Physics/Global Studies 280: Session 14

Plan for This Session

Questions

News

Module 5: Nuclear Weapon Delivery Systems

The Washington Post *Democracy Dies in Darkness*

Decades after Chernobyl, war raises nuclear fears in Ukraine

International Atomic Energy Agency plans an emergency meeting Wednesday, as an expert notes, 'We've never seen a full-scale war in a country that operates nuclear facilities'

The International Atomic Energy Agency announced it would convene an emergency meeting Wednesday as fighting closed in on the largest of Ukraine's functioning nuclear plants.

Six of the country's 15 reactors have been disconnected from the electricity grid to reduce cooling needs, according to the State Nuclear Regulatory Inspectorate of Ukraine. The 15 Soviet-era reactors had provided half of the nation's electricity in normal times.

Both sides vied for control of Ukraine's biggest nuclear power complex Monday. Russia's Defense Ministry was quoted in state-run media as saying its forces had taken control of "the territory around" the nuclear power complex in Zaporizhia. "The plant personnel are continuing to service the site and control the radioactive situation as usual. Background radiation levels are normal," the defense ministry said.

However, Ukraine's state-owned firm Energoatom said the Russian claim was false. The International Atomic Energy Agency said that "additional information" from the operator of the reactors confirmed Russian forces were "operational near the site but had not entered it."

“It is extremely important that the nuclear power plants are not put at risk in any way,” said the IAEA’s director general, Rafael Mariano Grossi. Without naming the catastrophic Chernobyl accident, which took place four decades ago, Grossi said that “an accident involving the nuclear facilities in Ukraine could have severe consequences for public health and the environment.”

The Zaporizhia complex, 140 miles up the Dnieper River from the Black Sea, has six reactors, more than any other location in Ukraine’s nationwide fleet. Three of those are among the reactors disconnected from the grid.

Nuclear experts also said they feared fighting might accidentally damage the pools used for cooling spent fuel, posing a greater danger than any potential threat to the well-constructed vessels designed to protect the reactors’ cores. The open pools, which resemble regular swimming pools, are inside buildings that are not as robust as other structures.

“The largest radioactive inventories remain the spent fuel pools,” said Mycle Schneider, a Paris-based consultant and a member of the International Panel on Fissile Materials.

Operators often disconnect reactors to reduce the amount of heat they generate. Frank von Hippel, a senior research physicist and professor of international affairs emeritus at Princeton University’s program on science and global security, said that “when a reactor is operating, each ton of fuel is generating about 30 megawatts of heat.” Disconnecting it decreases the generated heat to about 300 kilowatts, lowering the required amount of cooling water by a factor of a hundred.

But disconnecting reactors from the electricity grid does not guarantee safe conditions and does not the need for electrical power, experts cautioned. If the grid is damaged or fails, the reactors must turn to standby diesel generators.

“All reactors need power to stay safe. That does not stop with the disconnection from the grid,” Schneider said. “Residual heat remains enormous in the core.”

The IAEA said Sunday that missiles hit the site of a radioactive waste disposal facility in Kyiv overnight, but there were no reports of damage to the building or any indications of a release of radioactive materials, Grossi said in a statement. Staff members at the facility were forced to take shelter during the night.

The incident came a day after an electrical transformer at a similar facility near the northeastern city of Kharkiv had been damaged, but there were no reports of a radioactive release. “Such facilities typically hold disused radioactive sources and other low-level waste from hospitals and industry,” the IAEA said.

Nonetheless, Grossi said, “these two incidents highlight the very real risk that facilities with radioactive material will suffer damage during the conflict, with potentially severe consequences for human health and the environment.” He said that “once again, I urgently and strongly appeal to all parties to refrain from any military or other action that could threaten the safety and security of these facilities.”

Module 5: Delivery Systems

Part 1: Overview of nuclear weapon delivery methods

Part 2: Aircraft

Part 3: Cruise missiles

Part 4: Ballistic missiles

Part 5: Technical and operational aspects

Part 6: Nuclear command and control

Part 1: Overview

Basic Propulsion Mechanisms

- None
  (examples: mines, depth charges)
- Explosives
  (example: artillery shell)
- Propellers
  (example: torpedo, speeds ~ 50 mph)
- Jet engines
  (example: bomber, speeds ~ 600 mph)
- Rocket motor
  (example: missile, speeds ~ 18,000 mph)
- Unconventional
  (examples: barge, boat, Ryder truck, backpack, shipping container)

Examples of Weapon Delivery Methods

Air-breathing vehicles —

- Aircrafts (manned)
- Cruise missiles (unmanned aircraft)

Rocket-propelled vehicles —

- Land-based ballistic missiles
- Submarine-based ballistic missiles
- [Surface ship-based ballistic missiles]*
- [Space-based ballistic missiles]*
- Short range rockets (no guidance)

Other —

- Artillery/howitzers
- Land mines
- Torpedoes

* Never deployed by US or USSR/Russia for nuclear weapons

Important Attributes of Delivery Systems

- Range
- Speed
- Accuracy
- Recallability
- Reliability
- Payload/throw-weight
- Ability to penetrate defenses
- Survivability (at deployment base)
- Capital and operational costs
- Safety

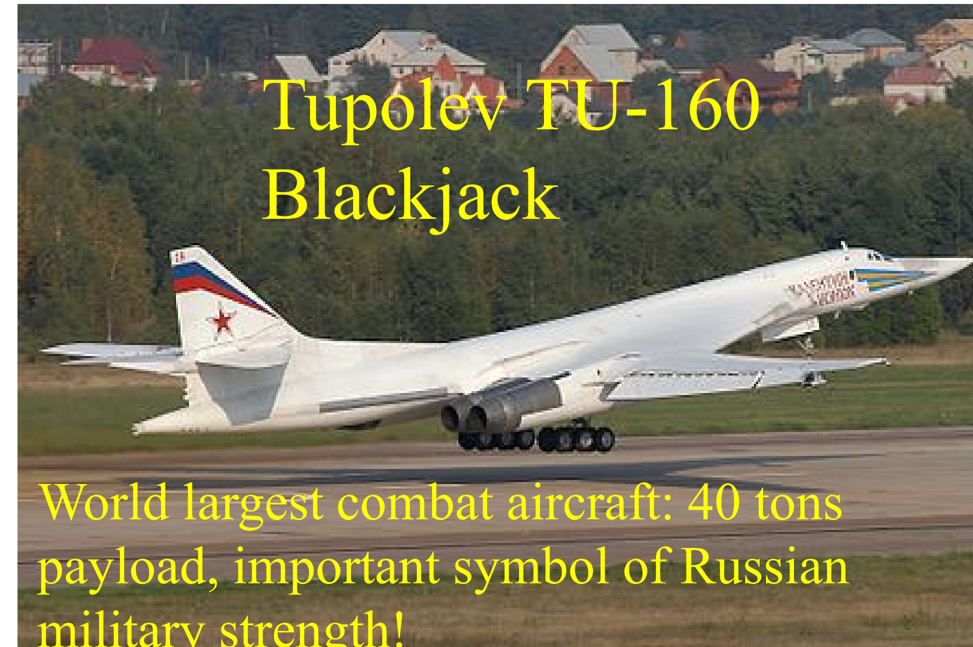
Air-Breathing Vehicles

Aircraft (manned) —

- Long-range (“heavy”) bombers
  (examples: Bear, Blackjack, B52, B-1, B-2)
- Intermediate-range bombers
  (examples: B-29, FB-111, …)
- Tactical aircraft
  (examples: F-16, F-18, F-22, …)

Cruise missiles (unmanned) —

- Air-launched cruise missiles (ALCMs)
- Sea-launched cruise missiles (SLCMs)
- Ground-launched cruise missiles (GLCMs)



Rocket-Powered Vehicles

Land-based ballistic missiles —

- Intercontinental-range ballistic missiles (ICBMs)
- Shorter-range ballistic missiles

Sea-based ballistic Missiles —

- Submarine-launched ballistic missiles (SLBMs)
- Surface-ship-launched ballistic missiles

Historical Examples of Other Nuclear Weapon Delivery Methods

Nuclear artillery shells:

- 16” naval guns
- 280 mm cannons (howitzer)

"Atomic Annie" 1953: 15-kt projectile to range of 17 miles

Operation Upshot/Knothole (1953)

Davy Crocket Nuclear Bazooka

- 76 lb., 10–250 t yield, 1.2–2.5 mile range
- Deployed 1961–1971; 2,100 produced

Atomic Demolition Munitions (ADMs)

Carried by back pack, 0.01 kt yield?

Nuclear-armed torpedoes

The U.S. Cold-War Strategic “Triad” – 1

Initially US nuclear weapons delivery systems were developed without an overall coherent plan, in the —

- Truman administration
- Eisenhower administration

Robert McNamara as President Kennedy’s Secretary of Defense changed this:

- Survivable basing
- Secure command and control
- Determine how much is enough by calculation!

    Concluded 400 ‘effective’ megatons (EMT) would be “enough”

- The need to organize the roles for the USAF and the USN defined the “Triad” paradigm
- Established the SIOP (Single Integrated Operational Plan) for targeting

The U.S. Cold-War Strategic “Triad” – 2

Strategic nuclear delivery vehicles (SNDVs) —

The definition of “strategic” nuclear weapons was important for arms control but was controversial during the Cold War: the Soviet Union wanted to count weapons on its periphery whereas the U.S. did not want to count these:

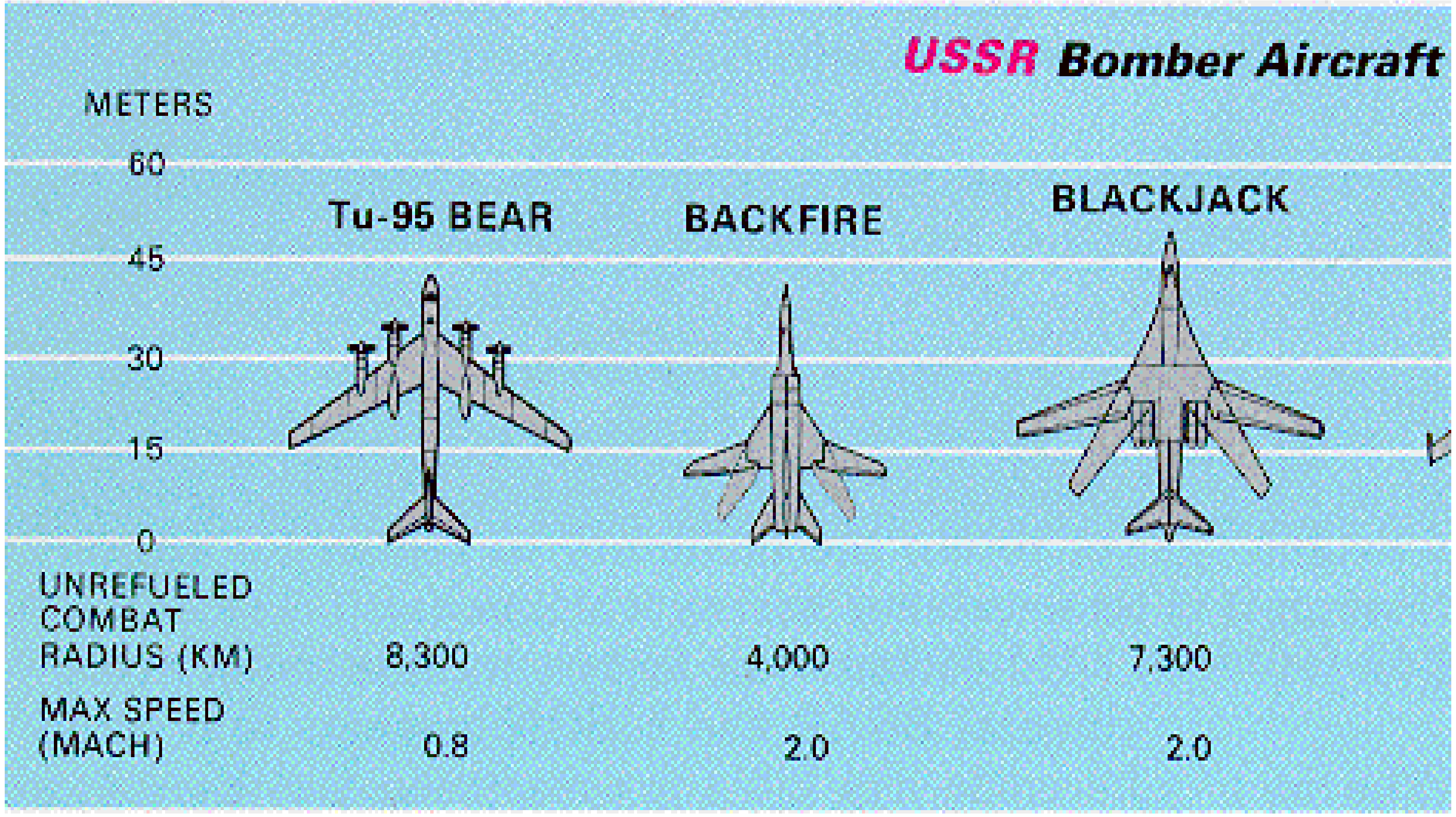
- Systems with intercontinental range (U.S. def.)
- Systems able to strike directly the homeland of the adversary (Soviet def.)

Systems in the Triad —

- Intercontinental-range bombers
- Intercontinental-range ballistic missiles (ICBMs)
- Submarine-launched ballistic missiles (SLBMs)

Part 2: Aircraft

Examples of Intercontinental Bombers – 1



Tu-95	Tu-22	Tu-160
65	160	16

Examples of Intercontinental Bombers – 2

U.S. B-2 Stealth Bomber

Speed: Mach 0.85

Altitude: 50,000 feet

Range: 7,000 miles
Refuel: 11,500 miles

Possible payloads:
• 16 B83 gravity bombs
• 20 B61 bombs
• 80 500 lb bombs

# of B-2s 20

Currently Deployed U.S. and Russian Bombers

Current US bombers —

- B-52 carrying bombs, or cruise missiles
- B1 carry conventional armament
- B-2 each can carry 16 B83 bombs

Russian bombers* —

- Bear carrying bombs
- Blackjacks carrying bombs

*few are currently operational

Intercontinental Bomber Issues

Evolution of bomber missions —

- High-altitude bombing
- Low-altitude penetration and bombing
- As a stand-off launch platform for Air-launched cruise missiles (ALCMs)

Operational considerations —

- Launch, release to targets, and arming of weapons requires permission from the National Command Authority (NCA) (in the United States, the President or his designated successor)
- Can be recalled until weapons (e.g., bombs, cruise missiles, or air-to-surface ballistic missiles) are dropped or fired from the bomber
- The United States has substantial in-flight refueling capability; other countries have none

Part 3: Cruise Missiles

Introduction to Cruise Missiles – 1 (Important)

Cruise missiles (CMs) are pilotless vehicles powered by jet engines:

- Fly within the atmosphere
- Speeds are subsonic

Although cruise missiles were conceived 60 years ago, CMs did not become important until the late 1970s, when technological advances made them militarily useful. These advances were:

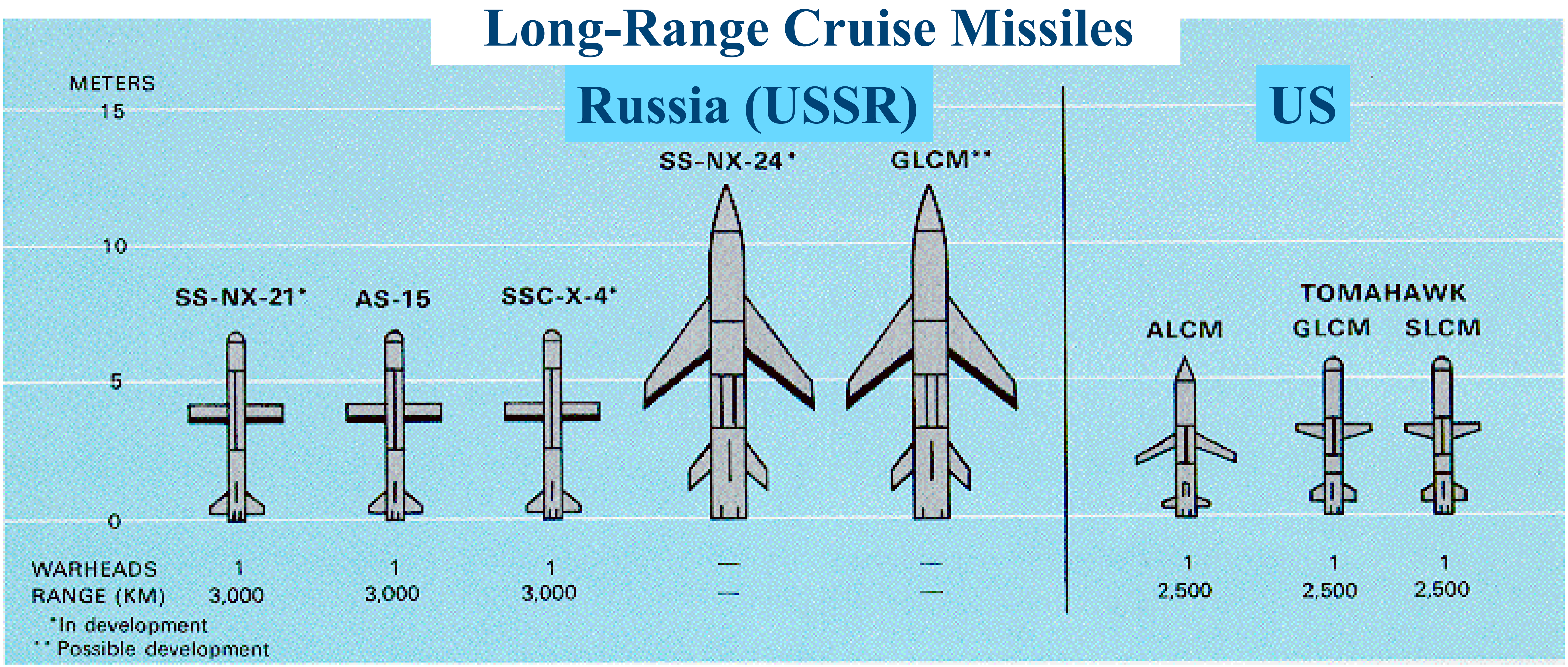
- Smaller and lighter nuclear warheads
- Efficient turbofan engines
- Highly capable miniaturized computers
- GPS, TERCOM (Terrain Contour Matching), and terminal guidance
- "Stealth" airframe technology

Introduction to Cruise Missiles – 2 (Important)

Key properties —

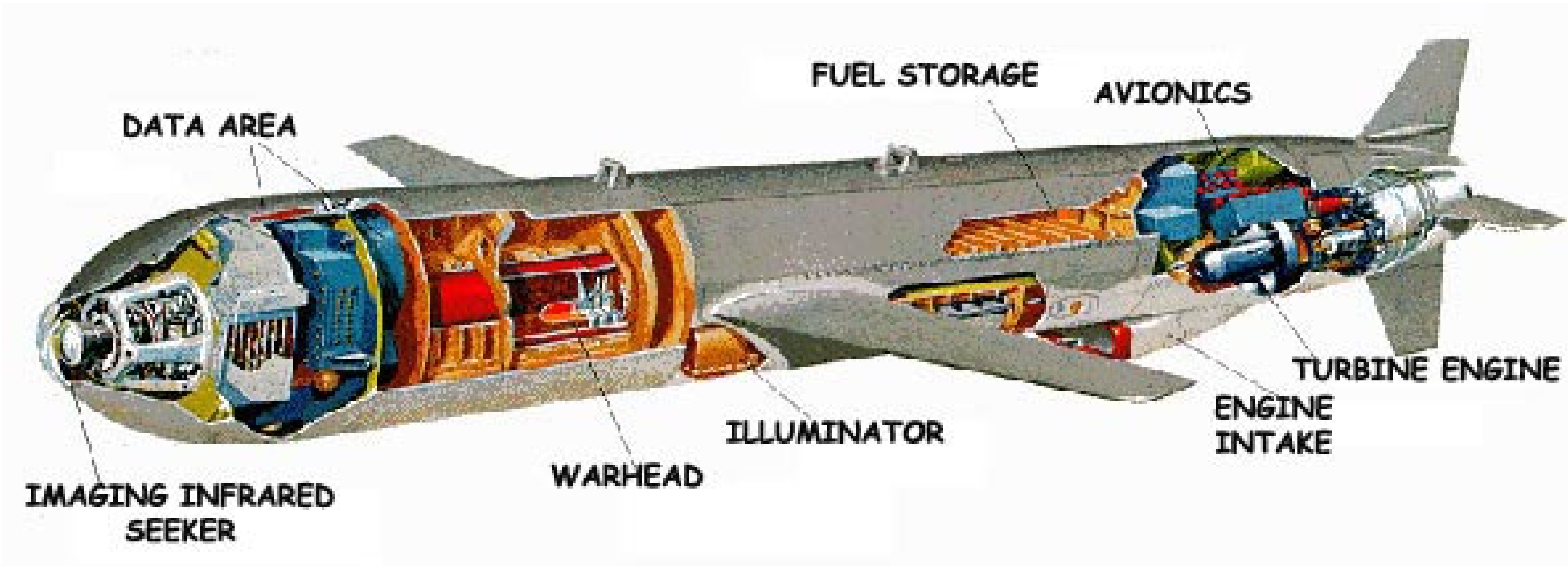
- Small
- Easily stored and launched
- Highly penetrating
- Versatile
- Highly accurate
- Very cheap (about ~ $1 million per copy)

Long-Range Cruise Missiles – 1



range :1000 – 2000 miles
pay loads : 500 – 1200 lbs

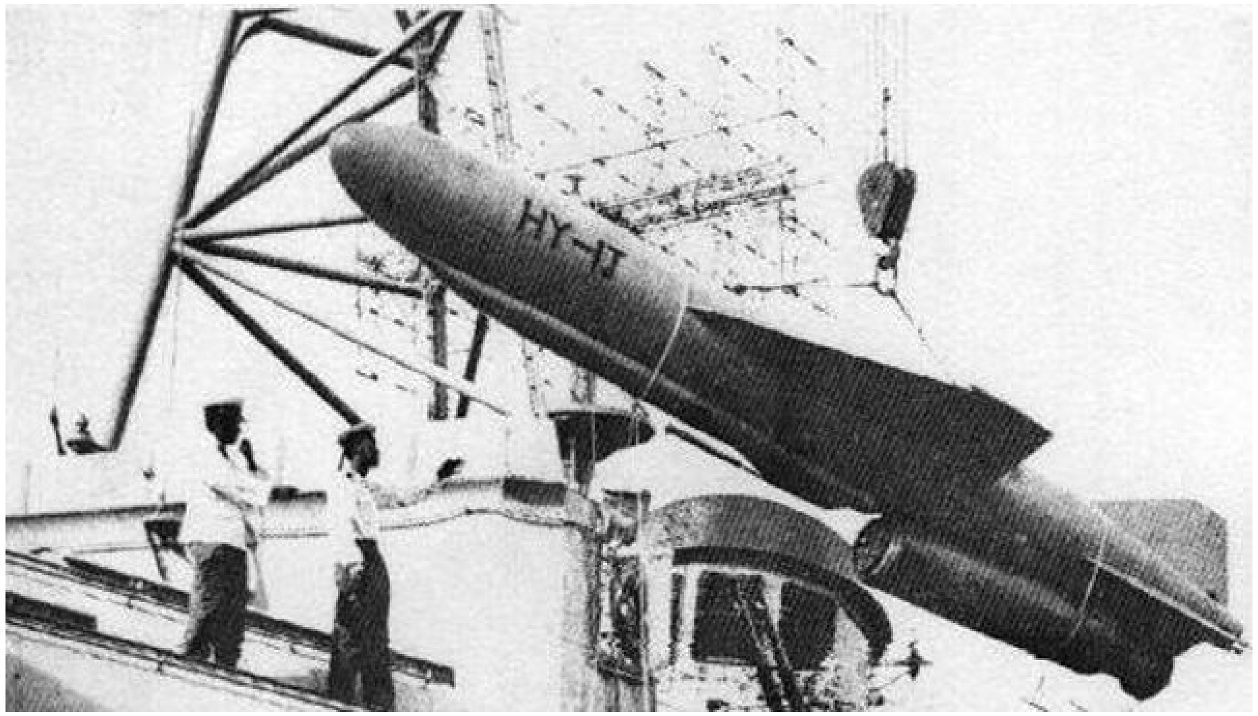
Long-Range Cruise Missiles – 2



Conventionally-Armed Tomahawk Cruise Missile

velocity: 550 mph
pay load: 1000 lbs
range : 1550 miles

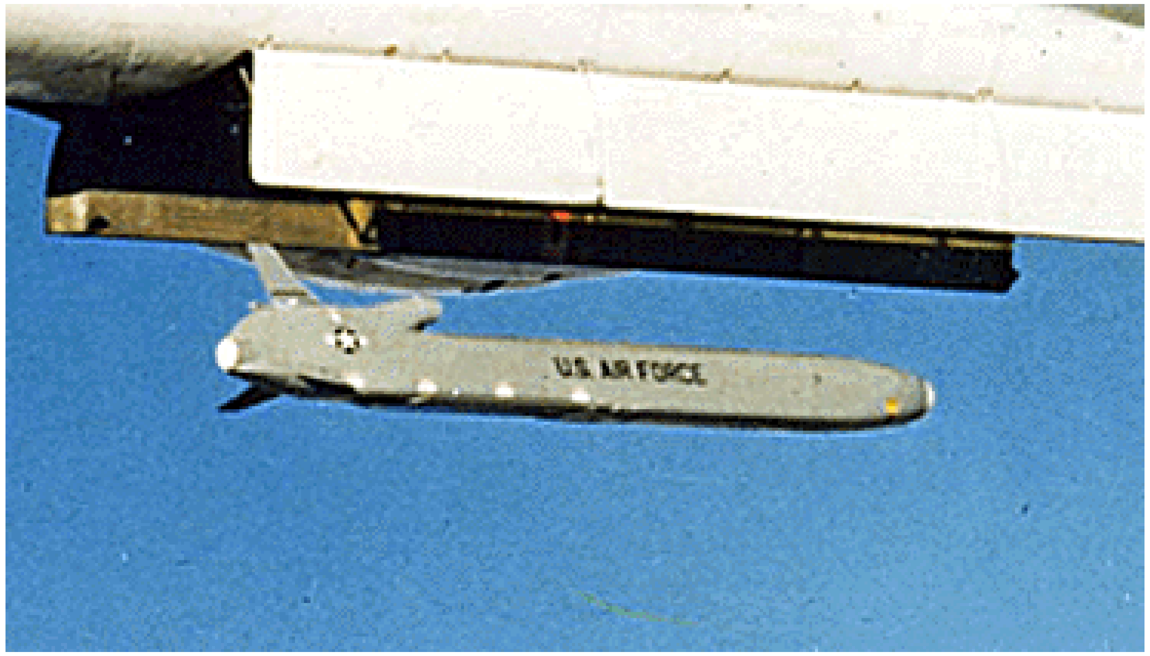
Chinese Silkworm Anti-Ship Cruise Missile



Chinese CSS-C-2 SILKWORM / HY-1 / SY-1 Anti-Ship Cruise Missile

Velocity: 680 mph
payload: 660 lbs
range: 180 miles

Launching Cruise Missiles – 1

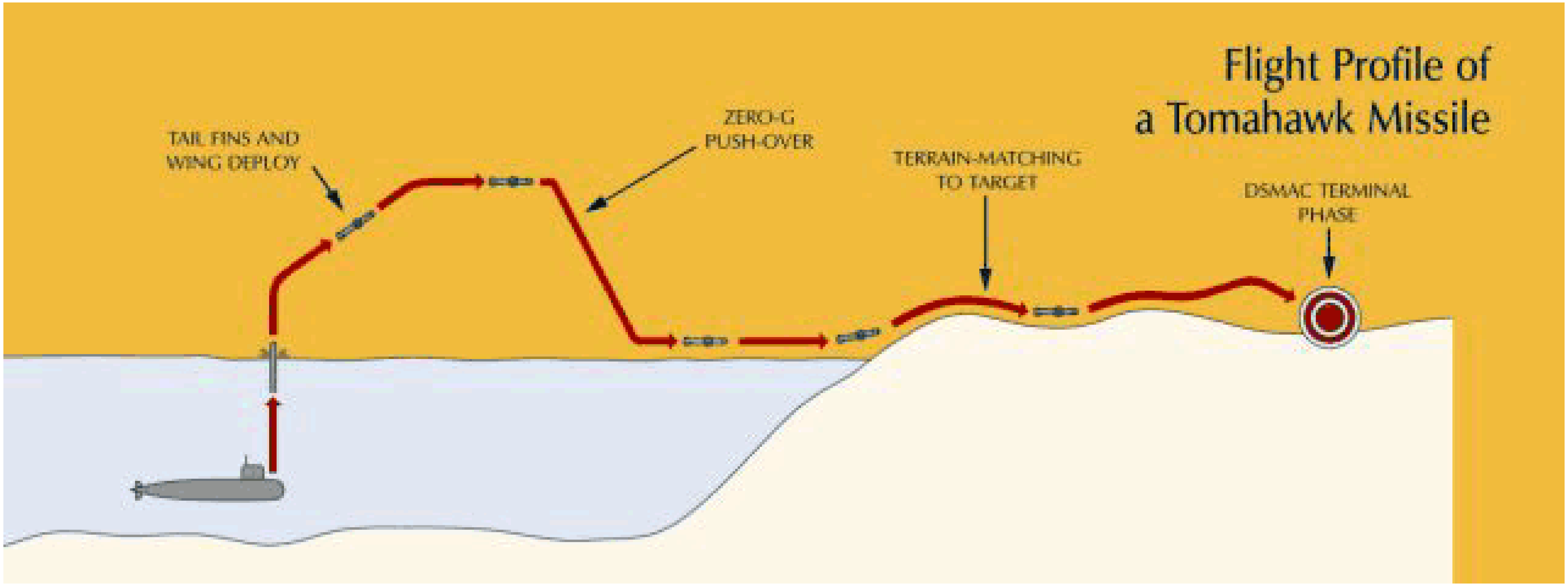


Launching Cruise Missiles – 2

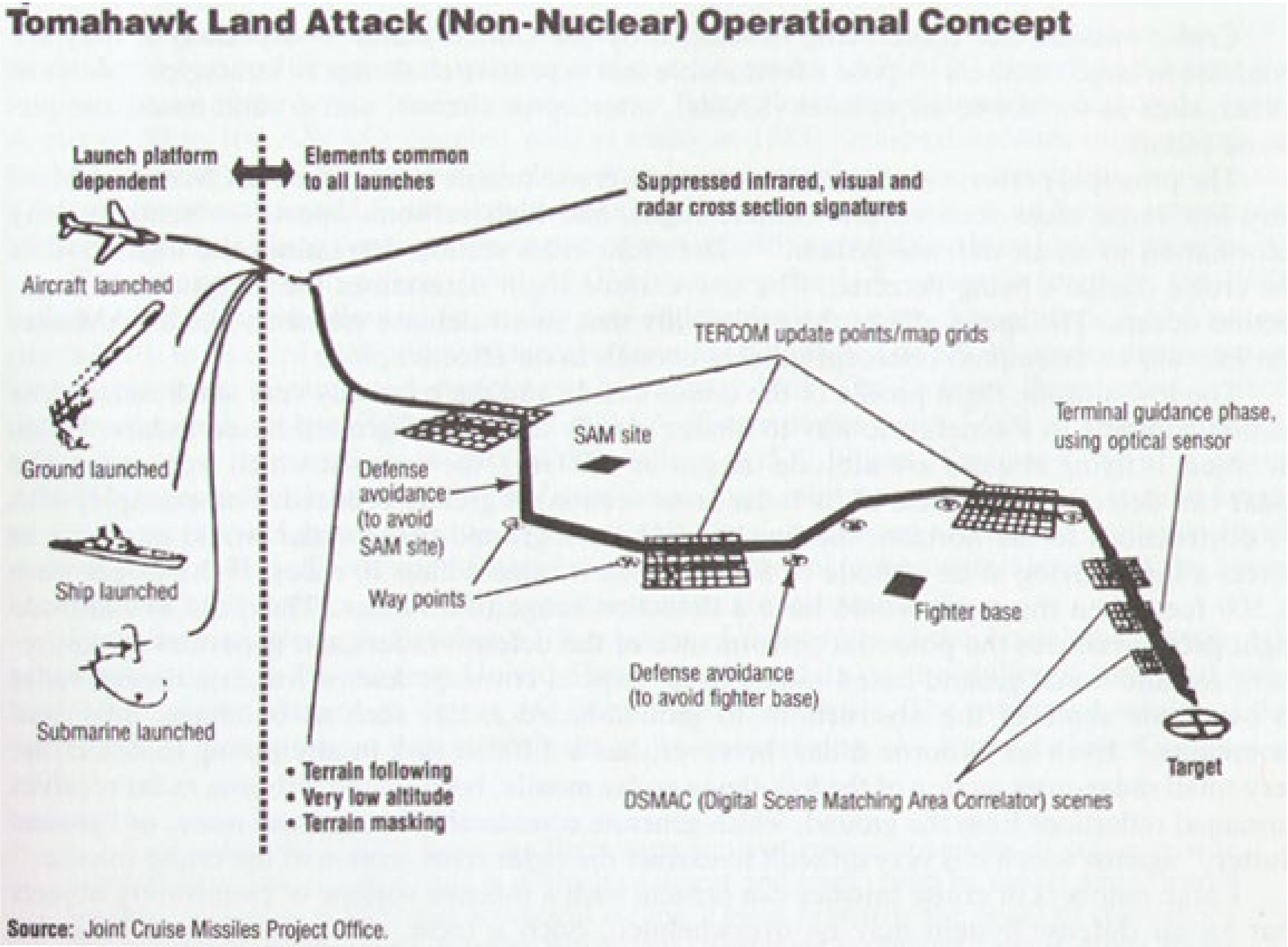
Cruise-Missile Guidance – 1

TERCOM: Terrain Contour Matching
DSMAC: Digital Scene Matching Area Correlation

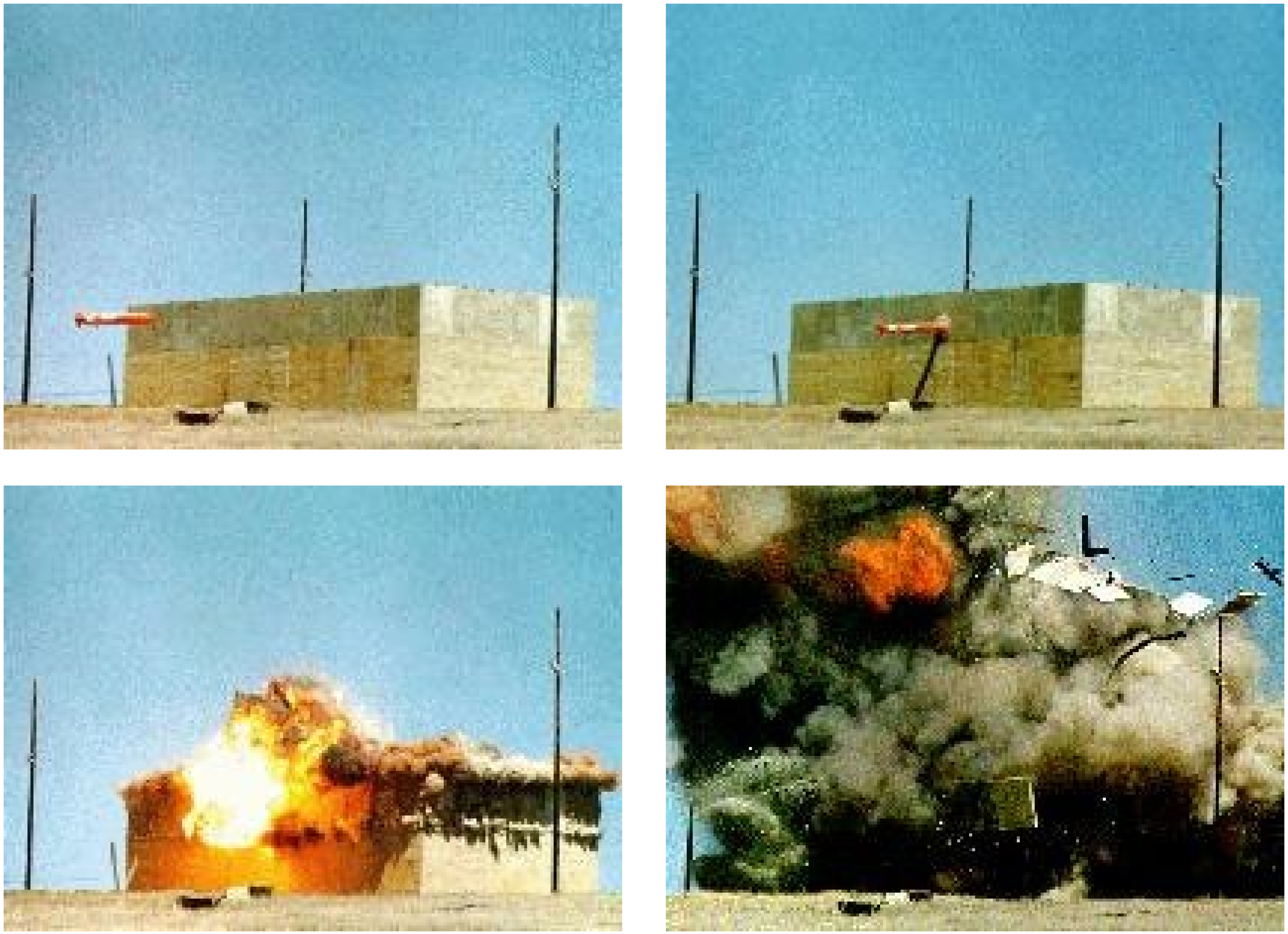
Cruise-Missile Guidance – 2



Cruise-Missile Guidance – 3



Accuracy of Cruise Missiles



Implications of Cruise Missiles – 1

The US developed and deployed CMs without coherent plan that considered the offensive, defensive, and long-range impact of their deployment.

Military history —

- Cruise missiles were the US countermeasure to the heavy Soviet investment in air defenses
- They capitalized on the temporary US lead in this technology
- However, the US is more vulnerable to CMs than Russia due to the proximity of potential targets to the sea shores.

Implications of Cruise Missiles – 2

Implications for U.S. security—

- Very small (hard to find with National Technical Means)
- Can be based almost anywhere (hard to count)
- Dual capable (almost impossible to distinguish nuclear from high-explosive warhead)
- Cheap (can be produced in large numbers)

Several countries could develop a mechanism to launch SRBMs, MRBMs, or land-attack cruise missiles from forward-based ships or other platforms

Physics/Global Studies 280: Session 15

Plan for This Session

News

RE3v2 due Wednesday at 10pm

Module 5: Nuclear Weapon Delivery Systems

The New York Times
https://www.nytimes.com/2022/03/07/world/europe/iaea-nuclear-plants-ukraine.html

An agreement on nuclear plants in Ukraine is urgently needed, the U.N. nuclear agency says.

March 7, 2022
Isabella Kwai

Concerns are rising over the operations of nuclear power plants in Ukraine without concrete agreements between Russia and Ukraine on safety and security, the head of the International Atomic Energy Agency said on Monday, adding that his agency, the nuclear watchdog of the United Nations, was working urgently to facilitate a meeting with the two parties.

There has been no release of radiation, he said, and the agency is remotely monitoring nuclear material there. Still, problems, including staffing and supply issues, have arisen at nuclear plants in Kharkiv, Mariupol and other places. If the plants can't get access to equipment, normal operations could be difficult to sustain.

"We should not be losing time," the agency's director general, Rafael Mariano Grossi, told reporters in Vienna on Monday, adding that the agency was getting reports from the Ukrainian nuclear regulator. "Almost every day there is a new episode."

An agreement on nuclear plants in Ukraine is urgently needed, the U.N. nuclear agency says.

March 7, 2022
Isabella Kwai

“All of these are indications — more than indications, confirmations — that we cannot go on like this,” Mr. Grossi said. “There has to be clear understanding and clear commitments not to go anywhere near nuclear facilities when it comes to military operations.”

Russian representatives rejected an initial offer from the agency to meet at the Chernobyl nuclear plant, Mr. Grossi said, adding that the agency was communicating with Ukrainian representatives. He said the agency had not ruled out sending support personnel to the plants.

The agency said on Sunday that, according to Ukraine, the Zaporizhzhia nuclear power plant — Europe’s largest — was under the control of Russian forces, though its regular staff were still on site. He expressed “grave concern” over reports from Ukraine that the management of the plant was subject to the approval of a Russian commander, and that communications with staff were not reliable.

Operations are safe, Mr. Grossi said, “but there are many, many questions on the ability to sustain this for much longer if we don’t support this in some way.”

The Washington Post

Russia's invasion of Ukraine threatens to derail Iran nuclear talks

Russian demands for relief on Ukraine-related sanctions have raised fears Moscow will seek to delay or sabotage an agreement to revive the Iran nuclear deal

VIENNA — Fears mounted Monday that the Iran nuclear deal may become collateral damage in the Ukraine war as Russia pressed its demand to be exempted from U.S. sanctions in any future business dealings with Iran.

Negotiators had hoped to finalize an agreement to revive the 2015 nuclear deal imminently and have already allowed several presumed deadlines to slip after 11 months of talks on ways to bring the deal back to life.

The talks have been focused on how to bring both the United States and Iran back into compliance with the Joint Comprehensive Plan of Action, or JCPOA as the deal is known, by rolling back sanctions imposed by the United States after it pulled out of the agreement in 2018 and the advances later made by Iran in its nuclear program in response to the U.S. sanctions.

Russia's invasion of Ukraine threatens to derail Iran nuclear talks

Russian demands for relief on Ukraine-related sanctions have raised fears Moscow will seek to delay or sabotage an agreement to revive the Iran nuclear deal

In a phone call with Iranian Foreign Minister Hossein Amirabdollahian on Monday, Russian Foreign Minister Sergei Lavrov reiterated that Russia wants the revival of the nuclear deal to be accompanied by U.S. guarantees that sanctions imposed by the West in response to Russia's invasion of Ukraine won't apply to Russian trade or investment with Iran.

Lavrov told Amirabdollahian that the deal's resuscitation "should ensure that all its participants have equal rights regarding the unhindered development of cooperation in all areas," the Russian Embassy in Iran said on Twitter.

The demand, first raised by Lavrov at a news conference in Moscow on Saturday, has rocked the negotiations underway in Vienna.

This was the first time Russia had given any indication that its position might have shifted, and diplomats are now scrambling to assess what the new demands mean and how they might affect the chances of getting a revived deal. Iran seemed as stunned as any of the other countries, with Iranian officials complaining to Iranian media that they only learned of the Russian demand from news reports.

WORLD

Iran Chief Negotiator Unexpectedly Leaves Vienna as Nuclear Talks Hit Standstill

Ali Bagheri-Kani says he will return to the negotiations soon, but Western diplomats warn the talks could fail

Iran's chief nuclear negotiator, Ali Bagheri-Kani, in Vienna last month.

PHOTO: LISA LEUTNER/ASSOCIATED PRESS

Iran Chief Negotiator Unexpectedly Leaves Vienna as Nuclear Talks Hit Standstill

Ali Bagheri-Kani says he will return to the negotiations soon, but Western diplomats warn the talks could fail

By Laurence Norman Follow
March 7, 2022 3:10 pm ET

VIENNA—Iran's chief negotiator at the nuclear talks in Vienna unexpectedly returned home Monday night, prompting European officials to say negotiations were at a standstill.

Iranian officials said Ali Bagheri-Kani, who leads the Iranian negotiating team, would soon return to Vienna. Two Western diplomats said it wasn't clear why Mr. Bagheri-Kani left or when he would return.

His departure comes after Russia's Foreign Minister Sergei Lavrov and his Iranian counterpart discussed Moscow's weekend demand that Washington provide it with written guarantees that Western sanctions on Ukraine wouldn't harm future Russian-Iranian trade.

Mr. Bagheri-Kani's sudden departure raises the prospect that the Vienna negotiations on reviving the 2015 nuclear deal, which have dragged on for 11 months, could fail. The 2015 agreement lifted most international sanctions on Tehran in exchange for tight but temporary limits on Iran's nuclear program.

Part 4: Ballistic Missiles

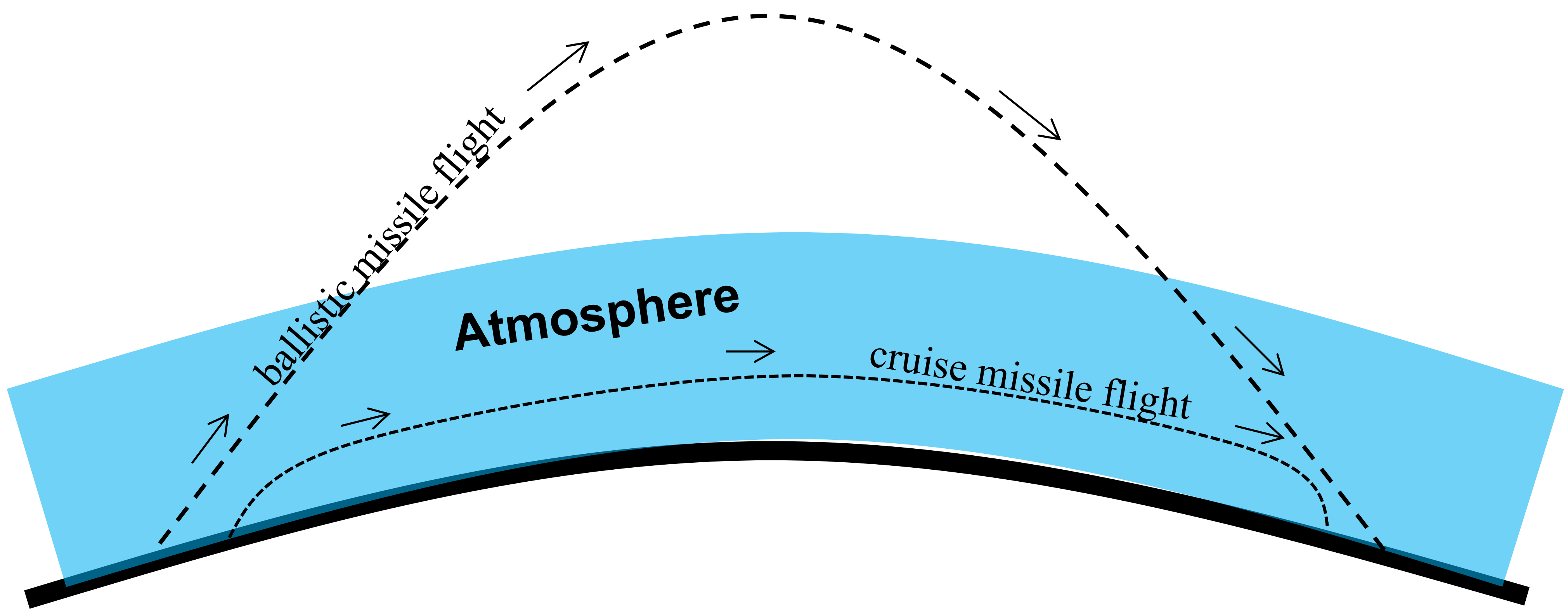
Air Breathing Delivery Systems (Bombers & Cruise Missiles) vs Ballistic Missiles

Air breathing systems:

- o carry the fuel on board but take the oxidizer from the atmospheres ➔ operate endo-atmospheric

Ballistic missiles:

- o carry fuel and oxidizer ➔ can operate exo-atmospheric



Attributes of Ballistic Missiles

Basing modes —

- Fixed (e.g., blast-hardened silos in the ground)
- Mobile (e.g., on railroad cars)

Propellants —

- Liquid (fuel and oxidizer are separate)
- Solid (fuel and oxidizer are mixed)

Payloads —

- Single warhead + penetration aids (“penaids”)
- Multiple warheads + penetration aids

Categories of Ballistic Missiles Based on Their Ranges (Important)

Short-range ballistic missiles (SRBMs) —

- Ranges under 1,000 km

Medium-range ballistic missiles (MRBMs) —

- Ranges between 1,000 km and 3,000 km

Intermediate-range ballistic missiles (IRBMs) —

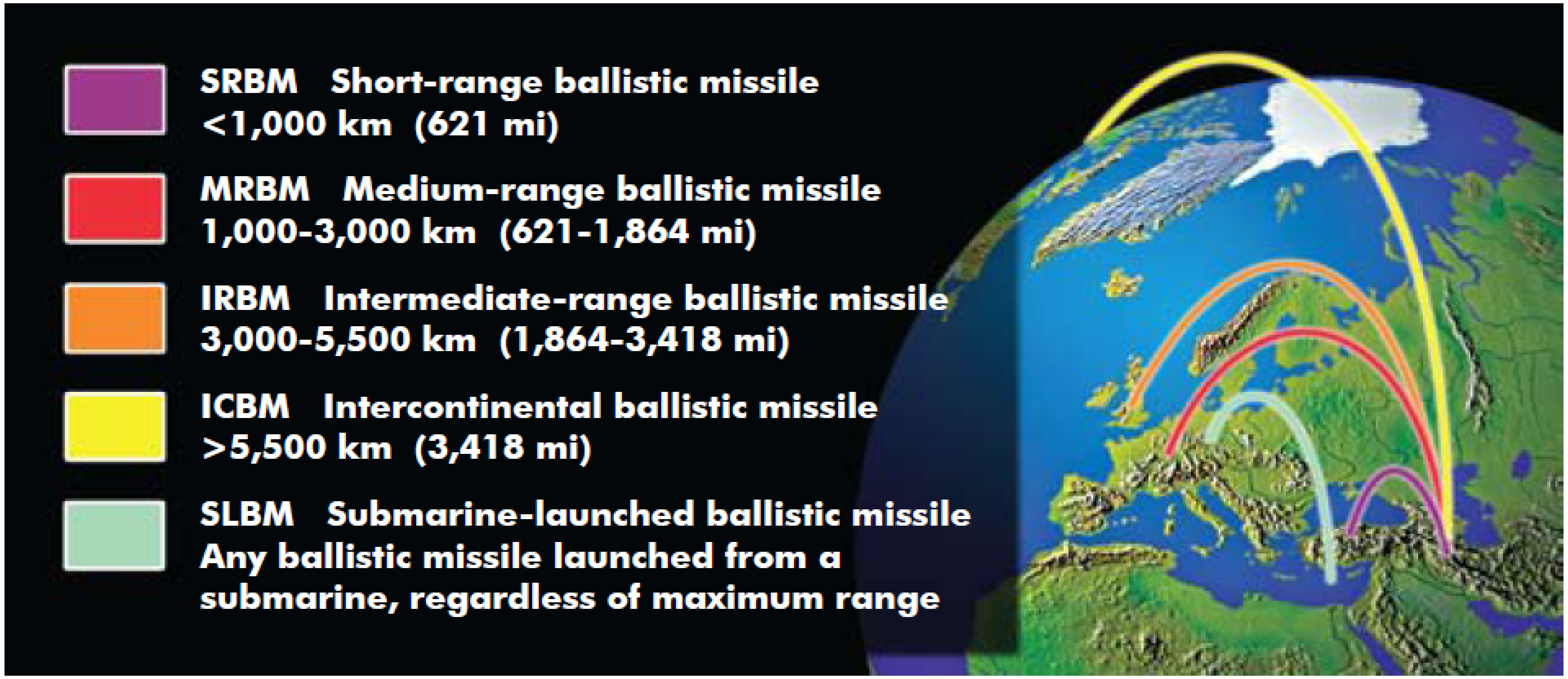
- Ranges between 3,000 km and 5,500 km

Intercontinental-range ballistic missiles (ICBMs, SLBMs) —

- Limited-range ICBMs (LRICBMs): 5,500 to 8,000 km
- Full-range ICBMs (FRICBMs): > 8,000 km
- Ranges of US and Russian ICBMs are ~ 12,000 km

These categories are not fluid, because they are based on the performance characteristics of the missile.

Categories of Ballistic Missiles Based on Their Ranges (Important)



Source: national air and space intelligence center

"Ballistic and Cruise Missile Threat", 2009

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Intercontinental-range ballistic missiles (ICBMs, SLBMs) —

- Limited-range ICBMs (LRICBMs): 5,500 to 8,000 km
- Full-range ICBMs (FRICBMs): > 8,000 km
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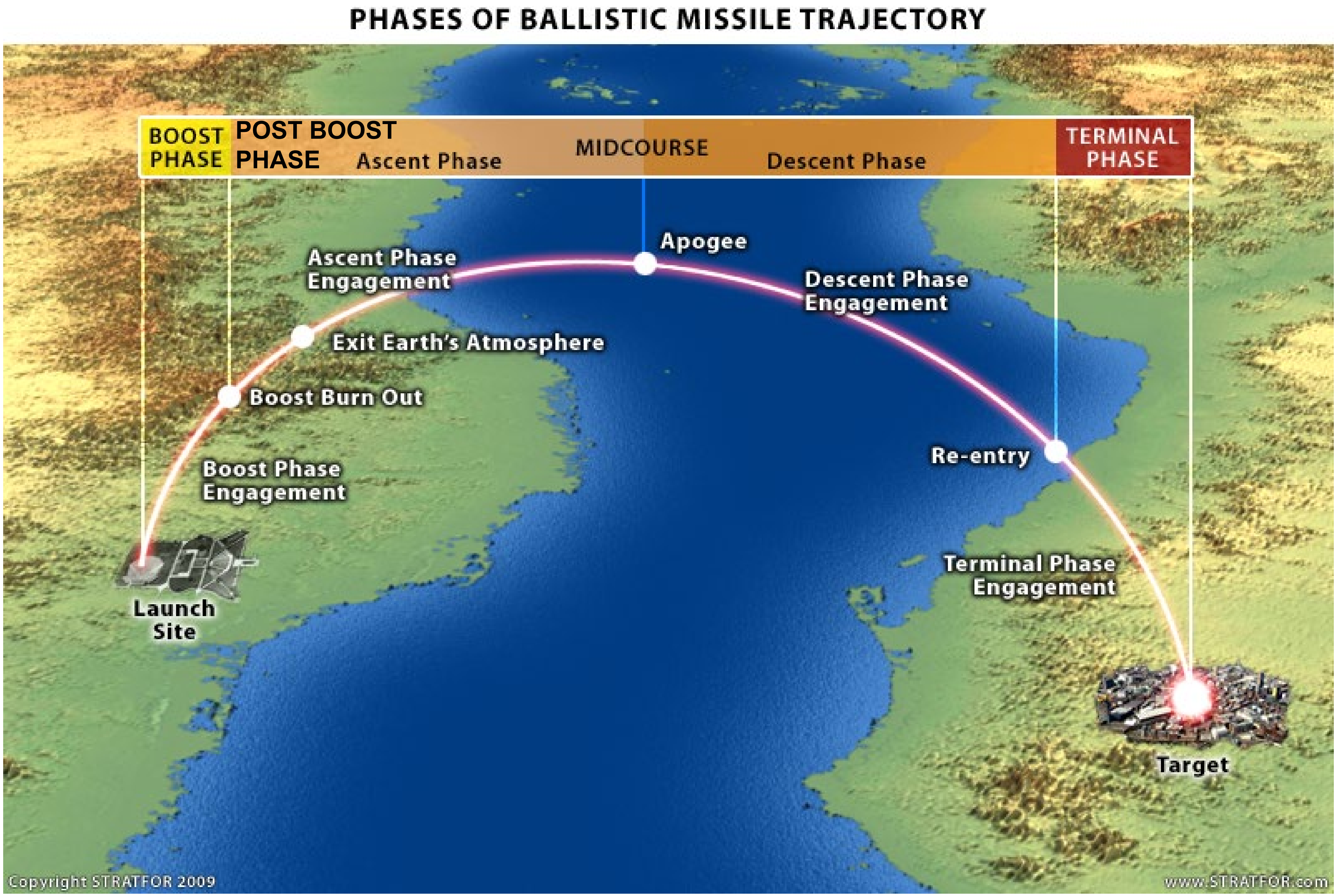
Phases of Flight of Intercontinental-Range Ballistic Missiles (Important)

Basic phases of flight of a (MIRVed) intercontinental ballistic missile (ICBMs and SLBMs) —

- Boost phase: rocket motors burning
- Post-boost phase (release of payload from bus)
- Midcourse phase: ballistic motion in space
- Terminal phase: re-entrance into atmosphere and passage through atmosphere

Phases of Flight of Intercontinental-Range Ballistic Missiles (Important)



Categories of Ballistic Missiles Based on Their Purposes

Tactical ballistic missiles (TBMs) —

- For use on the battlefield (e.g., on a particular front)
- Usually have shorter ranges (SRBMs)

Theater ballistic missiles (TBMs) —

- For use in an entire theater of war (e.g., the Middle East)
- Usually have longer ranges than tactical missiles

Strategic ballistic missiles (an example of SNDVs – Strategic Nuclear Weapons Delivery Vehicle) —

- For attacking the homeland of the adversary
- May have longer, possibly intercontinental ranges

These categories are fluid, because they are based on the intent of the user at the time the missile is fired.

Missile Guidance Technologies

Inertial —

- Uses gyroscopes and accelerometers
- No contact with outside world

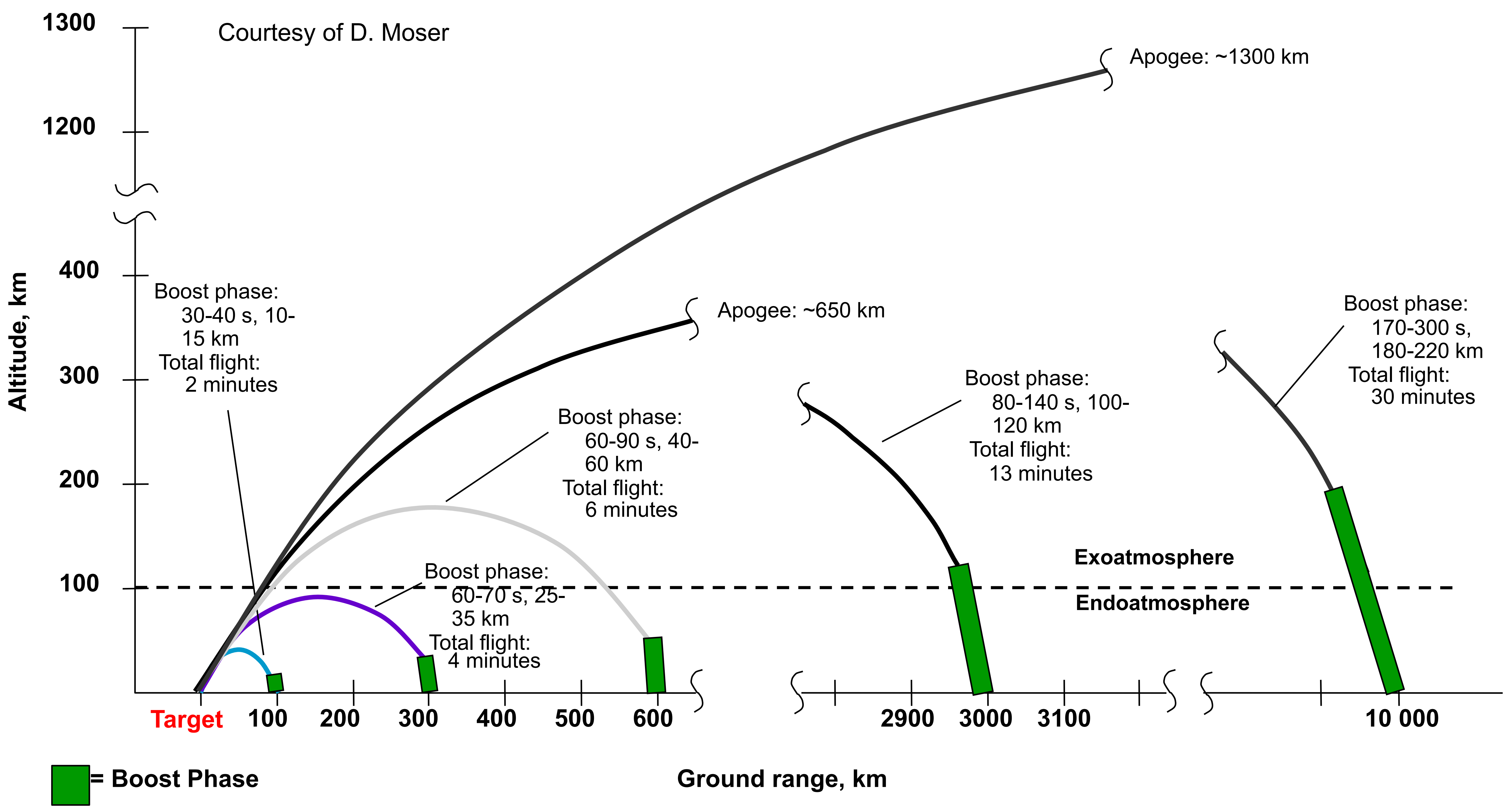
Stellar —

- Star trackers update inertial guidance system

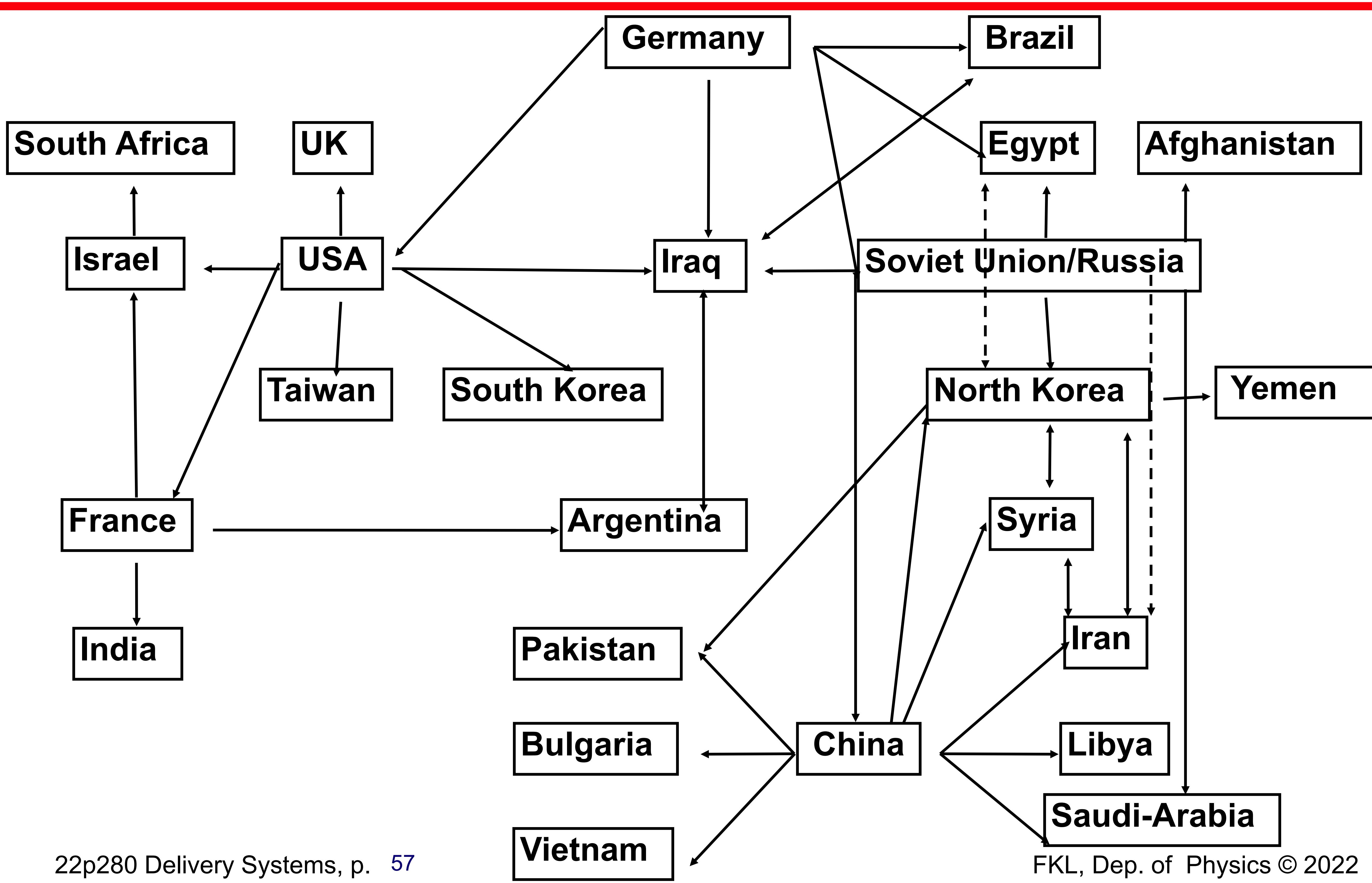
Satellite —

- Uses accurate (atomic) clocks on satellites
- Uses coded radio transmissions
- Uses sophisticated receivers
- Can determine both position and velocity very accurately using signals from 3 to 4 satellites

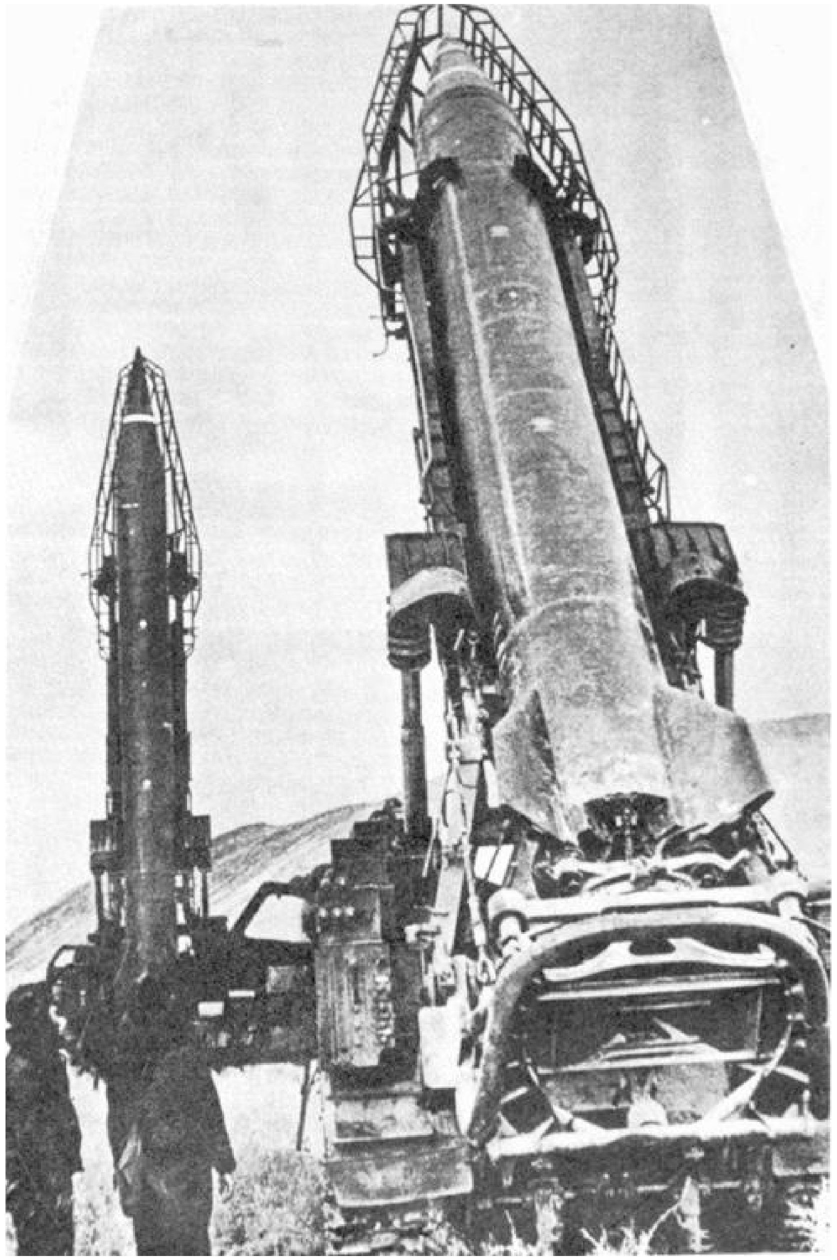
Trajectories and Phases of Flight of Missiles With Various Ranges



Proliferation of Ballistic Missile Technologies



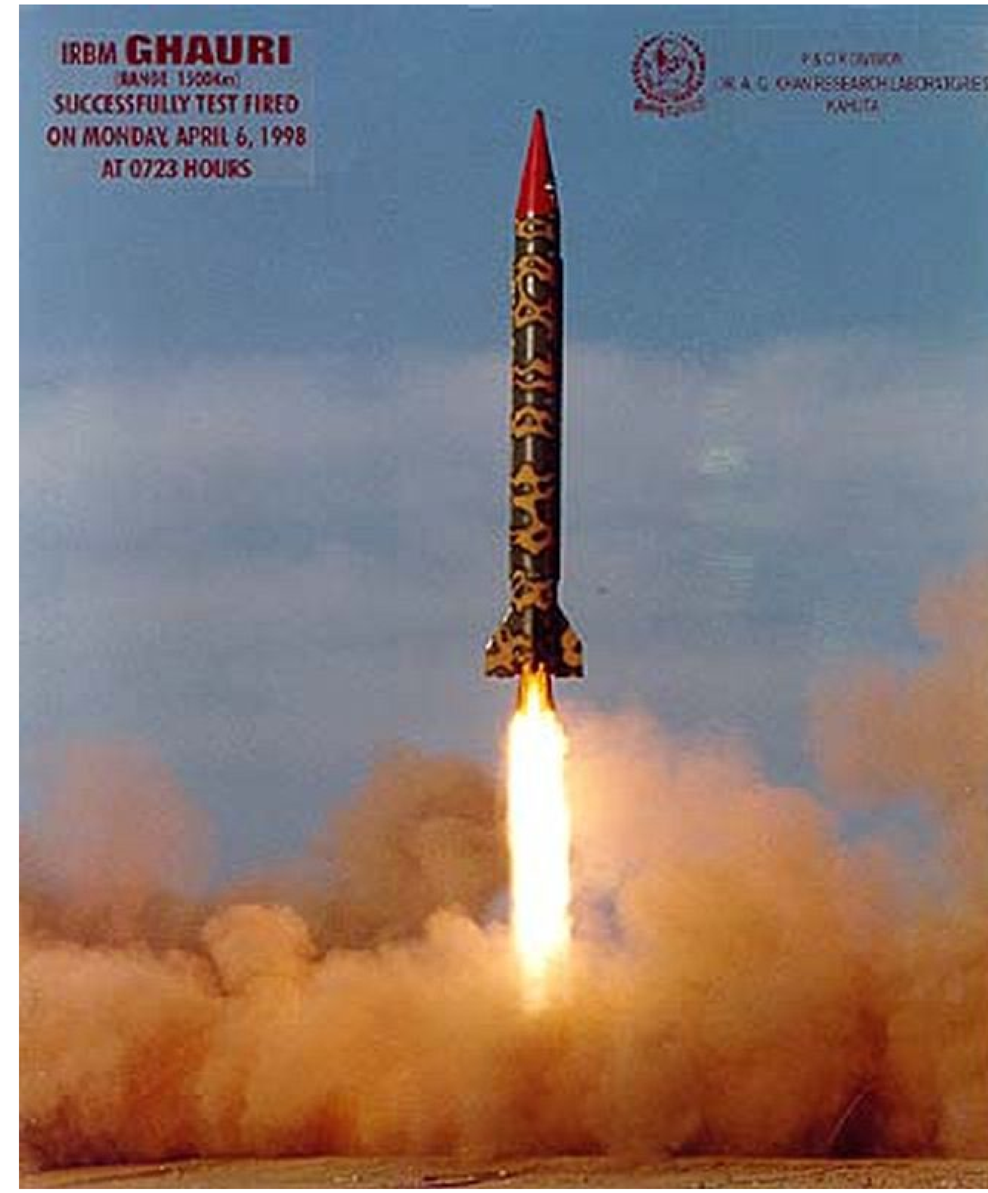
Soviet Scud Missiles and Derivatives - 1



Soviet Scud-B Missile
(based on the German V2)
Range: 300 km

Iraqi Al-Hussein SRBM
Range: 600–650 km

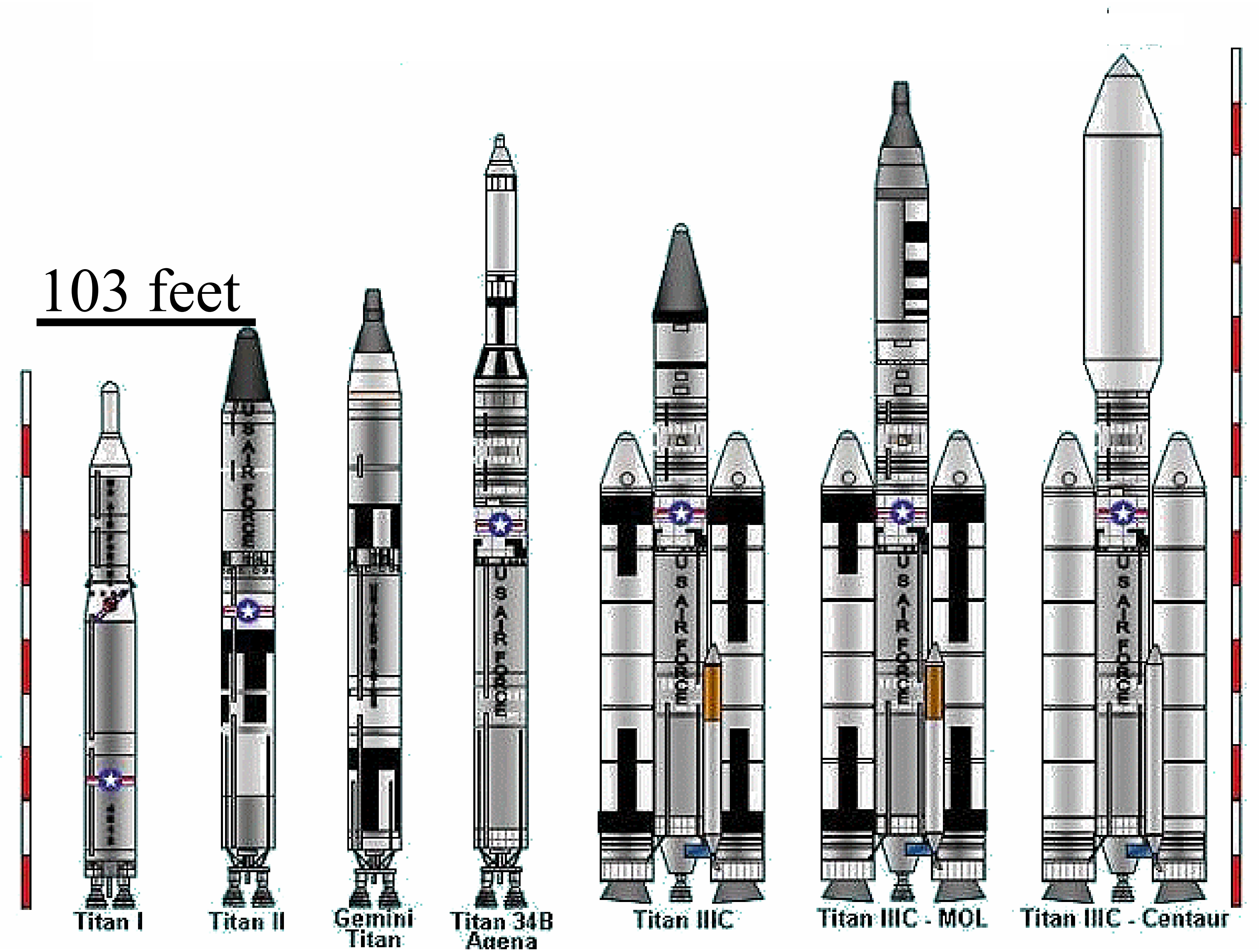
Scud Missiles and Derivatives – 2



Pakistan's Ghauri MRBM and transporter (range 1,300 km).
It is almost identical to North Korea's No Dong MRBM, which is based on Scud technology that North Korea got from Egypt in the 1970s.

Titan Family of Missiles and Launch Vehicles

1959 – 2005 ICMB & civilian uses



TIME Magazine, **Monday September 29th 1980**

Light on the Road to Damascus

Titan terror explodes in the Arkansas hills

Shortly after sunset one day last week, a maintenance worker on the third level of a silo housing a 103-ft. Titan II Intercontinental ballistic missile near Damascus, in the Arkansas hills north of Little Rock, dropped the socket of a wrench. The 3-lb. tool plummeted 70 ft. and punctured a fuel tank. As flammable vapors escaped, officials urged the 1,400 people living in a five-mile radius of the silo to flee. The instructions: "Don't take time to close your doors—just get out.“ And with good reason. At 3:01 a.m., as technicians gave up trying to plug the leak and began climbing from the silo, the mixture of fuel and oxygen exploded. Orange flames and smoke spewed out, lighting up the sky over Damascus. The blast blew off a 750-ton concrete cover. One worker was killed; 21 others were hurt.

Today: LGM-30G Minuteman III ➔ 3 stage solid rocket fuel
Range: 11,000km +
Speed : 24,100 km/h or 6.7km/s (terminal phase)

Re-Entry Vehicles (RVs)

Basic types —

- MRV = multiple RV
  - —Final stage carries more than 1 RV
  - —Final stage has no propulsion
  - —RVs are *not* independently targetable
- MIRV = multiple, independently targetable RV
  - —Final stage carries more than 1 RV
  - —Final stage has guidance package and propulsion
  - —RVs are independently targetable
- MARV = maneuverable RV
  - —RV has a guidance package
  - —RV maneuvers during the terminal phase, using, e.g., thrusters or aerodynamic forces

MK21 re-entry vehicles on Peacekeeper MIRV bus

MIRV Technology

MX Peacekeeper MIRV

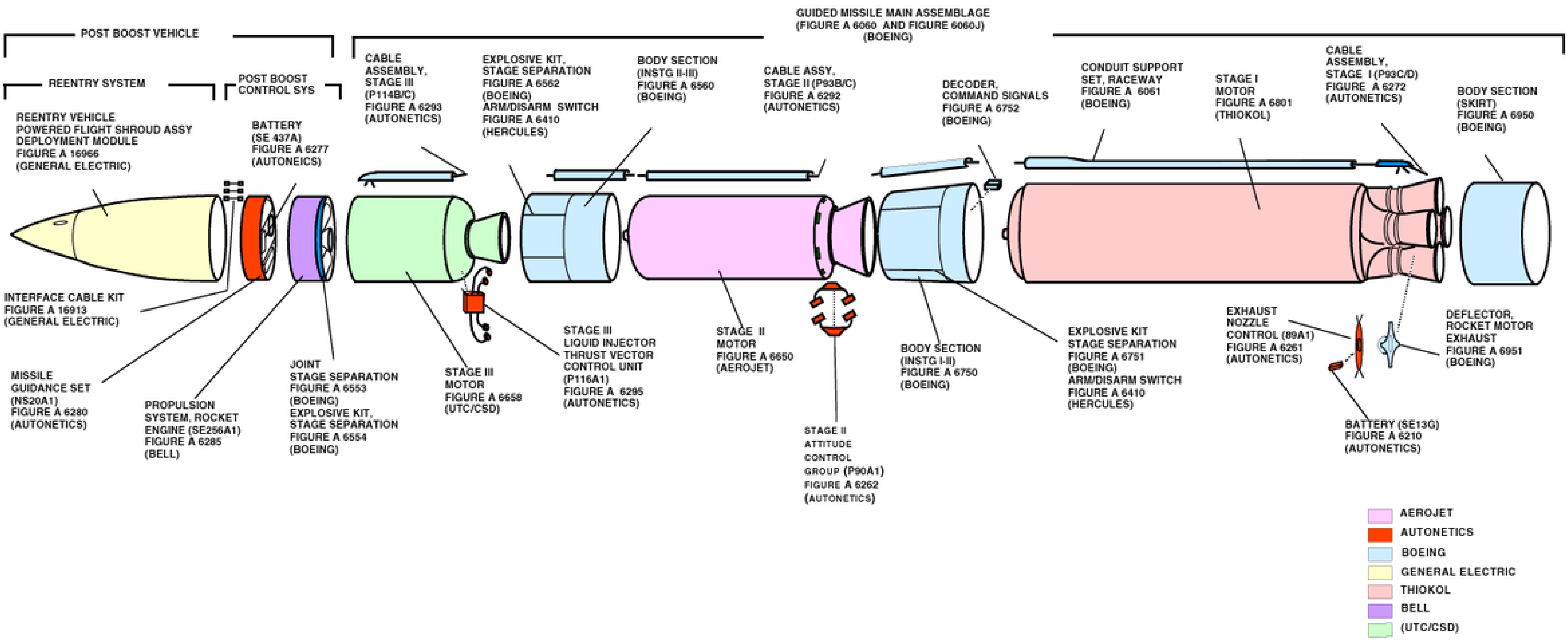
Soviet ICBM MIRV

MIRV Technology

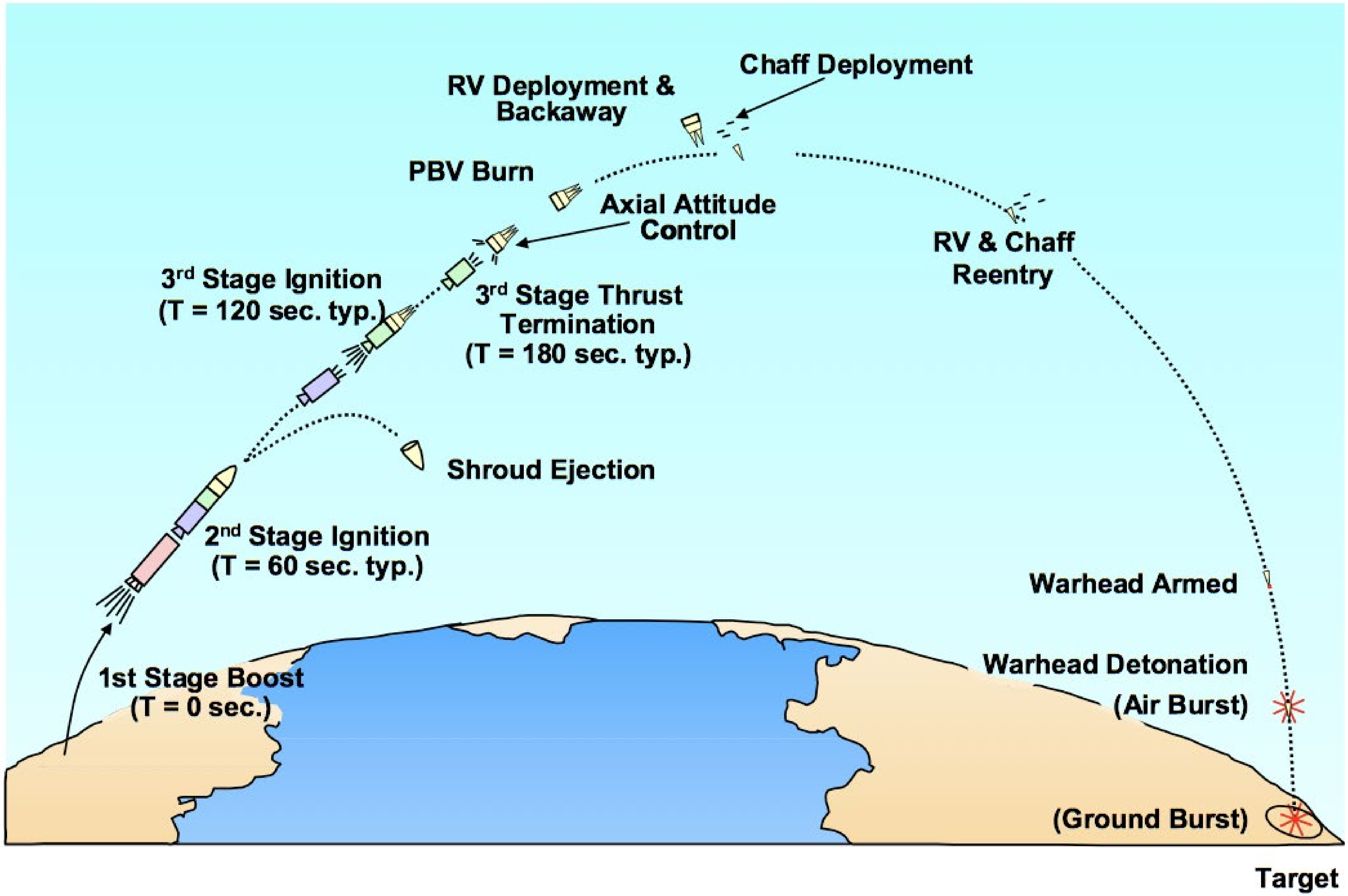
MX Peacekeeper missile tested at Kwajalein Atoll

Source:www.smdc.army.mil/kwaj/Media/Photo/missions.htm

Minuteman ICBM (Schematic)



Flight of a Minuteman ICBM (Schematic)



Flight of MIRV'd ICBMs

Four phases of the flight of an intercontinental-range missile armed with MIRVs (Multiple Independently Targetable Reentry Vehicles)—

- Boost phase (lasts about 1–5 min)
  - — Rocket motors are burning
  - — Missile rises through the atmosphere and enters near-Earth space
  - — Stages drop away as they burn out
- Post-boost phase (lasts 5–10 min)
  - — Bus separates from the final stage
  - — Bus maneuvers and releases RVs
- Midcourse phase (lasts about 20 min)
  - — RVs fall ballistically around the Earth, in space
- Terminal phase (lasts about 20–60 sec)
  - — RVs re-enter the Earth's atmosphere and encounter aerodynamic forces
  - — RVs fall toward targets, until detonation or impact

Examples of US and Russian ICBMs

Recent US ICBMs —

- MX Solid-propellant, range ~ 12,000 km,
  10 warheads (Peacekeeper, retired 2005)
- MMIII Solid-propellant, range ~ 12,000 km,
  Capability for 3 warheads (Minuteman)
  Presently deployed with 1 warhead

Recent Russian ICBMs —

- SS-24 Solid-propellant, range > 9,000 km
- SS-25 Solid-propellant, range > 9,000 km
- SS-27 Solid-propellant, range > 9,000 km

Physics/Global Studies 280: Session 16

Plan for This Session

Please turn in RE3v2 into 280 homework box in Loomis

News

- ➔ midterm will be Thursday March 24th
- ➔ midterm will cover modules 1 to 5 + news
- ➔ old tests are available on course web-page
- ➔ 50% of problems will be from old exams
- ➔ review session, Wednesday evening, March 23rd

Module 5: Nuclear Weapon Delivery Systems

Bulletin of the Atomic Scientists

Ukraine building a nuclear bomb? Dangerous nonsense.

By Mariana Budjeryn, Matthew Bunn | March 9, 2022

(Rusted) Missile silo of a SS-24 missile, Strategic Missile Forces Museum in Ukraine. Credit: Michael. CC BY 3.0. Accessed via Wikipedia.

Bulletin of the Atomic Scientists

The Kremlin is claiming that Ukraine is developing nuclear weapons. Like most of Russia's other pretexts for invading Ukraine, this is dangerous nonsense.

In his February 21 war speech, Russian President Vladimir Putin stated that Ukraine possesses delivery systems and nuclear technologies inherited from the Soviet Union and that, with foreign support, "it is only a matter of time" before Ukraine creates nuclear weapons. Echoing this concern, Russian Foreign Minister Sergei Lavrov in his address to the Conference on Disarmament on March 1, alleged that Ukraine "started dangerous games related to plans to acquire their own nuclear weapons."

It is true that Ukraine's President Volodymyr Zelensky, in his February 19 speech at the Munich Security Conference, questioned whether Ukraine was obligated to retain its non-nuclear status. He argued that Russia had grossly violated its security promises to Ukraine in the so-called Budapest Memorandum that set the terms for Ukraine eliminating the nuclear weapons it inherited from the collapsed Soviet Union. As a result, Zelensky argued, the whole "package of decisions" in that deal, including Ukraine's non-nuclear status, were "in doubt."

Prior to President Zelenksy's recent remark, other Ukrainian politicians have also called for Ukraine's withdrawal from the Nuclear Non-Proliferation Treaty (NPT) and reconsideration of its non-nuclear status. These statements referred to Russia's 2014 seizure of Crimea and instigation of a war in Ukraine's Donbas region, which blatantly violated Russia's commitments to respect Ukraine's sovereignty and territorial integrity pledged in the Budapest Memorandum.

Nuclear material. The first point is that Ukraine does not have the needed nuclear material for a bomb or the facilities to produce it. All of the highly enriched uranium (HEU) that used to exist at research and training facilities in Ukraine, including at the Kharkiv Institute of Physics and Technology which Russia recently shelled, was removed cooperatively during the Obama-era nuclear security summit process. Ukraine has uranium deposits, but no conversion facility for turning them into uranium hexafluoride gas used in enrichment plants. It also has no enrichment plants to separate out the uranium-235 used in weapons from the more than 99 percent uranium-238 in natural uranium. Building that set of facilities would take years and great expense.

The alternative path to the bomb is based on plutonium. There's a good deal of plutonium in the spent fuel from Ukraine's nuclear power reactors, but it is about one percent by weight in massive, intensely radioactive fuel assemblies. To use it in a bomb, Ukraine would need a "reprocessing" plant to chemically separate the plutonium from all the rest. Once again, that is a facility Ukraine does not have and would take years to build. The plutonium from power reactors is "reactor-grade," with a variety of undesirable isotopes that make it less than ideal for nuclear weapons, though still usable.

Nuclear warhead production. Even if Ukraine had the needed nuclear material, it would not be easy to turn it into nuclear weapons. Designing nuclear weapons requires specialized expertise. Ukraine has many experts in civilian nuclear matters, but 30 years after Ukraine's participation in the Soviet military-industrial complex, many of the weapons experts left over are no longer available. Today, Ukraine has modest remaining expertise in the many specialized technologies involved in nuclear weapons design and manufacture.

Delivery vehicles. The nuclear missiles left on Ukraine's territory when the Soviet Union collapsed were destroyed decades ago. Nevertheless, as President Putin noted, Ukraine has legacy Soviet industries capable of designing and producing weapons delivery systems, both aircraft and missiles. The Antonov design bureau and aircraft manufacturer in Kyiv are known for their cargo aircraft, including the largest airplane ever made, the AN-225 Mriya, that was recently destroyed on the airfield by a Russian strike. The Ukrainian city of Dnipro is home to the Pivdenne Design Bureau, Pivdenmash, once the largest missile factory in the world, capable of producing ballistic missiles. Kyiv's Luch is the designer and manufacturer of guided missile systems. Today, however, Ukraine has no missiles or aircraft designed to deliver nuclear weapons. Its missile building has been reoriented toward space projects. New missiles or planes would have to be designed and built or existing ones modified.

Bulletin of the Atomic Scientists

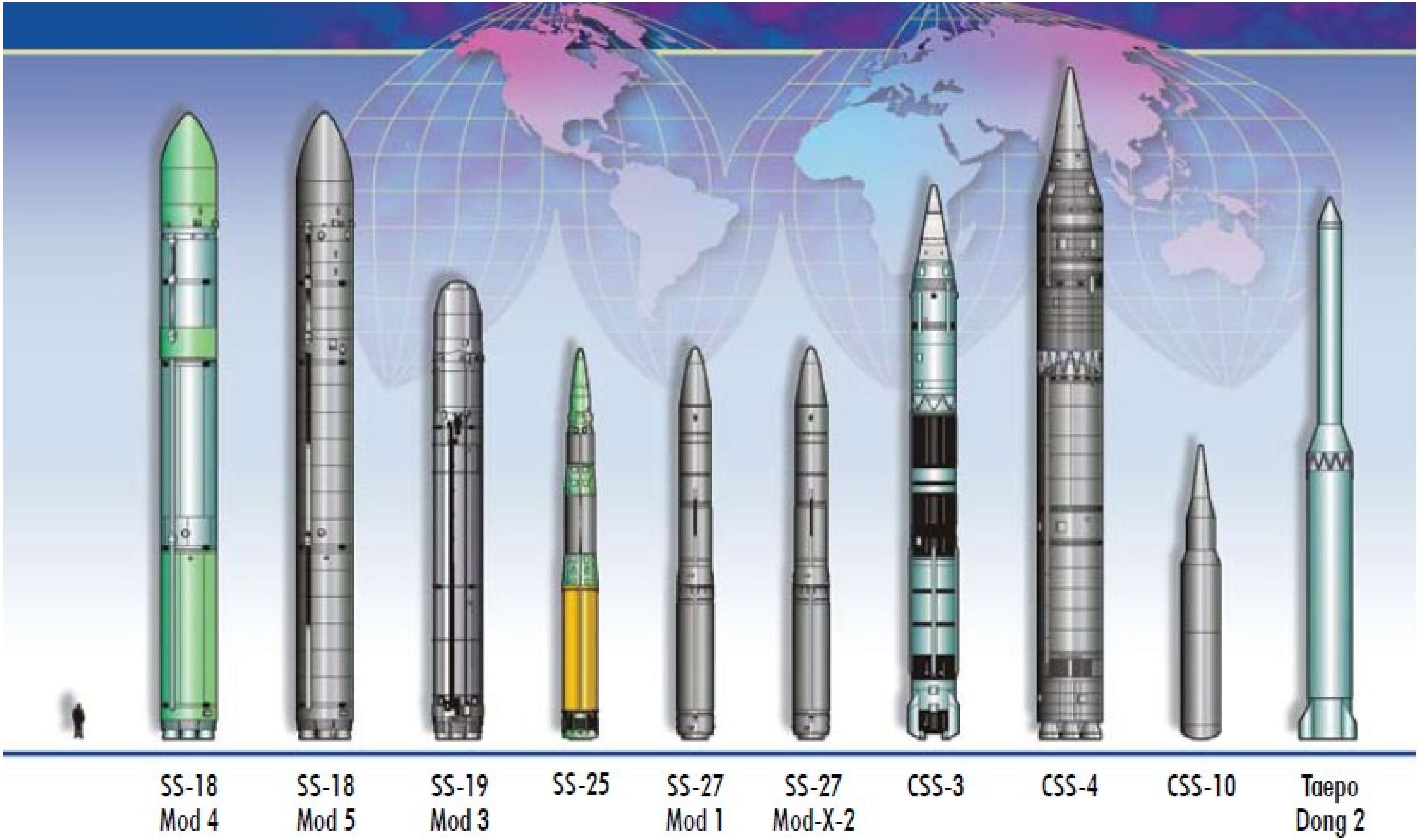
Treaties and inspections. Beyond all that, Ukraine is committed by treaty not to build nuclear weapons, and all its nuclear facilities are under international inspection. To try to build nuclear weapons, Ukraine would have to either withdraw from the NPT and kick out the International Atomic Energy Agency (IAEA) inspectors or try to proceed in secret, evading the IAEA inspectors, a practice that ultimately proved unsustainable for other states. Either one of these paths would risk sanctions and international censure. Any Ukrainian attempt to launch a nuclear weapons program would lose it the critical support of its Western partners, including the United States, whose decades-long policy has been to thwart the spread of nuclear weapons around the world even by its allies, and on whose support Ukraine greatly relies in its defense against Russia.

US ICBMs – 2

Launch of a Minuteman ➔ video!

Launch of an MX

Russian, Chinese and North Korean ICBMs – 1



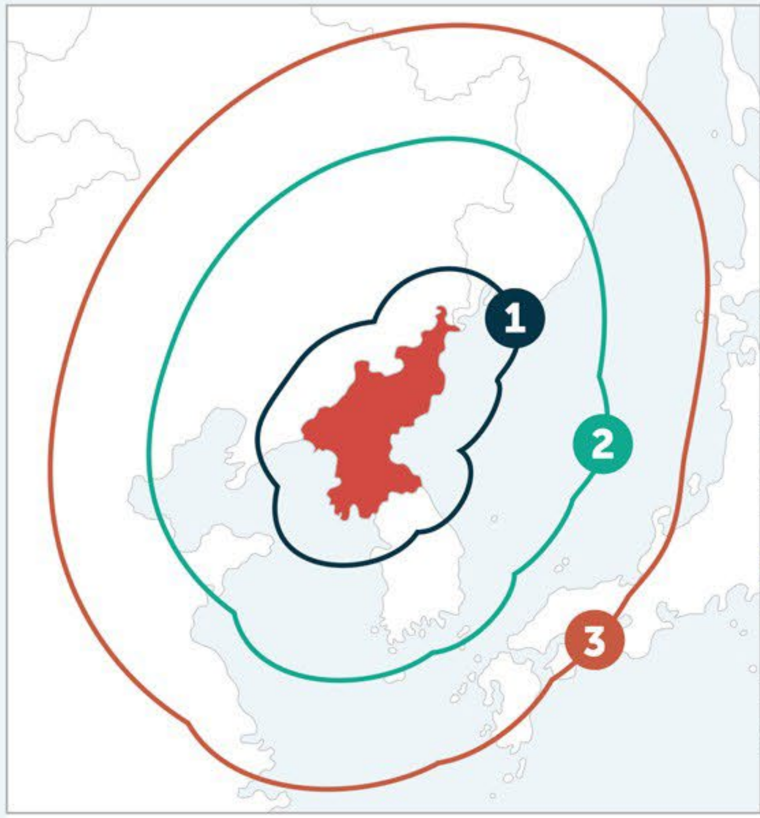
Source: national air and space intelligence center
"Ballistic and Cruise Missile Threat", 2009

Russian, Chinese and North Korean ICBMs – 2

Missile	Number of Stages	Warheads per Missile	Propellant	Deployment Mode	Maximum Range* (miles)	Number of Launchers
Russia						
SS-18 Mod 4	2 + PBV	10	Liquid	Silo	5,500+	104
SS-18 Mod 5	2 + PBV	10	Liquid	Silo	6,000+	(total for Mods 4 & 5)
SS-19 Mod 3	2 + PBV	6	Liquid	Silo	5,500+	122
SS-25	3 + PBV	1	Solid	Road-mobile	7,000	201
SS-27 Mod 1	3 + PBV	1	Solid	Silo & road-mobile	7,000	54
SS-27 Mod-X-2	3 + PBV	Multiple	Solid	Silo & road-mobile	7,000	Not yet deployed
China						
CSS-3	2	1	Liquid	Silo & transportable	3,400+	10 to 15
CSS-4 Mod 2	2	1	Liquid	Silo	8,000+	About 20
CSS-10 Mod 1	3	1	Solid	Road-mobile	4,500+	Fewer than 15
CSS-10 Mod 2	3	1	Solid	Road-mobile	7,000+	Fewer than 15
North Korea						
Taepo Dong 2	2	1	Liquid	Undetermined	3,400+	Not yet deployed

Source: national air and space intelligence center
“Ballistic and Cruise Missile Threat”, **2009**

NORTH KOREA'S BALLISTIC MISSILES



North Korea's ballistic missile program is one of the most rapidly developing threats to global security. In recent years, an unprecedented pace of missile testing has included new and longer range missiles, sea-launches, and the orbiting of satellites. The most notable of these advances has been North Korea's development of two new intercontinental ballistic missiles, the Hwasong-14 and -15, which can likely reach the continental United States.

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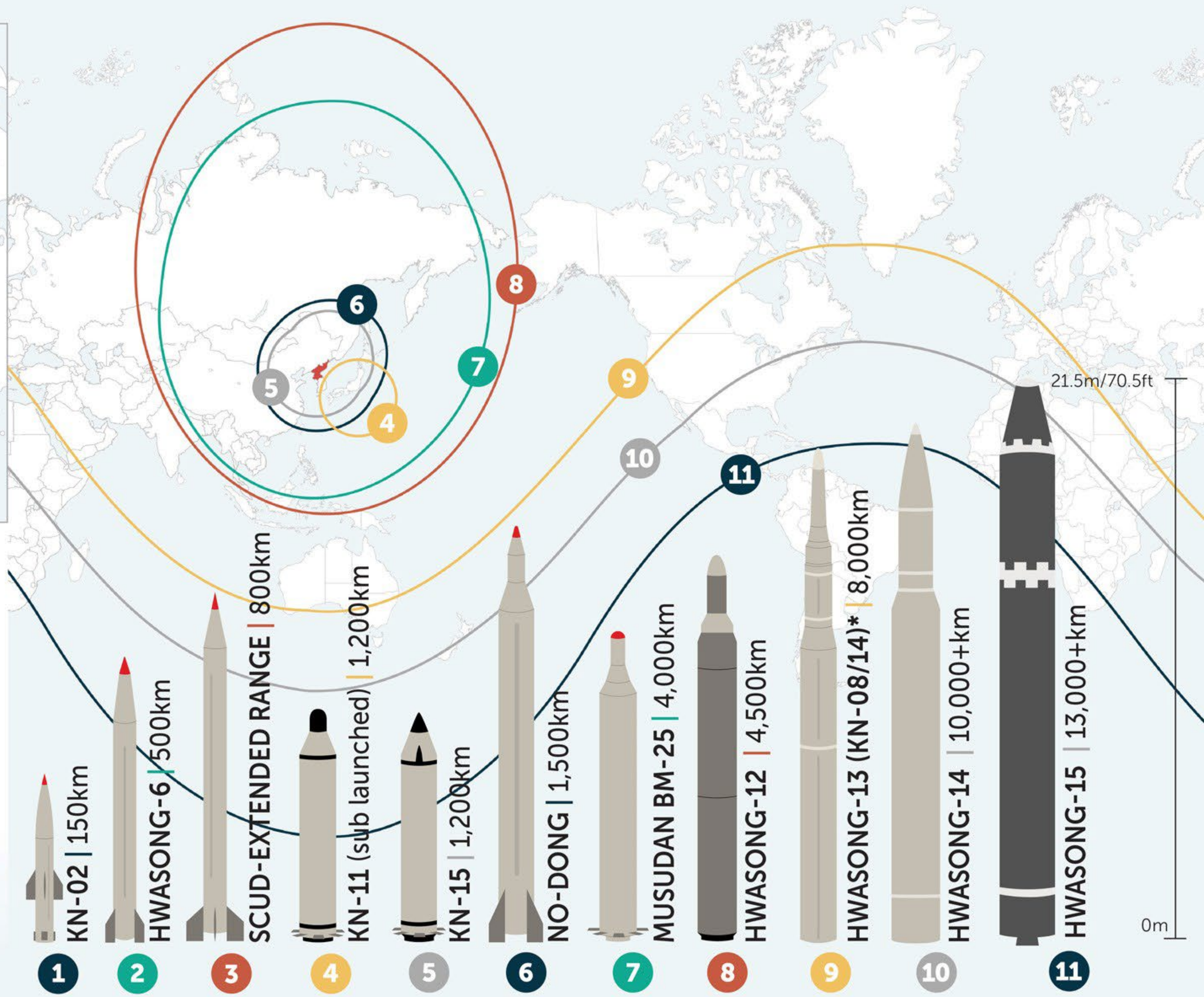


*Not yet flight tested.

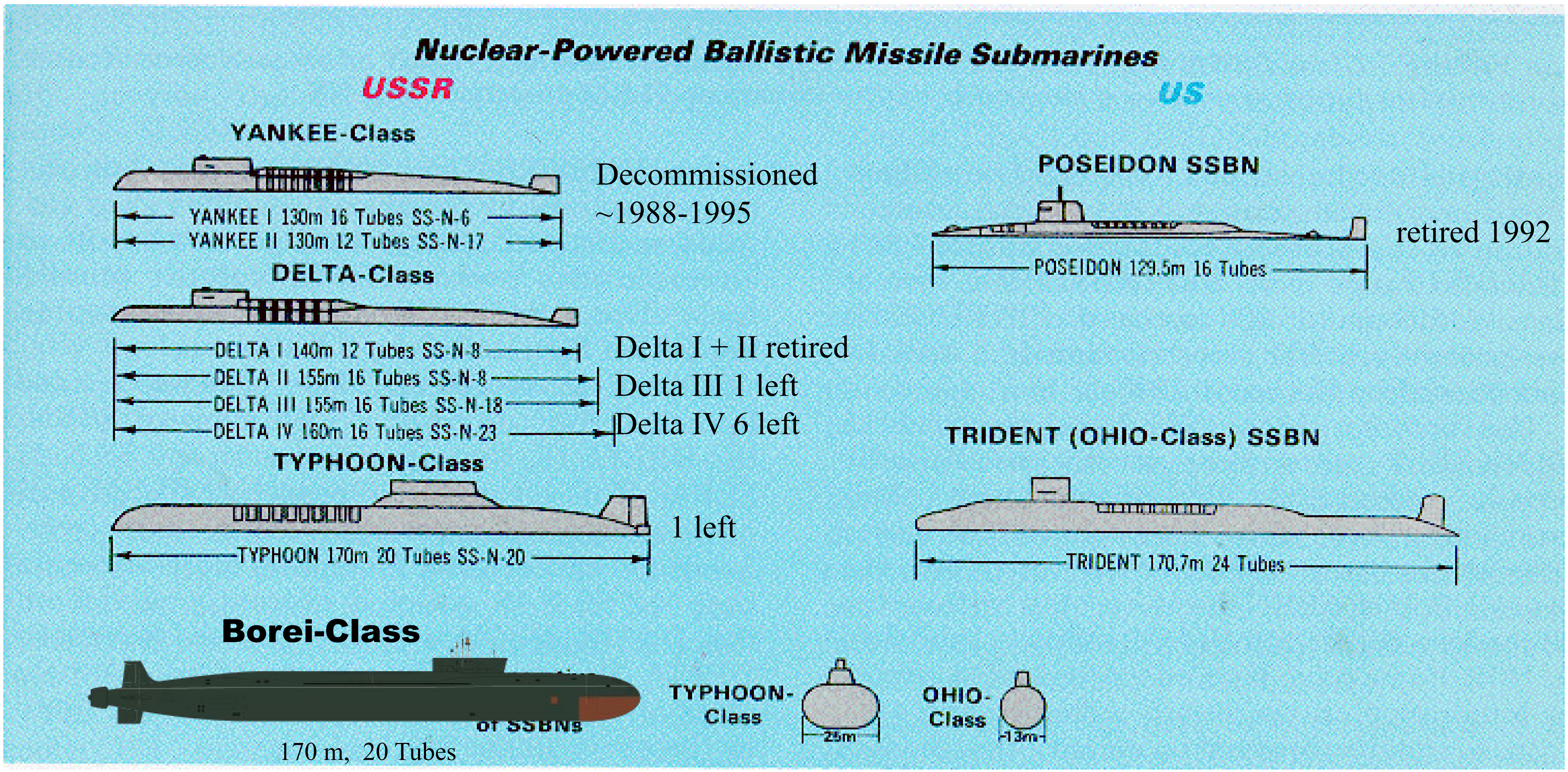
Russian, Chinese and North Korean ICBMs – 4

The Russian Dnepr space launch vehicle is based on the SS-18 ICBM.

Chinese CSS-10 Road-Mobile Launcher

Russian SS-27 Road-Mobile Launcher

US and Russian SSBNs



US Trident SSBN (14 SSBNs, 4 SSGNs)

Trident Missile Tubes
With Covers Open

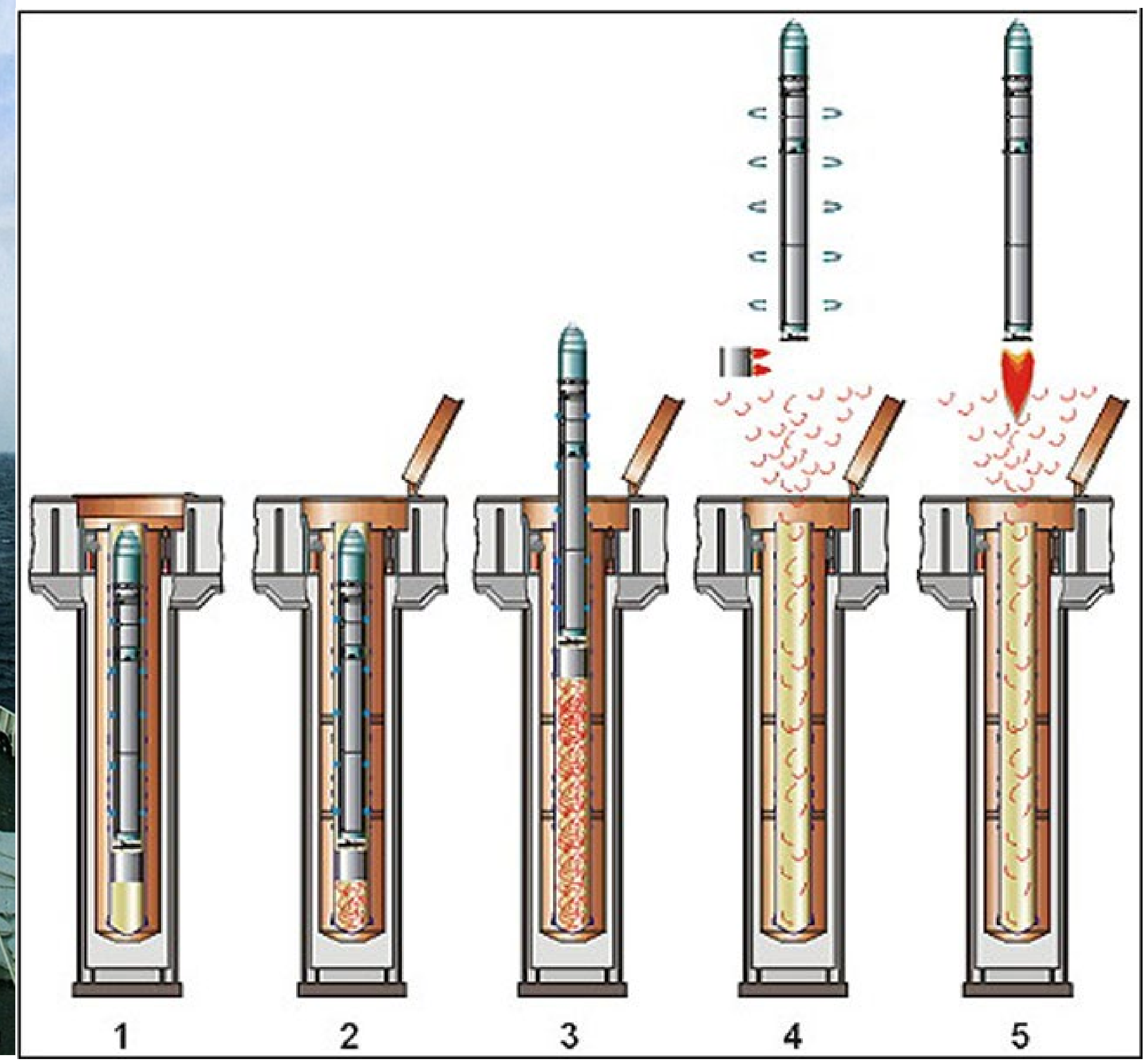
24 Trident C4 SLBMs
8 MIRVs with 100kt W76
➔ up to192 targets
SLBM range 7400 km

Trident Submarine Underway

speed	: 20 knots
SSBN range	: unlimited
deployment	: 70-90 days, two rotating crews
Displacement	: 16500 tons
Length	: 170 m
width	: 13 m

Cold Launch Mode

Missile is ejected with high pressure steam before rocket engines are started: “Cold Launch”



US Trident SSBN

Launch video

Submarine-Based Missiles

US SLBMs —

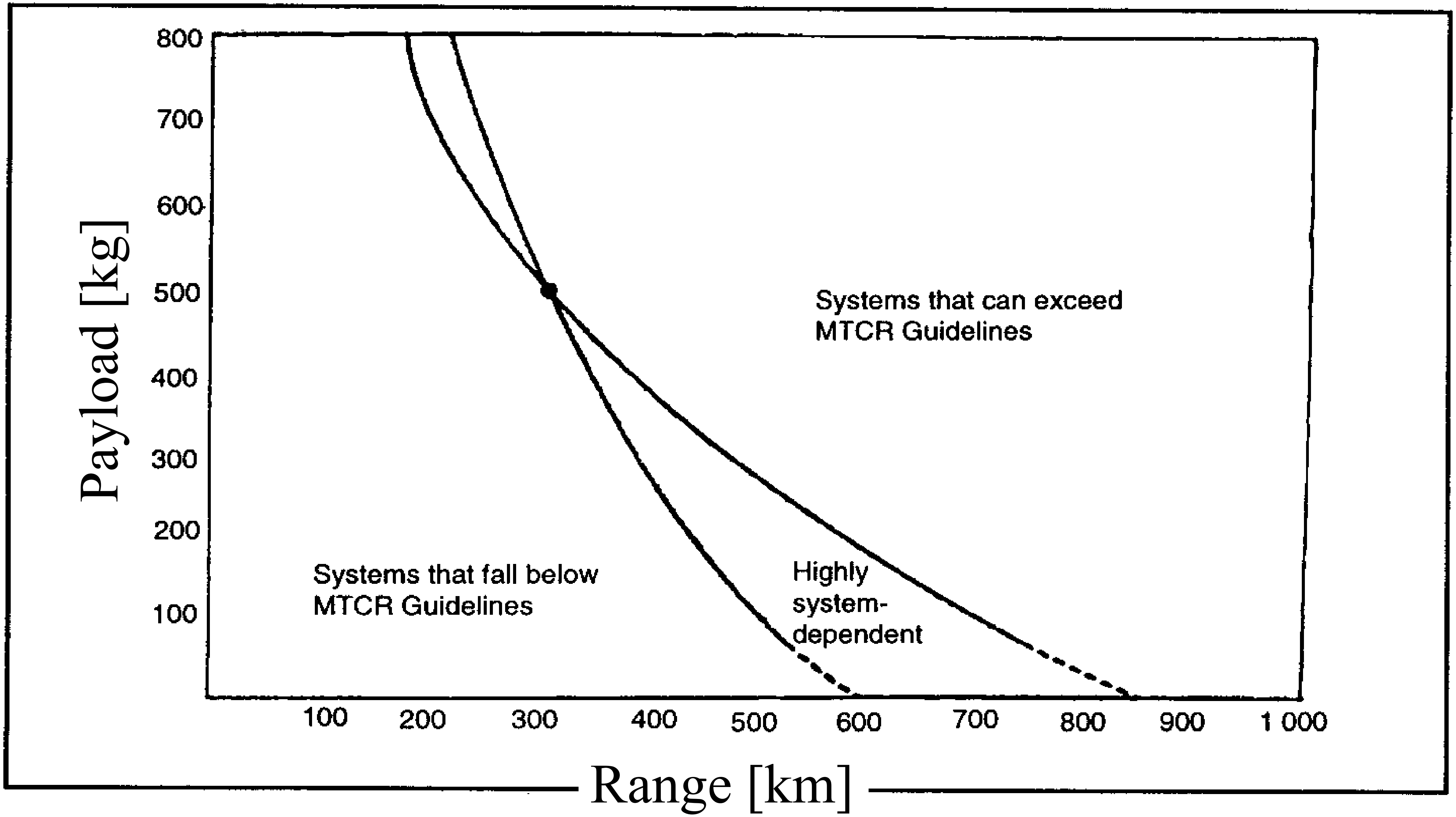
- Trident C4 missiles carried 8 MIRVs each (solid propellant, range 7400 km)
- Trident D5 missiles carry 8 MIRVs each (solid propellant, range 7400 km)

Russian SLBMs —

- SS-N-8 missiles carried 1 warhead each (range 9100 km)
- SS-N-18 missiles carried 3 warheads each (liquid propellant, range 6500 km)
- SS-N-20 missiles carried 10 warheads each (solid propellant, range 8300 km)
- SS-N-23 missiles carried 4 warheads each (liquid propellant, range 8300 km)

Part 5: Technical and Operational Aspects

MTCR: Range-Payload Limits

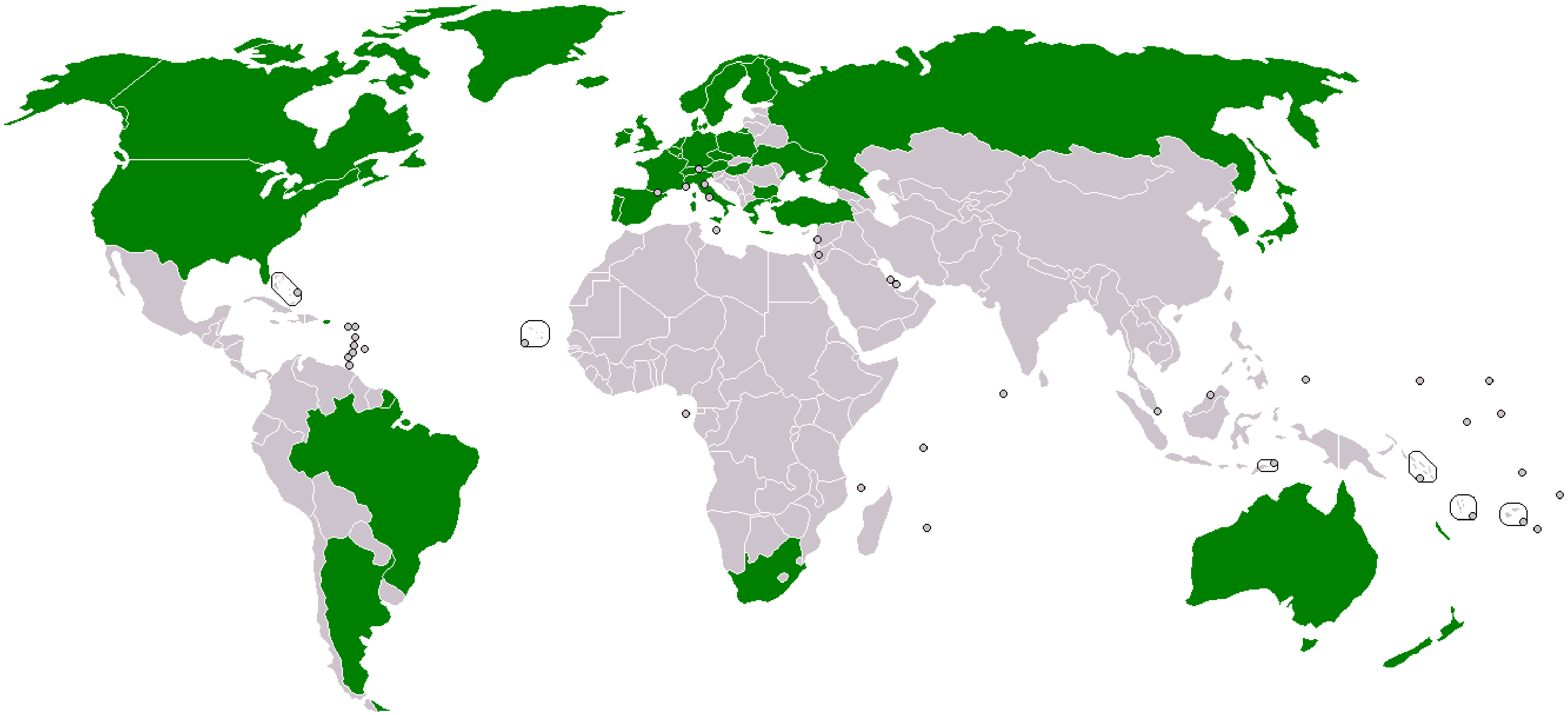


MTCR is the 1987 Missile Technology Control Regime to restrain missile exports

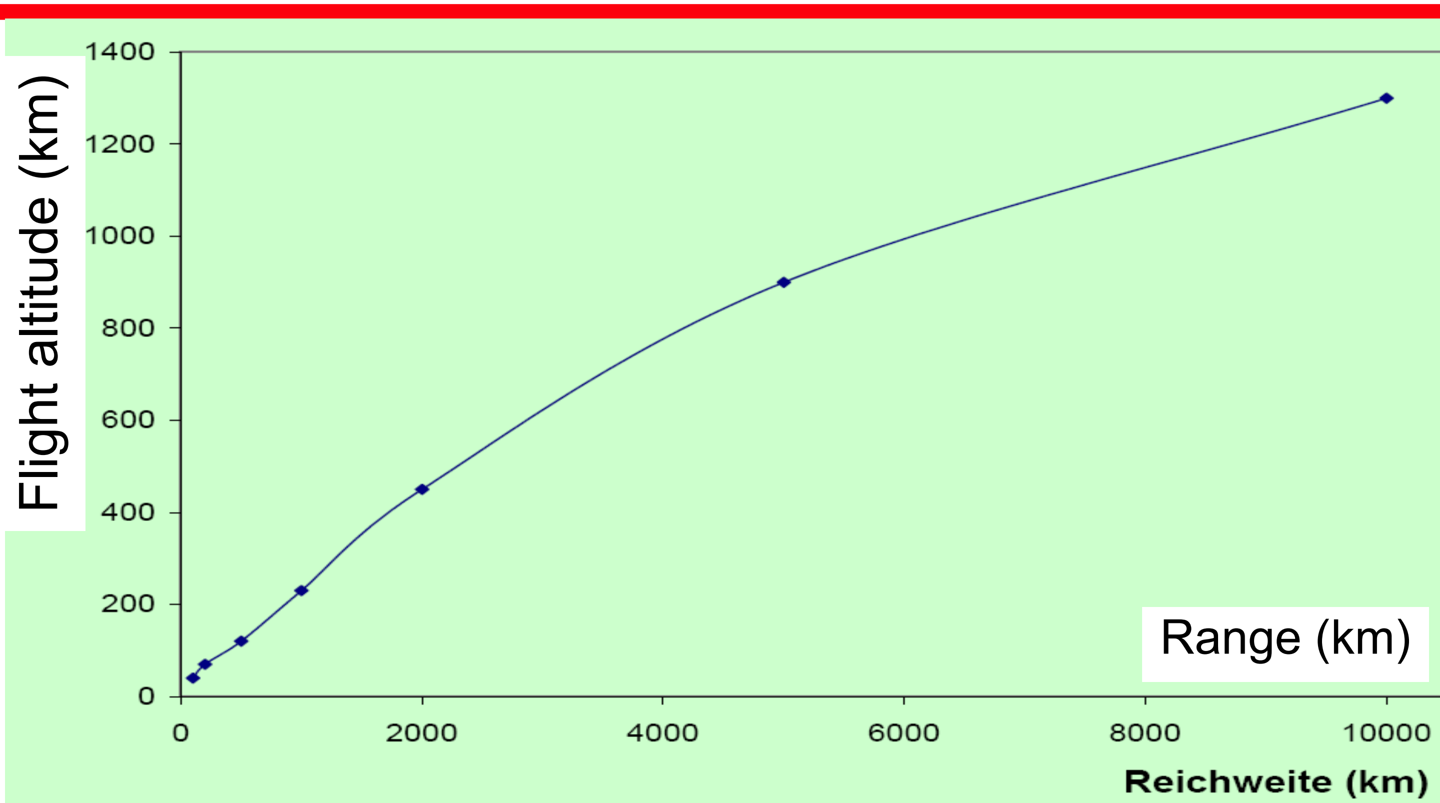
A. Karp, Ballistic Missile Proliferation, sipri, 1996, p. 157

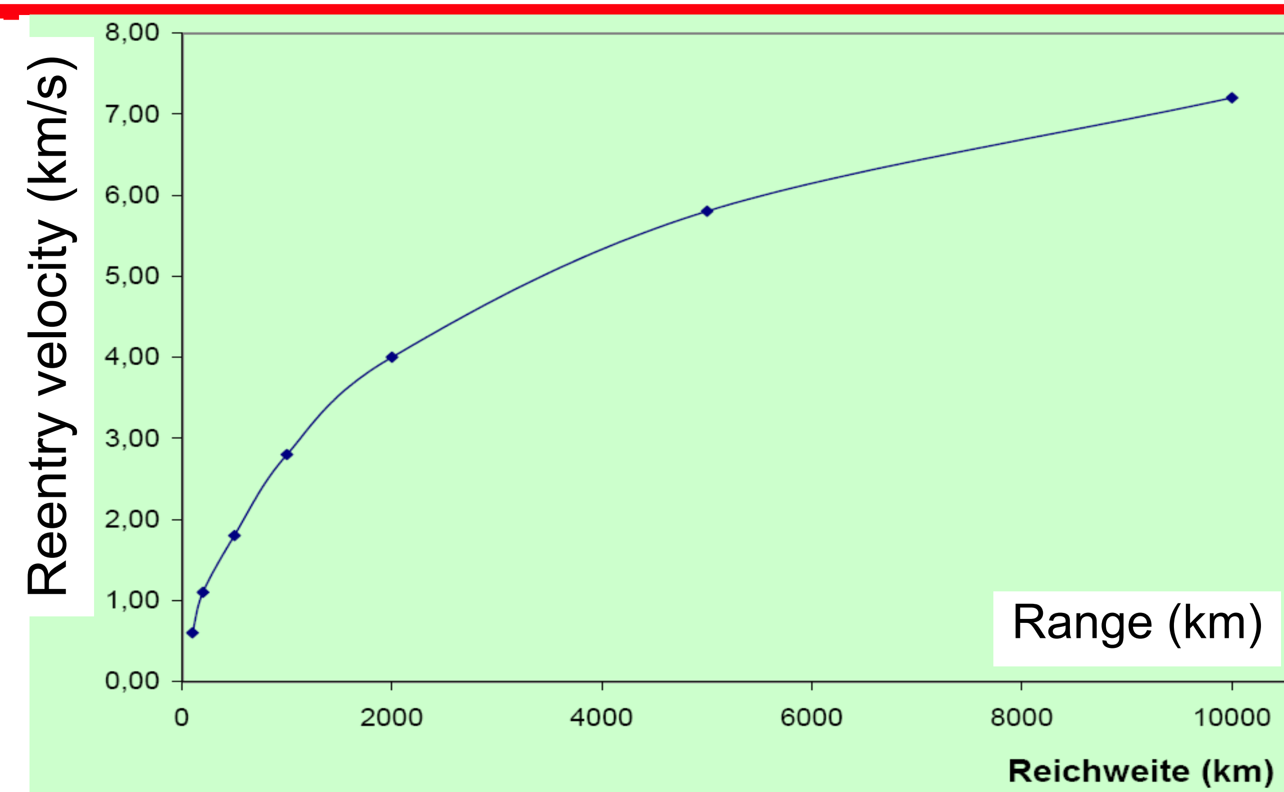
1987 Missile Technology Control Regime

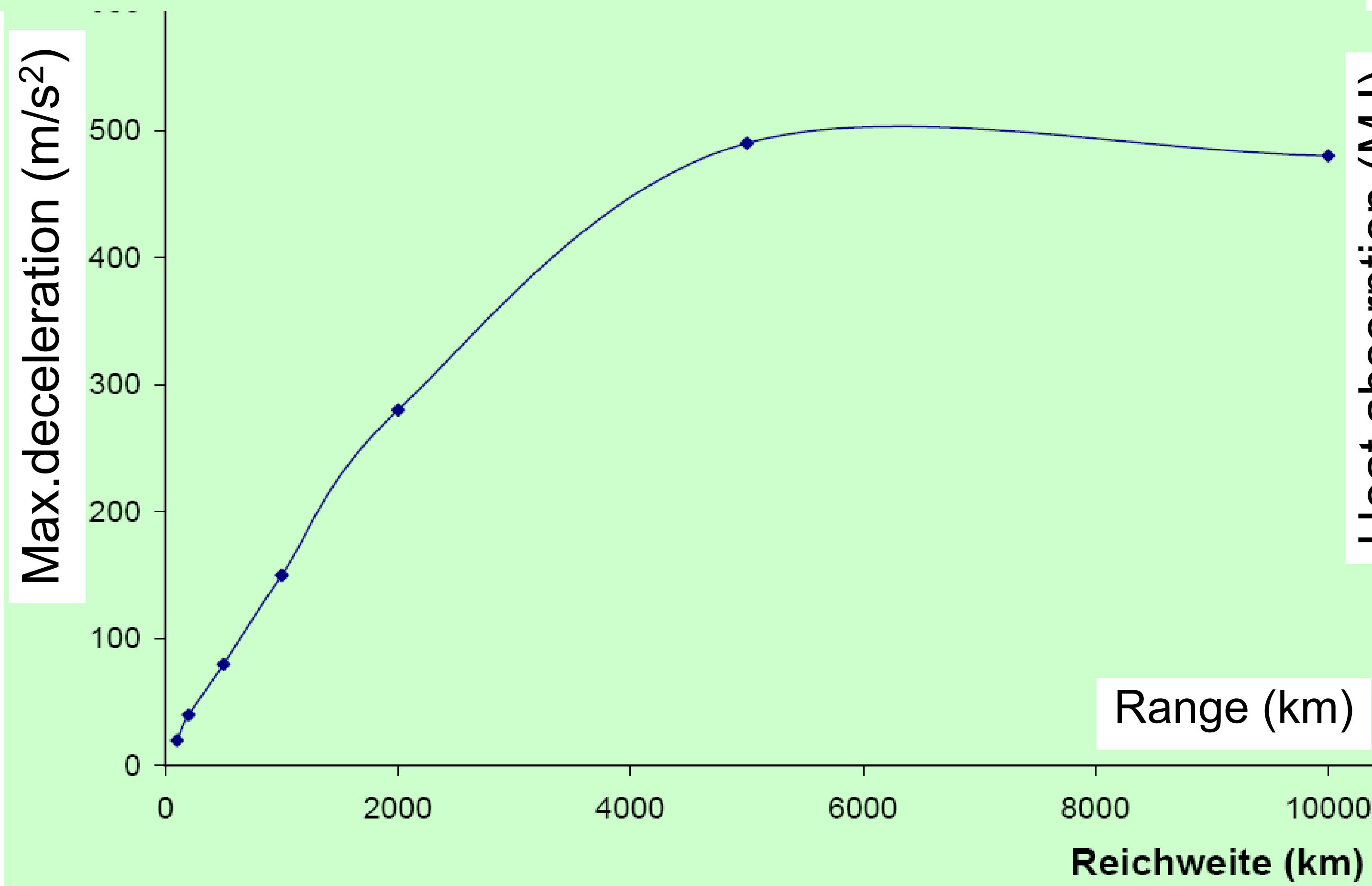
34 member countries (the leading missile producing countries have agreed to restrict missile exports).
China and Israel are not members but have agreed unilaterally to adhere to the provisions of the agreement.

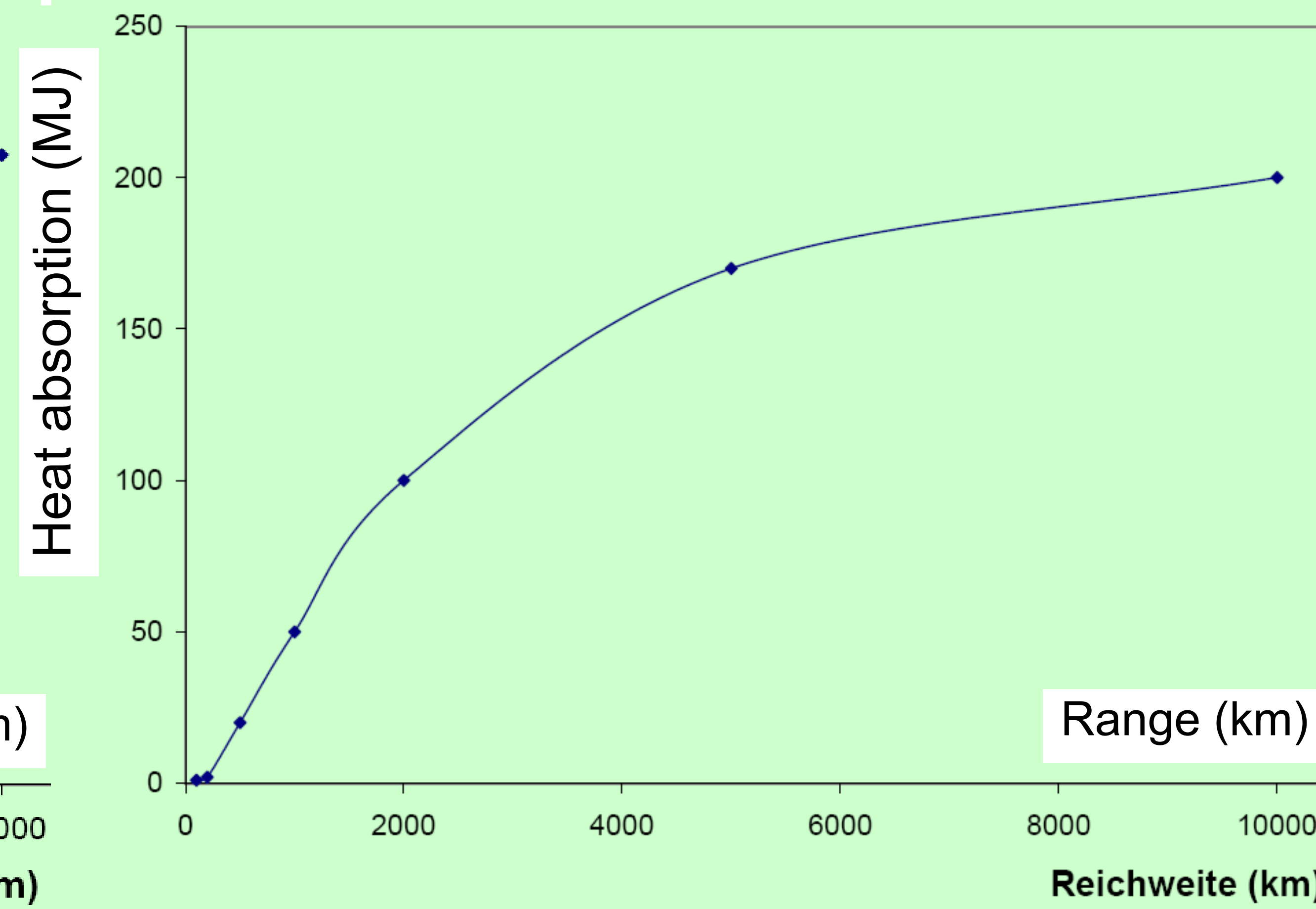


The Performance Required for Missile Warheads Increases Greatly with Increasing Missile Range









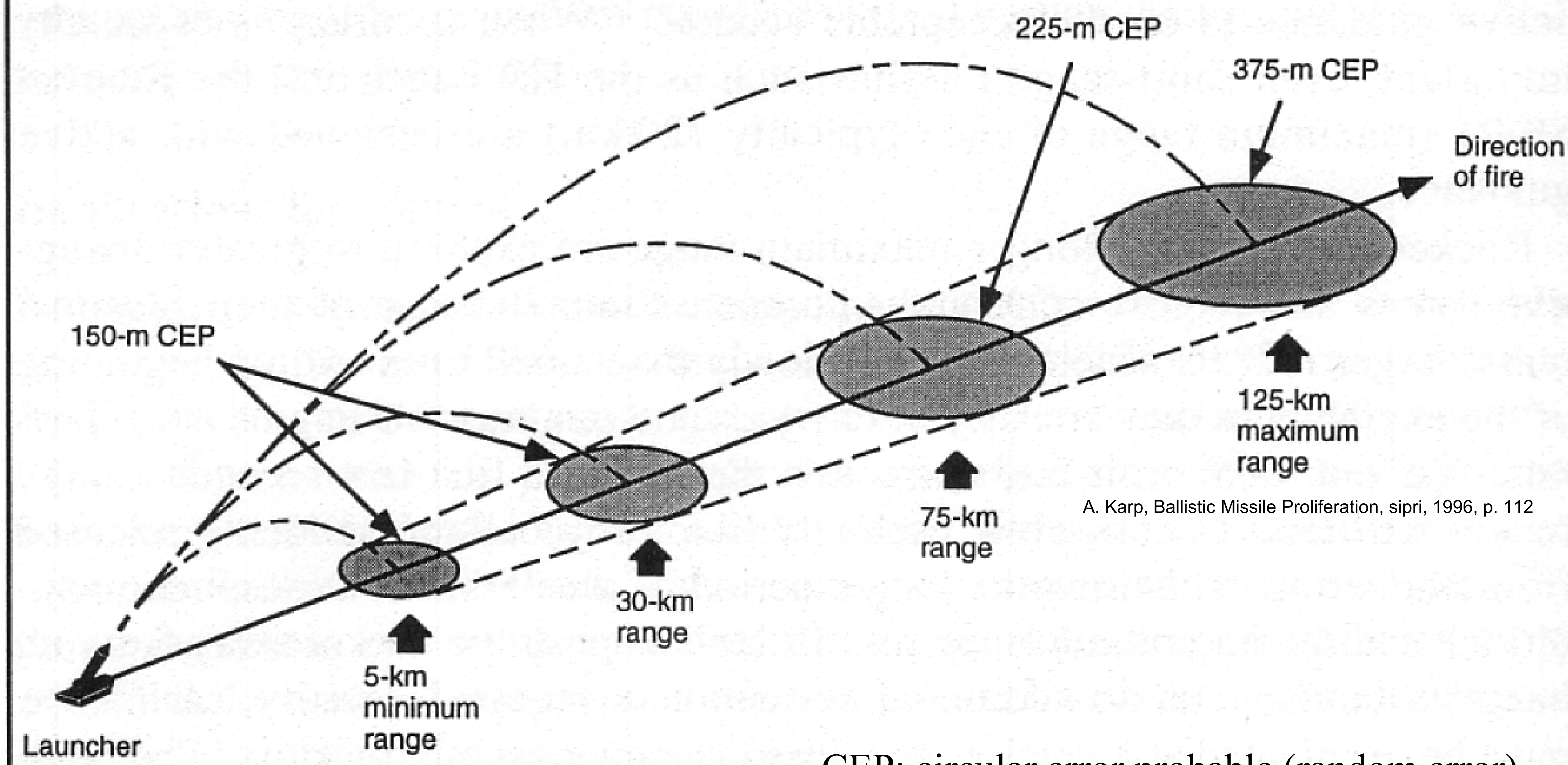
How Does this Translate into Challenges During Re-Entry into the Atmosphere?

Large frictional forces on re-entry lead to

➔deceleration up to 500 m/s^2 = 51 g
~ car with 70mph into concrete wall
g-forces can be lethal if > 25 g

➔200 MJ of energy is enough to heat
W76 warheads to the melting temperature
of iron ~ 1540 C !

Missile Range–Accuracy Tradeoff



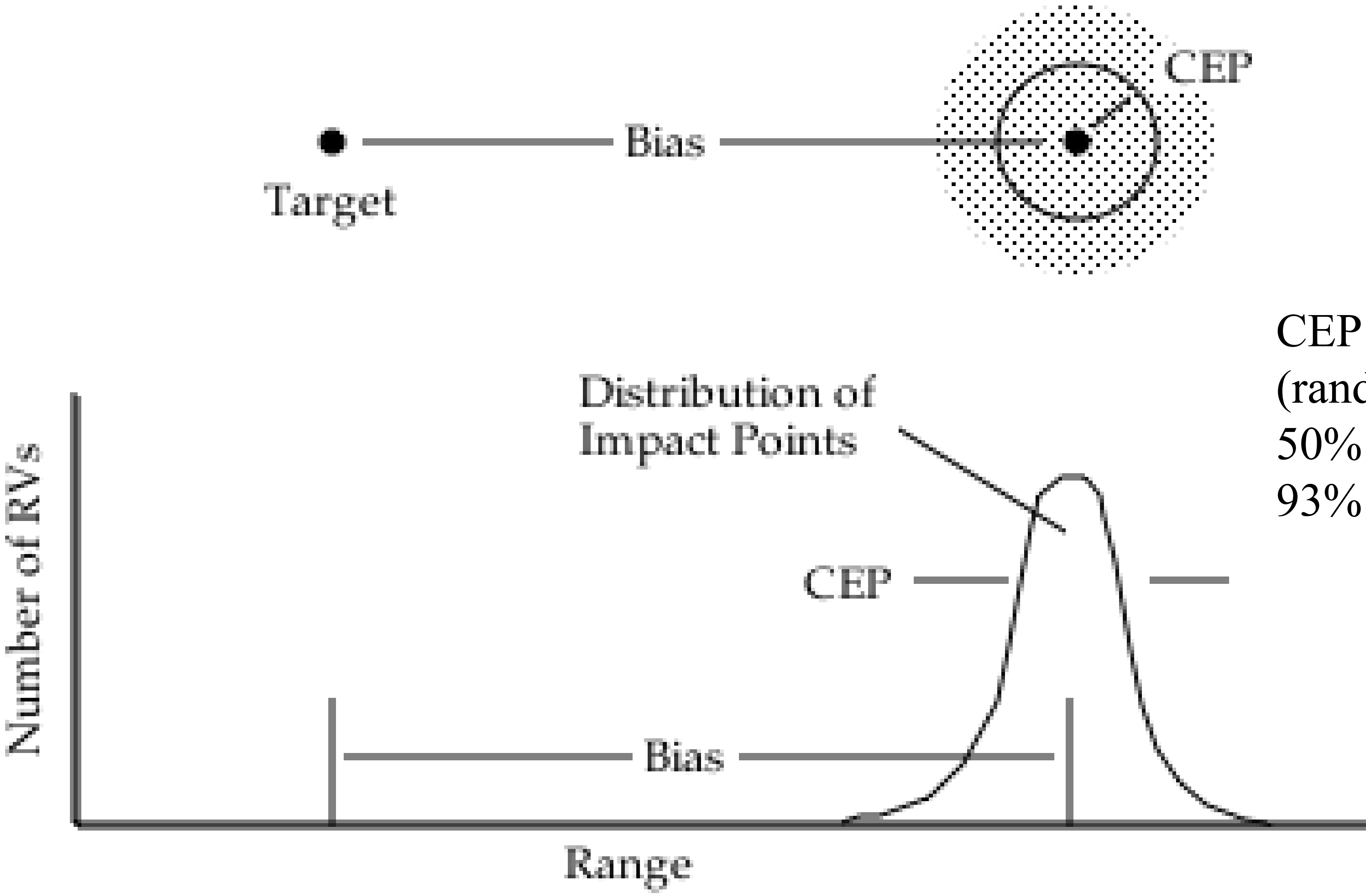
A. Karp, Ballistic Missile Proliferation, sipri, 1996, p. 112

Lance missile

CEP: circular error probable (random error)
50% of missiles land within CEP from target
93% within 2 x CEP from target

Ballistic Missile Accuracy

Distribution of RV impact points —



CEP: circular error probable (random error)
50% of missiles land within CEP,
93% within 2 x CEP from target

Ballistic Missile Accuracy

The accuracy of a ballistic missile—like the value of *any* physical quantity—can only be specified *statistically*.

Important concepts:

- D = total miss distance
- CEP = “circular error probable” (random error)
- B = Bias (systematic error)

Relation —

$$D = (B^2 + CEP^2)^{1/2}$$

CEP is *not* a measure of the miss distance. The miss distance is *at least as large* as the CEP, but can be *much larger* if there is significant bias.

Ballistic Missile Accuracy

Published CEPs for some ICBMs and SLBMs

	Missile	CEP
US	MMIII	220 m
	Trident II	100 m
Russia	SS-18	450 m
	SS-27	350 m
	SS-27 Sickle B	200 m

ICBM Accuracy & Vulnerability

Missile accuracy steadily improved during the Cold War as the result of technological innovation.

As ICBMs become more accurate, they become more vulnerable to attack by the adversary, increasing crisis instability.

Each ICBM and each SLBM was armed with more and more warheads during the Cold War.

As each missile was armed with more warheads, it became a greater threat to the nuclear forces of the adversary and a more attractive target for a pre-emptive or first strike, increasing crisis instability.

Silo-Based Missiles

Vulnerable to attack

- Silo locations are known very accurately
- MIRVed missiles make it possible to launch several warheads against an array of silos

Effect of silo hardness

- Hardening is expensive
- US assumes its silos can withstand 2,000 psi (5 psi will completely destroy a brick house)
- US assumes Russian silos can withstand 5,000 psi (example of ‘worst-case’ analysis)
- To destroy a silo this hard, a 300 kt warhead would have to land within 100 m

Silo-Based Missiles

Effect of missile accuracy

- Theoretically, missile survival is very sensitive to the miss distance D of incoming warheads
- An an example, assume
  - — 1,000 Minuteman silos are hardened to 2,000 psi
  - — Two 1.5 MT warheads are targeted to explode at ground level on each silo
- Computations predict
  - — If D = 300 ft, then 20 missiles survive (60 if 5,000 psi)
  - — If D = 500 ft, then 200 missiles survive (600 if 5,000 psi)

Sources of Systematic Error

- Gravitational field variations
- Atmospheric drag variations

Gravitational Field Variations

Some possible causes —

- Bumps on the Earth (mountains)
- Mass concentrations (masscons)
- Gravitational pull of the Moon

  (Motion of the Moon changes *g* by 3 ppm. An error in *g* of 3 ppm introduces a bias of 300 ft.)

The Earth's gravitational field is carefully measured over US and R (E-W) test ranges —

- US: Vandenberg to Kwajalein
- R: Plesetsk to Kamchatka and Tyuratam to Pacific

But wartime trajectories would be N-S over pole.

Atmospheric Drag Variations

Some possible sources —

- Jet streams
- Pressure fronts
- Surface winds
(30 mph surface wind introduces a bias of 300 ft.)

Density of the atmosphere —

- Is a factor of 2 greater in the day than at night
- Varies significantly with the season
- Is affected by warm and cold fronts

Data from military weather satellites and from models of weather over SU targets were reportedly used to update US warheads twice per day

Uncertainties on Silo-Based Missiles

Fundamental uncertainties

- Missile accuracy
- Warhead yield
- Silo hardness

Operational uncertainties

- System reliability
- Wind and weather
- Effects of other warheads (fratricide)
- Extent of 'collateral damage'
  ('digging out' missiles creates enormous fallout)

Effects of Explosive Yield, Missile Accuracy, and Silo Hardness on Land-Base Missile Vulnerability

Probability of destroying ("killing") a missile silo: $P_K = 1 - e^{-K/f(H)}$

- A 10-fold increase of warhead yield Y increases the kill factor K by about a factor of 5.
- A 10-fold decrease in the warhead miss distance D increases the kill factor K by 100.
- For a kill factor of 20, a 10-fold increase in the silo hardness from 300 psi to 3000 psi reduces the probability of silo destruction from about 85% to about 35%.

Counterforce Capabilities

U.S. ICBMs:	K = 107,000
U.S. Trident II D5:	K = 475,000
Russia ICBMs:	K = 131,000
Russia SLBMs:	K = 9,500

Submarine-Based Missiles

Operational considerations

- Vulnerability depends on
  size of operational areas, ASW threat, counter-ASW capability
- Ability to survive
- US SSBNs are quieter than Russian SSBNs
  (but Russia is improving rapidly)
- US leads in anti-submarine warfare (ASW) capability
  and access to high seas
- Fraction of forces on-station
  (duration of patrols, time required for repairs)
- System reliability
- Effectiveness of command and control

Submarine-Based Missiles

Effective number of warheads (example) before New START

- United States

2688	[SLBM warheads}
x 0.75	[fraction typically on-station]
x 0.90	[estimated reliability]
= 1,814	[effective number of warheads]

- Russia

2384	[SLBM warheads}
x 0.25	[fraction typically on-station]
x 0.70	[estimated reliability]
= 447	[effective number of warheads]

These examples show that many factors *other than just the number of warheads* are important in comparing the effectiveness of nuclear forces.

Module 5: Nuclear Delivery Systems

Part 5: Nuclear Command and Control

Nuclear Command and Control – 1

C3I: Command, Control, Communication, Intelligence

Specific goals—

- Provide strategic and tactical warning
- Provide damage assessments
- Execute war orders from National Command Authority before, during, and after initial attack
- Evaluate effectiveness of retaliation
- Monitor development of hostilities, provide command and control for days, weeks, months

Nuclear Command and Control – 2

Some important aspects and implications —

- Organizational structure of command and control
- Available strategic communications, command, control and intelligence (C^3I) assets
- Vulnerability of strategic C^3I assets to attack

Alert levels — (Defensive Readiness Condition)

DEFCON 5 Normal peacetime readiness
DEFCON 4 Normal, increased intelligence and strengthened security measures
DEFCON 3 Increase in force readiness above normal readiness intelligence and strengthened security measures
DEFCON 2 Further Increase in force readiness
DEFCON 1 Maximum force readiness.

Nuclear Command and Control – 3

Satellite systems

- Early warning
- Reconnaissance
- Electronic signals
- Weather
- Communication
- Navigation

Response Times for Attack or Breakout

The Threat of Accidental Nuclear War – 20 Dangerous Incidents

1) November 5, 1956: Suez Crisis Coincidence

2) November 24, 1961: BMEWS Communication Failure

3) August 23, 1962: B-52 Navigation Error

4) August-October, 1962: U2 Flights into Soviet Airspace

5) October 24, 1962- Cuban Missile Crisis: A Soviet Satellite Explodes

6) October 25, 1962- Cuban Missile Crisis: Intruder in Duluth

7) October 26, 1962- Cuban Missile Crisis: ICBM Test Launch

8) October 26, 1962- Cuban Missile Crisis: Unannounced Titan Missile Launch

9) October 26, 1962- Cuban Missile Crisis: Malstrom Air Force Base

10) October, 1962- Cuban Missile Crisis: NATO Readiness

Source: www.nuclearfiles.org/kinuclearweapons/anwindex.html

The Threat of Accidental Nuclear War
20 Dangerous Incidents

11) October, 1962- Cuban Missile Crisis: British Alerts

12) October 28, 1962- Cuban Missile Crisis: Moorestown False Alarm

13) October 28, 1962- Cuban Missile Crisis: False Warning Due to Satellite

14) November 2, 1962: The Penkovsky False Warning

15) November, 1965: Power Failure and Faulty Bomb Alarms

16) January 21, 1968: B-52 Crash near Thule

17) October 24-25, 1973: False Alarm During Middle East Crisis

18) November 9, 1979: Computer Exercise Tape

19) June , 1980: Faulty Computer Chip

20) September, 1983: Russian False Alarm

21) November, 1983 Able Archer

21) January, 1995: Russian False Alarm (Norwegian research missile)

Source: www.nuclearfiles.org/kinuclearweapons/anwindex.html

January, 1995: Russian False Alarm

On January 25, 1995, the Russian early warning radar's detected an unexpected missile launch near Spitzbergen. The estimated flight time to Moscow was 5 minutes. The Russian President, the Defense Minister and the Chief of Staff were informed. The early warning and the control and command center switched to combat mode. Within 5 minutes, the radar's determined that the missile's impact would be outside the Russian borders.

The missile was Norwegian, and was launched for scientific measurements. On January 16, Norway had notified 35 countries including Russia that the launch was planned. Information had apparently reached the Russian Defense Ministry, but failed to reach the on-duty personnel of the early warning system.

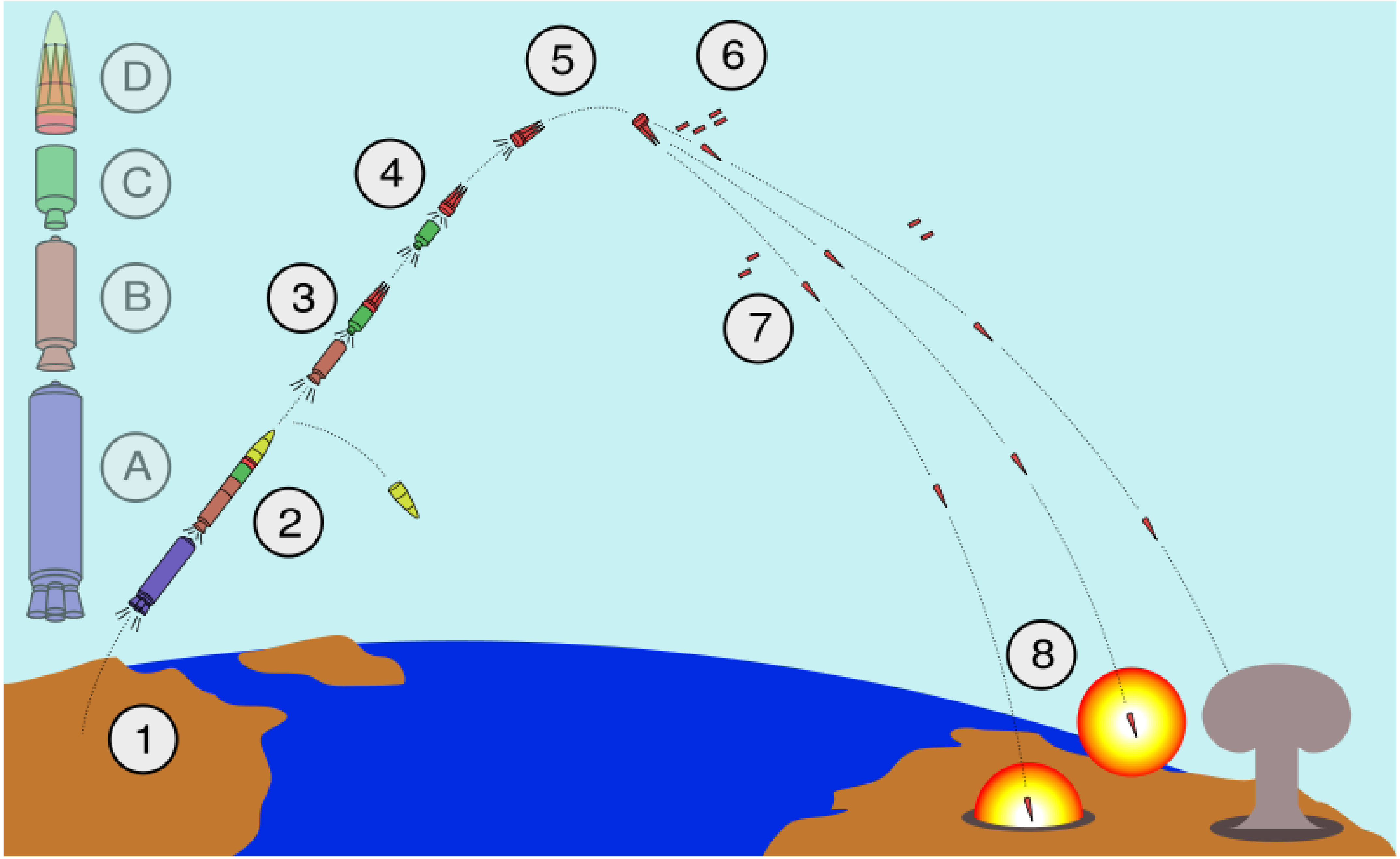
Possible Risk Reduction Measures

- Put ballistic missiles on low-level alert
- Reduce number of warheads on missiles
- Remove warheads to storage
- Disable missiles by having safety switches pinned open and immobilized
- Allow inspections and cooperative verification

Source: B. Blair, H. Feiveson. F. von Hippel, Taking Nuclear Weapons off Hair-Trigger Alert, Scientific American, November 1997

End of Module 5

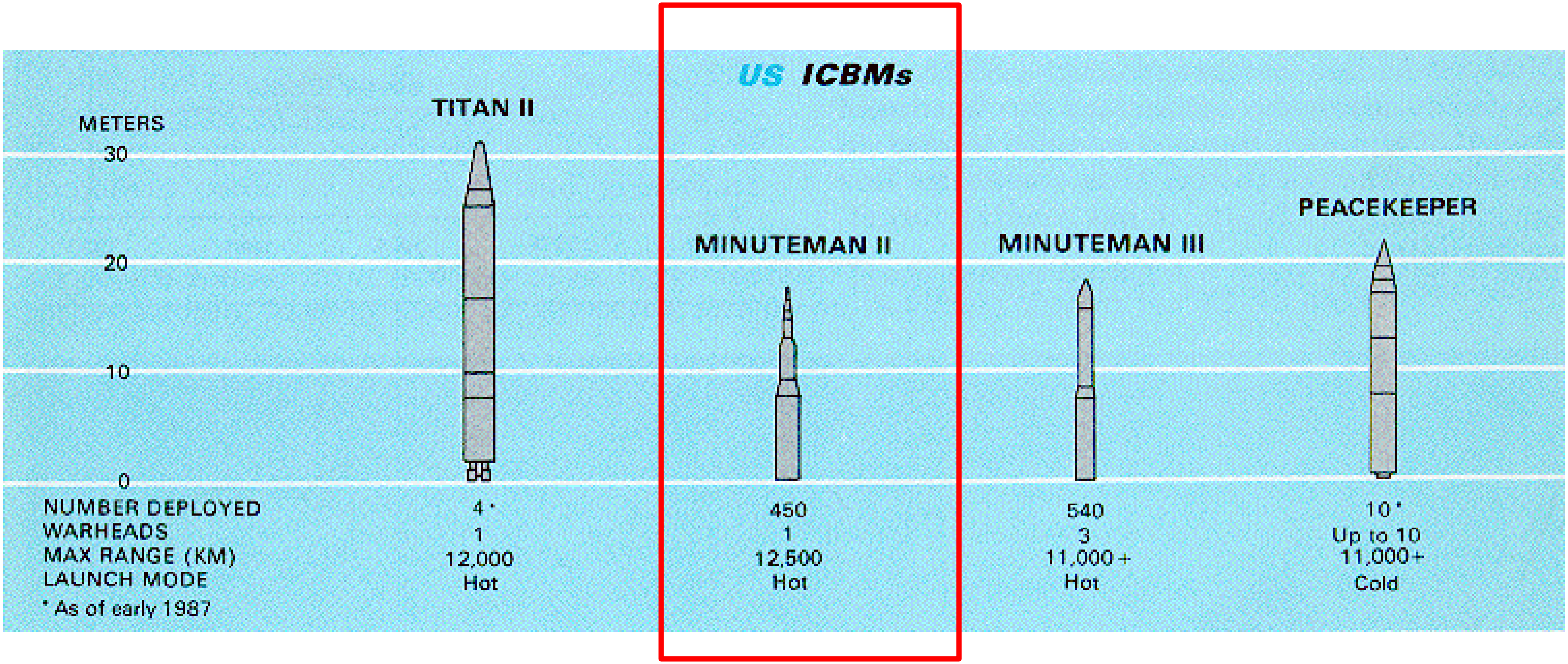
Flight of a MIRV'd ICBM (Schematic)



Flight of a MIRV'd ICBM (Schematic)

1. The missile launches out of its silo by firing its 1st stage boost motor (*A*).
2. About 60 seconds after launch, the 1st stage drops off and the 2nd stage motor (*B*) ignites. The missile shroud is ejected.
3. About 120 seconds after launch, the 3rd stage motor (*C*) ignites and separates from the 2nd stage.
4. About 180 seconds after launch, 3rd stage thrust terminates and the Post-Boost Vehicle (*D*) separates from the rocket.
5. The Post-Boost Vehicle maneuvers itself and prepares for re-entry vehicle (RV) deployment.
6. The RVs, as well as decoys and chaff, are deployed during backaway.
7. The RVs and chaff re-enter the atmosphere at high speeds and are armed in flight.
8. The nuclear warheads detonate, either as air bursts or ground bursts.

US ICBMs – 1



current land based
US ICMB

US and Russian SLBMs