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U.S. Army Research, Development and Engineering Command

Fuze Design in Harsh Environments

Malcolm Baldrige National Quality Award 2007 Award Recipient

ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER * PICATINNY ARSENAL, NJ *

Getting it Right the First Time

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Fuze Development Center

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Getting it Right the First Time

- INTRODUCTION
  - The Fuze Development Center
- What kind of Environments are we talking about?
  - Unique Challenges
- Approaches to Development
- Environmental Influences on Approach
  - Getting it Right the First Time, Strategy for Development
- Summary

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The Fuze Development Center

Fuze Development Center Mission: Accelerate New technology to the Field

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Challenges in Design

- Unique Challenges in Fuze Design:
  - Short service life (seconds) / Long storage life (20+ yrs)
  - Very high G shock (18,000 to 100,000 G and higher) with long duration (this is not a drop shock)
  - Little, if any, chance of prototype recovery for analysis after a flight test
  - Reliability critical / Mission critical items
  - Temperatures can be extreme in flight
  - Article testing without functioning often not possible after final assembly (Product Assurance is problematic)
    - Sample testing is getting more expensive
  - HERO, Lightning and other electromagnetic requirements add complexity

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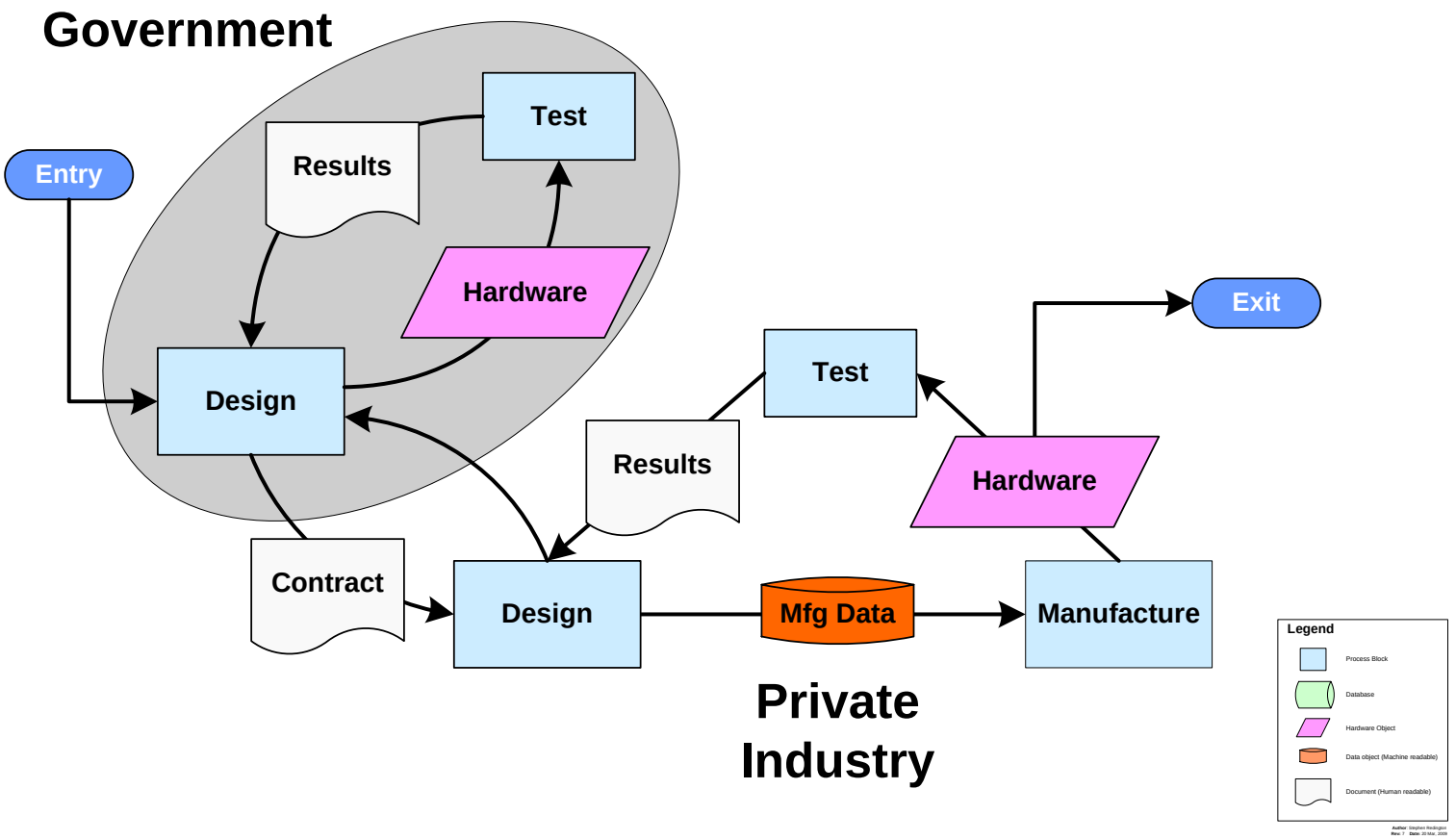
Design Methodologies

Concept Prototyping

A model for experimentation and development



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Design Methodologies

- Proof of Concept approach
  - Minimal investment up front. Larger investment downstream
  - Quick results but repeatability is often questionable
    - Documentation is often ambiguous or lacking
    - Often requires knowledge of a few key personnel that may, or may not be available in the future
  - Often problematic when transitioning to private industry for fabrication
  - Good concepts die late due to poor understanding of product requirements, poor documentation, lack of SMEs or cost overruns
    - Costs of canceled projects exceeds millions of dollars over several years

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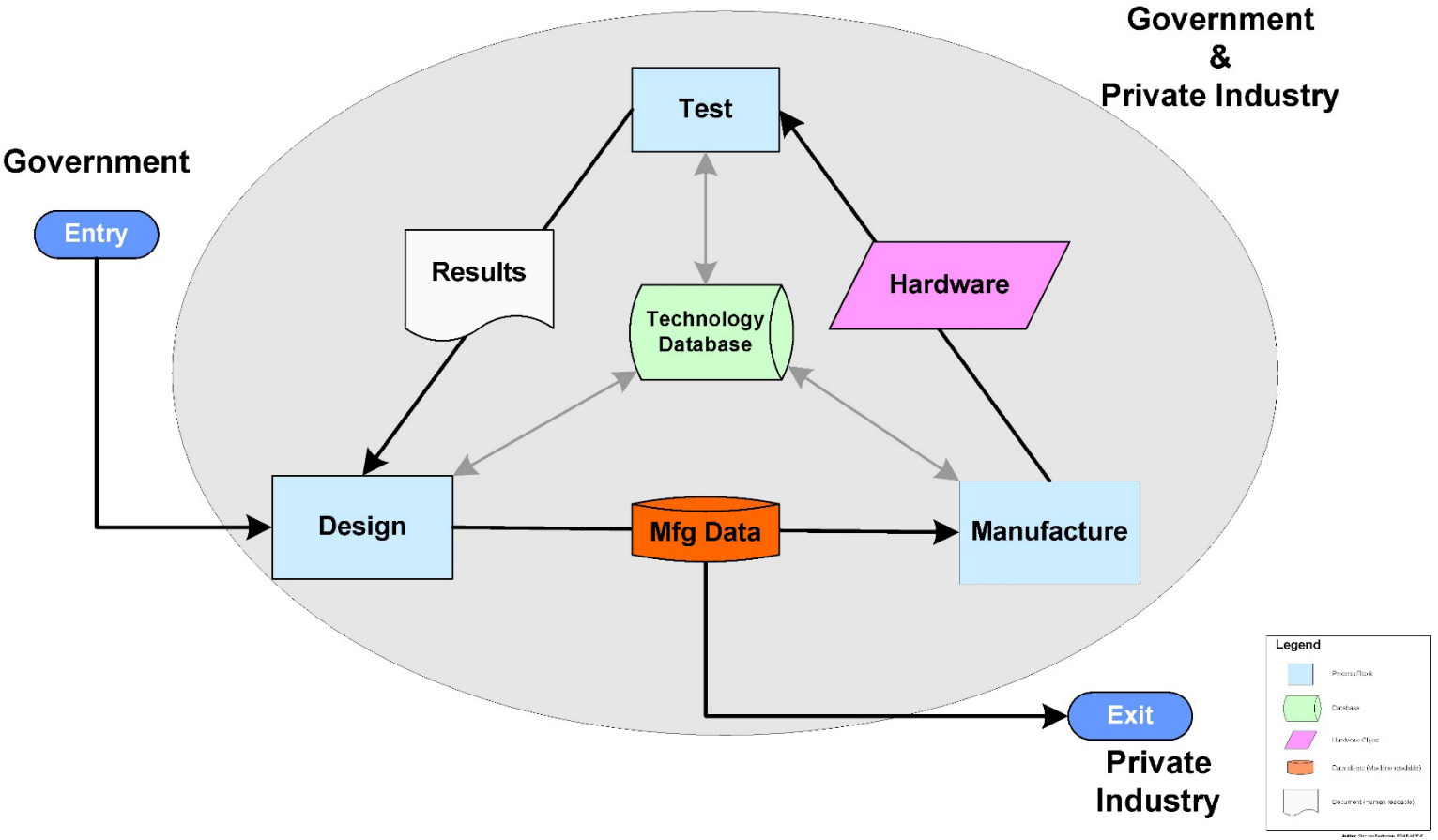
Design Methodologies

Integrated Manufacturability

An integrated model for experimentation and product development



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Design Methodologies

- Integrated Manufacturability approach
  - Higher up front cost. Smaller investment downstream
  - Longer schedule but highly repeatable
    - Manufacturing documentation is inherent in the process
    - Cycle times often improve with each iteration
  - Easy transition to private industry
    - Established baseline
    - A foundation for process improvement and cost reduction
  - Promotes teamwork and concurrent engineering
  - Quality is built in from the beginning

Environmental Influences

- Traditional Methods in Benign Environments
  - Build something
  - Test it
  - Analyze what went wrong
  - Fix it
  - Repeat as necessary
- Traditional Methods in Harsh Environments
  - Build something
  - Test it
  - Wonder what went wrong
  - Get more managers , engineers and ‘experts’ involved
  - Make recommendations and changes
  - Repeat until funding depleted

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Environmental Influences

- But what about Modeling and Simulation!
  - It can help but without grounding the model in reality results can be misleading
  - To ground the model in reality you need to….
    - Build something
    - Test it
    - Wonder why the model didn't match the result
    - Make recommendation and changes to the model
    - etc…….
  - Validated models should be taken with a grain of salt when pushed beyond boundaries (i.e. perform a reality check)

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Avoiding the Death Spiral

- The Death Spiral
  - Reluctance to make a change because too much time and money are already invested
    - Locked into a poor or problematic design
    - AKA Fix it but don't change anything
    - Ignoring root cause
    - Doing the same thing over again expecting a different result
  - Experts are called in that were not budgeted
    - The same experts who's advice was ignored up front?
  - Steps that yield insignificant progress for the program budget (i.e. death by risk mitigation)
    - Unproductive side experiments

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Avoiding the Death Spiral

- The problem
  - Reliability concerns are often ignored in favor of testing a new concept.
  - There is often little or no hardware to analyze after a test in the actual environment.
  - Design short cuts and band aids tend to make the problem worse since they do not hold up in harsh environments.
  - Programs with low budgets and tight schedules often take short cuts.
- How Integrated Manufacturability Helps
  - Increased focus on the entire solution up front (getting it right the first time).
  - Addresses manufacturing issues related to reliability by implementing and enforcing industry standards in development.
  - Increased focus on documentation and process
    - improved control over what is built, how it is built and what it was built with.

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Getting it Right the First Time

Do not rely on post test analysis for understanding what went wrong

Before

After

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- How Integrated Manufacturability Helps
  - Design reliability in up front; Avoid unanswerable questions downstream
    - Was the failure due to a poor solder joint?
      - Pay attention to solder quality and inspection
      - Was it inspected? Are there records?
      - Solder quality tends to be ignored in R & D
    - Was the failure due to ESD or poor handling?
      - Pay attention to handling during assembly
      - ESD procedures tend to be ignored in R & D
    - Was it put together correctly?
      - Avoid difficult manual assembly and procedures
      - Was it put together the same way?
      - R & D tends to ignore complexity of assembly

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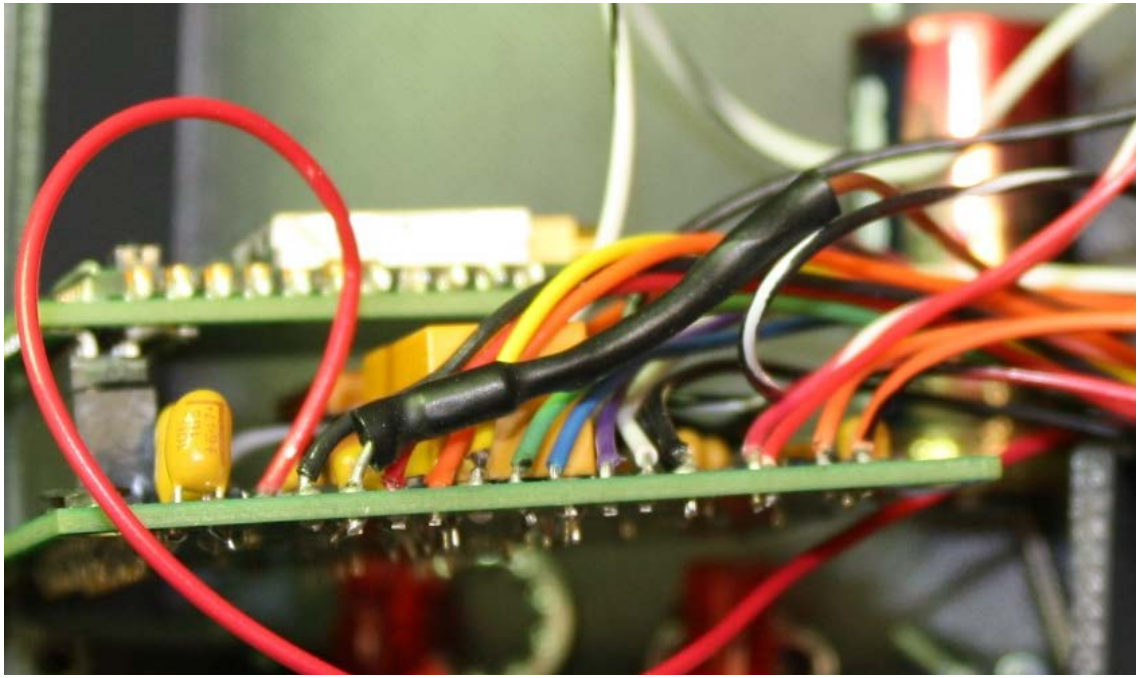
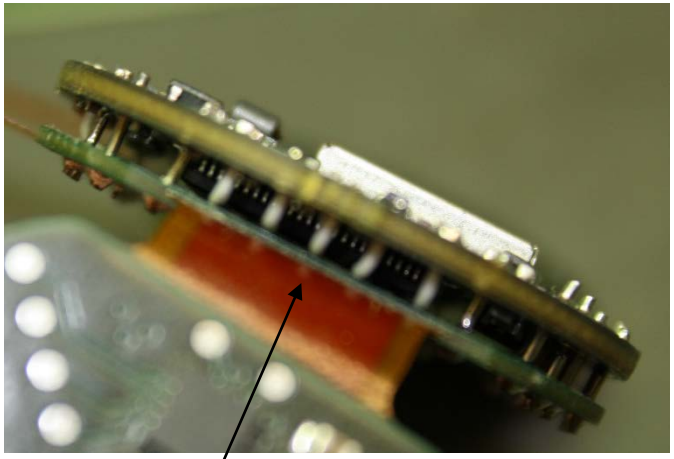
Getting it Right the First Time

- Avoid hand wiring and interconnects as much as possible

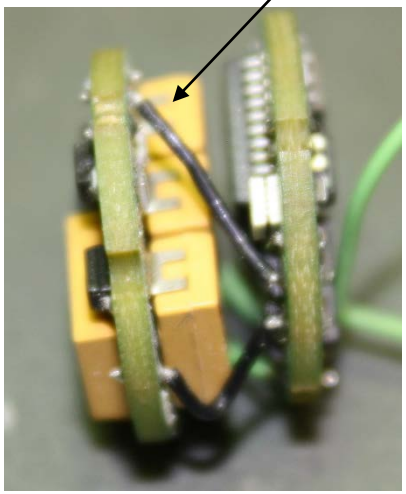


Unsuccessful High-G Prototypes

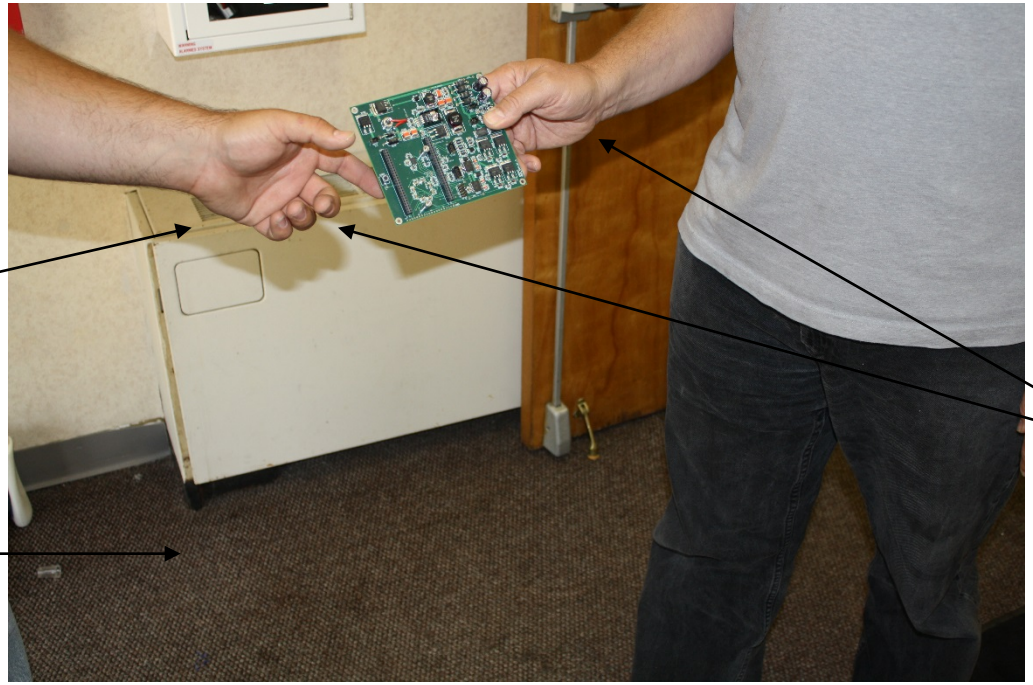


A GREAT WORK OF ART
BUT NOT A GOOD DESIGN

JOINTS FATIUGE AND
CRACK DURING
HANDLING



- Does this happen in your lab?



ESD is real. Even if you can't see a spark

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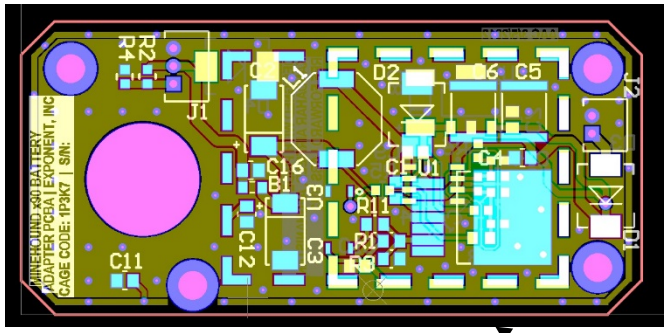
- Do you know what your building and how your building it?

A Gerber file set is not enough to fabricate a PCB repeatedly.



Does your BOM accurately describe what components are being used and where they come from?

A silkscreen print is not a good assembly drawing.

Can you identify this configuration by looking at it? Is there a part number on it?

Does your BOM document all the materials needed to create the assembly??

- Adhesives used?
- Mounting hardware?
- Firmware?
- Work Instructions?
- Other reference documents?

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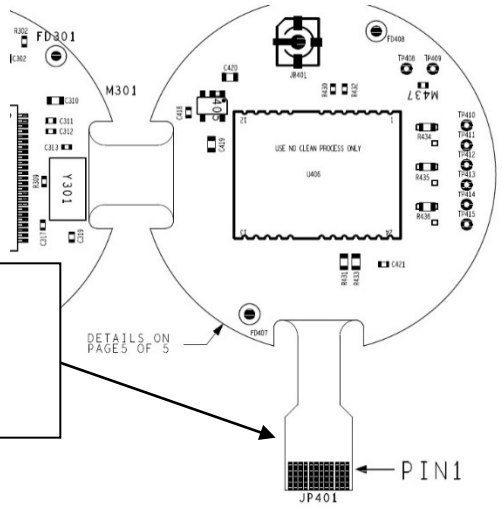
Getting it Right the First Time

- If you can't test it after you need to focus on testing it before.
  - Design testability in from the beginning
    - Provide test access after potting
    - Communication links on inductive power interfaces
    - Self monitoring and health checks
    - Telemetry
    - In-circuit programming for development



Test access designed in can be exposed after potting & final assembly

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- Other Tips
  - Avoid poor design practices
    - Poor footprint design in electronics
    - Inadequate or unobtainable manufacturing tolerances
    - Undocumented processes/materials
    - Lack of specifications or standards
  - Modularity is great for experimenting but……
    - Each interconnect adds cost and reduces reliability
    - Fuzes are a one time use item. Serviceability is not an issue

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In closing...

- Quality control is often left out of the equation when experimenting or developing
  - Not a big problem in benign environments but can lead to false conclusions in harsh environments
- Imagine the test goes wrong (Murphy's Law)
  - Ask yourself what questions arise and answer them before the test or design in a way to answer questions after the test
  - Integrated Manufacturability reduces the number of problems/questions to explore post test

Questions

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