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Challenges in Hard Target Fuze Design and Critical Technology Development

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The Challenge of Hard Target Fuze Design

harsh environment

- Stuff breaks in harsh environments
- Need reliability in future fuze development
  - Reliability, survivability, performance
- Too many failure modes for fly-fix-fly approach

Our Approach

A big problem needs a systematic approach….

1. Discover immature technologies
   - efficiently and effectively guide our development resources
   - system, subsystem, and component levels
2. Characterize and develop models
   - Target impact environments
   - Performance of fuze subsystems and components in target environments
3. Use models to design for reliable performance
   - impact environment models to determine requirements
   - Performance models as tools to design for reliability through the given target environment

Model Based Design Method

Have requirements and ability to design to meet them

- Understand the target environment
  - Mechanical and Electrical
    - e.g. Fuze subsystem must operate through….

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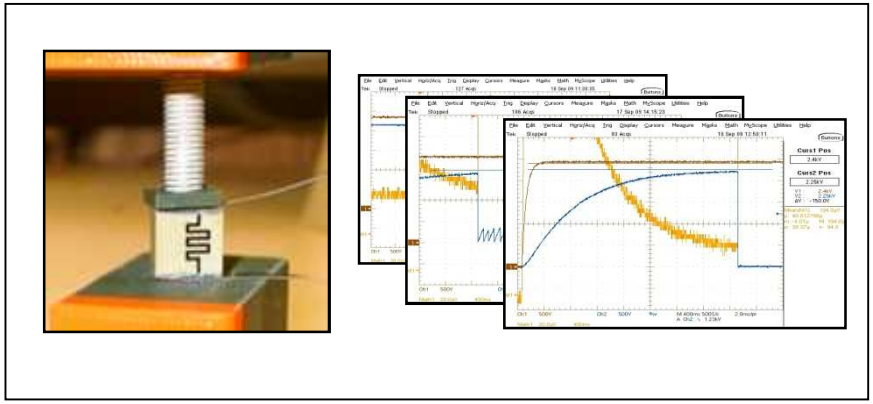
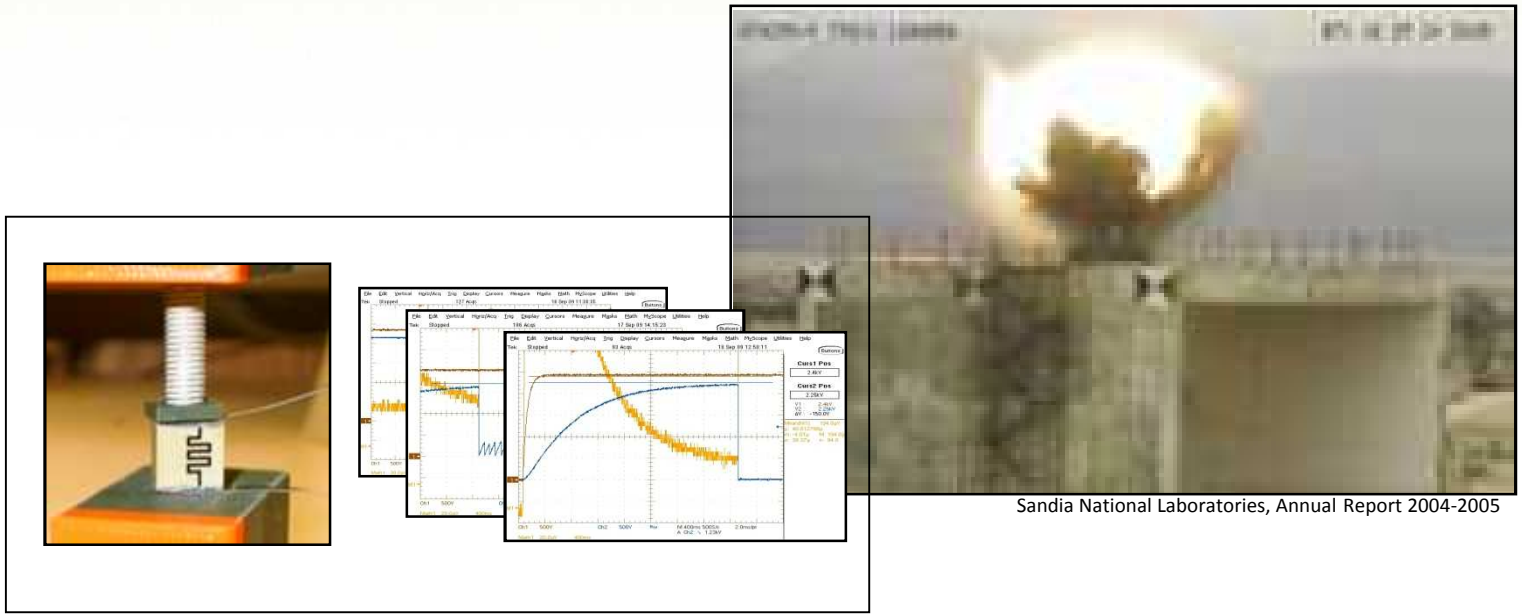
- Understand subsystem and component performance variation through stress and electrical disturbances
    - e.g. Given this stress, the current leakage will vary by….



Model Based Design Method

Have requirements and ability to design to meet them



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- Use performance models to design fuze electronics with margin for reliable operation through target environments

Too complex for an Edisonian approach

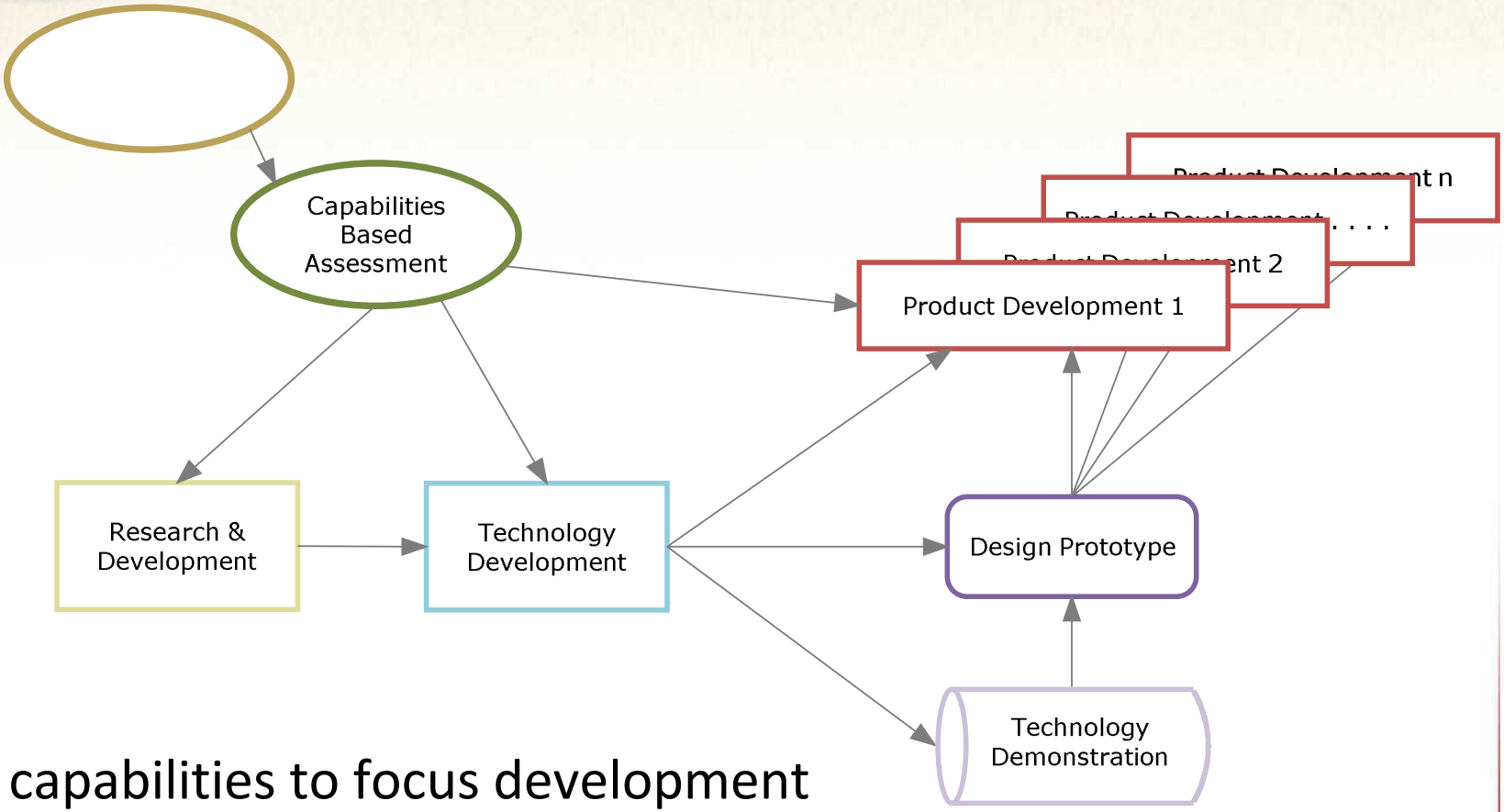
- Can't rely on full-scale tests to uncover all failure modes
- Full scale high-g testing is high dollar
- Development dollars are limited
  - If we're not learning,
    we're wasting resources

- Need to know what are we learning from our failures
  - If it didn't work….how do we fix it?
  - Finding 10,000 ways it doesn't work….doesn't work for us

"If I find 10,000 ways something won't work, I haven't failed….
because every wrong attempt discarded is another step forward."

- Thomas Alva Edison, *US inventor (1847 - 1931), Encyclopedia Britannica*

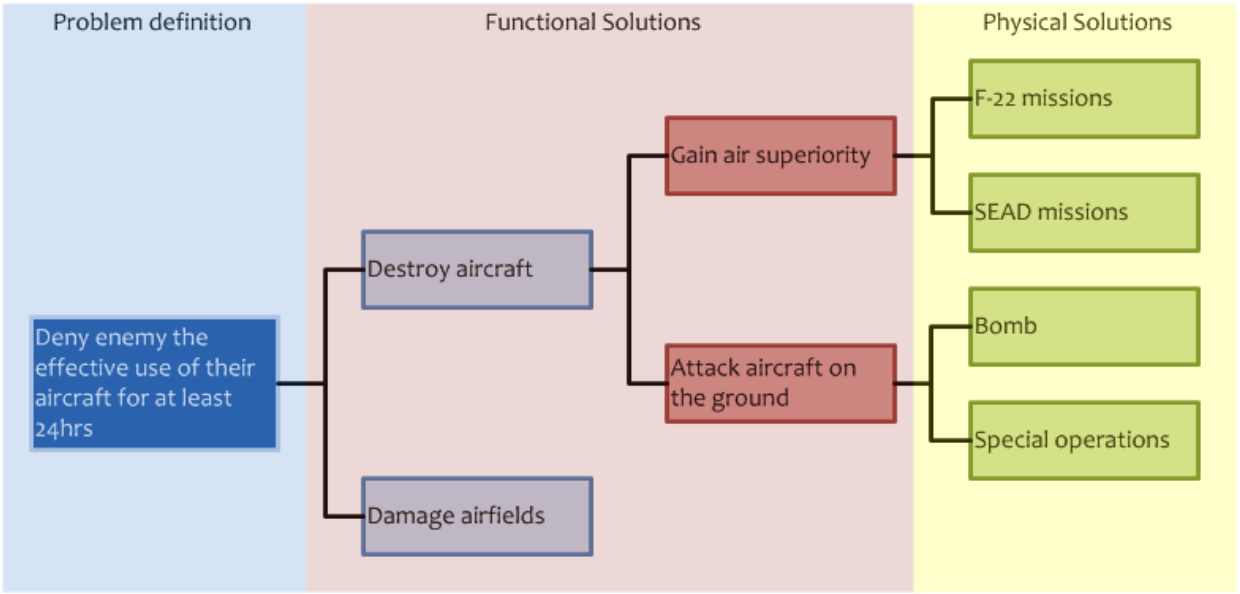
Systematic approach to development



- Asses capabilities to focus development
  - First step is to asses maturity of available technologies
  - At system, subsystem, component levels
  - Can't develop a reliable system without reliable components

Capabilities Assessment

- **Determine Gaps in Technologies**
  - System, subsystem, component levels
  - Multi-physics; Mechanical, Electrical, Explosive….
  - Help roadmap our long term goals and challenges
  - Efficiently and effectively guide our development resources



Research technology options and associated maturity levels (TRL)

don’t need full scale test to find failures

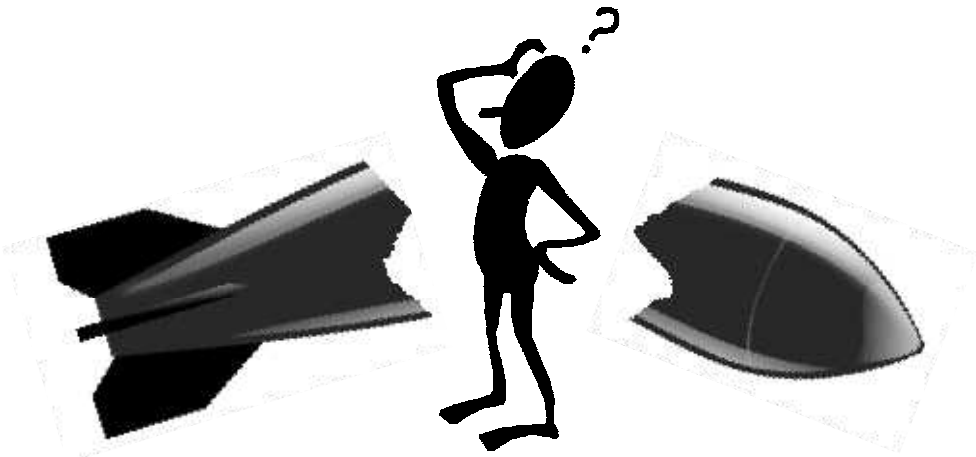
- Fuzes have one good outcome: Initiation when intended
- They have two glaring incorrect outcomes
  - Initiation before or after intended
  - Failure to initiate
- Perform failure analysis before failing expensive tests
  - Define immature technologies early

If we don’t understand failure modes….this is heavy risk

Focus Tests on Understanding Performance

- **Go / No-Go testing gives limited information**
- **If we simply increase g-levels until something breaks….**

  ….did we learn how to make it work the next time?



- **Engineer tests to understand performance success**
- **If it did work….do we know why?**
  - Want enough understanding for reliable transition to other programs, applications, form factors, industry

Need Capabilities to Understand:

- **What is the target environment?**
  - Mechanical and Electrical
  - Requirement for weapon performance

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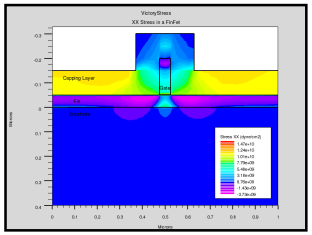
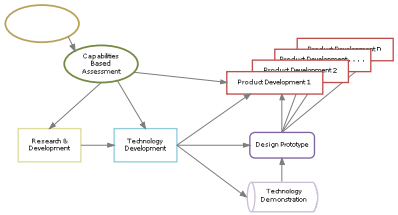
- **How does the fuze perform?**
  - Characterize subsystems and components to develop models for performance variations and failure modes in the target environment



http://www.silvaco.com/tech_lib_TCAD/simulationstandard/2009/oct_nov_dec/a1/a1.html

- **What can we do to prevent failures?**
  - Have tools in place to define requirements and design to satisfy them
  - Need systematic approach to development



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What is the target environment?

- **May survive in sub-scale, then fail in full scale**
- **Fundamental failure modes associated with full-scale environments are not understood**
  - Uncharacterized target environments
  - Uncharacterized system performance

http://search.janes.com/janesdata/binder/jalw/images/p0130675.jpg

http://search.janes.com/Search/imageDocView.do?docId=/content1/janesdata/captions/jdw/history/jdw2002/jdw05090_2.htm@captions&keyword=penetrator%20target&backPath=http://search.janes.com/Search&Prod_Name=JDW&

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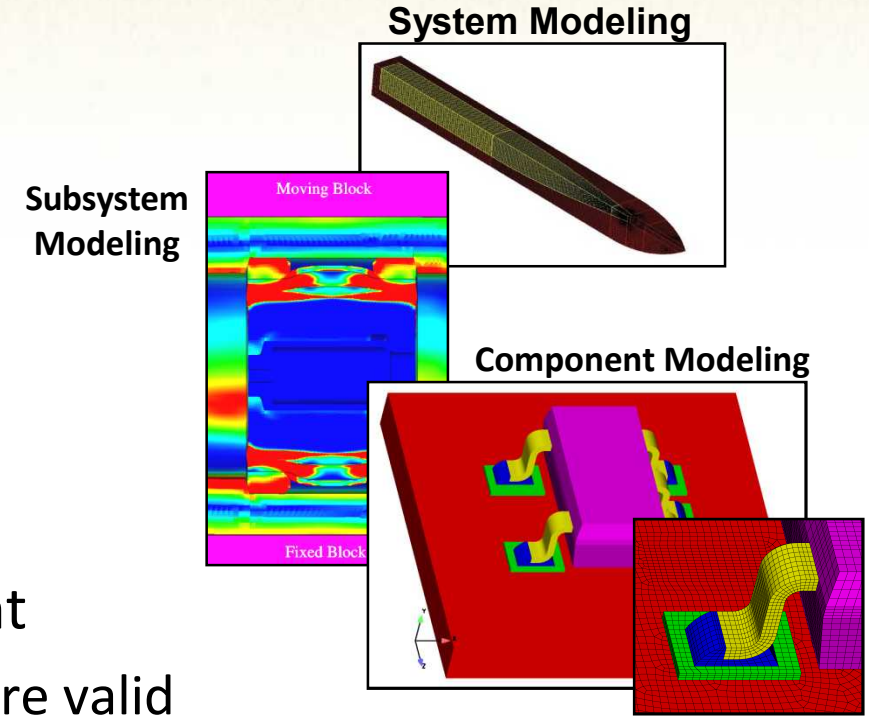
Characterize Target Environment

- Stresses seen on
  - Weapon body
  - Fuze subsystem
  - Fuze components



http://www.dtic.mil/ndia/2009fuze/2009fuze.html

- Induced electrical environment
  - Lot of theories….which ones are valid and what are the effects?
    - What types of energies and how are they coupled
      - Plasma from reentry body
      - Charged weapon body
      - System ground loops

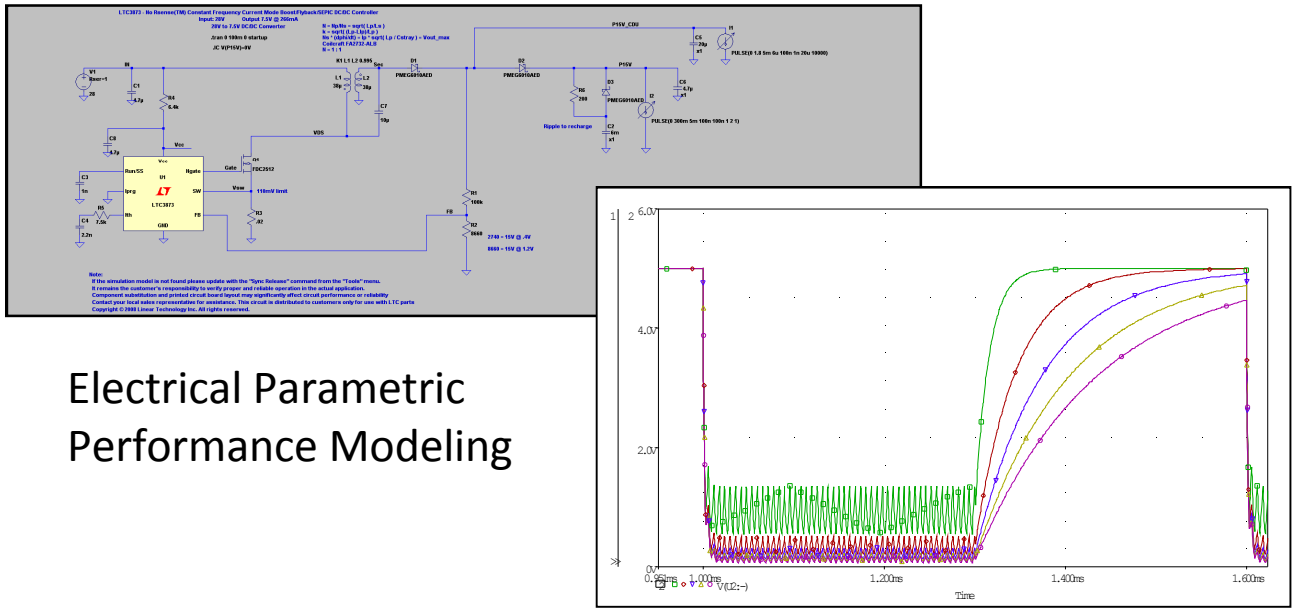
Understand our designs
Understand the electrical environment

- If we don't know what it ***must*** perform through

  ….We should at least know what it ***can*** perform through

  – Design for mitigation and understand our performance margins

    e.g. How much susceptibility to EMI, capacitive coupling….



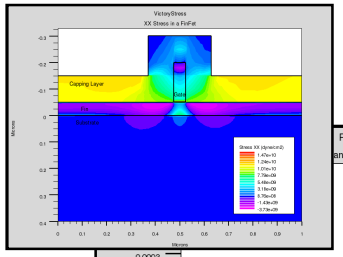
Electrical Parametric
Performance Modeling

How does the fuze perform?

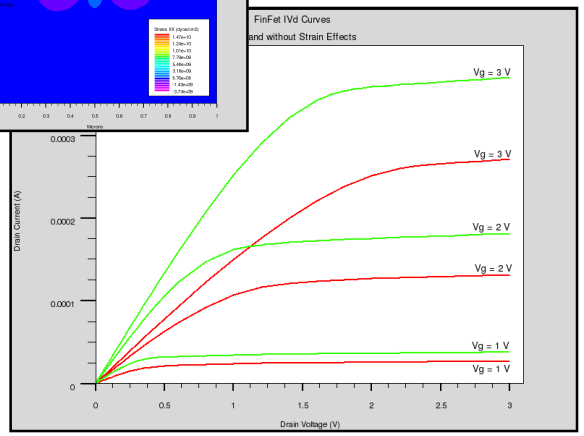
- Knowing the target environment is only useful if we can do something about it
- We need performance models to design for reliability
- What causes failure

  ….mechanical damage or electrical performance?

Physical Failure



Performance Failure



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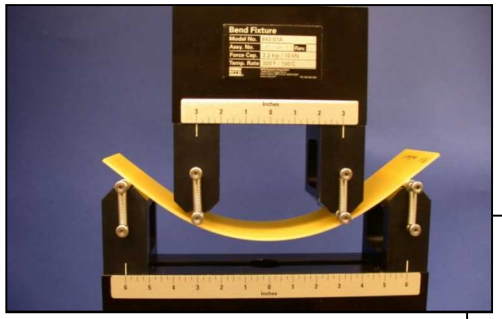
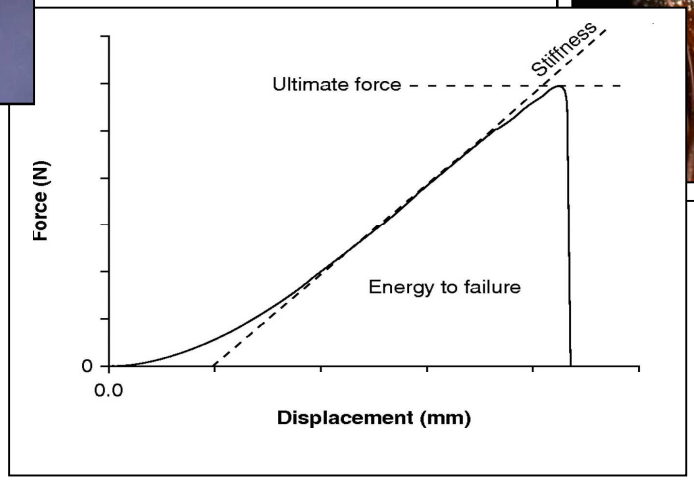
Mechanical Failure

- Model the breaking point of hard target components
  - Where does the part physically fail….?



4-point bend test

Physical Failure

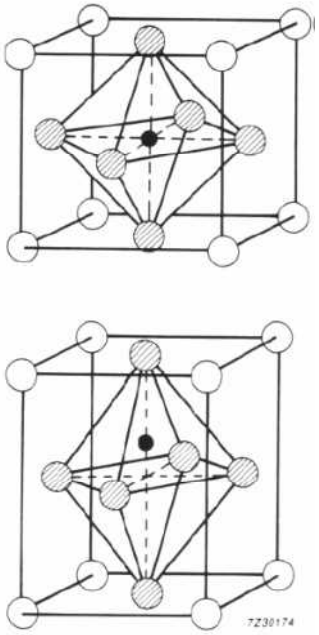


http://ajs.sagepub.com/content/34/7/1094/F3.large.jpg

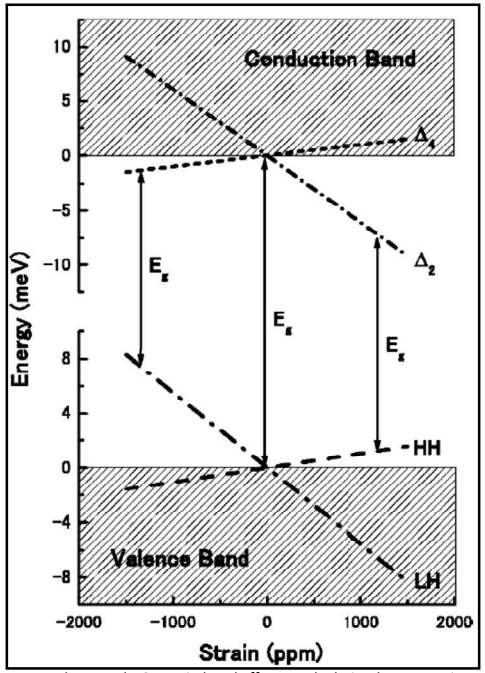
Force vs. Displacement

Electrical Component Performance

- If it survives mechanical impact….will it perform electrically?
- e.g. Stress can effect crystalline structures, effecting intrinsic properties of semiconductors and dielectrics
  - band-gap energy, dielectric constants , current-voltage relationships

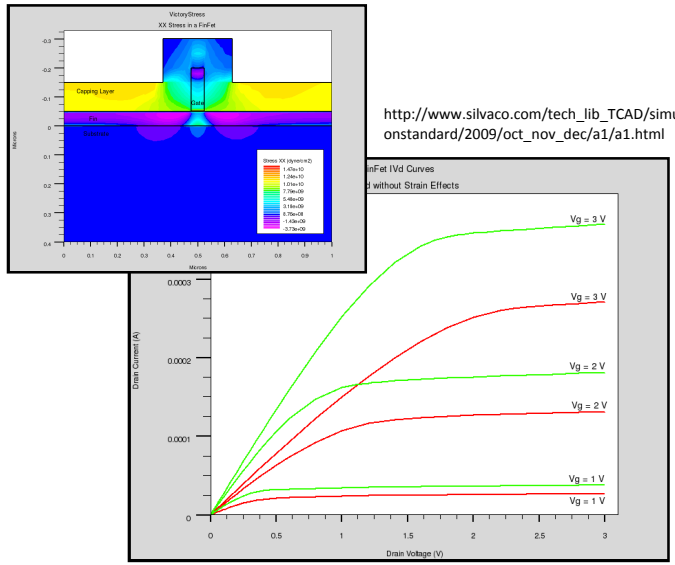


Lattice Deformation



K. Matsuda, Y Kanda, Stress-induced effects on depletion-layer capacitance of metal-oxide-semiconductor capacitors, Apllied Physics Letters, vol. 83, n 12, Nov. 24 2003.

E_g vs Strain



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Drain Current vs. Strain

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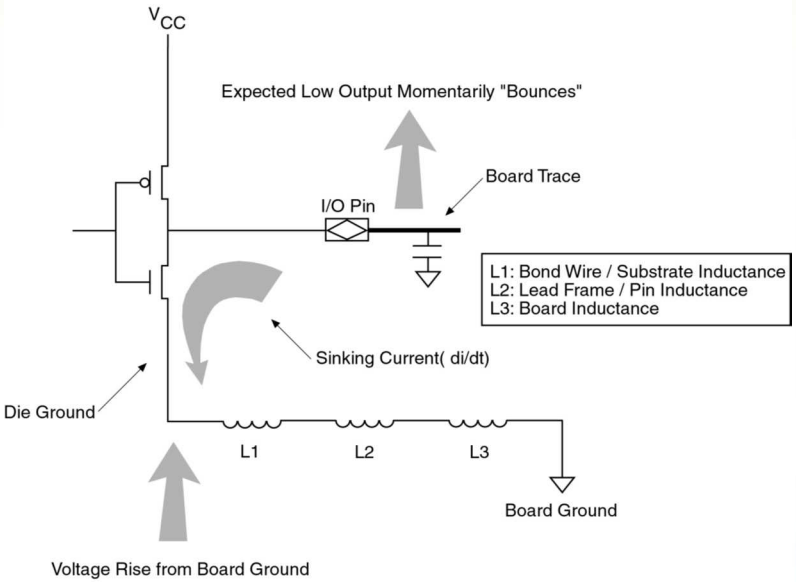
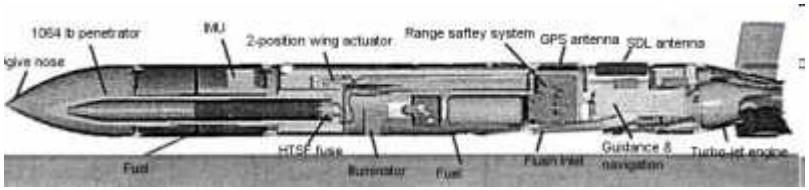
Electrical System Performance

- **At the fuze subsystem level**
  - Piezoelectric effects
  - EMI
  - Voltage level shifts
  - Ground bounce
- **At the weapon system level**
  - Coupled Energy
  - Ground loops



Altera Coporation, Minimizing Ground Bounce & V_{CC} Sag, *www.altera.com/literature/wp/wp_grndbnce.pdf*



http://search.janes.com/janesdata/mags/jmr/history/jmr2000/images/g0039465.jpg

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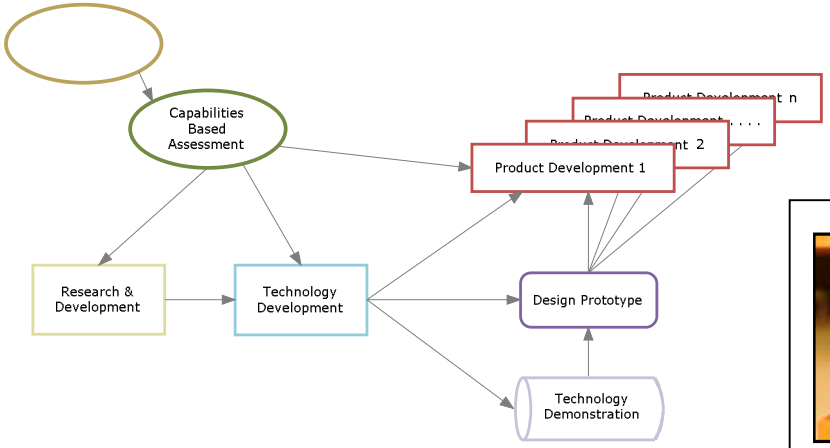
What can we do to prevent failures?

- Stuff breaks in hard target environments
- Big problem needs a systematic approach
  - At system, subsystem, and component levels
  - Identify critical technologies
- Focus resources to efficiently and effectively develop our gaps and immature technologies
- Model based engineering to design for reliable performance



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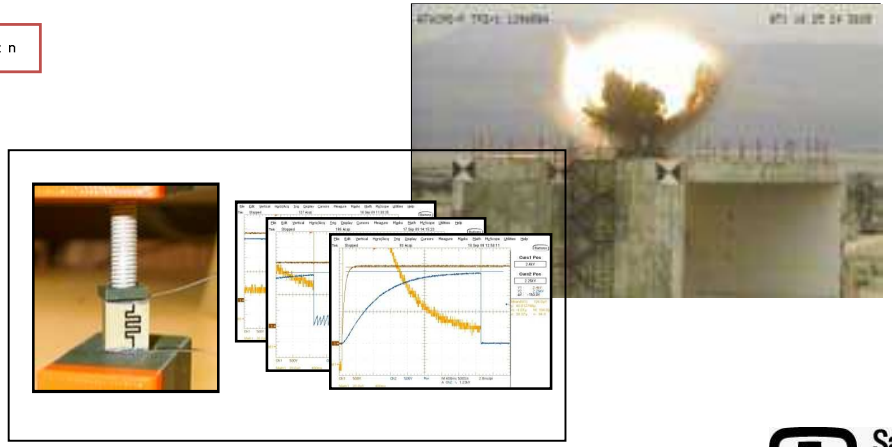

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Collaborations

- The Defense Threat Reduction Agency funds work to investigate the effects of stress on the electrical performance of components

- Air Force Research Labs is aiding in this effort

- Army RDECOM is modeling the mechanical effects of stress

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Questions / Comments ?

BACKUP SLIDES

22

What does it all Mean?

- **By failing to address the high-g fuzing problem holistically, the cost is high:**
  - **Poor collaboration**
  - **Duplicated effort**
  - **Poor understanding of high-g science**
  - **Poor integration of test results and analysis**
  - **Unclear understanding of the truly necessary areas of research (focus is lost)**
  - **No/little documented design guidelines for high-g**
    - **And no framework for getting there, either**

It is natural for a problem too big for one group to get to this state. However, when it is realized that the techniques/tools exist to correct the problem, they should be taken advantage of.