

---

Report on the American Physical Society Study of  
Boost-Phase Intercept Systems for National  
Defense

Dan Kleppner  
Professor of Physics, Emeritus  
Massachusetts Institute of Technology

Presented to the  
Lexington Computer & Tech Group

May 20, 2020



---

# PROLOGUE



---

January 1981

Ronald Reagan becomes President

Cold War was raging. Principal threat to U.S. perceived to be atomic attack by intercontinental ballistic missile (ICBM).

United States' strategy for countering ICBM threat:

MUTUALLY ASSURED DESTRUCTION: MAD!

# March 24, 1983 President Reagan addresses missile threat

## New York Times

NEW YORK, THURSDAY, MARCH 24, 1983

30 CENTS



President Reagan before his address. Photo at left shows Soviet-made MIG fighters in Cuba, White House said.

The New York Times/D. Gerton

### Late Edition

Weather: Sunny, not as cold today with diminishing winds; fair and quite cold tonight. Partly cloudy and cold tomorrow. Temperatures: today 45-50, tonight 25-30; yesterday 25-43. Details on page C23.

## REAGAN PROPOSES U.S. SEEK NEW WAY TO BLOCK MISSILES

### STRONG PLEA FOR OUTLAYS

#### He Looks to Use of Technology to Replace the Old Doctrine of Massive Retaliation

By STEVEN R. WEISMAN  
Special to The New York Times

WASHINGTON, March 23 — President Reagan, defending his military program, proposed tonight to exploit advances in technology in coming decades so the United States can develop an effective defense against missiles launched by others.

In effect, Mr. Reagan proposed to make obsolete the current United States policy of relying on massive re-

Transcript of speech, page A20.

taliation by its ballistic missiles to counter the threat of a Soviet nuclear attack.

In a television address from the White House, he coupled his proposal with his strongest appeal yet for his Administration's program to increase military spending.

## Proposal: develop space-based weapons

---

Goal: to create satellite-borne weapons capable of destroying targets anywhere on Earth at the speed of light,

Method: develop a new class of futuristic weapons such as: X-ray lasers, high power chemical lasers: neutral and charged high-energy particle beams. . . .

Program title: THE STRATEGIC DEFENSE INITIATIVE (SDI)

Commonly known as: STAR WARS

---

Public information on the new technologies was lacking.

The APS commissioned a study of SDI. Co-chairs:

Nicholas Bloembergen, Harvard University

Kumar Patel, Bell Laboratories.

Conclusion: none of the proposed SDI techniques was feasible

Reference: Rev. Mod. Phys. 59, S1 – July 1987



---

In the following decades, missile defense against ICBMS  
focused on intercepting missiles in mid course.

Two impediments stymied progress:

- Development of multiply independent targeted warheads (MIRVs) : many warheads from a single ICBM
- Ease of deploying decoys

---

November, 2000: George W. Bush elected president.

December 16, 2000 he presents his first Cabinet appointment.

Secretary of State: Colin Powell.



**THE 43RD PRESIDENT:** The Nomination

# Remarks at Announcement of Powell's Nomination as Secretary of State

Following are excerpts from remarks by President-elect George W. Bush designating General Colin L. Powell as secretary of state and General Powell's response as recorded by The New York Times.

**PRESIDENT-ELECT BUSH:** Many times during the course of my campaign I said that if all went well Gen. Colin Powell just might be called back into the service of his country. Today it is my privilege to make that call and ask him to become the 65th secretary of state of the United States of America.

Colin Powell first answered the call to duty as a lieutenant in the United States Army, where he served for 35 years. He's been a decorated infantry officer, an Army corps commander, a national security adviser, chairman of the Joint Chiefs of Staff, adviser to our last three presidents, providing good counsel, strong leadership and an example of integrity for everyone with whom he served.

His entire life has prepared him to fulfill the responsibilities that he will soon hold. General Powell is an American hero, an American example and a great American story. It's a great day when a son of the South Bronx succeeds to the office first held by Thomas Jefferson.

Much has changed since our country's early days. But the fundamental principles guiding American foreign policy are the same. Foreign policy in the coming years must serve our national interests in the world while speaking for the highest of America's ideals.

In word and deed we must be clear and consistent and confident that our values are real. And we must be true to our friends. We must conduct our foreign policy in the spirit of national unity and bipartisanship.

Our next secretary of state believes as I do that we must work closely with our allies and friends in times of calm so that we will be able to work together in times of crises. He believes as I do that our nation is best

across the years.

In this cause I've known of no better person to be the face and voice of American diplomacy than Colin L. Powell. Wherever he goes and whomever he meets, the world will see the finest of the United States of America.

In this office he follows in the footsteps not only of Jefferson but also of one of his personal heroes, Gen. George C. Marshall. And I would say of General Powell what Harry Truman said of General Marshall: He is a tower of strength and common sense. When you find somebody like that you have to hang on to him.

I have found such a man. In directness of speech, his towering integrity, his deep respect for our democracy and his soldier's sense of duty and honor, Colin Powell demonstrates the qualities that made George Marshall a great secretary of state — qualities that will make him a great representative of all the people of this country.

And so it is a great honor for me to submit the name to the United States Senate of Colin L. Powell as secretary of state.

**GENERAL POWELL:** Thank you so very, very, much ladies and gentlemen. Mr. President-elect and Mrs. Bush, Mr. Vice President-elect Cheney, ladies and gentlemen, citizens of Crawford, Tex., it's a great pleasure to be with you this afternoon and I am honored, honored to be given the opportunity to return to public service as the 65th secretary of state of the United States of America.

Mr. President-elect, I thank you for the confidence that you have placed in me and I look forward to serving you, the American people and the cause of peace and freedom around the world.

And it is a special privilege for me to once again have the opportunity to serve with Vice President-elect Dick Cheney. We have been through many adventures together and many more adventures await us in the future.

Mr. President-elect, during your administration you will be faced with many challenges, and crises that we don't know anything about right now will come along. But I believe that these challenges and these crises will pale in comparison to the wonderful opportunities that await us.

Opportunities that have been brought about by the end of the cold war, by the spread of democracy and the free enterprise system around the world



Gen. Colin L. Powell with President-elect George W. Bush yesterday.

**Questions and Answers**

**Q.** General Powell, Mideast peace proved elusive for many years. There, some preliminary talks this weekend in Washington. Will you be monitoring them? And when you become secretary of state when you're confirmed, what do you see the U.S. role. . . .

**GENERAL POWELL:** I will certainly be monitoring them. But, you know, you can't have one president, one secretary of state and one foreign policy team at a time. So although we'll be monitoring them, they're entirely in the hands of President Clinton, Dr. Albright and their team.

It is absolutely a given that under a Bush administration, America will remain very much engaged in the Middle East. I expect to be a major priority of mine and of my department. It will be based on the principle that we must always ensure that Israel lives in freedom and in security and peace. But at the same time, we have to do everything we can to deal with the aspirations of the Palestinians and other nations in the region who have an interest in this.

And so I think America will continue to be a friend to all sides. America will continue to put forward ideas. America will remain engaged until we can find that solution to this most difficult problem. But at the end of the day, it's going to be the parties in the region who will have to find that solution and come into agreement. They are going to have to live with each other.

And hopefully, in the near-future we can find ways that they can accommodate the differences and find that elusive solution. It is elusive, but it is out there somewhere. And hopefully, if it doesn't happen in the very near-future and it becomes something for you to manage, you can be sure that we'll be fully engaged in trying to find a solution to that problem.

**Q. Inaudible**

**GENERAL POWELL:** We have a different situation now than we had in 1991 and 1992. At the end of the Gulf War, the Iraqi regime agreed to the conditions that brought an end to the conflict, that they would fully account for the weapons of mass destruction and other evil technologies that they were working on. They have not yet fulfilled those agreements.

And my judgment is that the sanctions in some form must be kept in place until the

*I would say of General Powell what Harry Truman said of General Marshall: He*

---

From Powell's comments:

“The President-elect has made a commitment to national missile defense. I have watched the debates for national missile defense for many, many years, and I think a national missile defense is an essential part of our overall strategic force posture . . .”

---

The Administration's strategy was called  
Boost Phase Intercept (BPI)

Little was known about BPI but the NY Times had  
published a short article on **July 17, 2001**

*Advantage*

The missile is intercepted in the boost  
phase when it is moving relatively slowly and before  
it can launch decoys

*Disadvantage:*

It must be deployed quickly, leaving  
no time to call Washington.

---

Other public information about BPI: essentially NONE

In the spring of 2002 the American Physical Society commissioned a study of the feasibility of BPI. The study was on the *technical* issues involved. The report was published in 2004.



# Boost-Phase Intercept Systems for National Missile Defense

---

## American Physical Society Study Group

**Daniel Kleppner, Co-Chair**  
*Massachusetts Institute of Technology*

**Frederick K. Lamb, Co-Chair**  
*University of Illinois*

Reference to full report  
D. K. Barton *et al.*, Rev. Mod. Physics 76, S1 (2004)



# American Physical Society Study of Boost-Phase Intercept Systems

---

## Study Group

- David K. Barton, New Hampshire
- Roger Falcone, University of California, Berkeley
- Daniel Kleppner, M.I.T. (co-chair)
- Frederick K. Lamb, U. of Illinois (co-chair)
- Ming K. Lau, Sandia National Laboratory
- Harvey L. Lynch, SLAC
- David Moncton, Argonne National Laboratory
- David Montague, LDM Associates
- David Mosher, RAND, Washington
- William Priedhorsky, Los Alamos National Laboratory
- Maury Tigner, Cornell University
- David E. Vaughan, Rand, Santa Monica
- (Ref. Rev. Mod. Phys., 76, S425, 2004)



# Ballistic Missile Basics

---

Short and intermediate range, < 5,500 km

Intercontinental range (ICBM), > 5,500 km

## Types of ICBMs

Liquid-propellant, burn time 4-5 minutes

Solid-propellant, burn time 2-3 minutes

# Boost-Phase Intercept Systems Studied

---

- Kinetic-kill weapons based on land, sea and air
- Kinetic-kill weapons based on satellites



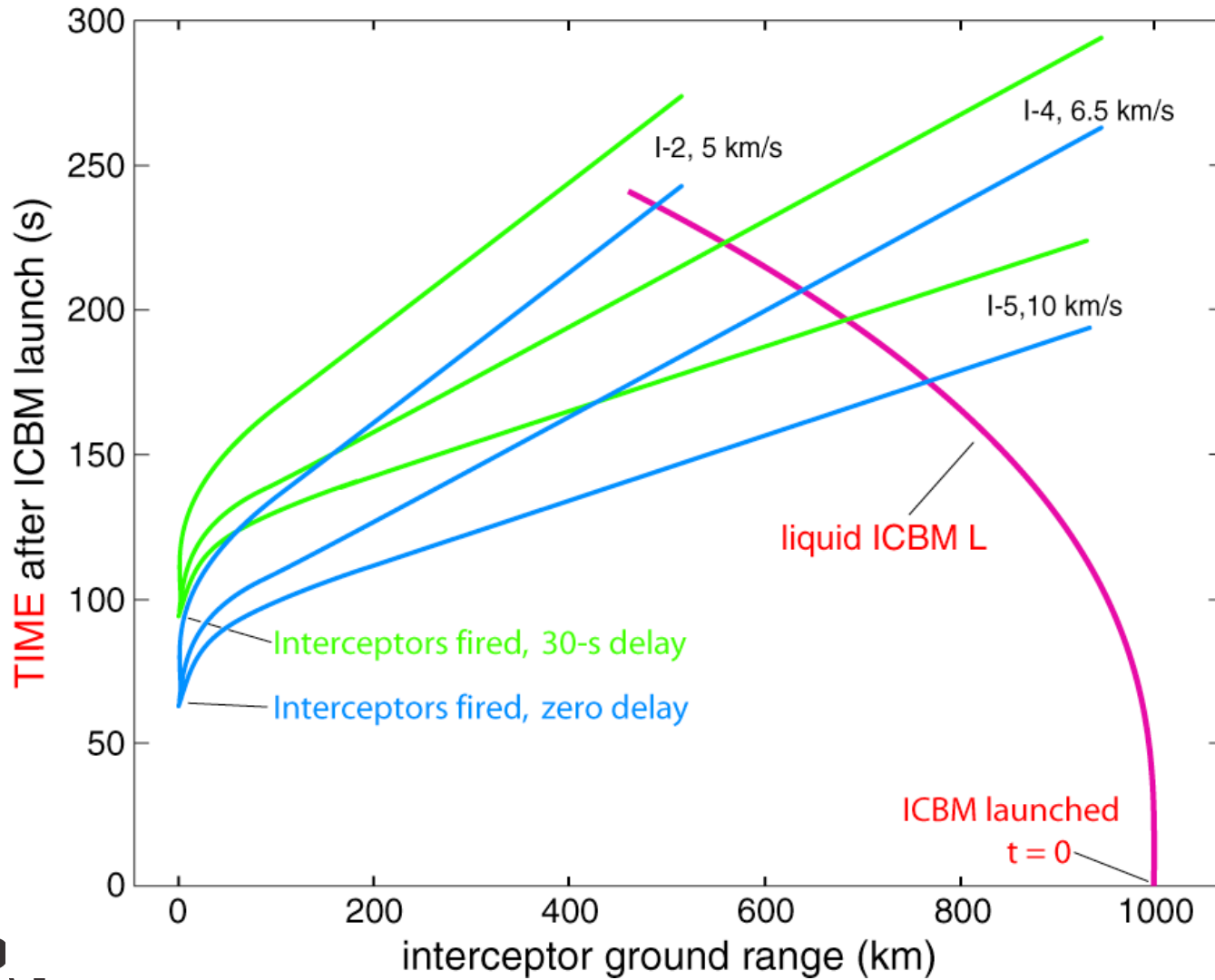


# Global Geography Determines the Chance to Intercept

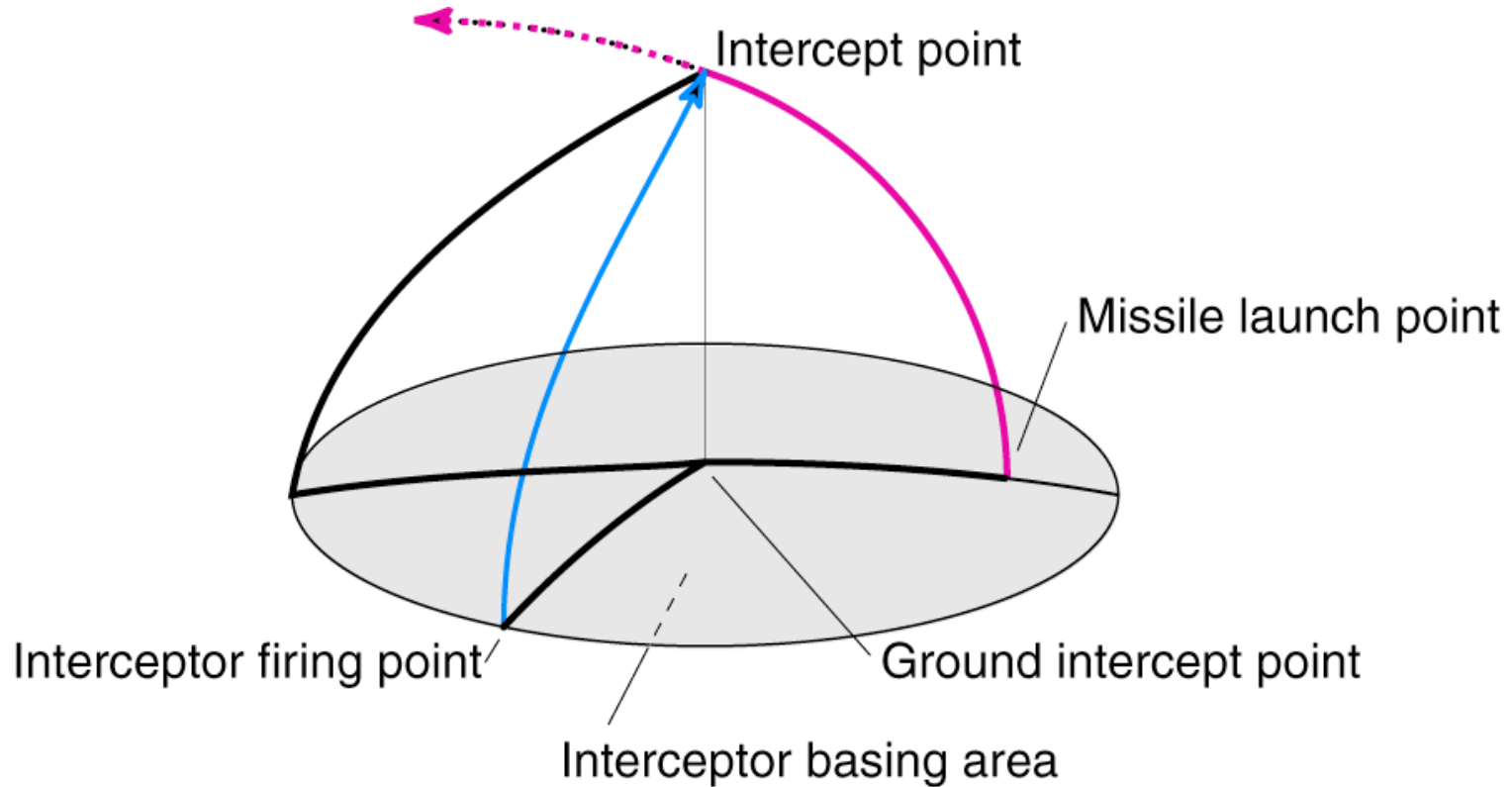
Liquid-propellant ICBM from North Korea



# Visualizing the Intercept

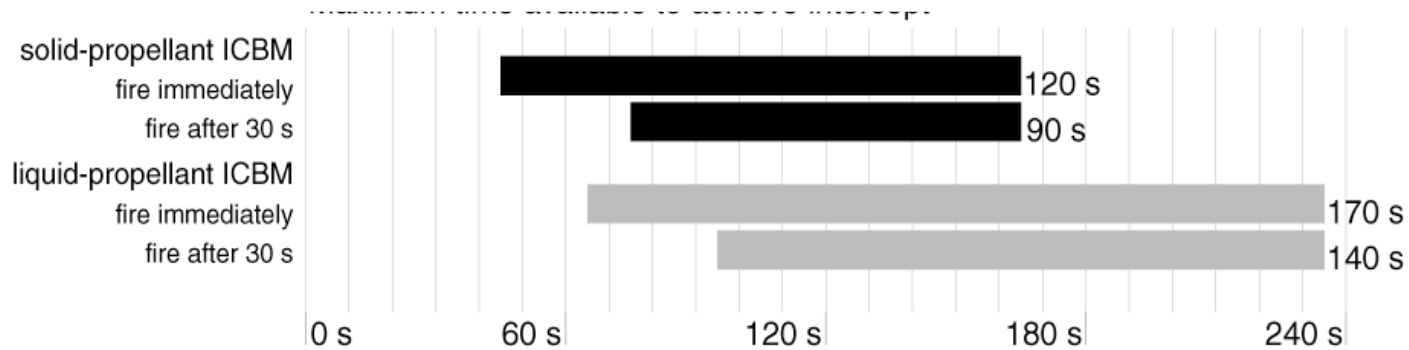


# Visualizing the Intercept



# Time is the Crucial Factor for BPI

Maximum time to intercept in boost phase



Approximate timelines for intercepting missiles to the U.S. from N. Korea or Iran

# Key Issues for Boost-Phase Intercept

---

ICB boost phases are short  
defense has little time to decide  
interceptors have little time to reach target

ICBMs in powered flight accelerate unpredictably:  
burn variations, programmed evasion;

Geographical constraints require high interceptor speeds  
intercept points in North Korea and Iran are likely  
to be 400km and 1000km from intercept point.

# The Study Group's Approach

---

Adopted threat estimates in recent National Intelligence Estimates and Congressional testimony by NIC staff

Made generally optimistic assumptions

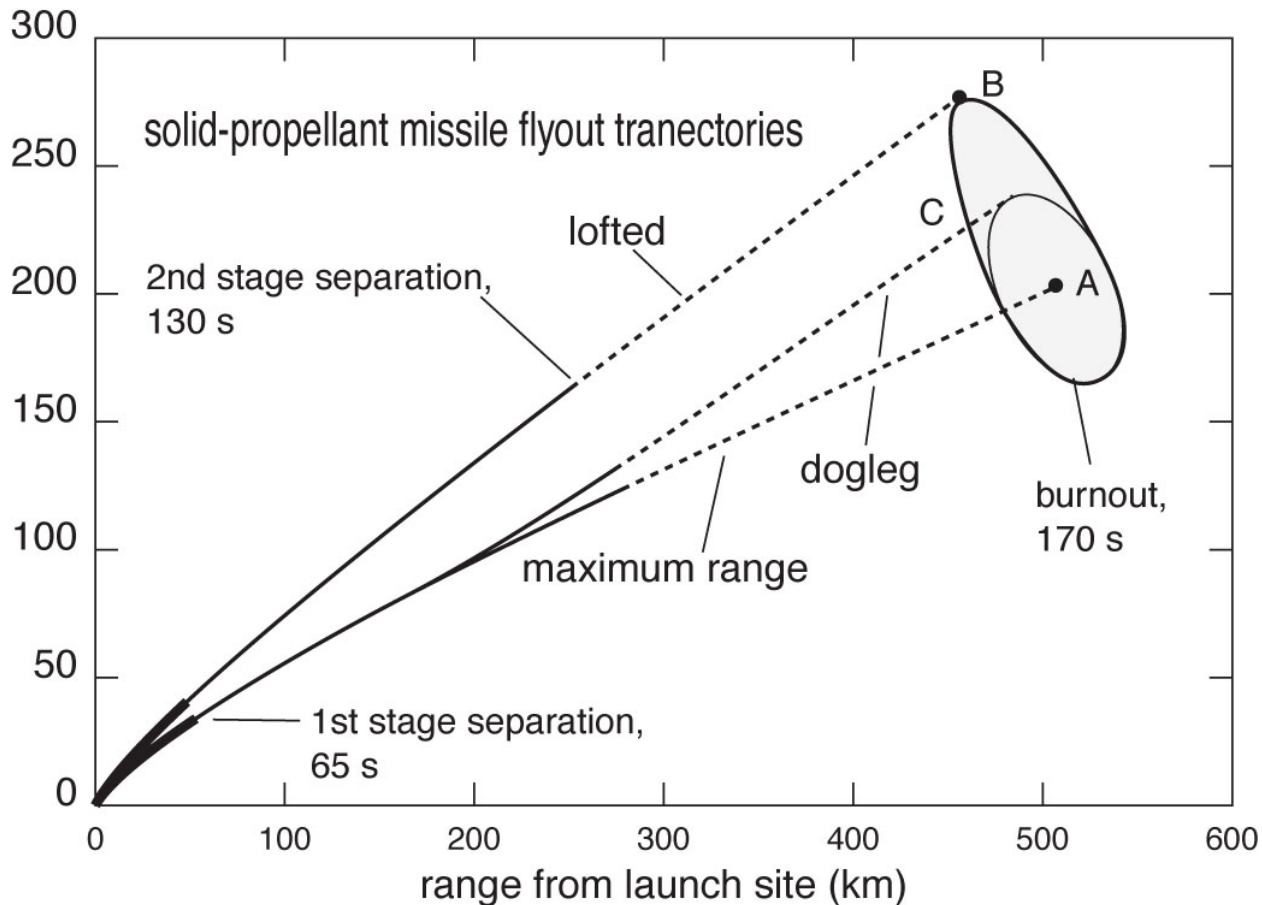
- Assumed defenders would have technologies developed in 10 years
- Set aside battle management, communications, counter measures, etc.

Constructed computer models of missiles, missile tracking systems, interceptors and kill vehicles.

Carried out simulations to determine required performance.

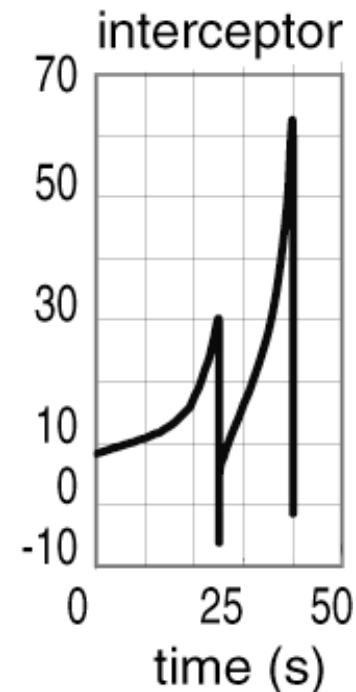
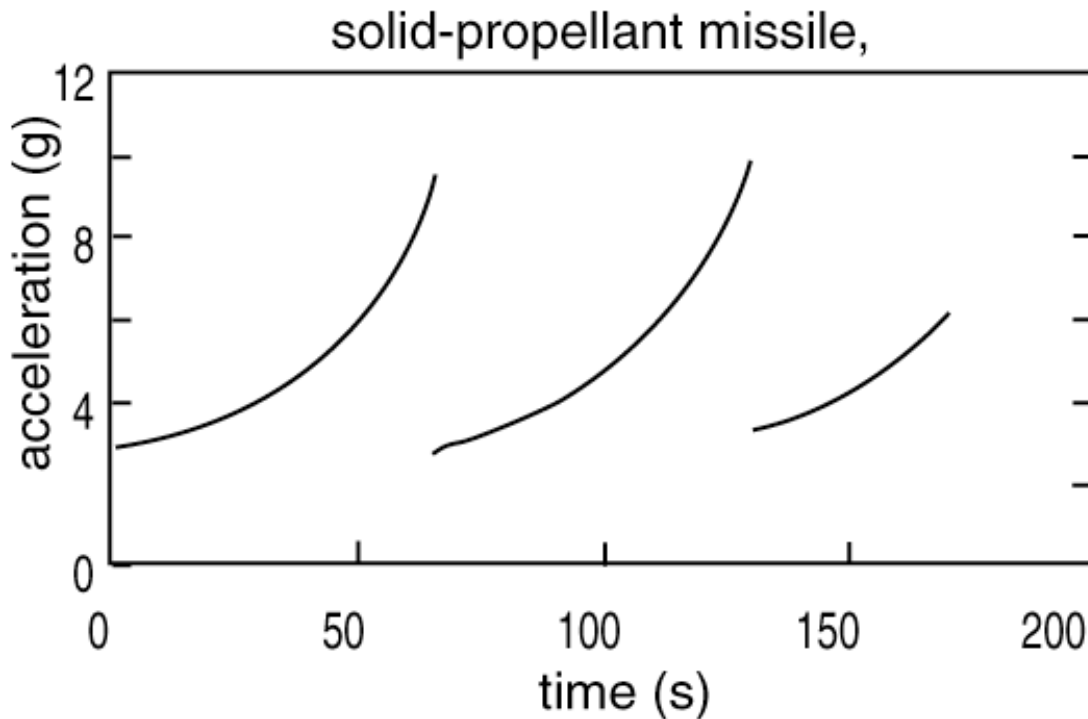
# ICBMs Fly in Unpredictable Ways

## Possible flyout trajectories for solid-propellant missile



# Interceptors Must Accelerate Much Faster Than Missiles

## acceleration profiles





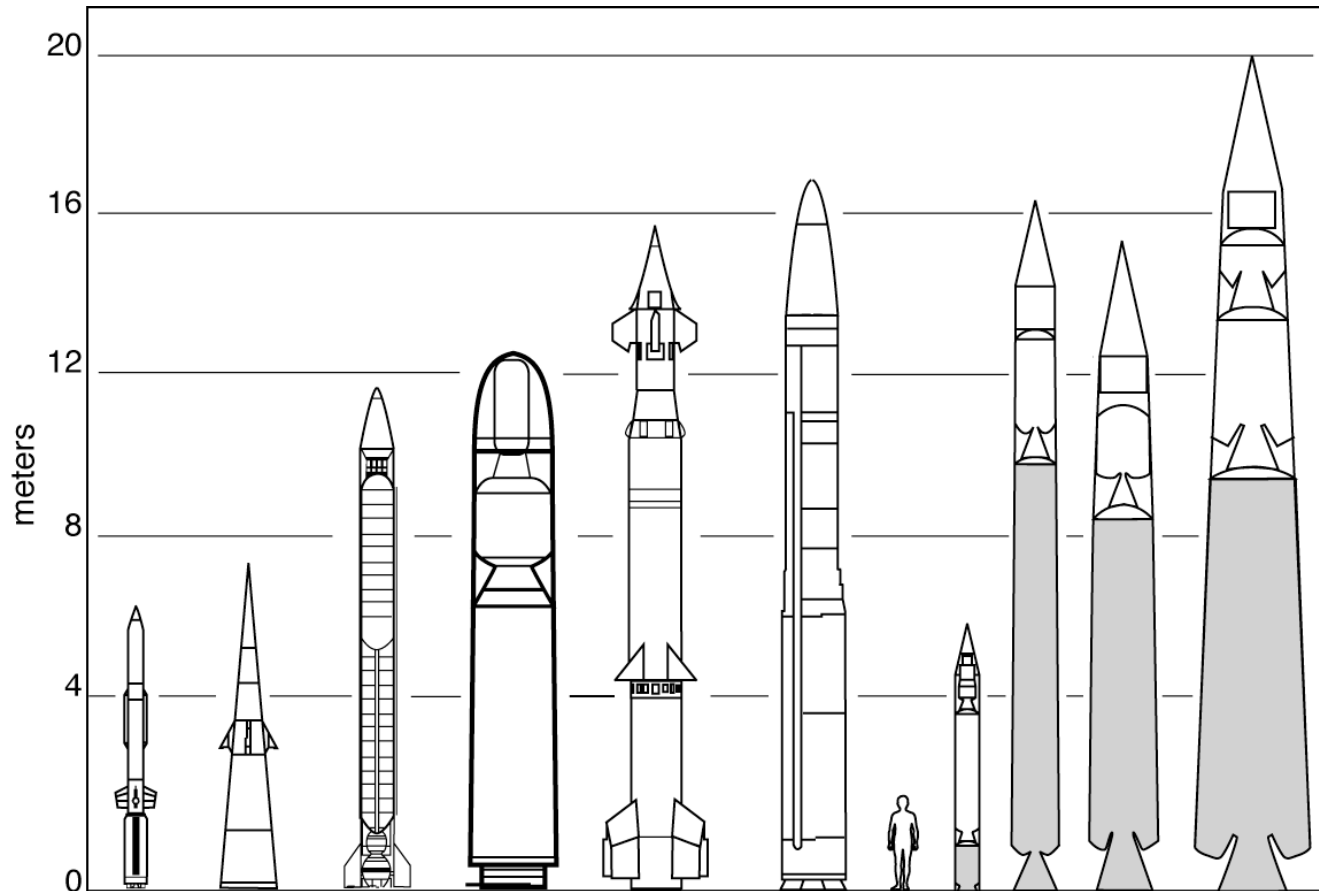
# Hitting the ICBM Requires Highly Capable Kill Vehicles

---

- **The kill vehicle must have**
  - **Passive infrared, optical, and UV sensors**
  - **Active sensors such as LIDAR**
  - **Adequate total divert capability (2.0 to 2.5 km/s)**
  - **Sufficient acceleration for the endgame (15 g)**
  - **Fast guidance and control and quick dynamic response (0.1 s or less total lag)**
- **Kill vehicles with these capabilities would be relatively heavy (90–140 kg)**

# Reaching the Target Demands

## Large, Fast Interceptors



Navy	Upper Tier	Sprint	Al-Hasseini	D-5	Trident II	Spartan	LGM-30	Minuteman III	I-2	I-3	I-4	I-5
	1.4 tn	3.4 tn	6.4 tn	59 tn	13 tn	32 tn			2.3 tn	15 tn	17 tn	66 tn

5 km/s    6.5 km/s    10 km/s

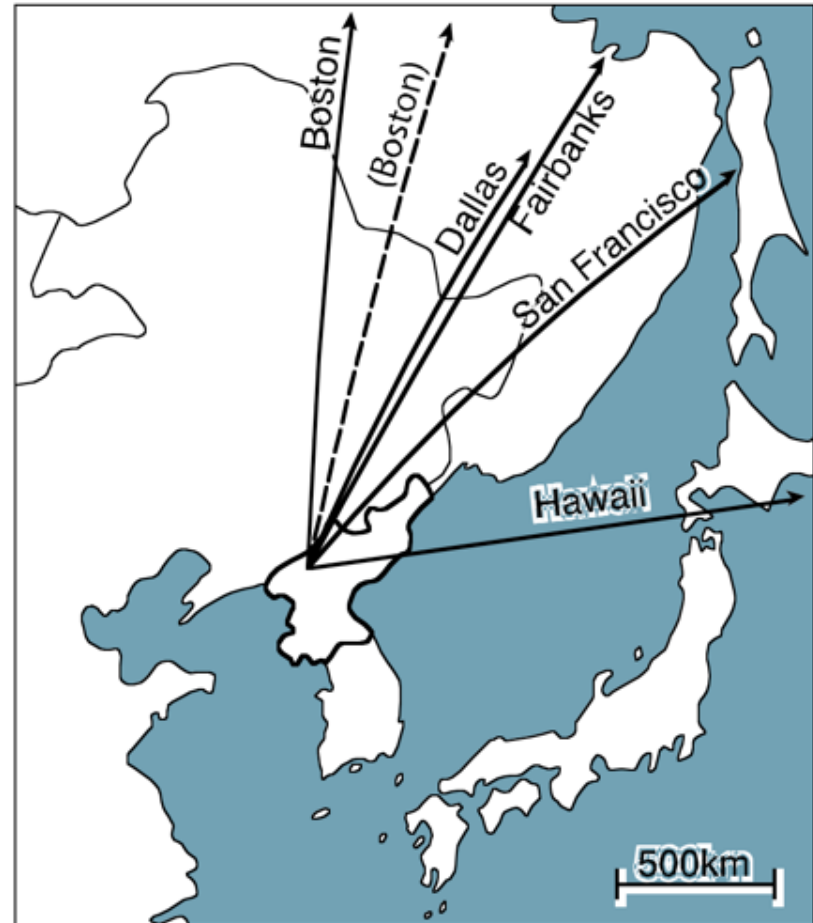
# Implications of Time Constraints

---

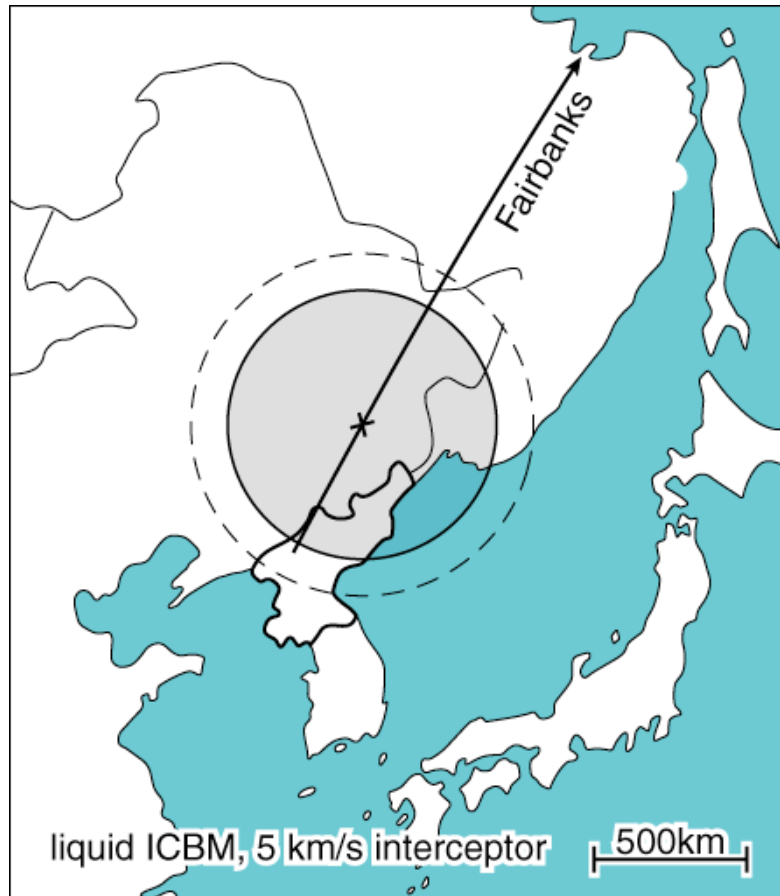
**The very short time available to complete the intercept poses significant command-and-control issues—**

- There would generally be too little time to determine whether the rocket is an attacking ICBM, a theater ballistic missile, or a rocket launching a satellite**
- Consequently, interceptors would have to be fired whenever a large rocket in powered flight is detected, without waiting until the nature of the rocket or its trajectory is established**

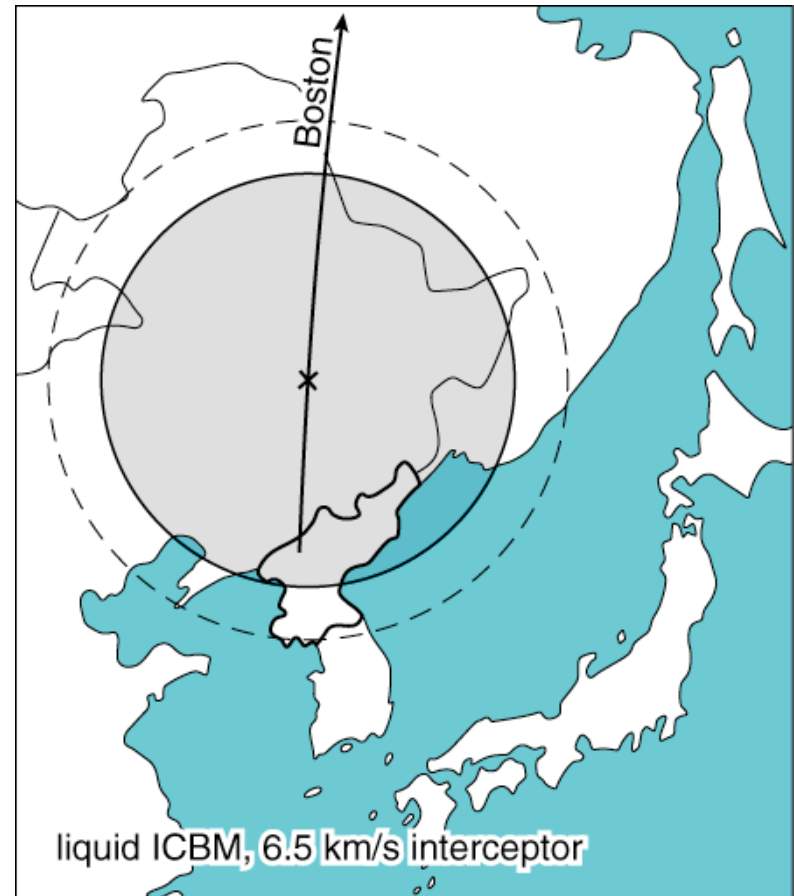
# Azimuths from North Korea to the U.S.



# Regional Geography Determines How Close Interceptors Could Be Based



Liquid-propellant ICBM from North Korea to Fairbanks

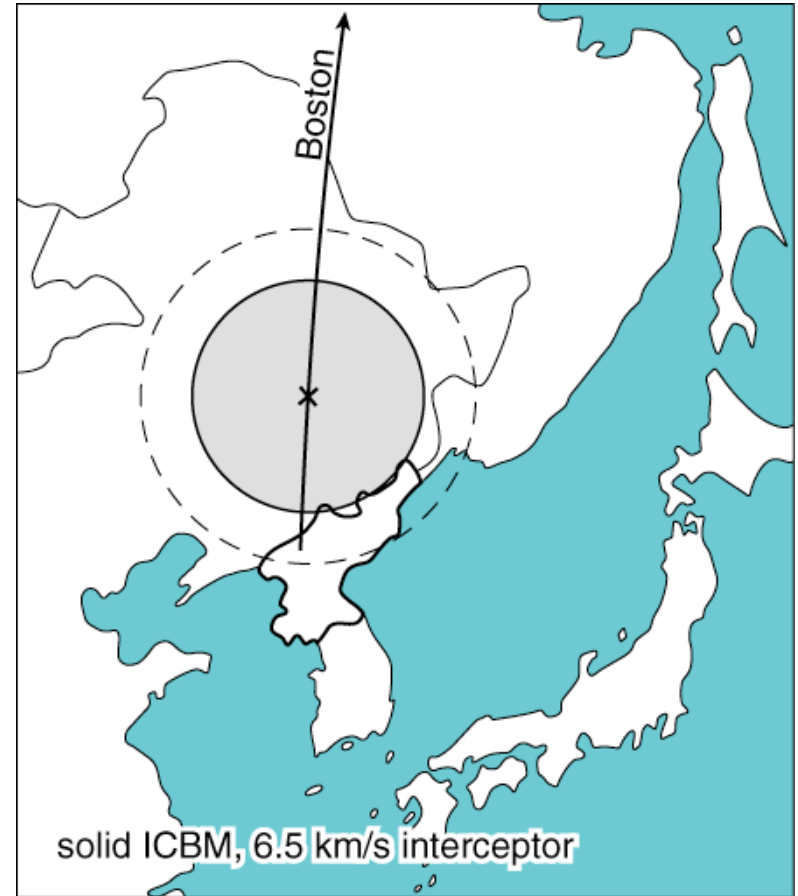


Liquid-propellant ICBM from North Korea to Boston

# Regional Geography Determines How Close Interceptors Could Be Based

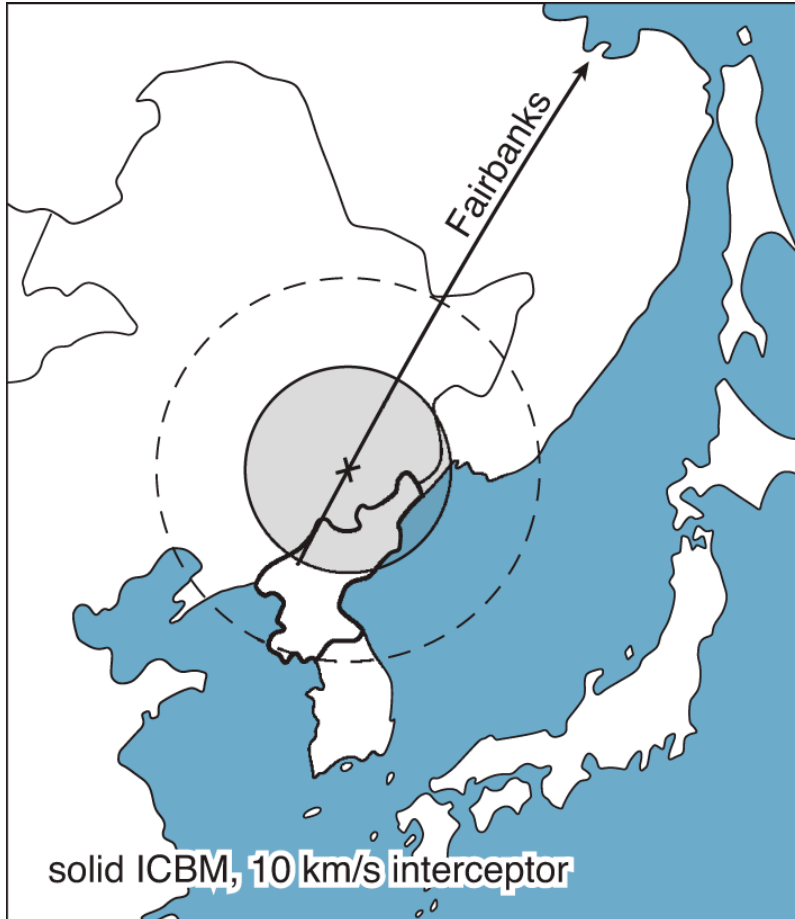


**Solid-propellant ICBM from  
North Korea to Fairbanks**

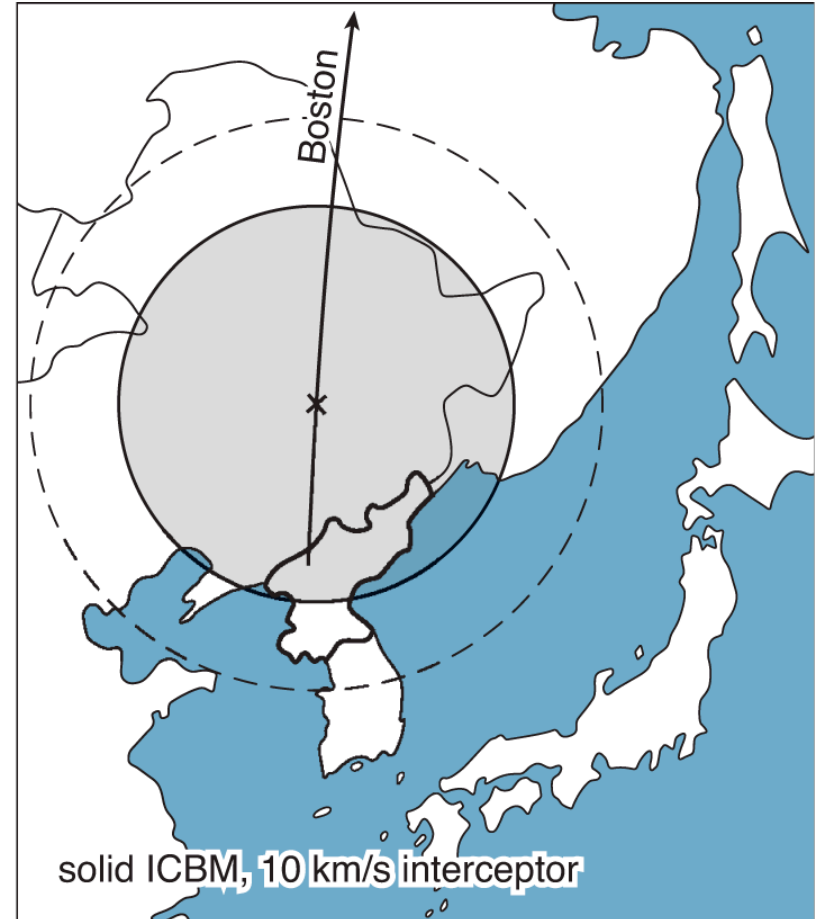


**Solid-propellant ICBM from  
North Korea to Boston**

# Regional Geography Determines How Close Interceptors Could Be Based



**Solid-propellant ICBM from  
North Korea to Fairbanks**



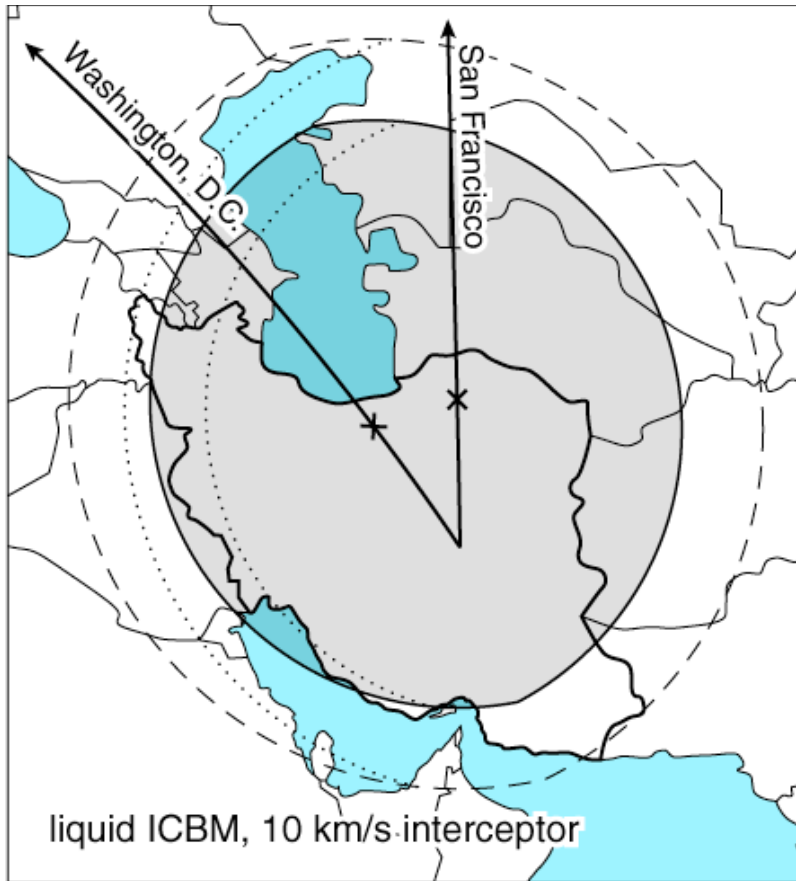
**Solid-propellant ICBM from  
North Korea to Boston**

# Iran and Surrounding Countries

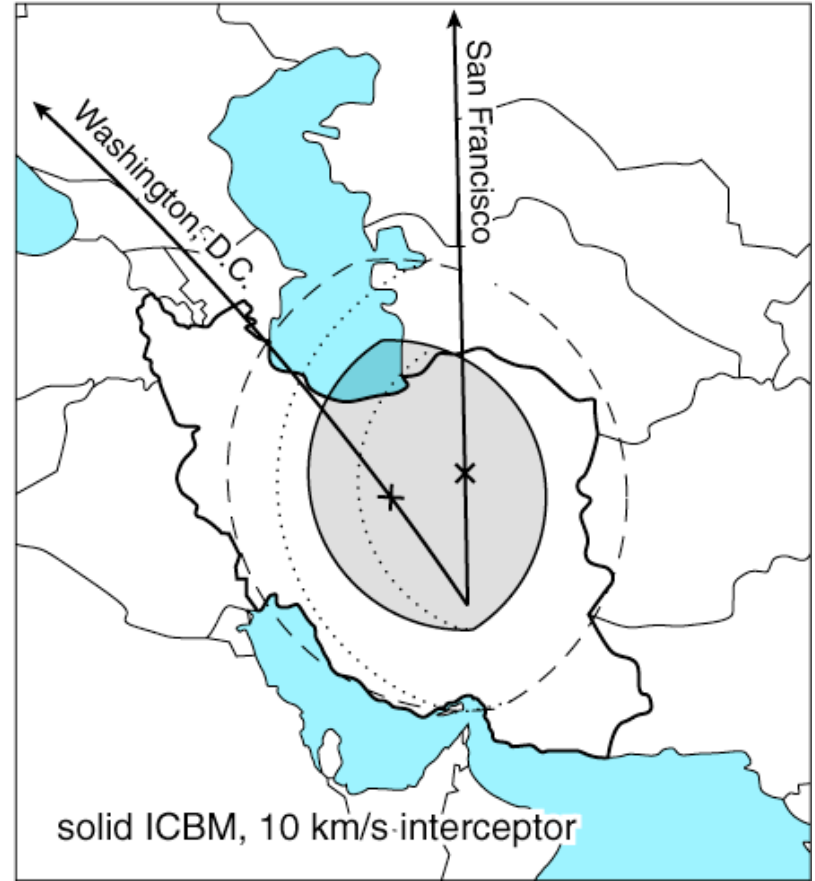




# Regional Geography Determines How Close Interceptors Could Be Based

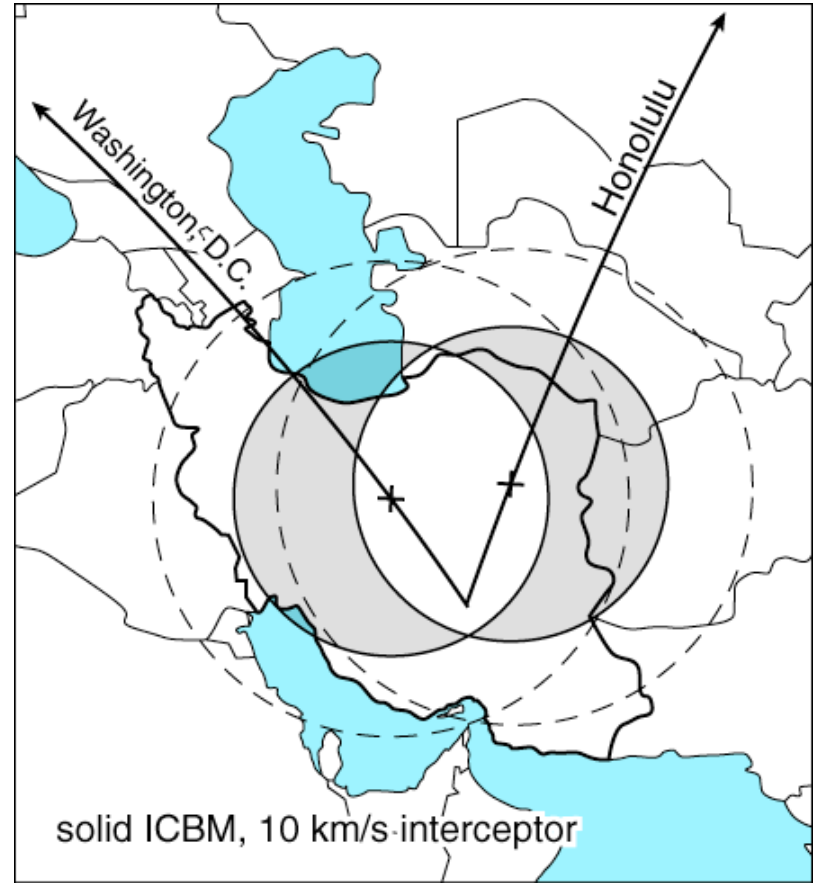
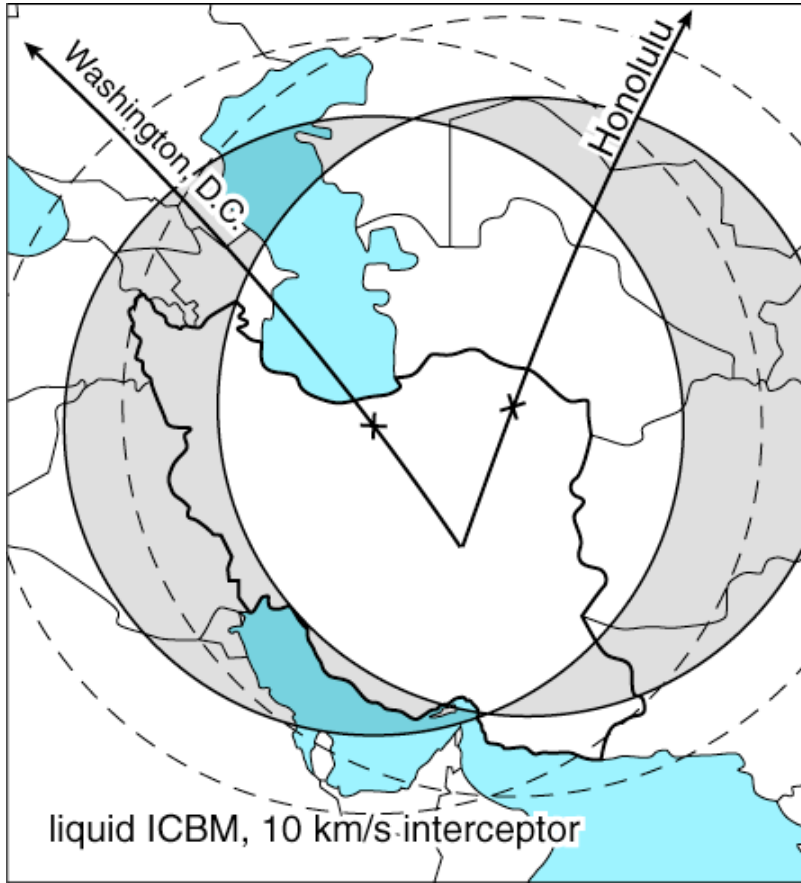


**Liquid-propellant ICBM from Iran  
to the Lower 48 States**



**Solid-propellant ICBM from Iran  
to the Lower 48 States**

# Regional Geography Determines How Close Interceptors Could Be Based



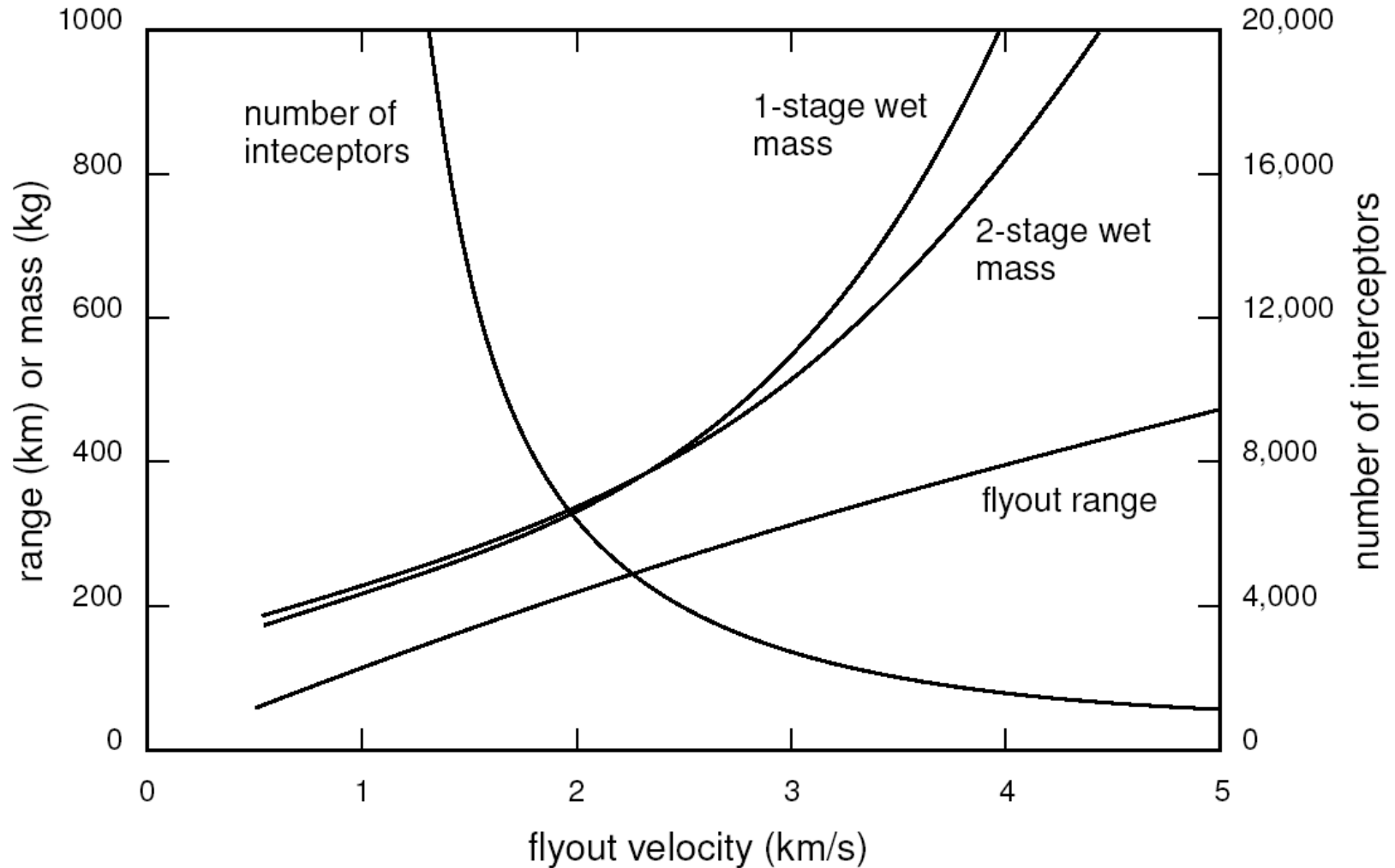
Defense **with** two interceptor launching sites

# Boost-Phase Intercept Defense Using Space-Based Interceptors

---

- A system of interceptors based on satellites could potentially defend the U.S. against missiles launched from *anywhere* on Earth.
- Such a system could also defend the U.S. against unauthorized or accidental missiles launches.

# BPI Mass, Range, and Constellation Size as Functions of Flyout Velocity



# Space-Based BPI

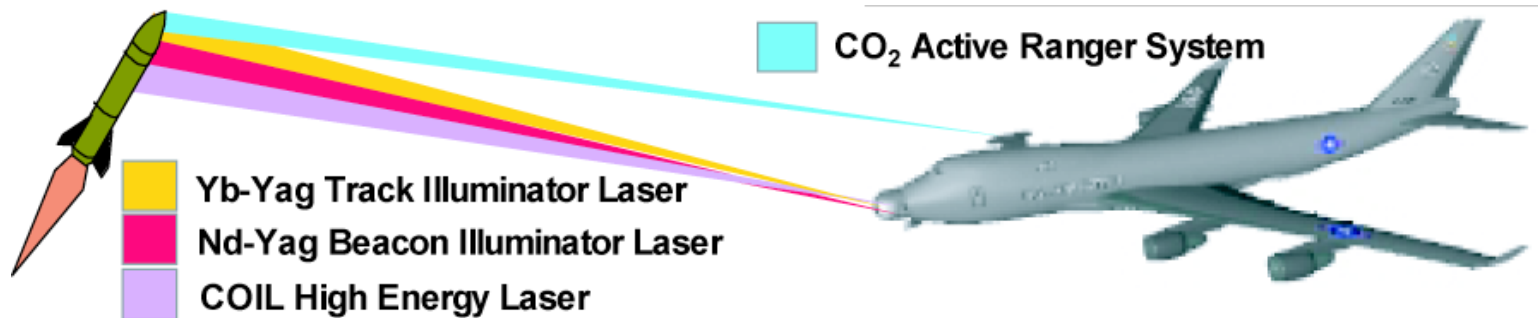
---

A space-based BPI system would require a huge number of satellite-based interceptors.

Defense against solid rocket missiles would require at least 1,600 interceptors, each at 840 kg, for a minimum mass in orbit of 2,000 tonnes.

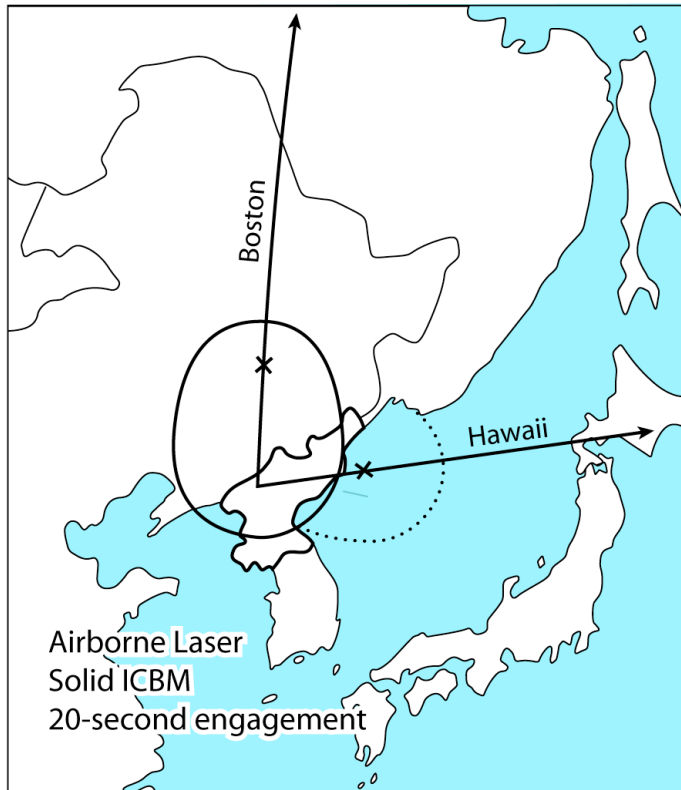
This mass would require a 5- to 10-fold increase in annual U.S. space launch capability

# Boost-Phase Intercept Defense Using the Airborne Laser

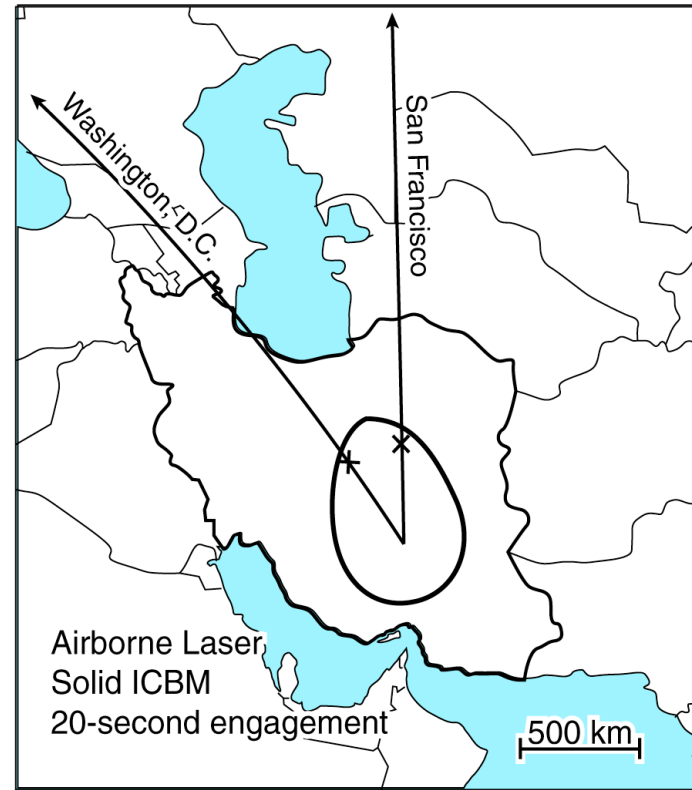


# The Airborne Laser Would Have Limited Range Against ICBMs

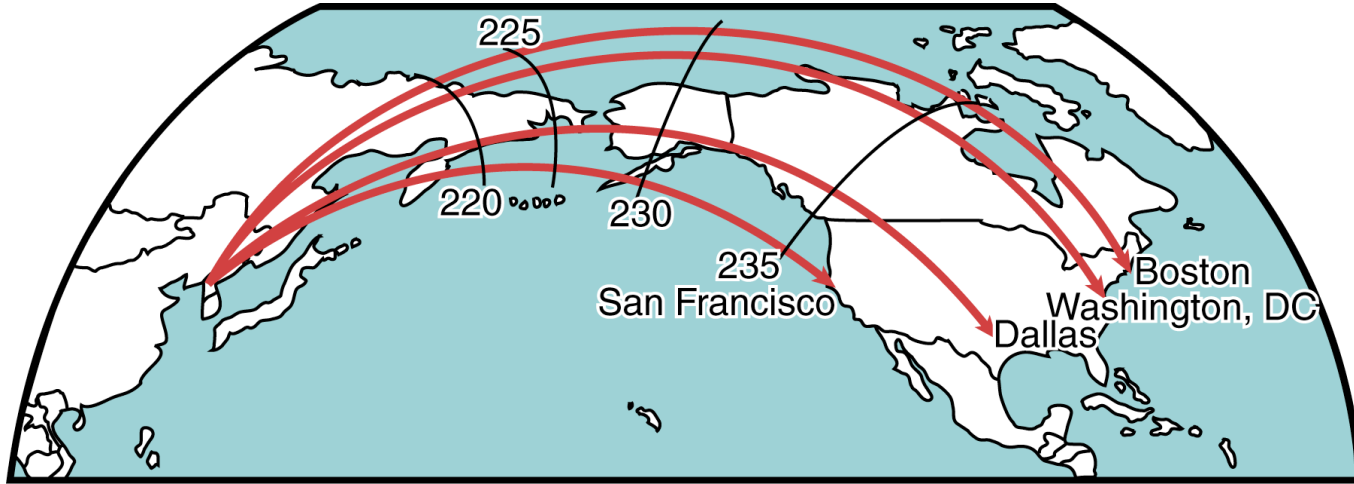
## Solid-propellant ICBM from North Korea



## Solid-propellant ICBM from Iran



# Shortfall Would Be Difficult to Manage





# Countermeasures to Boost-Phase Intercept

---

There are countermeasures for *all* defense systems.

For BPI, the leading countermeasure is to launch a salvo of ICBMs

# Release of the Report

---

The Missile Defense Agency was briefed before public release

The report was released early in 2004



# Possible impact of APS Study

---

(excerpt from)

## The Washington Times

[www.washingtontimes.com](http://www.washingtontimes.com)

---

### Changing the guard on missile defense

By James T. Hackett

Published July 28, 2004

---

For the longer term, Congress is skeptical about the course the Missile Defense Agency plans to follow. The Senate cut \$252 million from the \$511 million request to develop a very high-speed interceptor for a future boost-phase intercept capability known as the Kinetic Energy Interceptor (KEI). There is a growing realization this long-term project will absorb too much of the missile defense budget in future years and turn agency focus from deploying defenses to costly futuristic technologies.



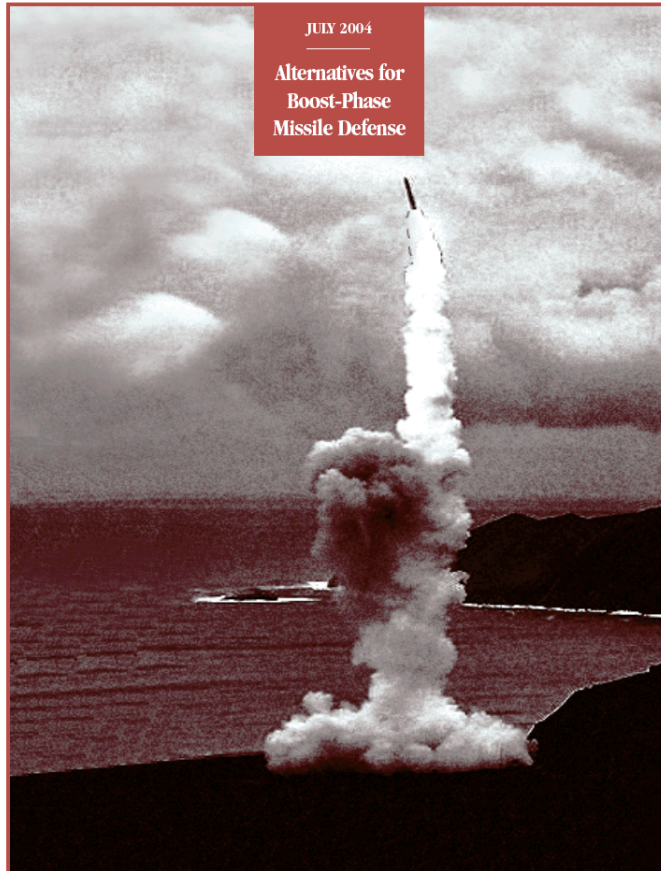
# CBO STUDY, July, 2004

CONGRESS OF THE UNITED STATES  
CONGRESSIONAL BUDGET OFFICE

A  
CBO  
STUDY

JULY 2004

Alternatives for  
Boost-Phase  
Missile Defense



# CBO STUDY, July, 2004

---

## Differing conclusions about defense against liquid-propellant missiles

**CBO: optimistic about defense of Iran using ground sites in Iraq and Turkmenistan**

**APS: defense of liquid-propellant missile possible, but cautions about need for base in “unusual locations”**

## Differing conclusions about defense against solid-propellant missiles

**CBO: no discussion**

**APS: defense not possible**

# Comments from the Physics Community

---

## Physics Today, July 2004, letters on the study

**Dean Wilkening: feasibility of N. K. defense with airborne interceptors**

**Richard Garwin: possibility of zero decision time**

**feasibility of early warning radar**

**usefulness of a limited missile defense system**

**Michael Levi: suggestion of firing salvo of interceptors immediately,**

**without waiting to obtain tracking information**

**Trueman Hunter: report exaggerates difficulties**

# Epilogue: 2020

---

Nuclear deterrence today



The time-honored strategy MAD!

---

**End of Presentation**

