Physics 280: Session 21

Plan for This Session

Questions

News and discussion

Module 7: Efforts to Defend Against Nuclear Attacks

Thursday: “Star Wars” video, more on history

News and Discussion: DPRK

The Washington Post Print

Why North Korea's bomb-grade plutonium plant might be good news

By Max Fisher, Updated: April 2, 2013

North Korea has vowed to restart the country's only nuclear reactor, which it shuttered in 2007 as part of an international deal. The plant can produce enough plutonium for about one small nuclear weapon per year.

The announcement would certainly seem like bad news, a sign that North Korea wants to expand its already-dangerous nuclear weapons program, another provocation after weeks of threats. And it is all those things. But there's potentially a major silver lining to this development: it suggests that North Korea has probably not learned how to develop nuclear weapons from uranium, as had been feared.

• • •

When North Korea conducted its third-ever nuclear weapons test in February, it dropped some strong hints that it had used highly enriched uranium. State media, for example, declared the military had "diversified" the nuclear program. But Pyongyang worked hard to keep the world from finding out for sure whether the bomb had been uranium, and it has so far succeeded.

THE WALL STREET JOURNAL.
WSJ.com

MIDDLE EAST NEWS | Updated April 2, 2013, 12:16 a.m. ET

Iran Cools Nuclear Work as Vote Looms

By JAY SOLOMON

WASHINGTON—Supreme Leader Ayatollah Ali Khamenei has decided to keep Iran's nuclear program within limits demanded by Israel for now, according to senior U.S., European and Israeli officials, in a move they believe is designed to avert an international crisis during an Iranian election year.

With a vote set for June, Mr. Khamenei is eager to place a leader more aligned with his positions than current Iranian President Mahmoud Ahmadinejad, without sparking a repeat of the nationwide unrest that followed a 2009 vote, these officials said.

Related Video

WSJ's Jerry Seib and National Security Editor Bob Ourlian discuss how the U.S. is edging closer to involvement in Syria, despite deep reluctance. Also, is North Korea really trying to pick a fight with South Korea?

U.S. and European officials have worried Mr. Khamenei might challenge Israel and the U.S. over the nuclear issue to consolidate his political position. But instead of pressing an agenda that could heighten tensions between Tehran and the international community, the opposite is happening, for the time being, these officials said.

Mr. Khamenei's approach is placing the Obama administration and its allies in a delicate strategic position, possibly constraining their response to Iran's nuclear program. U.S., European and Israeli officials have described 2013 as the "critical" year in Iran's nuclear program, which has been seen as a reference to the possible use of military force.

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

Module 7: Efforts to Defend Against Attacks

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, cruise missiles, etc.) before they reach their targets
- Must be nearly perfect to avoid enormous death and destruction (offensive weapons costing $1M can kill 1M people and destroy $1B 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 against fall out of 100)
  - — 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 very doubtful
- Many urban areas and host regions refused to participate in planning, finding the concept offensive, ludicrous, or dangerous
- By 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 2,000 strategic warheads on delivery vehicles on high alert; on course to reduce this number to 1,550 by 2018; may have as few as 150 land-based missiles by 2015
- *China*: currently has ~ 12 liquid-propellant long-range missiles; warheads are stored separately; has a solid-propellant program

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Countries of concern —

- *North Korea*: Taepo Dong-2, 5,000 km? failed its only test, in July 2006; Taepo Dong-2 tested as Unha-2 (4-5-2009 and 4-12-2012 unsuccessfully) and as Unha-3 successfully on 12-12-2012.
- *Iran*: Shahab-3, up to 2,000 km, liquid, deployed; Sejjil, 2,500 km, solid, tested; unlikely to field a 10,000-km missile by 2015 unless given one.

Delivery Methods Other Than Long-Range Ballistic Missiles 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. Some may develop such systems before 2015.

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.

Unclassified summaries of the most recent National Intelligence Estimates of Foreign Missile Developments and the Ballistic Missile Threat Through 2015

Nuclear Threats to the United States

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

There are 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
- ***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 bargaining chips
- To sidetrack or destroy arms control agreements
- To create a (false) sense of security
- To win partisan political advantage

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 —

- IR sensors, particle-beams and neutron detectors
- Kinetic-energy warheads 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

The Dream of 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 2013 dollars on technologies intended to intercept nuclear-armed long-range ballistic missiles in flight.
- We are currently spending about $10 billion per year on this effort.
- But this huge and costly effort has not significantly enhanced the real security of the United States.

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, 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 causes.

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

Past and Current U.S. Missile Defense Programs

Eisenhower Nike-Zeus Program (1950s)

Kennedy Nike-X Program (1960s)

Johnson Sentinel Program (1966–68)

Nixon Safeguard Program (1969–76)

Reagan Star Wars Program (1983–1990)

Patriot in the first Gulf War (1991)

Bush-I and Clinton GPALs Program (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 2013 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.

iClicker Question

What is the minimum range a missile must have to be considered an ICBM?

A. 2,500 km

B. 3,500 km

C. 4,500 km

D. 5,500 km

E. 6,500 km

iClicker Answer

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iClicker Question

Which one of the following is *not* a phase in the flight of an intercontinental-range ballistic missile?

A. Boost phase

B. Post-boost phase

C. Cruising phase

D. Midcourse phase

E. Terminal phase

iClicker Answer

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iClicker Question

Missiles

Which of the following acronyms refers to a missile configuration that can deliver nuclear warheads to several different targets?

A. RV

B. MRV

C. MIRV

D. MARV

E. MMARV

iClicker Answer

Missiles

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D. MARV

E. MMARV

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

Reagan's 'Star Wars' ABM Weapon Program

Why discuss Reagan's 'Star Wars' program in detail?

- *It remains a point of reference for many current discussions of missile defense*
- *It provides valuable "lessons learned"*

Reagan's 'Star Wars' ABM Weapon Program

Began with a paragraph in Reagan's speech on March 23rd, 1983 —

- Surprised and stunned the entire US government, including the Pentagon
- Expressed a grand vision to make nuclear weapons "impotent and obsolete", replacing nuclear deterrence by a defensive weapons system
- 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 'Star Wars' ABM Weapon Program

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).

Reagan's 'Star Wars' 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, exacerbating the enormous budget deficits of the Reagan years
- 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 'Star Wars' ABM Weapon Program

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 space weapons

Reagan's 'Star Wars' ABM Weapon Program

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 'Star Wars' ABM Weapon Program

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

Moreover, 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

A main ingredient of SDI was an X-ray laser concept that used a large nuclear weapon as its source of power.

Yet SDI was supposed to make nuclear weapons "impotent and obsolete".

Reagan's 'Star Wars' ABM Weapon Program

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 'Star Wars' ABM Weapon Program

As a result of its technological unreality, the emphasis of the SDI program fluctuated wildly 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 'Star Wars' ABM Weapon Program

Some consequences of the 'Star Wars' ABM weapon program —

- Spurred the race in offensive strategic weapons, until ~ 30,000 were deployed
- Spurred Soviet efforts to develop space weapons
- Poisoned arms control efforts
- Had an enormous opportunity cost
  - —Diverted money, manpower, and other resources from education and internationally competitive civilian industries and products to uncompetitive military industries and products
  - —SDI ended up costing more than $150B in 2013 dollars, but accomplished very little that was useful

The SDI program was greatly reduced by Bush-I and terminated in 1994 by Clinton, but Clinton felt compelled to restart a program to defend against long-range ballistic missiles in 1998. Bush-II greatly expanded this program.

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.
- If the weapons actually worked and were matched by the Soviets, U.S. allies would have been disarmed.
- There would have have been an enormous financial 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.

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

Lessons from Reagan's 'Star Wars' Program (Important)

- Missile defense technology is highly challenging
- Technology cannot be coerced by wishful thinking, 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

Physics 280: Session 22

Plan for This Session

Student questions

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

Today: "SDI" (Star Wars) video

Tuesday: "Missile Wars" video

iClicker Question

About how many *total* nuclear weapons does the UK now have?

A. 50
B. 100
C. 200
D. 500
E. 1,000

iClicker Answer

About how many *total* nuclear weapons does the UK now have?

A. 50

B. 100

C. 200

D. 500

E. 1,000

iClicker Question

About how many nuclear weapons does India now have?

A. 20–30

B. 60–80

C. 120–150

D. 2,000

E. 5,000

iClicker Answer

About how many nuclear weapons does India now have?

A. 20–30

B. 60–80

C. 120–150

D. 2,000

E. 5,000

iClicker Question

About how many nuclear weapons does Israel now have?

A. 20–30

B. 60–80

C. 120–150

D. 2,000

E. 5,000

iClicker Answer

About how many nuclear weapons does Israel now have?

A. 20–30

B. 60–80

C. 120–150

D. 2,000

E. 5,000

iClicker Question

About how many nuclear weapons does Pakistan now have?

A. 50

B. 100

C. 250

D. 3,000

E. 5,000

iClicker Answer

About how many nuclear weapons does Pakistan now have?

A. 50

B. 100

C. 250

D. 3,000

E. 5,000

iClicker Question

North Korea is thought to have enough Pu for for about how many nuclear weapons?

A. 1 or 2

B. 3–5

C. 6–10

D. 11–20

E. 20–50

iClicker Answer

North Korea is thought to have enough Pu for for about how many nuclear weapons?

A. 1 or 2

B. 3–5

c. 6–10

D. 11–20

E. 20–50

The Dream of a Technological Solution to the Problem of Nuclear-Armed Ballistic Missiles

Introduction to the “SDI” (Star Wars) video —

- Reagan’s science advisor George Keyworth II
- Gorbachev’s science advisors Roald Sagdeev & Evgeny Velikhov
- Lakota Sioux bullet-proof “red shirt” defense — produced a massacre then
- Faith in SDI’s “impenetrable shield” could have produced a catastrophe
- Faith in current missile defense systems could produce a catastrophe today

Module 7: Efforts to Defend Against Attacks

"SDI" Video

Module 7: Efforts to Defend Against Attacks

Discussion of "SDI" Video

Physics 280: Session 23

Plan for This Session

Questions

News

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

Today: "Missile Wars" video

News: North Korea Warns Foreign Citizens to Leave South Korea

theguardian

North Korea urges foreigners in South Korea to make evacuation plans

Regime says visitors might get hurt if war starts, while workers boycott joint factories and missile test talk heightens

Justin McCurry in Seoul
guardian.co.uk, Tuesday 9 April 2013 08.10 EDT

North Korean soldiers in a propaganda picture. Photograph: AFP/KNS

As the world waits to see if North Korea launches a ballistic missile, the regime has attempted to raise tensions further, warning foreigners living in South Korea to make evacuation plans because the peninsula is on the brink of war.

"We do not wish harm on foreigners in South Korea should there be a war," the official KCNA news agency quoted an official from a North Korean organisation calling itself Korea Asia-Pacific Peace Committee as saying.

News: North Korea withdraws 53,000 Workers from Kaesong Industrial Complex

Amid the bluster of recent weeks – during which the North has threatened to launch a nuclear attack on the US – the regime appears to have made good on its threat to withdraw its workers from the Kaesong industrial complex.

None of the 53,000 North Korean workers at the site, located just north of the border, arrived for work on Tuesday morning – a day after Pyongyang accused the South of turning the jointly run zone into "a hotbed of war".

The suspension of all operations at the site momentarily shifted attention from North Korea's east coast where, according to reports, preparations were being made to test launch at least one medium-range missile, possibly as early as Wednesday.

In response, Japan deployed PAC-3 missile interceptors in Tokyo on Tuesday. Japan's self-defence forces are under orders to shoot down any incoming North Korean missiles; Tokyo has also deployed two Aegis destroyers equipped with sea-based interceptor missiles in the Sea of Japan.

The two missiles, thought to be the untested Musudan, have a maximum range of 2 485 miles, putting South Korea, Japan and US bases on Guam within reach.

Lessons from Reagan's 'Star Wars' Program (Important)

- Missile defense technology is highly challenging
- Technology cannot be coerced by wishful thinking, 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
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The ‘Nitze Criteria’ for Deploying an ABM System (Important)

In the early 1980s, Paul Nitze (Reagan’s presidential advisor for Arms Control) 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**

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.

Nitze Criteria was abandoned by Bush-II administration in 2001 in order to deploy a missile defense system.

Impact of Patriot in the First Gulf War

Patriot in the 1991 Gulf War

Events that formed the 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**."

Patriot in the 1991 Gulf War I

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 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**

However, these results came too late and few included videos, so they had little impact on the public's perception that Patriot had succeeded.

Module 7: Efforts to Defend Against Attack

PBS Frontline Video

“Missile Wars”

Module 7: Efforts to Defend Against Attack

Discussion of "Missile Wars"

iClicker Question

Which of the following is **not** one of the "Nitze criteria" for considering deployment of an ABM system?

A. The system must be effective

B. The system must be able to survive an attack

C. The system must use the most advanced technology

D. The system must be cost-effective at the margin

E. None of the above are "Nitze criteria"

iClicker Answer

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iClicker Question

Missile Defenses

Which of the following is not a lesson of the Star Wars program?

A. Missile defense is highly challenging

B. The necessary technology cannot be produced by wishful thinking or ideology

C. An R&D program without clear goals will always waste time and money

D. Frequent testing is unnecessary

E. An independent evaluation and review process is critical

iClicker Answer

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iClicker Question

Missile Defenses

The reported success of the Patriot missile defense system during the 1991 Gulf War was a key argument used to restart the U.S. program to defend against ICBMs. In the end, how many intercepts of Iraqi short-range missiles were well-documented?

A. 0

B. 5

C. 10

D. 50

E. 100

iClicker Answer

Missile Defenses

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B. 5

C. 10

D. 50

E. 100

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

Bush's 'Capability-Based Acquisition' (Important)

The 'Nitze Criteria' were officially abandoned.

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

- It had no specific goals or requirements.
- 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.

Similar Problems With George W. Bush's and Reagan's Missile Defense Programs

- Missile defense was ideologically driven and highly politicized.
- Misleading "information" was abundant..
- The policy goals and conceptual framework kept shifting.
- The technical goals were unspecified.
- The R&D program was poorly defined and overextended.
- Tests were infrequent, often under unrealistic conditions , and budgets for testing were far too small.
- Tests and demonstrations of little relevance got wide publicity, while vital technical information was hidden from the Congress and the public behind a wall of secrecy.

Any program with these characteristics has serious problems.

Physics 280: Session 24

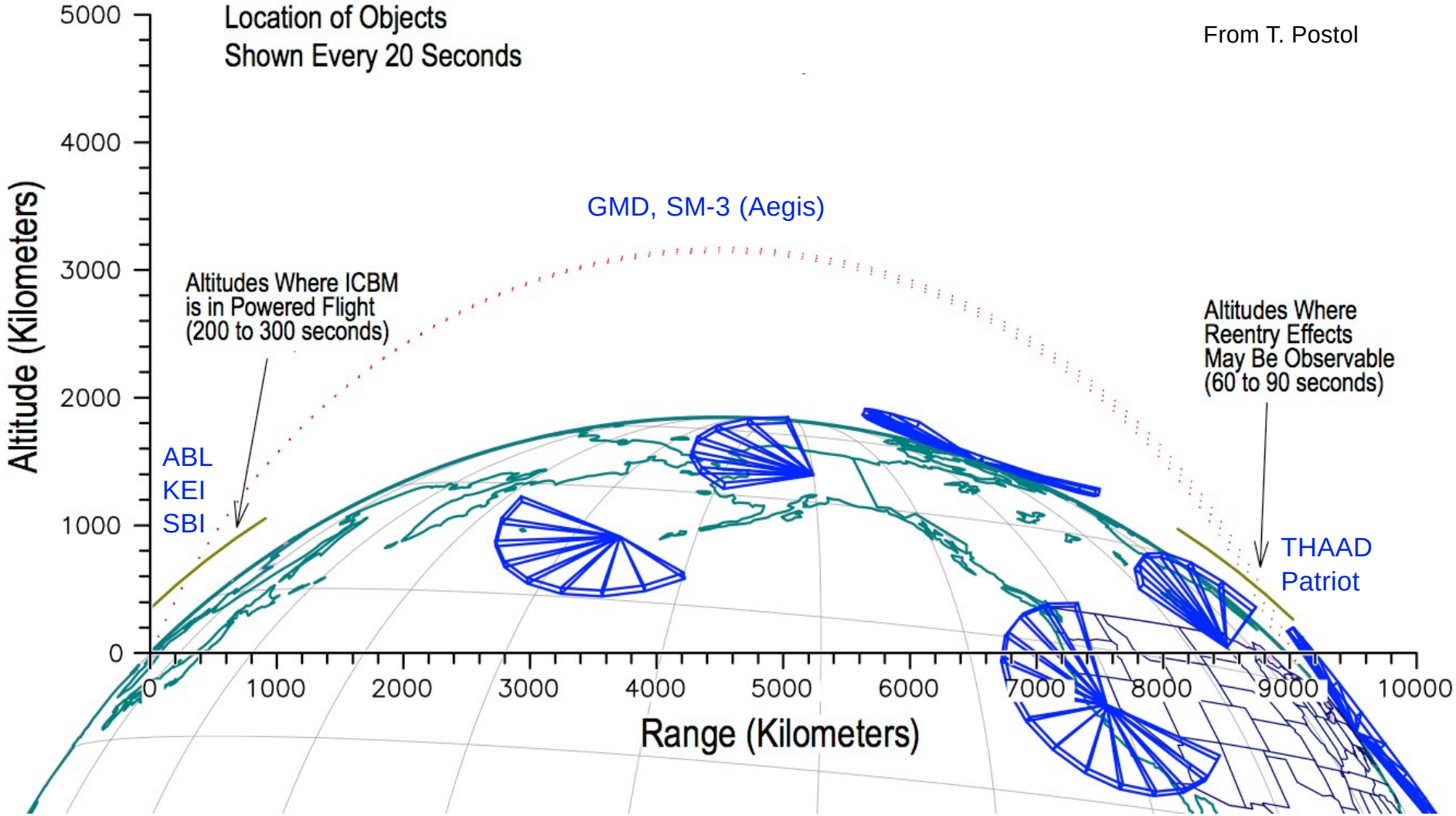
Plan for This Session

Questions

Module 7: Efforts to Defend Against Nuclear Attacks (final)

Next: Nuclear arms control

Defense Initiatives Against Nuclear-Armed Long-Range Ballistic Missiles



Almost All These Programs Have Since 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.
- Theater High-Altitude Area Defense (THAAD) — scaled back, deployed in 2009 to Hawaii and in April 2013 in response to North Korean Missile Threat .

Bush Administration U.S.-Based Midcourse Intercept System

Criteria for the Proposed GMD System

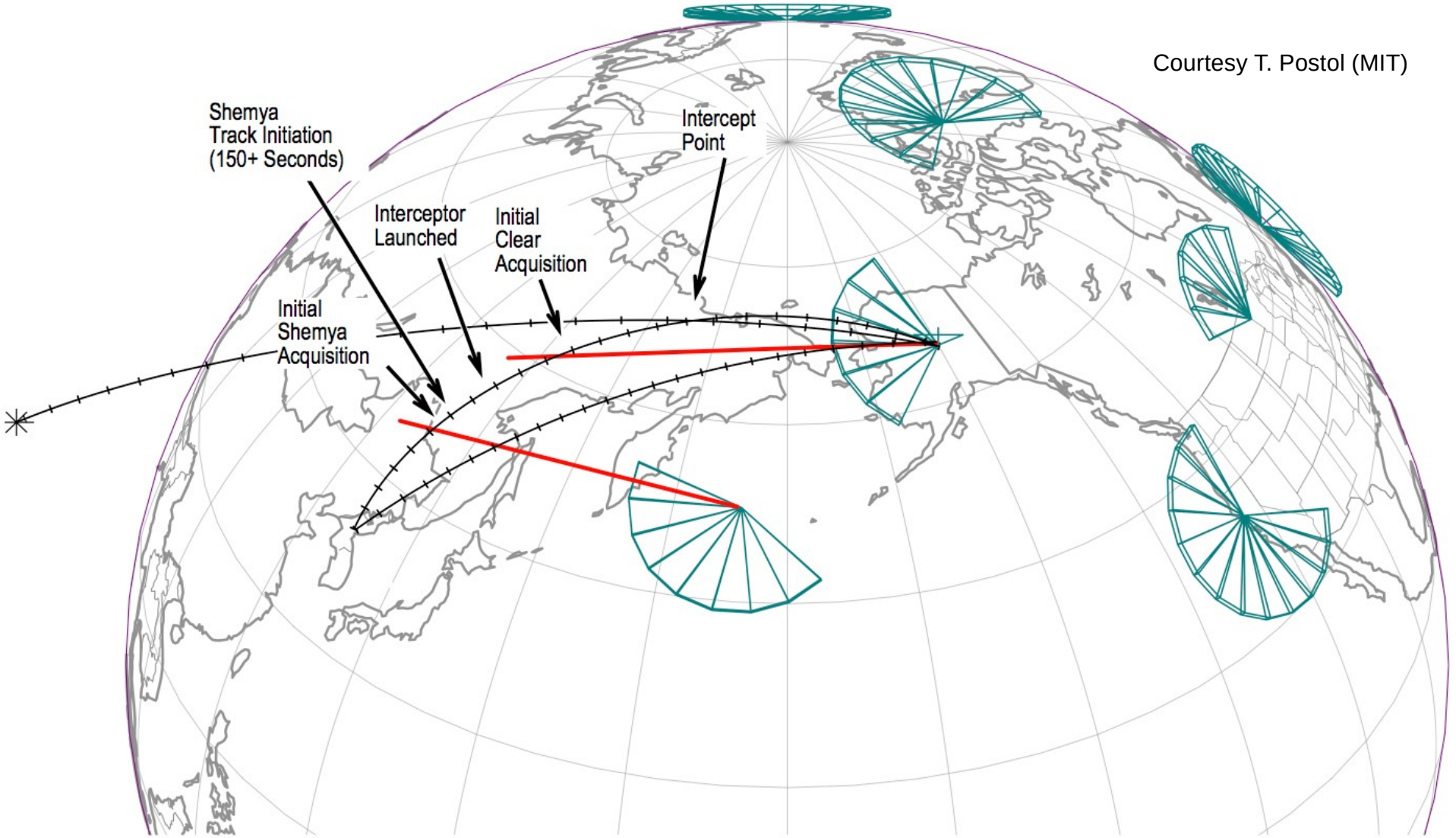
In addition to the Nitze criteria, President Clinton had established four criteria for deciding whether to move forward with deploying a system:

- 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.

The Concept of Midcourse Intercept

Theoretical Functioning of Proposed Ground-Base Midcourse Intercept (GMD) System



Challenges to Midcourse Intercept

- Each ICBM could launch —
  - Multiple warheads
  - Or dozens of chemical or biological submunitions

So many 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."

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.

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

MDA overran its budget by $150 million in 2008. The GMD program cost $56 million less than budgeted because it did not emplace *any* of the 3 GMD interceptors or conduct *either* of the two tests planned for 2008.

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.

Example: Raytheon Kill Vehicle Test Failed, Warhead Delivery Halted

Test fails; Raytheon warhead delivery halted

David Wichner Arizona Daily Star | Posted: Tuesday, April 5, 2011 12:00 am

The U.S. Missile Defense Agency has suspended deliveries of a warhead made by Raytheon for the nation's ground-based missile-defense system, pending the results of an investigation into the system's second failed intercept test.

Deliveries of the Exoatmospheric Kill Vehicle, or EKV, a non-explosive guided warhead made by Tucson-based Raytheon Missile Systems, were halted after the kill vehicle failed to hit its mark in a Dec. 15 flight test, Missile Defense Agency spokesman Rick Lehner said.

When deliveries are resumed depends on the results of a "failure review" launched shortly after the December intercept failure, Lehner said, adding that the agency is likely weeks or months away from releasing a final report.

Current Status of the GMD System

- The current GMD system:
  - —About 30 interceptors have been deployed in silos
  - —Most are in Alaska, a few are in California
- Test results:
  - 8 hits in 15 highly 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
  - The satellite systems needed to detect and track an enemy missile launch are not complete
- Stated capability of the current GMD system:
  - **In 2009, General James Cartwright, Vice Chairman of the Joint Chiefs of Staff**, in U.S. Senate testimony **claimed that the missile defense system in place in the United States was 90 percent effective (2009).**
  - **In 2010, the DOT&E stated that the current midcourse system provides only “emergency, low-confidence capability”.**

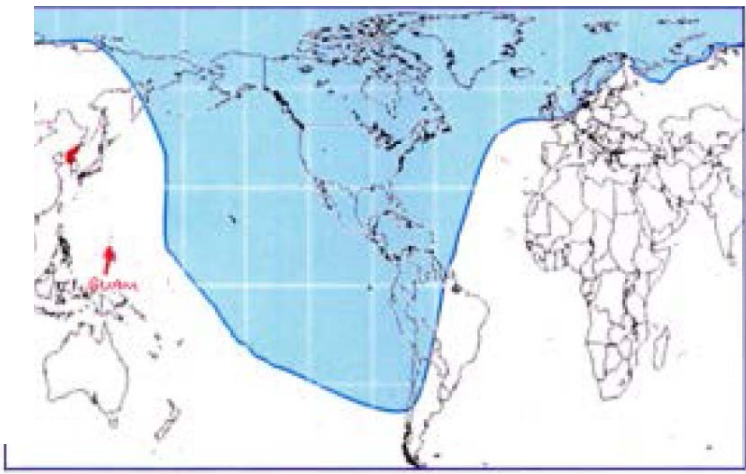
News: Does the GMD System Cover Guam?

Is Guam Covered by the U.S. GMD National Missile Defense System? (March 21, 2013)

In light of recent developments involving North Korea, including its threat this week to attack Andersen Air Force Base in Guam, questions have been raised about how well the U.S. territory was defended against a ballistic missile attack. Some in Guam have interpreted the statements made by Undersecretary of Defense James Miller and Vice Chairman of the Joint Chiefs of Staff Admiral James Winnefeld at a March 15 press conference that the current U.S. Ground Based Midcourse (GND) system covers "all the United States" and "the entire United States" as indicating that the system covers Guam. The response by Undersecretary Miller is particularly significant as he was specifically asked about "American possessions in Western Pacific — Samoa, Guam, those areas." On Monday, Guam's (non-voting) delegate to the U.S. House of Representatives, Madeleine Z. Bordallo, explicitly stated in a letter that this was the case: "Additionally, I am aware that DoD officials are confident that the Ground-Based Midcourse Defense System will provide protection not only for the continental United States, but for Guam as well.

In fact, it is clear that this is not the case. The figure below, from the 2010 Ballistic Missile Defense Review, shows the coverage of the GMD system against an ICBM from North Korea (I have added the arrow indicating Guam's location).

Re-call Defense Secretary Hagel announced that the number of GMD interceptors will be increased from 30 to 44 until 2017 (for $1 Billion). In response to DPRK missile threat.



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.

George W. Bush's Proposed Boost-Phase Intercept System

Why is There Interest in Boost-Phase Intercept?

Midcourse Intercept Appears Extremely Challenging

Each missile could launch —

- Multiple warheads
  - Dozens of chemical or biological submunitions
- This could overwhelm the defense

Each missile could launch —

- Countermeasures and penetration aids, including large numbers of lightweight decoys
- These would be difficult to distinguish from real warheads above outside the atmosphere
- This could confuse the defense

Why is There Interest in Boost-Phase Intercept?

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

- ICBMs are described as slowly-moving, fragile targets
- 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
- 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.

Key Issues 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")

Reaching the ICBM in Time

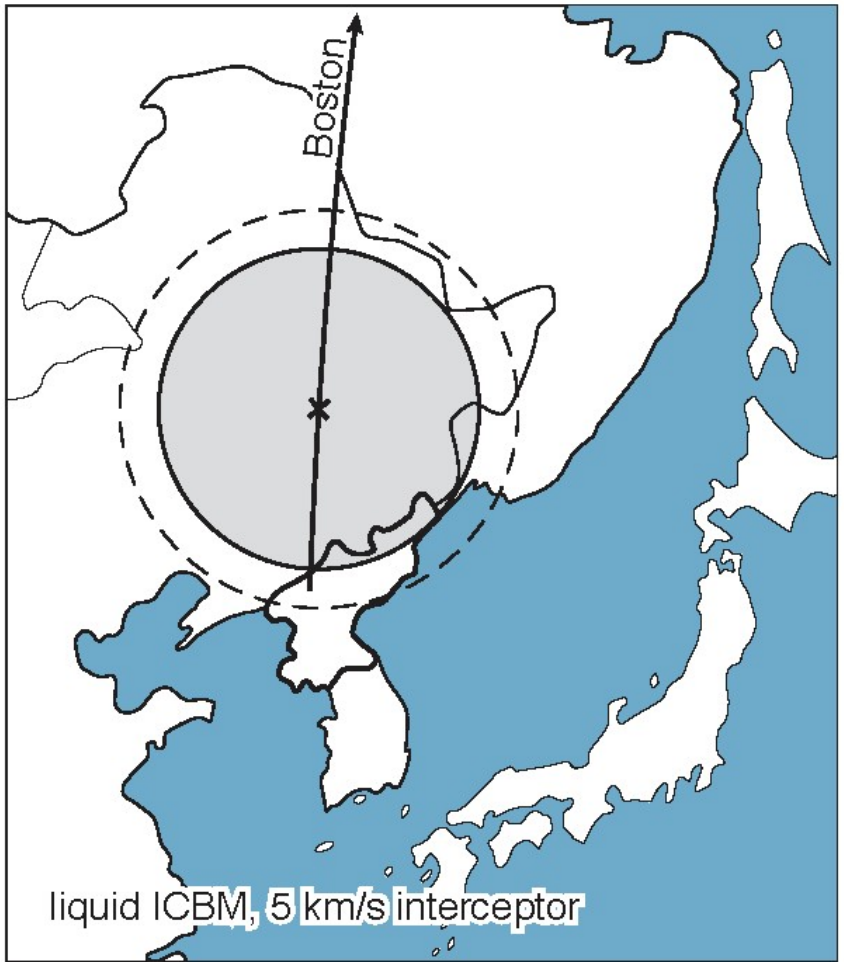
- In many situations the interceptor rocket would have only ~ 2 min (solids) or ~ 3 min (liquids) to reach the target ICBM, even with a state-of-the-art space-based detection and tracking system

- 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

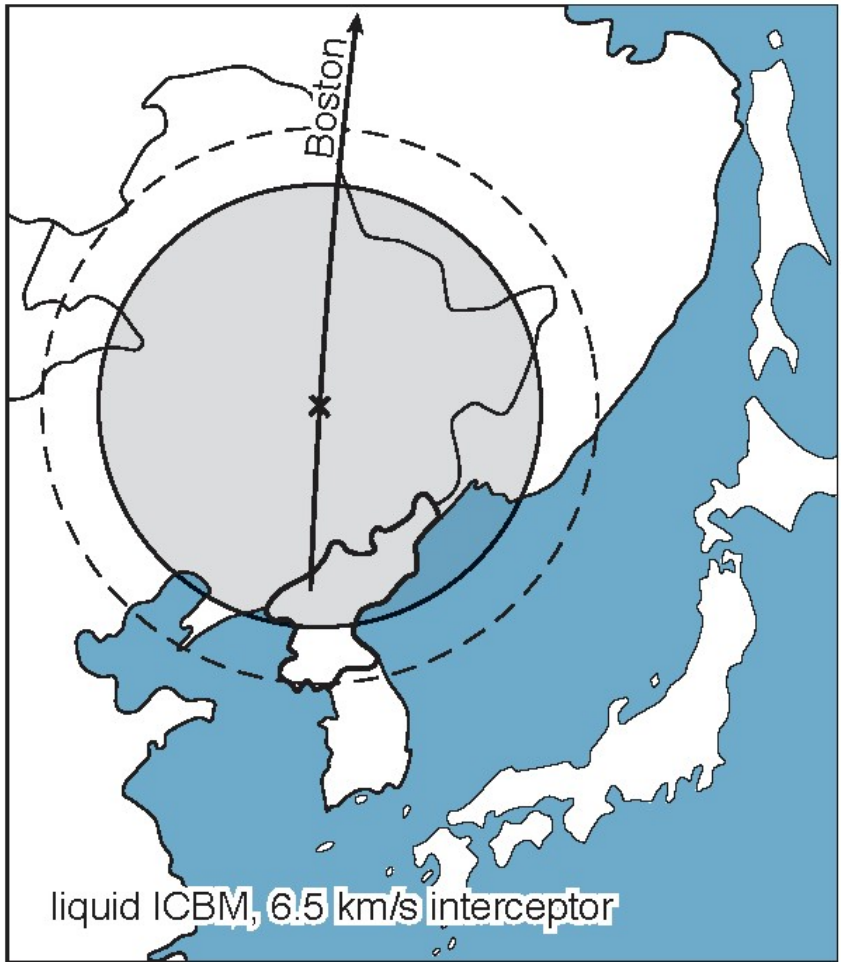
Regional Geography Constrains How Close Interceptors Could Be Based

Solid line: 30 sec. decision time

Dashed line: No decision t ime

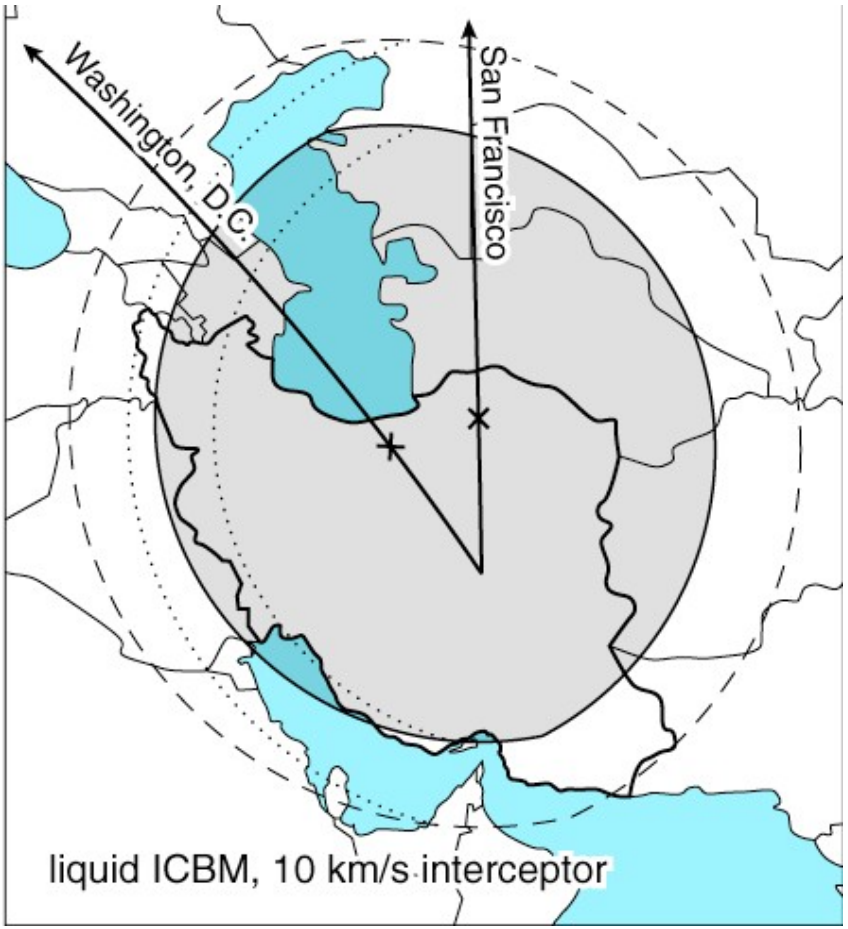


Basing areas for a 5 km/s interceptor to defend Boston against a liquid-propellant ICBM launched from North Korea

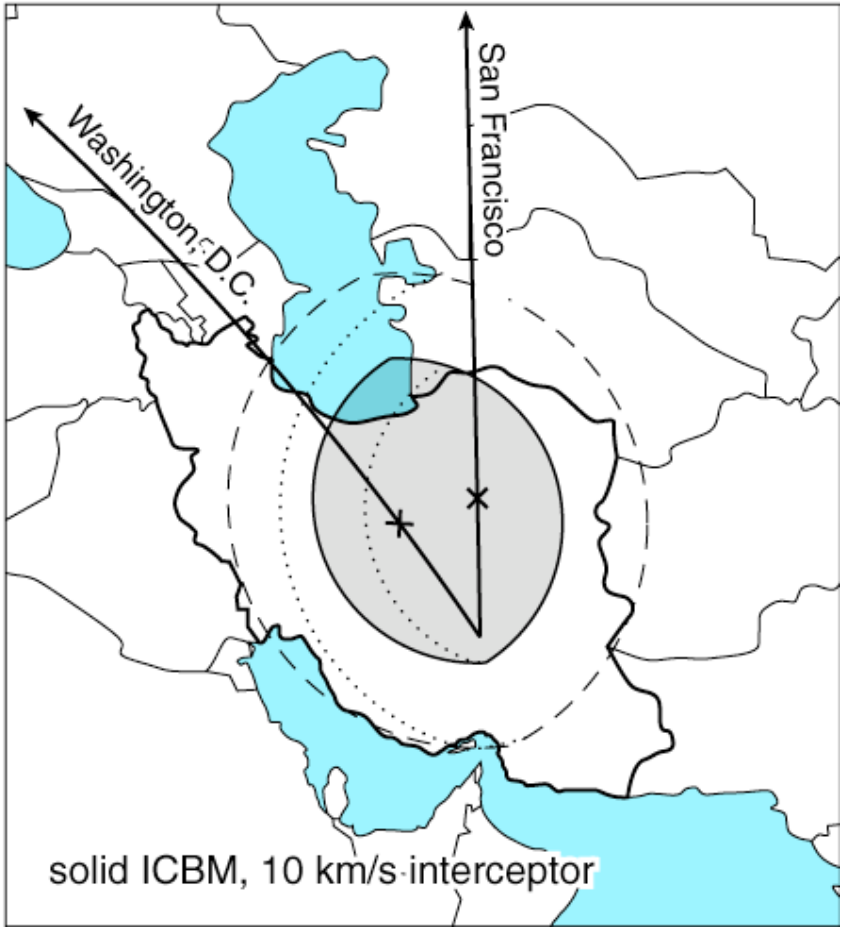


Basing areas for a 6.5 km/s interceptor to defend Boston against a liquid-propellant ICBM launched from North Korea

Regional Geography Constrains How Close Interceptors Could Be Based



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



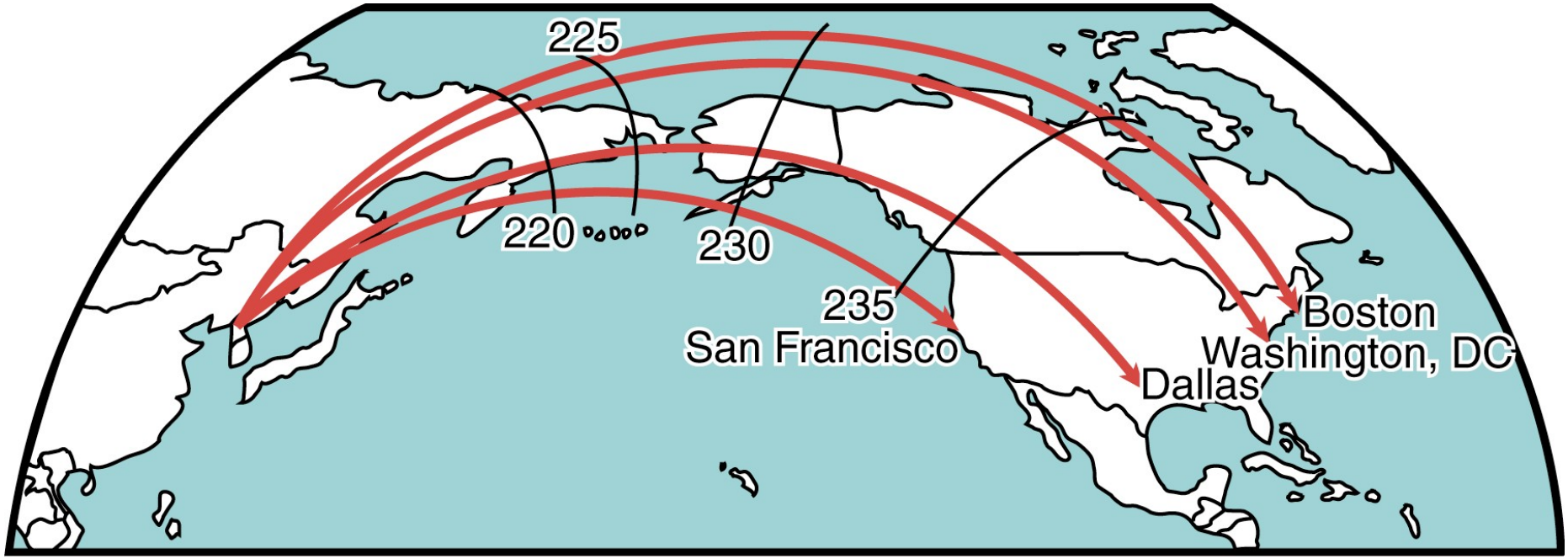
Basing areas for intercepting a solid-propellant ICBM from Iran to the Lower 48 States

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

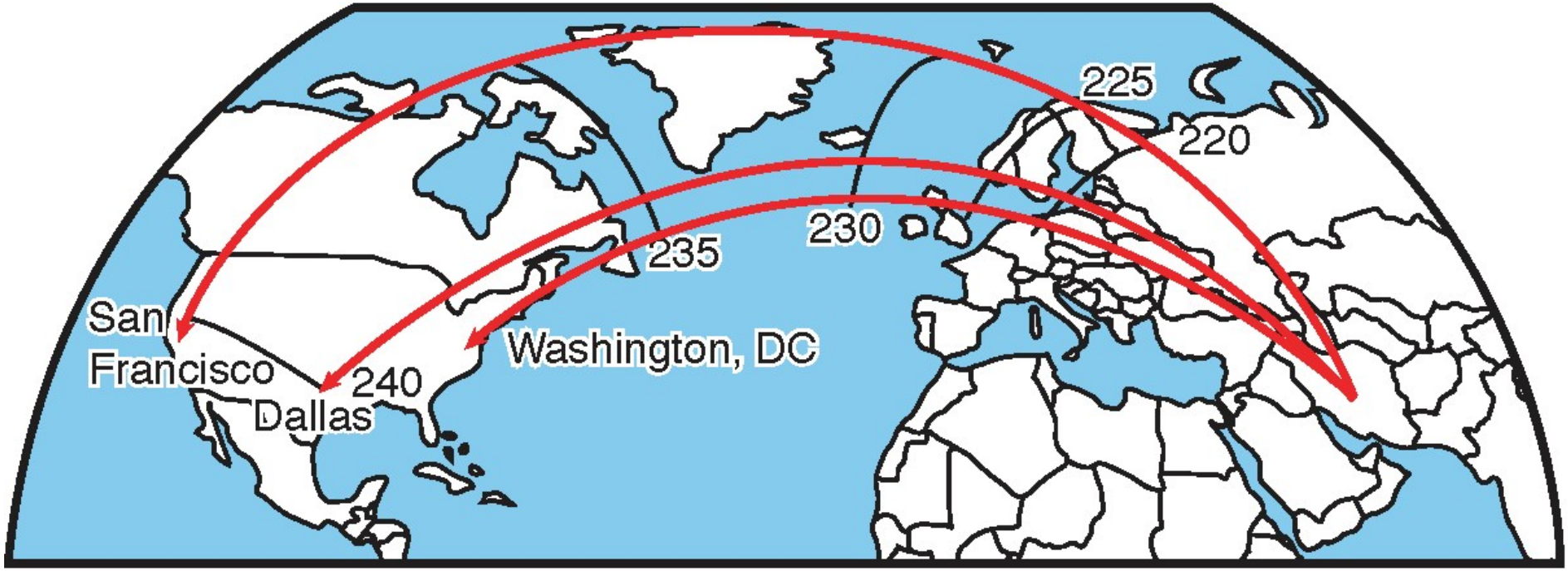
Munitions from North Korean Missiles Could Impact Russia or Canada



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 Iranian Missiles Could Impact Western Europe or Canada



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Issues Posed by Time Constraints

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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

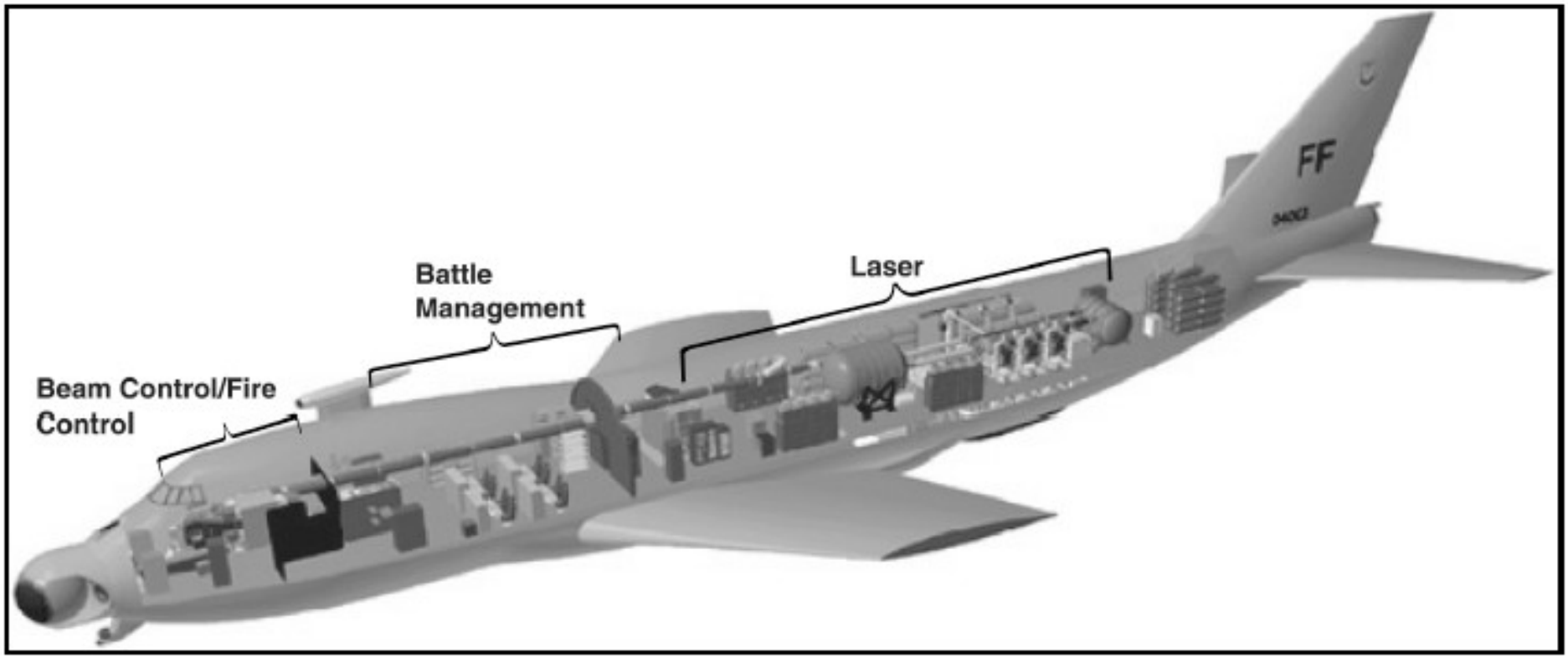
Airborne Laser Boost-Phase Intercept Program

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

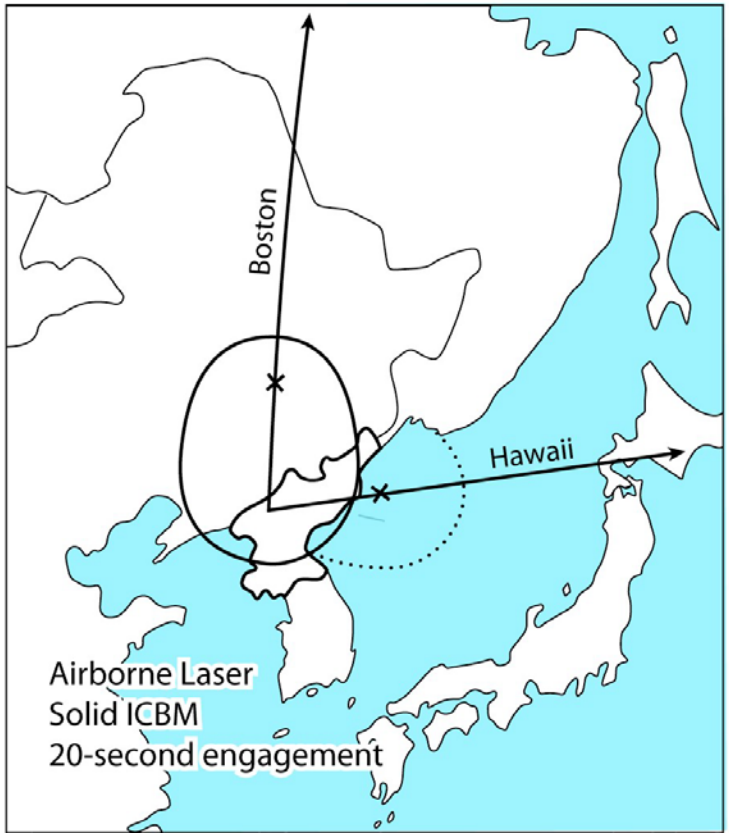
- Could be useful against ICBMs from North Korea, but not from Iran, unless ABL aircraft could fly over the lower Caspian Sea or Turkmenistan

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

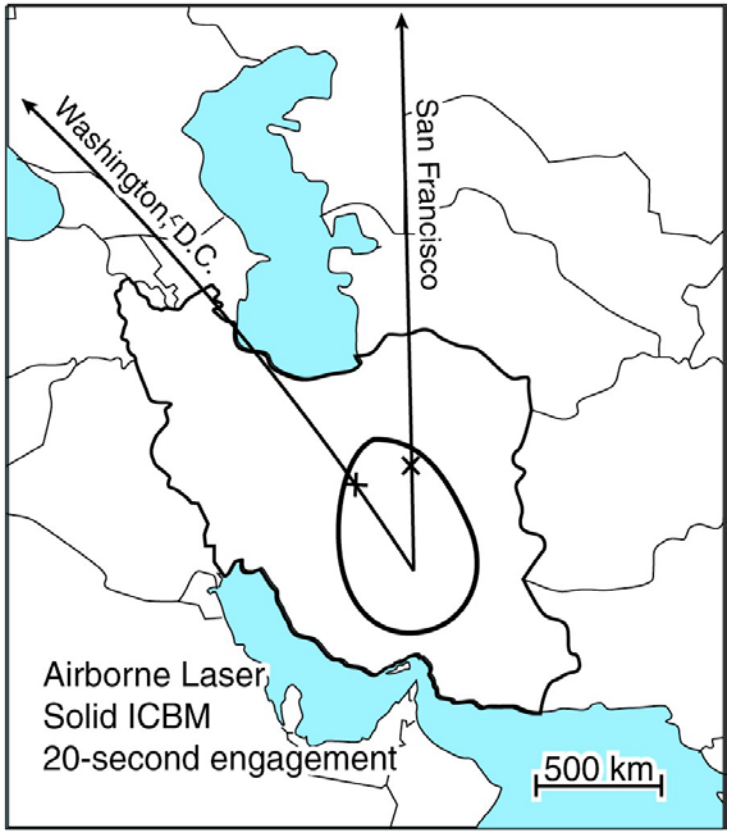
- Would not be effective in any of the scenarios examined by the APS

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



Countermeasures Would Challenge Boost-Phase Intercept

A boost-phase defense would not be susceptible to some of the proposed countermeasures to midcourse defense, but it would face countermeasures

Examples of countermeasures to both hit-to-kill and the ABL

- Launch several ICBMs nearly simultaneously
- Deploy solid-propellant ICBMs

Examples of countermeasures to hit-to-kill

- Deploy payload during powered flight
- Program evasive maneuvers
- Deploy decoys and jammers
- Deploy fast-burn boosters with multiple upper stages
- Mask the kill-vehicle aim point (to defeat warhead kill)

Examples of countermeasures to the ABL

- Attack the airframe
- Roll the ICBM
- Use ablative coating
- Change the optical properties of the ICBM

iClicker Question

Which of the following missile defense programs was cancelled because it was judged technically infeasible for the foreseeable future?

A. Sea-based Interceptor rockets

B. Interceptor rockets with multiple kill vehicles

C. The Airborne Laser

D. Space-based interceptors

E. All of the above

iClicker Answer

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C. The Airborne Laser

D. Space-based interceptors

E. All of the above

iClicker Question

Even though the tests have been highly scripted and have not included realistic decoys or other simple countermeasures, the ground-based midcourse defense (GMD) system has only achieved what success rate?

A. 0%

B. 10%

C. 50%

D. 80%

E. 90%

iClicker Answer

Even though the tests have been highly scripted and have not included realistic decoys or other simple countermeasures, the ground-based midcourse defense (GMD) system has only achieved what success rate?

A. 0%

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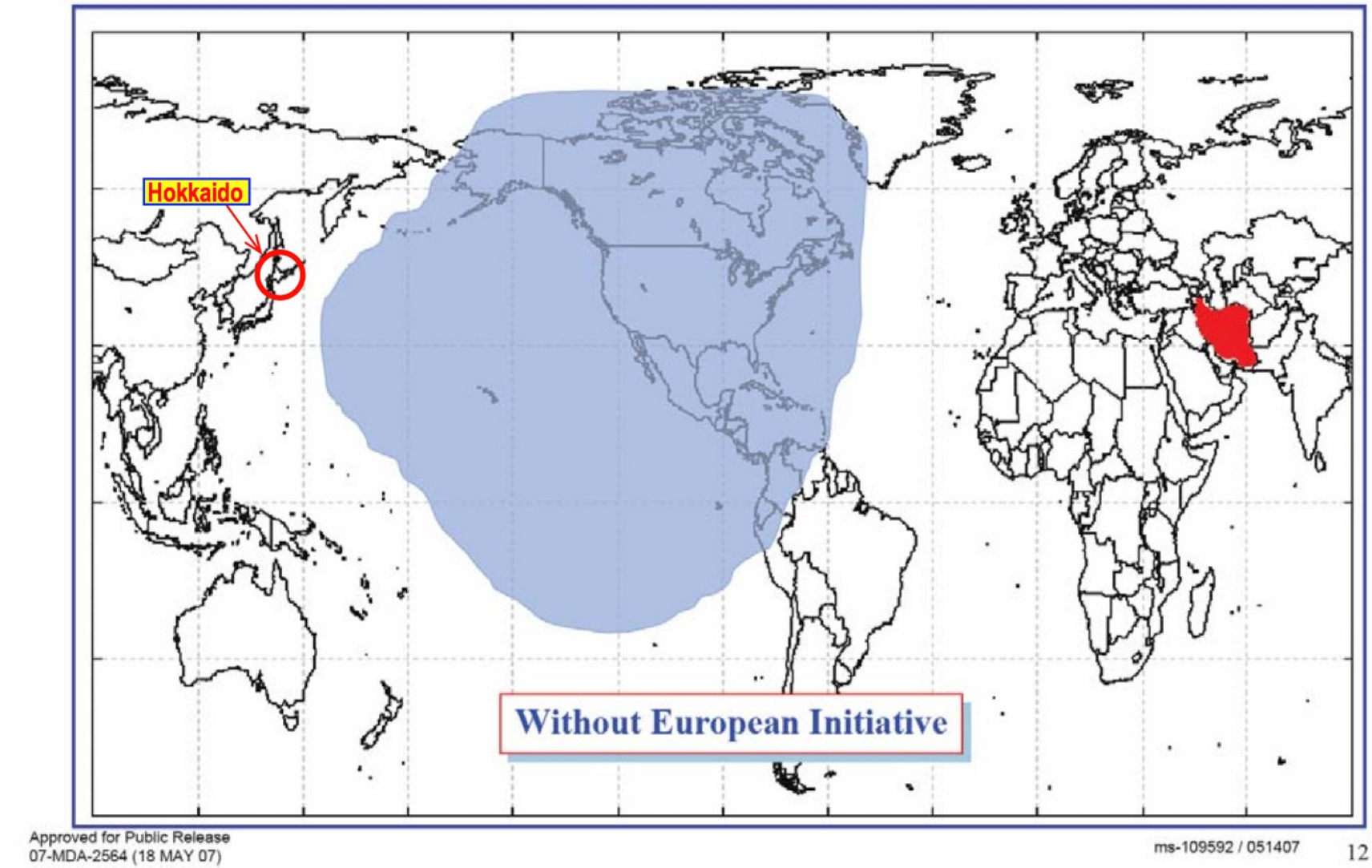
C. 50%

D. 80%

E. 90%

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

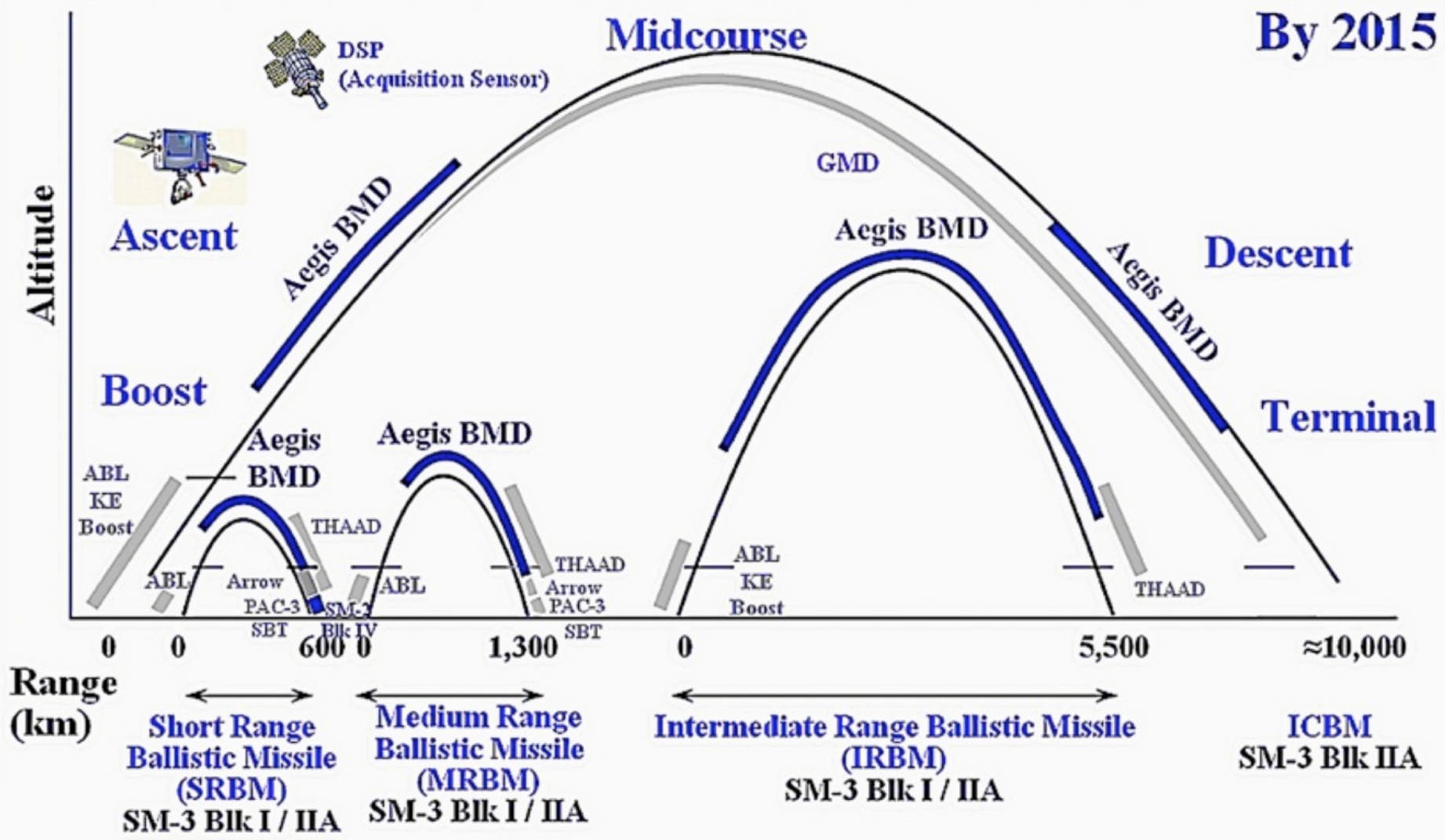


Module 7: Efforts to Defend Against Attacks

European Midcourse-Intercept System

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

Obama's Phased Adaptive Approach to EMD



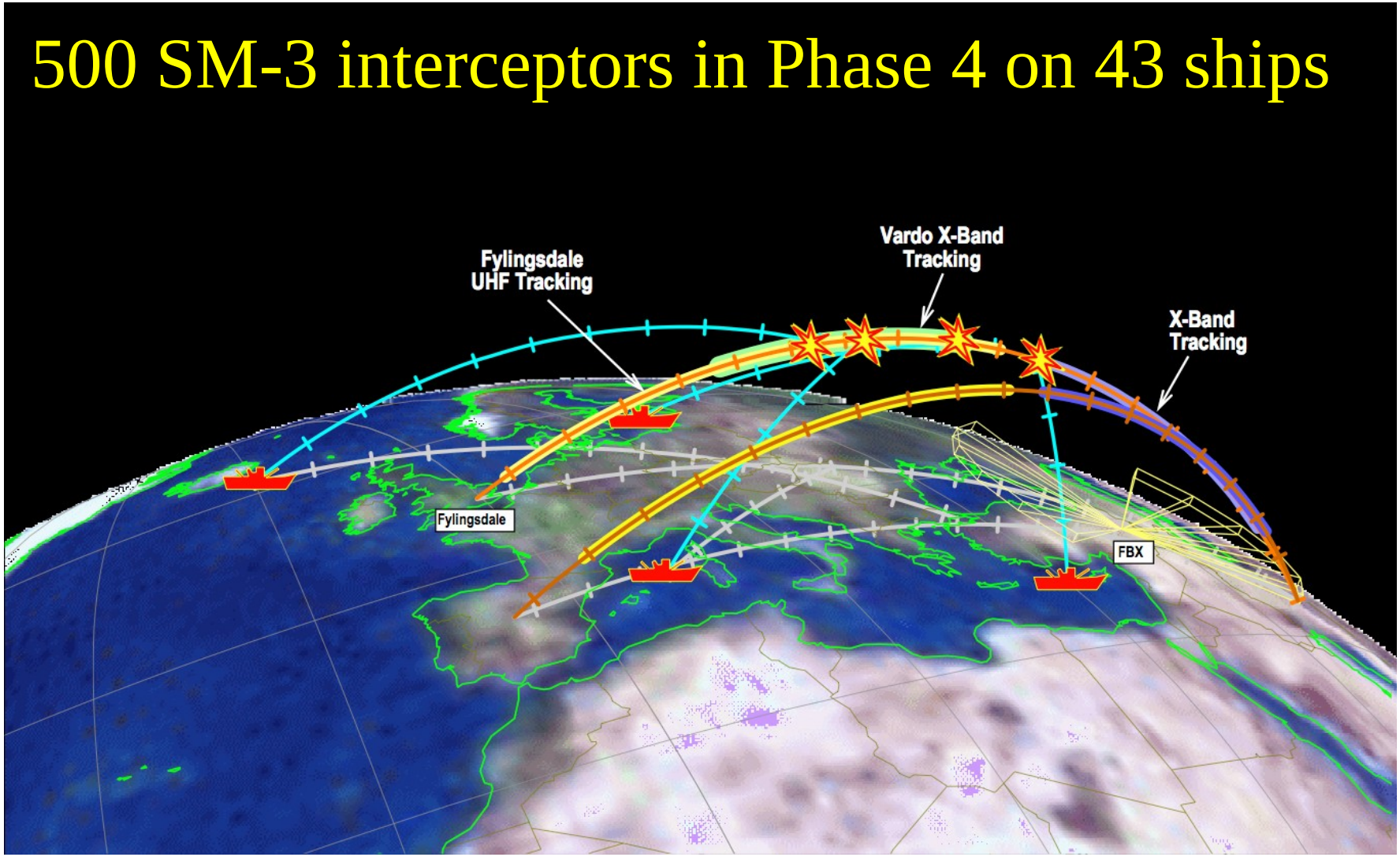
Obama's Phased Adaptive Approach to EMD

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.

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

Obama's Phased Adaptive Approach to EMD



Obama's 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.

Obama's Phased Adaptive Approach to EMD

- The current system consists of one SM-3 equipped ship on-station in the Mediterranean Sea working in conjunction with the AN/TPY-2 radar based in Turkey.
- NATO has announced that the EMD system now has "interim capability" to defend against MRBMs.
- Over the next decade, the United States, working with NATO, plans to ramp up the deployment of the mix of sea- and land-based SM-3 interceptors, including next-generation, longer-range interceptors around Europe that would attempt to guard against missiles launched from Iran.

Obama's Phased Adaptive Approach to EMD

- The PAA plan calls for more than 500 SM-3 interceptors to be based on 43 ships by 2018.
- The PAA plan calls for SM-3s with increasing capability to be stationed in Romania (in 2015) and in Poland (in 2018).
- 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 announced to cancel the final phase of PAA.

Recent Funding of Missile Defense Agency

Missile defense —

In FY10, the Missile Defense Agency received $7.9 B.

In FY11, the Missile Defense Agency received $8.4 B.

In FY12, the administration is spending a total of $10.4 B for missile defense.

For FY13, President Obama has requested a total of $9.7 B for missile defense, down 6.7% from FY12.

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 2018 – 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

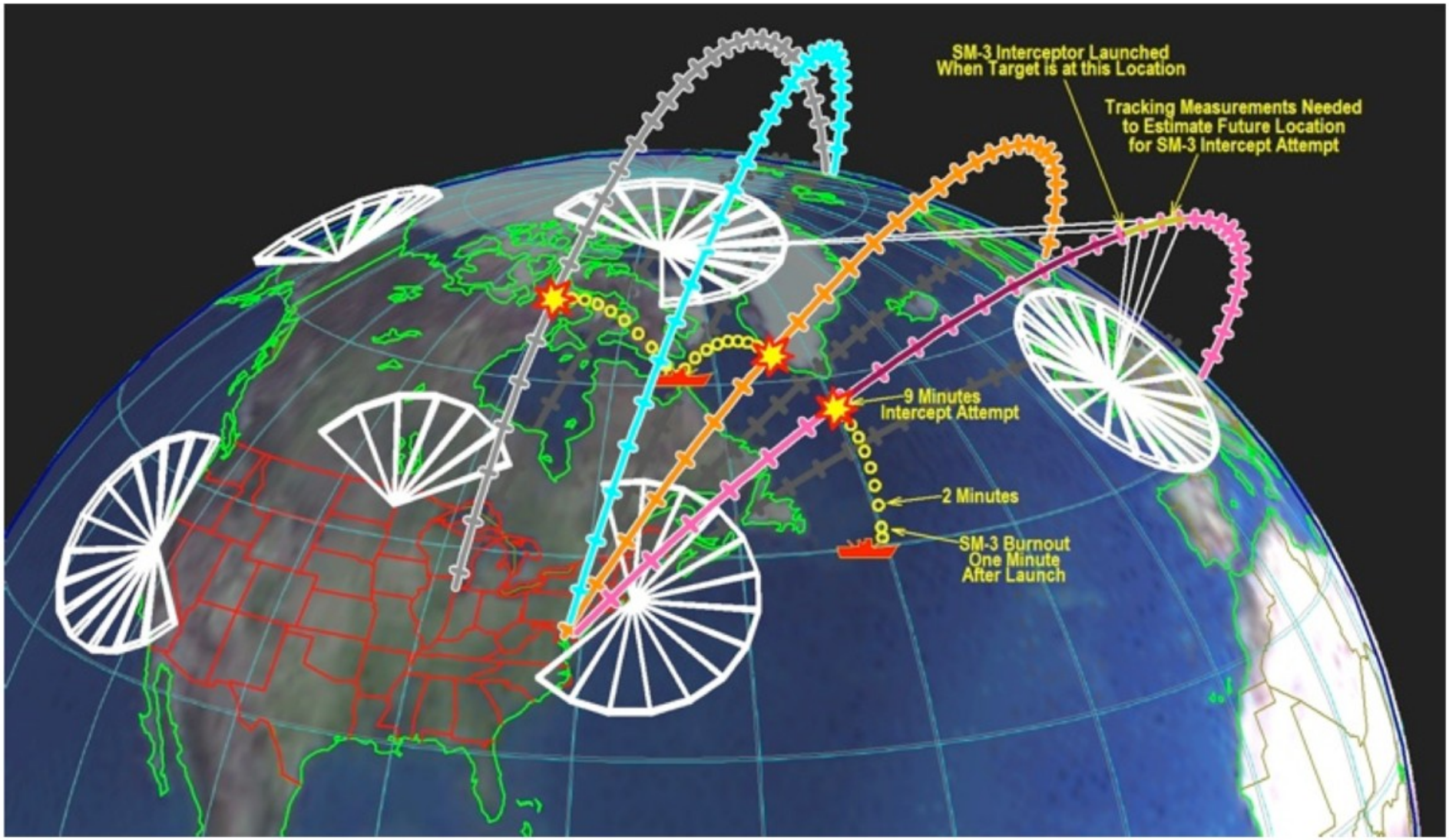
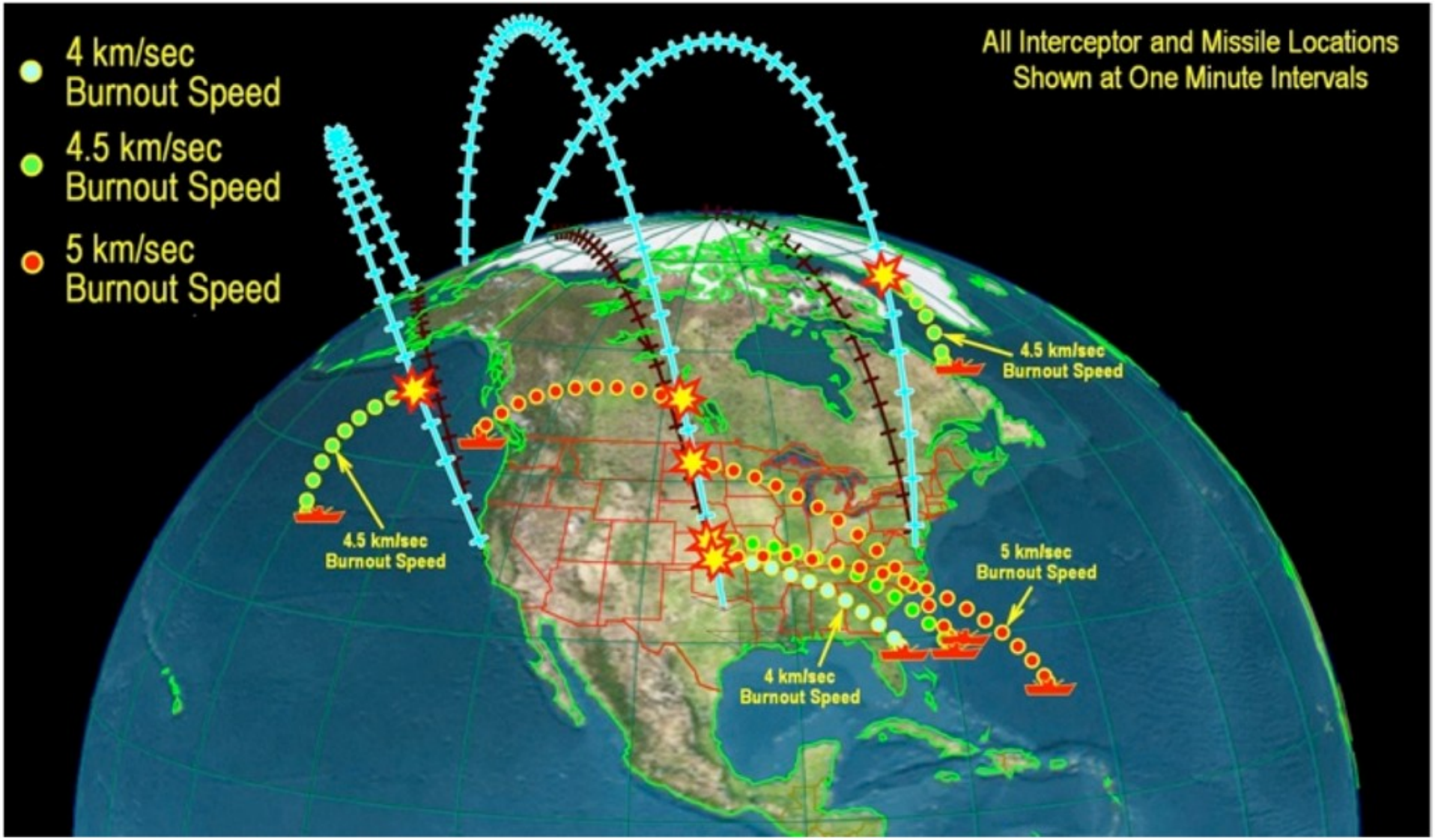


Figure 3: Northwest Atlantic-based SM3 Block II interceptors (with a conservative assumed burnout speed of 4 km/sec) engaging Russian ICBM warheads: each tick on the trajectories marks one minute.

Possible Russian Concerns About the Phased Adaptive Approach to EMD



Defenses Against Long-Range Nuclear-Armed Ballistic Missiles

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?
- Is it simply the inherent conservatism of governments in their inability to change past erroneous decisions?

One fact is clear: scientific-technical realities cannot be overcome by political claims or wishful thinking. Ignoring the scientific-technical realities creates grave risks for our nation.

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

Module 7: Defenses Against Nuclear Attack

Supplementary Slides

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)

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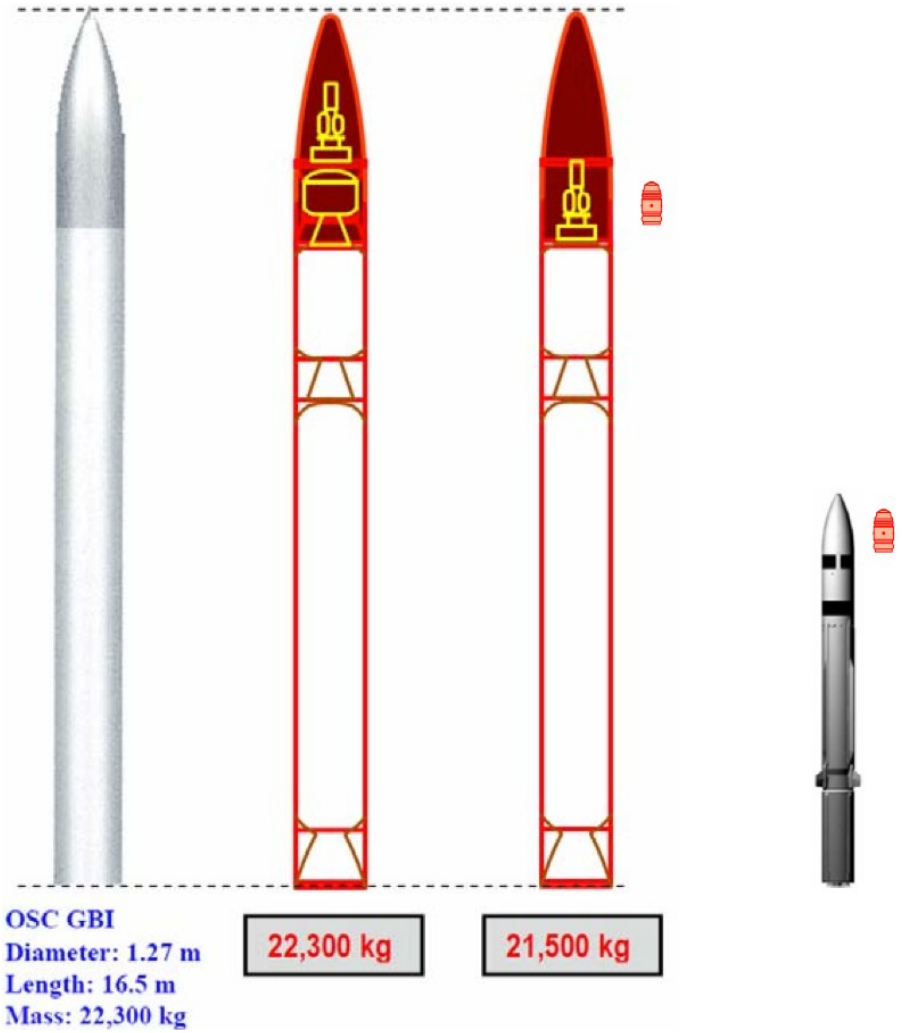
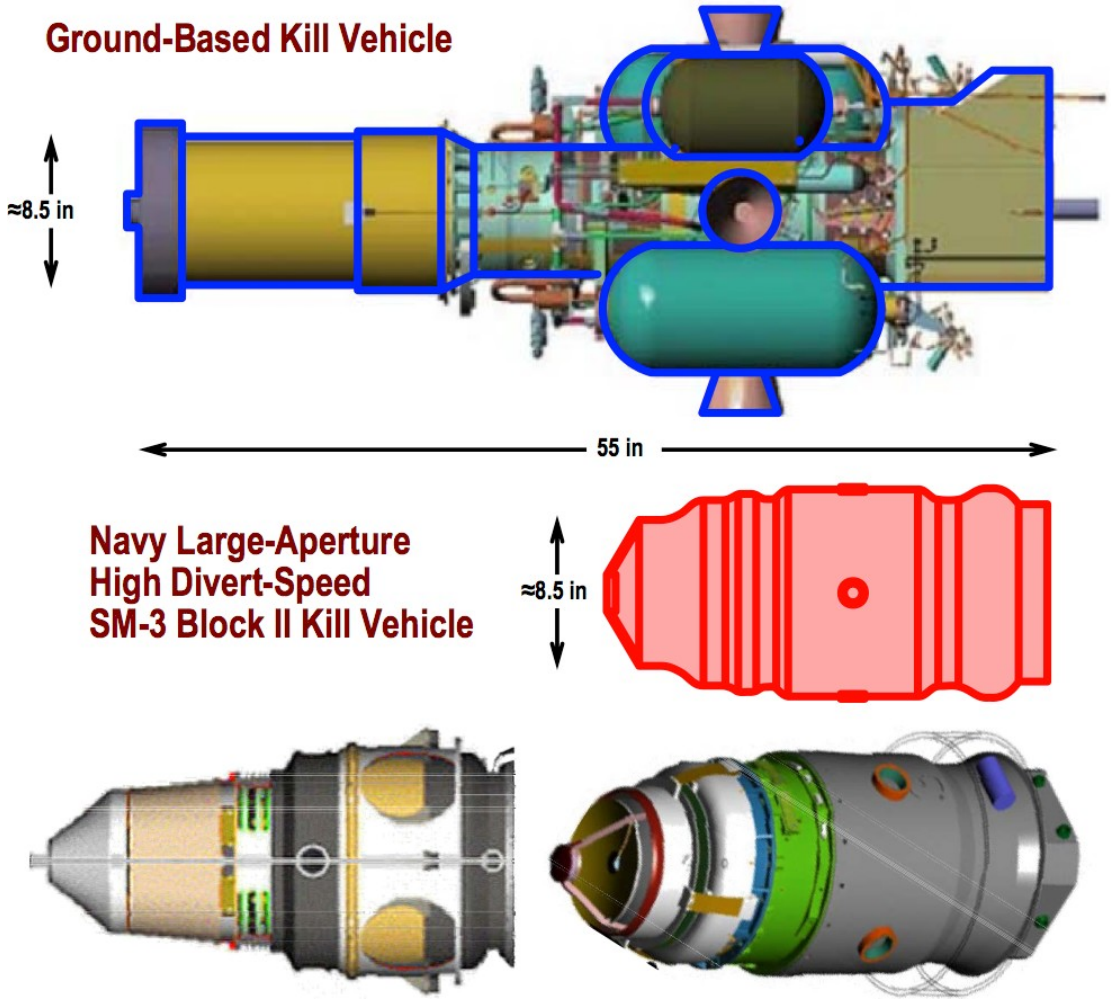
Planned Midcourse Intercept Rockets



Courtesy T. Postol (MIT)

Planned Midcourse Intercept Kill Vehicles



Courtesy T. Postol (MIT)

Proposed European Defense Against Ballistic Missiles

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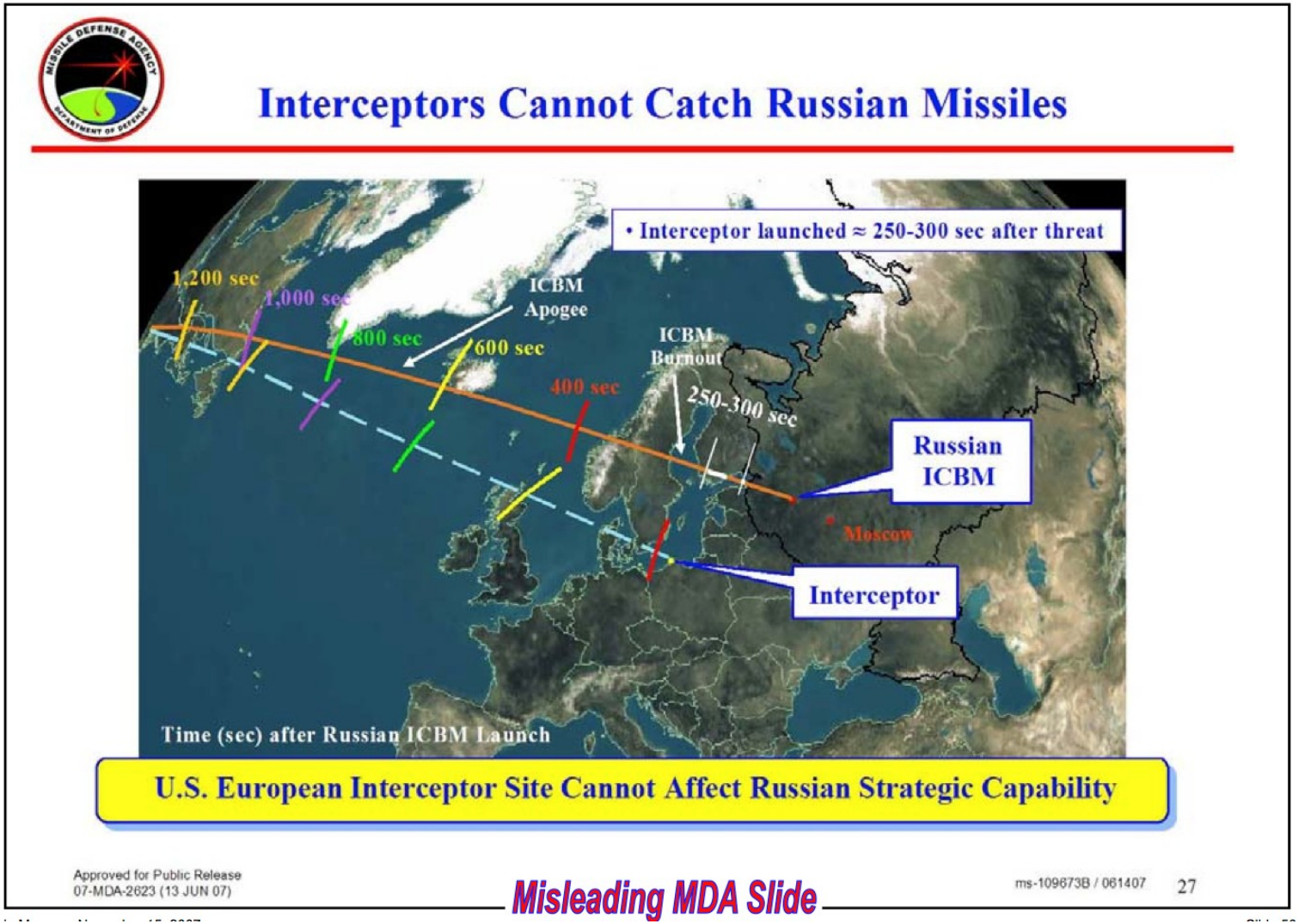
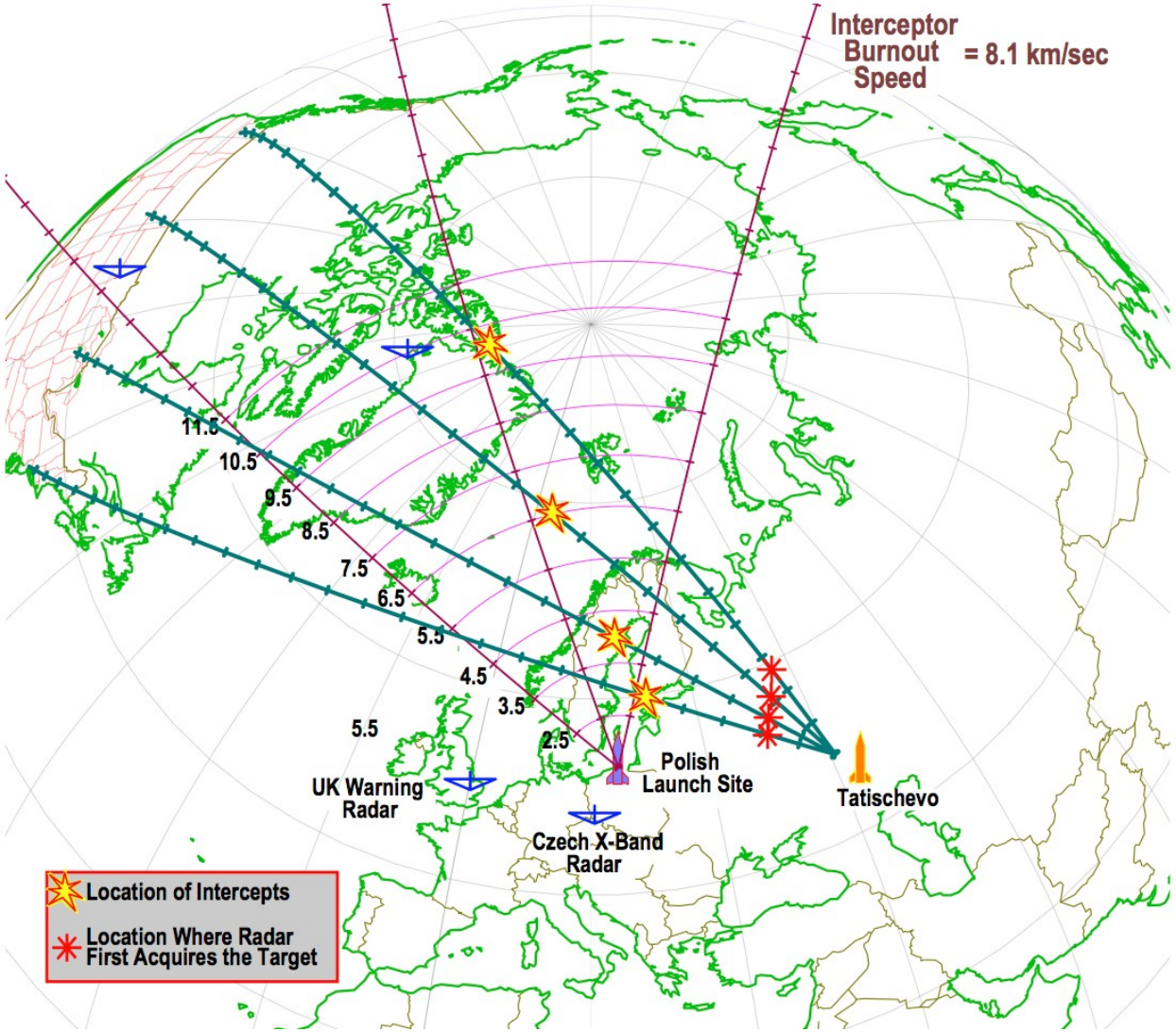
Proposed European Defense Against Ballistic Missiles



Misleading MDA Slide

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

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B. Small ship-based interceptor rockets
C. Ship-based lasers
D. Airborne lasers
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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

Aegis Ashore: 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 . . .

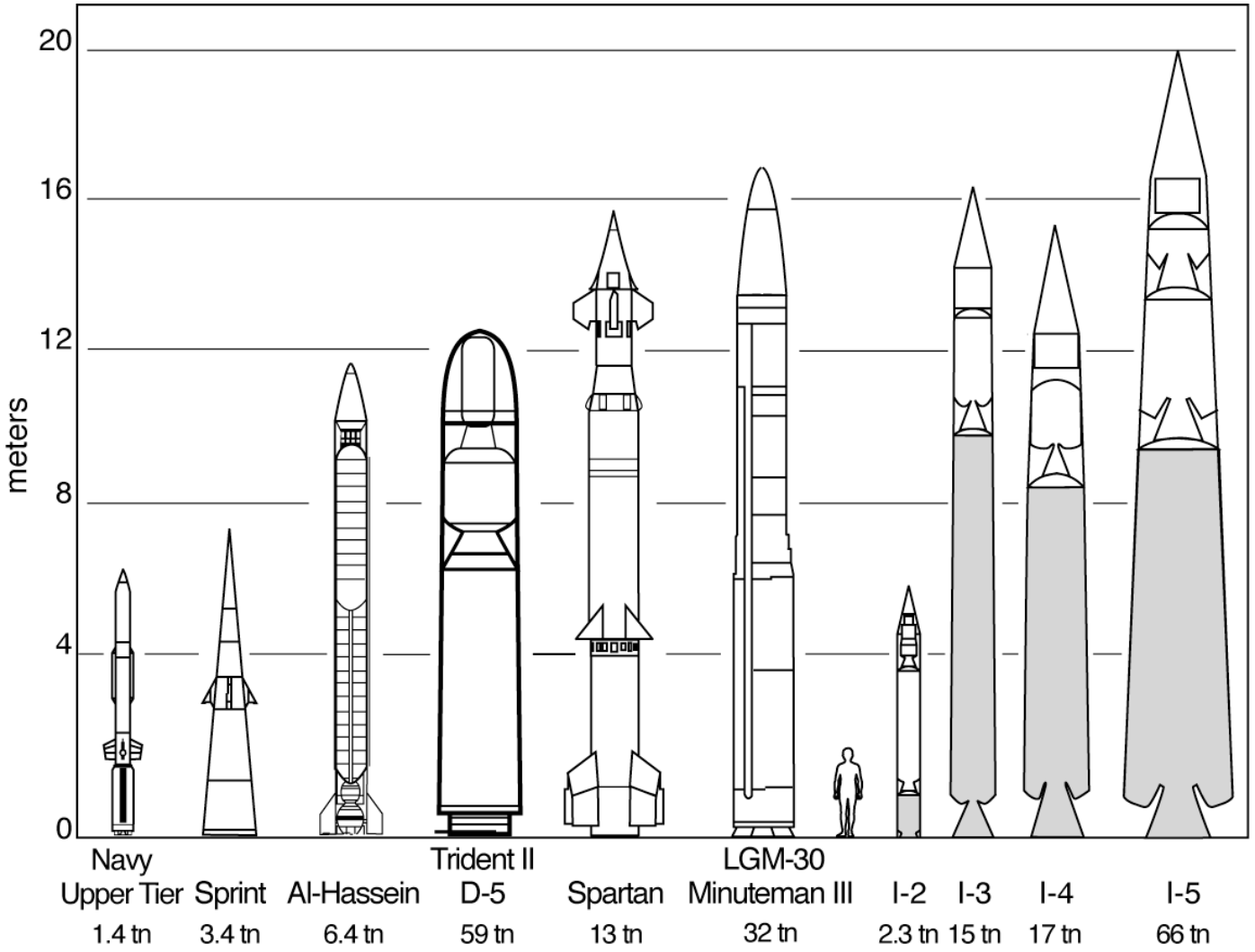
On whether the target ICBM is a liquid-or a solid-propellant missile

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

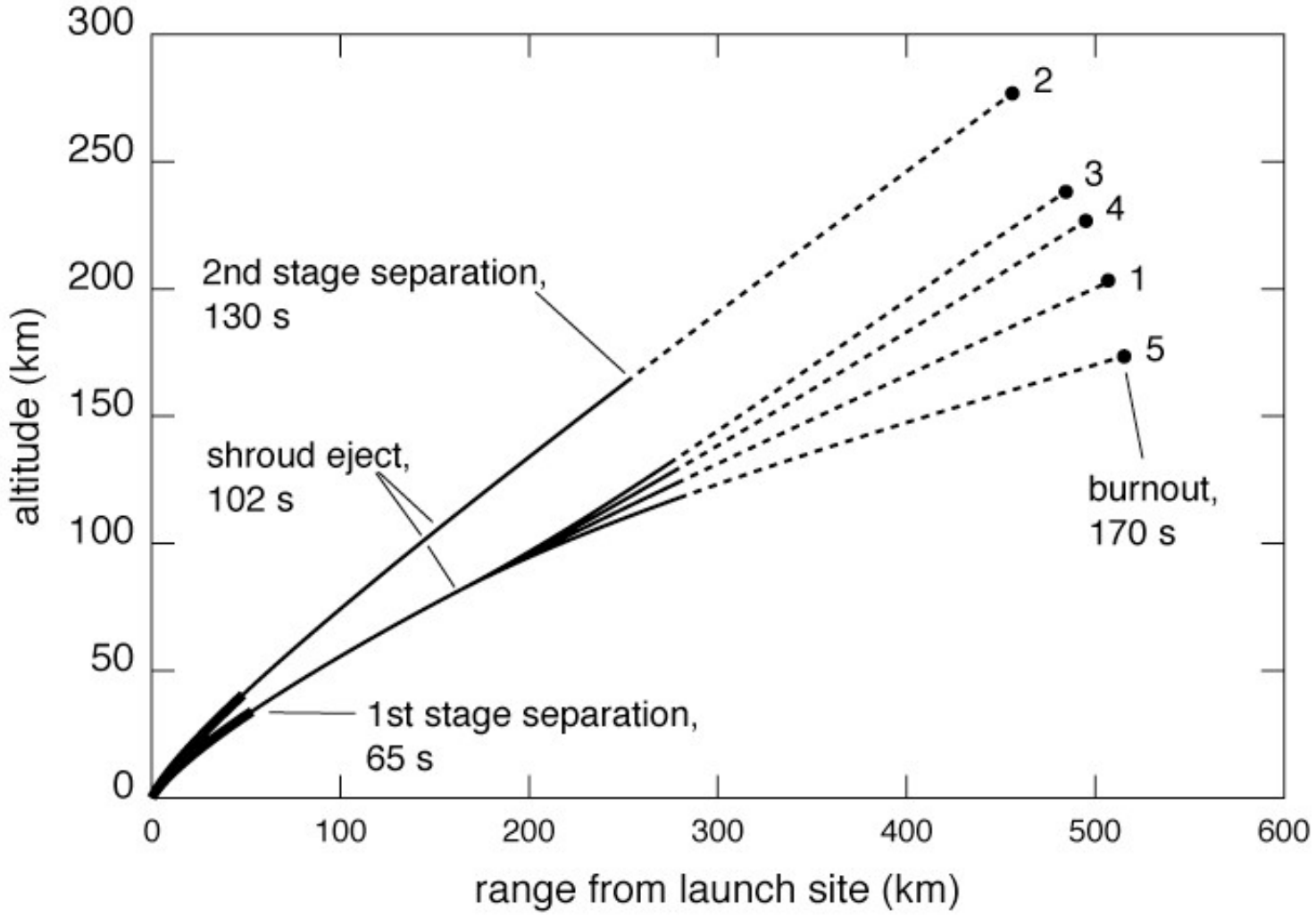
- Passive infrared, optical, and UV sensors
- Active sensors such as LIDAR

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)

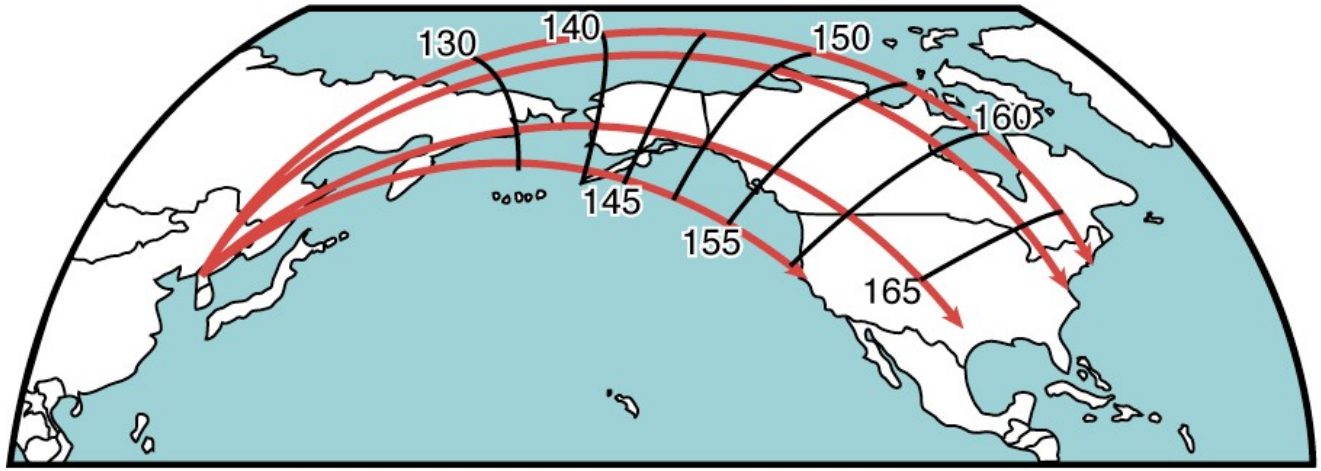
Hitting an ICBM in Powered Flight is Very Challenging



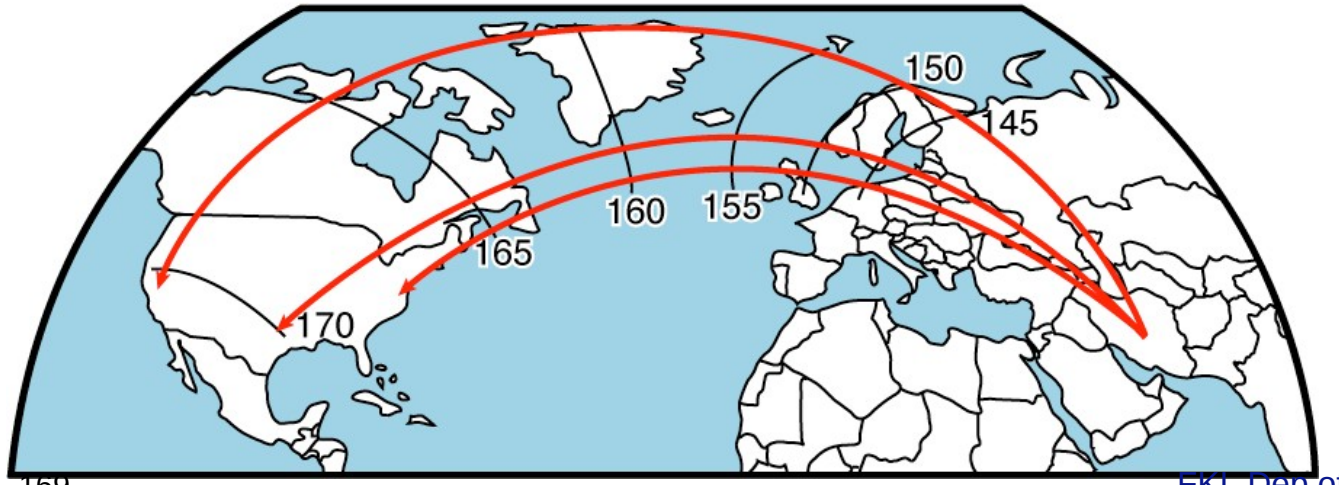
Global Geography Determines How Early the ICBM Must Be Intercepted

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.

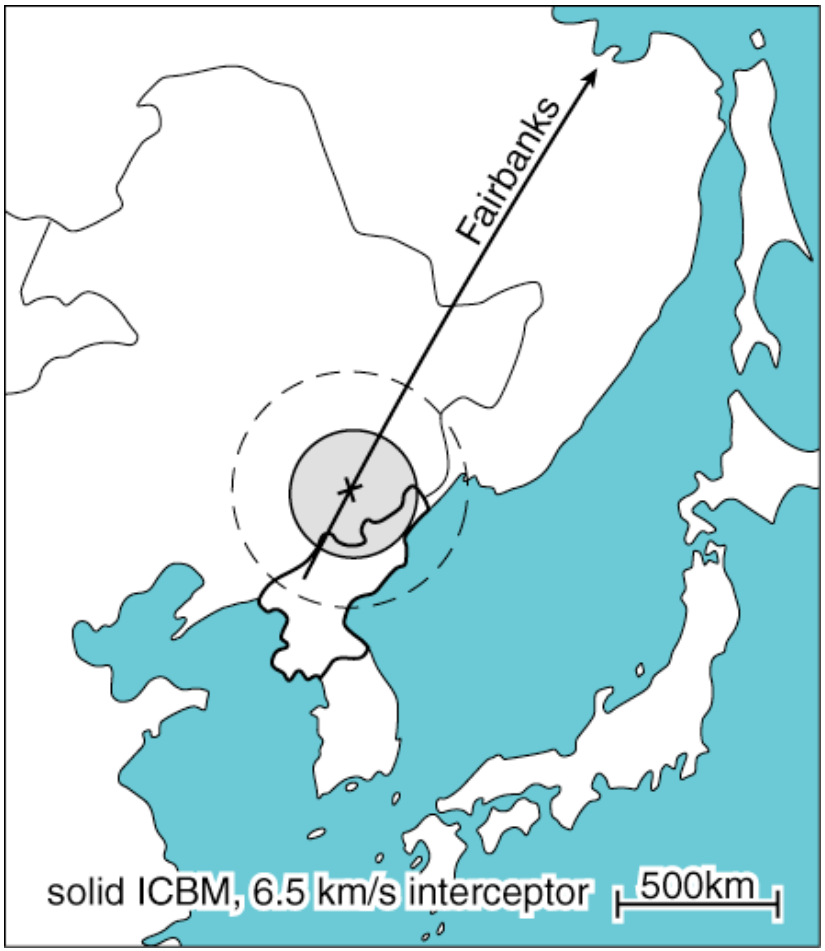
Solid-propellant from North Korea



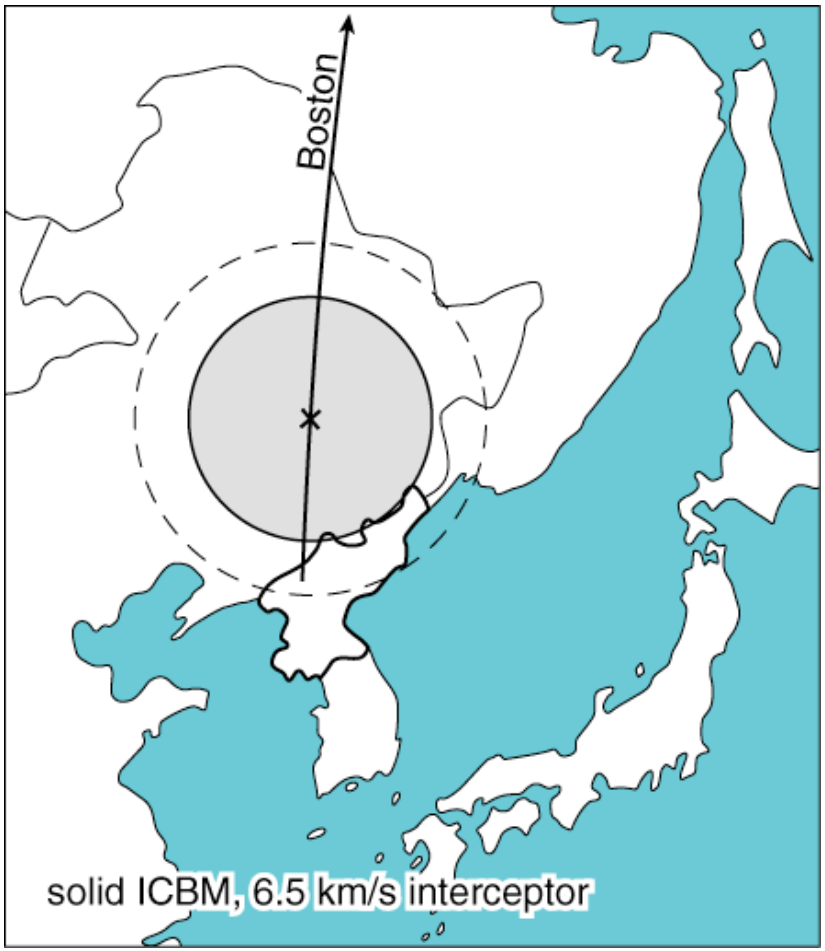
Solid-propellant from Iran



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

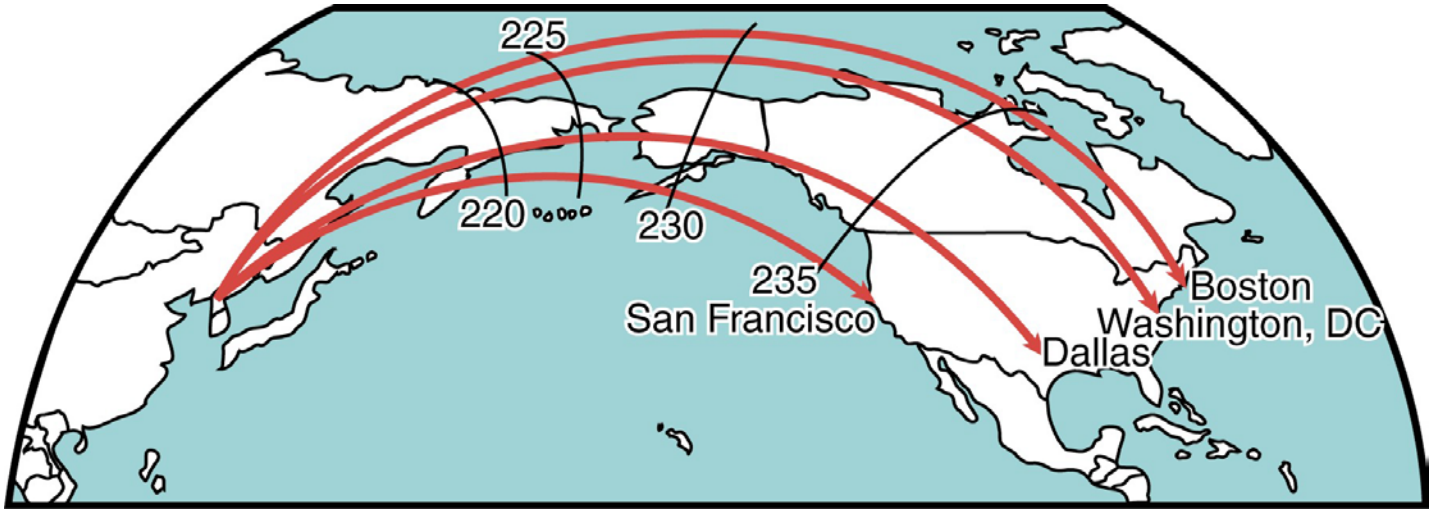
A problem inherent in boost-phase defense is that causing the attacking missile's munitions to fall short could cause nuclear, chemical, or biological weapons to impact other populated areas in the United States or other countries

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

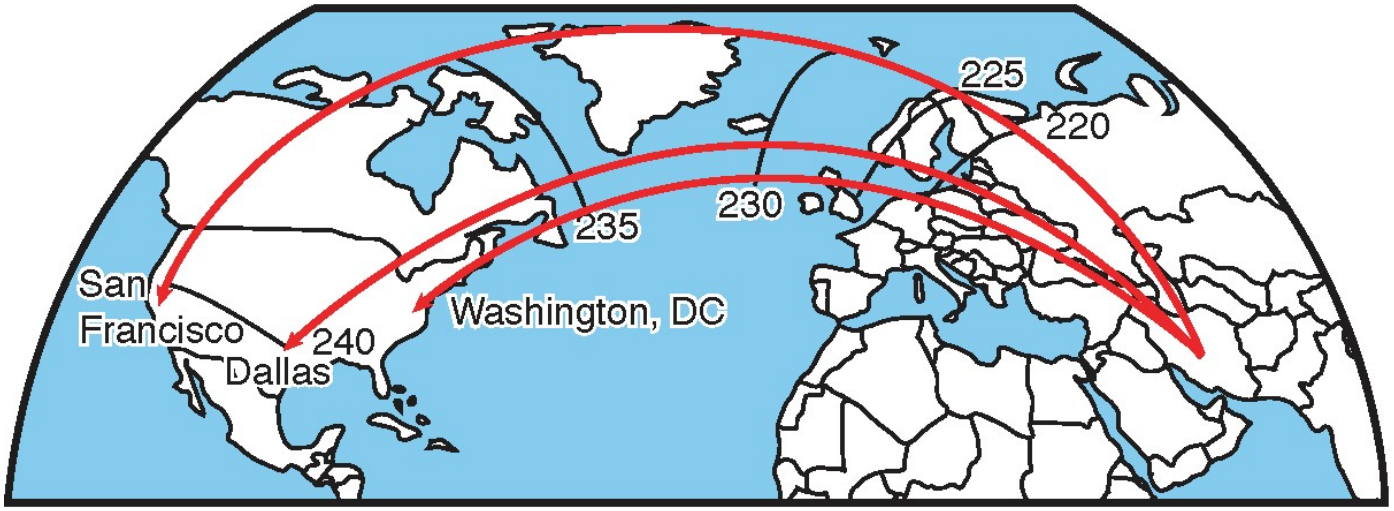


If launched against a target in the central United States, this particular missile would have to be intercepted in a small window between about 225 and 230 seconds after launch, to avoid dropping warheads on Russia or Canada

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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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