

**Lean
Aerospace
Initiative**



***Growing the
Lean Community***
An LAI Plenary Conference

**Understanding Risk
and Uncertainty**
April 10, 2001

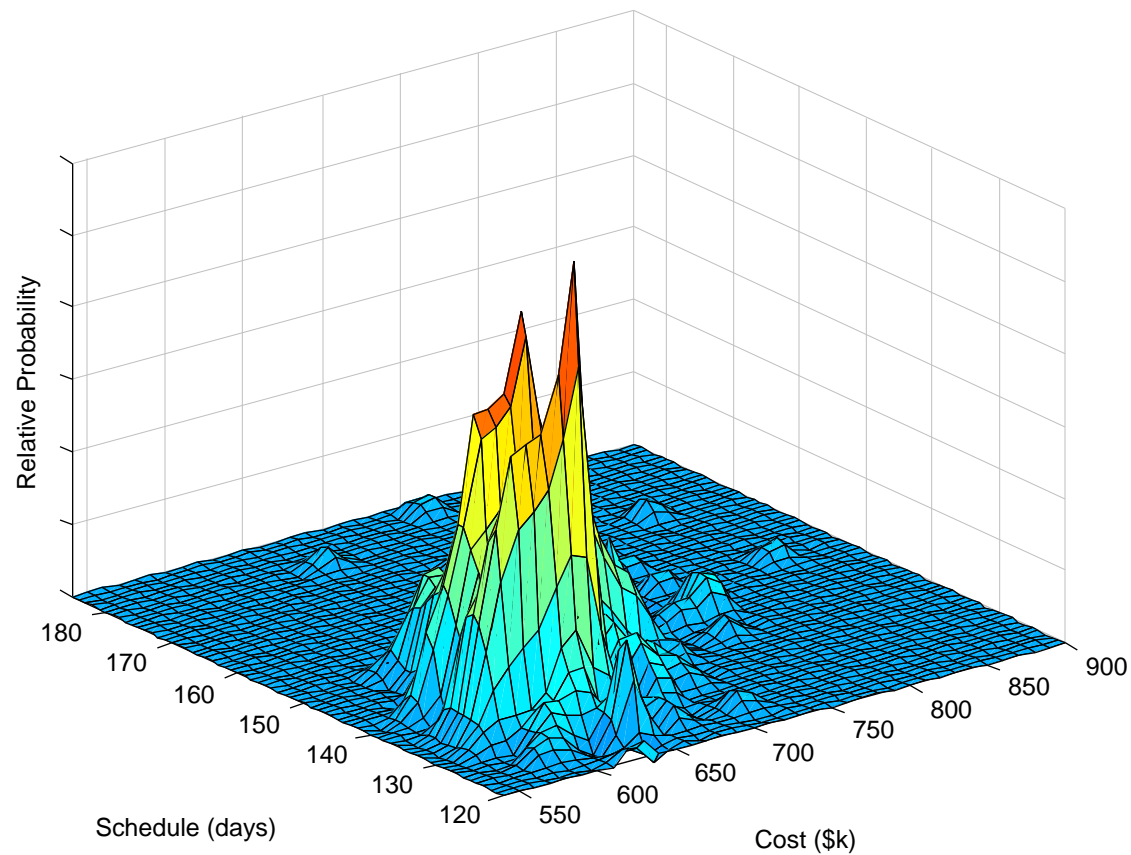
Presented By:
John Deyst
MIT

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Advanced DSM model example

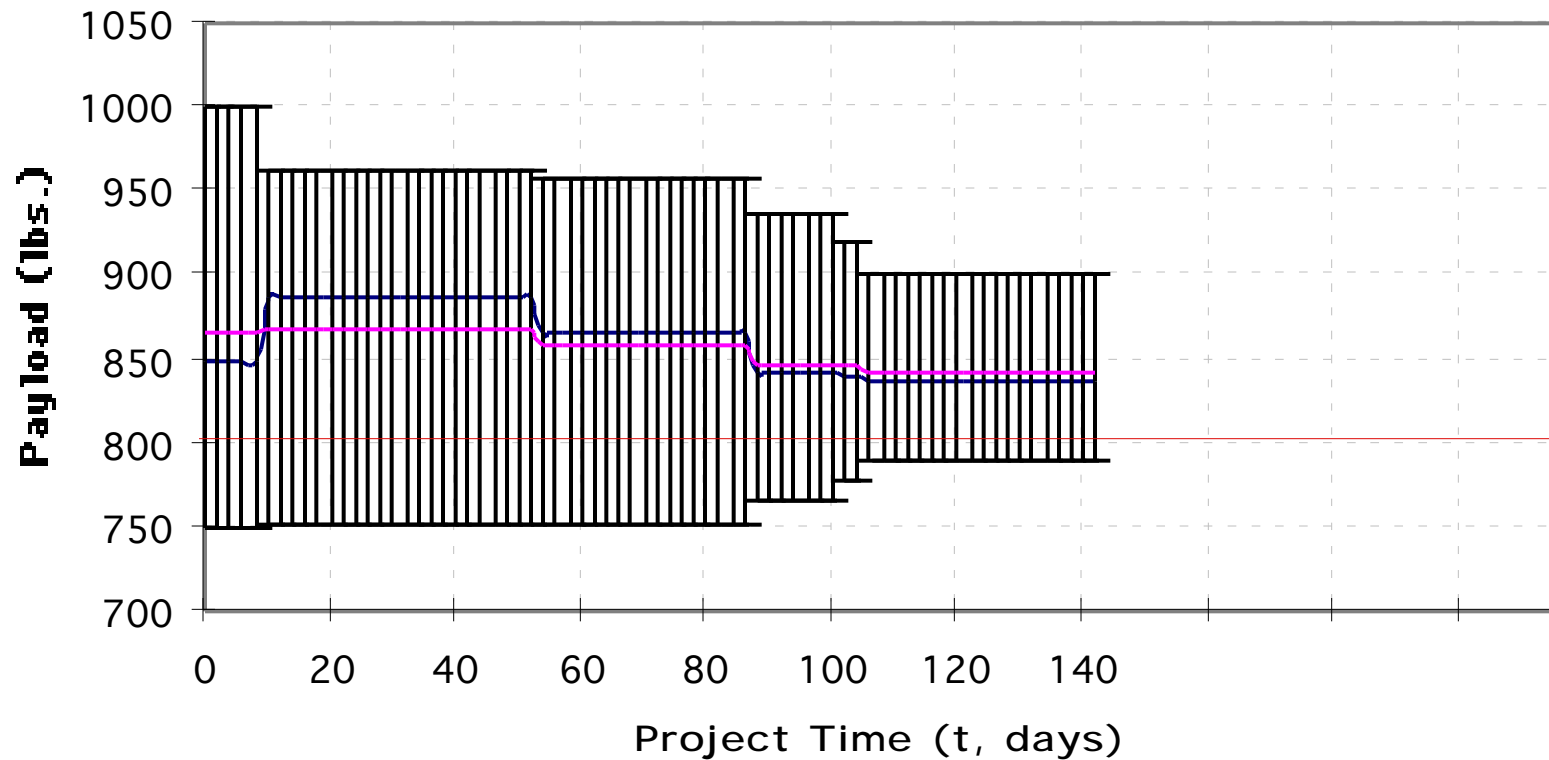
Joint PDF of Cost and Schedule for (real) PD process



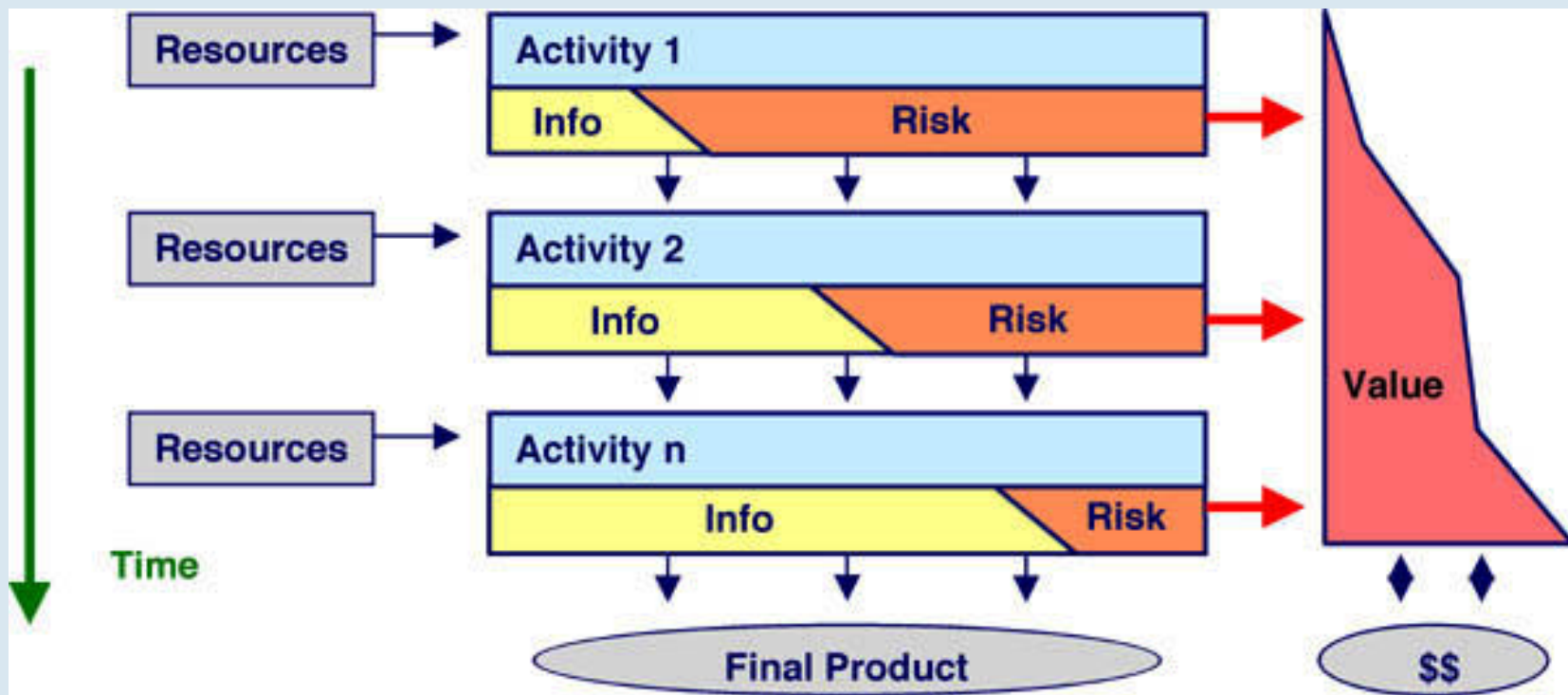
From
Browning,
1998



Evolution of Performance



From Browning,
1998



Graph Created by James Chase



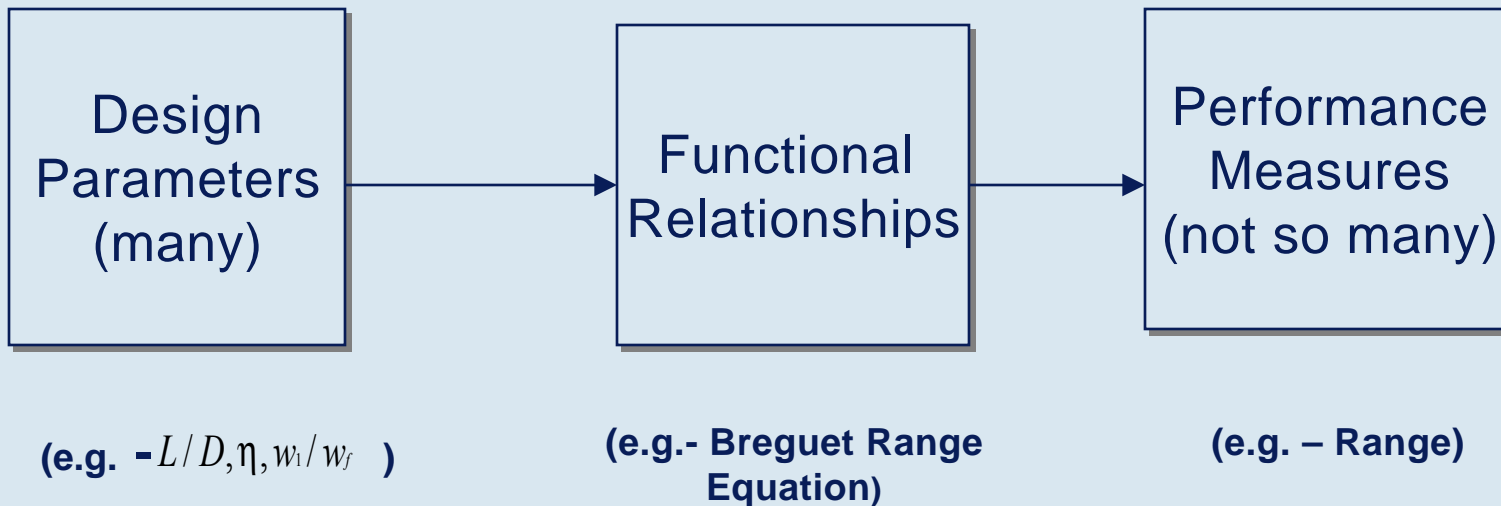
- **Product development is an investment**
- **Uncertainty and risk are inherent, to varying degrees, in all product developments**
- **Risk is the probability that the product requirements will not be achieved, thus imperiling the investment**



- **Quantifying uncertainty and risk will enable better management of product developments**
- **Value in product development is the amount by which risk is reduced per unit of resource expended**
- **Balancing risk across all aspects of product development is a significant lean principle**



Design Parameters vs. Performance Measures



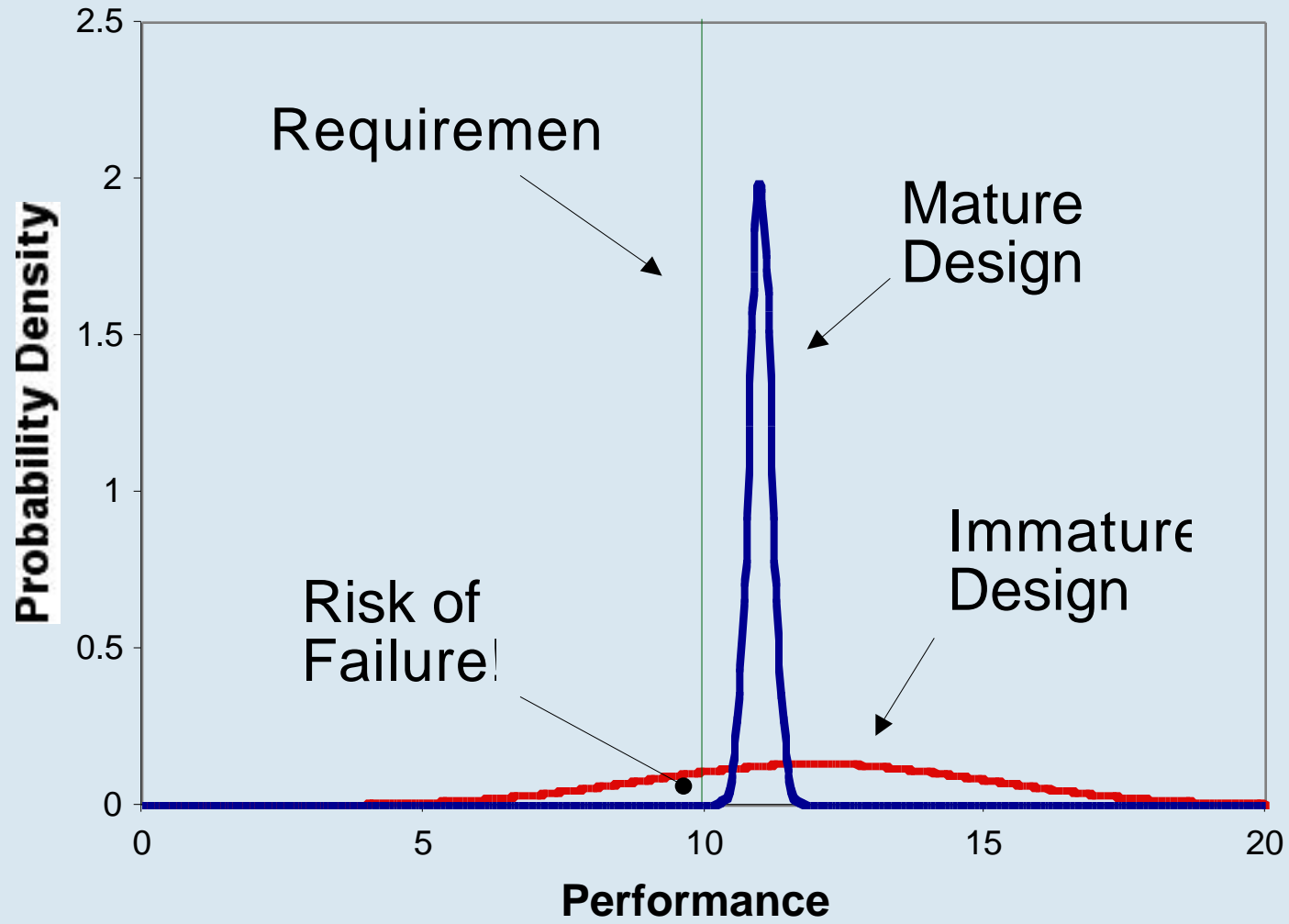


Viewing Product Development Uncertainty Reduction



(initial state)

(final state)





- **Effective product developments have the following characteristics**
 - **Processes are well calibrated so that error biases and trends are negligible**
 - **As new information is generated it is combined with old Information according to the relative qualities of new and old**
 - **All productive activities serve to reduce uncertainty**



- From these assumptions information theory yields the following differential equation

$$\frac{dp}{dt} = -up^2$$

Rate of change
of uncertainty
variance

Effectiveness
of the
expended
effort

Square of the variance of
uncertainty ($p = \sigma^2$)

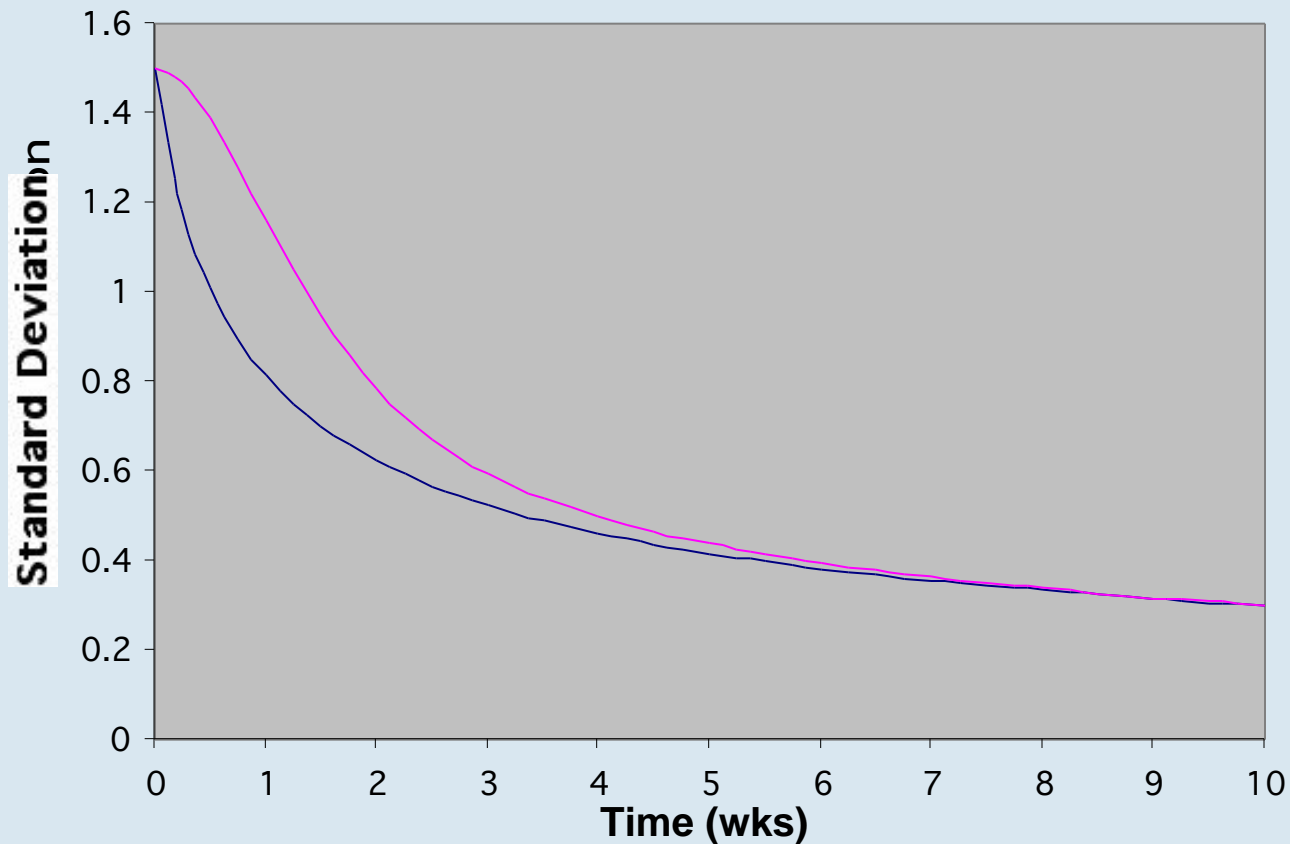
- Rate of variance reduction is proportional to

➤ effectiveness



Uncertainty Reduction Derived from the Model

Standard Deviations of L/D Estimation Errors
Upper Curve-2 Wk Spending Rate Ramp Up
Lower Curve-Constant Spending Rate





Multi – Parameter /Multi Activity Product Development

- Parameters are an array (n dimensional design vector)
- Uncertainty is a matrix (n x n covariance)

$$\dot{P} = -PH^T UHP$$

Rate of change of uncertainty

Effectiveness matrix

Activity matrix

Uncertainty matrix



Model of a Transport Aircraft Preliminary Design Study

- **Design Parameters-(3 dimensional)**
 - Lift – to – Drag Ratio L / D
 - Overall Efficiency (η)
 - Initial to Final Weight Ratio (w_i / w_f)
- **Performance Measure-(1 dimensional)**
 - Range > 13,000 km
- **Product Development Activities**
 - Aerodynamic design
 - Propulsion System Design
 - Structural Design



Model of a Transport Aircraft Preliminary Design Study (cont.)

- Initial design parameter estimates indicate range > 13,000km
- Uncertainty in these estimates produces a probability of 0.4 that the final product will not meet the requirements (unacceptable risk)
- Preliminary PD effort will refine the design and reduce uncertainty by a factor of 5
- Initial Plan-spend \$500K over a 10 week period to refine the design and reduce uncertainty by the required factor of 5
- Final Plan- for the same reduction in uncertainty, but by balancing risk over the three activities, the cost is reduced by 13% (saves \$66K)