Materials Capabilities for Predictive Reliability

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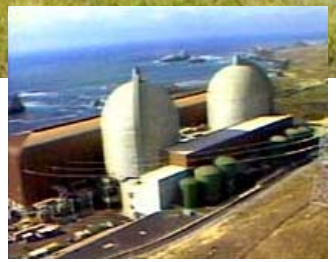
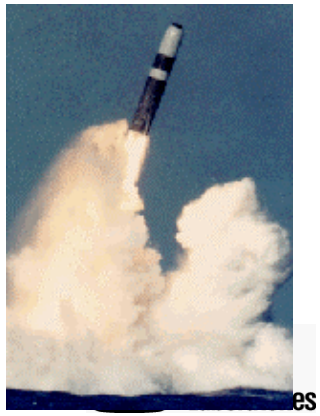
(Organization 1800)

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

Materials work has been an integral part of Sandia's evolving mission for 5 decades.





Materials capabilities are driven by Sandia's weapon-systems responsibilities.

The design, engineering, testing, system integration, production interface and surveillance for non-nuclear components

W88/MK5

- Radars
- Impact fuzes
- Shock absorbers
- Casing
- Detonators
- Firing sets
- Transverters
- Capacitors
- Switches
- Switch tubes
- Rectifiers
- Programmers
- Neutron generators
- Reservoirs
- Stronglinks
- Batteries
- Timers
- Spin generators
- Parachutes
- Ejector systems
- PAL controllers

B83 Strategic Bomb

Total parts - 6,519

- Sandia developed - 3,922
- Sandia specified - 2,378

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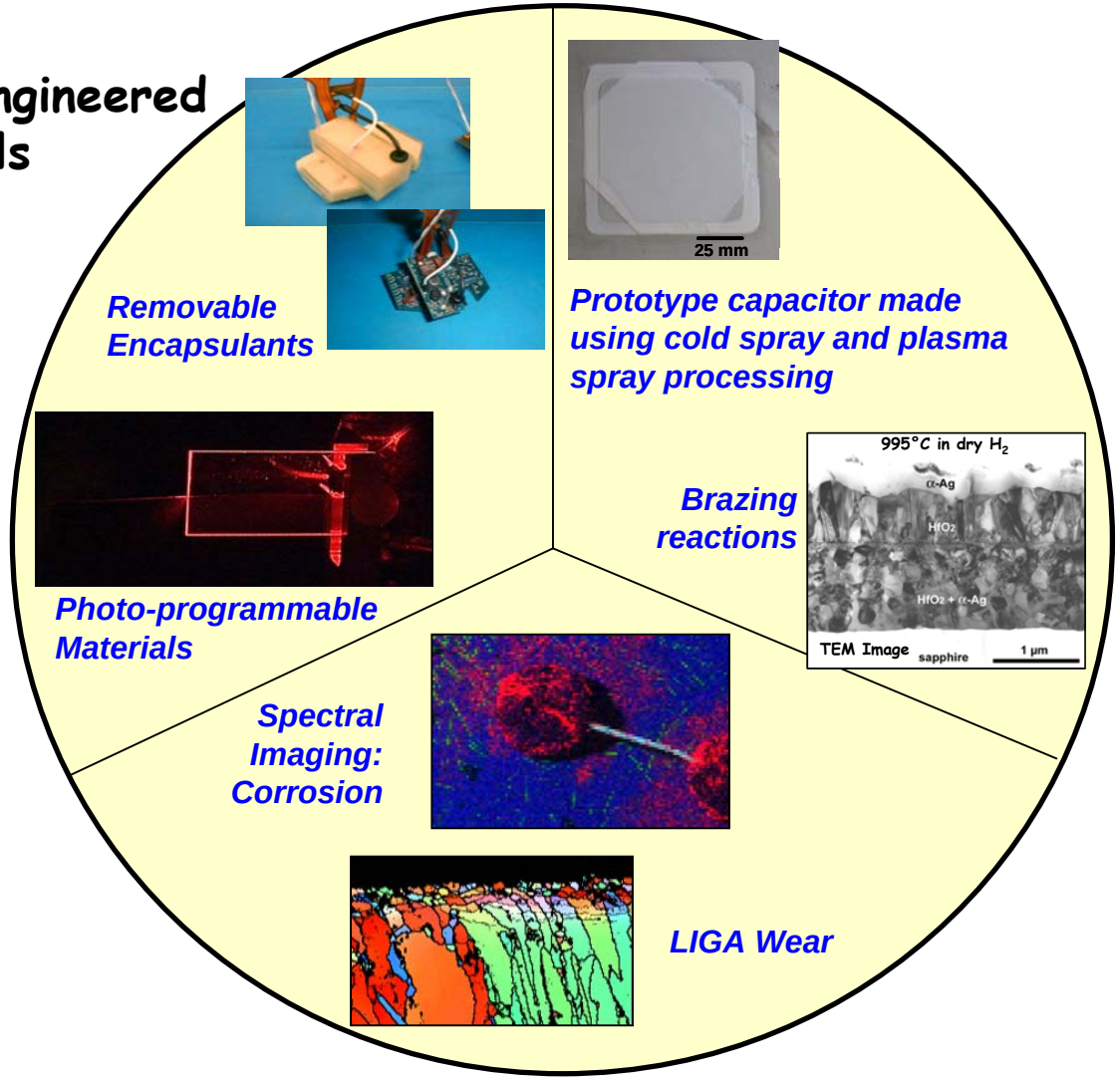
Our materials R&D is focused on three themes that correspond to NW needs.



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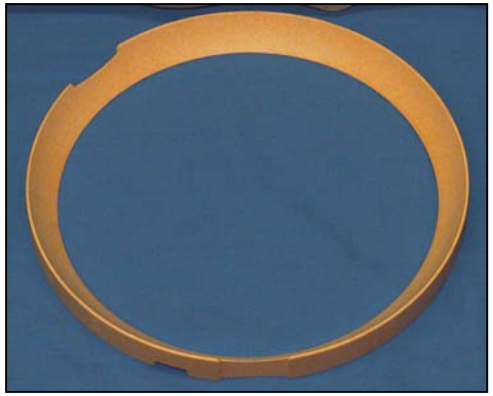
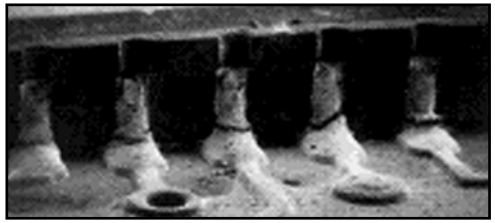
Age-related defects are traceable to time-dependent change of materials.

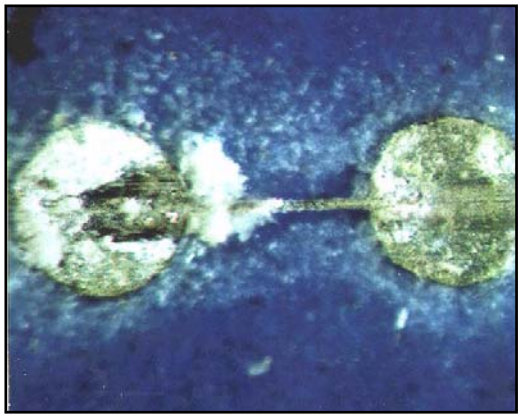
Examples include . . .



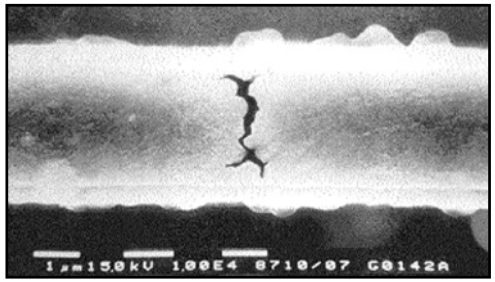
W80 Desiccant Life



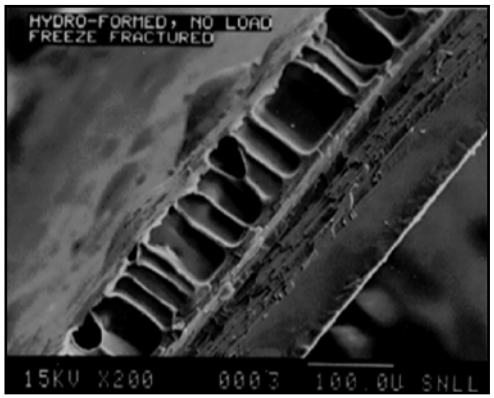
Solder Joint Fracture



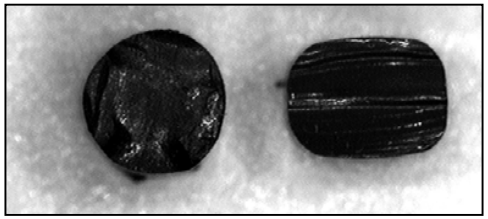
Bridgewire Corrosion



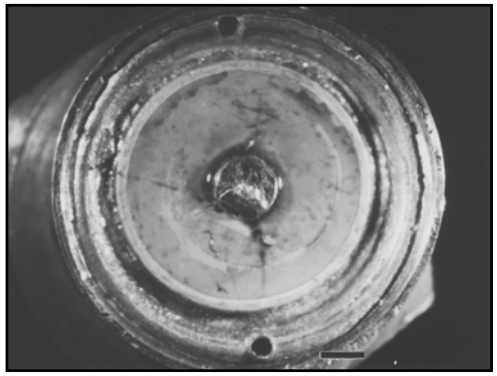
Stress Voiding



Interface Debonding



W76 O-ring
Compression Set



Ceramic Capacitor Failure

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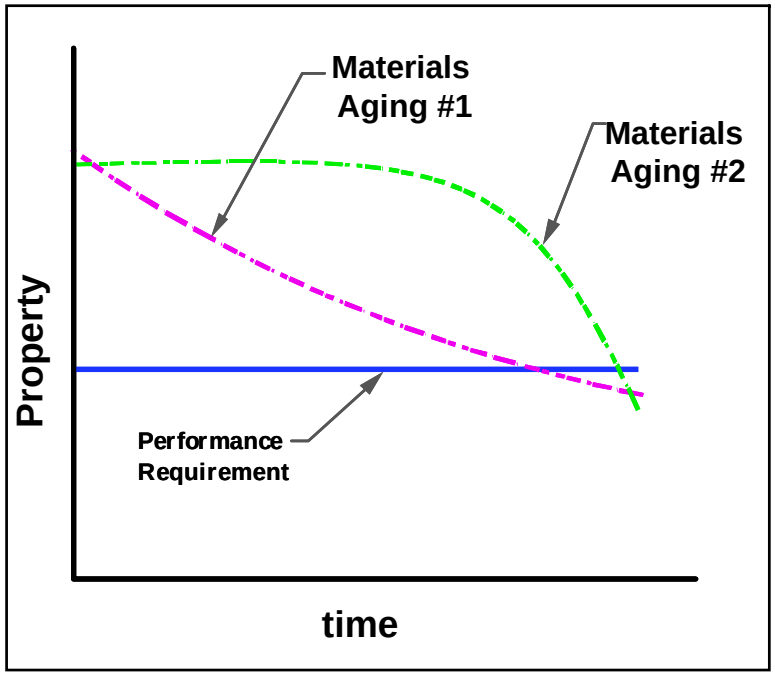
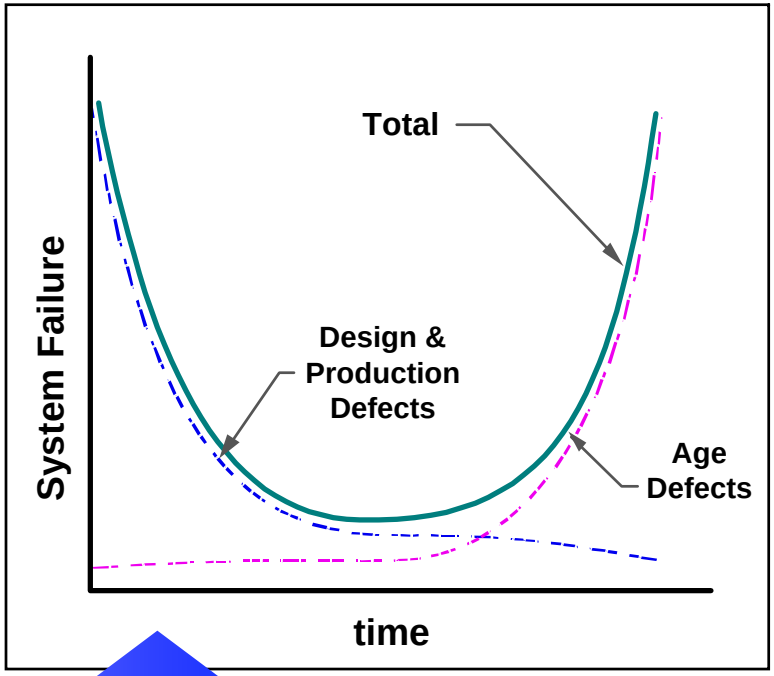
With extended stockpile life, a “U” shaped failure function will apply to many weapon components.





can lead to:

Prediction of the “useful life” of components / subsystems depends on a detailed understanding of materials aging.

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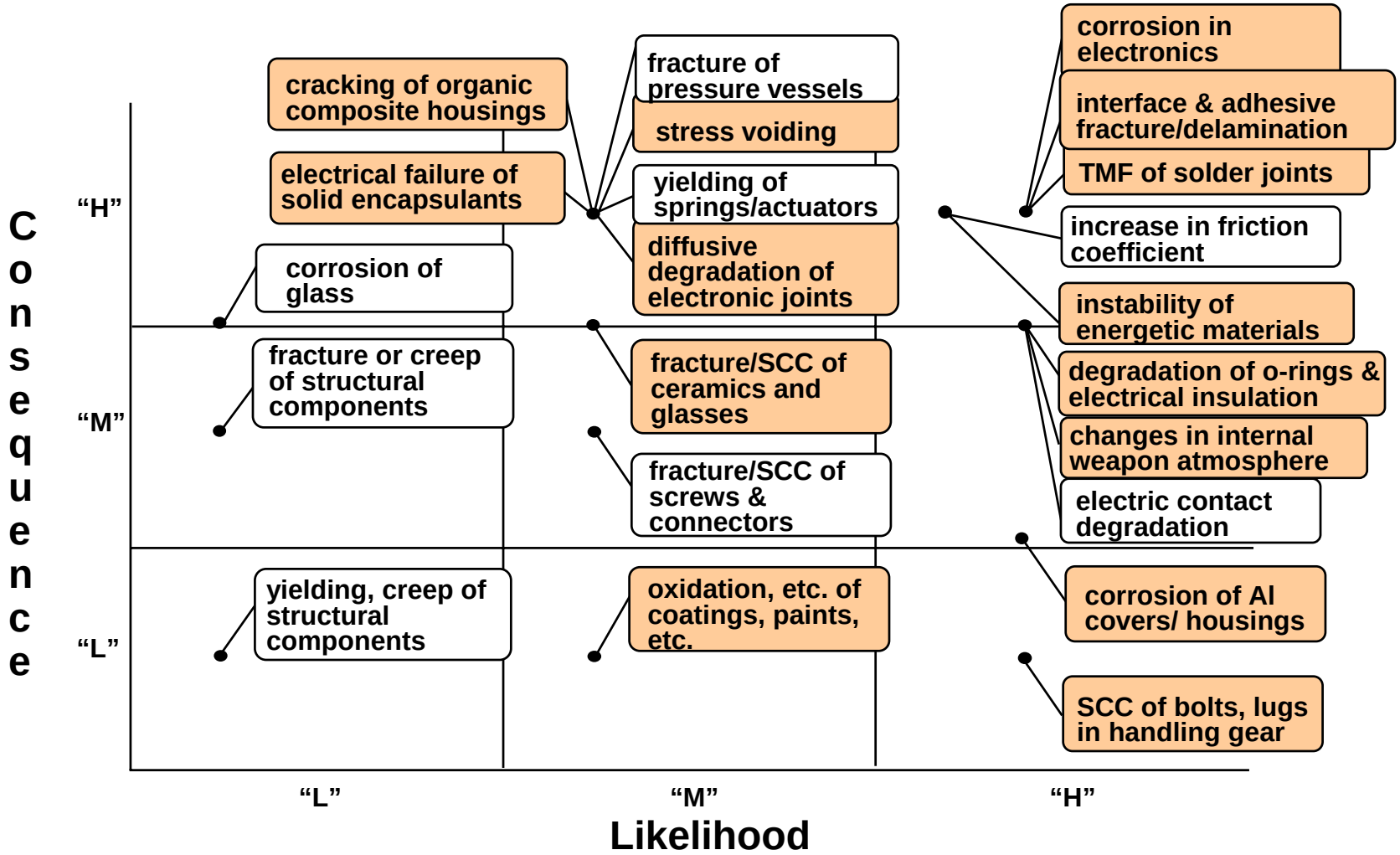
A “risk approach” identifies materials aging issues that have the highest impact on reliability.



= Observed materials failures in WR Product

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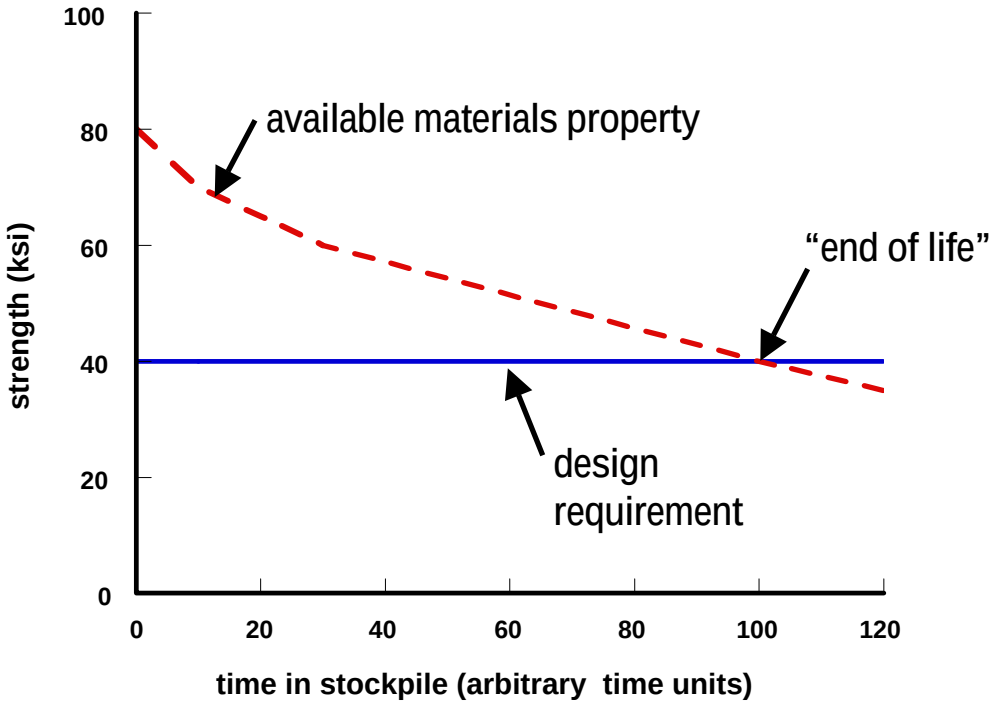
Engineered materials are metastable and their properties can change as a function of time.



Time-related change due to:

- **diffusion**
  - **compositional change**
  - **oxidation**
  - **impurity segregation**
  - **grain growth**
  - **2nd phase morphology**
  - **. . . . .**
- **fatigue**
  - **dislocation density**
  - **surface flaws**
  - **μstructure coarsening**
  - **. . . . .**
- **corrosion**
  - **compositional change**
  - **dimensional change**
  - **segregation**
  - **. . . . .**
- **wear**
- **. . . . . .**

Materials aging phenomena are driven by changes in chemistry and microstructure.

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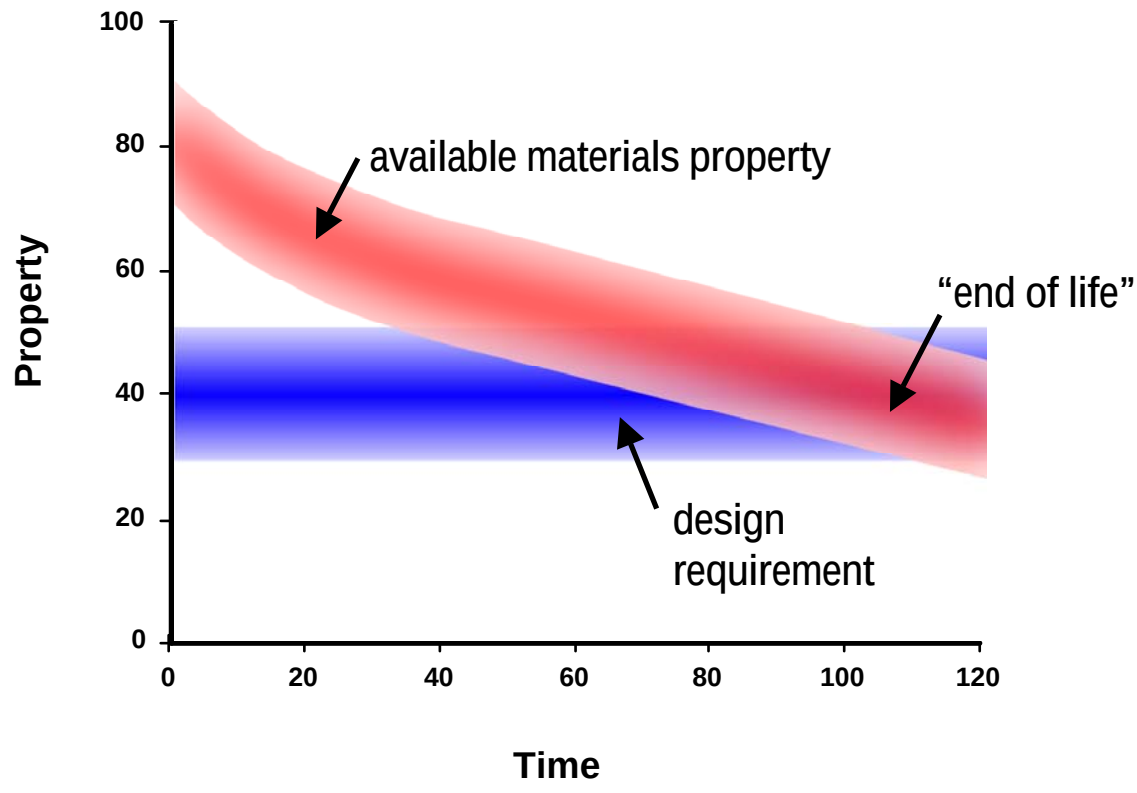
The influence of distribution can have a significant impact on our view of “lifetime.”



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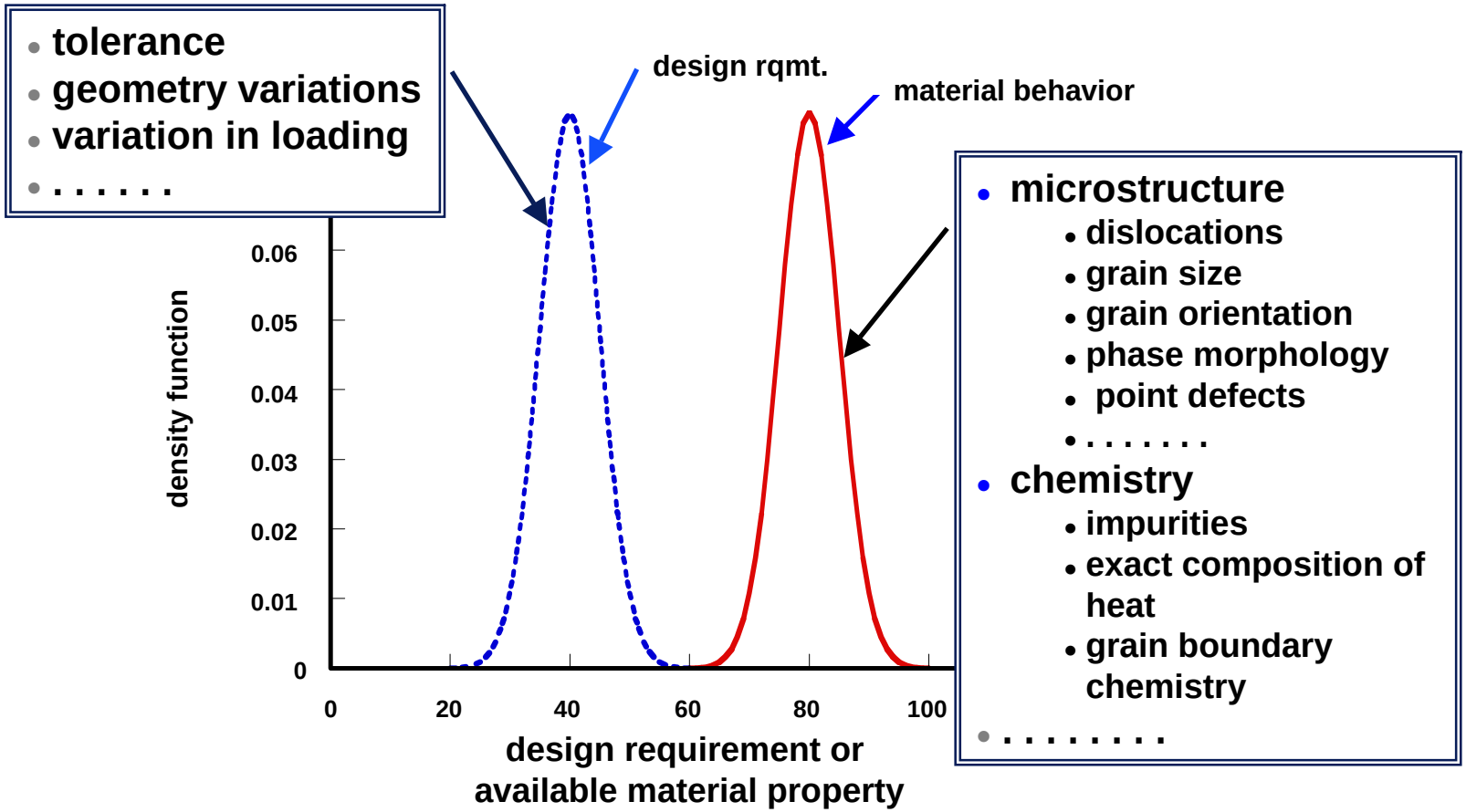
Applied “loads” and materials properties each have a distribution of values.



“Reliability” (defined as the “probability of success/survival”) can be calculated.*

* Oleg Vinogradov, *Introduction to Mechanical Reliability: A Designer’s Approach*, Hemisphere Publ., New York, 1991

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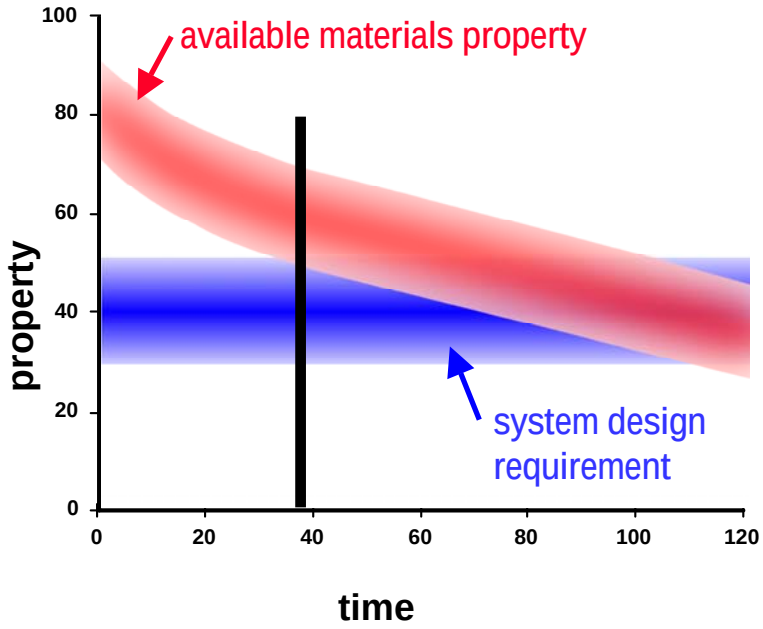
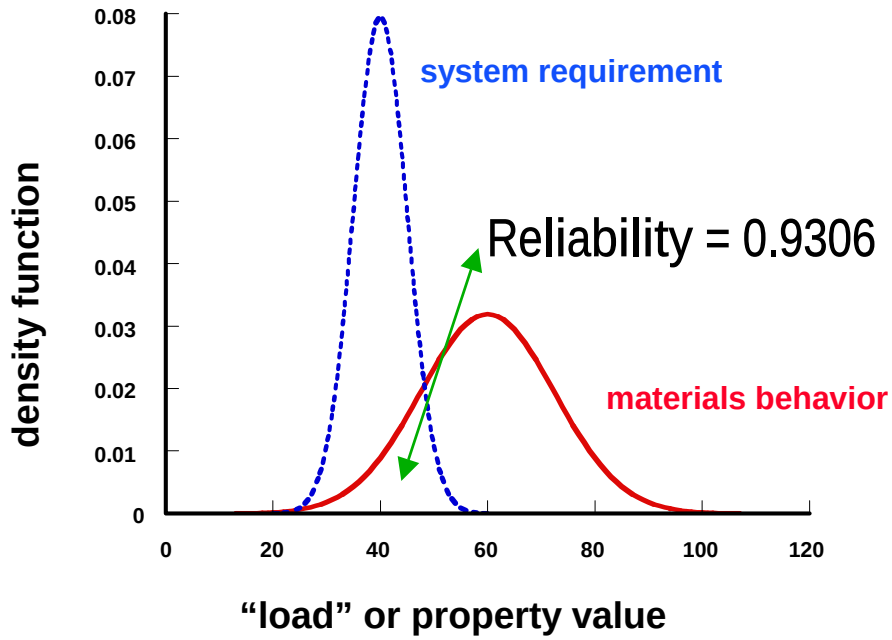
Our technical approach: compare *distributions* of materials properties and system requirements.





System requirements provide the context for defining "materials failure."

Materials Reliability is quantified as the *probability* that there will be sufficient (materials) property to meet system requirement.

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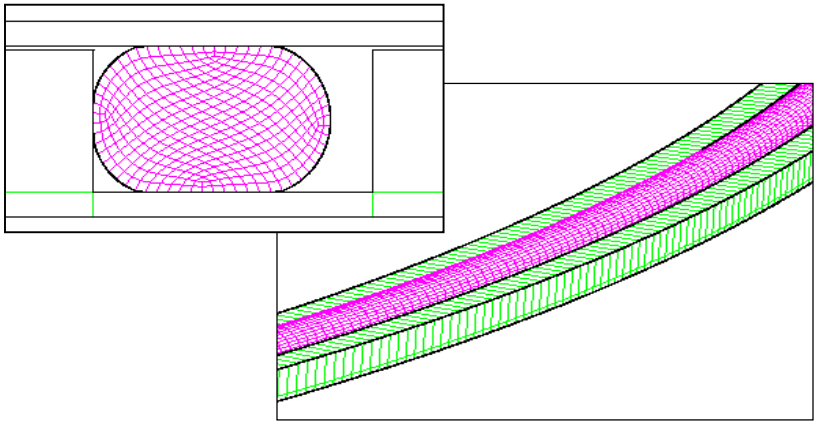
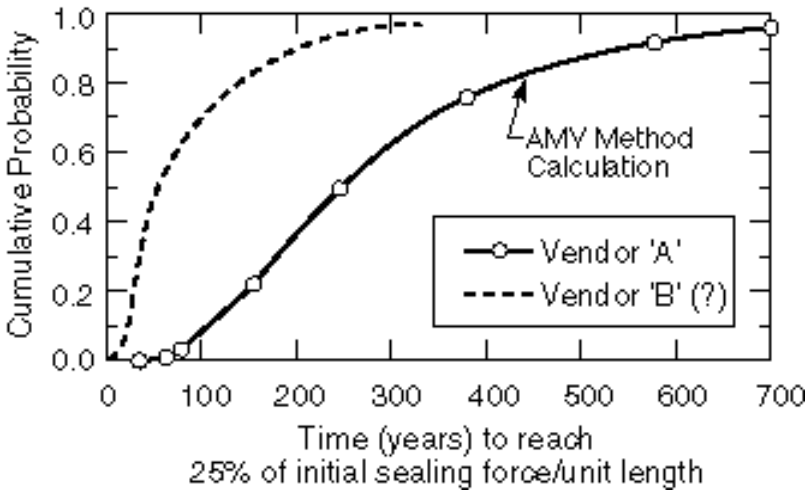
Elastomer aging can be inserted into finite element models to predict o-ring life.

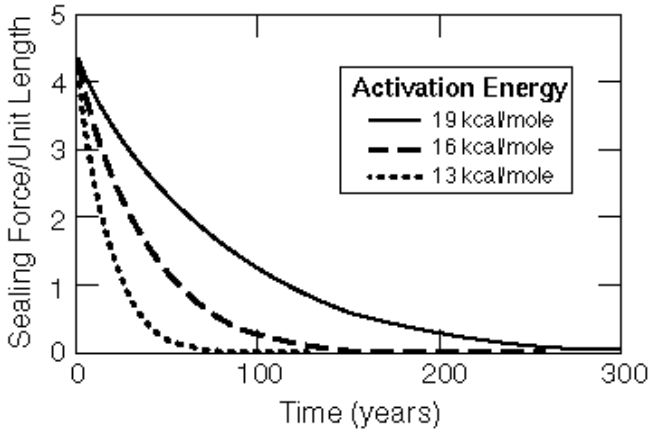
Finite Element Simulation



Reliability Prediction



Results of Materials Aging Study



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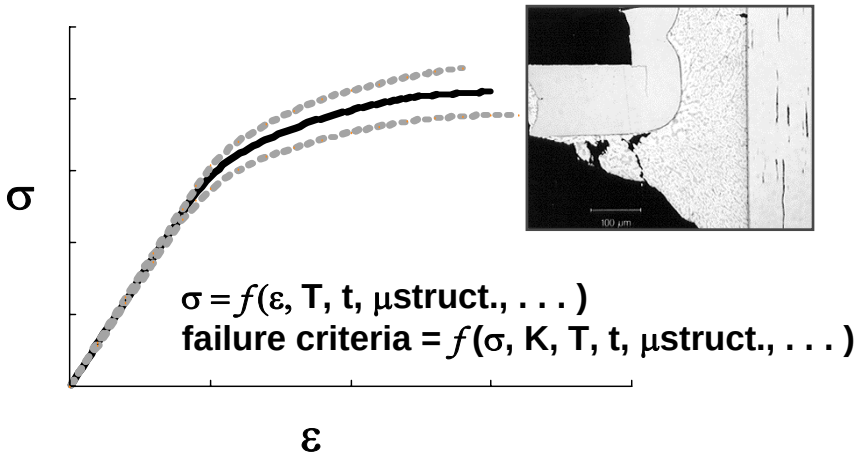
Materials aging information can be inserted into finite element models to predict reliability.



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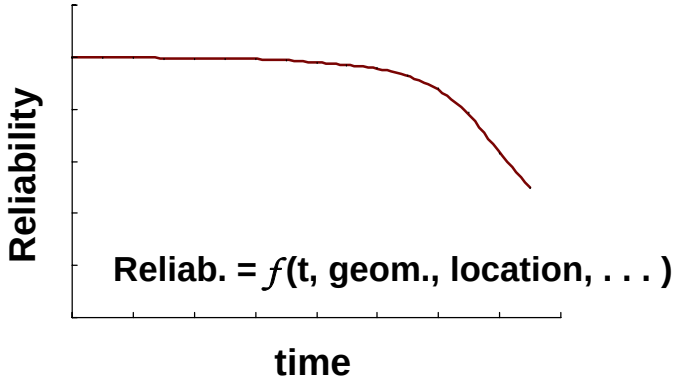
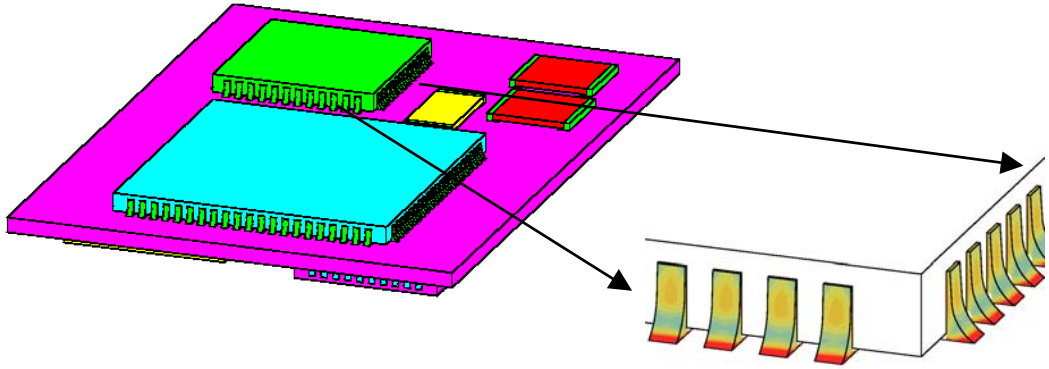


Reliability Prediction

Finite Element Simulation



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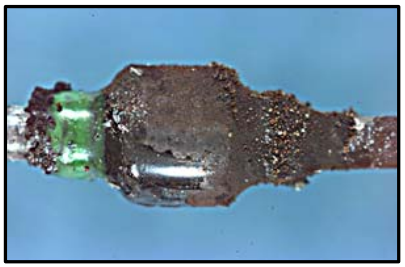
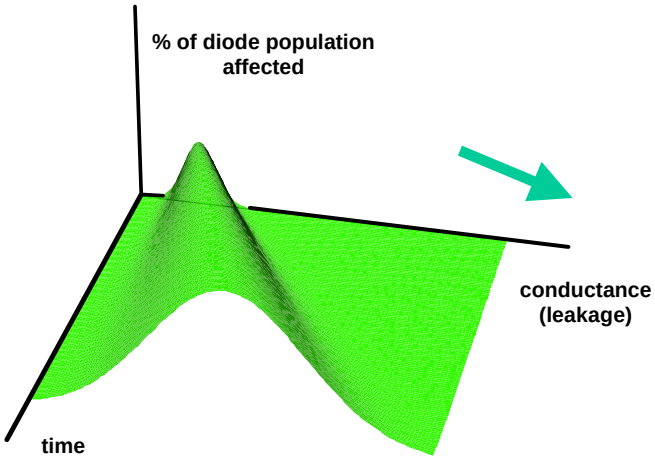
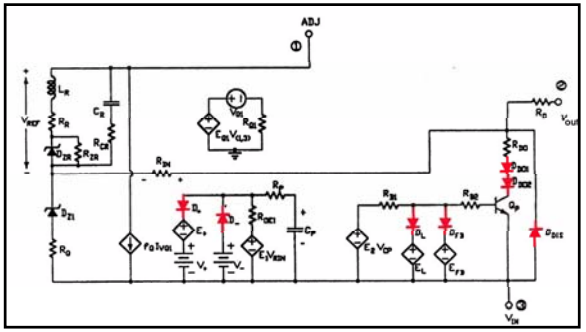
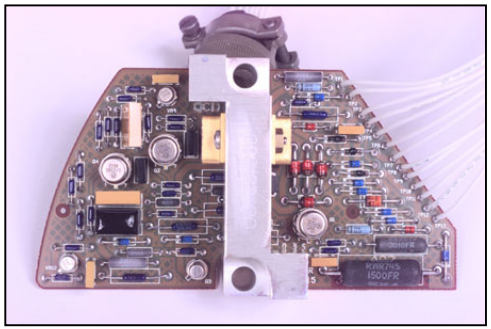
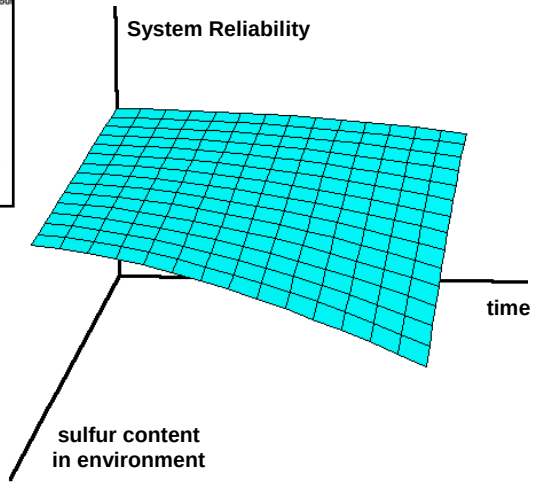
The materials model adds age awareness into the electrical system model.











The materials model is a time-dependent distribution of resistance.

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Aging and reliability concerns have led us to study many types of materials.

- lubricants
- electrical contacts
- encapsulants
- adhesives
- thin films
- welds
- brazes
- dielectric materials
- desiccants / getters

- corrosion
  (electronics and structural alloys)
- solder degradation
  (TMF, diffusion, μstructural evolution)
- hermetic seals (glass and ceramic)
- energetic materials
  (explosives, propellants, …)
- elastomer seals (o-rings), cable insulation
- stress voiding in ICs
- radiation hardness of electronics

Materials aging models must be coupled into component and system performance simulation models.

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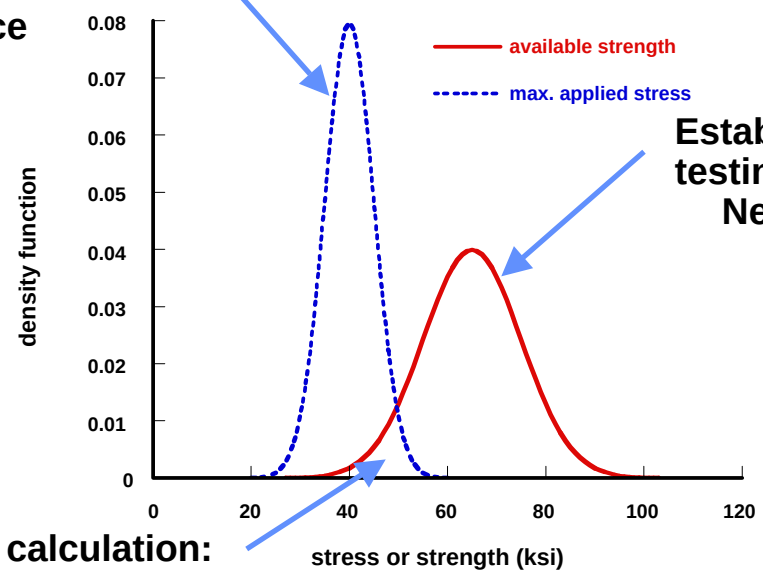
Quantifying the effects of materials aging on system reliability requires interdisciplinary effort.

Established by design, laboratory/field testing, and calculation:

Needs:

- systems designers
- component designers
- engineering science
- materials science
- sensors
- test / validation



Established by laboratory / field testing, and calculation:

Needs:

- materials science/physics/ chemistry
- high performance computing
- advanced engineering science simulation
- sensors
- test / validation

Established by test and calculation:

Needs:

- system and component designers
- reliability/surety assessors

Materials modeling/computer simulation will allow the time dependent distributions to be established with less reliance on empirical testing. Testing will always be required for validation.

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