

Outgunning the A-10 with an Apache or FARA: New Flight-Safe Sabotaged Ammunition for Attack Rotorcraft

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Mr. Nathan Wolf, MS Candidate
Aerospace Engineering Department
The University of Kansas, Lawrence, Kansas USA

*NDIA Future Force Capabilities Exhibition
Austin, Texas 19 – 22 September 2022
Paper No 24707*

Outline:

- i. Motivation***
- ii. The Close Air Support History, Army Challenges***
- iii. Struggles & Breakthrough: Flight Safe Sabots***
- iv. BASS & MASS Round Design Philosophies***
- v. Aerodynamics, Aeromechanics, FEM, Bench Testing***
- vi. Range Shots, Performance, Trades***
- vii. Intellectual Property Filings, Claims & Status***
- viii. Opportunities***

KU Aerospace Engineering Department

Adaptive Aerostructures Laboratory

- **Specialize in "Prime Mover" Military Technologies:**

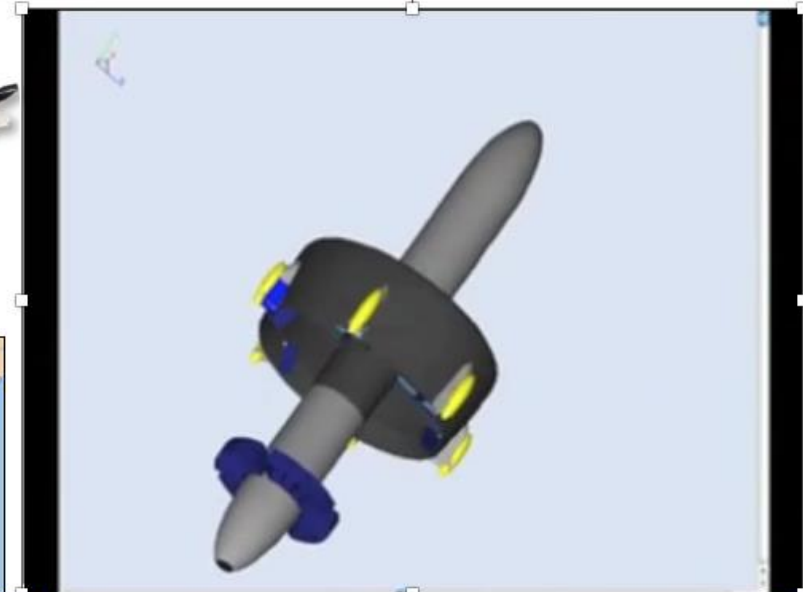
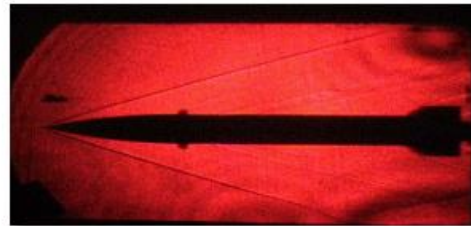
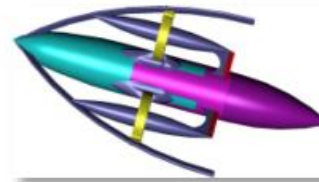
- Ultra-high performance drones
- Invisible drones
- Hovering missiles
- Guided ammunition 4 – 155mm
- Hypersonic ammunition
- Acoustic Vector Sensors

- **Advanced Commercial Technologies:**

- Adaptive Aerocompliant Surfaces
- Commercial Drones
- Toys

- **IP Protection & Litigation**

45 min. West of Kansas City



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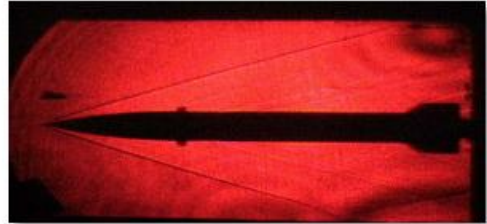
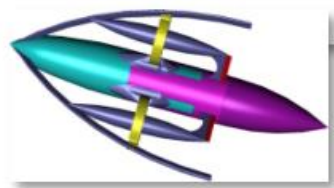
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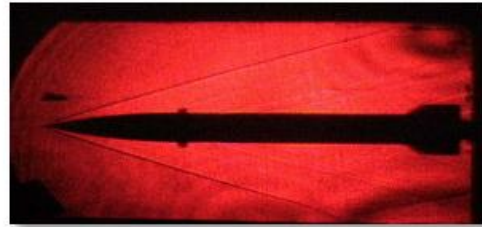
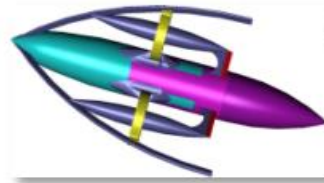
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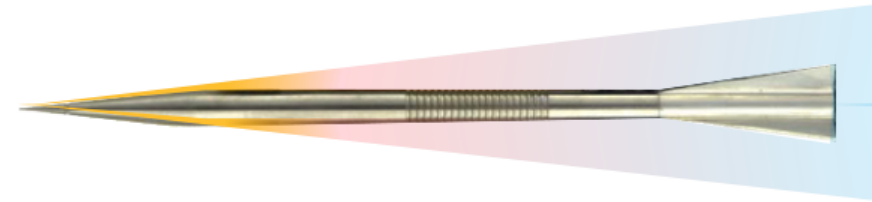
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1. Motivation: Why use flight-safe discarding sabot ammunition?

- Endows AH-64 & FARA with better than A-10 gunnery firepower
- Increased range, KE, lethality, P_k , flat fire
- Reduced TOF, CEP, system weight, volume, airframe MGWTO & LCC
- Enables both unguided and guided variants through hypersonic speeds

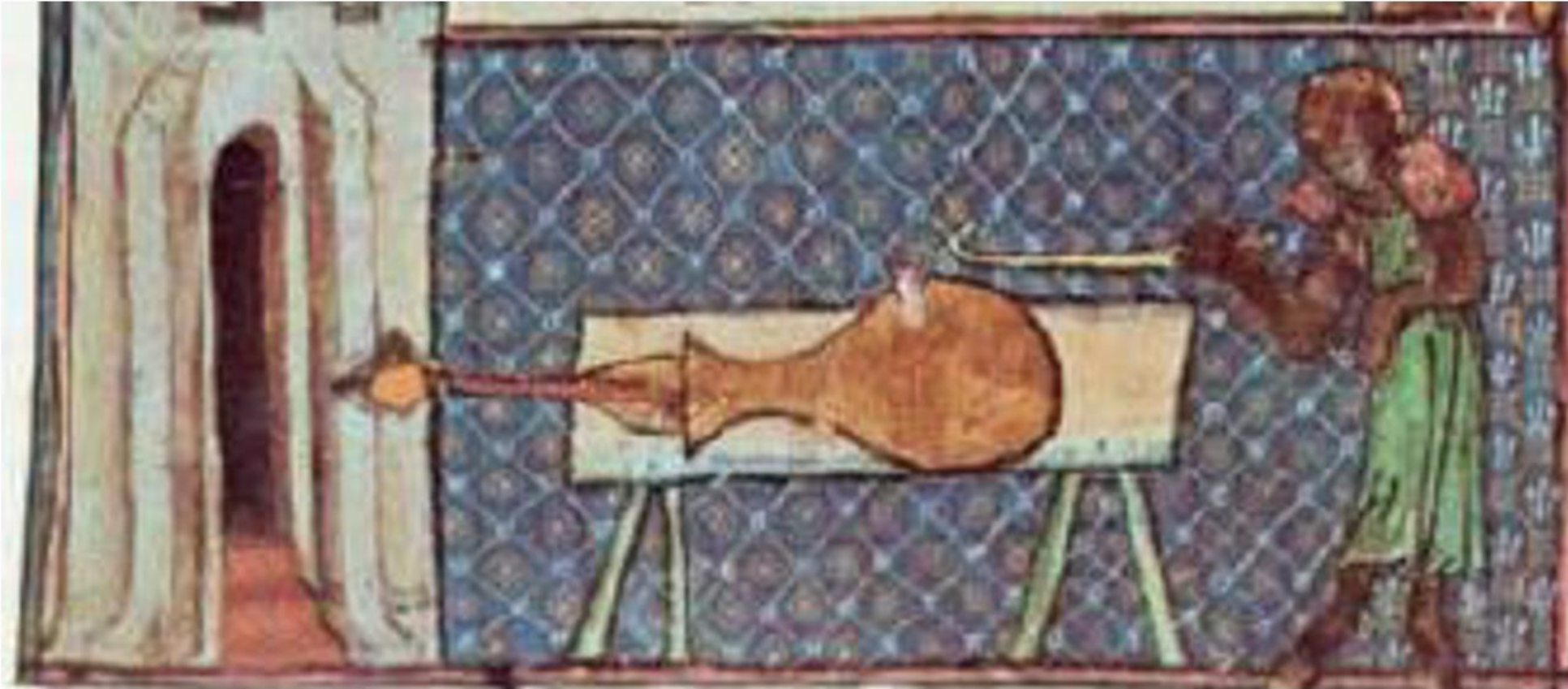


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2. Saboted Round & Aerial Gunnery History (condensed)

1st Archival Document Describing a Sabot

1326 Treatise of Walter de Milemete



W. de Milemete, "The Treatise of Walter de Milemete: de Nobilitatibus, Sapientiis, et Prudentis Regum," Christ Church, Oxford; digital ID: 3590ddc7-1ae2-4b23-b576-ec716fb24d01, 1326-1327.

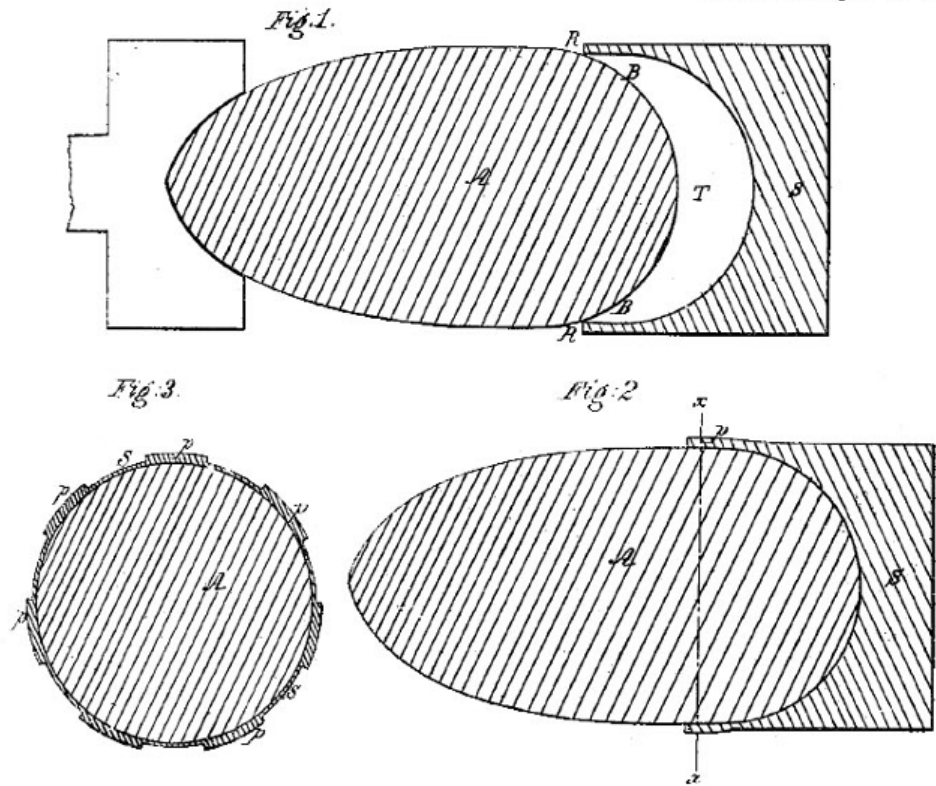
Image Source:

<https://catalog.hathitrust.org/Record/002098083>

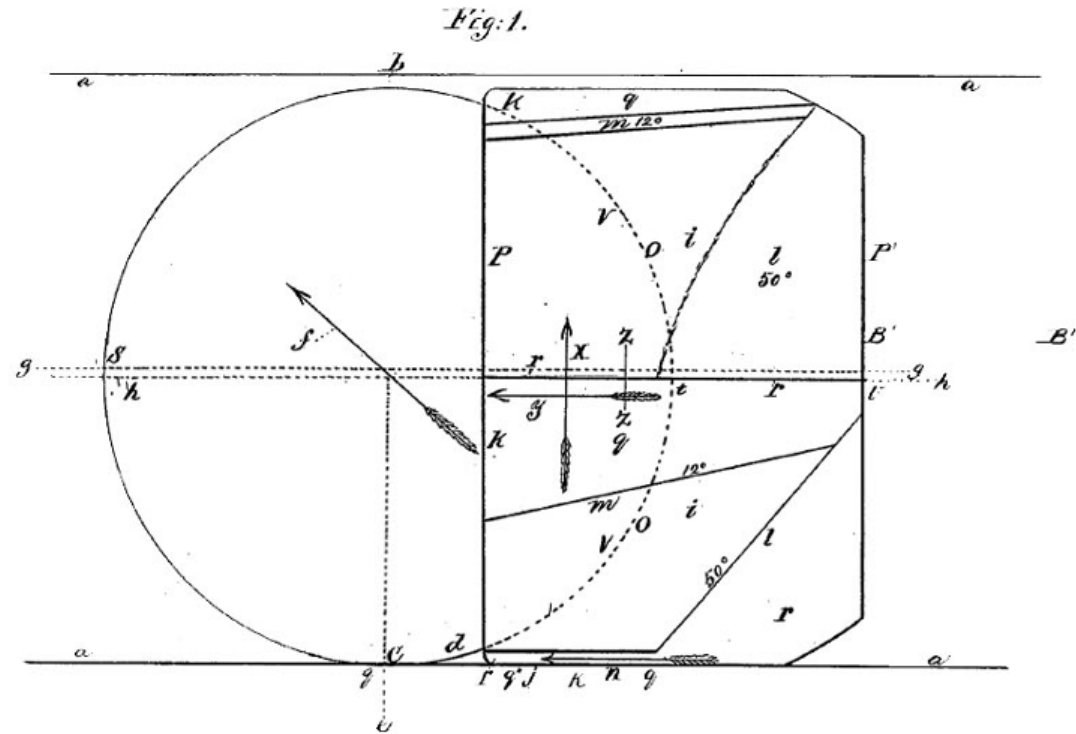
2. Saboted Round & Aerial Gunnery History (condensed)

• Increasing Chamber Pressures & Functions of Early Sabots – 1850's

L. HOUGHTON.
No. 12,629. Loading Ordnance. Patented Apr. 3, 1855



W. W. HUBBELL.
No. 15,075. Sabots and Wads. Patented June 10, 1856.



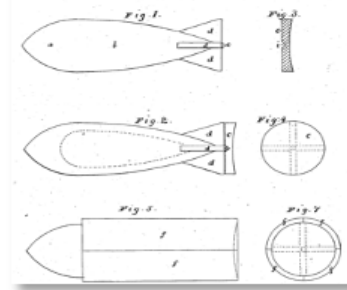
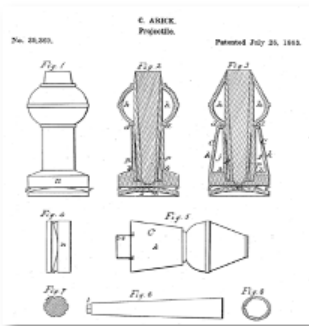
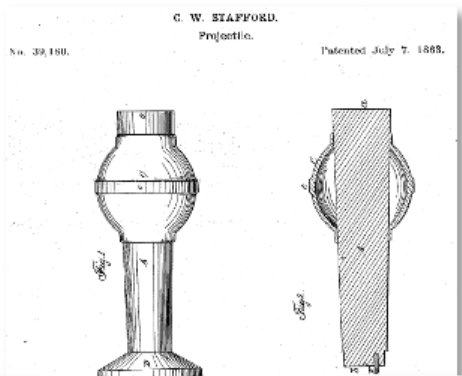
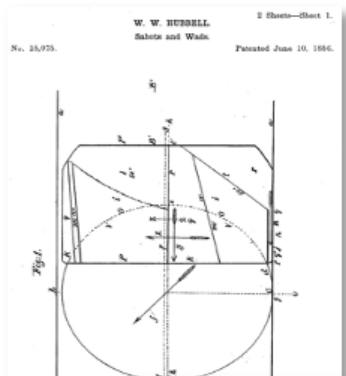
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2. Saboted Round & Aerial Gunnery History (condensed)

695 Years of Sabots...

US Civil War – Modern Sabots

Not one suitable for aerial gunnery



United States Patent [16] Patent Number: 4,833,995
G81a et al. [45] Date of Patent: May 30, 1989

[14] **STABILIZED PROJECTILE**
[15] **Inventors:** MA. GILG, Douglas; Dutton, Mollman; Ansh, Pisk, both of Schenectady, Adolf; Anshinsky, Alexander, all of Kiev, U.S.S.R. of Germany

[17] **Assignor:** Machine-Works Oboronat (GDR), Ulmanitzki, Fed. Rep. of Germany

[21] **Appl. No.:** 082,527
[22] **Filed:** Oct. 14, 1988
[23] **Foreign Application Priority Data:** Oct. 20, 1985 (GDR) Fed. Rep. of Germany 334384

[31] **Int. Cl.:** F42B 12/16; F42B 21/20
[32] **U.S. Cl.:** 102/210; 102/206; 102/257
[33] **Field of Search:** 102/210; 102/206; 102/257

[34] **References Cited:**
U.S. PATENT DOCUMENTS
1,225,935 1/1946 Thompson 244,628

[35] **Foreign Patent Documents:**
1,776,316 6/1984 Chou et al. 244,624
1,218,008 1/1978 Suga et al. 102,912
2,176,914 1/1977 Pisk et al. 102,912
4,109,582 8/1975 Pisk et al. 102,916
4,064,113 10/1974 Carroll 102,921
437,968 6/1983 Uchida et al. 102,921

[36] **Foreign Patent Documents:**
20,102 8/1981 Oasa Kagaku 149,124
Dreyer Zeitschrift—März 1, 1900
Dreyer, Opus 4 (1900—1911), Smith, Murphy & Turner

[37] **ABSTRACT:**
A stabilized projectile for weapons selectively portable either a smooth, and in particular, a rifled weapons barrel, which possesses a deformable, straight longitudinal axis, and is elongated relative to its diameter, and which is provided at the tail end of its projectile with a stabilizing stabilizing guidance mechanism which is rotatable about the longitudinal axis of the projectile.

15 Claims, 1 Drawing Sheet

W. ENGEL ET AL
CASING FOR THE SABOT OF A PROJECTILE
3,446,147
May 27, 1969
Filed March 1, 1967

Fig. 1
Fig. 2
Fig. 3
Fig. 4

United States Patent
Johanson
(11) Patent No.: US 6,814,006 B2
(21) Date of Patent: Nov. 9, 2004

Sub-caliber projectile and method of making same
Inventor: Bertil Johanson, 5-439 36, Canada

Abstract: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) to 4 days.

Filed: Sep. 26, 2002

Foreign Patent Documents:
70660 12/1990 France et al.
200000 1/1991 Germany
706218 9/1979 Japan

ABSTRACT:
The present invention relates to a conical projectile for sub-caliber projectiles comprising a sabot, a projectile and a driving mechanism, velocity and conical projectile comprising a projectile made of a solid material, preferably having a high density, and that the length of the conical projectile is not substantially longer than the projectile, as well as a cartridge comprising such a conical projectile.

17 Claims, 5 Drawing Sheets

E. N. HEGGE ET AL
MILITARY PROJECTILE AND SHOT FOR HIGH VELOCITY FIREARMS
3,148,472
Filed June 11, 1962

Fig. 1
Fig. 2
Fig. 3
Fig. 4

United States Patent
Campoli et al.
(11) Patent No.: 4,187,783
(21) Date of Patent: Feb. 12, 1980

Disintegrating sabot munition
Inventors: Ralph F. Campoli, Miss Hill, Ella L. Barstow, Morris Plano, Ada W. Blumel, Lake Hopewell, all of N.J.; Edwin G. Steiner, Junc. Swetz, Thomas A. Lantz, Waterloo, Iowa; Gary M. Miller, Waterloo, Iowa

Abstract: A plurality of discarding type segmented sabots are peripherally disposed circumferentially to the longitudinal axis of a sub-caliber projectile to support the sub-caliber projectile during launch. A preformed notch between said flange members securely attached to the sub-projectile assembly together during launch. As all four-discarding-type ring members secure the sub-projectile during launch, the sub-projectile is held in the longitudinal axis of the firing barrel until the sabot segments are separated from the projectile. A self-actuating flexible base web member is positioned in the aft end of the sabot segments to enhance efficient disintegration of the prelaunch gases.

5 Claims, 4 Drawing Figures

United States Patent
Kirkendall et al.
(11) Patent No.: 4,284,006
(21) Date of Patent: Aug. 18, 1981

Double ramp disintegrating sabot
Inventors: Richard B. Kirkendall, Bruce de Graaf, William H. Drabkin, Winston, Louis G. Kuchinski, Fullerton, Bruce P. Swain, Hartford County, all of Md.

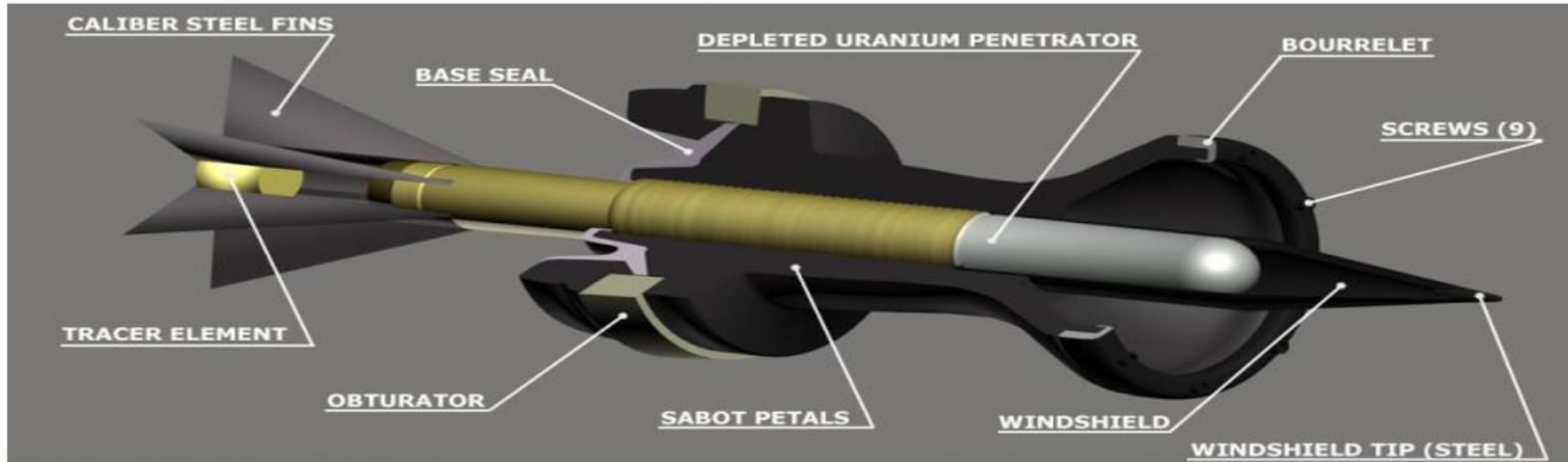
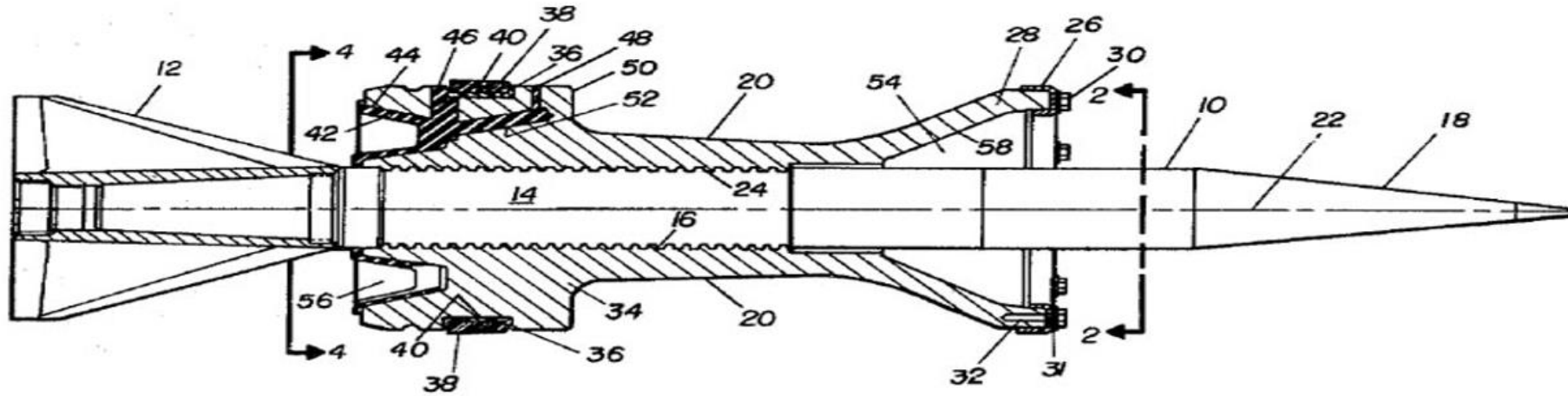
Abstract: A segmented sabot utilizes a double ramp configuration and a centrally positioned shearing band in alignment with the center of gravity of its in-line projectile to improve the uniformity of the shear reaction forces at the interface between the sabot segments and a sub-caliber projectile, to reduce prelaunch gas blow-off and to enhance projectile motion and trajectory stability. The increased uniformity of shear reaction forces between the sabot segments and projectile increases the self-actuating design permits a reduction in sabot weight at the muzzle end.

3 Claims, 6 Drawing Figures

Unlimited Distribution

2. Saboted Round & Aerial Gunnery History (condensed)

Modern Armor-Piercing Discarding Sabot Muniton



Distribution A Unlimited Distribution

2. Saboted Round & Aerial Gunnery History (condensed)

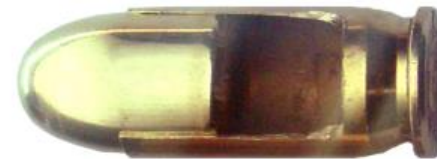
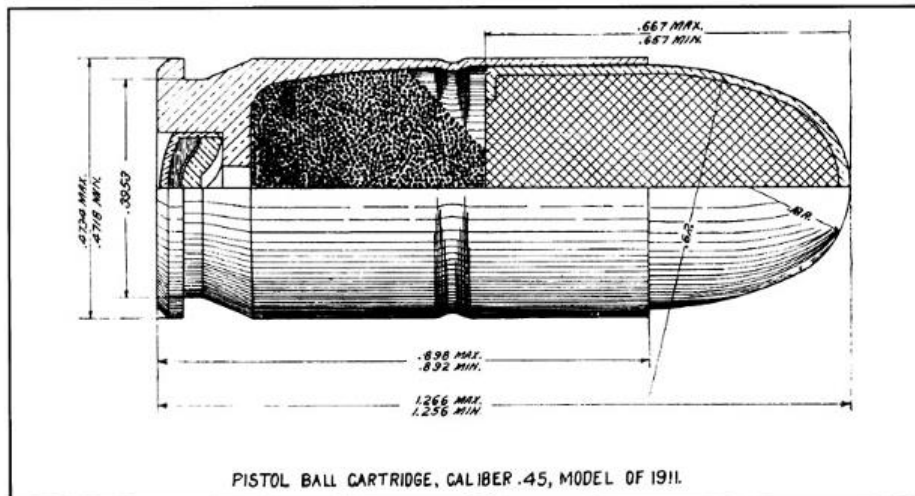
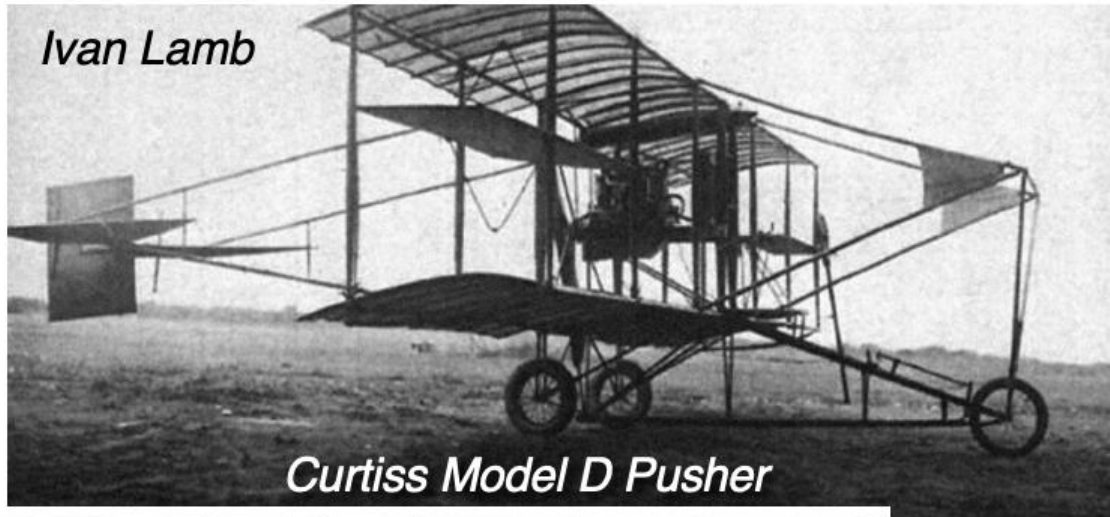
1st Aerial Battle 1913

*Dean Ivan Lamb & Phil Rader
Soldiers of Fortune
Naco, Sonora & Naco, Arizona*



2. Aerial Gunnery History (condensed)

1st Gun Duel



Model 1906 .45 Revolver Ball cartridge



US Army Colt 0.45 1909

The drawing above, from a 1918 "Manual of the Automatic Pistol Caliber .45 Model of 1911," illustrates components of the original military .45 ACP loading—a 230-gr. bullet traveling at 855 f.p.s.

Image Source https://en.wikipedia.org/wiki/M1911_pistol

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2. Aerial Gunnery History (condensed)

1st Air-to-Ground Strafing:

US Customs House, Naco, Arizona



Distribution A Unlimited Distribution

2. Aerial Gunnery History (condensed)

1st Air-to-Ground Strafing:



US Customs House, Naco, Arizona

*"Customs people are always irritating."
-Dean Ivan Lamb*



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2. Aerial Gunnery History (condensed)

Aerial Gunnery WWI



20mm Becker Autocannon in the Front of a Gotha G.1

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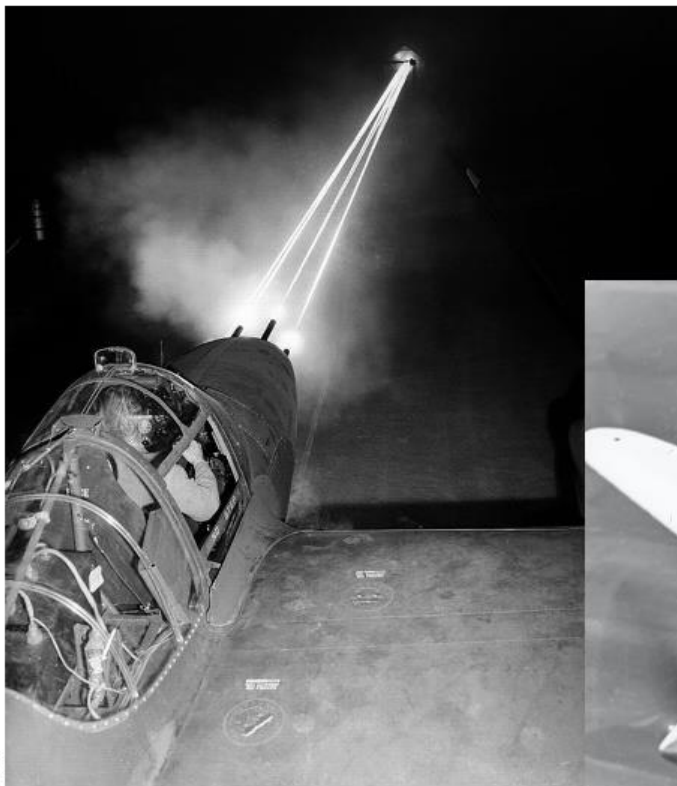
2. Aerial Gunnery History (condensed)



JU-87G-1 with 37mm Cannon (1937 – 1945)

2. Aerial Gunnery History (condensed)

WWII



20mm P-38 Lightning Autocannon

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3. Struggles & Breakthrough

***Post-Key West Drive for Army CAS:
US Army's 1st Gunship: YAH-32 Hornet***



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3. Struggles & Breakthrough

***Post-Key West Drive for Army CAS:
OV-1... Symptom of the Unmet Need***



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3. Struggles & Breakthrough

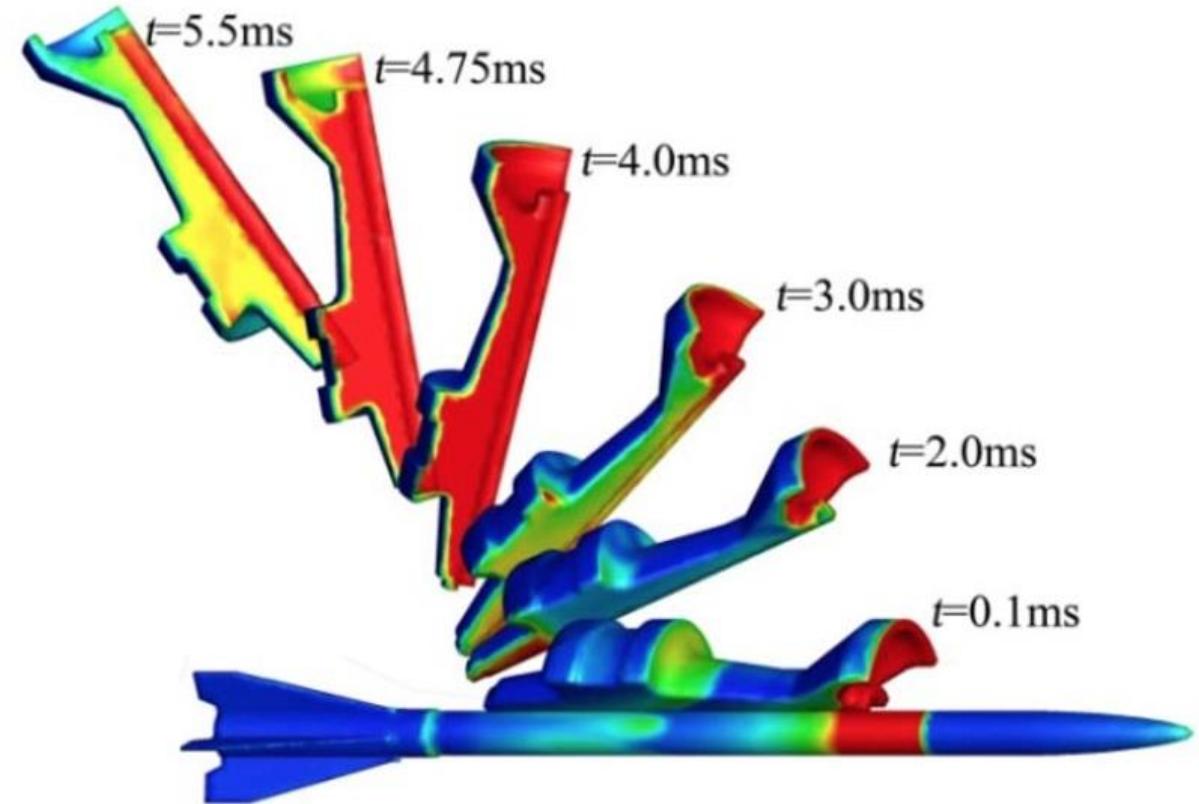
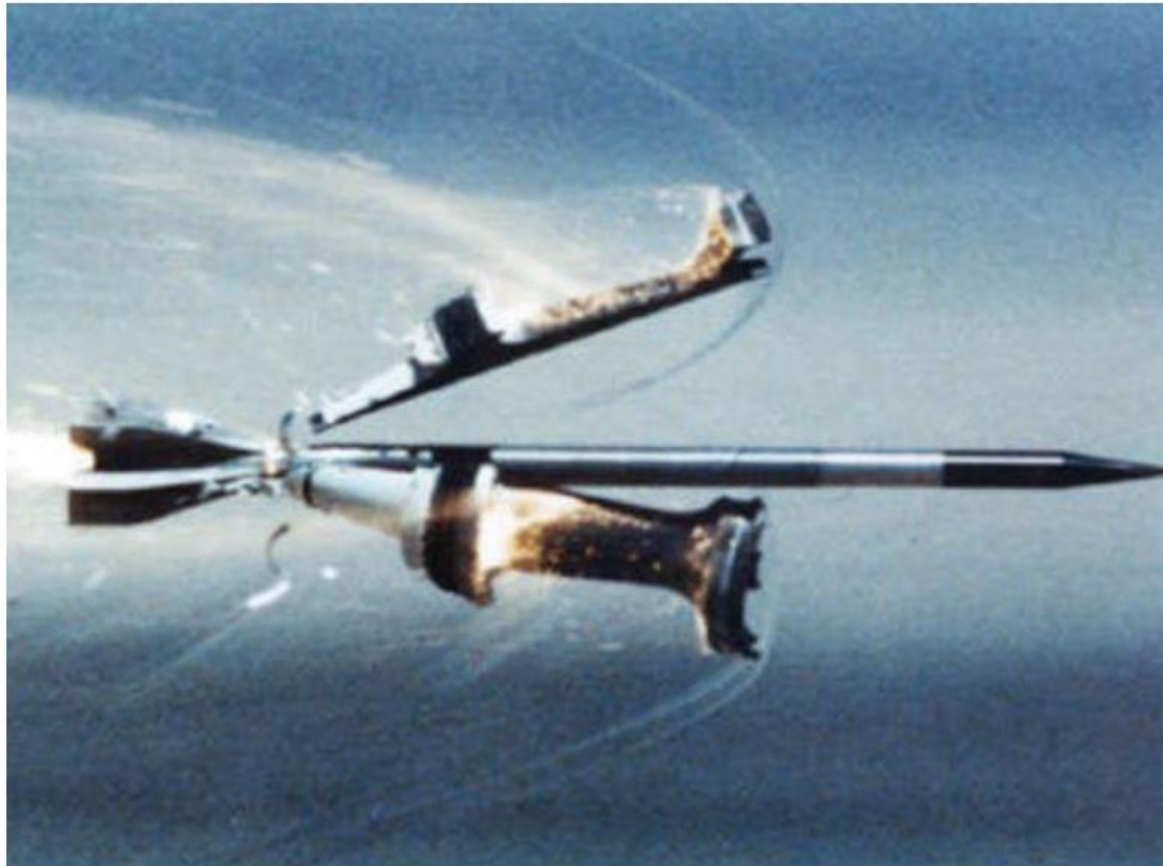
Post-Key West Drive for Army CAS: AH-1 Cobra



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3. Struggles & Breakthrough

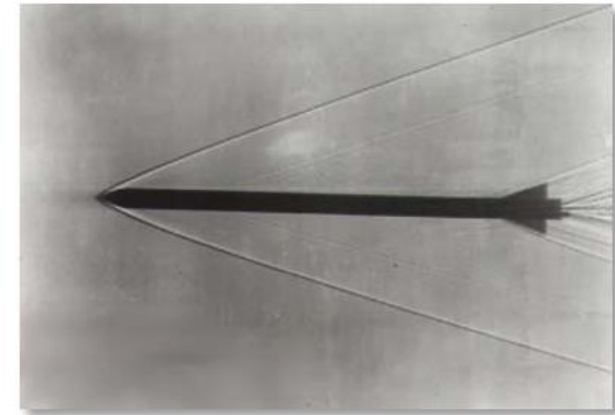
Conventional Discarding Sabot Design Philosophy and Aeromechanics



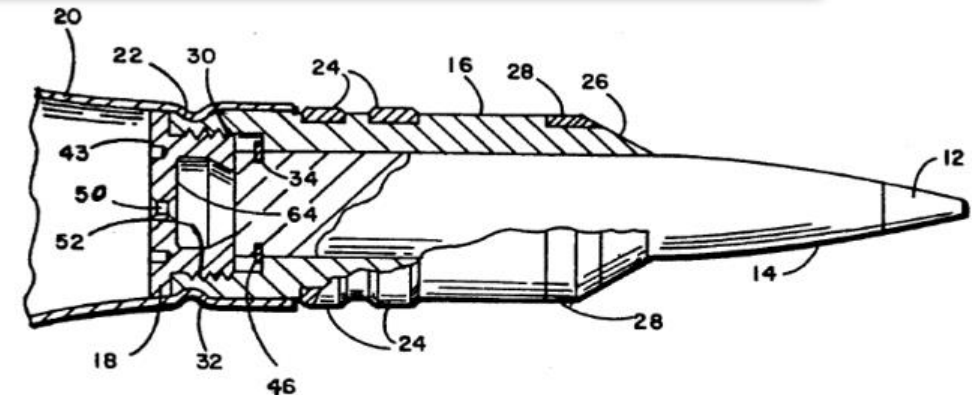
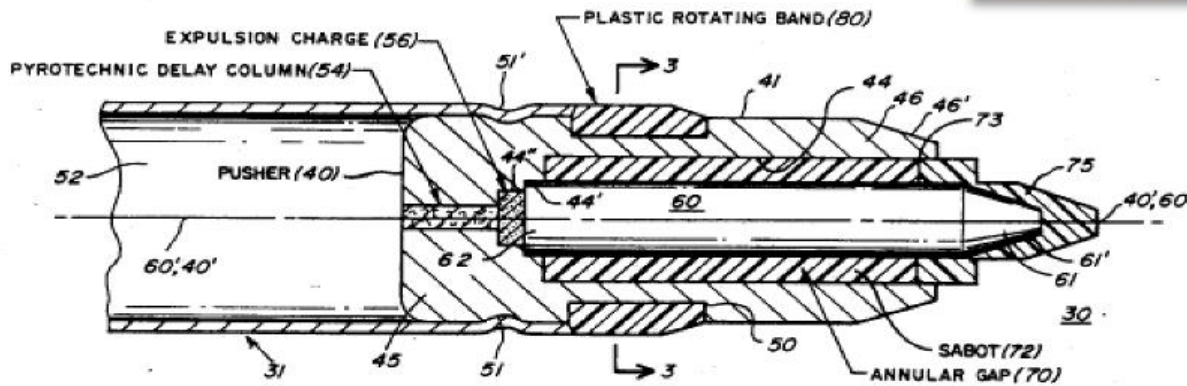
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3. Struggles & Breakthrough

- Tremendous Activity 1952 – 1998
- Sabot Diverters
- Hybrid Rocket-Assisted Projectiles
- Drag Fumers
- Rotating Bands
- Tubular Projectiles
- Disintegrating Sabots
- Meyer & Burnette Sabots



Aeroballistic Research Facility

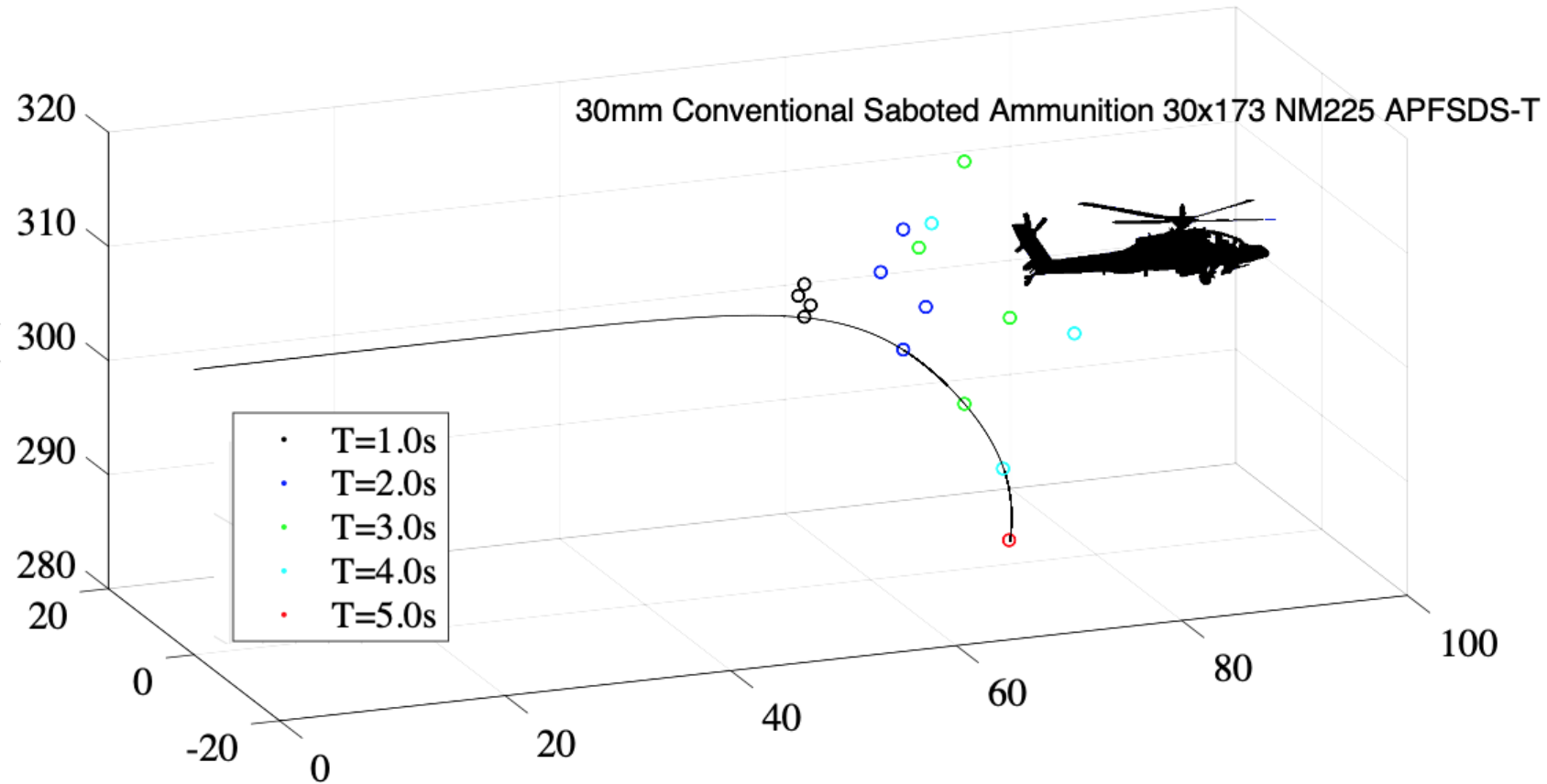


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3. Struggles & Breakthrough

Struggles with Aircraft & Sabots

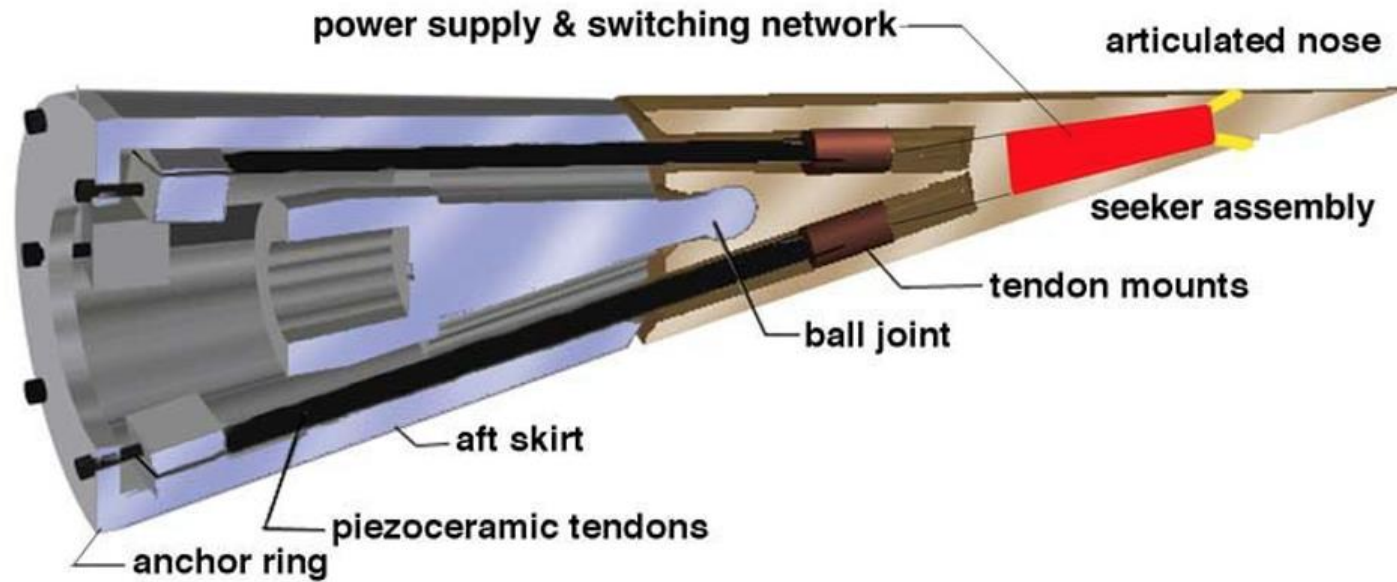
**The Great Show Stopper for conventional sabots:
Flight Safety**



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3. Struggles & Breakthrough

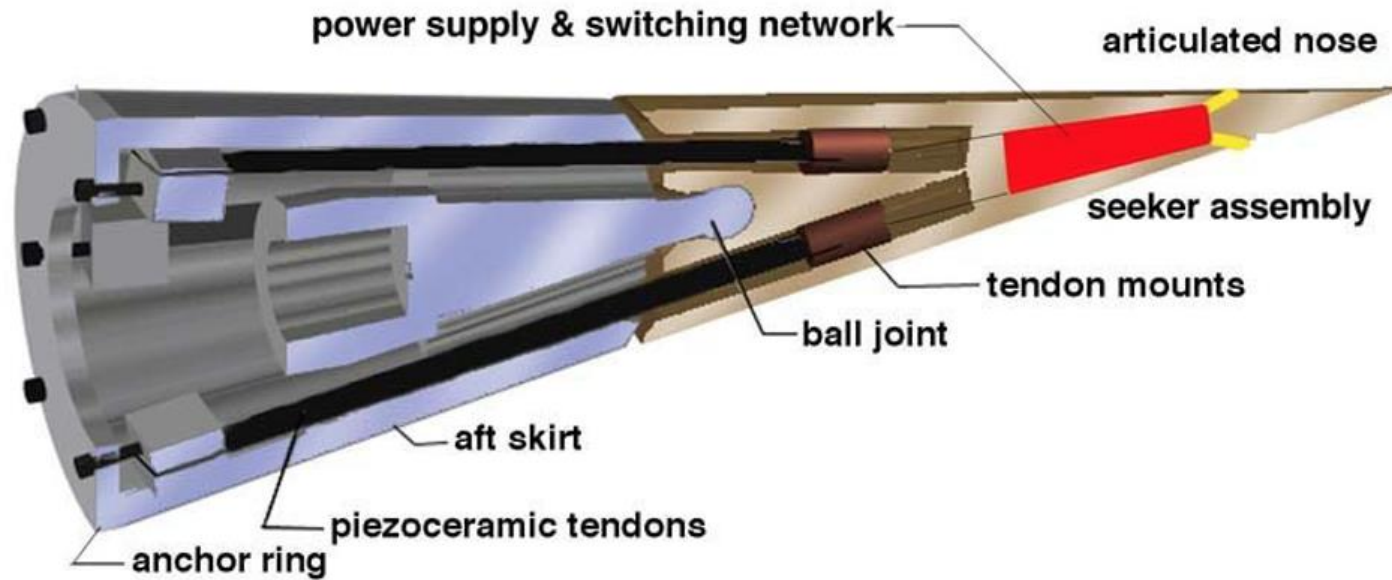
- USAF developed 1st guided aerial gunnery round prototypes 1995 - 1998
- *Barrel-Launched Adaptive Munition (BLAM) Program 1995 - 1998*



Distribution A Unlimited Distribution

3. Struggles & Breakthrough

- **USAF developed 1st guided aerial gunnery round prototypes 1995 - 1998**
- ***Barrel-Launched Adaptive Munition (BLAM) Program 1995 - 1998***



1998: USAF ceases all advanced/guided aerial gunnery & sabotaged ammo. RDT&E

The AFRL does not have an S&T portfolio in ammunition.

-David Lambert AFRL Munitions Directorate Chief Scientist, (via J. Ellison) 2021

3. Breakthrough

Ms. (now Dr.) Lauren Schumacher



2016 Co-Inventor

Ballistic Aeromechanically Stable Sabot (BASS) Ammunition

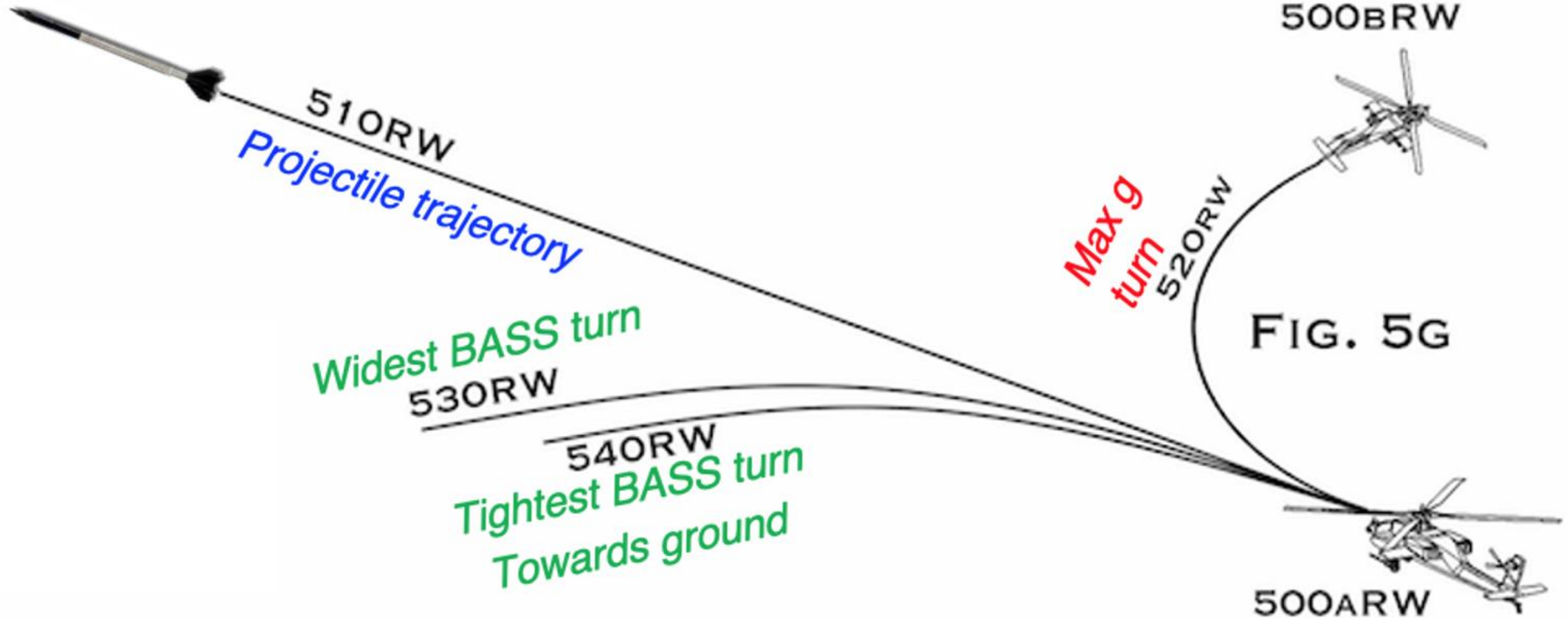
Maneuvering Aeromechanically Stable Sabot (MASS) Ammunition

Senior Systems Engineer, Raytheon

3. Breakthrough:

BASS Rounds: Design the Sabot to clear the launching aircraft

Ground Attack Case

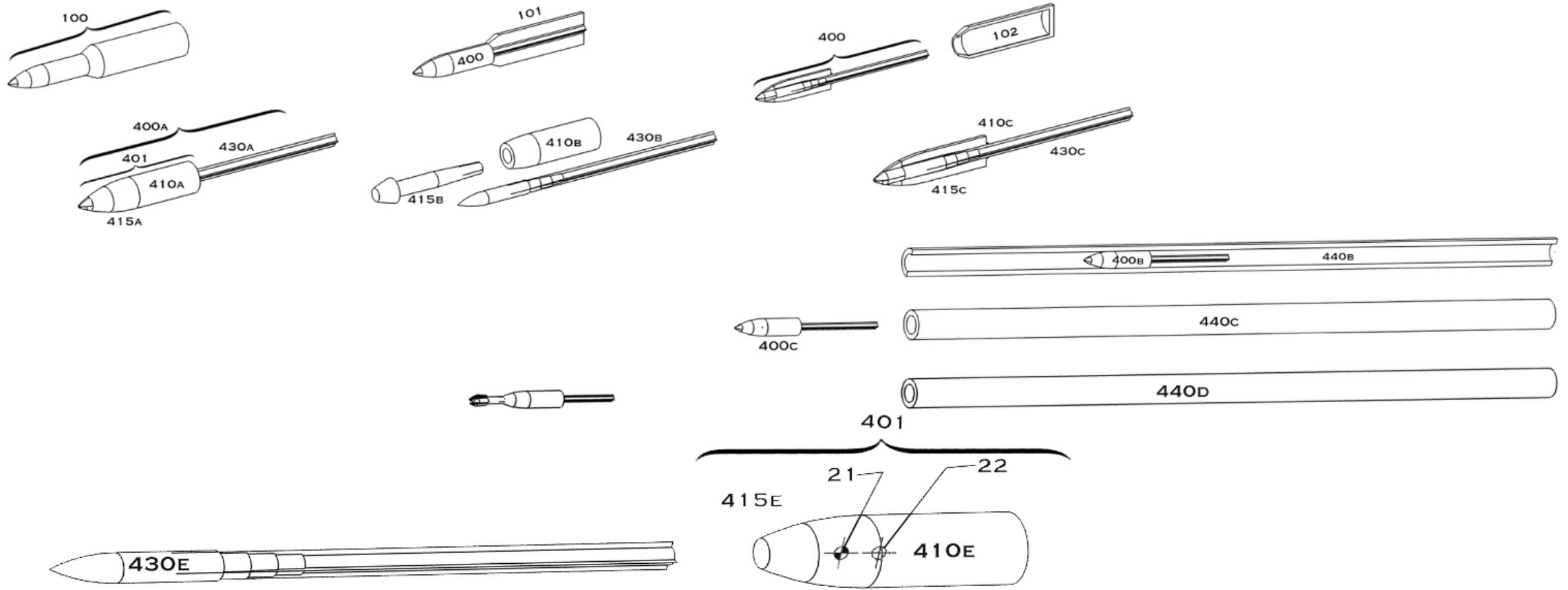


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4. MASS & BASS Rounds

What is claimed is:

1. An aeromechanically stable sabot...



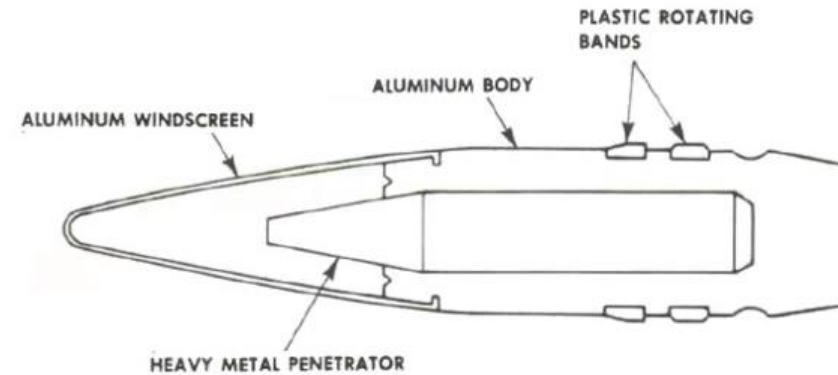
54 major families, >1,000 species covered in expansive patent filings

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4. MASS & BASS Rounds

Today's Aerial Gunnery Round

PGU-14



BASS 2081 Flechette/penetrator



Distribution A Unlimited Distribution

5. Modeling & Testing

- ***Conceived 2016 & reduced to practice***
- ***Modeled in CFD, FEM, DATCOM & PRODAS***
- ***Tested on Shock Table, Wind Tunnel, Range***
- ***>100 rounds fired, currently @ TRL-6***



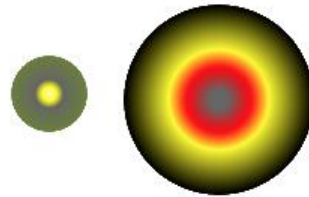
5. Modeling & Testing

Top-Level Drag and Stability Characteristics

Flechette

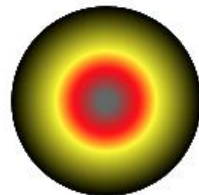


X-Sectional Area of PGU-14 >> Flechette



Supersonic Drag ~ proportional to X-Sectional Area, $Drag_{PGU14} \gg D_{Flechette}$

PGU-xx



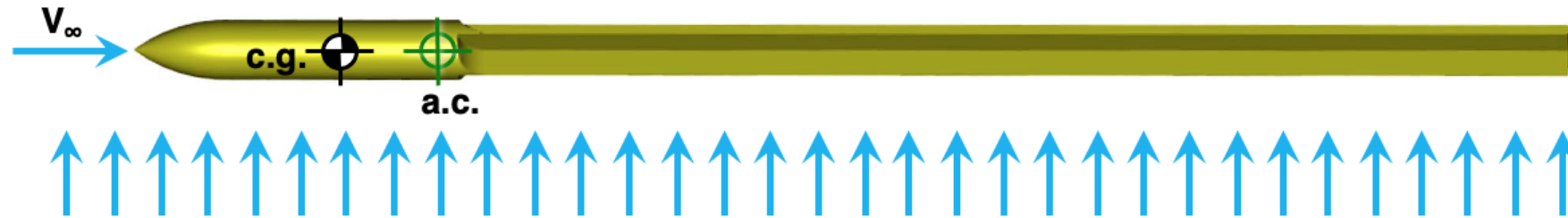
Distribution A Unlimited Distribution

5. Modeling & Testing

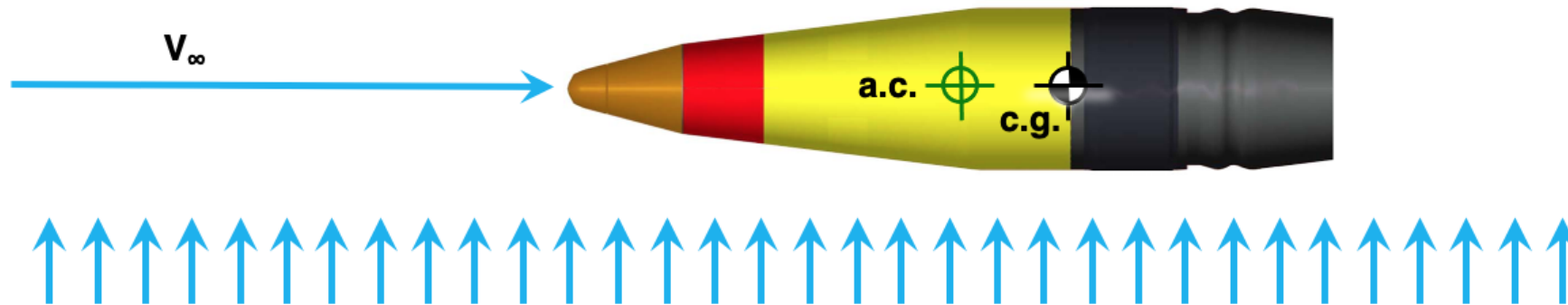
Projectile Aeromechanics & CEP Fundamentals

Flechette

Instantaneous introduction of lateral gust

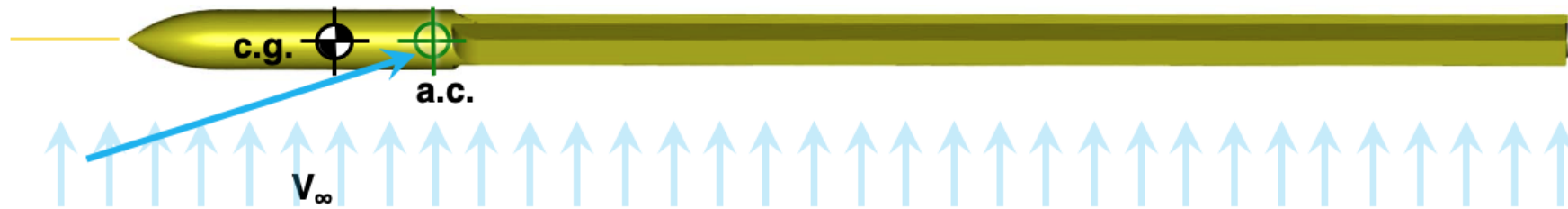


PGU-xx

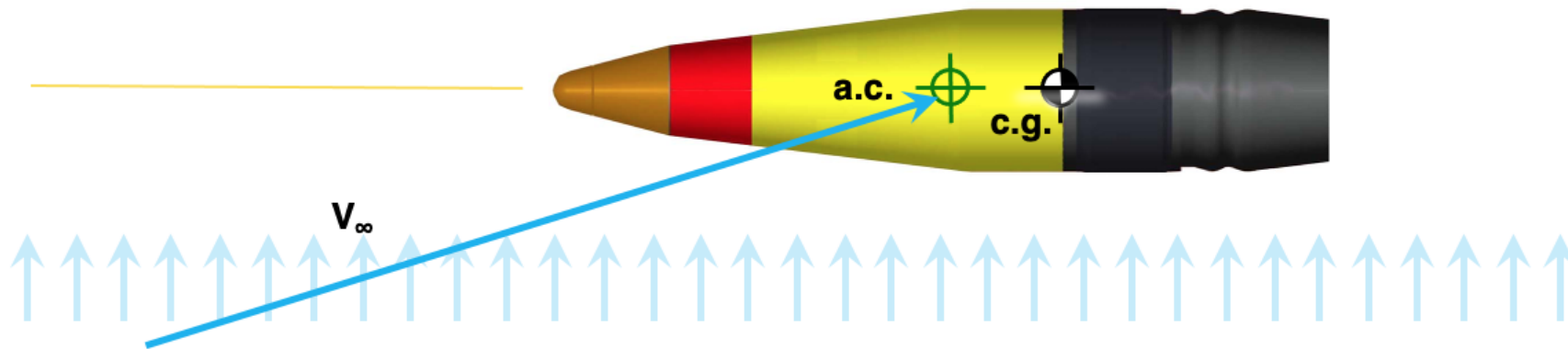


5. Modeling & Testing

Projectile Aeromechanics & CEP Fundamentals



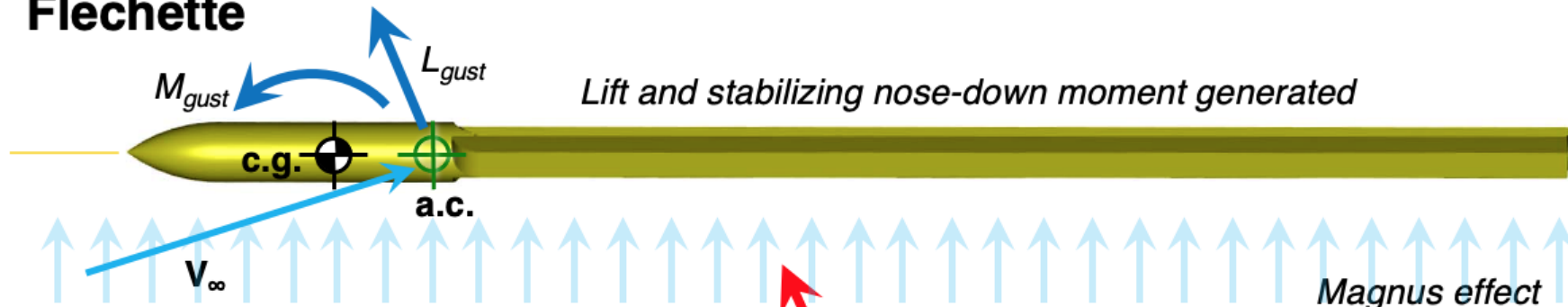
PGU-v



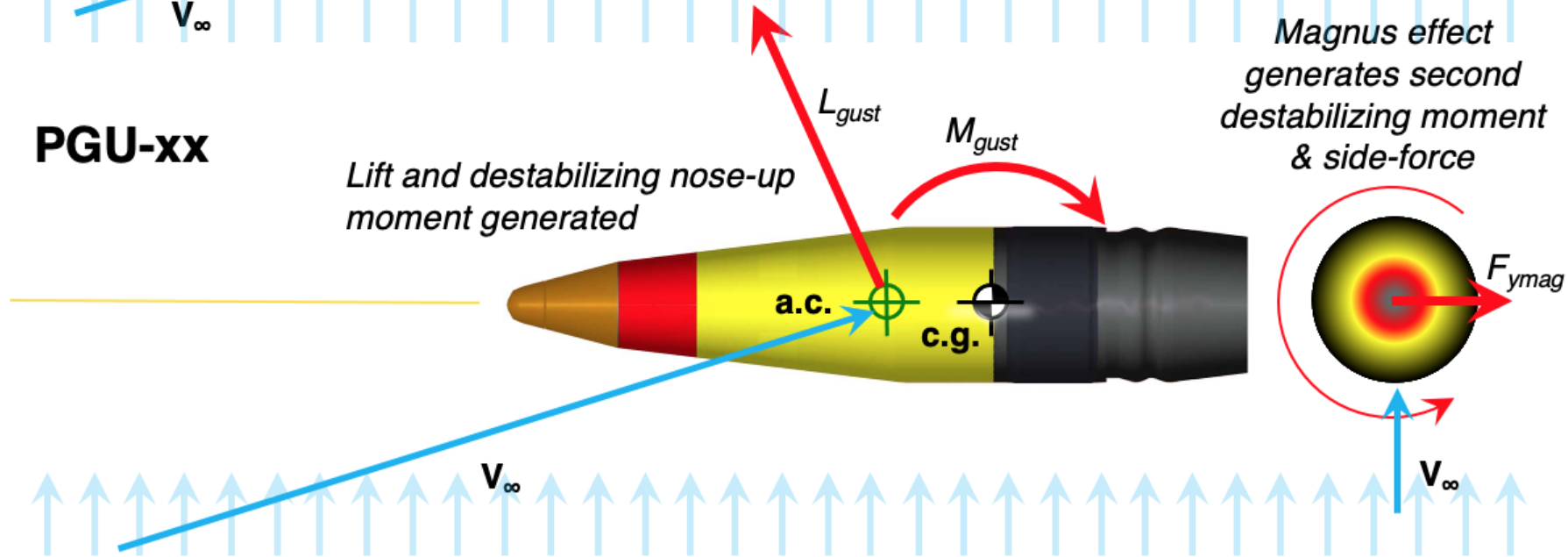
5. Modeling & Testing

Projectile Aeromechanics & CEP Fundamentals

Flechette



PGU-xx

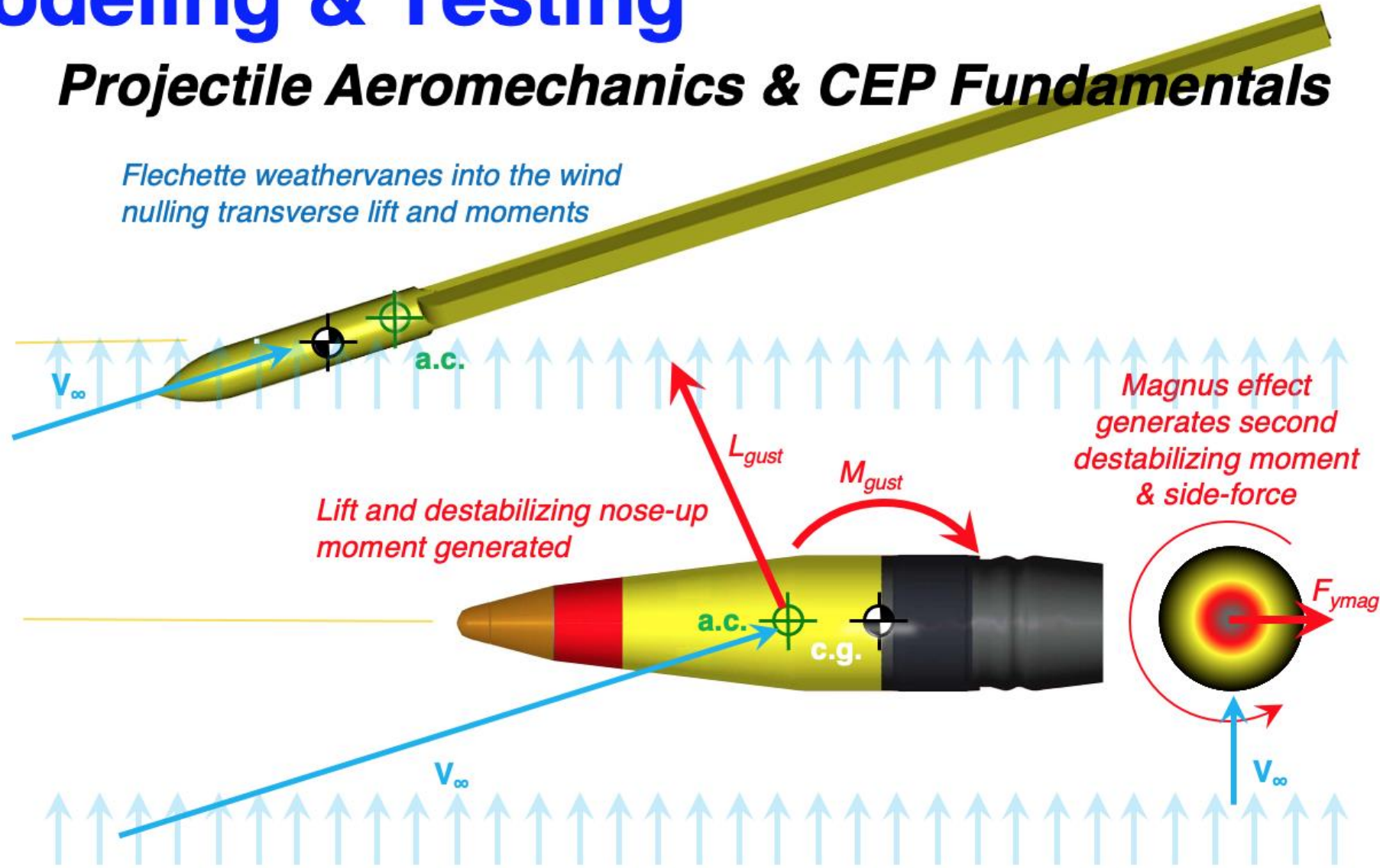


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5. Modeling & Testing

Projectile Aeromechanics & CEP Fundamentals

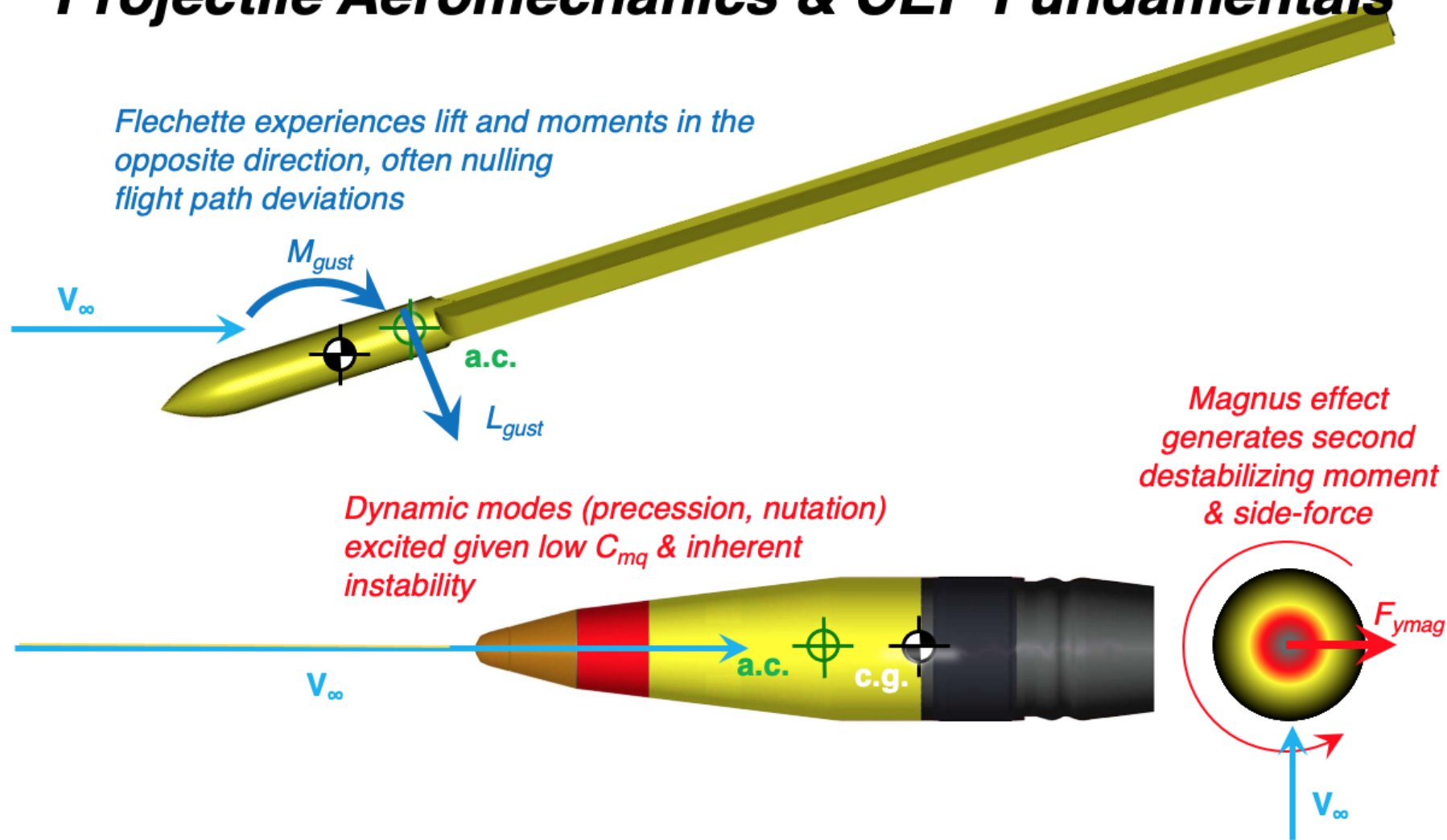
Flechette weathervanes into the wind nulling transverse lift and moments



Distribution A Unlimited Distribution

5. Modeling & Testing

Projectile Aeromechanics & CEP Fundamentals



Distribution A Unlimited Distribution

5. Modeling & Testing

Projectile Aeromechanics & CEP Fundamentals

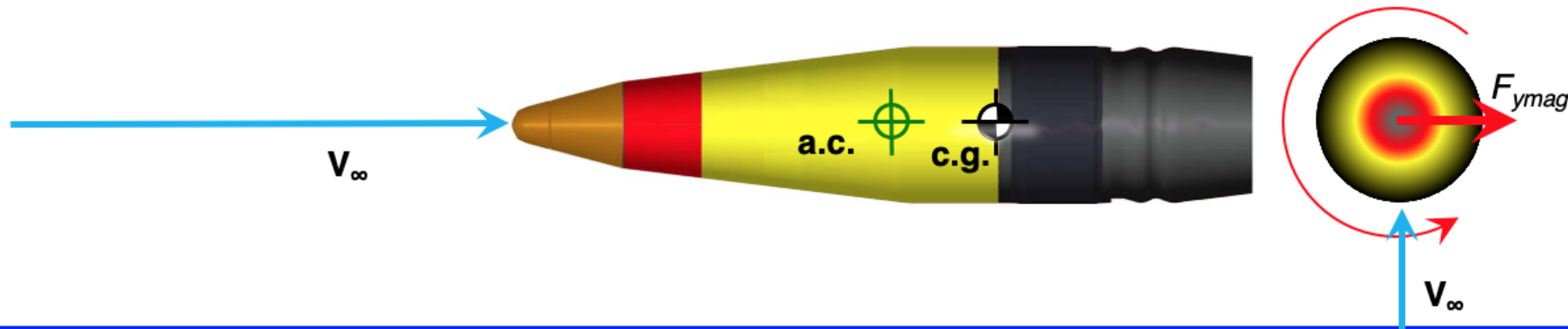
Flechette

Flechette returned to steady-state flight close to original flight path (maintaining very small CEP)



PGU-xx

CEP greatly increased due to steady-state and dynamic effects

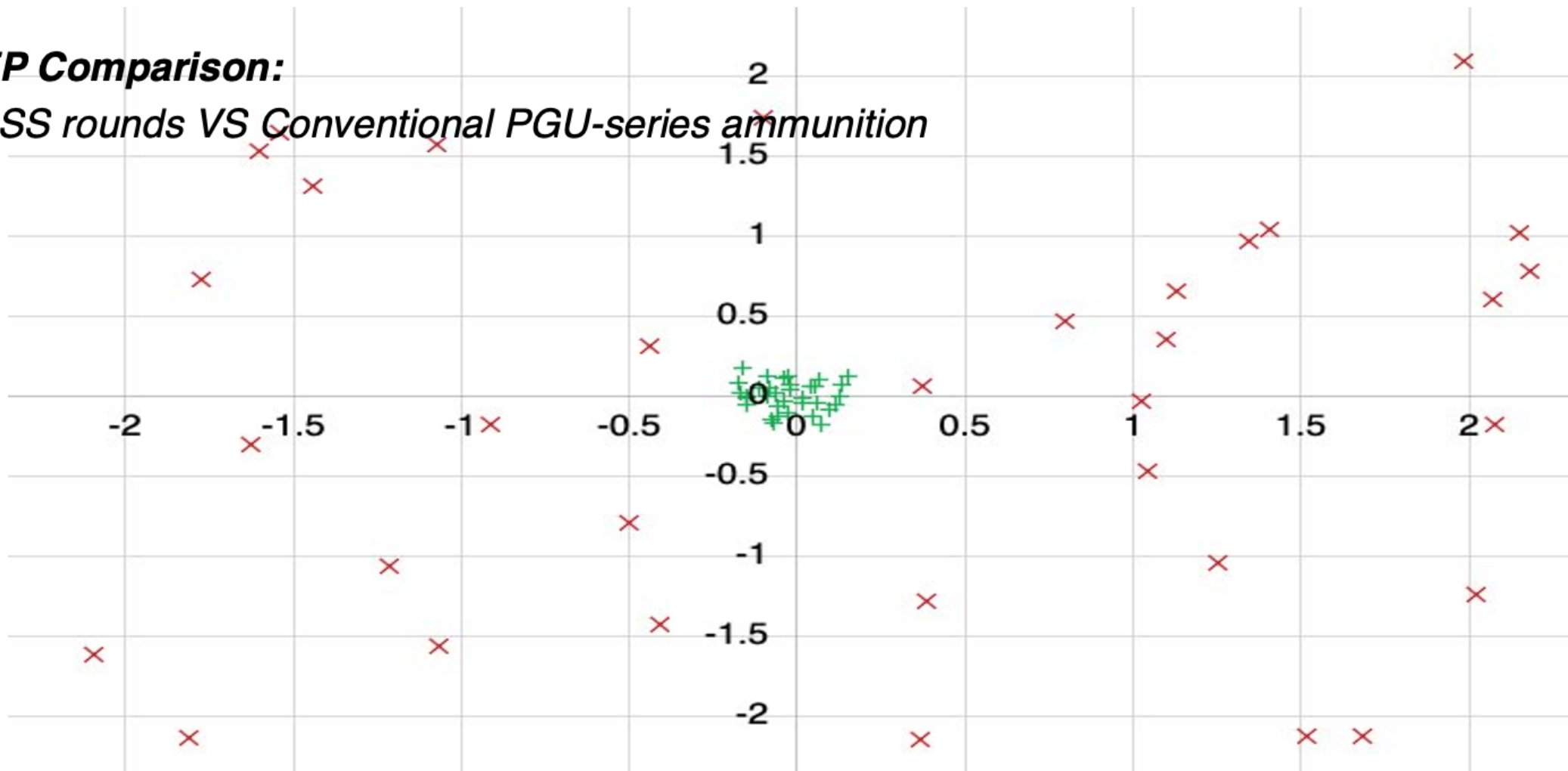


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5. Modeling & Testing

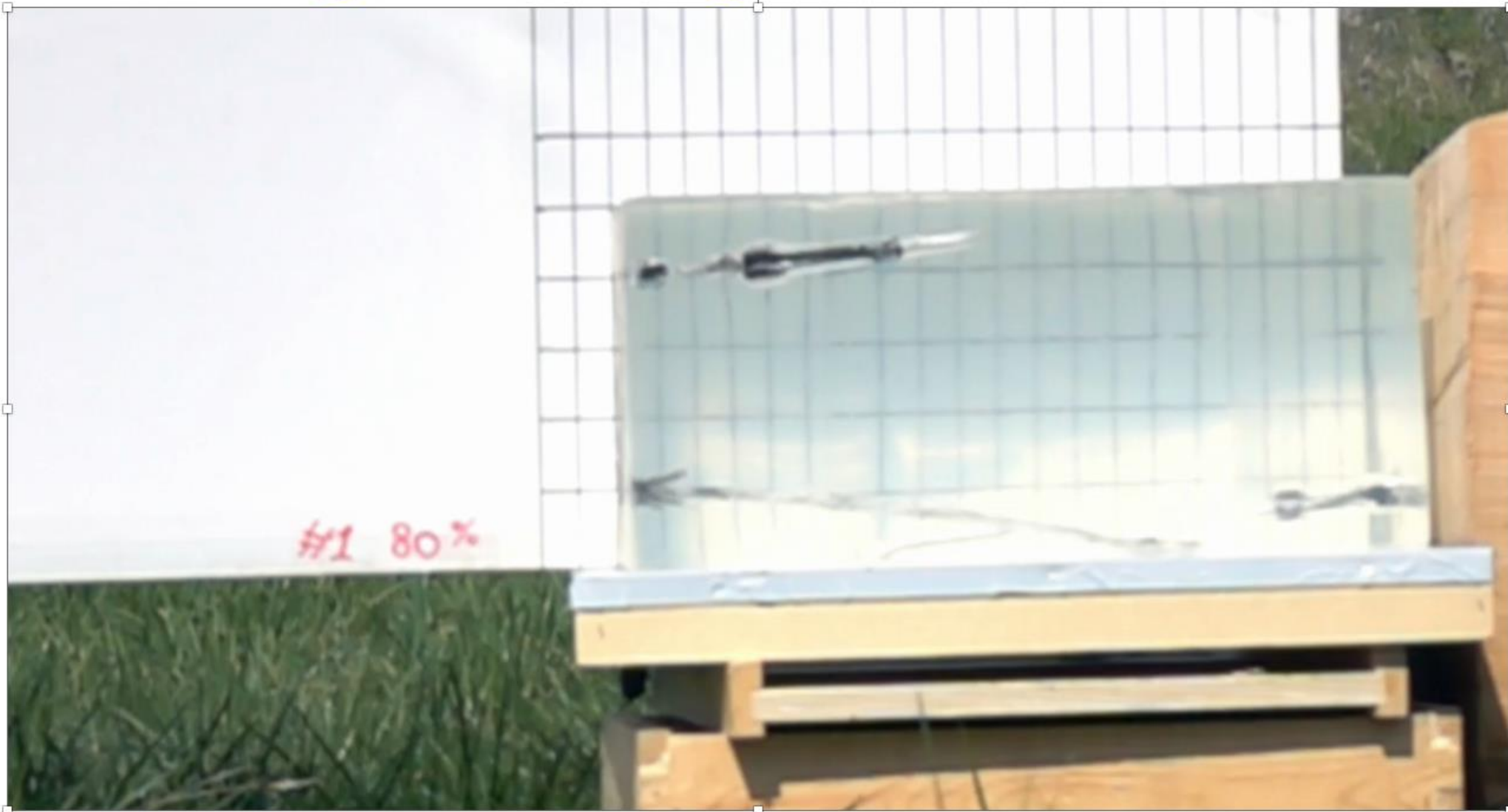
CEP Comparison:

BASS rounds VS Conventional PGU-series ammunition



Distribution A Unlimited Distribution

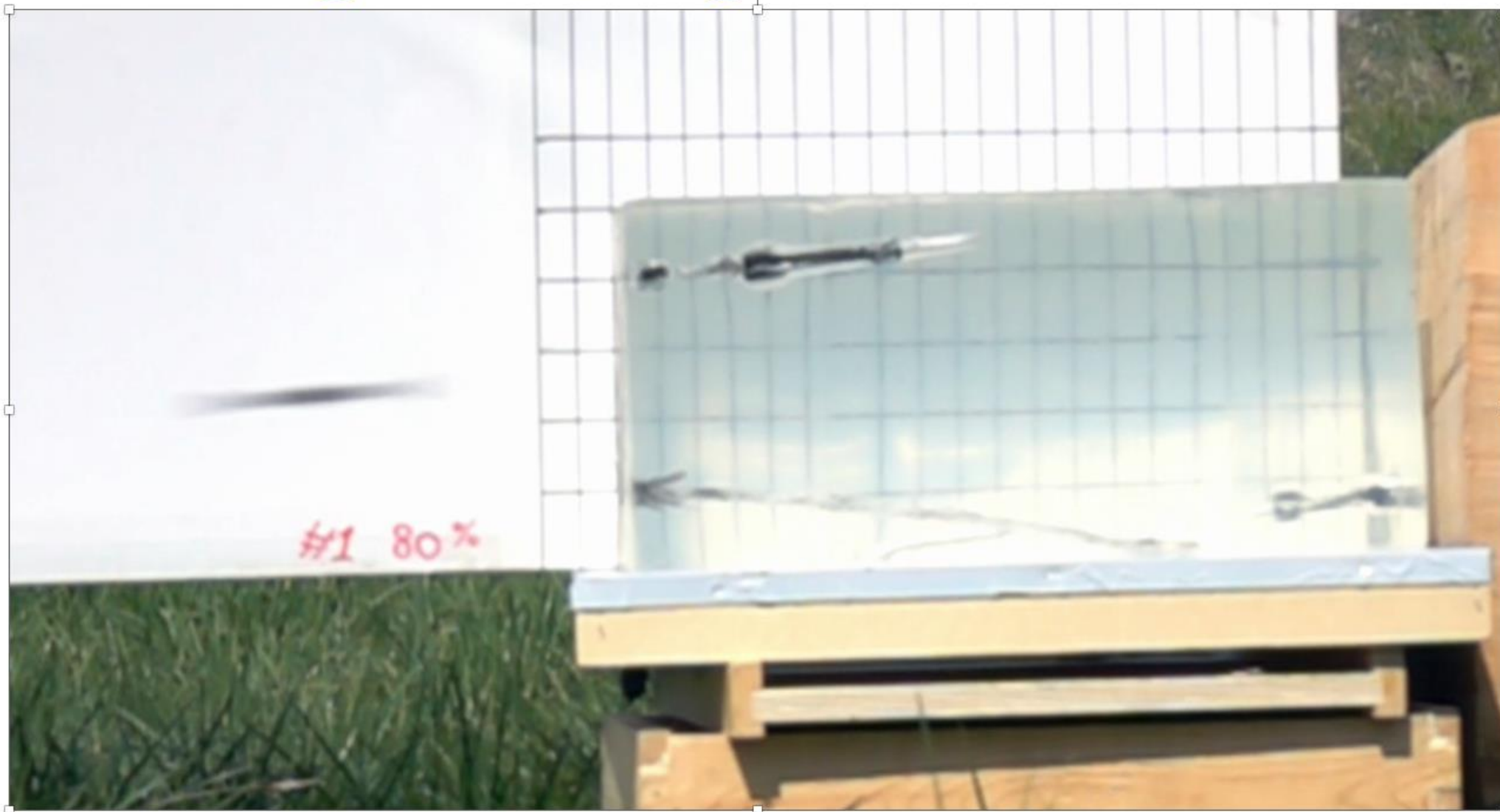
5. Modeling & Testing



Distribution A Unlimited Distribution

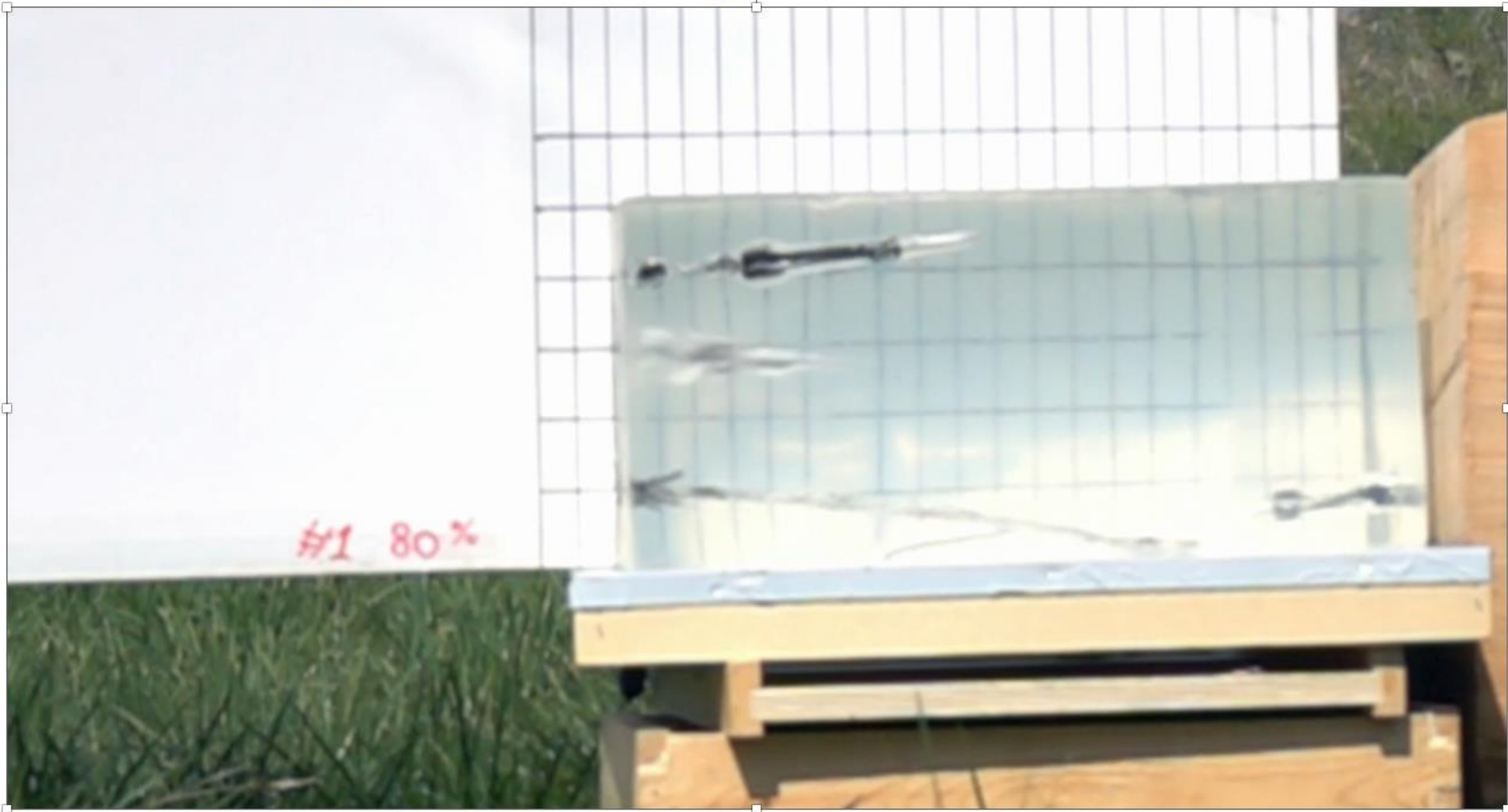


5. Modeling & Testing

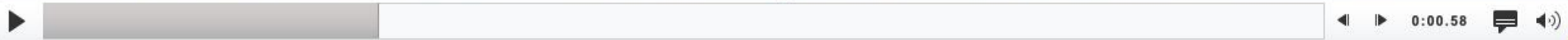


Distribution A Unlimited Distribution

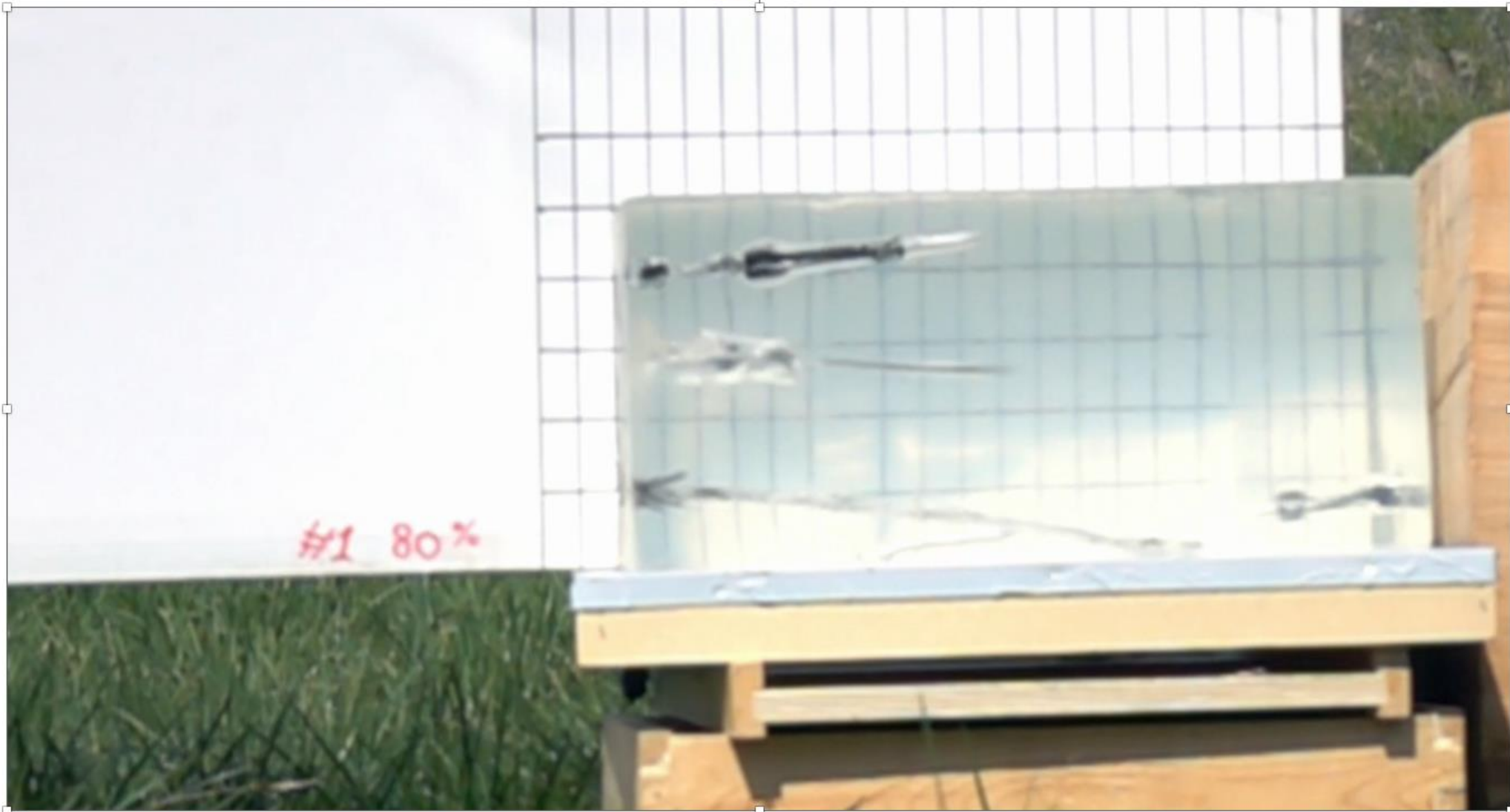
5. Modeling & Testing



Distribution A Unlimited Distribution



5. Modeling & Testing



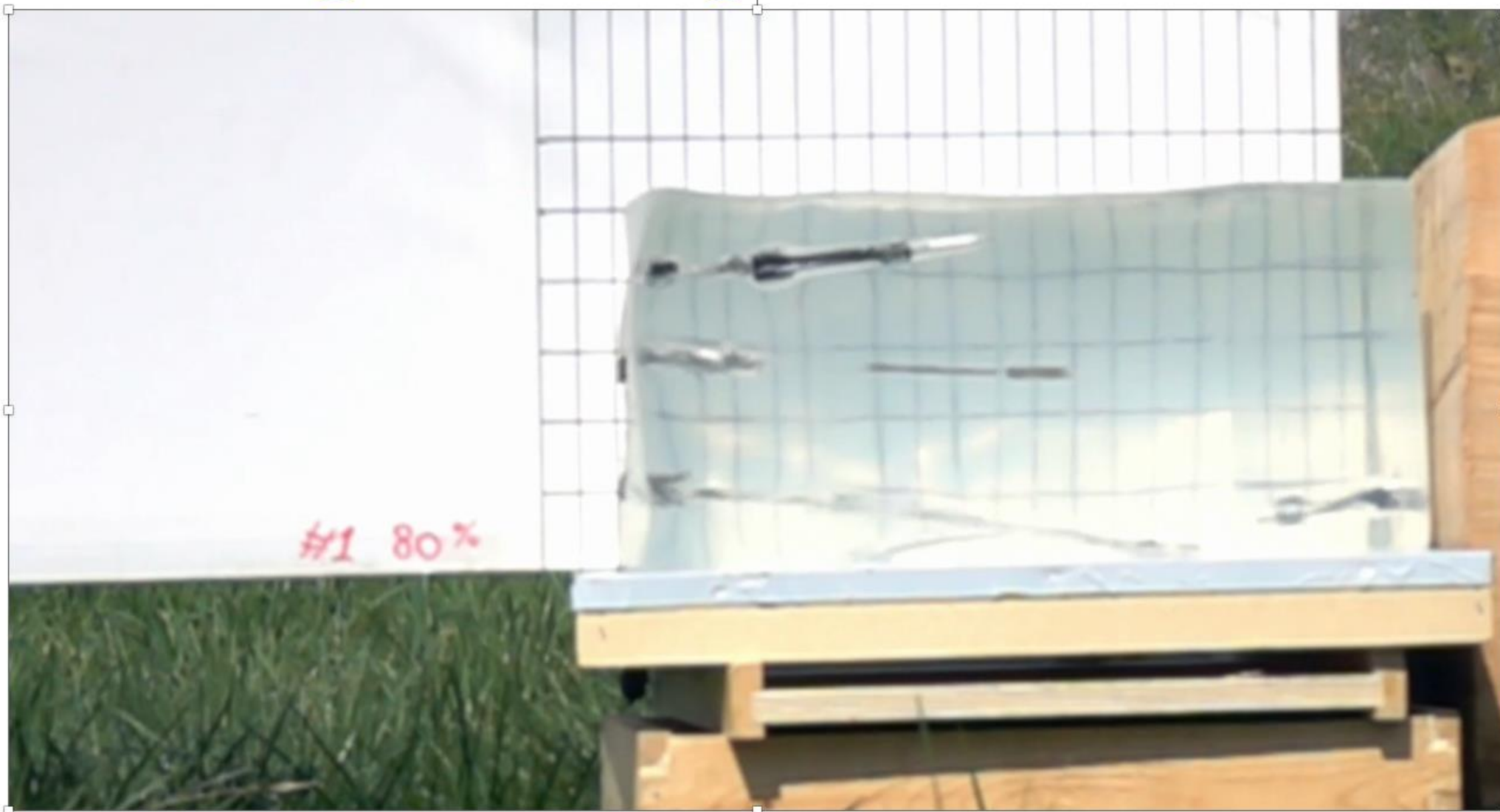
Distribution A Unlimited Distribution

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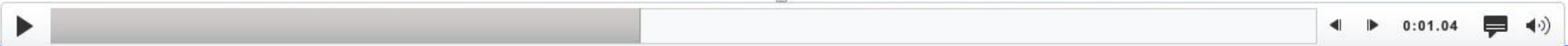


Distribution A Unlimited Distribution

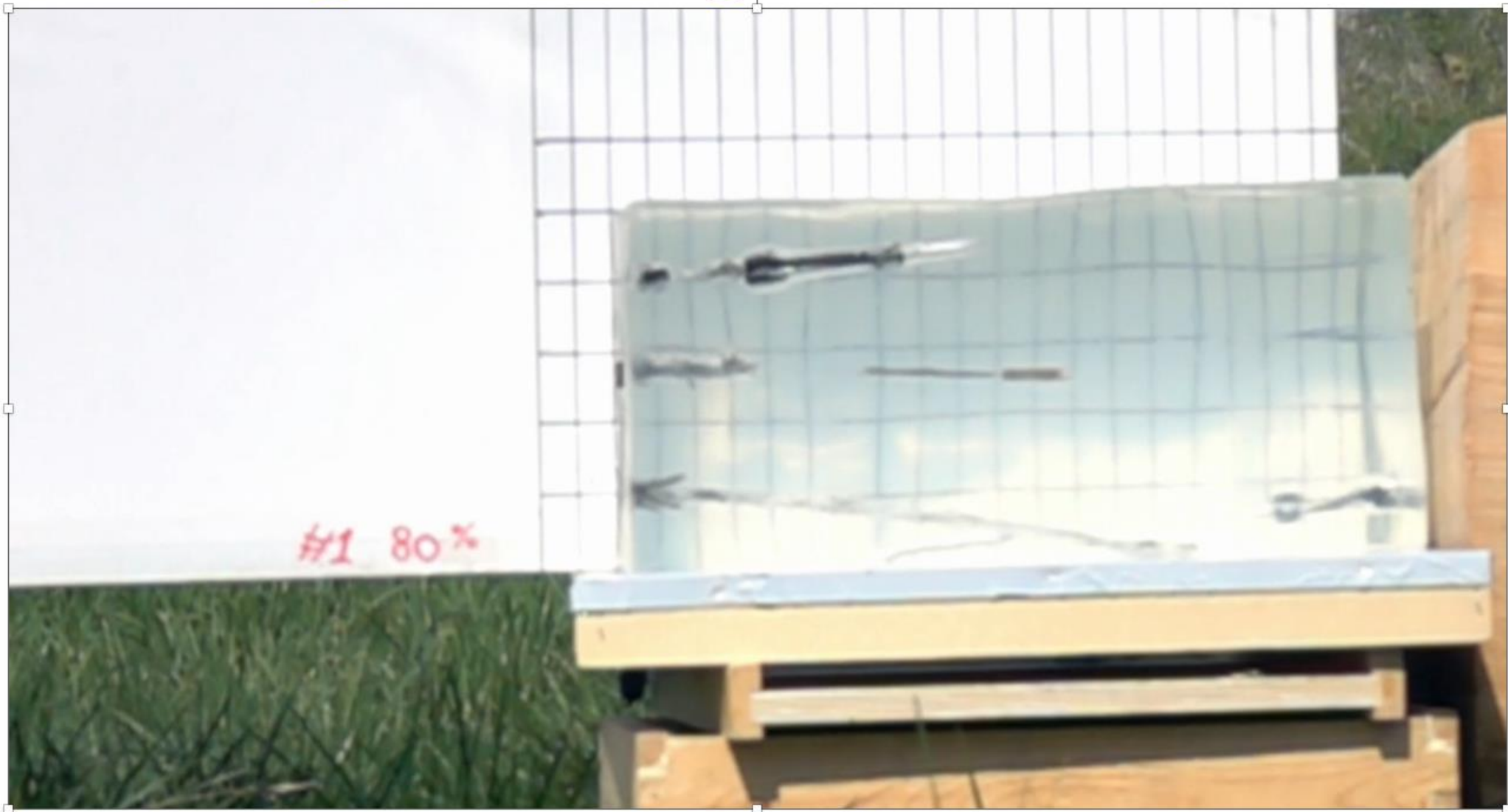
5. Modeling & Testing



Distribution A Unlimited Distribution



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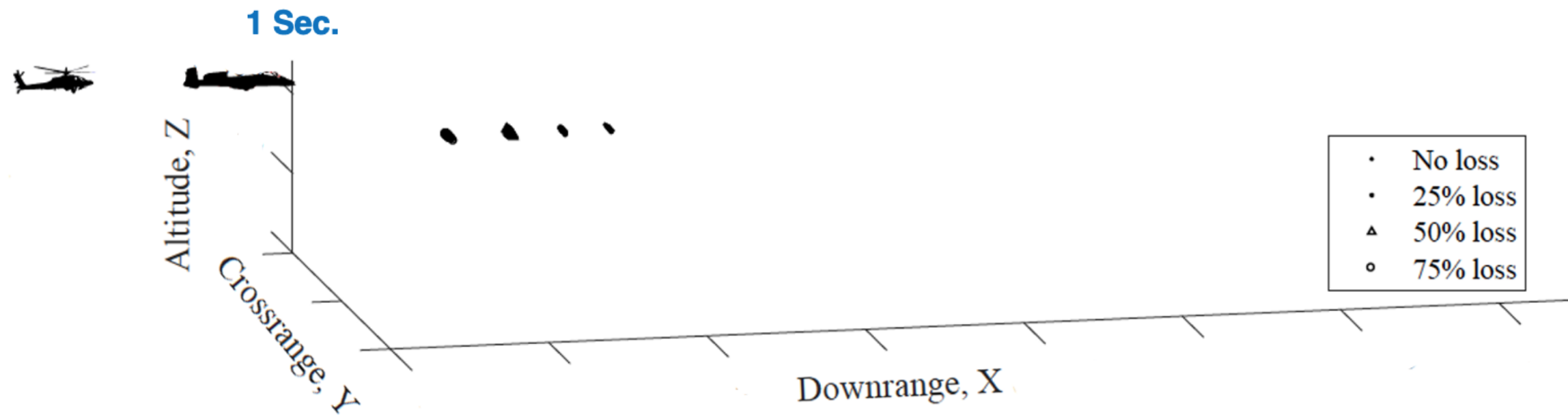


Distribution A Unlimited Distribution

6. BASS Performance

Flight Safety/Airframe Strike Check

AH-64 & A-10 Sabot separation Modeling (99% atmospheric)



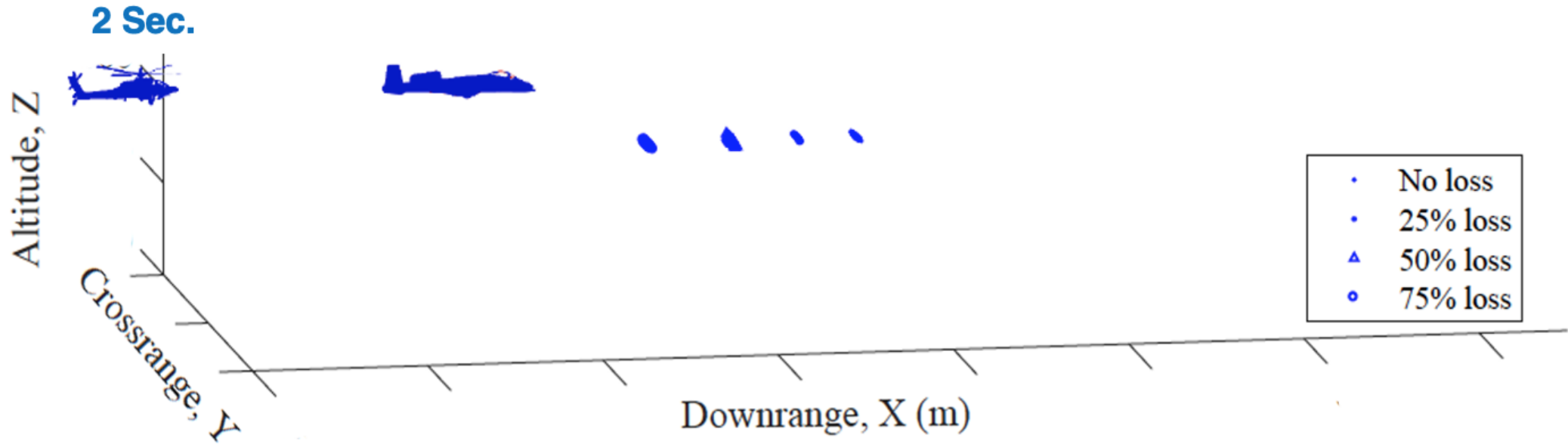
Source: Schumacher, L. N., "BASS Medium Caliber System Modeling: Proof-of-Concept and the Future of Aerial Gunnery with Advanced Munitions," Ph.D. Dissertation Defense, 29 June 2020, The University of Kansas Aerospace Engineering Department, Lawrence, Kansas.

Distribution A

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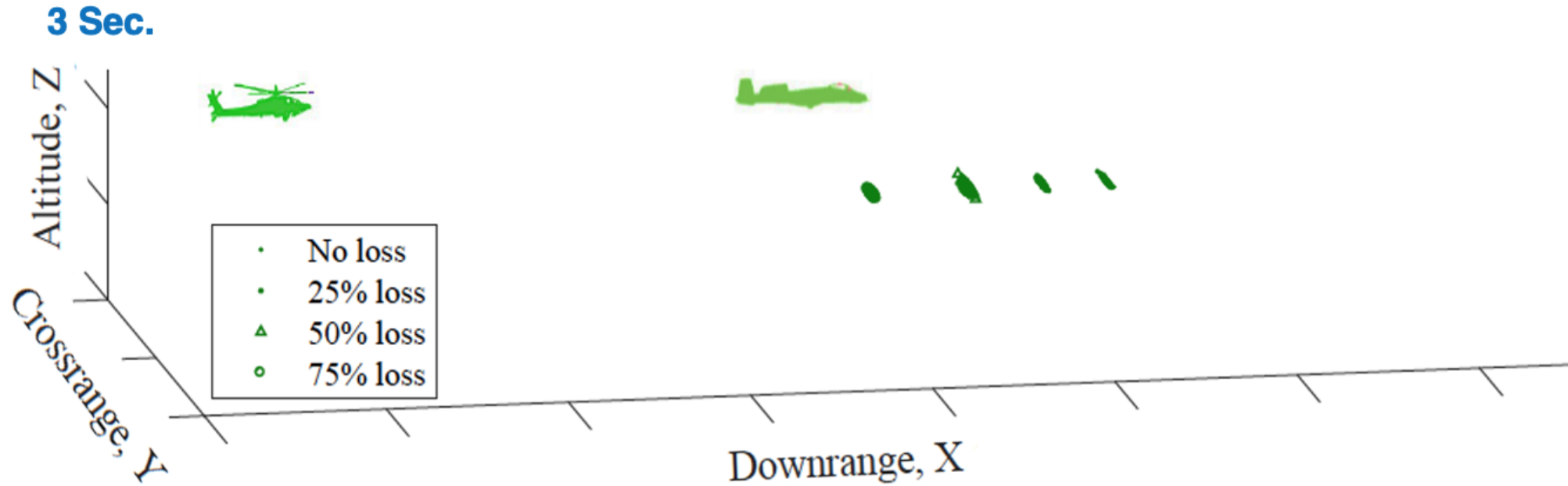


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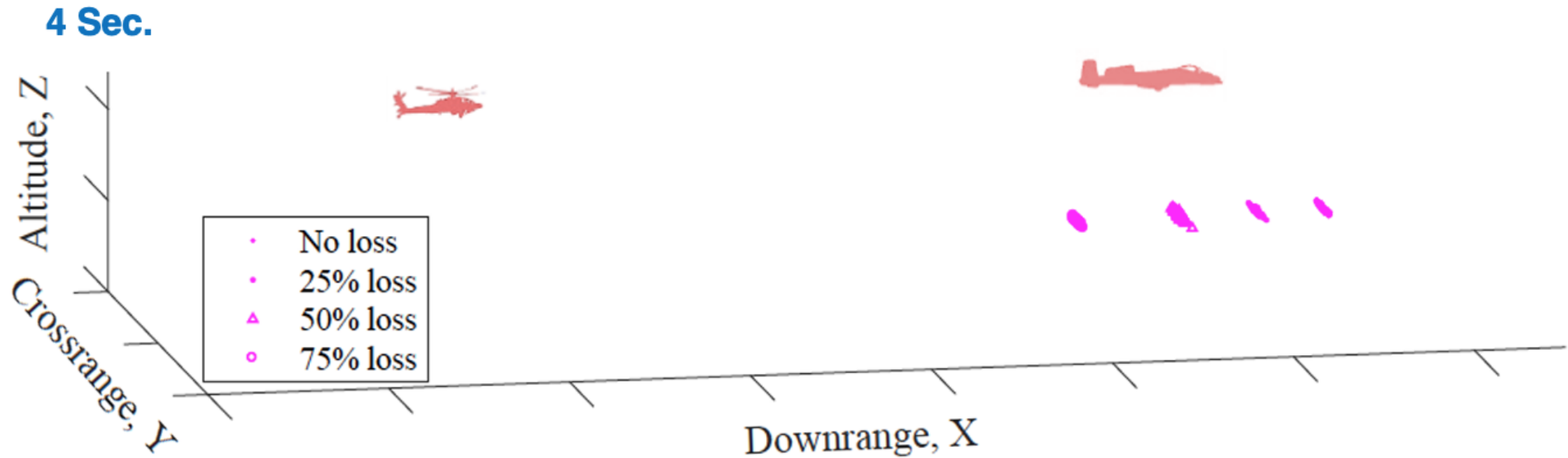
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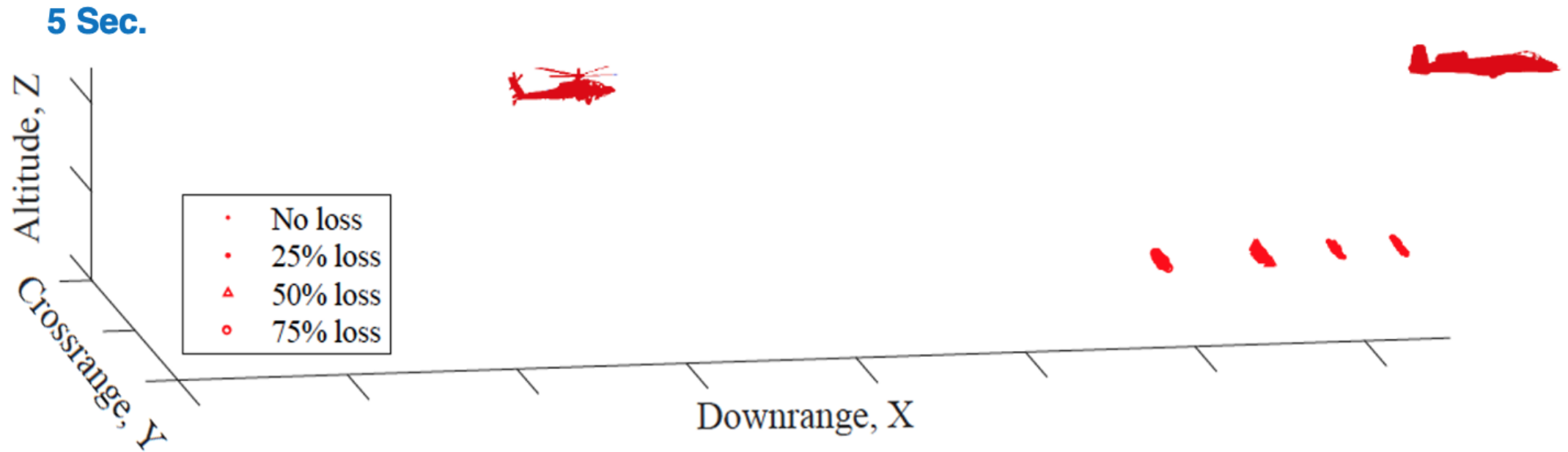
Source: Schumacher, L. N., "BASS Medium Caliber System Modeling: Proof-of-Concept and the Future of Aerial Gunnery with Advanced Munitions," Ph.D. Dissertation Defense, 29 June 2020, The University of Kansas Aerospace Engineering Department, Lawrence, Kansas.

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Distribution A Unlimited Distribution

6. BASS Performance

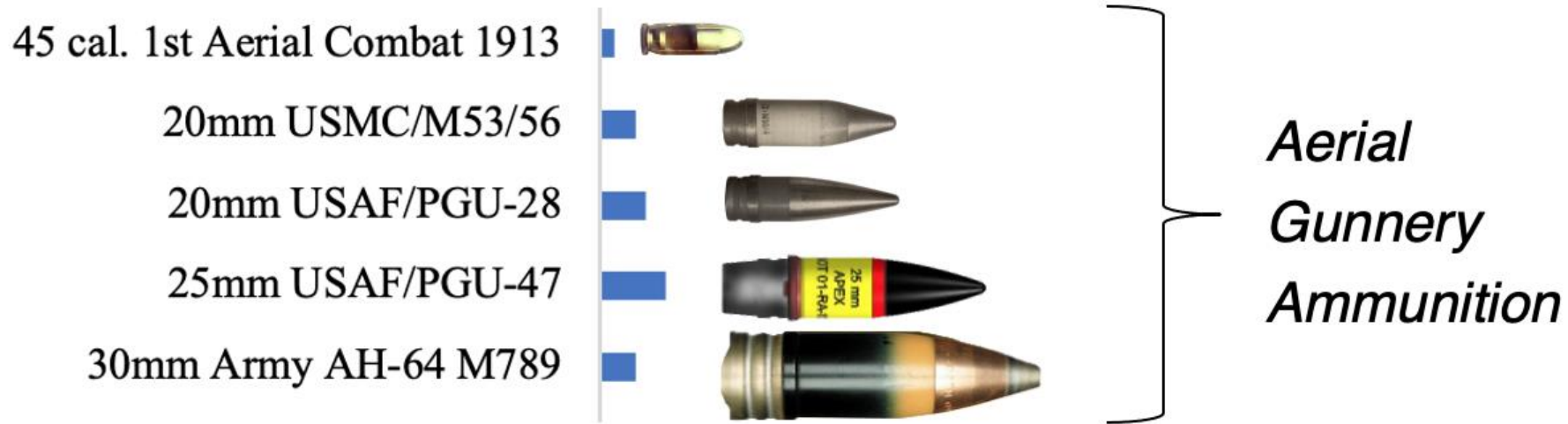
Relative Ballistic Coefficients



Distribution A Unlimited Distribution

6. BASS Performance

Relative Ballistic Coefficients



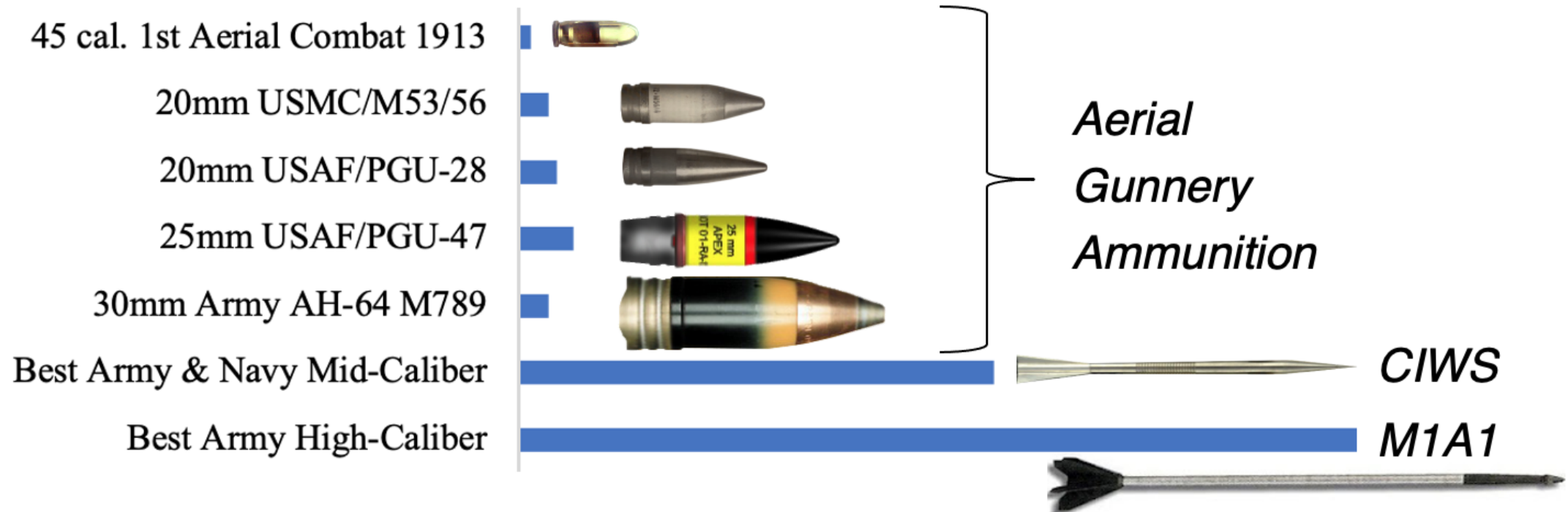
100 yrs



Distribution A Unlimited Distribution

6. BASS Performance

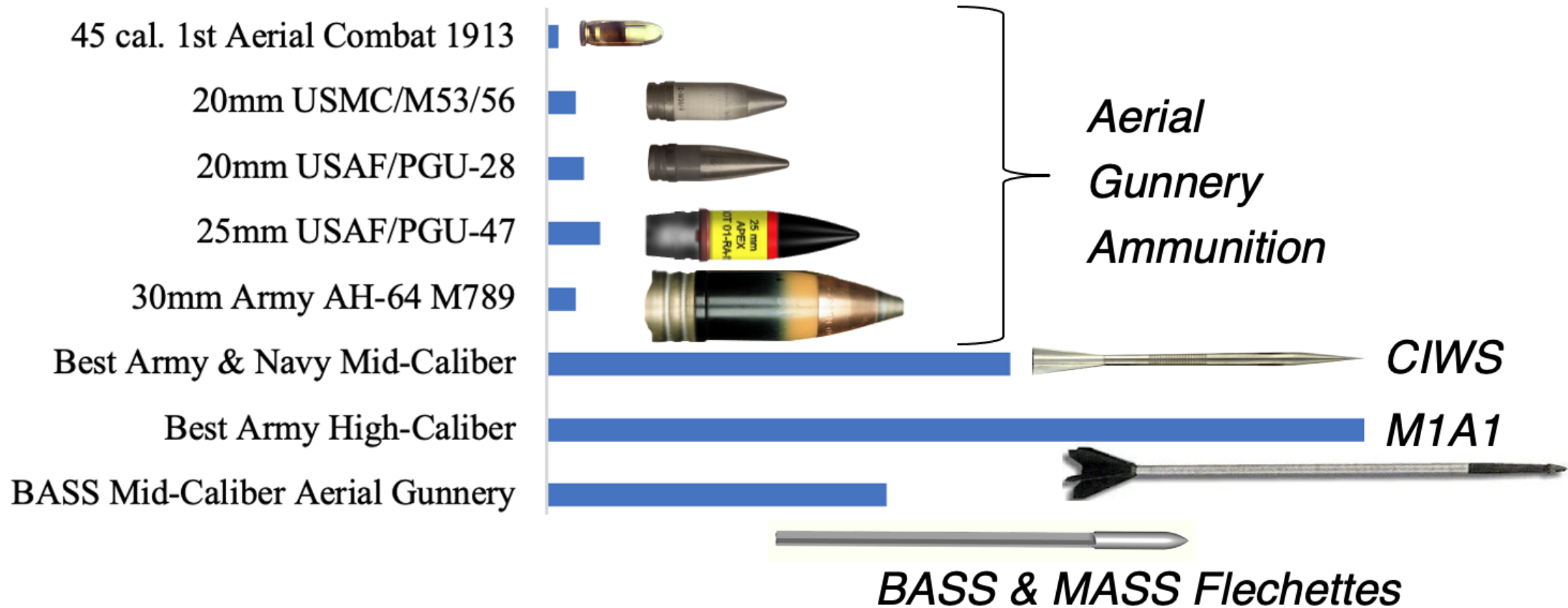
Relative Ballistic Coefficients



Distribution A Unlimited Distribution

6. BASS Performance

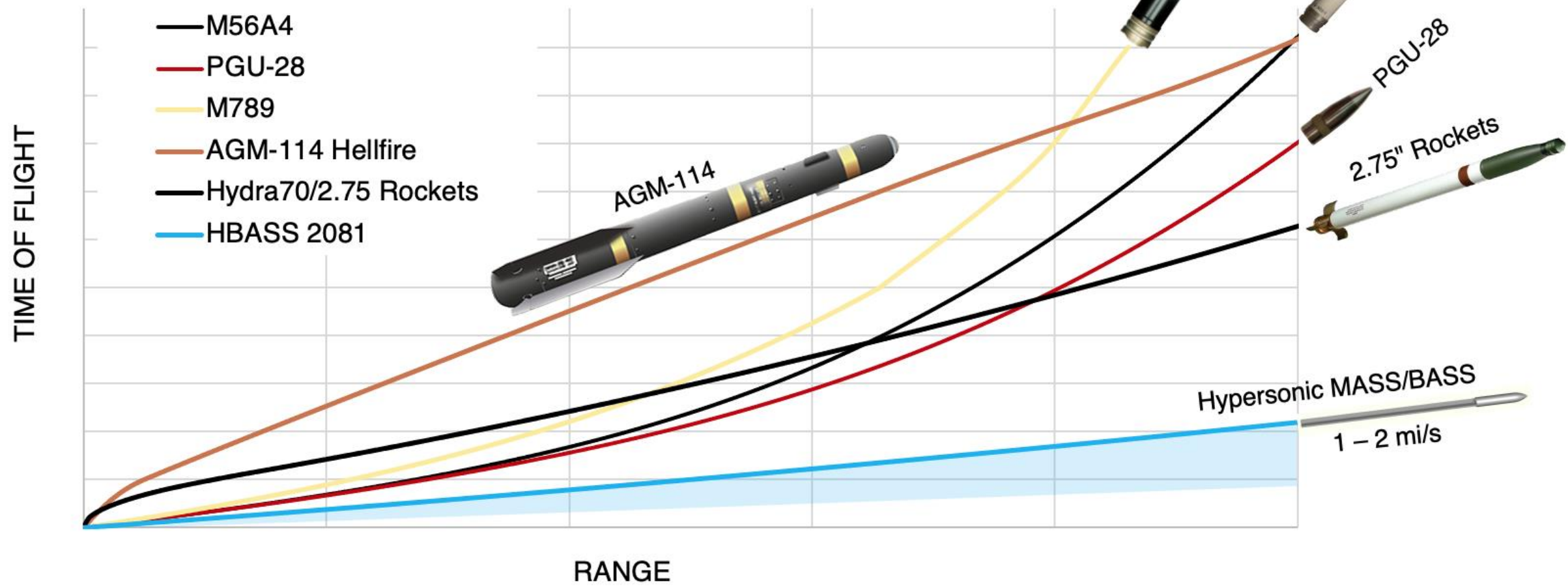
Relative Ballistic Coefficients



Distribution A Unlimited Distribution

6. BASS Performance

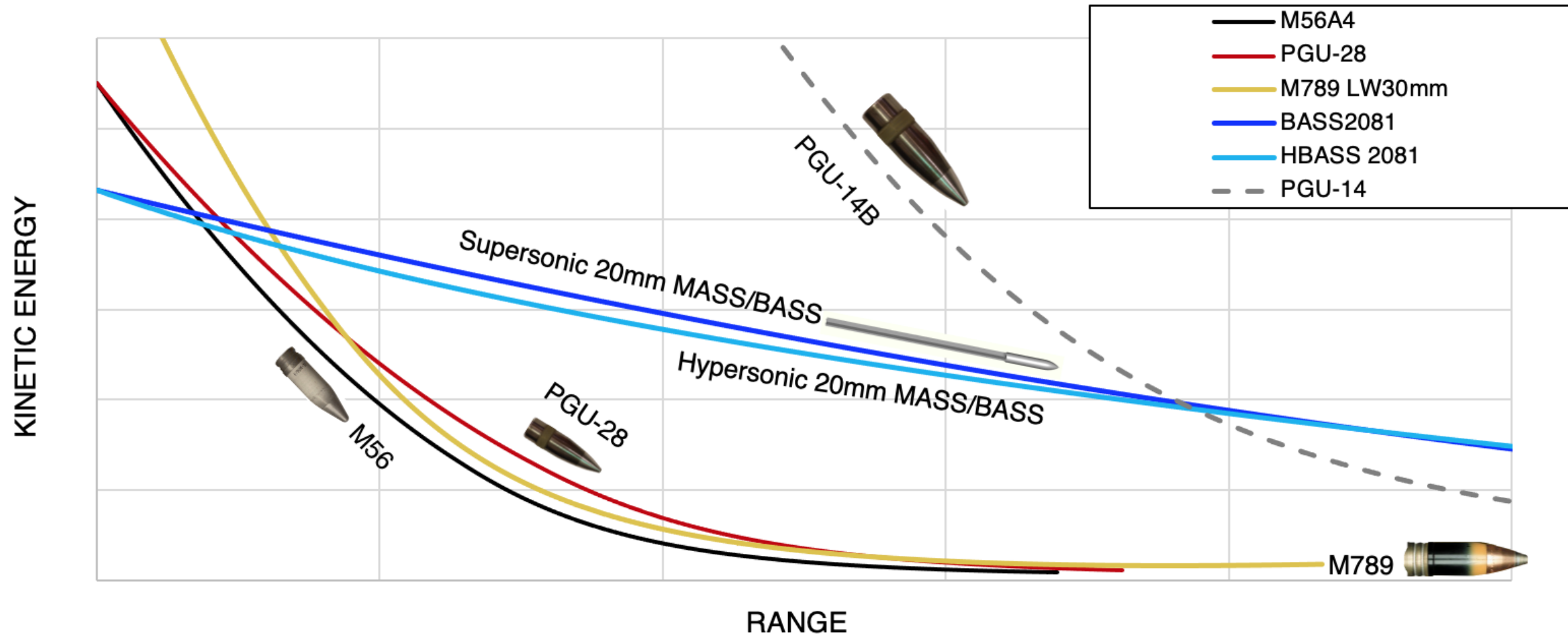
Relative Weapon Times of Flight from USA/USMC Aircraft



Distribution A Unlimited Distribution

6. BASS Performance

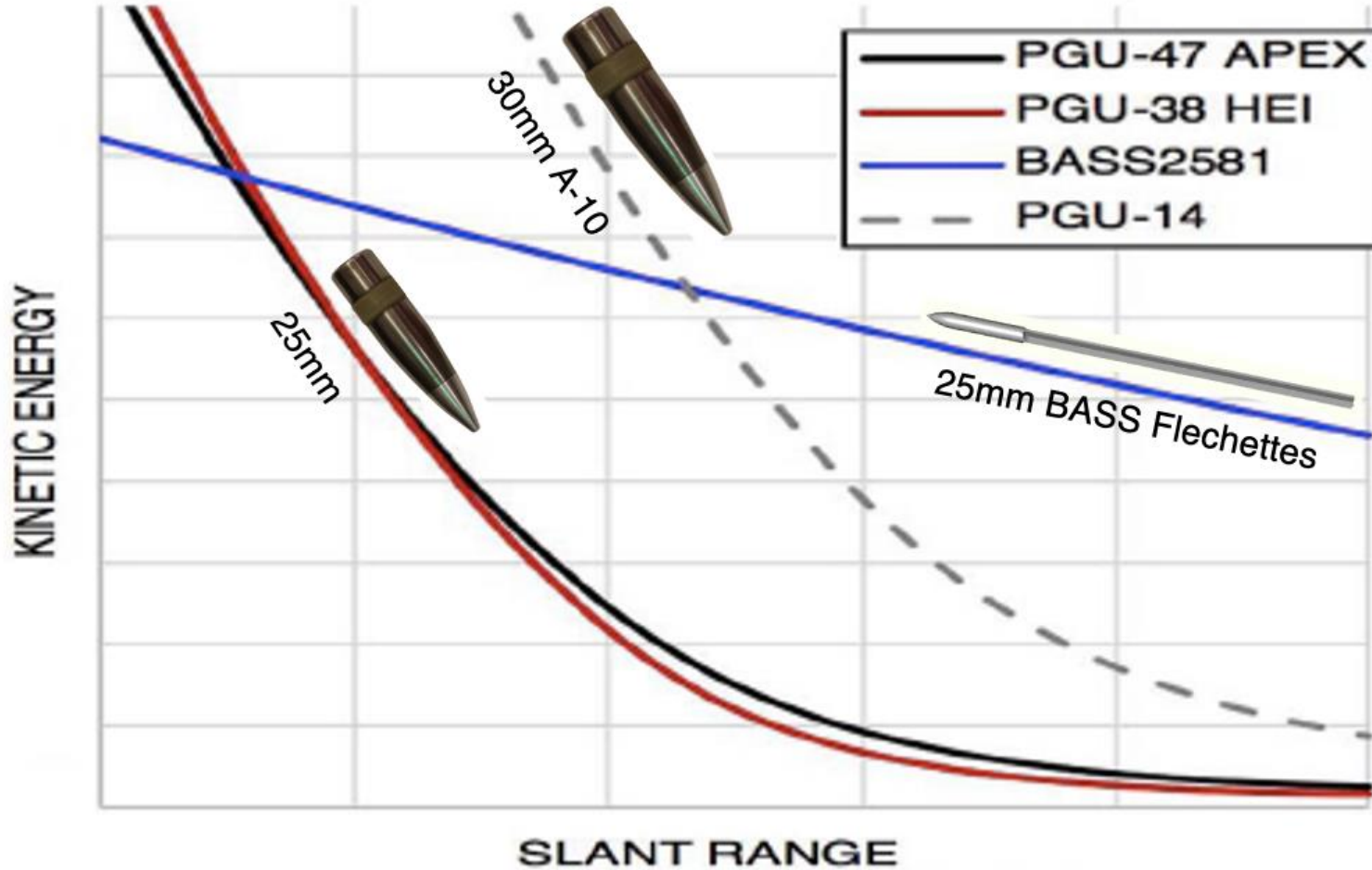
Relative Weapon Kinetic Energy from USA/USMC Aircraft



Distribution A Unlimited Distribution

6. BASS Performance

Relative Weapon Kinetic Energy from USA/USMC Aircraft

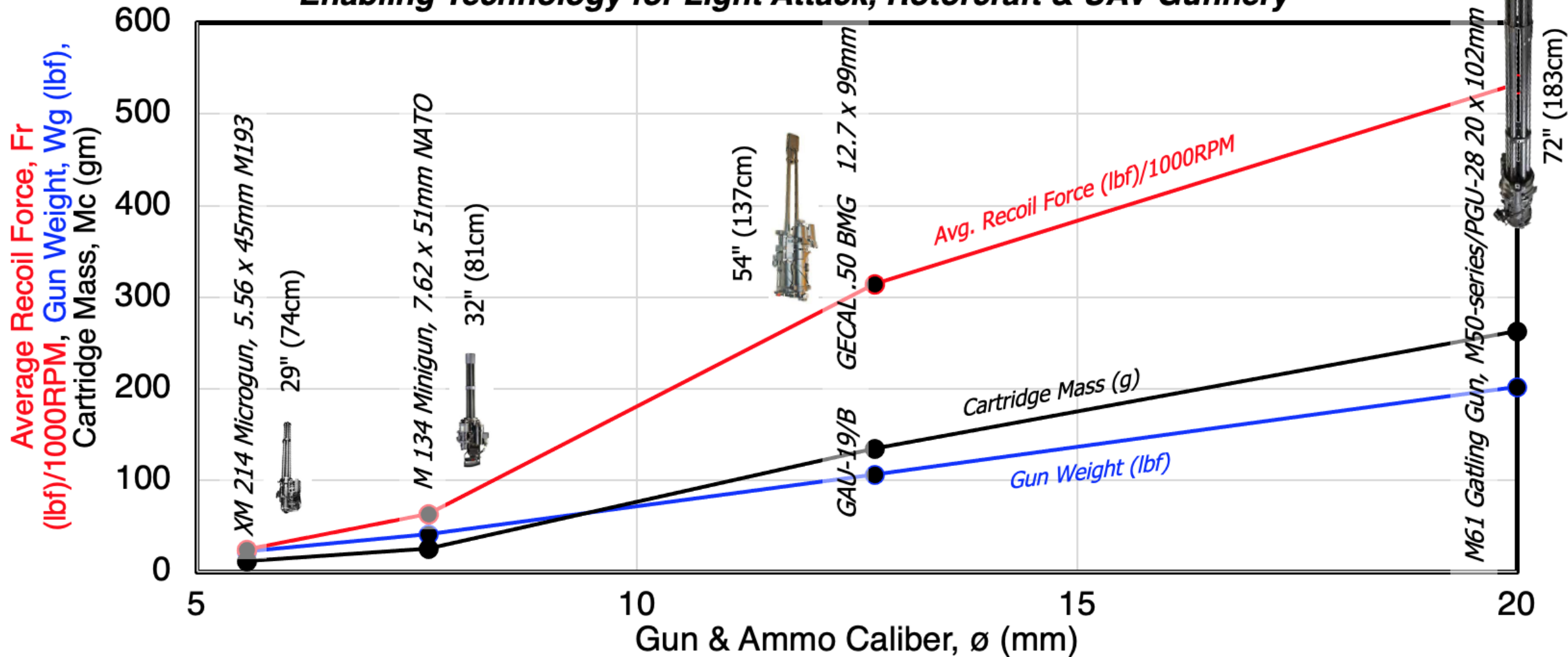


Distribution A Unlimited Distribution

6. BASS Performance

Smaller guns w/BASS rounds do the job of larger guns w/conventional rounds

Enabling Technology for Light Attack, Rotorcraft & UAV Gunnery



All data from public, Distribution A Sources

6. BASS Performance

**Enabling Technology for
Light Attack, Rotorcraft & UAV Gunnery**

Smaller guns w/BASS rounds do the job of much larger guns w/conventional rounds



Distribution A Unlimited Distribution

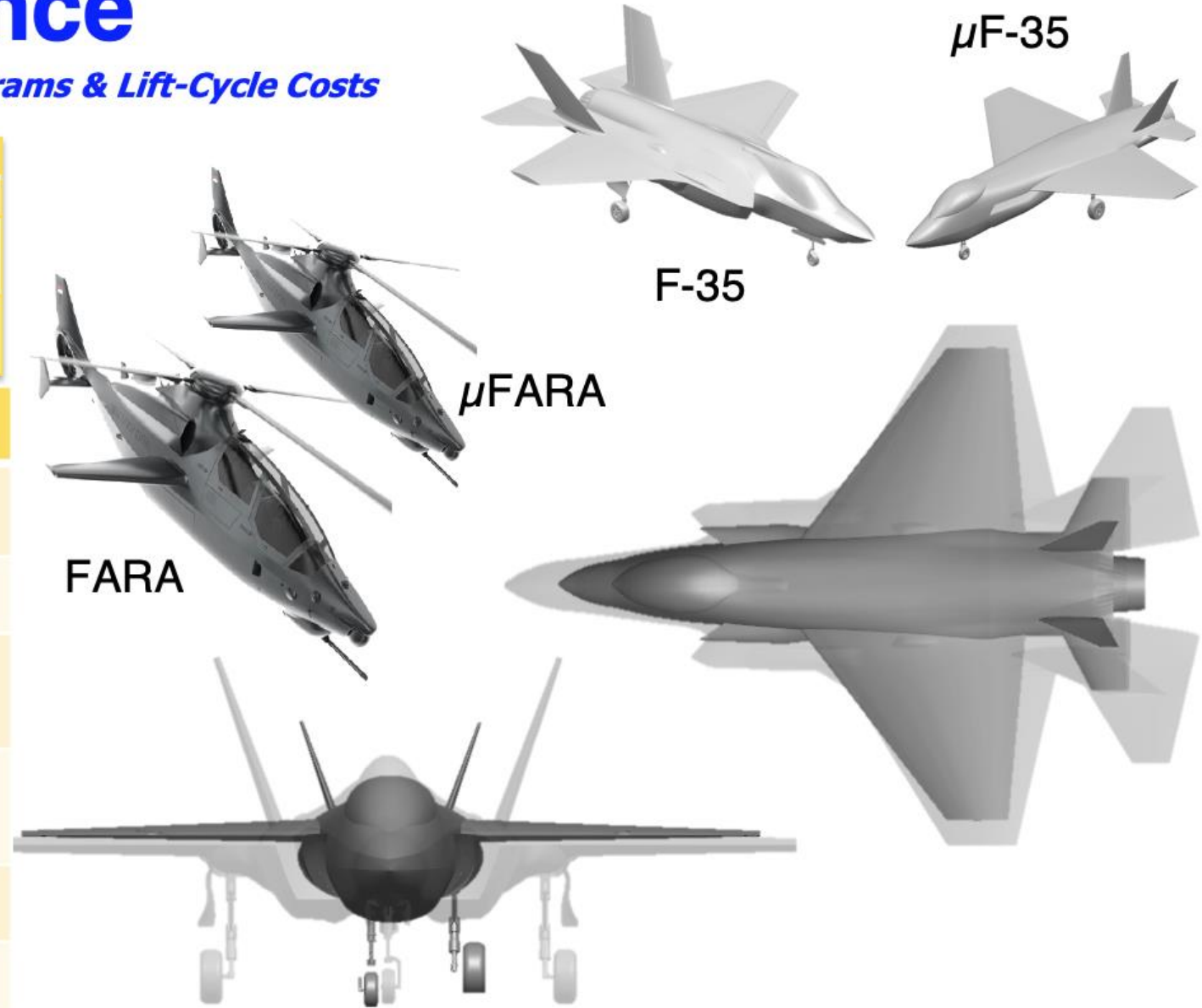
6. BASS Performance

Guided MASS Rounds Shrink Entire Airframes, Programs & Lift-Cycle Costs

Airframe Level Costs		
	F-35A	μ F-35
Unit Price (millions)	\$ 80.0M	\$ 56.5M
Operating Cost per Flight Hour	\$ 29,600	\$ 28,400

Parameter	F-35A	μ F-35	% Change
MGTOW (lb)	70,000	57,000	-19%
Wing Area, S (ft ²)	447	375	-16%
Stealth Payload Required (lb)	5,700	1,171	-79%
Stealth Targets Engaged	4	14	250%
Max Range (nmi)	1,200	1,200	0%
Max Speed, Mach	M 1.61	M 1.79	12%

Distribution A Unlimited Distribution



7. Intellectual Property Staatus

WHAT IS CLAIMED IS:

- 1. AN AEROMECHANICALLY STABLE SABOT...**
- 2. THE AEROMECHANICALLY STABLE SABOT OF CLAIM 1, WHEREIN THE ASSEMBLY INCLUDES AT LEAST ONE AEROMECHANICALLY STABLE SEGMENT...**

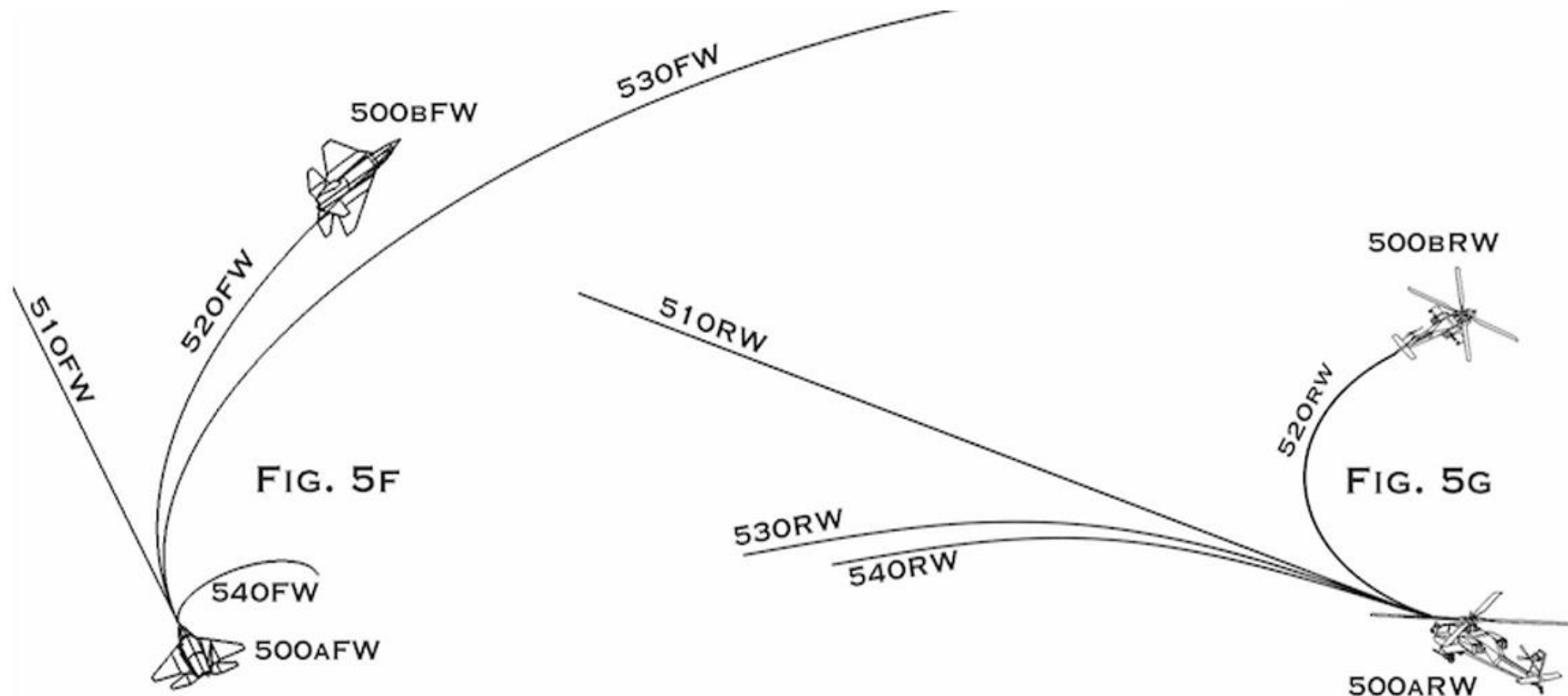


Image Source: PCT/IB2020/053899

Invented 2016

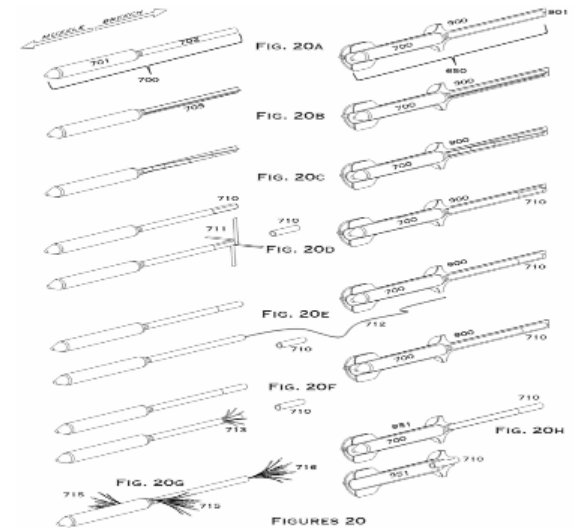
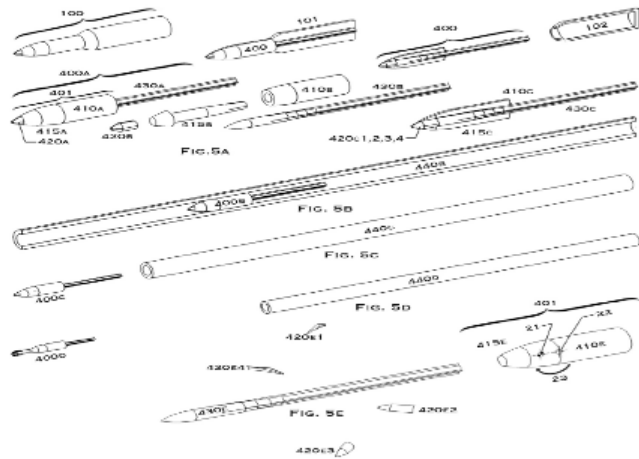
Modeled 2017

Reduced to practice 2018

Pat. priority date: 4/26/2019

7. Intellectual Property Staatus

- Strong, Broad US Patents Filed 2019, 2020
- Fed. Government Granted Export License & Exported
- Patents filed in: US, Europe, Germany, Norway, Australia, UK, Netherlands, France, Belgium, Italy, Spain, Japan, Korea, Singapore



PROVISIONAL PATENT APPLICATION 62/839,551 26 APRIL 2019 PRIORITY DATE 25 FIGURES, 83 CLAIMS, 80 PAGES

PCT FILING PCT/IB2020/053899 24 APRIL 2020 > 54 FAMILIES 1000+ SPECIES: 33 FIGURES, 130 CLAIMS, 106 PAGES

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8. Opportunities

Attack Rotorcraft

AH-64 (M789 30 x 113mm) AH-1 (M56 20 x 102mm) FARA



Fixed-Wing Attack Aircraft

A-10 (PGU-14 30 x 173mm)



Multi-Role Fixed-Wing Aircraft

F-15, F-16, F-18, F-22 (PGU-28 20 x 102mm)

F-35 (PGU-47 25 x 137mm)



Gunships

AC-130 (25mm, 40mm, 105mm)



Armed Drones

MQ-9, MQ-?, Bayraktar TB2, Shadow...



8. Opportunities ...Nontrivial chance of capturing a substantial part of the market

US Army: (DoD FY 2019 Budget Exhibit P-1 FY 2019, P. A-17C)

20, 25, 30mm \$113M/yr



USMC: (DoD FY 2019 Budget Exhibit P-1 FY 2019, P. N-20C)

20, 25, 30mm \$34M/yr



US Air Force: (DoD FY 2019 Budget Exhibit P-1 FY 2019, P. F-19C)

20, 25, 30mm+ \$193M/yr



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8. Opportunities KU Aerospace: open for business...

- **Exclusive & non-exclusive licenses available for:**

- US, Europe-Wide, Germany, Norway, Australia, UK, Netherlands, France, Belgium, Spain, Italy, Japan, Korea, Singapore

- **Engineering support: 3+ yr acceleration, data sets** (as allowed by law)

- On site support up to 2 yrs

- **Operational Units:**

- "What's possible – whole new mission sets" briefings (ITAR restricted)

- **Corporate Labs:**

- "What's possible" briefings (ITAR restricted & open)

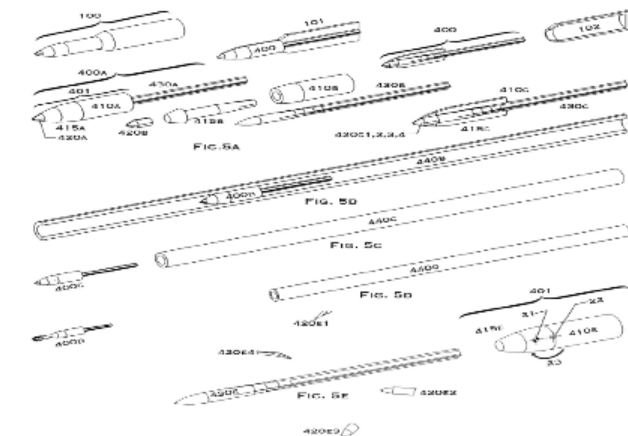
- Short courses (1 hr to 2 days)

- Patent/IP structure, legal offense/defense planning & weaponization

- **Government Labs:**

- Next research steps & navigating 15 CFR § 700 to 700.93 DPA

- Short courses (1hr to 2 days)



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Questions?

Visit us at Booth 412