estimate

estimate • analyze • plan • control

Addressing the Challenges of Systems Engineering Estimation

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SEER by GALORATH

ABSTRACT

Cost is a crucial factor in evaluating the viability of a project prior to its implementation.

Though there are many factors that go into the overall cost of a project, we know that we can reduce costs through the front loading of systems engineering efforts.

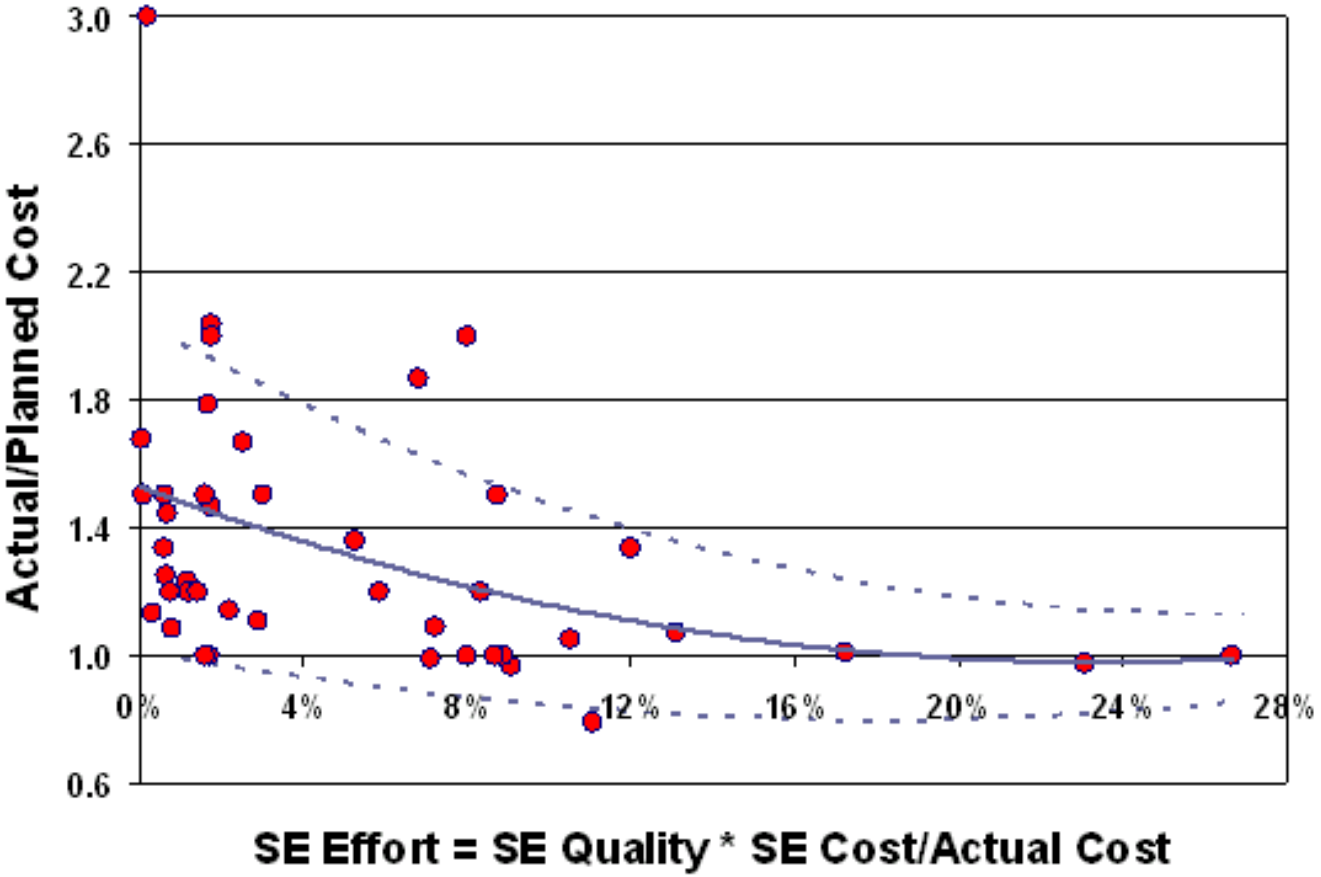
SEER-SYS (SEER for Systems Engineering) is a robust modeling environment that assists users in being able to make better upfront decisions regarding the systems engineering of a project.

This presentation will discuss:

- Issues and problems regarding systems engineering estimation seen by our user base
- Gaining a better understanding of systems engineering costs
- The background and research that has gone into development

Why estimate systems engineering effort?

Research has shown that adequate SE effort on the frontend leads to a lower likelihood of cost overruns



Honour, E.C., "Understanding the Value of Systems Engineering," *Proceedings of the INCOSE International Symposium, Toulouse, France, 2004.*

The Systems Engineering Estimating Conundrum

- Systems Engineering can be reasonably estimated as a percentage of contractor and/or subsystem costs.
- This is sometimes called a ‘tax’ model
  - SEER-H System Level Cost model uses this approach
- The tax approach requires a potentially time consuming estimate – often based on an assumed design approach before systems engineering effort can be estimated
- This fueled demand for a standalone, organic systems engineering estimation capability

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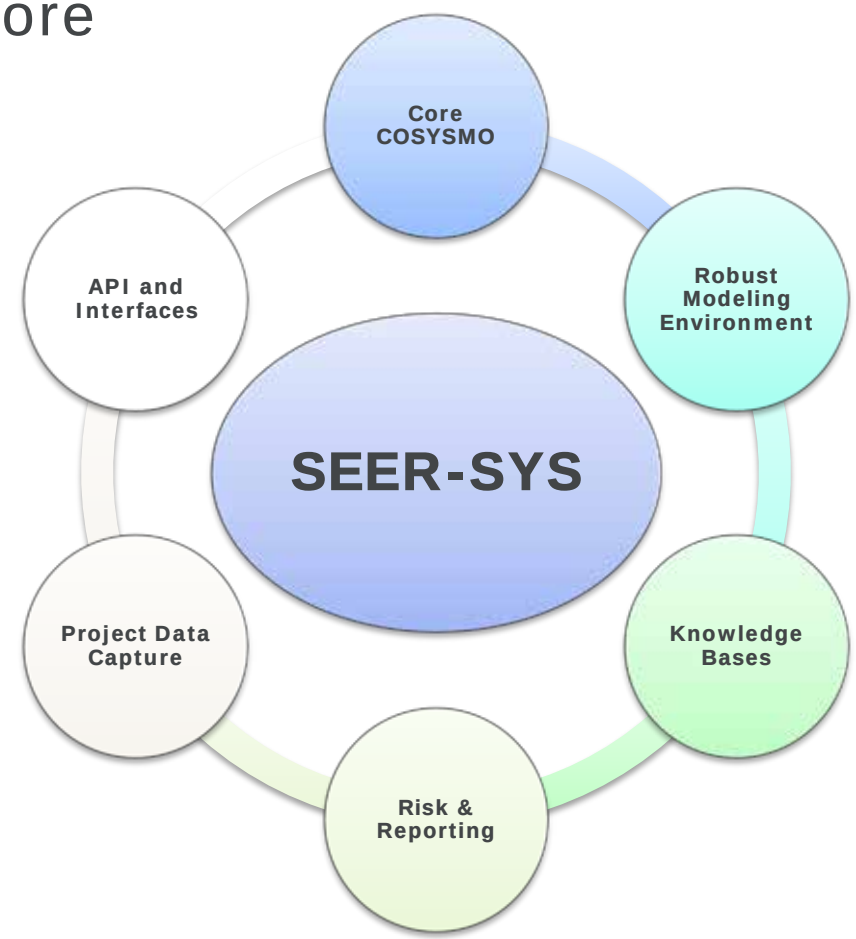
What is SEER-SYS?

- Shorthand name for SEER for Systems Engineering
- Offers the core COSYSMO systems engineering model and much more



SEER-SYS Value Added

- Stand alone parametric estimation model for Systems Engineering costs. Complementary to SEER-H System Level Cost capability
- Includes costs for Acquisition and Supply, Technical Management, System Design, Product realization, Technical Evaluation
- Research based on Galorath Systems Engineering research and COSYSMO data. Validated in the field with 3+ years of customer collaboration.
- Model can estimate at System of Systems level down to box level systems costs.
- Includes Knowledge Bases which help to preset its parameters to commonly validated ranges.

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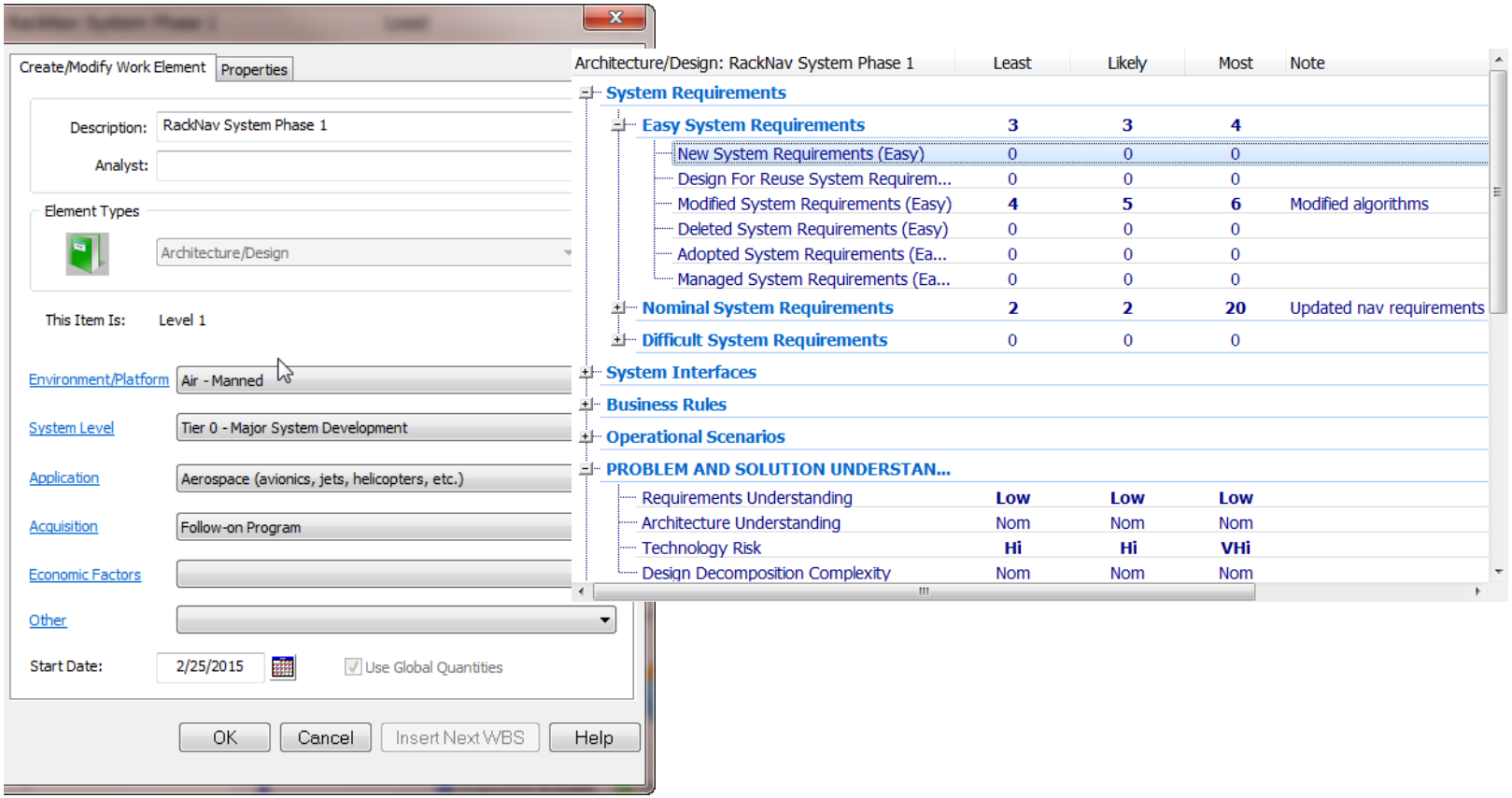
SEER-SYS

- Standalone Systems Engineering Estimates



Built In Risk with Monte Carlo

SEER by GALORATH

Parameters | Schedule | Economic Factors

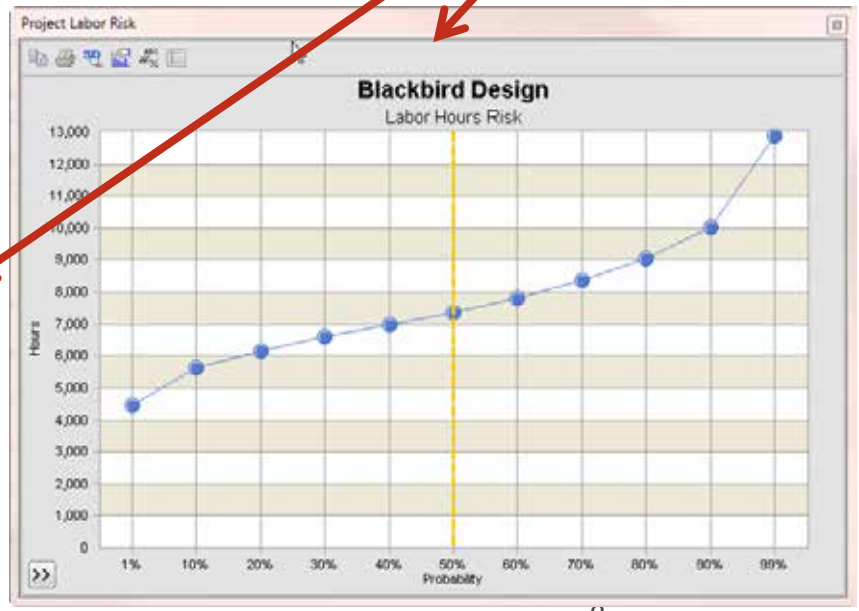
Architecture/Design: Blackbird Design	Least	Likely	Most	Note
PROBLEM AND SOLUTION UNDERSTANDING				
Requirements Understanding	Nom	**Nom+**	**Hi-**	
Architecture Understanding	Nom	**Nom+**	**Hi-**	
Technology Risk	**VLo+**	**Low-**	**Low**	
Design Decomposition Complexity	**VLo**	**VLo+**	**Low-**	
PRODUCT AND SYSTEM COMPLEXITY				
Complexity of Performance Measures	**Low**	**Low+**	**Nom-**	
Migration Complexity	Nom	Nom	**Nom+**	
Documentation Level	**Hi**	**Hi+**	**VHi-**	
Installations/Platforms Diversity	Nom	Nom	**Nom+**	
PERSONNEL AND TEAM CAPABILITIES				
Stakeholder Team Cohesion	Nom	**Nom+**	**Hi-**	
Personnel and Team Capabilities	Nom	Nom	Nom	
Personnel Experience/Continuity	**Hi-**	**Hi**	**Hi+**	
DEVELOPMENT AND PRODUCTIVITY AIDS				
Process Capability	Nom	Nom	Nom	
Multisite Coordination	**Hi+**	**VHi-**	**VHi**	
Tool Support	**Nom-**	Nom	**Nom+**	

Descriptive inputs drive effort, cost and schedule estimates

Quick Estimate | **Phased Activity** | Labor Category Cost By Activity | Cost By Fiscal Ye

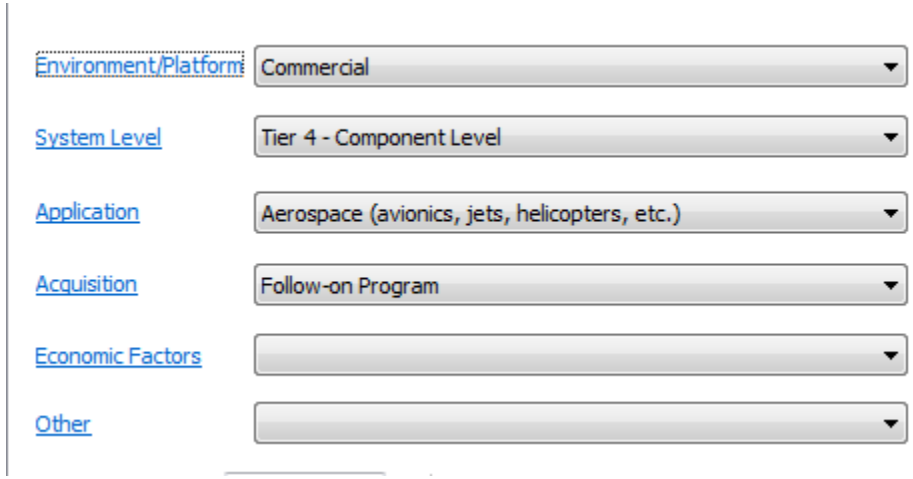
ACTIVITY	SCHEDULE MONTHS	HOURS	LABOR COST	MATE
Acquisition & Supply	1.63	515	79,385	
Technical Management	2.40	1,251	194,712	
Procurement	0.00	0	0	
System Design	2.97	2,208	343,610	
Product Realization	2.30	1,104	171,805	
Technical Evaluation	3.03	2,281	349,294	
Not Used	0.00	0	0	
Other	0.00	0	0	
Project Total	*12.00*	*7,359*	*1,138,806*	
Ongoing Support	0.00	0	0	
Total	12.00	7,359	1,138,806	

Currency Code: USD
Base Year: 2015
Exchange Rate: 1.00000



SEER-SYS Knowledge Bases

Four Kbase Categories included to provide default parameter settings



Environment/Platform

- !No Knowledge
- Air - Manned
- Air - Unmanned
- Commercial
- Ground
- Industrial
- Sea
- Space - Manned
- Space - Unmanned

Application

- !No Knowledge
- Aerospace (avionics, jets, helicopters, etc.)
- Automotive
- Data Systems/Information Technology
- Manufacturing
- Military/Defense (tanks, missiles, etc.)
- Scientific/Research
- Space Systems
- Telecommunications
- Transportation

System Level

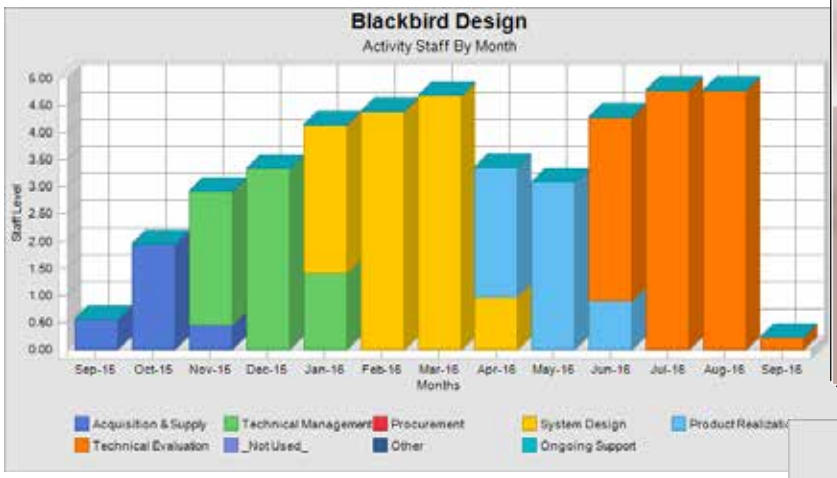
- !No Knowledge
- System-of-Systems (SoS)
- Tier 0 - Major System Development
- Tier 1 - Major Subsystem
- Tier 2 - Minor Subsystem
- Tier 3 - Line Replaceable Unit (LRU)
- Tier 4 - Component Level

Acquisition

- !No Knowledge
- Follow-on Program
- New Development/First Release

Wide Range of Reporting Options

- Totals, monthly, annual, by phase and labor category

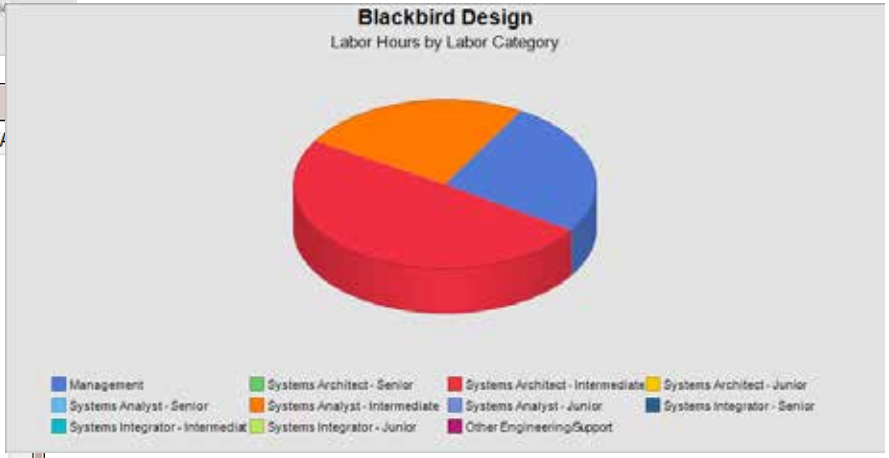


Cost By Fiscal Year

FISCAL YEAR	PROJECT IN-HOUSE	PROJECT CONTRACT...	PROJECT MATERIAL	PROJECT CUMULATIVE	ONGOI IN-HOU
Fiscal Year Start Month: 1 Base Year: 2015					
2015	**207,613**	**0**	**0**	**207,613**	
2016	**794,958**	**0**	**0**	**1,002,570**	
January	98,244	0	0		
February	103,997	0	0		
March	111,019	0	0		
April	79,720	0	0		
May	73,344	0	0		
June	100,279	0	0		

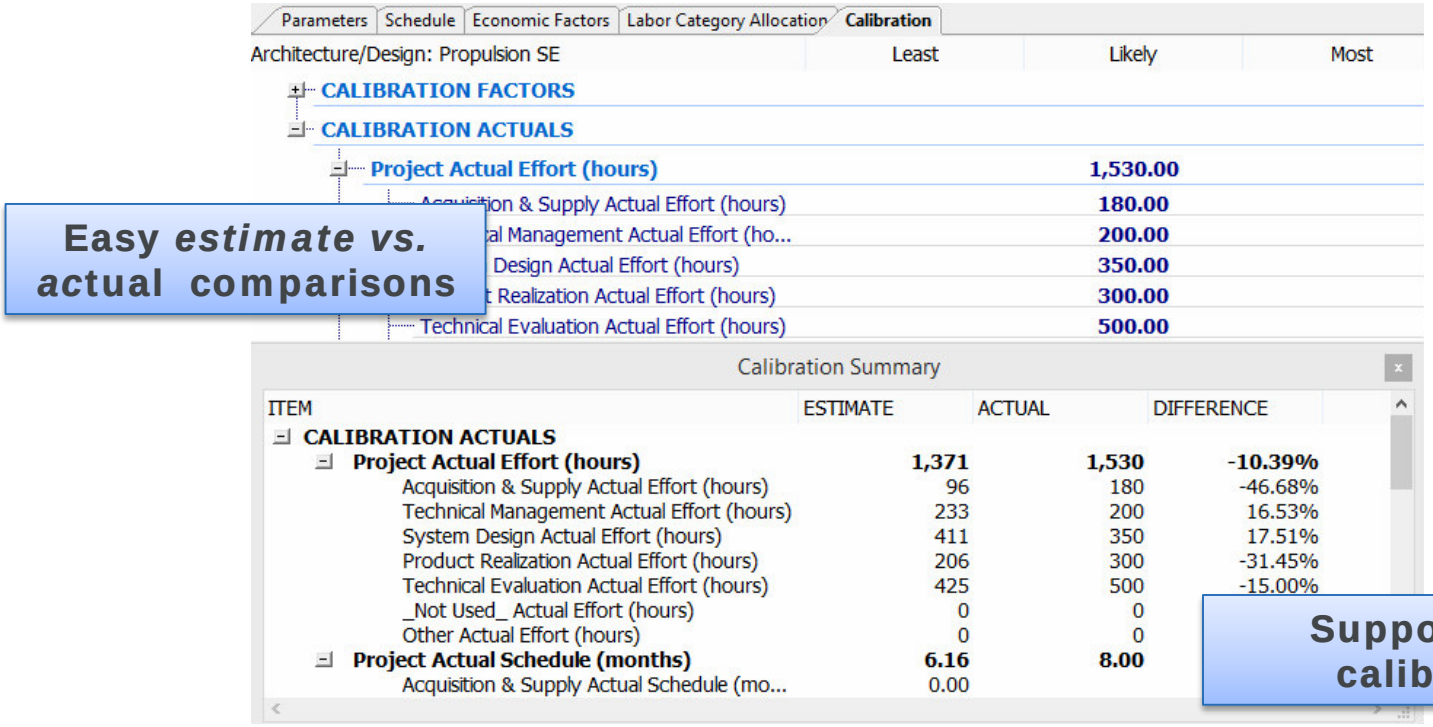
Phased Activity

ACTIVITY	SCHEDULE MONTHS	HOURS	LABOR COST	MATERIA
Acquisition & Supply	1.57	453	69,888	
Technical Management	2.30	1,101	171,419	
Procurement	0.00	0	0	
System Design	2.84	1,944	302,504	
Product Realization	2.17	972	151,252	
Technical Evaluation	2.90	2,008	307,508	
Not Used	0.00	0	0	
Other	0.00	0	0	
Project Total	*11.43*	*6,478*	*1,002,570*	
Ongoing Support	0.00	0	0	
Total	11.43	6,478	1,002,570	



SEER-SYS Calibration

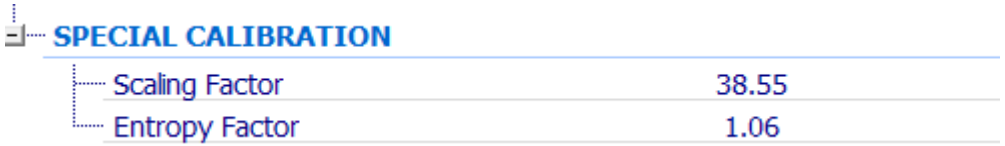
- SEER-SYS can be used out of the box



Easy *estimate vs. actual* comparisons

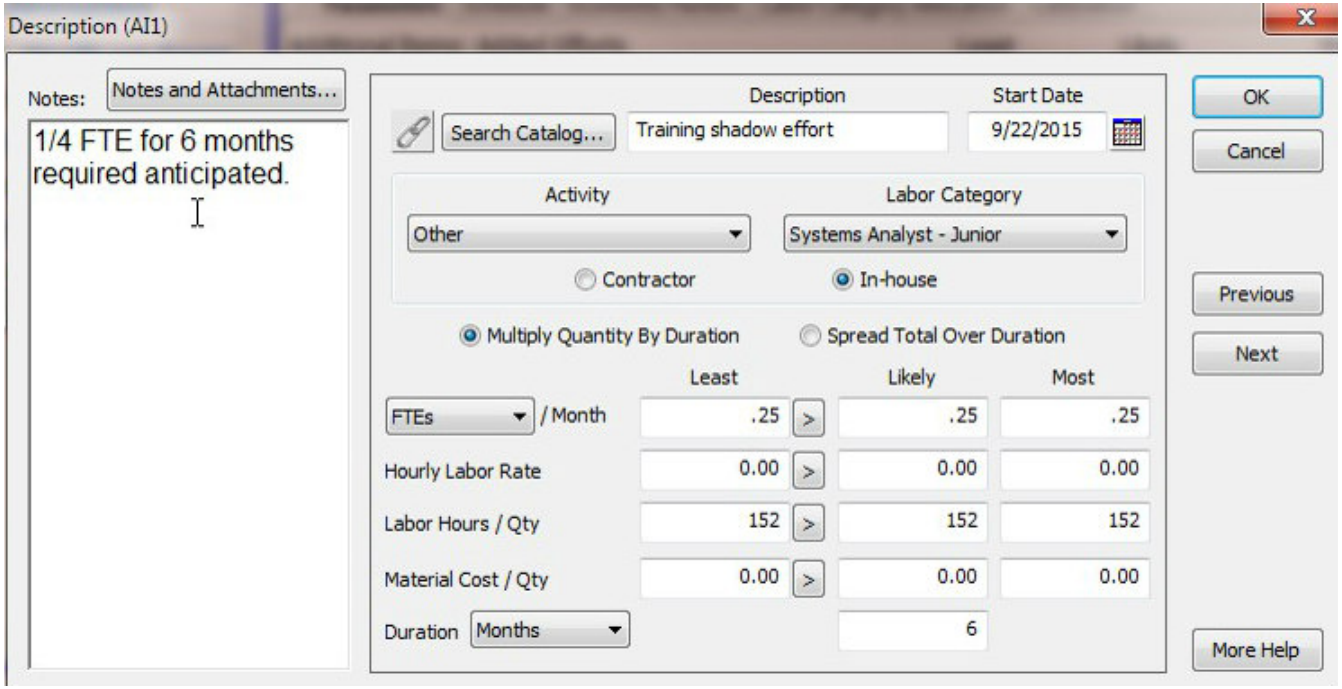
Supports local calibrations

- It does support capture of actual effort and calibration tools
- Offers both linear model adjustments as well as tuning of core COSYSMO model factors



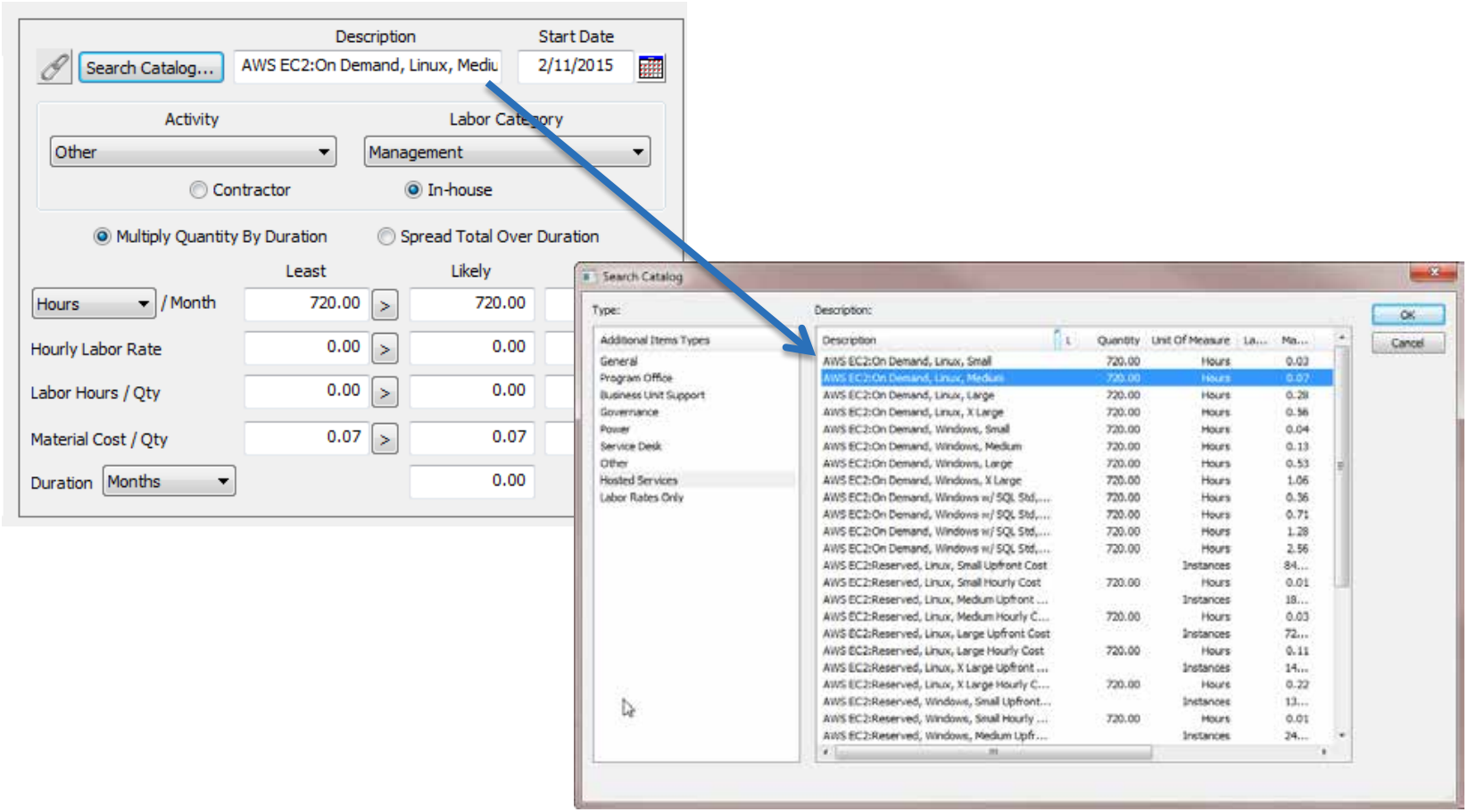
Supports Non-Parametric Costs

- Additional Items for non-parametric estimates
  - Purchased items (licensing, material, etc.)
  - Fixed efforts (200 hours)
  - Duration driven efforts or costs (1 FTE for 3 months)



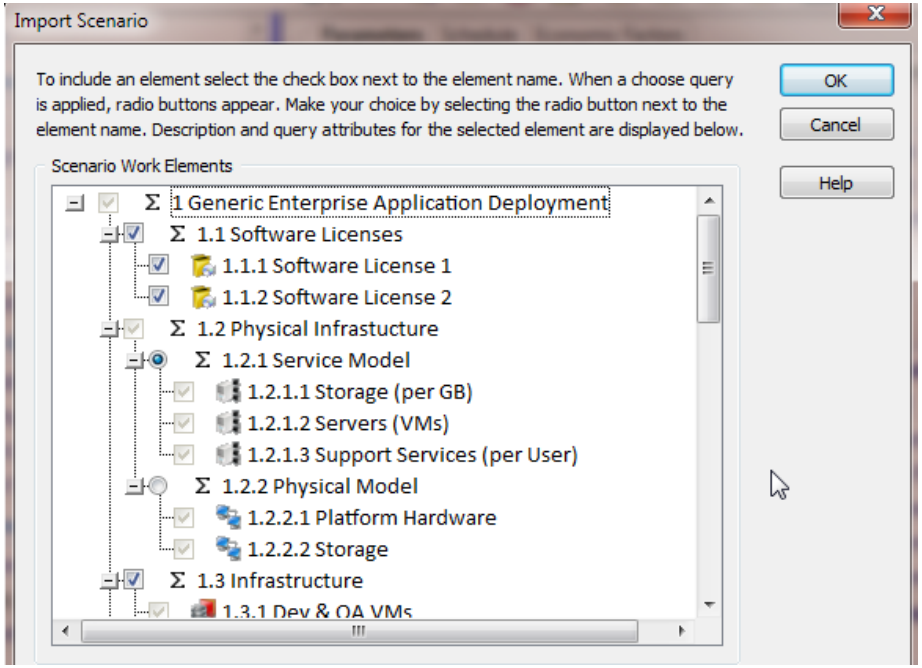
Building a Cost Catalog

- Can be used for standard labor hours or material cost for most anything
- Organization and content all configurable to user data



Scenarios

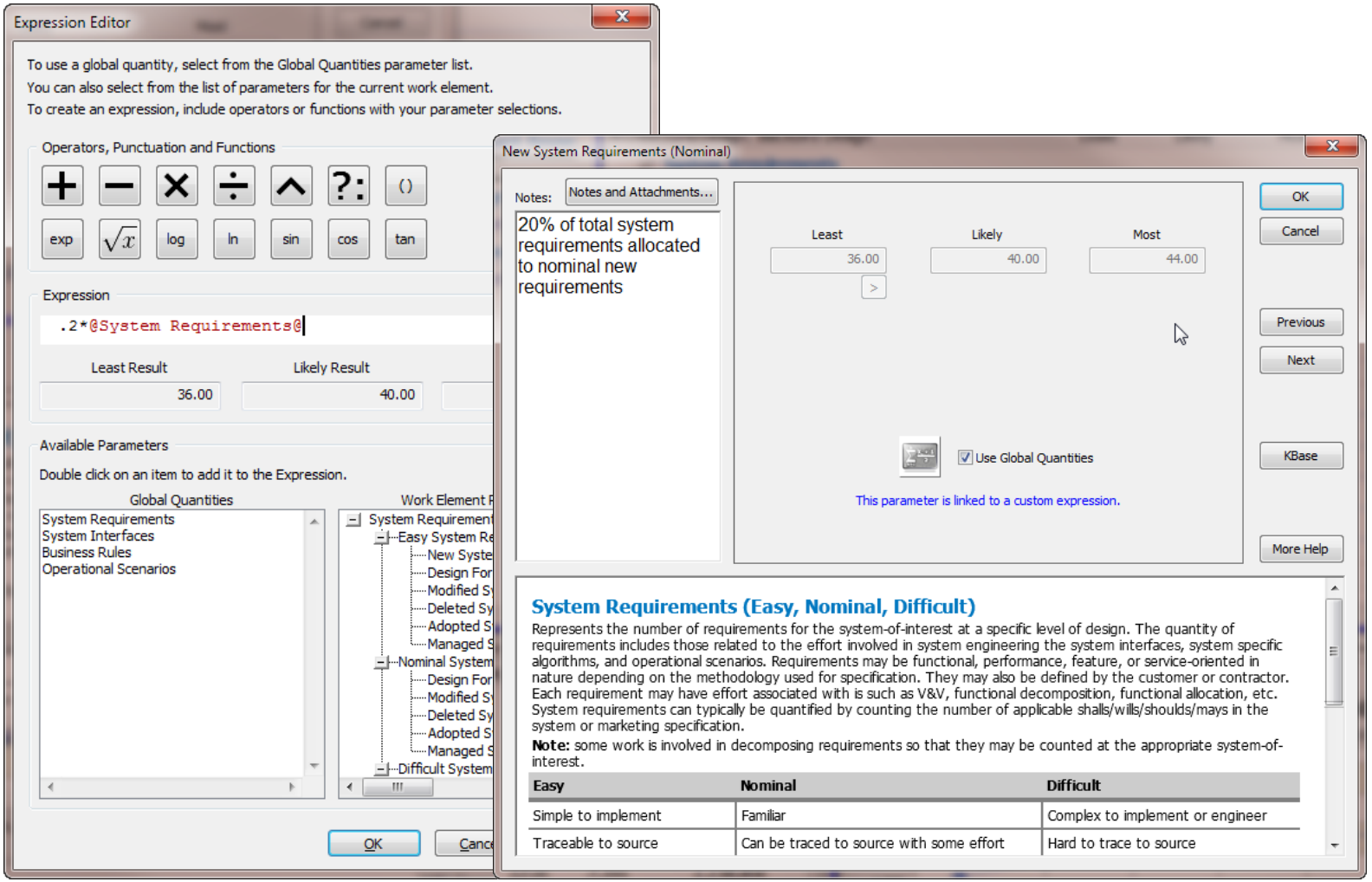
- Pre-configured WBS patterns may be stored as a “scenario”
- Scenarios may be configured with options for the user to select which elements to include
- The WBS structure will be loaded with the user’s tailoring



- Scenarios can be generated proactively or incidentally
  - Deliberately defining a standard estimation WBS pattern
  - Turning an exemplar estimate into a WBS pattern

Custom Estimation Relationships

- Tie costs, hours or quantities to custom expressions



Includes All The Favorite SEER Features

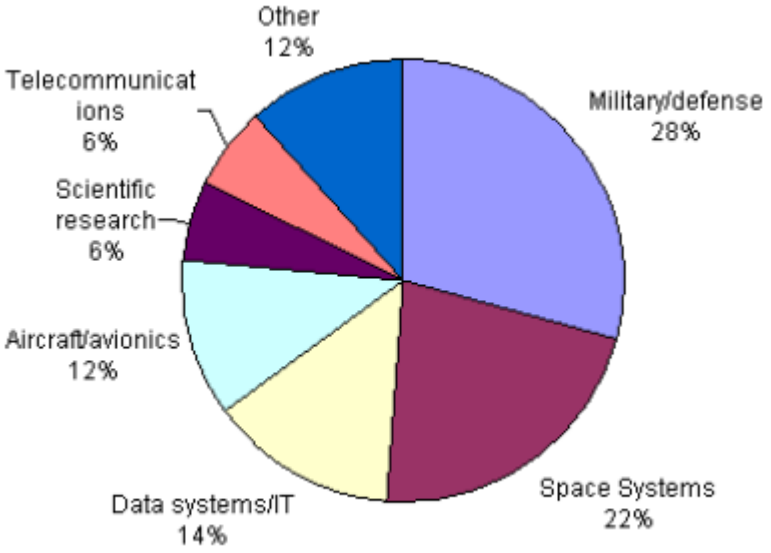
- Monte Carlo & Risk
- Flexible Export
- Server Mode API
- Knowledge Bases
- Scenarios
- Notes & Attachments
- Expression Editor

Galorath Added Research

- Research and development of a SEER Systems Engineering model began through customer feedback:
  - Demand for a stand-alone systems engineering model
  - Ability to create more detailed and defensible SE estimates
    - Account for issues such as personnel turnover and benefits gained from detailed SE plans, utilization of SysML, etc.
    - Wrap-factor approaches can not reflect these details
  - Alternative ability to estimate SE budget prior to estimating hardware (SEER-H wrap factor approach)

Research Background

- Leveraged the COSYSMO model and additional collaboration with industry champions to develop knowledge-bases.
- Data points included in SEER-SYS come from a range of industries.

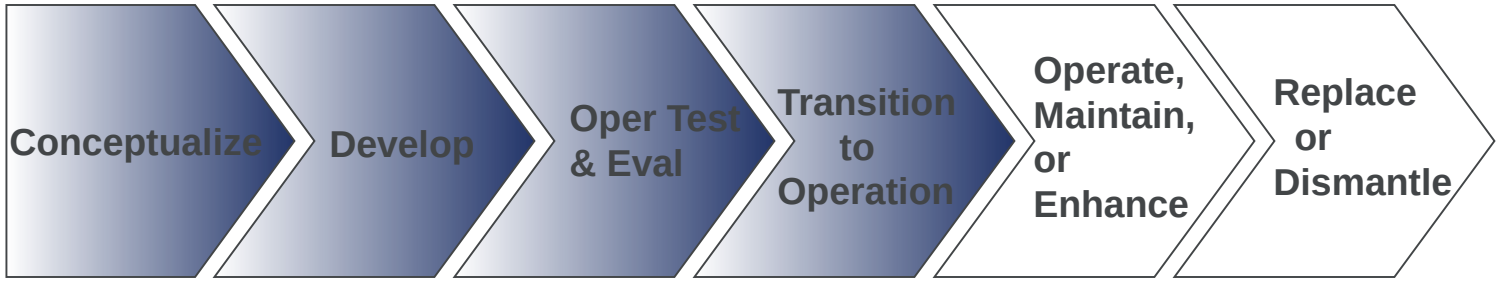


Research Background

- New data points from contractors and government agencies were used to develop the k-bases in SEER SYS.
  - This data is in addition to the original COSYSMO calibration.
  - Using this additional data, SEER is able to tune estimates based on system level, application, platform, and acquisition method.
  - The use of k-bases to provide industry default parameter settings assist in building more defensible estimates.
  - As new data is collected, k-bases are continually updated and new k-bases are developed

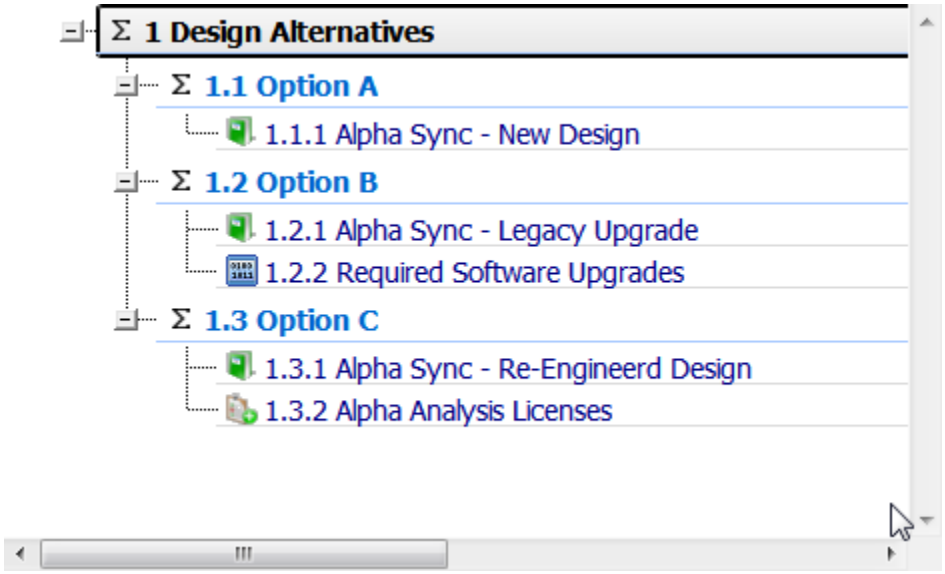
SEER-SYS Scope

- SEER-SYS addresses the first four phases of the systems engineering lifecycle (as defined by ISO 15288)



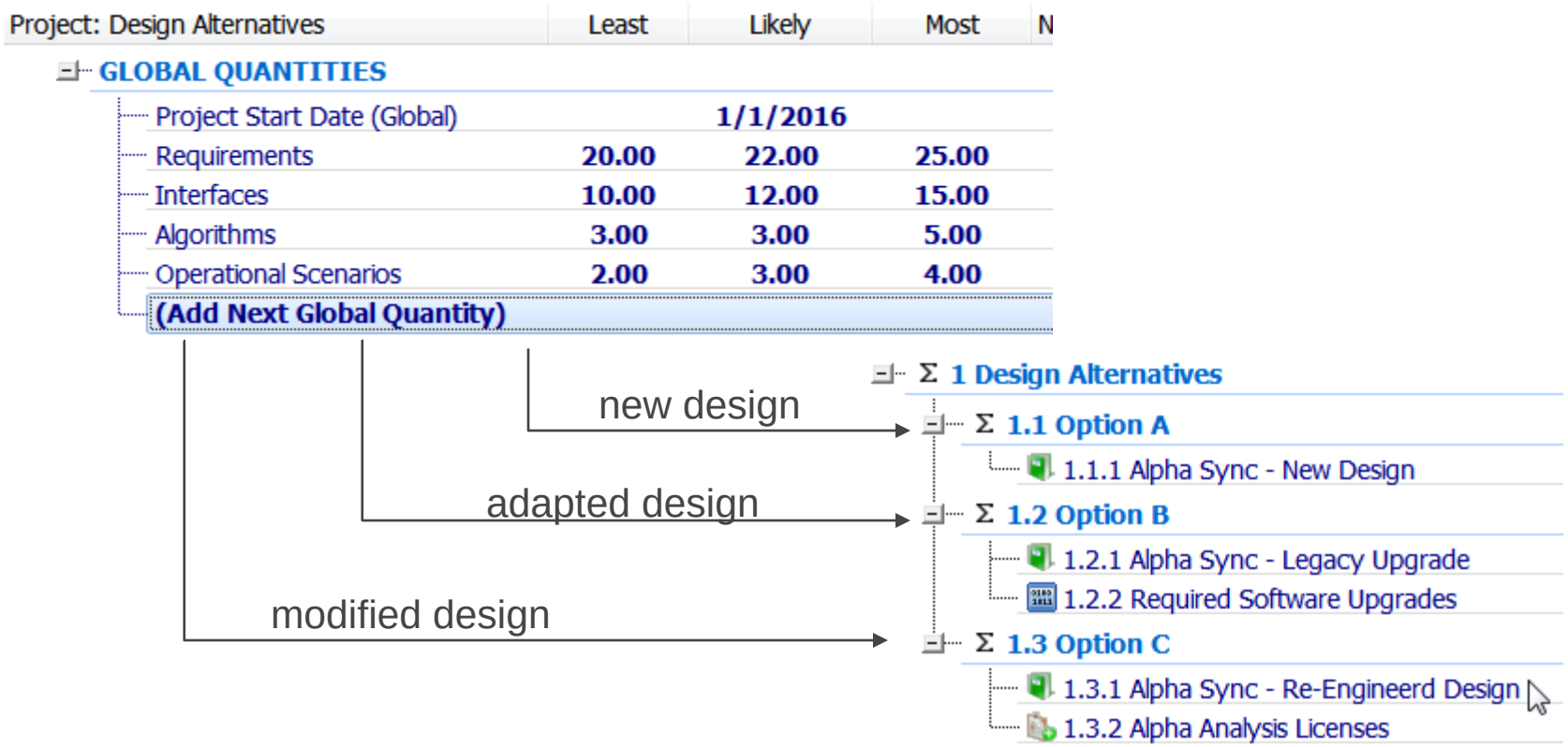
SEER-SYS Modeling Example

- Evaluating different design approaches
- Overall system requirements may be fixed, but design alternatives will introduce solution variances such as:
  - Extent of reuse/legacy
  - Technology licensing requirements
  - Experience levels
  - Etc.



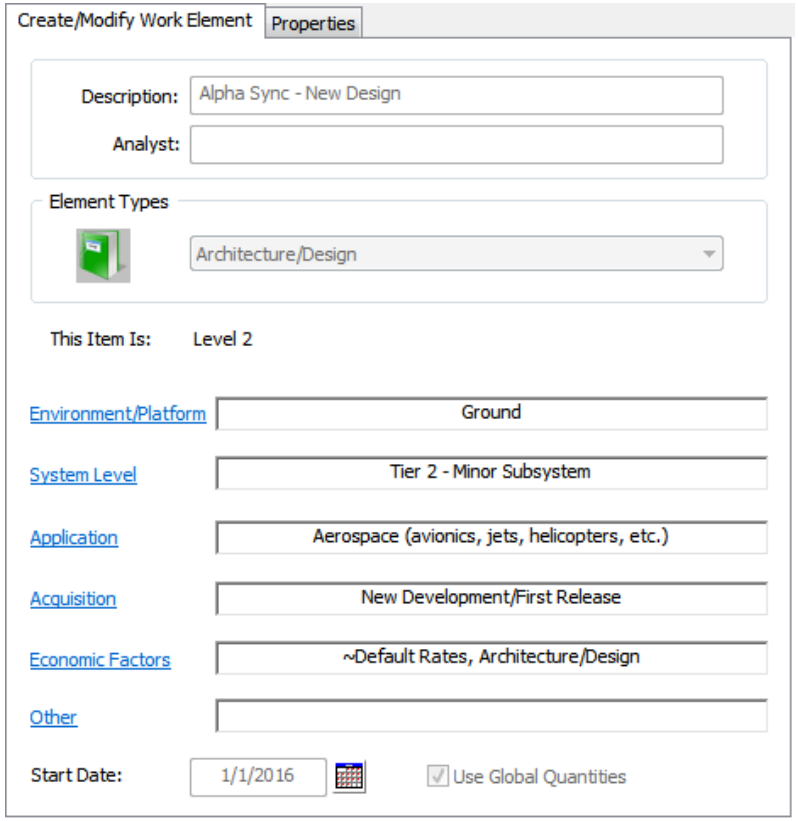
Defining System Parameters

- Overall system requirements may be established, regardless of the solution
- Each solution may differ in terms of difficulty, reuse, and adoption



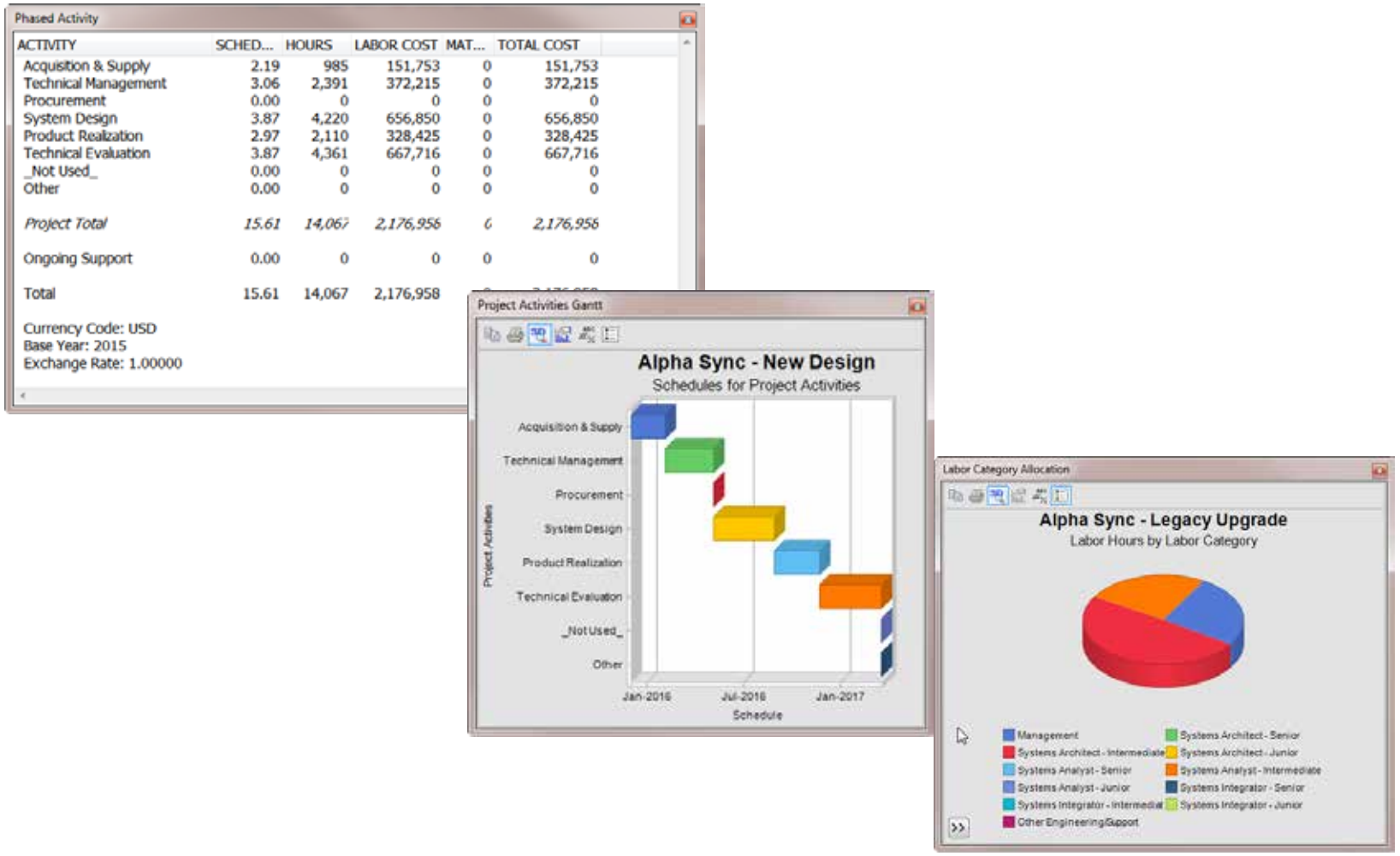
Common Attributes

- Knowledge bases can be used to set up default parameter settings



Option A - New Design

- All requirements design are designated as new & nominal difficulty



Option B – Adapted Design

- Some reuse opportunity, but requires added software upgrades

Project: Design Alternatives	Least	Likely	Most	N
GLOBAL QUANTITIES				
Project Start Date (Global)		1/1/2016		
Requirements	20.00	22.00	25.00	
Interfaces	10.00	12.00	15.00	
Algorithms	3.00	3.00	5.00	
Operational Scenarios	2.00	3.00	4.00	
(Add Next Global Quantity)				

Expression

```
@Requirements@*.7
```

Least Result	Likely Result	Most Result
14.00	15.40	17.50

linking inputs into the design alternatives

Parameters | Schedule | Economic Factors

Architecture/Design: Alpha Sync - Legacy Upgrade	Least	Likely	Most	Note
System Requirements				
Easy System Requirements	0	0	0	
Nominal System Requirements	10	10	12	
New System Requirements (Nominal)	0	0	0	
Design For Reuse System Requirements (Nominal)	0	0	0	
<<Modified System Requirements (Nominal)>>	6	6	7	30% of requirements will require mods
Deleted System Requirements (Nominal)	0	0	0	
<<Adopted System Requirements (Nominal)>>	14	15	17	70% of requirements can be adopted...
Managed System Requirements (Nominal)	0	0	0	
Difficult System Requirements	0	0	0	

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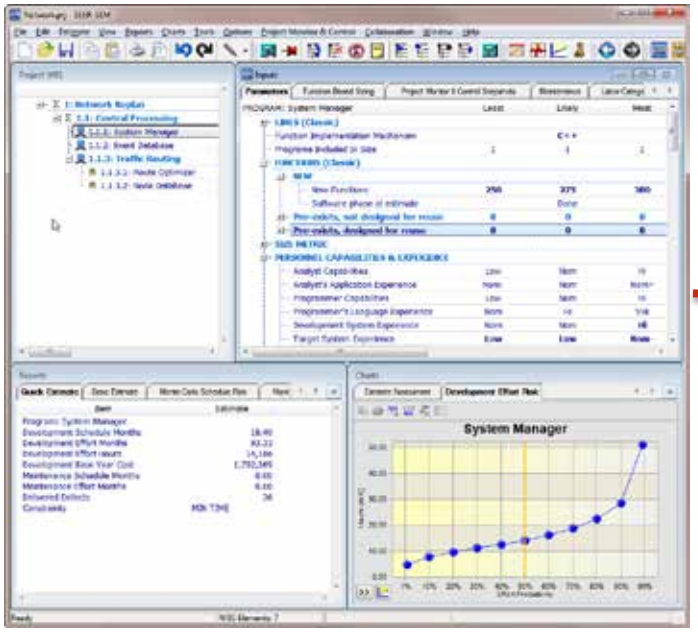
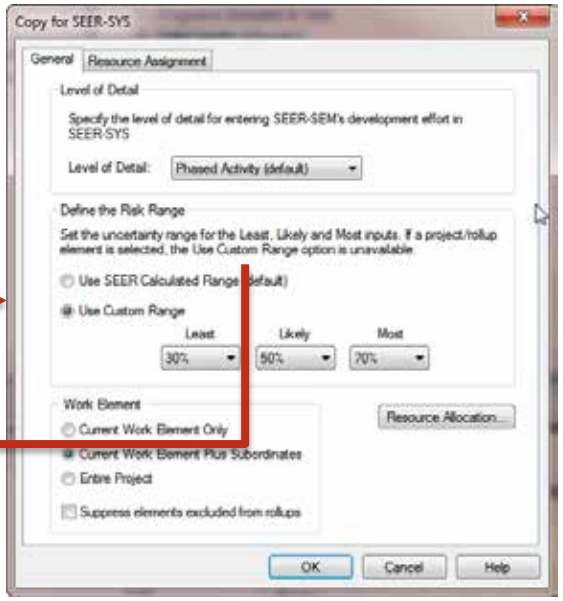
Option B – Adding In Software Costs

- Used SEER-SEM to estimate software





Application Development: Required Software Upgrades	Least	Likely	Most	Note
DEVELOPMENT				
Level of Detail		Phase		
Acquisition & Supply Hours	641.82	813.84	1,083.09	
Technical Management Hours	4,109.64	5,211.10	6,935.17	
Procurement Hours	0.00	0.00	0.00	
System Design Hours	2,335.97	2,962.05	3,942.04	
Product Realization Hours	4,100.44	5,199.42	6,919.64	
Technical Evaluation Hours	0.00	0.00	0.00	
Not Used Hours	0.00	0.00	0.00	
ADDITIONAL ITEMS				
(Add Next Item Here)				
ONGOING SUPPORT				
Ongoing Support Hours	0.00	0.00	0.00	
PROBABILITY		50.00%		

Option C – Modified Design

- Similar linking of requirements, but greater modification and some unused interfaces deleted

Project: Design Alternatives	Least	Likely	Most	N
GLOBAL QUANTITIES				
Project Start Date (Global)		1/1/2016		
Requirements	20.00	22.00	25.00	
Interfaces	10.00	12.00	15.00	
Algorithms	3.00	3.00	5.00	
Operational Scenarios	2.00	3.00	4.00	
(Add Next Global Quantity)				

linking inputs into the design alternatives

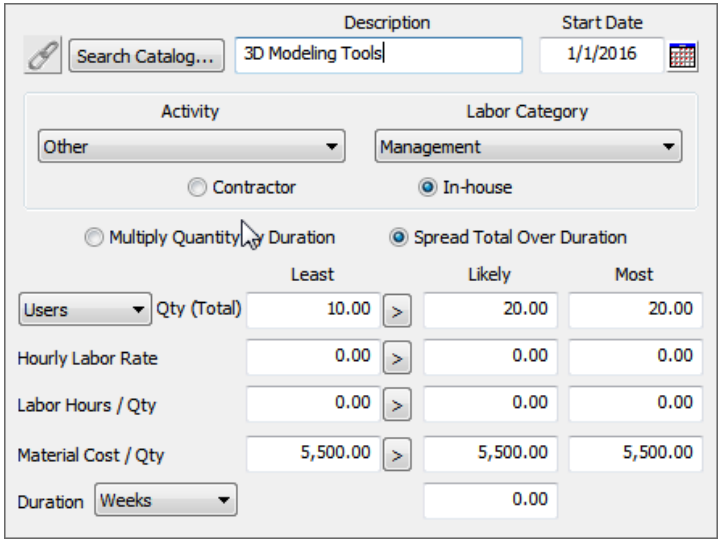
Parameters | Schedule | Economic Factors

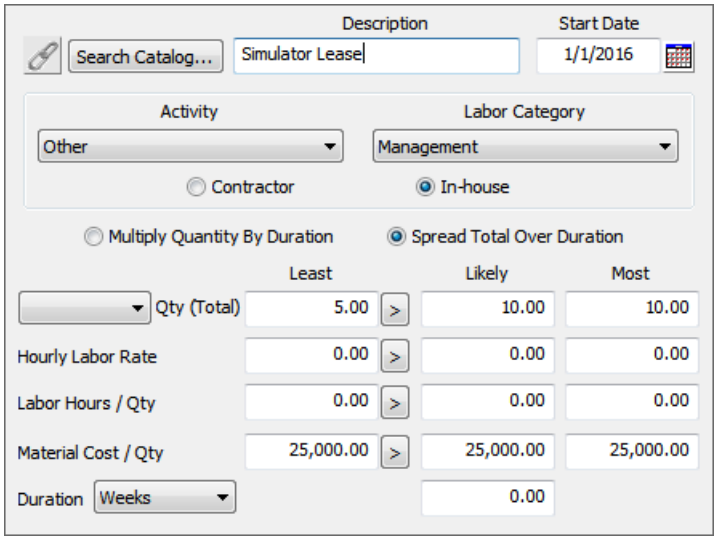
Architecture/Design: Alpha Sync - Re-Engineerd Design	Least	Likely	Most	Note
Difficult System Requirements	0	0	0	
System Interfaces				
Easy System Interfaces	0	0	0	
Nominal System Interfaces	11	13	15	
New System Interfaces (Nominal)	0	0	0	
Design For Reuse System Interfaces (Nominal)	0	0	0	
<<Modified System Interfaces (Nominal)>>	10	12	15	
Deleted System Interfaces (Nominal)	10	10	10	Interfaces not needed for this implem...
Adopted System Interfaces (Nominal)	0	0	0	
Managed System Interfaces (Nominal)	0	0	0	
Difficult System Interfaces	0	0	0	
Business Rules				
Easy Business Rules	0	0	0	

Option C – Modified Design

- Adding in license and simulator costs

Additional Items: Alpha Analysis Licenses	Least	Likely	Most	Note
LOCAL QUANTITIES				
Seats	10.00	20.00	20.00	
(Add Next Local Quantity)				
ADDITIONAL ITEMS				
3D Modeling Tools				
Simulator Lease				



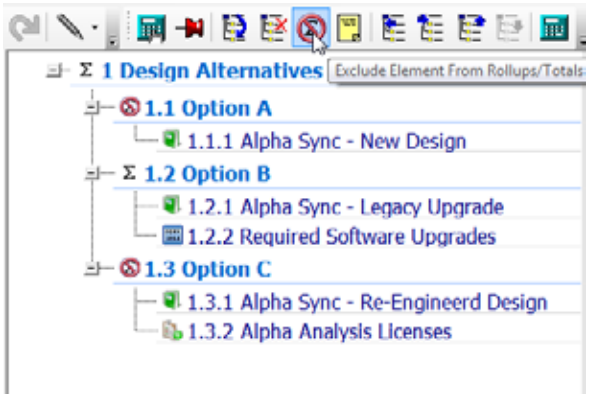


Evaluating Results

- Summary reports make it easy to compare alternatives in terms of cost & schedule

WBS Project Cost

ELEMENT	SCHEDULE MONTHS	LABOR HOURS	LABOR COST	MATERIAL COST	TOTAL COST
1 Design Alternatives	18.42	42,500	6,074,290	330,000	6,404,290
1.1 Option A	15.61	14,067	2,176,958	0	2,176,958
1.2 Option B	18.42	16,057	1,982,213	0	1,982,213
1.2.1 Alpha Sync - Legacy Upgrade	6.52	1,593	246,465	0	246,465
1.2.2 Required Software Upgrades	18.42	14,465	1,735,748	0	1,735,748
1.3 Option C	14.84	12,375	1,915,119	330,000	2,245,119
1.3.1 Alpha Sync - Re-Engineerd Design	14.84	12,375	1,915,119	0	1,915,119
1.3.2 Alpha Analysis Licenses	0.00	0	0	330,000	330,000



Keep a legacy of alternative estimates choosing which one is used in the totals for cost, risk and summary reporting

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Questions

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Backup Slides – COSYSMO Info

Research Background

- The COSYSMO calibration included data points from:

Boeing	*Integrated Defense Systems (Seal Beach, CA)*
Raytheon	*Intelligence & Information Systems (Garland, TX)*
Northrop Grumman	*Mission Systems (Redondo Beach, CA)*
Lockheed Martin	*Transportation & Security Solutions (Rockville, MD)* *Integrated Systems & Solutions (Valley Forge, PA)* *Systems Integration (Owego, NY)* *Aeronautics (Marietta, GA)* *Maritime Systems & Sensors (Manassas, VA; Baltimore, MD; Syracuse, NY)*
General Dynamics	*Maritime Digital Systems/AIS (Pittsfield, MA)* *Surveillance & Reconnaissance Systems/AIS (Bloomington, MN)*
BAE Systems	*National Security Solutions/ISS (San Diego, CA)* *Information & Electronic Warfare Systems (Nashua, NH)*
SAIC	*Army Transformation (Orlando, FL)* *Integrated Data Solutions & Analysis (McLean, VA)*
L-3 Communications	*Greenville, TX*

- SEER-SYS includes additional points from government contractors and government agencies.

Research Background

- To ensure that all data points collected included equivalent activities, ANSI-632 was used as a WBS

Acquistion and Supply	Supply Process	(1) Product Supply
	Acquisition Process	(2) Product Acquisition
		(3) Supplier Performance
Technical Management	Planning Process	(4) Process Implementation Strategy
		(5) Technical Effort Definition
		(6) Schedule and Organization
		(7) Technical Plans,
		(8) Work Directives
	Assessment Process	(9) Progress Against Plans and Schedules
		(10) Progress Against Requirements
		(11) Technical Reviews
	Control Process	(12) Outcomes Management
		(13) Information Dissemination
System Design	Requirements Definition Process	(14) Acquirer Requirements
		(15) Other Stakeholder Requirements
		(16) System Technical Requirements
	Solution Definition Process	(17) Logical Solution Representations
		(18) Physical Solution Representations
		(19) Specified Requirements
Product Realization	Implementation Process	(20) Implementation
	Transition to Use Process	(21) Transition to use
Technical Evaluation	Systems Analysis Process	(22) Effectiveness Analysis
		(23) Tradeoff Analysis
		(24) Risk Analysis
	Requirements Validation Process	(25) Requirement Statements Validation
		(26) Acquirer Requirements
		(27) Other Stakeholder Requirements,
		(28) System Technical Requirements
		(29) Logical Solution Representations
	System Verification Process	(30) Design Solution Verification
		(31) End Product Verification
		(32) Enabling Product Readiness
	End Products Validation Process	(33) End products validation

4 Size Drivers

1. Number of System Requirements
   Counted from system specification
2. Number of System Interfaces
   Counted from interface control document
3. Number of Business Rules
   Counted from system spec or mode description document
4. Number of Operational Scenarios
   Counted from test cases or use cases

SEER-SYS Sizing Inputs

- Sizing inputs for easy, nominal and difficult categories
- Reuse also supported

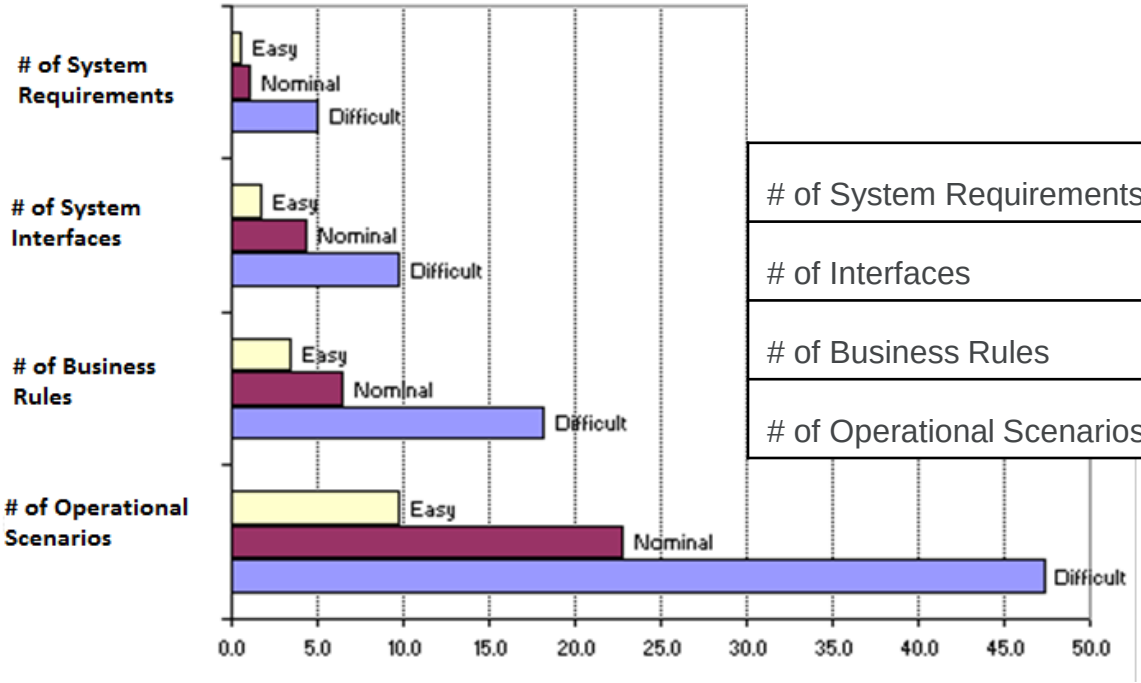
Architecture/Design: Systems Engineering	Least	Likely	Most	Note
System Requirements				
Easy System Requirements	91	91	91	
Nominal System Requirements	100	100	100	
Difficult System Requirements	32	32	32	
System Interfaces				
Easy System Interfaces	1	1	1	
Nominal System Interfaces	0	0	0	
Difficult System Interfaces				
Business Rules				
Easy Business Rules				
Nominal Business Rules				
Difficult Business Rules	0	0	0	
Operational Scenarios				
Easy Operational Scenarios	0	0	0	
Nominal Operational Scenarios	0	0	0	
Difficult Operational Scenarios	0	0	0	

Architecture/Design: Systems Engineering	Least	Likely	Most
Nominal System Requirements	100	100	100
New System Requirements (Nominal)	0	0	0
Design For Reuse System Requirements ...	0	0	0
Modified System Requirements (Nominal)	50	50	50
Deleted System Requirements (Nominal)	5	5	5
Adopted System Requirements (Nominal)	150	150	150
Managed System Requirements (Nominal)	10	10	10

Size Driver Weights

estimate

estimate • analyze • plan • control



	Easy	Nominal	Difficult
# of System Requirements	0.5	1.00	5.0
# of Interfaces	1.1	2.8	6.3
# of Business Rules	2.2	4.1	11.5
# of Operational Scenarios	6.2	14.4	30.0

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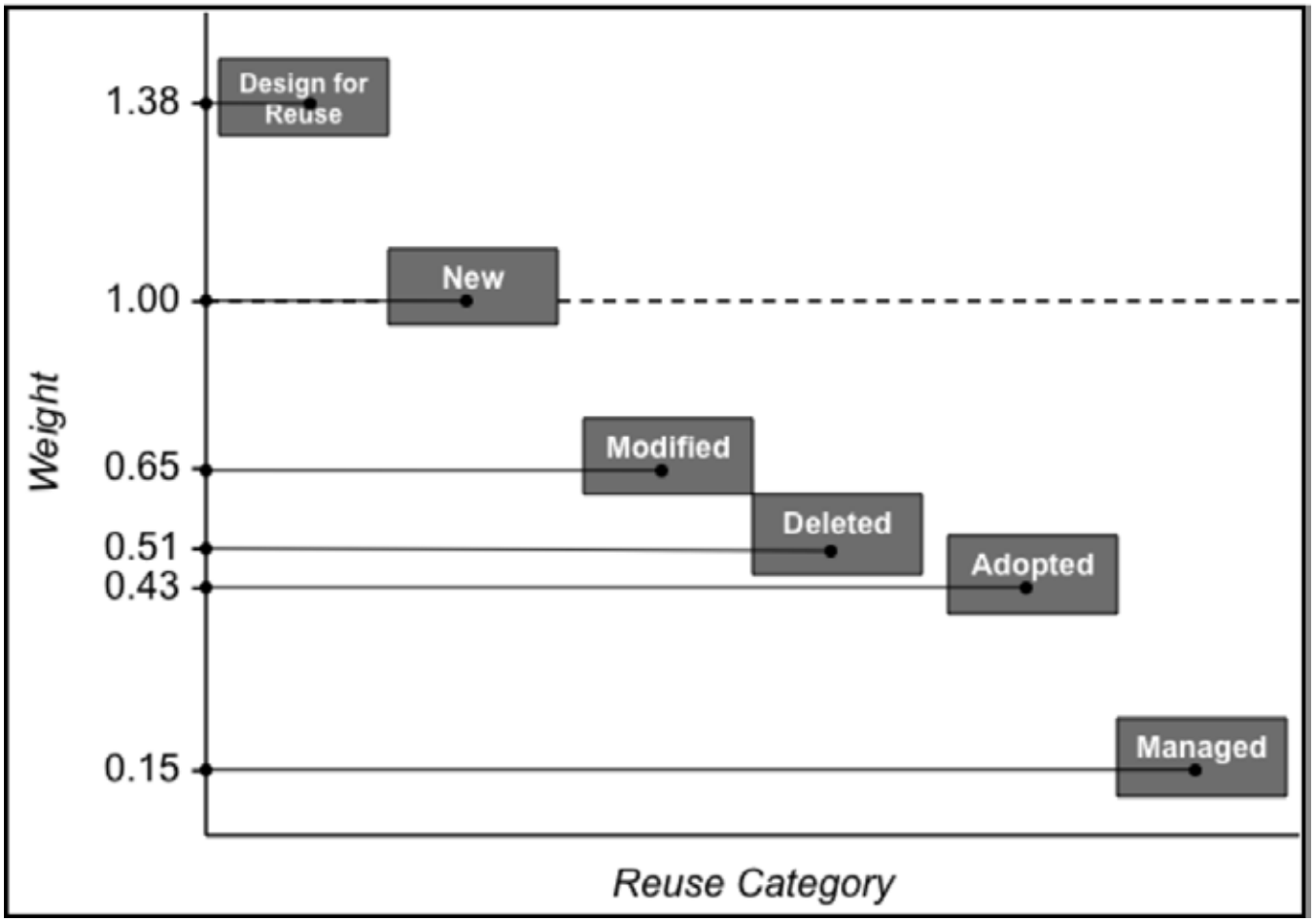
Reuse Category Weights



14 Cost Drivers

Problem and Solution Understanding

1. Requirements understanding
2. Architecture understanding
3. Technology Risk
4. Design Decomposition Complexity

Product and System Complexity

1. Complexity of Performance Measures
2. Migration Complexity
3. Documentation Level
4. Installations/ Platforms Diversity

14 Cost Drivers (cont.)

Personnel and Team Capabilities

1. Stakeholder Team Cohesion
2. Personnel and Team Capabilities
3. Personnel Experience/ Continuity

Development and Productivity Aids

1. Process Capability
2. Multisite Coordination
3. Tool Support

SEER-SYS Parameters

- All inputs are expressed as a range, allowing users to model uncertainty in the inputs.

Architecture/Design: Systems Engineering	Least	Likely	Most	Note
PROBLEM AND SOLUTION UNDERSTANDING				
Requirements Understanding	Nom	**Nom+**	**Hi-**	
Architecture Understanding	Nom	**Nom+**	**Hi-**	
Technology Risk	**VLo+**	**Low-**	**Low**	
Design Decomposition Complexity	**VLo**	**VLo+**	**Low-**	
PRODUCT AND SYSTEM COMPLEXITY				
Complexity of Performance Measures	**Low**	**Low+**	**Nom-**	
Migration Complexity	Nom	Nom	**Nom+**	
Documentation Level	**Hi**	**Hi+**	**VHi-**	
Installations/Platforms Diversity	Nom	Nom	**Nom+**	
PERSONNEL AND TEAM CAPABILITIES				
Stakeholder Team Cohesion	Nom	**Nom+**	**Hi-**	
Personnel and Team Capabilities	Nom	Nom	Nom	
Personnel Experience/Continuity	**Hi-**	**Hi**	**Hi+**	
DEVELOPMENT AND PRODUCTIVITY AIDS				
Process Capability	Nom	Nom	Nom	
Multisite Coordination	**Hi+**	**VHi-**	**VHi**	
Tool Support	**Nom-**	Nom	**Nom+**	