Prospects for Ballistic Missile Defenses and Nuclear Reductions

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- This is much expanded version of my talk

Prospects for Ballistic Missile Defenses (BMDs) and Nuclear Reductions

- Nuclear weapons and ballistic missile defenses.
- Overview of the U.S. ballistic missile defense program.
- Three missile defense programs and some possible implications:
  - The U.S National Missile Defense System
  - The European Phased Adaptive Approach (EPAA)
  - A U.S. global defense system?

(Focus here is on defenses against long-range (nuclear) missiles, not on defenses against short-range, conventionally-armed missiles.)

Why are Ballistic Missile Defenses a Problem for Nuclear Arms Reductions? (1)

- Nuclear deterrence remains central to the security policy of United States, Russia, China, and other nuclear nations.
- The primary mechanism of nuclear deterrence for these countries are nuclear-armed ballistic missiles.
- Nuclear deterrence depends on confidence that missiles will get through in a retaliatory attack.
- Ballistic missile defenses at best introduce uncertainty about retaliatory capability, at worst directly threaten retaliatory forces.

Why are Ballistic Missile Defenses a Problem for Nuclear Arms Reductions? (2)

- Responses to missile defenses can include:
  - Deployment of additional nuclear missile forces
    - More missiles
    - Multiple-warhead missiles (MIRVs)
  - Refusal to limit (or further limit) nuclear missile forces, either quantitatively and qualitatively, via agreements.

Why are Ballistic Missile Defenses a Problem for Nuclear Arms Reductions? (3)

- Responses to missile defenses can include:
  - Other measures to defeat defenses
    - Countermeasures (decoys, etc…)
    - Rapid launch strategies
    - Planned attacks on defenses
    - Other delivery means (cruise missiles, etc…)
  - Deployment of own defenses
    - Could lead to offense-defense competition
  - All of above

Ballistic Missile Defenses and Stability

- In Cold War language, ballistic missile defenses can create or worsen several types of instabilities:
  - *Arms Race Instability*: Deployment of defenses by country A is seen as threatening by country B, leading country B to deploy more missiles and/or defenses, which in turn is seem as threatening by country A.
  - *Crisis instability*. If either side believes it can destroy the other's nuclear forces (or if it believes its forces are similarly vulnerable), there is an incentive to strike first in a crisis. Missile defenses can make this situation worse because might be able to defeat small retaliatory attack.

The Anti-Ballistic Missile (ABM) Treaty (1)

- Signed by US and Soviet Union in 1972, in conjunction with first offensive strategic arms limitation treaty.
- Treaty was based on common understanding that:

  -- Neither country could build an effective defense against the other's large nuclear arsenal

  -- Even attempting to do so would be both extremely costly and potentially destabilizing, and could lead to an offense-defense arms race.

The Anti-Ballistic Missile (ABM) Treaty (2)

- The Treaty prohibited either country from deploying a nationwide National Missile Defense (NMD) system.
  - A single, regional NMD system was permitted.
  - R&D was permitted
  - Defenses against shorter-range missiles (theater missile defense of TMDs) were permitted.

The Anti-Ballistic Missile (ABM) Treaty (3)

- Treaty sought to prevent infrastructure for nationwide NMD system from being established.
  - Limits of on large phased-array radars.
  - Limits on new technologies.
  - Needed to give assurance against Treaty breakout.
- Treaty provided confidence that offensive nuclear forces could be reduced without endangering deterrence.
- United States withdrew from Treaty in 2002 in order to begin deployment of current Ground-Based Midcourse (GMD) NMD system.

Why Do Strategic Missile Defenses Create Uncertainty?

- Conservative assumptions on both sides (worst case planning).
  - Assumption other side knows what they are doing.
- Could be used to counter retaliatory strike.
  - Even a small defense could used this way.
- Effectiveness is difficult to assess.
  - Cannot be realistically tested.
  - Effectiveness depends on steps taken by other country.
- Concerns about possible future developments.
  - Rapid expansion of defenses, if possible
  - Technological surprise

New START Treaty (2011)
(Strategic Arms Reduction Treaty)

- Current U.S.-Russia nuclear arms treaty.
- 1,550 strategic nuclear weapons by 2/2018.
  - Russia now at about 1,500, U.S at about 1,720.
  - Previous limit was 2,200 under 2002 SORT Treaty.
  - All strategic missile warhead count, bombers count as one each.
  - No limit on thousands of tactical/reserve weapons.
  - Maintains verification provisions
- Reductions well below this level necessary to bring in other countries.

New START Preamble (non-binding)

Recognizes that there is an:

"*interrelationship between strategic offensive arms and strategic defensive arms*"

but that:

"*current strategic defensive arms do not undermine the viability and effectiveness of the strategic offensive arms of the Parties.*"

The Situation Today

- Large-scale U.S deployments of strategic capable defenses planned to begin ~ 2018. Infrastructure already being put in place.
- Deployment is open-ended, ultimate scope is unknown.
- Russia and China object to regional deployments and some response is likely.
- Russia in particular objects to EPAA Phases III-IV.

Overview of U.S. Missile Defense Program
(1) National Missile Defense

- The core of the National Missile Defense (NMD) System is near completion.
- Known as the Ground-based Midcourse Defense (GMD) System.
- This system, with 30 interceptors deployed, is intended to defend U.S. territory from intercontinental-range ballistic missiles.
- Nominally aimed at N. Korea and Iran. Some people also want capability against China.

Overview of U.S. Missile Defense Program (2) Theater Missile Defenses

- U.S. currently deploys and/or is developing several Theater Missile Defense (TMD) systems against shorter range missile threats.
- The most important of these are:
  - Patriot
    - Shorter-range, intercepts within atmosphere.
  - THAAD (Terminal High Altitude Area Defense)
    - Intermediate range, upper atmosphere and above.
    - TPY-2 X-band radars
  - Navy Aegis Ballistic Missile Defense
    - Wide-area, above atmosphere, four phases by 2021.

Overview of U.S. Missile Defense Program (3)Regional Defense Systems

- Obama Administration introduced plan for regional Phased Adaptive Approaches for TMDs
- Most developed so far is European Phased Adaptive Approach (EPAA). But also N.E. Asia and Middle Eastern plans.
- Key feature of PAAs is integration of sensors and interceptors into a single system.
- The EPAA:
  - Envisions three phases of increasingly capable TMD systems (including land-based Aegis) defending Europe by 2018.
  - Bush European System was defense only of U.S. territory.

Overview of U.S. Missile Defense Program (4) Global Ballistic Missile Defense

- Ultimately the GMD and the regional defenses are to be integrated into a single global defense system.
- Could involve space-based tracking and guidance.
- This integration could begin as early as Phase IV of EPAA (2020), which deployed interceptors in Europe to defense U.S. territory.
- Missile Defense Agency (MDA) goal for 2020: "deal with fifty missiles in the air at once" under "seamless world coverage."

U.S. National Missile Defense

-- Ground-Based Midcourse Defense (GMD) System --

- Declared operational in late 2004, with eight interceptors and two radars.
- Currently has 30 large Ground-Based Interceptors (GBIs) based in silos on central Alaska (26) and California(4). No current plans for more.
- Interceptor are initially guided by large ground-based radars. As they approach target, release homing Exo-atmospheric Kill Vehicle (EKV).
- EKV homes in on heat from target, destroys it in high-speed collision. Operates only in outer space.

How the GMD System is Supposed to Work

(Hypothetical Single Missile Attack)

(1) Early warning satellites detect launch. ✓

(2) Early warning radars detect and begin to track target. ✓

(3) Radars discriminate (identify) warhead target. ???

(4) Multiple Ground-Based Interceptors (GBIs) are fired towards predicted intercept points. ✓

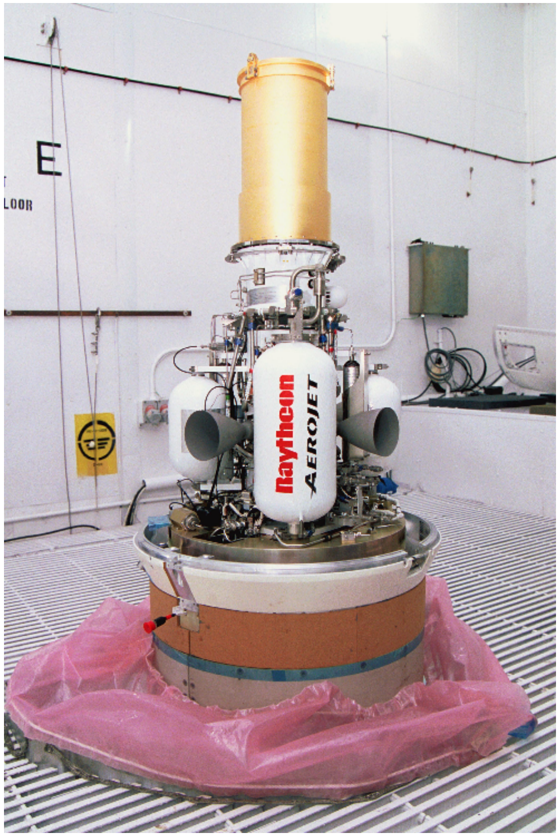
(5) At least one kill vehicle homes in on target and destroys it in direct, high-speed collision. ???

(6) Kill assessment is performed.

GBI + EKV

Ground-Based Interceptor (GBI)

Exo-Atmospheric Kill Vehicle



GMD Sensors

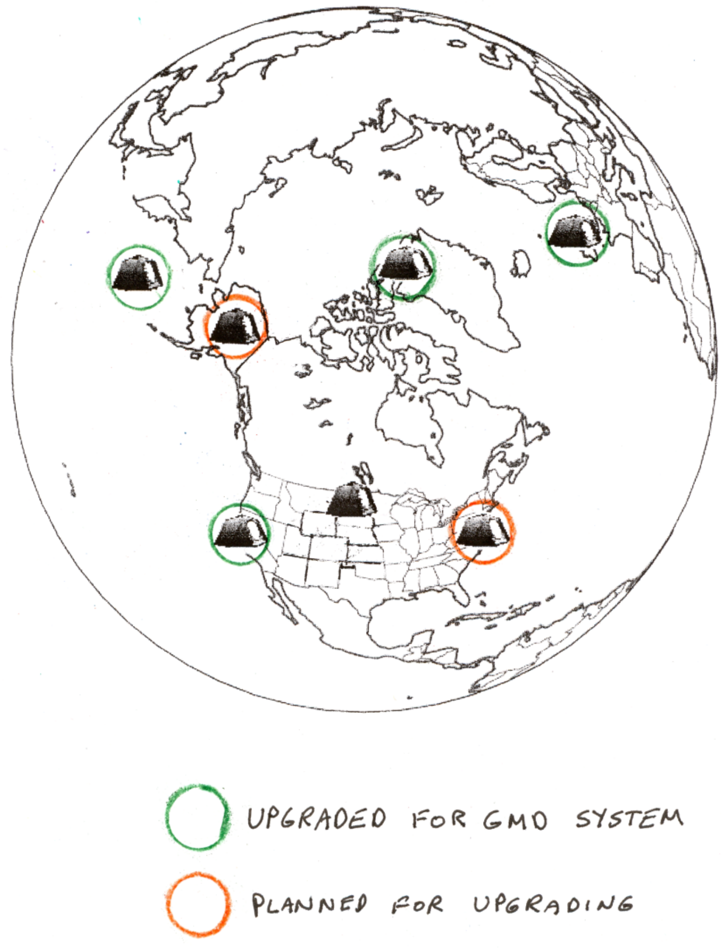
- Early warning satellites provide first warning.
- Primary sensors for tracking targets and guiding interceptors are upgraded early warning radars.
- These early warning radars can track targets at thousand of kilometers but have essentially no discrimination capability.
- Also small forward-based X-band radars (TPY-2s) in Japan and Turkey and large Sea-Based X-Band (SBX) test radar in north Pacific Ocean.

GMD Radars

Upgraded Early Warning Radar

Sea-Based X-Band (SBX) Radar

Upgraded Early Warning Radars



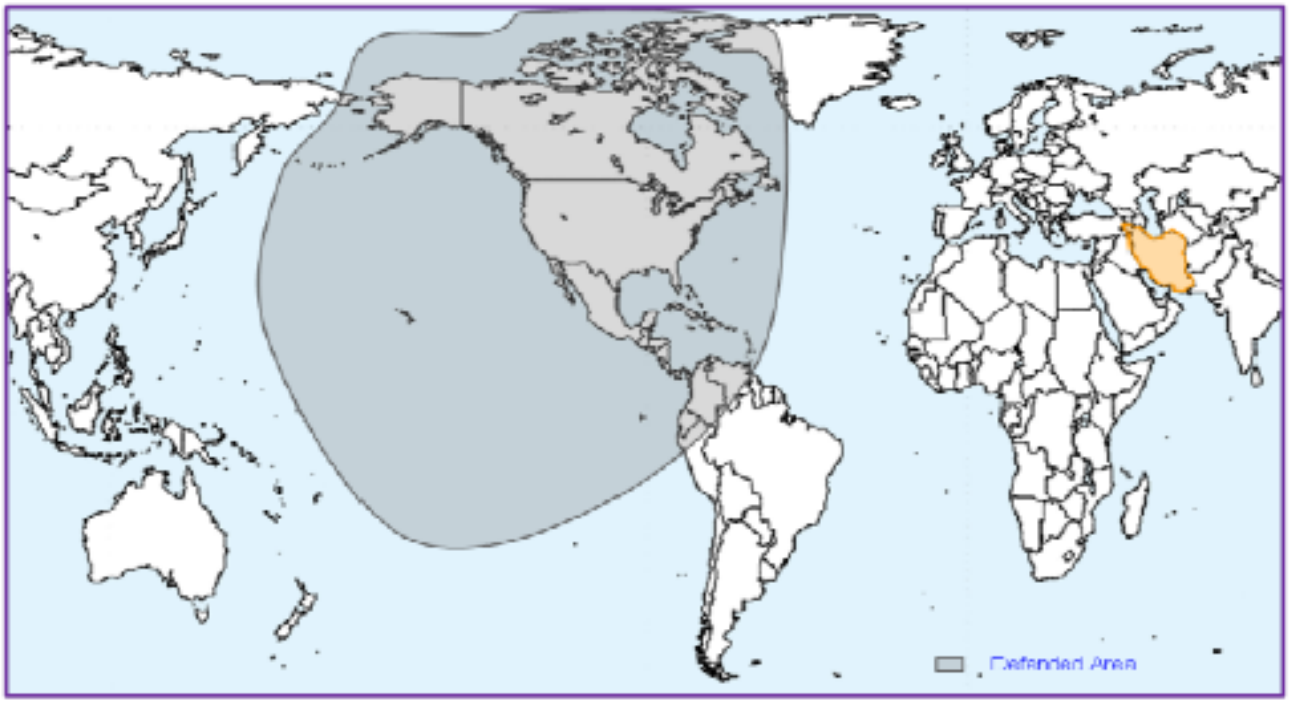
Current GMD – North Korea

(Source: U.S. DoD)

PROTECTION AGAINST ICBM ATTACKS FROM NORTH KOREA. With ground-based interceptors fielded in Alaska and California, land-based radar in Alaska and Japan, and sea-based Radar in the Pacific, the United States can defend the shaded areas from any future long-range missile attack from North Korea.

Current GMD – Iran

(Source: U.S. DoD)



PROTECTION AGAINST ICBM ATTACKS FROM IRAN. The ground-based interceptors fielded in Alaska and California will provide protection from any future Iranian ICBM capability.

GMD Status Summary

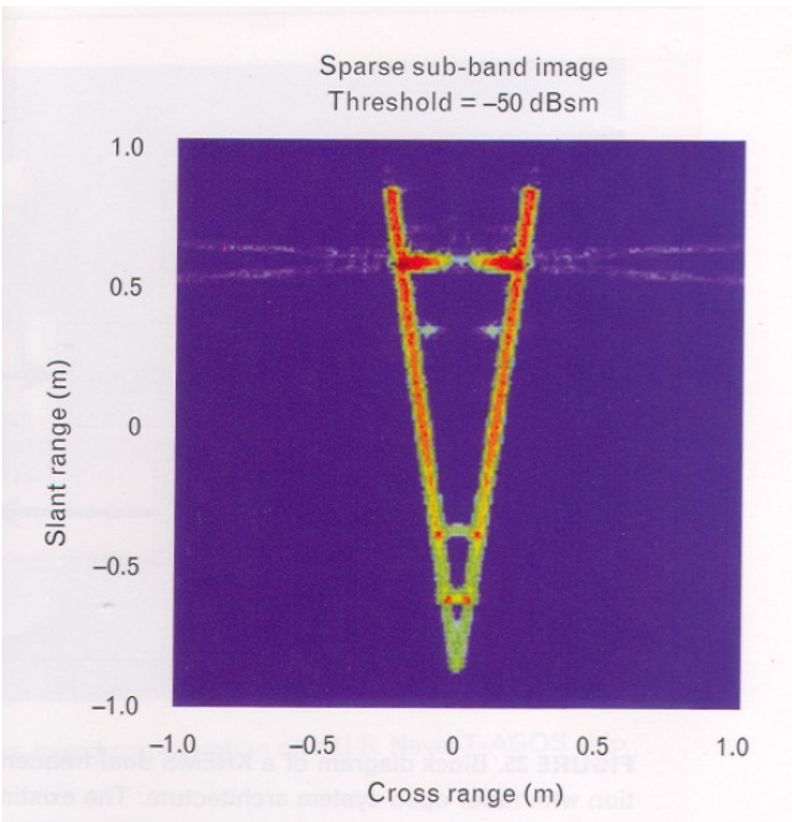
- System has 30 interceptors.
- Nominally effective against small N. Korea or Iran attack.
- System nearly complete.
  - Two more warning radars to be upgraded
  - Possible space-based tracking system (2020s)
- Very limited discrimination capability

Why GMD Should Not Be a Problem for Russia and China

- Only 30 interceptors
  - Low capacity: four interceptors per target
- System has almost no discrimination capability
- Interceptors don't work very well.
  - 8 out of 15 in intercept tests (at best).
  - Last successful intercept test in 2008
  - New version of kill vehicle 0 for 2 in tests.
    - 10 out of 30 deployed are this type
  - No test against ICBM target

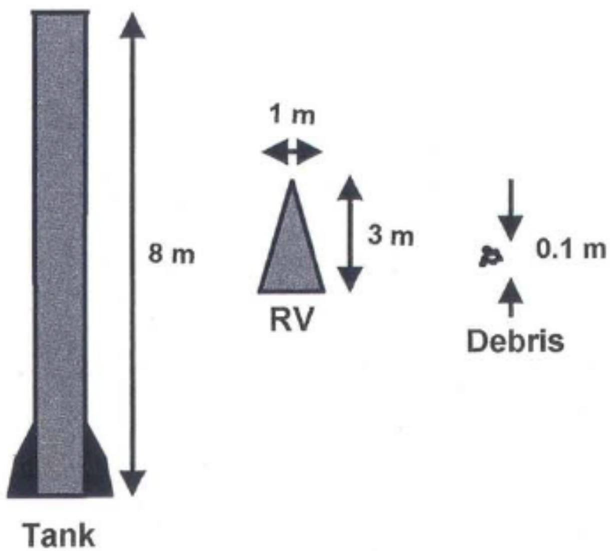
Bandwidth and Discrimination

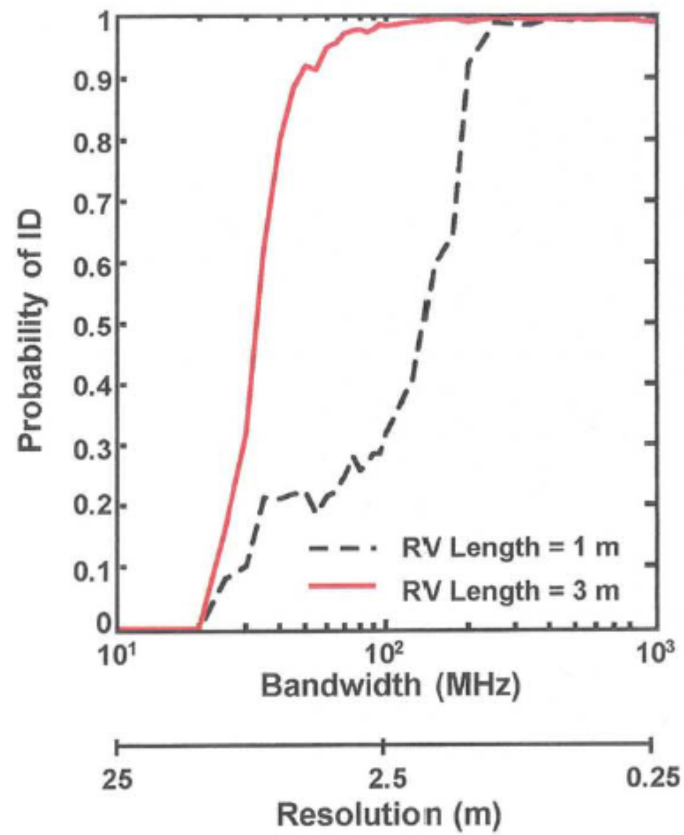
6 GHz Bandwidth
(Source: Lincoln Laboratory)



Bandwidth Requirements for TBM Length Discrimination

UNCLASSIFIED

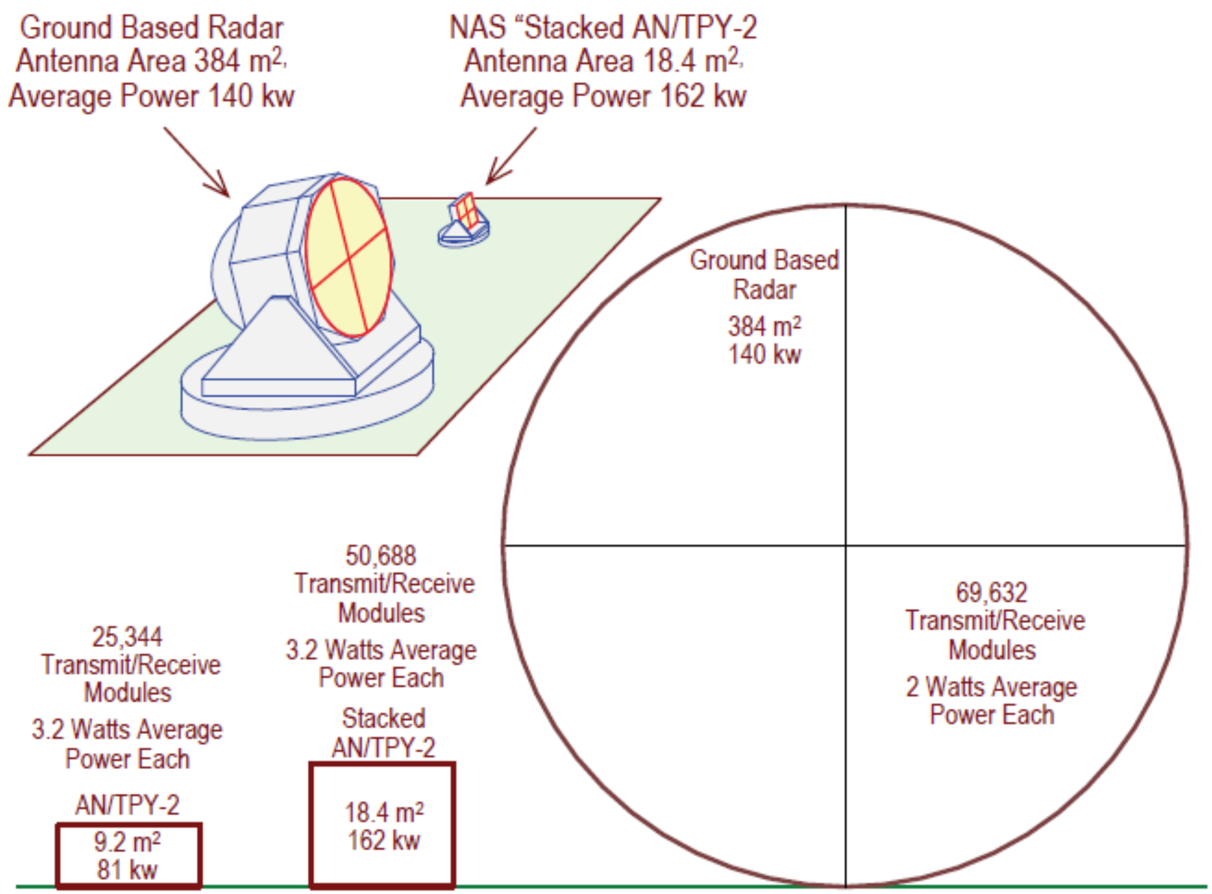




300 MHz Bandwidth (1 m resolution) Required Against Near-Term Threat

UNCLASSIFIED [Source: S. Wilson, 1996]

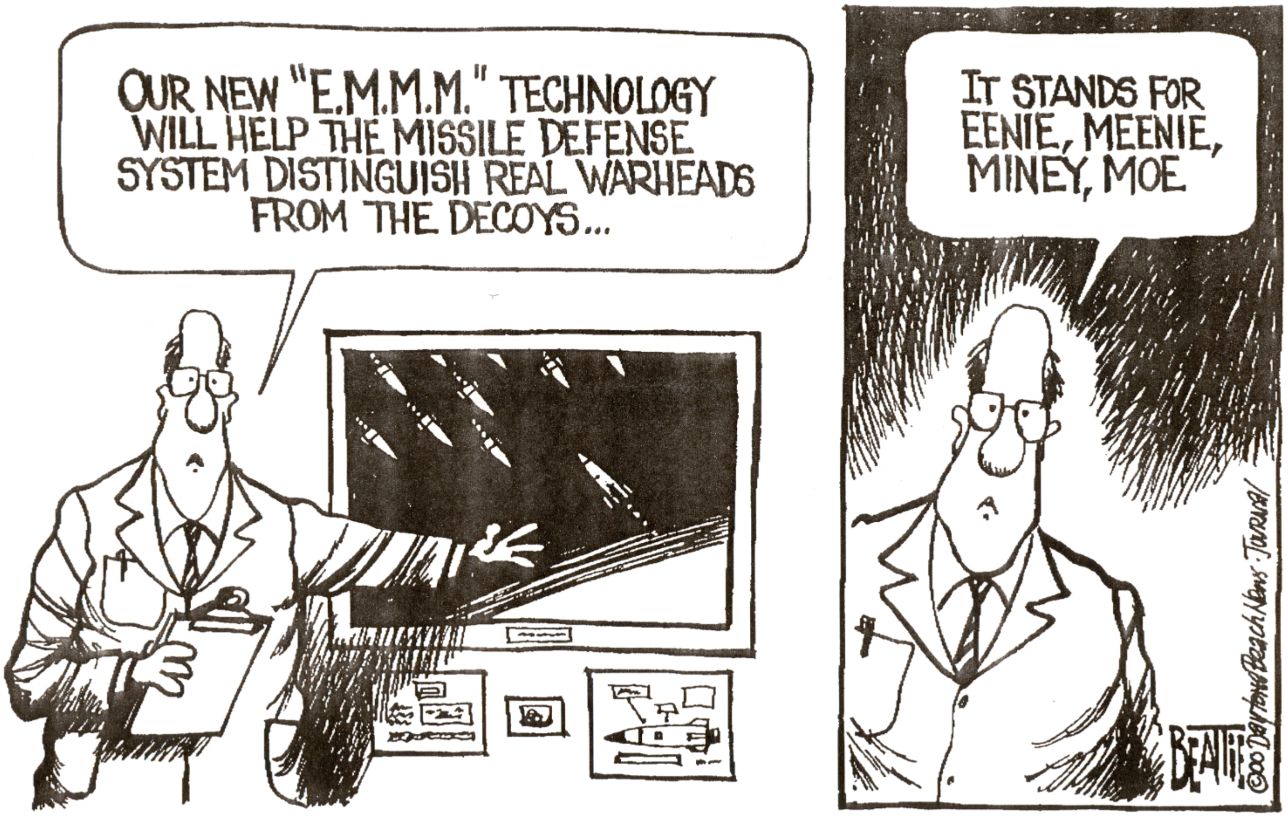
Comparison of NAS' X-band radar to Clinton's GBR.



The GMD System and Discrimination

- The core sensors of the GMD system, the Upgraded Early Warning Radars, have no discrimination capability.
- They cannot be given such a capability.
- There are no plans (at least publicly) to build any new system that can even attempt discrimination for missiles approaching U.S. territory.
- This situation indicates that the current system is not aimed at Russia or China.

How Decoys Are Supposed To Work



The Last Eight GMD Intercept Tests

12/11/2002: Kill vehicle did not separate from booster.

12/15/2004: Interceptor failed to launch.

02/13/2005: Interceptor failed to launch.

09/06/2006: Classified as Success, but target was not destroyed (2012).

09/01/2007: Successful intercept.

12/05/2008: Successful intercept.

01/31/2010: Both SBX radar and kill vehicle fail.

12/15/2010: Failure due to design flaw in kill vehicle.

U.S. Exo-Atmospheric Hit-To-Kill Intercept Tests since 1999

U.S. Hit-to-Kill Intercept Tests since 1999

Year	GMD	AEGIS SM-3	THAAD
1999	☺		
2000	X X		
2001	☺ ☺		
2002	☺ ☺ X	☺ ☺ ☺	
2003		X ☺	
2004	X		
2005	X	☺ ☺	
2006	X	☺ X	☺
2007	☺	☺ ☺ ☺ ☺ ☺ ☺	☺ ☺ ☺
2008	☺	☺ ☺ X X	☺
2009		☺ ☺	☺
2010	X X	☺	☺
2011		☺ X	☺ ☺
2012		☺ ☺ X	☺

Tests of Operationally-Configured GBIs (as of 09/13/2012)

- Average 1.0 flight test/year since first test in 2005 (0.63 intercept tests/year, 0.25 successful intercept/year).
- No tests against an ICBM-range target. Possibly may not occur until 2020 or later.
- No salvo tests.
- No test against more then one target.
- No successful intercept test against "countermeasures."
- Design of CE-II kill vehicle not yet verified.
- No test of repaired CE-I interceptor.
- Developmental tests to continue at least through 2022.

Testing Parameters

- Time of day, Sun orientation, etc…
- Intercept geometry (depends on launch site and aimpoint, type of trajectory)
- Intercept closing speed
- Size, temperature of target, target tumbling, rotation, etc…
- Number of targets
- Presence of other objects
- Deliberate countermeasures

Realistic Testing

Trident II

First launch from submarine (1986)

- GMD is fundamentally a defense against nuclear weapons
- Trident II (at left), 137 consecutive successful flight tests since 1989 (as of 03/12)
- ~ 6 tests per year.
- Much more complex GMD system averages about 1 test per year

Why So Few Tests?

- Tests are complex and expensive. Recent intercept tests have cost $240-300+ million each. GMD funding under pressure.
- Test plan had and still has no allowance for failure built into it.
- Lack of urgency. MDA now argues that 1 flight test per year is the right pace.
  - No threat
  - Belief system already works??

Consequences of Testing Problems

- Only 30 GBI interceptors deployed, 10 of which (CE-IIs) are not operational.
- Every operational GBI flight test has revealed needed software or hardware fixes.
- GBIs highly unreliable (5-6 out of last eight intercept tests failed).
- GBI Unit Acquisition Cost: $421+ million. Current buy cost: ~ $85 million.
- Cost of repairing older CE-I GBIs: $14-24 million each. These repairs do not address all known problems.
- Cost of fixing new CE-II interceptors: ~ $18 million each, if problem is correctly understood.

Why GMD Should Not Be a Problem for Russia and China

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    - 10 out of 30 deployed are this type
  - No test against ICBM target

4.0-4.5 km/s Naval Interceptors vs. Chinese ICBMs

(Source: Butt and Postol, FAS, 2011)

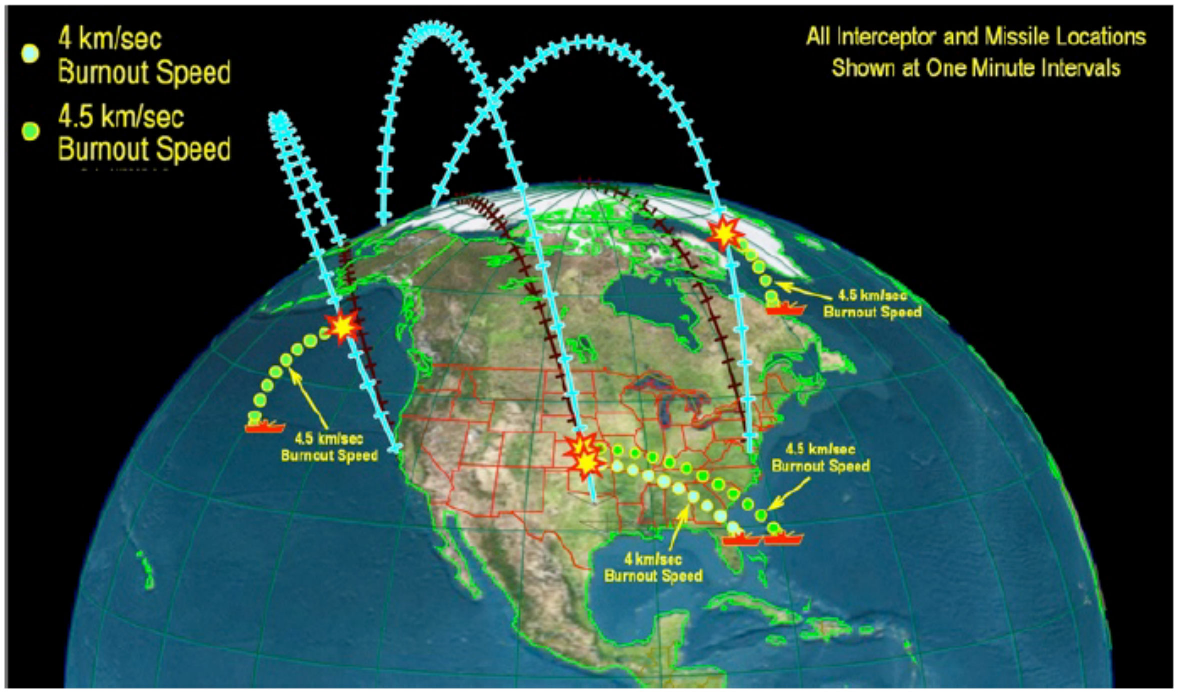


Figure 4: Atlantic- and Pacific-based SM-3 Block II interceptors (of assumed 4.5 km/sec burnout speed) engaging Chinese (light blue) ICBM warheads. Each tick on the trajectories marks one minute. An additional 4 km/sec simulation for the Aegis ship off of Florida is also included to show that slower interceptors would have a considerable reach deep into the U.S. mainland to attempt an intercept.

1992 SDIO Slide of Naval Coverage with Predecessor of Block II

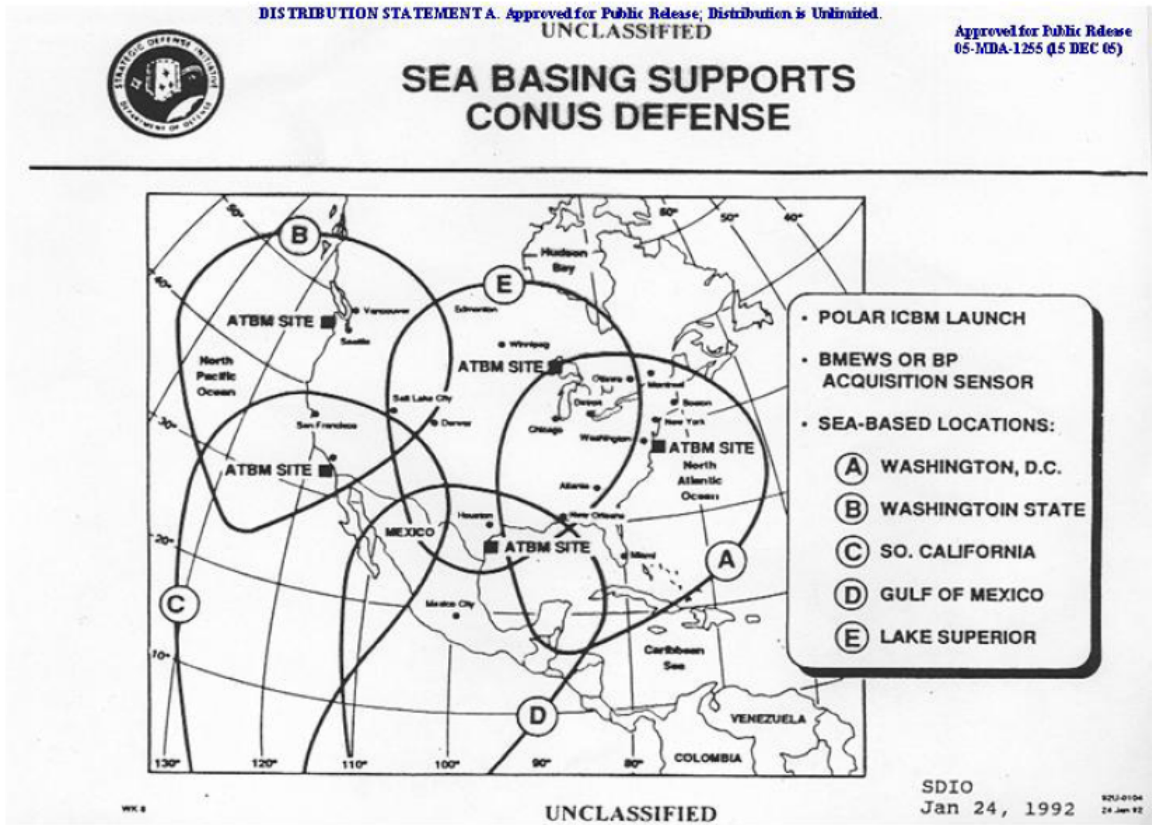


Figure 2

GMD Effectiveness Against A North Korean ICBM

- *"I'm very confident that American defense capabilities are able, no problem, to block a rocket like this one."* U.S. Secretary of Defense Leon Panetta, in response to a question from CNN on the capabilities of U.S. missile defenses, December 12, 2012.
- *"…the probability will be well in the high 90s today of the GMD system being able to intercept that today."* MDA Director Lt. Gen. Patrick O'Reilly, House Armed Services Committee, December 1, 2010.
- "*ninety percent plus*." MDA Director Lt. General Patrick O'Reilly, Senate Armed Services Committee, June 16, 2009.

How Are Such Claims of Effectiveness Possible?

- Current firing doctrine appears to be to salvo fire four interceptors.
- (0.6 single-shot kill probability)^4 = 97.5%
- MDA claims GMD capacity can be doubled by improving reliability of existing GBIs.
- GBIs have not yet demonstrated even close to 60% effectiveness in completely scripted tests – no unexpected events.
- Last two intercept test failures involved common-mode failures, which could have caused *all* interceptors to fail.

A More Accurate Assessment

- "*There are a lot of things that go into [determining] effectiveness. Everybody can be right.*"

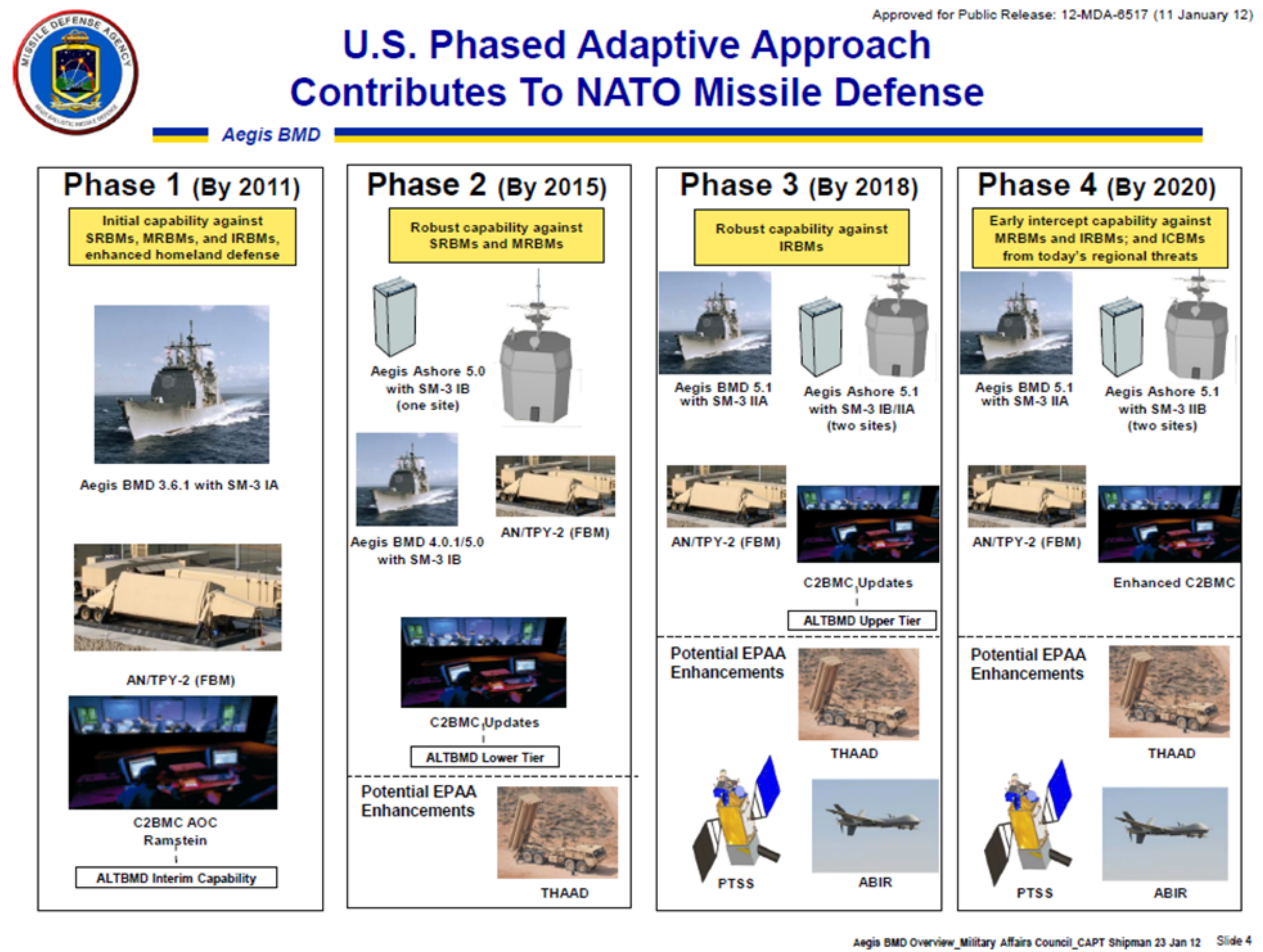
MDA Director Ronald Kadish, March 2003, in response to a question about DoD congressional testimony stating that the system would be 90% the moment it is turned on.

The European Phased Adaptive Approach (EPAA)

- Three phase (though 2020) approach to deploying defense of Europe against Iranian ballistic missiles.
- Fourth phase (2020+) would deploy missiles in Europe to defend U.S territory against possible future Iranian ICBMs.
- Key feature is integration of TMD components into a single, integrated system.

The EPAA's Four Phases

- Phase I (now): Limited deployment of existing TMD systems.
- Phase II (~2015): Continued deployment of TMD (Aegis Ashore) + some sensor integration.
- Phase III (~2018): Full sensor integration + high speed interceptors.
- Phase IV (~2021): EPAA and GMD integration + even higher speed interceptors (needed for U.S. coverage).
  - Space-based tracking?


Approved for Public Release: 12-MDA-6517 (11 January 12)
MISSILE DEFENSE AGENCY
U.S. Phased Adaptive Approach
Contributes To NATO Missile Defense
Aegis BMD
Phase 1 (By 2011)
Initial capability against SRBMs, MRBMs, and IRBMs, enhanced homeland defense
Aegis BMD 3.6.1 with SM-3 IA
AN/TPY-2 (FBM)
C2BMC AOC Ramstein
ALTBMD Interim Capability
Phase 2 (By 2015)
Robust capability against SRBMs and MRBMs
Aegis Ashore 5.0 with SM-3 IB (one site)
Aegis BMD 4.0.1/5.0 with SM-3 IB
AN/TPY-2 (FBM)
C2BMC Updates
ALTBMD Lower Tier
Potential EPAA Enhancements
THAAD
Phase 3 (By 2018)
Robust capability against IRBMs
Aegis BMD 5.1 with SM-3 IIA
Aegis Ashore 5.1 with SM-3 IB/IIA (two sites)
AN/TPY-2 (FBM)
C2BMC Updates
ALTBMD Upper Tier
Potential EPAA Enhancements
THAAD
PTSS
ABIR
Phase 4 (By 2020)
Early intercept capability against MRBMs and IRBMs; and ICBMs from today's regional threats
Aegis BMD 5.1 with SM-3 IIA
Aegis Ashore 5.1 with SM-3 IIB (two sites)
AN/TPY-2 (FBM)
Enhanced C2BMC
Potential EPAA Enhancements
THAAD
PTSS
ABIR
Aegis BMD Overview_Military Affairs Council_CAPT Shipman 23 Jan 12
Slide 4

The EPAA's Major Components (1)

- Aegis radars and launchers
  - U.S. Navy cruisers and destroyers (4 to be based in Spain)
  - Aegis Ashore sites in Romania (2015), Poland (2018)
- Aegis SM-3 interceptors
  - Low-speed SM-3 Block IA (now), SM-3 Block IB (~2015)
  - High-speed SM-3 Block II
    - Block IIA (2018). Co-developed with Japan.
    - Block IIB (2021+). Faster than Block IIA. Intended to be fast enough to intercept ICBMs from Iran in ascent phase.

Aegis Ships
(U.S. Navy Photographs)

Aegis Destroyer

Aegis Cruiser

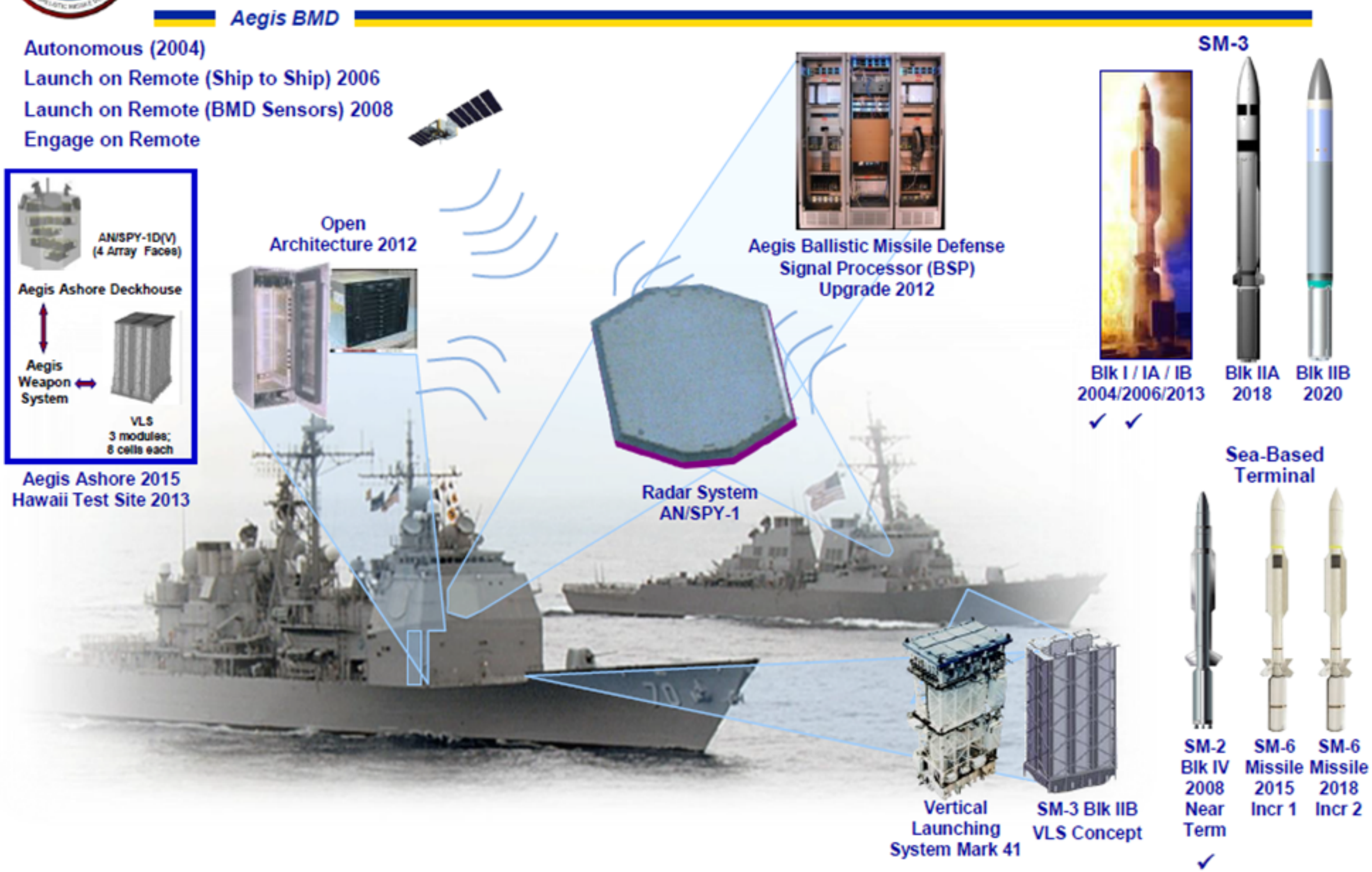
Aegis Ships

- U.S currently has ~80 Aegis-equipped destroyers and cruisers.
- Number projected to peak at about 90 in about fifteen years.
- Ships equipped with Aegis radars (3 different variants, but similar) and roughly 90 (destroyers) to 120 vertical launcher cells.
- Launch cells also used for air defense, anti-submarine, land-attack and anti-ship weapons.

Aegis BMD Upgrades

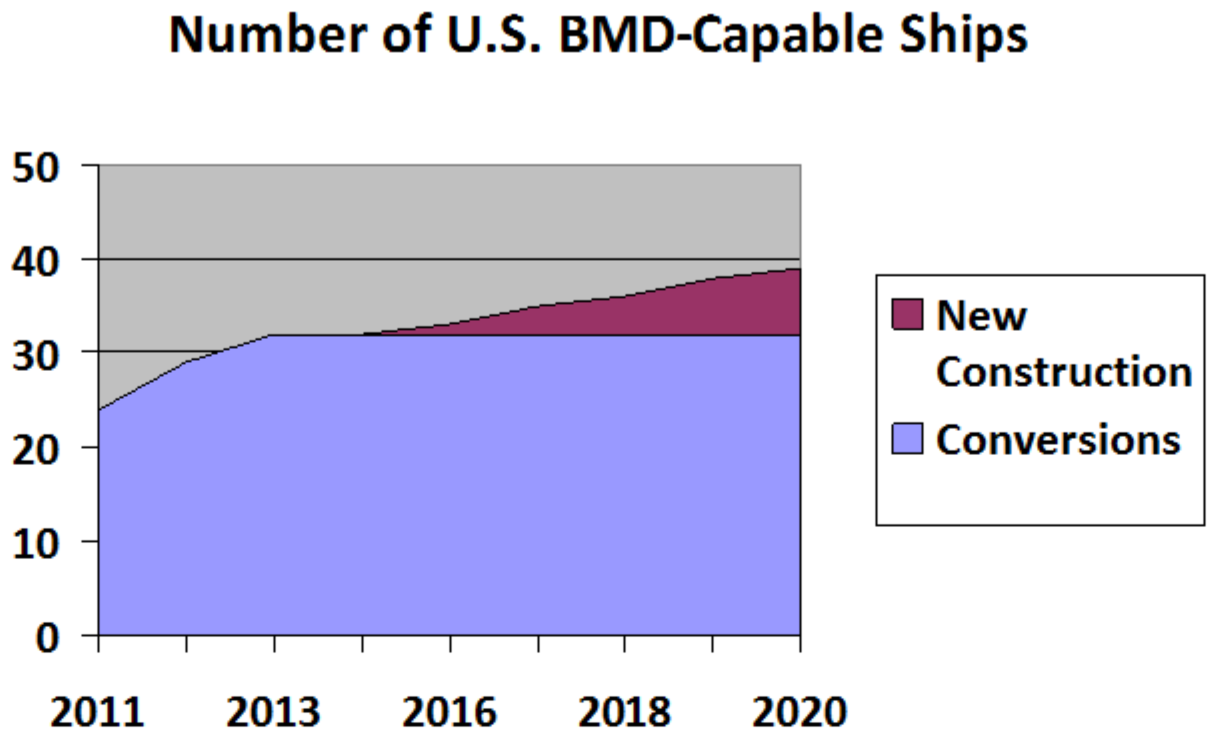
- Some U.S. cruisers and destroyers being upgraded to be able to operate in missile defense mode.
- Relatively minor upgrades. No change in radar power output or appearance.
- Roughly 32 ships to be upgraded. Most are done.
- 10 new construction Aegis destroyers with BMD built in to be deployed 2016-2023.
- Ships with new AMDR radar may be deployed as early as 2023.

Aegis BMD Program



Number of U.S. BMD-Capable Ships

(U.S. CRS data, August 2012)



Aegis Radar

- S-Band (3.1-3.5 GHz).
- Bandwidth ~ 300-400 MHz. Range resolution ≤ 1 m.
- 12 m^2 antenna aperture.
- Power-aperture probably several times smaller than TPY-2. Gain 10 times smaller. So tracking range against warheads may be only 300-400 km. (RCS is roughly 3x greater)

Aegis SM-3 Block IA Interceptors

- Aegis SM-3 Block IA is currently deployed version.
- Evolved from SM-2 air defense missile, with additional propulsion and kill vehicle added.
- Burnout speed ≈ 3 km/sec (maybe less?)
- Intercepts above the atmosphere, range of several hundred km.
- Relatively few (100+) will be built, since will be superceded by SM-3 Block IB.
- Eventually (2018?) new version of SM-2 Block IV (SM-6) will be deployed for short-range missile defense.

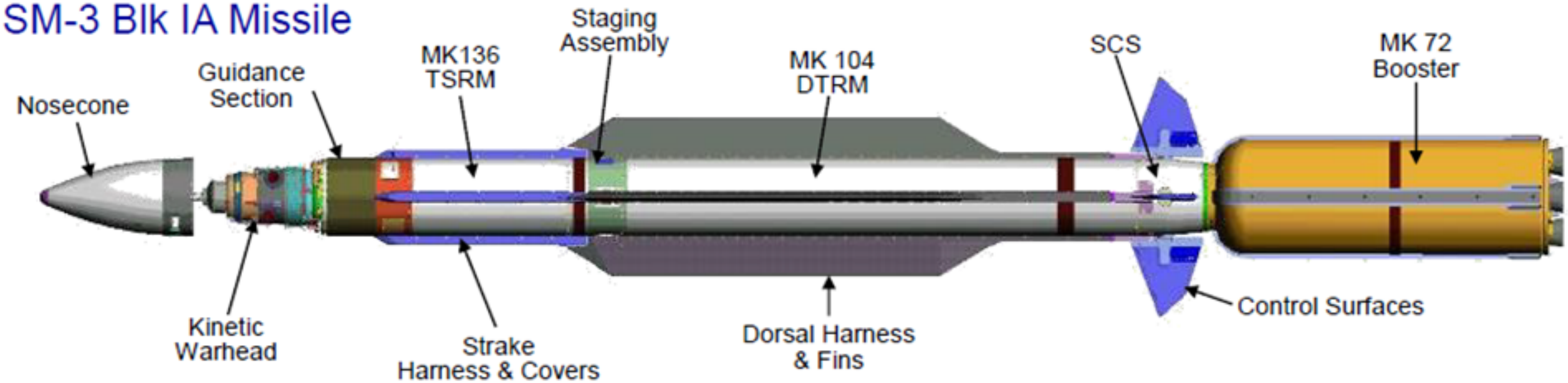
SM-3 Block IB Interceptor

- Same as Block IA, except for improved guidance and new kill vehicle.
- This is the version of SM-3 Block I that will be built in large numbers (many hundreds)
- New kill vehicle has improved seeker (two color) and divert system.
- Currently undergoing flight testing.
- To be deployed as part of EPAA Phase II (~2015)

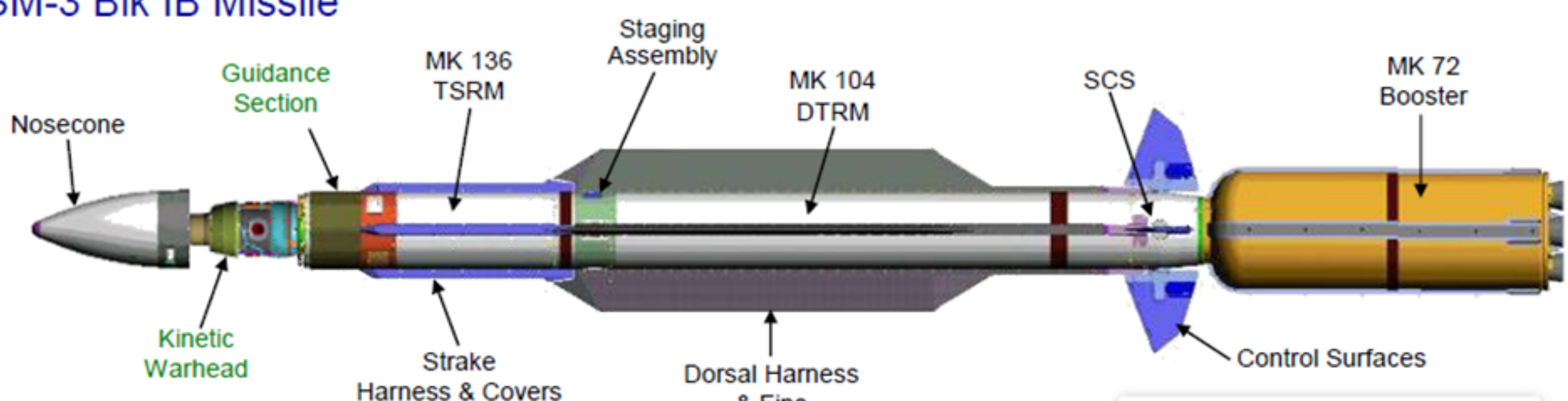
Aegis BMD SM-3 Missile Profile

Aegis BMD

SM-3 Blk IA Missile



SM-3 Blk IB Missile

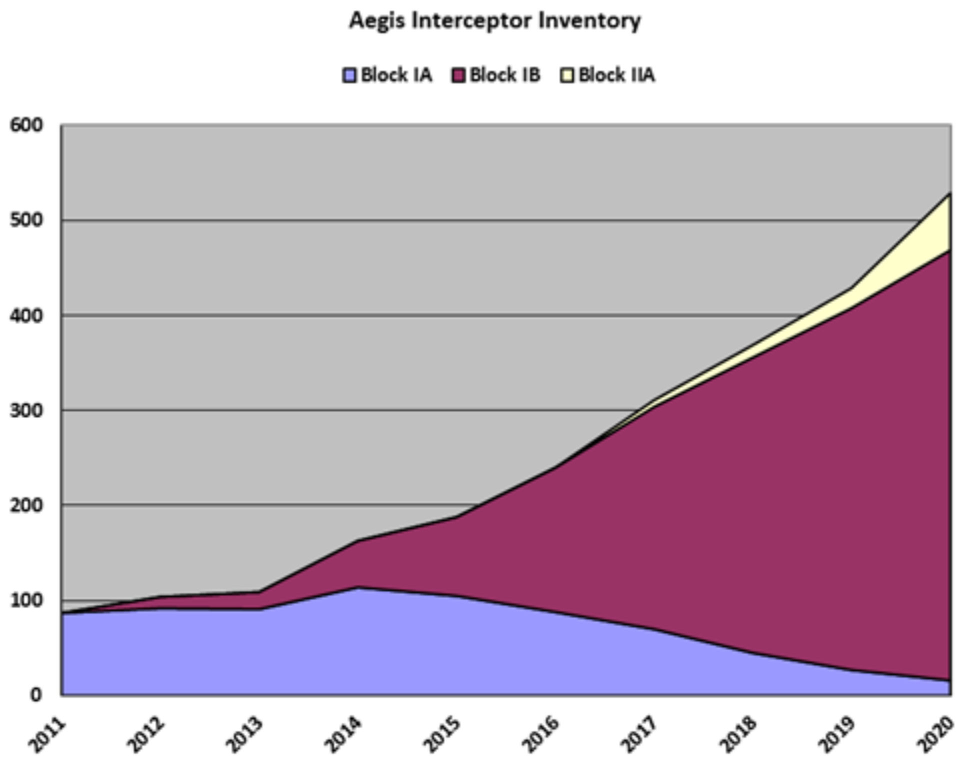


TSRM – Third Stage Rocket Motor
DTRM – Dual Thrust Rocket Motor
SCS – Steering/Control Section

Common with SM-3 Block IA
Changed for SM-3 Block IB

U.S. Aegis Interceptor Inventory

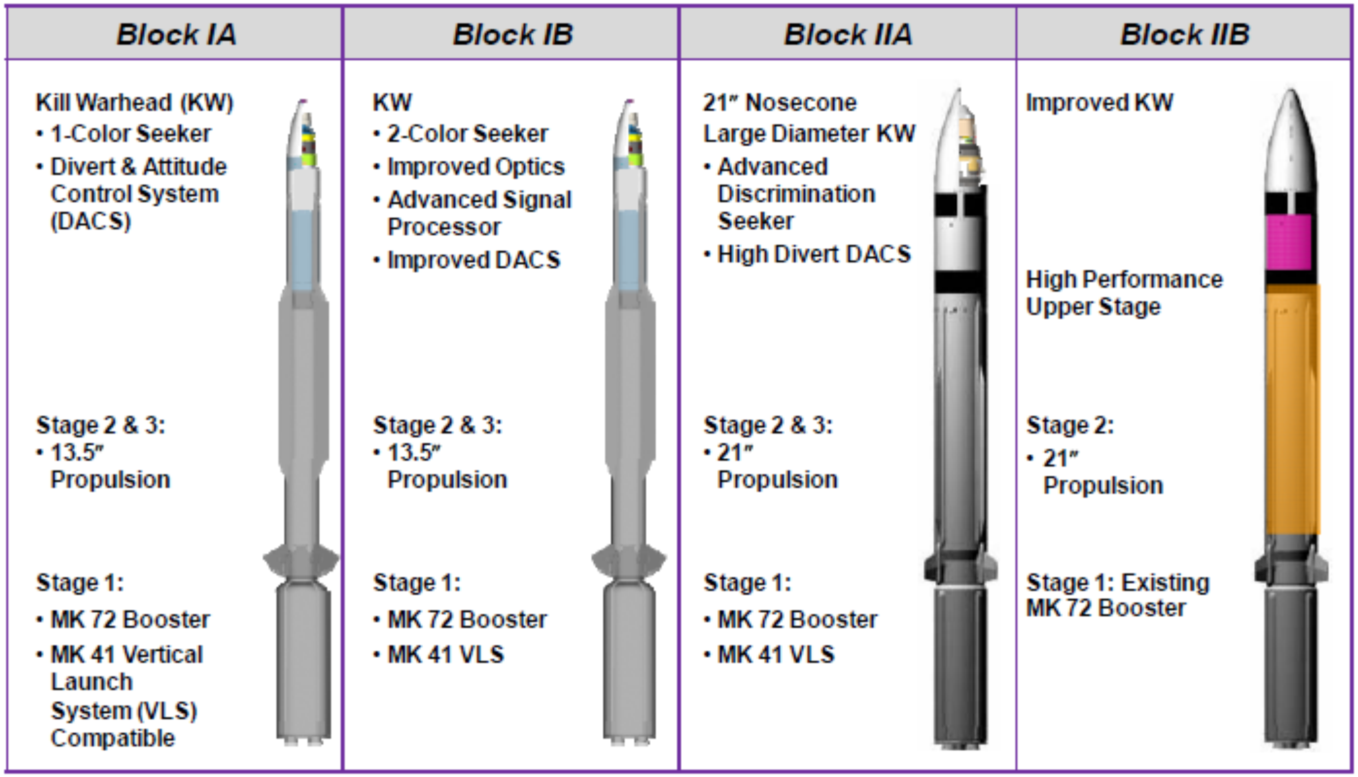
(< than # delivered)(Source: CRS data, August 2012)



SM-3 Block IIA

- To be deployed starting with EPAA Phase III (2018). Both on ships and on land.
- Larger missile, higher speed (4.0-4.5 km/s?).
- Larger, more capable kill vehicle.
- Number to be deployed not yet known.
- Co-developed with Japan.

SM-3 BMD Interceptors



AEGIS BMD SM-3 EVOLUTION. The SM-3 is being fielded in "blocks" as technology advances, enabling improved defense through upgrades to the interceptor.

SM-3 Block IIB

- Faster (4.5-5 km/s + ??), with new kill vehicle. May need to exceed vertical launcher size (21") to meet requirements.
- Intended to be capable against ICBM class missiles from forward deployments.
- To be deployed as part of EPAA Phase IV (2020). Role in EPAA is to defend U.S. territory.
- Few details available. Almost certainly will not be ready by 2020. NAS argues should be cancelled, but DSB says is important.

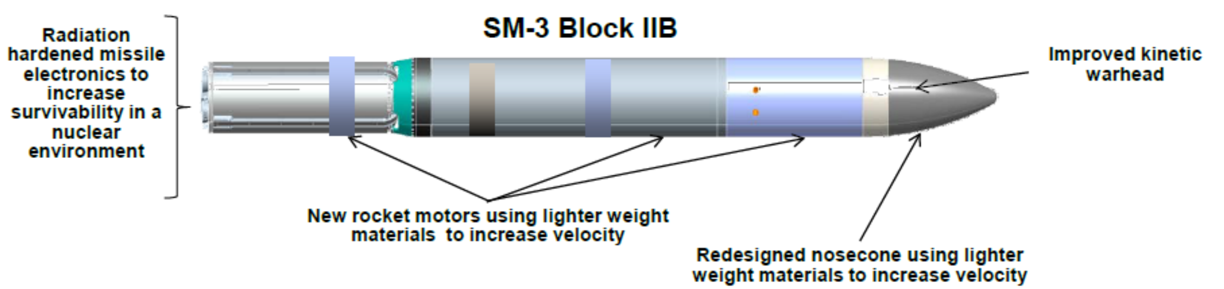
PAA Phase 4

– Early Intercept Capability And Capability Against Potential ICBM Threat As A Secondary Mission –

Capability Development

FY10 – Contract preparation for SM-3 Block IIB definition / program planning
- SM-3 Block IIB System Concept
- USN-MDA feasibility assessment MK 41 Vertical Launcher System for SM3 IIB

FY11 – *Competitively award 3 SM-3 Block IIB concept definition / planning contracts*
- *Award contracts to multiple vendors to increase maturity of critical SM-3 Block IIB components*



The EPAA's Major Components (2)

- X-band radars (TPY-2)
  - More capable than Aegis radars (for missile defense)
  - Same as radar for THAAD TMD system
  - One now in Turkey, possible future ones in Romania, Poland, elsewhere?
- Lower-tier TMD systems
  - Provide second (third) layer, defense of forward areas
  - Terminal High-Altitude Area Defense (THAAD)
  - Patriot, particularly PAC-3 (U.S., Germany, Netherlands)
  - Navy SM-6

Theater Ballistic Missile Defense Patriot PAC-3

- Air-transportable. Defense against aircraft, cruise missiles, ballistic missiles.
- U.S. currently has about 60 fire units (radar + launchers +control equipment)
- Currently U.S. has about 800+ interceptors, with a total of about 2,000 planned. Also many older PAC-2 missiles.
- Defends areas of with dimensions of tens of kilometers.
- Hit-to-kill, radar-homing, within-the-atmosphere. Intercepts low enough to use atmospheric filtering.
- Sold to at least Japan, Germany, Netherlands, UAE (292), and Taiwan (388 – 4 to 6 batteries planned). Japan produces under license, and has 16 PAC-3 batteries. Pac-2 sold to additional countries
- PAC-3 is interceptor for U.S.-Germany-Italy MEADS Program. Unclear if this system will be deployed.

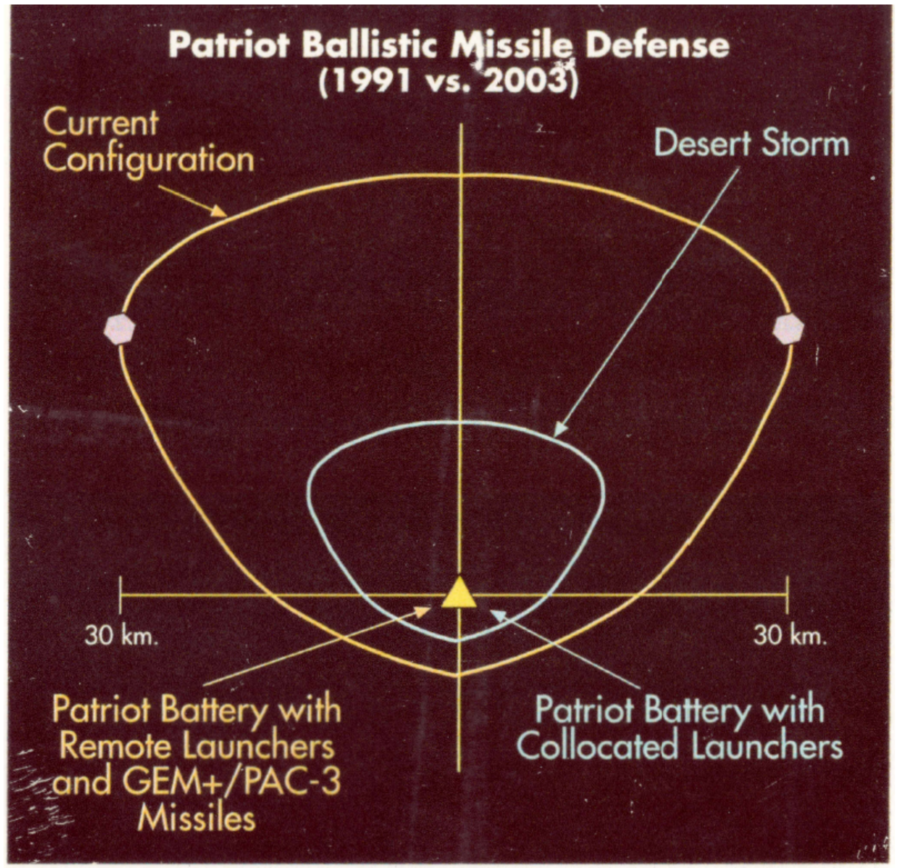
Patriot

Patriot PAC-2 Equipment

Patriot PAC-3 Launcher

PAC-3 Footprint

(Source: Aviation Week?)



Patriot modifications during the past decade have increased by a factor of seven the area defended by the air and missile defense system.

THAAD

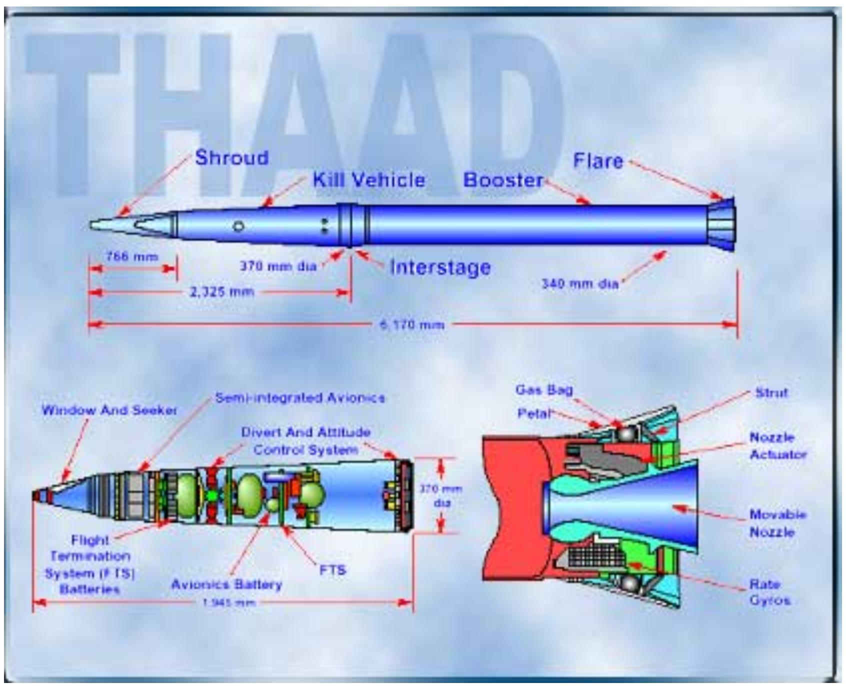
- Terminal High-Altitude Area Defense
- TMD program begun in about 1992.
- Hit-to-kill, intercepts above or in upper layers of atmosphere.
- Interceptor speed ~ 2.6 km/sec (1990s)
- Intermediate between Patriot and Aegis, but closer to Aegis (Block I).
- Proposal to develop extended-range THAAD interceptor not funded (~2009)

THAAD

- THAAD battery consists of TPY-2 radar, 6-9 launchers (8 missiles each), command and control facilities.
- Current plans call for six batteries (by ~ 2016, reduced from 9 in 2012), ~ 500 interceptors, although pace of planned deployments decreased.
- Two batteries operational so far. Not yet deployed outside U.S.

THAAD

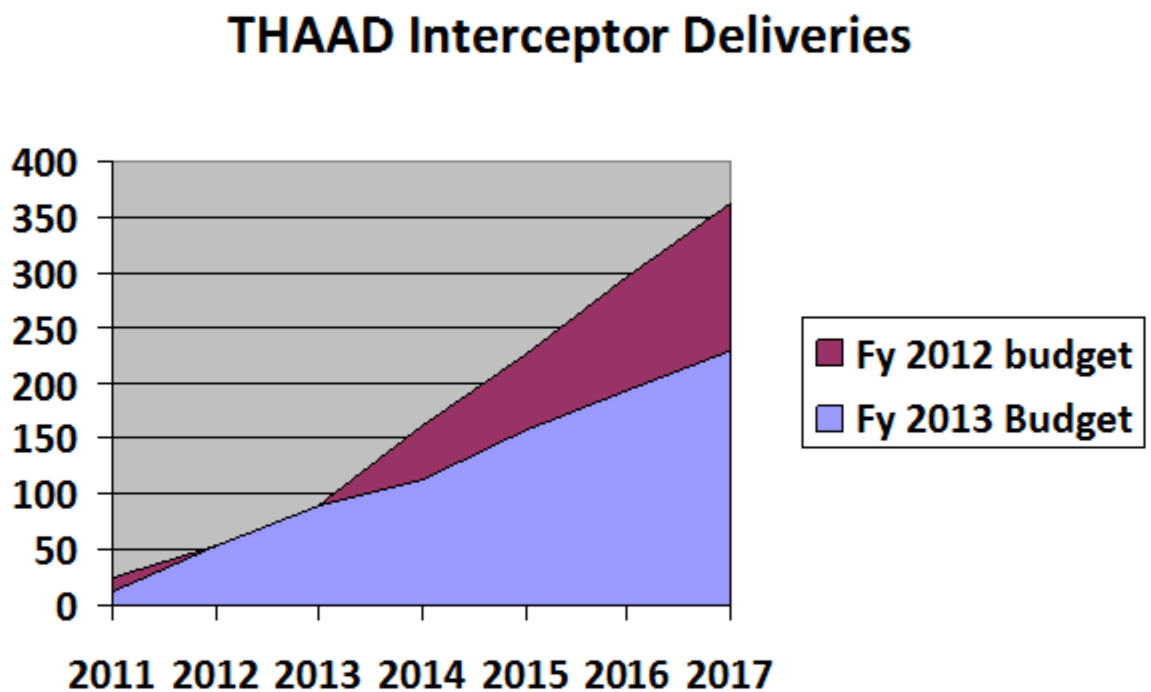
THAAD Missile



THAAD Equipment

Planned U.S. THAAD Interceptor Deliveries

(February 2002 DoD data)



TPY-2 Radar

- Air-transportable, X-Band radar used as both Forward-based X-band radar and as THAAD missile defense battery radar.
- Aperture = 9.2 m^2, average power ≈ 81,000 W.
- 10 GHz frequency, 1 GHz bandwidth, ~25 cm range resolution.
- Nominal range: 500-1,500 km (small warhead - missile body).
- Current plans U.S. plans call for 11 by about 2016 (reduced from 14 in February 2012).
- Two sold to UAE (as part of THAAD sale, early 2012)

TPY-2 Radar

Where are the U.S. TPY-2s?

- Northern Japan (2006)
- Israel (2008)
- Turkey (2011-12)
- Qatar (2012?)
- Southern Japan (2012-13)
- 1-2 testing, overhaul
- Possible future sites: S.E. Asia (Philippines?), Romania, Poland
- Foreign sales: UAE 2 (2011), Qatar 2 (2012)

The EPAA's Major Components (3)

- NATO command and control system.
- Space-based tracking system?
  - Precision-tracking space system (PTSS) (2020+)
- Early-warning sensors
  - U.S. early warning satellites
  - Fylingdales (Britain) radar?
    - Also part of GMD system

Launch-on-Remote/Engage-on-Remote

- The networking of sensors allows additional modes of missile defense. The first two are essential for the PAAs.
- **Launch on Remote (LOR)**: Interceptors are launched based on information from remote sensor (possibly of a different type). The interceptor system's own radar subsequently detects target and takes over engagement. Can greatly increase coverage relative to **organic** capability.

  --Currently some limited capability with Aegis ship-to-ship.
- **Engage on Remote:** Remote radar provides all information on target. Interceptor's radar may track interceptor and relay information.

  --Planned for EPAA Phase III
- **Shoot-Look-Shoot (S-L-S):** Fire second (or more) interceptor after observing results of first intercept attempt. Allows more efficient use of interceptors relative to **salvo** firing of multiple interceptors.

European Phase Adaptive Approach (EPAA) -- Phase I --

- By about 2011-2012.
- One U.S. Aegis BMD ship on station in Mediterranean (of four to be based in Spain).
- Aegis SM-3 Block IA interceptor
- U.S. X-band (TPY-2) radar in Turkey.
- NATO command and control network.
- Primarily coverage of limited areas (southeastern Europe) against short- and medium-range missiles.
- Possible lower tier deployments (all phases)

European Phased Adaptive Approach – Phase II

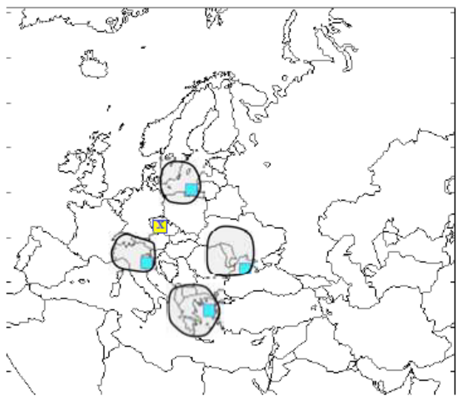
- By about 2015
- Adds Aegis SM-3 Block IB (better kill vehicle).
- Adds Aegis Ashore radar + interceptor site in Romania.
- Launch-on-Remote.
- Some capability against longer-range missiles (IRBMs, 3,000-5,500 km).
- Covers more of Europe

Effect of Launch on Remote – Aegis Phase I→ Phase II

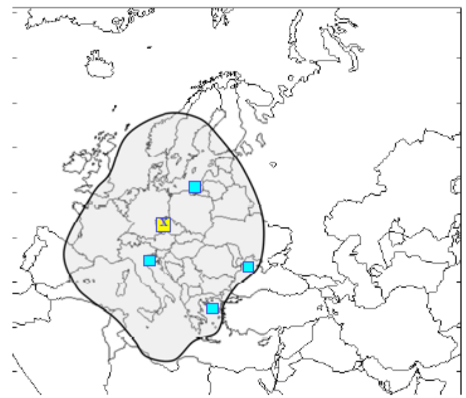
European Midcourse Radar Contribution

– Aegis Ship Weapon System –

Aegis Ship Weapon System Without European Midcourse Radar



Aegis Ship Weapon System With European Midcourse Radar



Adversary
- Iranian intermediate range missile under conditions challenging to defend

Architecture
- Aegis in the Black Sea, Aegean Sea, Adriatic Sea, Gulf of Gdansk
- European Midcourse Radar at Czech Republic

Defended Area Increases 140% / Ship (560% Total) Against Iranian Intermediate Range Missile When Using European Midcourse Radar For Launch On Remote

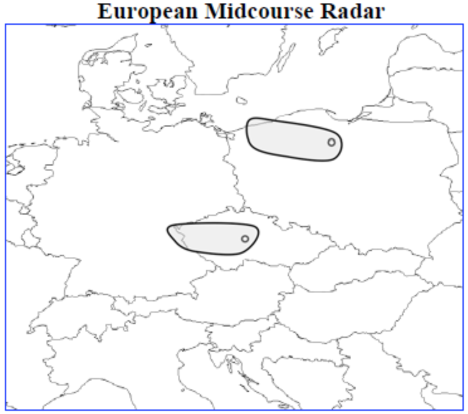
Effect of Launch-on-Remote –THAAD

(THAAD ~ 2.6 km/s ?)

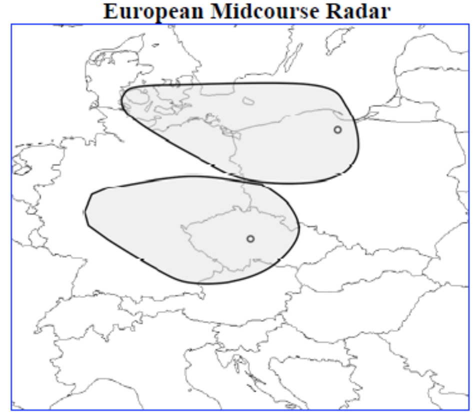
European Midcourse Radar Contribution

– THAAD Weapon System / Notional Locations* –

THAAD Weapon System Without European Midcourse Radar



THAAD Weapon System With European Midcourse Radar



Adversary

- Iranian intermediate range missile under conditions challenging to defend

Architecture

- THAAD Battery in Czech Republic* and Poland *
- European Midcourse Radar at Czech Republic*

Defended Area Increases Against Iranian Intermediate Range Missile When Using European Midcourse Radar For Launch On Remote

European Phased Adaptive Approach -- Phase III --

- By about 2018.
- Adds high-speed interceptor – Aegis SM-3 Block IIA. (Likely 4.0 -4.5 km/second). Co-developed with Japan.
- Second Aegis Ashore site in Poland.
- Engage-on-Remote.
- Covers most or all of Europe, with improved capability against IRBMS (3,000-5,500 km).
- Russia strong objections begin with this phase.

Aegis Single-Shot Engage-on-Remote
-- Phase III --

(Source: September 2012 National Academy of Sciences Report)

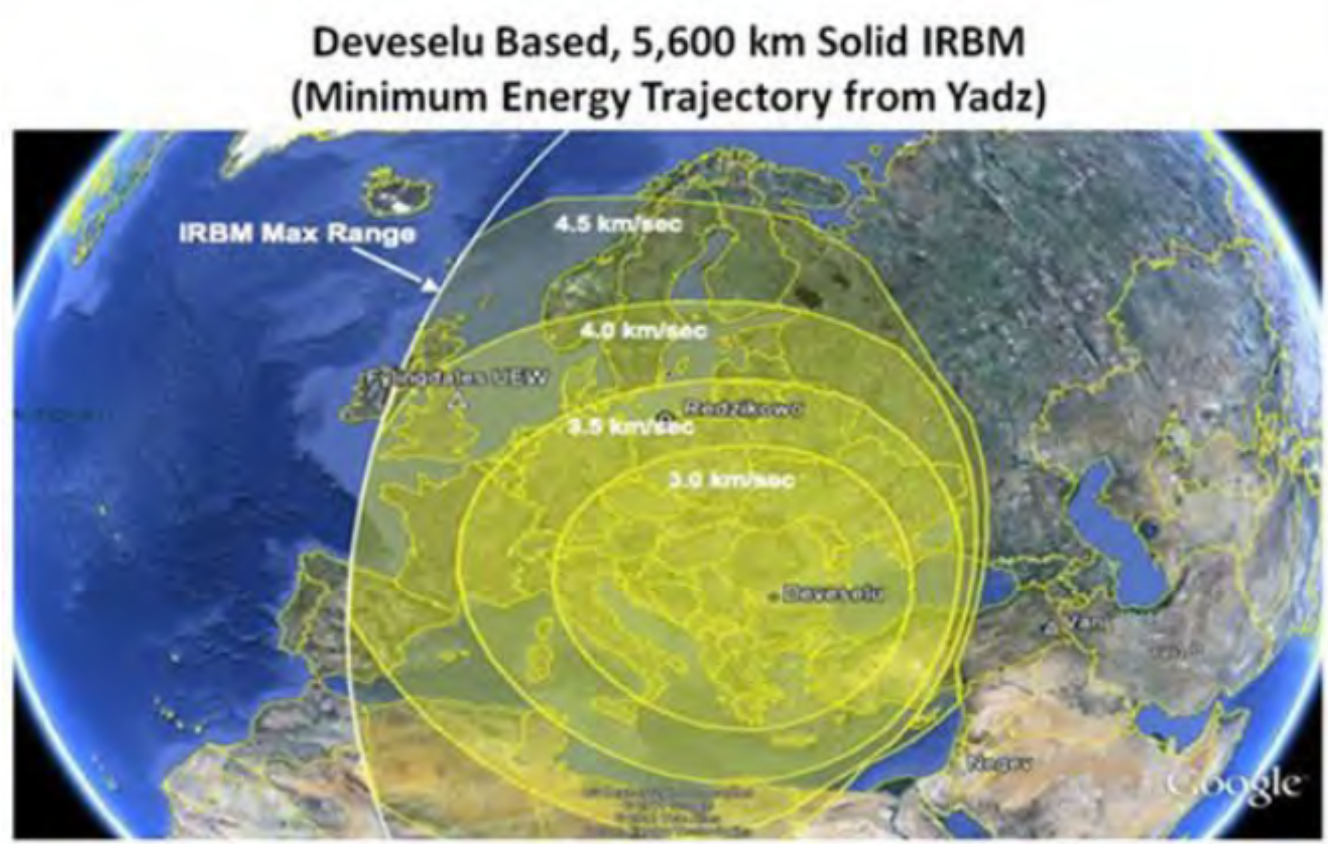
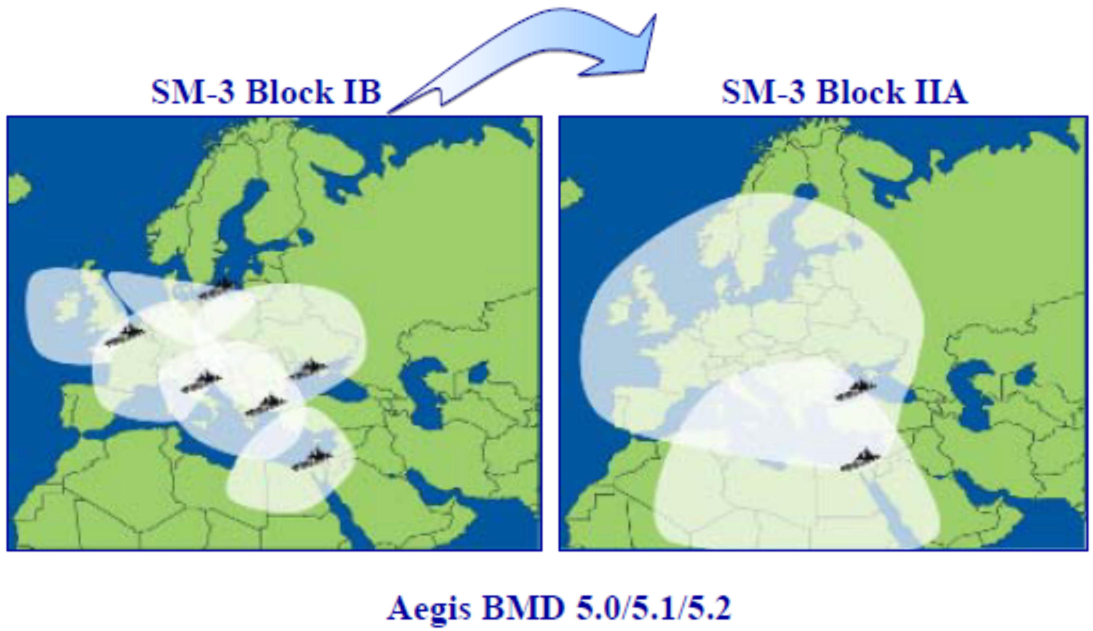


FIGURE 3-4 Notional single-shot coverage for interceptors with fly-out velocity varied parametrically between 3.0 and 4.5 km/sec against minimum energy notional 5,600-km solid IRBM trajectories from central Iran. EOR is assumed.

MDA Slide (2008)



Japan Aegis Engage-on-Remote

(Source: September 2012 NAS Report)

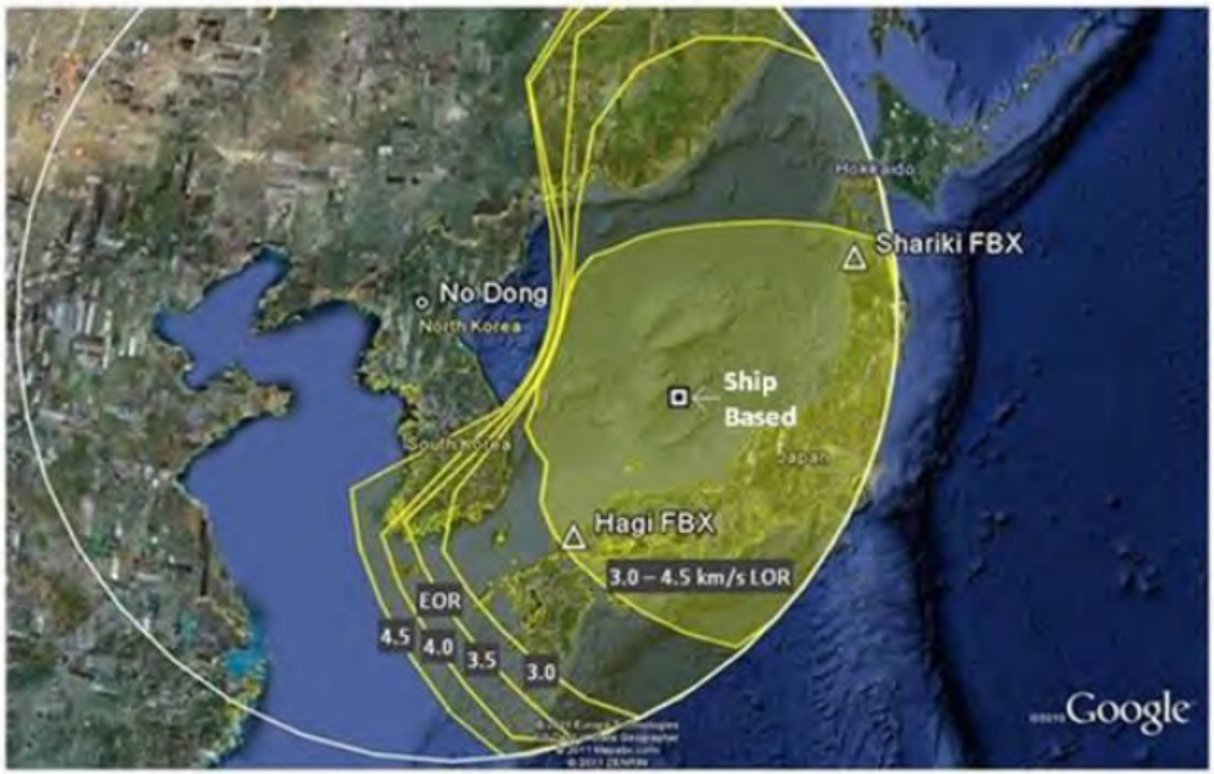
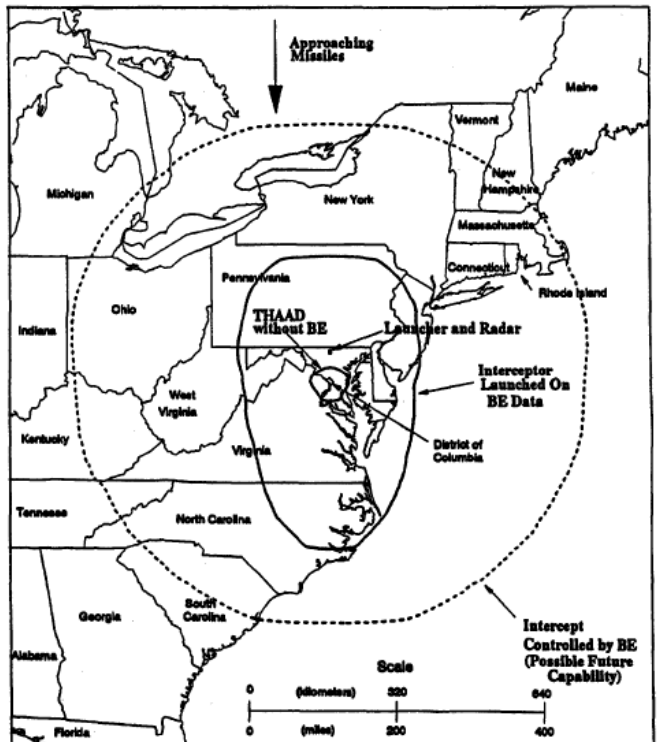


FIGURE 3-11 Notional ship-based single-shot LOR coverage of Japan: minimum energy MRBM trajectories. Note Hagi FBX location is notional.

CBO (1994) –THAAD (2.6 km/s) EOR and LOR

FIGURE 6. AREAS DEFENDED BY A THAAD-LIKE DEFENSE AIDED BY BRILLIANT EYES AGAINST A MISSILE TRAVELING AT 7 KILOMETERS PER SECOND



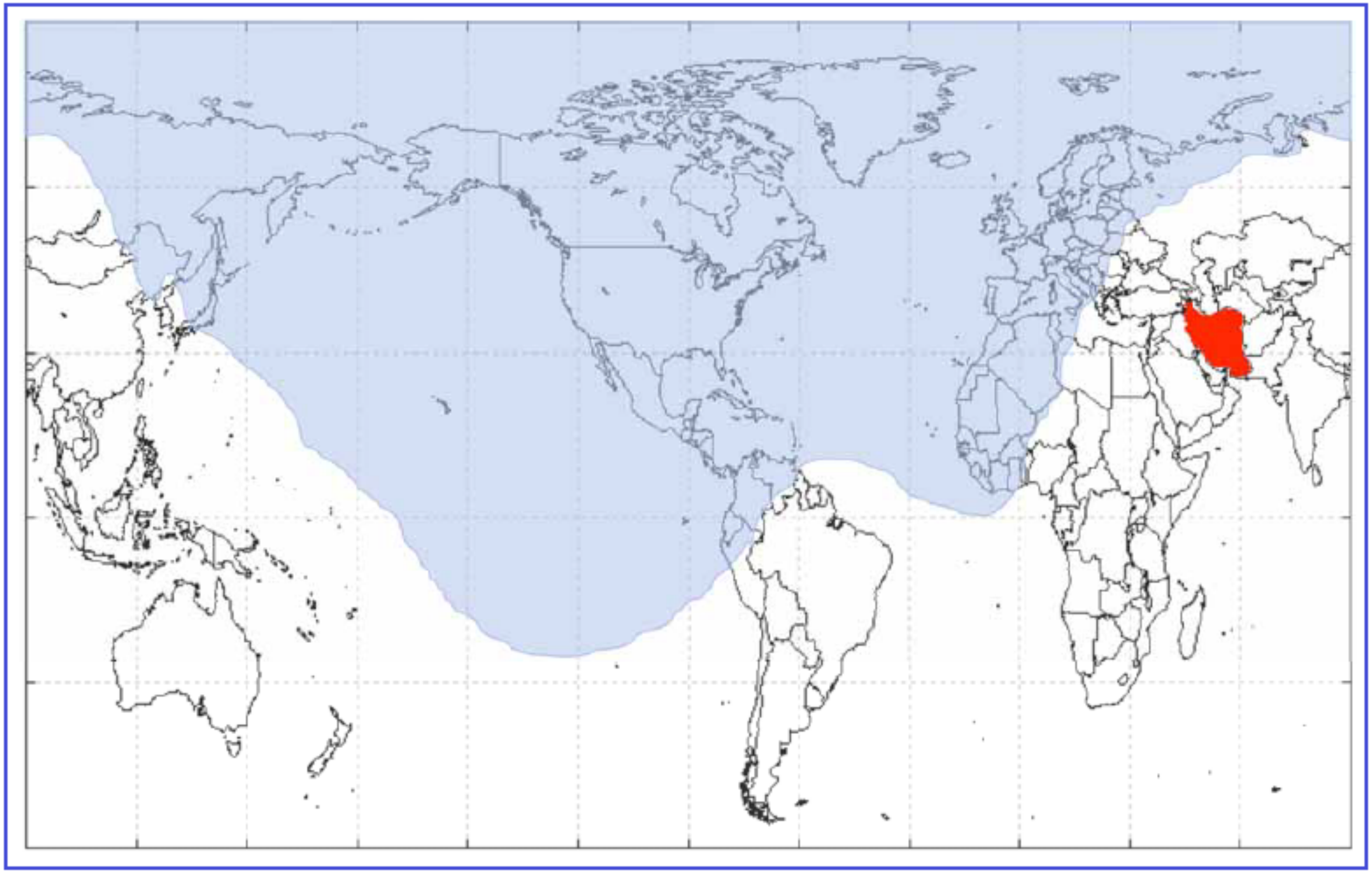
SOURCE: Congressional Budget Office based on a model provided by the Ballistic Missile Defense Organization. The results reflect CBO's assumptions about the capability of the defense.

European Phased Adaptive Approach – Phase IV

- By 2021 or later.
- Primarily adds defense of U.S. territory against Iranian ICBMs.
- Adds even higher speed interceptor, SM-3 Block IIB. Missile size or speed not yet defined. Initial deployment in Poland.
- Possible PTSS space-based missile tracking system.

Capability Provided Versus Iranian Ballistic Missile

Baseline Block 2008 + Interceptor Field (Poland)
+ Midcourse Radar (Czech Republic) + Forward-Based Radar



Will the EPAA Work?

- Two general concerns:
  - Capabilities and schedule
    - Are EPAA's currently planned radars adequate?
    - Rush to deploy GMD has caused severe problems

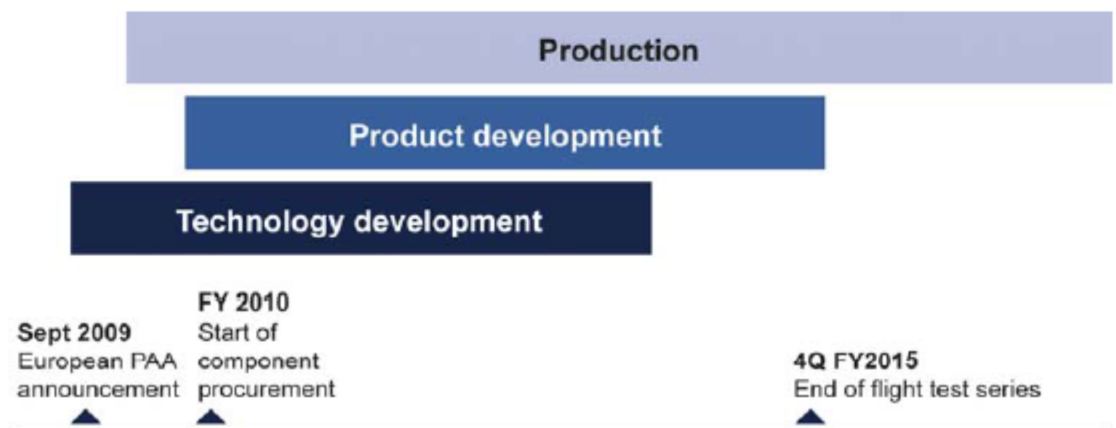
      --- Is 2015-2020 realistic for Phases II – IV?
  - Discrimination and Operational Effectiveness
    - Above-the-atmosphere discrimination unsolved
    - Defense must work first time
    - Is realistic testing possible? Practical?

EPAA Schedule

- Phase I deployed on schedule (end of 2011). However, this consisted largely of deploying TMD systems under development since mid-1990s.
- Current plans call for development and deployment of two new missiles and three new kill vehicles for Aegis by 2020.
- GAO (GAO-12-486, April 2012):
  - **SM-3 Block IB**: "The SM-3 Block IB is facing both developmental and production challenges that are exacerbated by its concurrent schedule"
  - **SM-3 Block IIB**: "The need to meet the 2020 time frame announced by the President to field the SM-3 Block-IIB for the European PAA Phase IV is a key driver for the high levels of concurrency"

Aegis Ashore Schedule

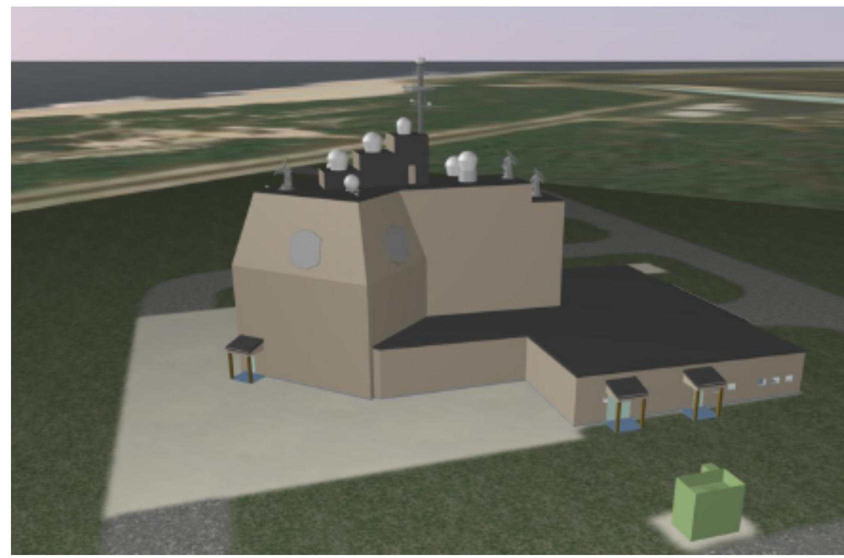
Figure 6: Aegis Ashore Concurrent Schedule



Source: GAO analysis of MDA data.

EPAA Schedule: Aegis Ashore

- GAO (2012): "The need to meet the 2015 time frame announced by President to field the Aegis Ashore for European PAA Phase II is a key driver for the high level of concurrency." (p. 24).
- Construction of the first operational deckhouse (for Romania) to start in 2012 – before construction of the test deckhouse (in Hawaii) or the first flight test in 2014.



Are EPAA Sensors Adequate?

- The systems making up the EPAA were originally designed as theater missile defenses.
- They were not intended to defend a continent. In particular, current sensors do not have enough range.
- 2011 Defense Science Board Report agrees. 2012 National Academy report says they are OK.
  - Aegis radars just communication relays
- Discrimination ranges even bigger problem

Defense Science Board Report (September 2011)

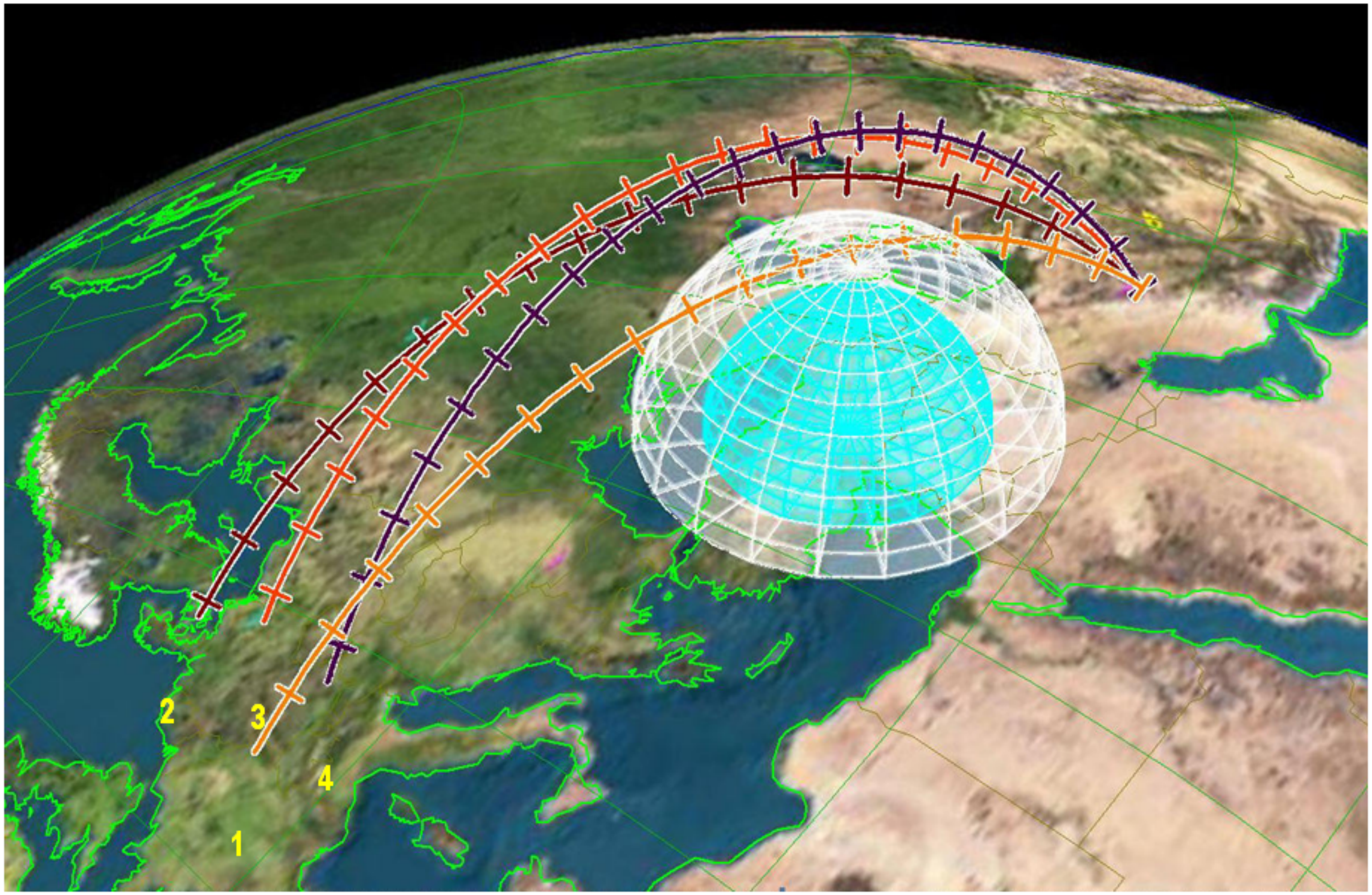
- "The current Aegis shipboard radar is inadequate to support the objective needs of the EPAA mission." (p. 26)
- "Radars of much more substantial operating range than the current radar on the Aegis ships will be necessary for the full realization of a robust regional defense." (p. 8)
- "Overall, the basic components in inventory now, namely Aegis ships with radars and long-range interceptor missiles, are well suited as the foundation of the regional defense mission, including the defense of Europe." (p. 8)

Discrimination and Operational Effectiveness

- Above-the-atmosphere, hit-to-kill defenses vulnerable to decoys and other countermeasures.
- Discrimination still unsolved problem.
- Operational effectiveness
  - Will it work the first time?
  - In unexpected circumstances?
  - No operational exo-atmospheric defense ever been tested against a realistic countermeasure.

X-Band Radar Coverage

(Calculations: Lewis & Postol)



A Global Ballistic Missile Defense System?

- "Since 2002, the Department of Defense (DoD) has emphasized the development and fielding of a globally integrated, interconnected, and layered ballistic missile Ballistic Missile Defense System (BMDS) composed of "elements" that include radars, interceptors, and command and control systems, which together are to be capable of addressing all ranges of threatening ballistic missiles in all phases of flight." (GAO-09-856 (2009), p.1)
- MDA Director Lt. General Patrick O' Reilly: By 2020 MDA wants the ability to "deal with fifty missiles in the air at once" under "seamless world coverage." (Defense Daily, March 22, 2010)

Precision Tracking Space System (PTSS)

- Possible space-based missile tracking system.
- Track missiles accurately enough to guide interceptors.
- Covers almost all of northern hemisphere.
- Two prototypes to be launched in 2017, operational as early as 2022.

PTSS -- Which Is It?

- MDA Director Lt. General Patrick O' Reilly:
  - "**The greatest potential future enhancement for both homeland and regional defense in the next ten years is the development of the Precision Tracking Space System (PTSS) satellites…**" (April 25, 2012, bold in original).
- National Academy of Sciences Letter:
  - "The committee finds no valid justification for pursuing PTSS and recommends terminating all effort on it." (April 30, 2012)

What is PTSS (1)?

- Precision Tracking Space System, until recently Space Tracking and Surveillance System (STSS).
- Baseline of nine satellites in low (1,000-1,500 km) north-looking equatorial orbits.
- Six satellites is lower limit, twelve is goal.
- Two demonstration satellites to be launched in 2017, nine to be operational by 2022
- Five year (FY 2013-2017) projected spending is $1.53 billion (+ $200 million for STSS operation)

What is PTSS (2)?

- Primary purpose is missile tracking with sufficient accuracy to guide interceptors
- Is to track missiles over entire flight, above and below horizon.
- No acquisition sensor, must be cued.
- Covers more than 70% of Earth's landmass
  -- Northern hemisphere = 67%
- Intended to enable the Ballistic Missile Defense System (BMDS) to handle larger-scale attacks.
  -- MDA: Handle 50 missiles in flight at same time by 2020.
- Discrimination appears to a secondary objective at best.

PTSS, formerly known as…

- 1986-87: SDI Phase I Design included *Space-Based Surveillance and Tracking System*.
- 1990: Program restructured and renamed *Brilliant Eyes*.
- 1993: Transferred from BMDO to Air Force, and renamed *Space and Missile Tracking System*.
- 1996: Program renamed *Space-based Infrared--Low Earth Orbit (SBIRS-Low)*. Two demonstration satellites started before program was cancelled.
- 2002: Program restarted as *Space Tracking and Surveillance Program* (STSS). Demonstration satellites completed and launched in 2009.
- 2010-2011. Program scaled back and renamed *PTSS*

Two Perspectives on PTSS

- Essential for a global defense. Ties widely separated missile defense elements together into a single system. It would require dozens of radars to get same coverage. Adds some additional discrimination capabilities. (MDA)
- Adds nothing new to national or regional defense. Radars already provide adequate coverage. Adds no discrimination capabilities. Will be extremely expensive. (NAS)

Two Perspectives on PTSS

- Essential for a global defense. Ties widely separated missile defense elements together into a single system (particularly in Asia). It would require dozens of radars to get same coverage. Adds some additional discrimination capabilities. (MDA)
- Adds nothing new to national or regional defense. Radars already provide adequate coverage. Adds no discrimination capabilities. Will be extremely expensive. (NAS)

Some Cost Estimates

- NATO missile defense command and control: $1.2 billion
- U.S. Missile Defense Agency budget FY 2012): $8.4 billion
- U.S. GMD system (since 1996): ~ $35 billion

    Current GBI interceptor cost: $70-86 million (total buy of 57)

- Aegis Ashore site: ~ $900 million (24 Block IIB missiles)

    --Block IB interceptors: $12-15 million each

    --Block IIA interceptors: $20-24 million each

- THAAD Battery (incl. Radar): $700-900 million (~50 missiles)
- New U.S. Aegis destroyer: $1.7 billion (without missiles)
- Patriot PAC-3 battery: $550 million (96 missiles)
- Missile defense sales to UAE + Qatar in last year: ~ $20 billion