U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – ARMAMENTS CENTER

Fuze Development Center – Building 1530

65th Annual Fuze Conference - Renton, WA: May 10-12

Authors: Stephen Redington, Mark Maselli, Christopher Macrae, Matthew Sargent, Sean Beighley

Presented By:
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Sr. Engineering Lead
CCDC-ACM-FF (Fuze Division)
US Army Fuze Development Center, Building 1530, Picatinny NJ 07806

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Accelerating New Technology to the Warfighter

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Keeping Pace with Challenging Fuze Applications

- **Outline**
  - Fuzing: Unique, Harsh and Unforgiving Environment for Design
  - The Impact of Experience (or lack thereof)
  - Proof of Concept vs Product Design – The cause of many problems.
  - How do we merge the R & D world with the manufacturing world?
  - Common Mechanical Design Problems/Mistakes
  - Common Electronics Design Problems/Mistakes
  - Other Problems/Mistakes
  - Summary

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DEVCOM ARMAMENTS CENTER

Our Mission: Accelerate New Technology to the Field

- **Who Are We?**
  - Fuze Technology Prototype Advancement Center - FTPAC
    - AKA the Fuze Development Center (FDC)
  - Building 1516 – Energetics Assembly and Testing Facility
  - Building 1530 – Electro-Mechanical Fab and Assembly Facility
  - Building 3208 – Electromagnetic Environmental Effects (E^3) Testing Facility
- **What Are We?**
  - A state-of-the-art Electro-Mechanical Fabrication and assembly line with energetics handling and E^3 evaluation capabilities
  - Representative of a typical full service modern Contract Manufacturer
  - If we can do it, anyone can.
- **What do We do?**
  - Support the R&D mission by fabricating prototypes and hardware for fuze, munitions and other military applications
  - Our mission is not manufacturing but to make it manufacturable.

Fuzing – A Challenging Environment

- **Unique Safety Requirements of Munitions**
  - Must be both safe and lethal, just not at the same time
  - Must be safe to manufacture, handle and ship at all times
- **Harsh Environments**
  - Gun Launch (20 – 100 KG's, 50 – 120 KSI)
  - Users (drop, misuse and abuse)
  - Weather (extreme temperatures, corrosive atmospheres, lightning)
  - Storage (often in uncontrolled environments, desert to arctic climates)
- **High Reliability Requirements**
  - Items are mission and safety critical
  - Energetic items cannot be 100% tested but are expected to work 100% of the time.
- **Long Life Requirements**
  - 20 years or more storage life expected but service life can be very short

Meeting the Challenge

- **Experience Influences the Core Competency and Time to Market**
  - The workforce will always undergo turnover so where does Fuze experience come from?
    - Our public educational institutions do not teach students how to make munitions
  - Most employees learn by doing more than by reading.
    - 'Lessons-learned' reports can only go so far in promulgating knowledge.
    - Failure is the most powerful teacher but routinely comes at a high price.
  - Corporate culture plays a significant role.
    - Does management encourage and facilitate teamwork and training?
    - Do new employees find themselves ‘thrown to the wolves’?
    - Can new employees shadow or mentor under experienced ones?
      - Replacements often not hired until the experienced leave
    - Is there an infrastructure for retaining and disseminating core competency knowledge?
    - Are peer reviews encouraged or required for critical requirements?

Proof of Concept Design Vs. Product Design

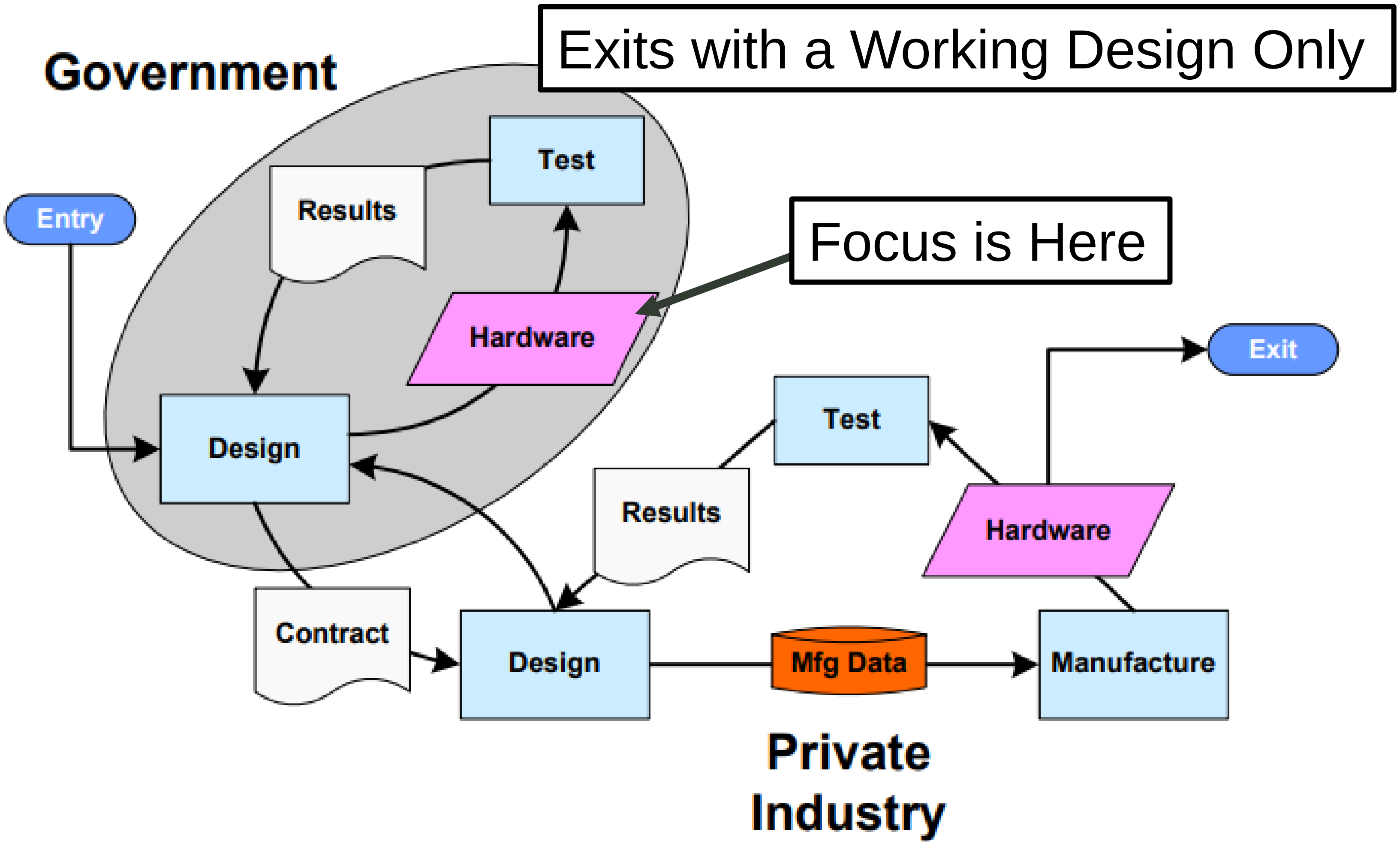
- **Proof of Concept Design (the R in R & D)**
  - Focuses on performance or data, not a product (faster).
    - Product requirements are minimized or ignored.
  - Minimal budget
    - Budget drives schedule and deliverables, not the other way around.
  - Output is technical data, a test report, or a demonstration.
  - No requirement for fabrication documentation.
- **Product Design (the D in R & D)**
  - Focuses on manufacturing and reproduction (slower).
    - Well defined requirements for cost, performance, size, reliability, maintainability, etc.
  - Fabrication documentation is essential.
    - Material specifications, assembly drawings and instructions, quality control metrics, testing and acceptance procedures, records, and more.
    - Real world issues of tolerance stack up and manufacturing capabilities addressed and fed back to engineering and design.

Integrating R&D with Manufacturing

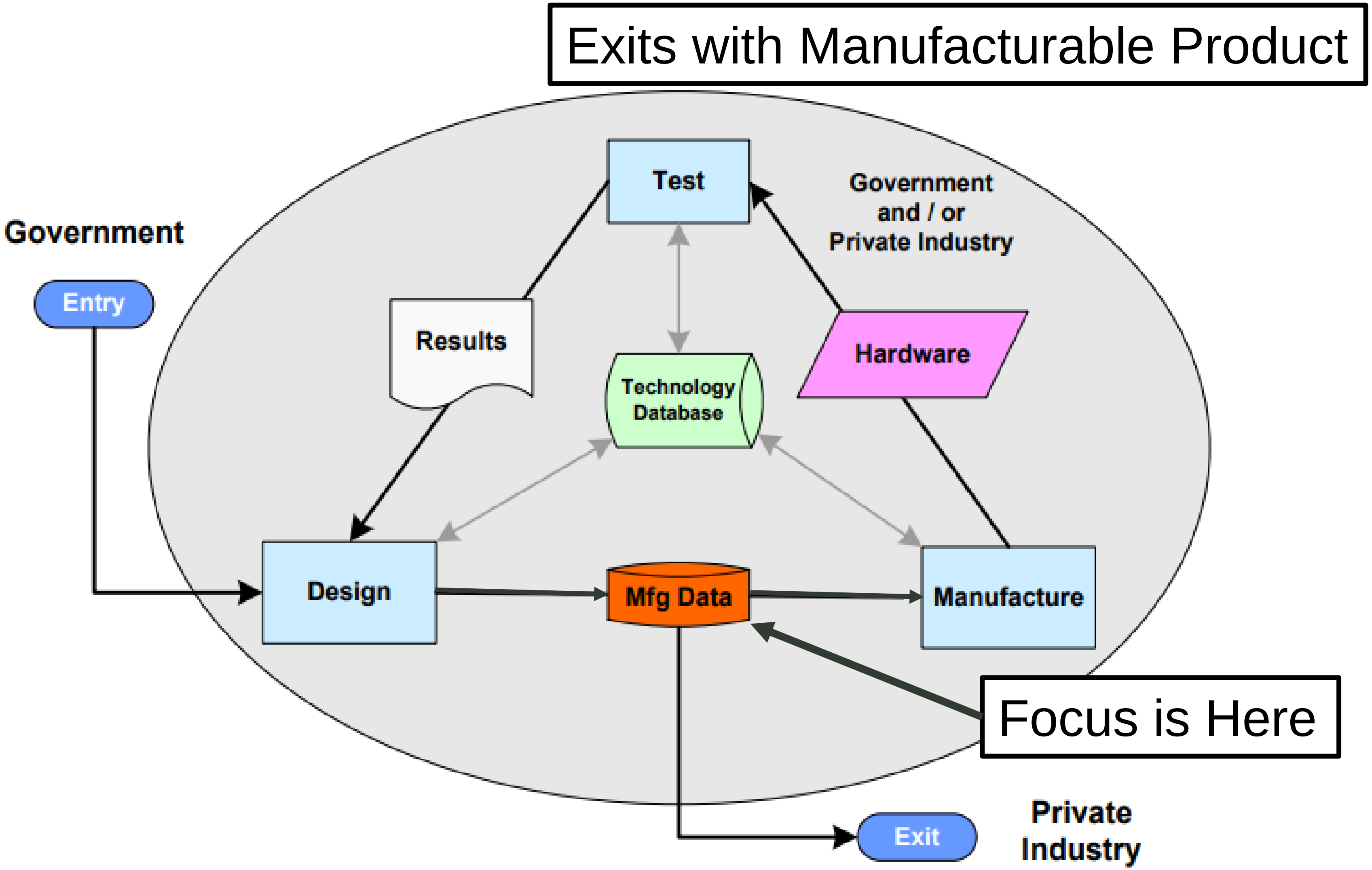
- **A Key to Transitioning from the Laboratory to the Field**
  - A working and functional proof of design prototype is not the same as a product ready for the field, even if it was demonstrated in the field.
  - Environmental conditions often not accounted for or tested.
  - Manufacturing tolerances often not documented or tested
  - Materials and material controls often not accounted for
  - Documentation often uncontrolled or haphazard

- **Integrated Manufacturability Can Help**
  - First Presented in 2010 at the 54th Fuze Conference
  - Manufacturing vs Manufacturability (our definition)
    - Manufacturing: The making of articles on a large-scale using machines
    - Manufacturability: The ease of which an article can be reproduced exactly

INTEGRATING R & D WITH MANUFACTURING



INTEGRATING R & D WITH MANUFACTURING



Problems We See in Mechanical Design

- **Misuse of CAD tools**
  - Not using templates / Lack of standardization
  - Inappropriate CAD tools or no CAD model (sketches lack machining detail)
  - Remodeling vs. generating instances of an existing model (duplication of effort)
  - Model dimensioning does not reflect practical measuring for machining
- **Overuse and Misuse of GD&T**
  - Using multiple callouts when one will do
    - (e.g. perpendicularity, parallelism, AND position, when position captures all three)
- **Using 'Boiler Plate' Drawing Notes**
  - Potential cost increases / Potential confusion with conflicting standards
  - Examples:
    - Do not include ASME B1.1 if there are no threaded features on the part
    - You cannot anodize steel IAW MIL-A-8625

Problems We See in Mechanical Design

- **Unnecessarily Tight Tolerances**
  - Features interacting only with air do not need 4 decimal place tolerances.
  - If the feature is interacting with something toleranced to two decimal places, a three decimal place tolerance is likely unnecessary.
- **Difficult or Impossible Dimensions/Tolerances**
  - Dimensions based on mathematical, theoretical intersections or features but physically unavailable to measure to or from
- **Not Leveraging Established Tools and Templates**
  - Manually populating title blocks vs. using a template with auto-populating fields
  - Deviation from established and accepted formats

Problems We See in Electronic Design

- **Schematics**
  - Too much information crammed into one sheet
  - Inconsistent schematic symbols
  - Pinouts not matching the datasheet correctly
- **Fab Notes and Drawings**
  - Non-existent fabrication drawings or notes
    - What's on top/bottom? Especially for through hole components.
    - Lack of an exploded view or 3D model
  - Notes that have no bearing on the current design
  - Inconsistent notes that contradict the design files
  - Missing exposed polarity indicators post component installation

Problems We See in Electronic Design

- **PCB Layout / Design - Copper**
  - Copper too close to the edge of the board (20 mil recommended)
  - Ganged connections of pins without modification of the solder mask layer
    - Inconsistent solder reflow causing shorts, opens, or skewed parts on reflow
  - No fiducials added to design (very difficult automated paste and assembly)
- **PCB Layout / Design - Silkscreen**
  - A silkscreen Gerber is not an assembly drawing (often this is all we get)
  - Improper notation of orientation for components (hours of research / rework)
  - Overlapping silkscreen / Silkscreen over drilled holes / Silkscreen over exposed copper (a real problem if PCB vendor is "build to print")
- **PCB Layout / Design - Solder mask**
  - No mask dam between exposed pads (cause of bridging in reflow)
- **PCB Layout / Design - Vias**
  - Annular rings insufficient for the required IPC class

Other Issues to Acknowledge

- **Testing**
  - Testing accommodations not made in the design
- **Lack of custom tooling design to ease assembly / manufacturing**
  - Hand assembly / manual labor is discouraged in manufacturing
- **You cannot comply with standards and requirements just by putting a note on the drawing**
  - You cannot make a design IPC-610-Class 3 compliant just by putting a note on the fabrication drawing
- **(Electronics) General Footprint Errors**
  - 9 times out of 10: if the electronics do not work, the footprint is the problem
  - Inconsistent footprints for standard packages
  - Design rules not consistent between different footprints

Our Solutions

- **Centralized Database(s) for CAD tools**
  - Electronics: Altium's Concord Pro. Mechanical: PTC's Windchill
    - Standard Templates
    - Established base design rules
    - Repository for work shared across multiple groups
- **Foundational Courses / Training**
  - Specific Training / Orientation by current experienced personnel
    - e.g. - Lifecycle of Electronics Design for Armaments Engineers (in development)
    - Reduce time to readiness for new engineers
    - Eliminate redundant CAD learning curves / Provide standards
  - Institutional Training / Conferences in the core competency
    - Helps replace lost experience with experience from outside sources
    - Industry specific conferences - Like this one for Fuzing / DMC / Apex
    - e.g. - Defense Ammunition Center

Our Solutions *continued…*

- **Technical Mentorship**
  - Temporary Rotations at the FTPAC
    - Exposure to manufacturing concepts and transitioning problems
    - Learning perspective from a technical peer
    - Transfer of knowledge between disjoint disciplines
    - Develop organizational relationships that can be leveraged later in career
- **Peer Reviews**
  - Build Readiness Reviews
    - Establish a level of design confidence before fabrication
    - Reduce schedule and budget risk by exposing problems early
    - Unbiased set of eyes on the design often exposes hidden weaknesses
  - Post Build Reports
    - Learn from manufacturing experts
    - Decrease revisions required to hit the full production

Effecting Positive Change

- **Start with the infrastructure**
  - IT Mechanisms for central information storage / dissemination
    - CAD libraries
    - Mechanisms for information identification and searching
- **Changing an established culture is difficult**
  - The stick approach does not work without management support
  - The carrot approach may work but can be slow
- **Word of mouth is very powerful**
  - Convert one sceptic and others will follow
  - Showcase your success stories

Demonstrated Results / Examples

- **Rocket motor igniter:**
  - Concept to successful demo in 8 months (10 out of 10 test firings)
  - Manufacturable Tactical design in under one year (includes COVID shutdowns)
    - includes complete redesign & adaptation of a Safe & Arm device
- **Fuze programming trainer:**
  - Concept prototype to practical manufacturing prototype (6 month effort over 2 years)
  - Reduce/Eliminate touch labor, obsolete components
  - Manufacturing prototype to manufacturable design (6 months)
  - Fabricated 500 units for the field in two year time frame.
- **Remote initiator:**
  - Conceptual prototype to practical manufacturing prototype (1 year)
  - Addressed human factors for environments and safety
  - Eliminated hand wiring and most touch labor

Questions?

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