PARADIGM CHANGE
IN SYSTEMS ENGINEERING

Richard de Neufville
Professor of Engineering Systems

Where this talk is going

- **You – system designers and managers – can greatly increase expected value of your products**

- **You need to:**
  - **"think outside the systems engineering box",**
  - **rethink process of system design and management.**

- **You can then**
  - **make system flexible – use "real options"**
  - **respond intelligently to inevitable uncertainties**

INCREASE EXPECTED VALUE

Serendipity in Design???

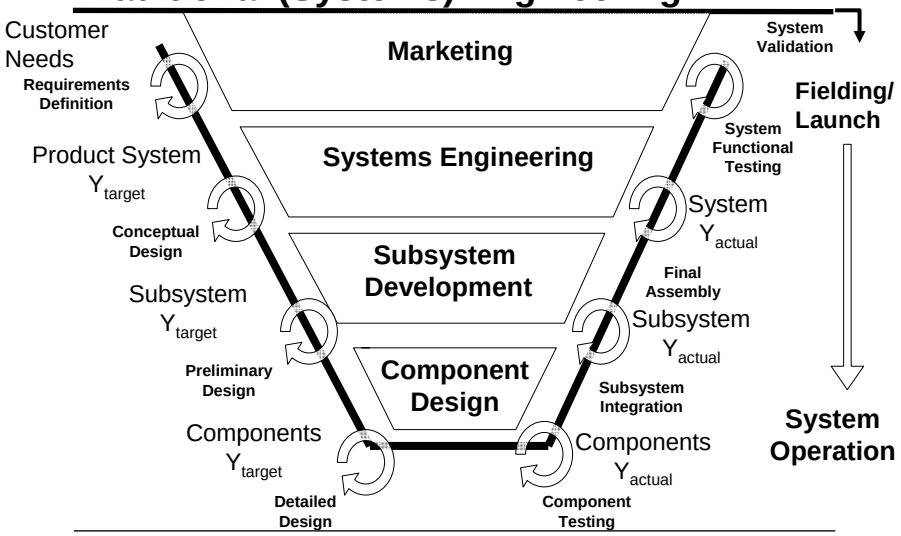
- This talk is not about being lucky…
- It is about "making your luck"
- … About thoughtful engineering design
- … About creating the conditions that enable you, the system managers, to
- Take advantage of upside opportunities
- Avoid downside eventualities

Part 1 – Rethinking Systems Engineering

- Engineering design has been linear:
  - Define "Requirements" -- These come from outside of engineering -- demand forecasts, customer survey, etc
  - Define, Analyze, Choose Modules, Components, etc.
  - Assemble Components, Module, System
  - Job done
- More formally…

Slide by O. de Weck 07

Traditional (Systems) Engineering



Slide adapted from O. de Weck 07

Implicit Assumptions of TSE

- **Customers know what their needs are**
- **The requirements are known and time-invariant**
- **The system or product can be designed as one coherent whole and is built and deployed in one step**
- **Only one system or product designed at a time**
- **The system will operate in a stable environment as far as regulations, technologies, demographics and usage patterns are concerned**

Slide adapted from O. de Weck 07

Assumptions of TSE – not Realistic!

- **Customers know their needs?** **New ones emerge!**
- **The requirements are known?**
  These change with needs and new regs, etc, etc.
- **The system can be designed as a coherent whole and built and deployed in one step?** **Often not**
- **Only one system being designed?** **Families likely**
- **The system will operate in a stable environment as far as regulations, technologies, demographics and usage patterns are concerned?** **We wish…**

Traditional (Systems) Engineering

- **Has been very successful, delivering highly complex systems of all sorts**
- **However, it can now do better…**
- **If we step outside its "box" of assumptions**
- **… which are unrealistic!**

The Reality Is

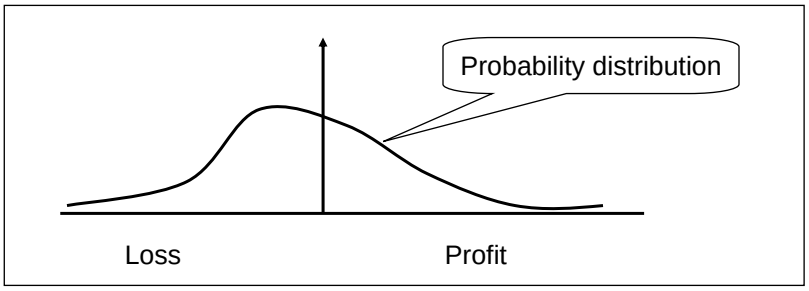
- **Our systems are in the middle of uncertainties**

- **Technological change … IT, Supply-Chain, …**
- **Economic Financial conditions … Boom and Bust**
- **Regulatory… Environmental, trade…**
- **Shape of Industry and Competition … Telecoms…**
- **Political… NAFTA, European Union, embargoes…**
- **Other … strikes, fires, hurricanes …**

Bottom Line: Outcomes only known probabilistically

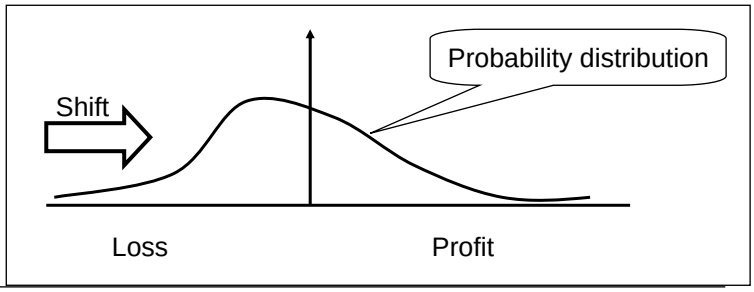
Design involves a distribution of risk

- **Outcomes vary in probability**
- **Consequences of outcomes x probability => pdf (probability distribution function)**
- **Example: communications satellite system:**



Part 2 – Opportunity for Greater Value

- **Change the distribution of outcome; increase value**
- **Key: flexibility to adapt design to actual circumstances**
  - **Avoid downside risks**
  - **Exploit Upside Opportunities**



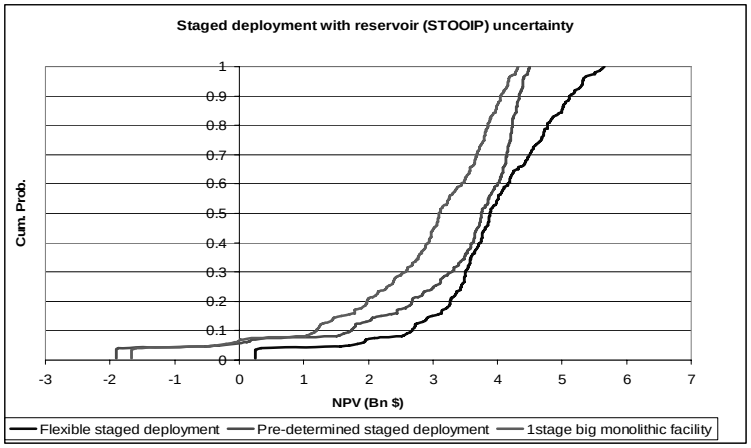
Opportunity Results from

- **Recognition of Uncertainty**
- **… Leading to Analysis of Possible Outcomes**
- **… And Motivation to Improve Performance**
- **… Measured in Expected Value**

20 to 30 % Increases in Value Routine!

Slide adapted from Jijun Lin

Example: Design for Major Oil Company



About 30% Increase in Value from 2.7 to 3.5 Billion $