

Using mixed methods research designs to identify challenges and opportunities in today's engineering work

Diffusion of designerly finite element analysis at Sandia National Laboratories †

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Goal: Increased utilization of FEA

Increased utilization of finite element analysis (FEA) in the product design and development process—a goal widely recognized across various disciplines and industries—is, at its core, an issue of technology diffusion.

Framing the issue: Context Assessment Survey

An online survey distributed to a wide audience in the product development community at Sandia National Laboratories in Livermore, California revealed a variety of difficulties, past failures, and conflicting points of view regarding the use of FEA.

- Submitted to approx. 160 Sandians
- Jan. 2012 and Jan. 2014
- CAS-pre: 67 respondents
- CAS-post: 55 respondents

(Percentages of comment volume shown)

TESTING category	No.	%
Diagnose test failures	14	
Reduce testing, design-test iterations	10	53.1
Complements experimental testing	10	
Guides design of experiments	9	
Required for model/results validation	38	46.9
Total	81	100.0

COST category	No.	%
FEA can reduce cost	11	47.8
Dollar cost too high	12	52.2
Total	23	100.0

TIME category	No.	%
Identify issues early, guide design	34	
FEA typically keeps pace with design	13	62.3
FEA can save time	9	
FEA typically leads design	5	
FEA typically lags design	21	37.7
FEA takes too long	16	
Total	98	100.0

The hypothesis: 'Designerly' FEA

This research explored a 'designerly' insertion of FEA into the design-build-test product development cycle. Designerly FEA contrasts with more established approaches and may help overcome several of the identified hurdles to the use of FEA.

- Simplified FEA models
- Designer-friendly software
- Analyst embedded in product design team
- Relative comparisons of design options
- Leverage 1st prototype test for model validation

- RQ1. What are product development teams' perceptions of FEA?
- RQ2. How does designerly FEA impact teams' design thinking?
- RQ3. How do teams' views change on common barriers to adoption?
- RQ4. How likely are product development teams to carry the use of FEA forward?

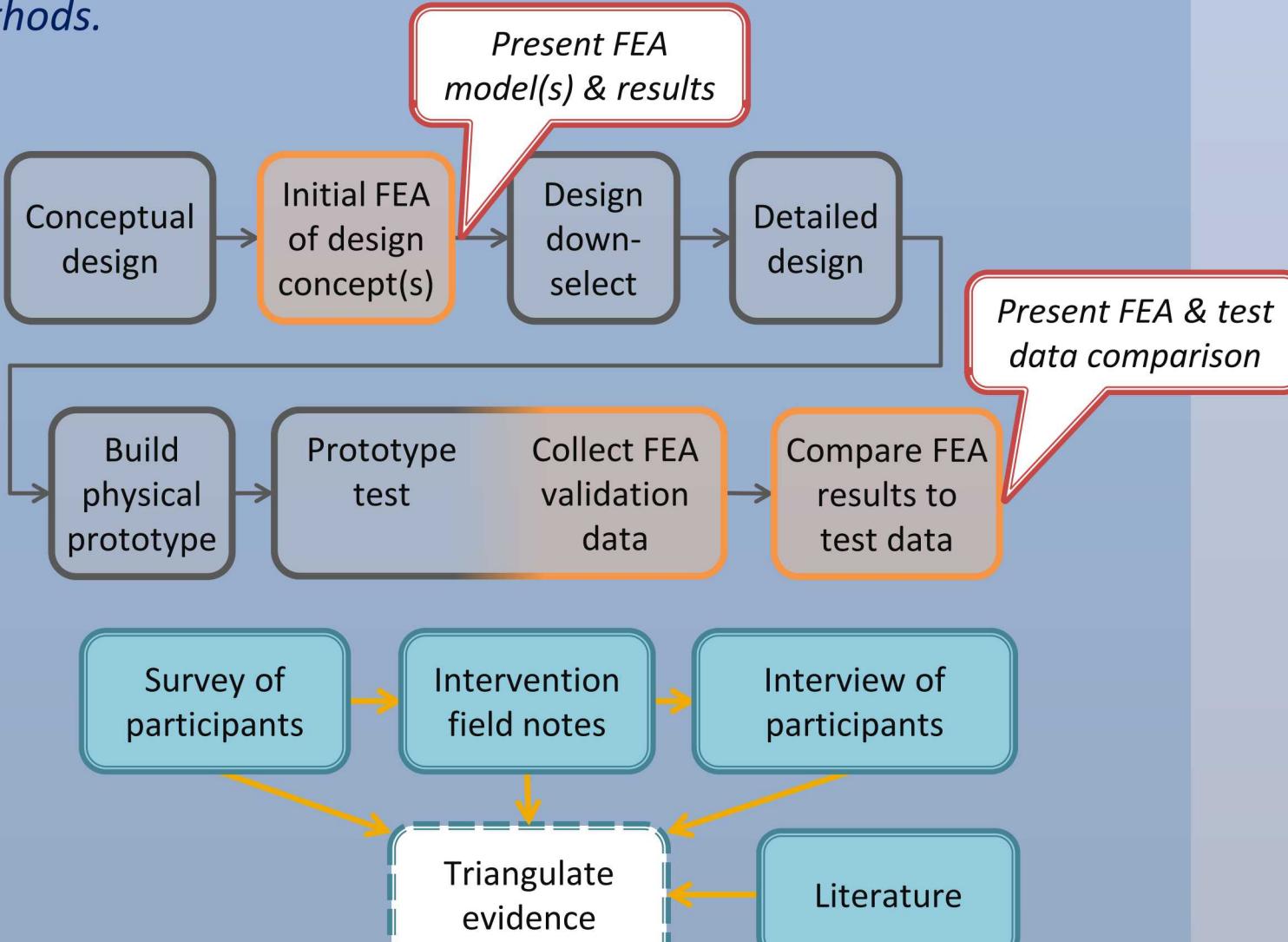
Case study research method using participant-observation and mixed-method data collection

Designerly FEA was implemented in two case study projects by the research investigator, and the resulting impact on the product development teams' thinking and perceptions of FEA was investigated via participant-observation using a combination of survey and interview data collection methods.

Intervention design

- Design-build-test development process
- Designerly FEA intervention
- Communication strategy

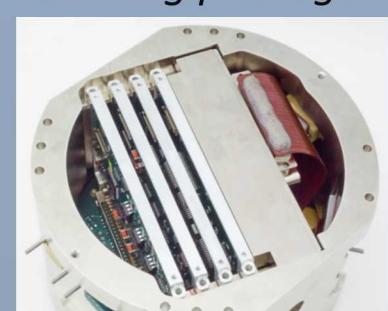
Theory-building analysis method



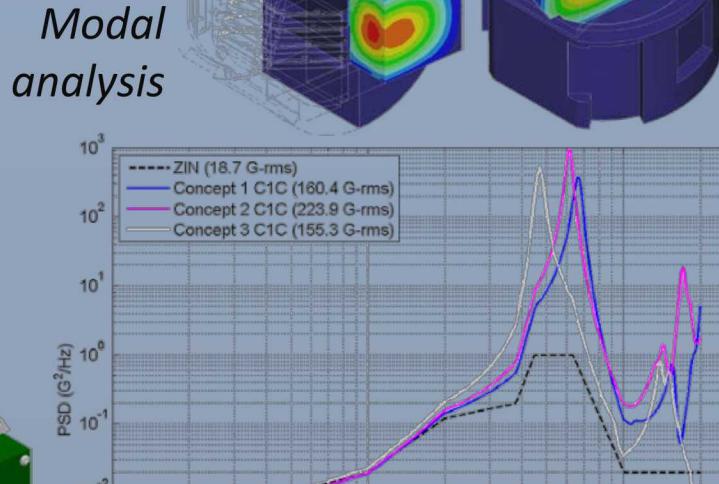
Case studies

The investigation drew on case study applications of FEA in the area of packaging design for ruggedized electronics. The first case study included 9 participants and focused on the modification of an existing electronics packaging design.

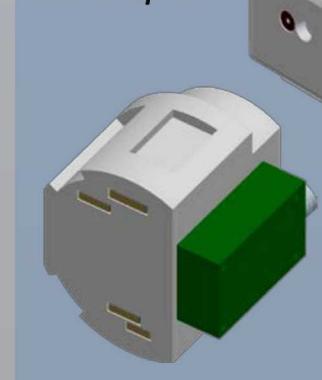
Existing package



Modal analysis

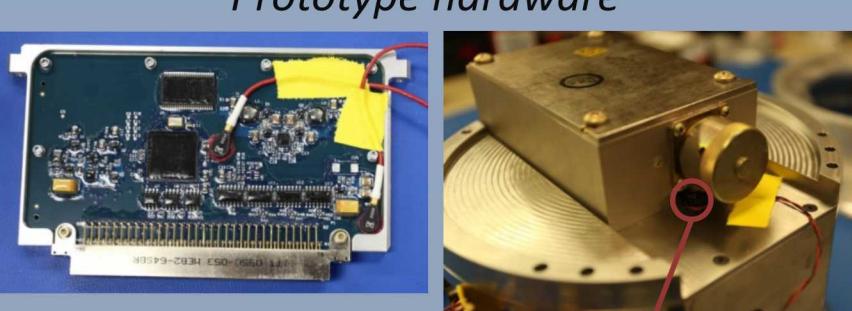


Design concepts



Example comparison of design options. Predicted vibration at center of plug-in cards. Concept 1 exhibited the highest 1st natural frequency and lowest peak response.

Prototype hardware



Example comparison to test data. Vibration measured at module. Response at module below design goal.

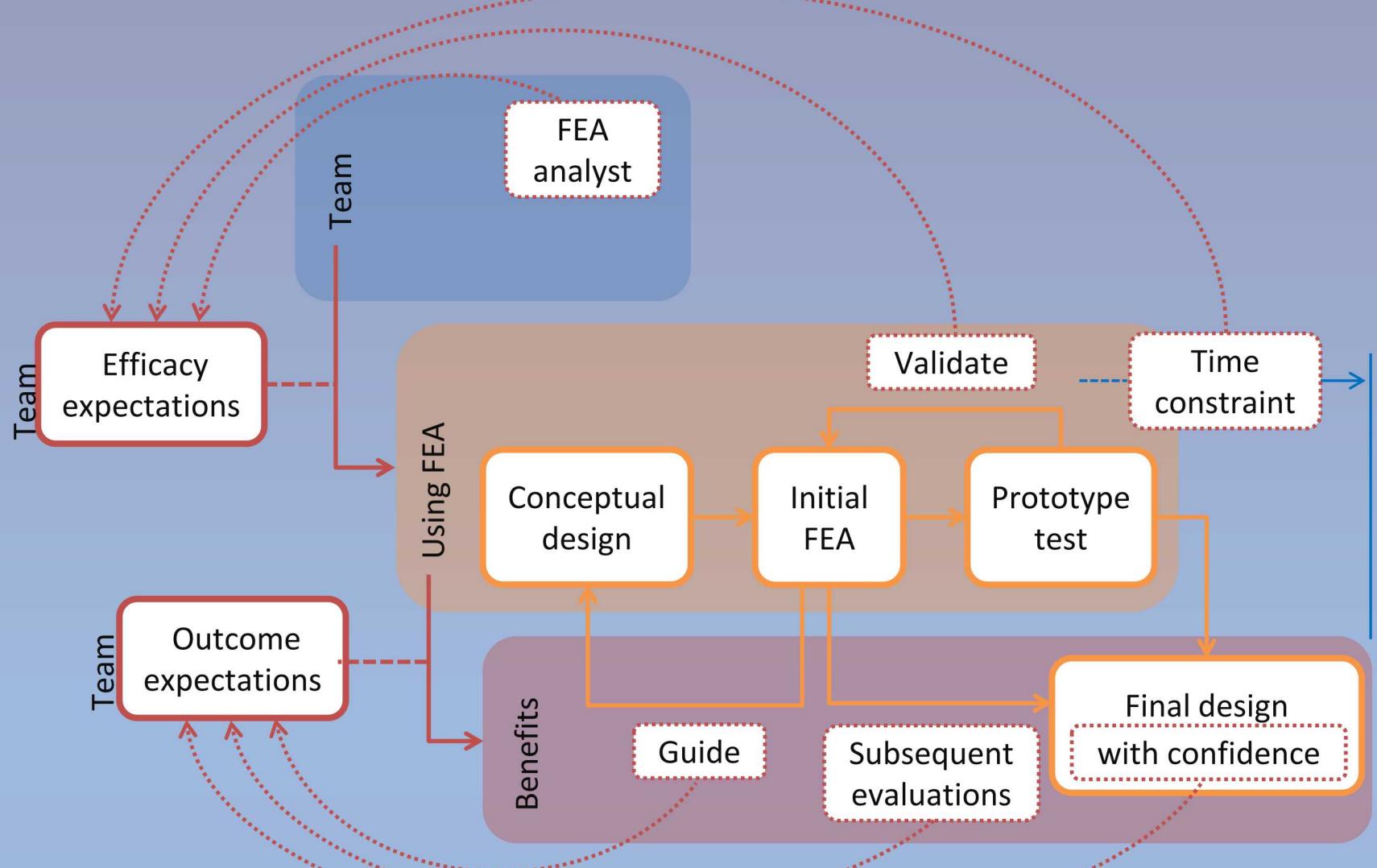
Recommendations to Sandia

The implications of this research may well extend to any organization that desires to increase the impact of FEA, computational fluid dynamics, electrical and electronics simulation, or multi-physics simulation in their product design and development process.

- Target product development activities where FEA can enhance design confidence.
- Demonstrate the applicability of FEA for evolutionary / experimentally-tested products.
- Emphasize tangible impacts of FEA on product design.
- Involve FEA analysts in testing, and ensure the visibility of FEA validation activities.
- Explore co-location of FEA analysts and design teams.
- Promote FEA training for design engineers.
- Strive for strong alignment between FEA and product deliverables.
- Expertly scope FEA to fit project timelines using a designerly approach.

Synthesis: Confidence Model

The resulting model describes how various factors identified in this investigation enhance (or erode) a team's outcome and efficacy expectations regarding the use of FEA, thereby increasing (or decreasing) their motivation to rely on it in their product development approach.



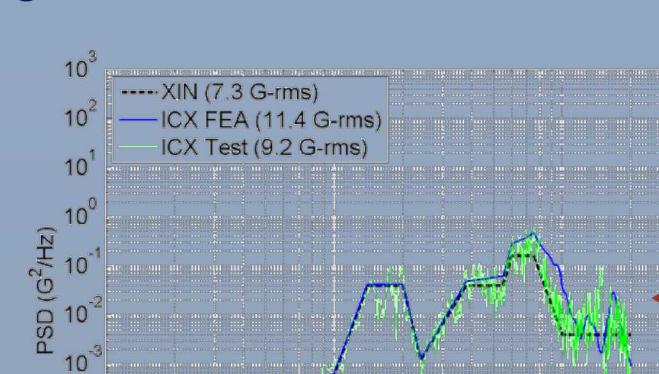
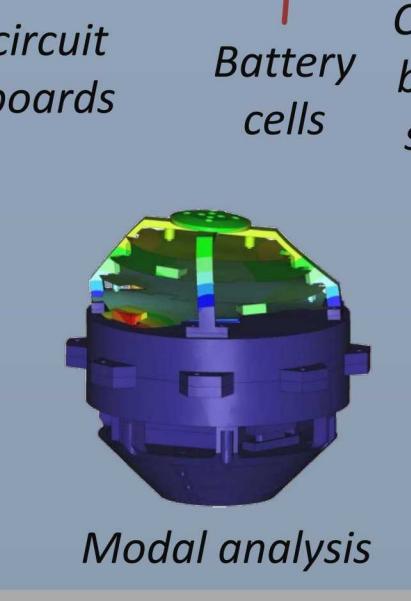
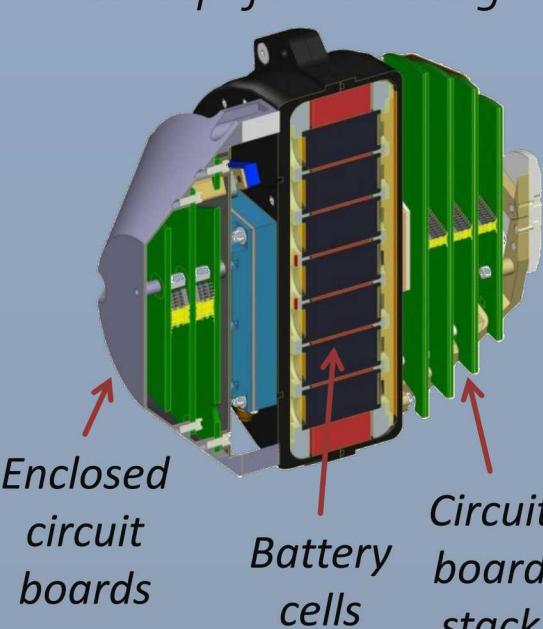
Findings

The case study data was analyzed using a theory-building approach to generate a framework for describing how the use of FEA to build confidence in a product design is related to the process by which product development teams gain or lose confidence in FEA itself. Both teams were strongly representative of the Sandia product development community, so the findings should hold applicability across a broad portion of the Laboratories' development work.

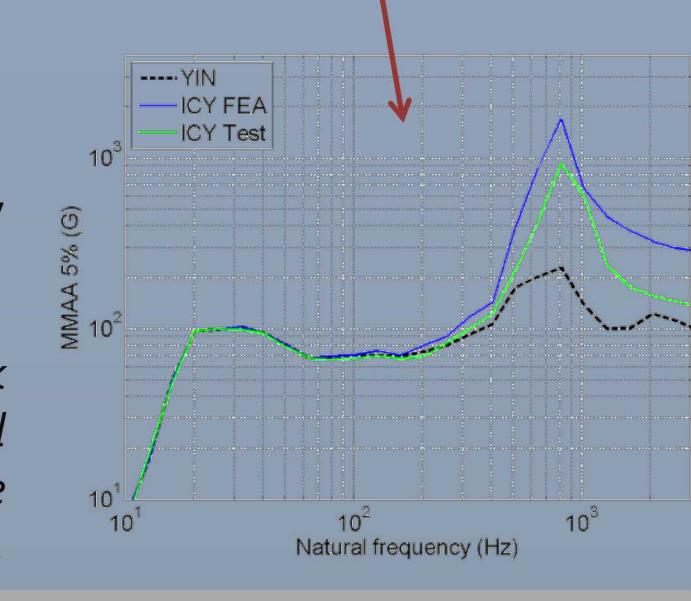
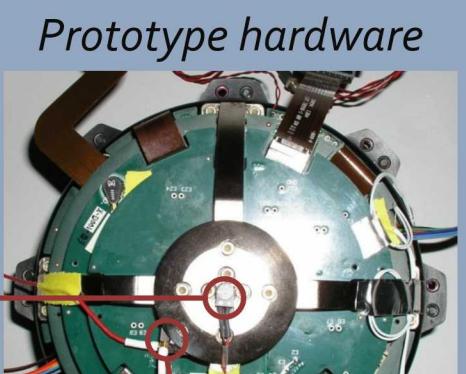
- Participants did not have confidence in FEA a priori; confidence in FEA had to be earned.
- Previous encounters with FEA strongly influenced their perceptions and expectations in the case studies.
- Participants primarily viewed FEA as a means to obtain design confidence.
- Participants expected to see tangible, direct evidence of FEA impacting product design and design decisions.
- Participants leveraged various sources of design knowledge to build confidence, but FEA served a supporting role.
- The time required to use FEA was a difficult barrier to overcome in the participants' thinking.
- Multiple participants conceived of their own potential applications of FEA over the course of the case studies.

The second case study included 7 participants and focused on the development of a new electronics packaging design.

Concept for new design



Example comparison to test data. Vibration of circuit board stack, normal direction. Low predicted response confirmed by test data.



Example comparison to test data. Shock response of circuit board stack, lateral direction. Moderate predicted resonance confirmed by test data.

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