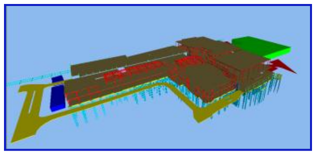
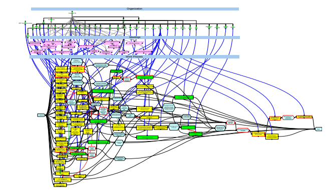
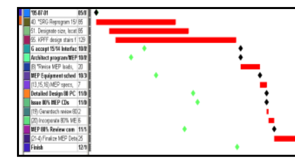
Integrated Concurrent Engineering



Function				Product Behavior		Qualitative Threshhold values				
Object	Attribute	Requirement Relationship	Requirement	Predicted value	Observed value	-2	-1	0	1	2
Product										
Product	Scope									
Product	Scope . Building Spaces	includes		-						
Project	Goals									
Project	Goal . Capacity (people)	>=	60	-	?o					
Project	Goal . Cost (M$)	=	70	-	?o					
Building	Goal . Net Energy Use (K-BTU/ft2)	<=	250	-	?o					
Building	Goal . Quality conformance (%)	>=	12	-	?o					
Organization										
Organization	Scope									
Organization	Scope . Actors	includes		-	-					
Organization	Goals									
Organization	Goal . Predicted . Cost (K$)	-	<=	-	?o					
Organization	Goal . Observed . Response Latency (days)	3	<=	-	?o					
Organization	Goal . Predicted . Peak Backlog (days)	3	<=	-	?o					
Organization	Goal . Predicted . rework (FTE-days)	-	<=	-	?o					
Process										
Process	Goals									
Process	Goal . Peak Quality Risk	<	0.50	-	-					
Process	Goal . Schedule Growth (months)	<		-	?o					
Process	Goal . Completion Date	<=	1/1/09	-	?o					
Process	Task . Action: Object									
Process	Task . Design:	Actor	Actor that designs							
Process	Task . Predict:	Actor	Actor that predicts							
Process	Task . Assess:	Actor	Actor that assesses							
Process	Task . Build:	Actor	Actor that builds							

John Kunz





	Rate	Baseline ($K)	Change	Year-1 (K$)
Revenue		100,000	2%	102,000
Cost of contracted work	85%	85,000	-2.0%	84,660
Cost of self-performed work	10%	10,000	2.0%	12,240
Gross Margin		5,000		5,100
Sales, G&A	2%	2,000		2,040
IT investment		70		
Amortized costs of IT/yr	33%			23
Net income		3,000		3,037
Time to payback (years)				1.9
Net Income change (%)				1.2

Big idea:

Integrated Concurrent Engineering (ICE) is a social method, helped by technology, to create and evaluate multi-discipline, multi-stakeholder VDC models extremely rapidly.

Overview

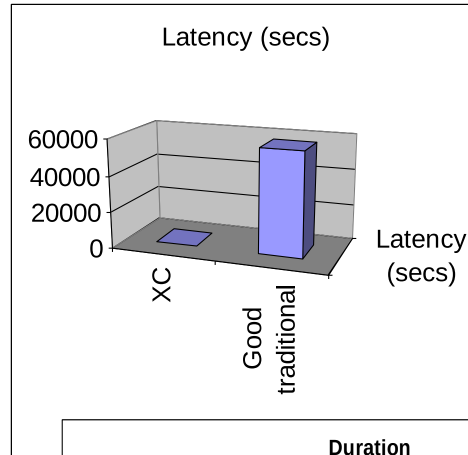
Session	Objectives
Integrated Concurrent Engineering (ICE):	Develop, show and explain the product, organization, process, POP and 4D models as well as analyses of each and recommendations for management based on the design exercise – collaboratively and quickly

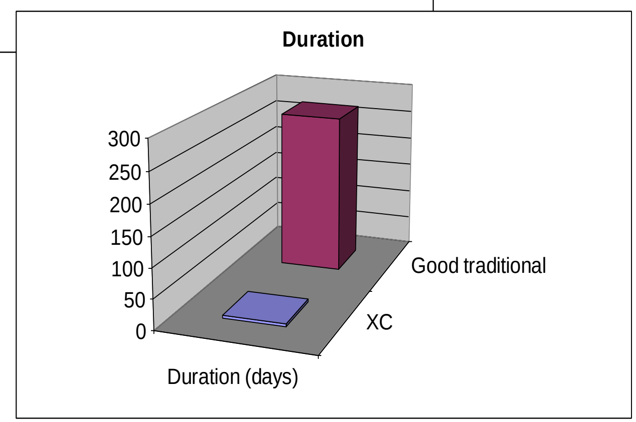
Integrated Concurrent Engineering (ICE) Background

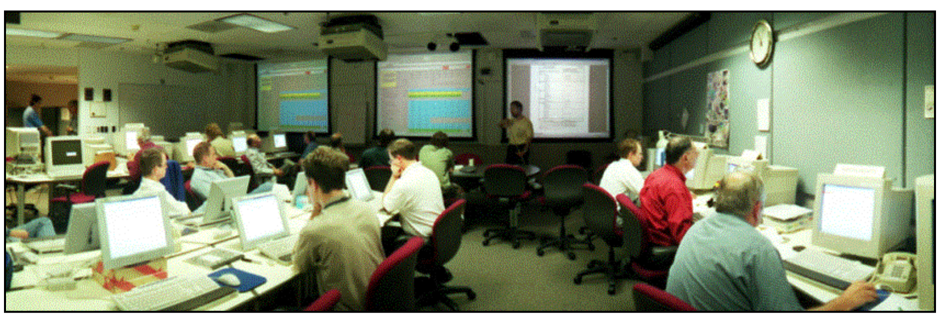
Given

- Objective = Rapid, effective design "extreme collaboration" (~1 week)
- Excellent POP software
- Collocated team
- iRoom
- Good generic POP model
- SD (DD) phase focus

Performance change







The big ideas of ICE

- The Big Ideas:
- Exceptional performance, e.g., Team-X at NASA-JPL
- It works because it achieves exceptionally short information latency and short task durations, reliably.
- Multiple factors enable ICE to work.

Goals of this design session:
Project Definition (v)

Define:

- What each of the teams expects to deliver
- What they expect from the other team members
- How can individuals coordinate their respective and collective scopes
- How team members know how work is progressing
- How team members know when (pre)construction is completed
- What work resources and methods can be used for (pre)construction work
- What resources and work methods will be used for the (pre)construction

Goals of this design session: *Project Definition (v)*

Define:

- What each of the teams expects to deliver (plans, commitments)
- What they expect from the other team members (commitments)
- How can individuals coordinate their respective and collective scopes (coordination commitments)
- How team members know how work is progressing (risks; measurable process performance metrics)
- How team members know when (pre)construction is completed (measurable outcomes)
- What work resources and methods can be used for (pre)construction work (controllable factors)
- What resources and work methods will be used for the (pre)construction (commitments)

Goals of this design session: *Project Definition (v)*

For the product, organization and process, project definition clarifies and aligns:

- Functional objectives – what project stakeholders want –
  - Specific deliverables, e.g., spaces, systems
  - Conforming and highly reliable safety, schedule, quality and cost
- Scope – "forms" you create -- periodic design and construction deliverables, including: designs of the
  - *Product* (~weekly or daily) – to update objectives, designed scope, predicted and measured behaviors
  - *Organization* – groups of people to do tasks that work on the design
  - Process (daily work) – tasks to design and manage, procure, fabricate, deliver, construct and inspect
- Behaviors – what you predict and what you did – predict and measure performance of designed scope
  - With respect to specific stakeholder objectives
  - Using methods of VDC, Integrated Project Delivery, Lean and Sustainable development

Potential value of VDC

- Better project or corporate performance (measurably)
  - Suggests need for ~weekly performance data: **specify >3 metrics**
- Better clarity of decision processes, for
  - Decision-makers
  - Execution team
  - Executive team
- Better plans and clear commitments for working team
- Increased profitability: ↓rework; ↓work effort; ↑business

VDC methods:

- Models: Product (3/4D), organization (commitments), process (plan, schedule)
- Collaboration methods: ICE
- Analyses (model-based): Clash, Structure, QTO, cost, energy, …
- Metrics: Outcome, process, controllable factors

Product – Organization – Process (POP) Model format:

A POP model has the format below:

	Function: Objectives	Form/Scope: Design choices	Behavior: predictions
Product	spaces, elements and systems	Designed spaces, elements and systems	Predicted cost ($)
	Measurable Objectives	Values	Predictions; Assessed values
Organization	Actors	Selected actors	Predicted cost (hours or $)
	Measurable Objectives	Values	Predictions; Assessed values
Process	Tasks	Designed tasks	Predicted cost (days or $)
	Measurable Objectives	Values	Predictions; Assessed values

Process of Project Definition

- Build POP model as a stakeholder team
  - Set *functions* (objectives) of Product, Organization, Process
  - Design form or *scope* of Product, Organization, Process
  - Identify project behaviors and define methods to predict, assess and observe them

	Function: Objectives	Form/Scope: Design choices	Behavior: predictions
Product	spaces, elements and systems	Designed spaces, elements and systems	Predicted cost ($)
	Measurable Objectives	Values	Predictions; Assessed values
Organization	Actors	Selected actors	Predicted cost (hours or $)
	Measurable Objectives	Values	Predictions; Assessed values
Process	Tasks	Designed tasks	Predicted cost (days or $)
	Measurable Objectives	Values	Predictions; Assessed values

Virtual Design and Construction (VDC) vs. Building Information Modeling (BIM)

	Function: Objectives	Form/Scope: Design choices	Behavior: predictions
Product	spaces, elements and systems	Designed spaces, elements and systems	Predicted cost ($)
	Measurable Objectives	Values	Predictions; Assessed values
Organization	Actors	Selected actors	Predicted cost (hours or $)
	Measurable Objectives	Values	Predictions; Assessed values
Process	Tasks	Designed tasks	Predicted cost (days or $)
	Measurable Objectives	Values	Predictions; Assessed values

VDC

BIM

	Function: Objectives	Form/Scope: Design choices	Behavior: predictions
Product	spaces, elements and systems	Designed spaces, elements and systems	= Empty =
	Measurable Objectives	Values	Predictions; Assessed values
Organization	Actors	Selected actors	= Empty =
	Measurable Objectives	Values	Predictions; Assessed values
Process	Tasks	Designed tasks	= Empty =
	Measurable Objectives	Values	Predictions; Assessed values

Integrated Concurrent Engineering at JPL (ICE)

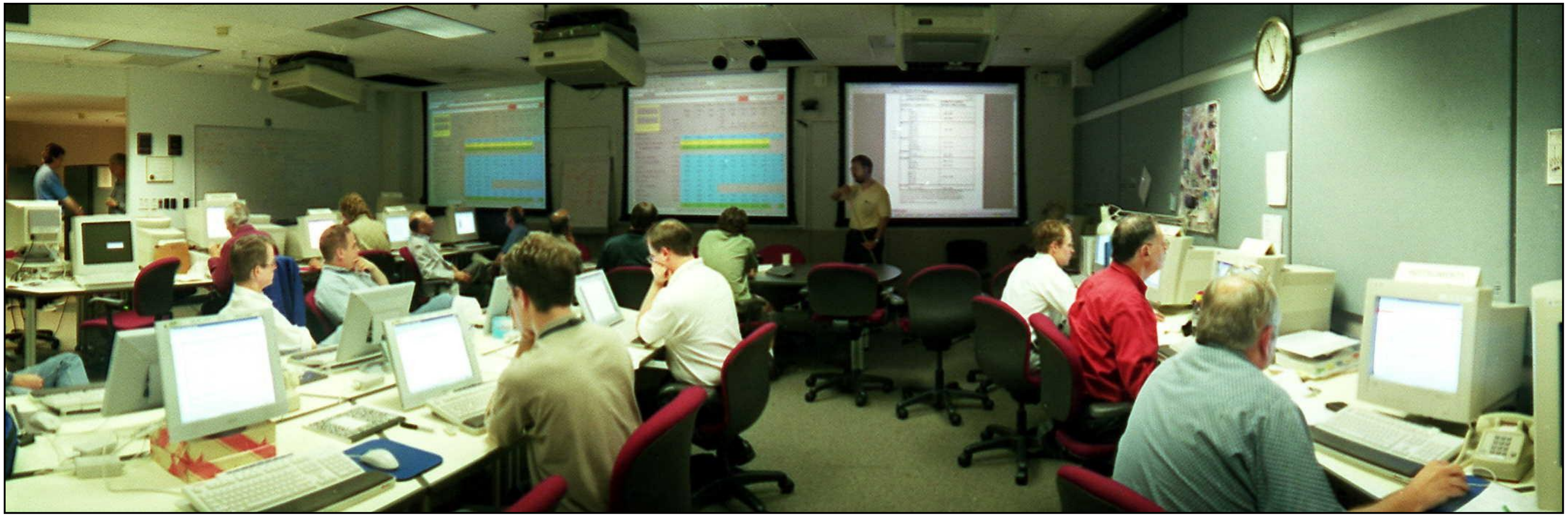
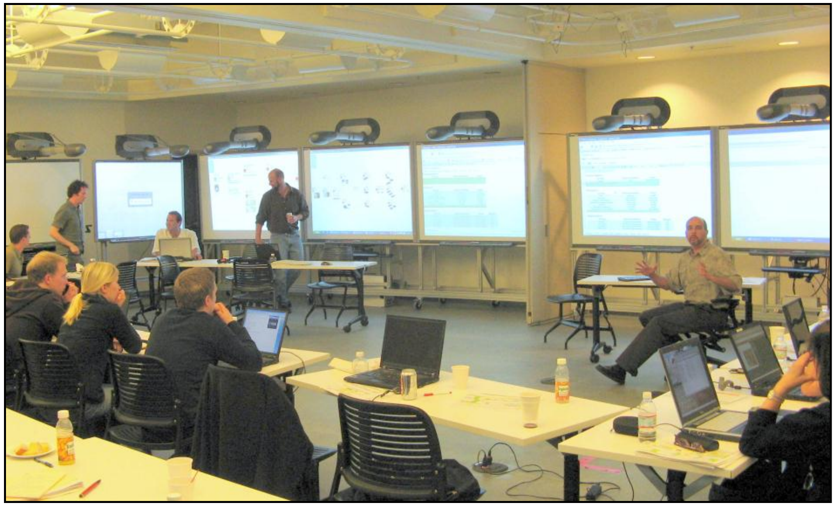


Photo thanks to JPL

Properties

- Collocated Organization (Closed Knowledge Network)
- Excellent Technical Infrastructure
- Formal Objective Metrics
- Informal Process and Culture

Integrated Concurrent Engineering at CIFE



Integrated Collaborative Engineering (ICE) at CIFE

- Collocated Organization (Closed Knowledge Network)
- Excellent Technical Infrastructure
- Formal Objective Metrics
- Informal Process and Culture

Without Integrated Concurrent Engineering

Source: @ammunition group: http://twitpic.com/5xs1vy

Observations

ICE at NASA-JPL characteristics

- Organization: Multiple stations (~18)
- Process: careful design
- Technology:
  - Multiple shared display screens
  - Shared database (Icemaker)

Coordination Latency is the fundamental performance metric for knowledge work

- *Response latency* = Time from a designer posing a question to receipt of a useful answer
- *Decision latency* = Time from receiving useful information to making a decision with it

- Good engineering practice for both: 2 days
  – weeks typical
- **Measurable ICE Objective for latency: minutes, reliably**
  – For and as assessed by all intended stakeholders

Simple analysis of Latency

Traditional

- Project requires
  - 100 “queries” per engineer @ Latency = 2 days (good!)
  - 100 modeling, analysis, meeting “tasks” @ task durations < 2 days

➢ Project duration ~ 200 calendar days (typical)

➢ *Latency paces schedule (typical)*

- *Not direct work*

ICE (Team-X)

- Project requires
  - 100 “queries” per engineer @ Latency = 1 minute
  - 100 modeling, analysis, sidebar “tasks” @ task durations ~8 minutes

➢ Project duration ~ 2 calendar days (Team-X)

➢ *Direct work* (modeling + analysis + documentation) *paces schedule (Team-X),*

- *Not coordination latency*

ICE requires latency management

- Latency extends schedules
  - Interdependent tasks have incessant information requests
  - Requests have response delays (latency)
  - Latency adds no value, measures collaborative waste
- Integrated Concurrent Engineering dramatically cuts time and latency
  - Reduces latency from days to minutes
  - Direct work tasks must run in minutes
  - Enables radically decreased project duration
  - Researchers, practitioners report improved cost, quality
  - Requires high reliability (> 99%) latency: one major latency source jeopardizes project success
  - New organizational form

How ICE (Team-X) works

Manages:

1. *Duration of direct work tasks*
   - Model, describe, predict, explain, evaluate, generate alternatives, decide
   - Requires highly skilled engineers with excellent tools that they know well and culture that provides good enough answers
2. *Coordination Latency*
   - Time for a designer to obtain usable information
   - Requires many enabling factors

Supports both:

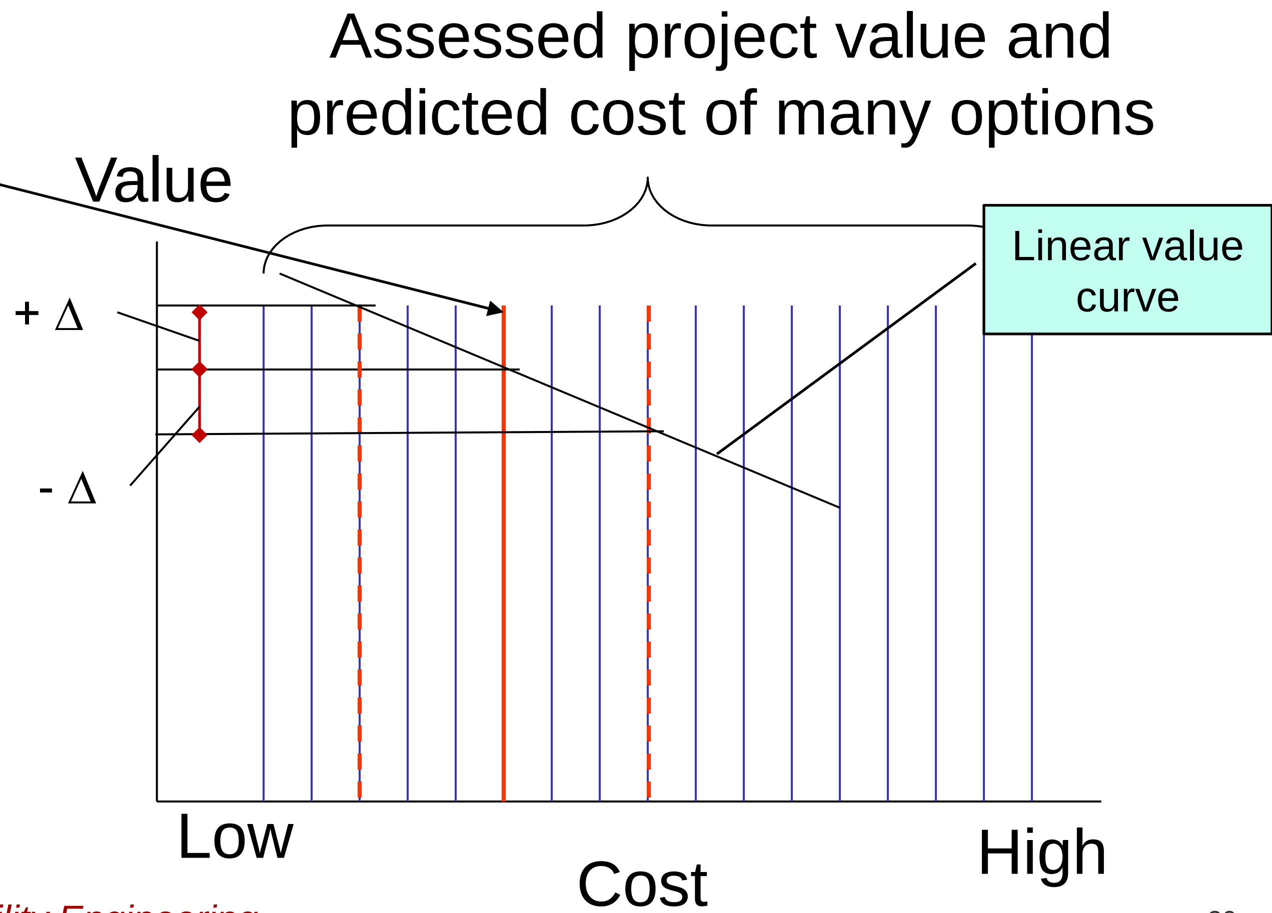
1. Associative (divergent) thinking
   - *Many* options, intuitive, including unique idea

   → Fluency (lots of options), Flexibility (different kinds), Original (at least one)
2. Analytical (convergent) thinking

   → data, prediction, analysis, evaluation and recommendations that believably support decision-making
   - Actionable

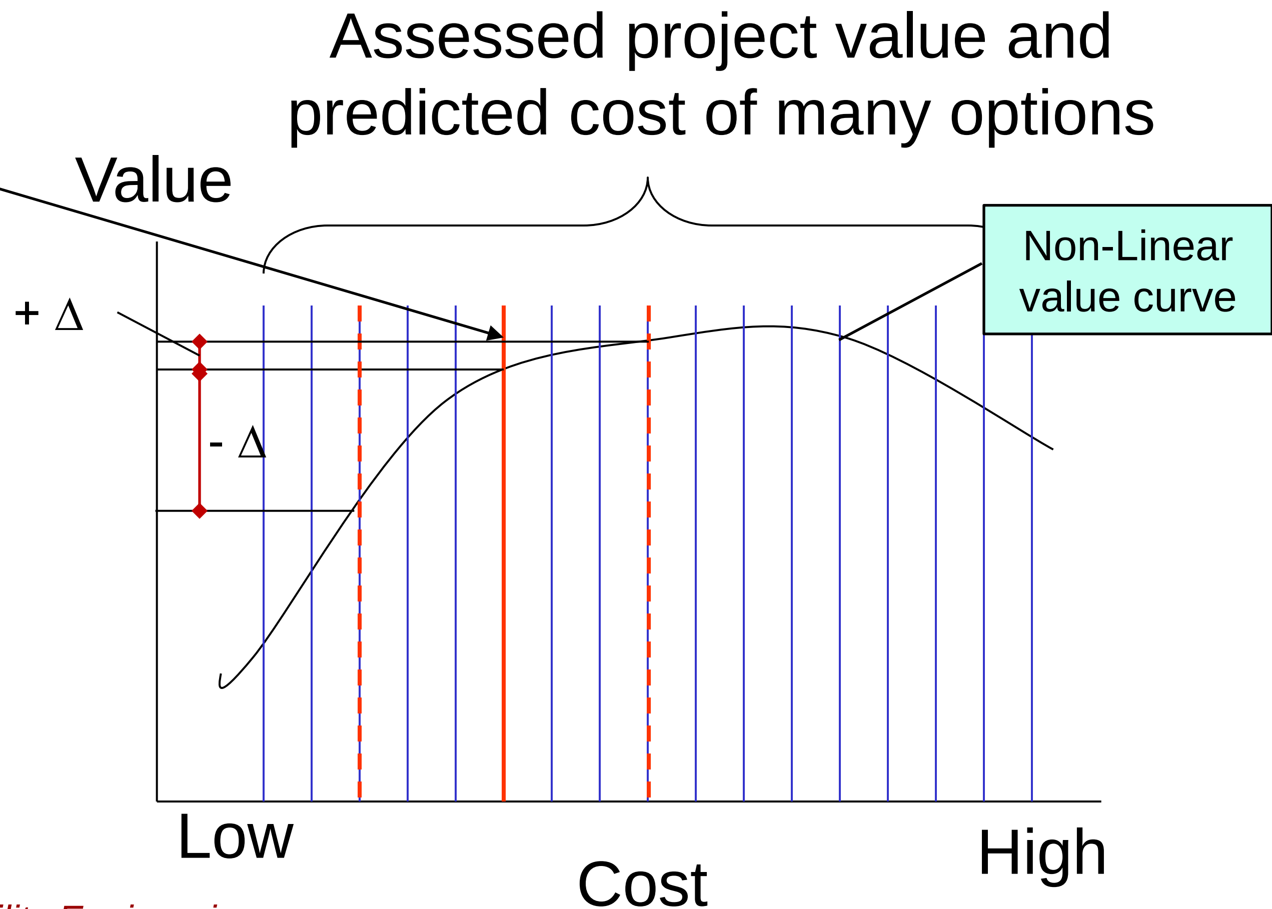
Use ICE for Target value design
for cost, schedule, energy, …

- Generate and evaluate many design options w/ICE
- Select target cost
- Rapid design method: PIDO http://network.modefrontier.eu/documentation/pido.html



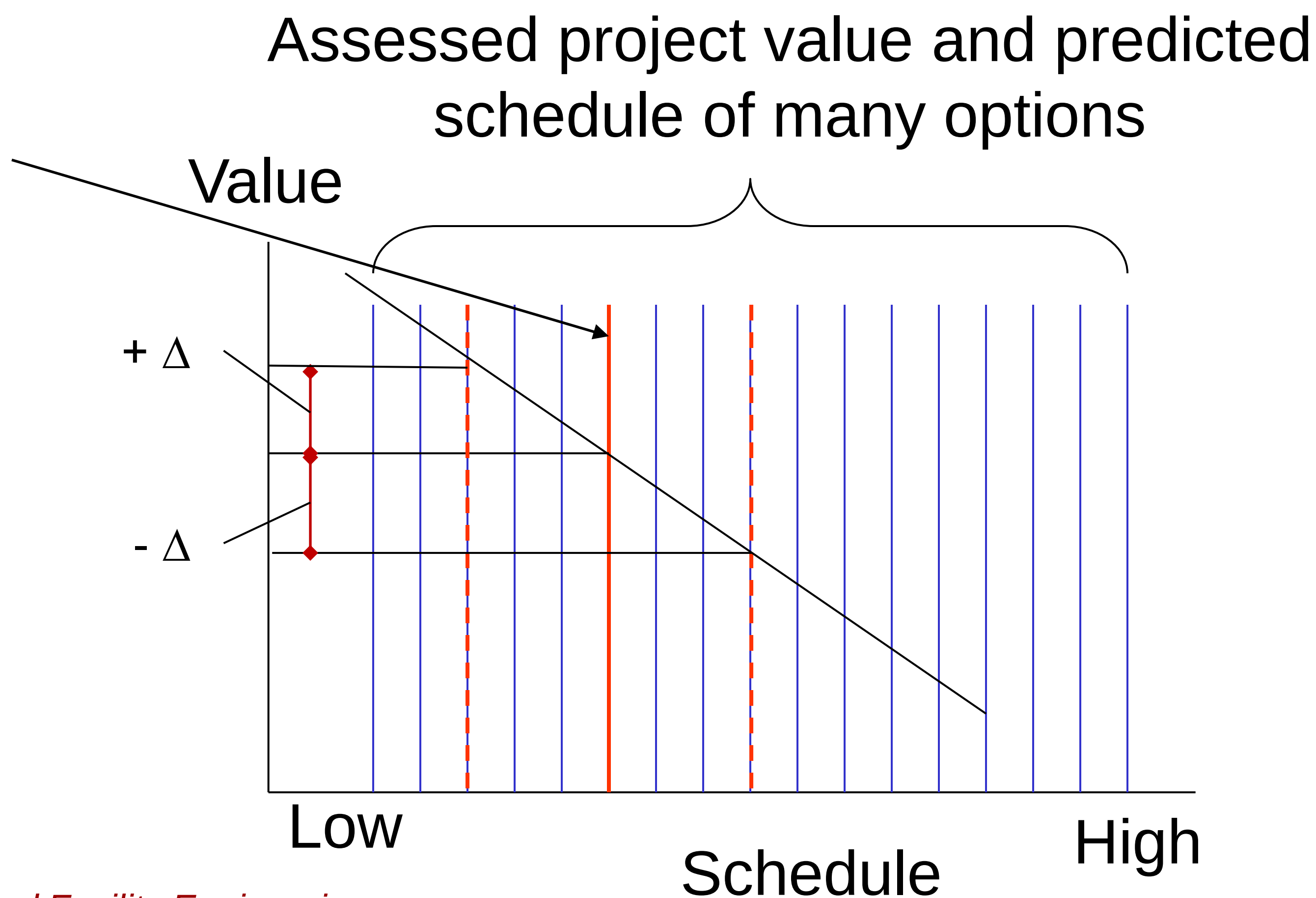
Use ICE for Target value design
for cost, schedule, energy, ...

- Generate and evaluate many design options w/ICE
- Select target cost



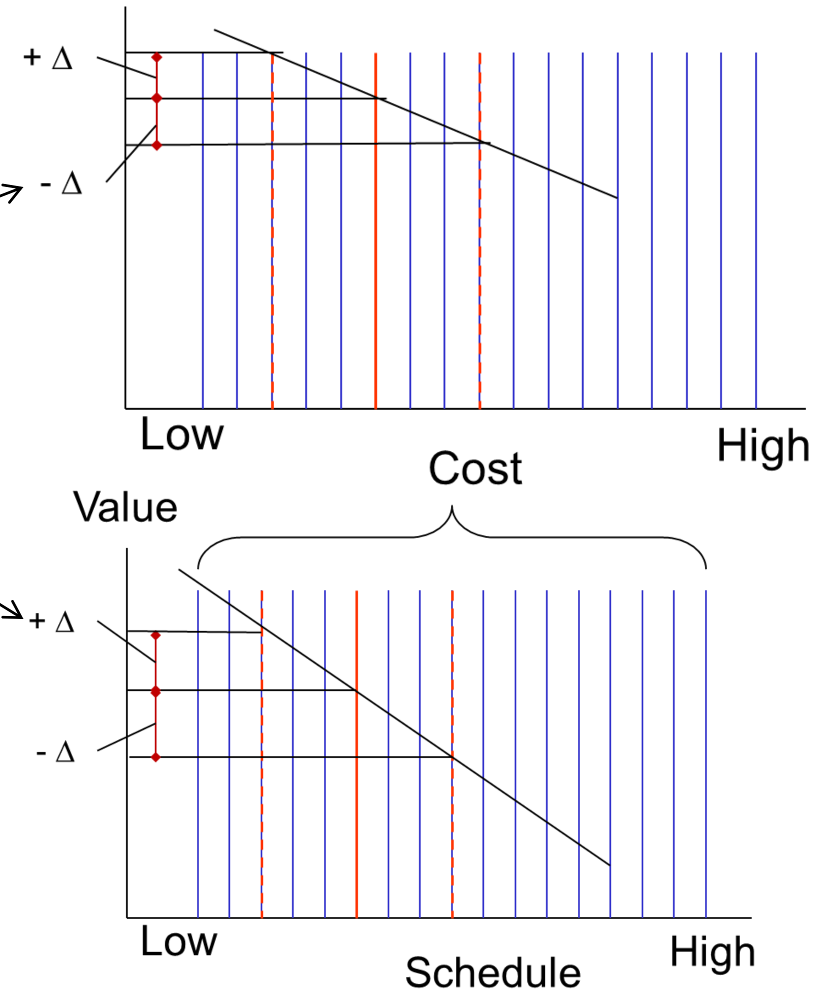
Use ICE for Target value design
for cost, schedule, energy, …

- Generate and evaluate many design options w/ICE
- Select target schedule



Use ICE for multi-discipline target value design:

- When a change affects two measures of project success,
  - Choose when upside value exceeds downside risk
  - E.g., - Δ cost risk
    - < + Δ upside schedule compression value



ICE Methods

Normal Stations

- Owner
- Product: model functions, scope, behaviors
- Organization: model functions, scope, behaviors
- Process: model functions, scope, behaviors
- Integrated project: POP model
- Facilitator (session leader)
- Project manager

Process

- All stations simultaneously develop model inputs
- Coordinate continuously
- Assess and evaluate first design option
- Deliver project:
  - Definition
  - Objective assessment
  - Option evaluation

Steps to perform ICE sessions …

- Pre-planning: a few days immediately prior to ICE sessions
  - Invite a very small set of project principals (2-4)
  - Do project definition and identify POP model at Level-B with ~10 each of P, O, P elements
- Determine the design space to explore in ICE session:
  - Invite participants of actors in POP model to ICE session
  - Select modeling and analysis tools and methods
    - Assure that facility and intended tools are available
- ICE session: ~3 sessions within one week
- Post-session: a few days immediately following ICE sessions to create formal deliverables

When to hold ICE sessions …

- For each major project phase
  - at least early (concept and schematic), detailed (DD, CD) and to plan construction
- Collaborating with your other stakeholders
- Hold a set of about 3 ICE sessions
- Build and analyze a project model for the next phase in enough detail to identify objectives, scope and predicted performance believably

Why to hold an ICE session

- Do project definition rapidly and believably
  - Define functional objectives, scope, behaviors of Project, i.e.,
    - Product, Organization, Process
- Clearly identify tasks and deliverables for next period (week or month)
  - Focus: product element and system(s) served
  - Who: responsible group, individuals
  - What: tasks to perform
  - When: according to broadly reviewed and accepted schedule
  - How: methods and resources to be used by responsible team(s) to coordinate, do work and verify work
  - Context: specific
    - risks and uncertainties to address based on broad project review
    - coordination tasks to assure success given risks

To plan a set of ICE sessions

- Enable effective use of ICE methods
  - Professional development of potential team members - create culture, methods, incentives
  - Implement enabling tools: P, O, P modeling and analysis applications, display technology, shared database
- Plan *each* set of ICE sessions: Identify
  - Objectives and intended deliverables: models, analyses, reports, recommendations, …
  - Number of sessions and calendar schedule: typically 2-4 over ~ 1 week
  - Intended participants, tasks for each session
  - Effort and time budgets for use of ICE sessions
  - Process performance metrics and methods: measured and assessed quality, schedule, cost

ICE deliverables …

- Functions: statement of project objectives for P, O, P
- Scope:
  - Design of multiple P, O, P options in large design space
  - P, O, P models for use by next phase
- Behaviors: predicted P, O, P performance
- Evaluation of acceptability of options given objectives
- Risk assessment and mitigation strategy
- Recommendation for new P, O, P design option(s)
- Proposed product design, team, schedule and responsibilities for next phase

ICE vs. traditional meetings in construction

Issue	ICE	Traditional meetings
Outcome re issue at hand	Resolution	Tracking of status
Agenda management	Focused on clear, shared agenda	Tangents, pursuit of personal agendas
Description of problem and context	Shared and clear	Individual perceptions
Number of options considered	Multiple; consider what-ifs	Focused on agenda of one individual
Supporting technologies	Interactive visual models and analyses	Paper and appeal to understanding of others

ICE Enabling Factors

(Committed) Organization	***(Dynamic) Process***	***(Visual) Technology***
*Stakeholders Present: (*Closed knowledge network)	Processes clear: (low equivocality)	*Excellent* discipline-specific modeling, visualization tools
Focused design staff: 100% committed in sessions	*Processes distinct:* High structure independence	*Rich* communications media
Flat organization structure	Resolve problems in small self-formed groups (*Pooled* communications)	*Integrated* database
Egalitarian culture		
High goal congruence		

Staff survey: Example of how senior management helps

1. I feel that I can challenge people at any level in my organization without fear.
2. I feel I can ask for and receive the resources (time, budget, equipment) I need to solve problems.
3. My Manager/Supervisor makes it easy to speak up when problems arise.
4. My Manager /Supervisor listens to bad news, yet still asks for unrealistic targets.
5. When we present bad news, our Manager/Supervisor repeatedly asks for more information focused on showing that the problem is not as bad as it seems.
6. My Manager/Supervisor encourages us to ask for help outside our organization or the chain of command (e.g., outside our project or work group or next level up) if we need it.
7. I am aware of what to do when a Manager/Supervisor doesn't respond appropriately to bad news and it needs to be escalated to a higher level.
8. My team uses metrics and processes effectively (e.g., trend program, standard metrics, etc.) to analyze, surface & solve problems.
9. In my organization, we live by our corporate values
10. The formal metrics in my organization often do not convey an accurate picture of performance.

Organization Enabling factor:
Stakeholders Present: (Closed knowledge network)

- *Objective:* knowledge and authority always present
- *Meaning:* Requisite knowledge, procedures, options, and authority are immediately available in the room (almost always)
- *Risk factors:* sidebars; unanswered sidebars
- *Team-X Methods:*
  - Heavy reliance on collaborative design sessions
  - Designer collocation during sessions
  - Careful participants selection and training
  - Pre-plan to identify needed participants

Organization Enabling factor: *Design staff focus*

- *Objective:* 100% available during meetings
- *Meaning:* Design session participants focus exclusively on project work during design sessions
- *Risk factors:* Designers have other responsibilities during design sessions, so team waits for expertise
- *Team-X Methods:*
  - Management support of focus
  - Short sessions enable managers to free valued staff

Organization Enabling factor: *Hierarchy structure*

- *Objective:* Flat
- *Meaning:* Minimal required decision-making structure and overhead
- *Risk factors:* Soliciting management approval challenges short latency
- *Team-X Methods:*
  - No managers
  - Culture of autonomy and respect
  - One facilitator (session leader)

Organization Enabling factor: *Egalitarian culture*

- *Objective:* Egalitarian
- *Meaning:* Positions assume empowered decision-making and low management overhead
- *Risk factors:* Soliciting management approval challenges short latency
- *Team-X Methods:*
  - Culture of autonomy and respect
  - Careful recruitment
  - Decisions and decision processes highly visible to all

Organization Enabling factor: *Goal Congruence*

- *Objective:* Highly congruent
- *Meaning:* participants know and aspire to same goals and methods
- *Risk factors:* positions debate priorities or methods
- *Team-X Methods:*
  - Discuss goals and methods at session start
  - Facilitator (session leader) attention
  - Culture of congruence
  - Analysis and decisions very visible to all

Process Enabling factor:
Processes clear: (low equivocality)

- *Objective:* design, coordination and construction processes clear
- *Meaning:* all participants understand and accept procedures, goals and objectives
  - Implies that method applies *only* to well-understood processes
- *Risk factors:* positions ask for and wait for facilitator (session leader) decisions
- *Team-X Methods:*
- Use only for well-understood processes
  - Pre-plan for process clarity
  - Culture of autonomy
  - Analysis and decisions very visible to all
  - *Excellent process facilitator (session leader)*

Process Enabling factor:

*Processes distinct: (*High structure independence)

- *Objective:* design processes clearly separated
- *Meaning:* Design tasks are distinct, positions all understand their responsibilities and can proceed with minimal management oversight
- *Risk factors:* positions solicit or wait for facilitator (session leader) decisions
- *Team-X Methods:*
  - Use only for projects that allow independence
  - Pre-plan for independence
  - Staff selection and training
  - Culture of autonomy
  - Analysis and decisions very visible to all

Process Enabling factor:

Resolve problems in small self-formed groups (*Pooled* communications)

- *Objective:* Pooled communications
- *Meaning:* Participants resolve problems in small self-formed groups
- *Risk factors:* Formal or inflexible coordination requirements
- *Team-X Methods:*
  - Collocation
  - Shared project (POP) model
  - Shared projection screens
  - Sidebar culture

Technology Enabling factor: Modeling, Visualization Tools

- Objective: Excellent
- Meaning: Discipline-specific tools allow all positions to do direct work very fast
- Risk factors: Manual design activities or poor tools bottleneck schedule; Other designers fail to understand a model
- Team-X Methods:
  - Modeling, visualization, analysis and decision support tools enable all critical path tasks
  - High team experience
  - Shared project (POP) model

Technology Enabling factor: *Communications Media*

- *Objective:* Rich
- *Meaning:* Shared and personal, visual, multi-disciplinary, showing functional requirements, design choices and predicted behaviors
- *Risk factors:* Slow process to describe models, explain rationale, evaluate choices, make predictions, create alternatives
- *Team-X Methods:*
  - Mature modeling and analysis tools
  - Personal workstations
  - Shared "iRoom" displays

Technology Enabling factor: Shared Project *Database*

- *Objective:* Integrated
- *Meaning:* Discipline-specific models all access and store *shared* data easily
- *Risk factors:* data reentry, missing *shared* data
- *Team-X Methods:*
  - Develop good shared generic (POP) model ontology
  - Applications have developed uniform semantics for shared data
  - Designated position assures consistency

Assessment of status of ICE Enabling Factors

(Committed) Organization	***(Dynamic) Process***	***(Visual) Technology***
Stakeholders Present:	Processes clear: (low equivocality):	*Excellent* discipline-specific modeling, visualization tools:
Focused design staff: 100% committed in sessions:	*Processes distinct:*	*Rich* communications media:
Flat organization structure:	Resolve problems in small self-formed groups:	*Integrated* database:
Egalitarian culture		
High goal congruence:		

ICE Enabling factors: so what?

- *Necessity:* excellent ICE performance requires *all* factors to work well
- *Sufficiency:* No one factor suffices
- Early evidence (Stanford classes) of necessity, sufficiency of these factors (from observations or theoretically-founded simulation)
- Process and team experience are crucial, so understanding factors may help understand how to change Team-X to
  - Make specific improvements
  - Replicate Team-X (in less than 10 years it to create it)

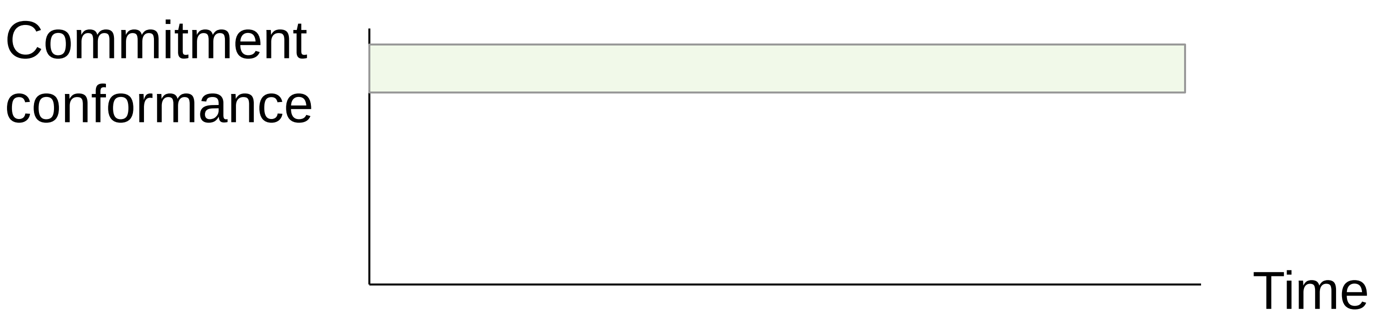
Goals of ICE sessions session: *Project Definition (v)*

Define:

- What each of the teams expects to deliver (plans, commitments)
- What they expect from the other team members (commitments)
- How can individuals coordinate their respective and collective scopes (coordination commitments)
- How team members know how work is progressing (risks; measurable process performance metrics)
- How team members know when (pre)construction is completed (measurable outcomes)
- What work resources and methods can be used for (pre)construction work (controllable factors)
- What resources and work methods will be used for the (pre)construction (commitments)

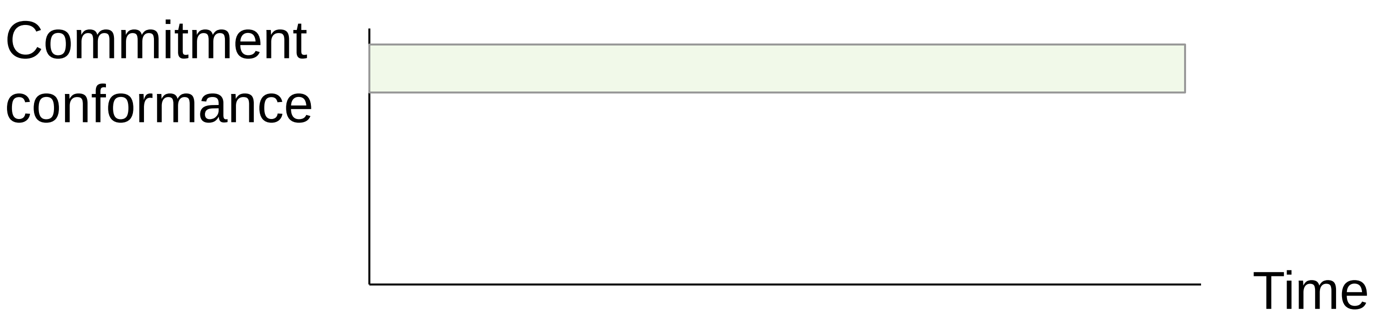
Deliverable commitment report: responsibility matrix

Planned deliverable	Responsible team, individuals	Receiving team	Due date	Due date met (y/n)?	Expected LOD	Comments



Coordination commitment report

Planned coordination activity	Responsible individuals	Due date	Due date met (y/n)?	Expected LOD	Comments



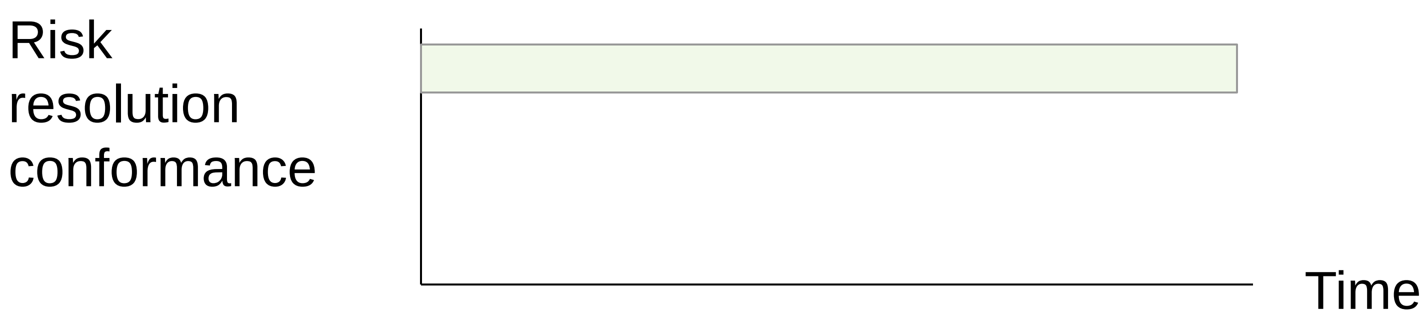
Metrics Implementation table

	Name	Type [C, P, O]	How to use in manage-ment	Source of data	Display	Collection frequency
M E T R I C S						

C: Controllable; P: Process; O: Outcome

Risk report

Identified risk	Responsible individuals	Earliest analysis/ last responsible moment dates	Resolution date met (y/n)?	Potential impact ($, time, effort)	Comments



To read more

- Section *Integrated Concurrent Engineering (ICE) supports VDC*
  - Pp 34-38 in VDC recommended reading
  - "Virtual Design and Construction: Themes, Case Studies and Implementation Suggestions," CIFE working Paper #97, 2011.

ORID: Focused Conversation and Analysis

Objective What do you recall seeing?	**Reflective Positive** What do you feel positive about?	**Reflective Negative** What do you find negative?	**Interpretive** What sense do you make of it?	**Decisional** What agreements can be made now?

Overview

Session	Objectives
Integrated Concurrent Engineering (ICE):	Develop, show and explain the product, organization, process, POP and 4D models as well as analyses of each and recommendations for management based on the design exercise – collaboratively and quickly