Close-Air-Support with <190 Rounds… A Practical Approach

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- Introduction
  - Conventional CAS
  - Guided Hard-Launch Munitions
- MASS Con-ops
- Retrofit Capability
- Future Airframe Design Implications
- Conclusions & Future Work

Close air support (CAS) is air action by fixed-wing and rotary-wing aircraft against hostile targets that are in close proximity to friendly forces and requires detailed integration of each air mission with the fire and movement of those forces

-DOD Joint Publication 3-09.3

[1]

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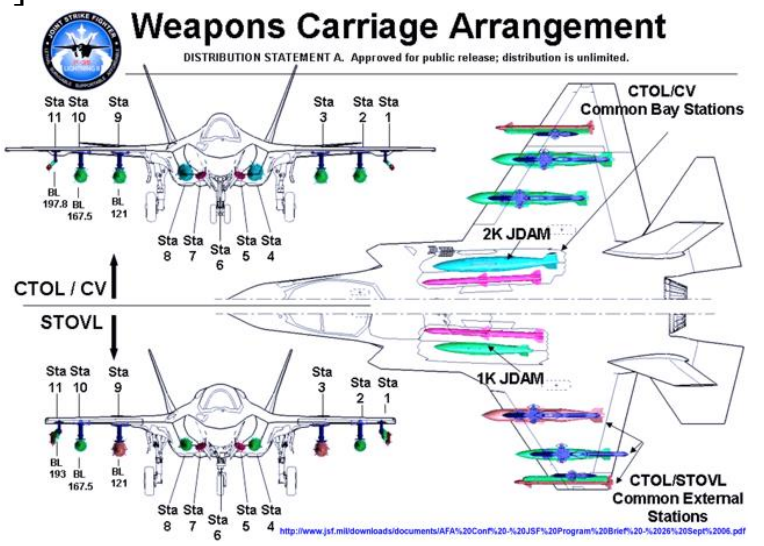
Current emphasis on stealth and BVR engagement…

- Air-to-air mission
  - 14 x AIM-120
  - 2 x AIM-9
  - 180 x 25mm (~3 sec.)
- Air-to-surface loadout
  - 2 x AIM-120
  - 6 x GBU-31 JDAM
  - 2 x AIM-9X
  - 180 x 25mm (~3 sec.)

[3]



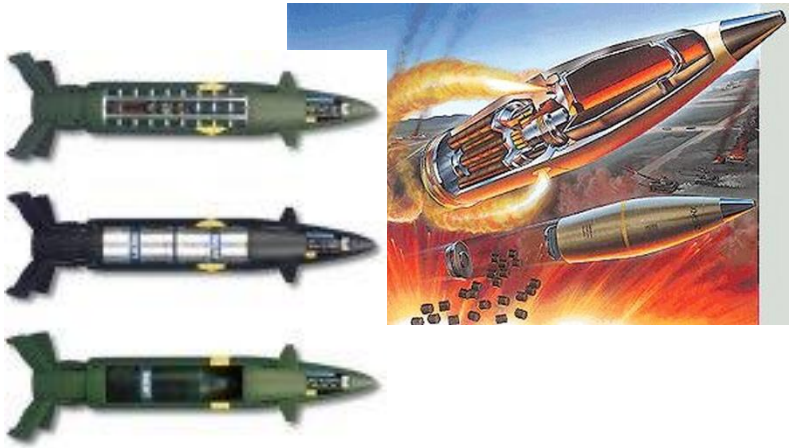
F-35 integration into a close-air-support (CAS) role

Design Philosophy: make every round count

- Increase P_{hit} / $P_{k/hit}$
- Increase energy at target impact
- Increase effective range

Thanh Hóa Bridge, 1972
873 air sorties... Vs 4 w/LGBs

M712 Copperhead 1975

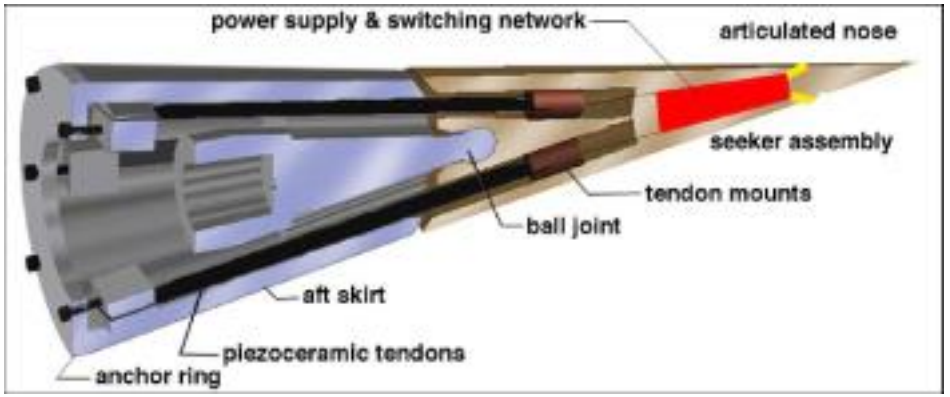


XM 982 Excalibur
& ERGM

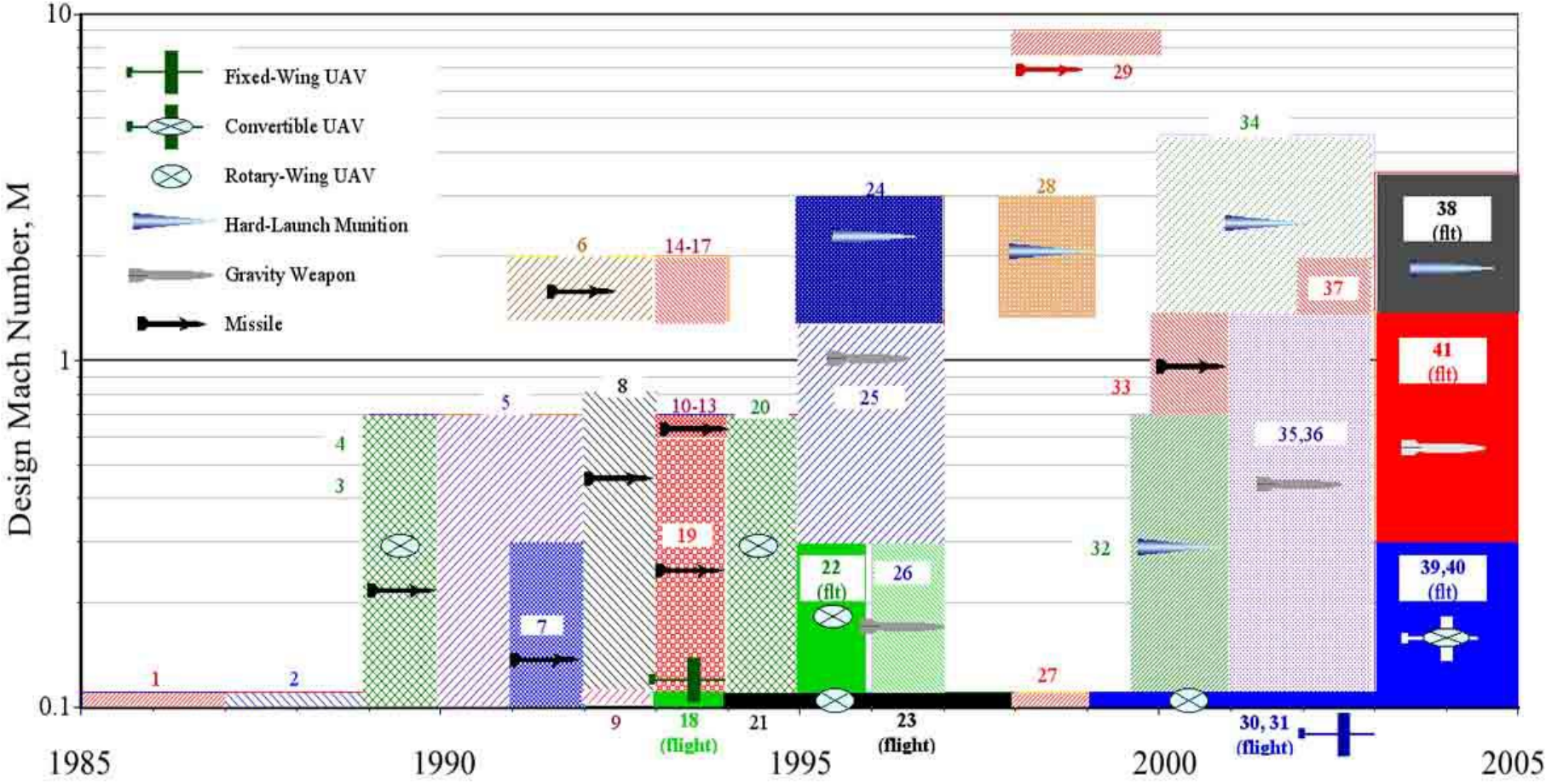
Barrel-Launched Adaptive Munition (BLAM) Program 1995 - ‘97

USAF/AFRL-MNAV

- Aerial Gunnery (20 - 105mm)
- Extend Range w/2g maneuver
- (Eglin AFB tests ‘97)
  (Mach 3.3 tests ‘96-’97)
- Increase hit probability
- Increase probability of a kill given a hit
- Reduce total gun system weight fraction

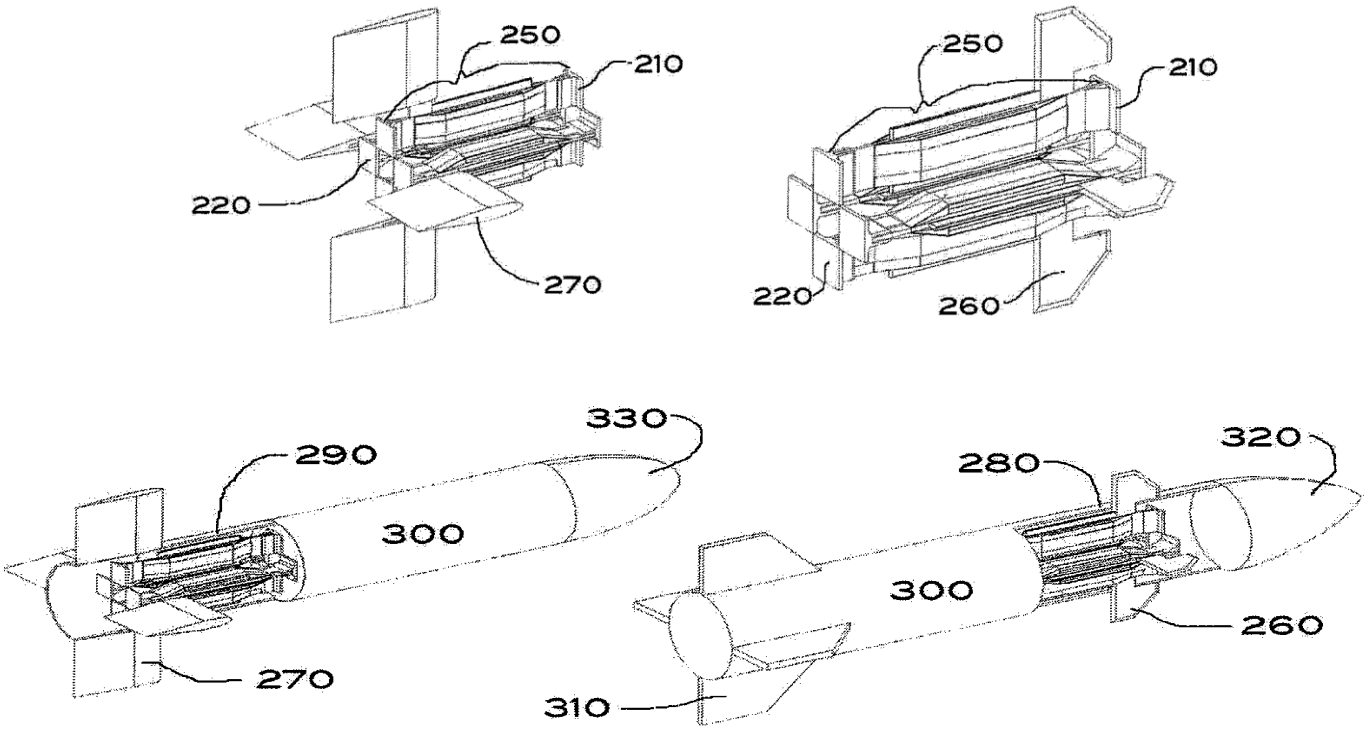


AAL: Building Adaptive Actuators for Hard-Launch Munitions since 1995



AAL: Issued patents & 2 decades of test data up to: Mach 11 & 100,000g's

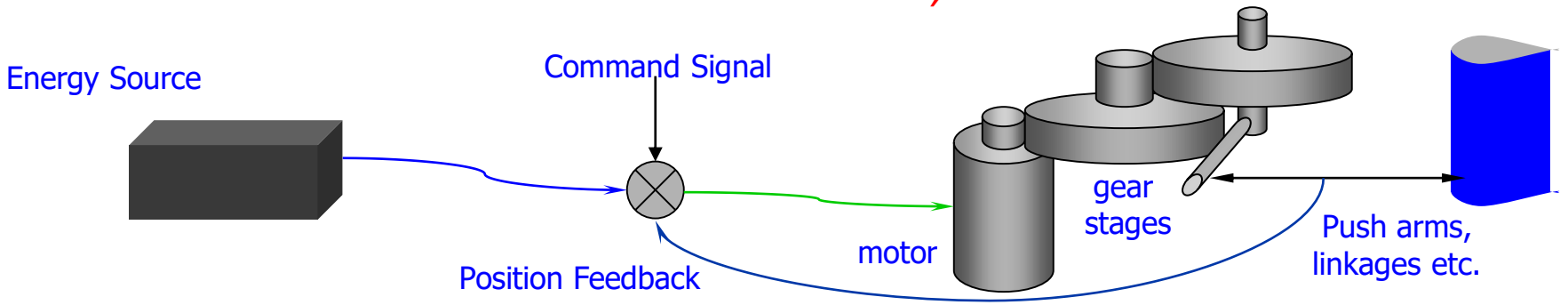
PBP-Class Hard-Launch Capable Actuator FCS Units:



AAL: Building the World's fastest fully proportional hard-launch flight control actuators

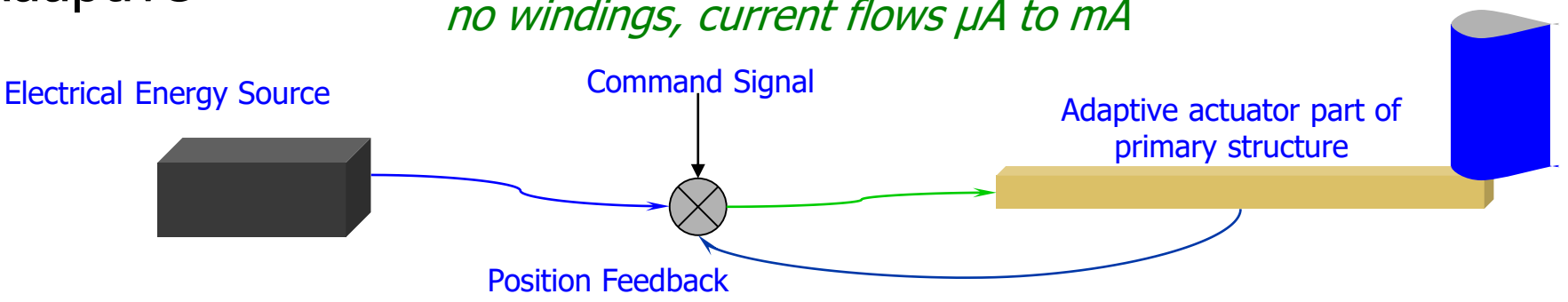
Conventional

dozens to hundreds of turns, current flows A to 10's of A



Adaptive

no windings, current flows µA to mA



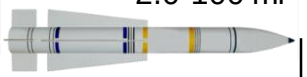
GHLM Potential

- Increased Number of Targets
- Expanded Engagement Range Envelope
- Airframe Defense with Maneuver Overmatch
- Decreased Cost per Kill

AIM-9
0.6-20 mi

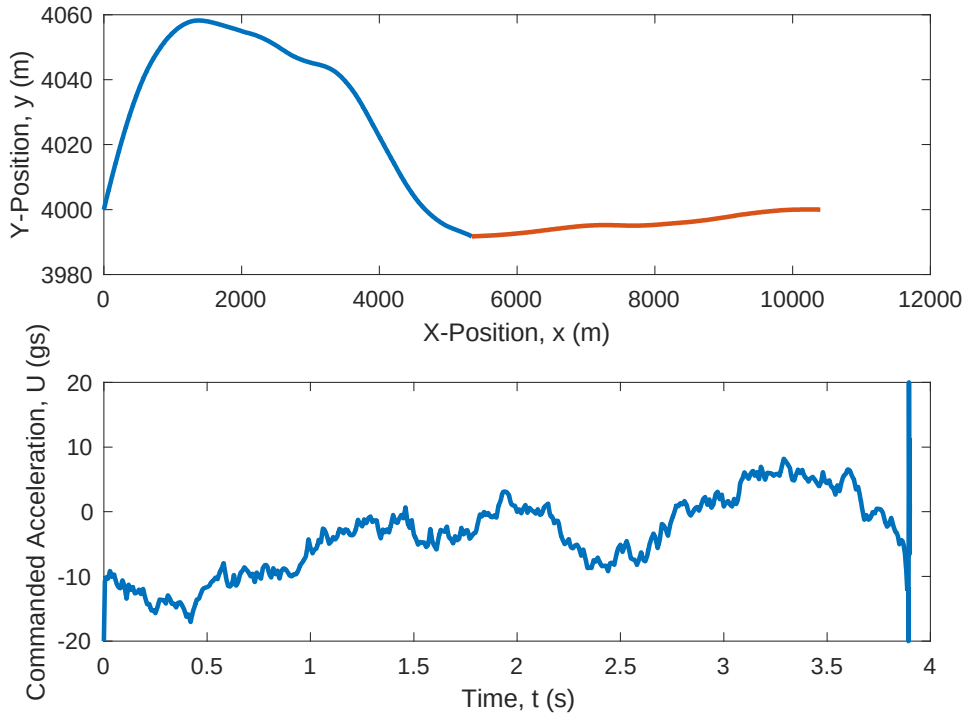
AIM-120C
1.0-60 mi

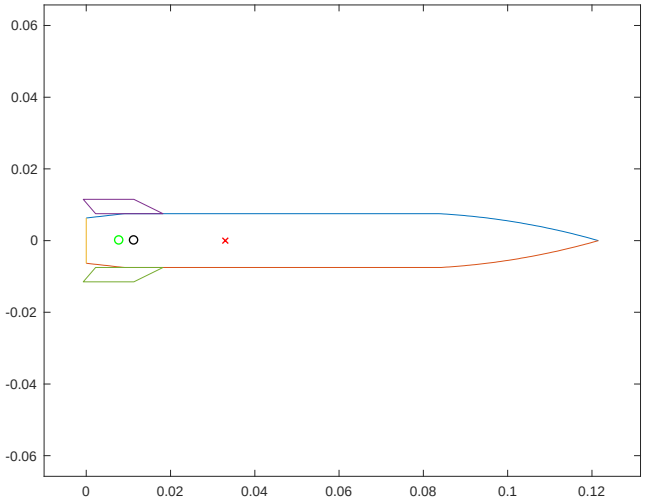
AIM-54
2.0-100 mi



Guided Hard-Launch Munitions
0-100+ mi

- Maneuver specification: real atmosphere



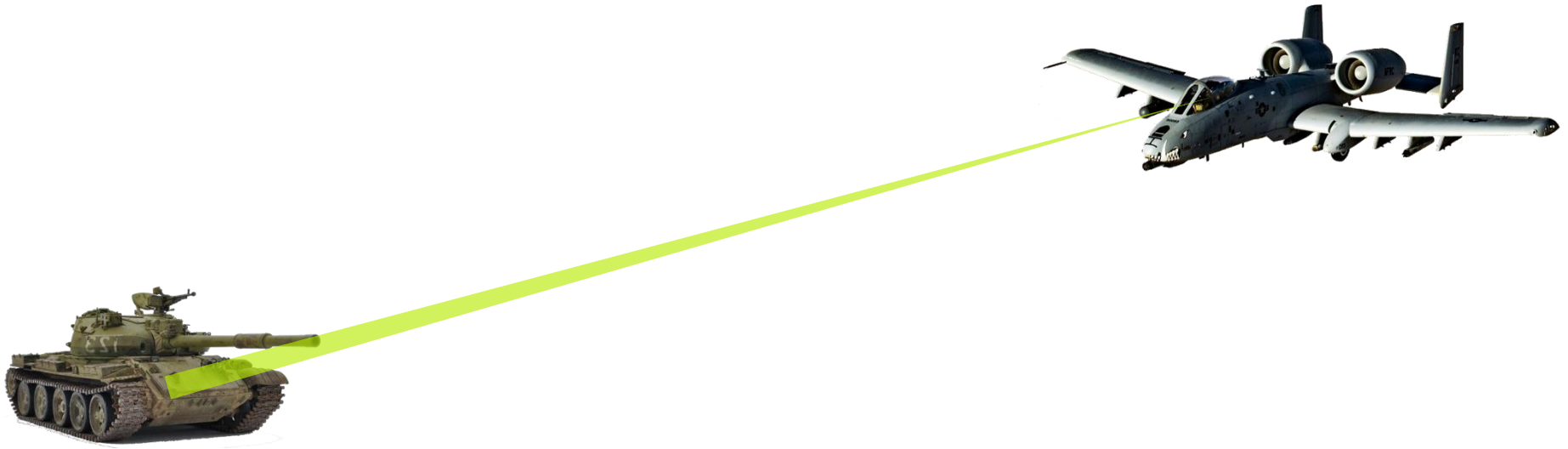


$$\Phi_w(\omega) = \frac{2\sigma_w^2 L_w}{\pi V} \frac{\left(1 + \frac{8}{3} * \frac{2.678 L_w \omega}{V}\right)^2}{\left(1 + \left(\frac{2.678 L_w \omega}{V}\right)^2\right)^{\frac{11}{6}}}$$

$$\frac{d\bar{V}}{dt} = -\frac{\rho V S C_D}{2m}\bar{V} + \frac{\rho S C_{L_\alpha}}{2m}\left(V^2\hat{x} - (\bar{V}\cdot\hat{x})\bar{V}\right) + \bar{g}$$

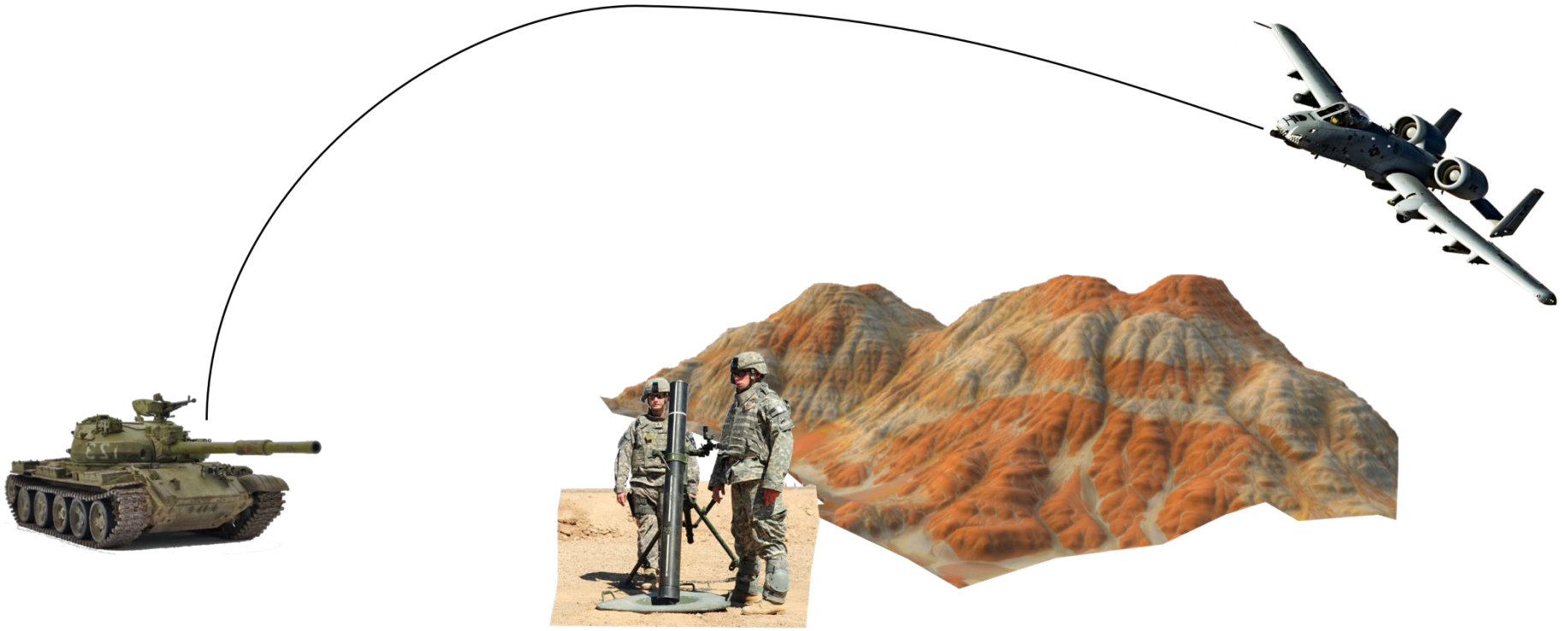
$$\frac{d\bar{h}}{dt} = \frac{\rho V S d^2 C_{l_p}}{2I_y}(\bar{h}\cdot\hat{x})\hat{x} + \frac{\rho V^2 S d \delta_F C_{l_\delta}}{2I_y}\hat{x} + \frac{\rho V S d C_{M_\alpha}}{2I_y}(\bar{V}\times\hat{x})$$

- Increase impact kinetic energy at Effective Range:
  - PGU-14 E_{impact}/E_{muzzle} ~ 50%
  - MASS GHLM E_{impact}/E_{muzzle} ~ 90%
- MASS Guided Variants



MASS Guided Indirect Fire

- Semi-ballistic path
- Terminal Guidance



Concept of Operations: Defensive Overmatch

- MASS GHLM IR defense
  - Flying “flare”
- MASS GHLM RF defense
  - Kinetic kill
  - Proximity with debris field

Conventional Performance

- Conventional F-35A
  - 180 x 25mm (~3 sec.)
  - ~$32,000 per flight hour
  - 14 x hardpoints + bays
- Conventional A-10
  - 1,174 x 30mm (~18 sec)
  - $11,500 per flight hour
  - 11 x hardpoints

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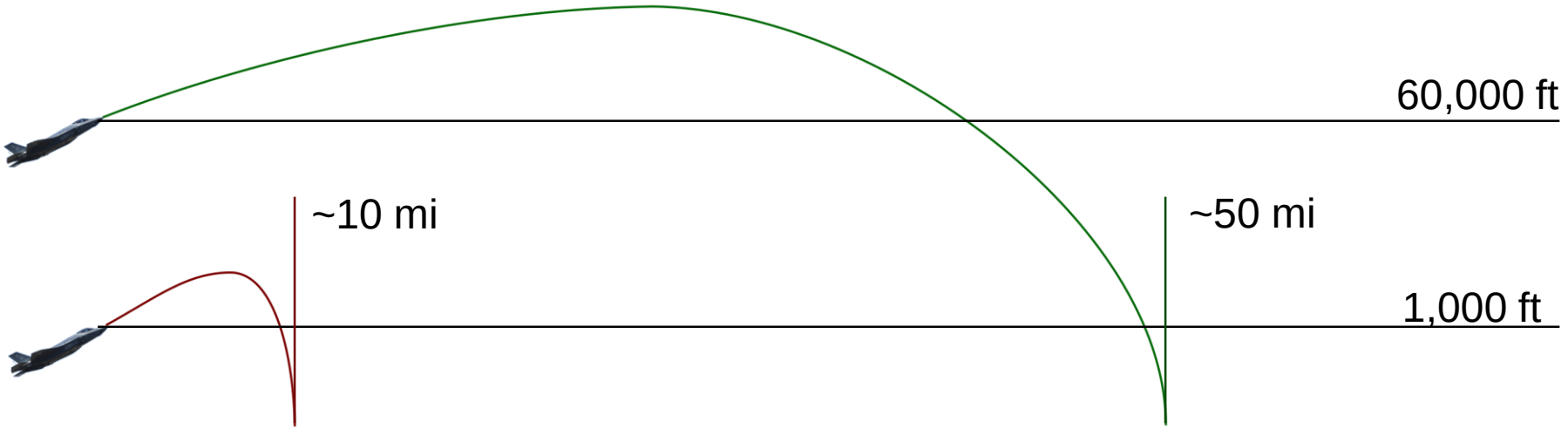
- Retrofit of conventional rounds for GAU-22

	A-10 (PGU-14/B)	F-35 (PGU-32)	MASS F-35
Projectile Mass (kg)	0.425	0.18	0.25
Kinetic Energy on Target	100%	56%	**109%**
E_{target}/E_{muzzle}	47.7%	39.3%	**85.8%**



MASS retrofit of conventional rounds for GAU-22

- Effective up-gunning of F-35 without airframe modification
- Guidance of rounds and MASS lends near A-10 like capability

	P_h*P_k	Rounds/Target	Max Targets Engaged
A-10**	0.082	35	34
F-35A	0.050	58.9	3
MASS F-35A	0.342	7.2	25

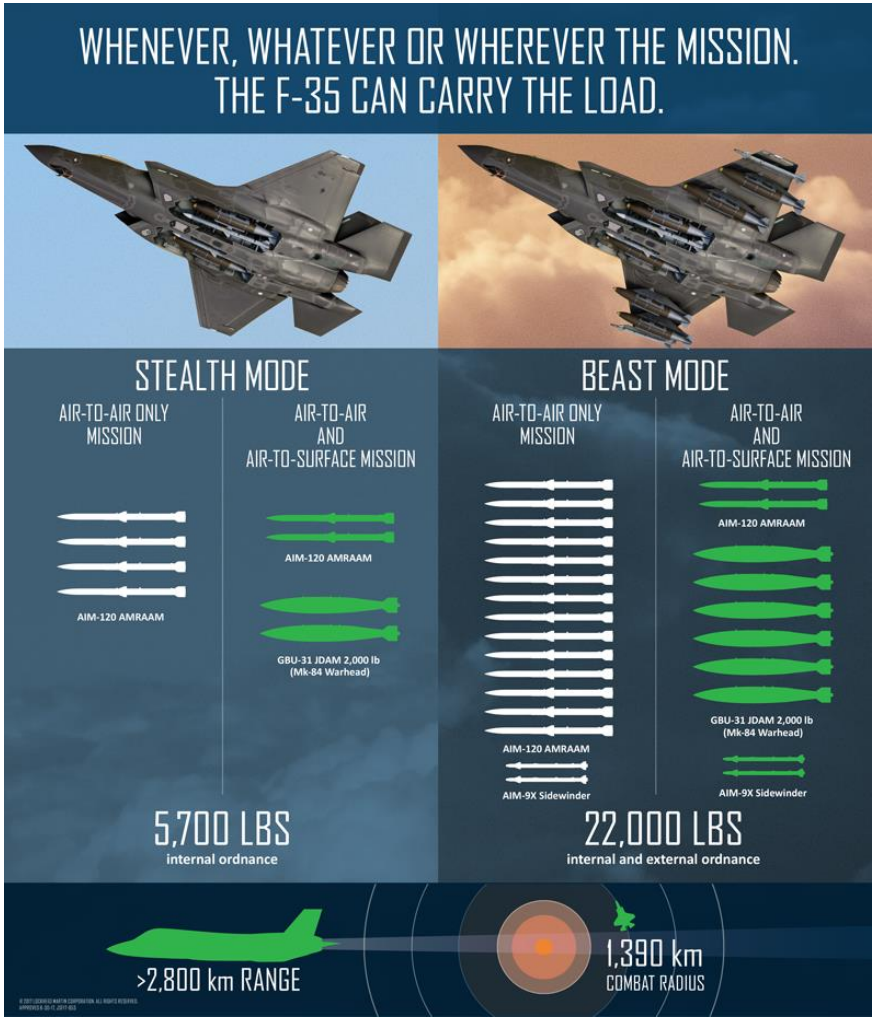
**Estimated assuming 0.5s per target

- Reduced Observables (RF, IR & Acoustic)
- Increased Airframe Performance
  - Reduction in platform weight, wetted area, and total volume

- Max 14 lightly armored targets with P_k assumed 99%
- Assume same airframe configuration and engine

Live atmosphere simulations of guided munitions show to achieve 14 kills at P_k = 0.99 at 50 miles:

- 45mm round with V_m = 1065 m/s
- P_{hit} = 0.295, 13.2 rounds per target to achieve P_k = 0.99
- 212 rounds required with no additional munitions (missiles, etc.)



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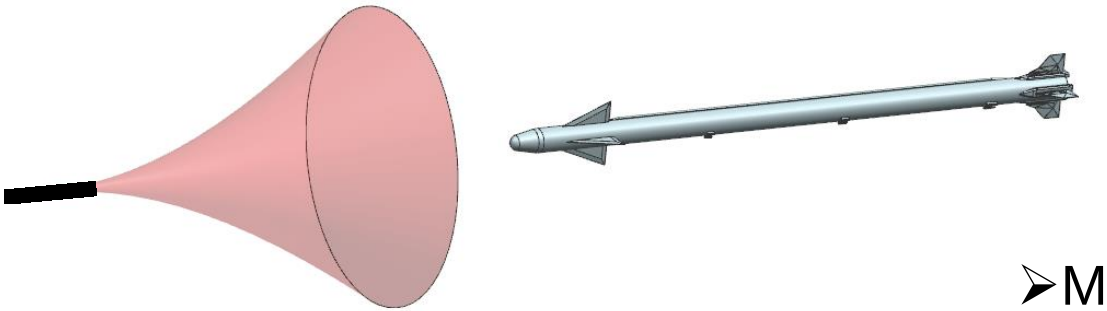

$$P_{k,projectile} = \mathrm{Pk}_{\mathrm{PGU28}} * \left(MR_{target}\right)\left(MR_{projectile}\right)$$

$$V_{fragment} = \sqrt{2E}\left(\frac{m_{metal}}{m_{charge}} + \frac{1}{2}\right)^{-\frac{1}{2}}$$

- Kinetic kill
  - Scaled from PGU-28 as a function of mass of target to mass of projectile ratio

$$N = \frac{\ln\left(1 - P_{k,desired}\right)}{\ln\left(1 - P_{k,projectile}\right)}$$

- Miss radius for P_k of 99%
  - Scaled from missiles with mass ratio of warhead and hydraulic diameter ratio
  - Assumed fragmentation size similar to PGU-28 and distributed evenly through explosive cone

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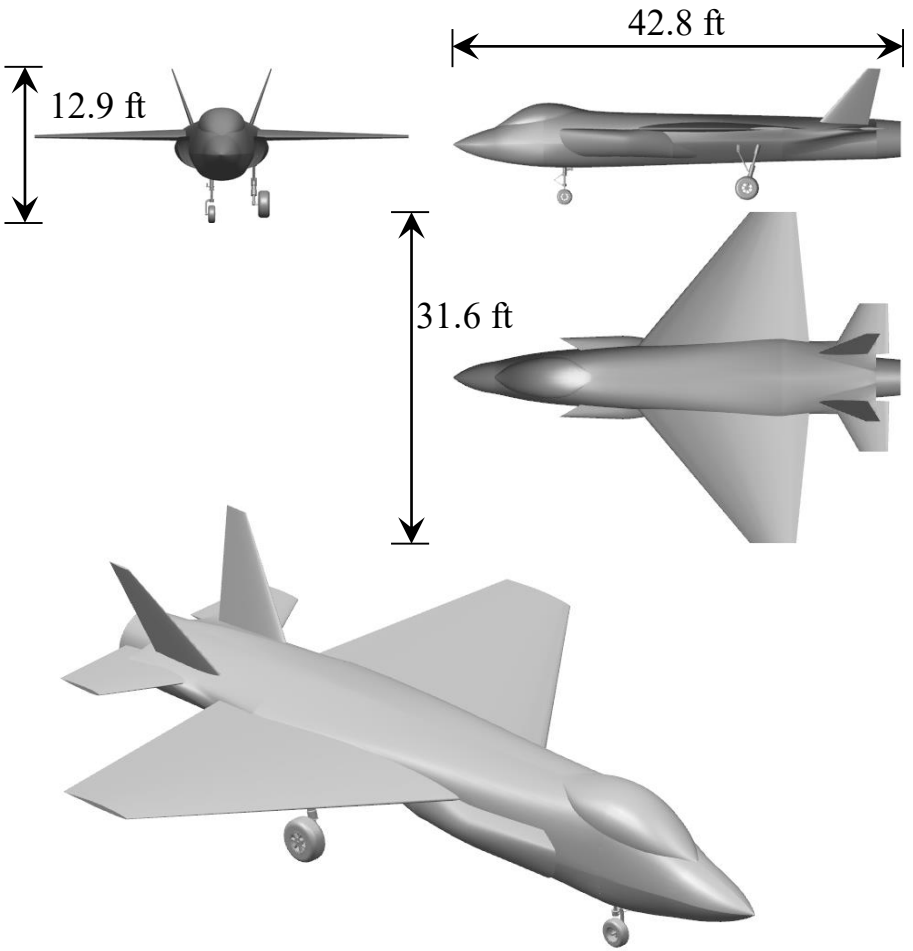
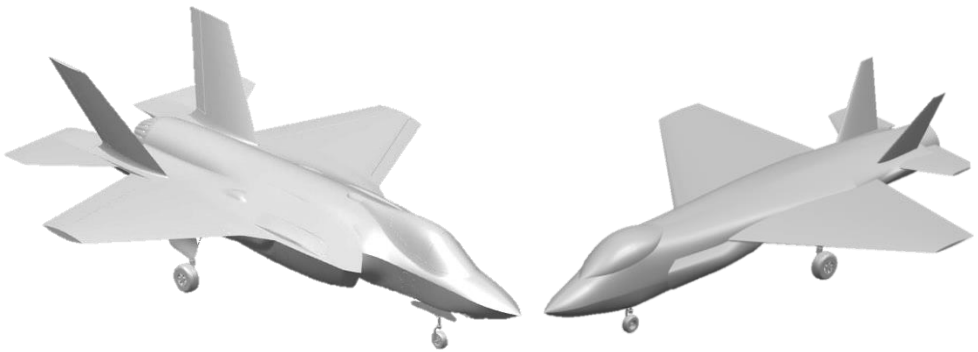
Roskam aircraft design methods through Class II



Parameter	F-35A	XF-36	% 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%



- Reduction in RCS
- Increased volumetric efficiency
- Maintain stealth with no bay door requirements
- Potential for aft barrel
- Defensive engagement capable
- Increased variety of targets engaged (attack and fighter roles)

Roskam aircraft design methods used for both aircraft, then scaled based on F-35A procurement cost per airframe. Assumed full batch 1768 airframes at uniform price.

Program Level Costs ($ billions)		
	F-35A	XF-36
RDT&E Total	$25.5B	$13.6B
Manufacturing Cost (Program)	$110.4B	$82.2B
Acquisition Cost	$115.9B	$86.3B
Program Operating Cost	$235.5B	$225.5B

Airframe Level Costs		
	F-35A	XF-36
Unit Price (millions)	$ 80.0M	$ 56.5M
Operating Cost per Flight Hour	$ 29,600	$ 28,400

For every $1 spent on GHLM RDT&E for aerial gunnery…

2 orders of magnitude in launching platform lifecycle cost savings

- Significant fleet multiplication possible
- Apparent caliber increase for retrofit of existing systems
- Future airframe design performance benefits

Enabling Technology: MASS

- Secure commercial partner for MASS tech. transfer
- Work with commercial partner to capture aerial munitions market

Acknowledgements

The University of Kansas
Department of Aerospace Engineering

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Questions