A Predictive Analysis Framework for Six Degrees of Freedom Vibration Qualification

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Research Task / Overview

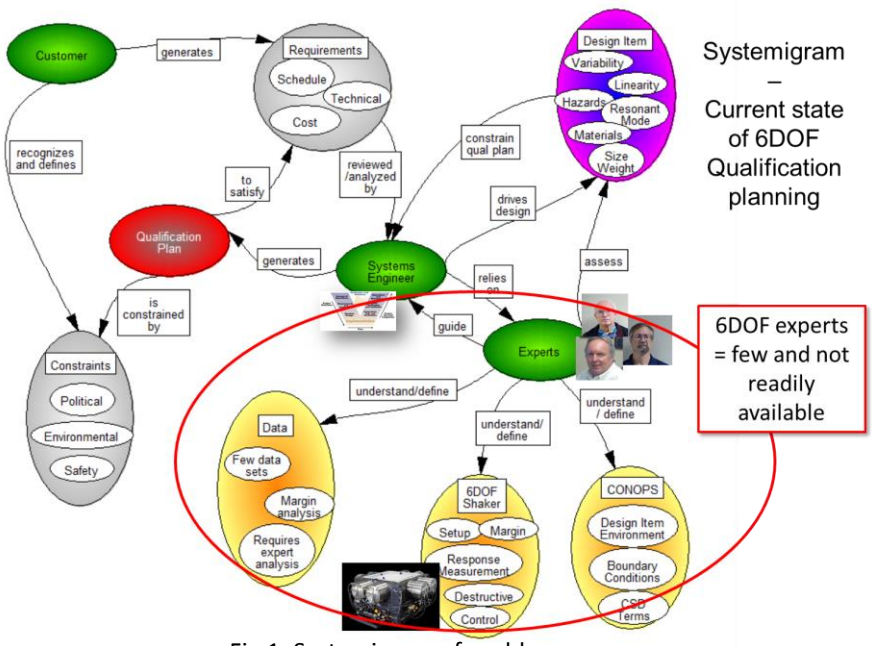

Fig.1. Systemigram of problem spare

Systems engineers must make decisions about complex problems early in a program when technical experts are not available[1]

- Qualification plans are an example of such problems[2]
- Decisions are hard to revisit when complex technical factors are involved and not understood[3]
- Existing qualification decision aids do not include technical factors nor expert knowledge[4]
- Six Degrees of Freedom (6DOF) vibration is a type of test that can be better than traditional vibration tests but is very difficult to execute[5] – technical factors are vital
- Bayesian Network models define causal factors/relationships, reason in data poor environments and incorporate expert knowledge[6]

Data & Analysis

Iterative Verification / Validation Process

- Verification of model
- Validation of model performance – **prediction metric 98.3%**
- Validation of model performance with historical test data - **historical prediction metric 83.3%**
- Validation test cases – two test cases examine the effectiveness of the model to aid decisions AND assess learning through the use of the model - **Validation case study metric 100%**

Demonstrated the model is effective as a decision aid in planning 6DOF qualification and (unexpected outcome) is effective in teaching key technical concepts

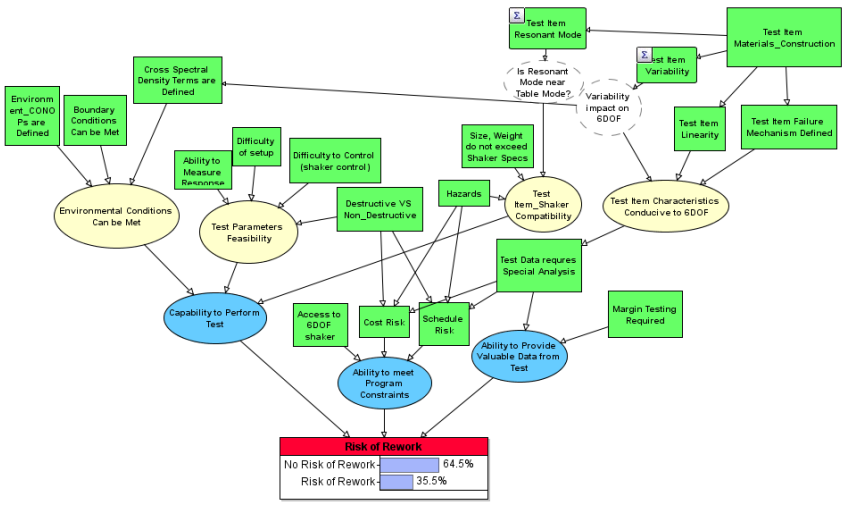

Fig.4. 6DOF BN Model: Output defines the risk the 6DOF test will not successfully gather meaningful qualification data

Results

- BN model **captures expert knowledge**, including **technical factors**, to **aid decisions**
- **New processes** for **eliciting expert knowledge** in data poor environment
- Method to **accelerate learning**

Goals & Objectives

Aid Systems Engineering (SE) decisions by:

- Incorporating **technical factors** into decision space
- Harnessing **expert knowledge**
- Utilizing **Bayesian Network (BN) models** to reason with the information
- Providing the capability to **identify driving technical** and programmatic factors and **reassess decisions**
- **Focusing** this research on a systems engineering decision problem that is very **technically complex**, has **extremely limited data**, and **few experts**
  - Determining if **6DOF vibration tests** should be used for a qualification plan

Methodology

Three steps to develop a BN model:

1. Identify factors (technical factors critical)
2. Identify relationships between factors
3. Identify probability distributions

Less than 25 data sets available – Expert elicitation crucial

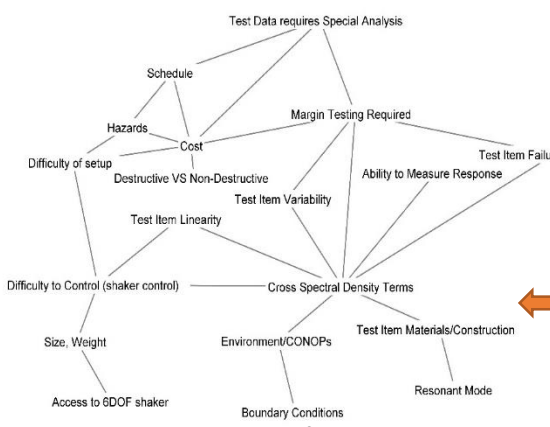

Fig.2. SKA results identifying relationships between factors

Novel Process: ***Structural Knowledge Assessment (SKA)[7]***

modified and repurposed to elicit relationship data from experts

Novel Process: ***Sheffield Elicitation Framework (SHELF)[8]***

Modified to support qualitative elicitation of probability distributions from experts and support validation

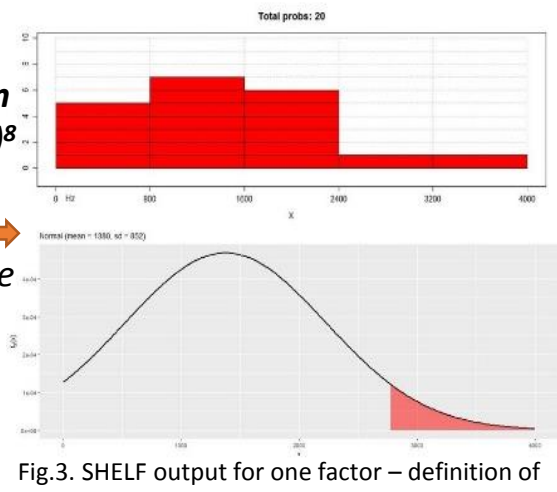

Fig.3. SHELF output for one factor – definition of probability distribution based on expert qualitative input

Future Research

Many Exciting Possibilities

- Metrics for expert based BN models
- Examine best use of BN models in SE – expensive to build
- Examine the use of BN models to accelerate learning
- Examine the use of BN models to reassess decisions after changes in the program

Contacts/References

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