Hypersonic AC-130 Gunnery

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Paper No 1855683

Recognition:

Dr. Lauren Schumacher

Co-Inventor
Ballistic Aeromechanically Stable Sabot (BASS) Ammunition

Senior Systems Engineer, Raytheon

Structure:

i. *Motivation*

ii. *BASS Basics – Aeromechanics, Kinematics*

iii. *Design Philosophy & Configurations*

iv. *Basic Physics*

v. *General Performance*

vi. *Intellectual Property Filings, Claims & Status*

vii. *Only Real Way Forward: ROC*

i. Motivation for Hypersonic AC-130 Gunnery:

i. Engage targets from outside of threat range

ii. Cut round time of flight by > 50%

iii. Increase KE on target by > 50%

iv. Allow smaller caliber guns & ammo to do the job of larger guns

v. More rounds on target for same weight & volume

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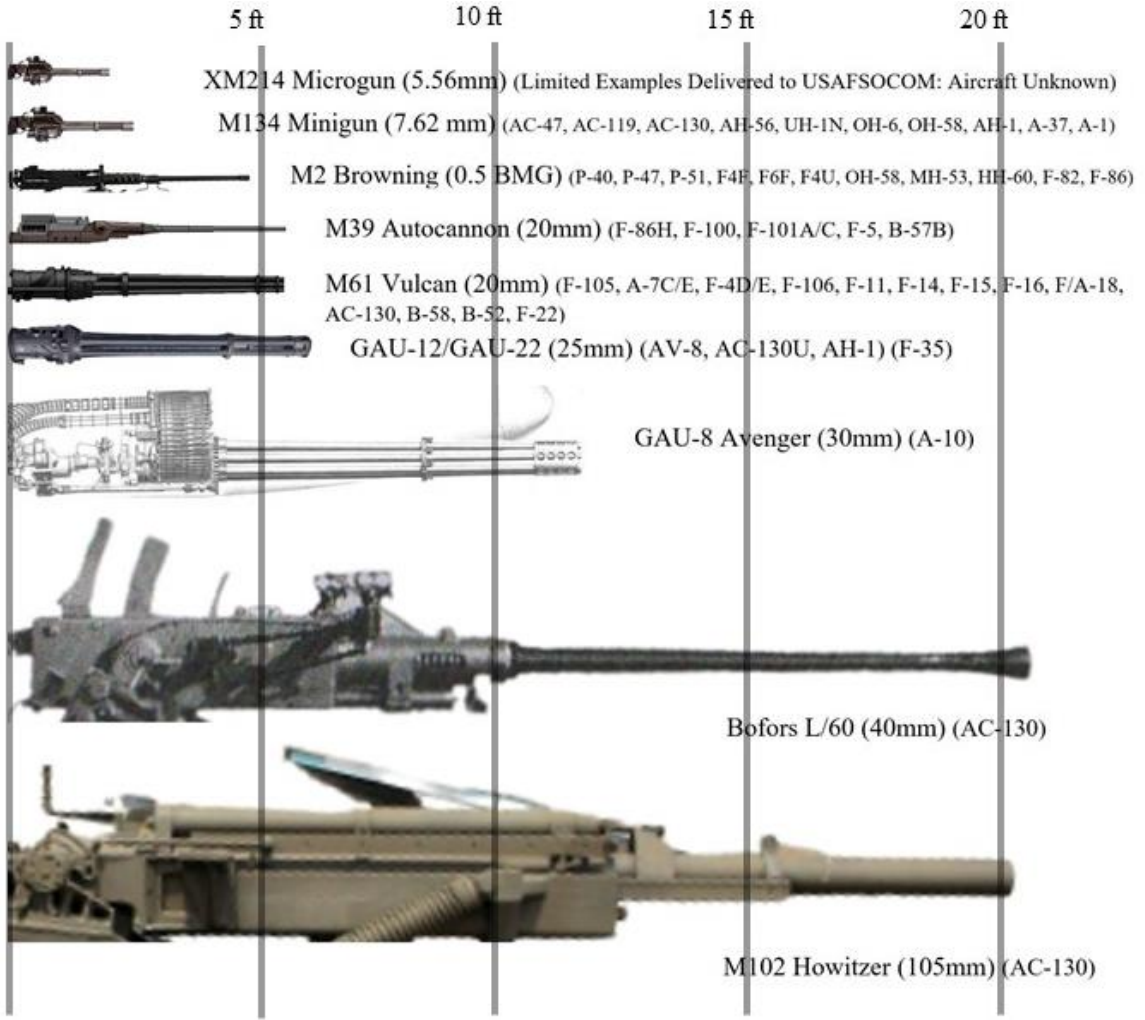
Aerospace Engineering

i. Motivation:
Give Smaller Guns & Ammo Greater Lethality & Range than Larger Guns & Ammo

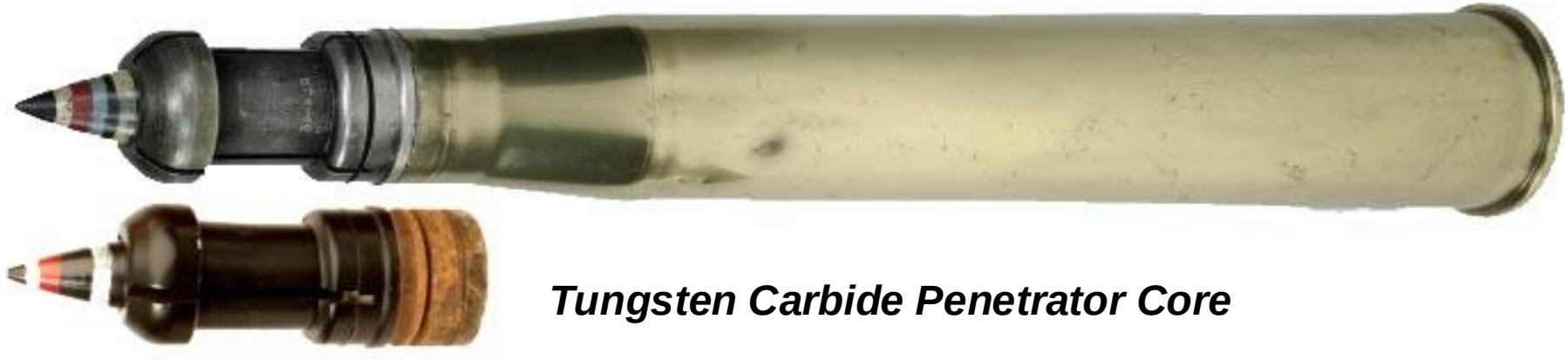


i. Motivation:

The same reason why the Allies first fielded discarding sabot ammunition…

British QF 6-Pounder Antitank Gun 1944

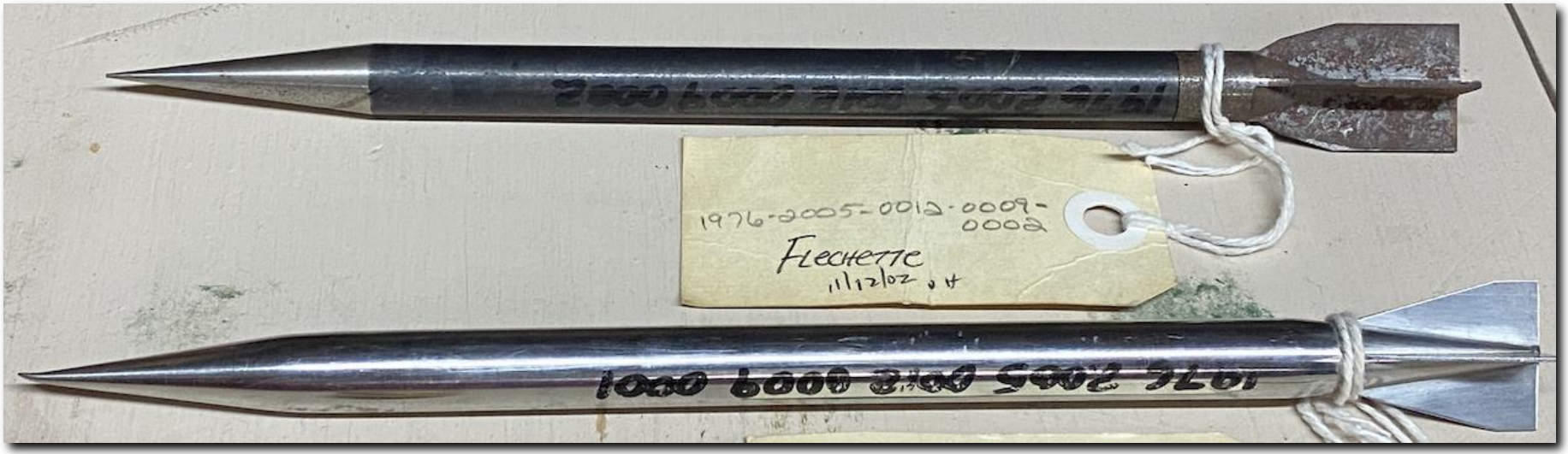
Armor-Piercing Discarding Sabot (APDS Round)



Tungsten Carbide Penetrator Core

ii. Ballistic Aeromechanically Stable Sabot (BASS) Round Basics

USAF Worked Hard 1948 – 1998 to develop discarding sabot ammunition for aerial gunnery:



ii. Ballistic Aeromechanically Stable Sabot (BASS) Round Basics

USAF Worked Hard 1948 – 1998 to develop discarding sabot ammunition for aerial gunnery:

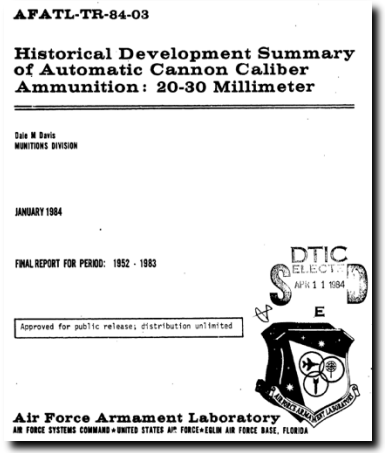
Dale M.Davis

ii. Ballistic Aeromechanically Stable Sabot (BASS) Round Basics

USAF Worked Hard 1948 – 1998 to develop discarding sabot ammunition for aerial gunnery:

Flechette ammunition by its nature must be sabot launched. Herein lies another advantage and its major disadvantage. The advantage of sabot launch is, of course, that the projectile has a low sectional density while in the gun bore and can be easily accelerated to velocities not readily attainable with conventional shot. The disadvantage of sabots is that they must be discarded at muzzle exit, and these rapidly decelerating sabots pose an unacceptable hazard to launching aircraft.

*-**Dale Davis**, Director, USAF Munitions Directorate 1984*



AFATL-TR-84-03

Historical Development Summary of Automatic Cannon Caliber Ammunition: 20-30 Millimeter

Dale M Davis
MUNITIONS DIVISION

JANUARY 1984

FINAL REPORT FOR PERIOD: 1952 - 1983

DTIC ELECTE APR 11 1984 E

Approved for public release; distribution unlimited

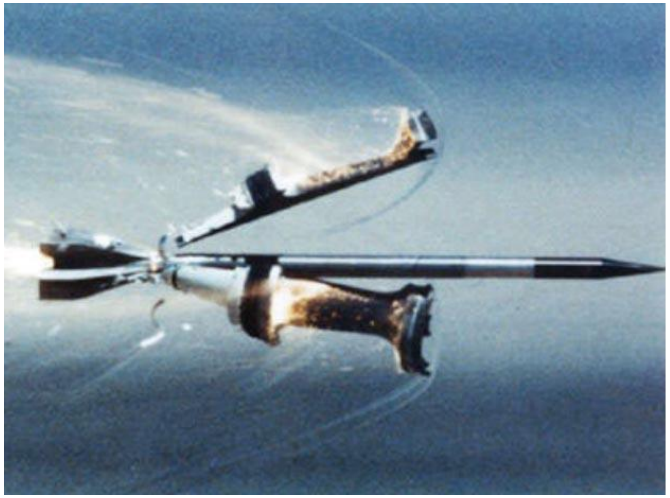
Air Force Armament Laboratory
AIR FORCE SYSTEMS COMMAND • UNITED STATES AIR FORCE • EGLIN AIR FORCE BASE, FLORIDA

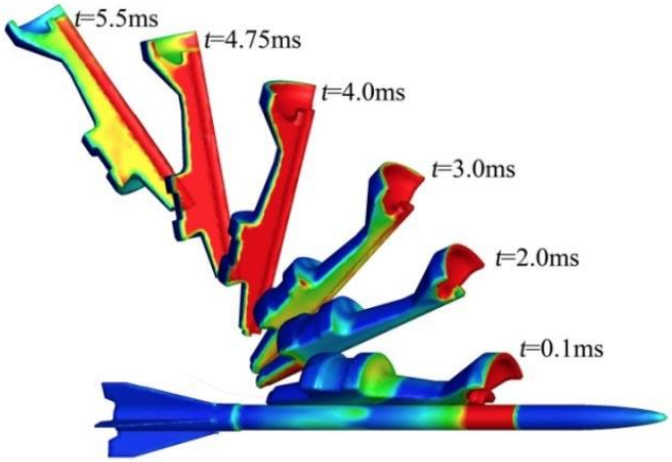
Dale M.Davis

ii. Ballistic Aeromechanically Stable Sabot (BASS) Round Basics[10]

Problems with Aircraft & Sabots

Conventional Discarding Sabot: Aeromechanically unstable by necessity...

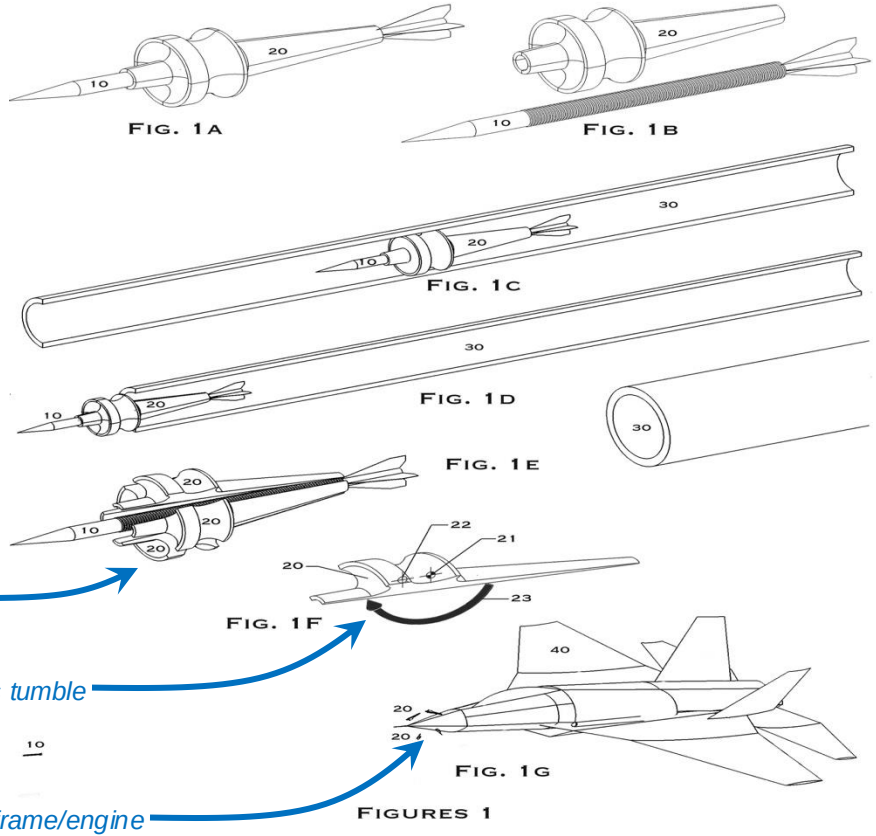




ii. Ballistic Aeromechanically Stable Sabot (BASS) Round Basics

Why a conventional sabot won't work for aerial gunnery

Dale Davis' Observations:



Conventional sabot pieces are designed to be aeromechanically unstable, by necessity, to separate from projectile

Aeromechanically unstable sabot pieces tumble

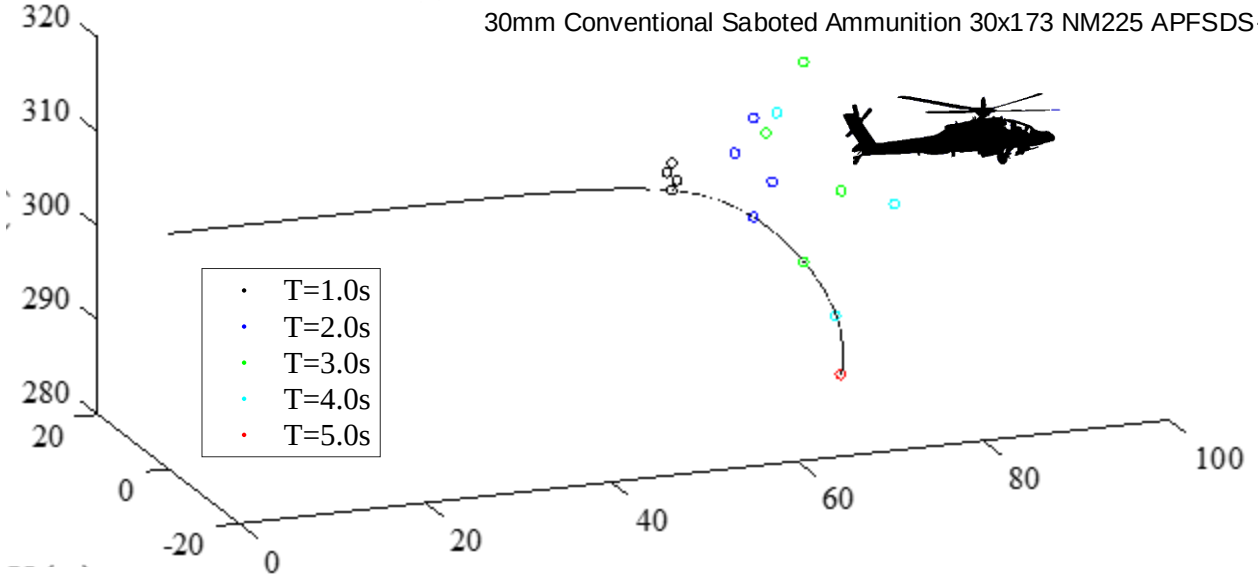
...and strike airframe/engine

Image Source: PCT/IB2020/053899

ii. Ballistic Aeromechanically Stable Sabot (BASS) Round Basics

Problems with Aircraft & Sabots

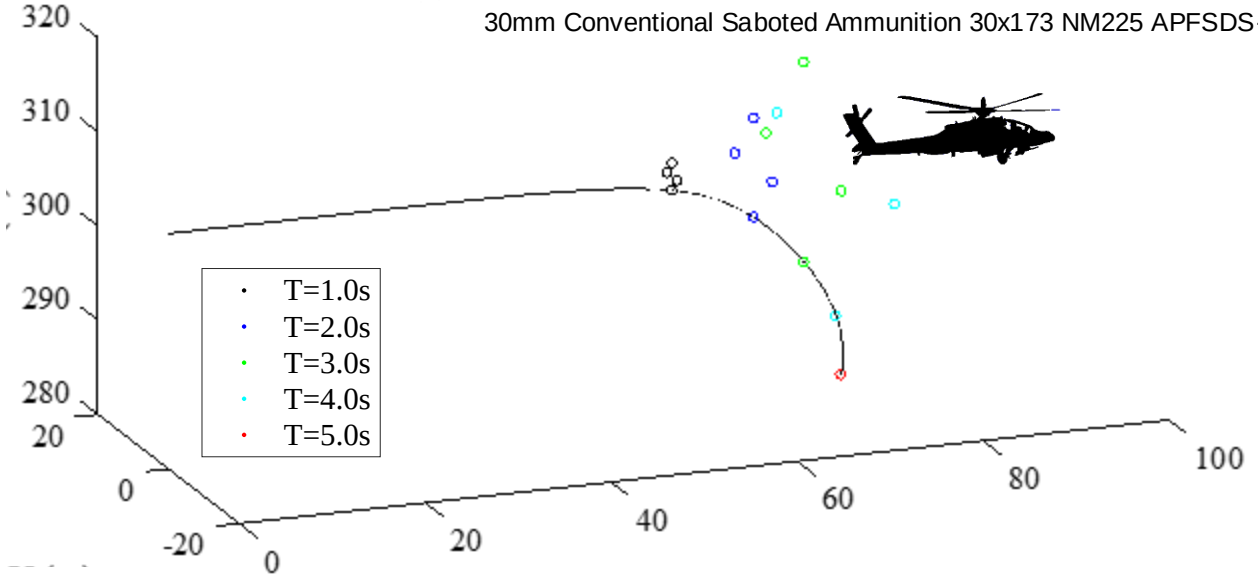
The Great Show Stopper for conventional sabots:



ii. Ballistic Aeromechanically Stable Sabot (BASS) Round Basics

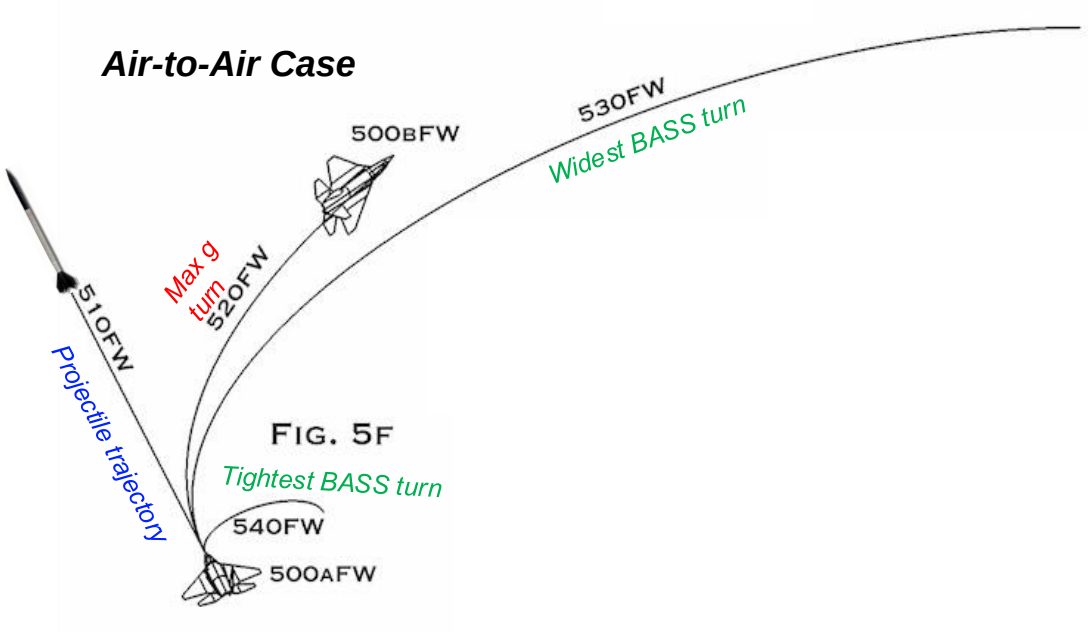
The Great Show Stopper for conventional sabots:

Flight Safety



Ballistic Aeromechanically Stable Sabot (BASS) Round Basics

BASS Rounds: Design the Sabot to clear the launching aircraft

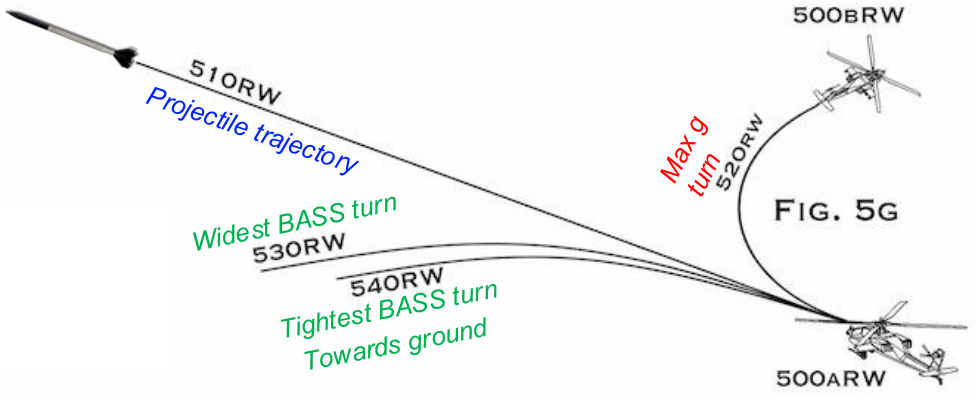


ii. Ballistic Aeromechanically Stable Sabot (BASS) Round Basics

Aeromechanics, Kinematics

BASS Rounds: Design the Sabot to clear the launching aircraft

Ground Attack Case



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Aeromechanics, Kinematics

BASS Rounds: Design the Sabot to clear the launching aircraft

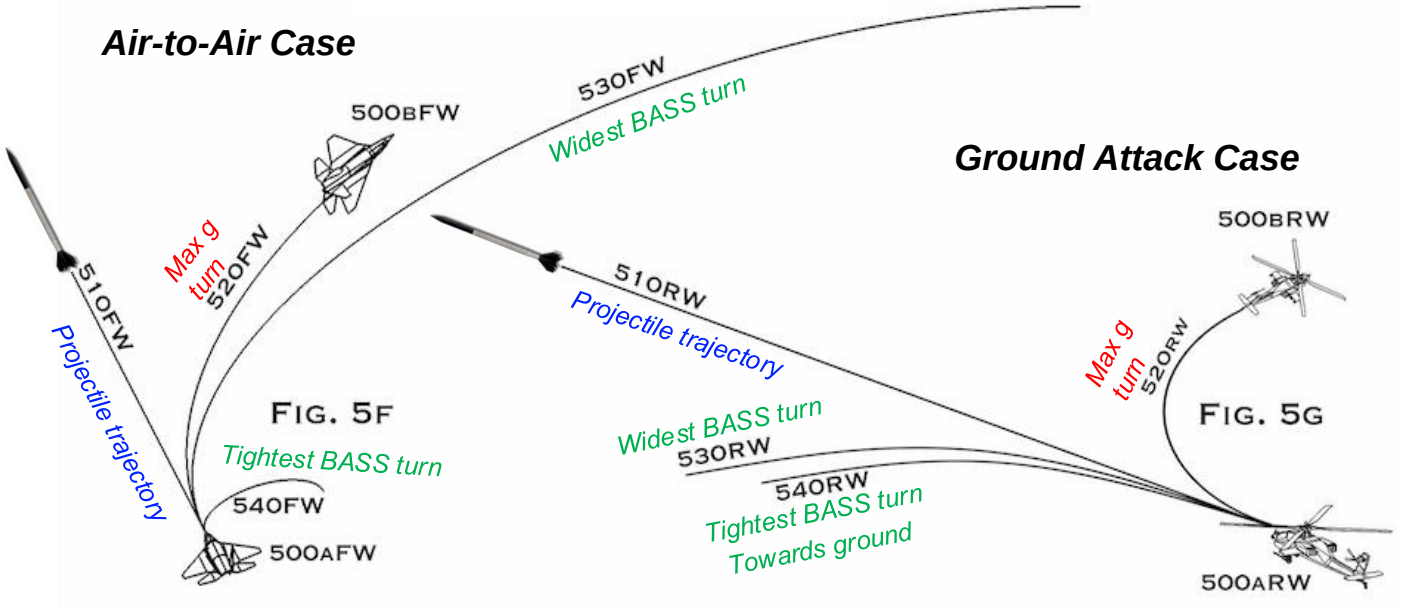

Image Source: PCT/IB2020/053899

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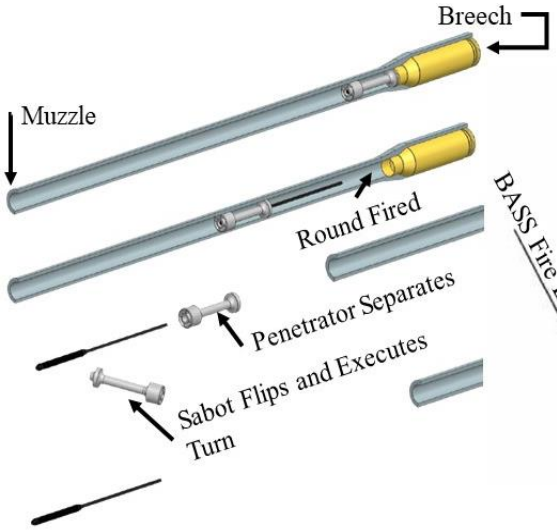
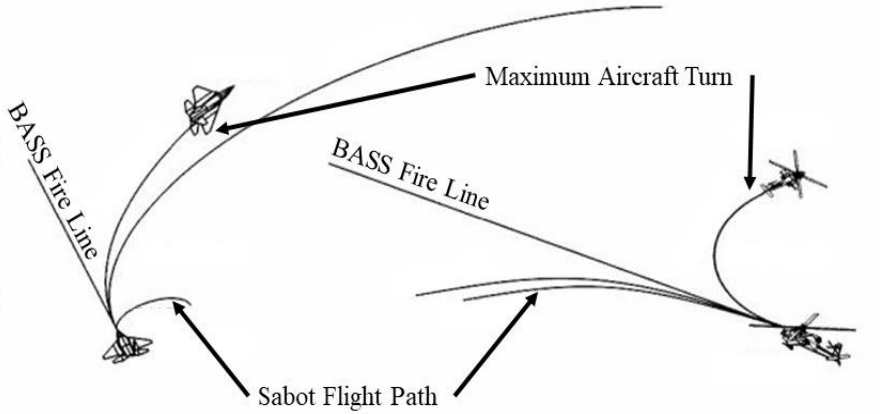
Aeromechanics, Kinematics

BASS Rounds: Design the Sabot to clear the launching aircraft





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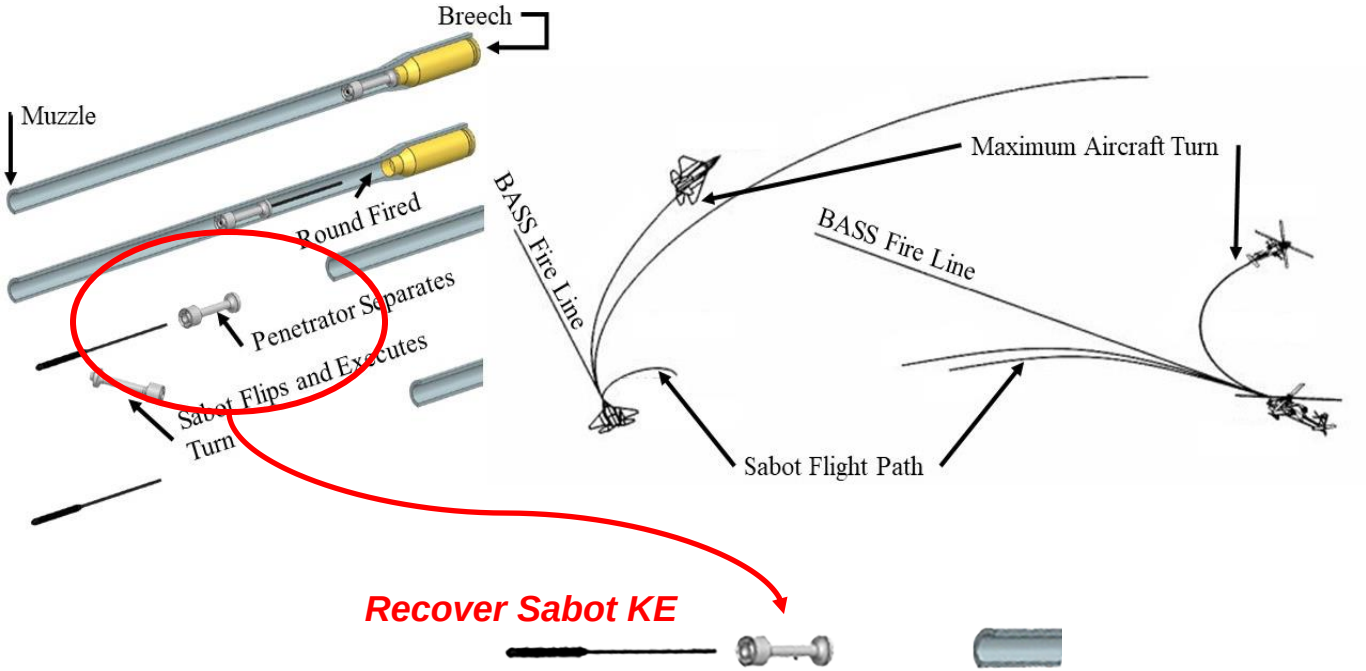
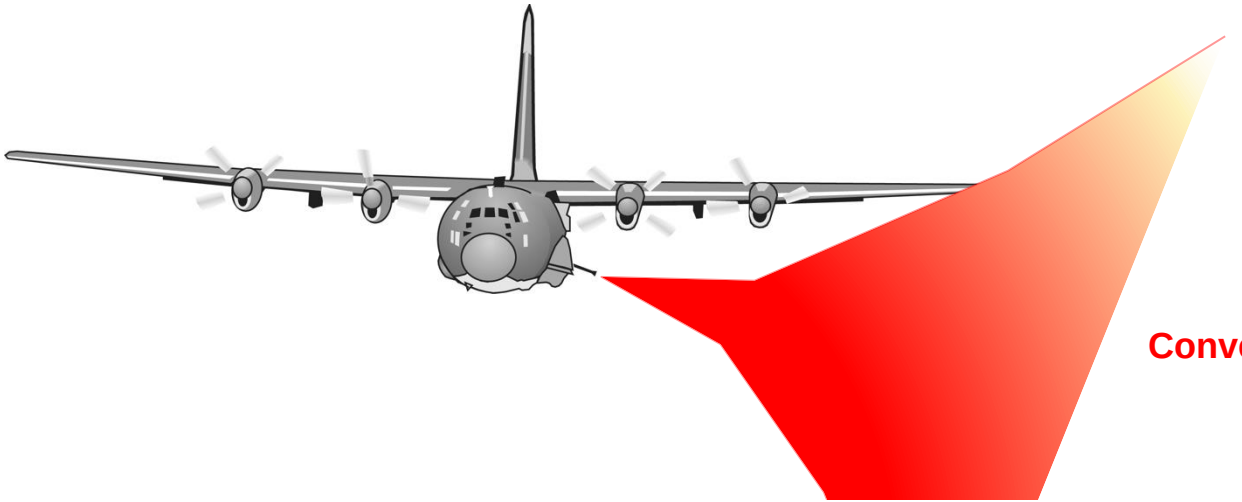
Aeromechanics, Kinematics

BASS Rounds: Design the Sabot to clear the launching aircraft



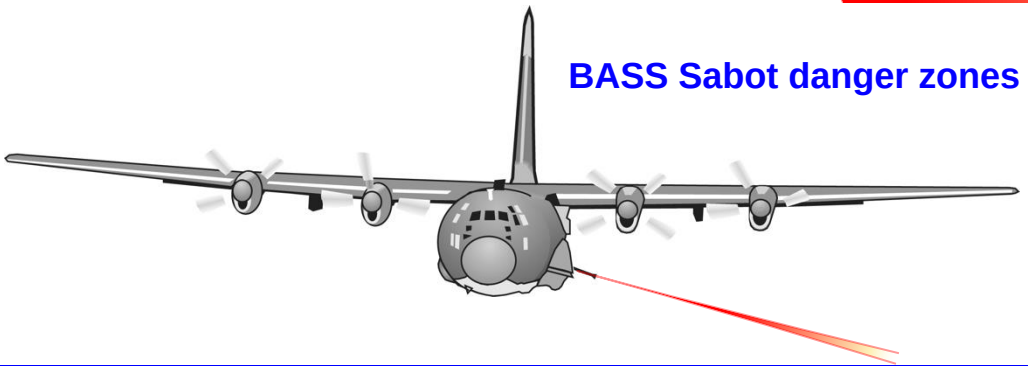
ii. Ballistic Aeromechanically Stable Sabot (BASS) Round Basics

Use BASS Configuration to clear all airframe compoents



Conventional Sabot danger zone

BASS Sabot danger zones < 0.5°



iii. BASS Design Philosophy

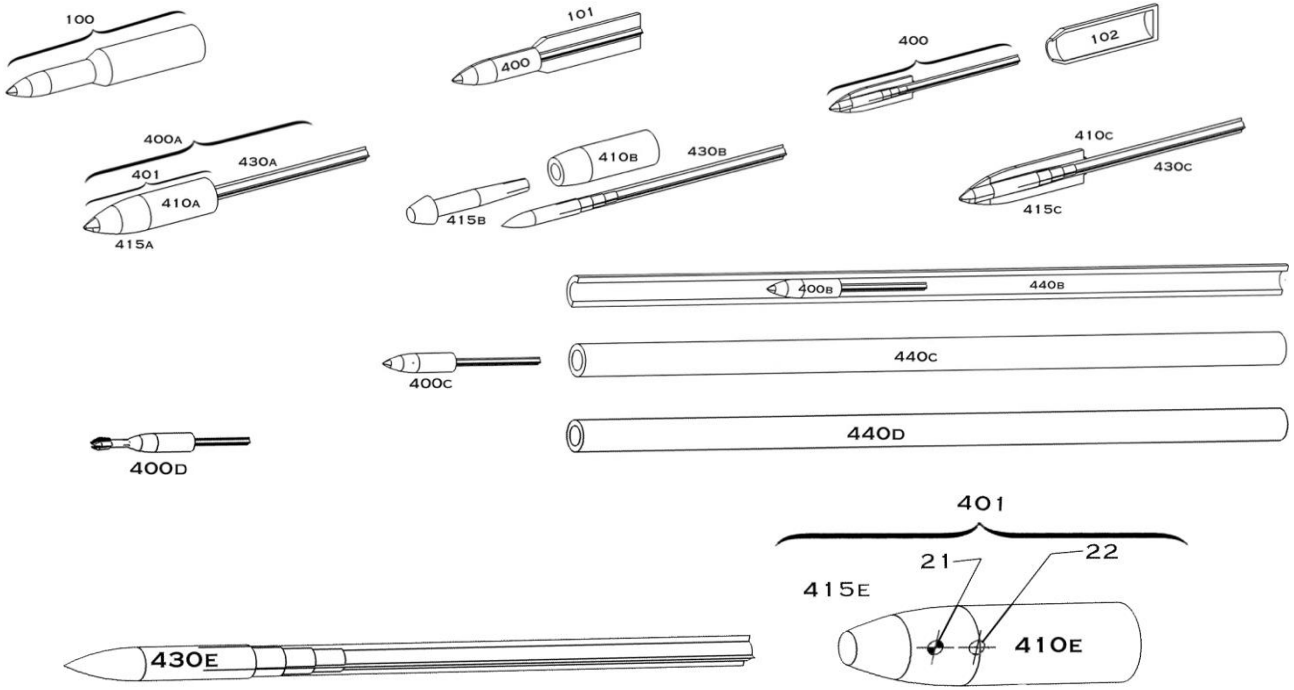
1. Use BASS to Increase projectile V_{flt} & KE at range;

2. Avoid unintentional airframe strikes via aeromechanically stable sabot;

3. Cut CEP by reducing flechette tipoff & gust sensitivity.

iii. BASS Design Philosophy

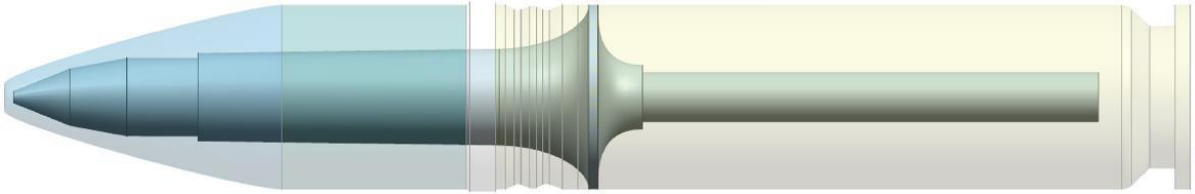
What is claimed is:
1. An aeromechanically stable sabot...



iii. BASS Design Philosophy

Today's "Advanced" 30mm Aerial Gunnery Round

BASS Round: Sub-caliber flechette goes into powder, seated in sabot

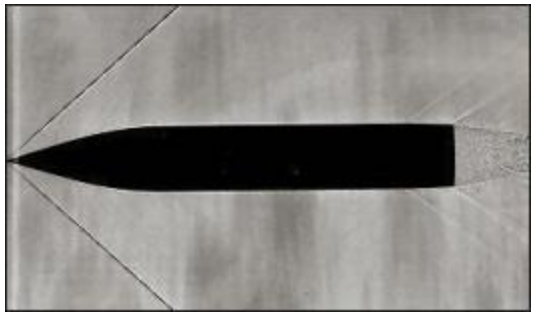


Freeflight Aeromechanics

Modeling, Analysis & Testing

Experimental Validation:

• Wind tunnel verification of preferred BASS sabot geometry center of pressure and aerodynamic center location with angle of attack changes.



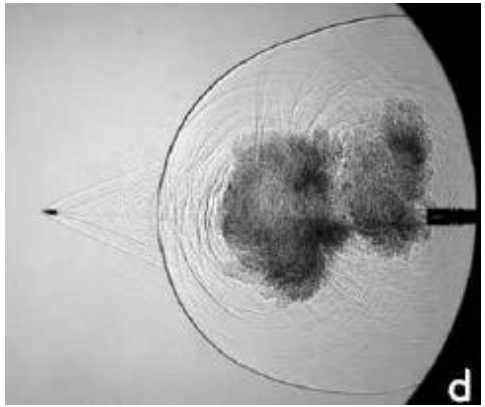
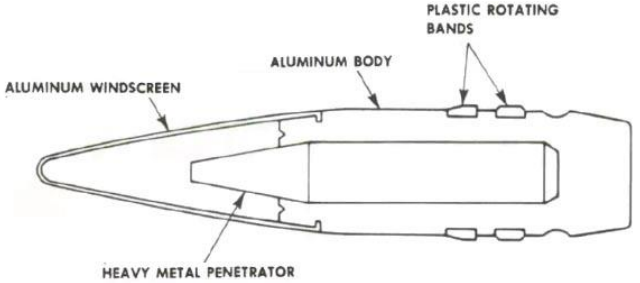


Image Sources:
https://nuclearprojects.com/blog/schlieren-flow-visualization/
https://www.researchgate.net/figure/Focused-shadowgrams-of-223-automatic-rifle-fire-a-sharply-focused-b-defocused-1m_fig3_226053639

iii. BASS Design Philosophy

Today's Premier API Aerial Gunnery Round

PGU-14



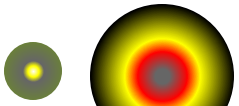
BASS 2081 Flechette/penetrator

iii. BASS Design Philosophy

Projectile Aeromechanics & CEP Fundamentals

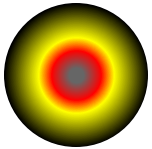
Flechette

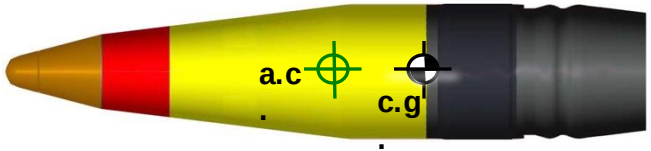
X-Sectional Area of PGU-14 >> Flechette



PGU-xx

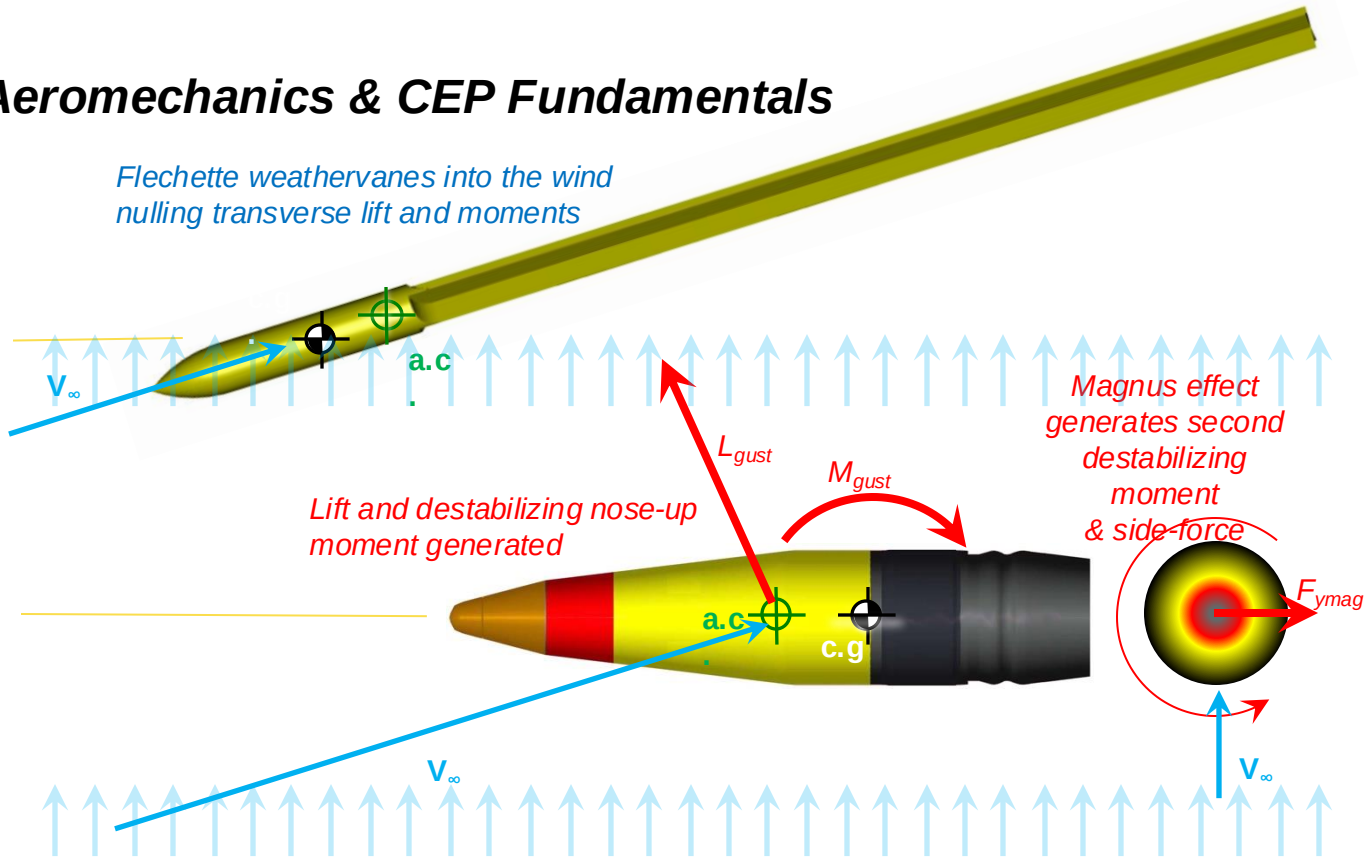
Supersonic Drag ~ proportional to X-Sectional Area, $Drag_{PGU14}$ >> $D_{Flechette}$





iii. BASS Design Philosophy

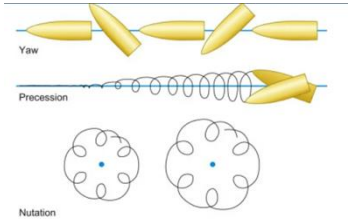
Projectile Aeromechanics & CEP Fundamentals



Projectile Aeromechanics & CEP Fundamentals

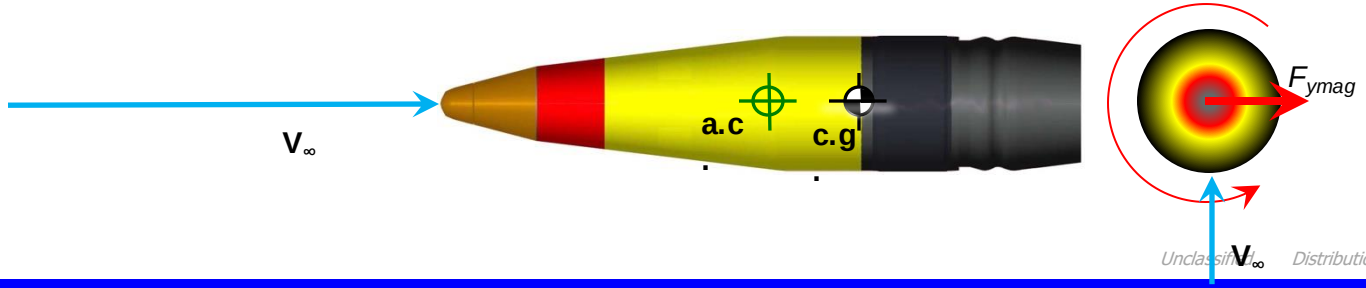
Flechette

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



iv. BASS Round Physics & Modeling

Aeromechanics, Kinematics

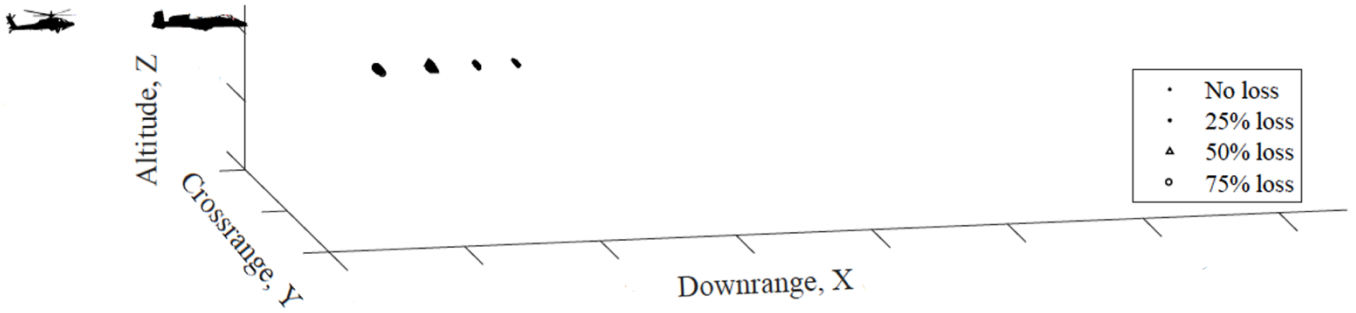
- ***Conceived & reduced to practice 2016 – Present***
- ***Modeled in CFD, FEM, DATCOM & PRODAS***
- ***Tested on Shock Table, Wind Tunnel, Range***
- ***>100 rounds fired, currently @ TRL-6***

How safe?
FAR-23: 10^{-6} air-to-air
FAR-25: 10^{-9} ground attack

iv. BASS Round Physics & Modeling

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

1 Sec.



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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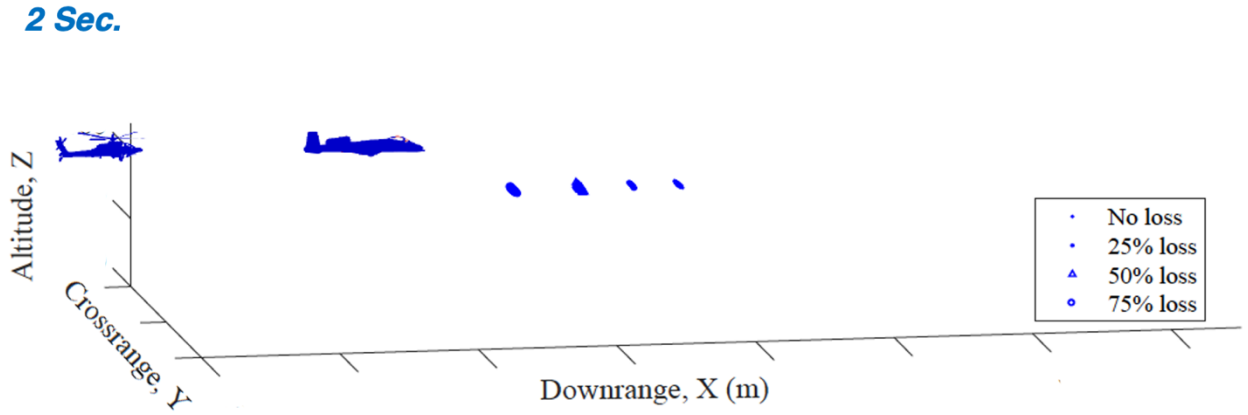

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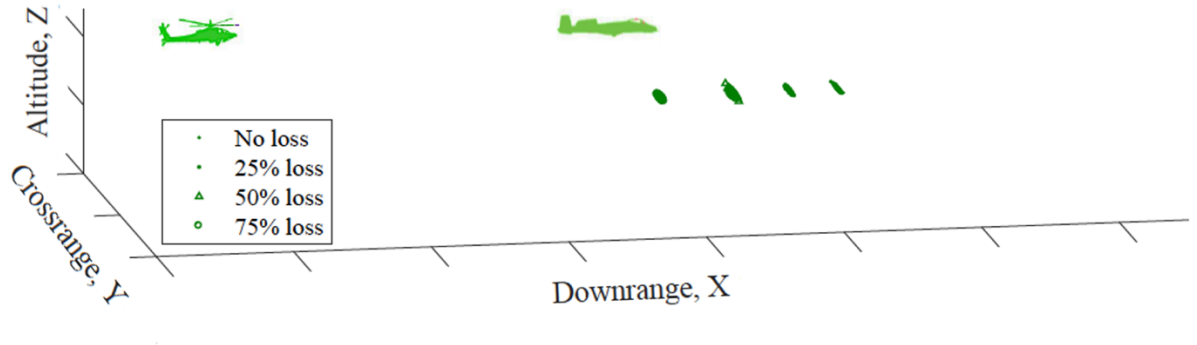
3 Sec.



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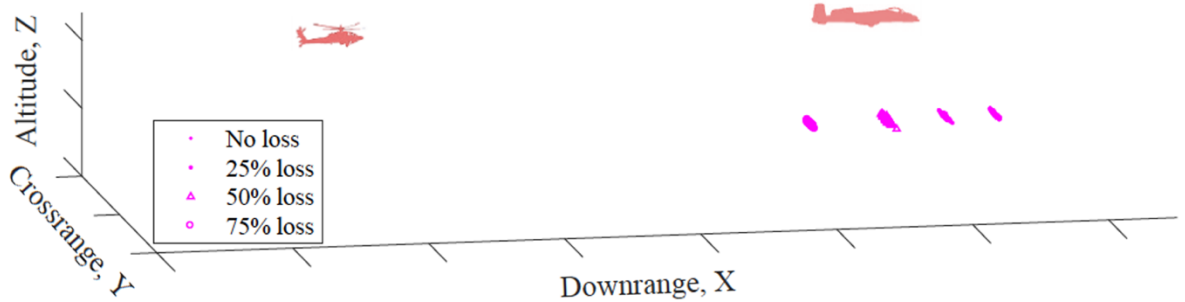

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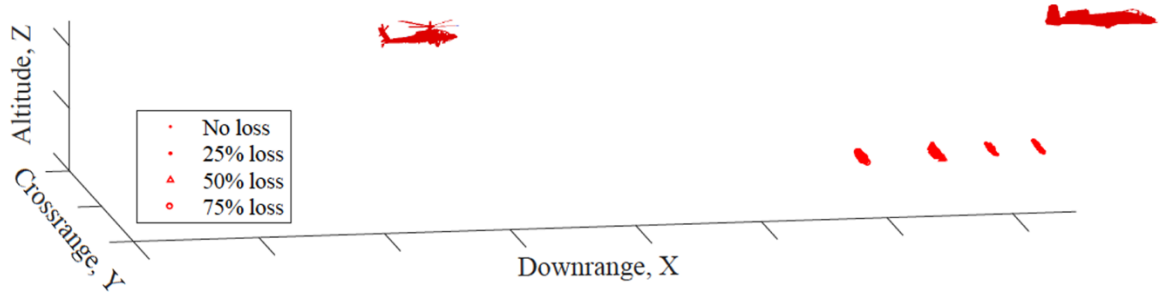
AH-64 & A-10 Sabot separation Modeling (99% atmospherics)

5 Sec.



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v. BASS Round Performance

Modeling, Analysis & Testing

Experimental Validation:

- Full scale range testing of preferred BASS configuration w/muzzle exit dynamics;
- Structural verification of BASS components via soft catch.

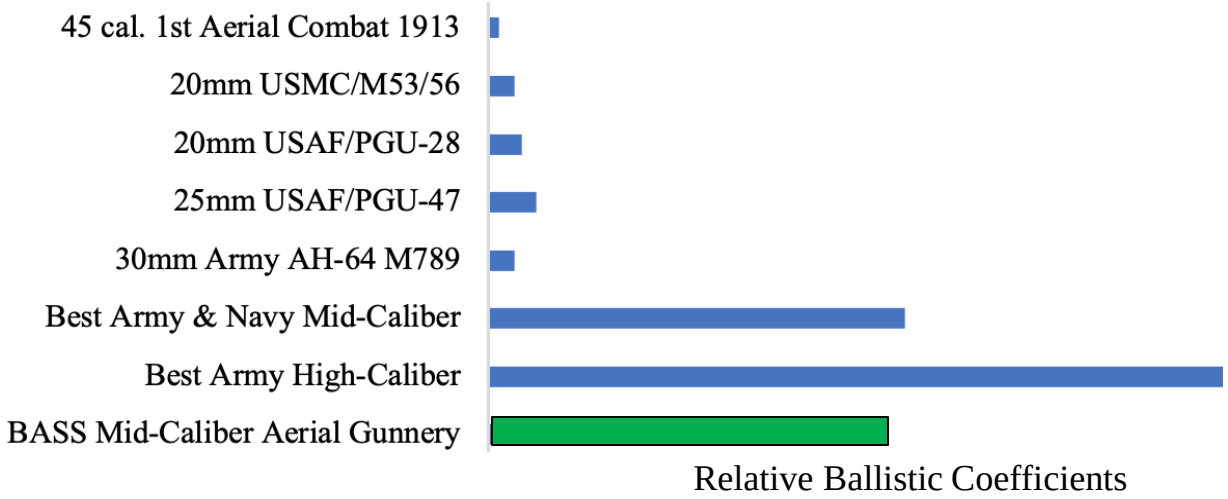
v. BASS Round Performance

Range Shots

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

v. BASS Round Performance

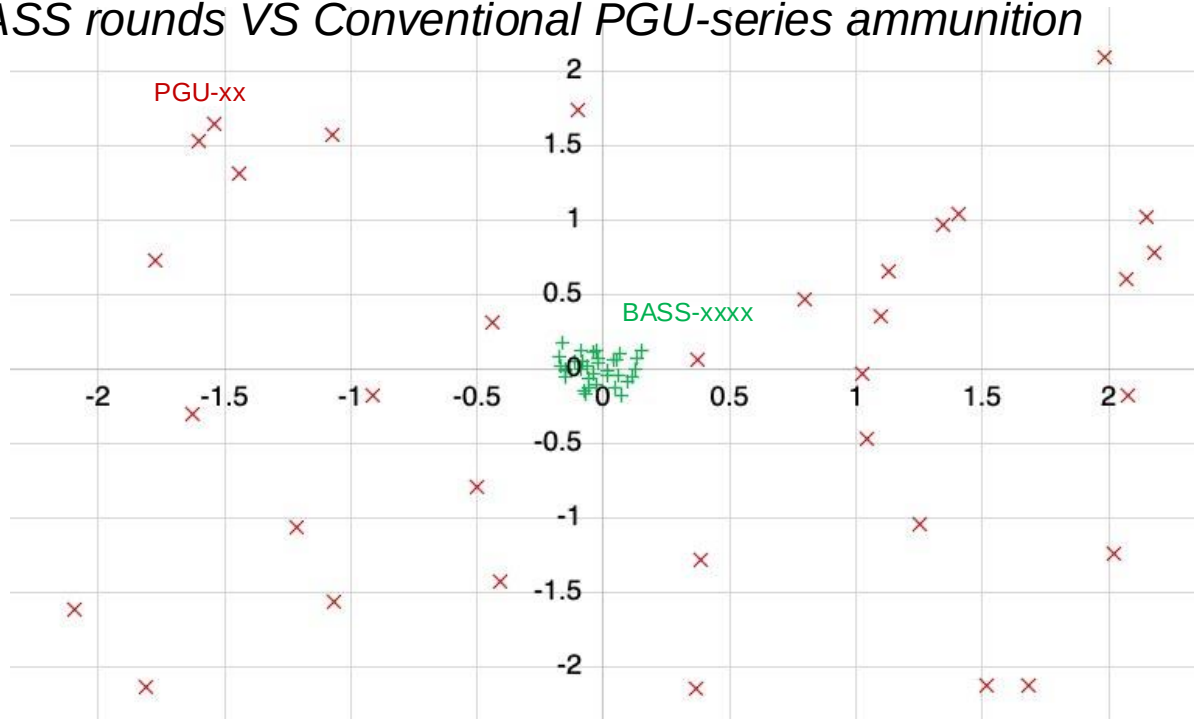
BASS Rounds Represent the First Major Advance in Ballistic Coefficients for Aerial Gunnery Ammunition in Over a Century



v. BASS Round Performance

CEP Comparison:

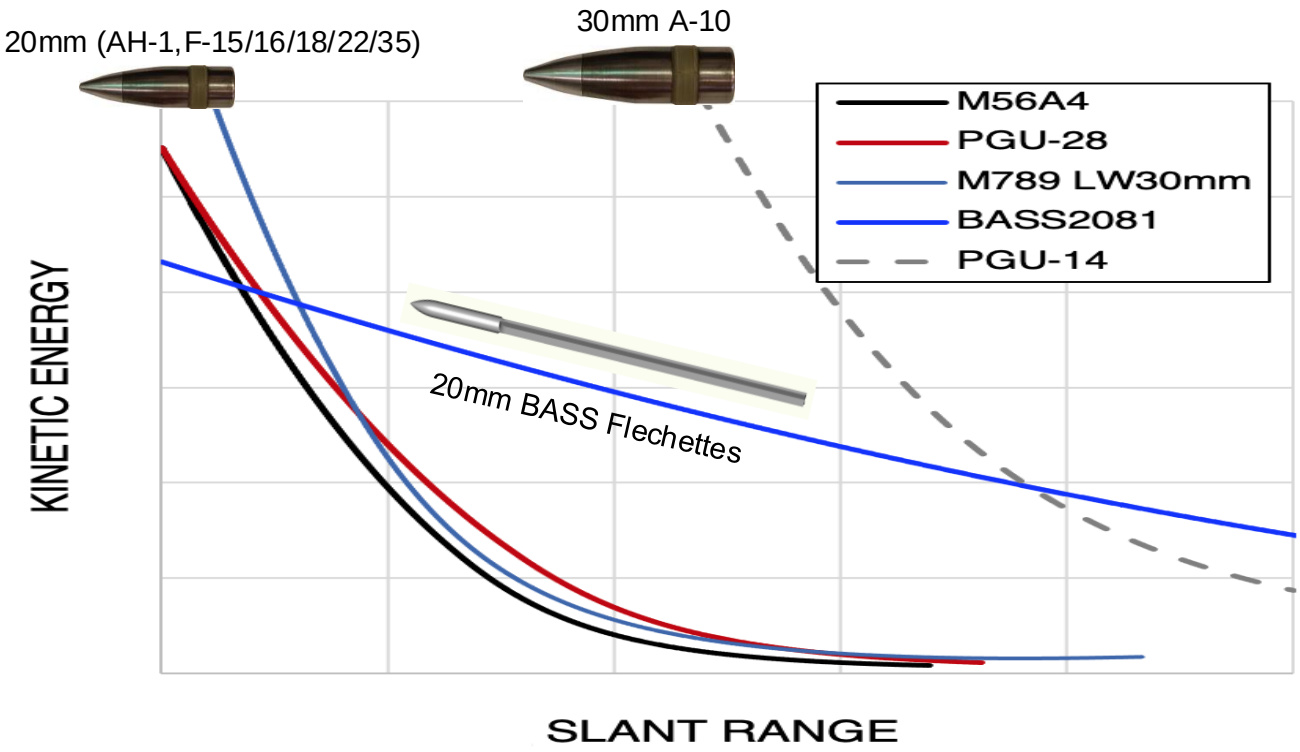
BASS rounds VS Conventional PGU-series ammunition



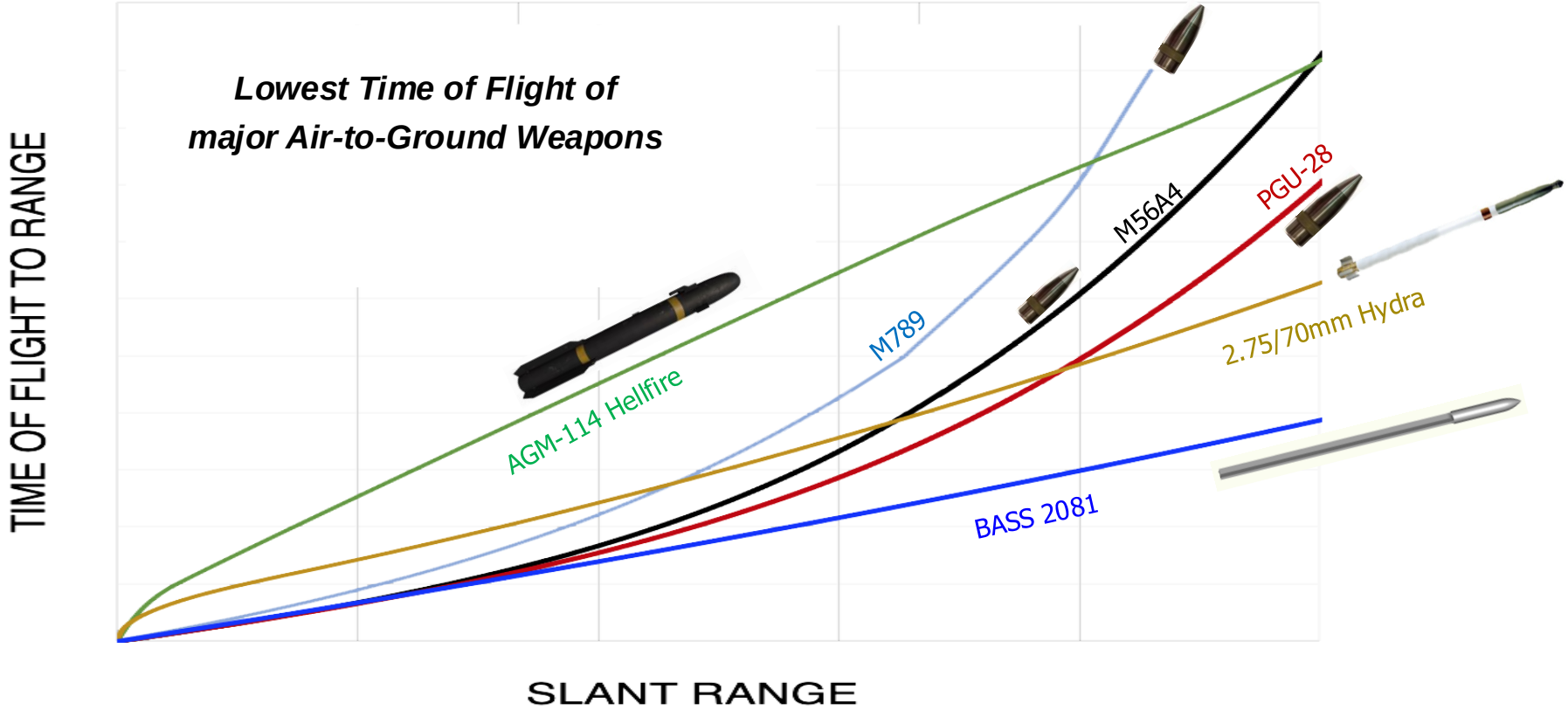
90% gust field for both round families

IV. BASS Performance

20mm Performance Comparison



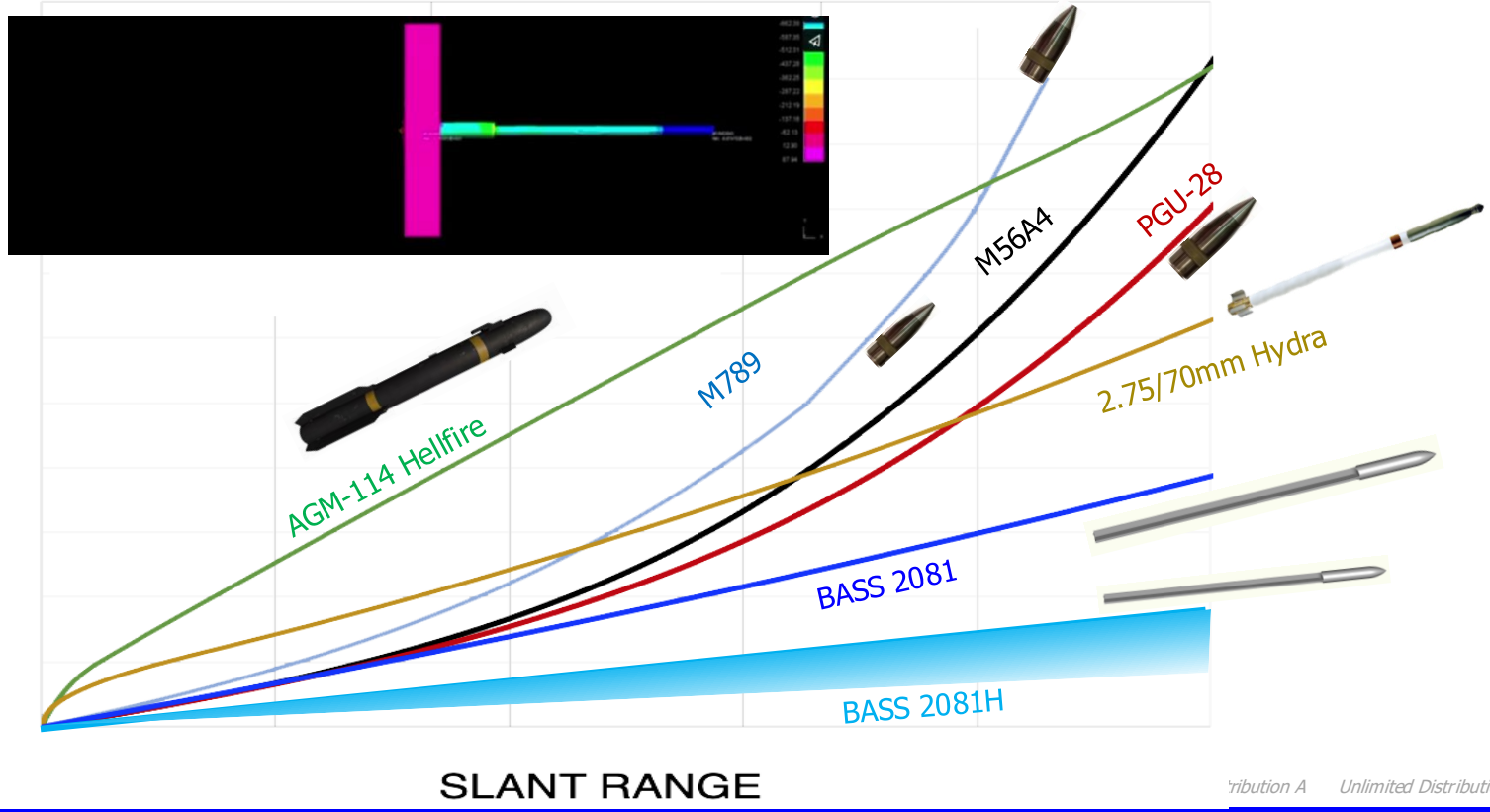
v. BASS Round Performance



v. BASS Round Performance

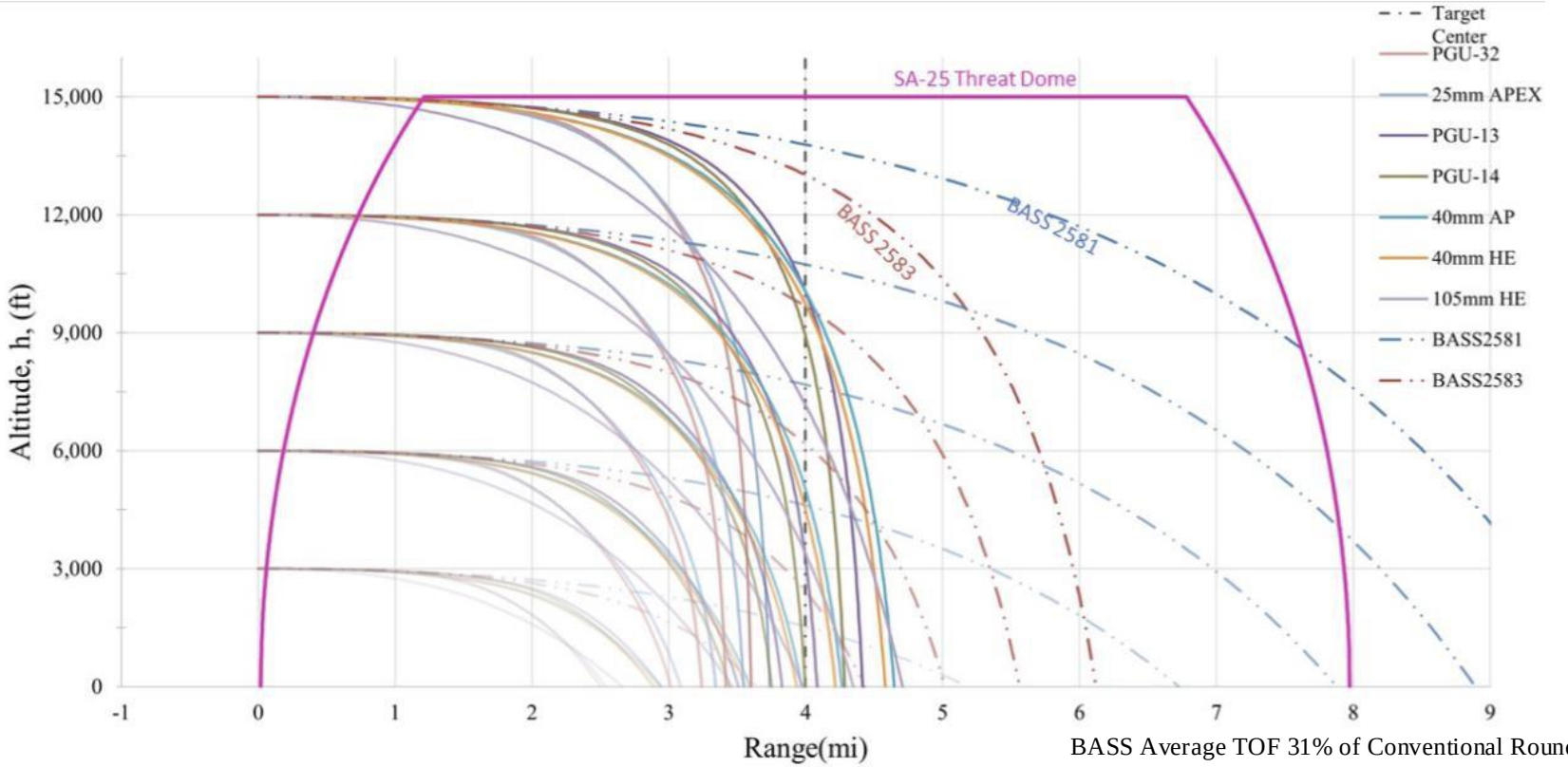
20mm Hypersonic BASS Rounds:

V_{flt} = 1 – 2 mi/s, cuts through T-72 top armor @ beyond MANPADS range



v. BASS Round Performance

AC-130 with Hypersonic Ammunition vs SA-25 Threat Dome



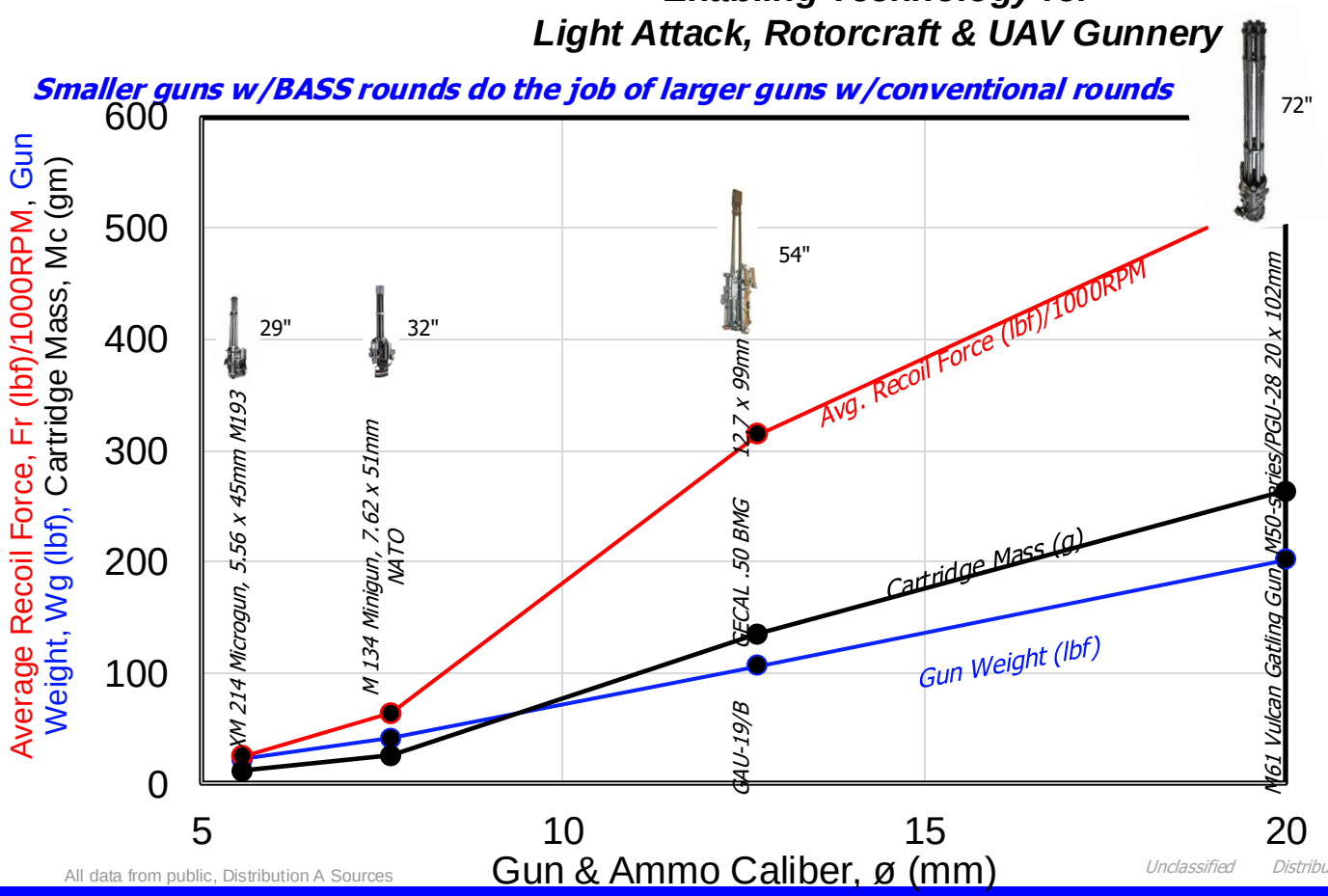
BASS Average TOF 31% of Conventional Round

Source: AIAA 2023 Ground Attack Aircraft Design Competition

v. BASS Round Performance

Enabling Technology for Light Attack, Rotorcraft & UAV Gunnery

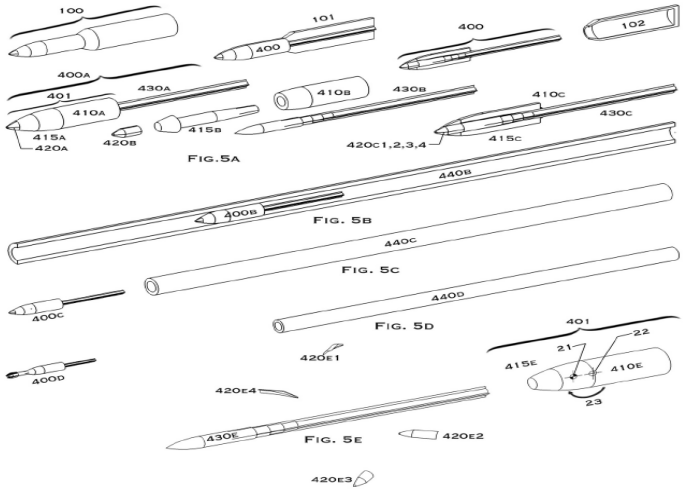
Smaller guns w/BASS rounds do the job of larger guns w/conventional rounds

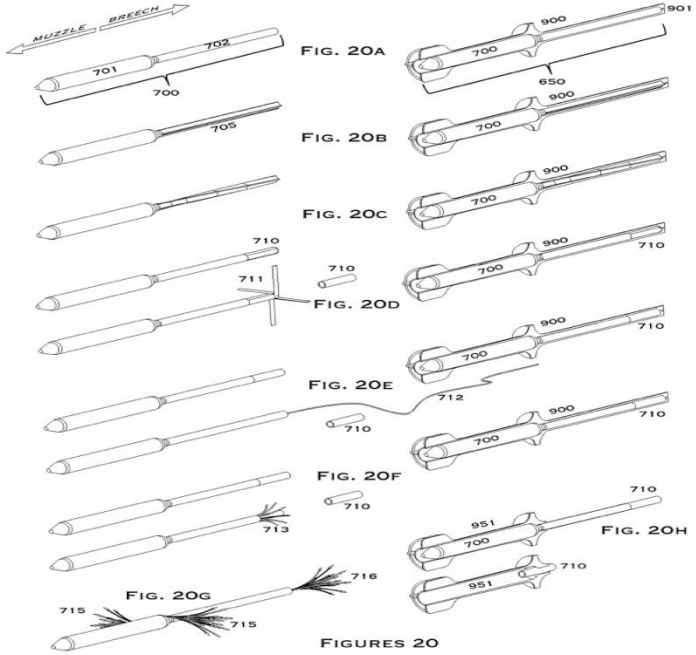


All data from public, Distribution A Sources

v. BASS IP Status

- **Strong, Broad US Patents Filed 2019, 2020**
- **Fed. Government Approved the Concept for Export & Exported**
- **Patents filed: US, Europe, Germany, Norway, Australia, UK, Netherlands, France, Belgium, Italy, Spain, Japan, Korea, Singapore**



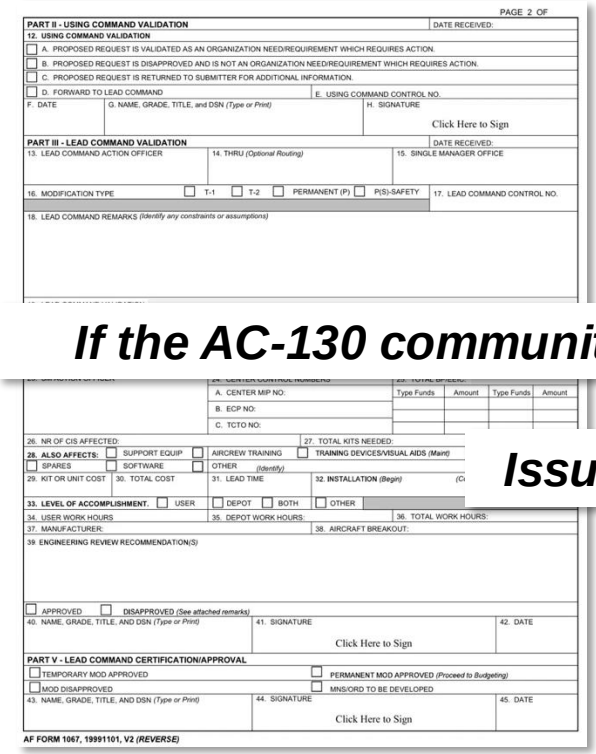


US Patent 11,852,447 Issued 26 December 2023

Licensed to Watson Aerospace and Defense

Provisional Patent Application 62/839,551 26 April 2019 priority date

vi. The Next Step:



PAGE 2 OF

PART II - USING COMMAND VALIDATION — DATE RECEIVED:

12. USING COMMAND VALIDATION

- A. PROPOSED REQUEST IS VALIDATED AS AN ORGANIZATION NEED/REQUIREMENT WHICH REQUIRES ACTION.
- B. PROPOSED REQUEST IS DISAPPROVED AND IS NOT AN ORGANIZATION NEED/REQUIREMENT WHICH REQUIRES ACTION.
- C. PROPOSED REQUEST IS RETURNED TO SUBMITTER FOR ADDITIONAL INFORMATION.
- D. FORWARD TO LEAD COMMAND — E. USING COMMAND CONTROL NO.

F. DATE | G. NAME, GRADE, TITLE, and DSN *(Type or Print)* | H. SIGNATURE — Click Here to Sign

PART III - LEAD COMMAND VALIDATION — DATE RECEIVED:

13. LEAD COMMAND ACTION OFFICER | 14. THRU *(Optional Routing)* | 15. SINGLE MANAGER OFFICE

16. MODIFICATION TYPE ☐ T-1 ☐ T-2 ☐ PERMANENT (P) ☐ P(S)-SAFETY | 17. LEAD COMMAND CONTROL NO.

18. LEAD COMMAND REMARKS *(Identify any constraints or assumptions)*

A. CENTER MIP NO: | Type Funds | Amount | Type Funds | Amount

B. ECP NO:

C. TCTO NO:

26. NR OF CIS AFFECTED: | 27. TOTAL KITS NEEDED:

28. ALSO AFFECTS: ☐ SUPPORT EQUIP ☐ AIRCREW TRAINING ☐ TRAINING DEVICES/VISUAL AIDS *(Maint)*
☐ SPARES ☐ SOFTWARE ☐ OTHER *(Identify)*

29. KIT OR UNIT COST | 30. TOTAL COST | 31. LEAD TIME | 32. INSTALLATION *(Begin)*

33. LEVEL OF ACCOMPLISHMENT. ☐ USER ☐ DEPOT ☐ BOTH ☐ OTHER

34. USER WORK HOURS | 35. DEPOT WORK HOURS: | 36. TOTAL WORK HOURS:

37. MANUFACTURER: | 38. AIRCRAFT BREAKOUT:

39. ENGINEERING REVIEW RECOMMENDATION(S)

☐ APPROVED ☐ DISAPPROVED *(See attached remarks)*

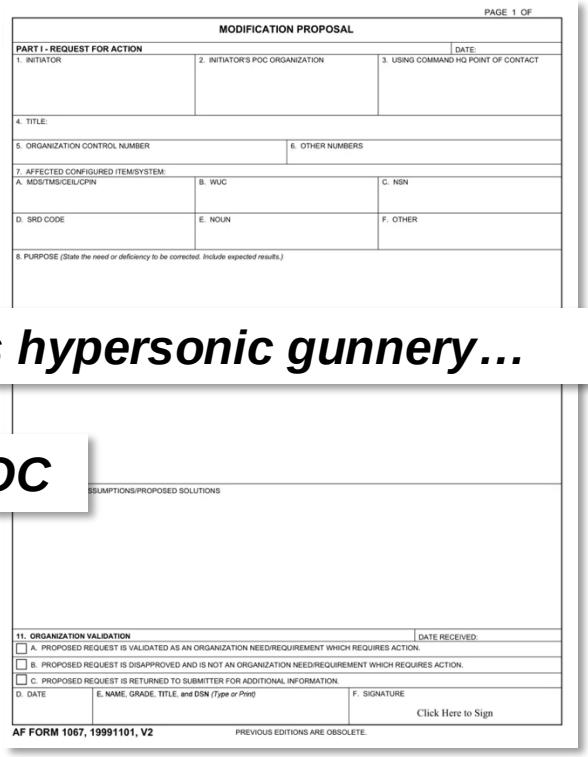
40. NAME, GRADE, TITLE, AND DSN *(Type or Print)* | 41. SIGNATURE — Click Here to Sign | 42. DATE

PART V - LEAD COMMAND CERTIFICATION/APPROVAL

☐ TEMPORARY MOD APPROVED ☐ PERMANENT MOD APPROVED *(Proceed to Budgeting)*
☐ MOD DISAPPROVED ☐ MNS/ORD TO BE DEVELOPED

43. NAME, GRADE, TITLE, AND DSN *(Type or Print)* | 44. SIGNATURE — Click Here to Sign | 45. DATE

AF FORM 1067, 19991101, V2 *(REVERSE)*



PAGE 1 OF

MODIFICATION PROPOSAL

PART I - REQUEST FOR ACTION — DATE:

1. INITIATOR | 2. INITIATOR'S POC ORGANIZATION | 3. USING COMMAND HQ POINT OF CONTACT

4. TITLE:

5. ORGANIZATION CONTROL NUMBER | 6. OTHER NUMBERS

7. AFFECTED CONFIGURED ITEM/SYSTEM:

A. MDS/TMS/CEIL/CPIN | B. WUC | C. NSN

D. SRD CODE | E. NOUN | F. OTHER

8. PURPOSE *(State the need or deficiency to be corrected. Include expected results.)*

SSUMPTIONS/PROPOSED SOLUTIONS

11. ORGANIZATION VALIDATION — DATE RECEIVED:

- A. PROPOSED REQUEST IS VALIDATED AS AN ORGANIZATION NEED/REQUIREMENT WHICH REQUIRES ACTION.
- B. PROPOSED REQUEST IS DISAPPROVED AND IS NOT AN ORGANIZATION NEED/REQUIREMENT WHICH REQUIRES ACTION.
- C. PROPOSED REQUEST IS RETURNED TO SUBMITTER FOR ADDITIONAL INFORMATION.

D. DATE | E. NAME, GRADE, TITLE, and DSN *(Type or Print)* | F. SIGNATURE — Click Here to Sign

AF FORM 1067, 19991101, V2 — PREVIOUS EDITIONS ARE OBSOLETE.

If the AC-130 community wants hypersonic gunnery…

Issue the ROC

Questions?