



Boeing Defense, Space & Security  
Phantom Works

Strategic Development and Experimentation

# Experimentation Estimating with ACEIT

Karen Mourikas SD&E - Experimentation

Denise Nelson BR&T – Affordability

January 2010

# How to Estimate Costs of Simulation-based Experimentation

Boeing Defense, Space & Security | Phantom Works 

## ■ Problem

- Need to estimate the cost of simulation-based experimentation
  - Accurately
  - Consistent approach
  - Easy to use
  - Defendable estimates
  - Value-added

## ■ Solution

- Develop a standard process and toolkit to estimate the cost and schedule of simulation-based experimentation
  - Using standard cost estimating tools
  - Incorporating standard processes
  - Based on historical data



# Outline

Boeing Defense, Space & Security | Phantom Works



- Problem to be addressed
- Simulation-based Experimentation

- In a Nutshell



- Experimentation Cost Estimating
  - Process and Toolkit



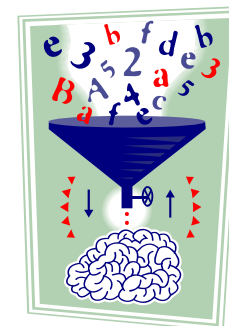
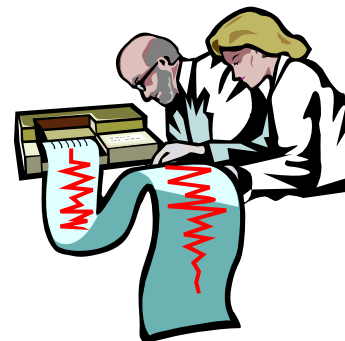
- Implementation in ACEIT
- Demo



# Experimentation

Boeing Defense, Space & Security | Phantom Works 

- Definition of Experimentation \*
  - The process of conducting a test under controlled conditions to
    - demonstrate a known truth,
    - examine the validity of a hypothesis, or
    - determine the efficacy of something previously untried.
  
- Experimentation in general
  - Consists of gathering and examining data
  - Explores and Answers Questions with Analyses and Observations

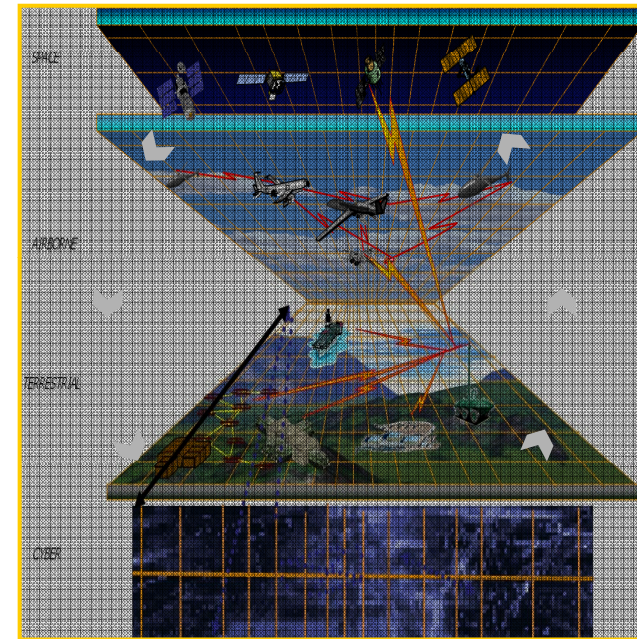
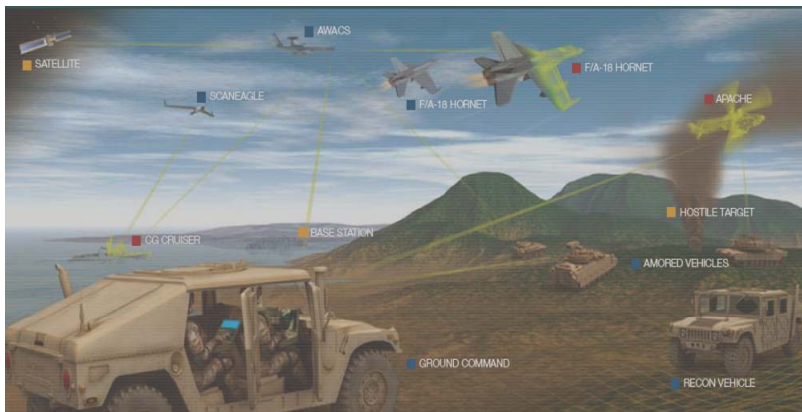


\* [www.thefreedictionary.com](http://www.thefreedictionary.com)

# Simulation-based Experimentation

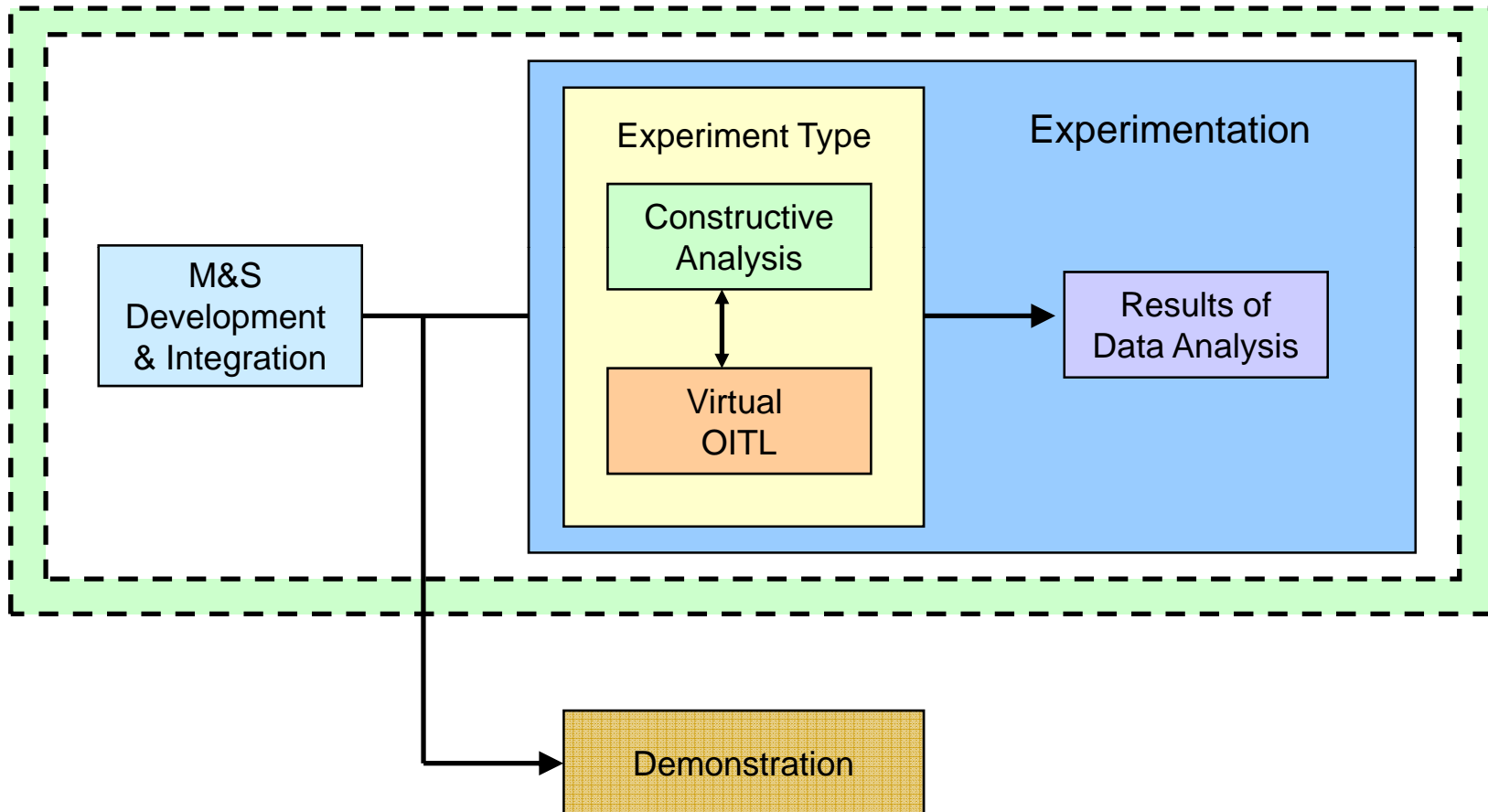
Boeing Defense, Space & Security | Phantom Works 

- Simulation-based Experimentation
  - Conducting experiments with the use of virtual and constructive
    - Models
    - Simulations
    - Visualizations
  - Live-Virtual-Constructive (LVC) Components
    - Live : Real people operating real systems
    - Virtual : Real people operating simulated systems
    - Constructive : Automated systems simulating the actions of people and systems



# Focus of Experimentation Data Collection

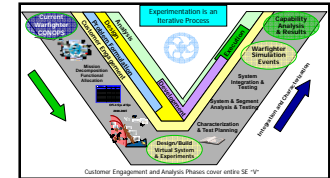
Boeing Defense, Space & Security | Phantom Works 



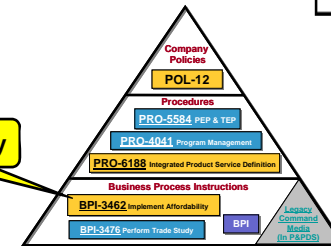
# Proposed Solution

Boeing Defense, Space & Security | Phantom Works 

- Develop a cost estimating toolkit that is
  - Easy to use
    - Excel-like interface / Web-based GUI (future development)
    - Limited inputs required
    - Quick estimates and standard reports produced
  - Incorporates Standard Processes and Terminology
    - Boeing and Industry
    - Experimentation and Cost Estimating
  - Based on comprehensive, historical Boeing data
    - 55 completed experimentation projects: cost and scope data
    - Multiple sites, organizations, project type and scope
  - Value-added to the users
    - Not just *another* task to do



Affordability



# Experimentation Estimating Process

Boeing Defense, Space & Security | Phantom Works



## ■ Five Step Iterative Process

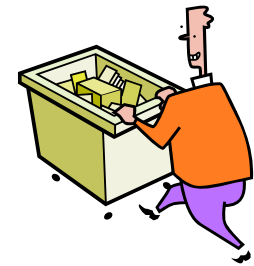
### – Identify

- Identify past, current, and future Experimentation projects



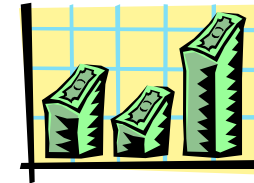
### – Collect

- Interview Project leads for scope and cost data (pre and post project)
- Maintain & Update database of Experimentation projects



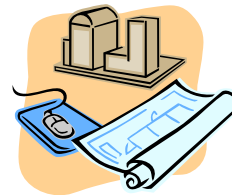
### – Analyze

- Perform Statistical Analysis
- Determine relation between cost/schedule and predictors
- Validate and Calibrate



### – Model

- Develop cost estimating model
- Create standard report templates



### – Estimate

- Cost of new projects using CostX model (pre-project)





# Process: Identify & Collect Project Data

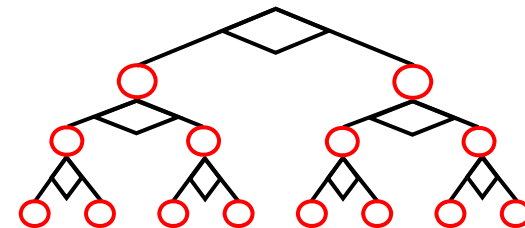
- 55 Completed Projects
  - 31 in work – to be collected
- Various project types
  - M&S development & integration
  - Constructive Analysis
  - Virtual OITL simulations
- Multiple organizations
  - Across Boeing
- Leverage reuse
  - Simulations
  - Environment
  - Team Management
  - Data / Analysis
- Scope & Complexity
  - Short to long range duration
  - Simple to Complex simulations and integration

	Proj Info	Complexity			Execution		Cost/Sched			
Project ID	POC	Type	Num Sys	VCL	Num MOEs	Num Sites	Mths	Cost (\$K)	POP	
a1	John Smith	Modeling	5	C	0	1	4	\$ 90	4Q 2008	
a2	Pocahontas	Analysis	12	C	4	2	10	\$ 450	mar 07- dec 07	
a3		Reusability							Team	
Project ID	Modeling	Tool Developmt	Tool Integration	Environment	Programatic	Data Collection	Analysis Results	Individual Experience	Team Dynamics	
a4										
a5	a1	B	B	E+	A	A	B	A	E	E
a6	a2	C	A	B-	B	B	C	B-	B+	B
	a3	E	B	A	A	E	E	C	C	D
	a4	C	C	A	E	D	A	B	D	E
	a5	B	B	A	B	A	B	A	A	B
	a6	E	B	E	B	D	E	D	B	B

# Process: Statistical Analysis

Boeing Defense, Space & Security | Phantom Works 

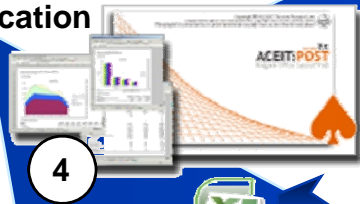
- Database constantly changing
  - Baselined database (configuration control)
  - To be updated 2 times per year
- Statistical Analysis
  - Current approach: Random Forests due to small number of data points and large number of potential predictors
  - Optional approach: Linear / Multivariate Regression
  - Issue with data
    - Lots of qualitative (categorical) data
    - Relatively small dataset
- Random Forests simulate multiple decision trees
  - Results in a cost number
  - Not a parametric equation



# Process: Model & Estimate

Boeing Defense, Space & Security | Phantom Works 

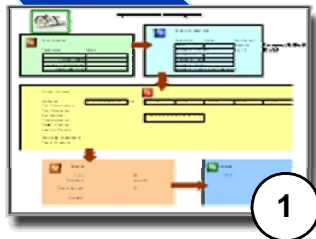
User extracts various POST reports and/or ACE returns total estimate to web application



Excel Plug-in



Estimator enters parameters via user-friendly web based application



Excel Plug-in



Parameters are sent to server hosted ACEIT tool via ACE-Excel plug-in

Excel Plug-in



ACE calls 'R' for Random Forest Statistics  
R returns expected value to ACE

# Cost-X User Interface Prototype

Boeing Defense, Space & Security | Phantom Works



### 1 IDENTIFICATION

**Point of Contact:** Karen  
**Project Name:** sample1

**Period of Performance Start:** 01 MM 09 YY  
**End:** 07 MM 09 YY

**Labor Site Allocations:**

User Defined: 35%

Allocations Set	
New Mexico	- 65%
User Defined	- 35%

### 2 PROJECT SCOPE

**Type:** Constructive Analysis

**Number of Systems:** 1-9 (selected), 10-19, 20-29, 30-39, 40+

**LVC Distribution:** CV - Most Constructive, Some Virtual

**Number of MOEs:** 3

**Number Sites During Experiment:** 2

**ANALOGOUS PROGRAM (If Any)**

Please Select any Analogous Programs...  
 Program 3

### 3 REUSE FACTORS

**Modeling**

[Tool Development](#)

[Tool Integration](#)

[Environment](#)

[Programmatics](#)

[Data Collection](#)

[Analysis Results](#)

---

[Individual Experience](#)

[Team Dynamics](#)

GRADE:	Help:
A: Minimal New Development	?
A: Minimal New Development	?
B: Limited New Development	?
C: Some New Development	?
D: Majority New Development	?
D: Majority New Development	?
E: All New Development	?

### 4 RESULTS

**Cost:** \$5.00

**Schedule:** 7 mos

**Reuse Savings:** \$2.00

**Drivers:** ???

**Generate & View Report**

**Export File**

Filename...

# ACE Import Data Sheet

		Cost or Non-cost
WBS/CES Description	Link ID	Total
<b>Identification</b>		
Point of Contact	POC	Karen
Project Name	ProjName	10_Karen_Test
Start Date (MMYY)	Start_Dt	01Jan2010
End Date (MMYY)	End_Dt	30Mar2010
<b>Labor Data</b>		
Main Labor Rate	Labor_Rt	150
Main Labor Site	Labor_Site	HB
<b>Scope Data</b>		
Type of Project	Proj_Type	Constr Analysis
LVC Category	LVC_Type	C
Number of Unique Systems	Systems_N	1 < 9
Number of MOEs	MOE_N	4
Number of Sites During Execution	Sites_N	2
<b>Analogous Project</b>		
Analogous Project	Proj_Base	09KarenTest
<b>ReUse Factors</b>		
Modeling	Model_ReF	B
Tool Development	Tool_ReF	A
Tool Integration	Int_ReF	B
Environment	Env_ReF	D
Programmatics	PM_ReF	C
Data Collection	Data_ReF	E
Analysis Results	Analysis_ReF	A
Individual Experience	Exp_ReF	B
Team Dynamics	Team_ReF	C

- Data from Excel User Interface linked to ACE Import Data Sheet
- Excel-ACE Plug-in loads data from Import Data sheet into ACE session

# ACE Import Data Sheet

	WBS/CES Description	EXCEL_ELEMENT_EXTERNAL_COD	EXCEL_TNC (!) Total (Non-Cost)
230	Identification		
231	* Point of Contact	POC	Karen
232	* Project Name	ProjName	10_Karen_Test
233	Start Date (MMYY)	Start_Dt	01Jan2010
234	End Date (MMYY)	End_Dt	30Mar2010
235			
236	Labor Data		
237	Main Labor Rate	Labor_Rt	150
238	* Main Labor Site	Labor_Site	HB
239			
240	Scope Data		
241	* Type of Project	Proj_Type	Constr Analysis
242	LVC Category	LVC_Type	C
243	Number of Unique Systems	Systems_N	1 < 9
244	Number of MOEs	MOE_N	4
245	Number of Sites During Execution	Sites_N	2
246			
247	* Analogous Project	Proj_Base	09KarenTest
248			
249	ReUse Factors		
250	Modeling	Model_ReF	B
251	Tool Development	Tool_ReF	A
252	Tool Integration	Int_ReF	B
253	Environment	Env_ReF	D
254	Programmatics	PM_ReF	C
255	Data Collection	Data_ReF	E
256	Analysis Results	Analysis_ReF	A
257	Individual Experience	Exp_ReF	B

- Excel-ACE Plug-in loads data from Import Data sheet into ACE session
- Values stored in Excel\_TNC field



WBS/CES Description	EXCEL_ELEMENT_EXTERNAL_COD	EXCEL_TNC (!) Total (Non-Cost)	EX
Identification			(
* Point of Contact	POC	Karen	(
* Project Name	ProjName	10_Karen_Test	(
Start Date (MMYY)	Start_Dt	01Jan2010	(
End Date (MMYY)	End_Dt	30Mar2010	(
			(
Labor Data			(
Main Labor Rate	Labor_Rt	150	(
* Main Labor Site	Labor_Site	HB	(
			(

# ACE Model Inputs

WBS/CES Description	Unique ID	Equation / Throughput	Point Estimate
<b>*User Inputs</b>			
<b>*Identification</b>			
*POC	POC		
*Project Name	Proj_Name		
<b>*Period of Performance</b>			
Start Date	ST_DT	XL_Start_Dt.EXCEL_TNC	01JAN2010 *
End Date	END_DT	XL_End_Dt.EXCEL_TNC	30MAR2010 *
Main Site or Org Rate	Hourly_RT	XL_Labor_Rt.EXCEL_TNC	150.000 *
<b>*Scope Parameters</b>			
*Type of project	Proj_Type		MS
*LVC	LVC		CA
Number of Systems	Sys_N	XL_Systems_N.EXCEL_TNC	1.000 *
Number of MOEs	MOE_N	XL_MOE_N.EXCEL_TNC	4.000 *
Number of Sites	Sites_N	XL_Sites_N.EXCEL_TNC	2.000 *
Analogous Project Code	Ana_Proj		A1
Database	DB	Database1	1.000 *
<b>*Reuse Grades</b>			
Modeling	Mod_RU	XL_Model_ReF.EXCEL_TNC	2.000 *
Tool Development	Tool_RU	XL_Tool_ReF.EXCEL_TNC	1.000 *
Tool Integration	Int_RU	XL_Int_ReF.EXCEL_TNC	2.000 *
Environment	Env_RU	XL_Env_ReF.EXCEL_TNC	4.000 *
Programmatics	Prog_RU	XL_PM_ReF.EXCEL_TNC	3.000 *
Data Collection	Data_RU	XL_Data_ReF.EXCEL_TNC	5.000 *
Analysis Results	Ana_RU	XL_Analysis_ReF.EXCEL_TNC	1.000 *

- Equation calls Excel-Ace Template Parameters (EXCEL\_TNC)
- Labor Rates stored in model

WBS/CES Description	Unique ID	Equation / Throughput	Point Estimate
<b>*Global inputs</b>			
<b>*Labor Rates Updated Ar</b>			
Avg Hourly Rate	Average_RT	140	140.000 *
BR&T	BRT_RT	200	200.000 *
St Louis	StL_RT	190	190.000 *
California	CA_RT	180	180.000 *
Philly	Phil_RT	170	170.000 *
Arizona	AZ_RT	160	160.000 *
Washington State	Wa_RT	150	150.000 *
Kansas	Ka_RT	70	70.000 *

# ACE Model Results

WBS/CES Description	Unique ID	Equation / Throughput	Point Estimate
*Estimate Outputs and su			
Project Estimate	AE_ \$	MatVal(@EstimateM, Ana_Proj, 1)	97.000 *
Reuse Factor	RU_F	(Mod_F*Mod_WT/WtSum+Tool_F*To	0.880 *
Expected EP	EP	BLE_ \$*1000/(Hourly_RT*HRS_MTH*S	0.889 *
Expected Schedule	Sched_M	MatVal(@ScheduleM, Ana_Proj, 1)	4.000 *
Reuse Percent	Save_Pct	1-RU_F	0.120 *
Reuse benefit/Savings (\$k	Save_ \$	AE_ \$-BLE_ \$	\$ 11.657 *
<b>Baseline Estimate</b>	<b>BLE_ \$</b>	<b>AE_ \$*RU_F</b>	<b>\$ 85.343 *</b>

Baseline estimate



ReUse Adjustment



Adjusted estimate

- POST customized reports generation in progress

- Current results limited to
  - Estimate
  - Schedule
  - Reuse Savings/penalties



# ACE Model Lookup Tables

WBS/CES Description	Unique ID	Equation / Throughput	Point Estimate
<b>*Factor Lookup</b>			
Modeling	Mod_F	MatVal(@FactorM, 1, Mod_RU)	0.250 *
Tool Development	Tool_F	MatVal(@FactorM, 2, Tool_RU)	1.000 *
Tool Integration	Int_F	MatVal(@FactorM, 3, Int_RU)	0.400 *
Environment	Env_F	MatVal(@FactorM, 4, Env_RU)	1.250 *
Programmatics	Prog_F	MatVal(@FactorM, 5, Prog_RU)	1.000 *
Data Collection	Data_F	MatVal(@FactorM, 6, Data_RU)	1.400 *
Analysis Results	Ana_F	MatVal(@FactorM, 7, Ana_RU)	0.800 *

- Reuse data determines cost savings/penalties
- Reuse adjustment factors stored in matrix format
  - A ~ Cost Savings
  - E ~ Cost Penalties

WBS/CES Description	Unique ID	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	F
<b>* ReUse Factor Matrix Headers</b>		<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>	
<b>Reuse Factors Matrix</b>	<b>FactorM</b>						
Modeling		.1	.25	.5	.75	1.1	
Tool Development		1.0	1.1	1.3	1.6	1.8	
Tool Integration		.1	.4	1.0	1.1	1.3	
Environment		.2	1.0	1.1	1.25	1.4	
Programmatics		.75	.85	1.0	1.1	1.2	
Data Collection		.8	.9	1.0	1.2	1.4	
Analysis Results		.8	.9	1.0	1.1	1.2	

# Next Steps for 2010

Boeing Defense, Space & Security | Phantom Works



- Collect new data
  - Update database
- Analyze additional data
  - Update cost estimating relation
- Develop Web-based User Front End