Golden Dome: A Science-based Assessment

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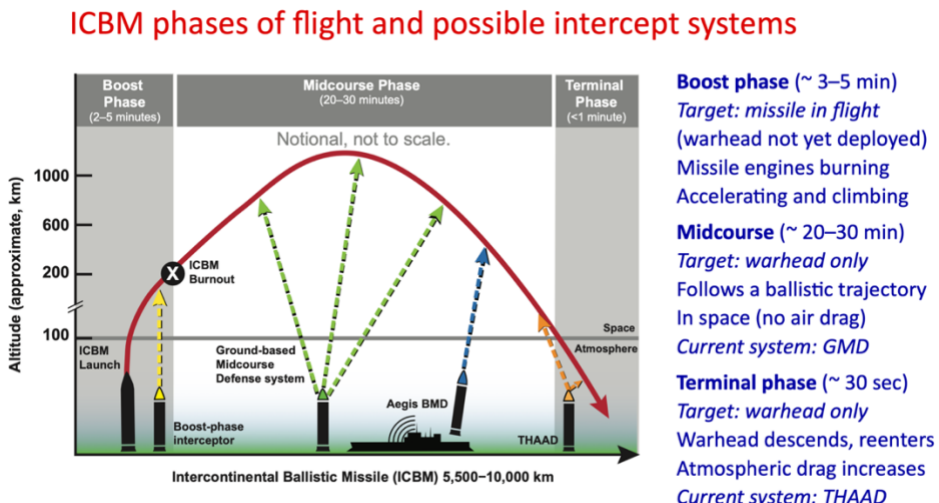
During the past 70 years, the United States has spent almost $500 billion on ballistic missile defense, mostly on systems intended to intercept nuclear-armed intercontinental-range ballistic missiles (ICBMs) that might be launched against the United States. Unfortunately, the ability of any of these systems to intercept even a single warhead under the conditions expected during a nuclear attack has not yet been demonstrated. A comprehensive system such as Golden Dome is almost certainly technically infeasible and pursuing such a system will likely waste hundreds of billions of dollars on inherently ineffective systems. Even so, pursuing Golden Dome is likely to provoke responses from potential adversaries that reduce U.S. security, including building more weapons and novel delivery systems, and would provide disincentives to engage in nuclear arms reductions. Additionally, misplaced faith in systems intended to defend against long-range, nuclear-armed missiles is dangerous and impedes more realistic and effective efforts to improve U.S. security.

The challenges of defending against nuclear-armed ICBMs

Despite significant investment of resources and decades of effort, the existing midcourse missile defense system with 44 ground-based interceptors has not been shown to be reliably effective even in carefully scripted tests, and its effectiveness in battlefield situations is likely to be low. Some design and reliability problems can be addressed, but the issue of effectively discriminating warheads from decoys remains unsolved. The Pentagon has made little progress in this area, and to assess the system as likely to be successful, optimistic assumptions must be made about the adversary's ability to field countermeasures.



Source: *Strategic Ballistic Missile Defense*, APS 2025

Due to its vulnerability to countermeasures, and the inability to expand it readily or cost-effectively, in a recent study, the American Physical Society assessed that the current midcourse intercept system cannot be expected to provide a robust or reliable capability against more than the simplest attacks by a small number of relatively unsophisticated missiles within 15 years.

Golden Dome versus Iron Dome

The limited successes of Israel's Iron Dome against simple rockets and the performance of other Israeli and U.S. missile defense systems in defending against ballistic missile attacks from Iran do not provide evidence that a Golden Dome program will be successful. Iron Dome is claimed to disable about 80%–90% of the short-range,

low-speed, small-yield, home-made rockets it engages. During Iran's retaliations against Israel in April and October 2024, with advance warning and time to prepare, the combined missile defenses of Israel, the US, and their allies were able to intercept 70%–80% of Iran's crude medium-range ballistic missiles carrying warheads with conventional explosives.

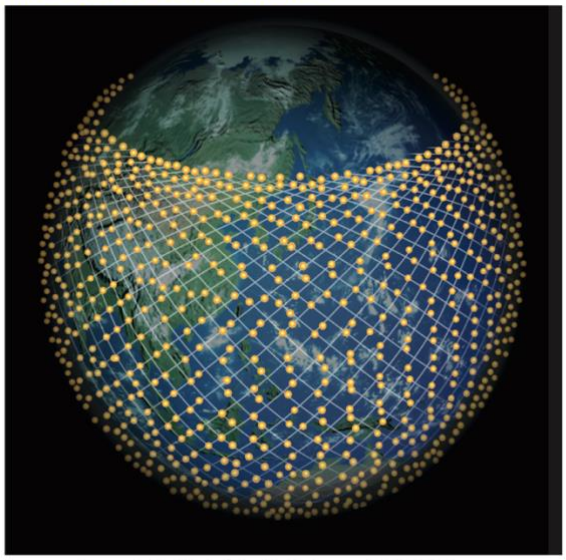
While that result was described as successful, these systems are not designed to defend against an attack by nuclear-armed ICBMs, which travel 6,000–8,000 miles at 15,000 miles per hour and carry a warhead with an explosive power up to one million times greater. The consequences of not intercepting nuclear warheads would be catastrophic.

Boost-phase interceptors

The chief challenge for boost-phase defenses against long-range missiles is that there is very little time to achieve intercept. ICBM boost phases are short (4–5 minutes for liquid-fueled missiles, three minutes for solid-fueled). Meanwhile, intercept points for ICBMs from North Korea—the "easiest" case—are greater than 500 km from potential interceptor basing locations. Hence the defense has little time to decide whether to fire and interceptors have little time to reach the ICBM (~100 to ~200 seconds). The timeline is very challenging and requires the interceptor to be based close to the intercept point.

Boost-phase intercept using space-based interceptors

What a constellation of 1,600 space-based rocket interceptors would look like:



Source: *Strategic Ballistic Missile Defense*, APS 2025

Because each space-based interceptor (SBI) moves rapidly around its orbit and any launch site rotates under its orbit as Earth rotates, a large constellation of SBIs is required to insure at least one is always in the right position.

According to the APS 2025 study, to defend against a salvo launch of four liquid-propellant ICBMs from North Korea against targets in the middle- and lower-latitude U.S. states—trajectories that make them easier to intercept—would require at least 1,600 SBIs, if the system is designed to fire interceptors automatically without verifying the threat and there is only one SBI assigned to intercept each ICBM. To counter a salvo launch of 10 solid-propellant ICBMs or prevent spoofing would require about 40,000 orbiting interceptors to defend all of the continental United States.

Golden Dome Counterproductively Expands Goals for Homeland Missile Defense

The goal of Golden Dome is to defend the United States and its allies and their armed forces against attack by aircraft, ballistic missiles, hypersonic glide vehicles, cruise missiles, and drones fired against them at any time from anywhere by any adversary, including peer and near-peer adversaries.

This is a departure from long-held bipartisan consensus that strategic missile defenses were to be sized to counter a small number of missiles from a non-peer state such as North Korea, while the strategic arsenals of China and Russia would be countered by nuclear and conventional deterrence. The National Missile Defense Act of 1999 called for defending against "limited" ballistic missile attack (whether accidental, unauthorized, or

deliberate) but *not* attempting to defend against peer or near-peer strategic arsenals. Similarly, the Trump administration's 2019 Missile Defense Review called defenses sized to defend the continental United States against the limited offensive missile threats posed by states such as North Korea.

Pursuing Golden Dome would undermine the decades-long deterrence relationship the U.S. has had with Russia and China. Without the limits of New START, this may lead to an arms race. We are already seeing this in the development of Russian and Chinese strategies to avoid, overwhelm, and directly attack elements of the current U.S. missile defense system.

The Extraordinarily High Costs of Golden Dome

Aside from the $175 billion cost and three year timeline that President Trump projected for Golden Dome—estimates that even Republican senators disputed—there are no public cost estimates for the full Golden Dome system as it has been described, nor is there a public description of the components the system would include to try to defend against a huge array of forms of attack.

However, the Congressional Budget Office estimated that even one piece of the system—a relatively small constellation of 1,000-2,000 SBIs that would seek to defend against one or two liquid-propellant ICBMs launched by North Korea—would cost $161 to $542 billion over 20 years. The American Physical Society estimated that, for the larger system of 40,000 SBIs needed to theoretically defend against a salvo of 10 solid-propellant ICBMs launched by North Korea, the construction and initial launch could alone cost ~$1 trillion.

Developing missile defense systems on a political timeline rather than based on technical readiness has led to costly failures in the Ground-based Midcourse Defense system. Repeating this approach is likely to do the same. Robust independent oversight is critical, including from Congress, the Pentagon's Department of Operational Test and Evaluation, the Office of the Inspector General, and the Government Accountability Office.

Misunderstanding the capabilities of strategic missile defense systems can lead to poor or dangerous policy decisions. Development of strategic missile defenses can also lead to US and allies missing opportunities for a more peaceful future including cooperative agreements to limit nuclear offensive and defenses

Dr. Frederick Lamb is a Research Professor of Physics and of Astronomy and a member of the Program in Arms Control and Domestic & International Security at the University of Illinois and chaired the 2025 American Physical Society study titled "Strategic Ballistic Missile Defense: Challenges to Defending the U.S." Dr. Laura Grego, Research Director and Senior Scientist in the Global Security Program at the Union of Concerned Scientists, was a co-chair of the study.