JOURNEY TO A DATA CENTRIC APPROACH FOR NATIONAL SECURITY

PRESENTED BY

Marcy Hoover, PhD
SANDIA’S HISTORY

- July 1945: Los Alamos creates Z Division
- Nonnuclear component engineering
- November 1, 1949: Sandia Laboratory established
The Garaged Mustang

- Ready to drive after 40 years in the garage?
- **Our products must work at a moment’s notice — even after decades of storage**
AN ADDITIONAL ENGINEERING CHALLENGE
Show video:
https://www.youtube.com/watch?v=xhs4VQ9dN3s
In the late 1990s, Sandia experienced a flight test failure due to a failure to pass electrical signals through a key component.

The failure prompted a review of all data, which uncovered a complex jet-fin interaction affecting the spin rate.

This was the beginning of our journey towards a more data-driven approach.
CULTURE CHANGE: A PROACTIVE APPROACH

- PERFORMANCE DATA COLLECTION AND ANALYSIS
- DESIGN QUALIFICATION
- QUANTITATIVE MARGIN ANALYSES

TEAMING IS PARAMOUNT
**Ideally would like to claim:** We are XX% confident that YY% of units will meet the requirement.

**Practical challenges for this claim:**
- Test data measurement uncertainty
- Model uncertainty
- Experts state of knowledge is imperfect
- Information comes from heterogeneous sources that are difficult to combine
- Separation of stochastic and knowledge uncertainty is infeasible
- Not all uncertainties can be straightforwardly quantified

Blindly applying statistical methods can be misleading!
SANDIA’S JOURNEY

**SME-DRIVEN**
- Reliant on judgment of SMEs
- Deep engineering experience is invaluable
- Disregards valuable test data
- Expertise lost as people depart

**DATA-DRIVEN**
- Decisions made using data
- Broad testing abilities provide deep data
- Data lacks perspective
- Ignores the deep expertise of our colleagues

Assessments relied heavily on go/no-go test data

Focused margin analyses began in the early 2000s to formalize NW assessment and certification methods in the absence of nuclear testing

Expectations that all weapon system teams apply a data-driven framework to all major components drove automation of simplistic methods.
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DATA-CENTRIC
- Statisticians and technical SMEs collaborate
- Qualitative and quantitative data used in decision making

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The formality and scope of analyses slowly increased over time—a statistical handbook formalizes the process.

Returning to a more balanced approach combining analyses with expert knowledge.

Expectations that all weapon system teams apply a data-driven framework to all major components drove automation of simplistic methods.
**BASING DECISIONS ON BOTH DATA-DRIVEN EVIDENCE AND ENGINEERING JUDGMENT**

<table>
<thead>
<tr>
<th>Evidence Building Blocks</th>
<th>Description of Activities</th>
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</thead>
<tbody>
<tr>
<td>Summary statistics</td>
<td>• The sample size (number of units) tested</td>
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<tr>
<td></td>
<td>• The mean and standard deviation of relevant performance parameters</td>
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<td></td>
<td>• The range of performance</td>
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<tr>
<td></td>
<td>• Calculate a k-factor with 95% confidence bound</td>
</tr>
<tr>
<td>Visualization of data</td>
<td>• A histogram of the performance parameter alongside the requirement</td>
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<tr>
<td>Representativeness of units</td>
<td>• Were the units a representative sample of units that will be fielded?</td>
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<td></td>
<td>• Are changes expected production?</td>
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<tr>
<td>Representativeness of use conditions</td>
<td>• What changes could occur across use conditions?</td>
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<tr>
<td></td>
<td>• What is the magnitude of measurement error?</td>
</tr>
<tr>
<td>Anomalies</td>
<td>• Were there any unexpected outliers or subpopulations?</td>
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<tr>
<td></td>
<td>• What further investigation was conducted to understand these anomalies?</td>
</tr>
<tr>
<td>Uncertainties</td>
<td>• What remaining uncertainties could impact margin?</td>
</tr>
<tr>
<td>Other Evidence</td>
<td>• What engineering judgment or past data are available to support a positive margin assertion?</td>
</tr>
</tbody>
</table>

We apply engineering analysis that sometimes uses statistics, not vice-versa. Good engineering judgment should always trump unvalidated statistical assumptions.
FUTURE RESEARCH THRUSTS

1. Data fusion for high-confidence, predictive multiphysics models
2. Data-driven statistical modeling for weapons lifecycle decision support
3. Intelligent data collection
4. Data-driven predictive aging
5. Human factors for data-informed decision analytics
THANK YOU

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