Analysis, Modeling, Simulation and Experimentation

Experimentation Estimating Toolkit

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January 2008

Agenda

- **Overview of Experimentation**
- **Experimentation Estimating Approach**
- **Implementation of ACEIT Model**
- **Lessons Learned**
- **Next Steps**
- **Summary**

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Overview of Experimentation

Experimentation Defined – Part I

- **Definition of Experiment ***
  - A test under controlled conditions that is made to
    - demonstrate a known truth,
    - examine the validity of a hypothesis, or
    - determine the efficacy of something previously untried.
- **Definition of Experimentation ***
  - The process of conducting such a test.

- **Experimentation in general**
  - Consists of gathering and examining data
  - Explores and Answers Questions with Analyses and Observations

* www.thefreedictionary.com

Types of Experimentation

- **Three Main Types of Experiments**
  - Discovery (to understand effects of innovation)
    - Effective Collaboration
    - German Battlespace
  - Hypotheses Testing (if A then B under conditions C)
    - Target Identification & Tracking
    - Information Sharing
  - Technical Demonstrations (to showcase technology, concept, etc)

- **Other Types of Experiments**
  - Wargames & Exercises
  - Seminars / Symposiums / Workshops

Discovery Experiments

- **Effective Collaboration**
  - Discovery Experiment analyzing the question “What makes for effective collaboration?”
  - “how do differences in group structure, communications patterns, work processes, participant intelligence, participant cooperative experiences, and participant expertise affect the quality of collaboration?” *

* Code of Best Practice for Experimentation, Alberts, Hayes, et al., 2002

Historical Discovery Experiments

- **Information / Communications CONOPS**
  - "Perhaps the most famous initial discovery experiments were those conducted by the Germans to explore the tactical use of short range radios before World War II. They mimicked a battlespace (using Volkswagens as tanks) in order to learn about the reliability of the radios and the best way to employ the new communications capabilities and information exchanges among the components of their force."

Code of Best Practice for Experimentation, Alberts, Hayes, et al., 2002

Hypothesis Testing

- **Objective: Investigate camera-only capabilities for identification and tracking**
  - Does tracking software XX provide sufficient target recognition and cueing to be used without radars?
    - Compare camera with tracking software versus camera without tracking software
    - If tracking software used (A)
      - then increased Target Recognition (B)
        - **without radars (C)**

- **Proposition: "information sharing will improve group situation awareness in combat"**
  - IF information sharing occurs,
    - THEN group situation awareness will increase
      - WHEN the subjects are military professionals working in a warfighting context.

Code of Best Practice for Experimentation, Alberts, Hayes, et al., 2002

Experimentation Defined - Part II

- **Experimentation**
  - Contains Variability
    - Demo ~ Broadway Play
      - Scripted event where outcome is always the same
    - Experimentation ~ Baseball Game
      - Outcome is never exactly the same
      - Current tactics are adapted for future games in light of observed outcomes

- **Campaigns of Experimentation**
  - Campaigns of Analyses or Experiments needed to build body of knowledge
  - Iterative Approach based on outcomes of previous experiments and analyses

Campaigns of Experiments

- **Command and Control for Stabilization Operations**
  - Such as ensure security, provide reconstruction and humanitarian assistance, act as peacekeepers and engage in military operations
  - Series of experiments evaluating competing and alternative approaches
    - Explore alternatives identifying strengths, weaknesses, limiting conditions and reduce potential approaches to most promising
    - Analyze final candidates under more realistic environments and identify best-value approach
    - Develop demonstration of best-value approach for specific operational environments
  - Purpose of campaign is to convince user community selected approach is the better candidate and to provide venue for user community to critique and improve approach

Campaigns of Experimentation, Alberts, Hayes, et al., 2006

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Experimentation Estimating Approach

Why are we doing this?

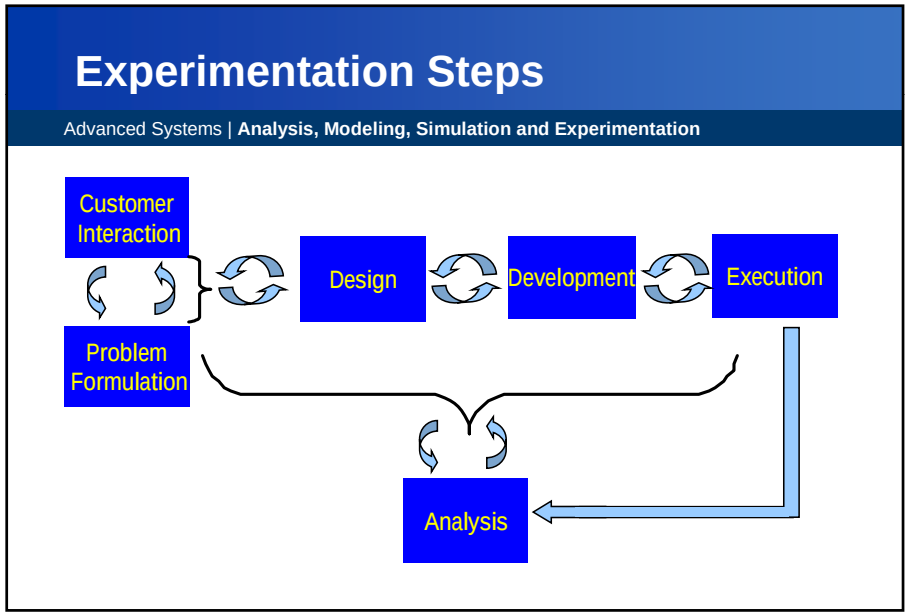
- **Each experiment is unique**
  - Different objectives, tasks, scope, domains, maturity, models, operators, personnel, etc
- **Standard method of estimating needed**
  - Define Experimentation cost drivers to be as minimally subjective as possible
    - System complexity-
      - defines number of various interactions between the systems and/or subsystems (or Platforms, SoSs etc)
      - Experimentation Type: Constructive/Virtual/Live
    - Leverage from previous efforts: re-design and new-design of work products
  - Properly capture data from future efforts to better refine estimating relationships

General Approach

- **Development Approach**
  - Establish generic WBS for Experimentation efforts
  - Develop Interview Process and Collect Data
  - Perform Statistical Analysis on Normalized data
  - Generate Cost Estimating Relationships (CERs)
  - Design and Implement estimating Model
- **Next Phase: Collect and analyze future data points**
  - Record labor data to distinguish time spent on each project/event
  - Collect information immediately at end of scheduled effort/phase
  - Update/calibrate model with new data points throughout the year
  - Train Project Leaders/Estimators on the estimating tools as a standard to validate (and generate) future estimates

Establish Generic WBS

- **Six general phases of Experimentation***
  - Discovery (Customer Interaction)
    - Understand customer needs and issues
  - Problem Formulation
    - Identify and Scope problem
  - Experiment Design
    - Decompose problem
  - Experiment Development
    - Build, Implement, Test & Verify
  - Experiment Execution
    - Conduct the Experiment
  - Analysis
    - Analyze data and interpret results



* From Guide for Understanding and Implementing Defense Experimentation GUIDEx, 2006

Representative Tasks in Each Phase

- **Discovery (Customer Interaction)**
  - Understanding the needs of the customer and capability gaps
- **Problem Formulation (Preliminary)**
  - Preliminary identification of problem
  - High level Plan of Action
- **Design (Refinement)**
  - Detailed design and planning of the experiment
    - Refined Experimentation Objective / Propositions / CONOPS
    - M&S Requirements (tools, scenarios)
    - Data, MOEs/MOPs, Analysis Planning
    - Architecture Products
    - Detailed Plans : Experimentation , Analysis, Communication and Training

Representative Tasks in Each Phase

- **Development (Implementation)**
  - Development & Integration of Mod&Sim Scenarios, Tools
  - Analysis of Metrics to ensure Experiment Questions are answerable
  - Training of Operators, Observers, & other Participants
- **Execution (Conduct)**
  - Conduct of the Experiment
  - Data Collection
- **Analysis (Assessment)**
  - Pre-Experiment Analysis Planning
    - Metrics, Data Generation, Transmission, Reduction, Collection, Analysis
  - Post-Experiment Reduction and analysis of the experiment data
  - Interpretation and documentation of results

Data Collection & Interview Process

- **First Attempt**
  - Asked “How much did it cost?”
    - Total and by phase, with schedule data
    - Provided detailed tasks for assistance
  - Result
    - Too much variability in scope and type of effort
    - No consistency in data or data format
- **Second Attempt**
  - Developed Interview Questionnaire to scope effort
    - Start/Stop work for given interval of work
    - Clearly defined questions and examples to guide the interviewee
  - Result
    - Consistent data format
    - Better defined scope and definitions
    - 22 completed Data Points plus 11 In-work efforts

Questionnaire Ground Rules

- **Data Point Defined Scope**
  - Schedule Start/Stop to distinguish “follow-on work” start times
  - Actuals/Budget of identified time interval
  - Actuals/Budgets/Tools/Personnel questions only refer to the primary work group under the supervision and control of the project lead (unless otherwise noted)
- **Data not captured**
  - Standard/indirect cost that would be spent regardless of the effort in question
    - Software licenses/maintenance
    - Hardware and facility upgrades
    - Training

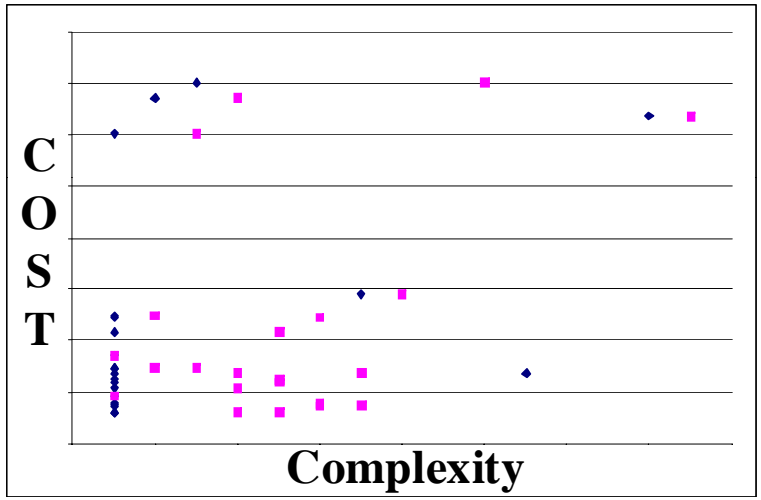
Questionnaire Focus

- **Experiment/System Complexity**
  - Number of interacting Classes/
  - Constructive, Virtual, Live
- **Tools/Models/Simulations**
  - Existing, Integrate As-is
  - Existing Modified
  - Newly Developed
- **Leverage from previous work**
- **Number of MOEs/MOPs**
  - Delivered/Calculated
- **Customer Involvement**
- **Integration**
- **Actuals/Budget $K**
- **Actual/Scheduled Months**
- **Man Months (EP)**
  - Developers/System Engineers and Designers
  - SME and PM
- **Other Costs**
  - HW/SW tools and licensing*
  - Training* and Travel
- **Security Level**
- **Special notes of interest**

*Costs above and beyond team's expected annual expenditures

Data Analysis

- **Minor trends and correlations noticed**
  - but no “statistical significance” calculated
- **Percent breakouts for PM/SME/etc. look promising**
- **Possible data nuances:**
  - Project actuals ($K , schedule, EP) vs. estimates
  - Regression on Qualitative Data
  - Subjective data
  - Limited data
  - Cost driver assumptions
- **Refinement of questions for future data collection is required**



All data is notional only

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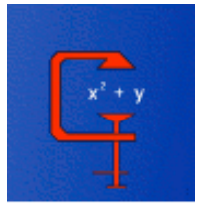
Implementation of ACEIT Model

Model Design and Development

- **Evaluated various tools**
  - Excel Based Customized Tools
    - Need to be developed
  - DesignSheet Tool
    - Not user friendly
    - Needs to be developed
- **ACEIT Selected**
  - Versatility to add/reconfigure body of model
  - Post Reports
    - Automated reports
    - Drill down Capability in Reports
  - Excel to ACEIT Capability
    - Input and extracting data in model
    - Possible GUI interface
  - Risk Capabilities
  - Inflation/Learning

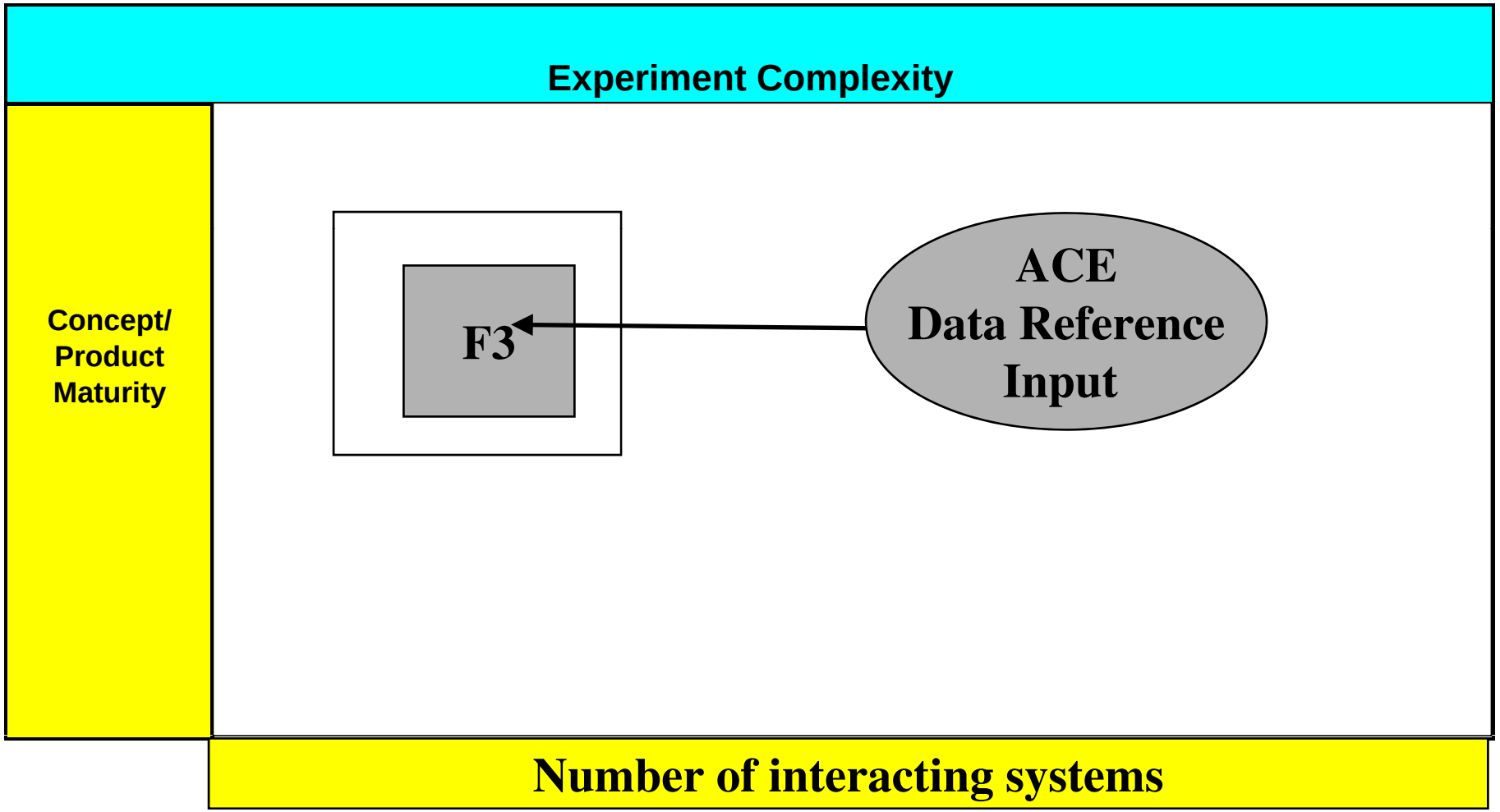


ACEIT
Automated Cost Estimating Integrated Tools

Model Inputs

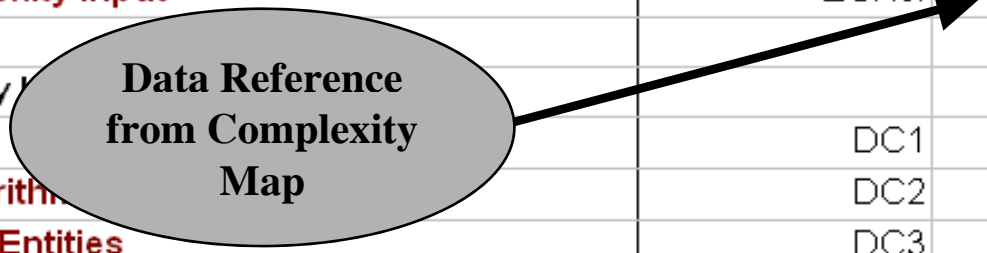
- **Experiment Complexity**
  - System Complexity (Approximate number of different types of interactions)
  - Experiment Type (Constructive Virtual Live)
  - Phase/Concept Maturity
- **Design Complexity**
  - Reuse/Redesign/Leverage from previous work
- **Integration Complexity**
  - Number of different tools used
  - Number of sites
  - Security
- **Other Drivers TBD**

Experiment Complexity - Determines Analog Data



User Inputs (in Red)

	WBS/CES Description	Unique ID	Equation / Throughput
16	*User Inputs		
17	Experiment Complexity Input	ECRef	F3
18			
19	*Design Complexity I		
20	New ESLOC	DC1	5
21	New Modules/Algorithi	DC2	4
22	Added Complexity/Entities	DC3	7
23	Briefings/schedule and other PM products	DC4	2
24	Customer Involvement/History	DC5	1
25			
26			
27	*Integration Complexity Inputs		
28	Number of different tools used Tool Suite by host team	IC1	5
29	Number of different tools used Tool Suite by other teams	IC2	3
30	Number of sites for Development	IC3	2
31	Number of sites for Main Event	IC4	4
32	Security Level (rate 1-7)	IC5	1
33			



All data is notional only

ACE Data Reference

- **Looks up Average Expected Cost based on data that fits the given Complexity Rating**

	WBS/CES Description	Unique ID	Equation / Throughput
16	*User Inputs		
17	Experiment Complexity Input	ECRef	F3
18			
19	*Design Complexity Inputs (rate 1-7)		
20	New ESLOC	DC1	5

	WBS/CES Description	Unique ID	Equation / Throughput	Point Estimate
341	F3 ROM	F3	F3$KperMo*F	55,600.000 *
345				
346				
347	F3 Average Cost Per Month	F3$KperMo	11120	11,120.000 *
348	F3 Average Months	F3Mo	5	5.000 *
349				

Data Reference Value

All data is notional only

User Inputs (in Red)

	WBS/CES Description	Unique ID	Equation / Throughput
16	*User Inputs		
17	Experiment Complexity Input	ECRef	F3
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25			
26			
27	*Integration		
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29	Number of different tools uite by other teams	IC2	3
30	Number of sites for Development	IC3	2
31	Number of sites for Main Event	IC4	4
32	Security Level (rate 1-7)	IC5	1
33			

Based off look up Descriptors, user enters level of complexity for various drivers

All data is notional only

Design Complexity Look-up Values

	WBS/CES Description	Unique ID	Equation / Throughput
16	*User Inputs		
17	**Experiment Complexity Input**	ECRef	F3
18			
19	***Design Complexity Inputs (rate 1-7)**		
20	**New ESLOC**	DC1	5
		DC2	4
		DC3	7
		DC4	2
		DC5	1
		IC1	5
		IC2	3
		IC3	2
		IC4	4
		IC5	1

Design Complexity for Effective Software Lines of Code (ESLOC) ESLOC = New SLOC equivelent (includes New Code and a discounted Code count based on redesign of existing code)	**Rating**
Does not require any new coding nor any redesign of existing software No changes needed	**1**
Minor adjustements to code, <5% change from original	**2**
Moderate adjustements to code, might include new code <20% change from original	**3**
Signifigant adjustements to code, includes some new code ~35% change from original	**4**
Major adjustements to code, signifigant new code required ~50% change from original	**5**
Major adjustements to code, more than half is new code >75% change from original state	**6**
No existing Code exists, need to be newly developed 100% New Design	**7**

Design Complexity Factor

	WBS/CES Description	Unique ID	Equation / Throughput
16	*User Inputs		
17	**Experiment Complexity Input**	ECRef	F3
18			
19	***Design Complexity Inputs (rate 1-7)**		
20	**New ESLOC**	DC1	5
21	**New Modules/Algorithms**	DC2	4
22	**Added Complexity/Entities**	DC3	7
23	**Briefings/schedule and other PM products**	DC4	2
24	**Customer Involvement/History**	DC5	1

		Design Complexity Factors						
Cost Driver Weights	DCX=	1	2	3	4	5	6	7
0.5	New ESLOC	0.1	0.25	0.5	0.8	1	1.3	1.5
0.3	New Modules/Algorithms	0.3	0.2	0.35	0.5	1	1.1	1.2
0.1	Added Complexity/Entities	0.1	0.25	0.5	0.8	0.9	1	1.1
0.05	Briefings/schedule and other PM products	0.1	0.25	0.5	0.75	1	1.5	2
0.05	Customer Involvement/History	0.25	0.5	0.75	1	1.1	1.25	1.5

Design Complexity Rating = (.5*1+.3*.5+.1*1.1+.05*.25+.05*1) **=.82**

Design Complexity Look-up Function

Advanced Systems | **Analysis, Modeling, Simulation and Experimentation**

	WBS/CES Description	Unique ID	Equation / Throughput
16	*User Inputs		
17	Experiment Complexity Input	ECRef	F3
18			
19	*Design Com		
20	New ESLOC		
21	New Modules		
22	Added Comp		
23	Briefings/sch		

49	*Design C	
50	New ESLC	
51	New Modu	

Design Complexity Rating =
.5*MatVal(@M_DCMPLX, 1, DC1) +
.3*MatVal(@M_DCMPLX, 2, DC2) +
.1*MatVal(@M_DCMPLX, 3, DC3) +
.05*MatVal(@M_DCMPLX, 4, DC4) +
.05*MatVal(@M_DCMPLX, 5, DC5) **= .82**

									2014
372									
373	*M_DCPLX								Factor7
374	MTX Design Complex								
375	New ESLOC		.1	.25	.5	.8	1	1.3	1.5
376	New Modules/Algorithms		.3	.2	.35	.5	1	1.1	1.2
377	Added Complexity/Entities		.1	.25	.5	.8	.9	1	1.1
378	Briefings/schedule and other PM products		.1	.25	.5	.75	1	1.5	2
379	Customer Involvement/History		.25	.5	.75	1	1.1	1.25	1.5
380									

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Model Outputs

- **Cost**
  - EP hours
    - Developers/SE
    - PM
    - SME
  - SW/HW, Training and Travel
  - % cost for CVL
- **Expected Schedule (months)**
  - Schedule Scrunched/Expanded costs
- **Risk Assessment**
- **Experiment Event Metrics**
  - EP to run experiment (body count)
  - Days
- **GUI interfaces**

	WBS/CES Description	Point Estimate
52	*Estimator Outputs	
53	Total Estimated Costs	55,600.000 *
54	Primary Team's Expected Hours	400.000 *
55	Developers/SE and Event costs	280.000 *
56	Project Management	80.000 *
57	Subject Matter Expertise	40.000 *
58	Hardware/Software/Training and Travel	20,000.000 *
59		
60	Expected/Optimal Schedule Months	4.000 *
61		
62	Percent Cost spent on Constructive Efforts	0.800 *
63	Percent Cost spent on Virtual Efforts	0.200 *
64	Percent Cost spent on Live Efforts	0.000 *
65		
66	*Experiment Event Metrics	
67	EP to run experiment (body count)	1.500 *
68	Hours projected for Event	60.000 *
69		
70	Cost by WBS	55,600.000 *
71	Discovery (Customer Interac	5,560.000 *
72	Problem Formulati	0.000 *
73	Design (Refin	0 *
74	Developme	
75	Execution	
76	Analysis (A	
77		

Phase 2 Implementation

All data is notional only

Analysis, Modeling, Simulation and Experimentation

Lessons Learned

Lessons Learned

- **Different Languages**
  - COBP-X/GuideX/Boeing
  - Tool/Model/Simulation
  - Processes
  - Phases

- **Different Opinions**
  - Naysayers
  - Enthusiasts

Next Steps

Next Steps

- **Refine time charging to better capture future efforts**
- **Resonate the modeling inputs and techniques to project leaders and estimators**
  - Use model to plan projects initially
  - Collect data at end of projects
- **Refine/verify collected data and assumptions**
- **Continue to collect data**
- **Calibrate/refine Model with new data**
- **Mature and refine model in conjunction with SMEs to better represent and define cost drivers and level of detail**

Summary

Summary

- **Experimentation**
  - Helps to assess concepts and technologies, causes and effects, and/or conclusions
  - Explores and Answers Questions with Analyses and Observations
  - Is not a scripted Demo
- **Developed standard method of cost estimation**
  - Each experiment unique
- **Experimentation WBS separated into six phases**
- **Data Collection and Comprehension the biggest task**
- **Implemented Model in ACEIT**
- **Biggest Lesson Learned : Need for common language**
- **Next Steps : Refine and Mature Model and Data Collection/Analysis**