Organizational Implications of "Real-Time Concurrent Engineering"

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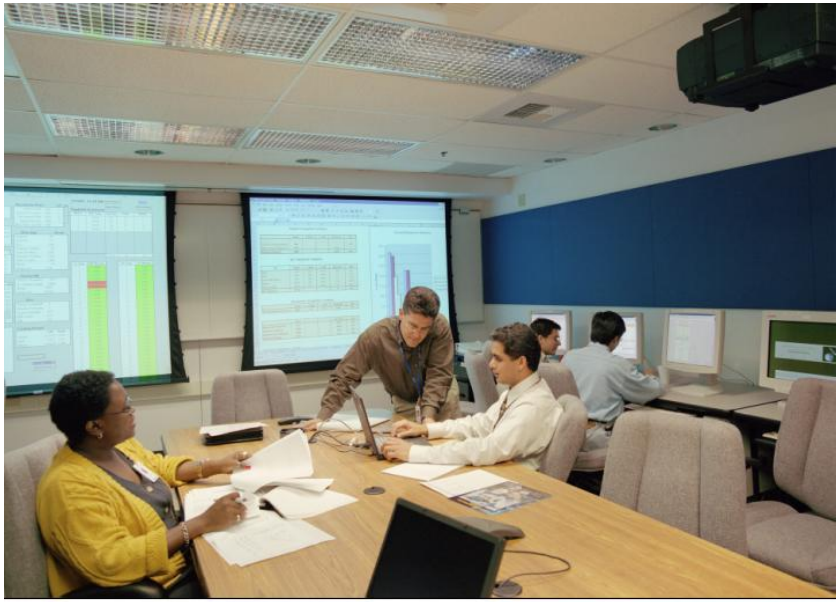
March 27, 2003

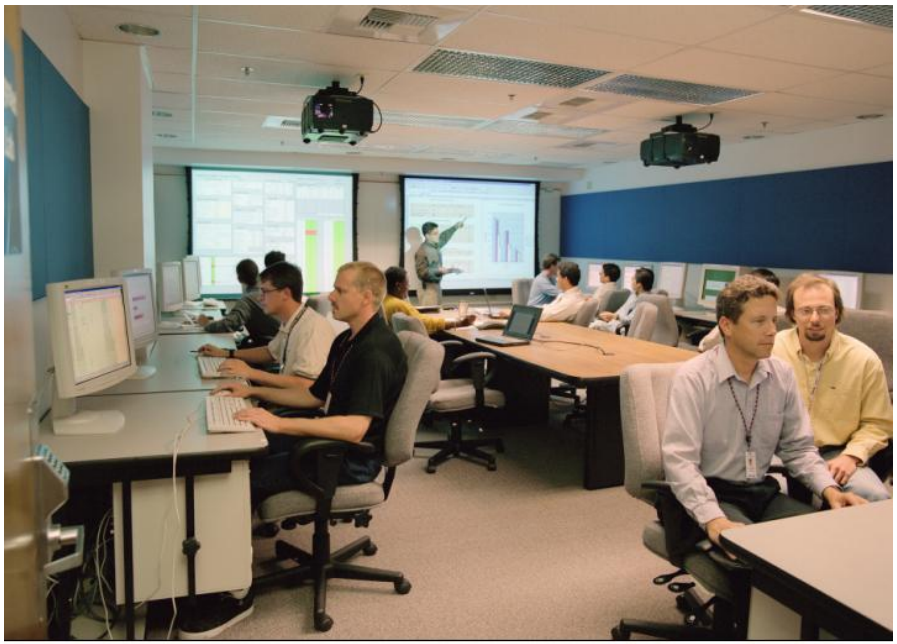
Research Sponsored Jointly By MIT's Leaders For Manufacturing Program

Agenda

- Introduction: ICE and RTCE
  - Implementation of RTCE Team
- Organizational Challenges
  - Structural
  - Cultural
  - Leadership
  - Financial
- Lessons for Practitioners



RTCE: "Real-Time Concurrent Engineering"



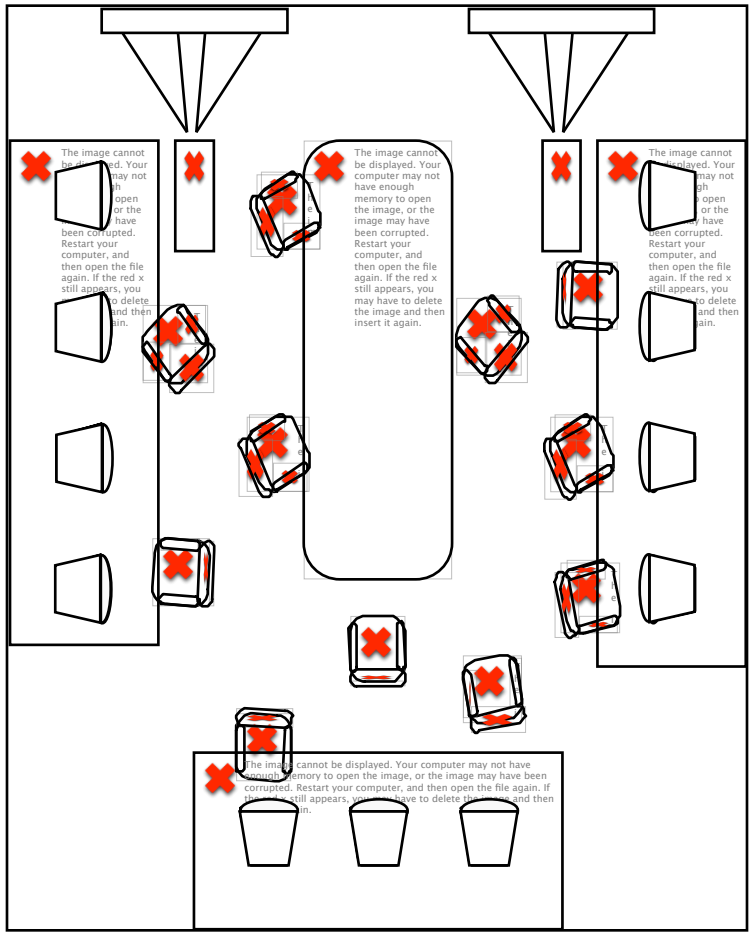
Today's Case Study

- Team chartered in the Product Development Group at a Major Aerospace Company, Fall 2001
- Set out to implement the "CON" portion of "MATE-CON"
- About 15 Engineering Specialists collaborate with Marketing and other Managers in carefully scripted, 4-hour, real-time design sessions

RTCE Structure Based on ICE

Evolution of a Revolution

- ICE: "Integrated Concurrent Engineering"
  - Developed initially at JPL's Product Design Center in 1994
  - Further enabled by creation of ICEMaker© software at Caltech
- Not talking about the design, but actually doing the work together!
- All design information is passed through a central server - each designer has access to the latest data and sees changes instantly



RTCE Team Context

Tremendous Success in the First 9 months!

- Completed at least 20 new product proposals this year
- Trimmed 33% lead time from their standard process
- Created new designs in as little as 4 hours – compared to up to 4 weeks previously
  - Distinct Competitive Advantage in time-sensitive situations
- Higher quality designs are being produced
  - More detail, earlier in process
    - Sharing over 7000 design variables in real time
  - Objective decisions
  - Focus on System Design - no sub-optimization
  - Efficient Process and Motivated Team

External Pressures

Steep Market Decline in 2002

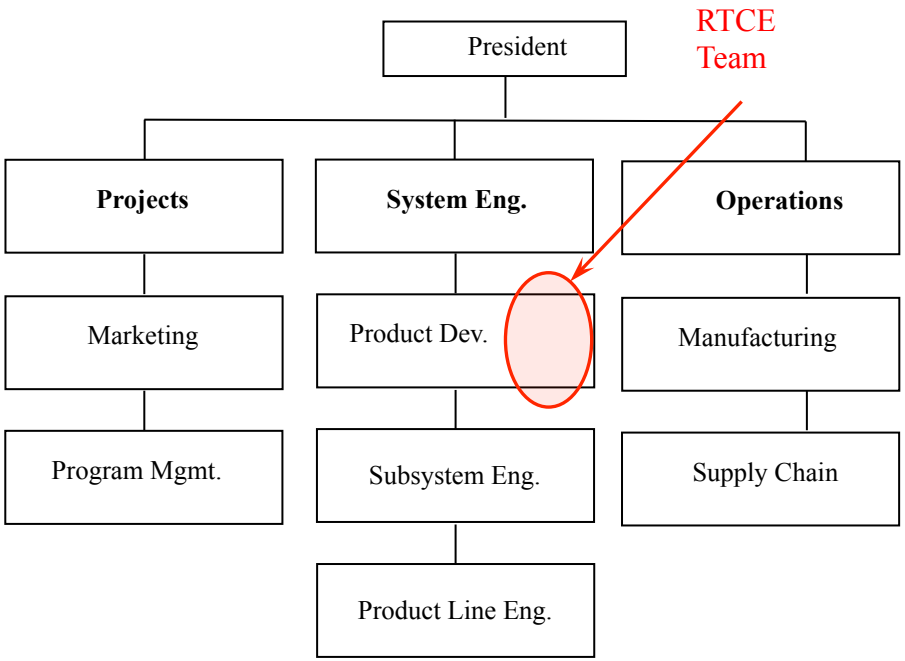
- Company forced to announce large lay-offs
- New Product Proposals cut in half
- Customers more demanding on price and lead-time

RTCE team gains offset by corporate situation

- No productivity gains measured because team size maintained while available work fell
- Market Managers asked team to produce MORE design options, thus incurring additional costs

Structural Challenges

The organizational structure created barriers between the RTCE team, and the critical people and information they needed



- The RTCE team was not able to effectively tap into customer data
- Manufacturing and cost data were NOT available in real-time
- As the team expanded its scope, functional managers quarreled over who's budget would pay for new work

Cultural Challenges

RTCE participants were thrust into entirely new types of jobs

- Their training, motivation and incentives were not yet properly aligned with their new responsibilities

Managers of other divisions within the company did not see the potential positive impact of RTCE

- This lack of buy-in manifested itself in the form of minimal support that detracted from the potential gains the team could make.

Managers in peer departments judged the project based on second-hand information and with respect to their own personal agendas

Leadership Challenges

The company's senior management team did not adequately understand the vision for the RTCE project.

- Focus was on short-term profitability
- RTCE leadership was unable to articulate a cohesive message to the proper audience

The RTCE leadership team faced difficult personnel and management issues

- Yet they lacked the authority to make tough decisions
- Were not able to effectively push team members to make changes outside of their comfort zones

Financial Challenges

The company based new costs on historical costs

- Their corporate systems demanded minimum profit levels
- Functional managers were risk averse and built padding into cost estimates
- As a result, they were unable to match industry-wide price cuts

The accounting system prevented well-intentioned people from spending their time on work that would help make the company more profitable in the future.

- The only charge numbers available were dedicated to specific projects
- Team members were not authorized to work on process improvement by project managers

Summary of Challenges

Structural, Cultural, Leadership and Financial Barriers are preventing the RTCE team from realizing the complete set of new values they have created

Despite these issues, the RTCE team has made tremendous gains. Each of these challenges represents an opportunity for even more value to be captured!

Lessons for Practitioners

The implementation of RTCE techniques cannot be managed in the same manner as engineering "Tools" such as Pro-E

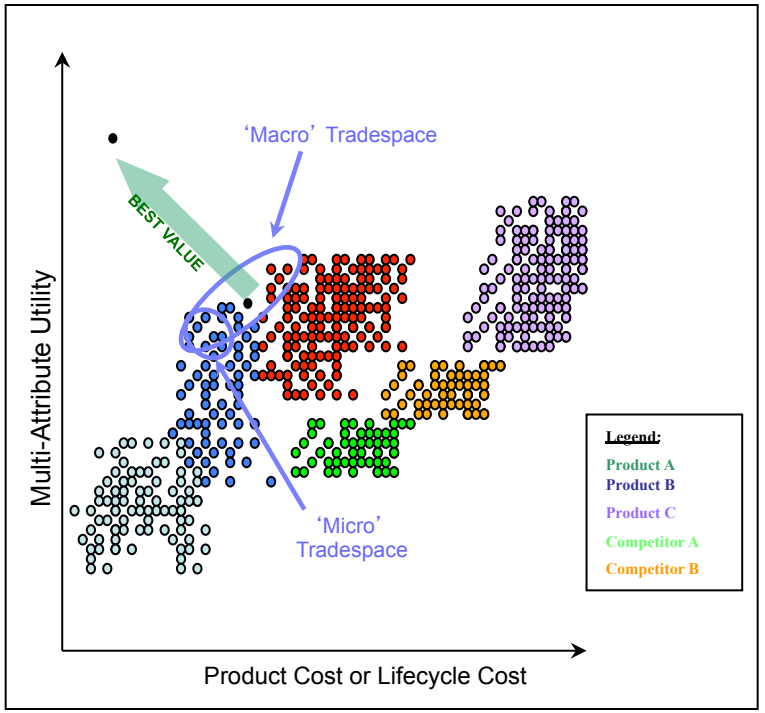
- These are complex, evolving group processes
  - Team members cannot be sent to training then expected to contribute immediately
  - The personal attributes of high-performing team members are different than those of the best solo engineers
- Effective applications of RTCE require the entire organization to come to the table and collaborate towards system-wide solutions
- RTCE projects cannot be evaluated via traditional "ROI" calculations
  - They change the fundamental nature of work within an organization

Implementation will result in the creation of elegant new designs that are lower cost to manufacture, of extremely high quality and deliver exceptional value to the customer.

Lessons for Practitioners

The Addition of "MATE" to the existing "CON" would create a powerful unifying and guiding force

- Addresses Structural Challenges by uniting all disciplines through a common language and shared objectives (create best value for CUSTOMER)
- Addresses Cultural Challenges by enabling clear visualizations of complex inter-relationships and facilitating communication
- Addresses Leadership Challenges by giving the team a mandate to return objectivity and system-wide optimization to the design process
- Addresses Financial Challenges by creating a team that has the ability and authority to innovate rather than relying on standard designs and historical costs



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Q & A

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Back-Up Slides

What Participants Think

"Since I had no schedule input, I felt like I wasted 1 to 2 hours of my time listening to schedule discussions"

"People were forced to sign up for previous aggressive schedules w/o time to review justifications"

Participants (Survey Data)

Rate your level of participation in the session:

- 17% said "Focused only on my worksheet"
- 48% said "Talked to one or two other people"
- 26% said "Solved a minor problem (group of 1 or 2)"
- 0% said "Solved a major problem (group of 3 to 5)"
- 4% said "Helped entire group work through an issue"
- 4% said "Was involved in a major design decision"

Average confidence in Technical output: 3.75 (5-point scale)

- Cost: 3.00; Schedule: 2.69

Corporate Myths about RTCE

Myth #1: *"RTCE is a great new tool for the company. Once this team is finished developing it, we can deploy it to many other divisions to realize similar gains."*

- Real-time concurrent engineering is a **process** – not a technical tool
- RTCE enables designers to try out new ideas quickly and work together to find innovative solutions to unexpected problems

Myth #2: *"RTCE is going to save us tons of money because it automates the design process"*

- Experience has shown the need for creative human intuition is actually far **more** necessary in the new business process than in the old

More Myths

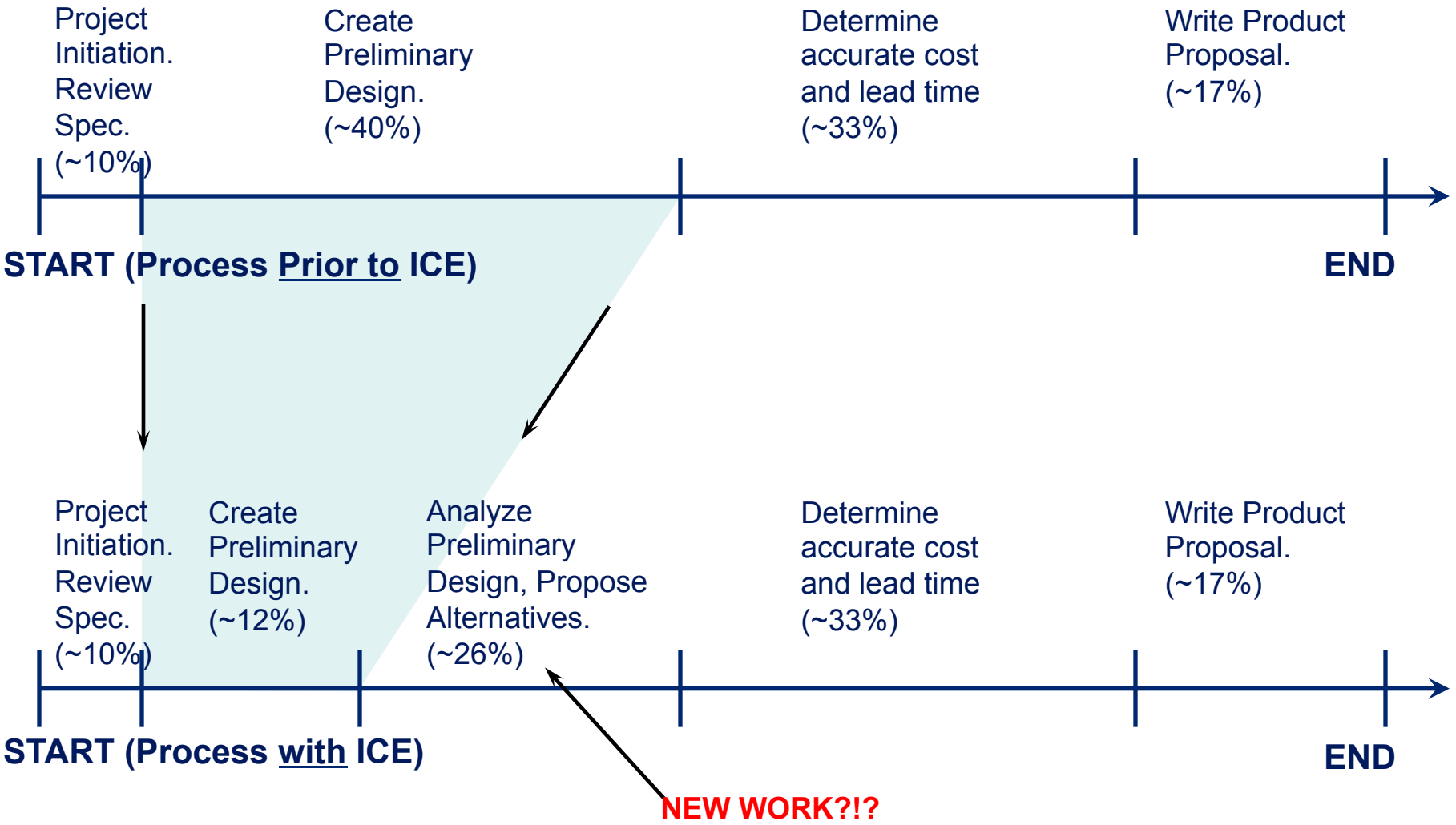
Myth #3: *"RTCE is dangerous because it creates 'template engineers' who know nothing about the complex hardware they are designing."*

- Fine balances between knowledge re-use and innovation must be drawn and constantly monitored
- The most powerful solutions come from discussions between different designers regarding a difficult problem, not from a pull-down menu

Myth #4: *"RTCE designs cost just as much as traditional designs – there's no payback for the R&D money we invested."*

- Traditional, team-level metrics do not adequately capture the improvements RTCE has made on the whole enterprise
- Due to the nature of the process, teams are able to uncover hidden inconsistencies that otherwise would have not been addressed until final assembly or beyond

A Matter of Time



Lessons for Practitioners

INTEGRATION and FINE TUNING

- See next slides

A "Spiral" Development Process is Necessary

- The RTCE team won funding based on specific deliverables and projected cost savings
- After the first phase, the team learned that certain parts of the process were not working well together
- If the team scrapped those parts and modified their process, the R&D funding council would have declared the project a failure and cancelled future funds
- So instead, the team kept pushing a process forward that they knew was flawed

Lessons for Practitioners

Operations, Supply Chain and Marketing Stakeholders MUST be brought into the RTCE Team

- The company President must build support for the RTCE process at all levels of the organization
- The President should expand the team charter to include these important people

Lessons for Practitioners

The RTCE Team Should be Staffed with Full-Time, Dedicated Personnel

- Team members should be chosen on the basis of their energy, cooperative spirit, innovativeness and system-level perspective as well as technical competence.
- The leadership should effectively communicate their expectations to the team, and should explicitly evaluate and reward individuals and the team when expectations are met.
- The team should also create a forum for the training of new team members as well as an opportunity for others in the company to visit and learn about their process.

Lessons for Practitioners

RTCE Leadership should Consist of One Technical Lead and One Process Lead Person

- During the design sessions, two leaders are required to focus on different aspects of the process so that each team member can be free from administrative burdens.
- This approach will smooth the flow of the process and will enable the team to operate at their maximum efficiency and have time to think innovatively.

Lessons for Practitioners

The RTCE Team must create a feedback mechanism so that team members can improve the process over time

- Metrics and goals should be posted and evaluated daily with a focus on continuous improvement.
  - **Examples:** Percent Total Cost Trimmed from Initial Design, Number of Designs Proposed to each Customer,
- The team must avoid sub-optimization by encouraging system-level solutions even if one or two subsystems are less efficient than they would otherwise be.

Strengths of RTCE

- *"The RTCE and ICE processes create value by increasing the Quality of the company's designs and manufactured products and the Speed at which they are created. This is accomplished by fostering product and process Innovation, and enhancing Learning opportunities for all participants."*

RTCE: Effects on Quality

- More design options examined, each more rigorously
- Each designer has continuous access to latest design variables and assumptions
- Details otherwise overlooked or forgotten are discussed by the team in real-time
- Key suppliers and manufacturing personnel are included in the earliest stages of the design

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RTCE: Effects on Speed

- Reduced Lead Times as competitive advantage
- Shorter programs less expensive
- Design Matures more quickly resulting in a program with less uncertainty and rework

RTCE: Effects on Innovation

- Process focuses on *system optimization based on customer value* – rather than sub-system optimization based on rigid specifications
- Sub-system specialists who may never have worked together have the opportunity to share ideas and seek out new solutions to historical problems – classic organizational barriers are broken
- Participants take ownership in their process as well as their product

RTCE: Effects on Learning

- System-level perspective yields tremendous viewpoint for each engineer and technician to understand the impacts of their decisions and work
- Dynamic model allows each new team member to "try-out" numerous what-if scenarios quickly and realistically
- New ideas are evaluated objectively rather than subjectively based on status or perceived cost

Tradespace Exploration

- MATE = "Multi-Attribute Tradespace Exploration"

- *Objective* System Performance Parameters are ranked according to Customer Preferences and Cost to create an overall measure of Value
  - 5 to 7 Parameters, or "Attributes," are each assigned a utility function
  - Customer Representatives are interviewed to determine the relative importance of each attribute
  - The actual performance values for a particular spacecraft configuration are determined, and then rolled up into one multi-attribute utility value

Clarification

- MATE-CON = “MATE” + “CON”
  - “MATE” = “Multi-Attribute Tradespace Exploration”
  - “CON” = “Concurrent Engineering” (ICE or RTCE)

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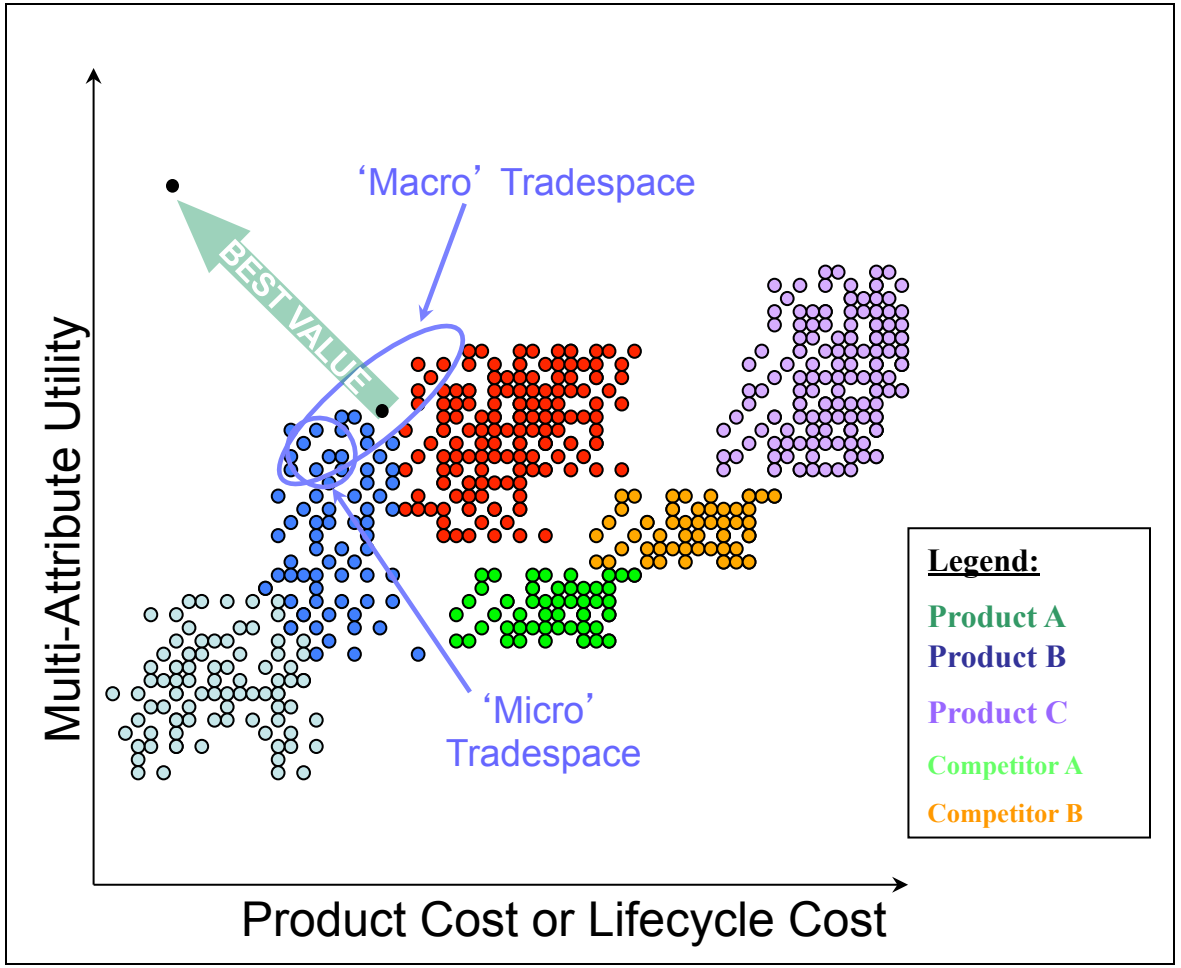
Applicability

- MATE-CON can be applied to ANY process that requires groups of specialists to make tradeoffs within a complex system.

- It is a powerful tool for uniting representatives with diverse interests and bringing to each participant a unique and powerful system-level perspective.

Tradespace Exploration (MATE)

- Enables clear visualizations of complex inter-relationships in order to facilitate communication between System Designers, Customers and Leadership
- Allows sensitivity studies to be run which help create more robust designs



Objectives of Tradespace Exploration

- Search out Best Value Solutions
- Expand beyond a simple decision-making process
  - We can actively engage the entire enterprise and work towards systems that provide value to all stakeholders
  - We can more clearly visualize complex inter-relationships and communicate those objectively to our customers and leadership

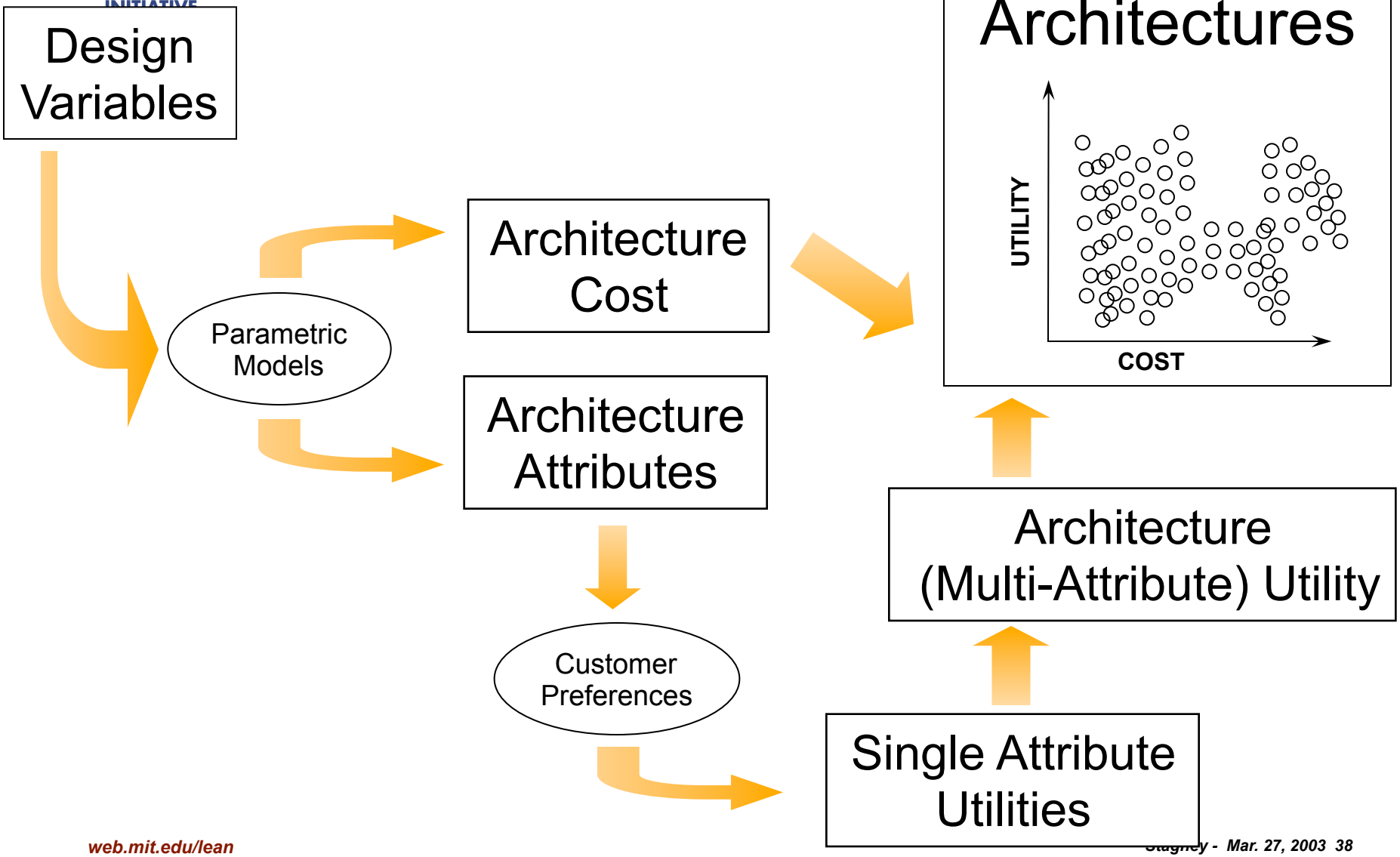
Advantages of MATE-CON

- Captures thousands of architecture options in one place
  - Promotes a rigorous examination of options before jumping to a point-design
  - Fosters objective evaluation of competing architectures
  - Aids in system-thinking by helping people to visualize the benefits and sacrifices of complex trade-offs
- Allows sensitivity studies to be run which help create more robust designs

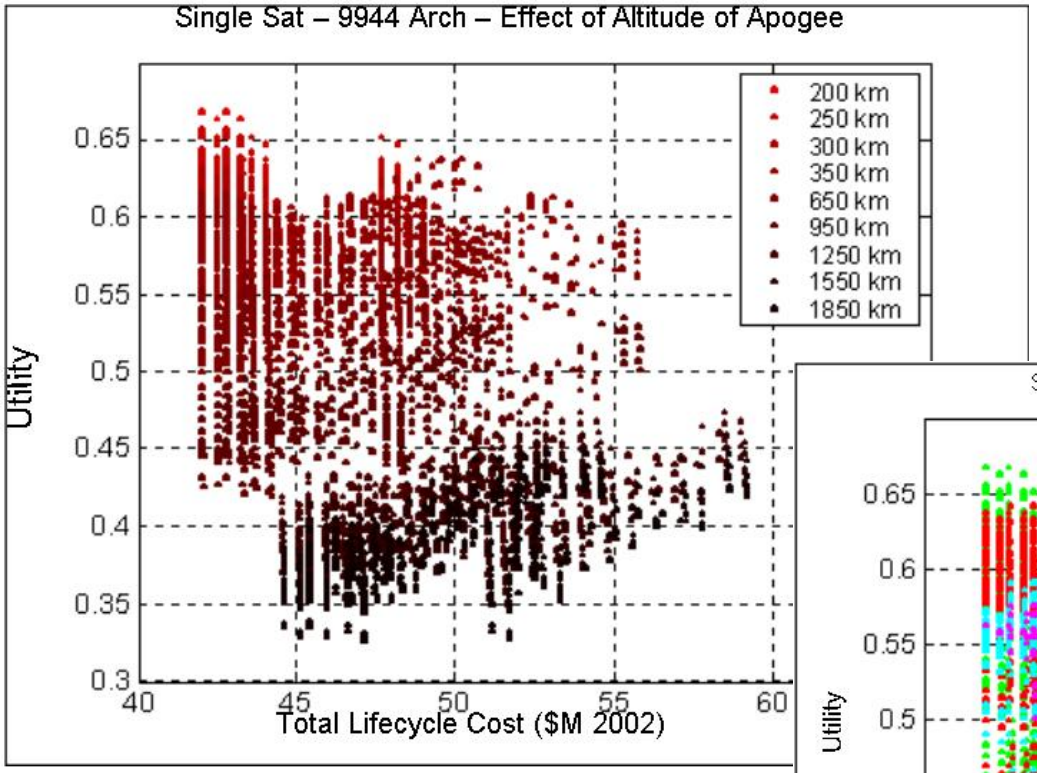
Advantages of MATE-CON

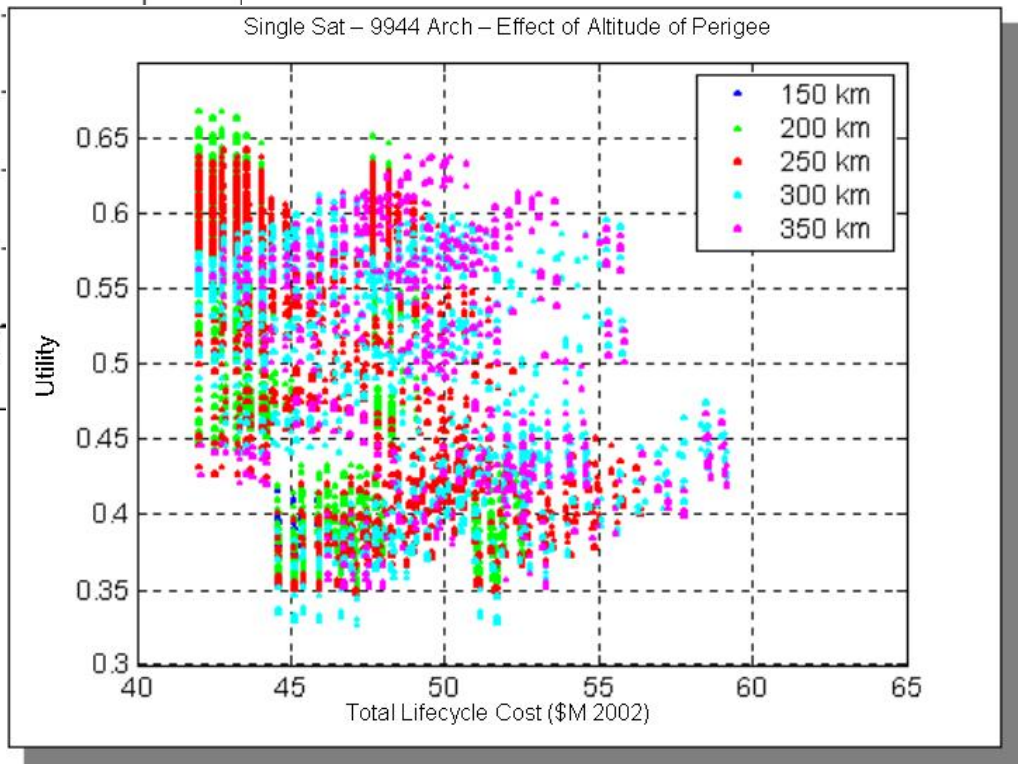
- Pushes a team to define customer values and justify each potential solution based on those criteria
  - Guides a team dynamically – giving rapid and accurate feedback about new design ideas
  - Helps designers quickly gain an intuitive feel of very complex systems
  - Provides an interactive roadmap for each design session
  - Creates a common, visual language that helps elicit very meaningful conversations between customers and designers
- Sets a new paradigm in proposal deliverables – not just the best option(s), but why they are better than every single alternative (including the competition)

Process Flow

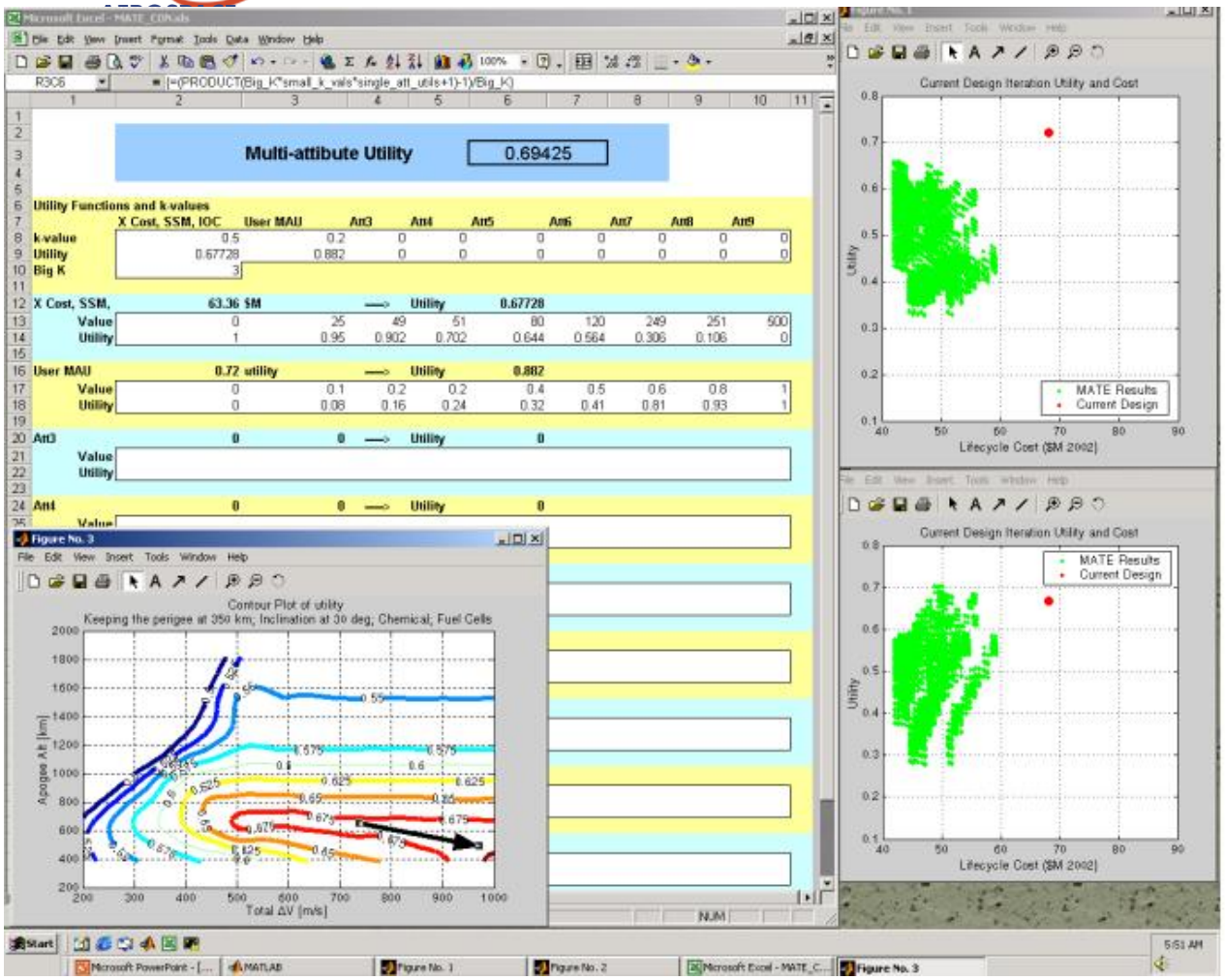


MATE-CON Output: Project X-TOS



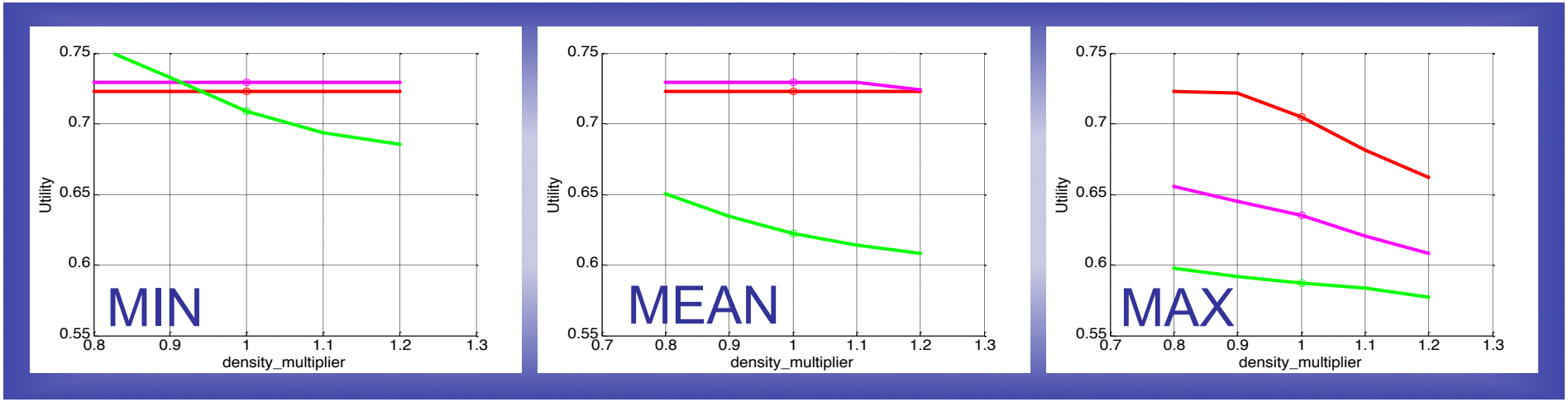


MATE-CON Feedback to ICE



The MATE-CON Chair continuously monitors the progress of the design team relative to the customer preferences and helps them achieve a higher-value design

Example of Sensitivity Analysis



- At solar min Architecture 1 surpasses both Architecture 2 and Architecture 3; while at solar max Architecture 1 quite low
- Choose Architecture 3 because most robust to external uncertainties

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Realities of MATE

- True customer collaboration is essential
- Defining Attributes is labor intensive and requires skill and patience
- The Utility Interview is difficult and elicits the voice of only one key decision-maker at a time
- Modeling the system at an appropriate level of detail takes discipline and coordination
- If team members do not work together as system designers, but merely as independent analysts, potential gains will not be realized

Cautions (Lessons Learned)

- Parametric Models are difficult to construct
  - Need to incorporate error-checking and limits
  - Challenge: How to model systems that have never been tried before
- Cost Models can be very influential
  - The basis for the models will drive your design – make sure you agree with them!
  - Example, SSCM uses mass as primary input, so designers drive to lower mass
  - If you base new costs on historical costs, you may never achieve new innovations

Cautions (Lessons Learned)

- MATE-CON is intended to be an iterative process
  - You should maintain an open line of communication with key decision-makers and validate output continuously
  - Don't waste time in the beginning trying to make perfect models
    - Go for a uniform accuracy target (+/- 5%) at first, then hone in on the important areas of the tradspace and improve your models there

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Alternative Applications of MATE-CON

Indirect Expansion Strategies

- Short Term / Small-Scale Options
  - System-Immersion Workshop
  - Targeted, Deep-Dive Study
  - Team Resource

System-Immersion Workshop

- Goal:
  - Create among your team a concrete, universal understanding of the most important aspects of your system
- Approach / Attendance:
  - A one or two week full-time workshop – preferably in a remote or insulated venue.
  - Full team plus facilitators
- Output:
  - A unified mental and electronic model of the potential design solutions. Each team member would come away rejuvenated and with a renewed sense of direction and clarity of purpose.

Targeted, Deep-Dive Study

- Goal:
  - To objectively examine a particularly important or stubborn aspect of your system
- Approach / Attendance:
  - A small team of 3 to 5 people (broken from the main group or assigned from outside). Working full time for two to four weeks, this team would create a low-resolution *Tradespace Model*.
- Output:
  - Parametric system model that can be used by the full team to pose "what-if" scenarios and and explore the potential outcomes and value propositions. In addition, they could uncover some of the risks associated with particular design options and install robust countermeasures.

Team Resource

- Goal:
  - To expose an existing team to an innovative new technique in order to refocus their efforts or generate new ideas of their own
- Approach / Attendance:
  - One-day interactive presentation given by experienced ICE practitioners (e.g. current RTCE team members).
  - It would examine, in ‘testimonial’ format, the fundamentals of the ICE and Tradespace Exploration processes. Team members could then participate in a live exploration of an existing model as a means of understanding the potential capabilities and applications

Indirect Expansion Strategies

- Long Term / Larger-Scale Options
  - Enterprise Design Technique
  - System Design Technique
  - Dynamic System Model
  - Standing Tiger Team
  - Customer Input Device
  - Supplier Input Device

Enterprise Design Technique

- Goal:
  - To approach the design of the entire Enterprise (technical and business) with a completely new technique
- Approach / Attendance:
  - Key stakeholders (senior managers) meet one full day per week to create a Tradespace and ICE Models of their Enterprise.
  - Assisted by trained facilitators. An experienced programmer is assigned to each participant.
- Output:
  - Dynamic business models that can uncover new business synergies, vulnerabilities, effects of price changes, value of R&D investments, etc

System Design Technique

- Same as Enterprise Design, but targeted in scope to one division or operating unit
  - Supply Chain Design
    - Strategic outsourcing decisions can be evaluated for each new program
  - Operations
    - Factory planning and costing can be done quickly and efficiently

Dynamic System Model

- Goal:
  - To objectively examine a particularly important or stubborn aspect of your system
- Approach / Attendance:
  - Essentially the same as the "Targeted Deep Dive" but would apply to a much larger challenge impacting the entire company rather than one program. It could be applied to the study of market dynamics, system shocks, scenario planning, costing initiatives, etc
  - A full team of approximately 15 personnel would work for 1 to 6 months (depending on scope) to create in-depth Tradespace Exploration and ICE models for the problem at hand.

Standing Tiger Team

- Goal:
  - To have a team of personnel fully trained in ICE and Tradespace Exploration 'on-call' to attack any important issue that is holding up a program or project team.
- Approach / Attendance:
  - The 5 to 15-person Tiger Team would be trained in a hands-on manner by performing a variety of small workshops focusing on small but real problems. It could then be assembled at any time to work a specific issue (failure analysis, unexpected change in market or customer preferences, etc)
- Output:
  - If called into action, the team would work for 1 to 4 weeks to produce a dynamic analysis of the problem at hand that could be used by the project team to understand an issue and analyze solutions

Customer Input Device

- Goal:
  - This idea is intended to harness the powers of the Tradespace Exploration technique with regards to decision-maker preferences.
- Approach / Attendance:
  - This option would involve the creation of a universal Tradespace Exploration model that could then be analyzed according to the unique attributes and preferences of each customer.
  - A team of approximately 15 members would create the models, and then teams of 3 to 5 would conduct interviews with each customer to determine their most important attributes and the corresponding utility functions.

Supplier Input Device

- Goal:
  - To tap into the ideas and strengths of key suppliers by integrating them into the early stages of the new business and detail design processes.
  - To build trusting, long term relationships that derive maximum mutual benefits
- Approach / Attendance:
  - Invite 3 to 5 strategic suppliers to join the RTCE team on a full-time basis
  - Have each of these companies start their own RTCE labs to support their on-site representatives at the company