Missile Defense and Strategic Stability

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Note: *The views and opinions presented in this briefing are those of the author and do not necessarily reflect the position of the RAND Corporation*

Purpose and Agenda

Purpose

Describe and discuss implications of “strategic” missile defense systems, i.e., those intended to defend against intercontinental ballistic missiles

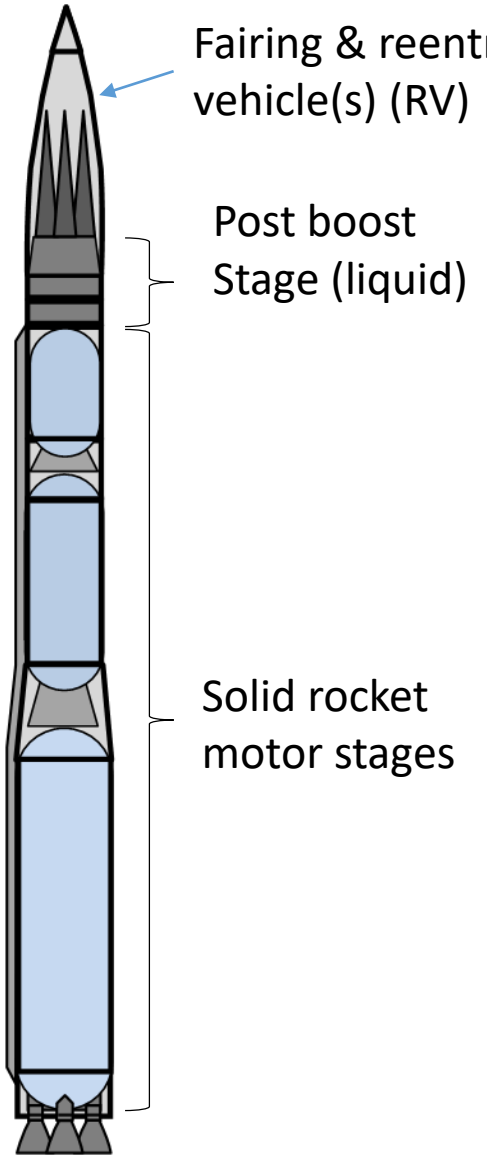
Outline

- Quick description of ballistic missiles
- History and basic description of anti-ballistic missile (ABM) systems
  - Russia
  - USA
- ABM effects on strategic stability

Quick description of Ballistic Missiles

Introduction to Ballistic Missiles

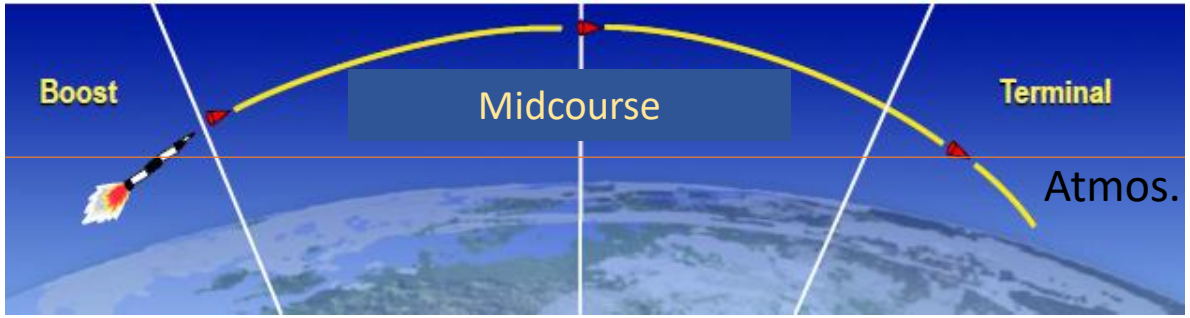
- Description
  - Typically consists of several solid or liquid propulsion stages, and a weapon payload. Normally ground (fixed/mobile) or submarine based
- Ballistic missiles are categorized by range
  - Short range (SRBM): < 1000 km
  - Medium range (MRBM): < 3000 km
  - Intermediate range (IRBM): < 5000 km
  - Intercontinental ballistic missiles (ICBM): > 5000 km



Flight Phases of Ballistic Missiles

- Ballistic missile flights can be approximated by 3 phases:

1. Boost phase (powered flight)
2. Midcourse (exo-atmospheric)
3. Terminal (includes reentry)



Anti-Ballistic Missile Systems

Anti-Ballistic Missile (ABM) Systems

- ABM, or ballistic missile defense systems (BMDS), integrate sensors, weapons and battle management systems to destroy ballistic missiles or reentry vehicles (RV) during flight (exclude left-of-launch and non-kinetic operations)
- BMDS can provide “point” or “wide area” defenses
  - Point defenses are used to protect high value assets, e.g., leadership and command & control (C2) sites, missile fields, and cities
    - Destroy missiles in terminal phase
  - Wide area defenses are used to defend very large areas, e.g., nations
    - Destroy attacking missile during boost up to midcourse flight phase

Basic Description of Anti-Ballistic Missile Systems: Russia

Inception of Anti-Ballistic Missile Systems: USSR

- First to develop an ABM system to defend Moscow, i.e., point defense system
  - Initiated in early 60's, limited to 100 interceptors by ABM treaty update in 1974
    - Initially consisted of exo-atmospheric command guided interceptors (A-350), i.e., guided by ground Radars
    - Used a nuclear warhead (reported yield of 1 to several megatons) to destroy incoming RVs
    - Limited effectiveness against some countermeasures
  - Undergone several updates since inception (latest version is the A-135)

A-350 USSR Interceptor

Ref: Air Power Australia, Technical Report APA-TR-2009-1203

Anti-Ballistic Missile System- **Russia**

- Current ABM reportedly uses endo-atmospheric interceptors (GAZELLE), unknown if armed with nuclear or conventional warhead, command guided by a phased array radar
- Russia is integrating together its ABM and Air Defense systems
  - Will merge advanced air defense missiles (S500) and advanced mobile radar stations

GAZELLE ABM Launch

Ref: Russia's ABM system to be upgraded by late 2017, TASS Jan 23, 2017

Basic Description of Anti-Ballistic Missile Systems: USA

Anti-Ballistic Missile Systems- **United States**

- Retired US ABM system- Safeguard
  - Was similar to the Soviet ABM system. Consisted of Exo-atmospheric (Spartan) and Endo-atmospheric (Sprint) interceptors with nuclear warheads to destroy incoming RVs
    - Spartan was armed with megaton class nuclear warheads
    - Command guided by ground Radars
  - Mission: Protect ICBM missile field, i.e., point defense system

Source: Library of Congress

Safeguard Missile Silo

Ref: http://www.themilitarystandard.com

US ABM System: From Safeguard to SDI

- US Safeguard: Operational 10/1975, and deactivated on 2/1976
- The Ford administration concluded that a ground based missile defense system would easily be overwhelmed by a Soviet attack and was not worth maintaining…
- In 1983 the US initiated pursuit of global missile defense under President Reagan's strategic defense initiative (SDI)
  - President Reagan's goal was "…to give us the means of rendering nuclear weapons obsolete"
  - Major technical problems remained and SDI was significantly scaled back to defend against a limited "accidental launch", forms basis of current system

Ref: "Brief History of BMD and Current US programs", Carnegie Endowment for International Peace, Feb 2000

Current US Ballistic Missile Defense System (BMDS)

- SDI evolved into current US BMDS, uses hit-to-kill interceptors to defend against limited attacks
- BMDS uses multiple layers, where possible to intercept

  - Boost: Best, but most challenging to access (time and reach)
  - Midcourse: Provides wide area defense, but very challenging technically
  - Terminal: Effective against non-maneuverable, but point defense only

Multi layers improve overall probability of intercept, i.e., system effectiveness

BMDS Basic Architecture- Sensors

Principal elements of BMDS include:

- Sensors
- Weapons, i.e., interceptors
- Battle management, command and control (C2)

Sensors include

- Space based
- Ground based
- Sea based

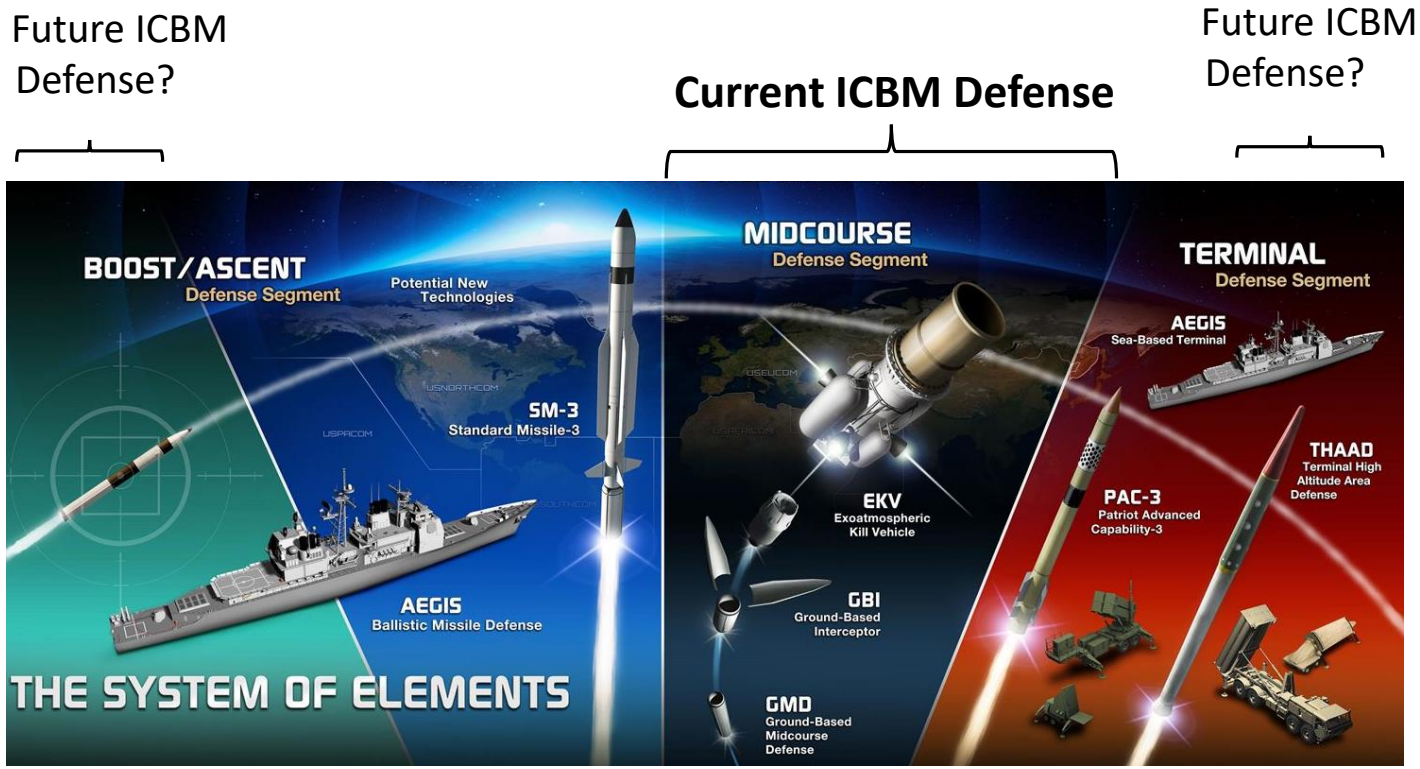
Sensors for midcourse defense

Source: Missile Defense Agency

BMDS Basic Architecture- Interceptors

Interceptors (hit-to-kill)

- Boost phase
  - AEGIS
- **Midcourse (ICBM)**
  - **Ground based missile defense (GMD)**
- Terminal
  - AEGIS/PAC-3/THAAD



Source: Missile Defense Agency

Battle Management

- Command and control, battle management and communications (C2BMC) system used to manage and operate the BMDS

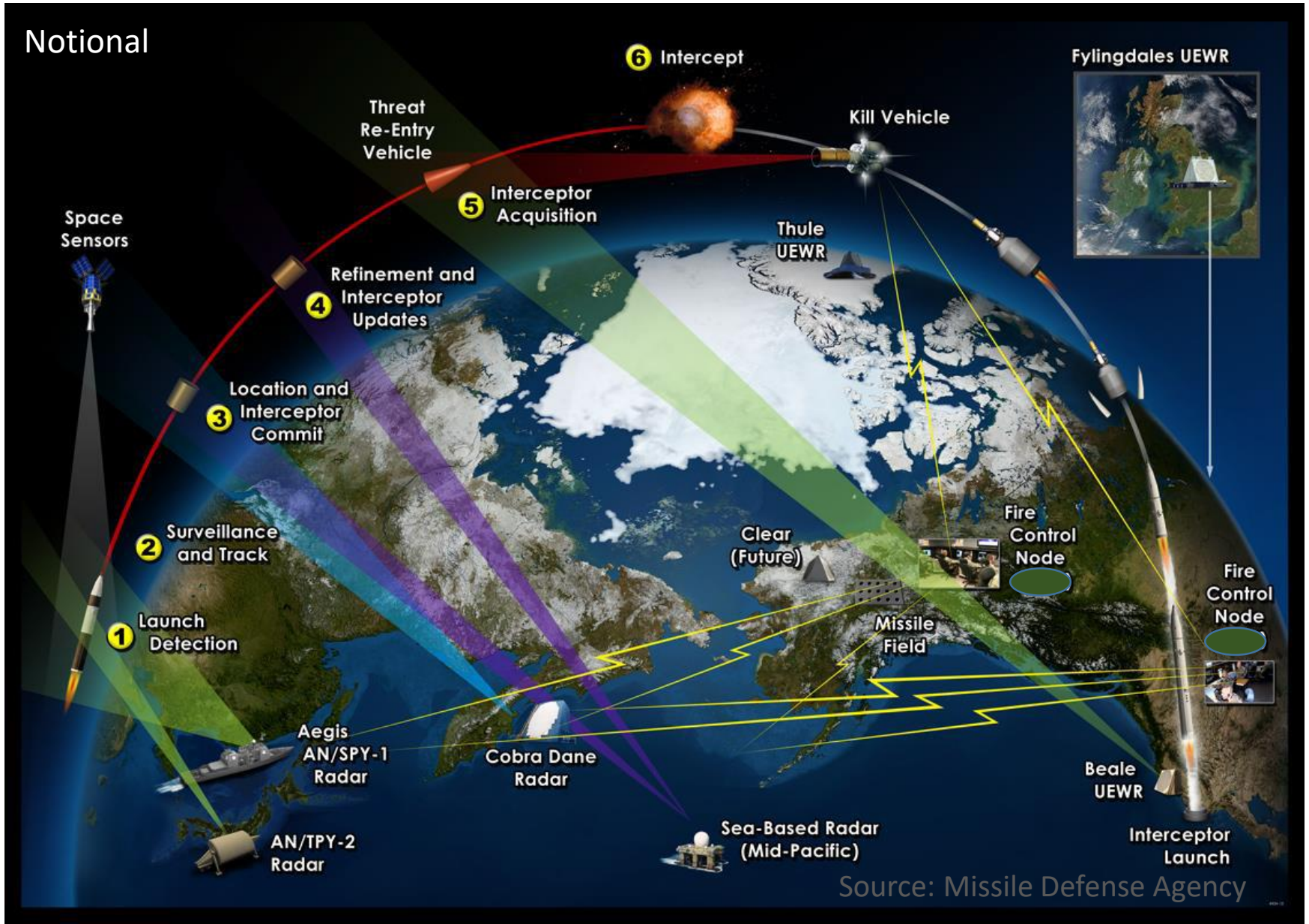
US ICBM Midcourse Defense

- US Ground Based Midcourse Defense (GMD) system currently the principal system for defending US mainland against ICBMs
  - Includes 44 ground based interceptors
  - Interceptors based in Alaska (Ft. Greely), and California (Vandenberg). Locations effective against NK & Iranian launches against US mainland

Note: US also deployed a regional ballistic missile defense system in Europe- **European Phased Adaptive Approach** missile defense

- Intended to defend against Iranian missiles aimed at Europe
- Uses AEGIS system as its principal defense system

ICBM Defense (Midcourse) Kill-Chain* is Complex…



GMD Notional Steps

Missile launch (time = 0)

1. Launch detection by space sensors
2. Radar detection/tracking
3. Interceptor launch
4. X-band radar tracking
   - Interceptor flight refined
5. Kill vehicle deployment and target acquisition
6. Kill vehicle endgame and intercept **(time < 30min)**

*Kill chain: functions needed to successfully execute mission

Potential Near-Term US ICBM Missile Defense Upgrades

- Given current NK ICBM status, US contemplating additional elements/layers for its BMDS[1,2]
  - Potential boost phase intercept system: Use armed unmanned aerial vehicles (UAV) loitering in friendly airspace, to intercept ICBM in boost phase[1]
  - Pentagon is reported to be considering deployment of terminal defense system, i.e., THAAD, on west coast of the U.S., to defend it against a NK ICBM attack[2]
- If deployed, these systems would improve BMDS effectiveness against limited NK missile launches

1. https://news.usni.org/2017/12/13/missile-defense-agency-looking-intercept-ballistic-targets
2. https://www.reuters.com/article/us-usa-defense-westcoast-exclusive/pentagon-evaluating

Missile Defense Effectiveness- Challenges

- No existing missile defense (MD) system is perfect!

- Current and foreseeable future MD have a limited capacity, i.e., number of interceptors and limited capability, i.e., probability of successfully defeating a missile attack
  - Attacking missiles can use a variety of countermeasures, including decoys, chaff and other to reduce missile defense effectiveness

Missile Defense Effectiveness- **Notional** Example

- Multiple shots, and layers, e.g., boost-phase vs. midcourse, improve defense effectiveness
  - Important: assumes shots are independent[1]
  - Different layers usually yield independent shots
- Example- four shots with 0.5 probability of kill (Pk) per shot => overall effectiveness = 0.94, six shots => 0.98

1. Implies interceptors won't fail for the same reason…

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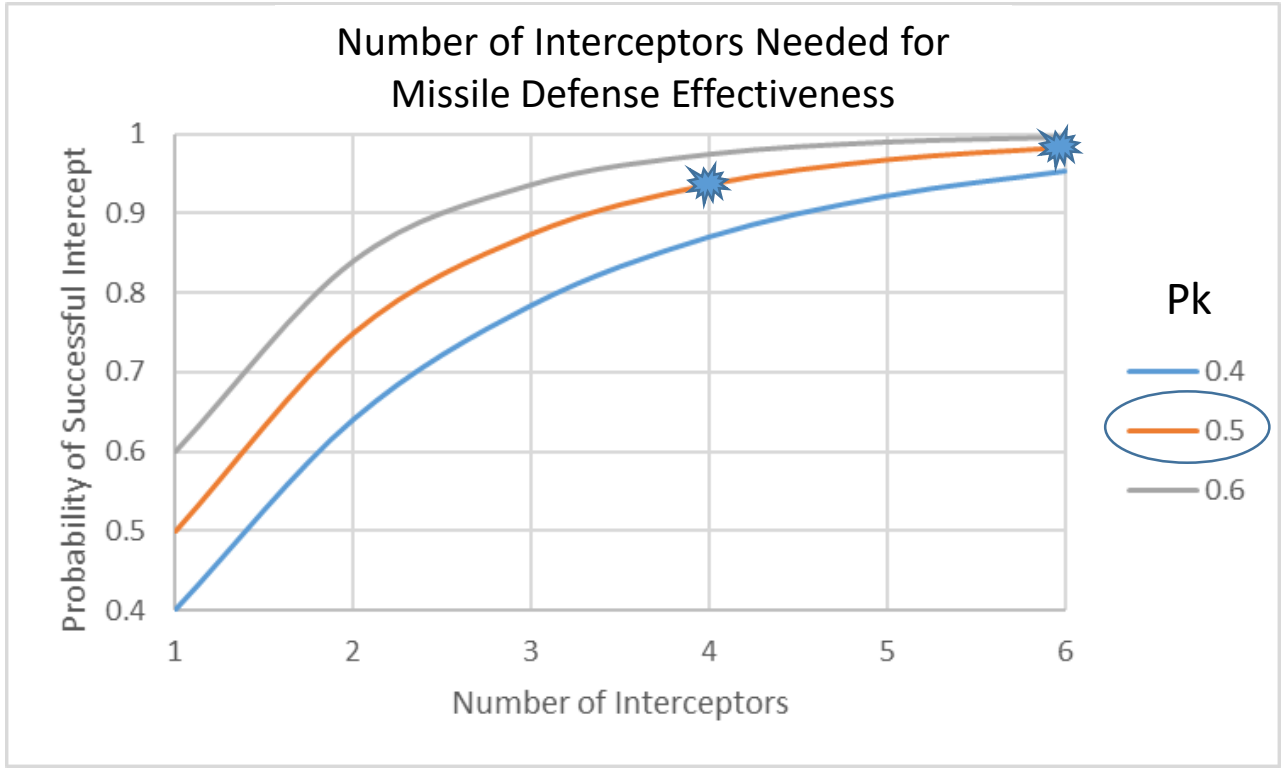

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Missile Attack Effectiveness- **Notional** Example

- Consider previous example of 0.94 overall effectiveness
  - A 6 missiles attack size results in about 30% probability of at least one missile defeating BMDS
  - Ignores effects of attack strategies, e.g., simultaneous missile effects…

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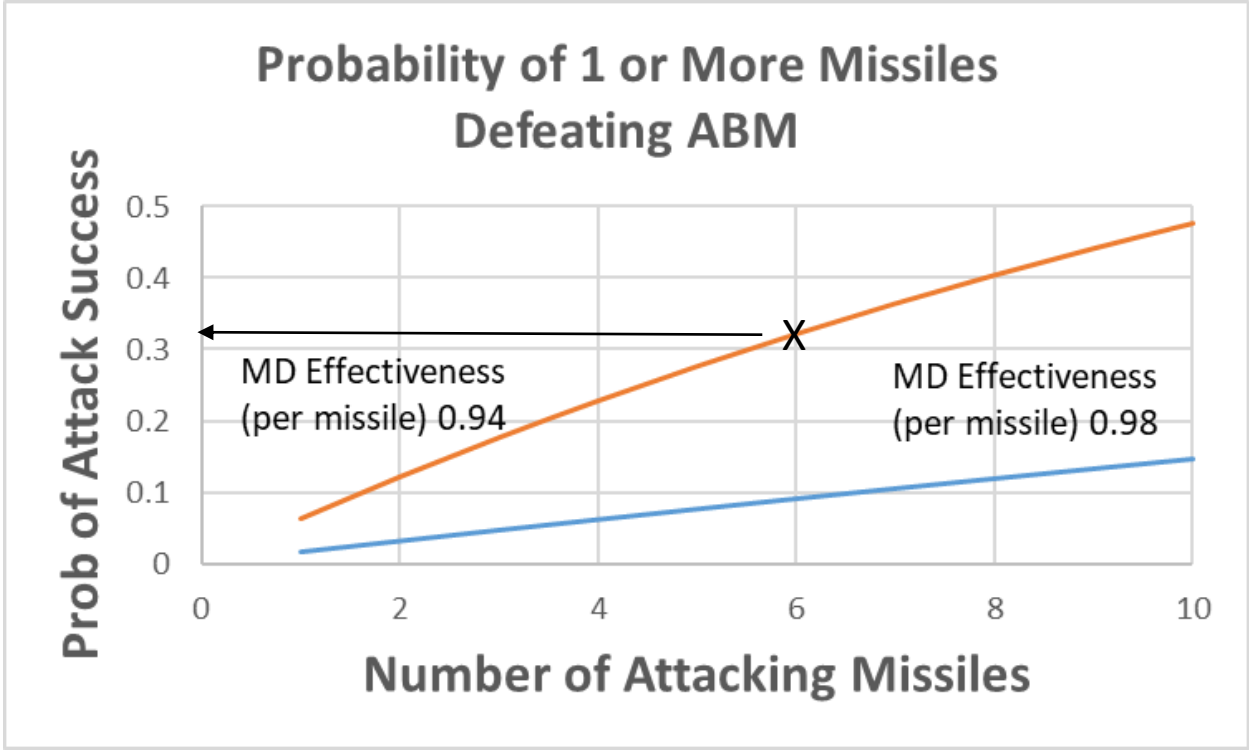

Attack size (and sophistication) lowers effectiveness of missile defenses

Missile Defense Effectiveness- Current Reality

- Ability to completely stop more than a handful of simultaneous missiles, is very challenging (technical and cost)
- Likelihood of some missiles penetrating missile defenses increases with attack size and sophistication
- Layered defenses typically improve overall effectiveness, however is also limited, i.e., number and reach of weapons

Defending against small attack is possible, but not perfect. Cannot defend effectively against large attack with current BMDS technologies…

Other Missile Defense Weapon Systems

- SDI architectures included space based interceptors and space based lasers- Technical challenges and high cost eliminated these options
  - No current space based missile defense programs
- Airborne laser (ABL) tested, then cancelled in 2010
  - Boost phase intercept using a high power chemical laser on a 747
  - Limited range, high cost, unclear success…
- “Left of launch” systems possible, but very limited information available, e.g., cyber, Electromagnetic pulse weapon (CHAMP) disables (unhardened) electronics within a very small area

Emerging Technologies & Missile Defense

Advances in sensors, processors, AI, materials, miniaturization, directed energy (solid state lasers), will improve missile defense effectiveness

MD Operation	Technologies	Impact
Surveillance/Detection/ Tracking	Sensors (space & terrestrial), processors, AI, miniaturization	Earlier detection, persistent tracking: earlier interceptor launch (Increased “battlespace”)
Battle management/C2	Processors, algorithms (AI)	Improve BM and C2 decisions
Weapon reach	Hypersonics, directed energy, UAVs?	Increased battlespace, defense against maneuverable missiles
Endgame target selection	Sensors, AI, miniaturization	Improved effectiveness
Intercept/Lethality	Interceptors subsystems, materials	Improved effectiveness

Discussions on Strategic Stability- Further Considerations

Summary of Missile Defense Weapon Capabilities

- Missile defense systems are **ineffective against large**, sophisticated attacks…
  - Complex BMDS architecture, *limited capacity*, limited operational/test data, and various *countermeasures* marginalize MD effects vs. large attacks
  - Additionally, advanced nations have capability to counter many of the elements in the BMDS architectures, potentially breaking the MD kill chain
  - Current BMDS ineffective against hypersonic missiles being developed by Russia and China, submarine launched ICBM…
- Multiple shot doctrine can enable “reasonable” effectiveness against **limited** attacks
  - May be augmented by counter launch site operations…

ABM Legal Framework- No Restrictions

- ABM treaty (1974) limited each nation to 100 missile interceptors and defense of a single area, e.g., capital or missile field
- President Bush withdrew US from the treaty in 2002 and announced that “the US would develop and deploy a missile defense system against limited missile attacks”[1]
- New 2010 START treaty explicitly places no constraints on missile defense systems[2]

1. https://www.armscontrol.org/act/2002_07-08/abmjul_aug02
2. https://www.state.gov/t/avc/newstart/

BMDS Impact on Retaliatory Force Structure

Although BMDS is effective only against limited attack, it can influence the calculus regarding minimum survivable number of weapons/delivery systems nations estimate they need to assure retaliatory capability to respond to a first strike

- Current capacity not a driver, however
- If future number of warheads/delivery systems is drastically reduced from current levels, number of interceptors will need to be limited

Chinese Perspective

- China perceives U.S. BMDS as a long-term strategic threat[1]
  - However assesses that the near term BMDS is less threatening (newly deployed THAAD in South Korea regarded by some as threat)
- China has a smaller nuclear arsenal than US/Russia
  - Needs to assure its retaliatory capability from a first strike
- China may be increasing the number of nuclear weapons, and diversifying its delivery platforms, e.g., submarine launched ICBM[2], hypersonic vehicles, bombers
  - Partially resulting from fears of an evolving BMDS?

1. https://www.ucsusa.org/sites/default/files/legacy/assets/documents/nwgs/china-missile-defense.pdf
2. https://chinapower.csis.org/ssbn/

Russian Perspective

- Moscow worries that US BMDS could neutralize Russia's nuclear deterrent and upset strategic stability
  - The fear is that a massive counterforce nuclear first strike coupled with an effective BMDS could neutralize Russia's retaliatory second strike capability
  - Russia has also stated that it can defeat US BMDS

- Russia is concerned about the European Phased Adaptive Approach (EPAA) missile defense, considers it a potential offensive weapon…

https://calhoun.nps.edu/bitstream/handle/10945/44008/14Sep_Talamantez_Kendrick.pdf?sequence=1
http://www.cnn.com/2016/05/11/politics/nato-missile-defense-romania-poland/index.html

US Perspective

- US believes it needs a more robust BMDS to defend against threats from hostile nations
  - Tensions between US and NK continue to escalate
  - NK continues to improve nuclear weapons and ICBM capabilities
  - NK persistently threatens US/allies with nuclear attack, internal political pressure for US to deploy defenses…
- Pre-emptive attack is not a desirable option
- Effective ICBM defense provides a level of protection of US homeland, additional deterrence against limited ICBM attack

http://www.weeklystandard.com/what-do-we-need-missile-defense./article/2010078
https://www.washingtonpost.com/world/national-security/launch-of-new-missile-increases-pressure-on-us-policymakers-to-confront-north-korean-threat/2017/11/29/3dfc4ce2-d514-11e7-b62d-d9345ced896d_story.html?utm_term=.52f69bcd5079

Adversary Nations Perspective

- BMDS introduces uncertainty in attack success
  - However is US' low risk tolerance a vulnerability?, i.e., BMDS reduces, but may not completely eliminate risk of an ICBM penetrating defenses
- An effective BMDS could reduce the value of a small arsenal of nuclear weapons (vs. US)
  - Demotivates future development of nuclear weapons, or,
  - motivates increase in countermeasures and size/type of arsenal

Practical Considerations- Effects of BMDS on Retaliatory Capability of Russia/China

Retaliatory response relies on capability to inflict unacceptable damage

- Impossible to stop a large retaliatory attack… a major fraction of attacking missiles will penetrate missile defenses
  - Future defense systems will improve but remain imperfect and limited
  - Attacking missiles continue to improve, need fewer to achieve attack goals
- Hypothesis: the level of unacceptable damage (from retaliatory response) relative to gain from a first strike in current environment has changed dramatically, i.e.,
  - Cold War era estimates: ~25% of population and 50% of industry

What is the acceptable level of damage US is willing to accept today from a retaliatory strike?

How many nuclear warhead would US be willing to absorb (countervalue)? **< 1**

Additional Questions to Consider

- Does assured nuclear retaliation against a rogue nation eliminate risk of future nuclear attack?
  - What are the consequences of US retaliation on strategic stability?
    - Impact on neighboring powers…
- Could a successful intercept (by US) of a limited ICBM attack avoid nuclear response, i.e.,
  - If BMDS stops nuclear missile attack from hostile nation, then nuclear retaliation may not be only response option
- Does an “effective” BMDS alter US conduct towards nuclear armed rogue nations? (risk considerations…)

Summary and Conclusions

- Present and foreseeable BMDS will have insignificant effect on large ICBM attacks from Russia or China
  - But could discourage limited nuclear strikes from these nations
- An effective BMDS could affect a rogue nation's decision to develop, or use an ICBM in an act of war (against US)
- As future treaties intend to reduce the number of strategic nuclear weapons much further, BMDS limits will need to be implemented

A new trilateral ABM treaty limiting number of "shots", or interceptors, but allowing for nation defense would help alleviate concerns over future growth of BMDS