Technology and Strategy

Decision Making

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G21 approach

- Takeshi Uchiyamada
  - lacked experience
  - *"...the best person, because you are not the expert of the current method!"*
- G21 Team remit
  - authorized to develop components from scratch
  - cross-functional team – architectural transition
  - 100% improvement in fuel economy – hybrid
  - technical uncertainty
- Unique approach to product development – engine, vehicle and production processes in parallel

Hybrid engine technologies and commercialization

- Toyota believed it had internal capabilities develop all the key components except the batteries
- Thorough investigation of all available hybrid technologies
- *"… I did not want to choose an easy technology which would allow us to introduce hybrid cars to the market first, but might be replaced by superior technology later"*
- *"We should …anticipate what will come in the future, and develop products in order to create new markets"*
- No backup plans – 100% of resources devoted to hybrids
- *"…meeting mass production reliability and quality targets accounted for 85-90% of development work for the Prius"*

Value capture

- Batteries (JV with Matsushita Electric) and control software were the two key technologies
- Battery development is slow and difficult
  – overheating – monitoring to avoid bursting into flames
  – manufacturing and cost challenges
- Other system components pose challenges
  – regenerative braking system
  – control semiconductors – IGBTs
- Long way from technological feasibility to marketable production car that can be built at a reasonable cost
- $3-4k in additional variable cost per vehicle

Prius' timeline

- NHW10 launched December 1997 in Japan
- NHW11 launched in 2001 $20k in US
- NHW20 redesigned larger version in 2004
- Most fuel efficient car sold in the US

- Customer satisfaction rates ~98% are very high
- >750,000 sold by June 2007
- >500,000 sold in the US by November 2007

- Lithum Ion batteries considered
- Plug-in Hybrid now being evaluated, targeting 2010

Architecture

- Overall modular architecture: *"…bits and pieces – from electronics and doors to other components – that readily fit in place…"*
- Six sub-systems stand out
  - Inverter/converter
  - Engine control module
  - User-interface/dash module
  - Navigation/display system
  - Airbag control module
  - Anti-skid systems

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Effective decision-making in *high-tech* involves conflict - challenging leads to better decisions

- Incomplete and ambiguous information
- Significant uncertainty
  - innovation trajectories
  - how customers will respond, the demand opportunity
  - how co-opetition will play out
- Limited time
- Wide range of viable strategic options

- *"Management teams whose members challenge one another's thinking develop a more complete understanding of the choices, create a richer range of options, and ultimately make the kinds of effective decisions necessary in today's competitive environments"*

Building the team

- Assemble a heterogeneous team, including diverse ages, genders, specialist expertise and professional experience
- Meet together as a team often and regularly
- Encourage team members to assume roles that go beyond their nominal responsibilities of product, market or function
- Apply multiple mindsets to any issue, using tools such as scenarios, role-playing and 'war games'
- Actively manage conflict – but don't make it personal, or seek to suppress it

How can you make good decisions, when conflict is likely?

Context

Common goals
- collaborative problem solving
- inquiry rather than advocacy

Balanced power
- value diversity
- cultivate minority views
- fair process
- leverage expert counsel

Agenda

Focus on issues
- **not** a slow regular (annual) cycle
- not by organizational (business) unit

Debate and decide
- **not** review and approve
- facts, options and choices

- **Focus on the facts – more, rather than less, objective and timely information – not just opinions**
- **Consider multiple alternative options (>2 ➔ ~4-5) together**
- **Make sure strategic decisions consistent with one another and with execution**

Outcome

Make it fun!
- inject humor into the process

Resolve issues without consensus
- collective ownership
- dissent and revisit

For high-tech businesses, fast decision-making is critical to success

- Fast decision making allows decision makers to keep pace with change and is linked to strong performance

- Fast decision makers use more, not less, information

- Fast decision makers develop more, not fewer, parallel alternatives

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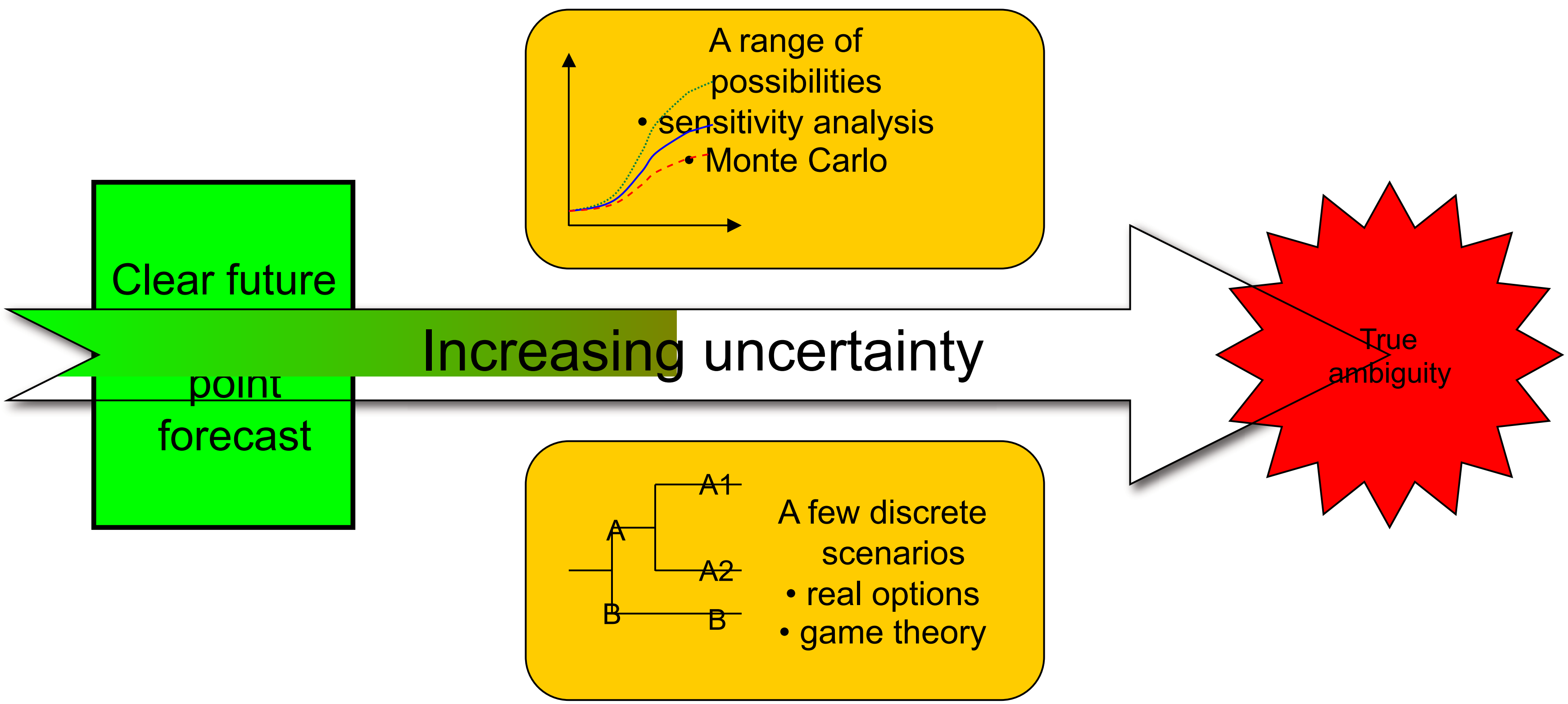
Resolution without consensus

- Multi-step process
- Beforehand, identify skateholders and experts
- Explicitly agree how the rules for resolution:
  - expertise – who has the best information
  - experience – who has encountered this challenge
  - effects – who are the stakeholders, most affected
  - executive power – who is most senior
- Seek consensus
- If you can't reach it, defer to the agreed decision-makers
- Set a timetable or an event which triggers review

As a key part of focusing on the facts, recognize and embrace *uncertainty*



Types of uncertainty

Discrete scenarios

- Does it work?
- Does anyone buy it?
- Competitor entry
- Collaborator partnership
- Patent litigation
- Standards battles

A range of possibilities

- Innovation trajectories
  - performance
  - cost
  - timing
- Pricing
- Adoption rates and ultimate penetration

Once the possible futures are understood, you have a foundation for choosing your posture

Shape

- Play a leadership role in establishing which future comes to pass
- Drive endogenous demand
- Fight standards battles
- Build strong platform positions

Adapt

- Focus more narrowly
- Recognize and capture opportunities as they emerge
- Win through speed and agility
- Be prepared to reconfigure if circumstances change

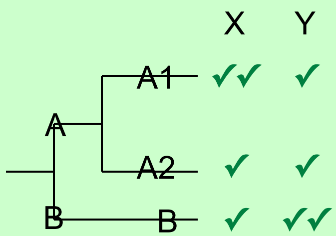
Wait

- Invest sufficiently to be able to participate
- Avoid premature commitments
- Build real options

Three basic types of *strategic option*, with increasing risks and levels of commitment

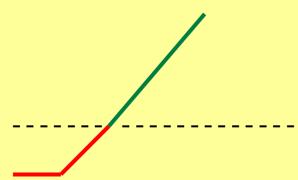
No-regrets moves

- worth doing anyway
- positive payoffs in most scenarios



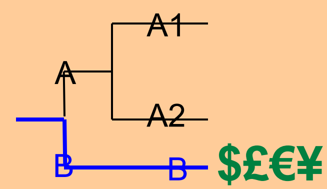
(Real) options

- positive payoff in some outcomes
- otherwise, small cost to play
- parallel or sequential



Big bets

- work in some scenarios
- high cost, negative effects in other cases



Increasing risk

Increasing investment and commitment

Traditional Approach

- Decide what kind of service should be offered
- Conduct a market survey for this type of service
- Derive system requirements
- Define an architecture for the overall system
- Conduct preliminary design
- Obtain FCC approval for the system
- Conduct detailed design analysis and optimization
- Implement and launch the system
- Operate and replenish the system as required
- Retire once design life has expired

Conceptual Design (Trade) Space

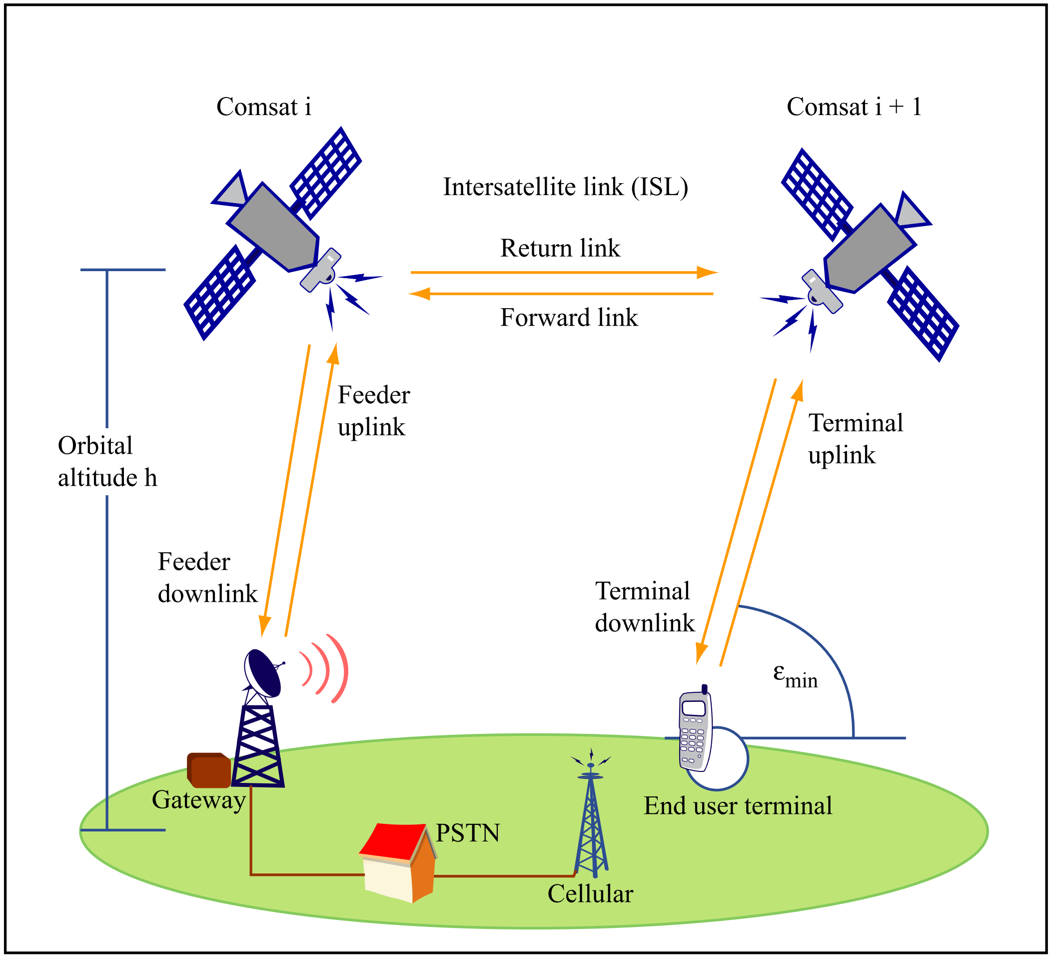


Image by MIT OpenCourseWare.

Design (Input) Vector

Simulator

Performance
Capacity
Cost

Design (Input) Vector X

- The design variables are:

Astro-dynamics	– Constellation Type: C	Polar, Walker	
	– Orbital Altitude: h	500,1000,1500,2000	[km]
	– Minimum Elevation Angle: ε_{min}	2.5,7.5,12.5	[deg]
Satellite Design	– Satellite Transmit Power: P_t	200,400,800,1600,2400	[W]
	– Antenna Size: D_a	1.0,2.0,3.0	[m]
	– Multiple Access Scheme MA:	MF-TDMA, MF-CDMA	[-]
Network	– Network Architecture: ISL	yes, no	[-]

X_{1440}=

```
   C: 'walker'
   h: 2000
emin: 12.5000
  Pt: 2400
  DA: 3
  MA: 'MFCD'
 ISL: 0
```

This results in a <u>1440</u> full factorial, combinatorial conceptual design space

Objective Vector (Output) J

- Performance (fixed)
  - Data Rate per Channel: R=4.8 [kbps]
  - Bit-Error Rate: $p_b=10^{-3}$
  - Link Fading Margin: 16 [dB]
- Capacity
  - C_s: Number of simultaneous duplex channels
  - C_{life}: Total throughput over life time [min]
- Cost
  - Lifecycle cost of the system (LCC [$]), includes:
    - *Research, Development, Test and Evaluation (RDT&E)*
    - *Satellite Construction and Test*
    - *Launch and Orbital Insertion*
    - *Operations and Replenishment*
  - Cost per Function, CPF [$/min]

Consider

$J_{1440}=$

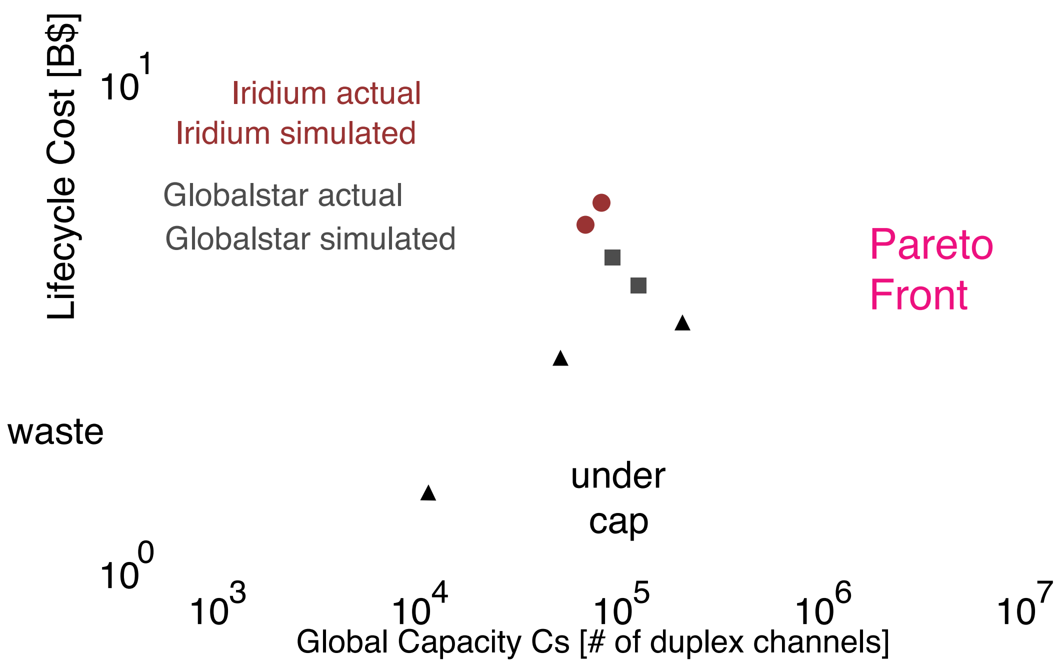
```
   Cs: 1.4885e+005
Clife: 1.0170e+011
  LCC: 6.7548e+009
  CPF: 6.6416e-002
```

Traditional approach

- The traditional approach for designing a system considers architectures to be fixed over time.

If actual demand is below capacity, there is a waste

If demand is over the capacity, market opportunity may be missed



Demand distribution
Probability density function

$$P\{a < C_s \leq b\} = \int_a^b f_{C_s}(C_s)\mathrm{d}C_s$$

$$0 \leq f_x(C_s) \text{ for all } C_s$$

$$\int_{-\infty}^{\infty} f_{C_s}(C_s)\mathrm{d}C_s = 1$$

Staged Deployment

- The traditional approach doesn't reduce risks because it cannot adapt to uncertainty
- A flexible approach can be used: the system should have the ability to adapt to the uncertain demand
- This can be achieved with a staged deployment strategy:
  - A smaller, more affordable system is initially built
  - This system has the flexibility to increase its capacity if demand is sufficient and if the decision makers can afford additional capacity

Staged deployment strategy reduces the economic risks via two mechanisms

- The costs of the system are spread through time:
  - Money has a time value: to spend a dollar tomorrow is better than spending one now (Present Value)
  - Delaying expenditures always appears as an advantage
- The decision to deploy is done observing the market conditions:
  - Demand may never grow and we may want to keep the system as it is without deploying further.
  - If demand is important enough, we may have made sufficient profits to invest in the next stage.

Focus shifts from picking a "best guess" optimal architecture to choosing a valuable, flexible path

- Decide what kind of service should be offered
- Conduct a market survey for this type of service
- Conduct a baseline architecture trade study
- Identify Interesting paths for Staged Deployment
- Select an Initial Stage Architecture (based on Real Options Analysis)
- Obtain FCC approval for the system
- Implement and Launch the system
- Operate and observe actual demand
- Make periodic reconfiguration decisions
- Retire once Design Life has expired

Δt

First, figure out what the nature of the 'real options' are – partition the design vector

Then, explore the possible paths in the 'trade space' – the sequences of options

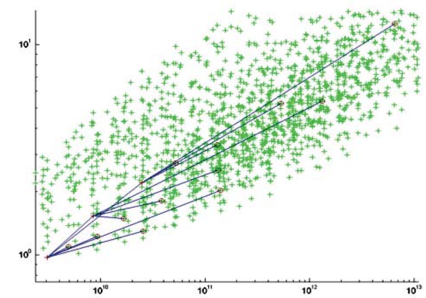
Then, calculate the costs

Using real options for LEO satellites

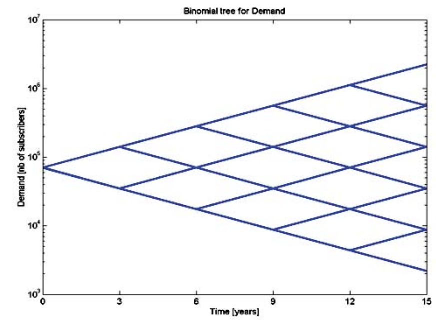
Identify Flexibility

$$x = \begin{matrix} x_{flex} \\ x_{base} \end{matrix}$$

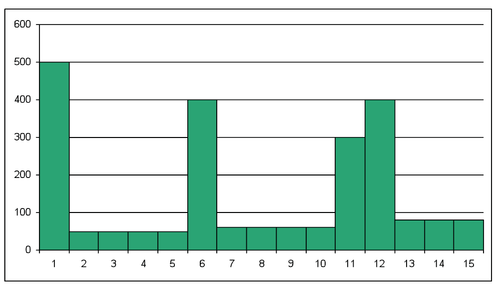
Generate "Paths"



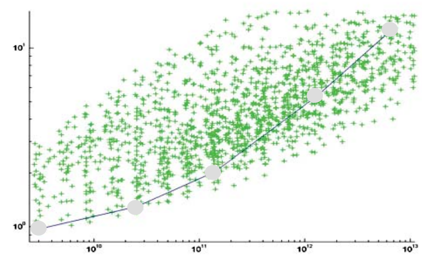
Model Demand



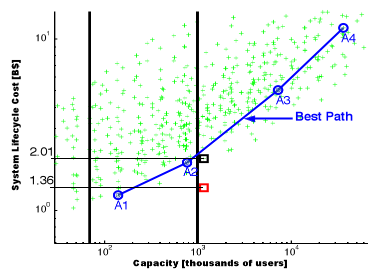
Estimate Costs



Optimize over Paths



Reveal opportunity



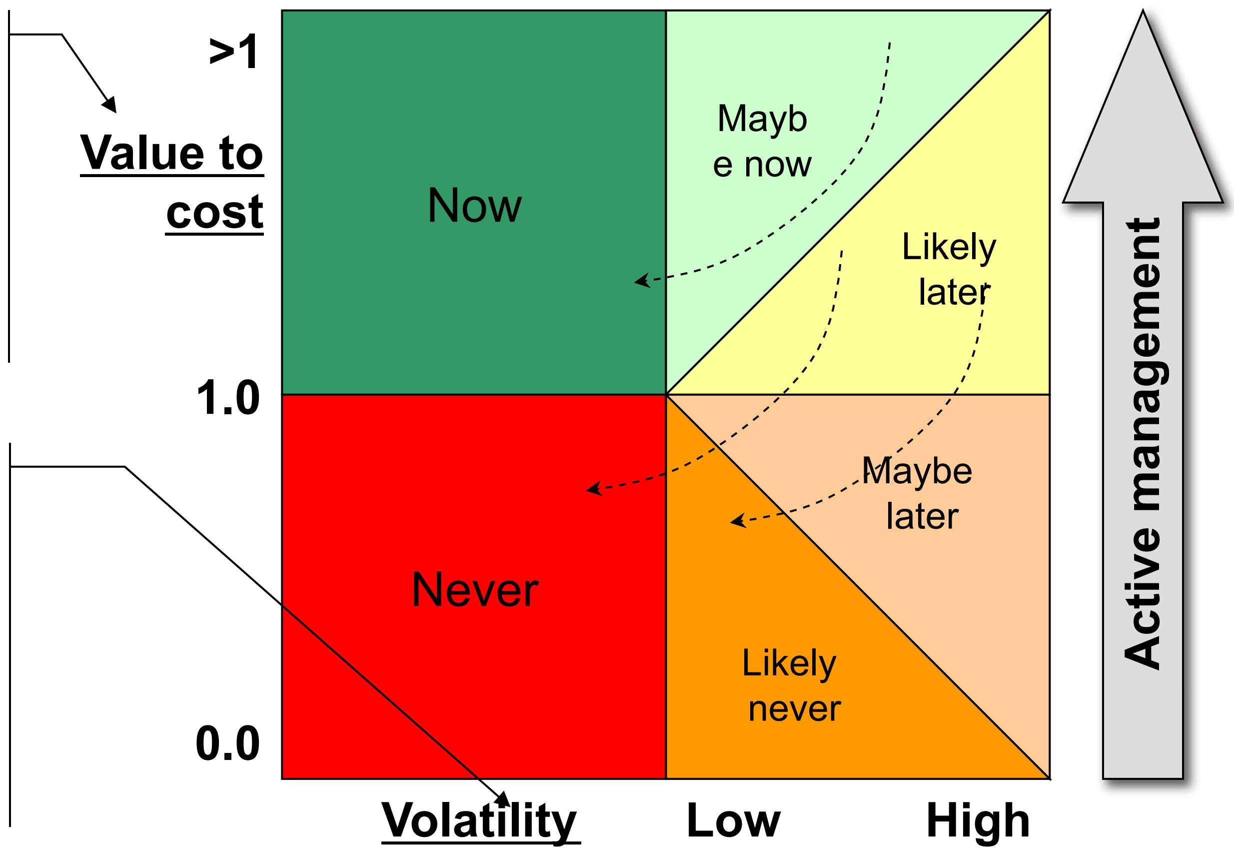
An Architectural Principle

- Economic Benefits and risk reduction for large engineering systems can be shown by designing for staged deployment, rather then for worst case, fixed capacity.
- Embedding such flexibility does not come for free and evolution paths of system designs do not generally coincide with the Pareto frontier.

What you do about real options, and when you do it, depends on *value to cost*, and on *volatility*

Net present value, taking into account time value of being able to postpone the decision

How much things can change
- variance
- time horizon



For high-tech businesses, timing - and hence (active) waiting - is critical to success

- High-tech involves volatility
  - innovation
  - diffusion
  - co-evolution
- Steady stream of small and medium-size opportunities
- A few *golden opportunities* or *life-and-death threats*

- Anticipate
  - analyze
  - reconnoiter
- Prepare
  - build resources
  - create options
- Commit
  - make the big bet

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Interestingly, one of the key facets of Toyota's product creation is postponing design decisions

- Acknowledged leadership in manufacturing
- Apparent leadership in product creation
  - shorter lead-times in design
  - higher productivity
  - superior designs
- Albeit slowly evolving demand opportunity, stable technical architecture and business ecosystem
- Focus of recent study by National Center for Manufacturing Sciences
  - different paradigm
- Five articles in Harvard Business Review and MIT Sloan Management Review

A Second Look at Japanese Product Development
Rajan R Kamath and Jeffrey K Liker
Harvard Business Review, November-December 1994

The Second Toyota Paradox: How Delaying Decisions Can Make Better Cars Faster
Allen C Ward, Jeffrey K Liker, John J Cristiano and Durward K Sobek II
Sloan Management Review, Spring 1995

Another Look at How Toyota Integrates Product Development
Durward K Sobek II, Jeffrey K Liker and Allen C Ward
Harvard Business Review, July-August 1998

Toyota's Principles of Set-Based Concurrent Engineering
Durward K Sobek II, Allen C Ward and Jeffrey K Liker
Slaon Management Review, Winter 1999

Comments on the Second Toyota Paradox
Steven J Spear
Harvard Business School Teaching Note 9-602-035 (5 March 2003)

Three key facets: deadline-driven optimization; set-based development; rapid low-cost iterations

1. The team defines a set of solutions at the system level, rather than a single solution
2. It defines sets of possible solutions for various sub-systems
3. It explores these possible sub-systems in parallel, using analysis, design rules and experiments to characterize a set of possible solutions
4. It uses the analysis to gradually narrow the set of solutions, converging slowly towards a single solution
5. Once the team establishes the single solution for any part of the design, it does not change it unless absolutely necessary

Marketing Concept

Styling

Product Design

Component A

Component B

Manufacturing System Design

Set Narrowing Phase

Problem-Correction Phase

The Second Toyota Paradox: How Delaying Decisions Can Make Better Cars Faster
Allen C Ward, Jeffrey K Liker, John J Cristiano and Durward K Sobek II
Sloan Management Review, Spring 1995

Decision-making: summary

- Conflict inevitable, challenge valuable
- Common goals and balanced power
- Focus on facts, debate and decide
- More objective and timely information
- Consider several options together
- Strategic decisions consistent with each other and with execution
- Embrace uncertainty
  - range of possibilities
  - discrete scenarios
- Real options
  - value to cost
  - volatility
- Active waiting

Projects

- Final paper due in one week, by 08:59:59 on Monday 11 May
- Focus on a specific business within domain
- Set out what the strategy should be
- Analysis and recommendations, with clear rationale
- Presentations will be seven (7) minutes long with three (3) minutes for questions each
- Presentations must be no more than twelve (12) slides long (including significant animations)