ESD.84 Doctoral Seminar – Session 6 Notes
Guests Presenting: Olivier de Weck

Initial Session Design:

- Welcome and Overview and Introductions (5-10 min.)
- Generating Key Questions from Readings (10-15 min.)
- Establishing a Common Language and Set of Methods for Systems Design and Systems Architecture – Olivier de Weck (30-45 min.)
- Break (15 min.)
- Student Presentations (10-15 min. each)
  - A Critical Analysis of Contributions (enabling and constraining) by Well-Known Systems Architects (such as Taiichi Ohno, W. Edwards Demming, General Marshall, Robert McNamara, Steven Jobs, Bill Gates, or others) – Eun Suk Suh
  - Approaching the Question, "How to Determine the Best System Architecture" – Tom Speller
- Book Reviews (5-7 min. each):
  - William Baumol, *The Free-Market Innovation Machine.* Princeton: Princeton University Press (2002) -- Marcus Sarofirm
  - Christensen, Clayton, *Innovator's Dilemma* – Chris Musso
  - Lessig on *Code (*1999) – Ben Koo
- Integrative Discussion (10-15 min.)
- Next Steps (10-15 min.)
  - Assignment on key themes in advance of ESD faculty seminar and course suggestions

Initial Brainstorming of Questions:

- What is the cost trade-off between an iso-performance approach and a simpler multi-optimization?
- How to explain the use of the iso-performance curves with a complex product such as a supersonic transport?
- What if you don't come up with the right iso-performance levels – how robust is the approach?
- Is the burden of achieving performance evenly distributed? How to deal with issue of robustness in a system when approached in this way?
- Is there way to ensure you are getting a complete set of solutions with the iso-performance approach? Similarly, if you get many solutions, how do you narrow the set?
- How to deal with spaces where there are solutions that just won't work?
- What is definition of the performance parameter in a socio-technical environment – particularly how to model social dimensions?
- How to handle non-linearities – is there a pareto optimal solution?
- How do you define complexity?

Presentation:

- This presentation is designed to look beyond simple design issues of increasing performance in a given parameter.
    - Issue of utility theory – do you specify preferences in advance (and constrain the design space) or turn to utilities after you have explored the architecture options and design space).
- Key focus of this presentation is a disconnect between the system architecture and system design processes
    - Contrast between ESD 34J (System Architecture) versus ESD.77J (Multi-Disciplinary System Design Optimization)
    - There are not good feedback loops from design back to architecture
- Key lesson from work with satellites involves the observation that architectural choices are often discrete, while design choices are often continuous
- There is a grey area where architecture stops and design starts
- The value to decision makers of being about to display different architectures on a pareto frontier
- The comparisons across different architectures can be very sensitive to underlying assumptions – including assumptions on technical feasibility and other factors – issue of fidelity of assumptions
- The sensitivity to assumptions means that the pareto frontier should really be seen as a fuzzy band
- Key issue is the lack of iteration back from design to architecture – there is lots of iteration among design options, but not back to the underlying set of architecture options
- Notion from Ed Crawley that a systems architect is not a generalist but a specialist in simplifying complexity, resolving ambiguity and focusing creativity
- The concept of a “balanced” design where the burden of achieving performance is distributed among sub-systems.

Discussion:

- Is there a contradiction between concentrating your "fragility" in one place so you know where it is vs achieving balance in designs so the burden of achieving performance across sub-systems? Response is that the first issue is a system architecture principle while the other is a design principle.
- Issues of ease or difficulty of "migration" within trade space – so you can reconfigure among architectures.
- Some points might be pareto sub-optimal, but allow more flexibility in moving across different architectures.
- Key issue around levels of abstraction from Architecture to Design – but the same "fractal" can be found at lower levels where there are still architectural challenges with design processes embedded in them
- Key issue around how far to go with architecture without the ability to anticipate design show-stoppers – art of knowing when to reach down into design details to surface these show-stoppers early versus after sunk costs
    - This may be where many elements are coming together on a design-structure matrix
    - This may be where the performance/function frontiers are being pushed
- There is a lack of a good nomenclature to distinguish design and architecture – such as the use of the term "design vector" in two different ways, one concerning architecture and one concerning design
- It may be that the distinction between architecture and design may have more to do with the nature of the outputs than with the nature of the inputs (discrete versus continuous)

Presentation by Eun Suk Suh:

- Key concluding points:
    - Job of system architect is to architect an engineering system which exhibits robustness, quality, flexibility, etc…
    - To enhance the performance of engineering system, system architect develops *Enabler* to apply to engineering system.
    - By implementing Enabler, some attributes of the engineering system can be improved. However, because of changes in engineering system due to the application of Enabler, it can have 'side effect', which can decrease performance of another attribute.
    - As a case study, Toyota Production System developed by Taiichi Ohno was presented.
    - Toyota Production System was improvement of Ford Production System through implementation of JIT, Jidoka and other Enablers to enhance flexibility, agility, and quality. However, it also generated weak link in supply chain
- Key concluding questions:
    - Was Lean Manufacturing evolutionary process? Or was it product of system architect's vision?
    - If Lean Manufacturing Concept is a "Concept Platform", what are "Variant Concepts" which can be derived from such platform?
    - It took Taiichi Ohno 30 years to implement the Toyota Production System. Would it take just as long to develop next generation of concepts?

Discussion with Eun Suk Suh:

- Lessons from the Toyota fire – it revealed a fragility, but it also revealed a hidden strength of the supply relationships
- Discussion on the importance of Henry Ford's instituting the $5 day as a core architectural decision – perhaps more important than the mass production system

Presentation by Tom Speller:

- The challenge of overcoming the rush to design
- Normative issues in finding the "best" architecture
- The leverage associated with upstream architecture – 70-80% of final outcomes
- Concept of "quantum virtual reality" – use of quantum computing to simulation multiple options
- Key issue of strategies for moving from a complex system back to a revealed underlying code – consider the challenge of the human genome project
- Similarly – the mapping of the genetic code for the Caenorhabditis Elegans by Sydney Brenner – which was just awarded the Nobel prize
- Implication of devoting intense time up front to system architecting
- Importance of lessons from biology

Discussion with Tom Speller:

- Issue of how to create "genetic algorithms" in the design process for products and services.
- Issue of how to also build in the readiness of the marketplace for what may be a conceptually optimal design.
- "Least action" as a concept – that needs to be quantified to be able to better find the path of least resistance
- The dynamics of one individual with a single point design versus a team coming to a consensus versus competing teams (which is resource intensive and hard to manage)
- Evolutionary processes in nature are not necessarily optimizing

Book Reviews:

William Baumol, *The Free-Market Innovation Machine.* Princeton: Princeton University Press (2002) – Review by Marcus Sarofirm

- Major periods where per-capita GDP did not grow – but recent period of major growth can be attributed to the free market concept
- Innovation as the most important yield from free markets, more than efficient allocation of resources
- This holds even with the ways that the free market might dissuade innovation or constraints on innovation (such as patents and other IP protections that give incentives, but constrain further spread of ideas)
- Innovation is distinct from invention
- Issue: Based on the separation of innovation and invention – what about invention? Basic research is not fully addressed, which is a key source of invention. Same with universities, which have a complicated relationship with the free market.
- Need for more analysis of policy implications
- The book is to be complemented for highlighting innovation, more than entrepreneurial invention that has historically been the focus of much economic scholarship

Christensen, Clayton, *Innovator's Dilemma* – Review by Chris Musso

- Disk drives as the "fruit fly" of innovation given rapid change
- Contrast between sustaining innovation – example of SDM program that then allows industry to do new things better – and disruptive innovation
- Disruptive innovations – generally not fully aligned with mainstream market initially, generally less expensive, lower margins, steeper performance improvement trajectory, and end up changing the nature of the market
- This is the innovator's dilemma – do you go after the sustaining innovations that serve your best customers or do you support the disruptive technologies at the expense of your best customers?
- Issues: It is extremely hard for a manager to even see a disruptive technology coming – and to distinguish that from something that is just not well conceived
- This is just a two-way taxonomy – the world may be more complex
- This may be too much of a tilt toward invention rather than innovation