Raytheon
Customer Success Is Our Mission

Presentation to 43nd Annual Gun & Missiles Conference

Alternatives for Architecturing Low Cost Guided Projectiles
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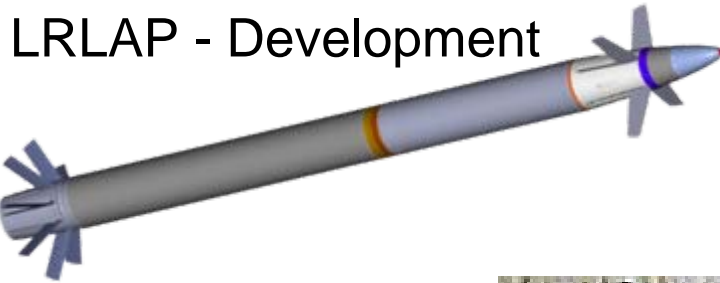Stephen Bennett
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April 23, 2008

NOTE – All equations, weapon descriptions, and equipment specific materials are from open sources, usually the internet to avoid ITARS or classification issues

Existing Projectile Guidance Activities
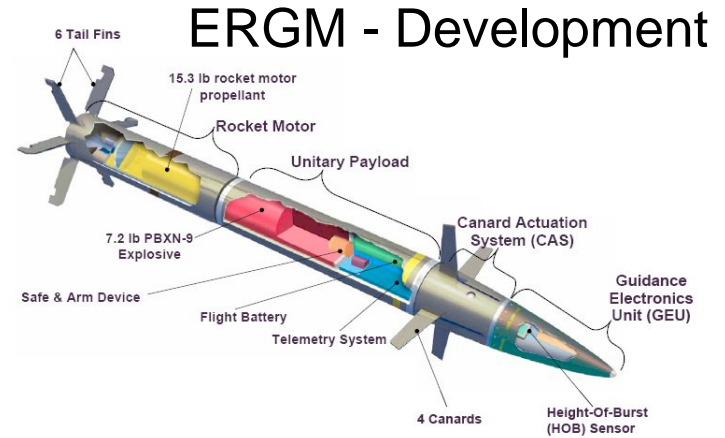

EXCALIBUR - Production

ERGM - Development

LRLAP - Development

Krasnopol - Production

Copperhead (OOP) – In Service

PGK - Development
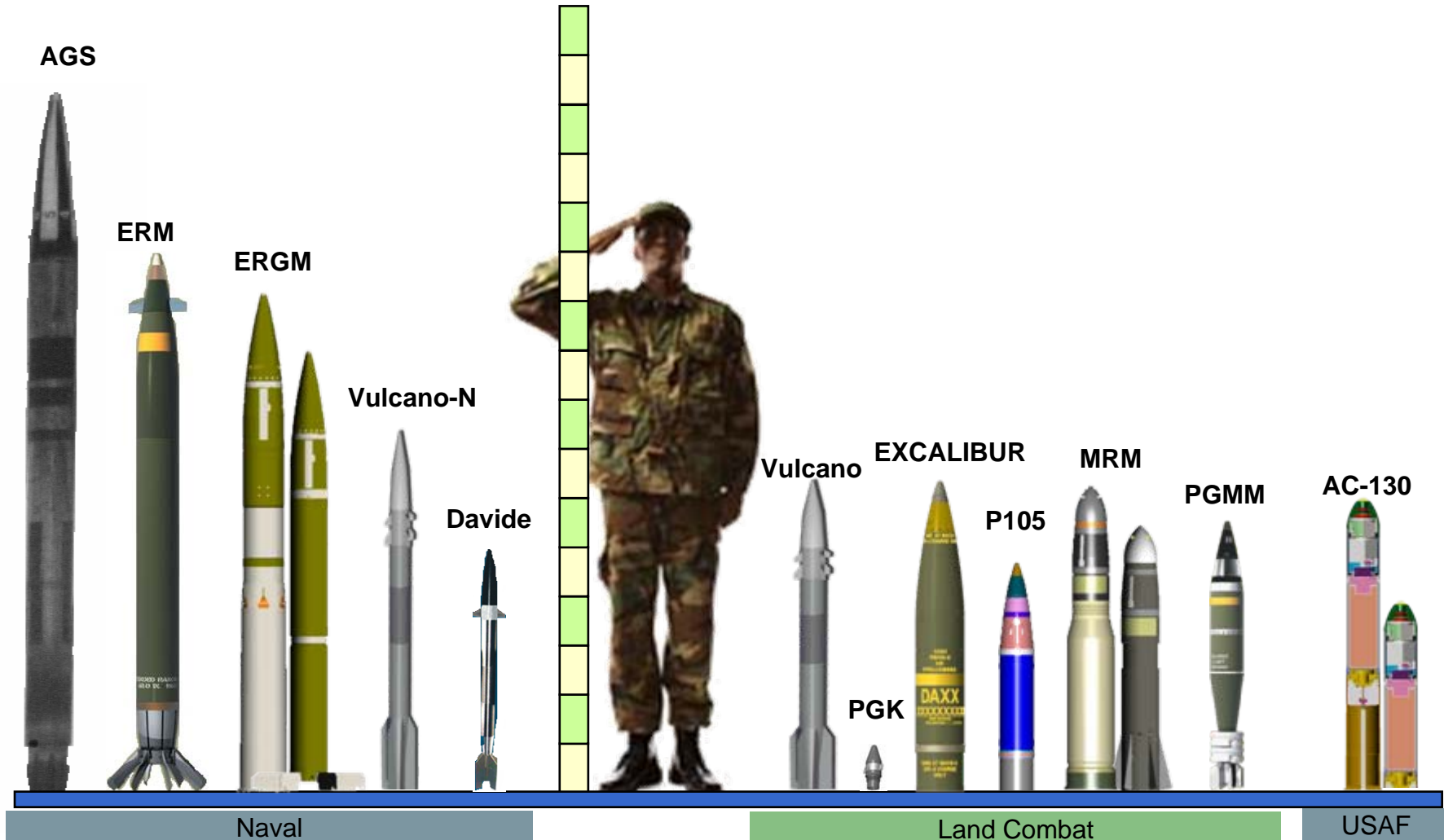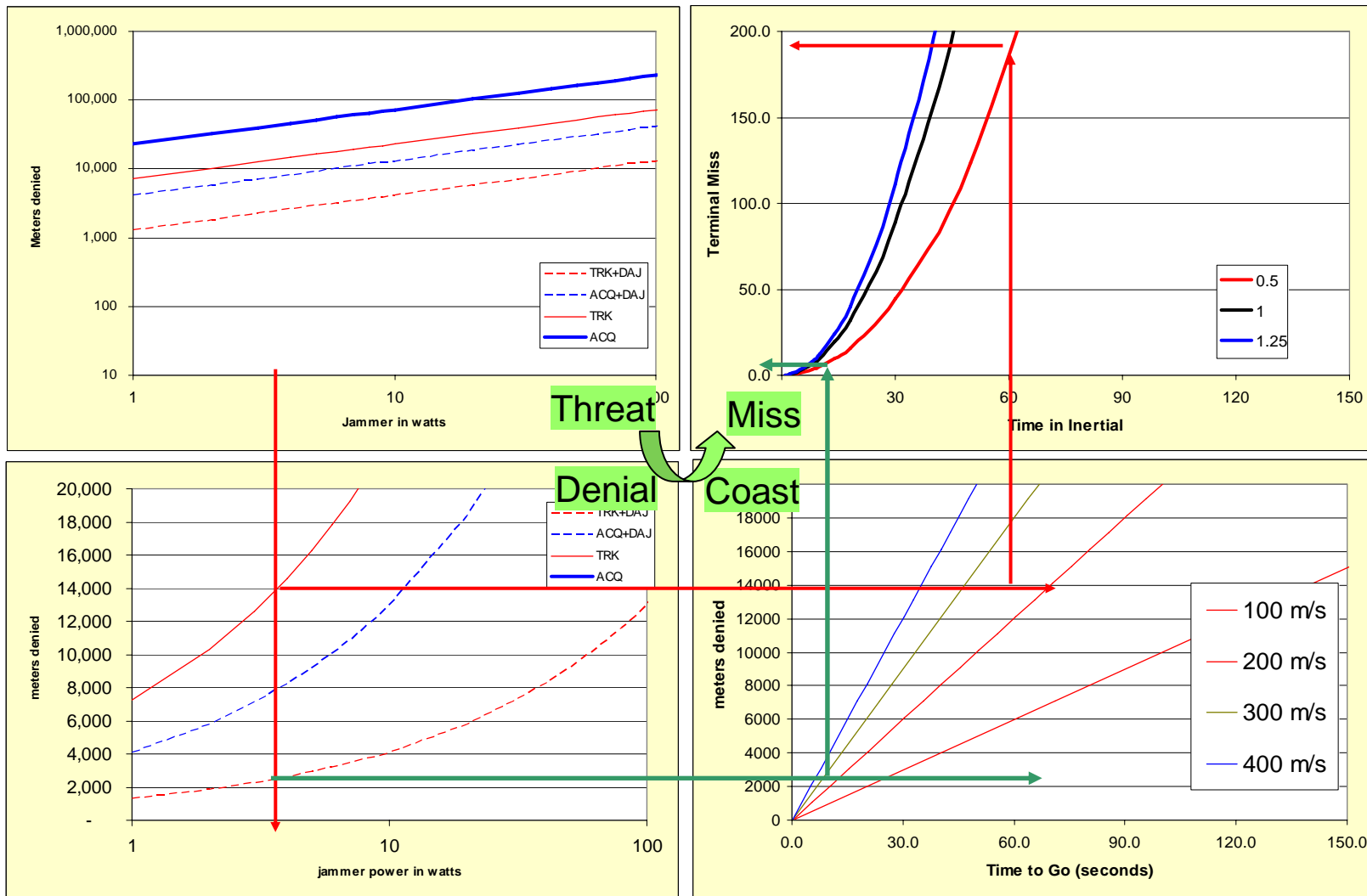
Vulcano - Development

Present generation build with missile-like Specifications

Wide Variety of Concepts and Programs

AGS

ERM

ERGM

Vulcano-N

Davide

Vulcano

EXCALIBUR

P105

PGK

MRM

PGMM

AC-130

Naval

Land Combat

USAF

How we tradeoff GPS AJ and CEP performance (gliding weapons w IMU)

Traditional Trade Off between GPS and IMU Specifications

NOTE – All equations, weapon descriptions, and equipment specific materials are from open sources, usually the internet to avoid ITARS or classification issues

How we tradeoff GPS AJ and CEP performance (trajectory correcting weapons)
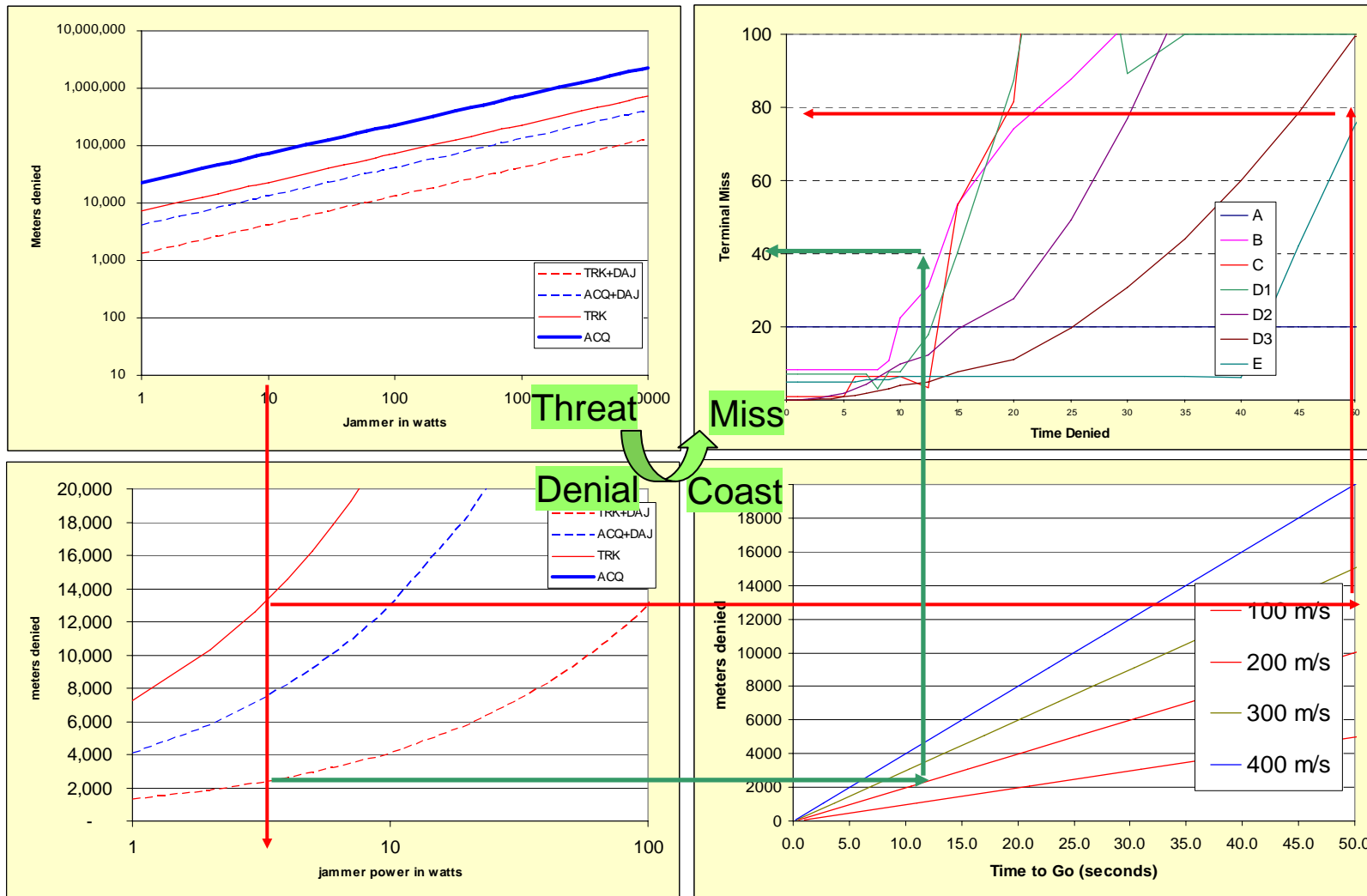
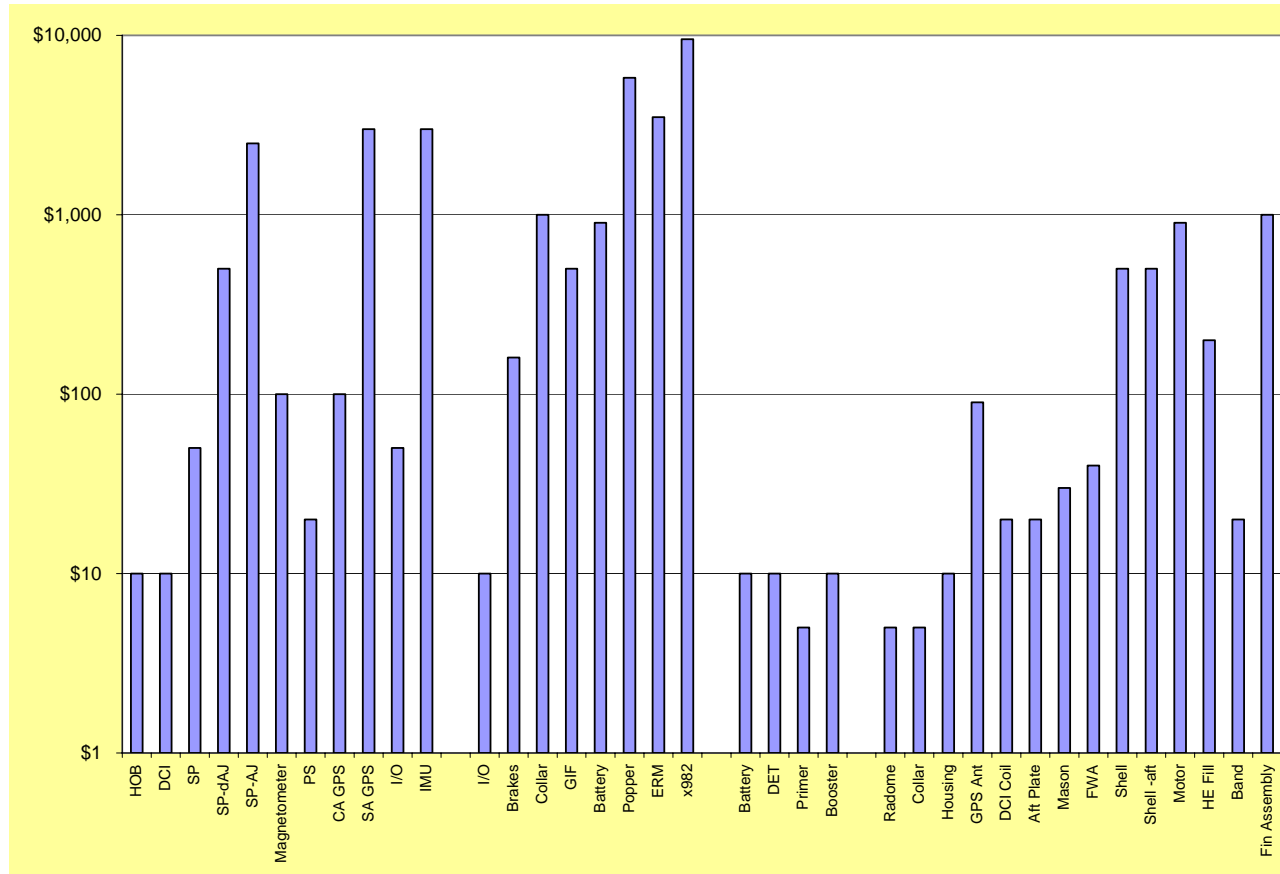**Trade Off between GPS and Trajectory Correction**

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Study used "Functionality Based Costs"

Technique in NATO Study Groups to Compare Concepts

Technology / Cost – Best Architecture Evolves
(use for relative – not absolute costs analysis)

PGK (<50 m CEP)

A   B

1D-PGK   2D-PGK
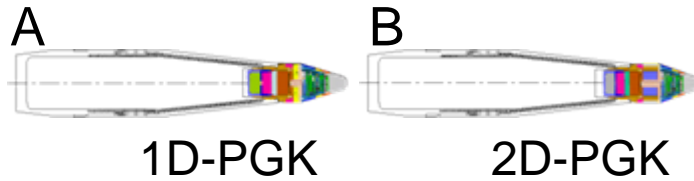
AUPC ($K)	2.2	3.4

Hybrid (<20 m CEP)

C1   C2

2D-CCF   2D-GIF
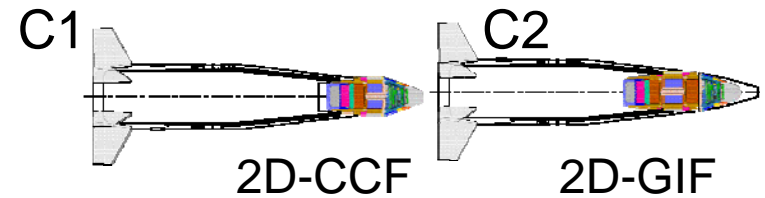
AUPC ($K)	4.6	10.3

Precision (<10 m CEP)

D1   D2   E

3D-"ERM"   6D-"Excal"   2D- "HAMR"
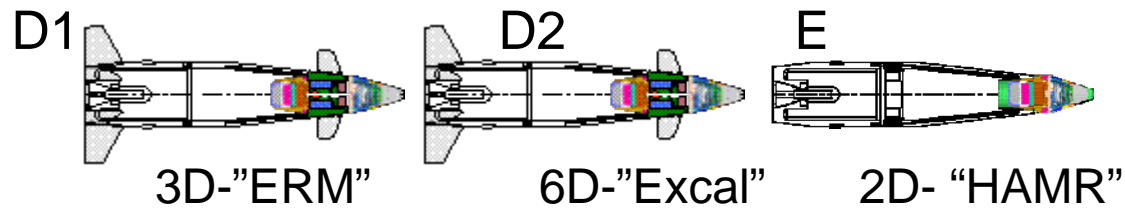
AUPC ($K)	14.5	31.0	17.3

Concept A 1D PGK	Concept B 2D PGK	Concept C1 2D "PGK"	Concept C2 2D "GIF"	Concept D1 2D "ERM"	Concept D2 6D "Excal"	Concept E 2D HAMR
DCI HOB CA GPS Power Design MOFA Flight Computer I/O to 1D	Magnetometer I/O CCA to 2D		I/O to Act	I/O to Act	I/O to Act I/O to IMU	(I/O to TC)
Brake Assembly	2D CAS		Collar Assembly Extra battery	ERM CAS Extra Battery	CAS IMU Extra Battery	TC Assembly Extra Battery
		Finned base	Finned base	Finned base	Finned base	
PGK-like Weapon Architecture		**Hybrid Weapon Architecture**		**Precision Weapon Architecture**		

SW Functionality is Remarkably Consistent

PGK, **Hybrid**, **Precision**

Concept	Aimpoint estimation	Arming function - Brake	Arming function - FS&A	Ballistic aiding of GPS	BIT	DCI	Fail Safe	Fuzing	GPS HOT START	GPS Processing Interface	Jamming Detection	Latitude / Altitude compensation	Launch detection	Mini- TM/HOB interchange	Operating system	Optimum braking timing	Power up processing	Precession Drag count	Provisions – Unique projectile characteristics	Reprogramability	Telemetry Output Subsystem	WGS-84 Earth Model Transformations	Winds Aloft compensation	PIL/HIL data entry test ports	Special factory tests	Telemetry	Collar braking command	Control "UP"	DOD WMM 2005 Integration	Magnetometer "UP"	Magnetometer calibration function	CAS commands	Control section BIT	GPS- AJ / or Coast Logic	Trajectory shaping	Autopilot	IMU	Popper firing logic
today	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x							
A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x												
B	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x							
C1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x							
C2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
D1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
D2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
E	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x				x

Factory / Manufacturing / Test Functions

New 2D KIT FUNCTIONS

New Projectile variants FUNCTIONS

Insertion Of new function into SW

Software Infrastructure Needs Support Many Solutions

Concepts vs. Precision 105 Requirements (of 8-2007)

Attribute	B PGK	C1 PGK	C2 GIF	D1 ERM	D2 982 jr	E HAMR	Comments
Precision							HAMR depends on achievable popper impulse
Reliability							.90
Net Ready							All support NET
Lethality							New Pre-formed fragment warhead
Range							Min 5km, Max 20 km
Compatibility							All EPIAFS compatible
Initialization							All Support requirements
Fuze Function							All Use MOFA fuze well
SAL Compatible							All would require different packaging to support
Angle of Fall							70 degree angle achievable at 2/3 range (spec)
Projectile Weight							<54 lbs
Projectile Length							<40 inches
Render Safe							Unused Poppers may still initiate
Reset							
Reset after Ram							
Extraction							
Query							Power up charges caps and fuze can answer queries
20 year Shelf							IMU 20 yr uncertain
IM Compliant							Poppers on surface and are "projectiles"
Risk of meeting KPPs							Combined assessment of simultaneously meeting CEP / impact angle / packaging / concept risk

Candidate Space Offers Multiple Potential Solutions

COST of High AJ Spec

System cost delta to
provide system architecture
supporting High A/J specification

AJ
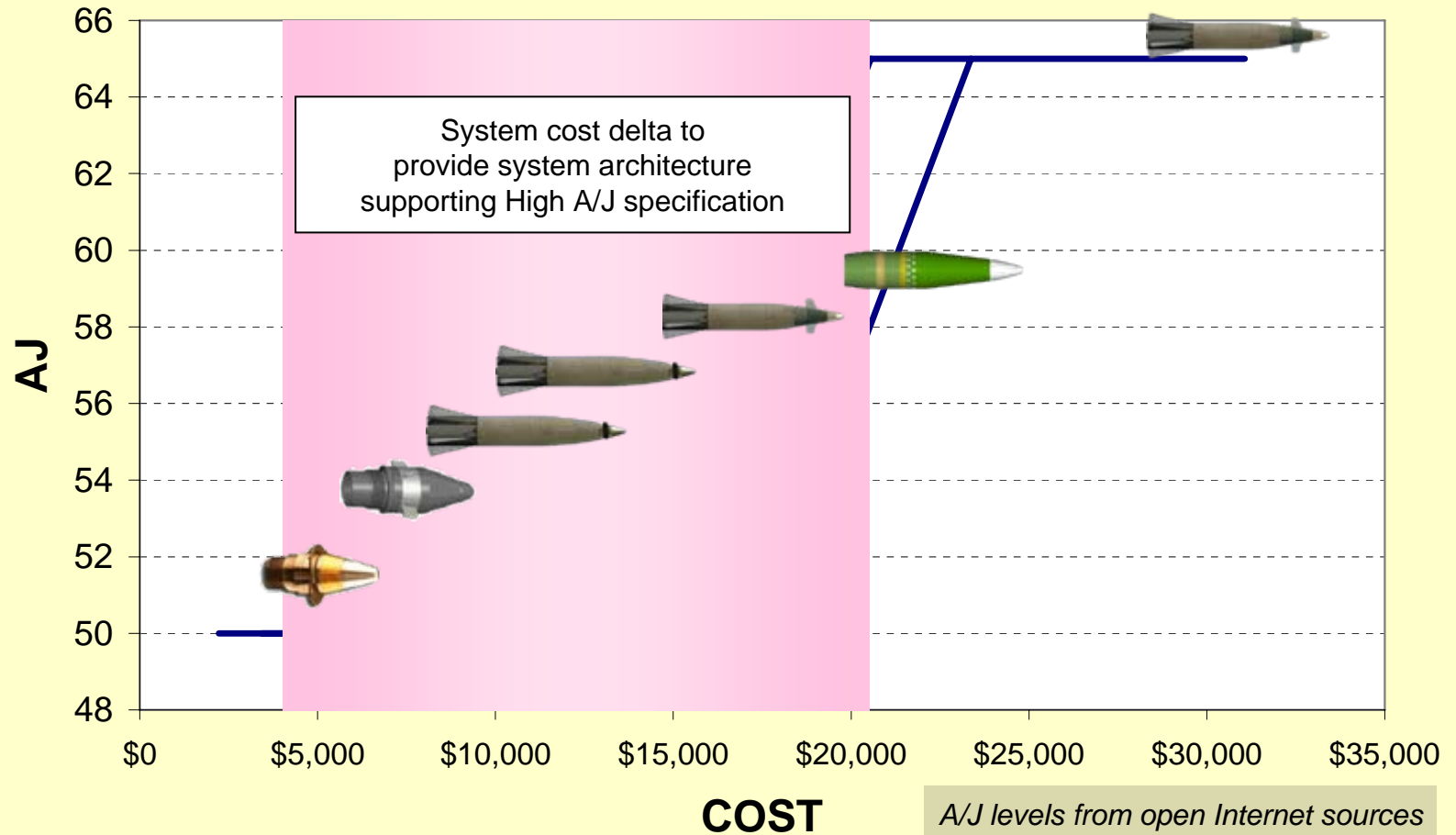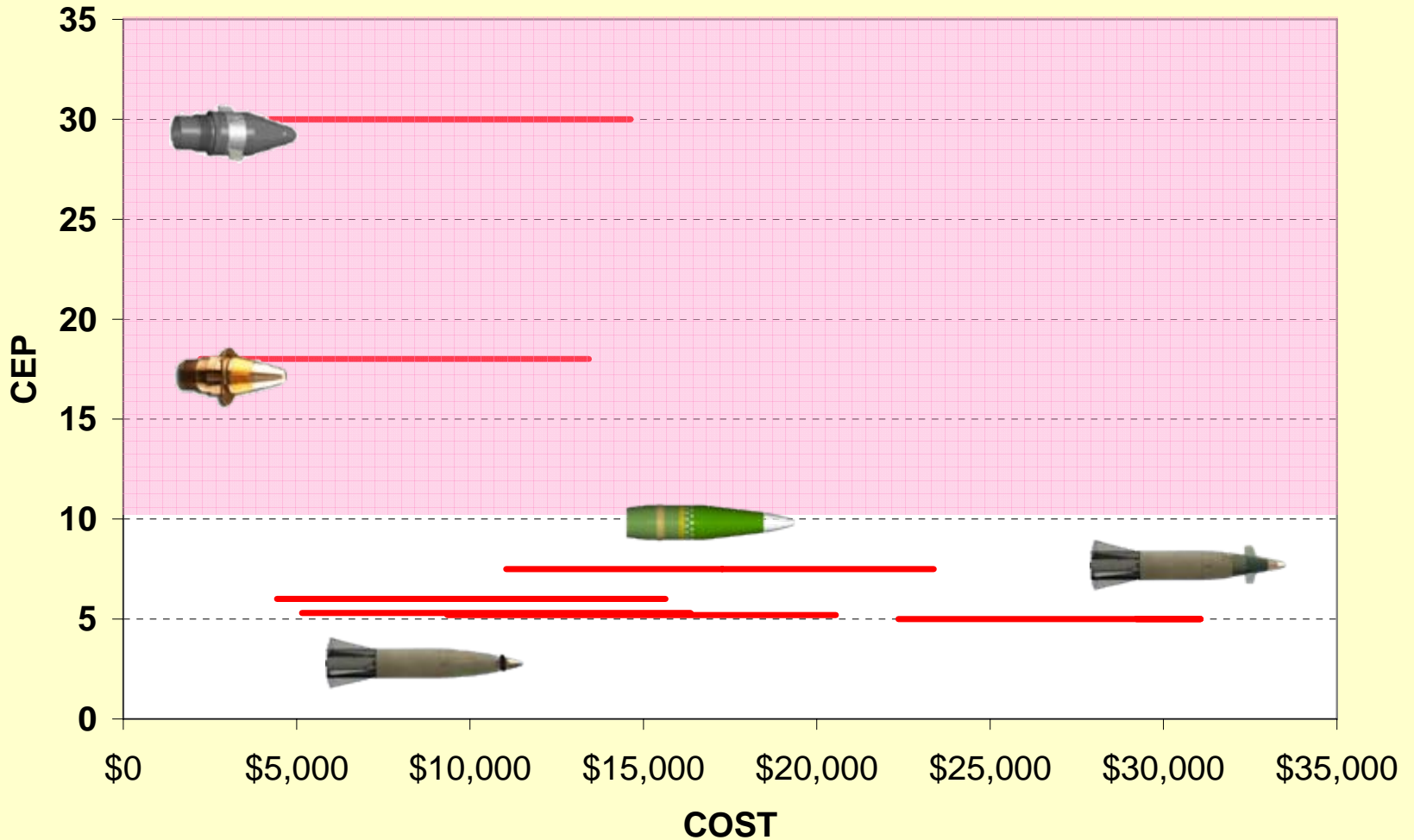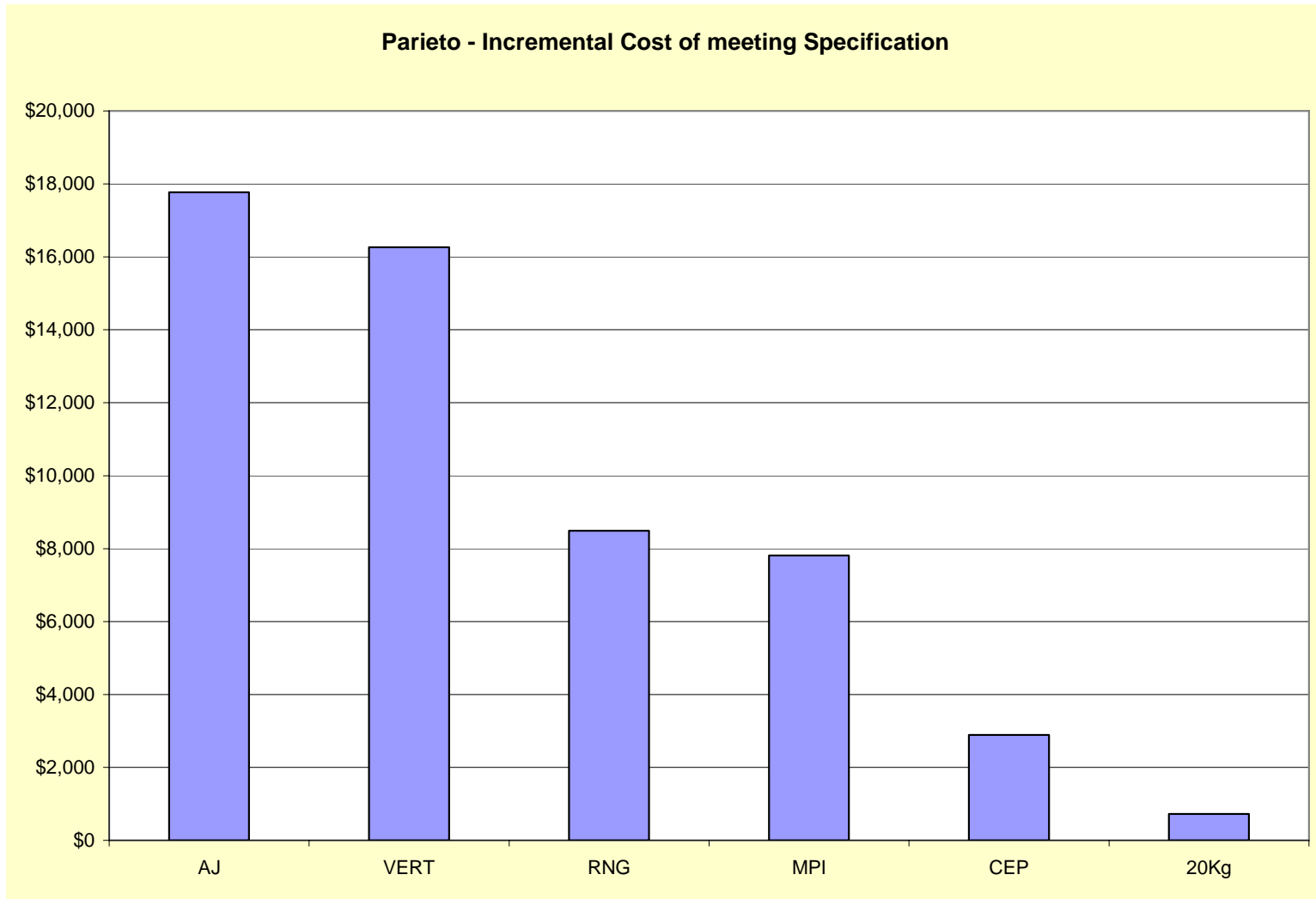
COST

*A/J levels from open Internet sources
(used in place (**without correlation**)
to any knowledge of US capabilities)*

COST vs Accuracy

Potential Cost of Specification Compliance

Parieto - Incremental Cost of meeting Specification

Some Requirements Drive Majority of Architecture Costs

Summary

- There are a number of viable guided projectile concepts that can meet both 20km and 10 meters CEP
  - PGK like
  - Other trajectory correcting concepts
  - Gliding / guiding concepts
- Specifications will drive viable concept architecture
  - GPS A/J performance
  - Verticality
  - Maximum Range
  - Robustness to MET / MPI variations
- Concept architecture will drive cost
- A/J level specified is largest potential cost driver
  - High A/J eliminates most projectile concept architectures
  - Remaining concepts are EXCALIBUR like in components required
- Interpretation of Vertical requirement next largest cost driver

> Customer is in control of the specification and therefore
> The customer is in control of the potential system AUPC