MIT
Science, Technology, and
National Security Working Group

Analysis of Fordow Bombing Locations and Some Implications

Dialogue Works
June 28, 2025

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Massachusetts Institute of Technology, Cambridge, Massachusetts

Basic Conclusions Provided by This Analysis

Iran Certainly *Now* Has Enough Enriched Uranium to Quickly Produce Atomic Bombs Even If Almost All Centrifuges at Fordow Have Been Destroyed

The *Massive Ordnance Penetrator* is very Unlikely to do Significant Damage at Fordow

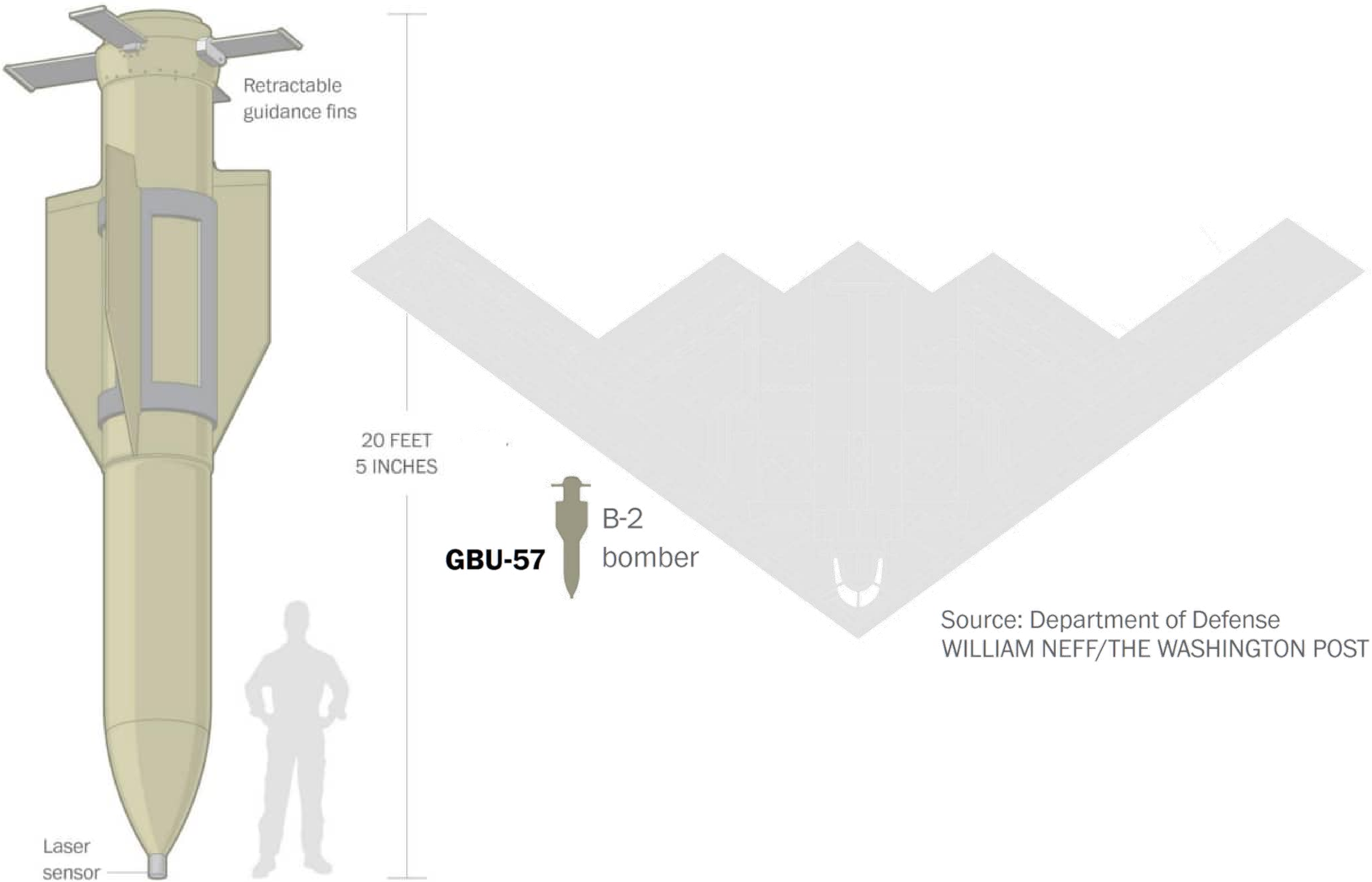
US Strategy For Using the *Massive Ordnance Penetrator* is Very Unlikely to Have Succeeded in Destroying Many, If Any, IR-6 Centrifuges at Fordow

The Israeli Government is Likely *Now* Under Significant and Increasing Domestic Pressure Due to Highly Visible Damage Inflicted By Iranian Long-Range Missiles

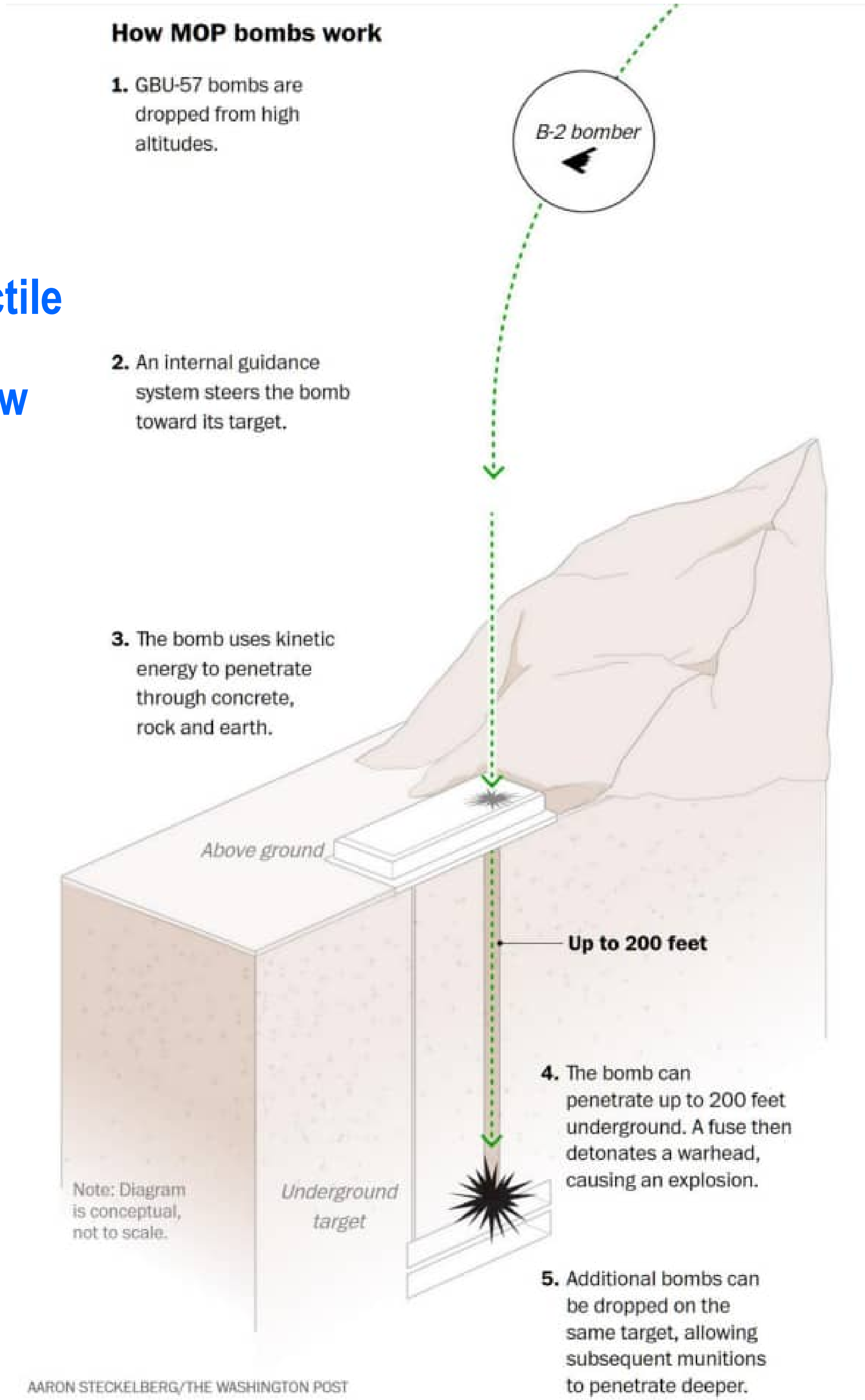
Massive Ordnance Penetrator
Very Unlikely to Be Able to Do the Job at Fordow

Massive Ordnance Penetrator

Massive Ordnance Penetrator (MOP)

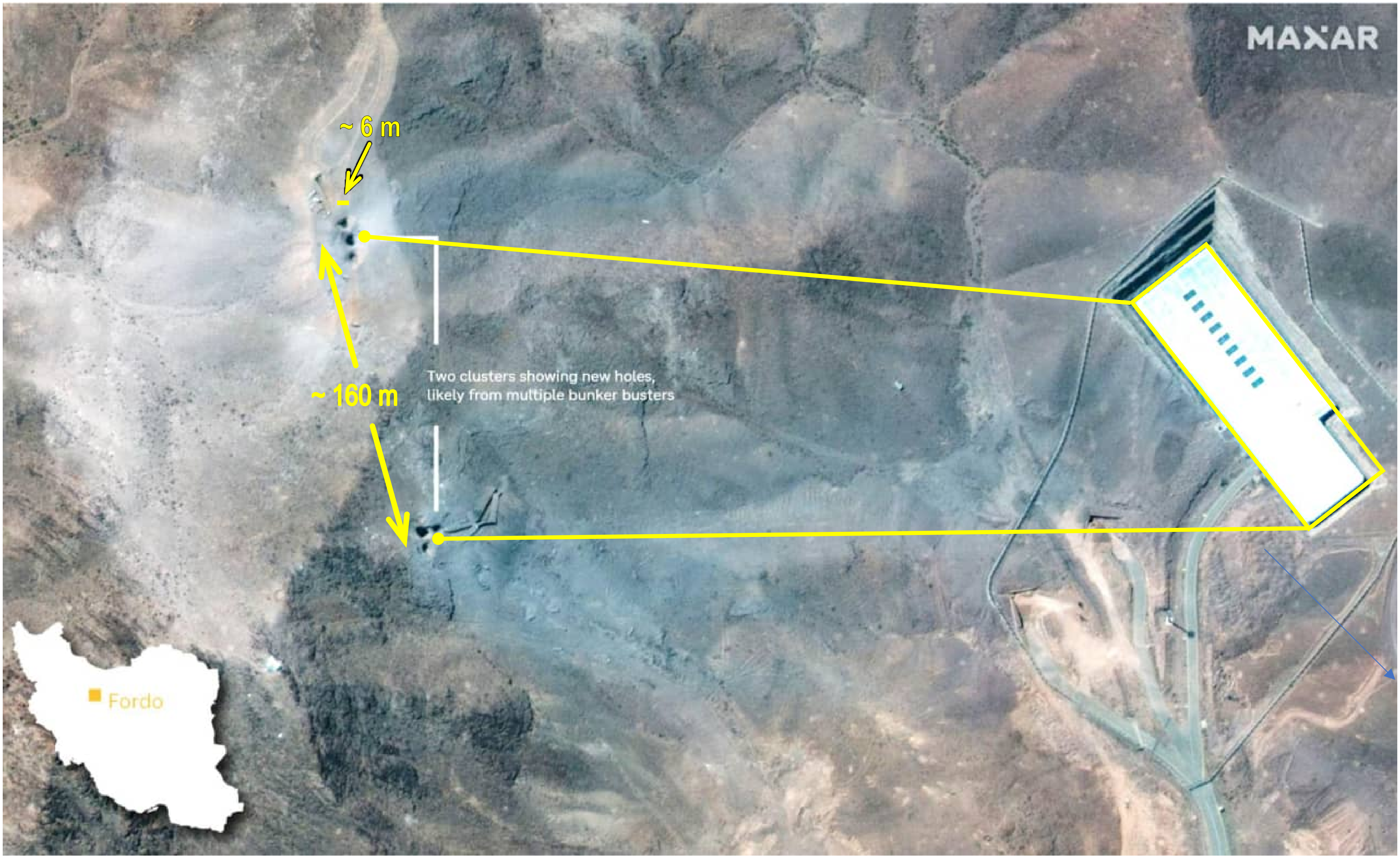


Roughly Six
Massive Ordnance Projectile (MOP)
Holes Visible at Fordnow Enrichment Site



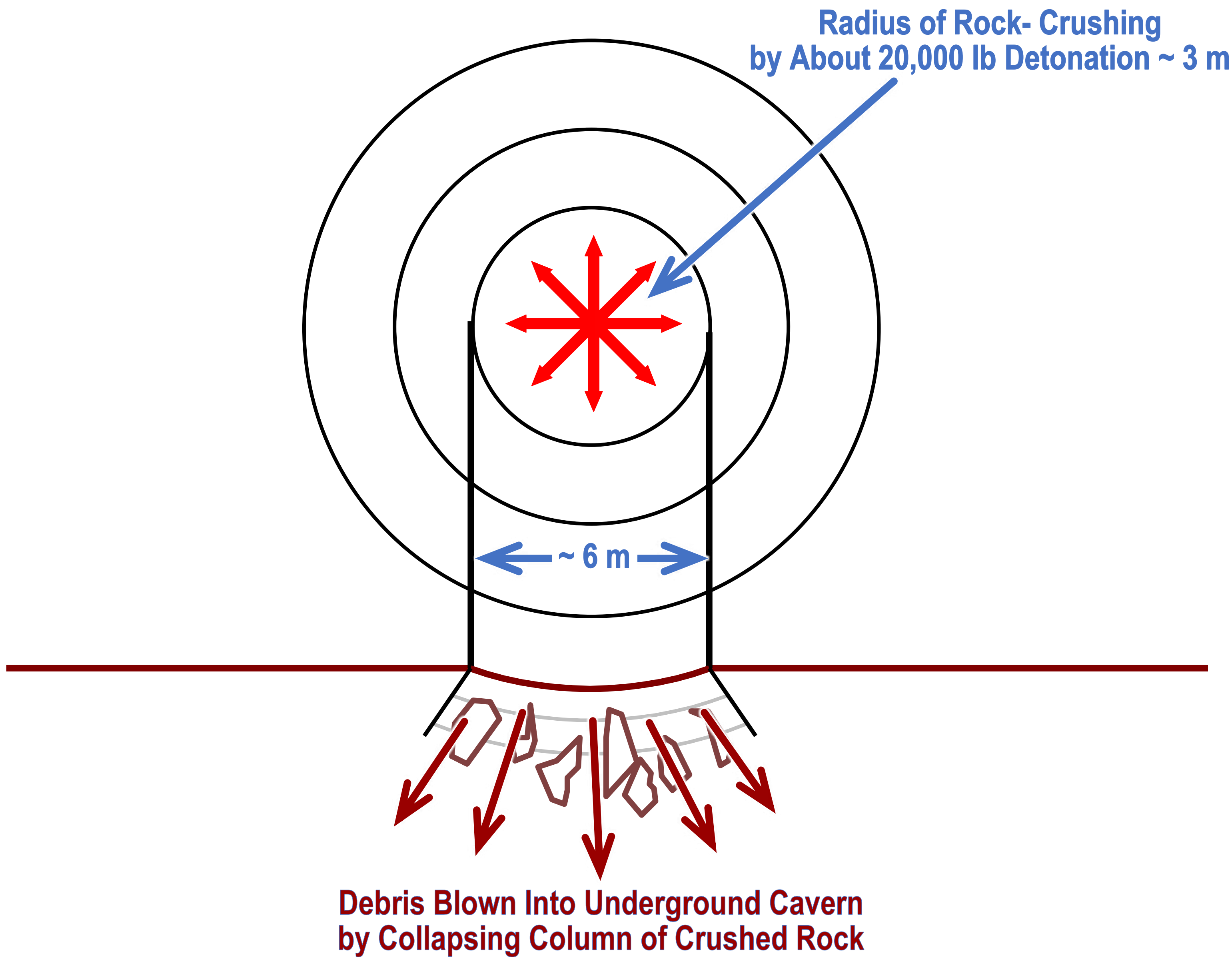
Visible Results of US Attack on Fordow on June 15, 2025

Dropped By US B-2 Bombers
At Two Ground-Zero Locations
Diameter of Column of Rock that Might be Collapsed ~ 6-7 Meters

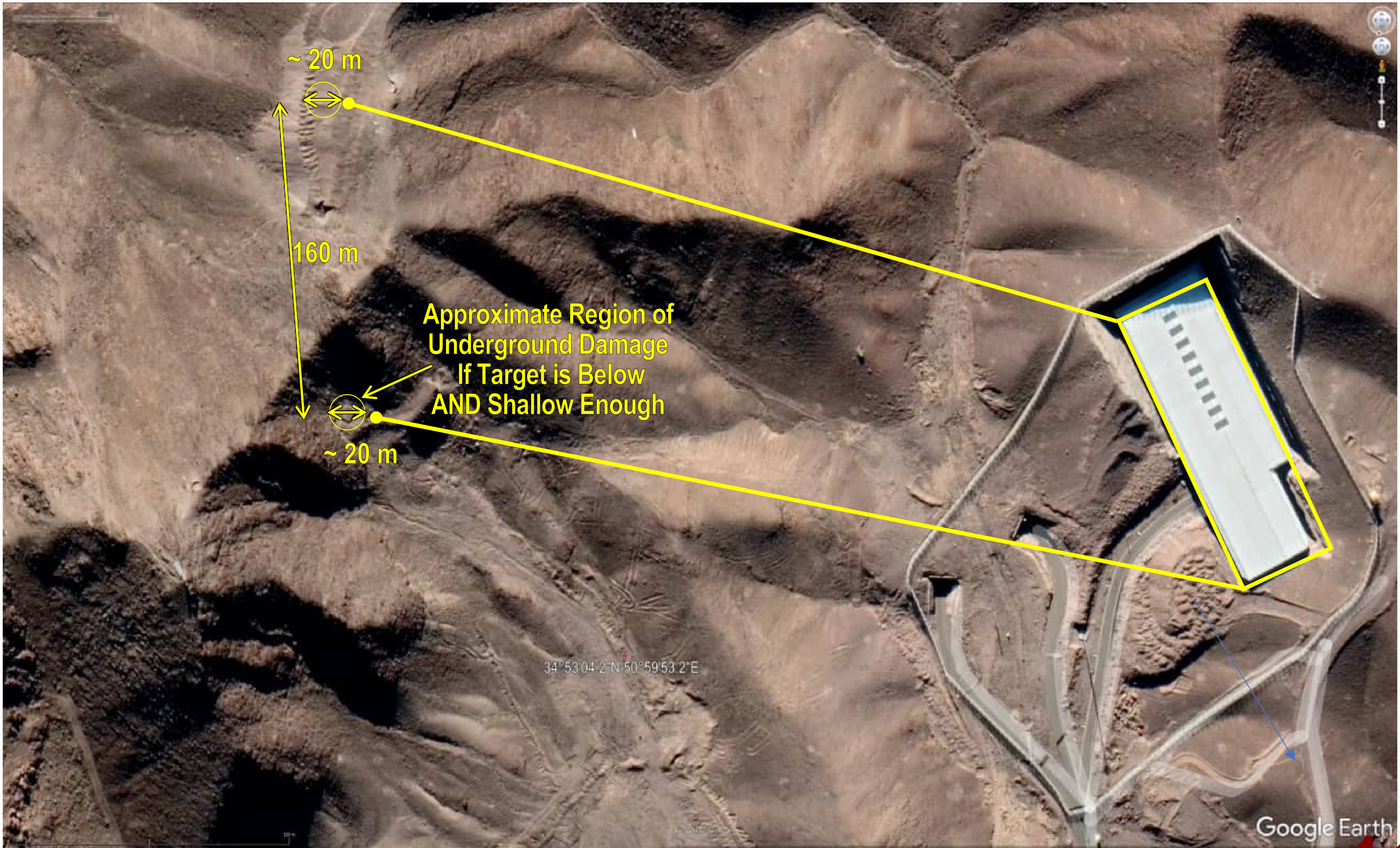


Apparent Bombing Strategy
Was to Try to Damage Underground Structures
by Directing Shockwave through Apparent Venting Systems
or Collapsing Tunnels with Crushed Rock

Underground Blast Has Only *Modest* Potential to Cave In Cavity Below (Assuming It is Placed Accurately and Penetrates Deep Enough) Diameter of Column of Rock that Might be Collapsed ~ 6-7 Meters



Roughly Six Massive Ordnance Projectiles (MOP) Dropped By US B-2 Bombers At Two Ground-Zero Locations Diameter of Column of Rock that Might be Collapsed ~ 6-7 Meters



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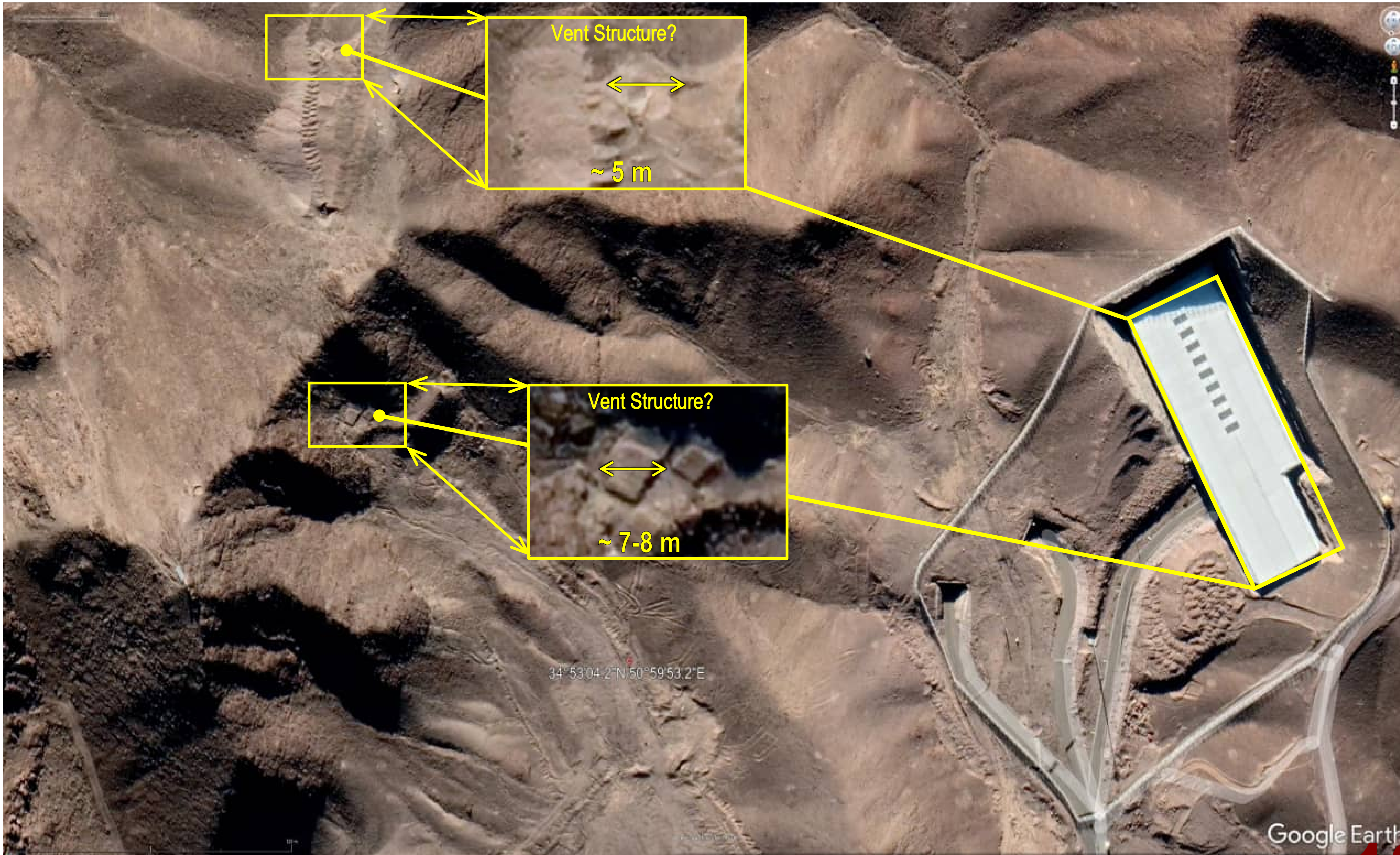
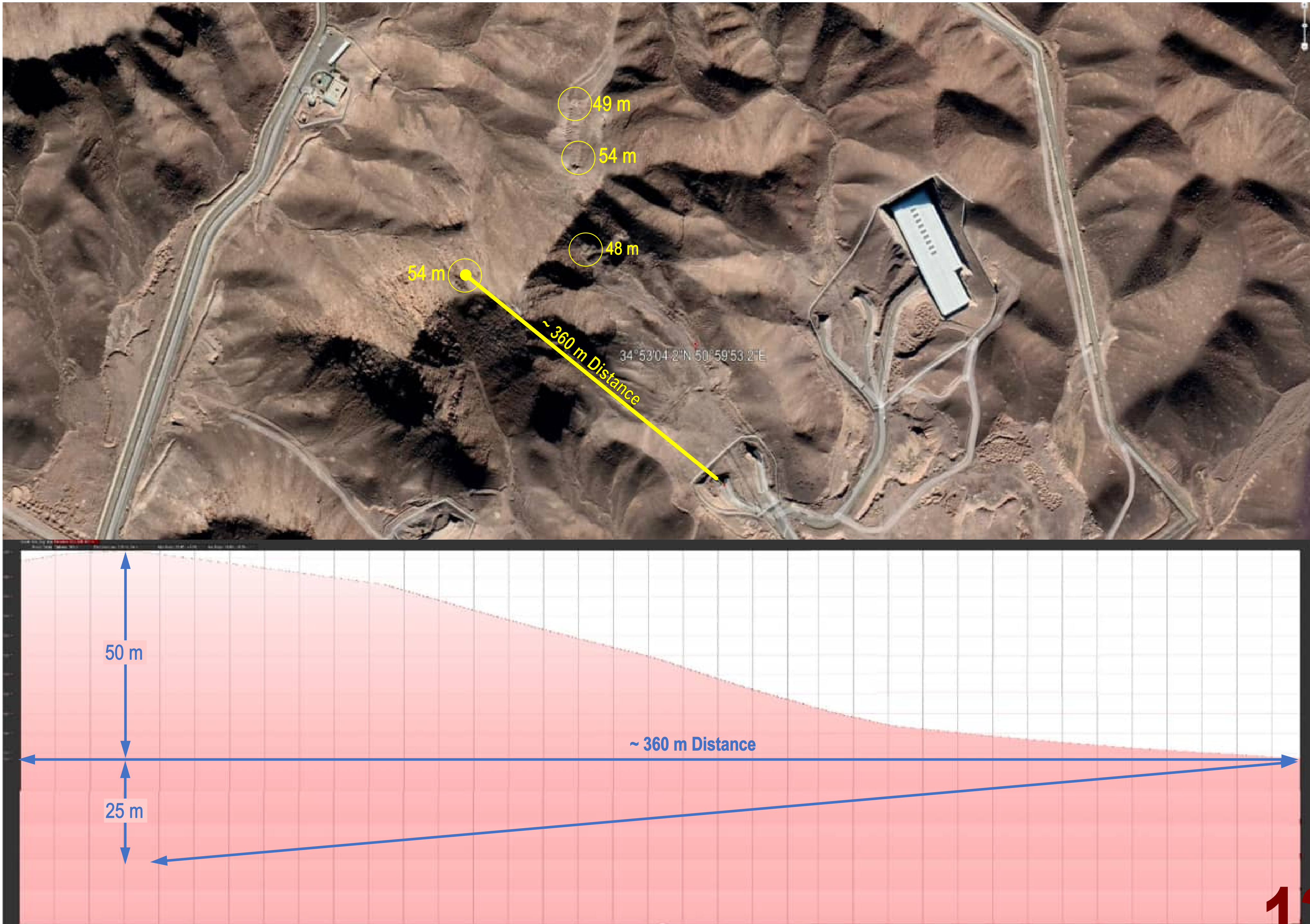


Heights Above Tunnel Entrance at Selected Locations on Mountain



Estimates of Explosive Cavity Sizes from Glasstone and Dolan's *Effects of Nuclear Weapons*

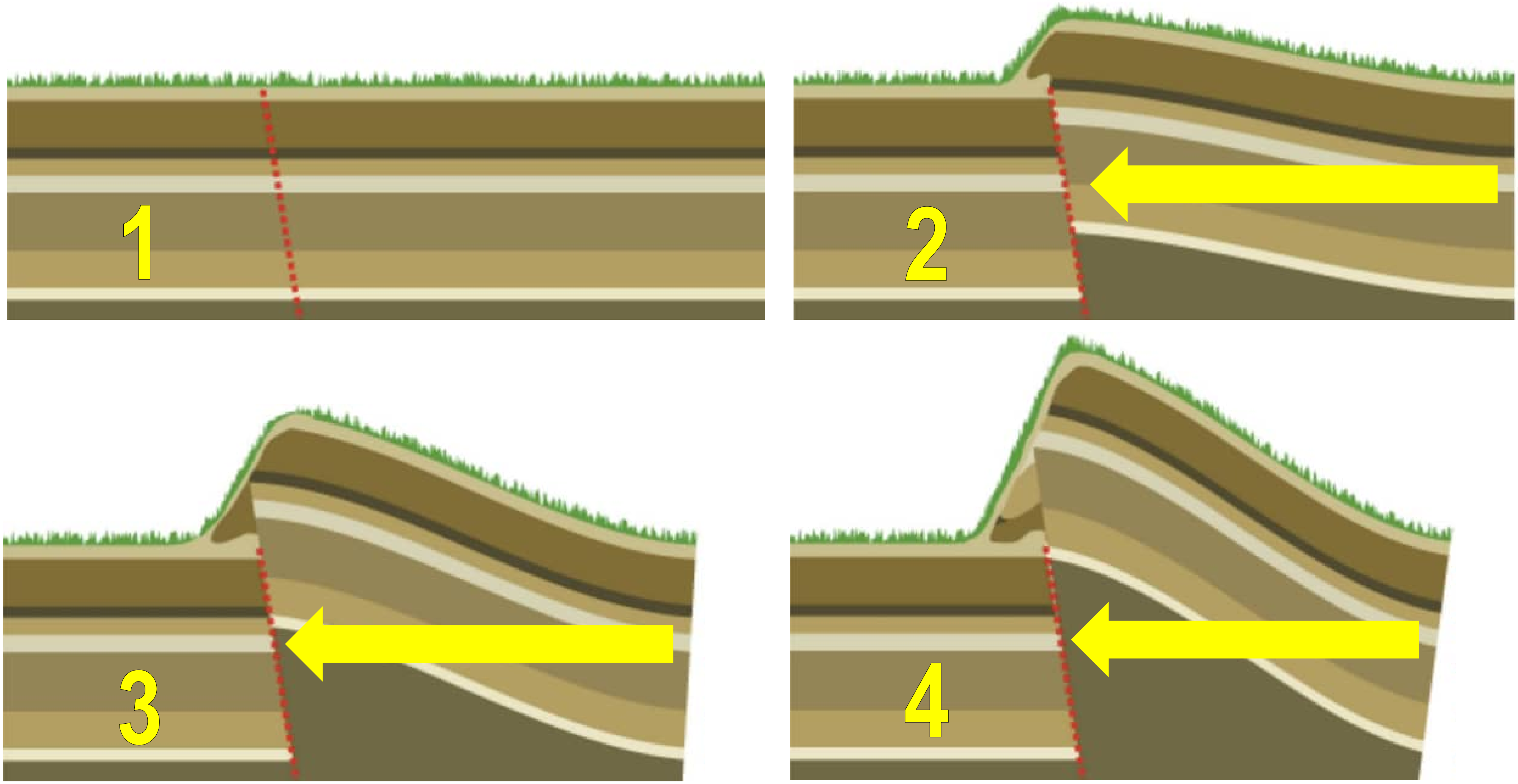
Dense silicate rocks
(e.g., granite). . . . . . .35 feet/KT$^{1/3}$
Dense carbonate rocks
(e.g., dolomite, limestone)
. . . . .25 feet/KT$^{1/3}$

$$35\times (20 \text{ tons}/1000 \text{ tons})^{1/3} = 9.50 \text{ ft}$$

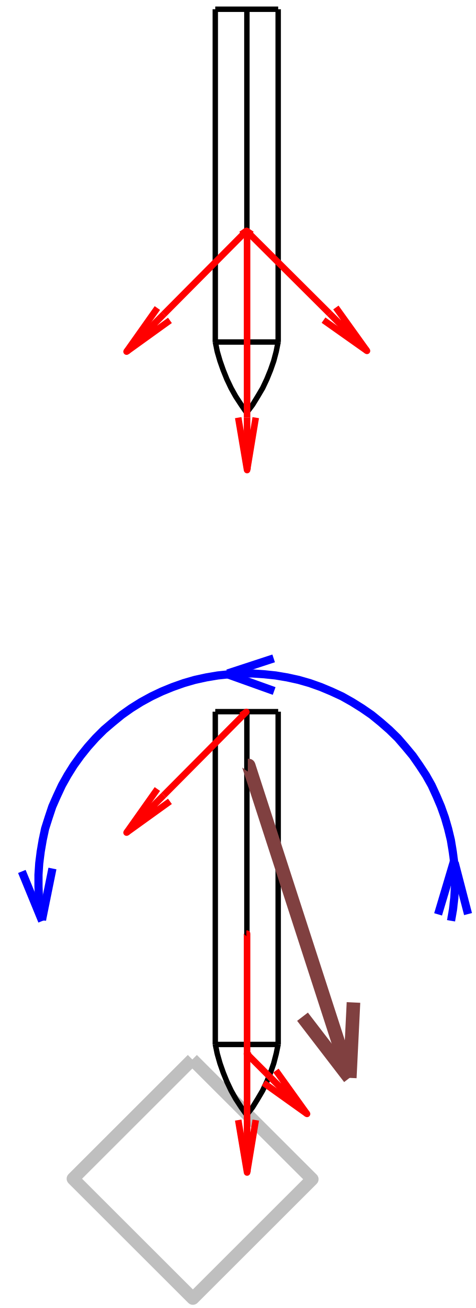
Fordow Location: 34.8845°N 50.9981°E

Unpredictable Deflections of the *Massive Ordnance Projectile* from Inhomogeneous Layers in the Mountain Soil and Rock

How Inhomogeneous Layering of Mountains Occurs by Uplifting from "Fault-Blocking"



Deflections of Ground-Penetrating Munition
Produced by Encountering An Inhomogeneous Ground-Layer



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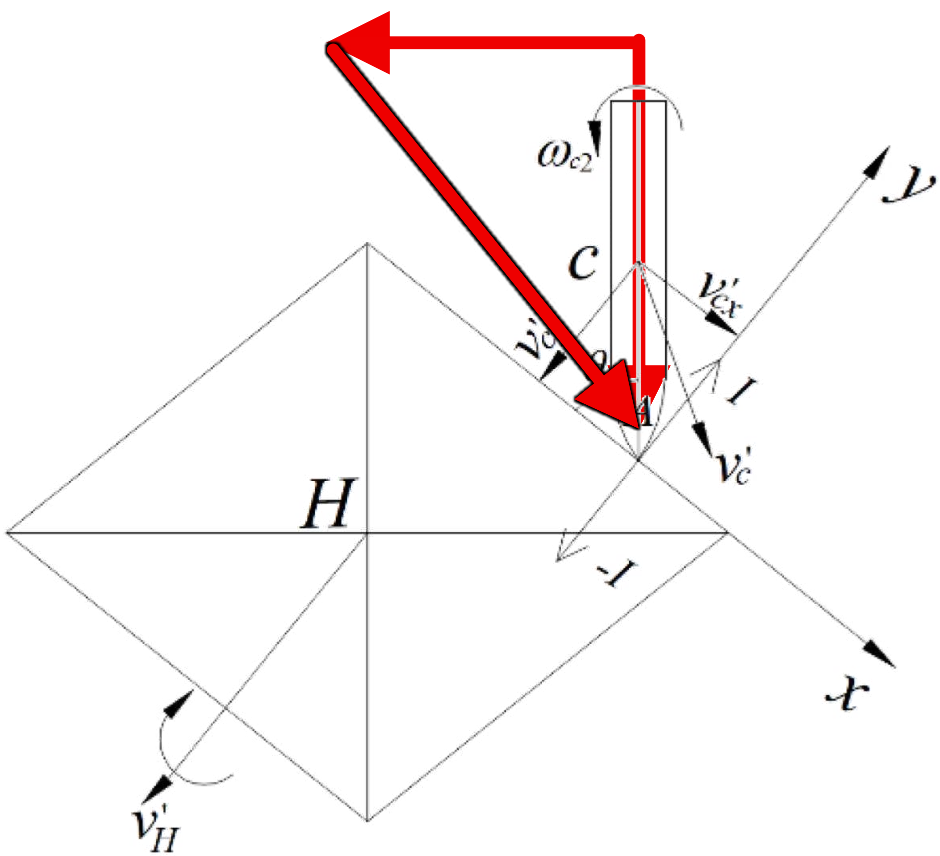
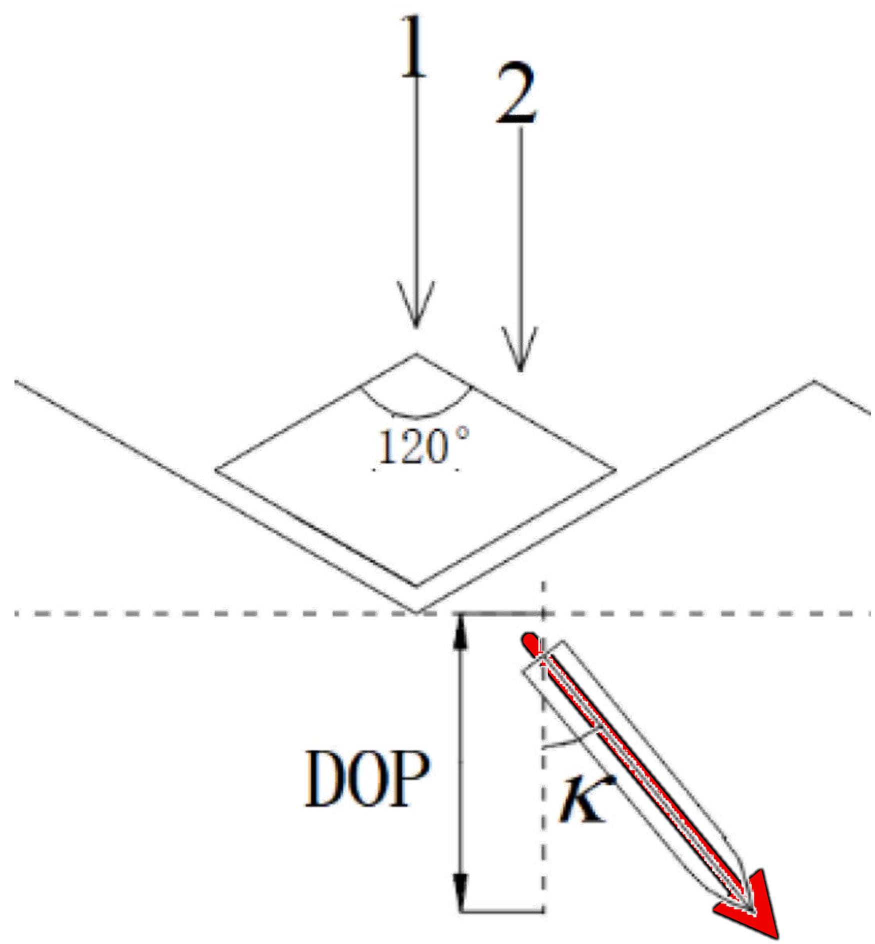




materials

MDPI

Article

Analysis on Deflection of Projectile Penetrating into Composite Concrete Targets

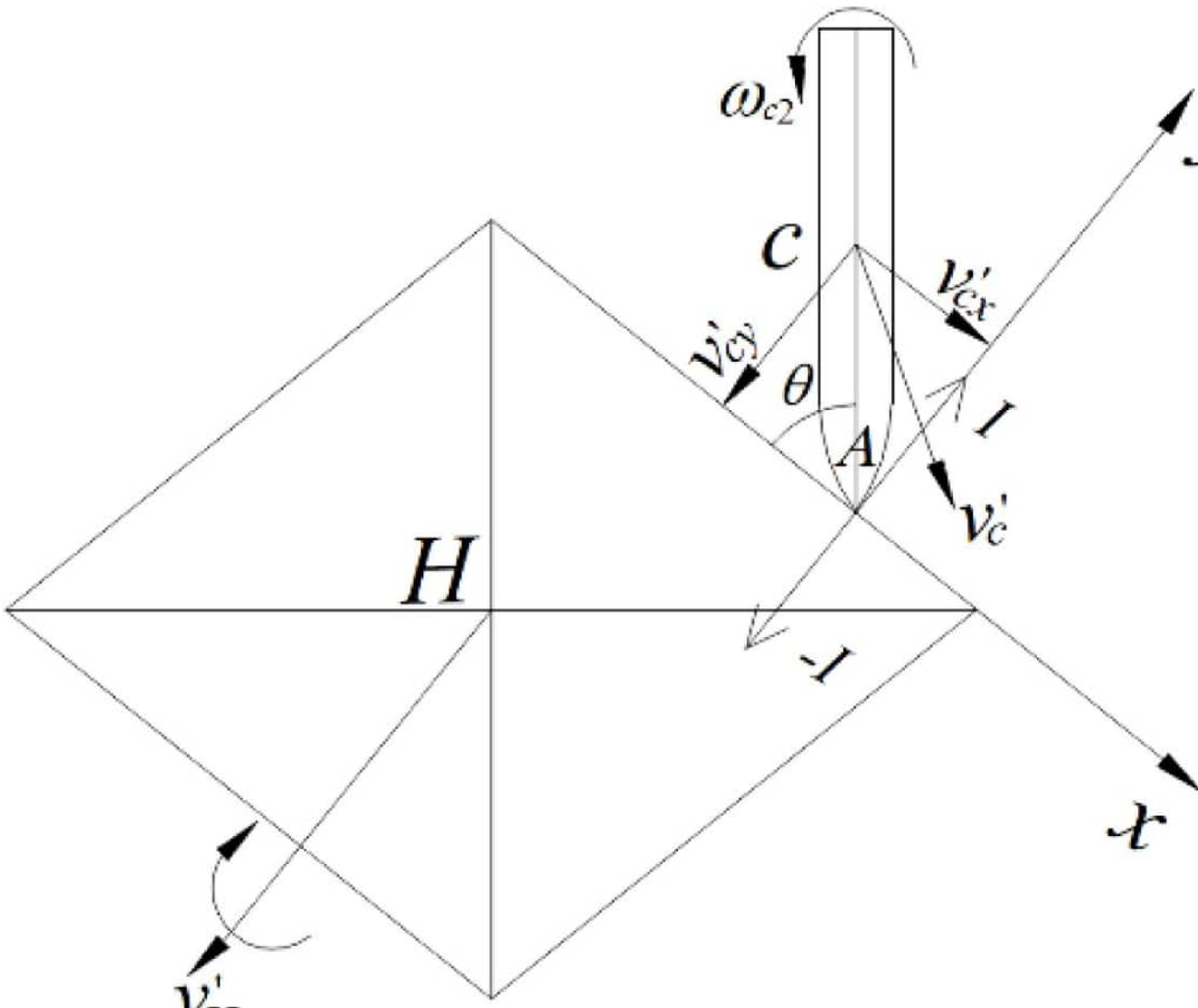
Yingxiang Wu [1], Xigui Tao [1], Yan Liu [2], Qingming Zhang [3] and Yijiang Xue [3,*]

1. Institute of Defense Engineering, AMS, PLA, Beijing 100850, China
2. Shandong Non-Metallic Materials Institute, Jinan 250031, China
3. State Key Laboratory of Explosion Science and Technology, Beijing Institute of Technology, Beijing 100081, China

* Correspondence: bitxue@bit.edu.cn

Table 1. Experimental conditions and results.

Number	Types of Target Plates (With or Without Diamond-Shaped Moving Target)	Impact Position	Velocity of the Projectile (m/s)	DOP (mm)	Deflection Angle (Degree)
1	without	2	393	>800 (pierce)	3.0
2	with	2	416	538	22.6
3	with	1	415	674	15.0
4	with	2	311	426	16.8
5	with	2	509	612	28.3



ω_{c2}
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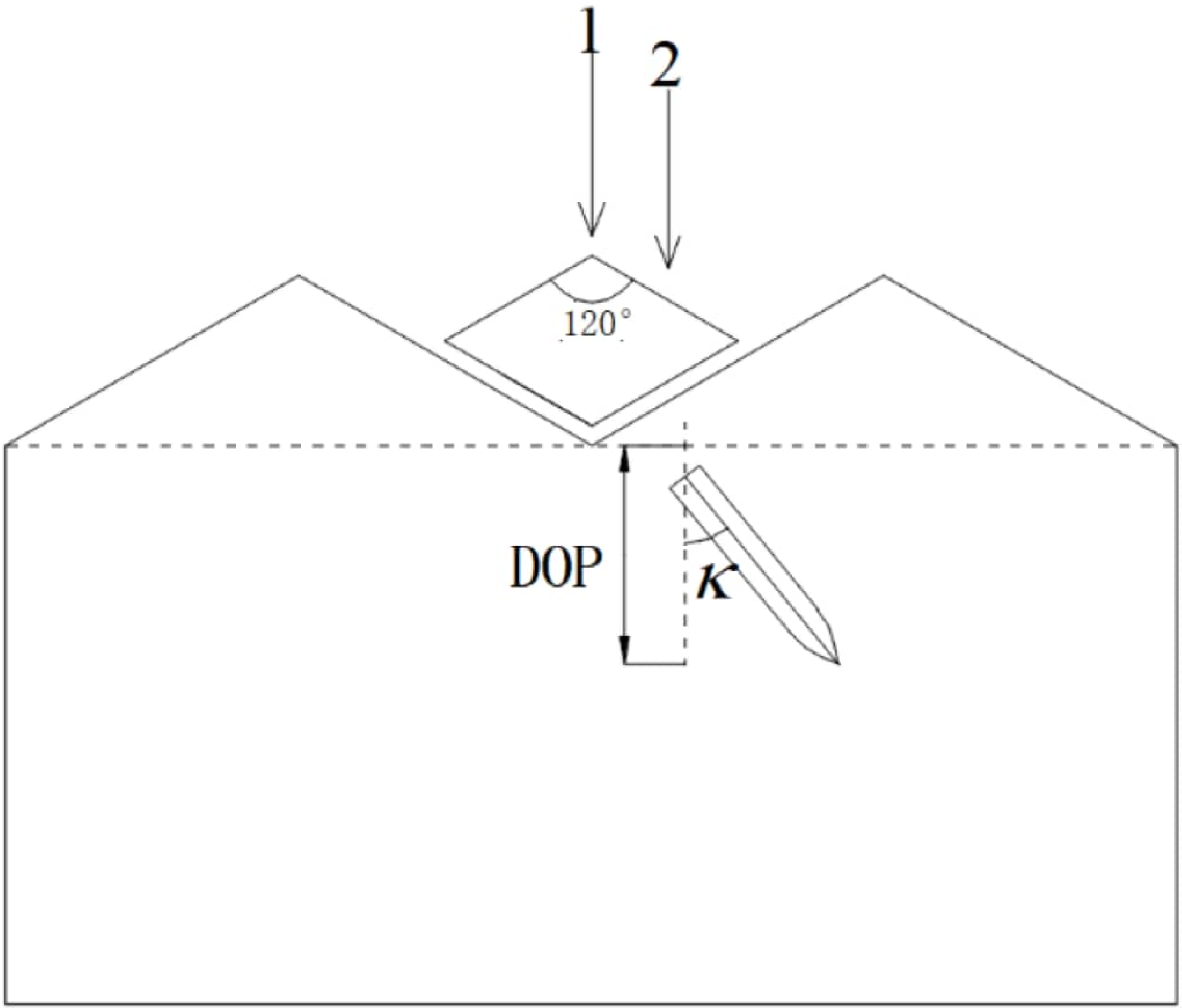
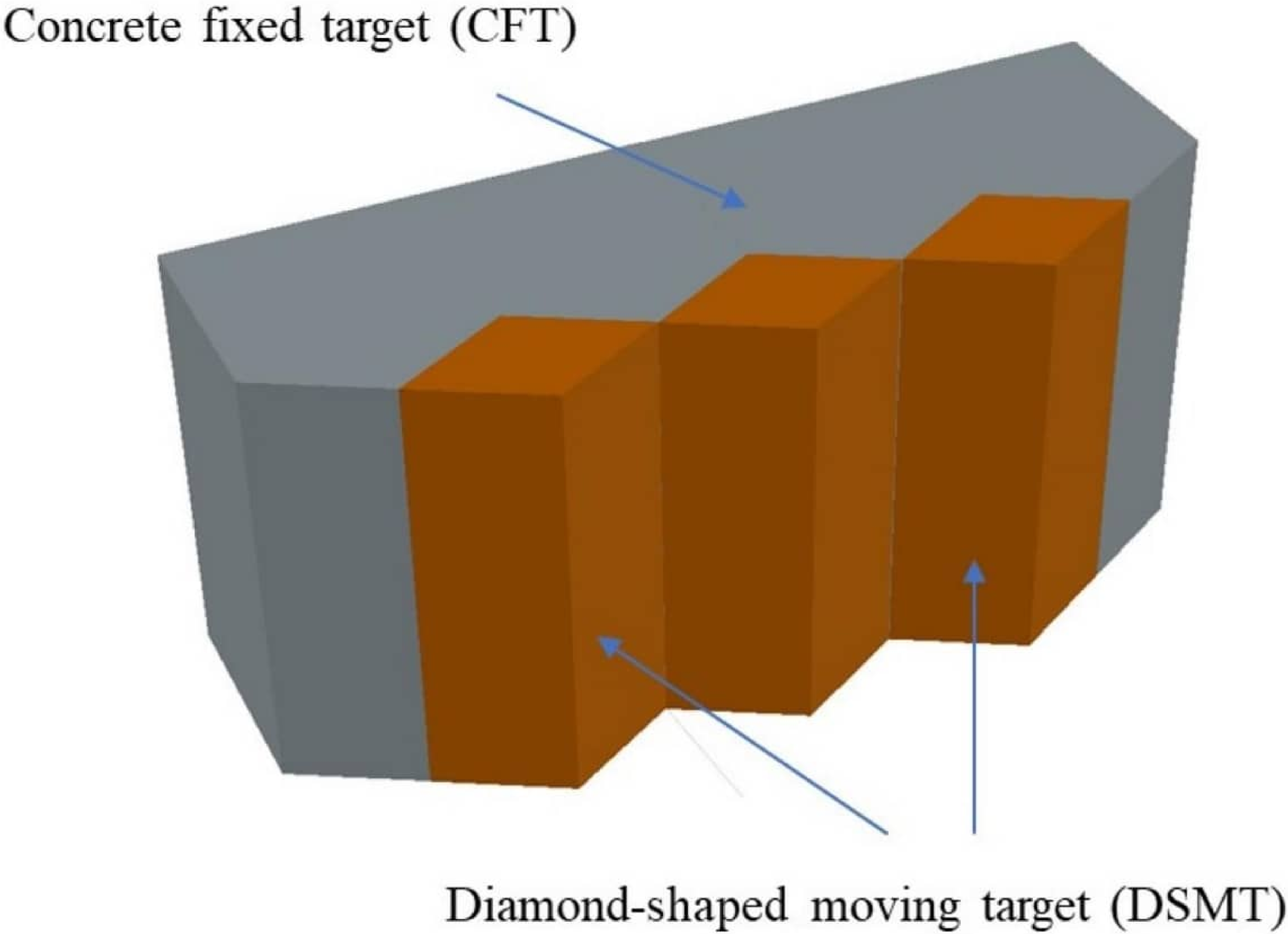


Figure 10. Schematic diagram of experimental measurement.

Figure 5. Photograph of the composite target plate with diamond-shaped moving target.

(a)


Concrete fixed target (CFT)
Diamond-shaped moving target (DSMT)

What is Ultra-High-Performance Concrete?

- Fiber-reinforced, cementitious composite
  - Low w/cm (typically < 0.20)

e.construct

Page 4

What is PCI-Ultra-High-Performance Concrete?

- Characterized by:
  - Higher compressive strength than currently in AASHTO LRFD-BDS
  - High pre- and post-cracking tensile strength
  - Ensured strain hardening to allow for exceptional flexural and shear behavior
  - Enhanced durability due to high density and discontinuous pore structure

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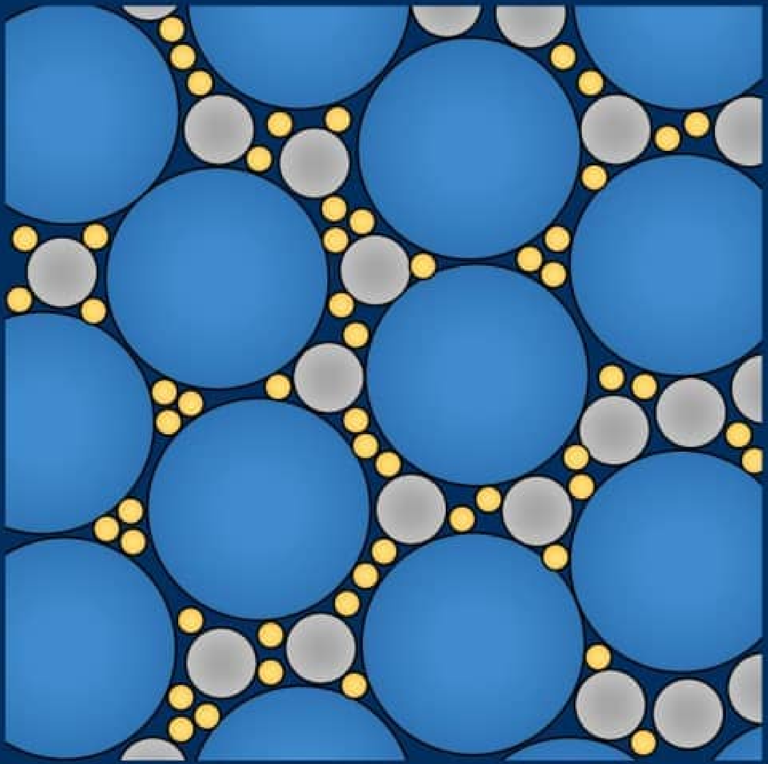
Page 5

PCI-UHPC Mix Design Based on Local Materials

- Type I/II Cement
- Silica Fume
- Supplementary powder (slag, ground limestone, etc.)
- Masonry Sand
- Steel Fibers
- High-range water reducer
- Admixture to extend flowability



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Deceptive Pentagon Briefing Providing Misleading Evidence of Success at Fordow Enrichment Site in Iran

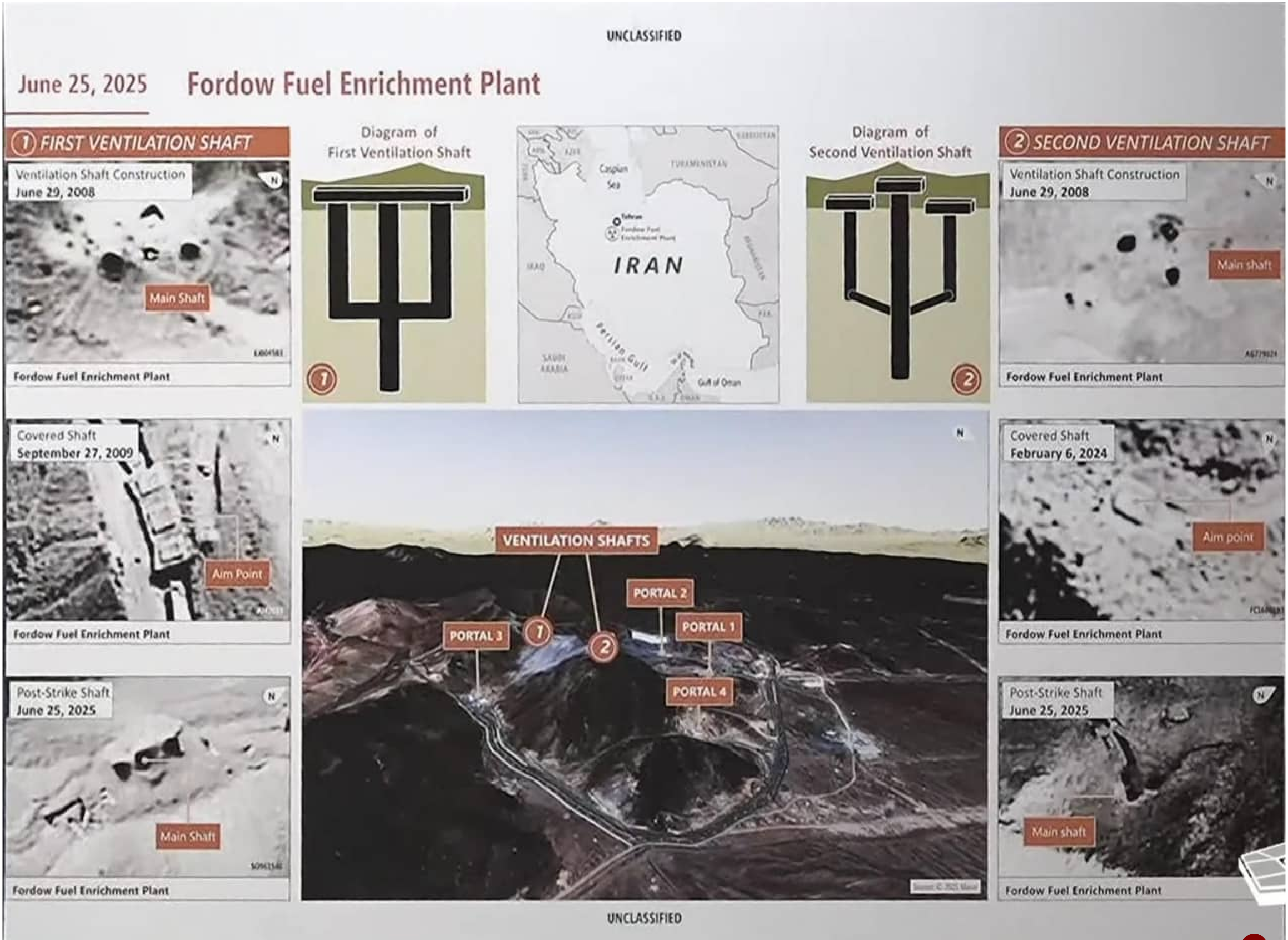
UNCLASSIFIED
June 25, 2025
Fordow Fuel Enrichment Plant
1 FIRST VENTILATION SHAFT
Ventilation Shaft Construction
June 29, 2008
Main Shaft
Fordow Fuel Enrichment Plant
Covered Shaft
September 27, 2009
Aim Point
Fordow Fuel Enrichment Plant
Post-Strike Shaft
June 25, 2025
Main Shaft
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Diagram of
First Ventilation Shaft
1
Caspian Sea
TURKMENISTAN
Tehran
Fordow Fuel Enrichment Plant
IRAN
IRAQ
Persian Gulf
SAUDI ARABIA
Gulf of Oman
Diagram of
Second Ventilation Shaft
2
2 SECOND VENTILATION SHAFT
Ventilation Shaft Construction
June 29, 2008
Main shaft
Fordow Fuel Enrichment Plant
Covered Shaft
February 6, 2024
Aim point
Fordow Fuel Enrichment Plant
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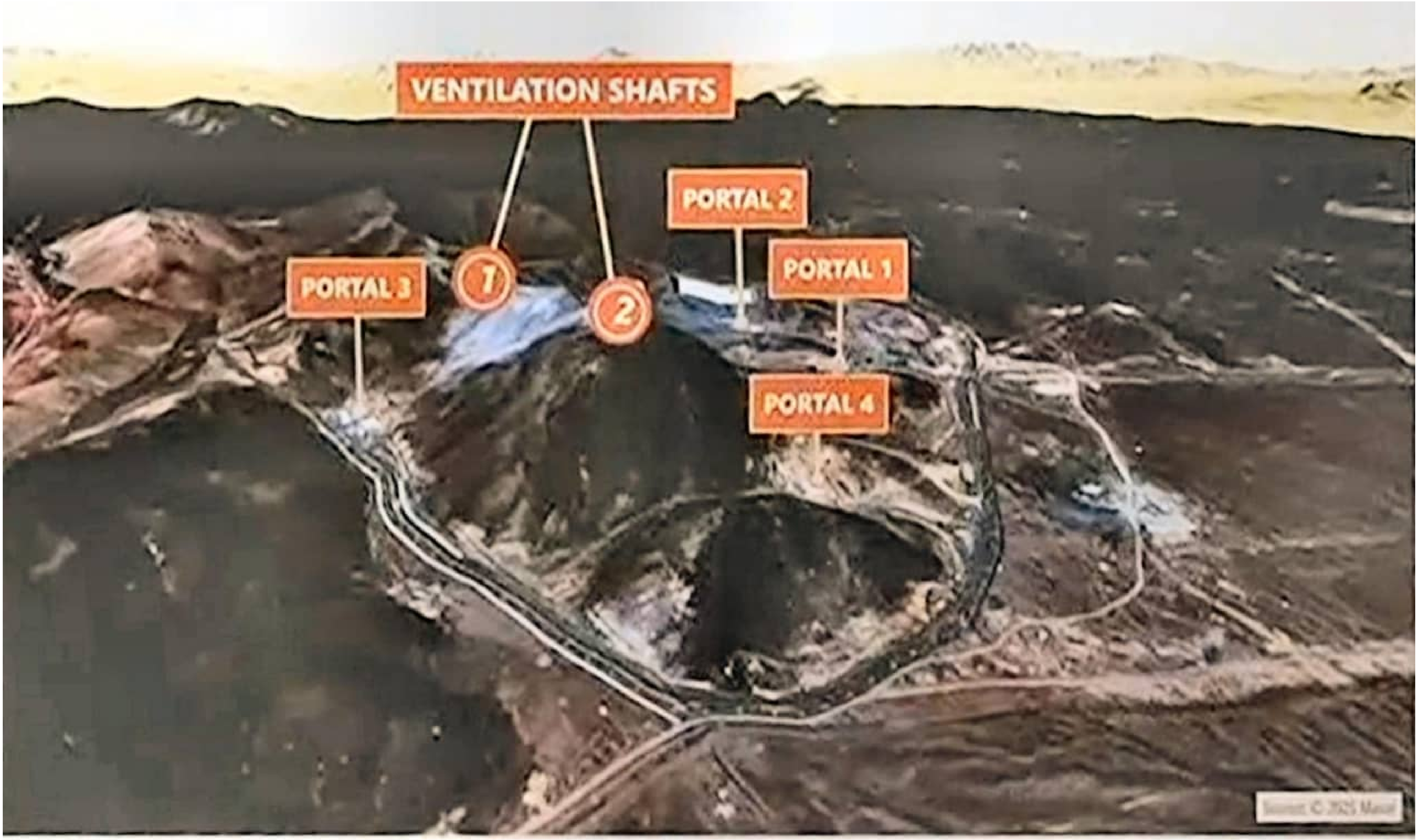
VENTILATION SHAFTS
PORTAL 3
1
2
PORTAL 2
PORTAL 1
PORTAL 4
UNCLASSIFIED


VENTILATION SHAFTS
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PORTAL 2
PORTAL 1
PORTAL 3
PORTAL 4


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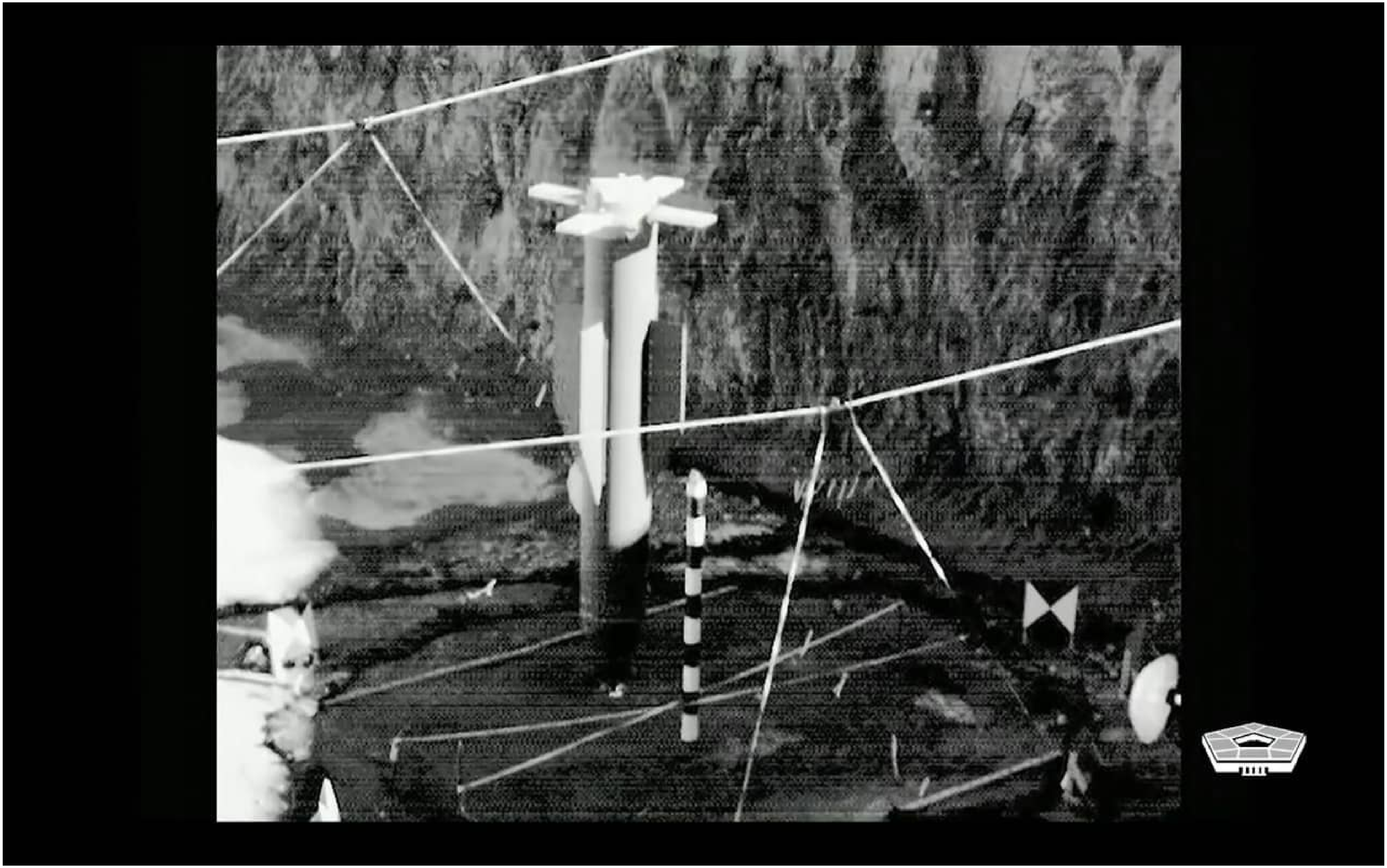

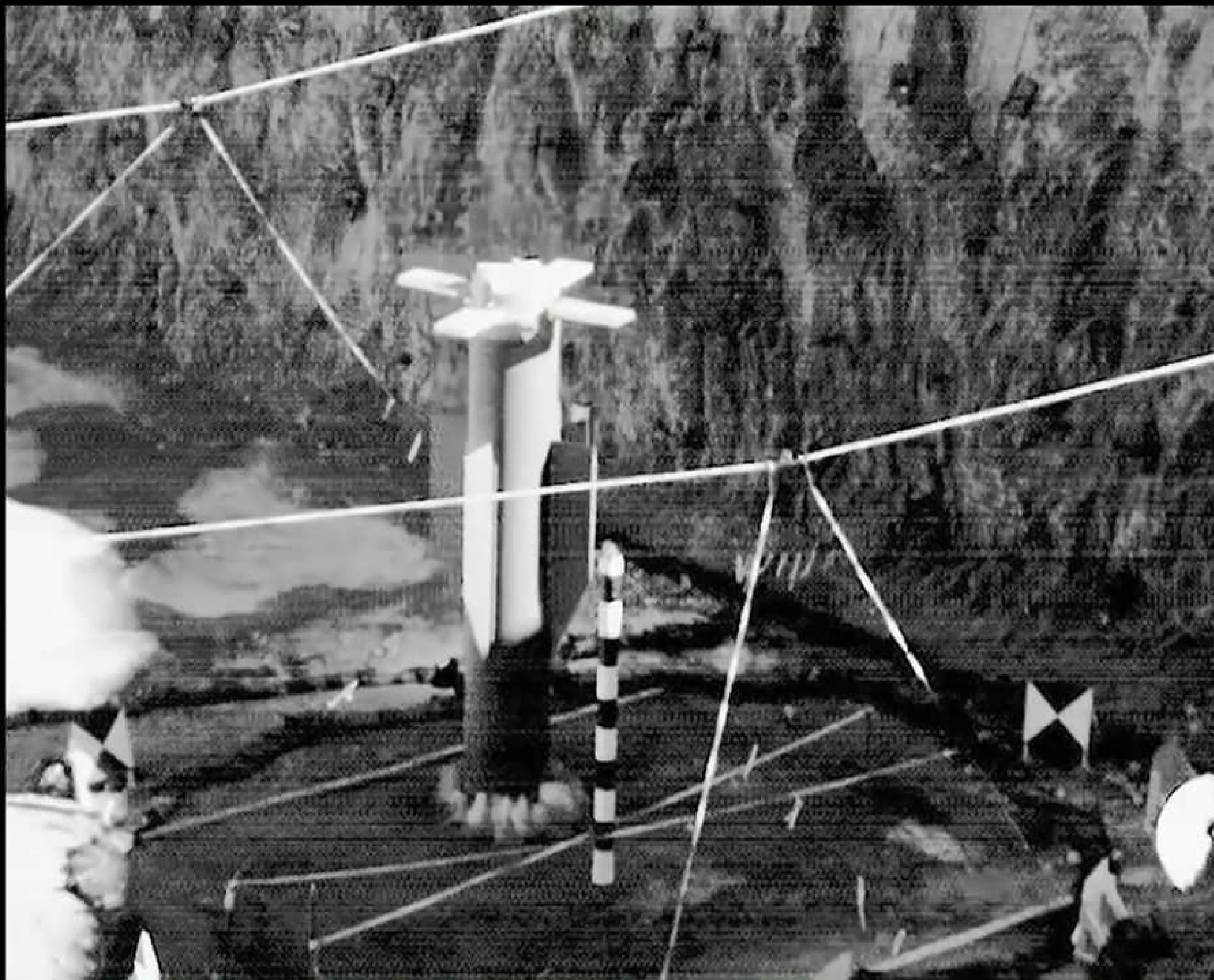

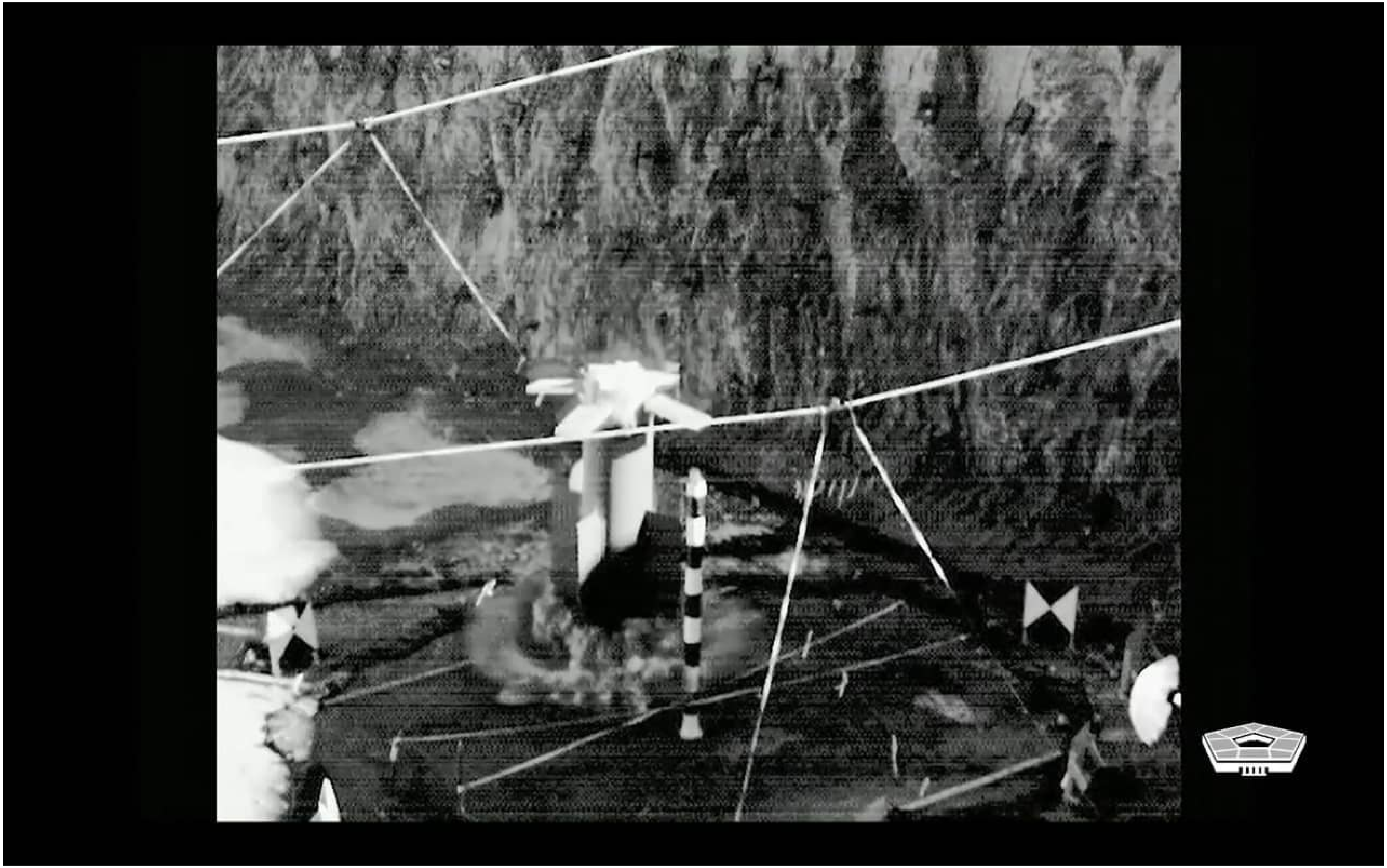

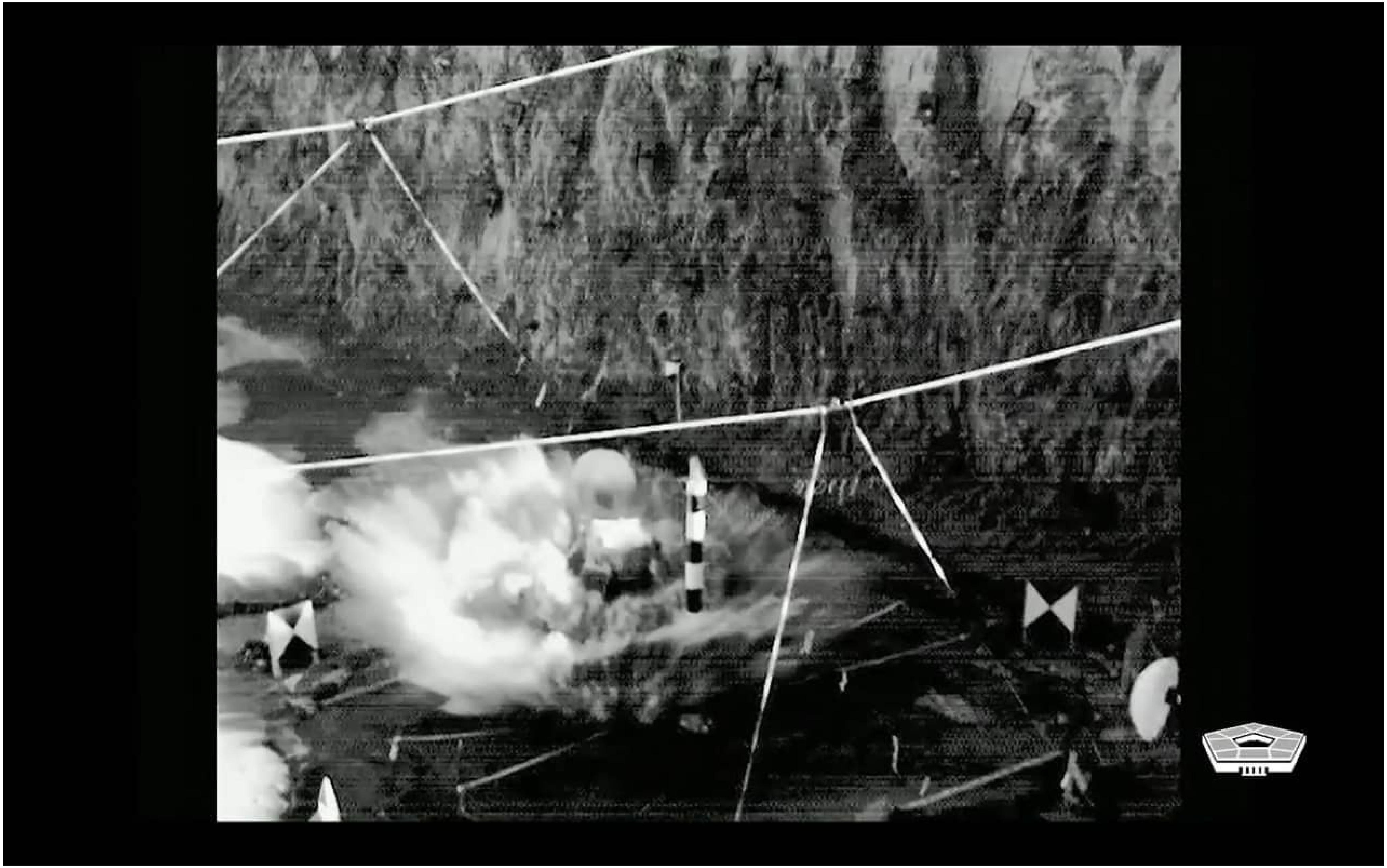

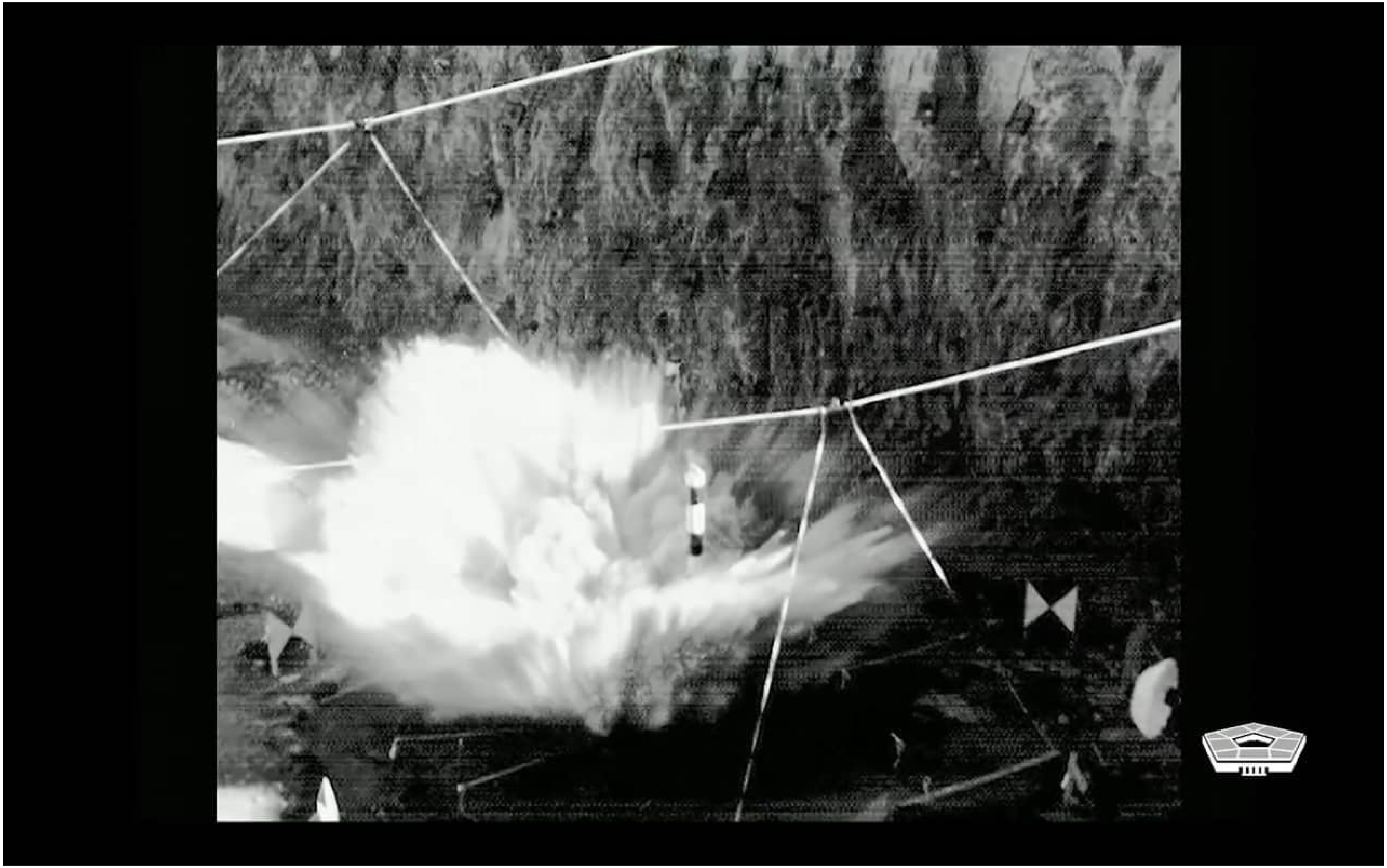


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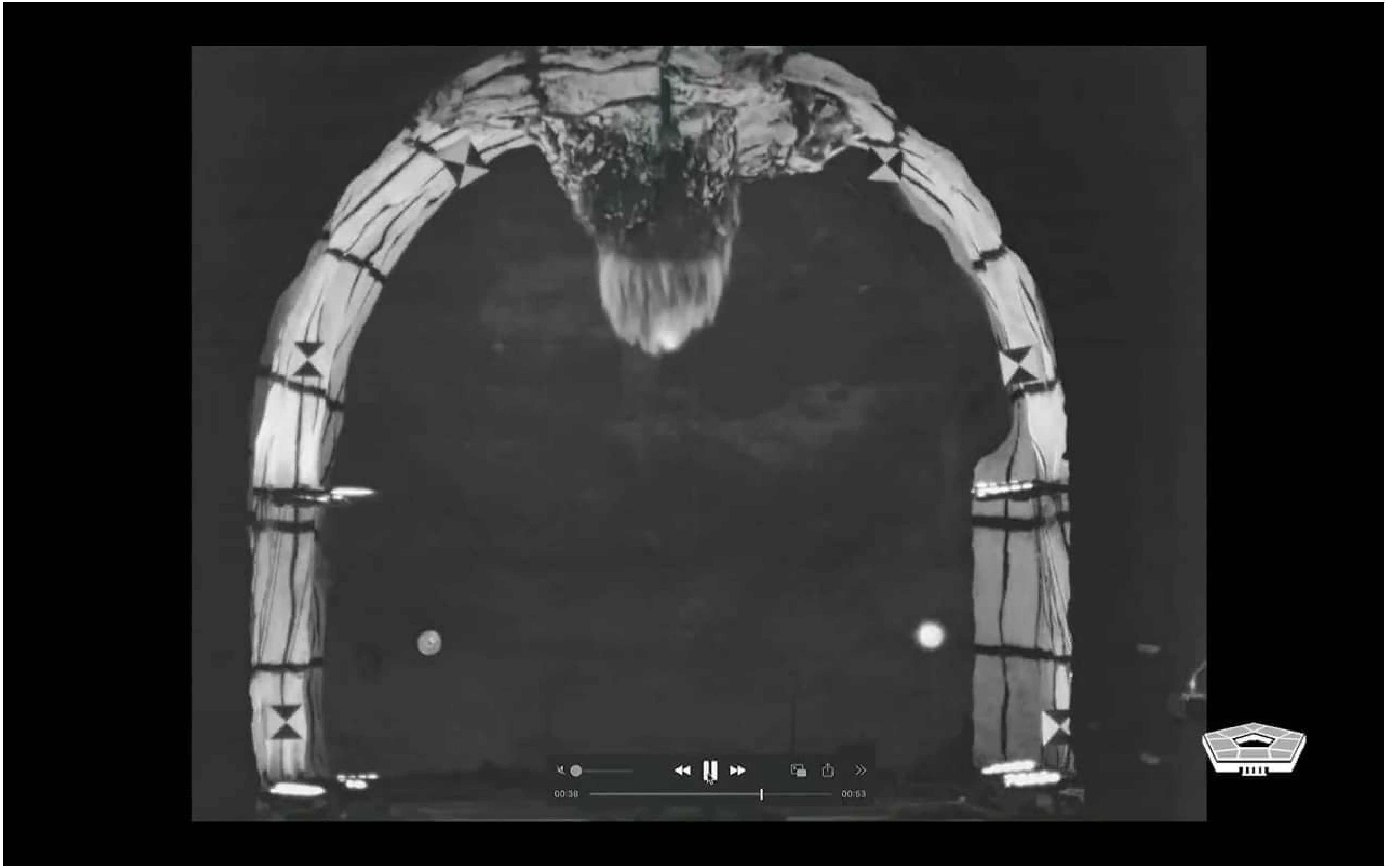
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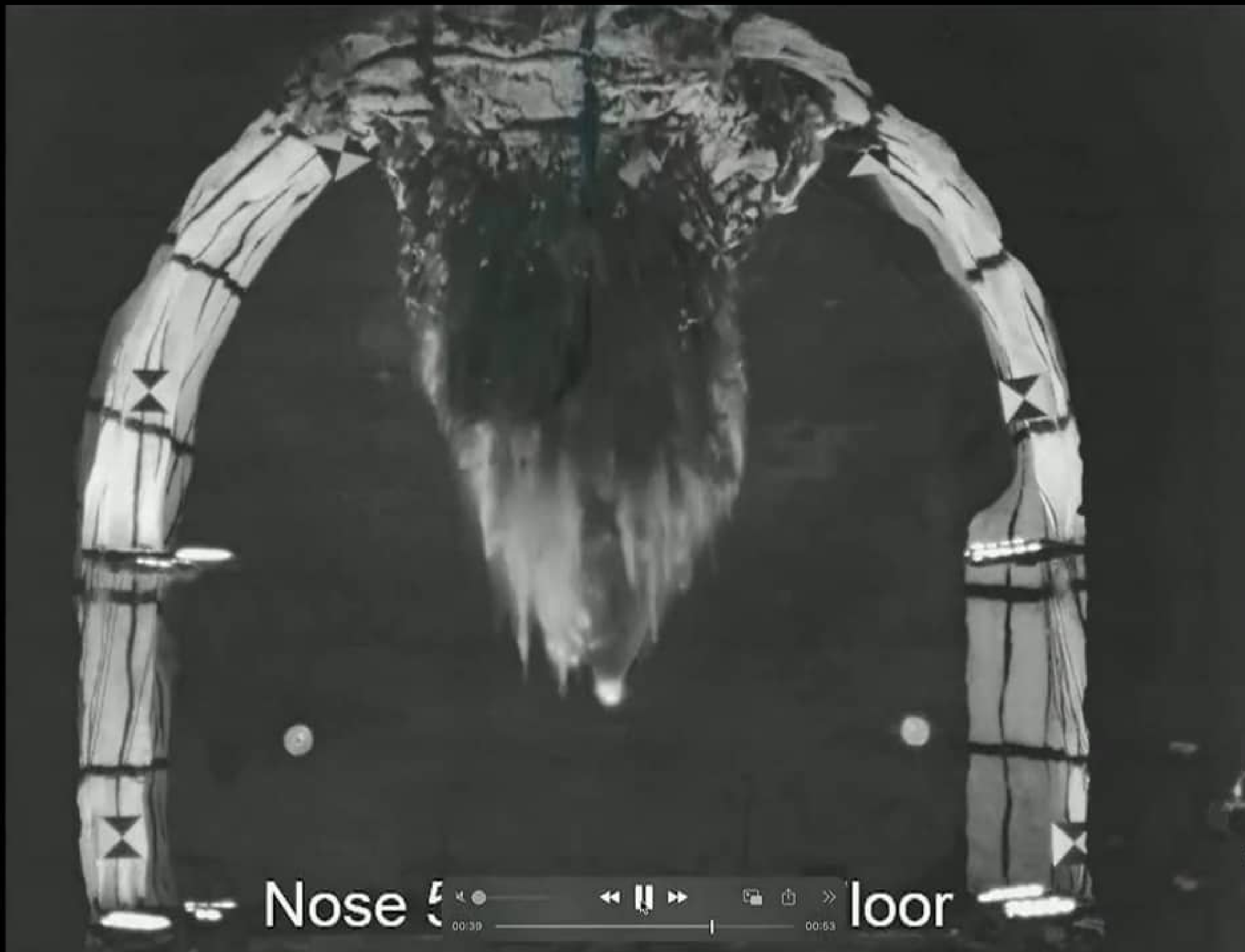
Nose 5
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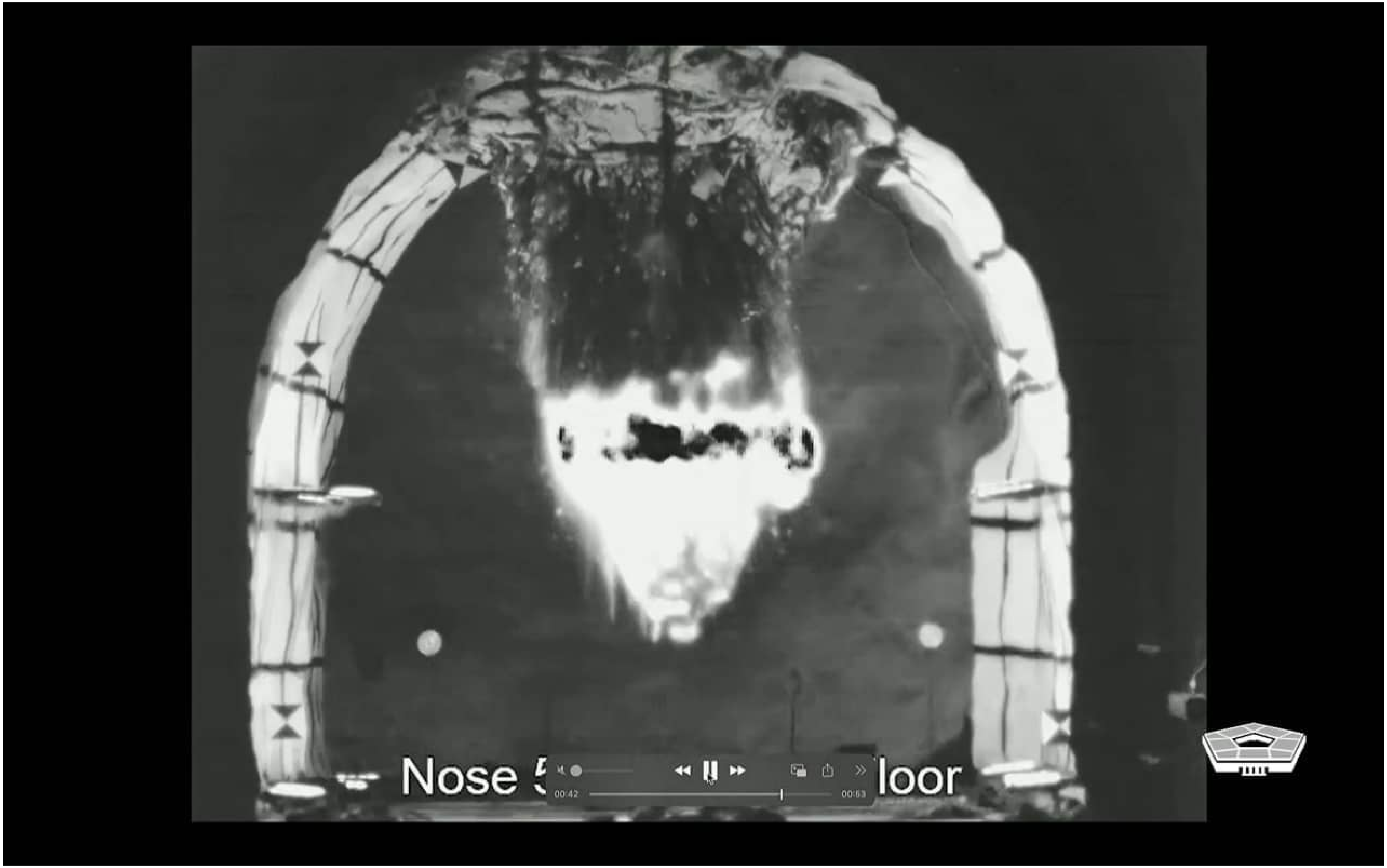
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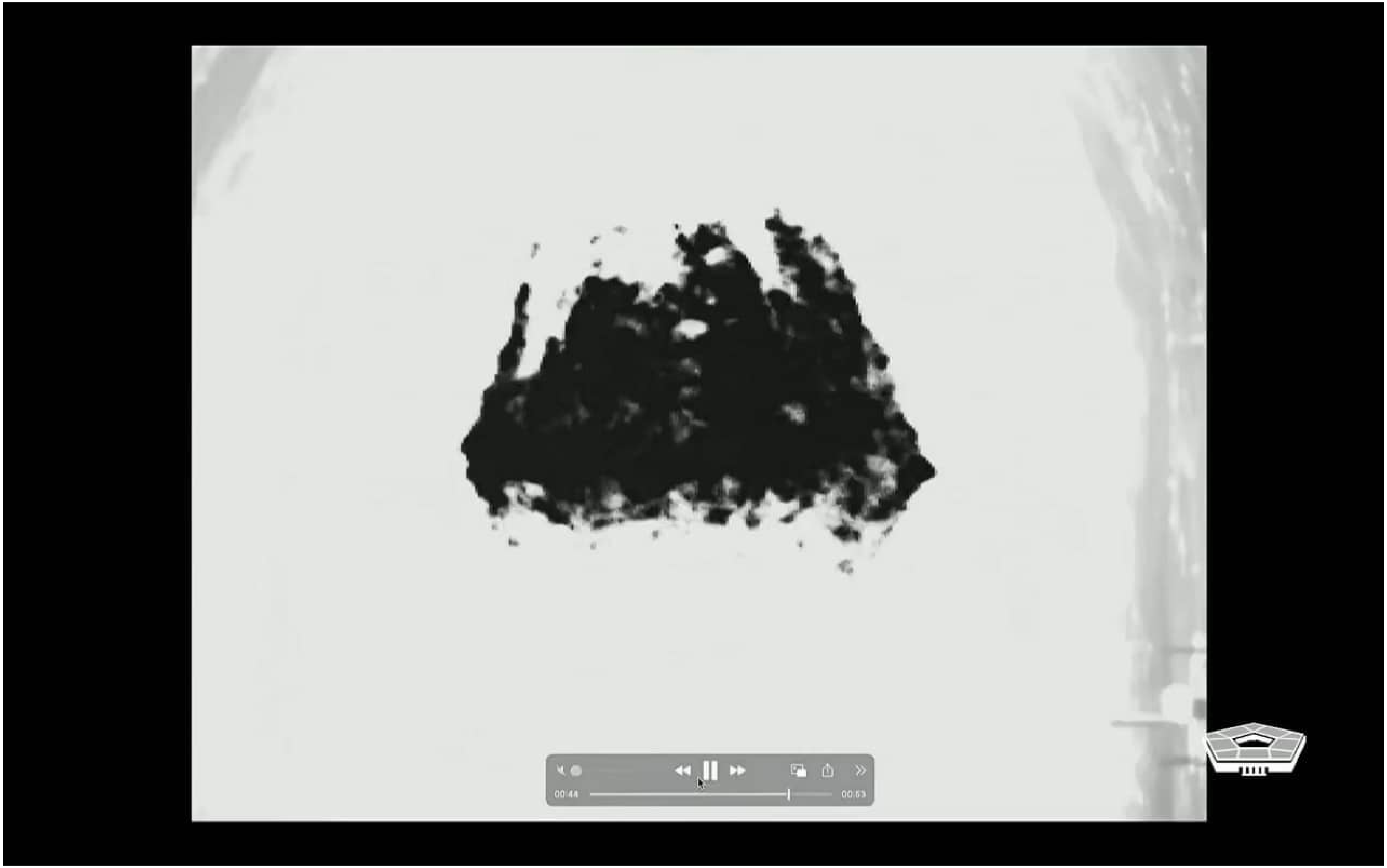
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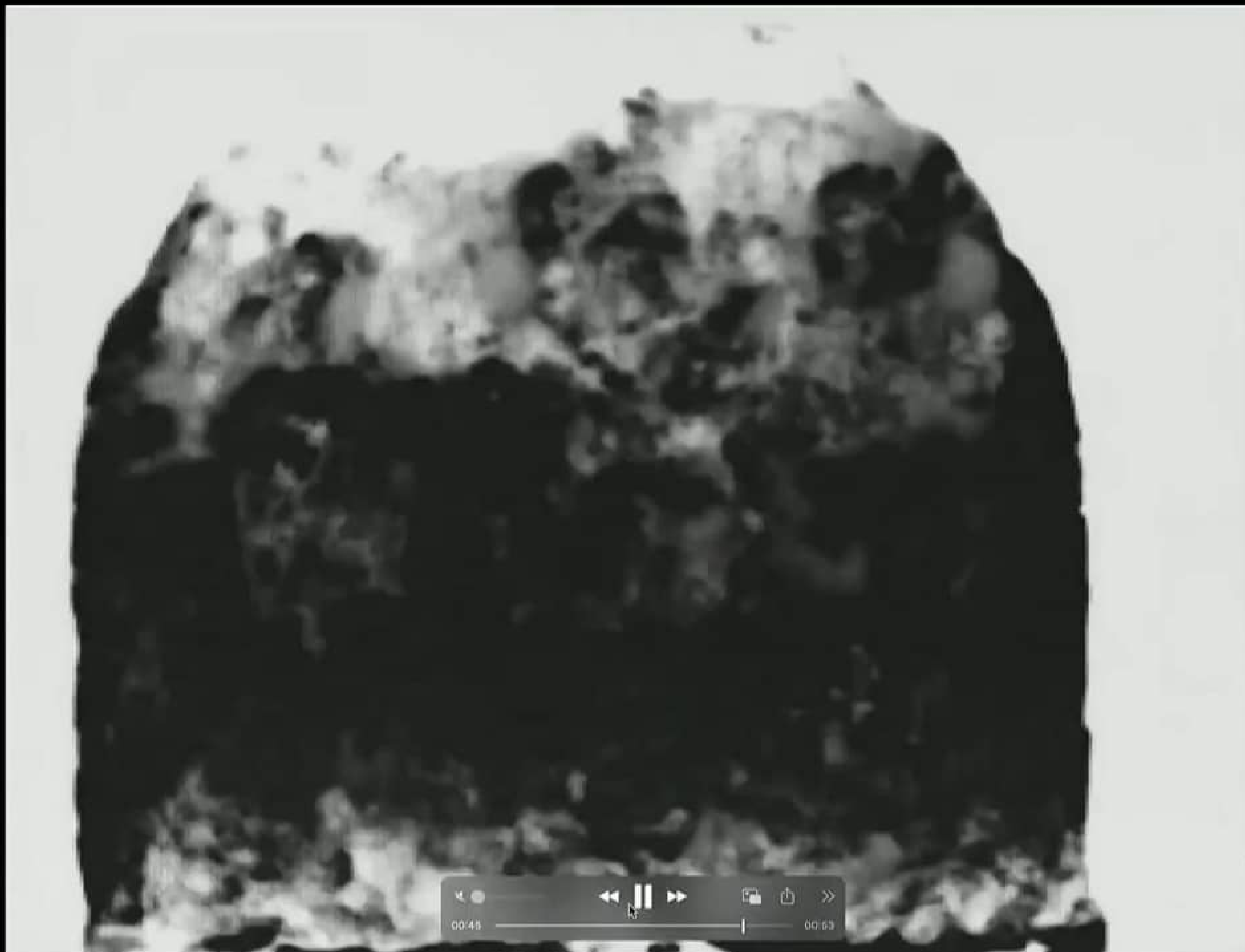
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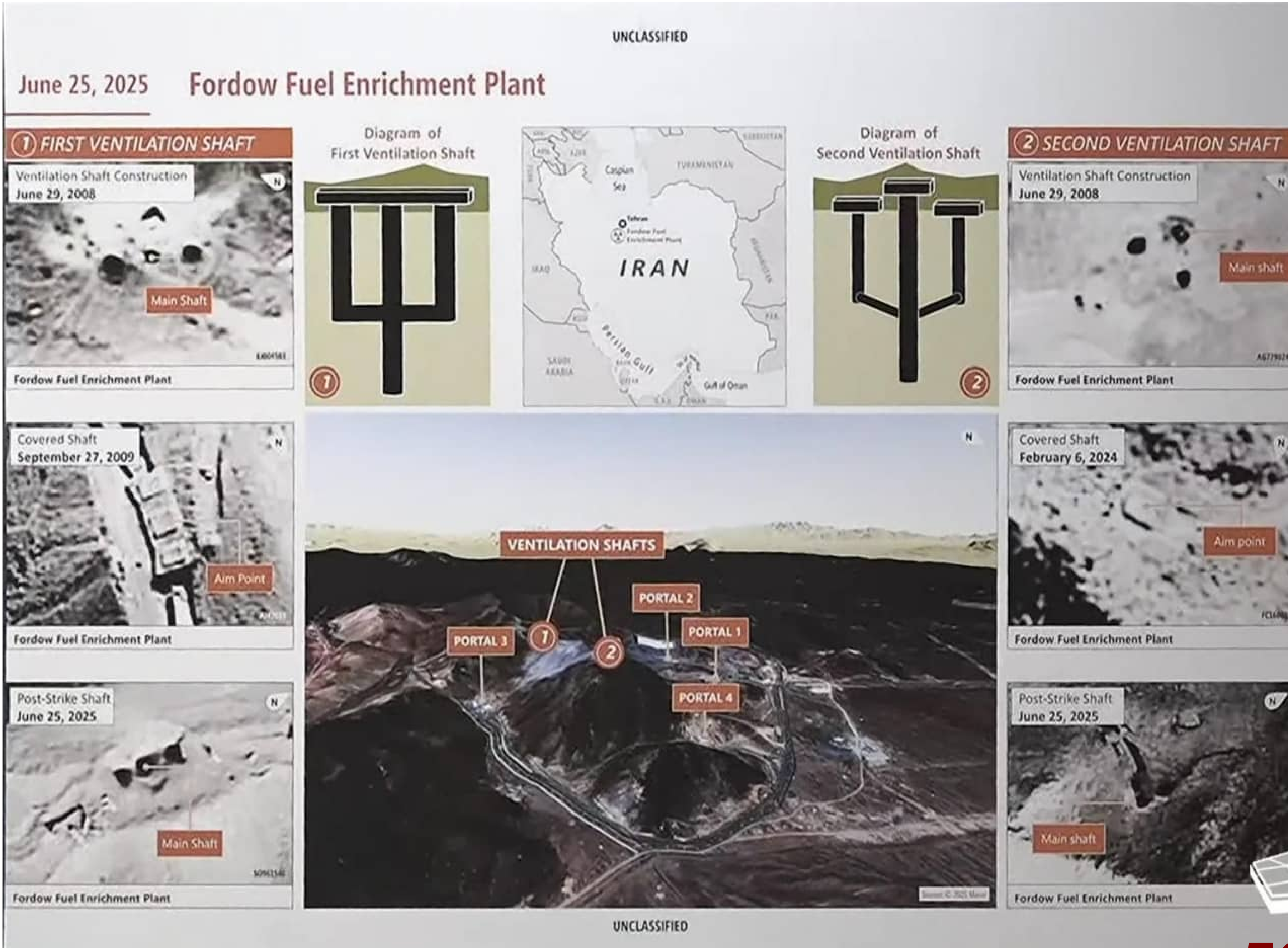
Data the US Already Has That Can Be Used to Assess The Success of the GBU-57 Bombs Used Against Fardow

Infrared Satellite Measurements of the Brightness and Time-Evolution of Hot Explosive Gasses Escaping from GBU-57 Strike Holes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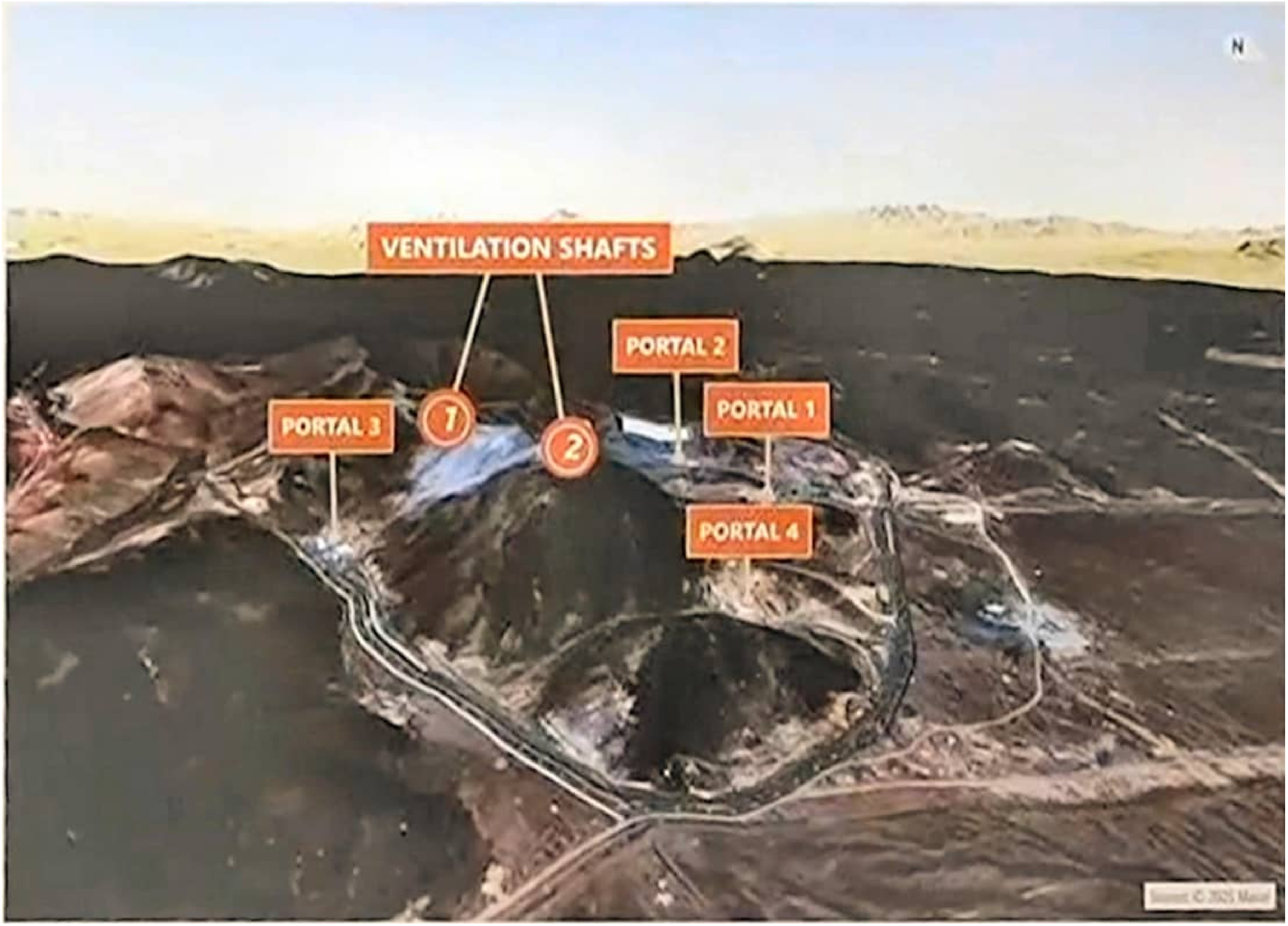
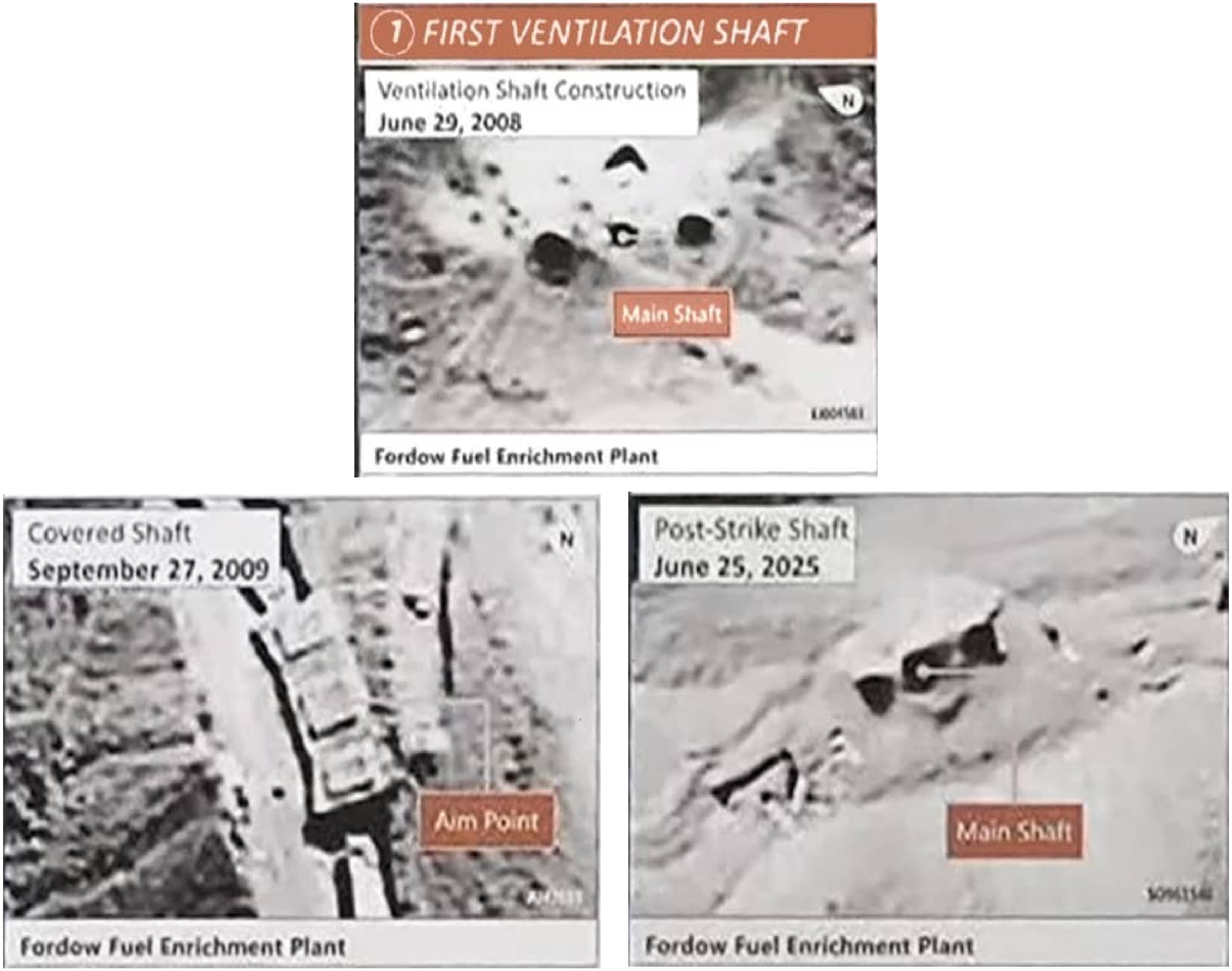
Main shaft
Fordow Fuel Enrichment Plant
UNCLASSIFIED

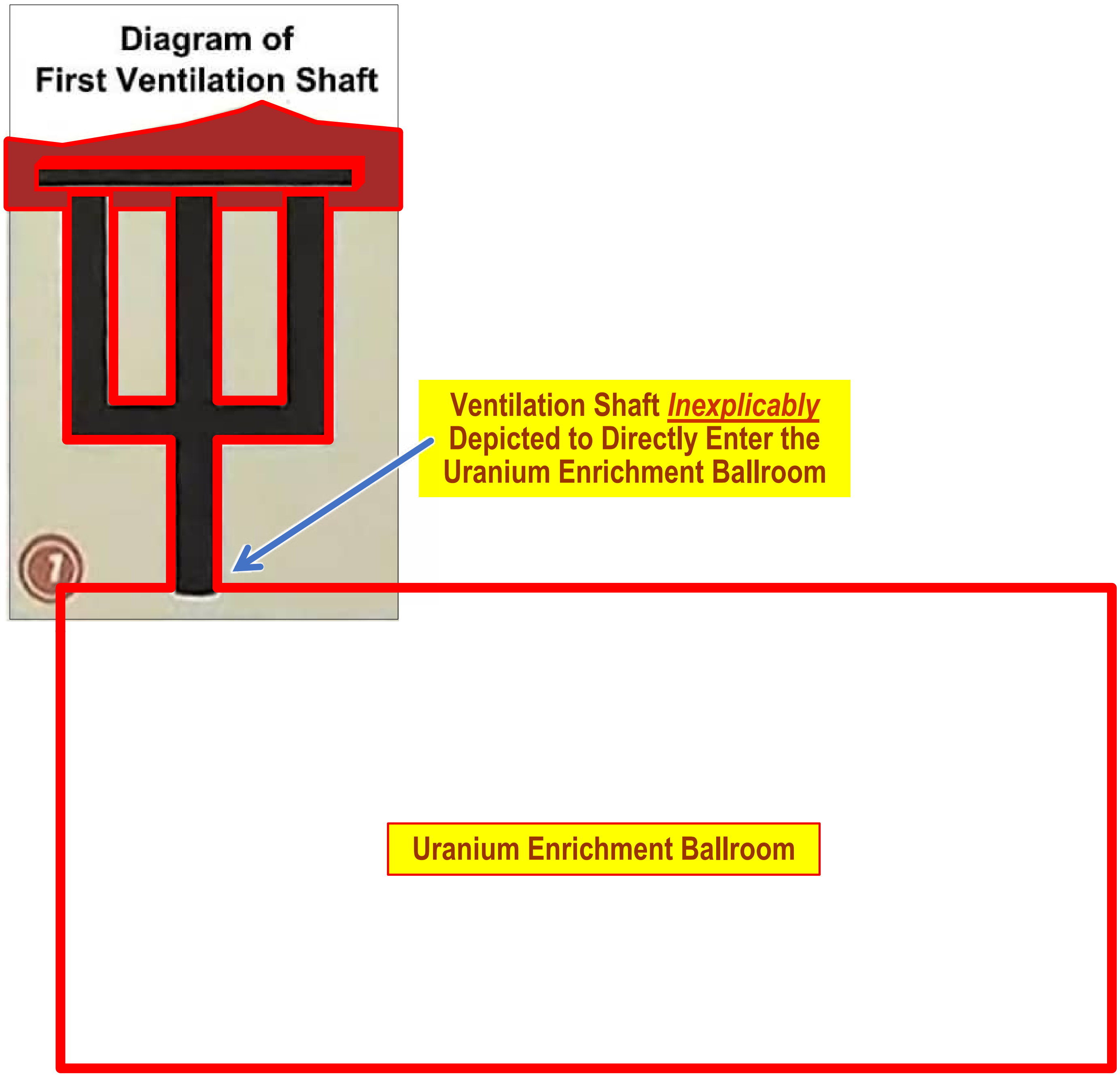
Location of Ventilation Shafts at Porto As Described in the Pentagon Briefing of June 26, 2025



Before and after Satellite Images of the First Ventilation Shaft



Misleading Pentagon Diagram that Suggests a Much Higher Target Vulnerability Than Should Be Expected



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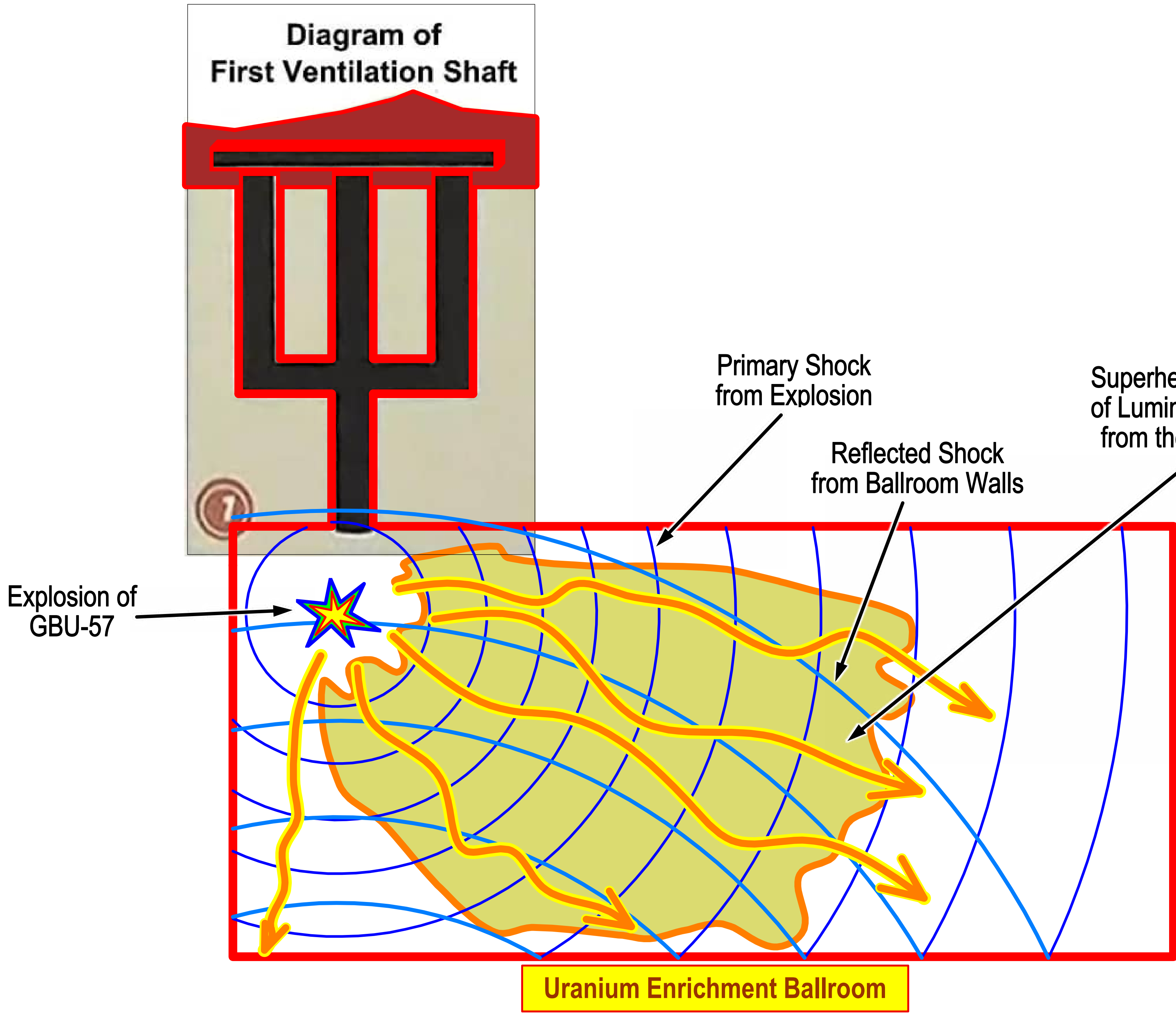
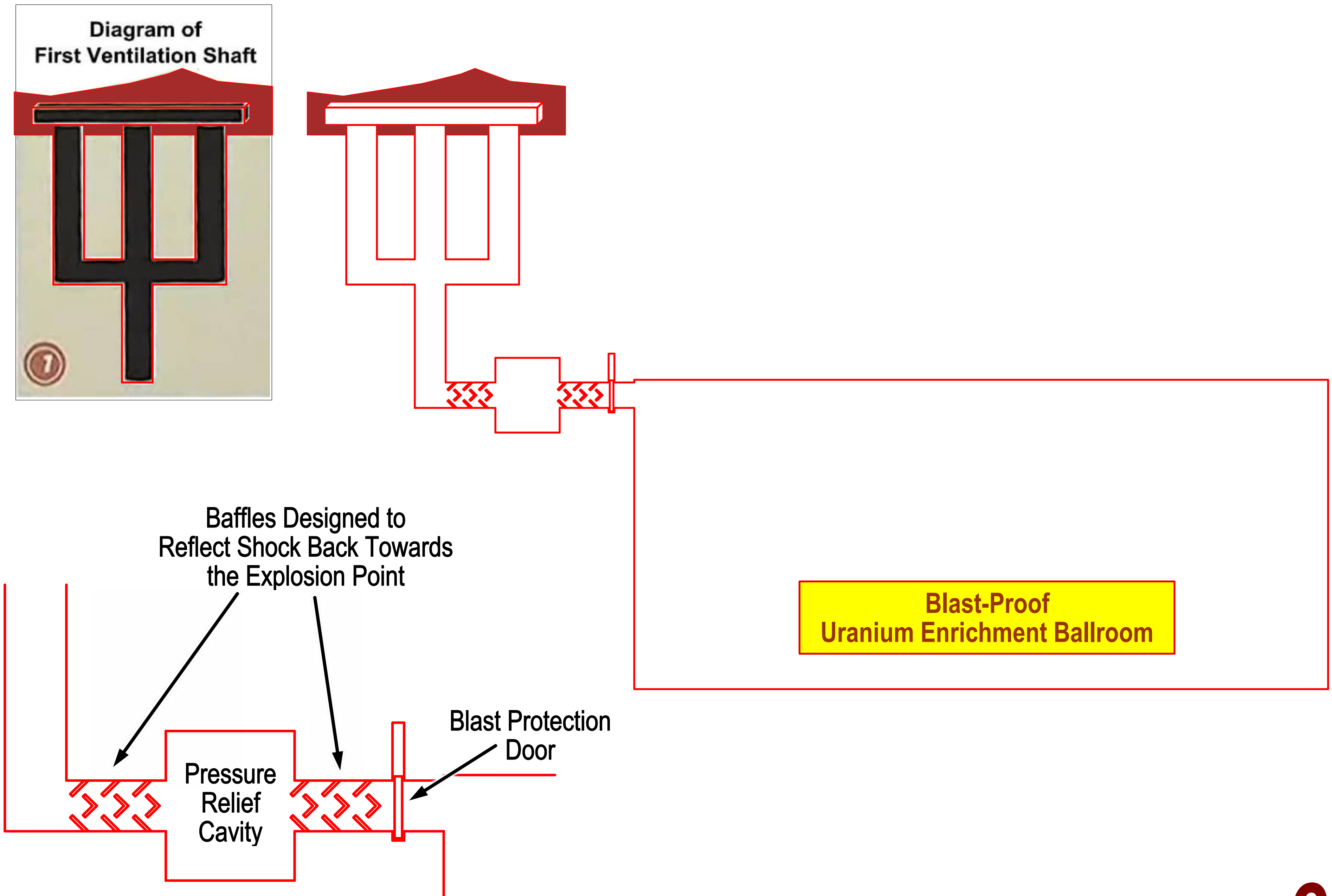


Competently Designed Blast-Proof Ventilation Shaft Uses Multiple Techniques to Prevent Damage

Ventilation Shaft Designed to Attenuate and Stop Blast from Entering the Centrifuge Ballroom
As a Result is Explosive Gases Are Redirected Back to the GBU-57 Surface Entry Point



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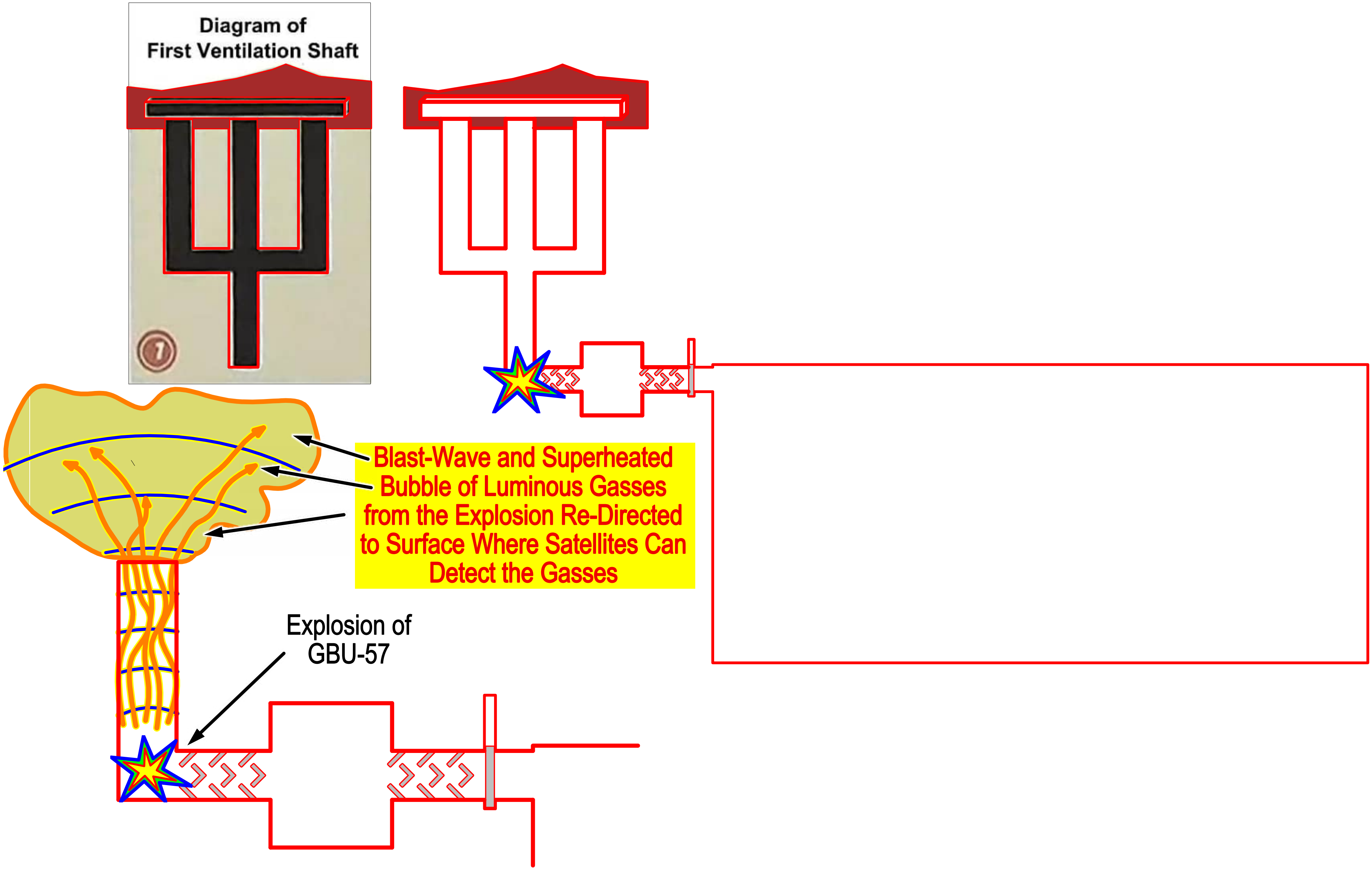


EXTREMELY IMPORTANT FOR THE CONGRESS

Ventilation Shafts Properly Designed to Attenuate and Stop Blast from Entering the Centrifuge Ballroom will Cause the Explosive Gases to Be Redirected Back to the GBU-57 Surface Entry Point.

The Hot Gases from the GBU-57 Detonation **Can Be Easily Detected and MEASURED** by the Space Based Infrared (SBIRS) Satellites.

The Data on the Brightness, Wavelength, and Fireball Evolution-Time, In Combination with Explosive Modelling Calculations, Makes It Possible to Assess the Effectiveness of EACH GBU-57 Impact and Detonation.

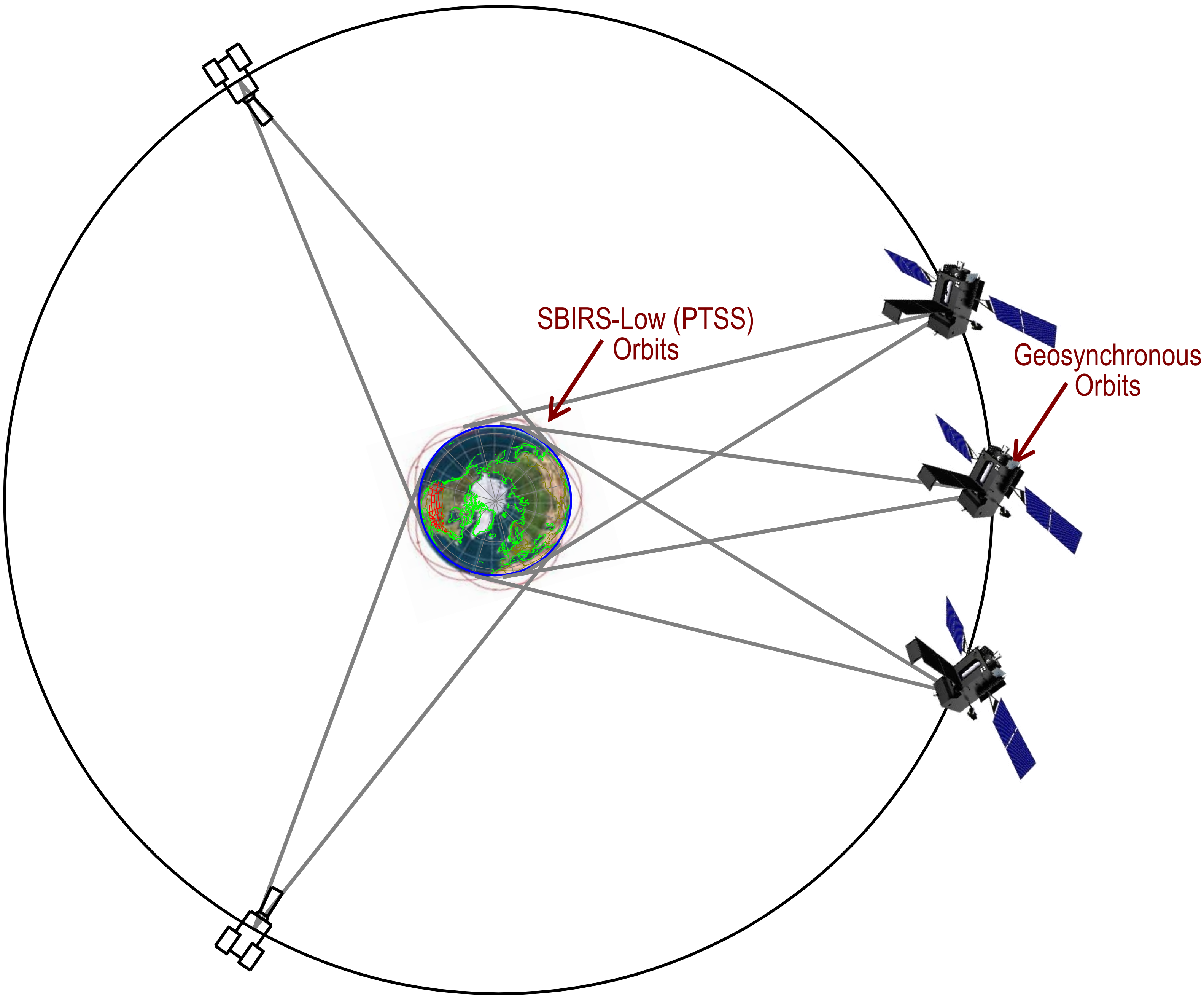
If Congress Wants a Relatively Quick and Reliable Assessment of Each GBU-57 Impact at Fordow, the Already In-Hand Data from SBIRS Should be Briefed to Them.

There is NO Legitimate Security Reason to Deny This Information to Congress. All of the Generally Known Capabilities of SBIRS Relevant to This Information Is Already Publicly Known, Along with the Explosive Modelling Procedures.

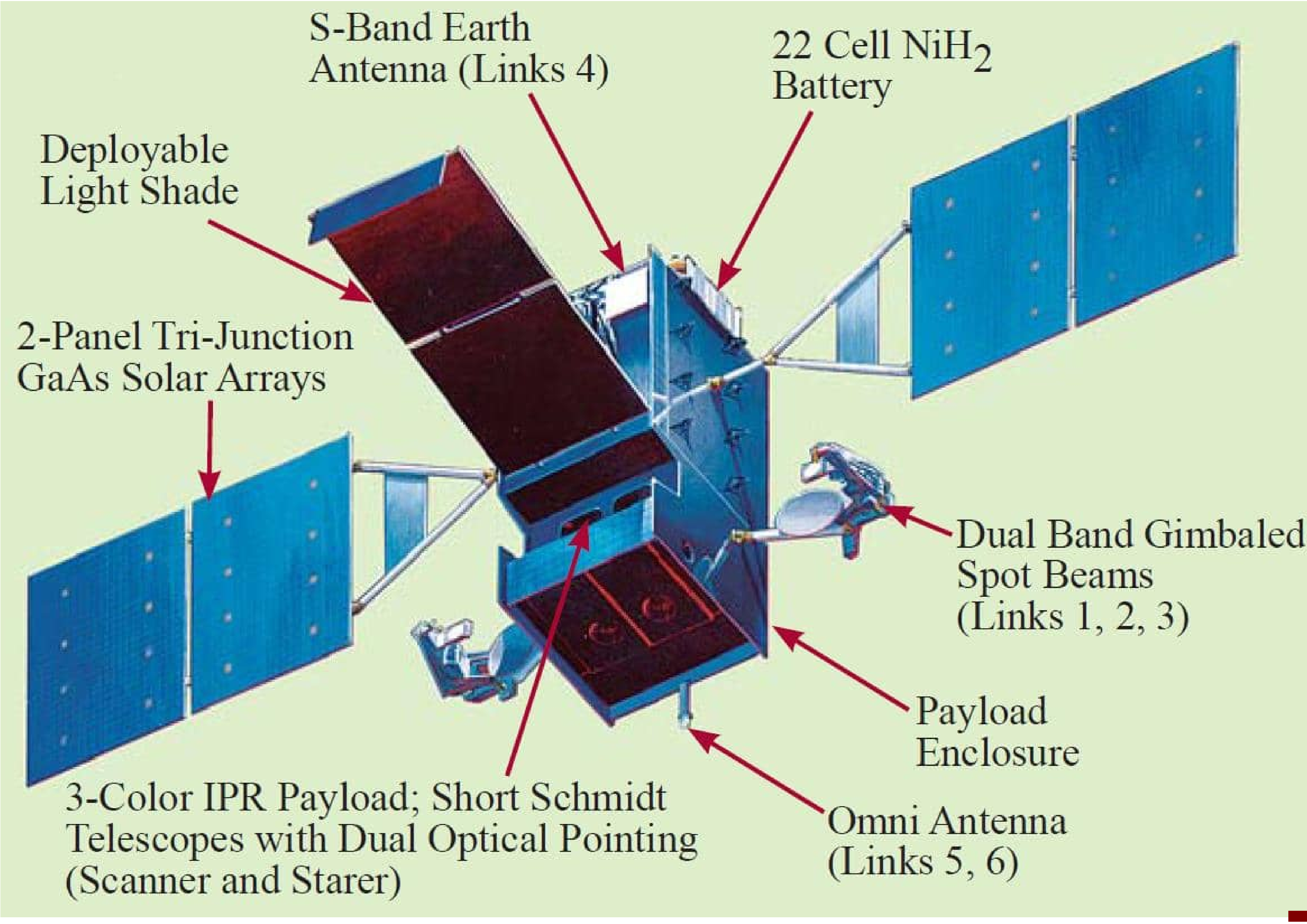
Some Characteristics of the Space-Based Infrared System Relevant to Its Capabilities to Provide Detailed Information About The Success or Failure of GBU-57 Strikes at Fordow

Characteristics of Space-Based Infrared (SBIRS) High-Altitude Ballistic Missile Warning and Tracking Systems

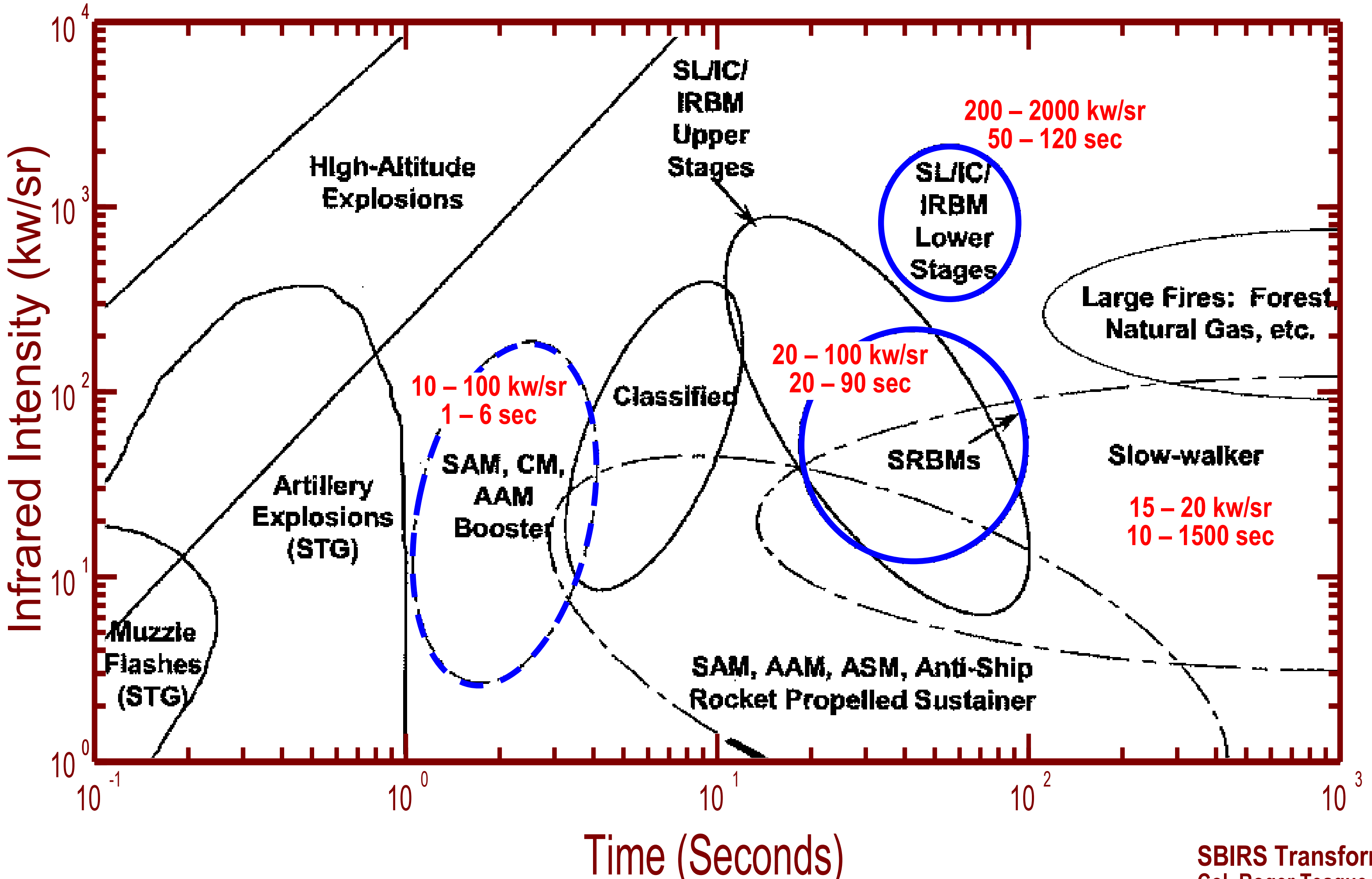
SBIRS-High and DSP Satellites Configuration for Tracking Launches



The Space-Based Infrared Satellite (SBIRS) Geosynchronous Spacecraft

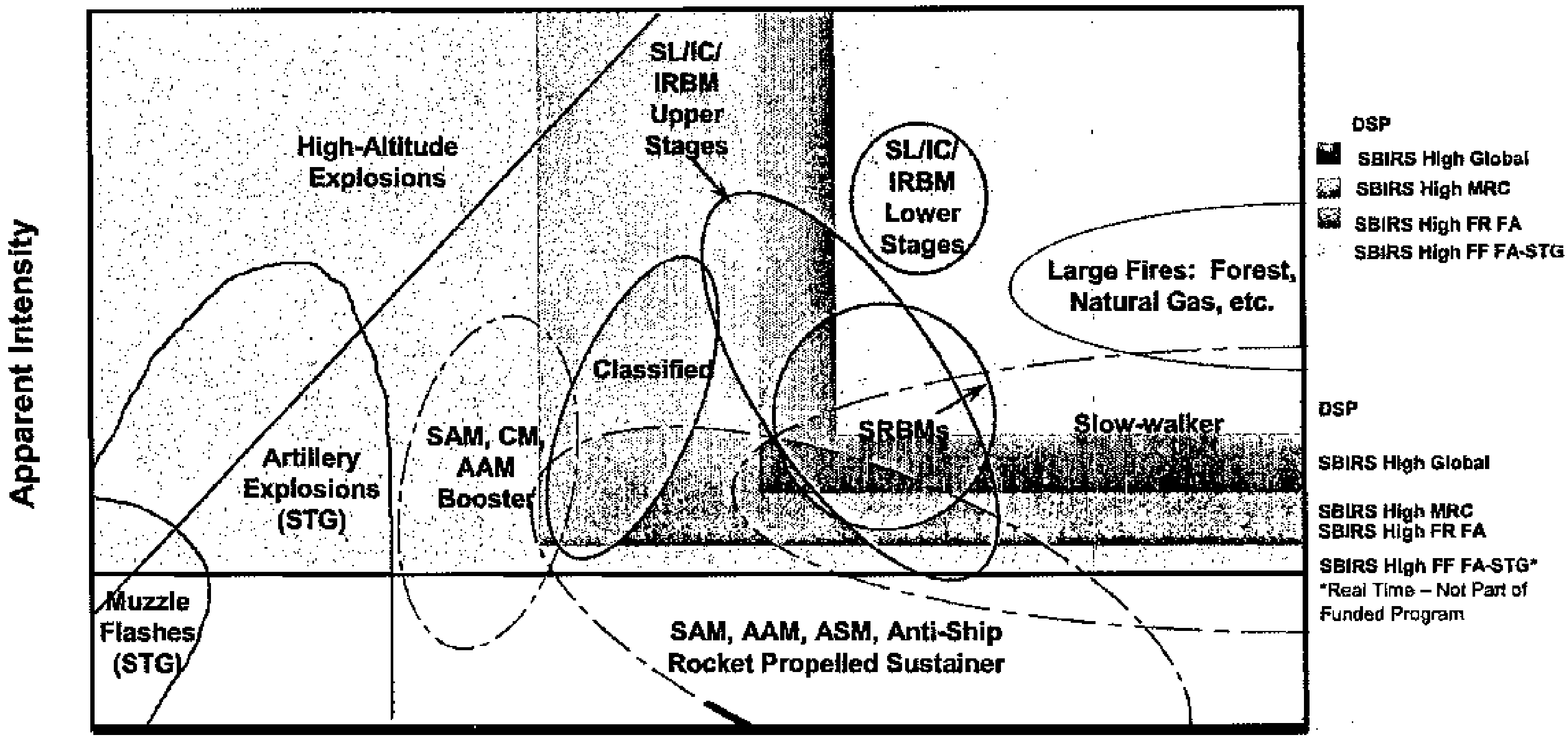


Representative SWIR & STG Intensity and Duration of IR Events



SBIRS Transformational Capability
Col. Roger Teague
Commander, Space Group
Space Based Infrared Systems Wing
Space and Missile Systems Center
30 November 2006

Representative SWIR & STG Intensity and Duration of IR Events



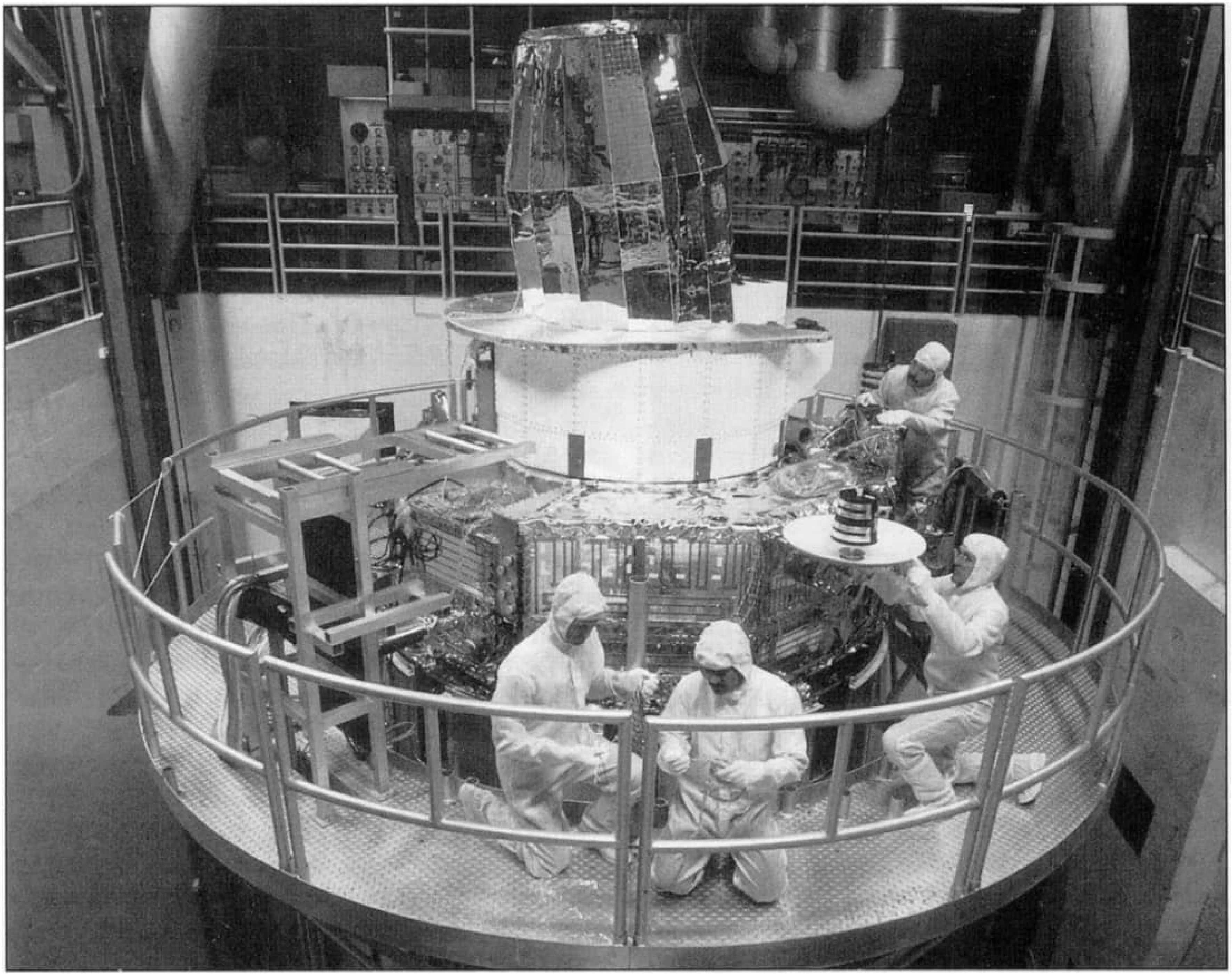
Duration (Notional Scale)

__SBIRS High Starer Modes__

- Step-Stare - Theater Major Regional Conflict (MRC)
- Step-Stare - TI Fast Revisit Focused Area (FR FA)
- Dedicated Stare – Fast Frame Focused Area (FF FA)*
- *Step-Stare - TI High Sense Focused Area (HS FA) – not shown*

The Space-Based Infrared Satellite (SBIRS) Geosynchronous Spacecraft

DSP-1 Satellite Prior to Final Integration – Probably Satellite 14



Satellite Features

- A2100 derived spacecraft, 12-year design life, 9.8-year MMD
- ~10,000-lb predicted wet weight at launch
- 3-axis stabilized with 0.05 deg pointing accuracy; solar flyer attitude control
- RH-32 rad-hardened single board computers with reloadable flight software
- ~2800 watts generated by GaAs solar arrays
- GPS receiver with Selected Availability Secure Anti-Spoof Module (SAASM)
- ~1000-lb infrared payload: scanning and staring sensors
  - 3 colors: short-wave, mid-wave, and see-to-ground sensor-chip assemblies
  - Short Schmidt telescopes with dual optical pointing
  - Agile precision pointing and control
  - Passive thermal cooling
- Secure communications links for normal, survivable, and endurable operations

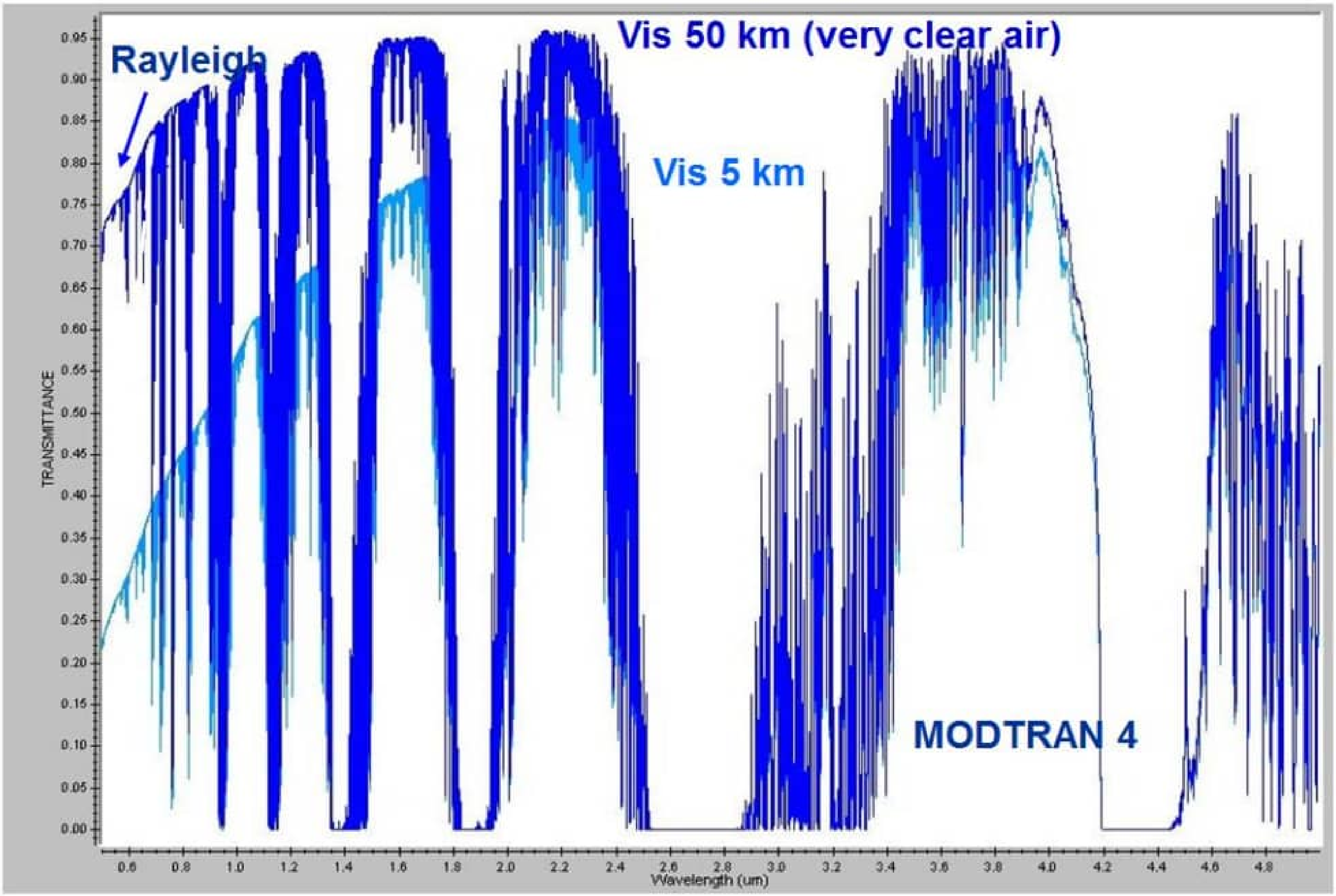
100 Mbs data-rate to ground

~500+ lb Infrared Sensor Payload: Scanning and Staring Sensors

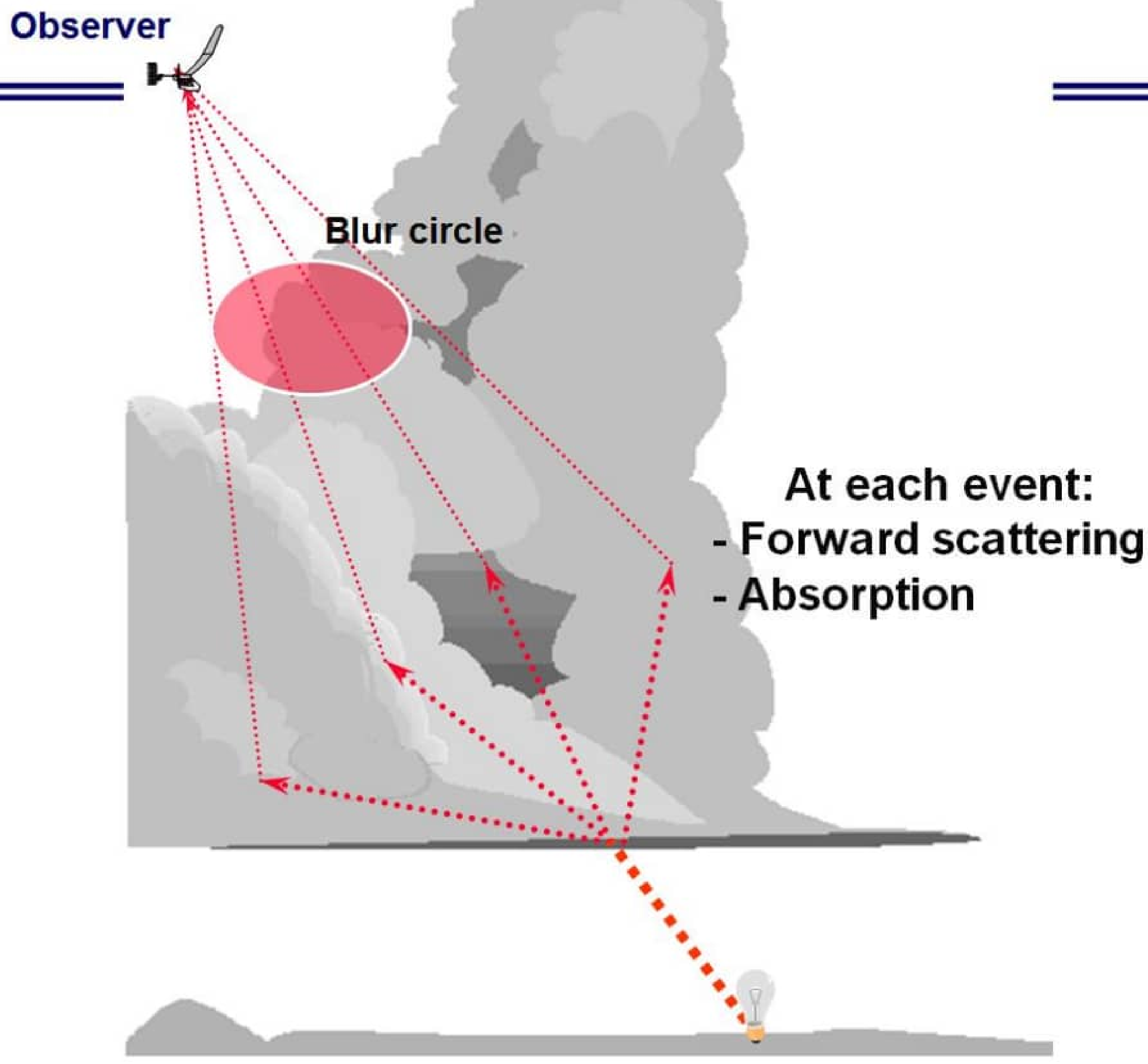
SWIR~2.69-2.95 μm, MWIR~4.3 μm, and 0.5-2.2 μm (see-to-ground)

Effects of Atmospheric Aerosol Load
(scattering and absorption)
(no clouds)

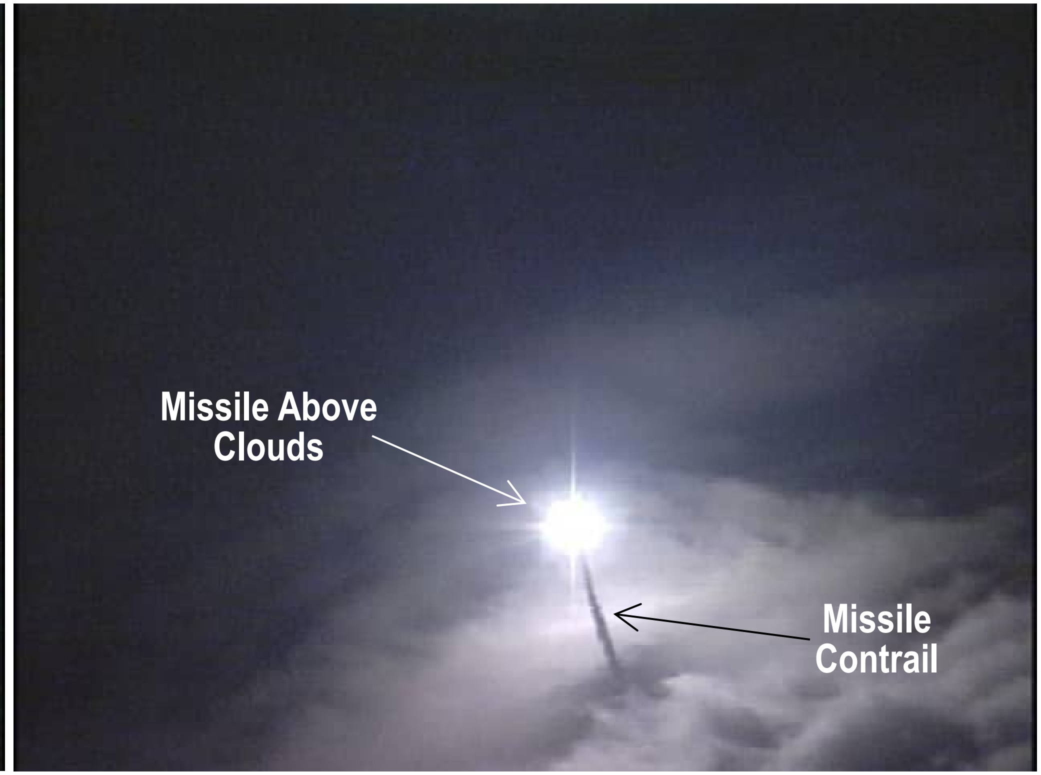
Clear Air



Photons are Forward Scattered Through Clouds



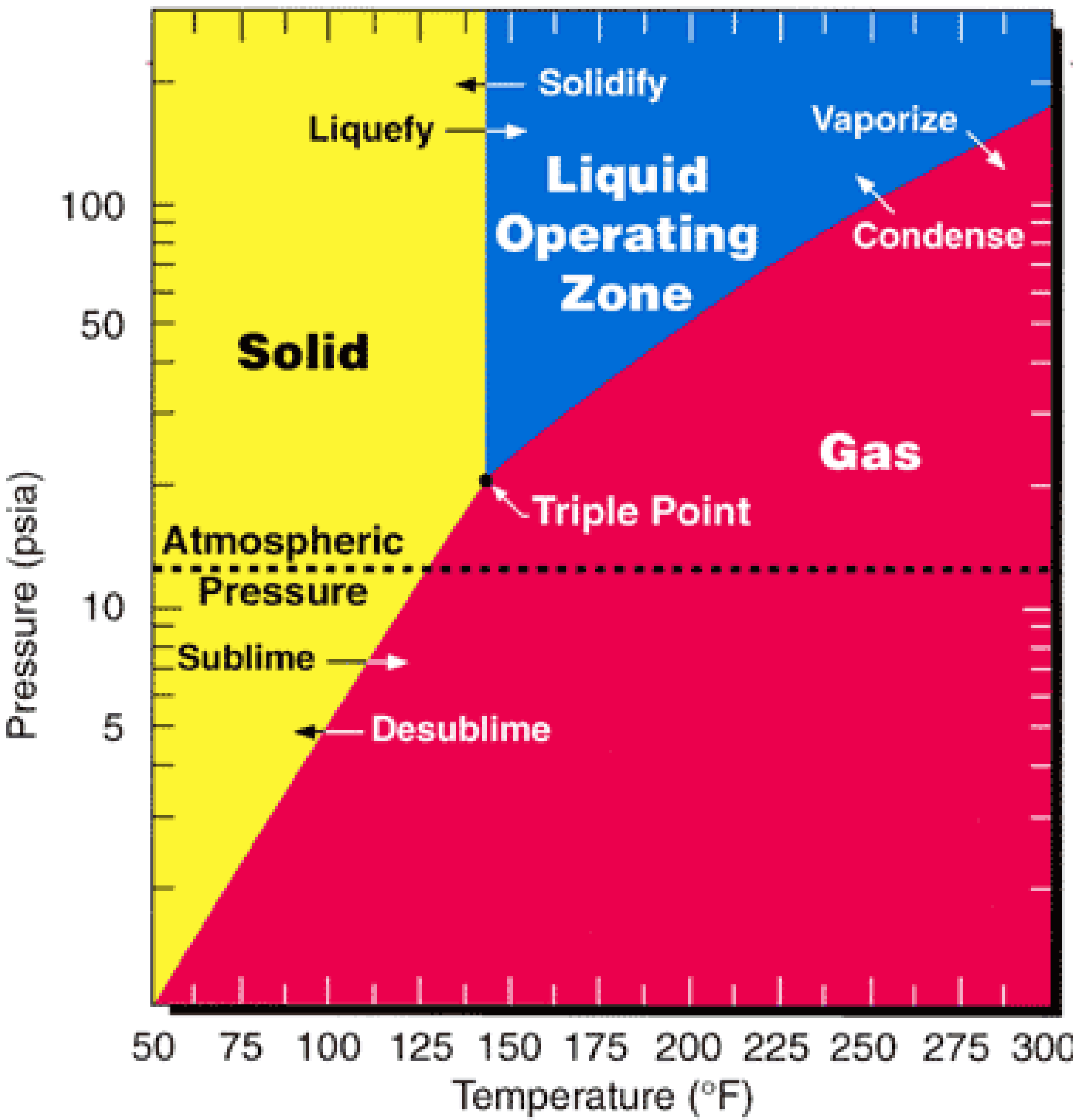
Optical/Short Wave Infrared Observations of Missiles in Powered Flight Above and Below Heavy Cloud Cover



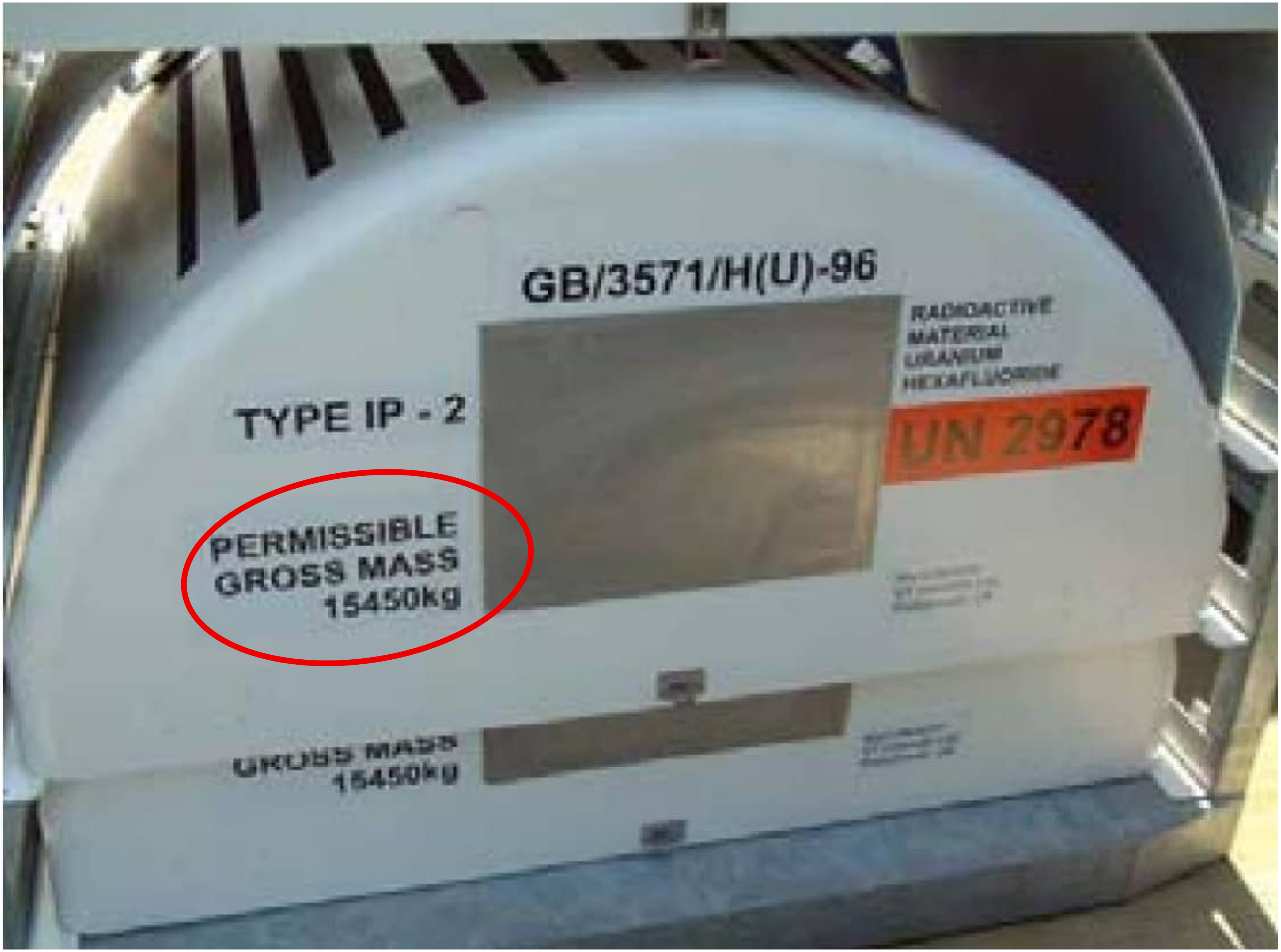
High Spatial Centroid Determination Achieved by Dithering and/or Pixel-to-Pixel Intensity Interpolation
Achievable Sensitivity Against Sun Backgrounds ~ 10^{-5} to 10^{-6}
Achieved by Frame-to-Frame Subtraction and by Temporal Signal Variations at Ignition and During Powered Flight
Even DSP Could Easily See Aircraft and SCUD Signals Against Backgrounds (~ 20 kW/sr in-band)

Proceeding to a Bomb Not Easily Stopped
Enriched Uranium and Further Enrichment Capacity Already There

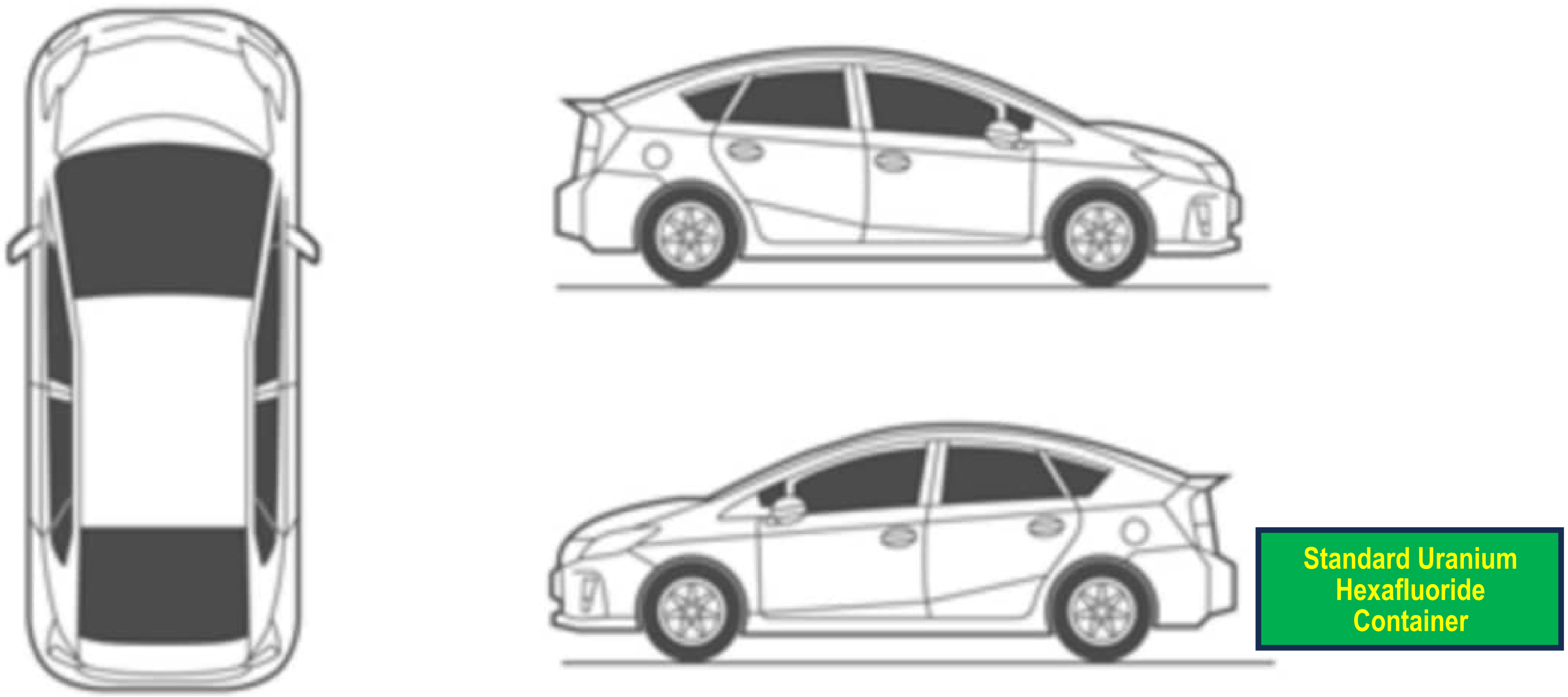
Phase Diagram of Uranium Hexafluoride



Iran’s Inventory of 60% Enriched Uranium Hexafluoride As of May 20, 2025


GB/3571/H(U)-96
RADIOACTIVE
MATERIAL
URANIUM
HEXAFLUORIDE
TYPE IP - 2
UN 2978
PERMISSIBLE
GROSS MASS
15450kg
GROSS MASS
15450kg

Toyota Prius Hatchback Compared with Uranium Hexafluoride Container



Total Amount of 60% Enriched UF_6 Uranium is About 408 kg, see table below.
Standard Container Dimensions = 2.5 feet Diameter, 6.33 feet Long

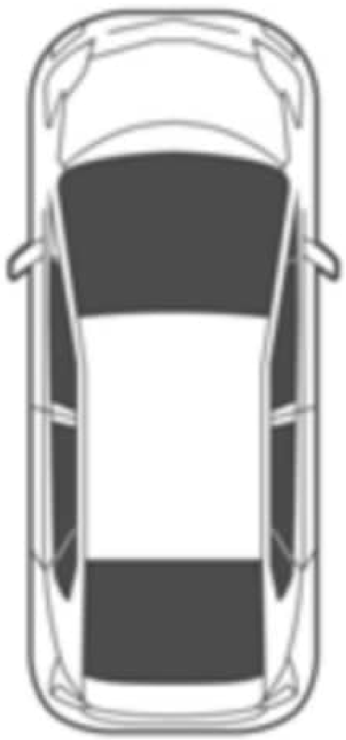
Iran's Inventory of 60% Enriched Uranium Hexafluoride As of May 20, 2025

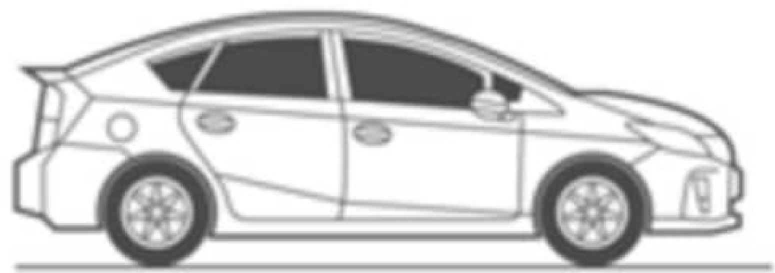
Table 1. Enriched Uranium Inventories,* including less than 5%, up to 20%, and up to 60% enriched uranium (all quantities in uranium mass), as of May 17, 2025

Chemical Form	**5/10/2024**	**8/17/2024**	**10/26/2024**	**2/8/2025**	**5/17/2025**
UF_6 (kg)	5841.3	4951.1	5807.2	7464	8413.3
Uranium oxides and their intermediate products (kg)	203.5	645.2	615.8	626.9	619.6
Uranium in fuel assemblies, rods and targets (kg)	51.6	50.1	48.7	65.2	75.4
Uranium in liquid and solid scrap (kg)	104.9	105.4	132.7	138.3	139.3
Enrichment Level Subtotals					
Uranium enriched up to 5 percent (kg) but more than 2 percent, in UF_6	2376.9	2321.5	2594.8	3655.4	5508.8
Uranium enriched up to 2 percent (kg), in UF_6	2571	1651	2190.9	2927	2221.4
Uranium enriched up to 20 percent (kg), in UF_6	751.3	813.9	839.2	606.8	274.5
Uranium enriched up to 60 percent (kg), in UF_6 (including 6.5 kg that were dumped and are likely far below 60 percent)	142.1	164.7	182.3	274.8	408.6
Enriched Uranium in chemical forms other than UF_6 with unspecified enrichment level (kg) (including 60.6 kg up to 20% LEU and 2 kg up to 60 % HEU)	360	800.7	797.2	830.4	834.3
Totals of Enriched Uranium in UF_6, <5 % (kg)	4947.9	3972.5	4785.7	6582.4	7730.2
Totals of Enriched Uranium in UF_6, including near 20 % and near 60 % (kg)	5841.3	4951.1	5807.2	7464	8413.3
Totals of Enriched Uranium in all chemical forms, <5 % <20 % and <60 % enriched	6201.3	5751.8	6604.4	8294.4	9247.6

* These totals do not include undisclosed stocks of enriched uranium exempted by the JCPOA Joint Commission.

Toyota Prius Hatchback Compared with Uranium Hexafluoride Container





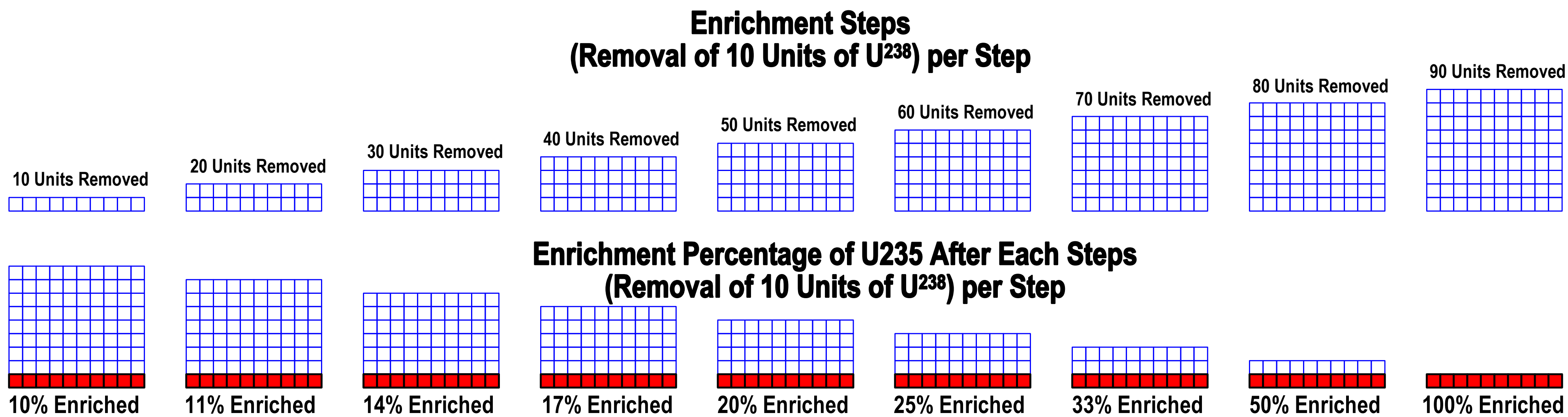
Total Amount of 60% Enriched UF_6 Uranium is About 408 kg, see table below.
Standard Container Dimensions = 2.5 feet Diameter, 6.33 feet Long

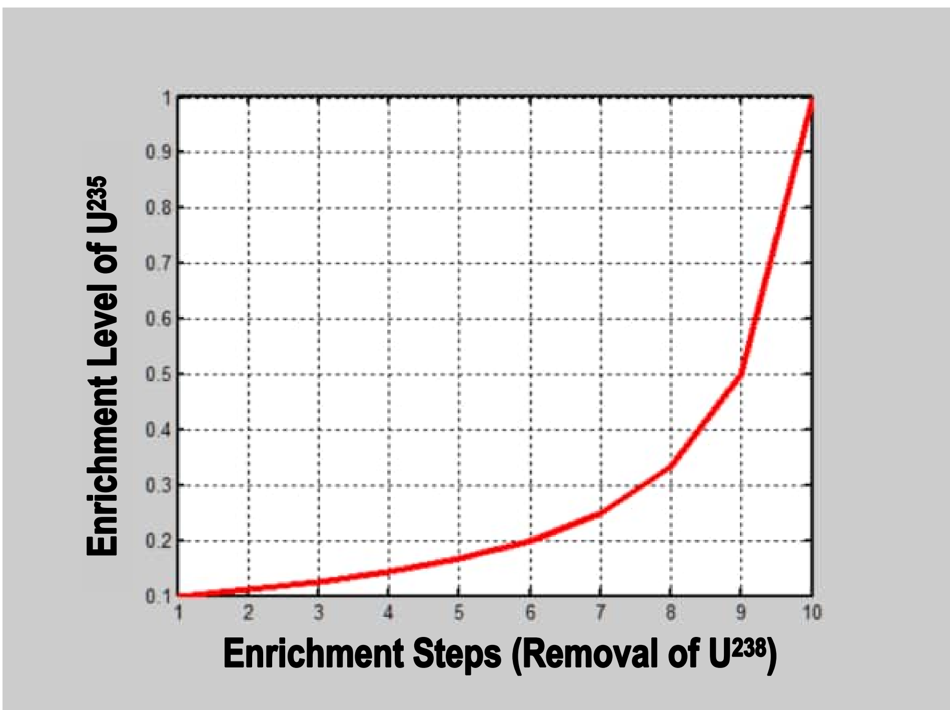
50% Full Uranium Hexafluoride Container with 408 kg of 60% Enriched

90% Full Uranium Hexafluoride Containers with 408 kg of 60% Enriched

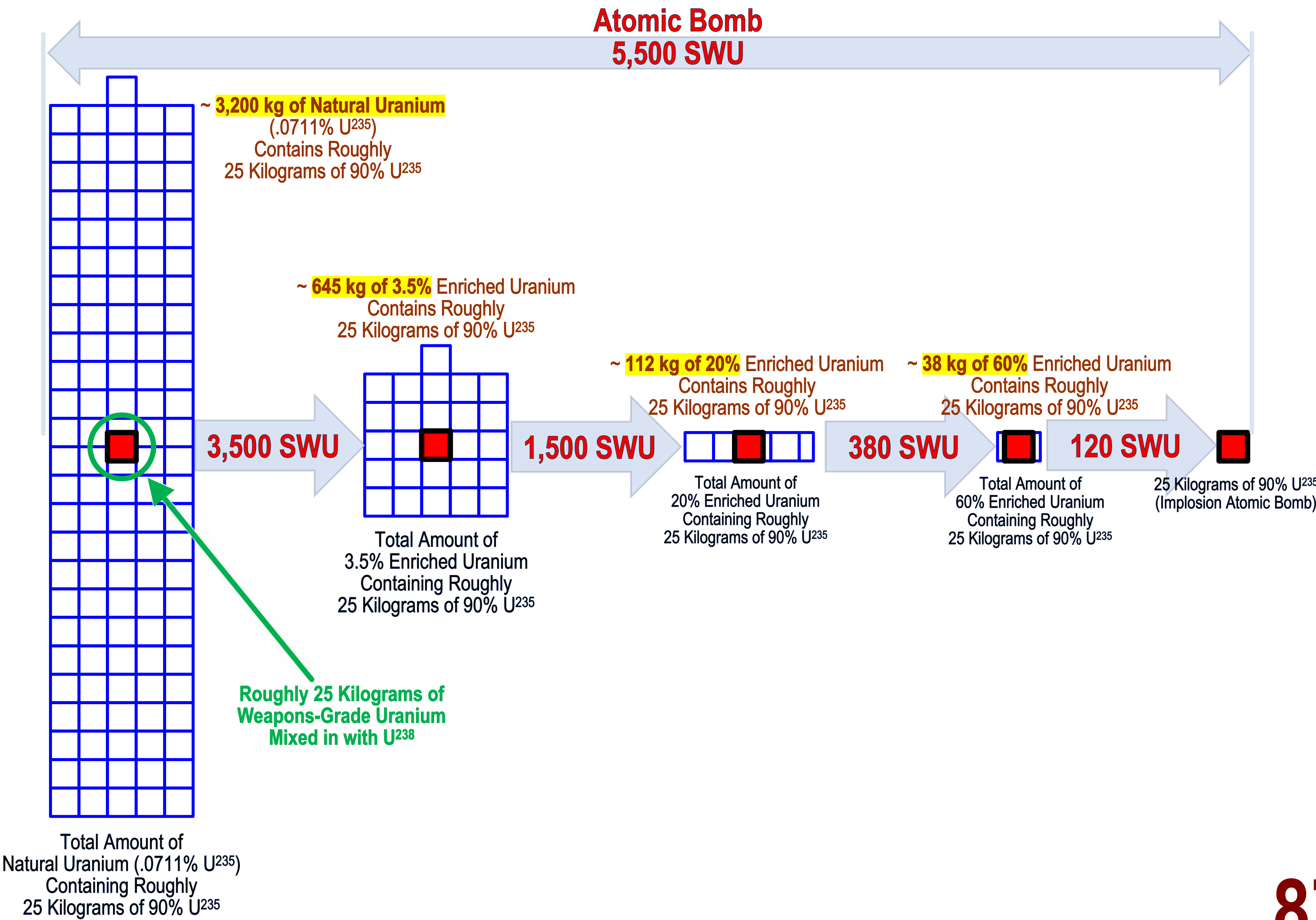
Conceptual Picture of Enrichment Process

Increase in Concentration per "Step" Gets Significantly Larger as Each Enrichment Step Proceeds





Separative Work and Quantities of Uranium Required to Get to Various Levels of Enrichment



How Much Damage to Fardow Centrifuges Needed to Delay Production of Atomic Bombs?

Before Attack

10 Cascades of 174 IR-6 Centrifuges (1740 Centrifuges)

Centrifuge and Cascade Enrichment Capacity

IR-6 Centrifuge ~ 4.5 swu kg/yr

4.5 swu kg/yr ×174 Cascade of IR-6 Centrifuges = 783 swu kg/yr per Cascade

Required Enrichment Capacity to Produce Atomic Bomb

120 SWU for 37.5 kg U^{235} of 60% Enriched to 25 kg 90% Enriched

500 SWU for 112 kg of 20% Enriched U^{235} to 25 kg 90% Enriched

Number of Atomic Bombs Producible from Available Uranium

Bombs per Year from 60% Enriched Uranium =

783 swu kg/yr per Cascade/120 SWU for 60% ~ 6.5 Bombs

In reality 6.5/1.5 = 4.35 (Convert from UF_6 to U^{235} Metal)

Number of Iranian Enriching Centrifuges and Their Enrichment Capacities, As of May 2025

	Number of centrifuges	Enrichment capacity in swu/yr	IR-1 equivalent
Natanz	14192	35993	39992
Fordow	2264	7345	8161
Natanz Above-Ground PFEP*	701	2964	3293
Natanz Below-Ground PFEP*	802	3821	4245
Total	17,959	50,123	55,691

* The values for IR-5 and IR-6s centrifuges at the PFEP areas are rough estimates based on the use of estimated and measured values for the separative output of these centrifuges in cascades, as drawn from IAEA and Iranian information.

Source: Institute for Science and International Security
Analysis of IAEA Iran Verification and Monitoring Report — May 2025
By David Albright, Sarah Burkhard, and Spencer Faragasso
June 9, 2025

How Iran's Nuclear Enrichment Program Has Developed since 2018

	Under 3.67%	3.67–5%	20%	60%
Pre-2019 Iran adhered to nuclear deal limits for low enriched uranium at **3.67%**	**149kg** 3.67%			
2019 Iran incrementally violates nuclear deal restrictions by exceeding stockpile limits and enriching up to **4.5%**	**213kg** 3.67%	**160kg** 4.5%		
2020 Stockpile grows, especially in production of **4.5%** enriched uranium	**215kg** 3.67%	**2,228kg** 4.5%		
2021 Major escalation with **20%** and **60%** enrichment. IAEA monitoring weakened. Biden takes charge.	**560kg** 2%	**1,622kg** 5%	**114kg** 20%	**18kg** 60%
2022 Iran grows **60%** enriched uranium stockpile and announces plans to expand a centrifuge facility	**1,845kg** 2%	**1,030kg** 5%	**386kg** 20%	**62kg** 60%
2023 The IAEA finds traces of **83.7%** enrichment. Iran says was "unintended fluctuations" and the IAEA agrees Iran hasn't enriched over 60%	**1,217kg** 2%	**2,218kg** 5%	**567kg** 20%	**128kg** 60%
2024 Iran's stockpile of **60%** enrichment and capacity grew significantly	**2,191kg** 2%	**2,595kg** 5%	**839kg** 20%	**182kg** 60%
2025 Iran now has enough material for at least **10 nuclear bombs if further enriched to 90%**	**2,221kg** 2%	**5,509kg** 5%	**275kg** 20%	**409kg** 60%

https://www.cnn.com/2025/06/13/middleeast/iran-nuclear-program-explainer-intl-cg

Number of Installed Iranian Centrifuges by Date