

UNDERSTANDING THE LIMITATIONS OF MODELS AND ANALYSES

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Models are an essential tool used for any human space-faring program.

- *They help us deduce conditions for environments we've never been in before or can't directly see.*
- *They help us deduce conditions for different periods of time, including decades in the future.*
- *They allow us to do on paper what is challenging, expensive or schedule-prohibitive on the ground so that we can do more with less.*
- *They let us do on paper what we can't emulate on earth.*
- *They provide confidence, reduce uncertainty*

Space exploration and travel is likely not plausible without the use of models.



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For all their merit, however, there are limitations associated with the use of models and analyses.

- *The accuracy of even the best models depends on the fidelity of the data used to build it.*
 - Sometimes that data are limited.
 - Sometimes dissimilar data are used to model different equipment or environments.
- *Simplifying assumptions can add uncertainty*
- *Model results can mean completely different things.*

Understanding the limitations allows the most effective use, and prevents misuse, of models and their results.



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Models using limited data

– *Why?*

- Sometimes, data are only available for a subset of the range, such as wind tunnel data for hypersonic craft.
 - *This **may not** be a resource limitation but just a reflection of data that cannot be obtained. Reasons for this include:*
 - Environmental data cannot be directly observed
 - Test facilities cannot duplicate the conditions
 - *Data are generally extrapolated or interpolated from the data that is available.*
 - *Extrapolated models provide estimates of conditions that cannot be tested.*



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Models using limited data

– *Why?*

- Sometimes, only a few data points are available.
 - *Data points dependent on a limited source, like past flights.*
 - *Test samples/fixtures/facilities are prohibitively expensive.*
 - *Tests require extensive testing over a long period of time.*
 - *Other resource limitations.*
 - *Unique nature of space hardware makes drawing on existing engineering data problematic in many cases.*

Extrapolation/interpolation or working from a small number of data points introduces uncertainty to model results.



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Models can be made from dissimilar data

- *Using dissimilar data may allow for a much larger pool of data, but adds uncertainties that may be hard to quantify.*
- *New hardware may rely on data from previous designs.*
- *Test data may be used from facilities that can only partially emulate conditions.*
- *Data may be used from the same equipment or materials, but in a different application or to a different environment (such as damage data from foam impacts to emulate ice)*

The uncertainties from dissimilar data may be difficult to quantify without in-depth knowledge of both the tested and modeled systems.



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Models generally require simplifying assumptions

- *Models are often trying to duplicate very complex processes*
 - Simplifying assumptions often standardize a process or eliminate variables.
 - Simplifying assumptions allow reasonable computer runs and make building these models practical.
- *However, every assumption adds uncertainty*

**A mistaken or outdated assumption can invalidate results.
It is essential assumptions are documented and understood.**



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Model results are not all built the same: uncertainties

- *In order to use that result effectively one must understand the uncertainty (or the confidence).*
 - Two risks calculated at the same value may not represent the same risk. Uncertainties can vary by a few percent or orders of magnitude.
 - Results are often provided as a 1-sigma or 2-sigma value; this is more conservative than an average and should not be compared on equal grounds.

Risk trades using risks that are not comparable can skew results and result in inappropriate risk priorities.



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Methods to evaluate models

- ***Ask questions!***
- *Is it a certified model? Certified models are:*
 - Generally peer reviewed
 - Board reviewed
 - Configuration controlled
 - This generally means that the uncertainties, data sources and assumptions have been examined and accepted.
- *Review data from any independent or peer reviews*
 - Especially take note of recommendations that were made and how they were addressed.
- *Examine other models available and ask experts, especially outside experts.*

To evaluate a model, you must be willing to become somewhat expert.



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Is the model valid for the case at hand?

- *Have new data invalidated assumptions?*
- *Have new data become available that makes this model out of date for this case?*
- *Is this model being used within the original constraints?*
 - Using a model for something it was not designed for can lead to improper results for even the best model.

Things change and it is essential that the models used still be relevant and up to date.



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Summary:

- *Models are good, **even essential**, for space travel.*
- *Even the best models have limitations.*
- *Understanding those limitations, uncertainties, and assumptions is key to evaluating the results effectively.*
- *Understanding the model and the process modeled will ensure proper risk comparisons and the relevance to the model for the case in question.*

