Tech Brief:
Goden Dome Technology Challenges

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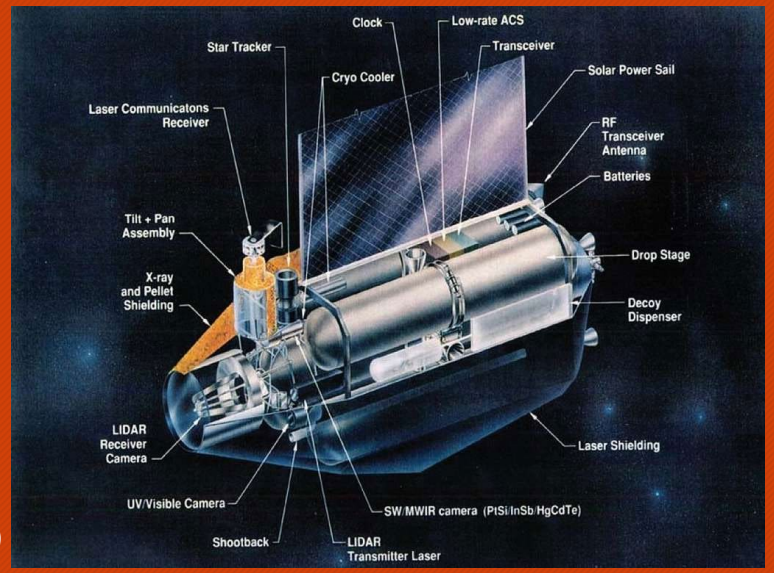
Space-Based Missile Defense: A Brief History

- 1960 Dwight D. Eisenhower requested ARPA look into boost phase intercept of ICBM – project ***Bambi***, space-based interceptors proposed but unfeasible
- 1965-1973 ***Sentinel*** terrestrial missile defense system (canceled) and scaled-down ***Safeguard*** system deployed
  - Limited by 1972 ABM treaty and shut down in 1976
- 1982 Heritage Foundation & High Frontier publish "***High Frontier: A New National Strategy"*** laying out a multilayer missile defense with a space component
- 1983 Ronald Reagan announced the Strategic Defense Initiative – SDI
- 1984 Strategic Defense Initiative Office (SDIO) with a focus on Lawrence Livermore National Labs *EXCALIBUR* nuclear pumped X-Ray laser promoted by Teller
- 1990 Brilliant Pebbles space-based missile selected by SDIO after 1986 EXCALIBUR test failures – morphs into GPALS -Global Protection Against Limited Strikes – canceled 1992
- 1990 to present, focus moved to ground-based midcourse, theater, and terminal missile defense under the new Missile Defense Agency (MDA)
- 2018 US Space Force (USSF) and Space Development Agency (SDA) formed
  - Proliferated Warfighter Space Architecture (PWSA) & Next-Generation OPIR, including HBTSS (hypersonic track)
- 2025 Donald Trump announces Golden Dome with $25b approved for FY 2026

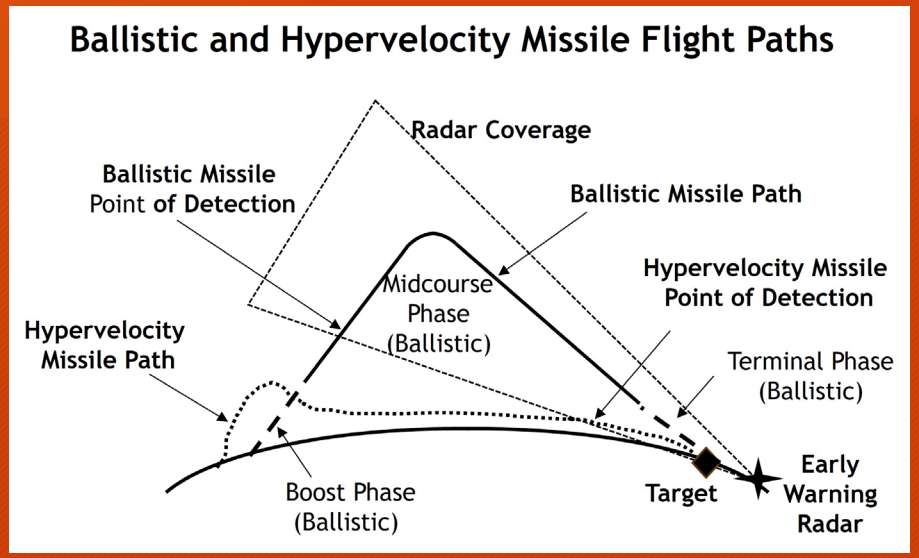
EXCALIBUR – nuclear pumped Xray Laser

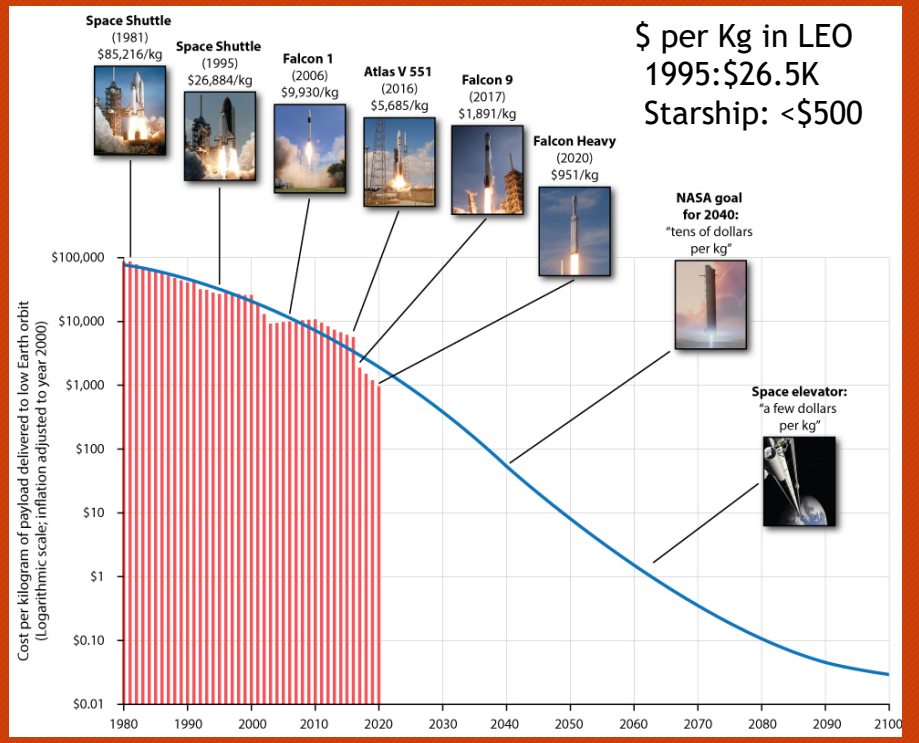


Brilliant Pebble in "life Jacket"

Why Now?
Need and Feasibility of Golden Dome

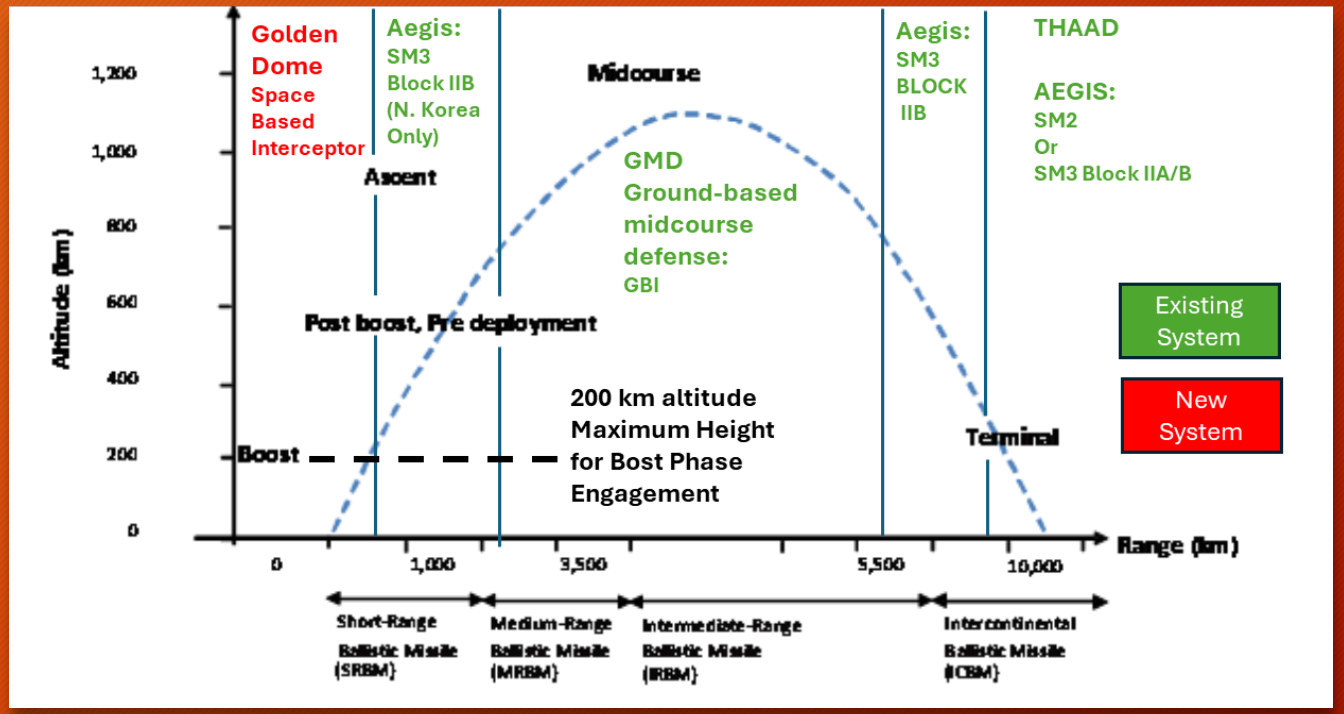
- THE NEED
  - **Expanded Threats:** proliferation of new extended-range cruise missiles and hypersonic glide vehicles. Expanded enemies with expanded arsenals
  - **Early Warning Systems Gaps:** Our terrestrial (earth-based) early warning radars and current-generation space-based infrared detection satellites no longer provide adequate early warning for cruise and hypervelocity weapon threats.
  - **Boost Phase Intercept Is Necessary:** Terrestrial missile defenses are not enough. Boost phase intercept of the expanded threats is required before MIRV and countermeasure deployment
- Economic and Technology Feasibility
  - **Launch Cost Reduction to LEO:** 1995/SDI $26,500/kg with SpaceX Starship <$500/kg over 50x cost reduction
  - **Additive Manufacturing:** Components are printed, not cast or built by CNC
  - **Compute and Storage:** Moore's law – 100K times more powerful / less cost
  - **Sensors and other components:** Equally improved by computing and manufacturing improvements
  - **AI and Distributed Computing:** Command, Control, Battlefield Management, and Communications mature and improving (e.g., 12-Day War missile defense)
  - Iterative Development Methodology: fast fail and continuous improvement
  - **Experience: ground-based weapons experience transfers to Golden Dome**
  - **Early Warning: PWSA and OPIR – These systems are in deployment**



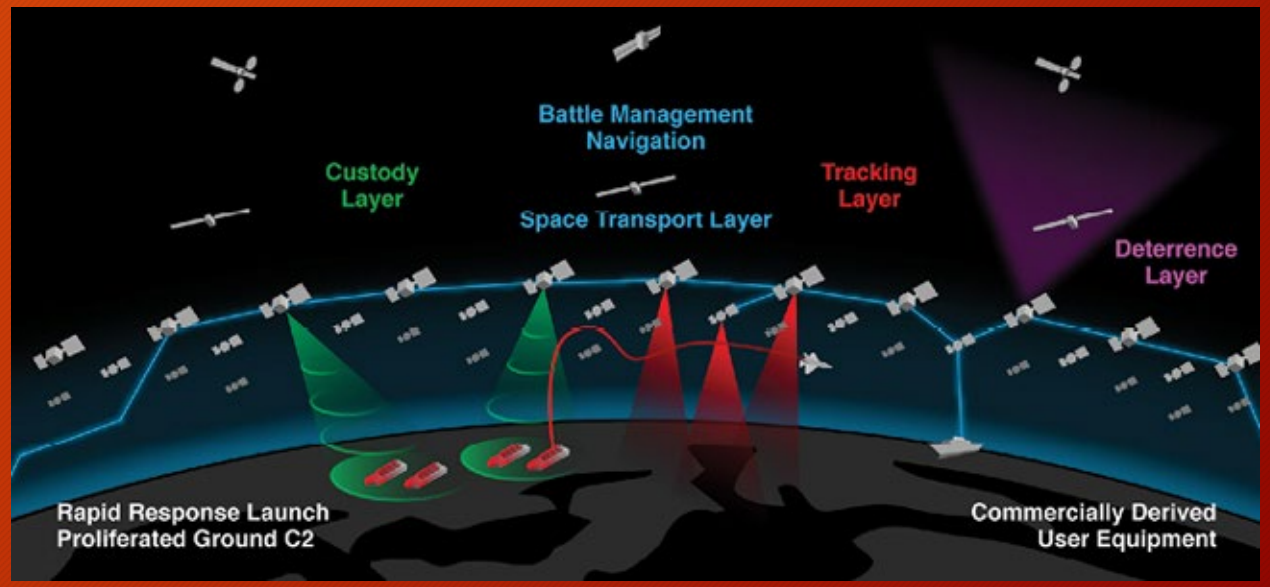


Golden Dome
Basic Architecture

- Golden Dome will offer a layered defense
- Space-Based Interceptors will provide the proximity for Boost Phase intercept of missiles launched from China, Russia, and Iran
  - Japanese Destroyers armed with AEGIS SM3 Block IIB have Boost Phase intercept proximity to North Korean launches
- The Architecture provides four opportunities to engage a threat:
  - Boost Phase
  - Midcourse Phase
  - Descent Phase
  - Terminal Phase
- Proliferated Warfighter Space Architecture will play a central role in Command, Control, Battle Management, and Communications (C2BMC)
- Initial deployment will be in the range of 1000 to 2000 interceptors
  - Only a limited number of interceptors will be in range



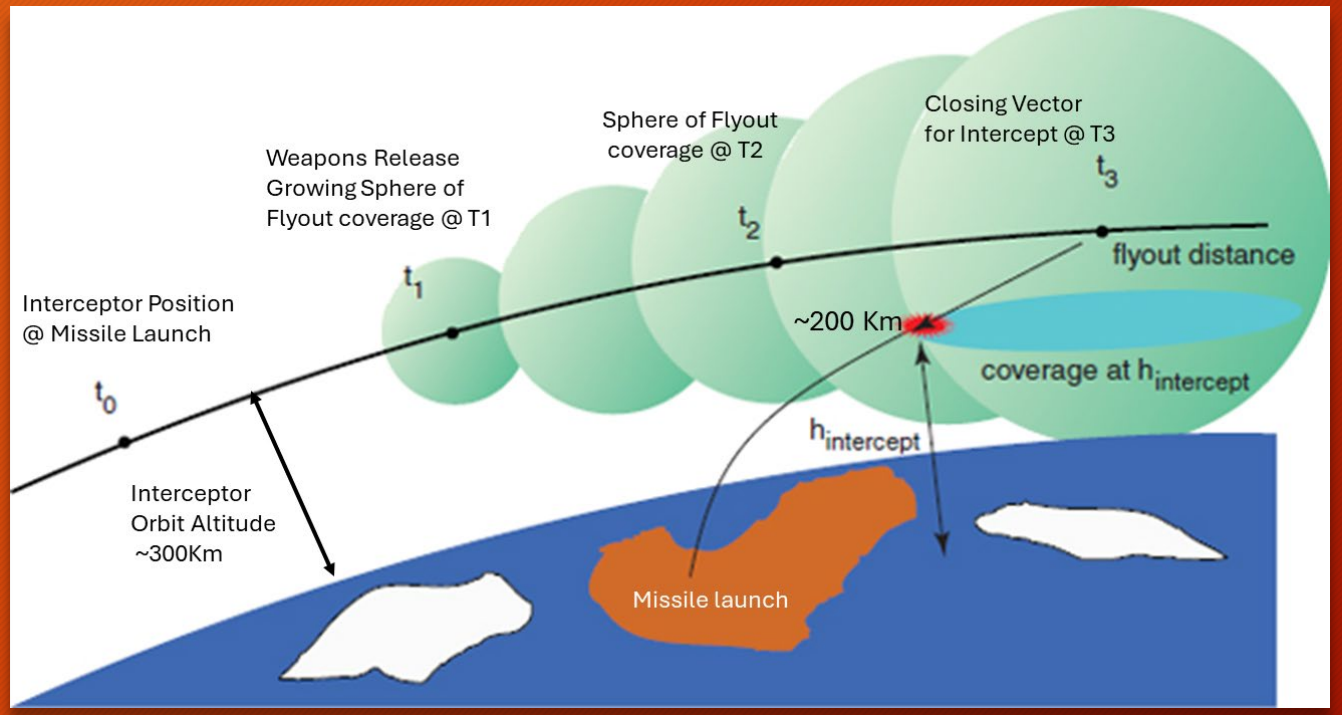
Phases of ICBM Trajectory & Defense System for Engagement



PWSA - Proliferated Warfighter Space Architecture for C2BMC

Interceptor Flyout & The Absentee Problem

- Constellations of interceptors spend most of their time (71%) over water, 3.4% Russia, 1.8% China, and 0.025% North Korea
- At any time, only a handful of Space-Based Interceptors are in range to engage in the Boost Phase – This is the **"Absentee Problem"**
- Simulations developed by the Center for Strategic International Studies (CSIS) based on "flyout" criteria:
  - 836 Km interceptor maximum kill radius
  - 200 Km intercept altitude
  - VLEO 300 Km Interceptor orbit (limit fly down)
- CSIS results show that even for large constellations with 1K to 2K interceptors in range are limited:
  - 5 for North Korea
  - 4 to 7 for China
  - 5 to 36 for Russia
- The American Enterprise Institute determined a "Robust Defense" would require ~ 80,0000 interceptors and $ trillions to deploy and operate
  - An unlikely deployment that would upset the strategic calculus
  - We Are stuck with MAD for the foreseeable future

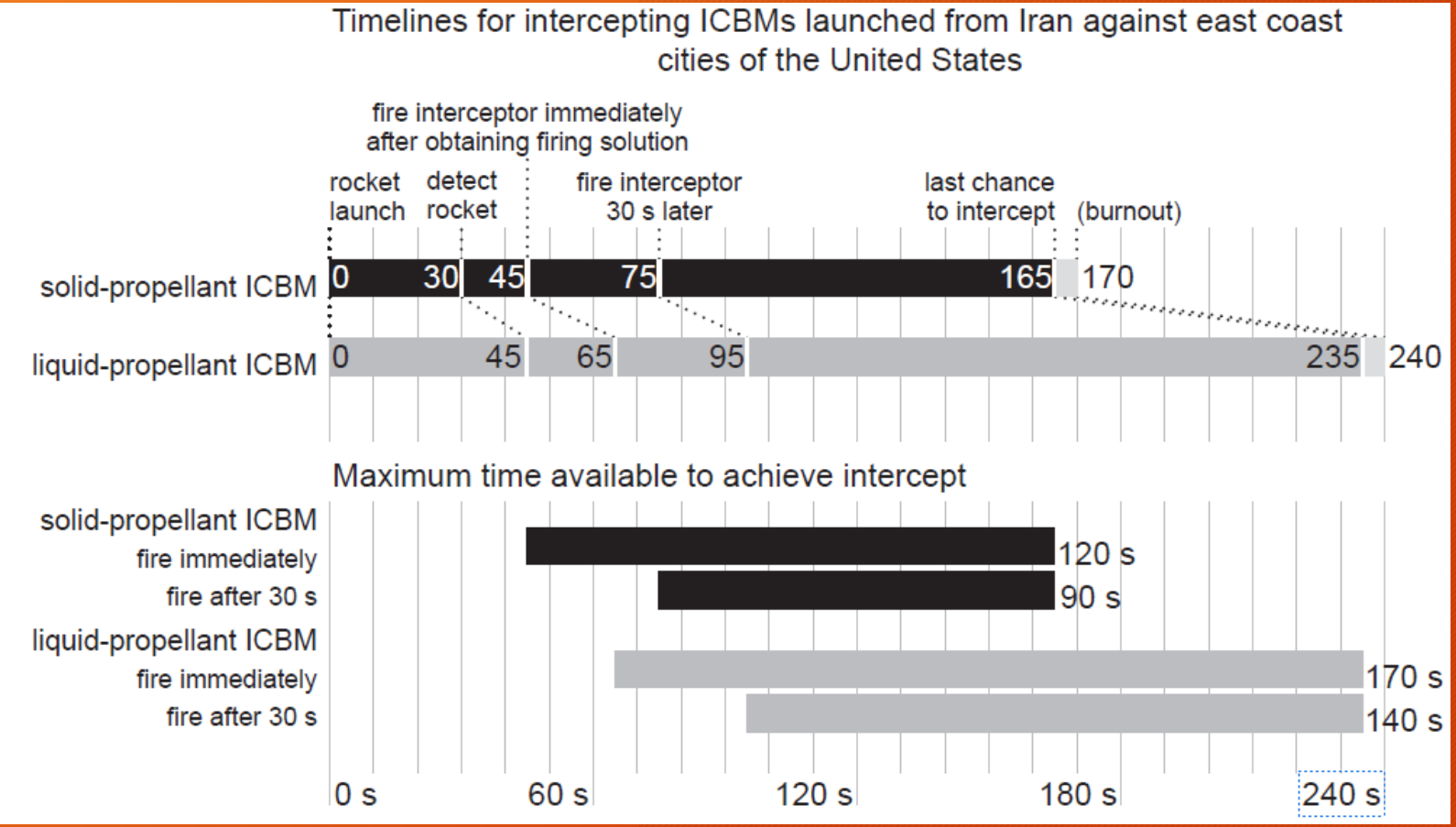


Flyout Distance over time and Intercept with the Target Missile

Constellation Size	Orbit Inclination	Interceptors In Range	In Range Iran	In Range North Korea	In Range China	In Range Russia
1012	60 deg	1 to 7	2 to 3	2 to 3	2 to 7	0 to 7
1012	90 deg	1 to 37	2	2	2 to 3	2 to 17
2013	60 deg	2 to 18	4 to 5	5	4 to 7	5 to 33
2013	90 deg	1 to 76	4 to 5	5	4 to 7	5 to 36

Orbital Interceptors in Range At All Times
(Center for Strategic and International Studies)

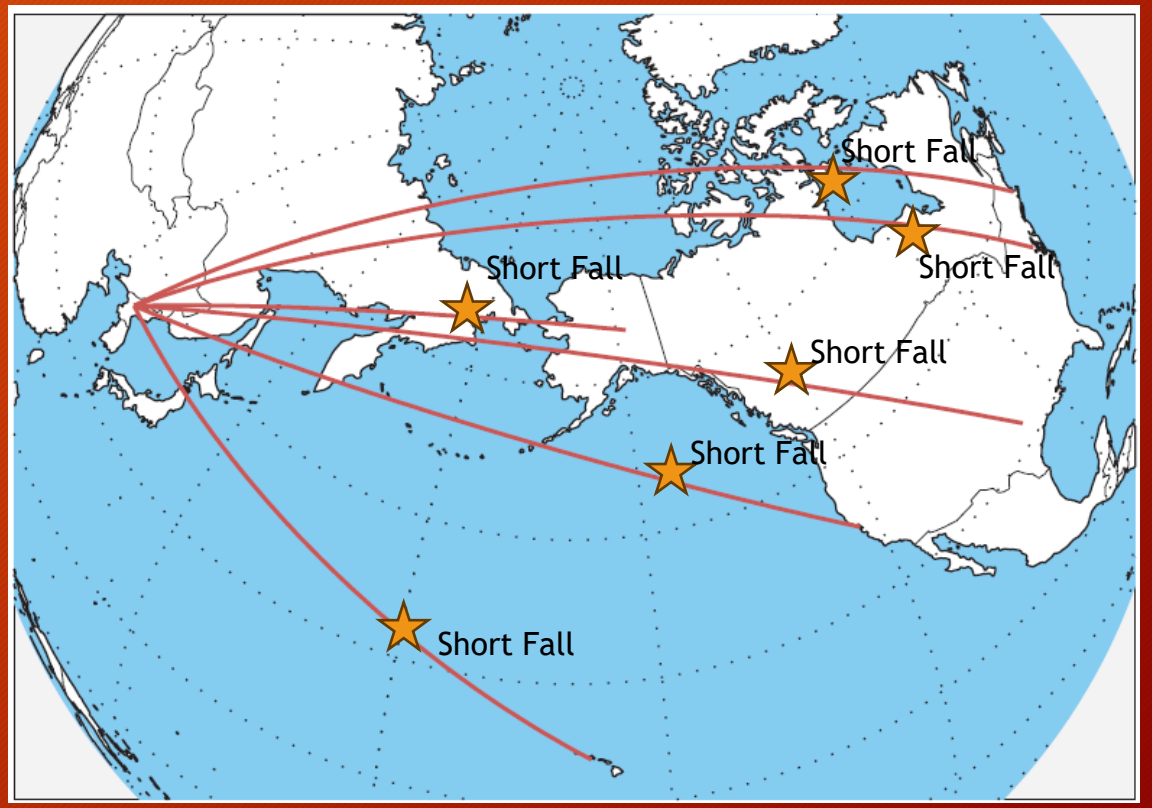
Time: The Greatest Challenge



- Time is Short to Intercept in The Boost Phase
- It takes roughly 45 seconds to obtain a firing solution
- For solid-propellant ICBM
  - **Zero Time Decision:** 45 seconds to interceptor launch and 120 seconds maximum intercept time
  - **Extend Time decision:** 75 seconds to interceptor launch and 90 seconds maximum intercept time.
- A priori knowledge of missile locations and nuclear armament are required to make a **Zero Time Decision**
  - **Strategic Reconnaissance and targeting are provided by NRO, NGA, NSA, and DIA**

Boost Phase Intercept Short Fall

- A successful missile intercept will make the weapon fall short of the target
- The interceptor may not destroy the warhead(s)
- Live nuclear warheads could fall on populated areas short of the target
- **A new complication**: sequencing of an intercept must factor in short fall timing
- Most ICBM attacks will be on Polar or near-polar trajectories
  - Sorry, Canada! Golden Dome Success will end up destroying some wilderness



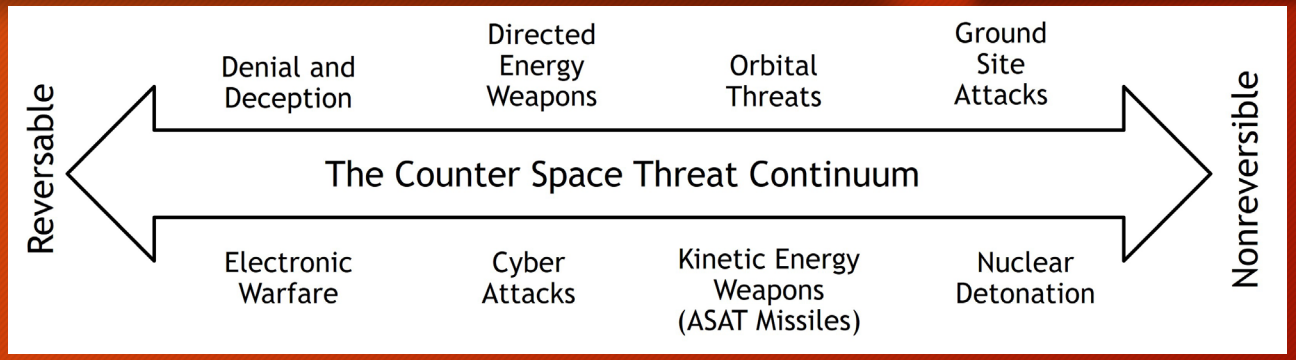
Weapons Short Fall in North Korean ICBM missile trajectories to hit Boston, Washington DC, Dallas, Fairbanks, and Honolulu

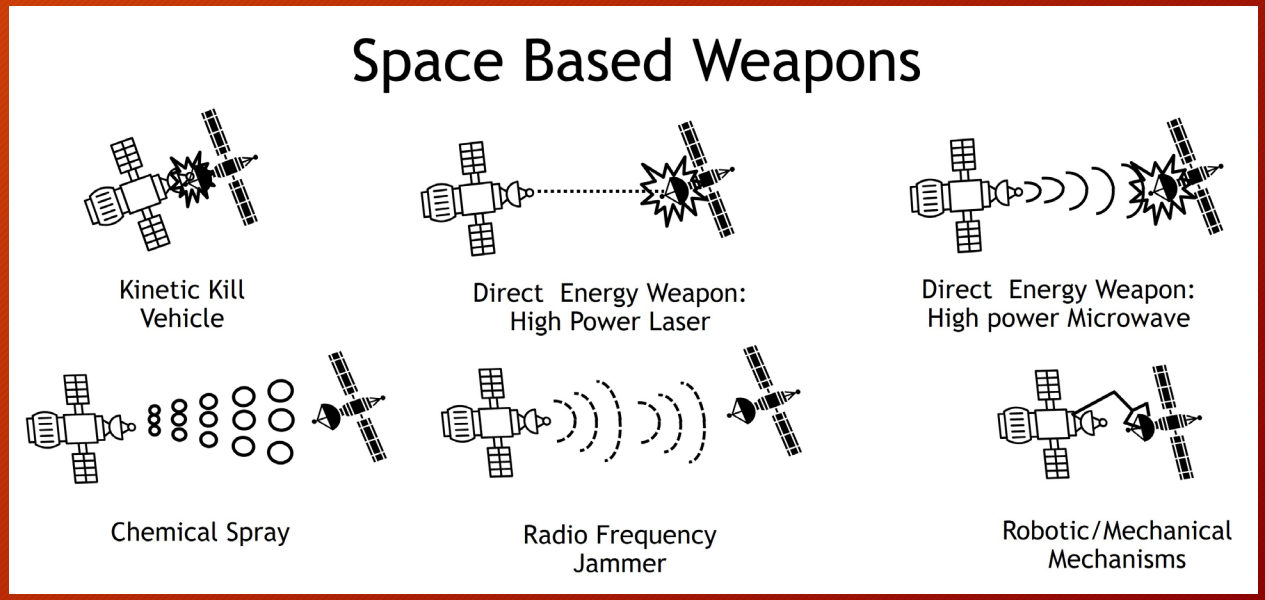
Threats and Countermeasures

Golden Dome is not impervious to attack.

China and Russia are fielding ground and space-based weapons to neutralize US and Allied satellites. These include:

- **Ground-based Directed Energy Weapons**
  - (lasers) to blind our IR and Optical satellites and will, at some point, achieve power levels to disable spacecraft
- **Space-based Directed Energy Weapons**
  - (lasers and RF) to disable spacecraft
- **Space-based mechanical systems**
  - grapple our satellites and effectively alter their orbits burn up in the atmosphere
- **Ground-based anti-satellite missile systems**
  - A targeted Golden Dome satellite (Life Jacket + interceptor) would likely engage such an attack with the net result of expending a Golden Dome Interceptor
- **Upper Atmospheric Nuclear Weapons Release**
  - EMP, direct radiation, and charge pumping of the Van Allen belt

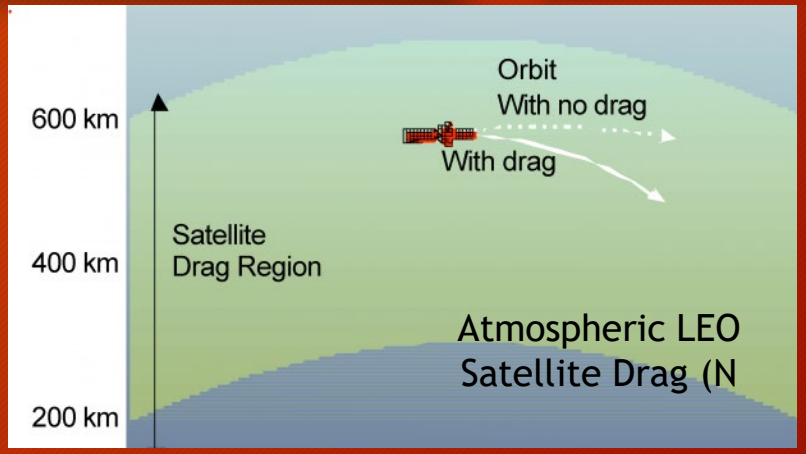


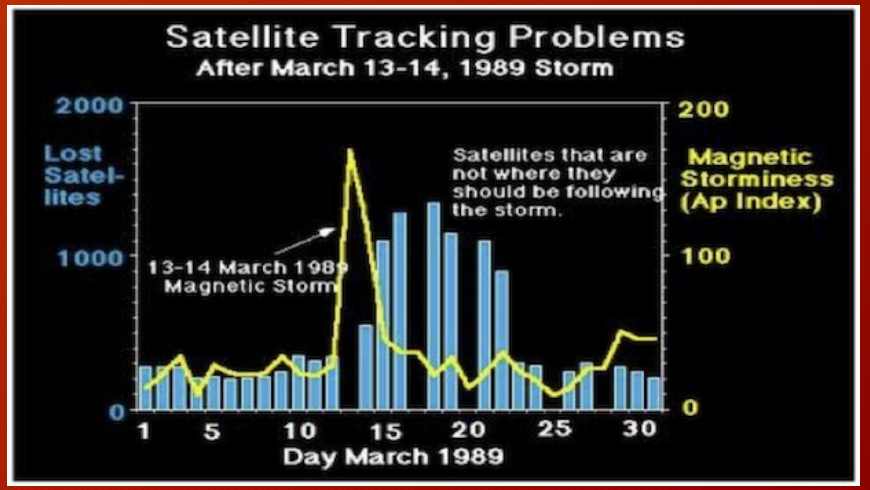


Atmospheric Drag & Station Keeping

- Golden Dome Satellites will likely be in VLEO orbit, ~300 Km
- VLEO satellites have significantly higher drag/orbit decay than other LEO satellites
  - Interceptor “Life Jacket” will need attitude fuel for a service life of ~5 years
- Solar activity (11-cycle) increases satellite drag
  - Low solar activity: orbital boost (thrust maneuver) ~four times per year
  - High solar activity: orbital boost every 2 to 3 weeks
  - Geomagnetic storms can produce large short-term increases in upper atmosphere temperature and density –(e.g.1989 Geostorm event)
- Drag is difficult to model and requires active monitoring - space situational awareness
  - Space Surveillance Network (SSN) - 18th Space Defense Squadron (military)
  - New NOAA - Traffic Coordination System for Space (TraCSS) – LEO Labs (civilian)
  - Navigation Layer of PWSA – which will also be necessary for accurate fire control tracking
- Fuel Reserves must account for LEO debris and satellite collision avoidance
  - Each SpaceX Starlink satellite made 35 collision avoidance maneuvers in 2024

Question: Is In orbit refueling to expand lifespan an option?





Thank You

Missile Defense and Strategic Surveillance are just part of the overall US and Allied Deterrence regime. Find out more in my new book:

About the Book

About Me

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