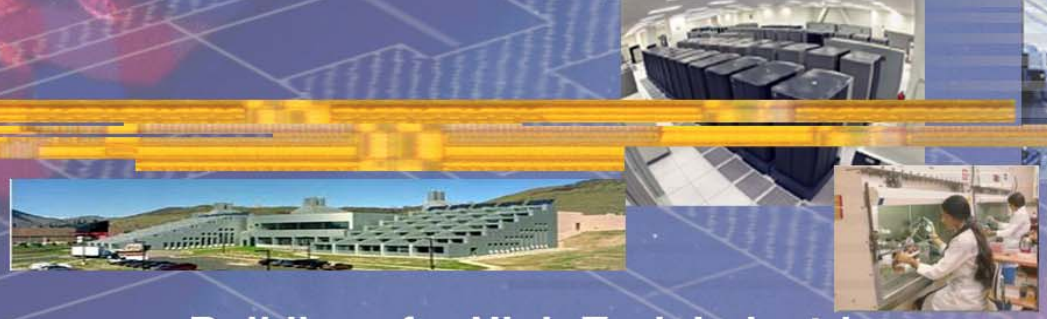


High-Performance Buildings for High-Tech Industries

DC Power Distribution for Data Center Efficiency

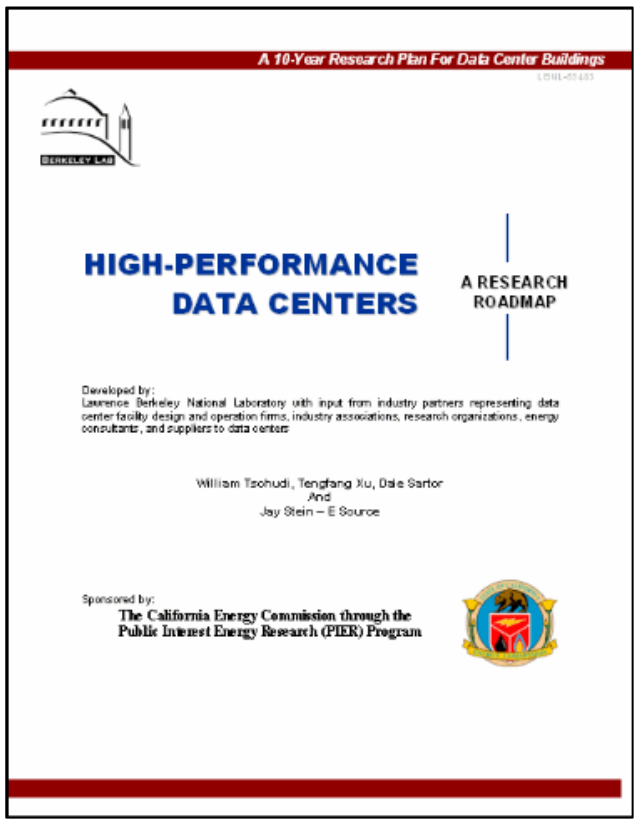
Outreach and Coordination Wrap Up

My Ton – Ecos Consulting
Brian Fortenbery – EPRI Solutions
Bill Tschudi – Lawrence Berkeley National Laboratory

Sponsored by:
California Energy Commission (CEC)–Public Interest Energy Research (PIER),
California Institute for Energy Efficiency (CIEE).

California Energy Commission Public Interest Energy Research High-tech Buildings Project Objectives

- Research, develop, and demonstrate, innovative energy efficient technologies
- 10-year initiative focusing on high-tech industries – e.g. data centers
- Help move market to more efficient technologies
- Research and demonstration projects include technology transfer



A 10-Year Research Plan For Data Center Buildings

BERKELEY LAB

HIGH-PERFORMANCE DATA CENTERS

A RESEARCH ROADMAP

Developed by:
Lawrence Berkeley National Laboratory with input from industry partners representing data center facility design and operation firms, industry associations, research organizations, energy consultants, and suppliers to data centers

William Tschudi, Tengfang Xu, Dale Sartor
And
Jay Stein – E Source

Sponsored by:
The California Energy Commission through the Public Interest Energy Research (PIER) Program

California Energy Commission Public Interest Energy Research High-tech Buildings Project Objectives

DC Architecture Demonstration

The demonstration was able to show:

1. DC powered server equipment exists in the same form factor or can readily be built from existing components
2. DC powered server equipment can provide the same level of functionality and computing performance when compared to similarly configured and operating AC server equipment
3. Efficiency gains from the elimination of multiple conversion steps can be measured by comparing traditional AC delivery to a DC architecture

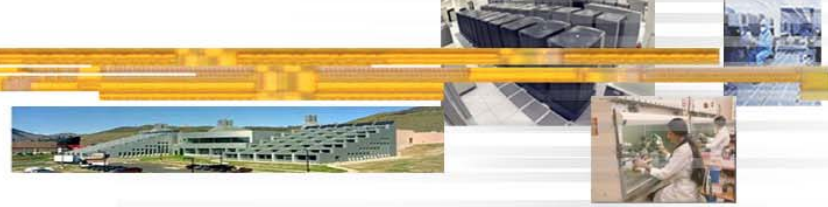
DC Architecture: Information Outreach and Dissemination Objectives

1. Inform industry of the energy savings potential for DC distribution systems compared to conventional AC distribution.
2. Identify issues and seek industry input on solutions applicable to DC distribution
3. Seek “early adopters” and provide informational and logistical support

DC Architecture Issues

Issues requiring additional investigation

- Advancing the topic at Green Grid, CENELEC, etc
- On-site implementation: Recruit partners for on-site DC architecture delivery option
- Cost Comparison: Perform a cost model comparison between typical high reliability AC systems vs. a DC system topology, as well as collect data for TCO analysis.



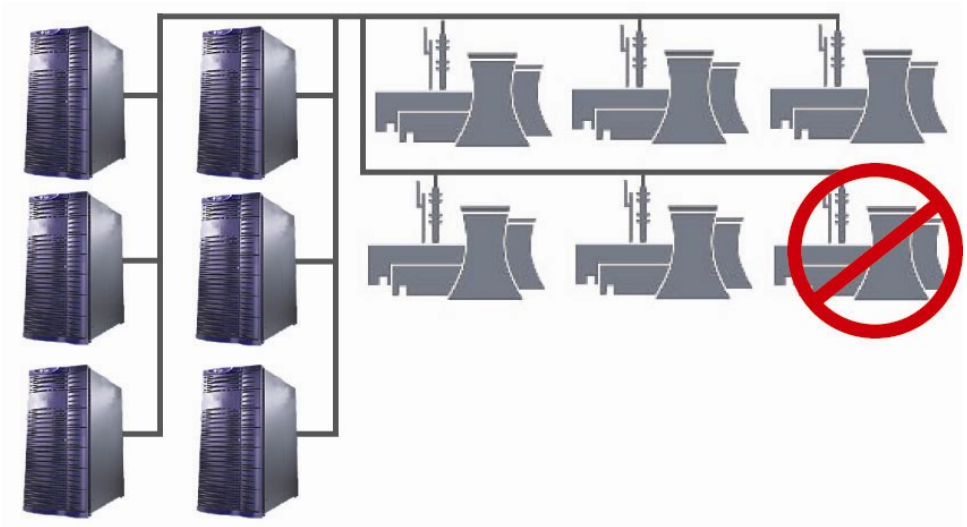
DC Architecture Issues

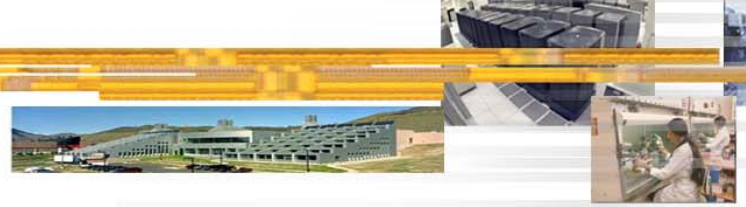
Issues requiring additional investigation

- Update Efficiency Data: Perform more efficiency data measurements within a real life data center environment.
- Education and Outreach: Continue to publicize the potential energy savings for a DC system and obtain involvement of code and standard development organizations to begin the development of universal standards for high-voltage (350V up to 500V DC) systems for data centers.

Reminder

Why do we want to increase efficiency?





Additional Information

Project Coordination & Contacts:

- My Ton, **Ecos Consulting** mton@ecosconsulting.com
- Brian Fortenbery, **EPRI** bfortenbery@epri.com

Lawrence Berkeley National Laboratory

- Bill Tschudi, Principal Investigator wftschudi@lbl.gov
- Dr. Evan Mills, Press and publicity contact emills@lbl.gov

THANK YOU FOR YOUR INTEREST!

DC Power Distribution for Data Centers

A Report from the Trenches

What We're Hearing

- Not Ready for Primetime
  - **No Push from Early Adopters**
- First Cost is Prohibitive
  - **TCO has not been Establishes**
- H/W Manufacturers are not Supportive

The Problem is .....

What We're Hearing

- Not Ready for Primetime
  - **No Push from Early Adopters**
- First Cost is Prohibitive
  - **TCO has not been Establishes**
- H/W Manufacturers are not Supportive

The Problem is .....

This is What We Hear about Free Cooling!

There's Significant Inertia to Overcome

- C-Level – CEO, CFO, CIO, CSR
  - Reliability/Availability
  - First Cost
  - Lately, Sustainability
- IT Manager
  - Reliability/Availability
  - Strategic Control
  - Flexibility
- Facilities Manager
  - Reliability/Availability
  - Maintainability

Needed to Overcome Inertia

Address Reliability and Safety Concerns

- Common Requirement of all Decision-makers
- Will Require Standards and Codes to Satisfy Concerns

Tap Into Sustainability Momentum

- Express Building load in Carbon Terms
- Enlist Utility Support

Develop Credible TCO Calculator

- Use EPRI as a Clearinghouse for Suggested Models
- Produce Methodology that Recognizes Site Characteristics

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Availability, Power Quality and TCO Assessment of a DC Data Center

Brian Fortenbery

Program Manager

EPRI

Future Work

- Based on conclusions from last year's demonstration (and agreed to today)
- Needs are defined as
  - Cost benefit analysis (TCO)
  - Power quality studies
  - Safety studies
  - Reliability studies (availability)

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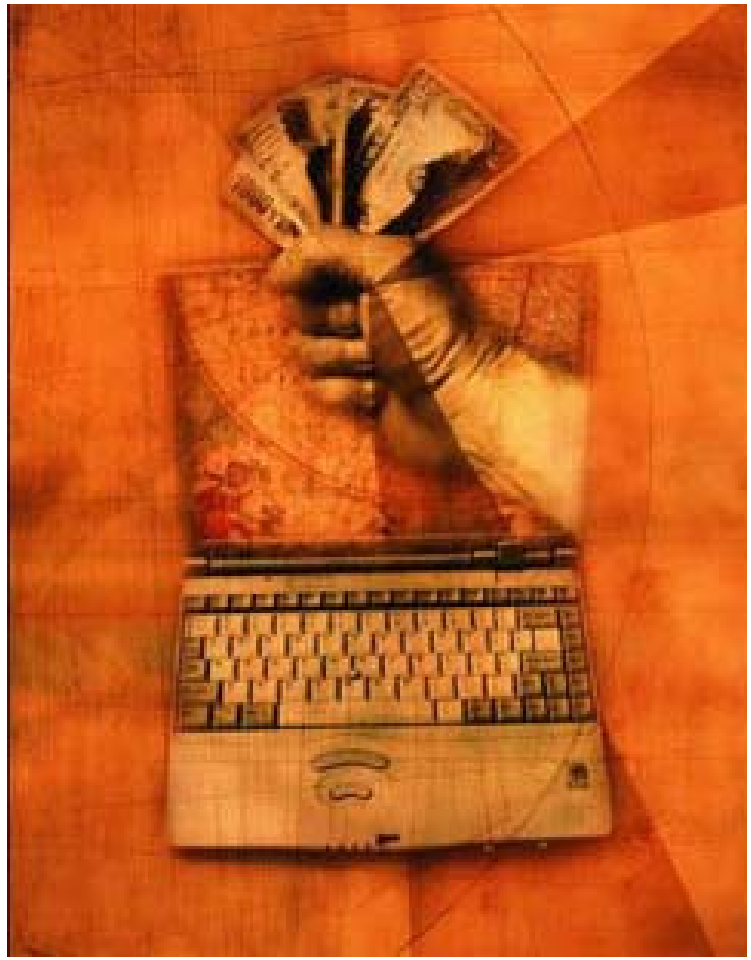
Cost Benefit

- Taking into account
  - Installation costs
  - Material costs (copper, converters, etc)
  - Maintenance
  - Efficiency benefits
  - Other benefits



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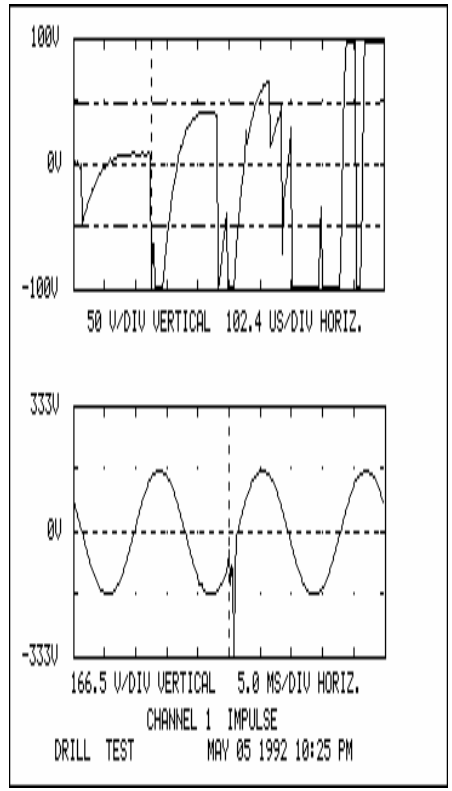
Power Quality

Categories	Spectral Content	Typical Duration	Typical Magnitudes
1.0 Transients			
1.1 Impulsive			
1.1.1 Voltage	> 5 kHz	< 200 µs	
1.1.2 Current	> 5 kHz	< 200 µs	
1.2 Oscillatory			
1.2.1 Low Frequency	< 500 kHz	< 30 cycles	
1.2.2 Medium Frequency	300–2 kHz	< 3 cycles	
1.2.3 High Frequency	> 2 kHz	< 0.5 cycle	
2.0 Short-Duration Variations			
2.1 Sags			
2.1.1 Instantaneous		0.5–30 cycles	0.1–1.0 pu
2.1.2 Momentary		30–120 cycles	0.1–1.0 pu
2.1.3 Temporary		2 sec–2 min	0.1–1.0 pu
2.2 Swells			
2.1.1 Instantaneous		0.5–30 cycles	0.1–1.8 pu
2.1.2 Momentary		30–120 cycles	0.1–1.8 pu
2.1.3 Temporary		2 sec–2 min	0.1–1.8 pu
3.0 Long-Duration Variations			
3.1 Overvoltages		> 2 min	0.1–1.2 pu
3.2 Undervoltages		> 2 min	0.8–1.0 pu
4.0 Interruptions			
4.1 Momentary		< 2 sec	0
4.2 Temporary		2 sec–2 min	0
4.3 Long-Term		> 2 min	0
5.0 Waveform Distortion			
5.2 Voltage	0–100th Harmonic	steady-state	0–20%
5.3 Current	0–100th Harmonic	steady-state	0–100%
6.0 Waveform Notching	0–200 kHz	steady-state	
7.0 Flicker	< 30 Hz	intermittent	0.1–7%
8.0 Noise	0–200 kHz	intermittent	



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Safety

- Taking into account
  - Touch potential
  - Arc Flash
  - Grounding

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Reliability

- The probability that a system or component will operate for a given time
  - can be function of time, events, environment
  - Reliability tends towards 0 (all things fail)
  - $R = 1 - P_f$ (Probability of Failure)
  - most useful for analysis of missions during which equipment may not be repaired
  - mission length must be known

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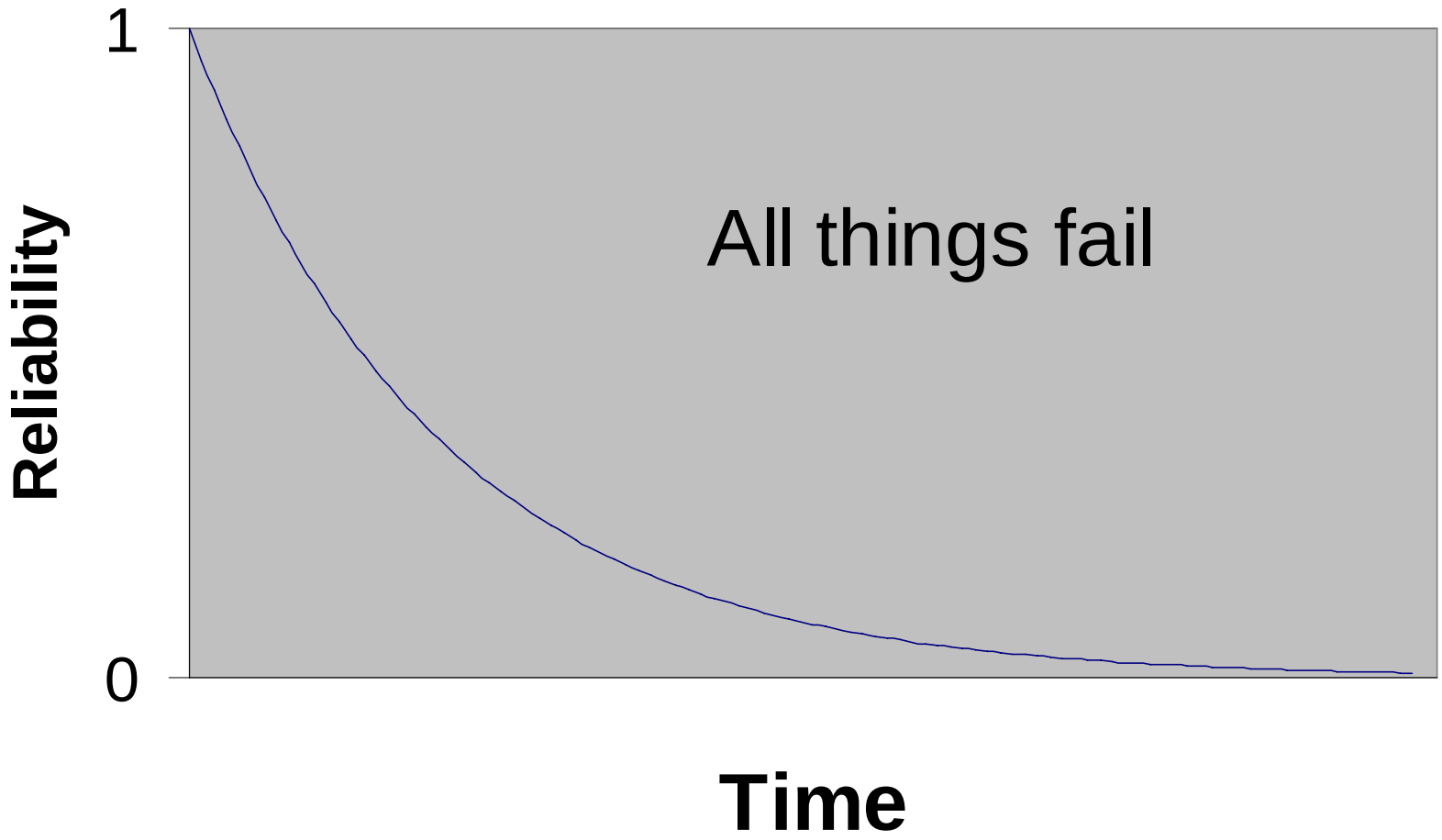
Reliability with Constant Failure Rate



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Availability

- Probability that a system will function at a future instant in time
  - most useful in analysis of repairable systems
  - does not <u>require</u> defined mission length
  - does not have to go to zero

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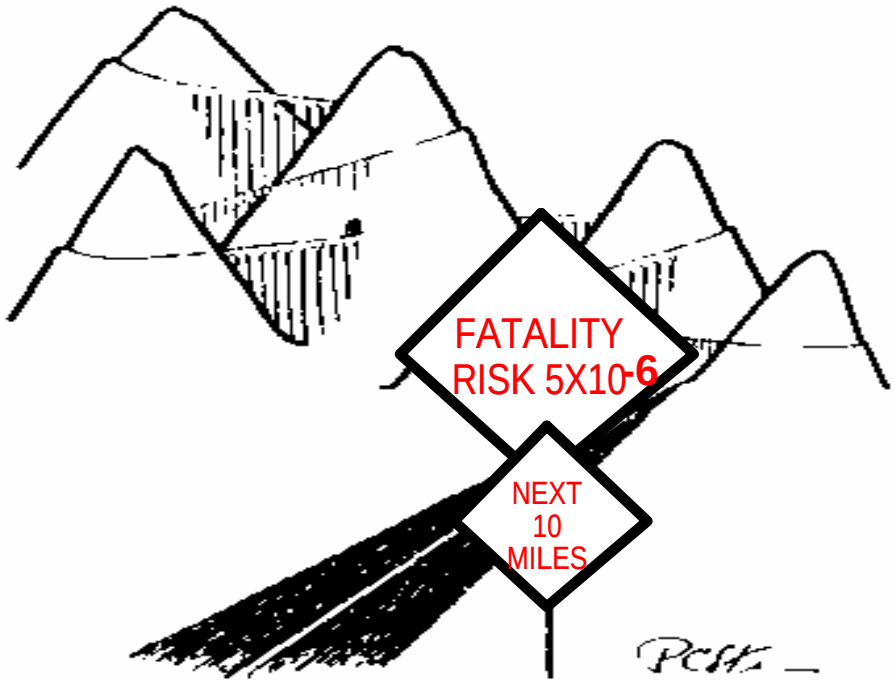
Unavailability

- 1 - Availability Q = 1 - A
- Q more useful, precise when A ≈ 1
  - Q = 2 x 10^{-3} A = 0.998
  - Q = 3 x 10^{-7} A = 0.9999998 “six nines, almost 7 nines, 6 nines and an 8”



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The Science of Availability

- Probabilistic Risk Assessment - PRA
  - Initially driven by missile development
  - Modern systems are not chains:
    - much weaker than their weakest link
  - Military analysis showed electronic equipment repairs costing $2/year for each $1 spent in acquisition
  - 50 years development for military, aerospace, nuclear industries

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PRA Design Tools

- Hazard Analysis
  - identifies, quantifies hazards and mitigation
- Fault Tree Analysis
  - Traces *System Failures* back to *Initiating Events*
- Event Tree Analysis
  - Trace *Initiating Events* forward to *Failure*
- **Failure Mode and Effects Analysis**
  - Exhaustive identification of component failures, their effects, and ability to detect and respond to them

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PRA Operating Tools

- Root Cause Analysis
  - Rigorous identification of failure mechanisms
- Risk/Reward Measures
  - Identify which components contribute most to availability/unavailability
- Procedure Development and Maintenance
  - Traceable standards for anticipated events
  - Risk-informed guidance for troubleshooting
- Performance-based maintenance
  - quantitative recognition of benefits, limits, hazards of PM

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Limits of PRA

- Risk aversion is highly individual
  - virtually all Americans accept risk of driving
  - many reject risks of nuclear fission, 100-1000x less
- True value of risk assessment
  - formal, quantitative thinking
  - identification of causal relationships
  - predicting effects of proposed improvements
- Acceptance of risk is more dependent on confidence in risk manager than on PRA results

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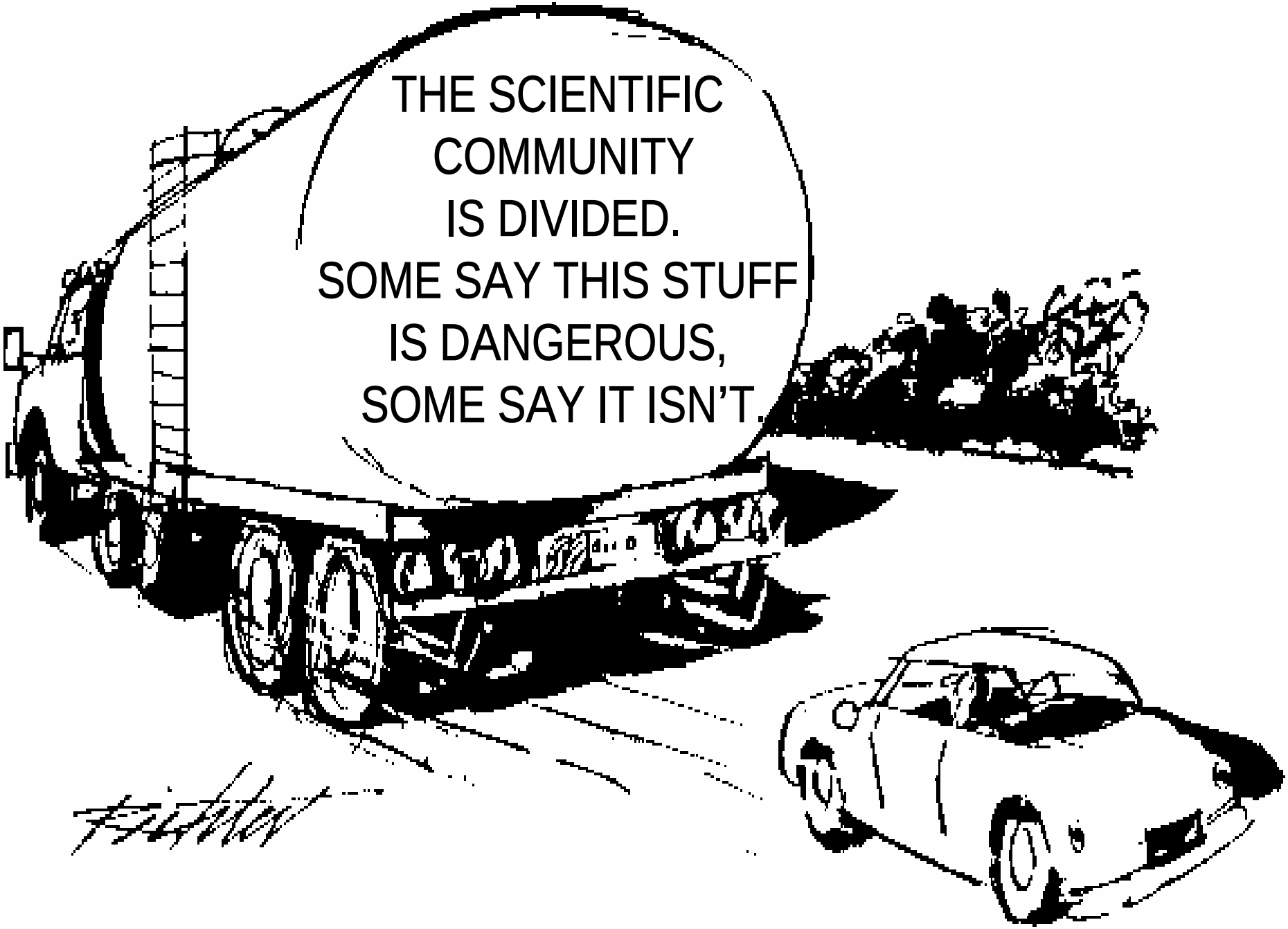

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Performing the Studies

- Issues have been identified
- Expertise is widely distributed
- EPRI can offer to collect and incorporate from multiple sources
- Provides an independent, third party assessment of all these issues

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