

Digital Engineering Design: Opportunities and Dangers

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Opportunities

- To integrate processes – drawing, analysis, manufacturing
- To speed the design process
- To eliminate the need for mock-up
- To enable optimization
- To eliminate testing
- To manage

Major economic advantages are a significant driver toward digital design.

Dangers

- We become more removed from reality
 - Less testing
 - Less interaction between the designer and the product or system
 - More reliant on computation, less reliant on judgment, experience and common sense

We need to know that the methods we chose to use are valid

Validity

- It doesn't come easy – you can't make stuff up and expect it to be correct
- Anecdotal evidence does not validate methods
- Take stock of your failures (look in the bone yard)
- To assure validity, careful mathematical derivation is required

An engineering design example

- You are designing an airplane
- Question: what will it weigh?

We model (there is no other way)

$$W_A = W_1 + W_2 + W_3 + \dots$$

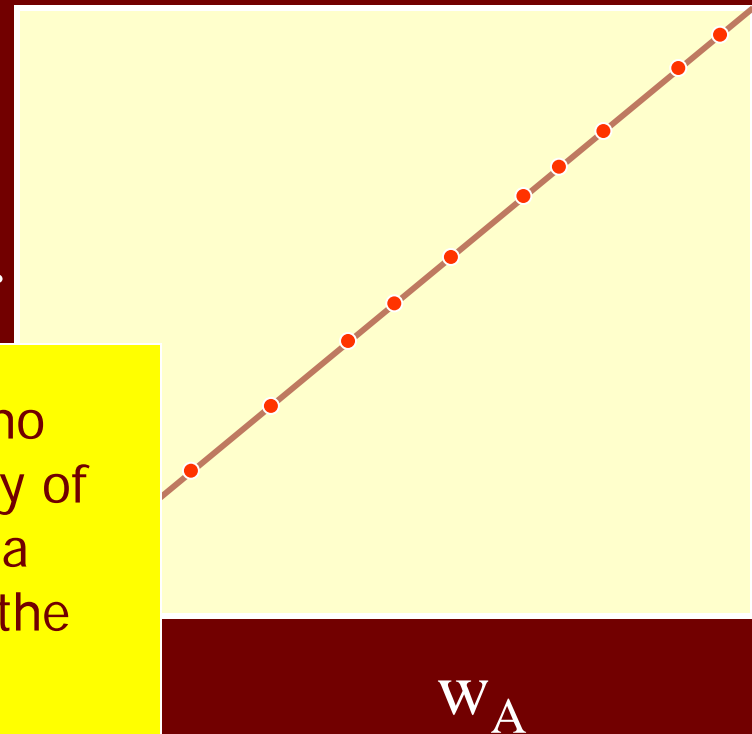
The model

$$W_A = W_1 + W_2 + W_3 + \dots$$

- Can we validate the model?

$$W_1 + W_2 + W_3 + \dots$$

We have made absolutely no statement about the validity of the model between the data points (the other 100% of the model)



Using the model

$$w_A = w_1 + w_2 + w_3 + \dots$$

- Where do the w_i come from?

But since the w_i are themselves estimates, they are random variables

Random variables

- Are neither random nor variables
- Are functions that map outcomes onto the number line
 - Arithmetic (+ \$K,) does not apply to random variables

The equation

$$W_A = W_1 + W_2 + W_3 + \dots$$

cannot be mathematically correct

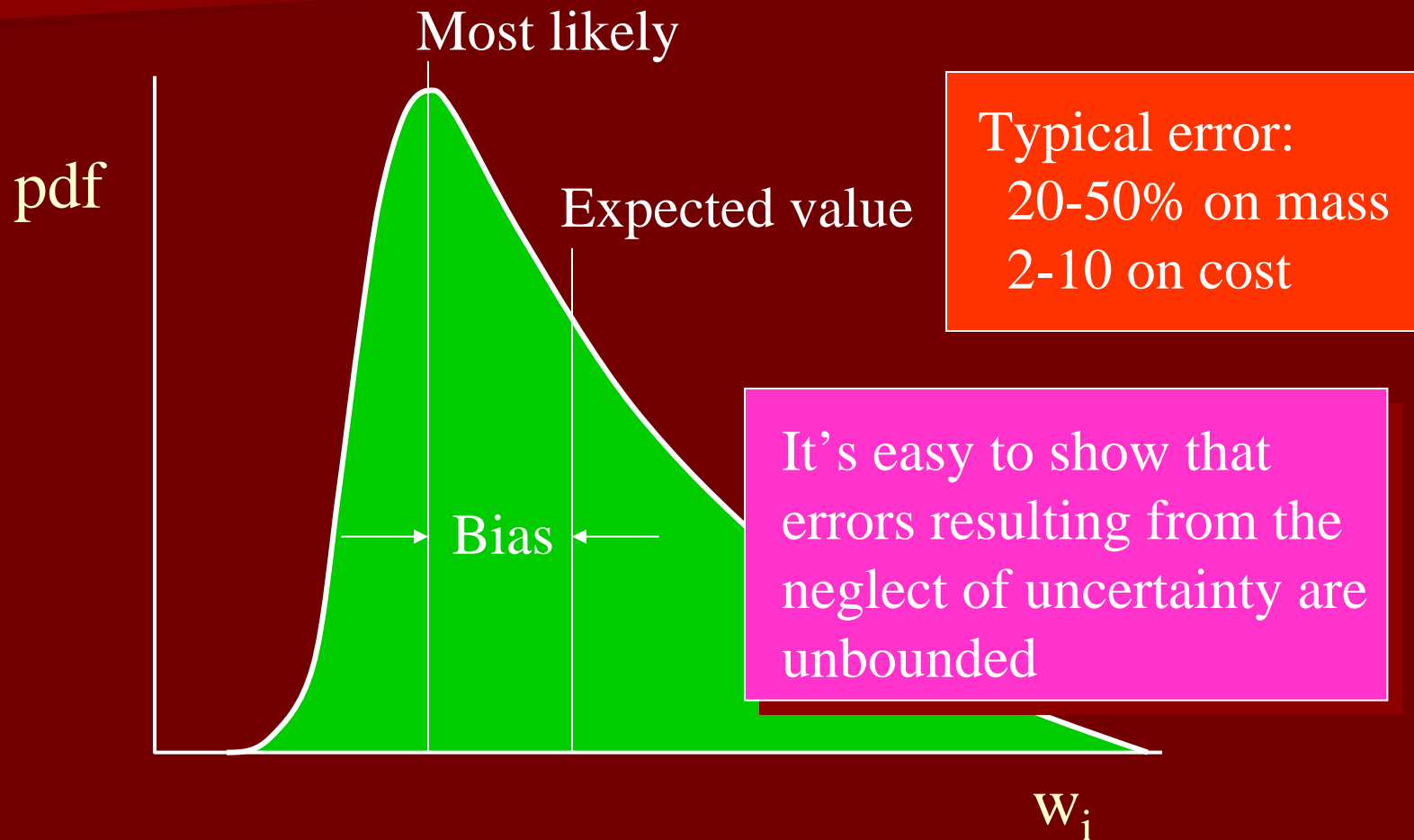
Correcting this equation

- The equation must make use of numbers
- Expected values are numbers

Thus, the equation can be written

$$E\{w_A\} = E\{w_1\} + E\{w_2\} + E\{w_3\} + \dots$$

But, be careful with the $E\{w_i\}$



A serious reality

- The methods we use are often flawed:
 - Predictive modeling
 - Probability theory vs. fuzzy logic and other ad hoc non-probabilistic methods
 - Decision methods
 - Multi-objective optimization and other generally inappropriate objective functions
 - Model validation

Bogus stuff

- Quality function deployment (QFD)
- The Pugh method
- Analytical hierarchy process (AHP)
- Voice of the customer
- Be especially careful with:
 - Six sigma
 - Axiomatic design
 - Group processes (group decision methods)
 - All forms of voting

Conclusions and advice

- Doing design correctly isn't easy
- Rely on classical decision theory
- Use only probability theory in dealing with the future
- Acknowledge uncertainty – it cannot be computed away
- Don't make up mathematics