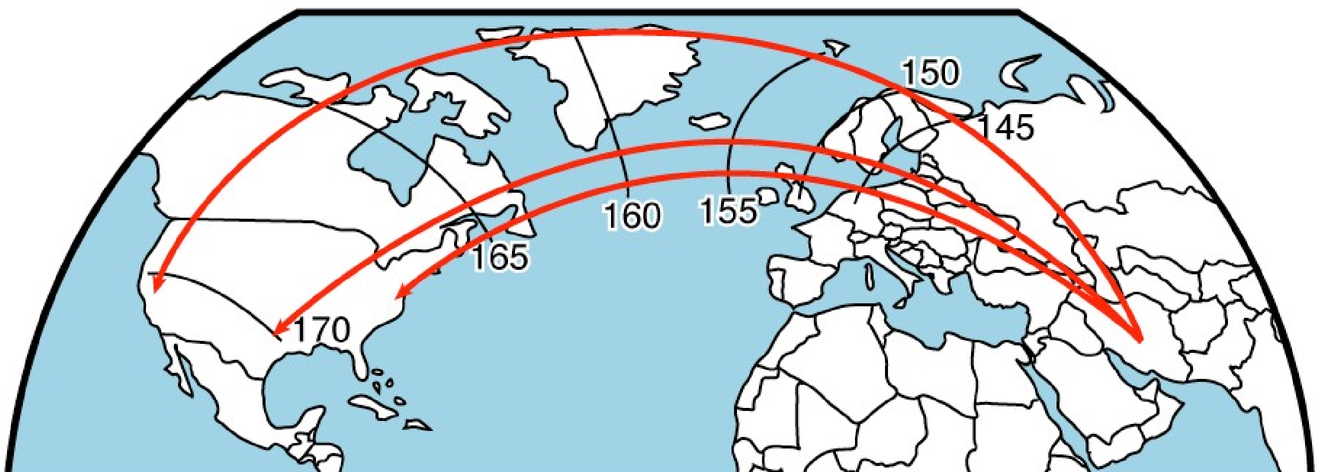
Global Geography Determines How Early the ICBM Must Be Intercepted

These maps show *when* an attacking missile could release its warheads to strike U.S. territory; all warheads would be released *within 500 km* of the missile launch site.

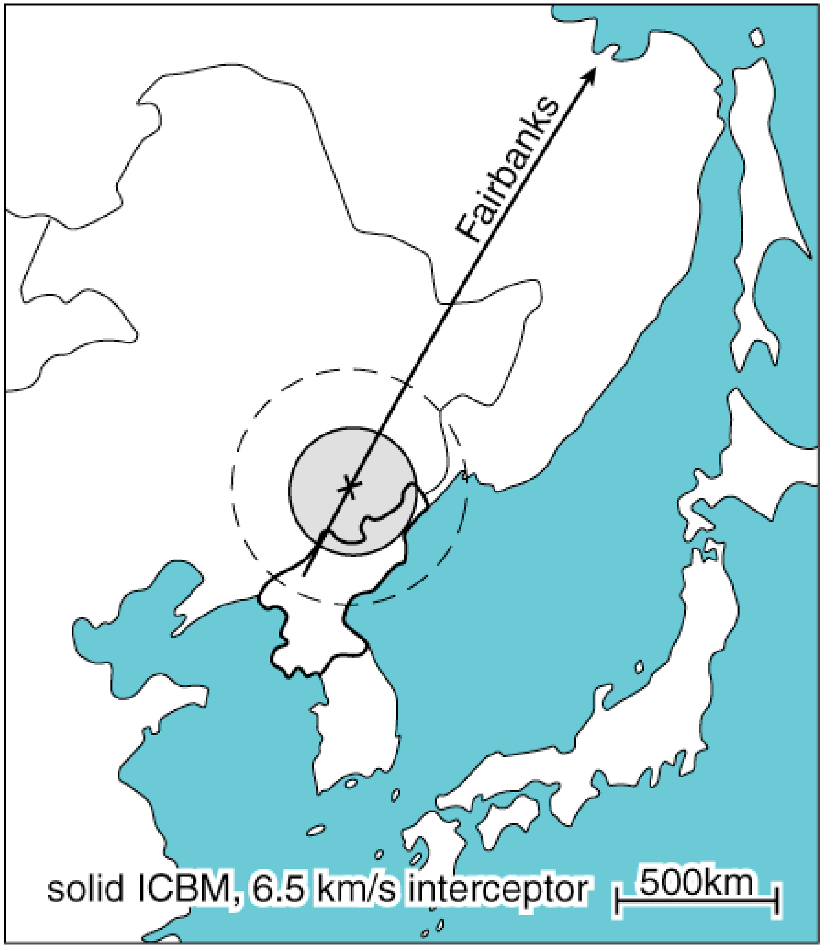
Solid-propellant from North Korea



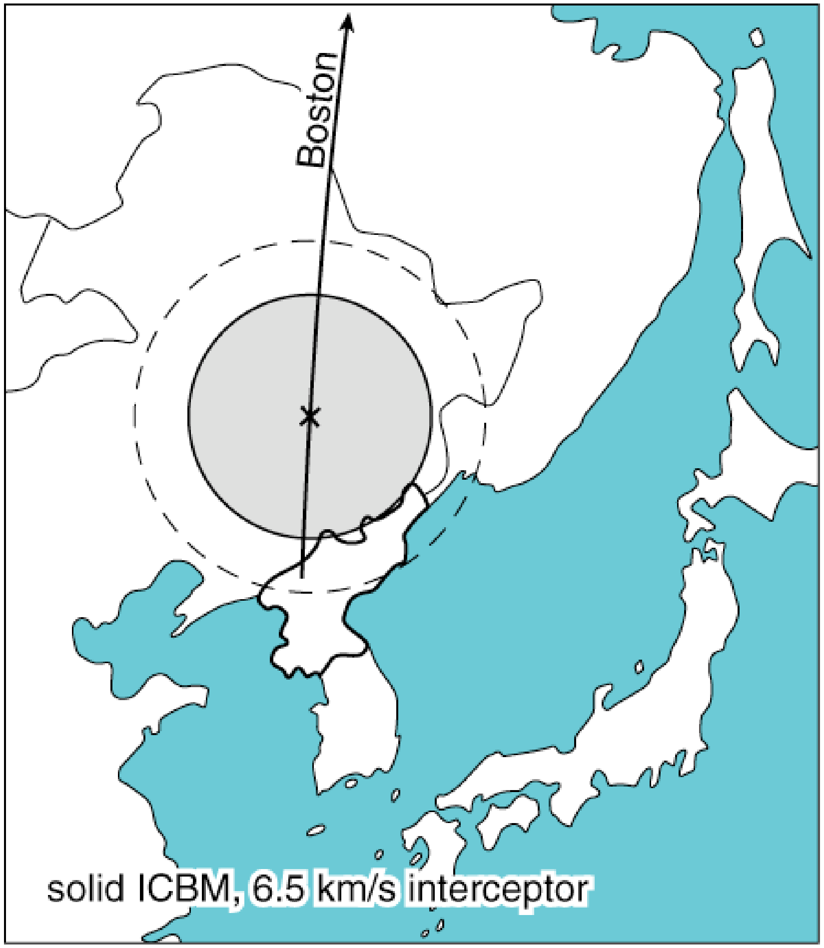
Solid-propellant from Iran



Regional Geography Determines How Close Interceptors Could Be Based



Basing areas for intercepting a solid-propellant ICBM from North Korea to Fairbanks



Basing areas for intercepting a solid-propellant ICBM from North Korea to Boston

Shortfall Would Be Difficult to Manage

The goal of a boost-phase defense is to protect the target by causing the attacking missile's munitions to fall short

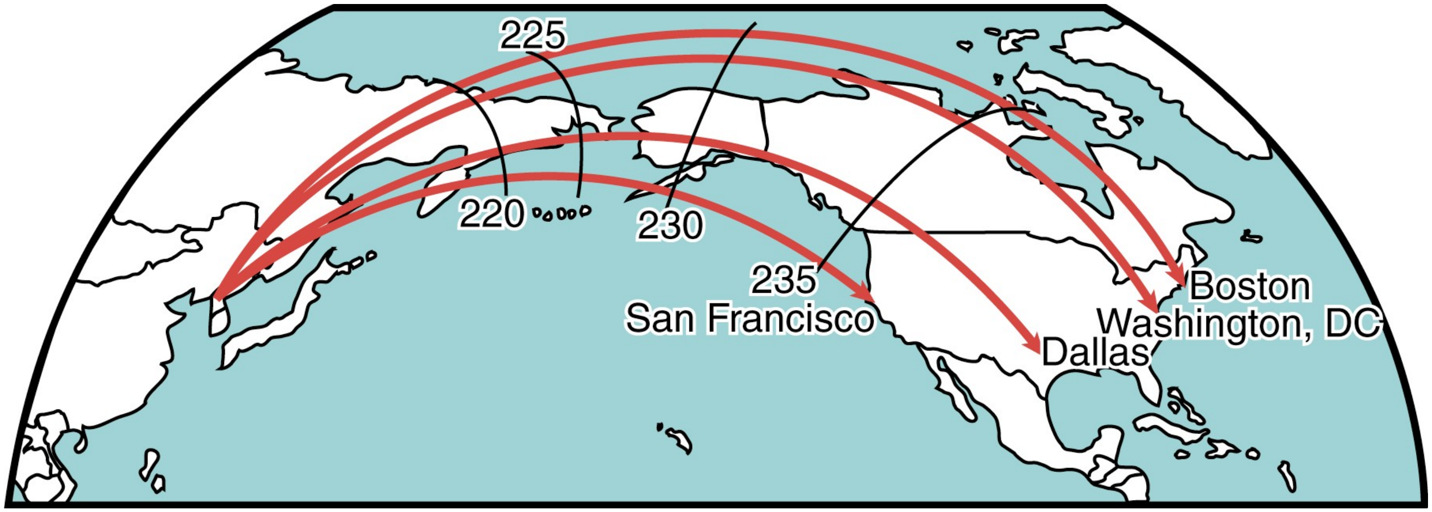
A problem inherent in boost-phase defense is that causing the attacking missile's munitions to fall short could cause nuclear, chemical, or biological weapons to impact other populated areas in the United States or other countries

Some or all of these weapons could be live when they impact

Timing intercepts accurately enough to avoid causing this would be very difficult, if it's possible at all

An alternative would be to design the interceptor to destroy all warheads or submunitions, but this is likely to be difficult

Munitions from North Korean Missiles Could Impact Russia or Canada

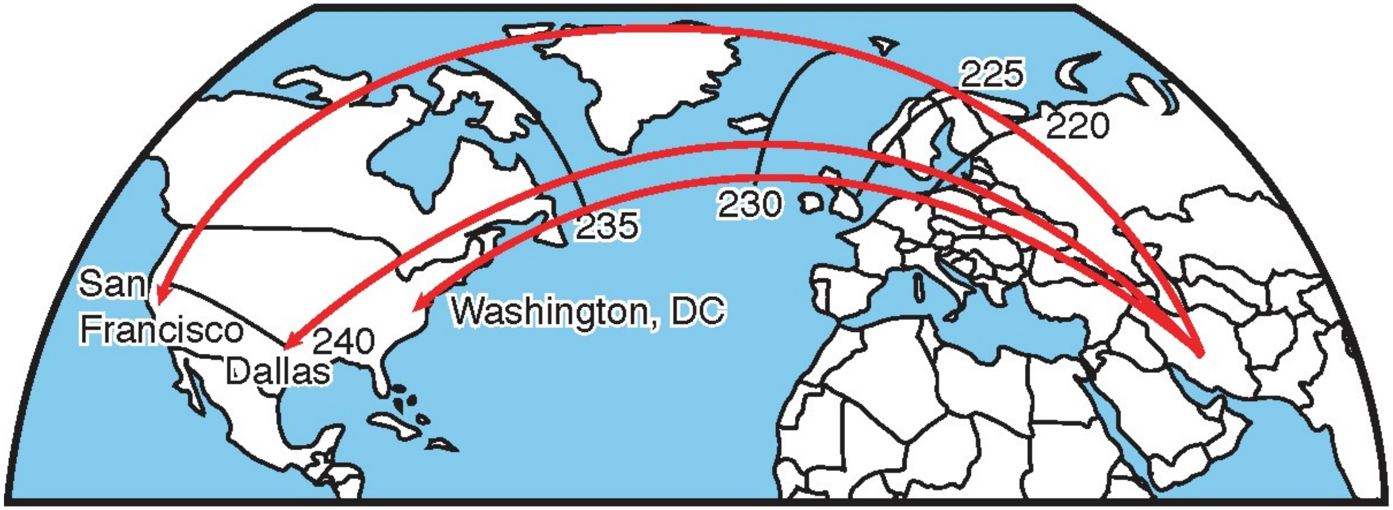


If launched against a target in the central United States, this particular missile would have to be intercepted in a small window between about 225 and 230 seconds after launch, to avoid dropping warheads on Russia or Canada

In reality, the performance characteristics of attacking missiles and their targets are unlikely to be known exactly in advance

Hence timing intercepts accurately enough to avoid causing possible live munitions to fall on Russia or Canada would be very difficult, if it's possible at all

Munitions from Iranian Missiles Could Impact Western Europe



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In reality, the performance characteristics of attacking missiles and their targets are unlikely to be known exactly in advance

Hence timing intercepts accurately enough to avoid causing possible live munitions to fall on Russia or Canada would be very difficult, if it's possible at all

Summary of the Findings of the APS Study of Boost-Phase Missile Defense

Hit-to-kill interceptors could potentially defend the United States against liquid-propellant ICBMs launched from some countries

Boost-phase defense against solid-propellant ICBMs is unlikely to be practical during the next decade, when all factors are considered

A boost-phase defense against short-or medium-range missiles launched from platforms off U.S. coasts appears feasible

A space-based boost-phase intercept system appears infeasible until the masses of kill vehicles can be reduced substantially

The ABL's range is likely to be too short for it to be useful except against liquid-propellant ICBMs from North Korea

Countermeasures are possible and should be expected

Test of the Aegis Ship-Based Anti-Missile System

Global Security Newswire
by National Journal Group

Daily news on nuclear, biological and chemical weapons, terrorism and related issues.

U.S. Readies Key Ballistic Missile Interceptor Test

Friday, April 8, 2011

The United States is readying for its initial trial of a ship-based antimissile system against an intermediate-range ballistic missile target, Reuters reported on Thursday (see ***GSN***, March 2).

The April test is likely to affect Obama administration assurances that it can meet a self-imposed schedule for establishing a missile shield to defend Europe against potential Iranian missile attacks.

Missile Defense Agency spokesman Richard Lehner said the test would involve a ship-based Aegis antimissile system developed by Lockheed Martin and a Raytheon-produced missile interceptor. The vessel will be located in the south central Pacific and the missile target is to be fired from the Marshall Islands in the central Pacific.

Test of the Aegis Ship-Based Anti-Missile System

Earlier ship-based tests have targeted mock enemy missiles with more restricted flight ranges. This month's test would be the first to involve an intermediate-range target that can travel from 2,000 to 3,500 miles. Such a range would put European capitals Berlin, Paris and London within striking distance of missiles fired from Iran's western edge.

The forthcoming test is "to demonstrate a capability against a class of ballistic missiles, and is not country-specific," Lehner said told Reuters by e-mail.

"During [the test] Aegis BMD (ballistic missile defense) will demonstrate for the first time its capability to negate the longer-range threats that must be countered in Phase 1" of the Obama missile defense plan for Europe, Defense Department operational test and evaluation chief Michael Gilmore told Congress in March.

Summary

The technical performance of the U.S. ABM system is dubious.

None of the few tests has been realistic operational exercises.

Moreover, a very substantial fraction of these tests have resulted in failures, not because of fundamental design flaws but because of insufficient quality control needed by complex systems. The items that failed in these tests had functioned previously.

The target missile trajectories were known beforehand and no decoys or other means of deceptive tactics to defeat the ABM system were employed.

Technically, such decoys are considerably easier to produce than the missile itself; therefore, any nation capable of ballistic missile delivery against the United States could also employ countermeasures adequate to render the system useless.

Missile Defense Conclusions

The current defense of the United States against nuclear weapons is seriously unbalanced.

We have spent more than $300 billion on defenses against nuclear armed long-range ballistic missiles and are currently spending $10 billion per year.

But nothing stemming from this effort enhances the real security of the United States.

As one example, relative to defenses against ballistic missiles, the effort to improve the security of the vast foreign stockpiles of nuclear weapons and critical nuclear weapons usable material has been less by about a factor of 10.

But this effort is the principal way we can prevent clandestine delivery of nuclear weapons against this the United States.

Module 7: Defenses Against Nuclear Attack

End of Module

Reagan's 'Star Wars' ABM Weapon Program

What if Star Wars weapons had been deployed?

- It would have aggravated crisis instability.
- It would have shortened decision times, removing humans from the loop.
- Very large cost [the cost of the originally proposed prototype system exceeded $1 trillion in 1985 $].
- It could have created a false sense of security, possibly leading to tragic mistakes.

Bush II's Missile Defense Program ("Total Defense")

Bush II: Capability-Based Acquisition

The ‘Nitze Criteria’ were officially abandoned.

Instead, the Bush program was “capability-based”, which meant —

- No specific goals or requirements. Instead, provide system with best possible technology capabilities and explore and use its utility.
- Congress was asked to fund the Missile Defense Agency (MDA) without transparency in the program goals and accounting.
- President Bush asked Congress to increase MDA’s budget by large amounts every year.
- MDA’s budget in FY2009 year was $10 billion, twice the entire budget of the National Science Foundation.

Criteria for the Proposed GMD System

In addition to the Nitze criteria, President Clinton had established four criteria for deciding whether to move forward with deploying a system:

- The threat
- The expected cost
- The technological maturity of the system
- The impact on arms control efforts

President Bush decided to “deploy” the system by 2004, without requiring any of these criteria.

Common Issues with Missile Defense Programs during Bush II and Reagan Administrations

- Missile defense was ideologically driven.
- The policy goals and conceptual framework kept shifting.
- The technical goals were unspecified.
- The R&D program was not well defined and overextended.
- Tests were infrequent, often under unrealistic conditions , and budgets for testing were far too small.
- Vital technical information was hidden from the Congress and the public behind a wall of secrecy.

The Conundrum of Midcourse Missile Defense

It creates incentives for adversaries and competitors of the United States to increase or modernize their missile forces, but offers no credible defense against them.

iClicker Question

Why would one consider terminal phase interceptors that engage incoming nuclear warheads inside the atmosphere?

A. Lower cost for interceptors

B. Decoys burn up in atmosphere

C. Limited range of radar for defense systems

D. Avoids EMP from explosions in space

E. Possibility of visual interceptor guidance

iClicker Question

iClicker Question

Why would one consider terminal phase interceptors that engage incoming nuclear warheads inside the atmosphere?

A. Lower cost for interceptors

B. Atmosphere stops decoys

C. Limited range of radar for defense systems

D. Avoids EMP from explosions in space

E. Possibility of visual interceptor guidance

Module 7: Efforts to Defend Against Attacks

Discussion of "SDI" Video

Physics 280: Session 22

Plan for This Session

Questions

Module 7: Efforts to Defend Against Nuclear Attacks (cont'd)

Physics 280: Session 23

Plan for This Session

Questions

News

Module 7: Efforts to Defend Against Nuclear Attacks (cont'd)

Video Presenation "Missile Wars"

News

Q&A Can the U.S. defend against a North Korean missile strike?

By **David Willman** in the LA Times

APRIL 5, 2017, 1:00 PM | REPORTING FROM WASHINGTON

A flurry of recent missile tests by North Korea has set nerves on edge and stirred fresh concern about whether U.S. defenses could protect Americans against a sneak attack. North Korea has detonated nuclear devices and is trying to develop long-range missiles capable of reaching the United States.

The Pentagon has spent more than $40 billion on the Ground-based Midcourse Defense system — GMD for short. It's designed specifically to thwart a nuclear strike by North Korea or Iran. Yet there are grave doubts about whether it's up to the task.

What exactly is GMD supposed to do?

It's designed to defend the United States against a "limited" nuclear attack. That means a strike with a handful of missiles, as opposed to a massive assault of the kind that Russia or China could launch. The United States relies on deterrence — the threat of overwhelming retaliation — to prevent Russia or China from ever unleashing missiles against us. In the case of North Korea or Iran, we would rely on GMD to knock incoming warheads out of the sky.

News

Q&A Can the U.S. defend against a North Korean missile strike?

How would GMD do that?

By intercepting incoming warheads in space, just as they're about to begin their reentry into the atmosphere. That's the approximate "midcourse" point in a warhead's journey from launch pad to target.

What's an interceptor, and how does it work?

The GMD interceptors are 60-foot-tall, three-stage rockets. Each has a five-foot, 150-pound "kill vehicle" at its tip. In the event of an attack, interceptors would be launched from their underground silos. Once in space, the kill vehicles would separate from their boost rockets and fly independently toward their targets, at speeds up to 4 miles per second.

A kill vehicle on display at Ft. Greely, Alaska, with its silver thrusters protruding. (Al Grillo / Associated Press)

News

Q&A Can the U.S. defend against a North Korean missile strike?

How many interceptors are there, and where are they based?

There are 37 operational interceptors — four at Vandenberg Air Force Base in Santa Barbara County, Calif., and 33 at Ft. Greely, Alaska.

Map shows approximate locations of Ft. Greely, Alaska, and Vandenberg AFB in California. (Los Angeles Times)

News

Q&A Can the U.S. defend against a North Korean missile strike?

How would the kill vehicle destroy an incoming warhead? By blowing it up?

The kill vehicles carry no explosives. They're designed to destroy enemy warheads with kinetic energy, or energy of motion — in other words, by crashing into them.

How would the kill vehicle find the incoming warhead?

Satellites and powerful radars, stationed on land and at sea, track airborne objects. The GMD system receives data from these and other sources and would use it to guide the interceptors. The kill vehicle also has an on-board navigation system to help it zero in on its target.

Why are there doubts about GMD's reliability?

Intercepting a warhead traveling at hypersonic speed is a supreme technical challenge. It's been compared to hitting one speeding bullet with another. GMD has not shown that it could do that dependably.

The system has performed poorly in flight tests, and technical problems keep cropping up. In nine simulated attacks since GMD was deployed in 2004, interceptors have failed to take out their targets six times. And the flight tests are much less challenging than an actual attack would be. They're carefully scripted for success: The operating personnel know ahead of time when mock warheads will be launched, as well as their size, speed and approximate trajectory.

Q&A Can the U.S. defend against a North Korean missile strike?

Given that test record, why do Pentagon officials assume the system could knock out all the incoming warheads if an enemy attacked?

They don't assume that. To the contrary, defense planners assume that four or five GMD interceptors would have to be launched for every incoming warhead to have a good chance of destroying them all, according to current and former government officials. That's called the "shot doctrine," and it reflects GMD's shortcomings. It means that if an adversary launched multiple missiles, our inventory of interceptors could be quickly depleted.

What caused the failures in the GMD test flights?

It's no single problem — it's a variety of causes. And that's what so concerns experts who've studied the system. In some cases, divert thrusters were blamed. These are small rocket motors, four of which are attached to each kill vehicle. They're supposed to fire rapidly to make course corrections and keep the kill vehicle on course once it's in space and flying on its own. In some tests, the thrusters' "rough combustion" of fuel was found to have thrown off the kill vehicles' on-board guidance system.

News

Q&A Can the U.S. defend against a North Korean missile strike?

Why the rush?

American scientists had been working on missile defense technology for decades, with the aim of creating a reliable shield for the U.S. homeland. President Clinton, whose administration supported and funded such research, concluded that the technology wasn't ready for prime time. But his successor, President George W. Bush, had campaigned on a promise to deploy a homeland missile defense system quickly, asserting that the country was in imminent danger of a sneak attack by a "rogue state" such as North Korea or Iran.

In late 2002, Bush ordered the Pentagon to field a "set of missile defense capabilities" by the end of 2004. To speed things along, Defense Secretary Donald H. Rumsfeld exempted the program from the Pentagon's normal procurement and testing standards.

Analysts trace GMD's problems to these early decisions to prioritize speed above meticulous engineering and development of proven capabilities.

News

Q&A Can the U.S. defend against a North Korean missile strike?

What kind of marks has GMD gotten from experts?

The Government Accountability Office, a nonpartisan investigative arm of Congress, reported last year that GMD's test record has been "insufficient to demonstrate that an operationally useful defense capability exists." In July, a team of missile defense experts who studied GMD for the Union of Concerned Scientists said the system is "simply unable to protect the U.S. public."

In January, the Pentagon's Operational Test and Evaluation office, in its annual report on U.S. defense programs, rated GMD's reliability as "low." It said the day-to-day "availability," or readiness, of the system's interceptors was also "low." The report added that flight tests had revealed unspecified "new failure modes."

What does the Missile Defense Agency say?

The agency says it is "absolutely confident" in GMD's ability to protect the homeland.

News

Q&A Can the U.S. defend against a North Korean missile strike?

Is there any sign that the Pentagon is reconsidering this entire approach to missile defense?

Some generals have said the cost of an interceptor-based system is unsustainable, and that the U.S. needs to give greater thought to a "left of launch" strategy. That's military-speak for taking out missiles before they could be launched, as opposed to trying to shoot them out of the sky.

Yet for now the Pentagon is expanding GMD to 44 interceptors, with bipartisan support from Congress. (This is not a Trump initiative; it started under President Obama.) The government is also studying possible sites for a third interceptor field, in the eastern half of the U.S. That would add up to 60 interceptors to the GMD fleet.

Physics 280: Session 24

Plan for This Session

Questions

News

Module 7: Efforts to Defend Against Nuclear Attacks

Next Week: Nuclear arms control

Module 7: Efforts to Defend Against Attack

PBS Frontline Video
"Missile Wars"

Module 7: Efforts to Defend Against Attack

Discussion of "Missile Wars"