

Air and Missile Defense at a Crossroads



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- **Why this report now?**
- **Understanding the challenge**
- **A concept to defend U.S. theater bases against air and missile threats**
- **Comparing alternatives**
- **Recommendations**

Why now?

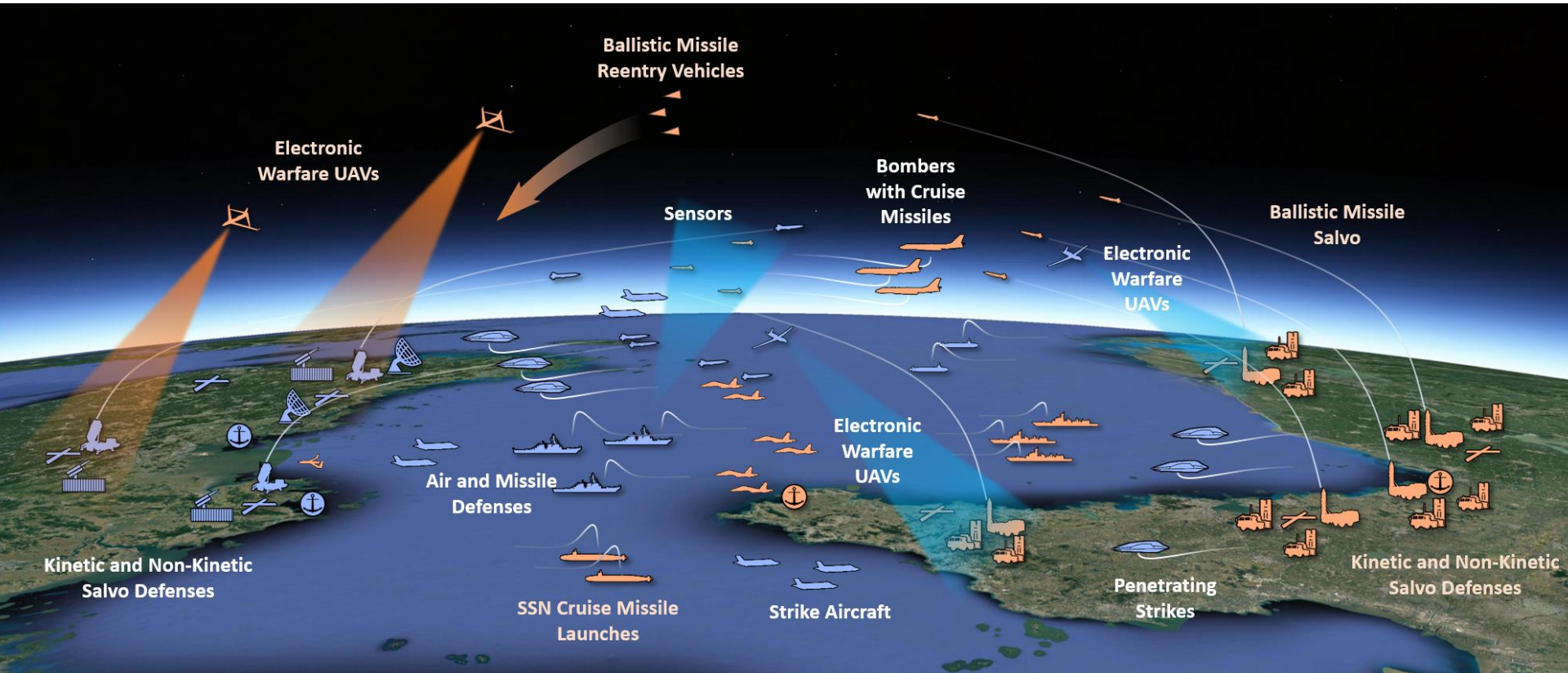
- Shift toward great power competition
- Growing threat to U.S. and allied/partner bases in Europe, the Pacific, and other regions
- Maturing technologies that could create higher capacity base defenses



Our objective: assess concepts and capabilities that could improve our military's ability to operate from bases in contested areas in the near- to mid-term

From U.S. dominance in precision strike to a mature precision strike regime

We are in the era of salvo competitions, which is the dynamic between competitors that have the ability to strike & defend against strikes with precision



Competitors continually seek to gain advantages by increasing the size and survivability of their strikes and their capacity to defend against strikes

The growing threat to U.S. bases: not just ballistic missiles



DF-26



CJ-20

H-6 with cruise missiles



H-20 (illustration)



- China's ballistic missile arsenal includes 1,200 SRBMs, 200-300 MRBMs, and IRBMs like the DF-26 that can reach the 2nd Island Chain
- The PLA has 1,000s of cruise missiles, including GLCMs like the CJ-10; its CJ-20 air-launched version has a range of ~1,500 km
- China's H-6 bombers are capable of launching cruise missiles
- Next-generation H-20 bombers could extend China's conventional airstrike capability to intercontinental range

Attacking U.S. and allied bases is a key element of China's A2/AD strategy



Mock airfield

Damaged parked aircraft target

U.S. Air Force F-22 at
Kadena Air Base in Japan



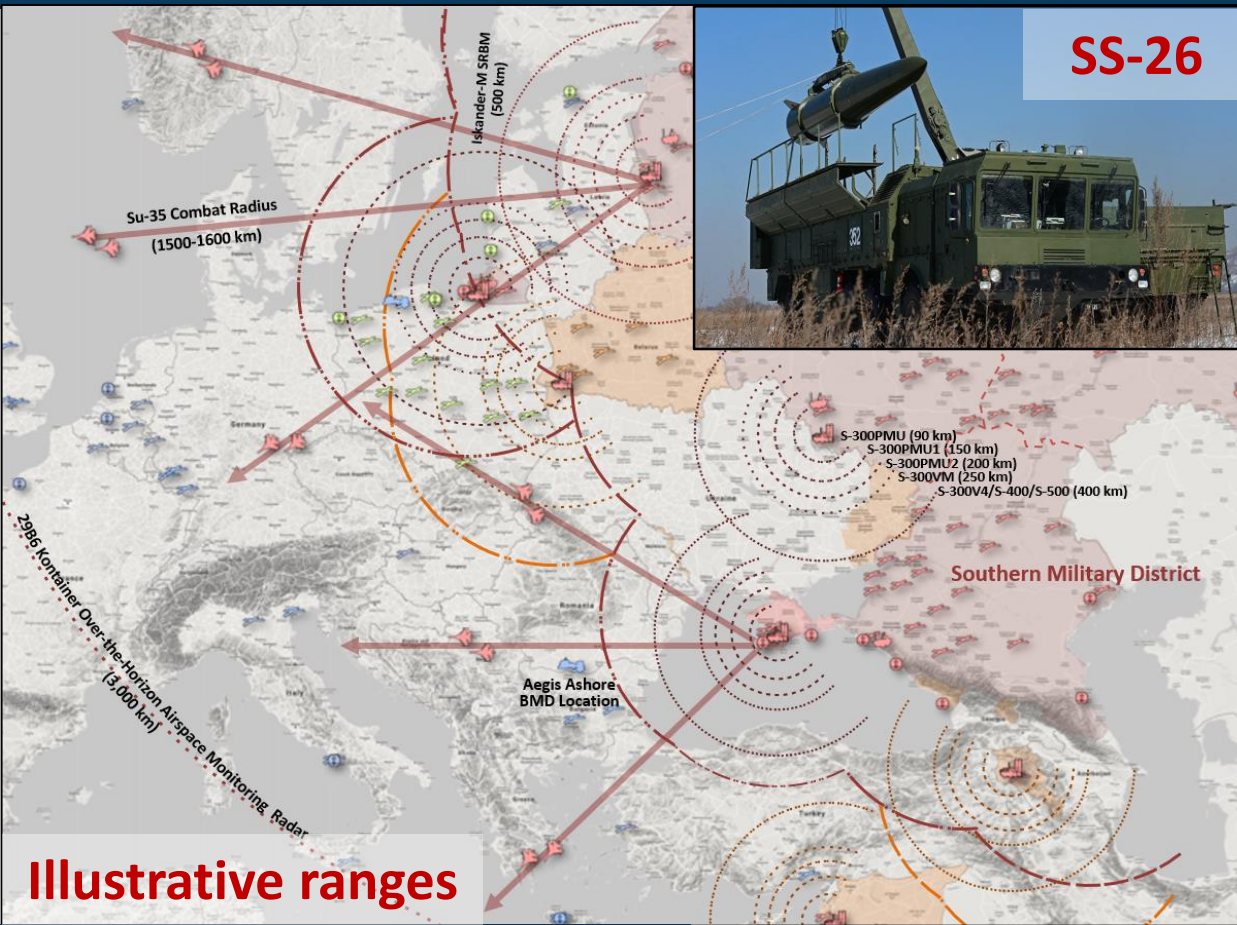
500 ft



500 ft

Chinese missile test range

There are no rear-area sanctuaries in Europe



- Russia has multiple SRBM variants, such as the 9K920 Iskandar-M (SS-26 Stone)
- Air-, ground-, and sea-launched LACMs, including a land-based GLCM that violates the 1987 INF Treaty, are a major threat to NATO bases located throughout Europe
- LACMs launched by Russia's long-range bombers could reach targets in North America
- Maturing threats: air- and ground-launched hypersonic weapons



- **Lack of sufficient networked sensors and integrated fire control systems to detect and cue intercepts of cruise missile salvos and swarms of unmanned aircraft**
- **Current defenses are weighted toward defeating a small number of ballistic missiles launched by a rogue state**
 - Lack capacity for salvos launched by great power aggressors
 - Insufficient land-based capacity for cruise missile defense
 - Affordability of defenses remains a major concern
- **Significant factor: continuing debate over which DoD organizations should fund programs needed to defend theater bases against air and missile threats**

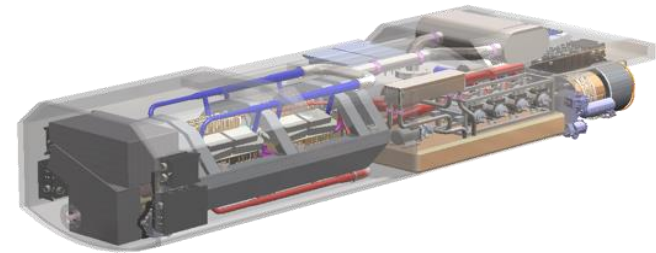


Concepts for future base defenses



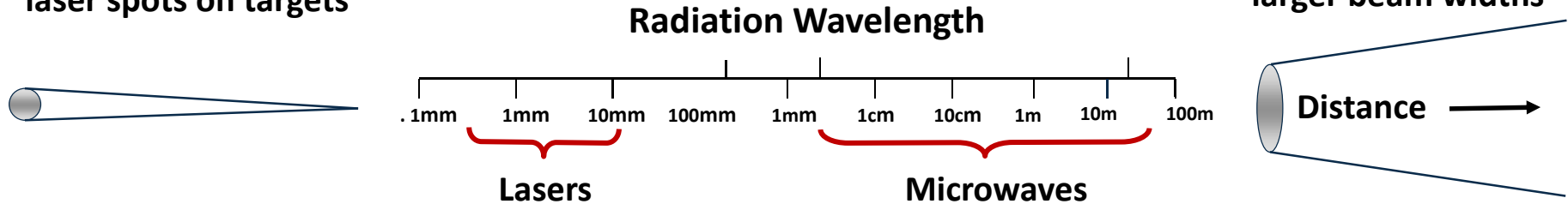
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- **DoD's shift toward developing solid state lasers (SSLs) has accelerated its development of practical operational HEL weapons**
 - Multiple SSLs are approaching maturity
- **DoD and defense industry are making progress toward reducing the size, weight, power, and cooling required by lasers, and are maturing their beam control and beam director systems**
 - Will soon allow SSLs to be integrated into manned and unmanned aircraft, including combat aircraft
 - Art of the possible: 100-150 kW-class HELs on military aircraft and 300 KW-class HELs on the ground within the next five years
- **SSLs carried by high-value aircraft could increase their survivability against air-to-air and surface-to-air missile threats**



High power microwave (HPM) defenses

Small, tightly focused
laser spots on targets



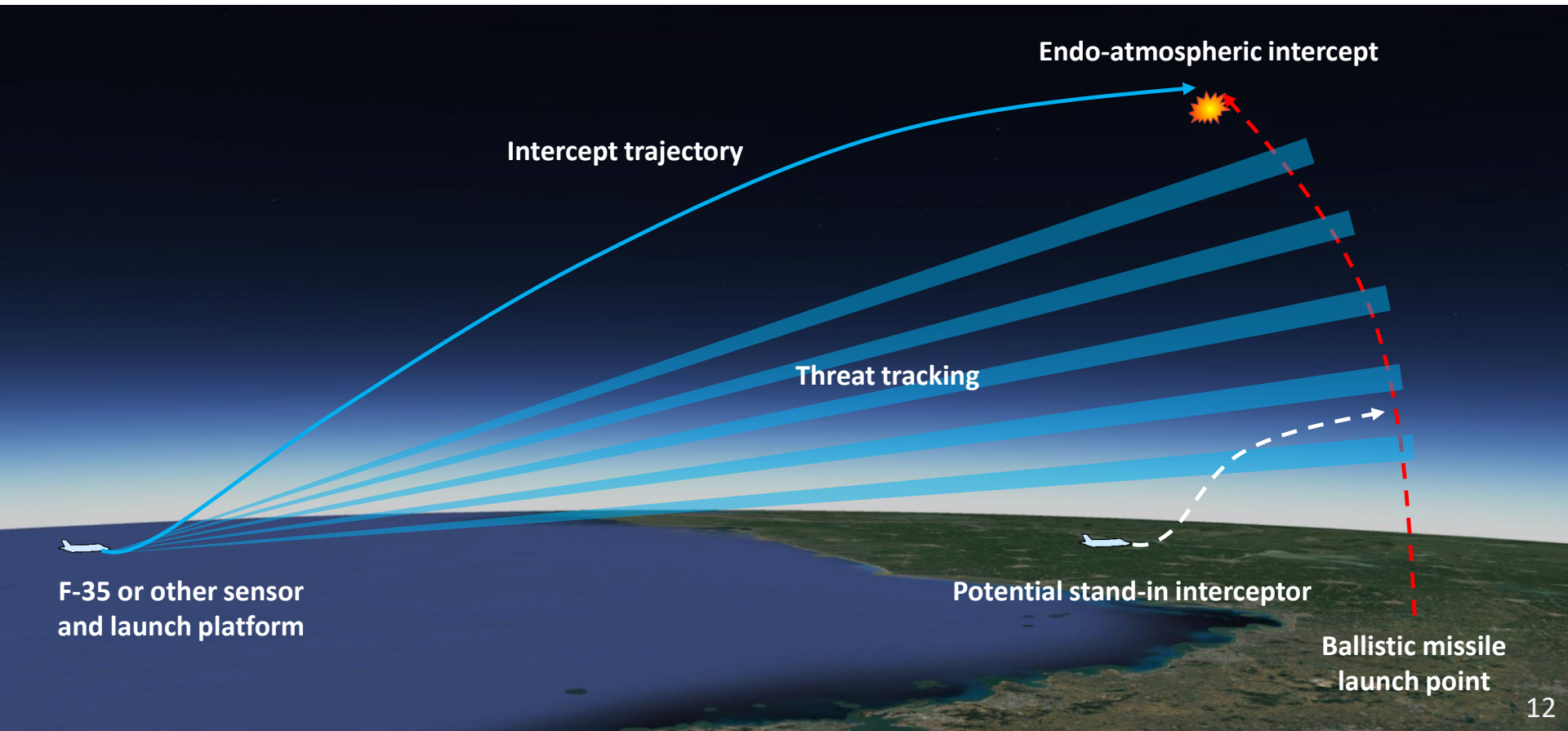
HPM systems have
larger beam widths

- HPM systems use short duration, high-power pulses of EM energy to damage internal electronic components of weapons such as PGM seekers, guidance components, and control systems
- May need only microseconds to create desired effects, so could engage more threats in an incoming salvo than a laser
- Future ground-based HPM systems could engage cruise missiles, unmanned aircraft and other threats
 - Could near-simultaneously disrupt / destroy multiple unmanned aircraft



Extended range air-to-air missiles for boost phase ballistic missile intercepts

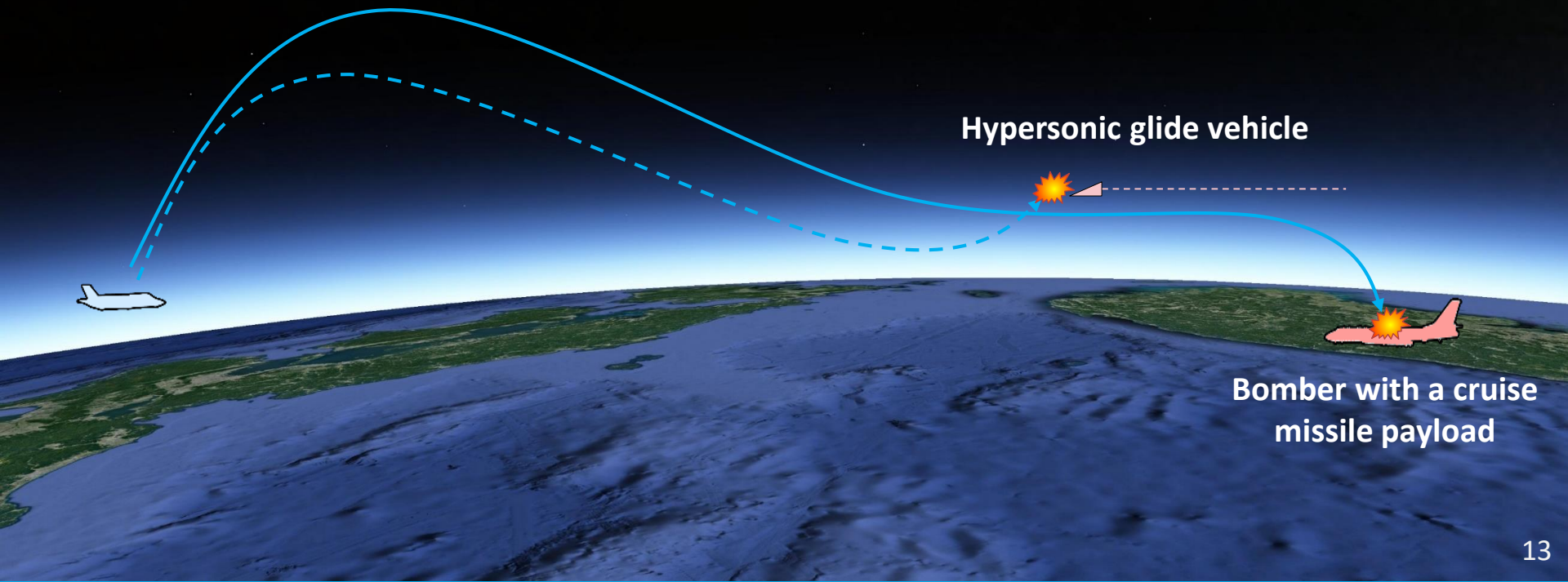
- Fighter-sized manned or unmanned systems carrying 2-4 interceptors could be a first line of defense against salvos
- Could be cued by on-board or off-board sensors; interceptors may require inflight target updates depending on range to threats



Extended range air-to-air missiles to defeat the “archers” and other threats

- Unmanned or manned aircraft with extended range interceptors could intercept enemy bombers before they launch their payloads
- May also be capable of intercepting challenging threats such as ballistic missile RVs and hypersonic glide vehicles (HGVs)

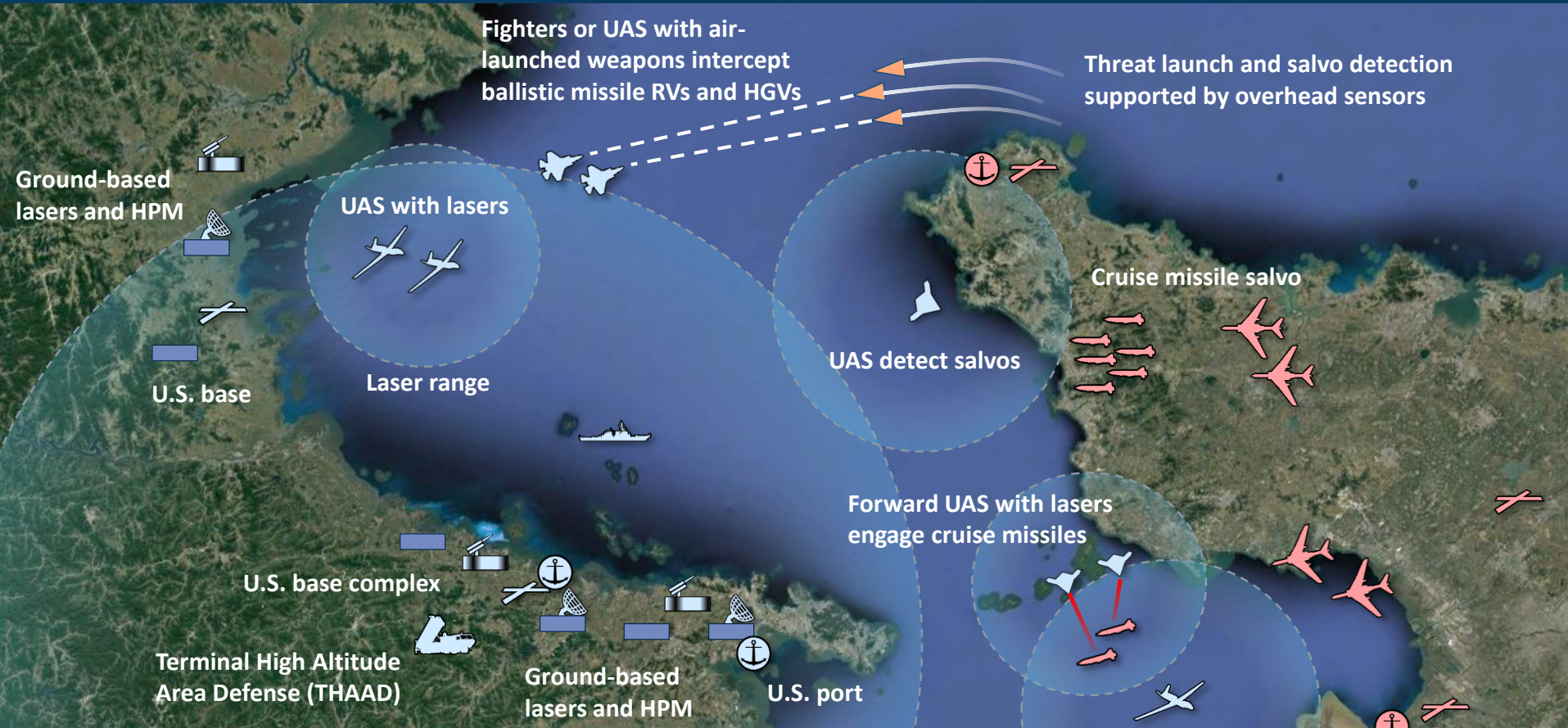
UAS or fighter with multi-stage, air-launched interceptors



Hypersonic glide vehicle

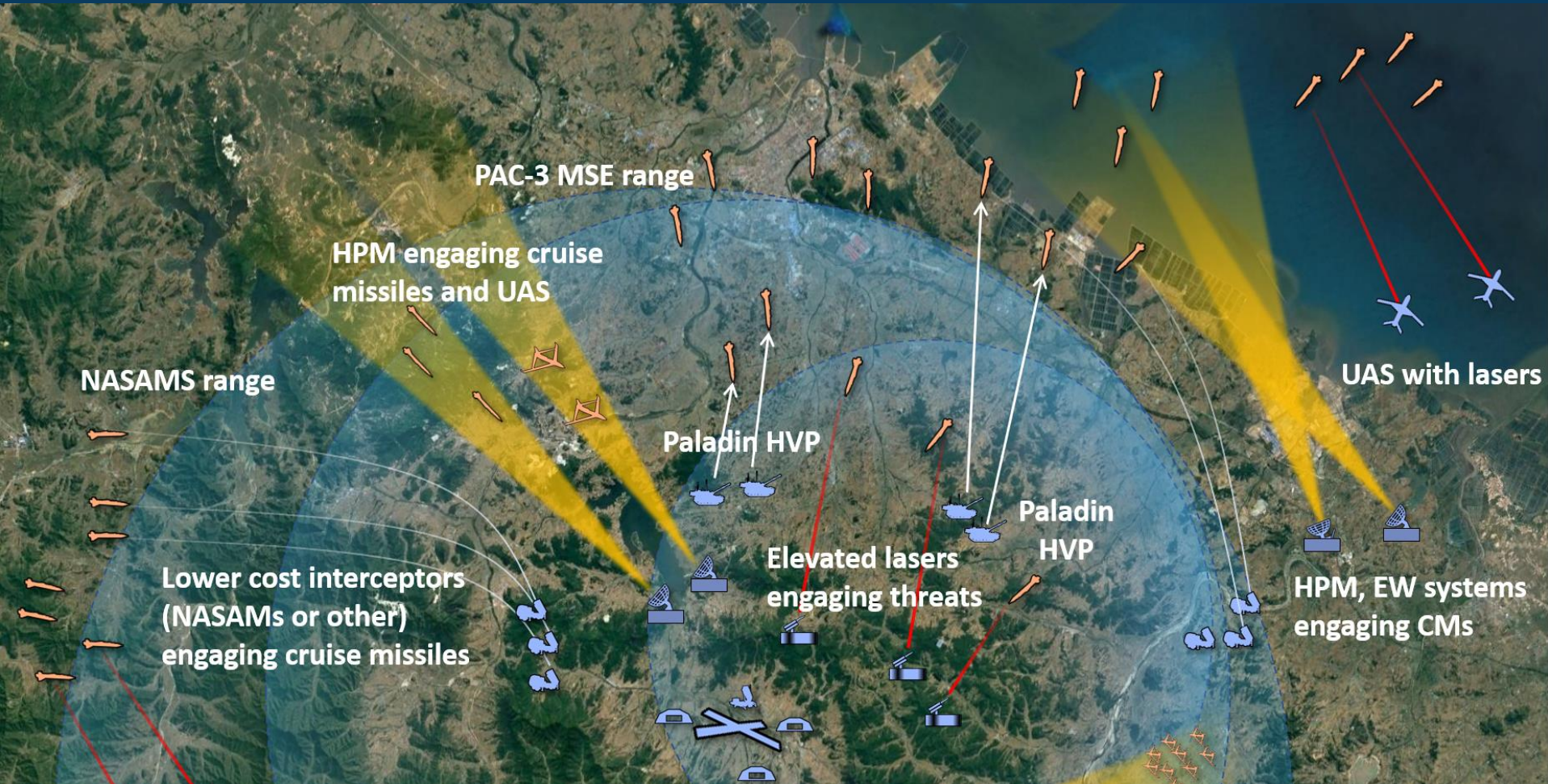
Bomber with a cruise missile payload

Concept: An “outer ring” layered defense to counter enemy salvos



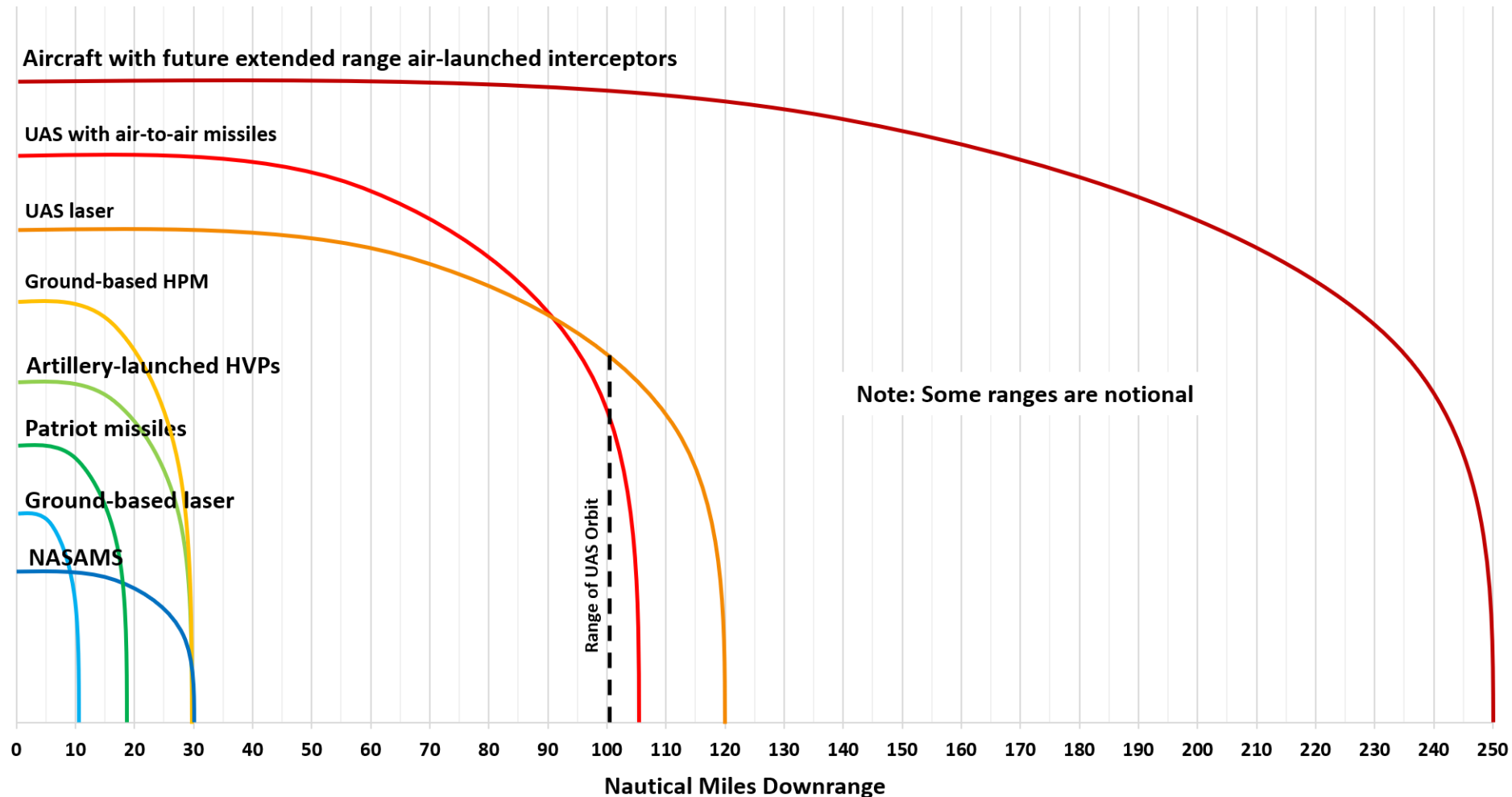
- **Sensor network detects salvos and cues intercepts**
- **Begin to reduce salvos from the outside-in using airborne HELs and aircraft launching long-range interceptors**
- **Kinetic + non-kinetic systems are complementary**

Concept: An “inner ring” of kinetic and non-kinetic defenses



- UAS with HELs and mobile /relocatable ground-based HELs
- HPM to counter cruise missile salvos and UAV swarms
- Kinetic SHORADs: low-cost interceptors, 155mm guns with HVPs...

Combining short-range, medium-range, and long-range systems



- In combination, potential to create higher capacity and more cost effective salvo defenses compared to today's limited defenses

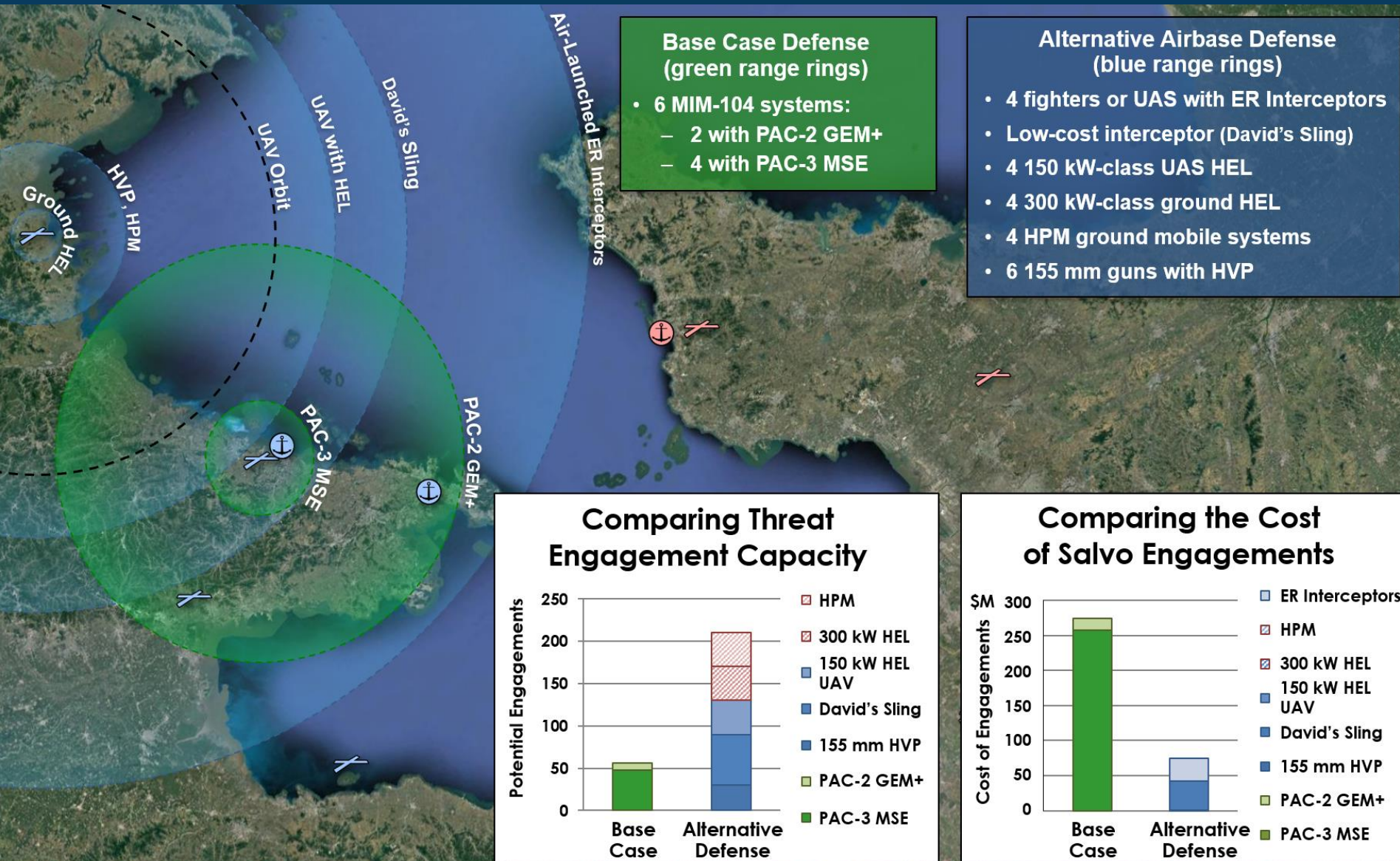


Illustrating the capacity and cost of an alternative base defense



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New technologies could greatly increase airbase threat engagement capacity



Patriot Missiles Only

Patriot System	Estimated Cost per Engagement	Total Cost of Engagements
2 PAC-2 GEM+ launchers	\$2 million	\$16 million
4 PAC-3 MSE launchers	\$5.38 million	\$258 million
	56 threat engagements for \$274 million	

Alternative			
Defensive System	Rate of Fire per Minute	Estimated Cost per Engagement	Total Cost of Engagements
6 155 mm HVP launchers	5 HVPs per launcher	\$25 thousand	\$750 thousand
4 David’s Sling-like launchers	16 interceptors per launcher	\$700 thousand	\$44.8 million
4 ground-based 300 kW-class lasers	10 shots per laser (assume 6 seconds for each threat engaged)	\$100	\$4 thousand
4 ground-based mobile HPM weapons	10 shots per system (assume 6 seconds for each threat engaged)	\$100	\$4 thousand
4 UAVs with 150 kW-class lasers	10 per laser (assume 6 seconds for each threat engaged)	\$500	\$20 thousand
4 fighters with multi-stage, extended-range interceptors	4 interceptors per fighter or UAV	\$2 million	\$32 million
		214 to 230 threat engagements for \$77.6 million	

- **The ability to defend and operate from bases that are located inside contested areas would enhance regional deterrence**
- **Existing base capacity to engage weapon salvos is lacking, especially to counter non-ballistic threats**
- **Mature and maturing technologies could support the fielding of base defenses with greatly increased threat engagement capacity relative to existing systems**
 - Defenses that are mobile / rapidly relocatable would also reduce the effectiveness of an enemy's counterfires
 - Non-kinetic systems could reduce strains on U.S. logistics systems

- **Develop and field UAS with sensors to detect and provide early warning of salvo attacks**
 - Integrate with other space, ground and sea-based sensors
 - Could help fill DoD's existing gap in capabilities to detect cruise missiles, unmanned aircraft, and other threats
- **Acquire UAS with HELs**
 - Integrate 150 kW-class lasers into current generation UAS
- **Acquire ground-based mobile HELs**
 - Develop, test and field 300KW-class lasers by combining two or more SSL modules

- **Acquire several types of HPM systems to counter cruise missile attacks and unmanned aircraft swarms**
 - HPM systems to counter small (Class 1 & 2) unmanned aircraft
 - Longer range HPM systems for cruise missiles and other threats
- **Develop and procure multi-stage, extended-range air-launched interceptors**
- **Field lower-cost, short- to medium-range kinetic ground-based defenses**
 - Hyper-velocity projectiles (HVPs) launched by Paladins
 - Lower cost surface-to-air interceptors

- **Consider adapting Naval Integrated Fire Control Counter Air (NIFC-CA) for base defense battle management and C2**
 - Creating an entirely new BMC2 architecture from scratch would be costly and take years
 - Could tie into existing sensor networks (e.g., Cooperative Engagement Capability)
- **Clarify responsibilities for base defense inside DoD**
 - Lack of clarity has been a barrier to the development of needed concepts and capabilities for base defense
 - Determine the right division of responsibilities to defend bases against salvos of guided weapons—not just ballistic missiles—between the Services and MDA

Questions?



<https://csbaonline.org/research/publications/winning-the-salvo-competition-rebalancing-americas-air-and-missile-defenses>



<https://csbaonline.org/research/publications/air-and-missile-defense-at-a-crossroads-new-concepts-and-technologies-to-de>

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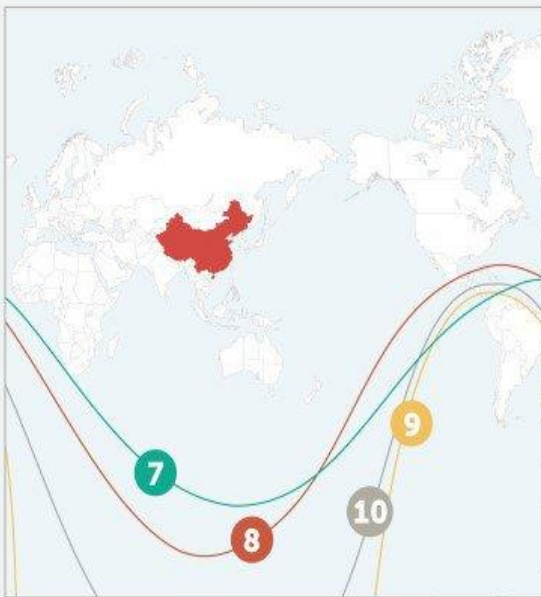
Backup

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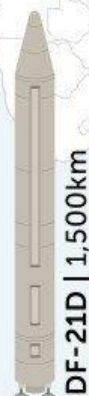
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CHINA'S BALLISTIC MISSILES



China has the most active and diverse ballistic missile development program in the world, upgrading its missile forces in number, type, and capability. China is modernizing its ICBMs, developing multiple independently-targetable reentry vehicles and maneuvering boost-glide vehicles, and has begun deploying a new fleet of nuclear ballistic missile submarines. Short- and medium-range cruise and ballistic missiles form a critical part of its regional anti-access and area denial efforts.



DF-21D | 1,500km

1



DF-21C | 1,750km

2



HN-2 (Cruise) | 1,800km

3



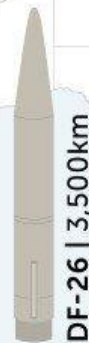
DF-21/21A | 2,150km

4



HN-3A (Cruise) | 3,000km

5



DF-26 | 3,500km

6



JL-2 (SLBM) | 8,500km

7



DF-31A | 11,000km

8



DF-41 | 13,500km

9



DF-5A/5B | 13,000km

10

36m/118ft

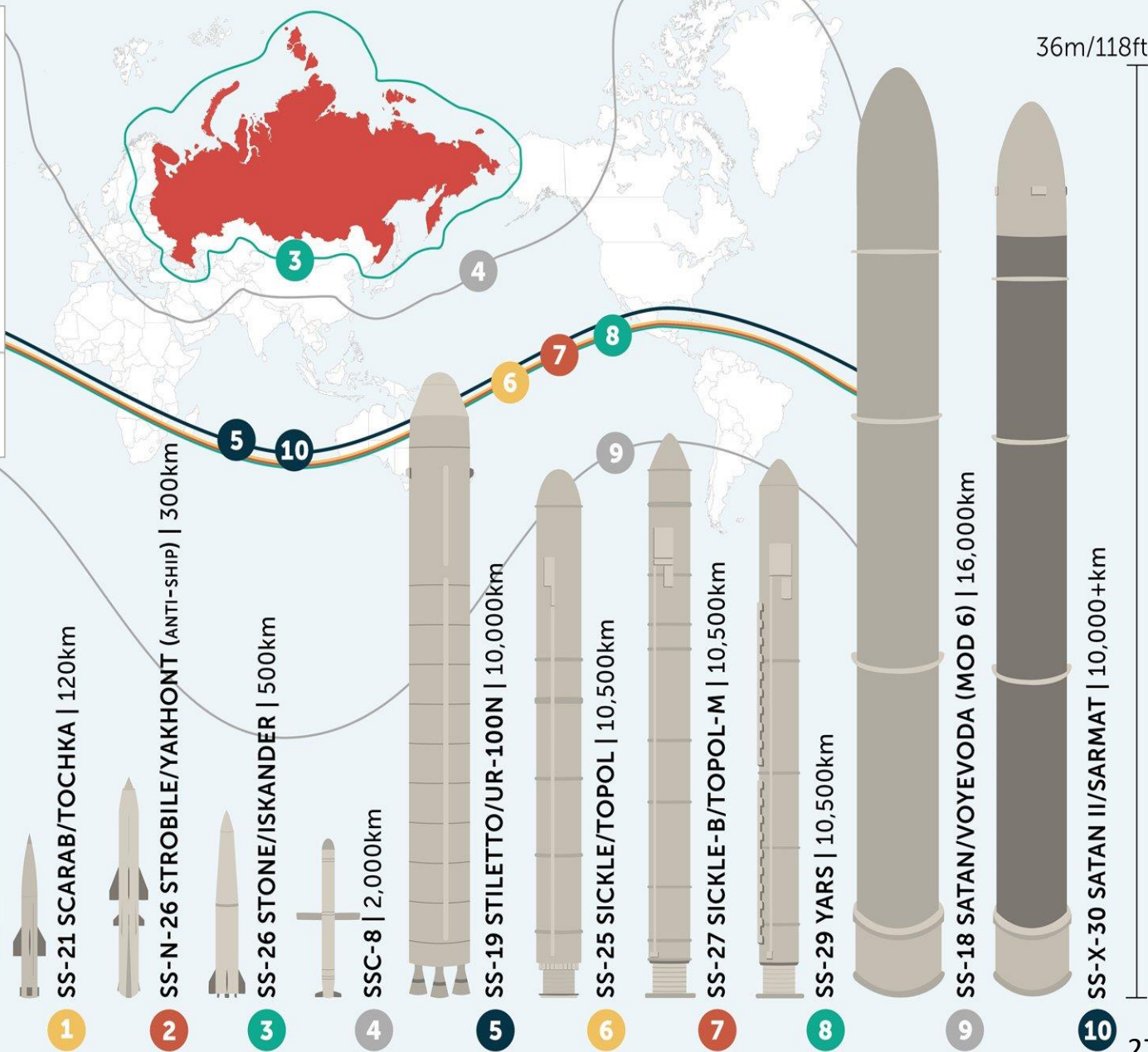


RUSSIA'S LAND-BASED MISSILES

KALININGRAD



Russia boasts the widest inventory of ballistic and cruise missiles in the world. Moscow's strategic rocket forces perform a variety of missions, from anti-access and area denial in local conflicts to the delivery of strategic nuclear weapons. Significant modernization efforts include new heavy ICBMs, as well as ground-launched cruise missiles in violation of the Intermediate-Range Nuclear Forces (INF) treaty.



Potential non-lethal applications: Active Denial System (ADS)

ADS 1R



- ADS counter-personnel system could project a MMW beam up to 1,000 meters
- Non-lethal, reversible effects; thousands of tests but never deployed
- Next gen compact, lightweight system can be integrated into military vehicles and vessels



*Ruggedized ADS
demonstrator with
generator*



*Vehicle-
based*



Sea-based



Building-based

China's and Russia's maturing air and missile defenses



China's HQ-9 TEL



Russia's S-400 TEL

Advanced SAMs

- Both are modernizing their SAMs; China first S-400 in January 2018, Russia reorganizing to improve effectiveness of its air defenses
- Relocatable, networked, increasingly capable against aircraft and missiles
- Both are proliferators



China's ASAT and BMD Missiles

DF-41 ICBM on a TEL



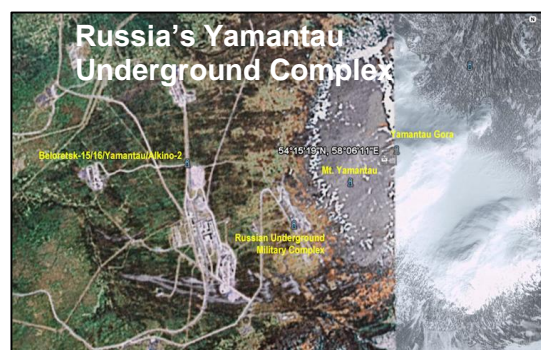
Russia's S-500 System

Missile defenses

- China's BMD is closely linked to its ASAT program; tested hit-to-kill weapon in 2018
- Russia's S-500 and other systems will give it a layered BMD system by 2020
- Both have increasingly capable active and passive cruise missile defenses



Areas of reported PLARF Tunneling (2011)



Russia's Yamantau Underground Complex

Underground facilities (UGFs)

- China is continuing its massive UGF building program
- Russia has reinvigorated its Cold War UGFs and is building more