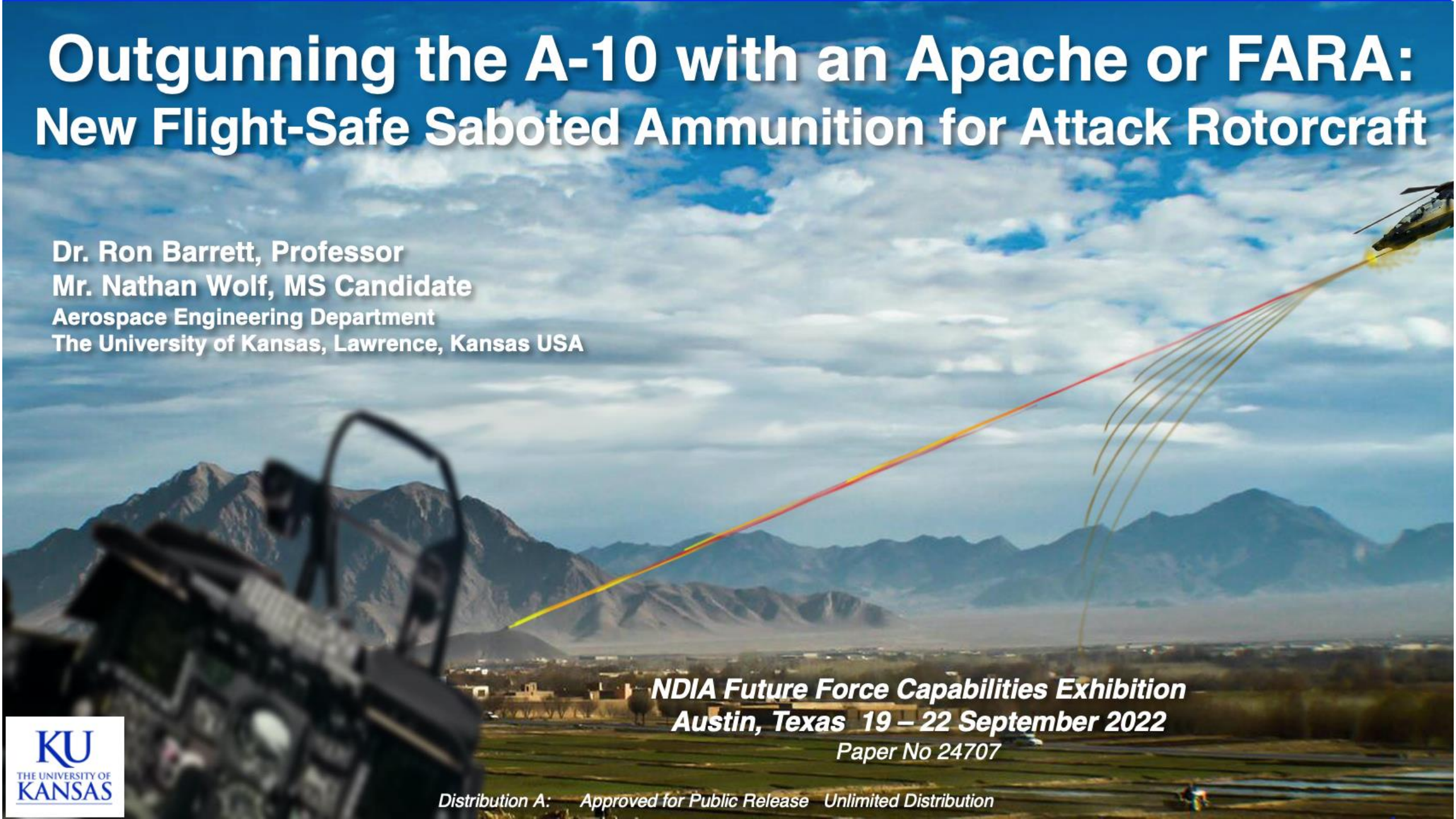
Outgunning the A-10 with an Apache or FARA:
New Flight-Safe Saboted Ammunition for Attack Rotorcraft

Dr. Ron Barrett, Professor
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

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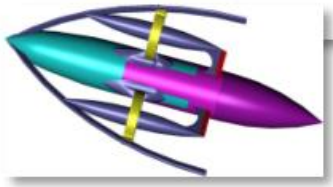
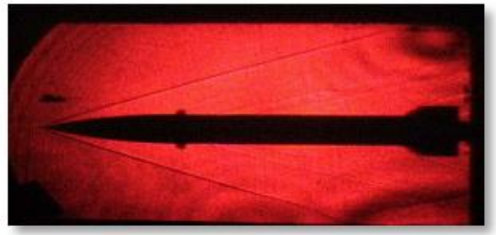
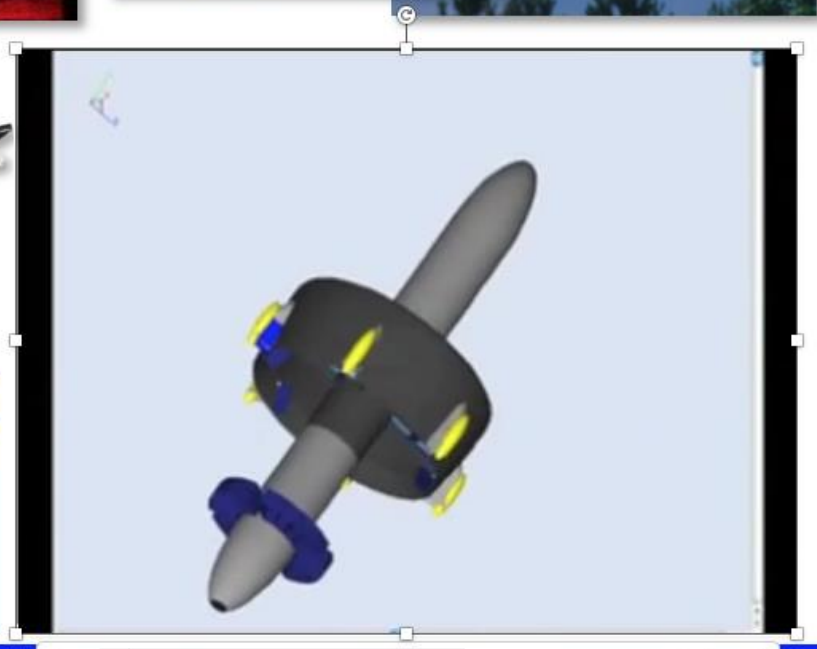
Adaptive Aerostructures Laboratory

- *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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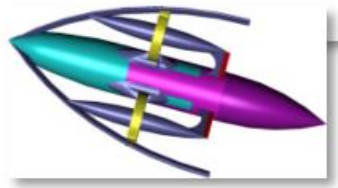

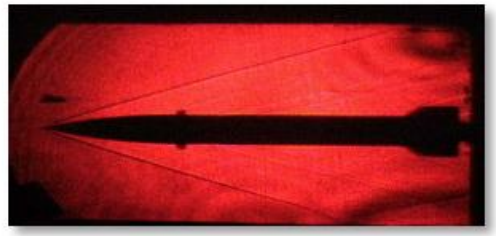


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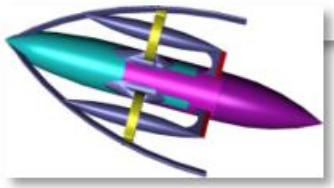

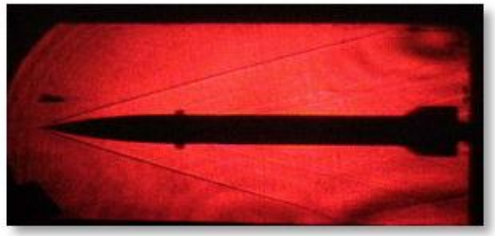


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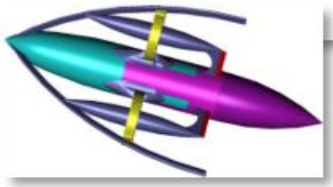

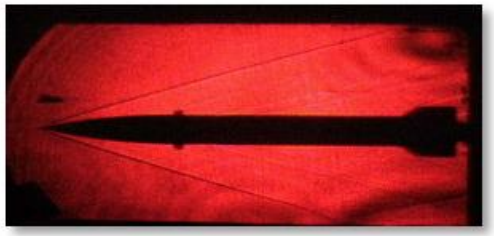

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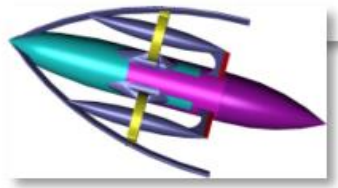

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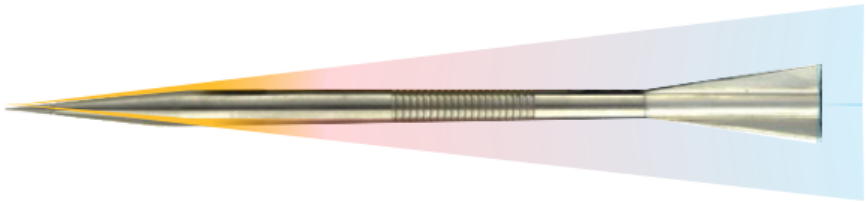
1.Motivation: Why use flight-safe discarding sabot ammunition?

- Endows AH-64 & FARA with better than A-10 gunnery firepower
- Increased range, KE, lethality, P_k, flat fire

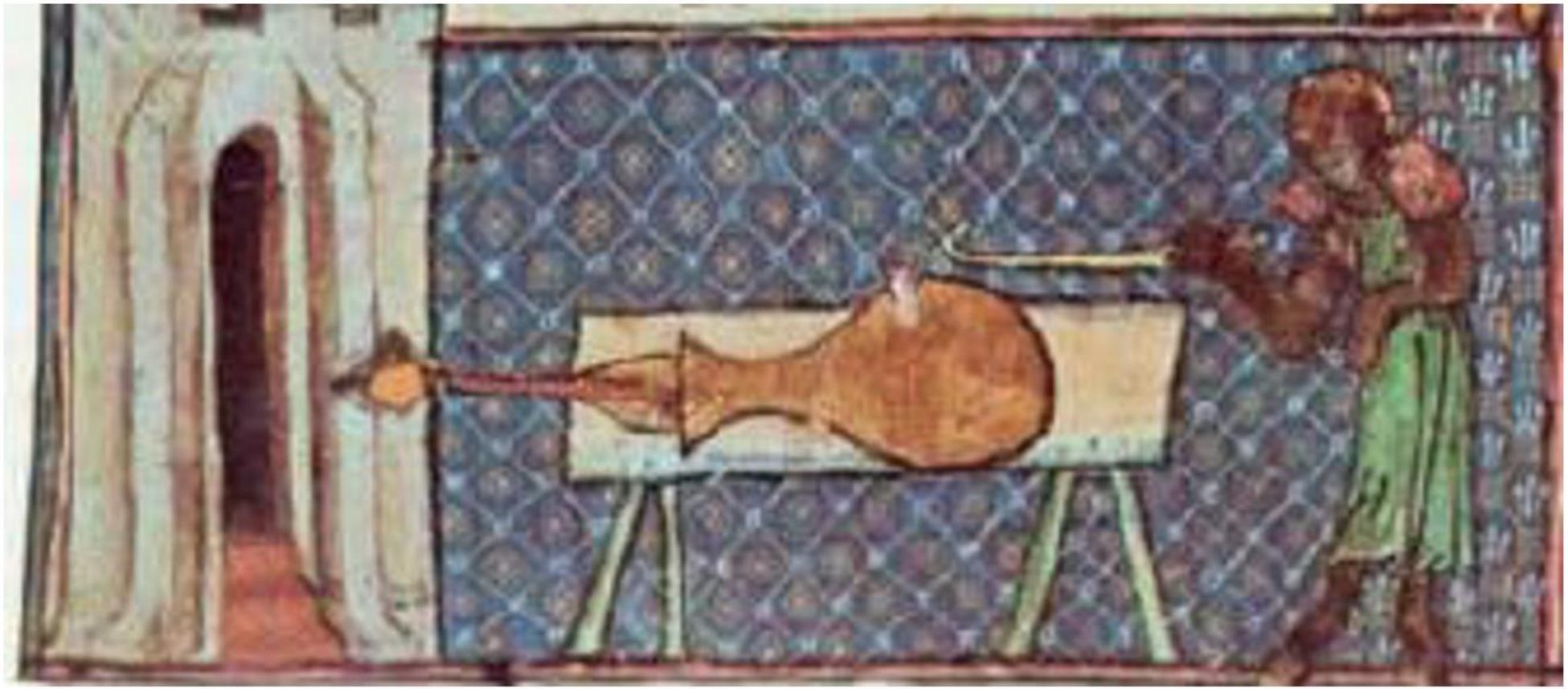


- Reduced TOF, CEP, system weight, volume, airframe MGWTO & LCC
- Enables both unguided and guided variants through hypersonic speeds

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 Prudentilis 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

Fig. 1.

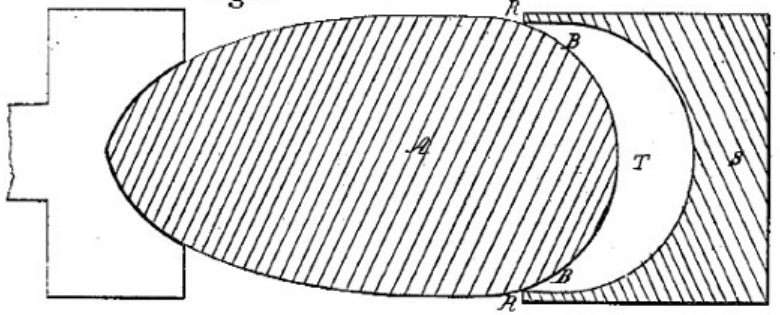


Fig. 3.

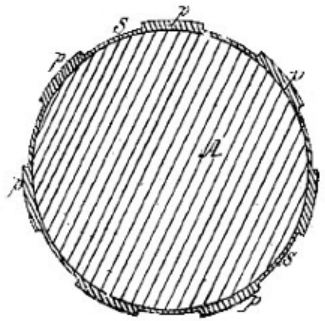
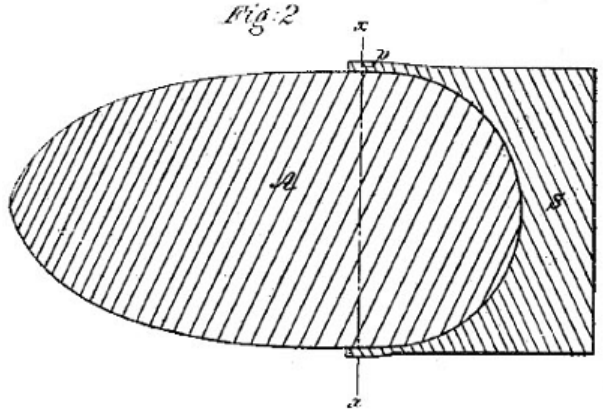


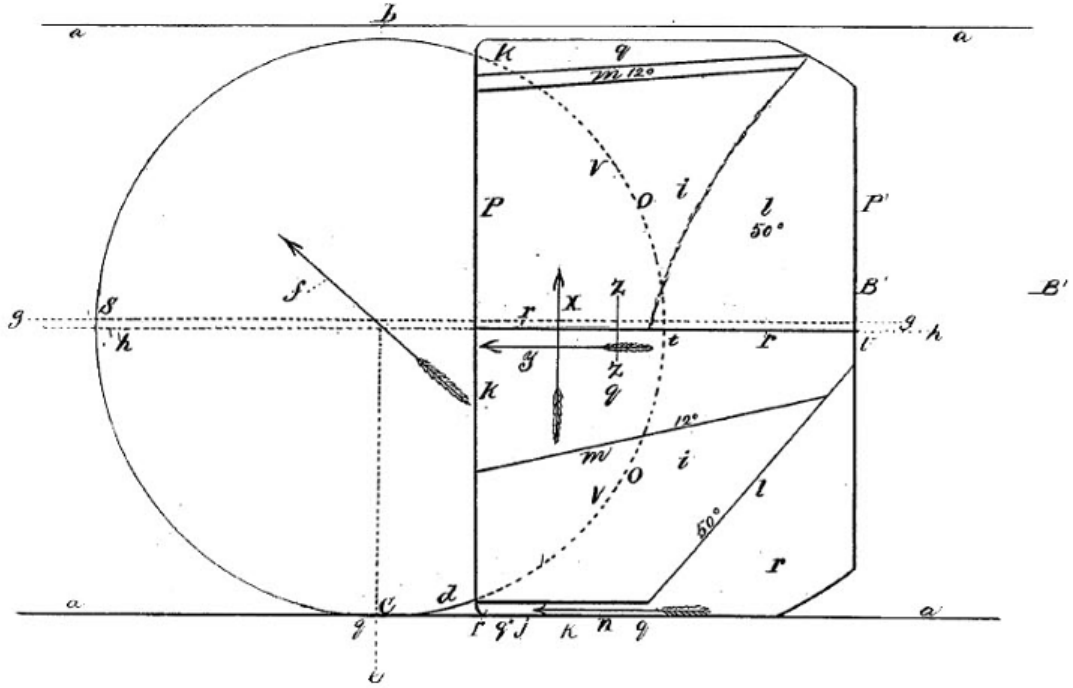
Fig. 2



W. W. HUBBELL.

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

Fig. 1.

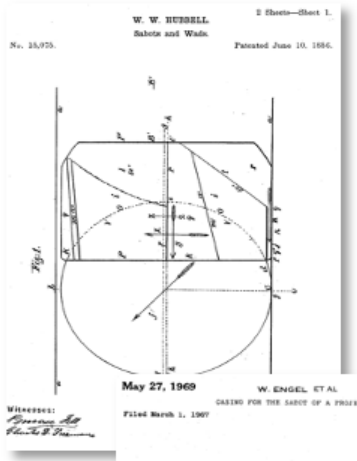


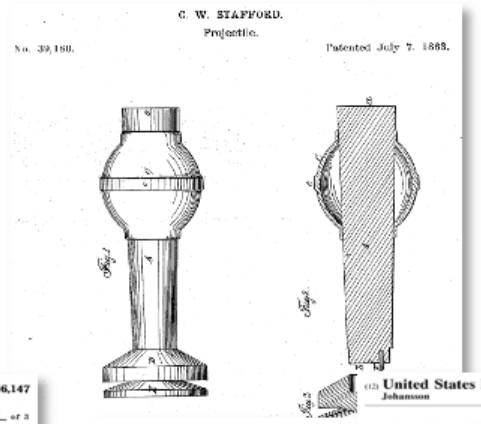
2. Saboted Round & Aerial Gunnery History (condensed)

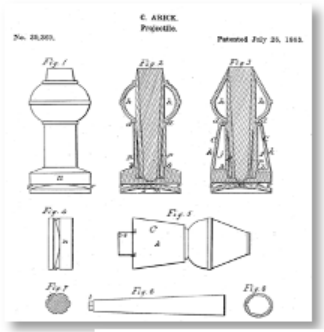
695 Years of Sabots…

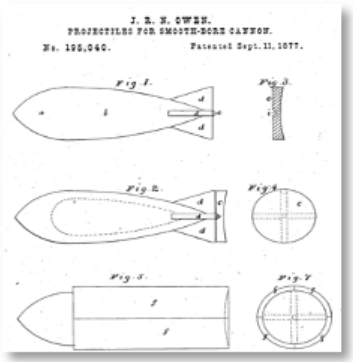
US Civil War – Modern Sabots

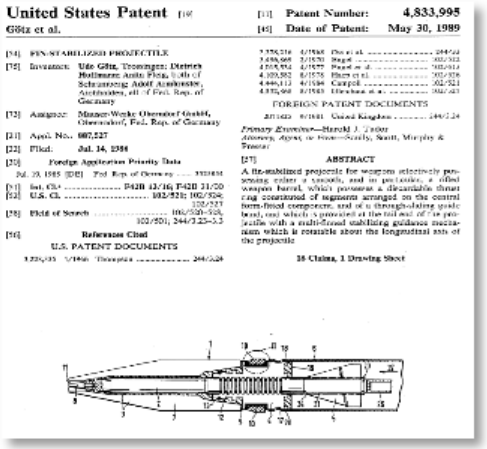
Not one suitable for aerial gunnery

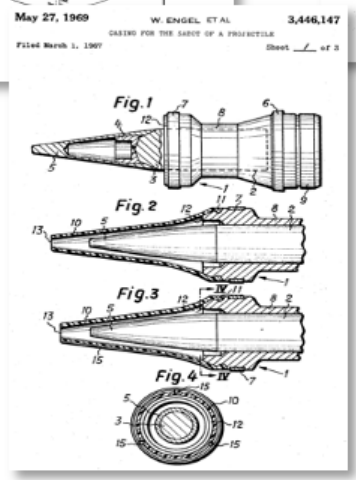


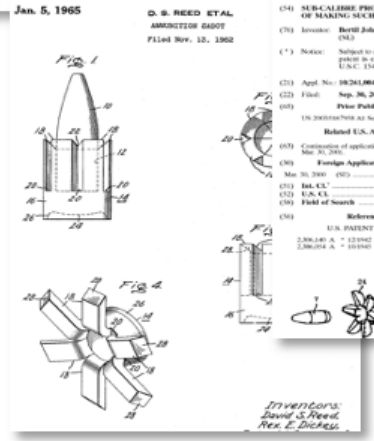


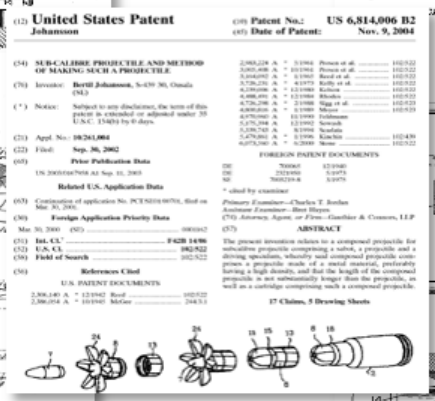


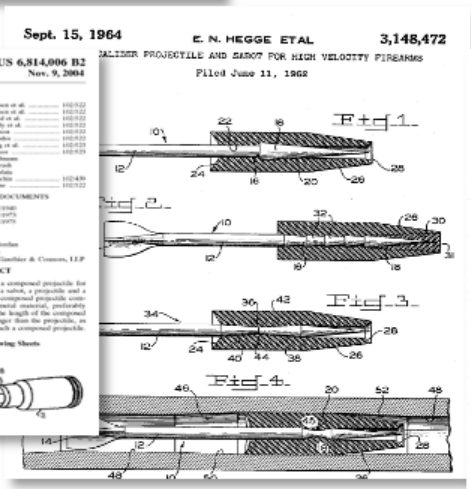


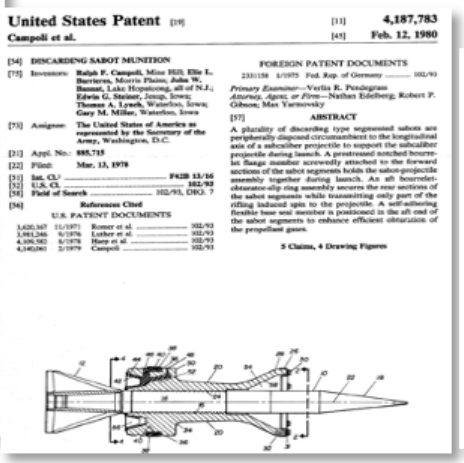


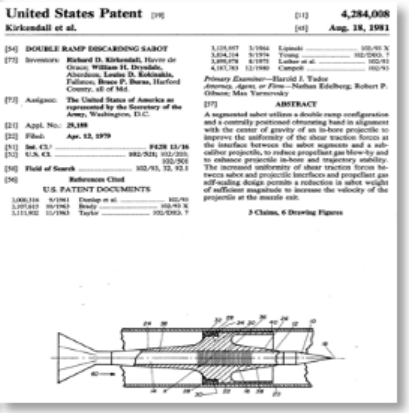






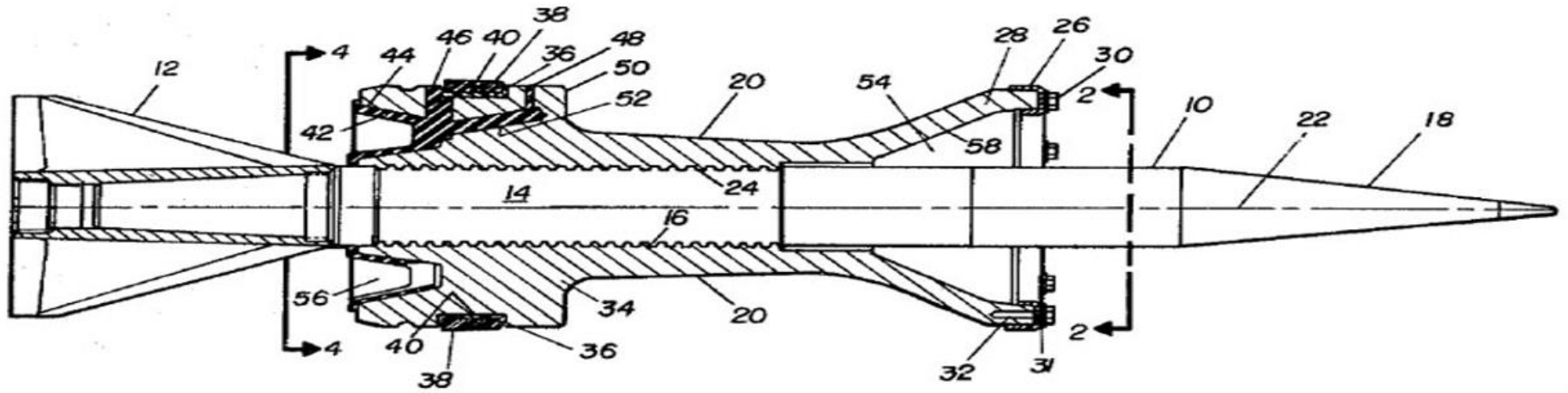


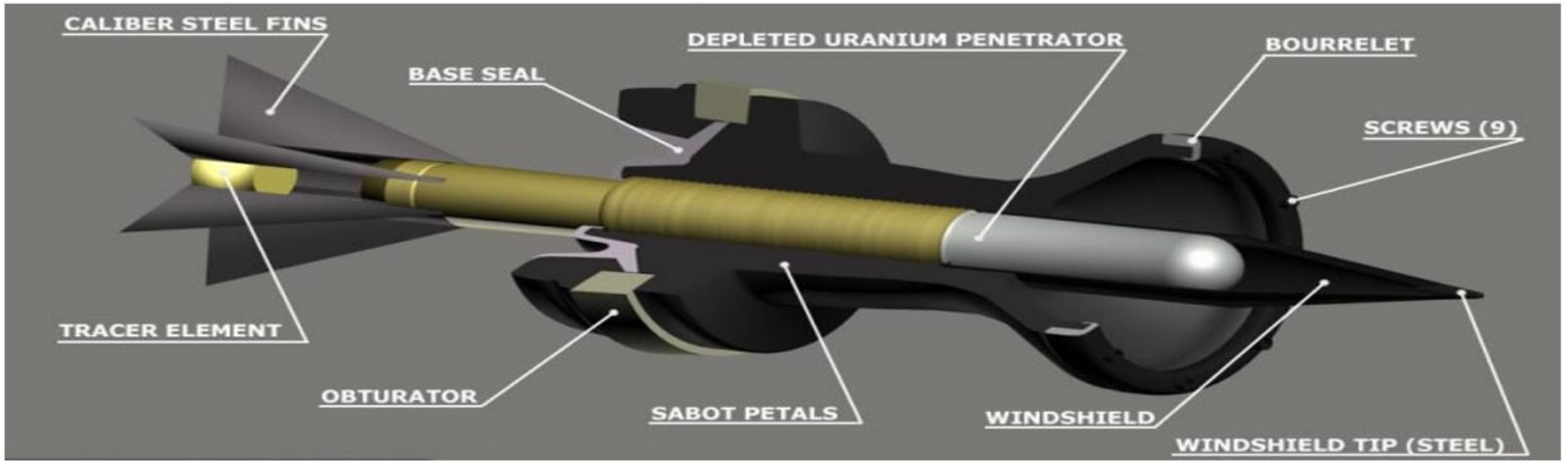




2. Saboted Round & Aerial Gunnery History (condensed)

Modern Armor-Piercing Discarding Sabot Munition



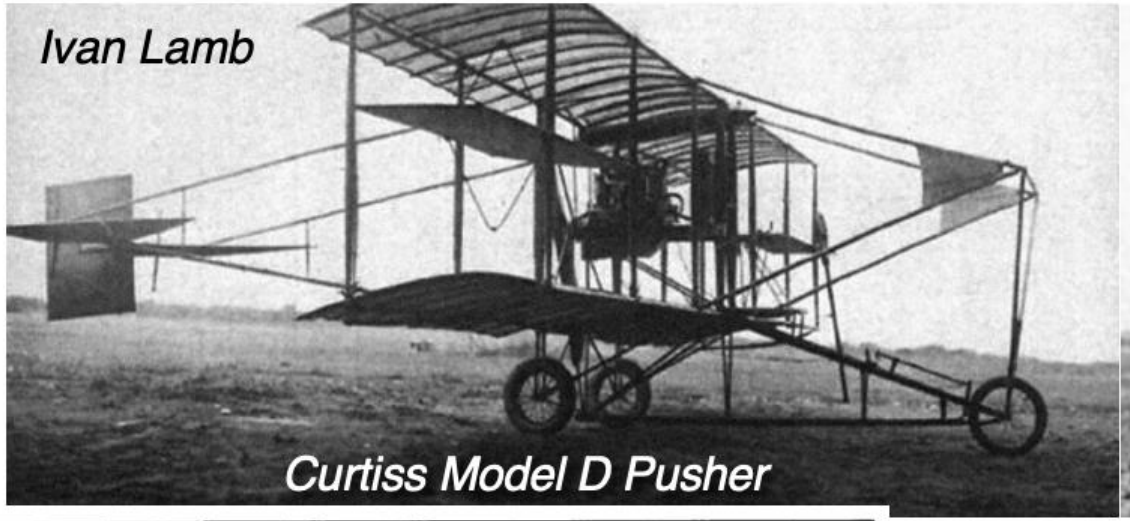


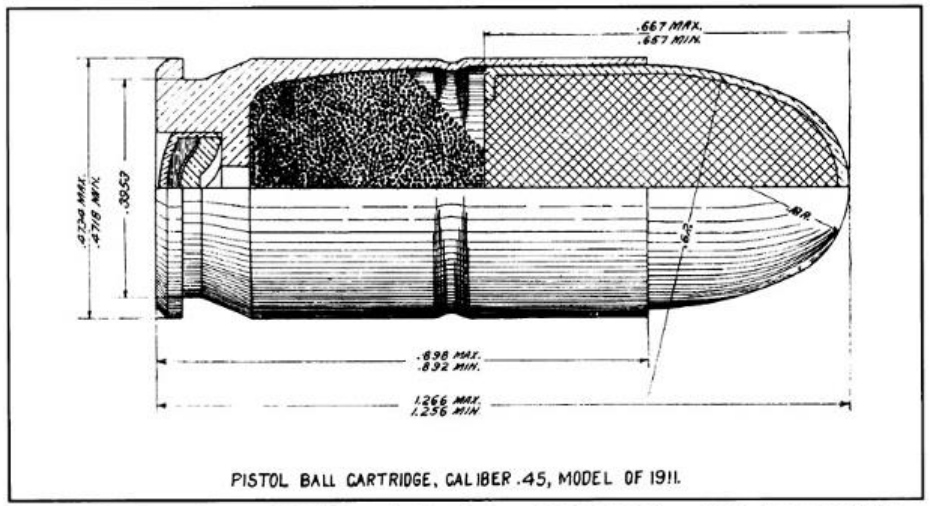
2. Saboted Round & Aerial Gunnery History (condensed)

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

2. Aerial Gunnery History (condensed)

1st Gun Duel





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.

Model 1906 .45 Revolver Ball cartridge

US Army Colt 0.45 1909

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

2. Aerial Gunnery History (condensed)

1st Air-to-Ground Strafing:

US Customs House, Naco, Arizona

2. Aerial Gunnery History (condensed)

1st Air-to-Ground Strafing:

US Customs House, Naco, Arizona

"Customs people are always irritating."
–Dean Ivan Lamb

2. Aerial Gunnery History (condensed)

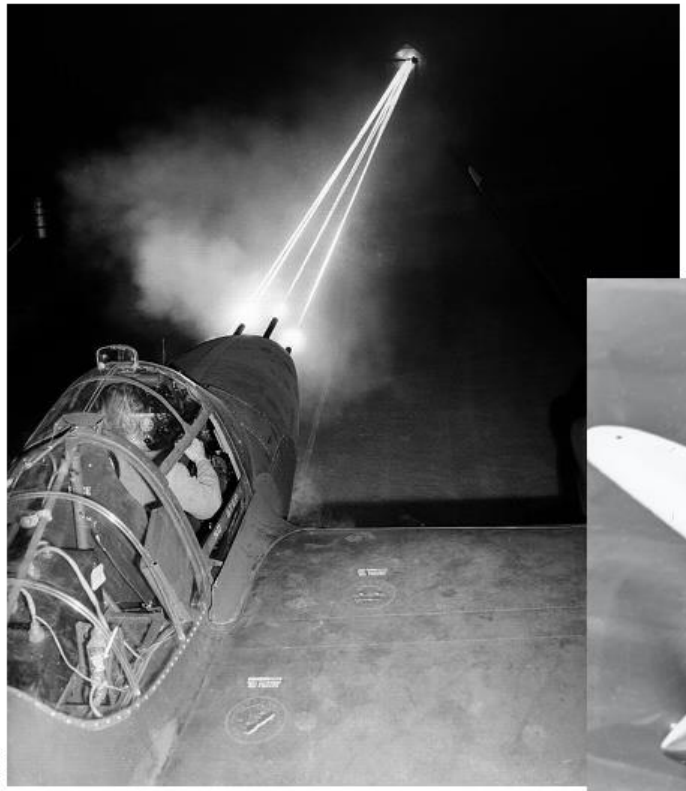
Aerial Gunnery WWI

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

2. Aerial Gunnery History (condensed)

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

2. Aerial Gunnery History (condensed)



WWII

20mm P-38 Lightning Autocannon

3. Struggles & Breakthrough

Post-Key West Drive for Army CAS:

US Army's 1st Gunship: YAH-32 Hornet

3. Struggles & Breakthrough

Post-Key West Drive for Army CAS:

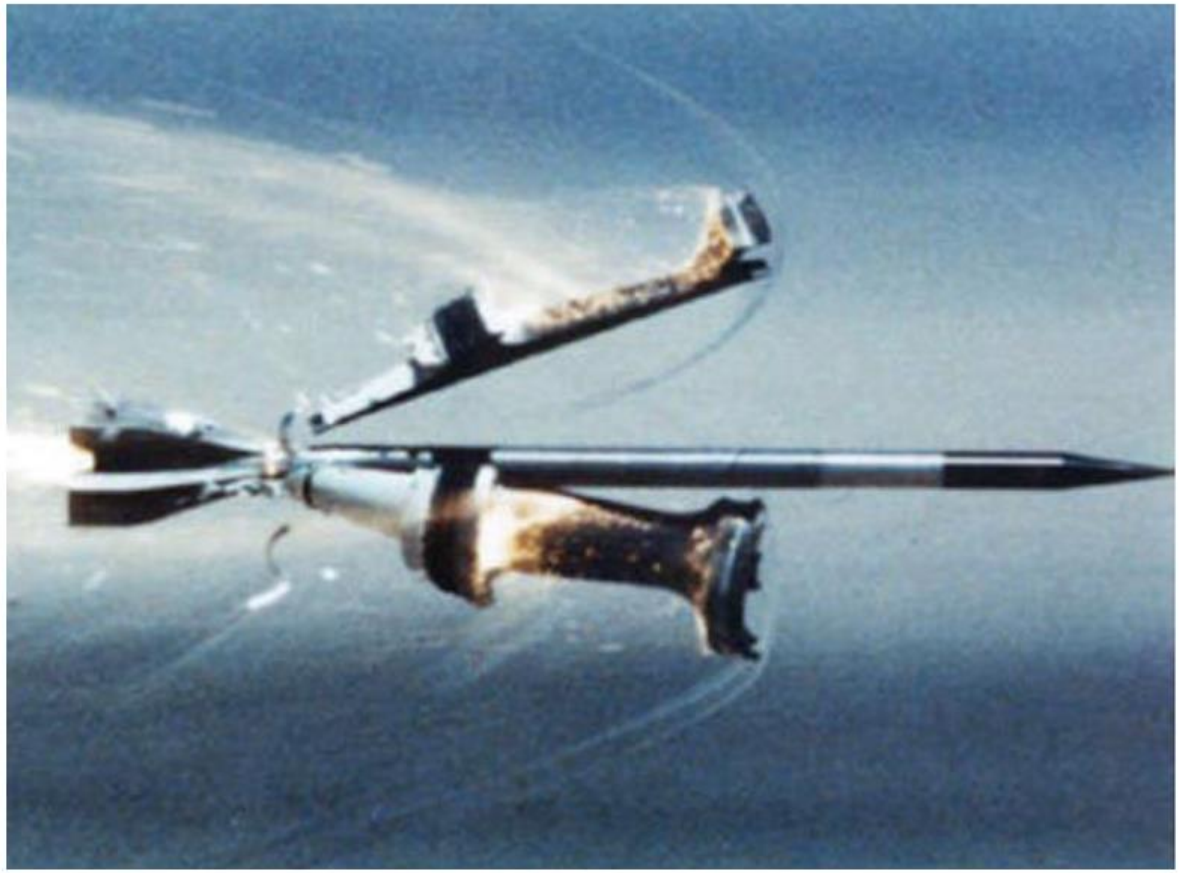
OV-1… Symptom of the Unmet Need

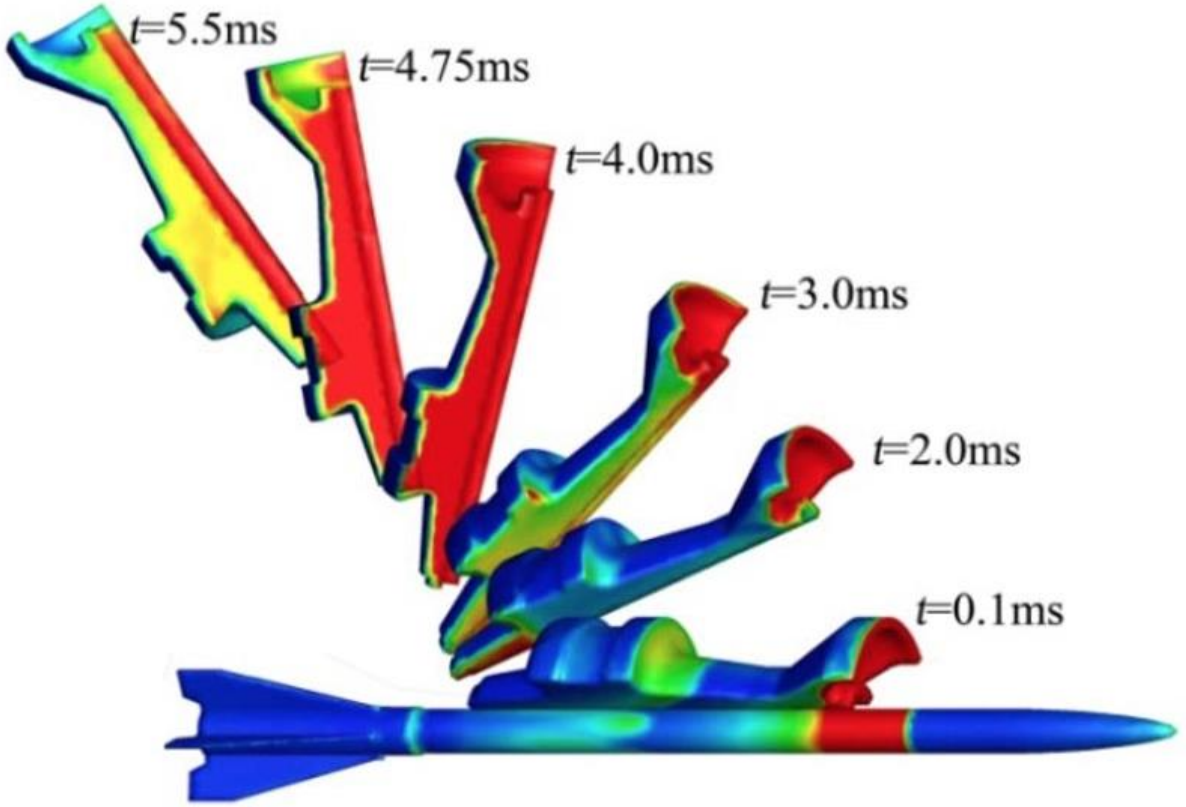
3. Struggles & Breakthrough

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

3. Struggles & Breakthrough

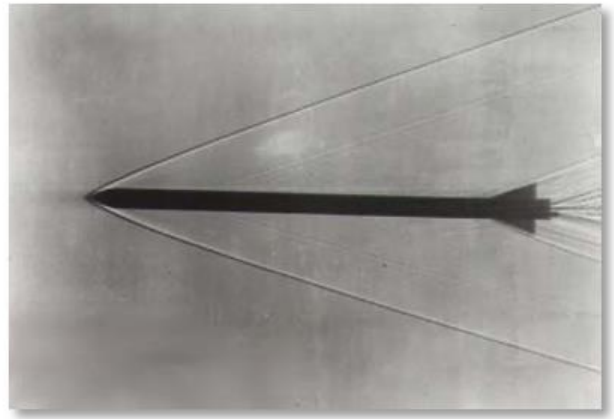
Conventional Discarding Sabot Design Philosophy and Aeromechanics



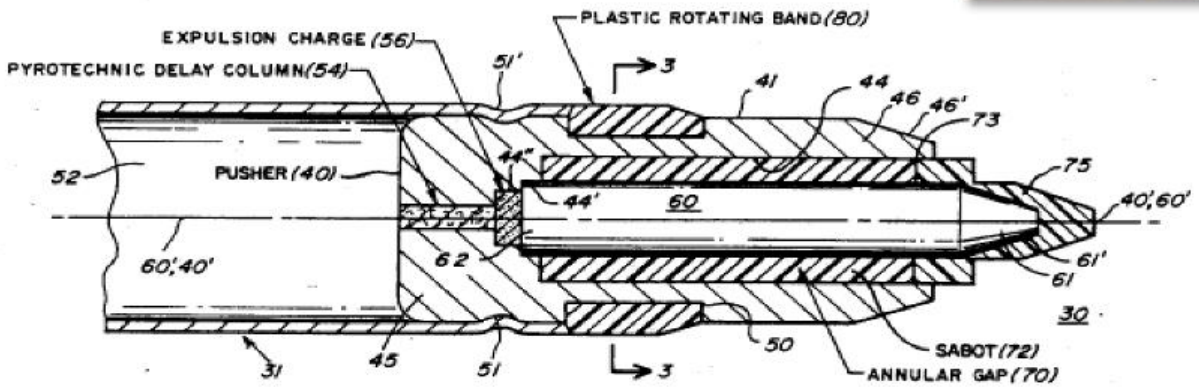


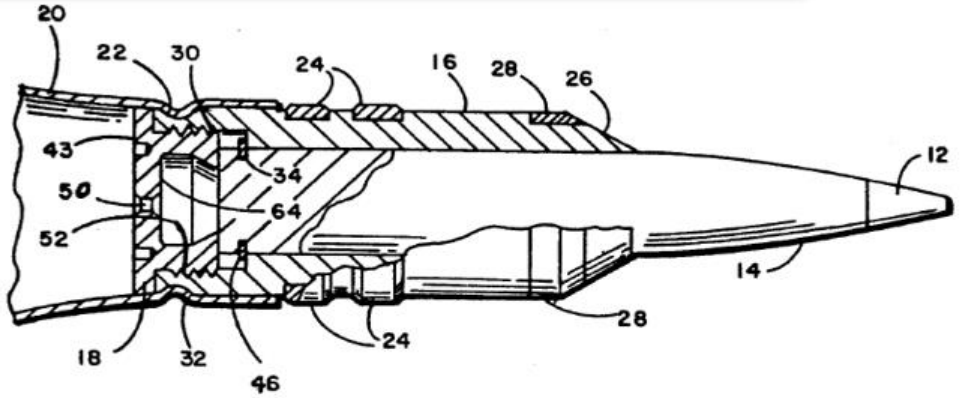
3. Struggles & Breakthrough

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

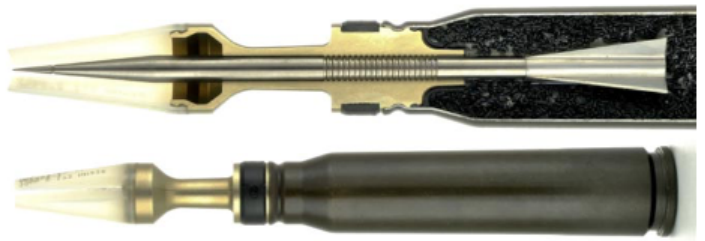


Aeroballistic Research Facility





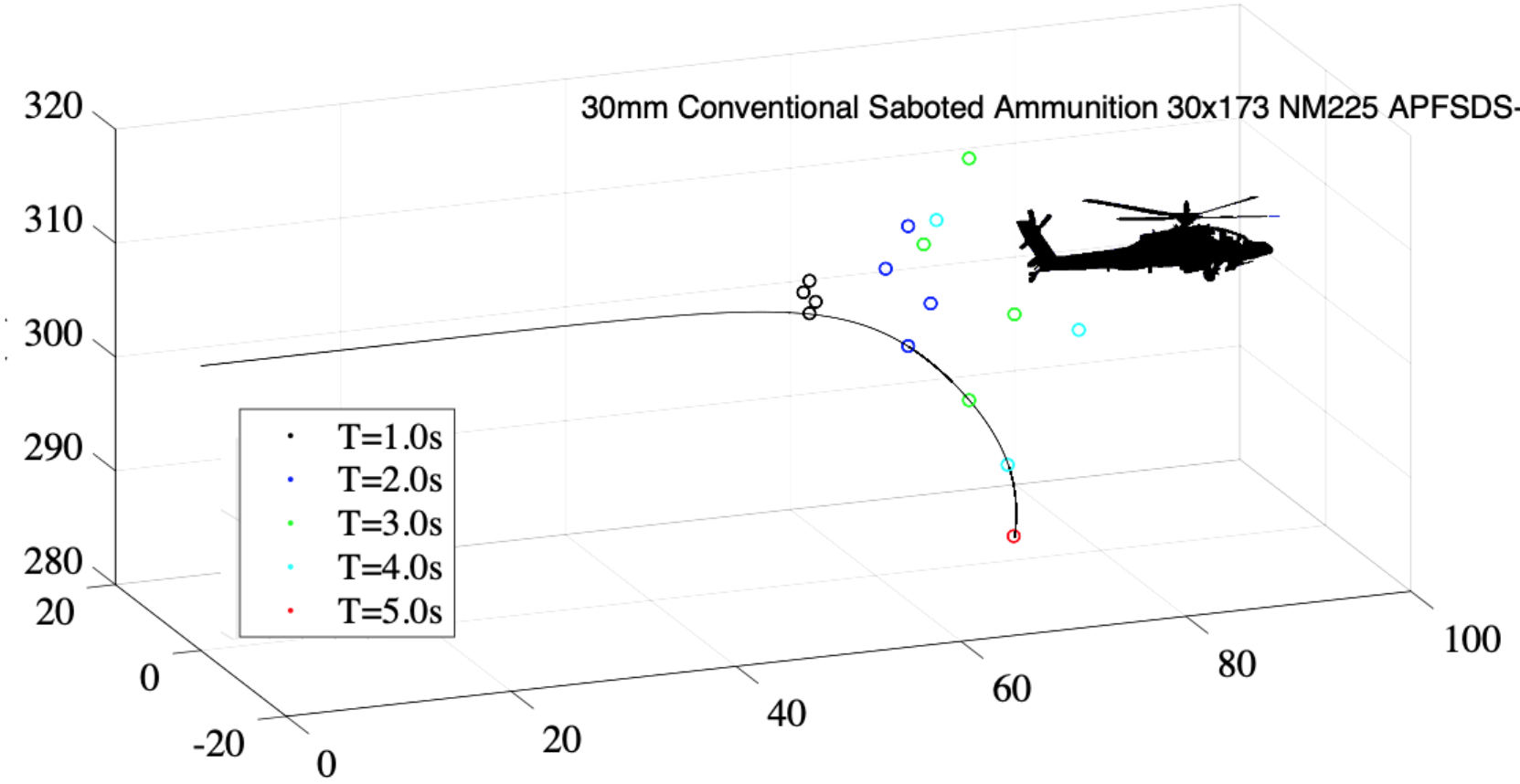
3. Struggles & Breakthrough



Struggles with Aircraft & Sabots

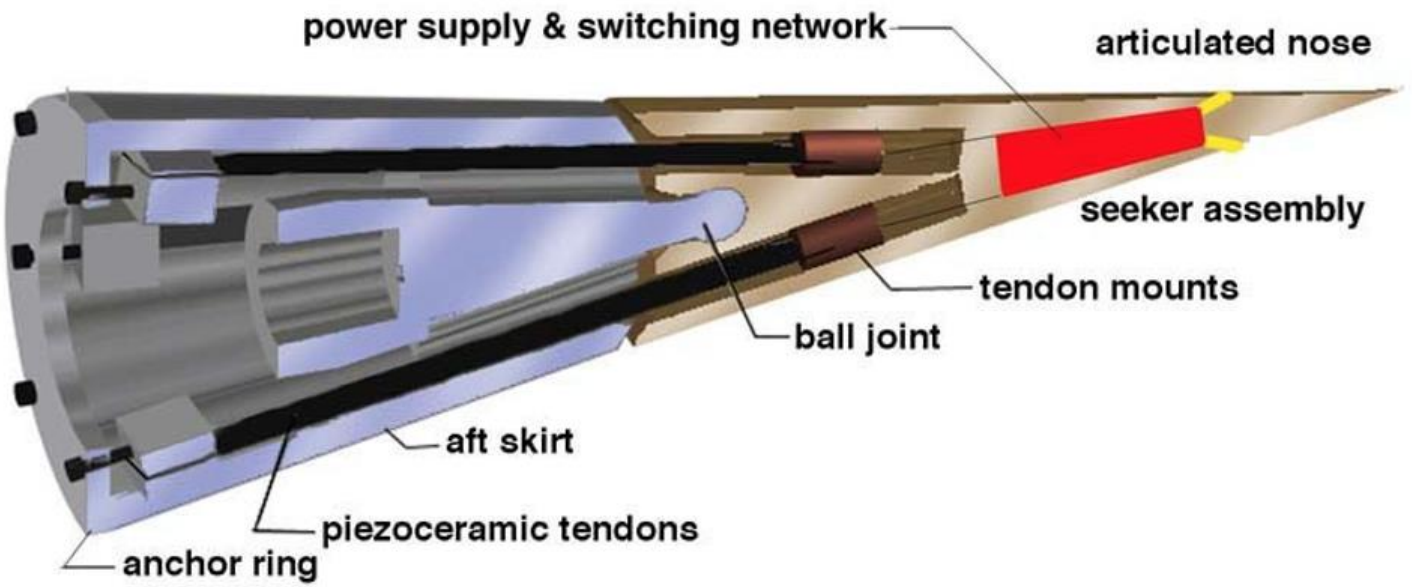
The Great Show Stopper for conventional sabots:

Flight Safety



3. Struggles & Breakthrough

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



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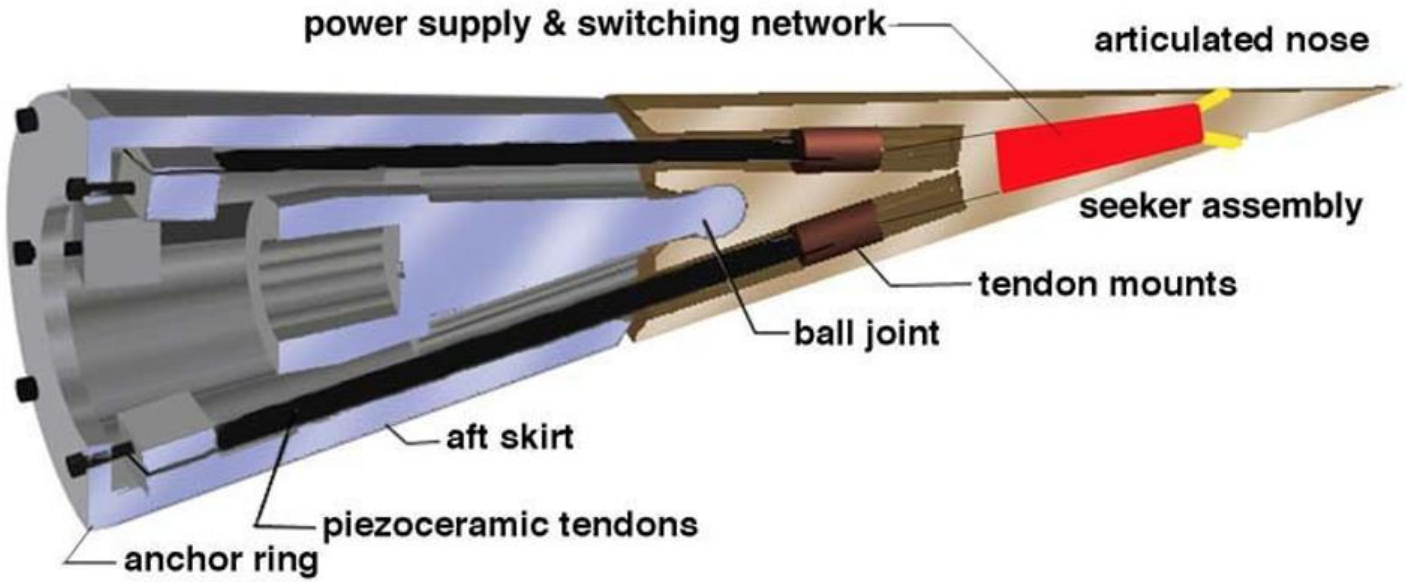


1998: USAF ceases all advanced/guided aerial gunnery & saboted ammo. RDT&E

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

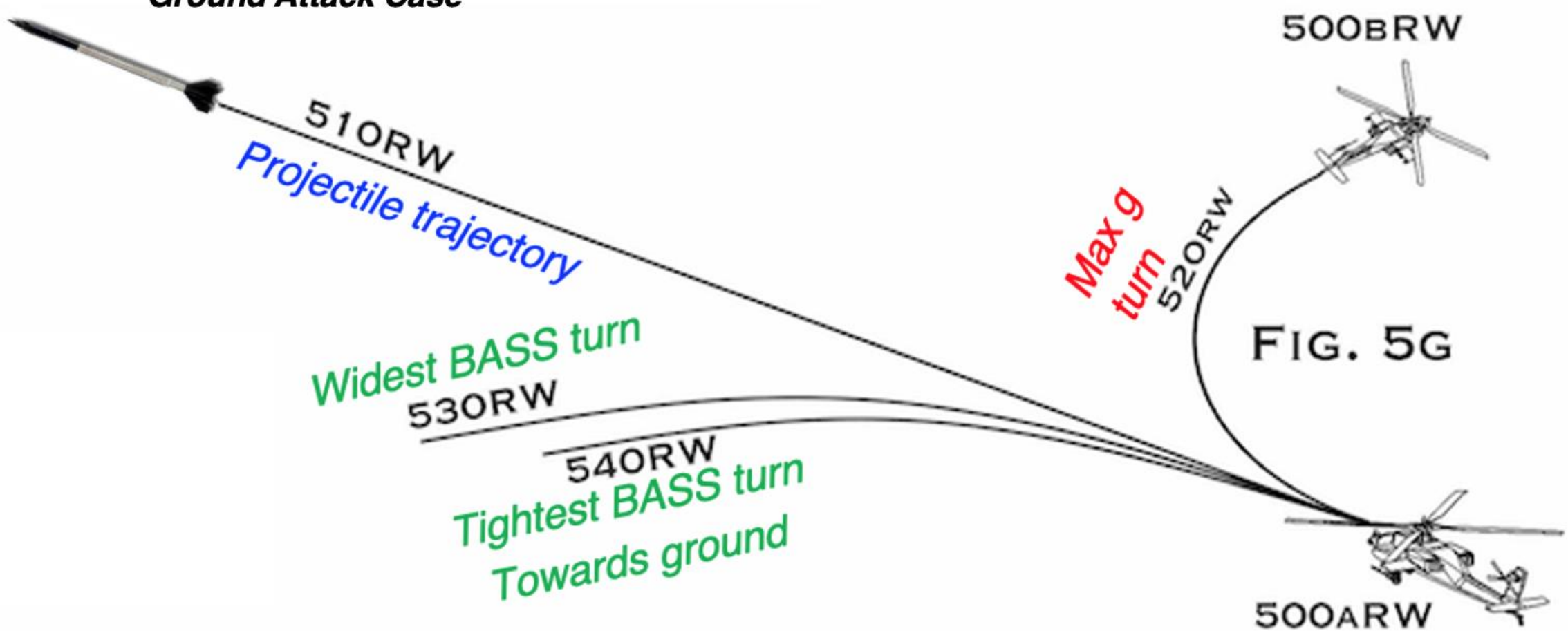
2016 Co-Inventor
Ballistic Aeromechanically Stable Sabot (BASS) Ammunition
Maneuvering Aeromechanically Stable Sabot (MASS) Ammunition

Senior Systems Engineer, Raytheon

3. Breakthrough:

BASS Rounds: Design the Sabot to clear the launching aircraft

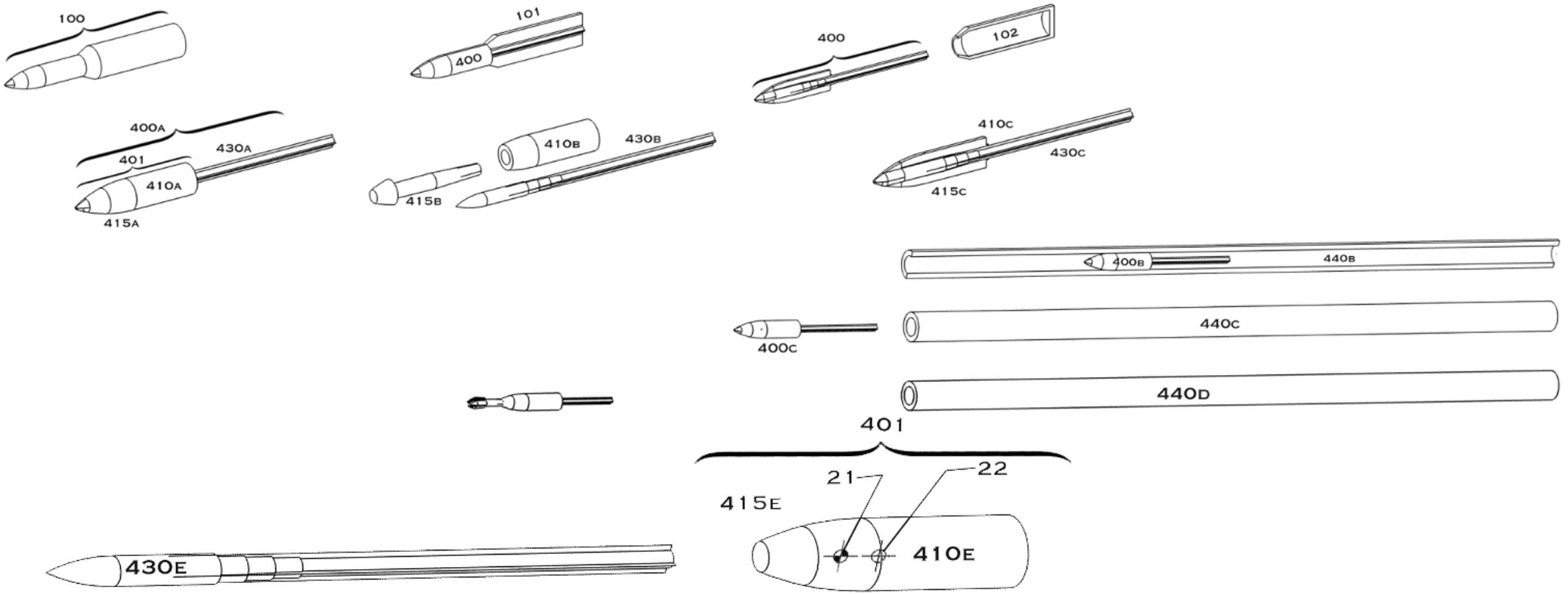
Ground Attack Case



4. MASS & BASS Rounds

What is claimed is:

1. An aeromechanically stable sabot...

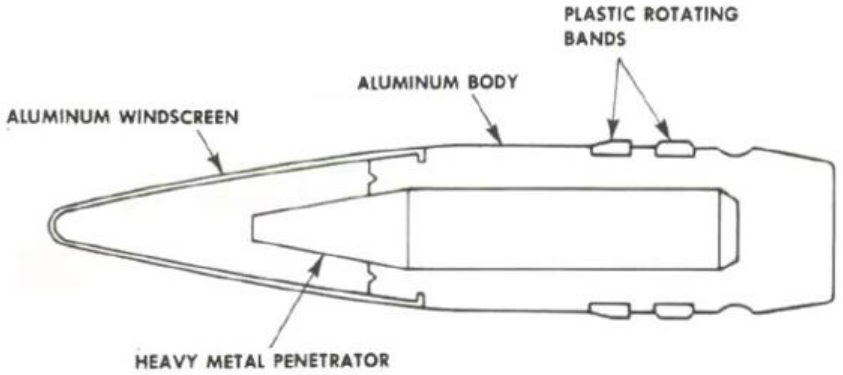


54 major families, >1,000 species covered in expansive patent filings

4. MASS & BASS Rounds

Today's Aerial Gunnery Round

PGU-14



BASS 2081 Flechette/penetrator

5. Modeling & Testing

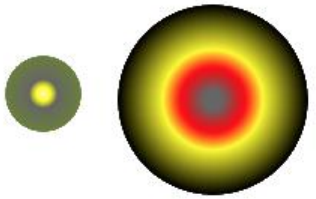
- *Conceived 2016 & reduced to practice*
- *Modeled in CFD, FEM, DATCOM & PRODAS*
- *Tested on Shock Table, Wind Tunnel, Range*
- *>100 rounds fired, currently @ TRL-6*

5. Modeling & Testing

Top-Level Drag and Stability Characteristics

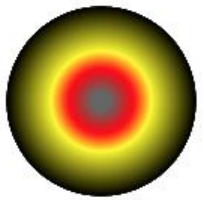
Flechette

X-Sectional Area of PGU-14 >> Flechette



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

PGU-xx

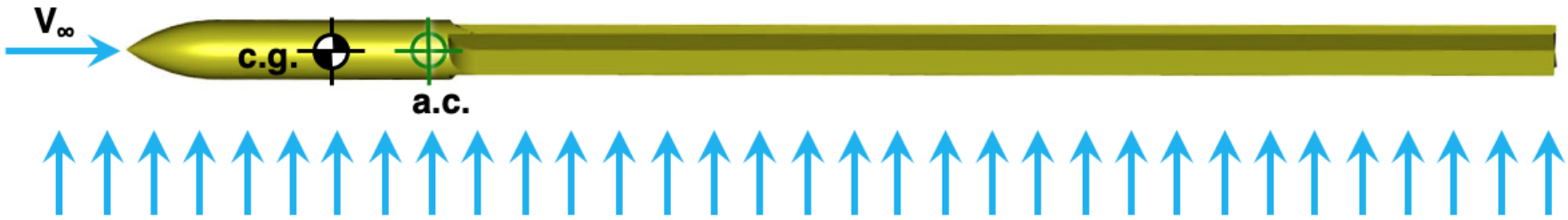


5. Modeling & Testing

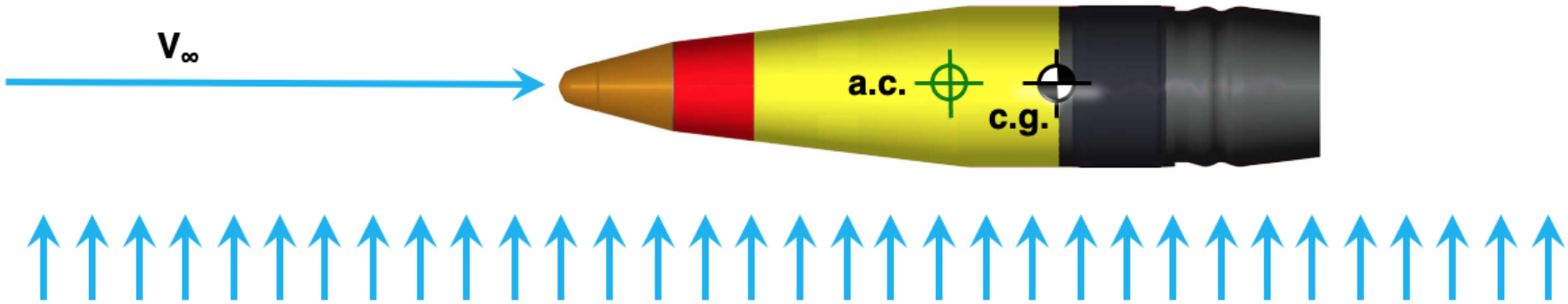
Projectile Aeromechanics & CEP Fundamentals

Flechette

Instantaneous introduction of lateral gust

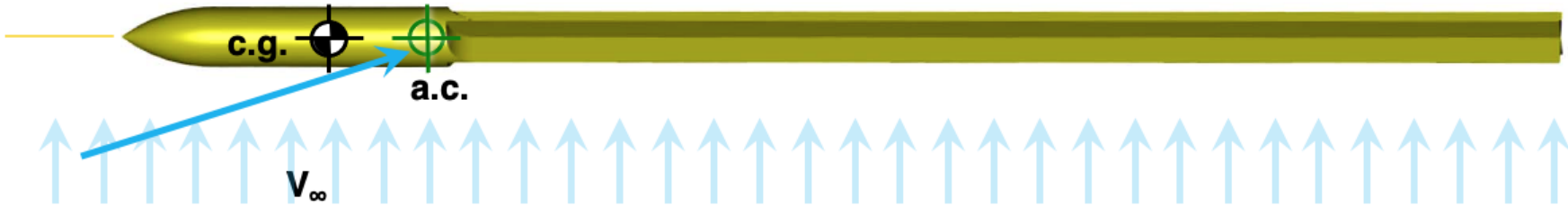


PGU-xx

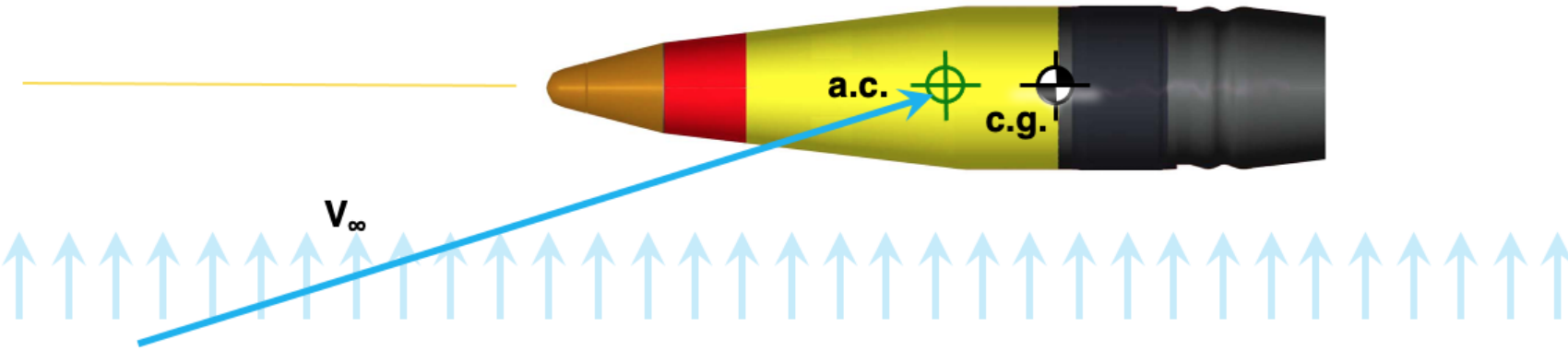


5. Modeling & Testing

Projectile Aeromechanics & CEP Fundamentals

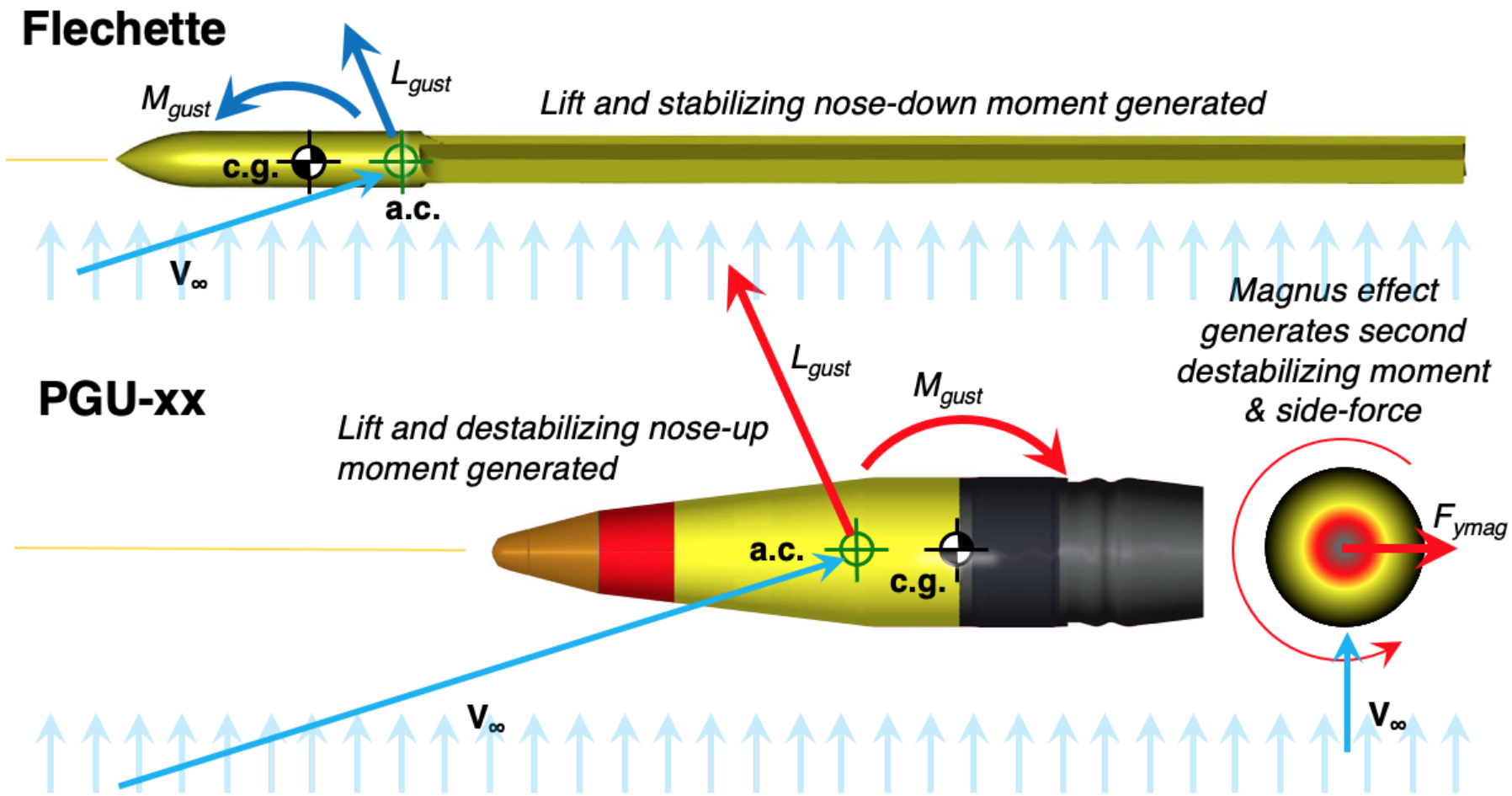


PGU-v



5. Modeling & Testing

Projectile Aeromechanics & CEP Fundamentals



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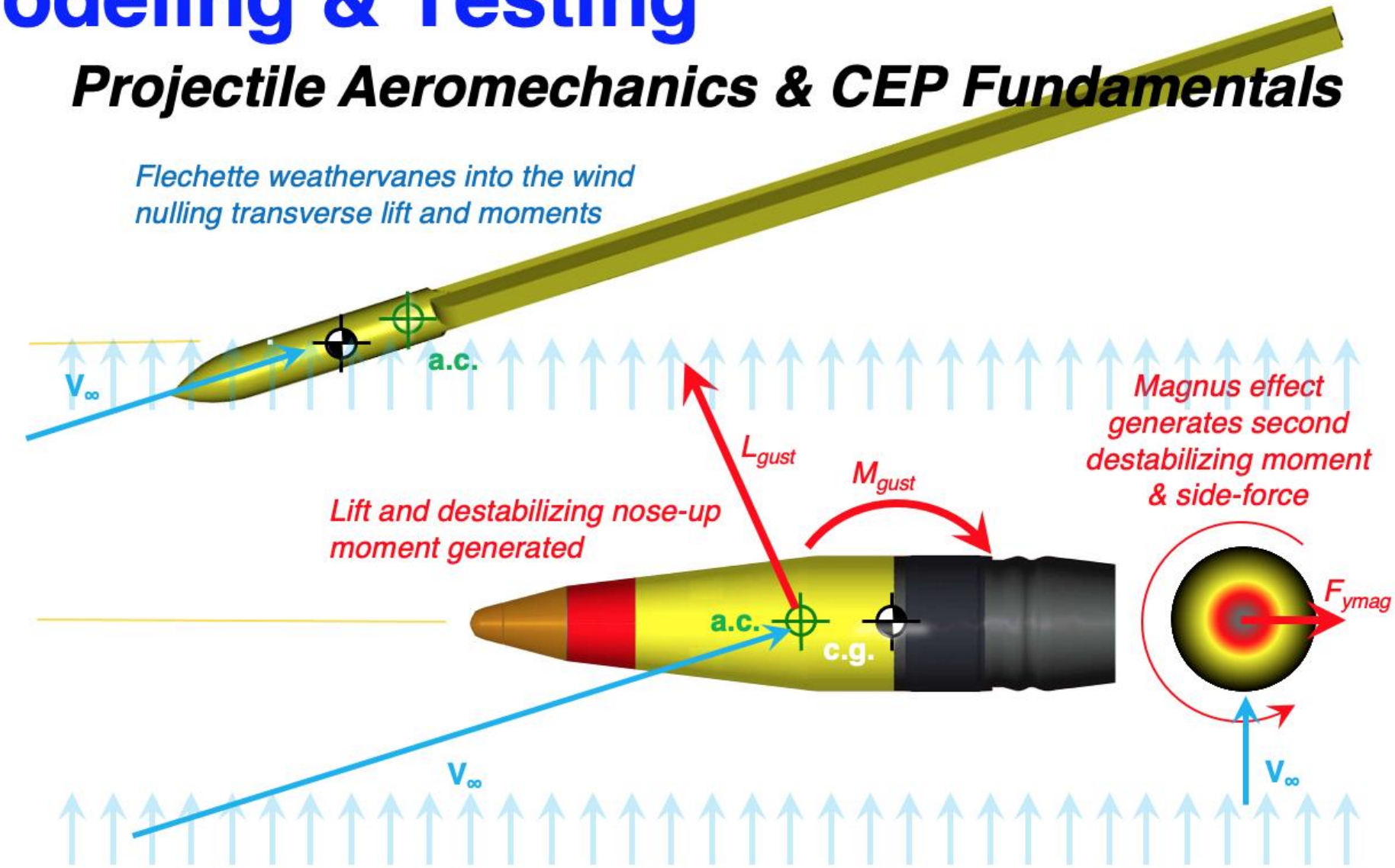
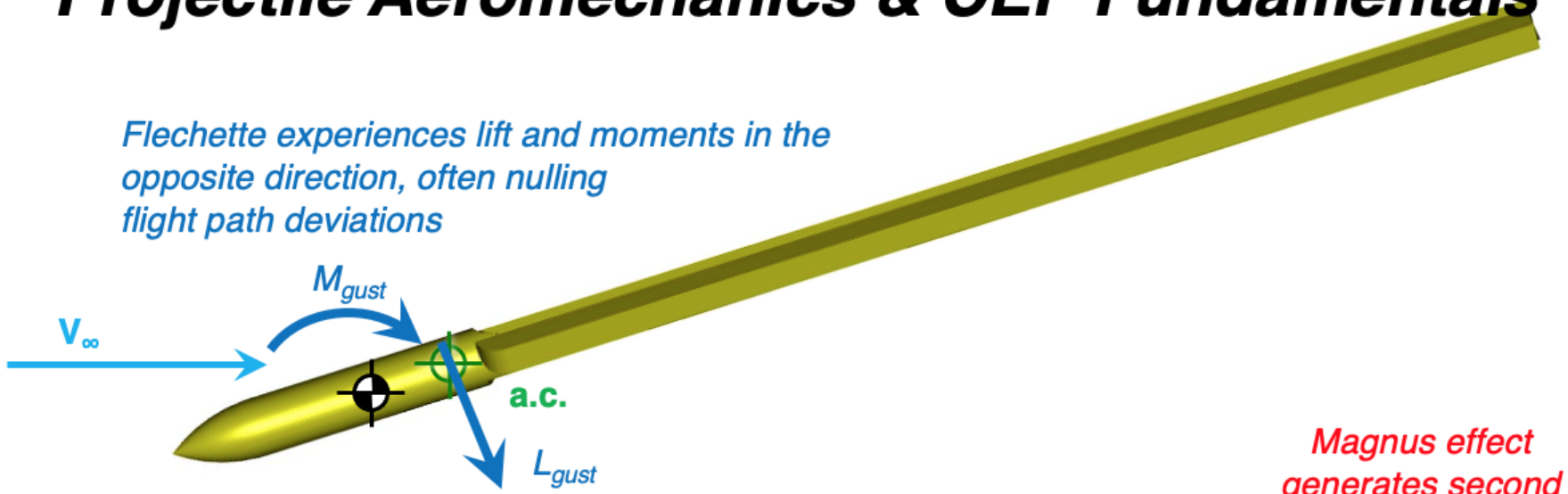
Projectile Aeromechanics & CEP Fundamentals



5. Modeling & Testing

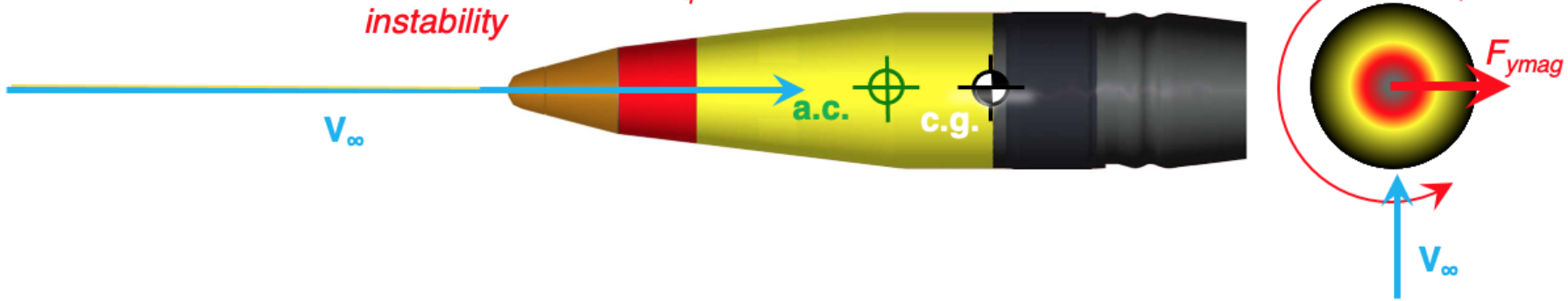
Projectile Aeromechanics & CEP Fundamentals

Flechette experiences lift and moments in the opposite direction, often nulling flight path deviations



Dynamic modes (precession, nutation) excited given low C_{mq} & inherent instability

Magnus effect generates second destabilizing moment & side-force



5. Modeling & Testing

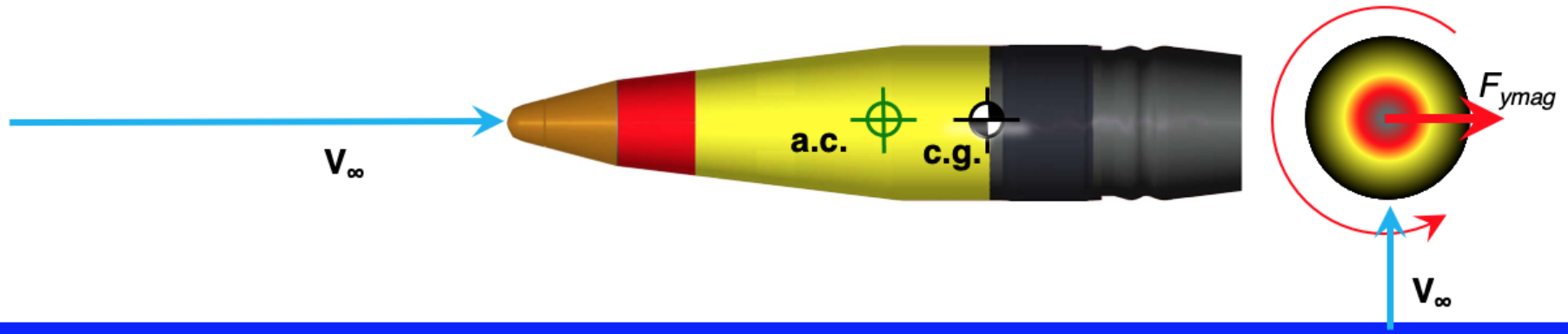
Projectile Aeromechanics & CEP Fundamentals

Flechette

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

PGU-xx

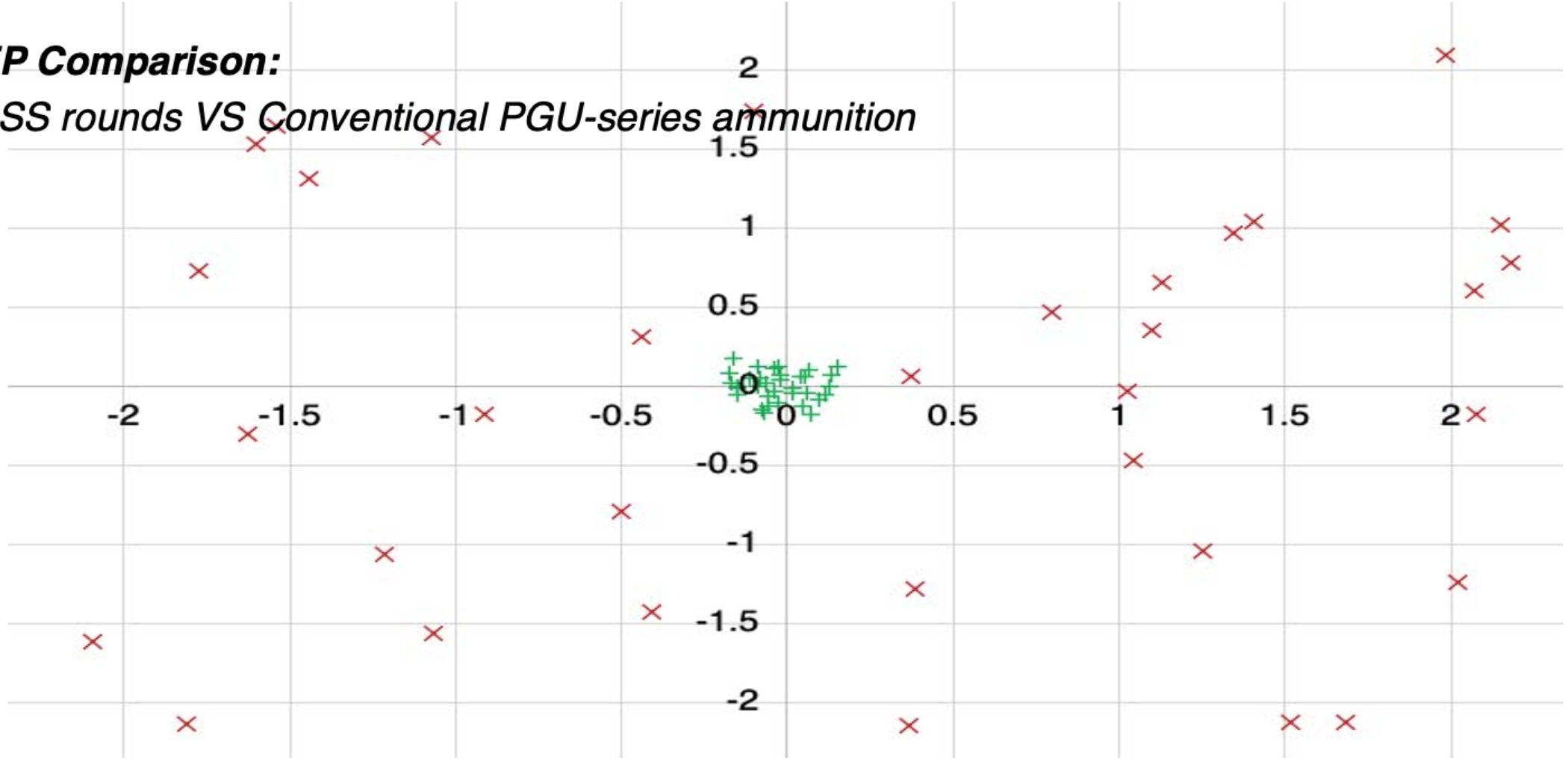
CEP greately increased due to steady-state and dynamic effects



5. Modeling & Testing

CEP Comparison:

BASS rounds VS Conventional PGU-series ammunition



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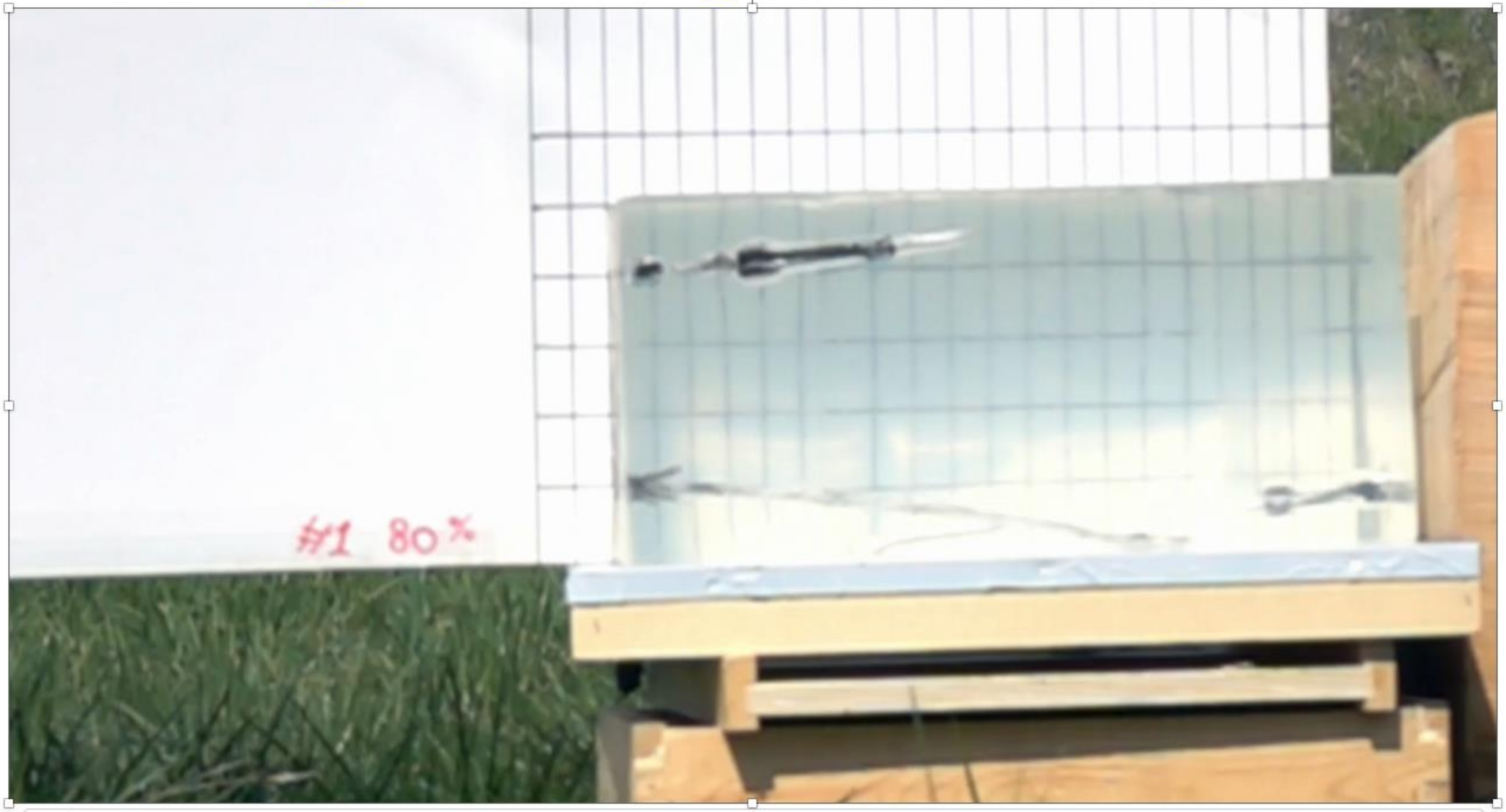

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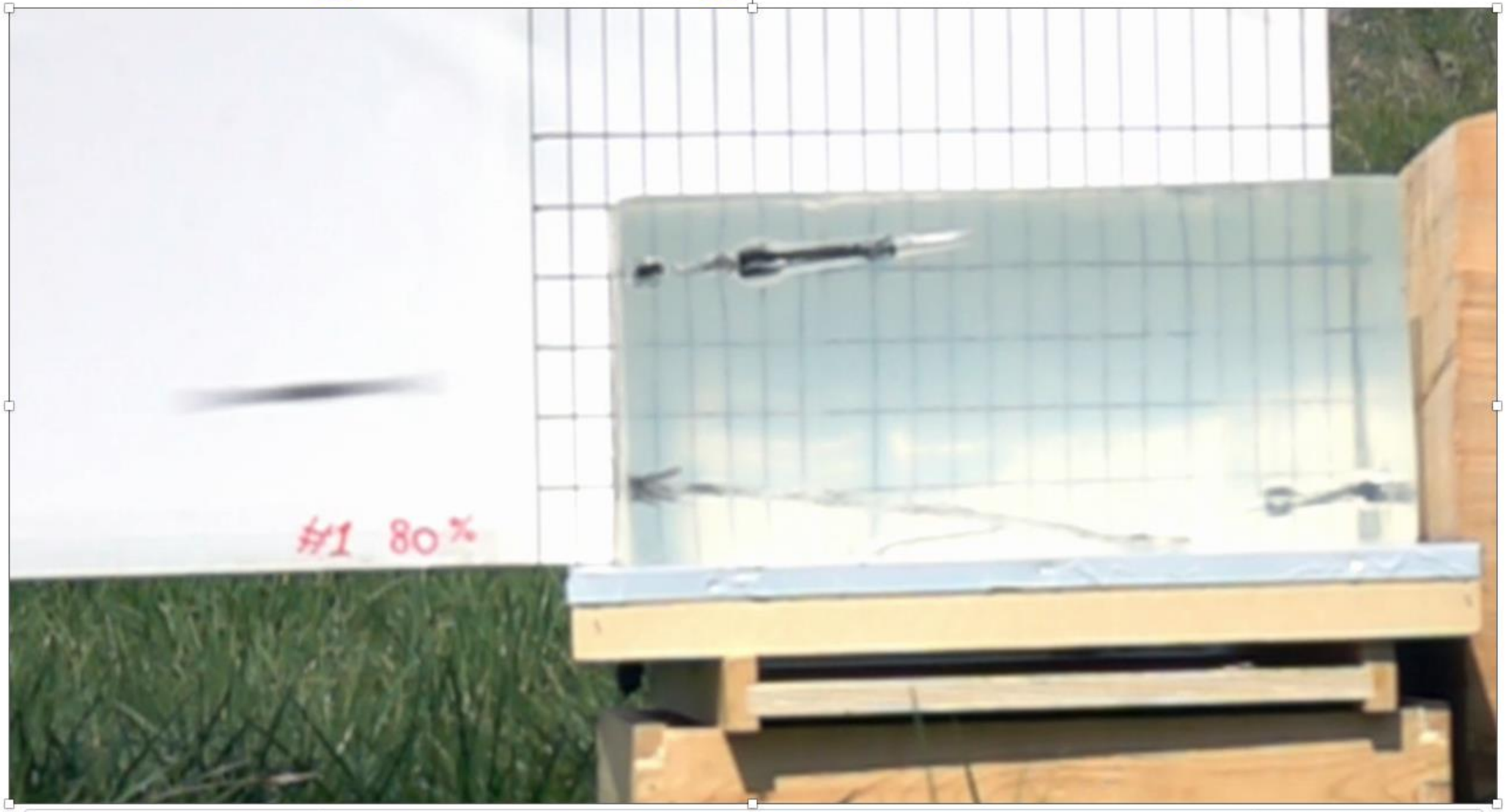

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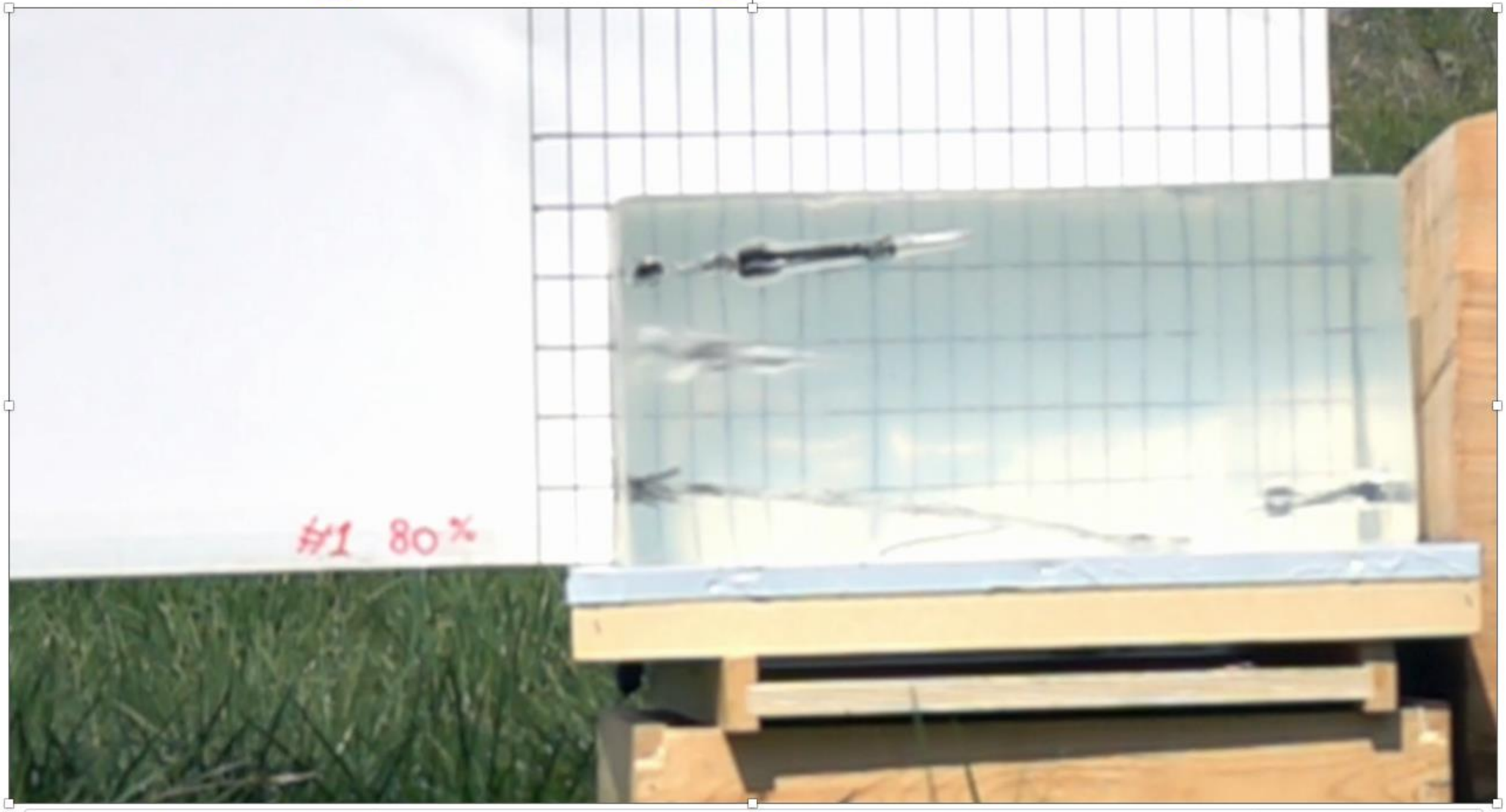

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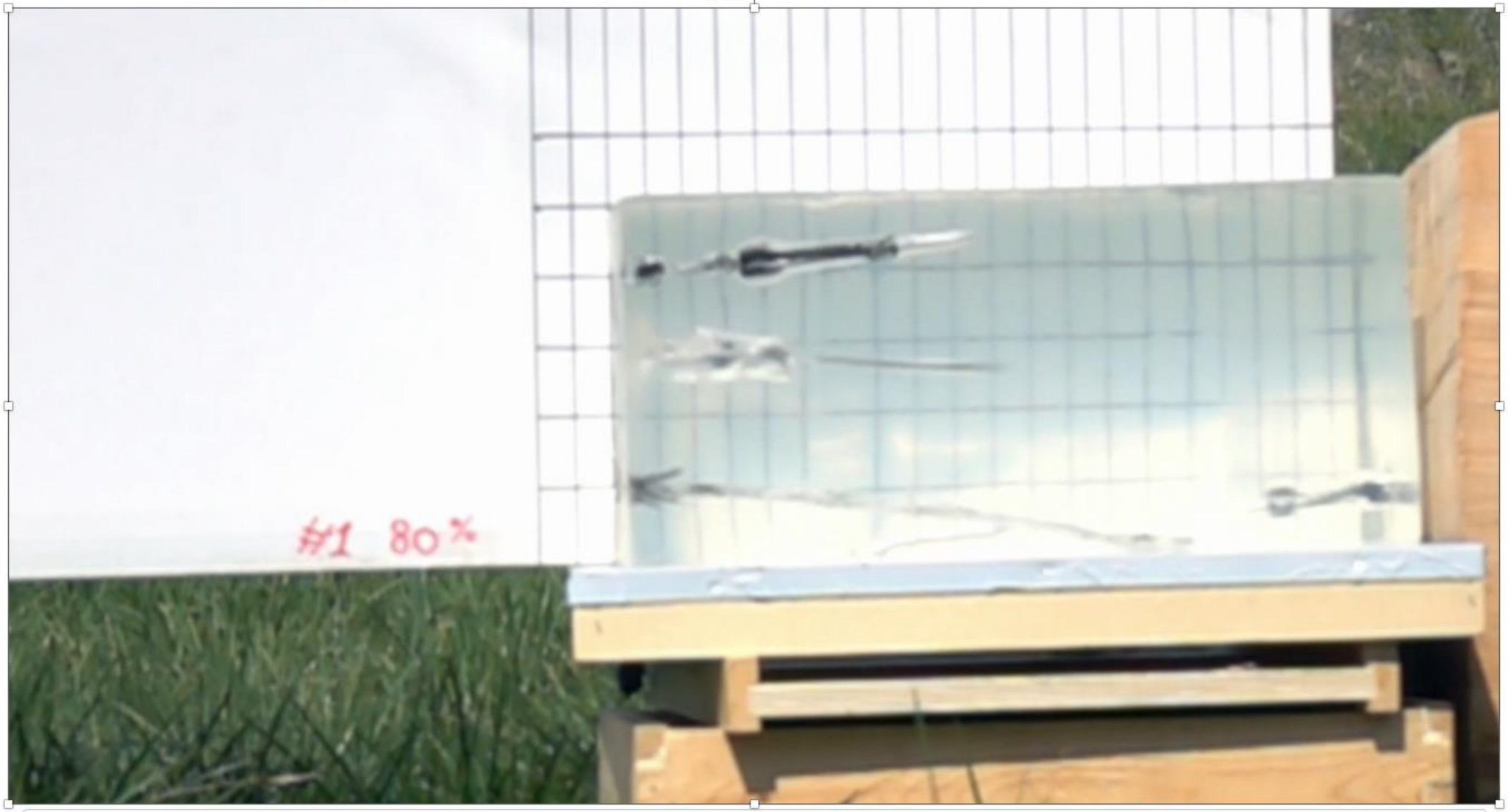

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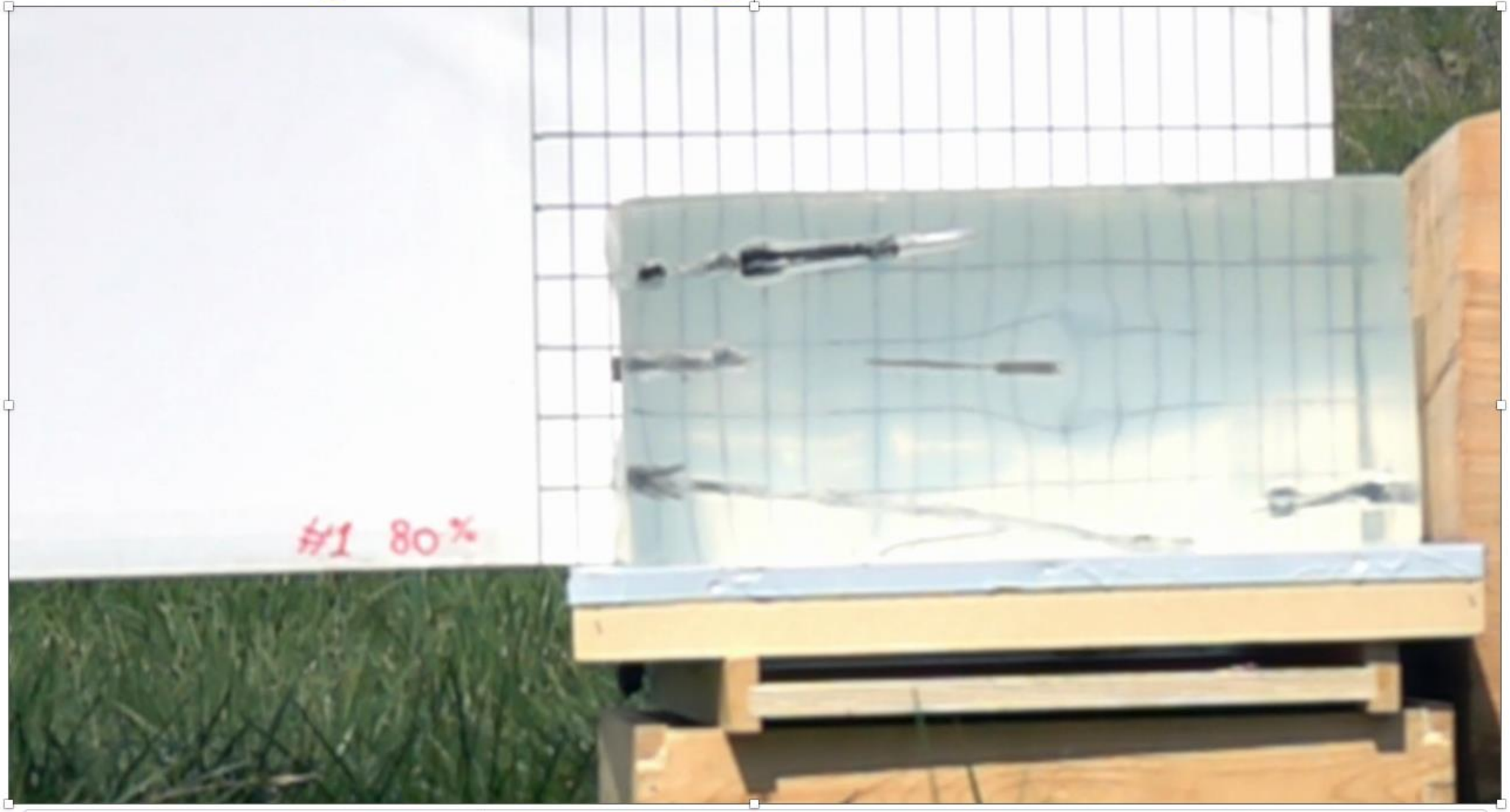

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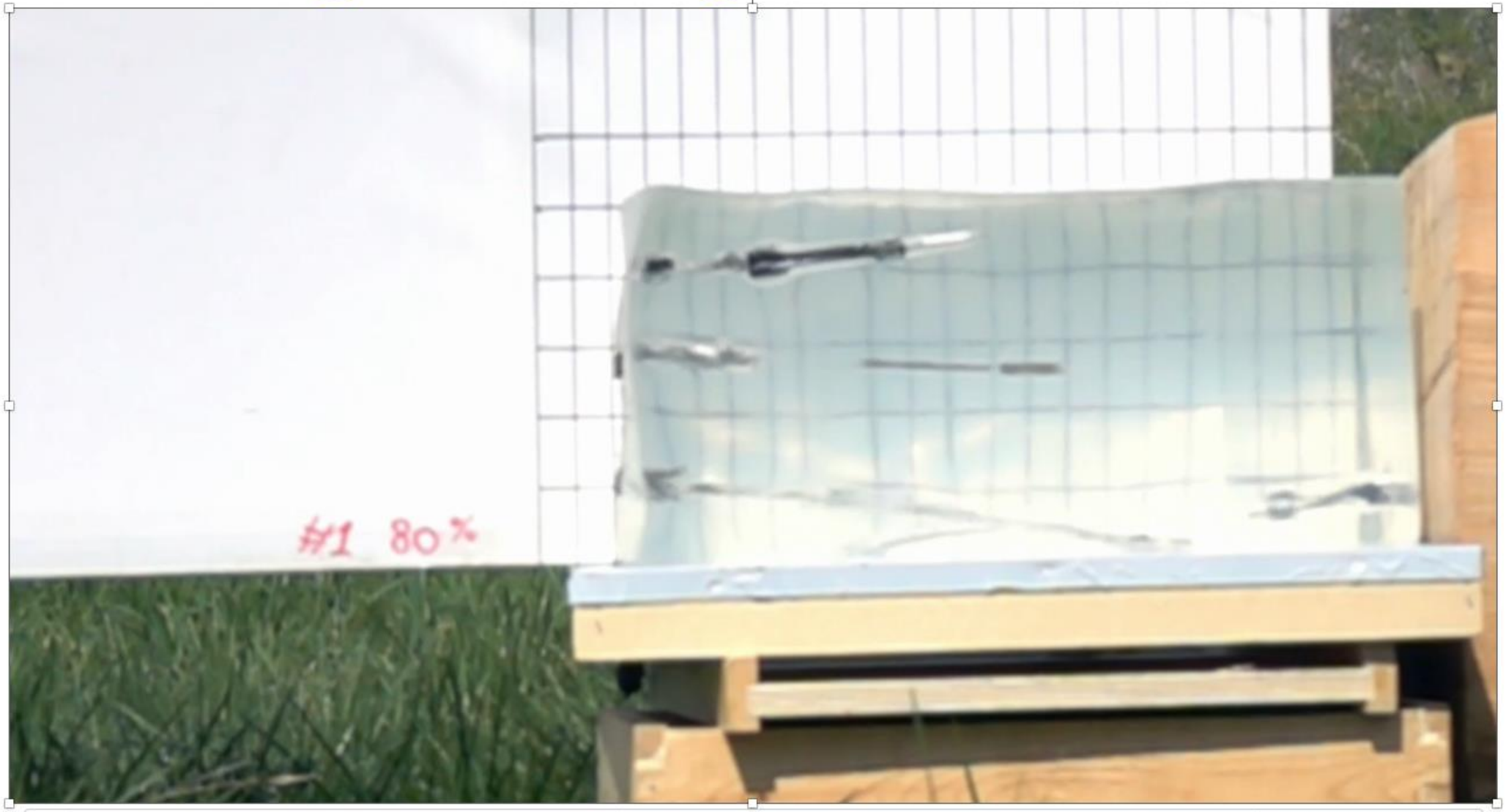

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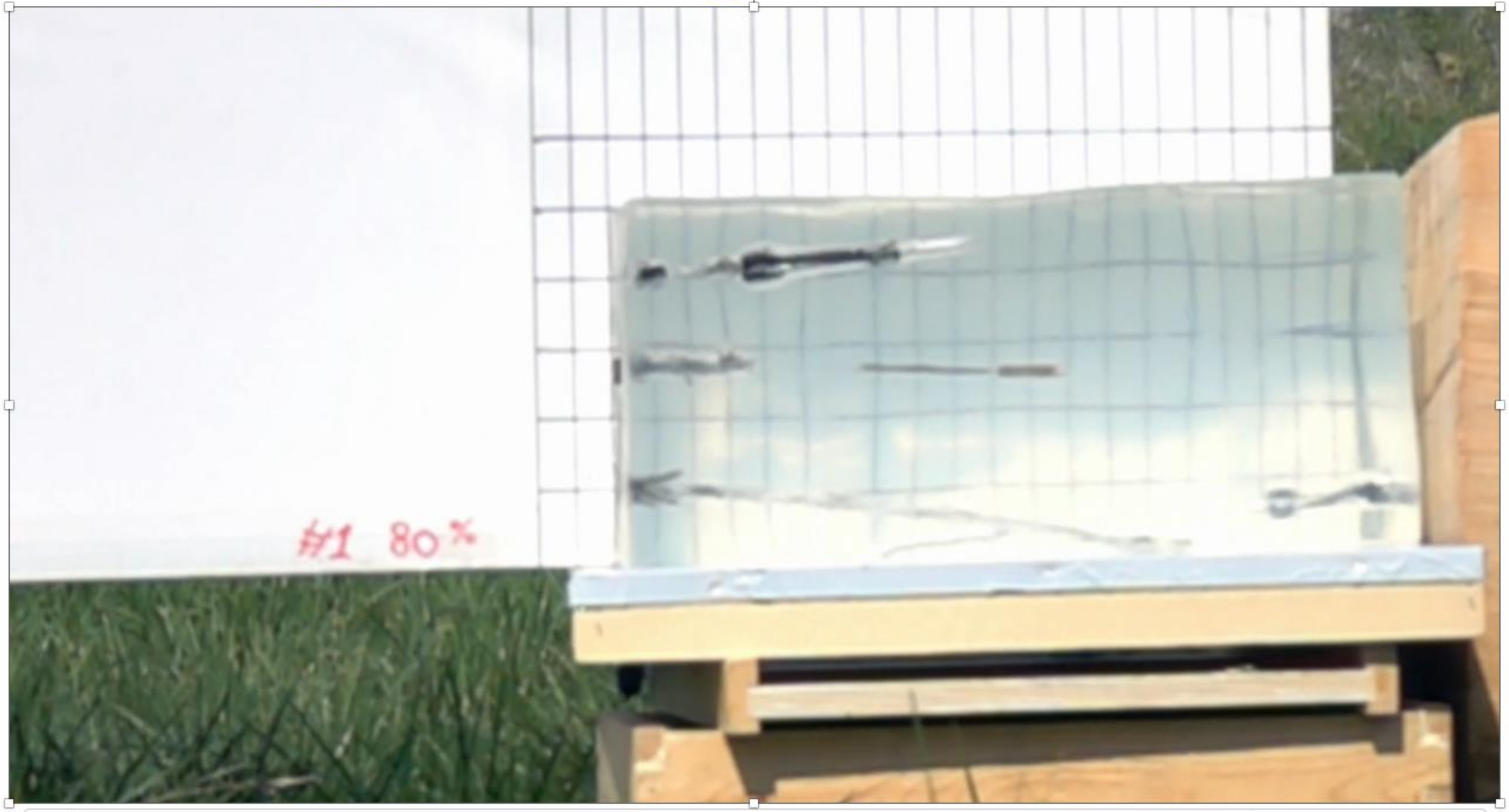
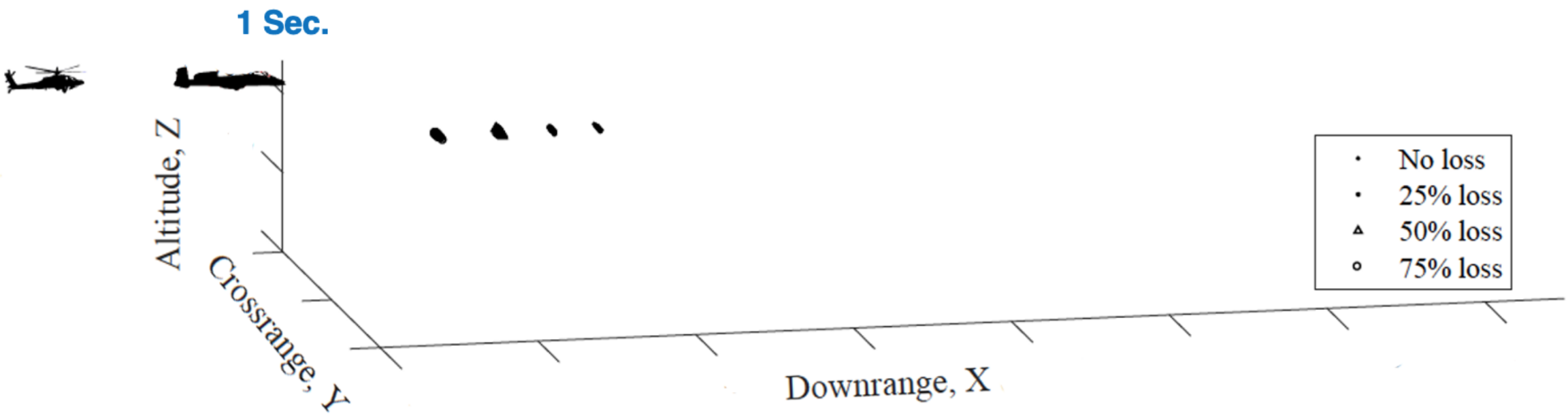


6. BASS Performance

Flight Safety/Airframe Strike Check

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



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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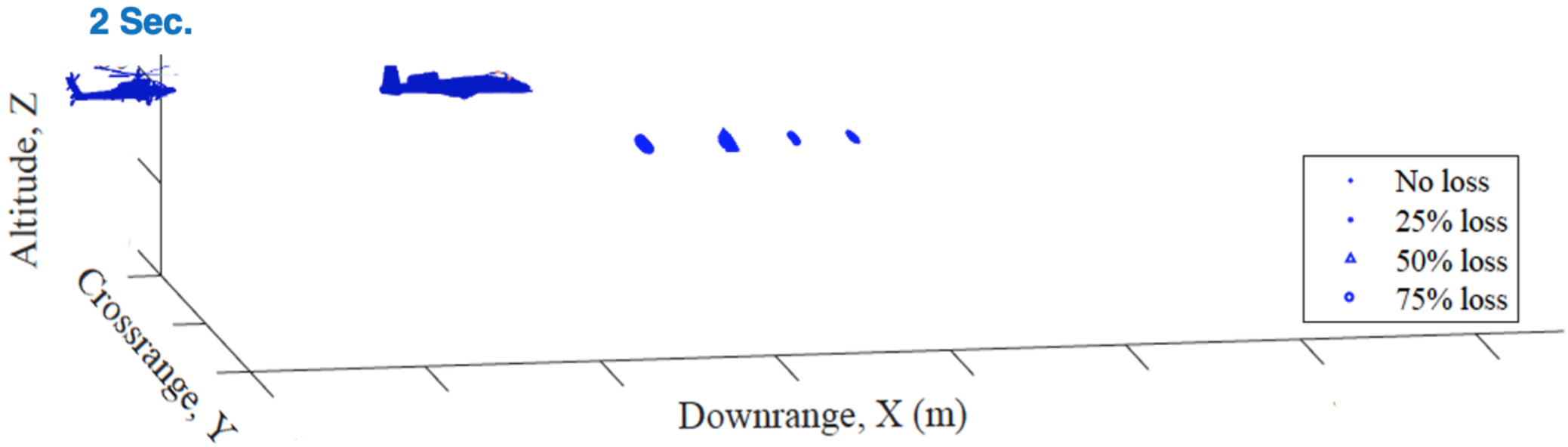

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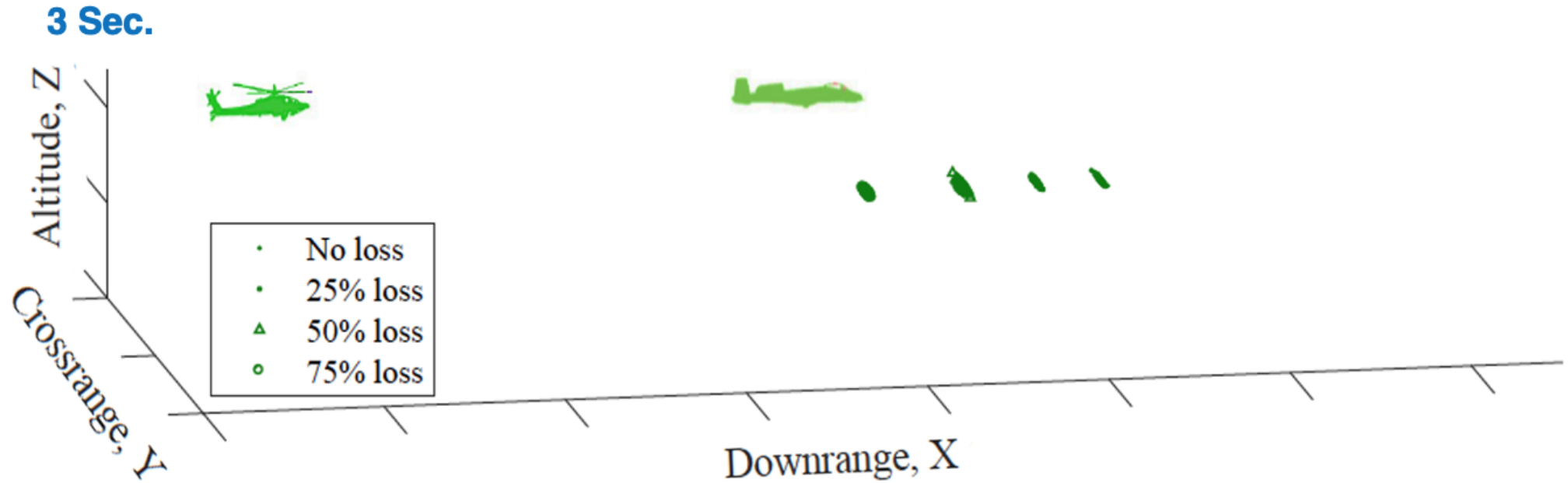

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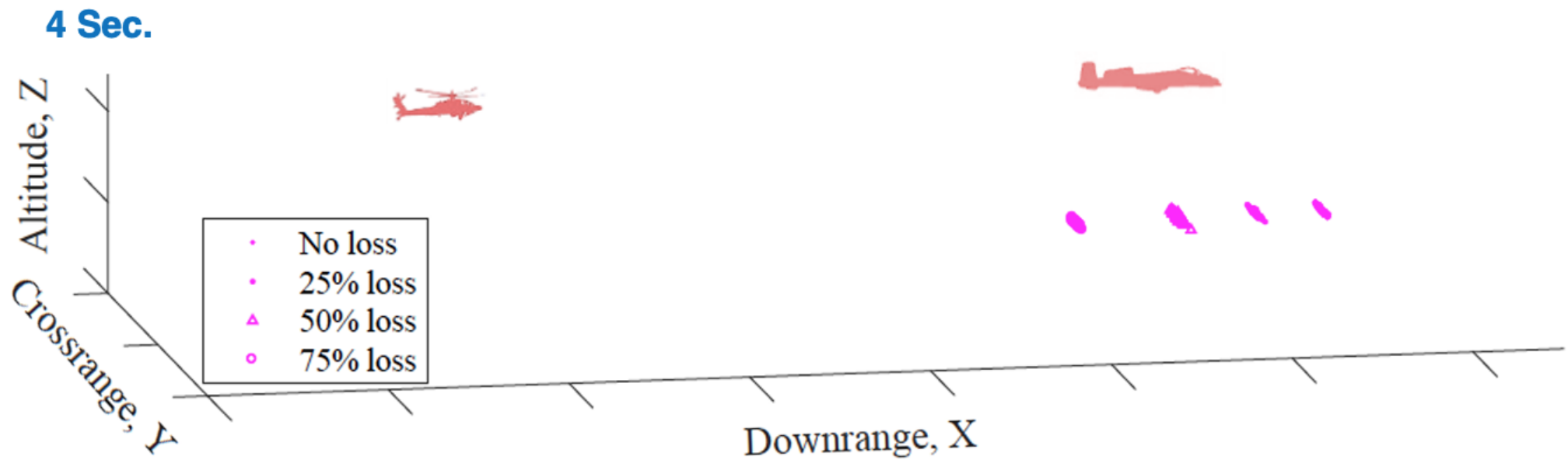

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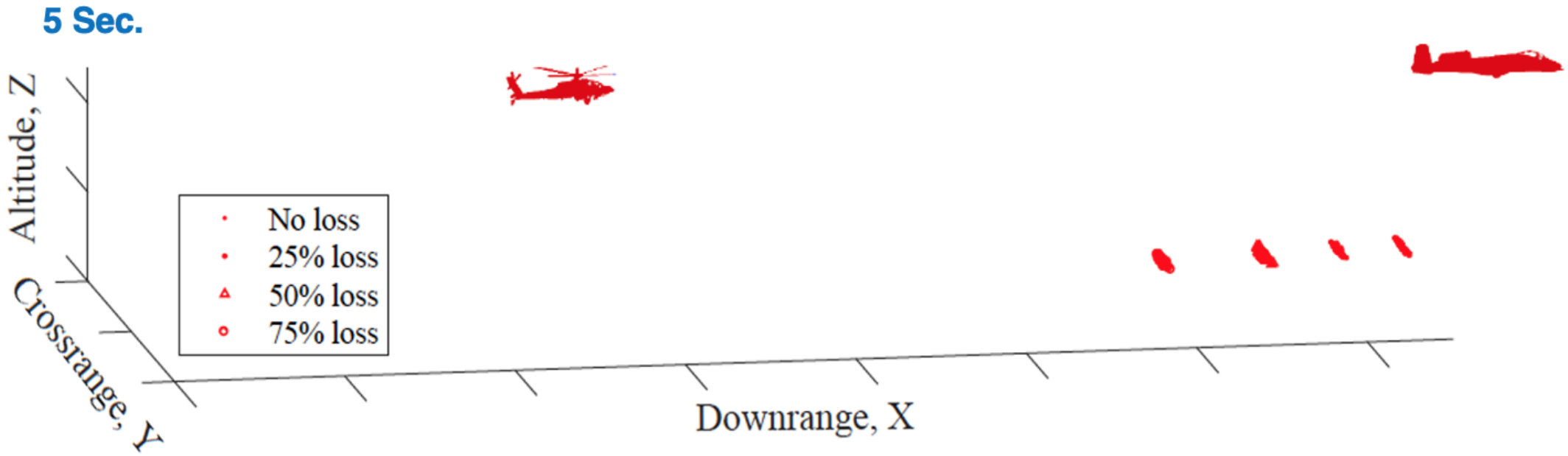

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6. BASS Performance

Relative Ballistic Coefficients

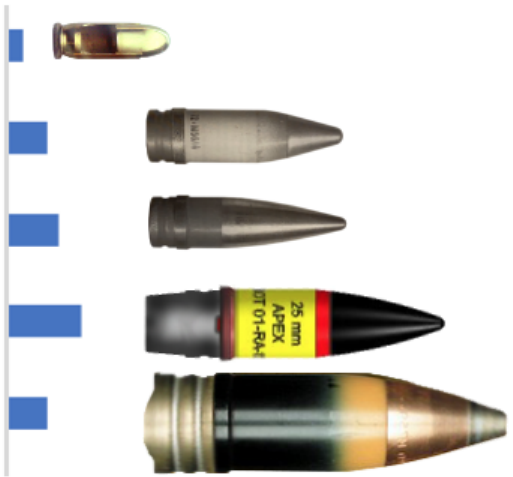
45 cal. 1st Aerial Combat 1913

20mm USMC/M53/56

20mm USAF/PGU-28

25mm USAF/PGU-47

30mm Army AH-64 M789



Aerial Gunnery Ammunition

6. BASS Performance

Relative Ballistic Coefficients

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20mm USAF/PGU-28

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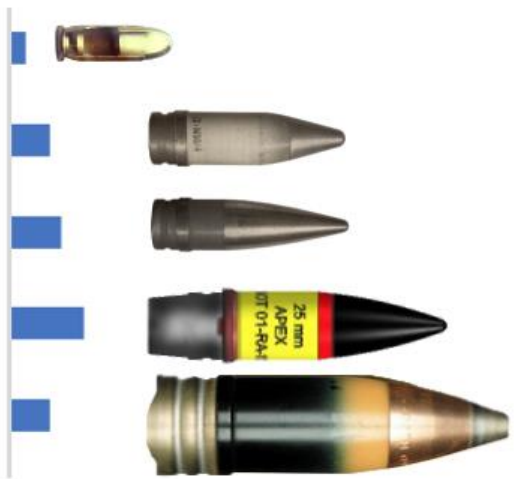
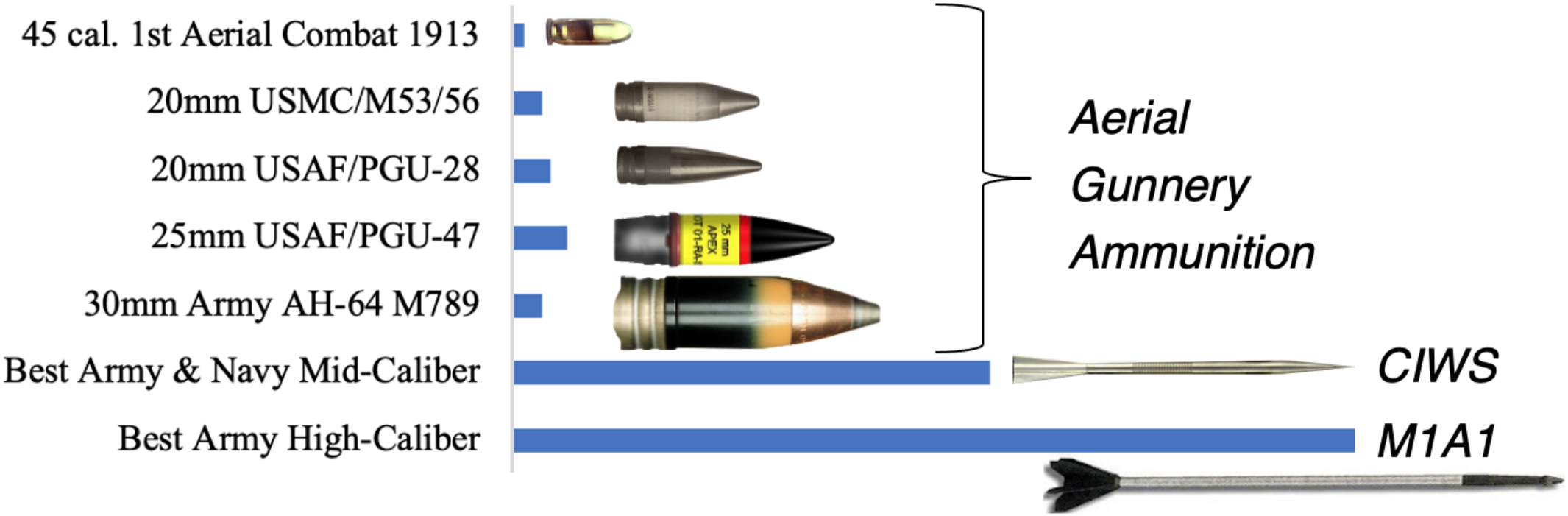


Aerial Gunnery Ammunition

100 yrs

6. BASS Performance

Relative Ballistic Coefficients



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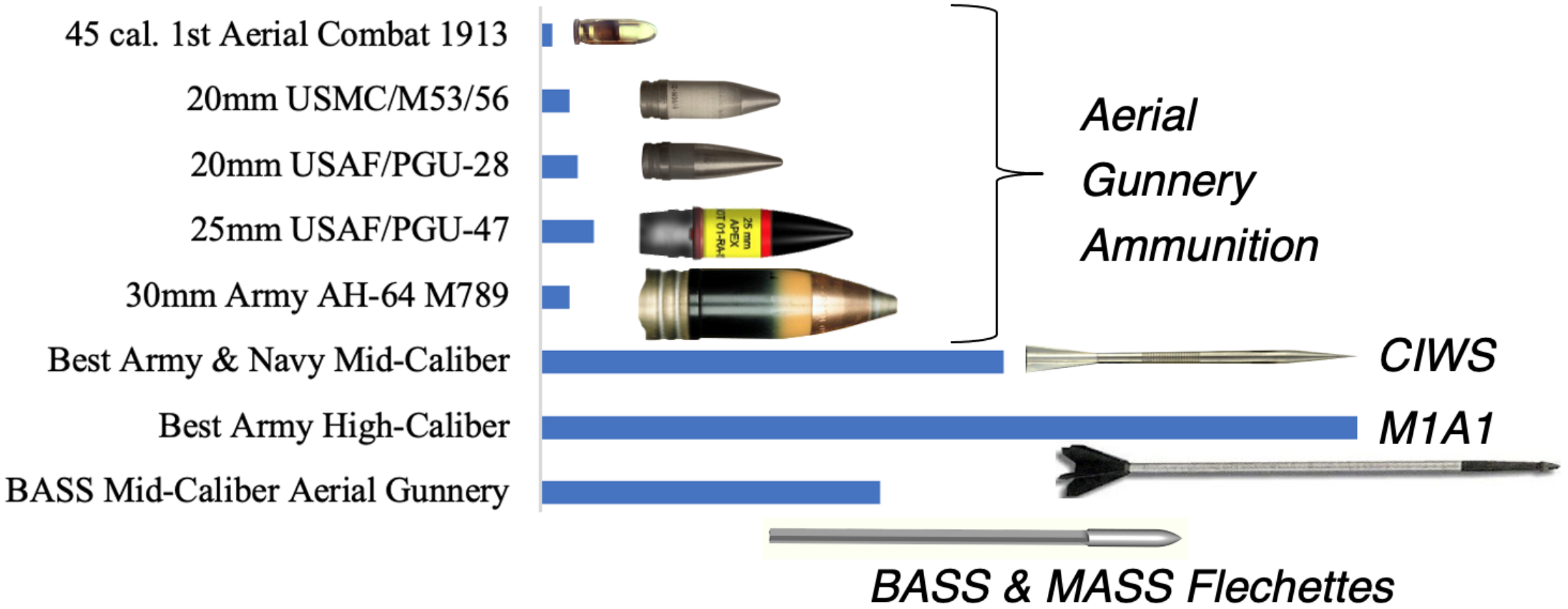
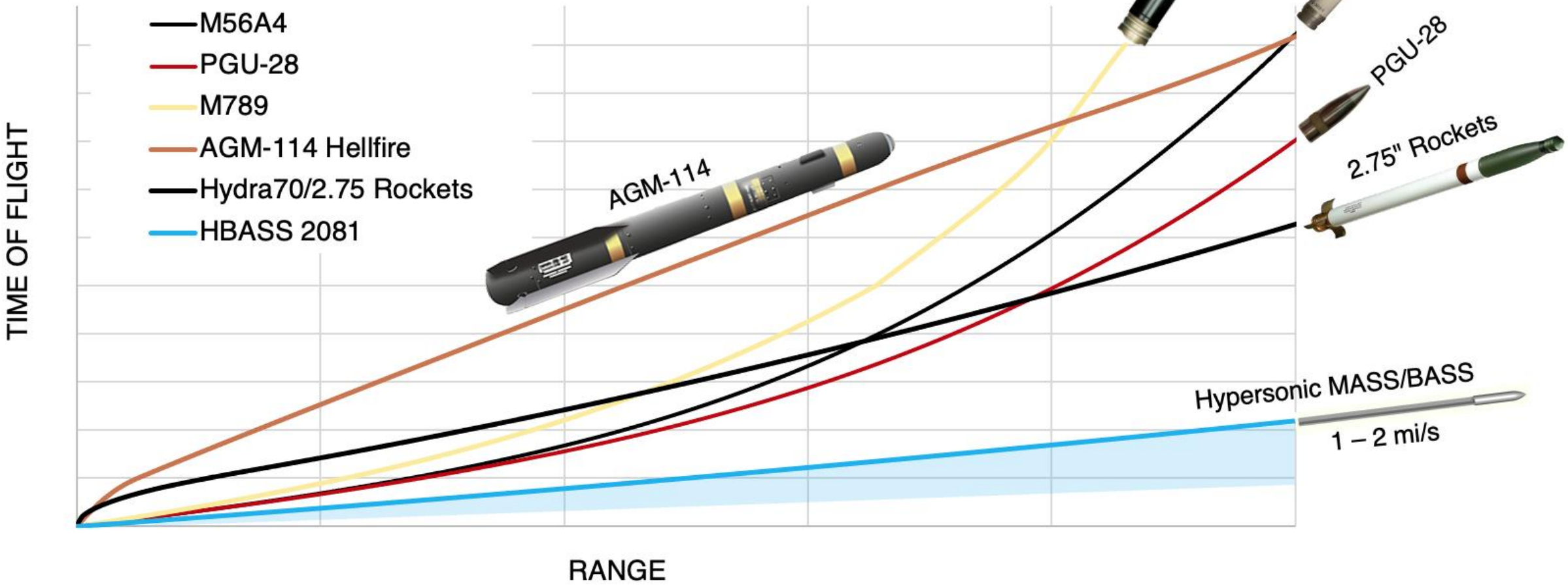


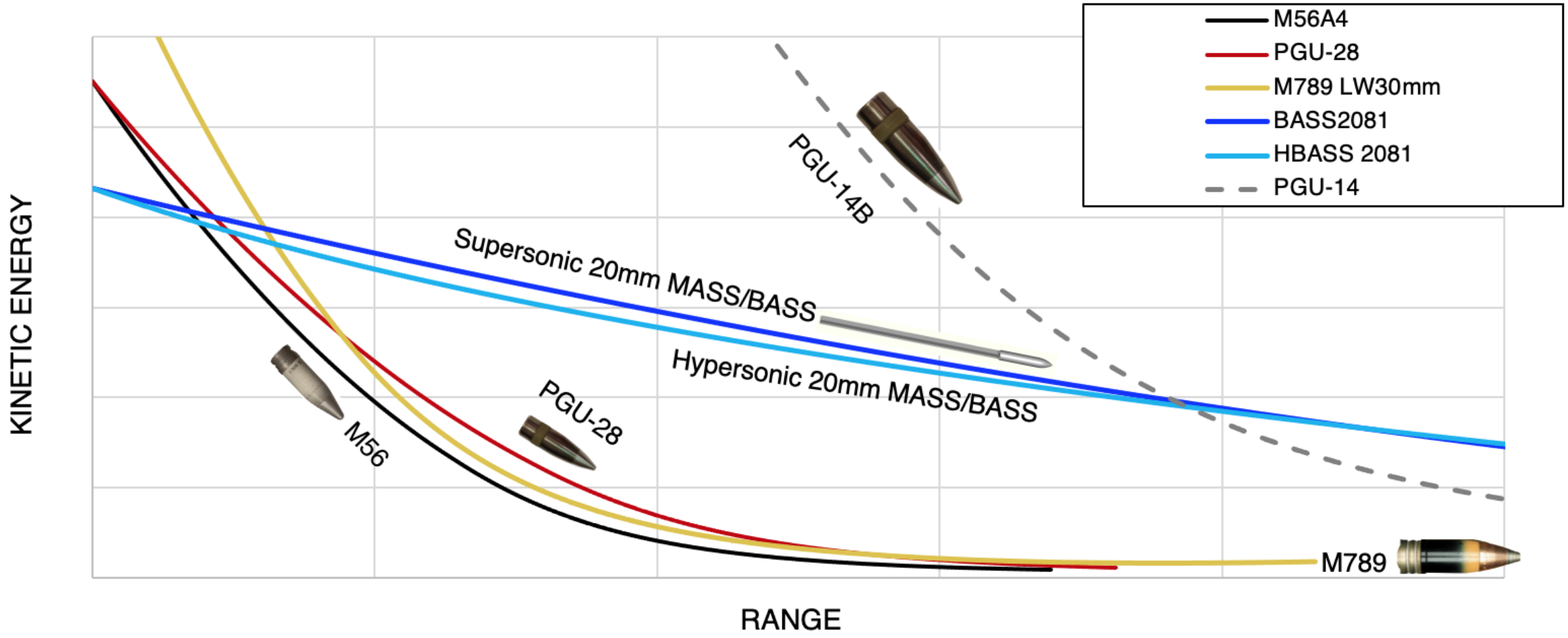
6. BASS Performance

Relative Weapon Times of Flight from USA/USMC Aircraft



6. BASS Performance

Relative Weapon Kinetic Energy from USA/USMC Aircraft



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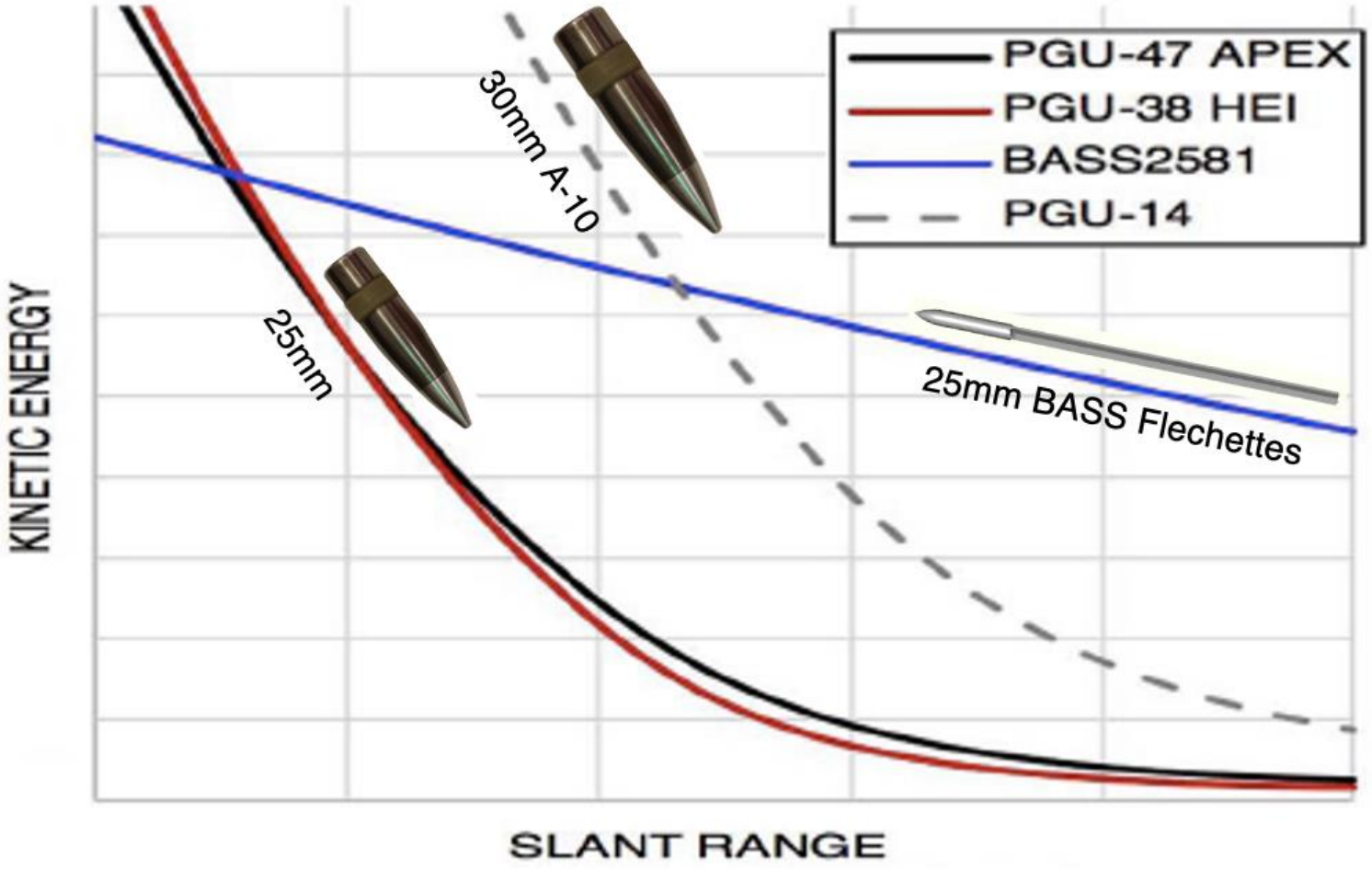
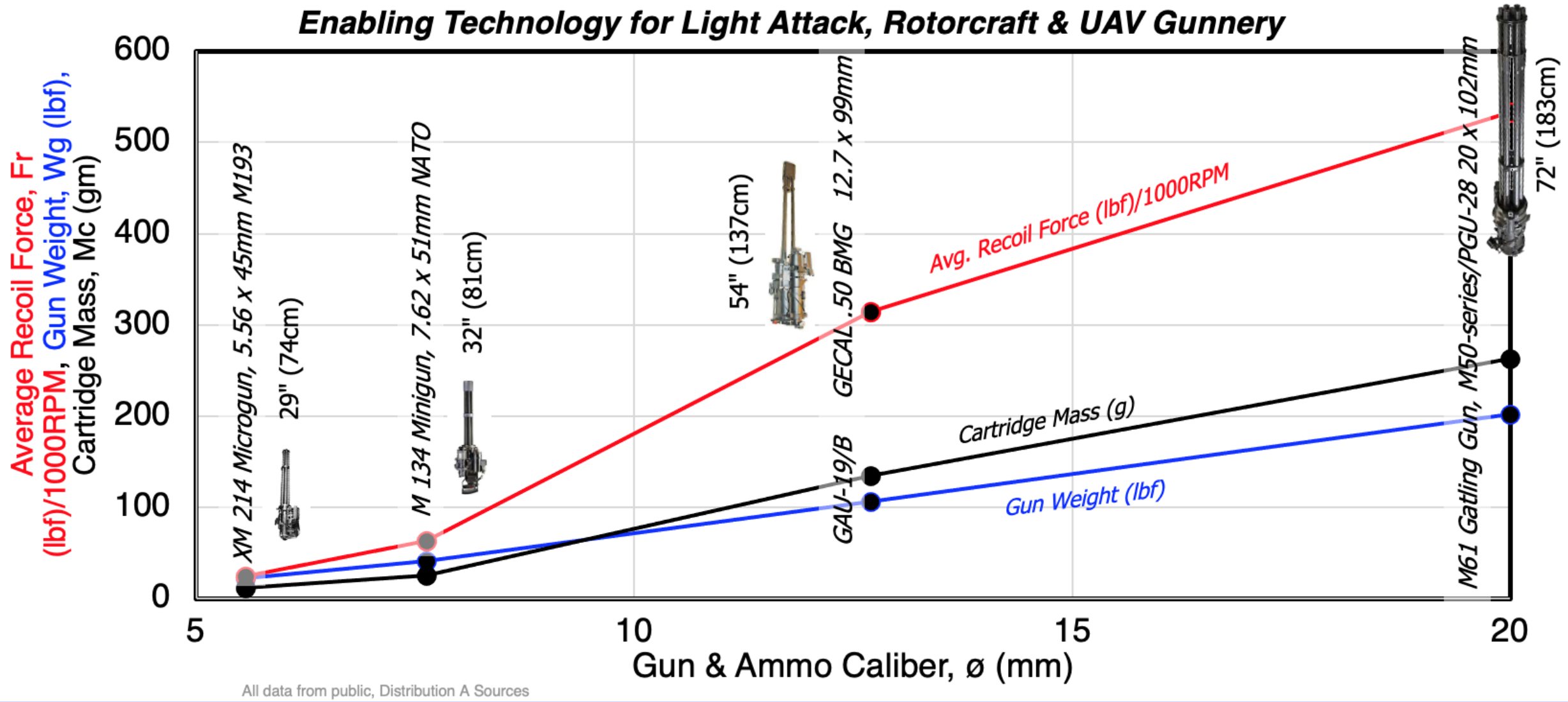


6. BASS Performance

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



All data from public, Distribution A Sources

6. BASS Performance

Enabling Technology for Light Attack, Rotorcraft & UAV Gunnery

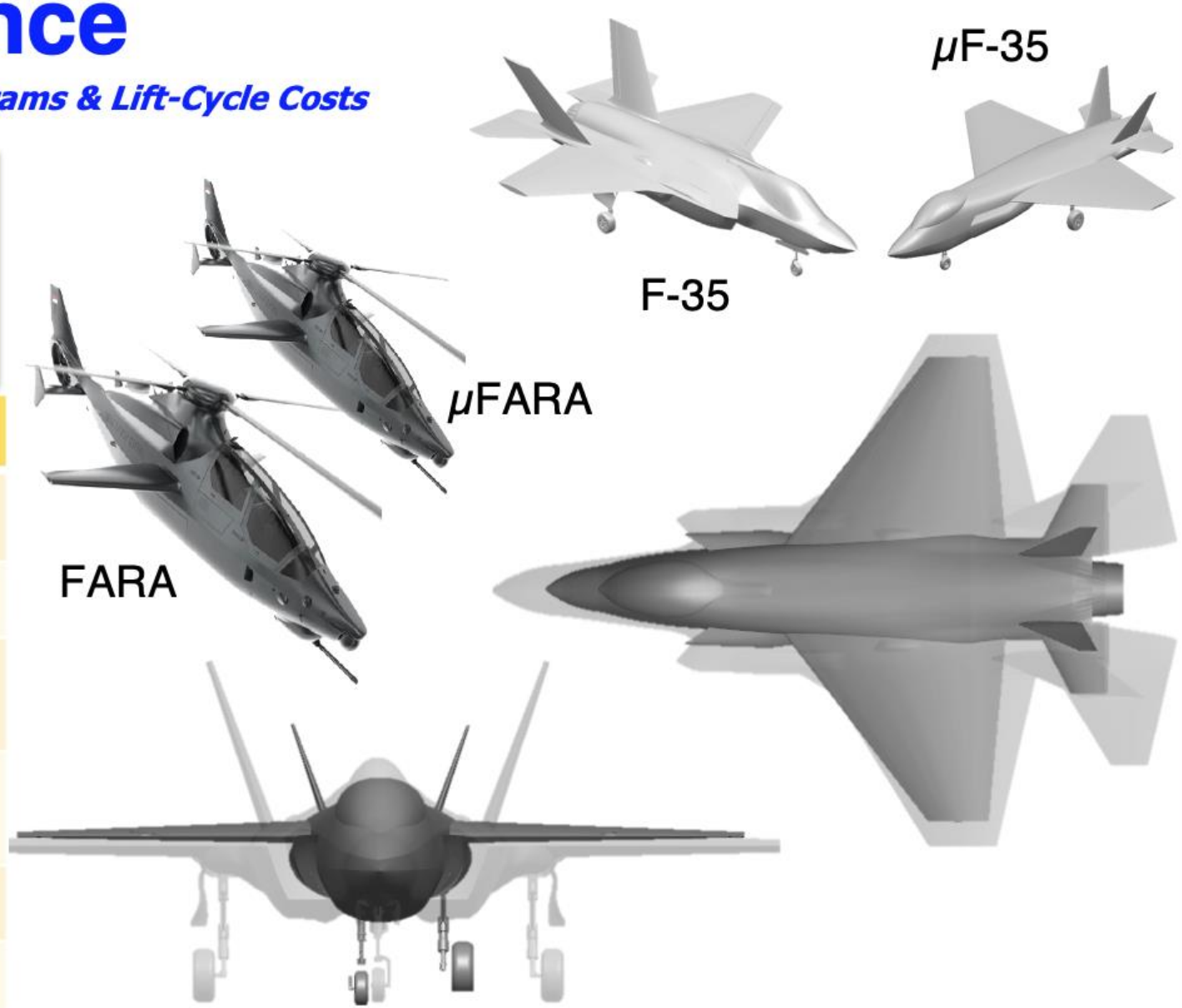
Smaller guns w/BASS rounds do the job of much larger guns w/conventional rounds

6. BASS Performance

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

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

Parameter	F-35A	μF-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%



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…

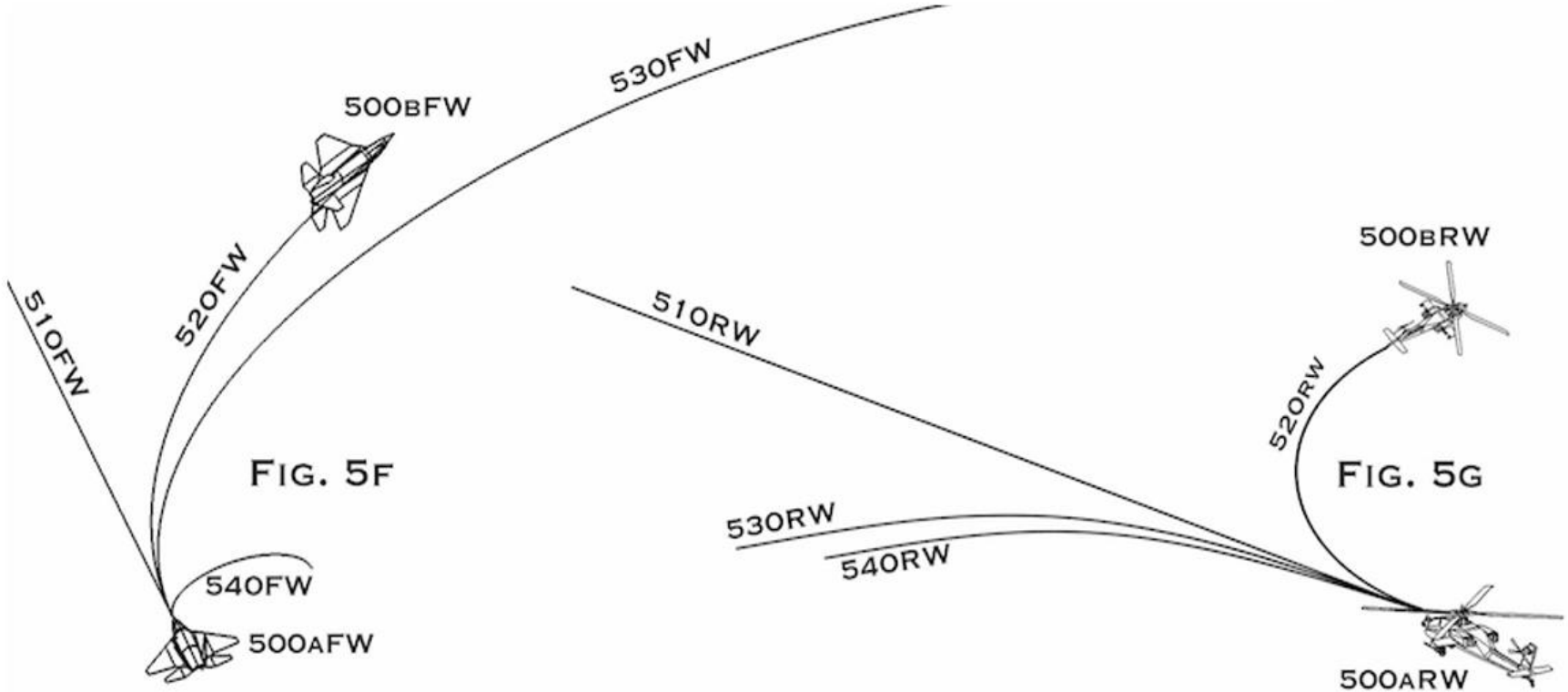
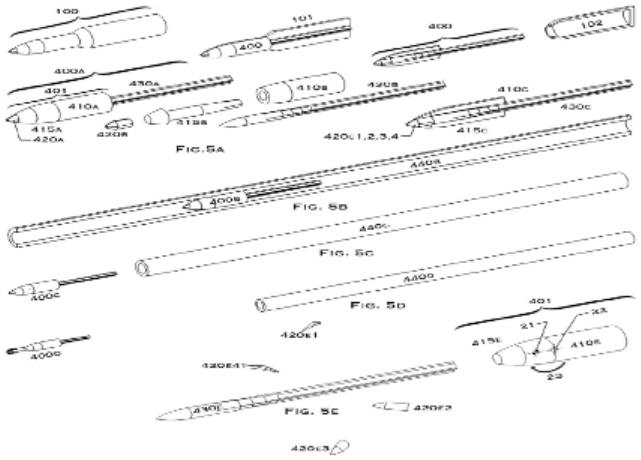


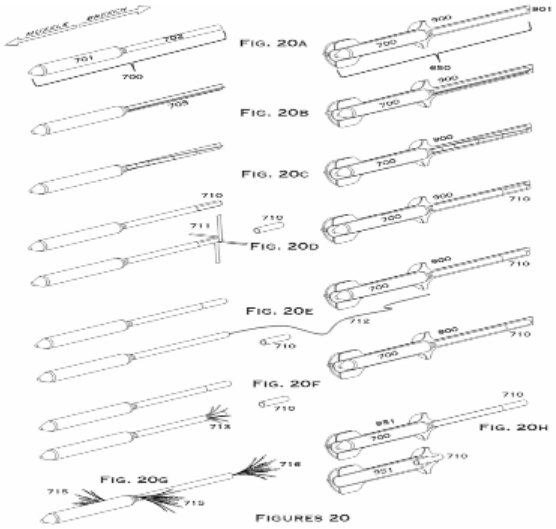
Image Source: PCT/IB2020/053899

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

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

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)

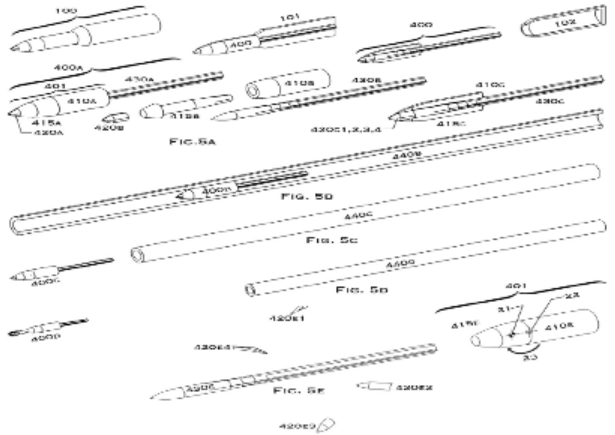
  -Short courses (1 hr to 2 days)

  -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)



Questions?

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