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Customer Success Is Our Mission

2011 NDIA Test and Evaluation Conference

Continuous Cost Reduction Feeds Back Into Product Reliability

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Raytheon Missile Systems

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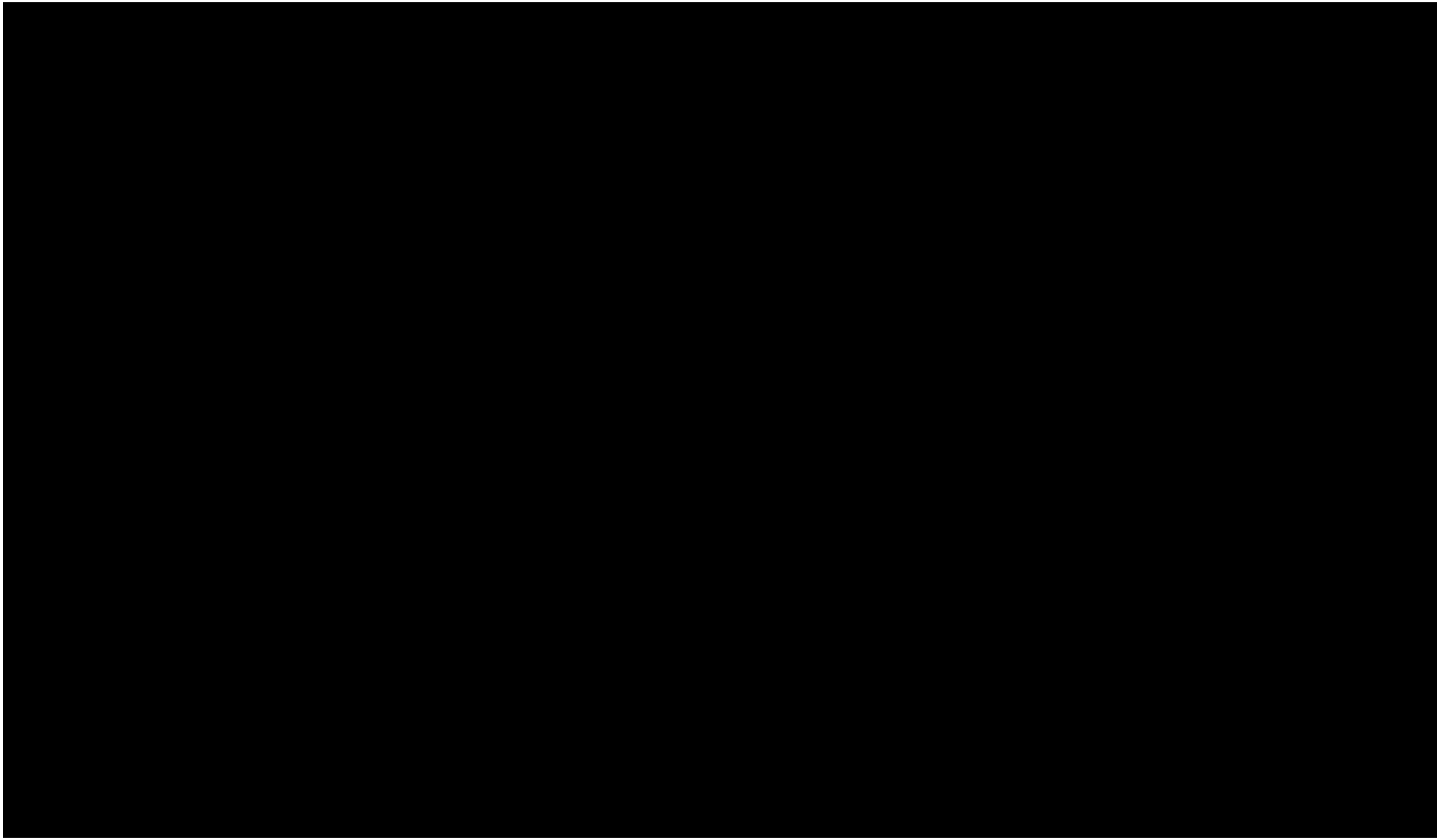
120GM Dagger™ Introduction



120GM Dagger™

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- Advanced Precision Mortar Initiative
  - 2009-Present Urgent Need Effort to Expedite Guided 120mm Mortars to Field
  - RMS was awarded a Phase 1 contract
  - APMI Phase 2 contract (sole source) was awarded to ATK

- Raytheon 120GM Dagger™ GPS-only Design was updated during APMI Phase 1 to include
  - Standard Weapon Interface Compatibility
  - SAASM GPS
  - Telemetry
  - Tri-Mode Fuze (Standard M734A1 Mortar Fuze)

Reliability

- Many definitions, a good definition:
  - "The probability that a *functional unit* will perform its required functions for a *specified interval* under *stated conditions*."
- How is reliability scored/evaluated?
  - Analytical Methods (mostly pre-CDR)
    - Our program conducted minimal effort here (quick turn, no time)
    - Created fault trees, use of Built-in-Test
  - Test and Evaluation (mostly post-CDR)
    - Heavy emphasis on component/system level repeatability testing and All-Up-Round Flight Testing
    - Simple sequence: Test system, find problems, fix them, test again.
- In general, product reliability is proportional to
  - Man-hours Invested in T&E
  - Number of Hardware Units Built/Delivered

Reliability

- Understanding and Achieving Reliability in Missile/Projectile Business can be a Difficult Problem Due to Intrinsic Nature of Expendable Systems

  (not to say it isn't difficult elsewhere…)
  - Long dormant storage life requirements
  - 1-shot devices (squibs)
  - No/minimal design capacity for built-in redundancy
  - Minimal information from systems under test (sometimes must disturb system to extract information)
  - Difficult environmental requirements
  - Shoe-string, leap-frog budgets
  - Tight schedules when money is present

Complex Technology Products Reliability Incentives

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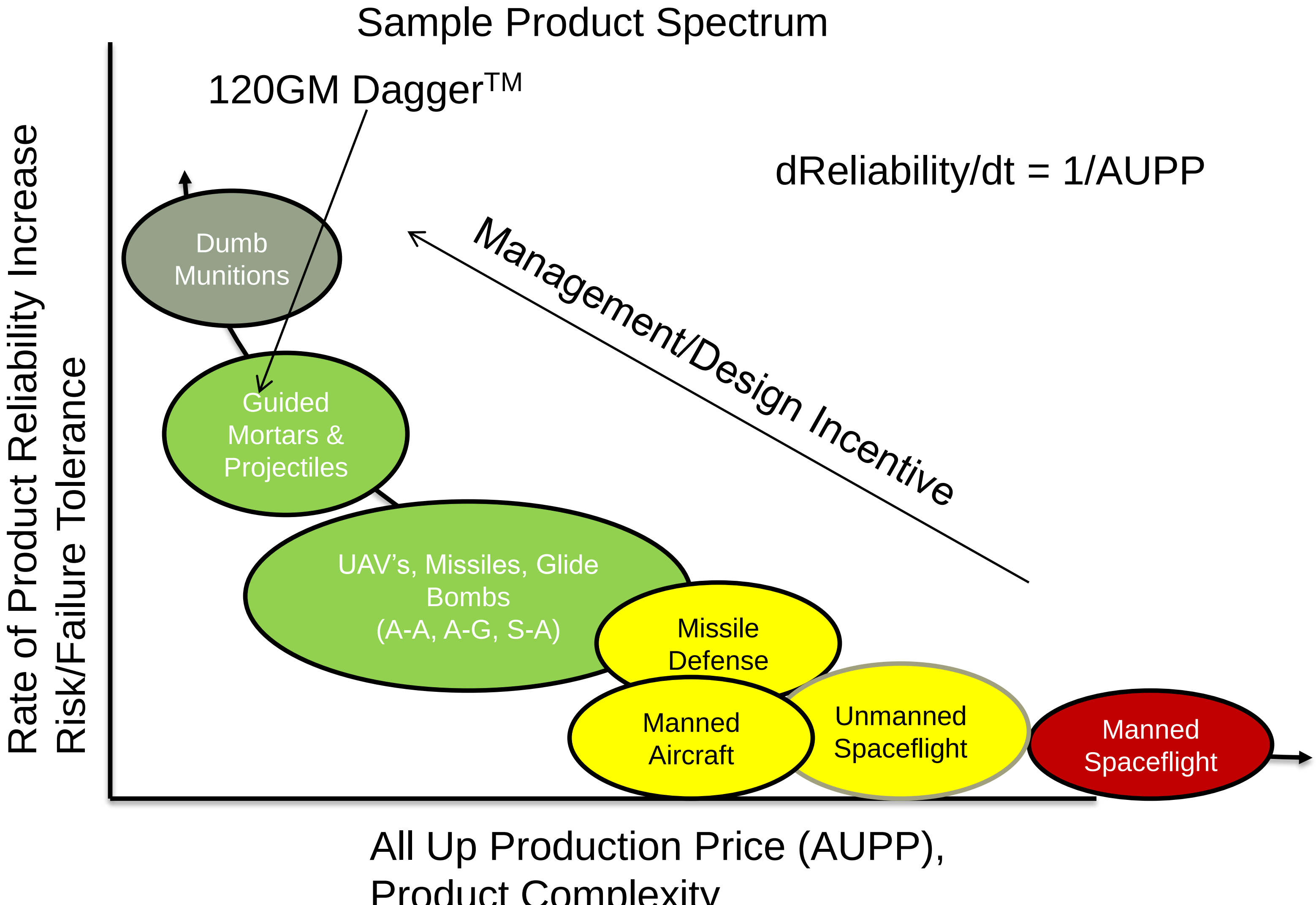

Location on this curve largely dictates T&E behavior.
We should strive to move towards less complexity/price!

Sources of Product Maturity

- Laboratory Testing
  - Use case parameter exploration with hardware
  - Software parameter exploration
  - Functional testing
  - **Repeatability testing**
    - **Extremely Boring, Extremely Effective!**
- Simulation
  - Some mix of real and simulated hardware and physics
  - Performance optimization
  - Rapid software evolution
  - Software parameter exploration
- Field/Flight Testing
  - Real product hardware in tactical or near-tactical environment

Optimal Mixture is Product Dependent

- Optimal Test Mixture Depends on Location in Product Space
- High Failure Tolerance/Low Production Price ← 120GM Dagger™
  – Laboratory testing as necessary
  – Minimalistic (low fidelity) simulation necessary to mature software algorithms and generate course performance estimates
  – Heavy weighting towards field/flight testing with real hardware, as soon as possible (10's to 100's of flights per year)
- Low Failure Tolerance/High Production Price
  – Heavy laboratory testing
  – Heavy work in low, medium, and high fidelity simulations
  – Field/Flight test minimally, and only once high confidence in success is achieved (1-10 flights per year)

Types of T&E – Pros/Cons

	Laboratory/Simulation Testing	Field/Flight Testing
PRO	•Usually Cheaper than Flight Testing (both monetarily and politically) •Easy to control, homogenize and selectively explore product parameter space •Failures have minimal political impact	•Highest Fidelity •High Political Impact •Exposes Product Issues Quickly •True Performance Estimates
CON	•Lower Fidelity than Flight Testing •Mountains of Data •Time Consuming •Inaccuracy in Performance Estimates due to Modeling Fidelity	•High (Negative) Political Impact •Expensive •Tendency to heavily script events due to political risks •Larger Non-Homogeneous, Random Parameter Space that is Difficult to Quantify/Measure/Control/Understand

On the "Fire and Fix" Mentality

- Thomas Edison vs. Nicola Tesla
  - Tesla hated the experimental, non-theoretical methods Edison used
  - Tesla was (and is still) revered for his theoretical prowess
  - In the end, Tesla was not a successful businessman – he was too academic!
  - Edison did not need to *fully* understand the underlying physics to make something work
- When time is short, and hardware is (relatively) cheap, one can resort to experimental methods.
- Even though it does not sound as "smart" (because it is not!), experimental methods can be (and have been for us) a legitimate approach to maturing a product.
- Both men and their methods represent extremes – a mix of laboratory, simulation, and flight testing is best

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Risk Aversion

- Why do we fear failure?
  - Yields Negative Customer Perception: "This Widget Will Never Meet Performance/Reliably Within a Schedule We Care About."
- Certainly, life is cozier if we never fail
- Failure is often a necessary step in maturing a product
  - We must increase our appetite to budget for failure, and build failure into (some) programs…this is difficult to sell in an era of declining expenditures.
  - Desire is to work testing towards the edge of the performance envelope, out of the cushy nominal areas, as political landscape allows. We want to understand where and why a widget fails!
  - Failure-tolerant programs are more likely to be successful in the end.
- Failure Often Yields More Knowledge and Product Improvement than Success, because Engineers are Forced to Dig Deeper
- Don't Dread the Failure Review Board – Embrace the Opportunity to Learn Something New

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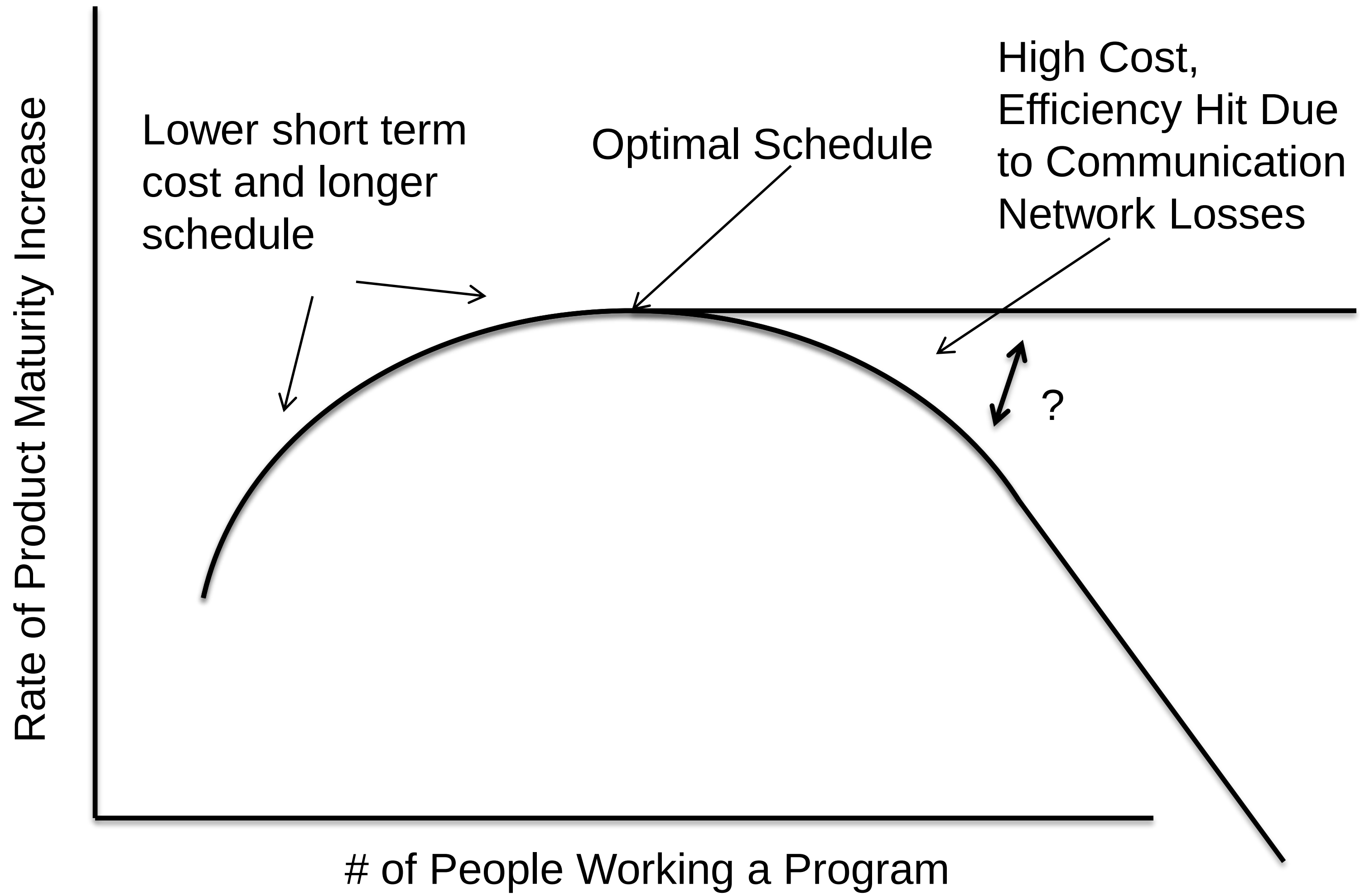
Product Maturity Incentives



More People != Success

Example AUPP vs. Flight Test Quantities Economies of Scale

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- Unit Cost Reduction Feeds Back Into Product Reliability by Allowing Us To Extract more Knowledge from a Given Budget
- Notional Analysis - synthetic costing/budget numbers, not real data
  - – Values used are for example purposes only
  - – Low Quantity or Initial AUPP: $19k
  - – Notional ~Logarithmic Price Breaks
  - – FYXX T&E Materials Budget: $800,000
    - Ie, customer gives us $800k for flight testing this year. What can we do with it?

AUPP vs. Flight Test Quantities (cont)

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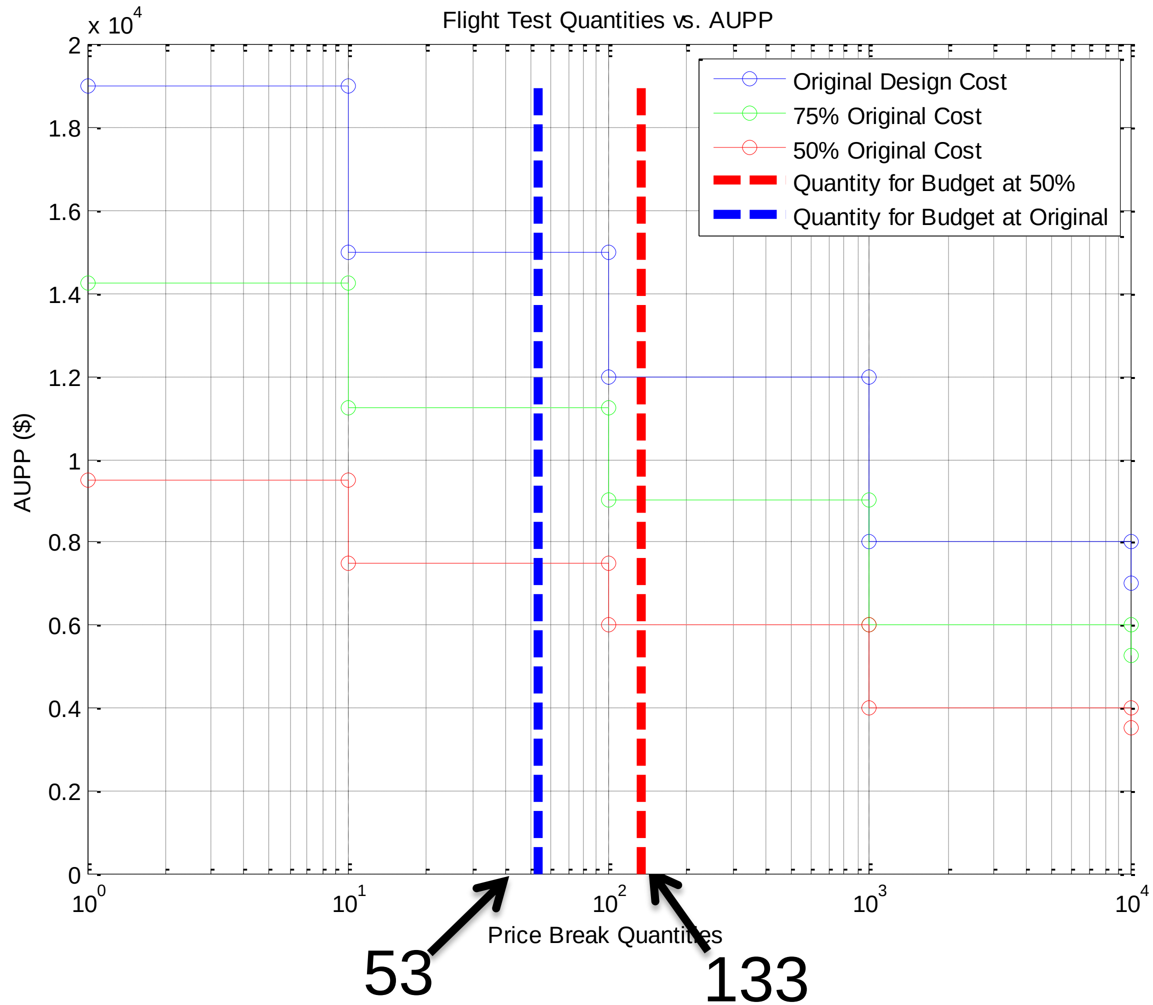
(Synthetic Information, Not Real Costing Data)

Example: Achieving 50% cost reduction more than doubles our test articles at this budget level, because we hit the next level of price break.

Accelerates us into regime of finding/fixing the nitty-gritty 1% failures!



Incentive: Cost Reduction Increases Impact of Price Breaks on Test Article Quantities

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How Do We Minimize Cost?

- A Few Strategies Employed
  - Migration functionality of multiple CCA’s into a single CCA
  - No wheel re-invention - use of proven COTS component parts
  - Move from milled to extruded or cast metal parts where possible
  - Reduce number of metal parts
  - Phase in next generation component parts (vendor produces a lower cost alternative)
  - Minimize Test Equipment NRE
  - Automate assembly and test processes to reduce test time

Where We Are

- Status
  - Post-APMI Phase 1, team size was significantly reduced
  - Reliability improvement work has continued on a shoe-string budget
  - An unconventional first: This program validated improvements in flight test with re-used spent flight hardware (shot out of a gun, impacted the ground), in one case with 3x re-use (guidance electronics only, no structural components). Third HW flight after problem fixes missed target by <1m!
  - We have conducted many recent successful firing tests, with major hardware components donated by suppliers!
  - We wish to thank our supporters at Picatinny Arsennal, Yuma Proving Ground, and New Mexico Tech
- 120GM Dagger^{TM}
  - Extended Range
  - High Accuracy, Even in Moderate Winds
  - No MET data required
  - Tri-mode Fuze

Impact Video from APMI Shoot-Off

Flight Test Results
June 2010 Reliability Improvements

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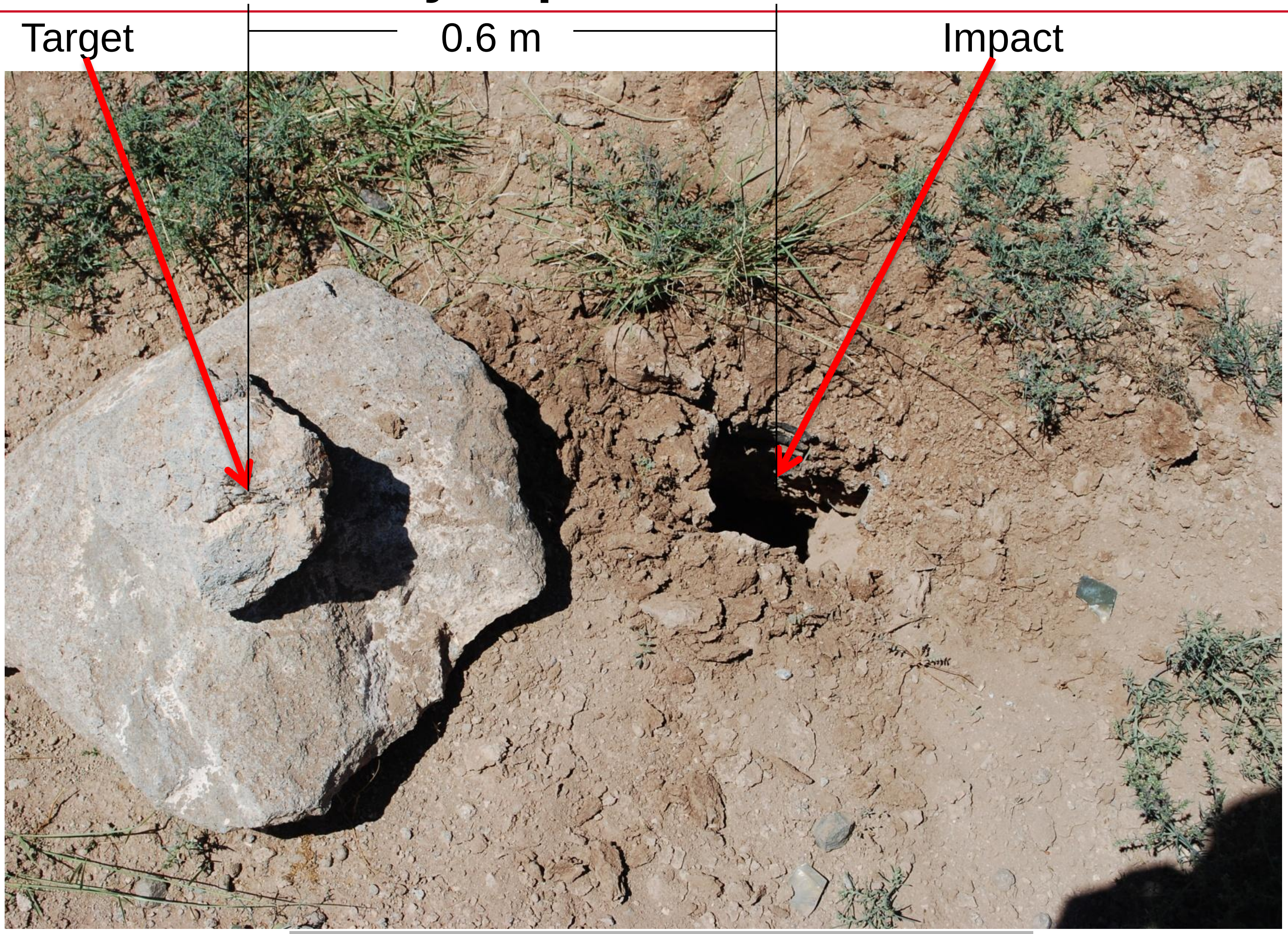

Fired with 2.5 deg ballistic azimuth offset from target!

Energy On Target!

Conclusions - Necessary Mindsets

- Drive Down Cost Early in the Design Cycle to Reap the Rewards of Economies of Scale
- Change is necessary to mature a product
- Challenge Consensus
  - The fact that 10 people believe something and agree with each other does not make them correct!
  - Just because something has always been done a certain way, does not imply it is correct!
  - Be the outlier…ask the question, even if you think you are going to get laughed out of the room!

Conclusions (cont)

- Abnormal/variable product behavior under constant conditions, even if it does not result in a high level product failure is not ok!
  - Don’t be the one who says: **“Oh it’s ok…it just does that sometimes…”**

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