PARADIGM CHANGE IN SYSTEMS ENGINEERING

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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”) to enable
  - efficient response 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
  - “Optimize” Design for these conditions; Define, Analyze, Choose Modules, Components, etc.
  - Assemble Components, Module, System
  - Job done

- More formally…
Traditional (Systems) Engineering

Customer Needs

Product System $Y_{\text{target}}$

Subsystem $Y_{\text{target}}$

Components $Y_{\text{target}}$

Marketing

Subsystem Development

Component Design

System $Y_{\text{actual}}$

Subsystem $Y_{\text{actual}}$

Components $Y_{\text{actual}}$

Detailed Design

Component Testing

System Validation

Fielding/Launch

System Operation

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
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!
- “Optimal” design not optimal over range of possibilities – often will perform poorly or inefficiently. “Optimization” can be illusory.
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:

![Probability distribution](image)
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

![Diagram showing probability distribution shift from loss to profit](attachment:image)

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!
Example: Design for Major Oil Company

Staged deployment with reservoir (STOOIP) uncertainty

NPV (Bn $)

-3 -2 -1 0 1 2 3 4 5 6 7


0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

Flexible staged deployment — Pre-determined staged deployment — 1-stage big monolithic facility

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

Take-away

Standard Process of Systems Design can be improved

- It unrealistically assumes that we can predict future requirements, situation
- It then seeks to deliver an “optimal” design for this possible future – ignoring the other possibilities
- On average, this “optimal” design misses opportunities

New approach recognizes uncertainties

- Develops designs to perform well for possible outcomes
- Delivers 20 to 30 % Increases in Value!