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JOINT ECONOMIC COMMITTEE

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Dear Colleague,

As Congress continues to consider a proposal for space-based missile defense, I want to share my perspective on why this is among the most technically complex challenges in the history of American defense policy and weapons systems development. I come to this topic not only as a member of the Armed Services and Intelligence Committees, but as an engineer, naval aviator, test pilot, and NASA astronaut with direct experience in the physics and engineering realities that govern what is and is not achievable in space. My point here is not to argue against missile defense categorically, but to ensure that our decisions are based on an honest and realistic assessment of what the physics requires, the cost of such a system and the strategic geopolitical impact.

An intercontinental ballistic missile travels at approximately four to five miles per second. A space-based interceptor must detect the launch, compute an intercept solution, separate from its satellite, and physically reach the missile, all within the missile's boost phase, which for a modern solid-fueled ICBM lasts about three to five minutes. That isn't much time and in engineering terms, it is very unforgiving.

The interceptor satellite must happen to be in the right place in its orbit at the precise moment of launch and orbital mechanics are not negotiable. A satellite does not hover over the threat. It is in continuous motion, and the coverage geometry changes by the second. To guarantee that at least one interceptor is within range of any Russian or Chinese ICBM field at any moment of every day requires an exceptionally large constellation. Compounding the physics challenges is the orbital velocity reality that to intercept a target in one orbital plane with an interceptor which is in a different orbital plane requires tremendous delta-V capability (the ability for a spacecraft to change its velocity). This means interceptors must also be very large because they would need to carry a lot of propellant. The other choice is to fly in highly elliptical orbits where the plane of the orbit of the interceptor intersects with the plane of the trajectory of the ICBM, but this too creates challenging geometry problems. The interceptor still must have sufficient onboard propellant to execute the maneuver needed to physically reach the rendezvous point in space, which requires a precise and rapidly computed solution under time pressure measured in seconds.

This is not like intercepting an aircraft or a cruise missile, which fly predictable paths at subsonic or low supersonic speeds. The closing velocities in a space-based intercept can exceed 10 miles per second or 36,000 mph. Terminal guidance corrections must be completed in fractions of a second. At those speeds even a tiny error can cause the interceptor to miss its target. The engineering and performance tolerances involved have no precedent in any other weapons system we have built. And when you consider the often-cited example of "hitting a bullet with another bullet," well, that is for a ground-based interceptor engaging a missile in space. This is much, much harder and is like hitting a bullet with a bullet fired from another bullet.

Missile defense is unique among weapons systems in its reliability requirement. A fighter aircraft that works 90 percent of the time would be a remarkable success. Realistic reliability rates for fighters often hover in the 40-80 percent range.[1] A space-based missile defense system that works ninety percent of the time is a catastrophic failure because the ten percent that gets through may carry nuclear warheads.

Consider what "reliable" means in this context. Each intercept attempt in a space-based system involves dozens of sequential steps: launch detection, satellite sensor acquisition, handoff to the fire control system, interceptor separation from the satellite, in-flight retargeting and guidance updates, terminal homing and then hit the target. Each step has its own probability of success. When you multiply those probabilities together, achieving even an eighty percent single-shot kill probability against a sophisticated target requires extraordinary performance at every single stage. And against a strategic strike involving dozens or hundreds of missiles, launched simultaneously or in close sequence, you have to achieve that performance repeatedly, across multiple intercepts, with no opportunity to hit the pause button and think about the shot doctrine or reconfiguring the constellation to handle systems failures or unexpected issues.

The existing Ground-Based Midcourse Defense system, our current national missile defense architecture, has a mixed test record against single, pre-announced targets with cooperative geometry and no countermeasures. A space-based system would face adversary missiles that are not cooperative, in unannounced launches and with decoys and jamming. The reliability bar for a system that must defend the continental United States against a nuclear-armed adversary is much higher than anything we have demonstrated.

Modern ICBMs do not carry a single warhead. They carry multiple independently targeted reentry vehicles, MIRVs, each capable of destroying a city. A single Russian SS-18 carries up to ten warheads. After the missile's boost phase ends, a maneuvering post-boost vehicle deploys each warhead on its own trajectory. If your interceptor misses the boost phase, one uninterrupted missile becomes ten midcourse targets.

Both Russia and China deploy sophisticated systems alongside their warheads: decoys, chaff, radar-absorbing shrouds, and maneuvering reentry vehicles. In the vacuum of space, a balloon, a piece of aluminum foil and a nuclear warhead follow identical ballistic trajectories. There is no meaningful aerodynamic drag at these altitudes to help distinguish the missile from the decoy. Finding the real warhead among a wave of decoys is an exceedingly hard problem in missile defense, and our adversaries have invested decades in making it harder. Russia's rocket forces specifically designed their ICBMs with integrated countermeasures to defeat exactly the kind of system being proposed.

A space-based intercept system capable of providing continuous coverage against the Russian and Chinese threat would require an exceptionally large constellation of purpose-built satellites,

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[1] J. A. Tirpak, "Air Force Mission Capability Rates Reach Lowest Levels in Years," *Air & Space Forces Magazine*, (February 18, 2025), https://www.airandspaceforces.com/air-force-mission-capable-rates-fiscal-2024/.

each carrying interceptors, supported by an entirely new sensor, tracking, and command-and-control infrastructure. The Congressional Budget Office has estimated that a program of this scope could exceed $1.2 trillion dollars over its full lifecycle, surpassing even the F-35 program as the most expensive weapons acquisition in American history. Given the technical complexity involved and the consistent pattern of cost growth in missile defense programs, that cost estimate is reasonable. It may, in fact, be a conservative estimate of the ultimate cost.

That cost should be weighed against the adversary's cost to defeat the system. Russia or China can add countermeasures, or develop anti-satellite weapons to degrade the constellation at a fraction of what we spend to build it. The math favors the offense. At the scale needed to stop a nuclear power like Russia or China, the United States would have to spend far more on defense. History has consistently proven this problem. It is not new and it is not a political argument; it is an engineering and economic reality.

There is also a strategic stability cost that does not appear in the defense bill or the appropriations budget, which is that both Russia and China would interpret a space-based intercept constellation as a first-strike tool, a system designed not to defend against a first strike, but to clean up the degraded counter strike from a weakened adversary after a U.S. first strike. While that is not our intent, it is a rational interpretation of the capability, and both countries could respond by expanding their offensive forces, moving towards more aggressive launch-on-warning postures, investing heavily in anti-satellite weapons and decoys and more sophisticated countermeasures. A system which delivers a level of false confidence in our safety would be destabilizing and the net effect would be a world that is less stable and more dangerous than the one we currently face.

None of this argues against missile defense research and investment. There are scenarios, such as a limited attack by a regional adversary or an accidental or unauthorized launch, where a well-designed system provides genuine strategic value at a justifiable cost. Early detection and left of launch capabilities have significant merit and call for further research and investment.

What does not make sense is committing to a full-scale space-based intercept architecture against Russia and China on the premise that it will provide a reliable defense of our nation. The physics does not support that. The reliability has not been proven. The economics does not favor the defense, and the strategic stability consequences could be severe.

Missile defense is a topic on which it is easy to be misled by the appeal of the concept. Of course, we should be able to shoot down a missile before it reaches an American city. The difficulty is that "should be able to" and "can reliably do" are separated by some of the hardest engineering problems in existence, an adversary who has spent decades designing specifically to defeat such a system, and a budget reality that has no precedent in peacetime defense spending.

A final consideration here must be diplomacy. With the end of the New START we could be heading into a new era of increasingly larger nuclear arsenals, novel delivery systems and an expanded risk of proliferation and miscalculation. The single most productive thing we could do to reduce risk is to restart negotiations with Russia and engage with China on the value of arms control, non-proliferation, and strategic stability. We have survived more than 65 years without nuclear Armageddon and there is merit in considering that the posture we were in was working. And one question in front of us isn't whether arms control and the status quo is the right answer but whether or not a trillion dollar system with low reliability accelerates the arms race.

I am happy to discuss any of this in more detail, including the classified assessments available to members of the Armed Services and Intelligence Committees in the appropriate settings. We owe all Americans and our national security an honest accounting of what this technology can and cannot do before we commit over one trillion tax dollars to a program that won't accomplish its goals or keep Americans safe.

Respectfully,

Mark Kelly

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United States Senator, Arizona