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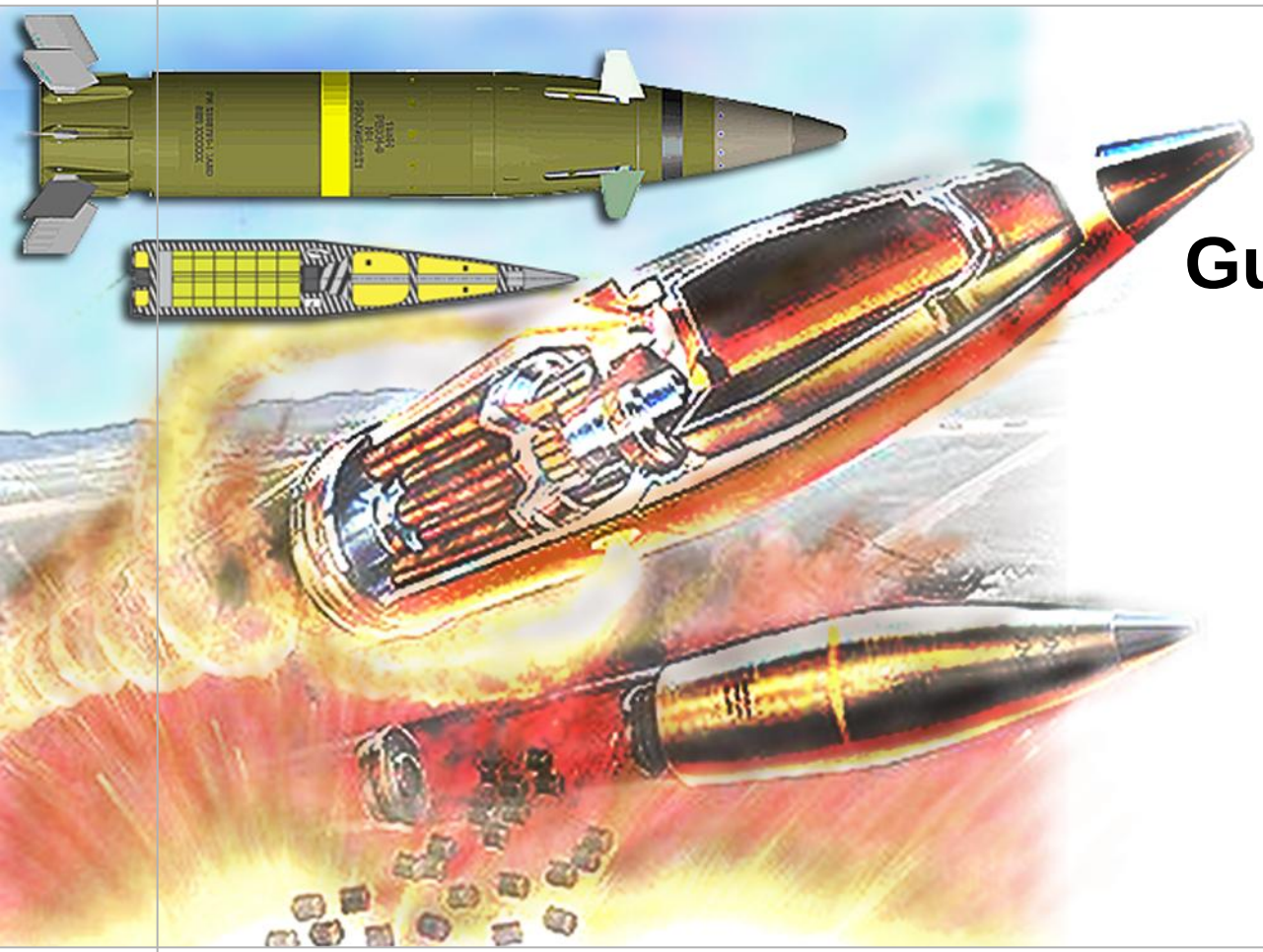
*Customer Success Is Our Mission*



# Presentation for the 46th Annual Guns and Missiles Conference

## Development History and Evolution of the XM982 Excalibur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EXCALIBUR

**NOTE —** All equations, weapon descriptions and equipment-specific information are from open (Internet) sources without correlation to U.S. products to avoid ITAR or classification issues.



Contains Excalibur Technical Data Approved for Public Release. PAO Log 36-11

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# Excalibur Description

- GPS-guided, extended-range 155 mm artillery projectile
- Precision and accuracy — consistently within 10 meters
  - Minimizes collateral damage and risk to civilians
  - Employment flexibility — close support missions
  - Achieves target effects with fewer rounds
- Steep terminal approach angle — optimizes unitary effects
  - Ideal for urban, complex and mountainous terrain
- Significant maneuverability — supports offset firing
- Integral multi-option fuze — point detonate, delay and HOB
- U.S. and Sweden international cooperative program
- Initial capability (XM982 Ia-1) — fielded to deployed forces in 2007
- Fully ORD-compliant — M982 Ia-2 pending full-rate production
- Low cost — M982E1 Ib in final design and qualification phase
- Exportable since 2008 — Excalibur Ia FMS cases in progress
- Current platforms
  - M777
  - M109A6
  - M198
  - FH77BW
  - AS90 (limited qual)

M109A6 Paladin — U.S. Army

M777 — U.S. Army, USMC, Canada

FH77BW Archer — Sweden

AS90 — U.K.

M198 — Australia

**Responsive, accurate and lethal precision effects**



EXCALIBUR

# IRAQ Urban Combat Experience — Avoiding Collateral Damage

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## Warfighter perspective on Excalibur

- More responsive than air-delivered assets — “Every soldier and Marine has access because the artillery directly supports every battalion and company in contact”

- “Incredibly accurate … at its minimum/maximum range, you get that same level of accuracy”
- Easy to use — “Firing Excalibur was similar, if not easier, than firing conventional artillery”

**Saving lives today — “The unit was able to fire an artillery round at a target within 50 meters of infantrymen on the ground. If we did not have Excalibur, we would not have been able to engage that target."**

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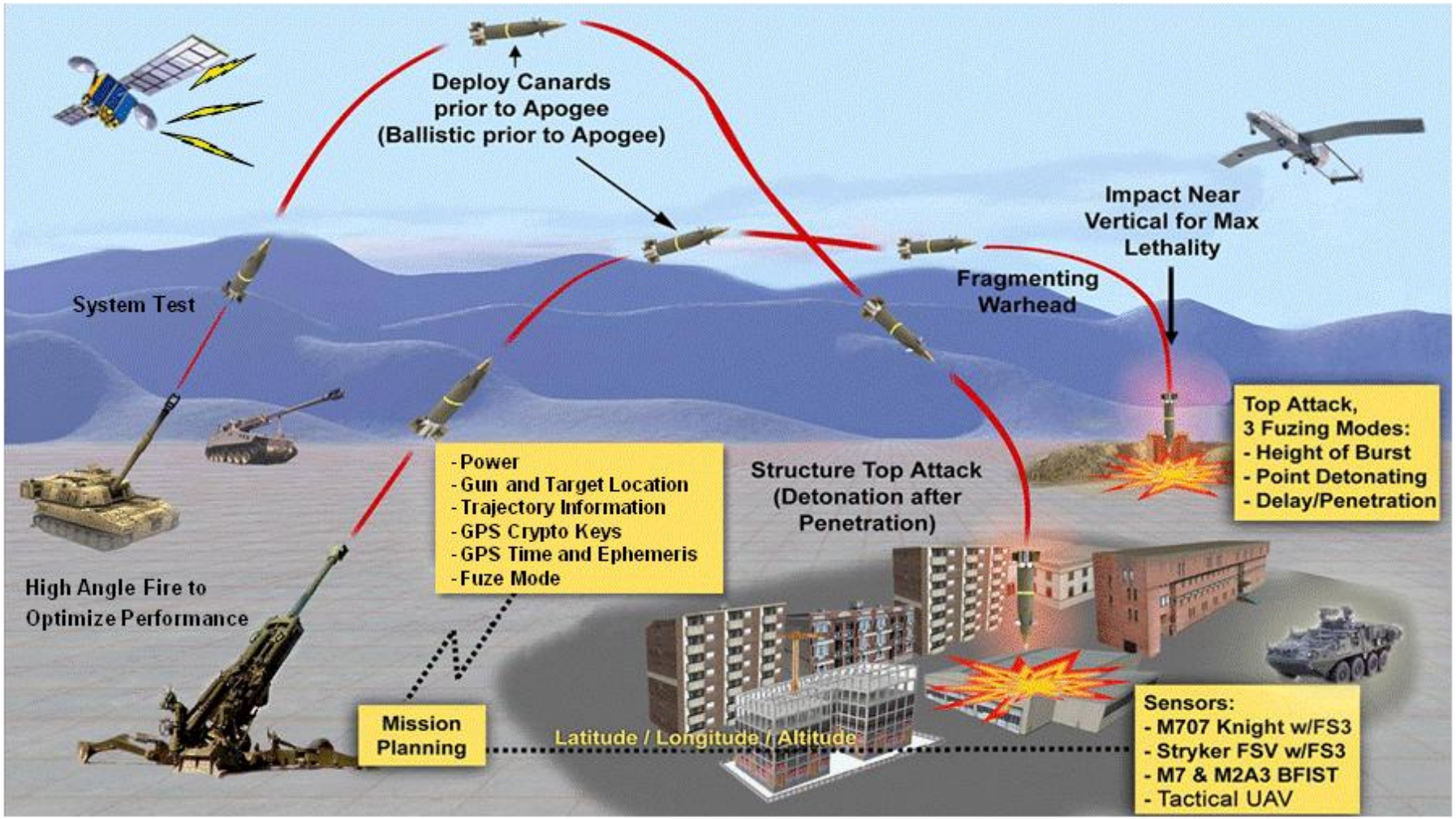
# Operational Concept

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# Excalibur Warfighter Rationale

- Extended-range fire extends maneuver's tactical reach
- Range-independent ten-meter Radial Miss Distance and off-axis capability increase operational flexibility
- Close-combat capability reduces risk to friendly forces while protecting civilians and minimizing collateral damage
- Near-vertical terminal attack angle permits urban and complex terrain uses
- Concrete penetration, integrated multiple-mode fuze, scalable effects — expands cannon artillery target set
  - Point detonate, Delay, Height of burst
- Fewer rounds to achieve target effects — minimizes logistics burden
- Minimal change to unit-level training and TTP

**Autonomous, all-weather, day and night — responsive, organic firing capability**

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# Original Excalibur Concept Was a Radical Departure From Initial Army Plans

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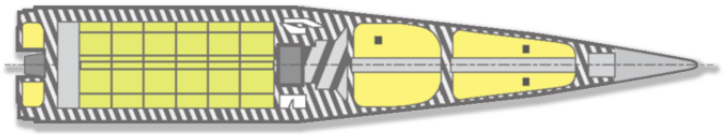

- Government design (ARDEC)
- LCCM guidance
- Tractor rocket motor
- IMU — N/A
- GPS — unknown
- Warhead(s)
  - XM-80 bomblets
  - One SADARM


- Fixed tail
- CAS — two axis
- IMU — FOG
- GPS — IEC
- Payloads via Block Insertions
  - DPICM – changed to Unitary warhead in ‘01
  - Smart sub-munition – 2 SFMs (SADARM)
  - Discriminating munition
- No propulsion

*www.globalsecurity.org/military/systems/munitions/images/*



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# Designing for Operational Challenges

- Gun hardening
  - Multiple charges
    - Angular acceleration variation (also a worn gun barrel issue)
    - Muzzle exit over pressure decay profile
    - Variable spin rate at tail fin deployment
    - Effective gas flow, engraving
  - Muzzle brakes
  - Ramming/handling
- Operational
  - EPIAFS
    - Carrier frequency
    - Message protocol
  - Integration with AFATDS
  - 20-year storage life
  - Handling
  - Training

# Naive Engineering Toolbox Slowed Early Progress

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- Models/analysis/understanding
  - FEA — modeling transient loads, high-pressure differentials
  - Material science — strength of materials to transients, elasticity/tear
  - Pressure management — obturation, muzzle exit
  - Base design — spin/overpressure/muzzle brake design tools
- GPS
  - Clock — loss of time reference
    - Vendors, orientation, suspension
  - Evolution — new environments
    - Hardware, software, integration
- IMU
  - FOG — did not gun harden — spool too fragile
  - MEMS #1 — did not gun harden — masses too large
  - MEMS #2 — did not gun harden — almost
- CAS
  - Two to four axis required
  - Increased span on canards
- Affordable testing
  - Early, aggressive gun engineering testing
  - Capable, affordable OBR development and use

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# Excalibur Evolved With the Market

- Major program restructure affects SDD (2001-December 2002) – merger with Swedish TCM; transition from DPICM to Unitary

Block I to Increment Ia

  - Structural design and testing to be done early
  - Critical components were still technologies — not products

- Early fielding (April 2004) to full compliance (October 2007)

Ia-1 to Ia-2

  - Test-structured, early program paid big benefits in execution
  - Clever algorithm design makes things possible without hardware changes

- Cost improvement; increased reliability; new, more stringent A/J requirement (September 2008 to present)

Ia-2 to Ib

  - Pay attention to **cost, cost, cost**
  - Systems expertise in many areas critical to good architecturing and execution

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# Demonstrated Capability Exceeded Some Requirements

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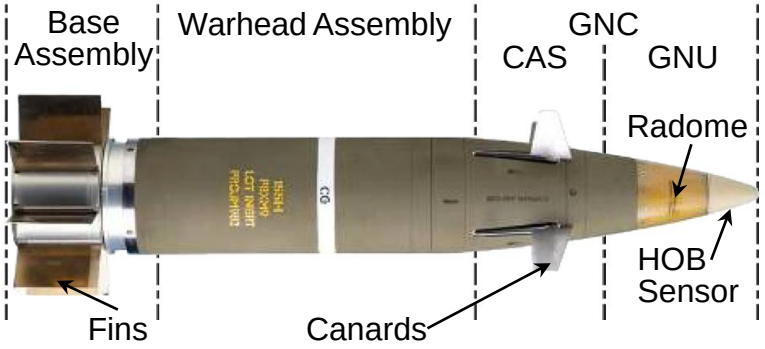
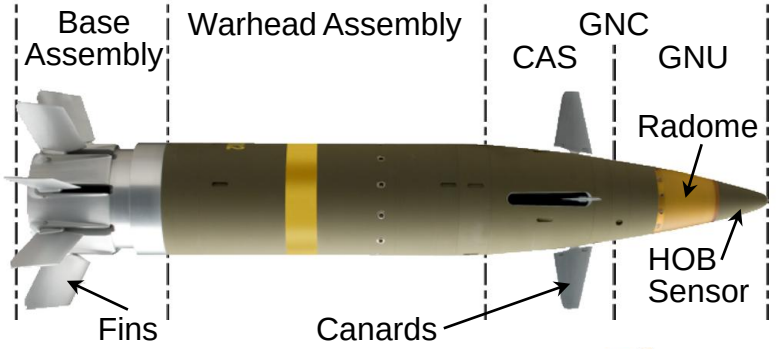
## Requirements Comparison Summary

| KPP | Threshold | | | Objective | | | Demonstrated | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ia-1 | Ia-2 | Ib | Ia-1 | Ia-2 | Ib | Ia-1 | Ia-2 | Ib |
| Precision (CEP) | 20 m | 20 m | 10 m | — | 10 m | 6 m | <6m | <6m | <5 m |
| Maximum Range | 24 km | 35 km 39-Cal<br>50 km 52-Cal | 35 km<br>50 km | — | 40 km<br>60 km | 40 km<br>60 km | >24 km | 41 km<br>39-Cal | >32 km 39-Cal<br>>46 km 52-Cal |
| Reliability | 60% | 85% | 93% | — | 96% | 96% | 85% | 85.9%–<br>91.5% | 93%<br>for shoot-off |
| Lethality | Effectiveness ≥ M107 | | | Effectiveness ≥ M107 | | | Effectiveness ≥ M107 | | |

### Increment Ia




### Increment Ib

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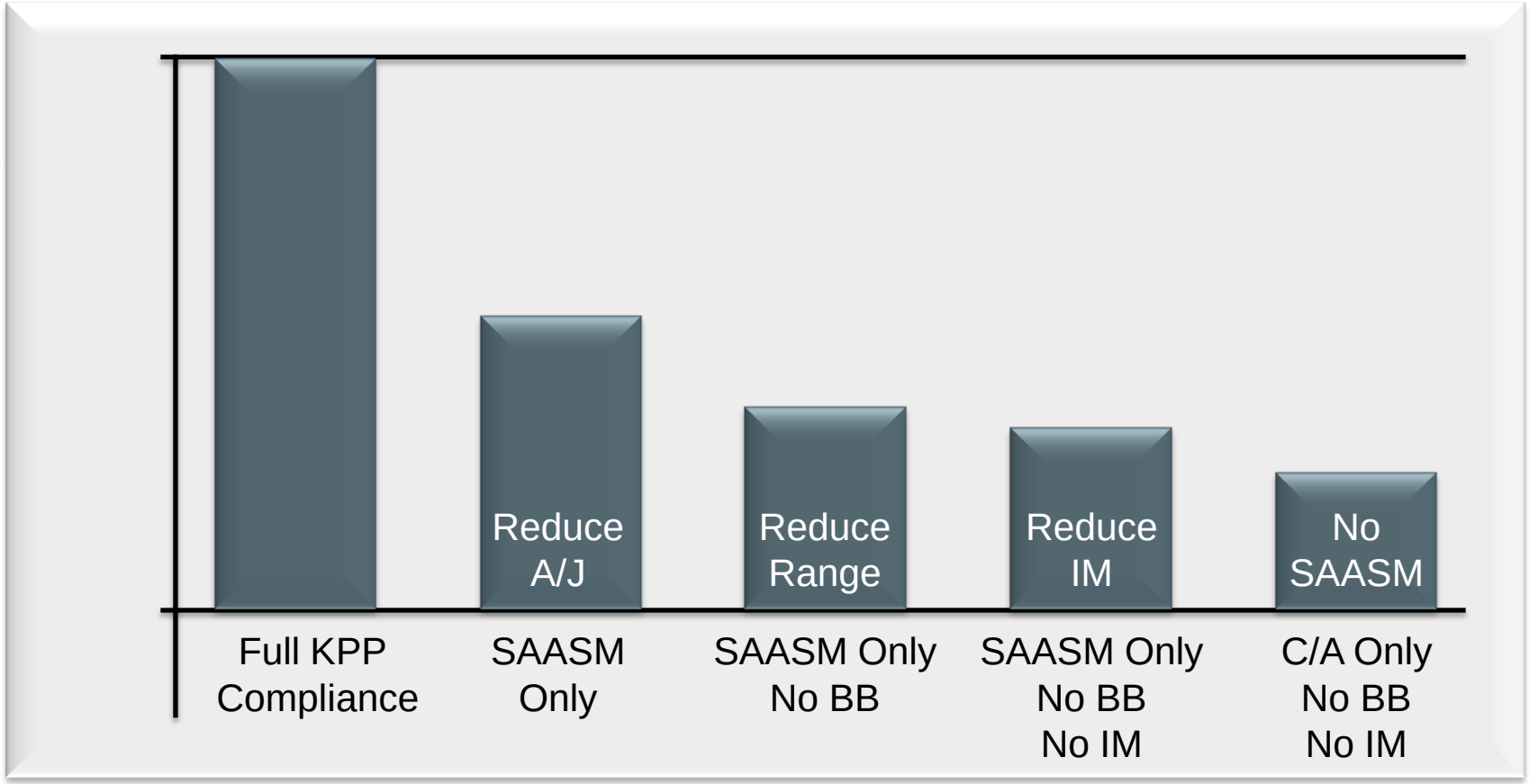
# Specifications Drive System Cost




**Majority of architecture costs driven by requirements (A/J requirement sets major architecture population)**





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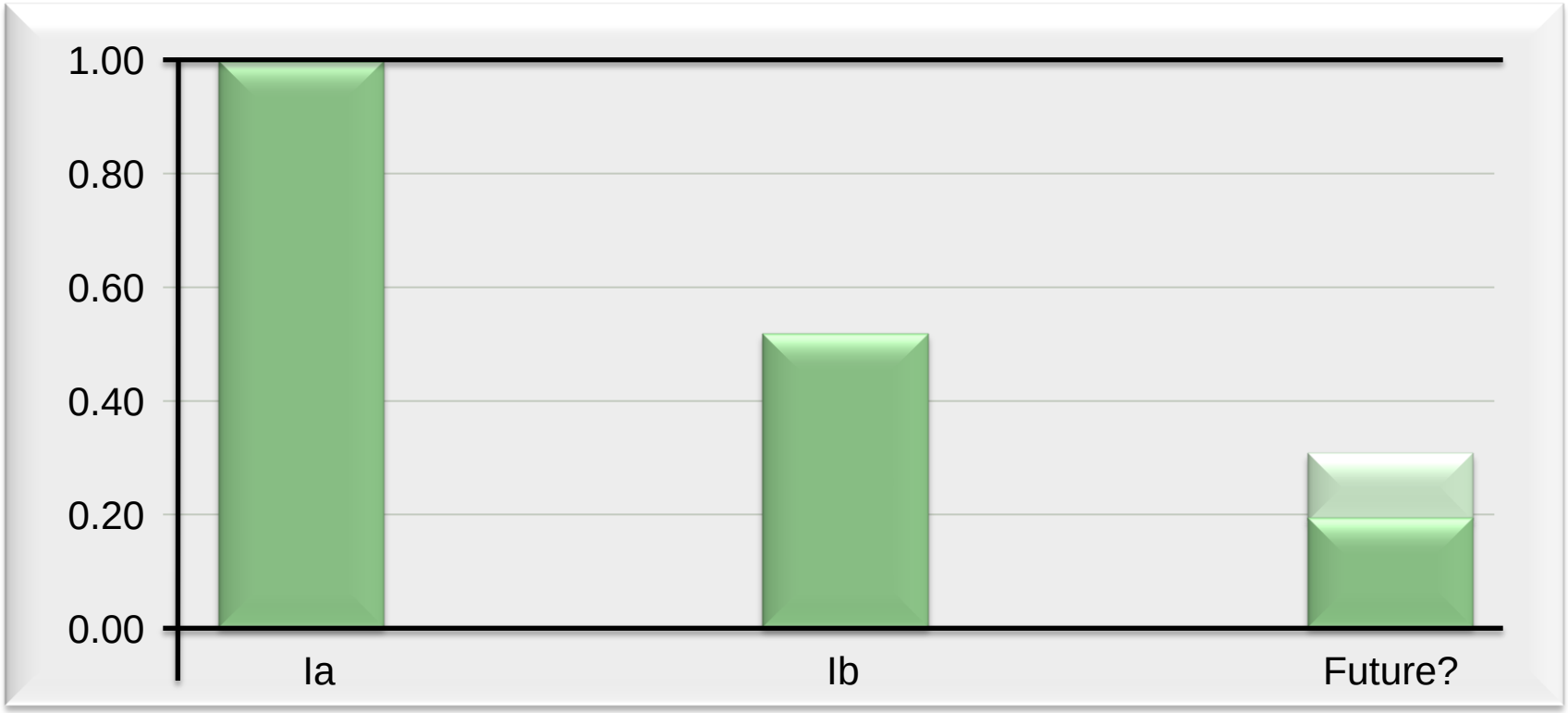
# What Is the Future Cost of Precision?




**Requirements and technology (and production quantity) likely to continue to have a significant impact on the future**

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# Excalibur Benefits the Warfighter

- Excalibur was the first and still the **only** fielded, autonomous, precision-guided, extended-range artillery projectile
  - GPS/IMU
  - CAS
  - Finned base
- When we started, we were unable to see the course
  - The industrial base overestimated readiness at SDD start
  - Analysis/models were naive
    - Impulsive loads — pressure variation — SOM under impulse
  - Requirements evolution increased the challenge (increased AJ, new payload, platform…)
- Increased experience denoted the turning point
  - Chasing subtle problems in IMU and GPS
  - Mechanical failures solved
  - A baseline set of tools and processes available
- More capable and able to evolve
  - Activities based on cost reduction, reliability improvement, large industry investment
  - ARDEC/RMS successfully supported warfighter

**Progress flowed from solid engineering and operational lessons**