Software Cost Estimating Using a Decision Graph: A Knowledge Engineering Approach

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Outline

- Background
- Knowledge Engineering Approach
- Decision Graph
  - Initial SEER-SEM Input Data
  - Mission Type, Developer, and Data Decision Dynamics
  - Quantitative Parameter Determination
  - Non-Default Parameter Identification
  - Program Output Mapping
- Estimate Results
- Summary and Future Work

Background - Software Cost Activities

- Proposal Estimates* (N_0 missions†)
  - Created estimates for spacecraft flight software
  - Strove for consistency in data and analysis
  - Required quick turnaround for estimates done in parallel
- Independent Cost Estimates (ICE’s)
  - Requested by the project
  - Initiated by the Costing Office
  - Required at milestone reviews
  - Performed separately from the project
- Cost Analysis Data Requirements (CADRe’s)
  - SW metrics page – 48 columns displayed for each SW element
  - Up to 40 rows of SW elements
  - Required at milestone reviews

* Main focus of this presentation

† N_0 represents a numeric value

Background - Specific Application

- Provided software estimates for N_0 proposals
- Tight schedule constraint
- Limited resources
  - 3 analysts (reduced to 2 shortly after start)
  - Funding less than half time for each analyst
- Provided results to individual proposal Cost Engineers
  - Conducted trade study and alternative estimates
  - Followed-up with additional data
  - Supported proposal meetings and responded to questions

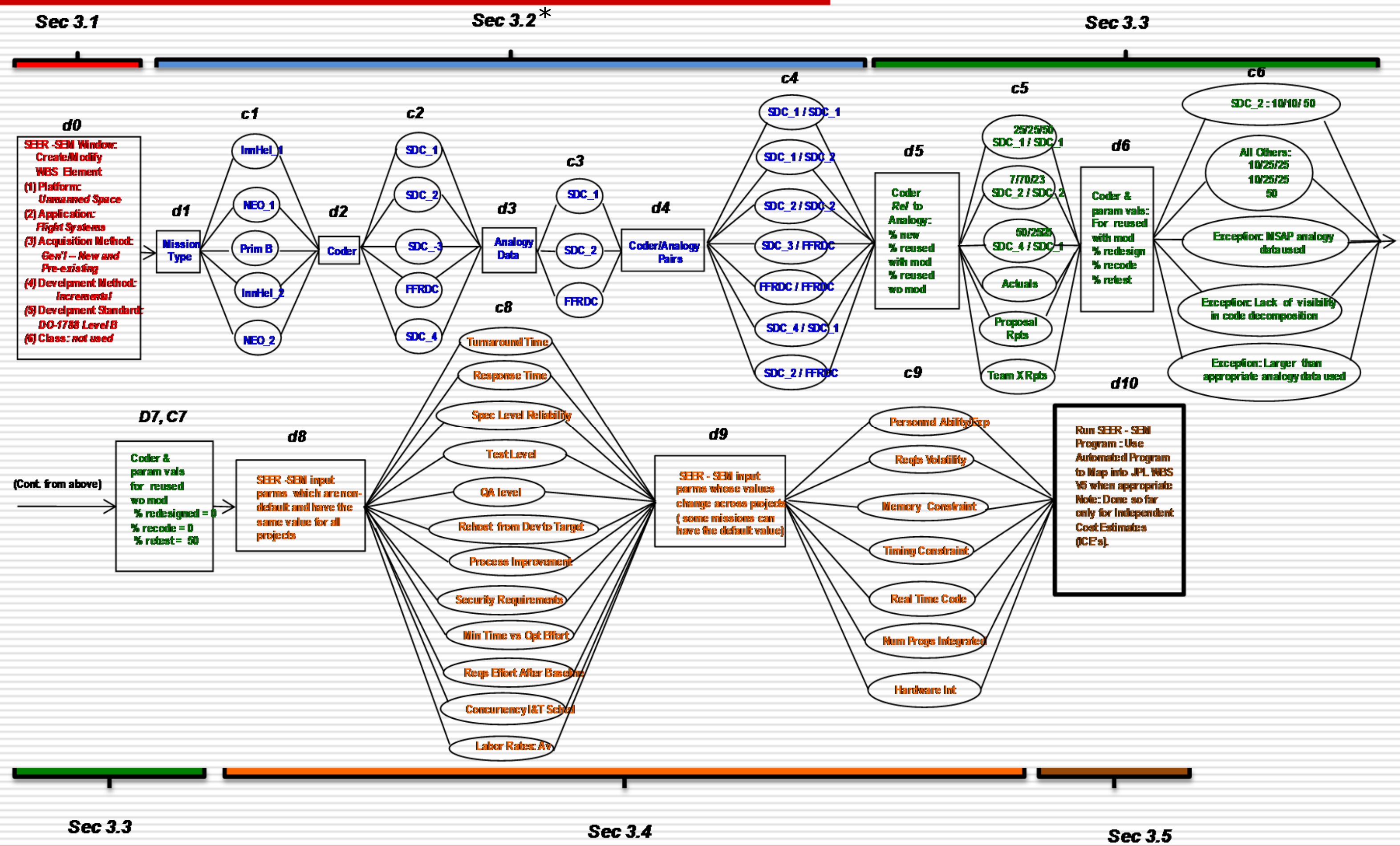
Knowledge Engineering Approach

- Experienced Software Cost Estimator
  - > 30 years in the Aerospace industry
  - Successfully engaged at many different technical facilities
  - Developing a software estimating tool for NASA
- Experienced Knowledge Engineer
  - Published and experienced in expert systems work
  - Brings a new perspective to the cost estimating profession
  - Organizes, makes consistent, and represents expert’s analysis
- Built Decision Graph
  - More compact and intuitively palatable than decision tree
  - Sufficiently expresses high level relationships and concepts
  - ***Had its genesis from a Spreadsheet constructed to aid in the FSW cost estimation process (discussed later)***

Decision Graph

Mission Type	Description
Inn_Hel_1	Inner Heliosphere Mission (examples: Venus, Mars)
Inn_Hel_2	Inner Heliosphere Mission (examples: Venus, Mars)
NEO_1	Near Earth Orbiter (examples: Earth , Moon)
NEO_2	Near Earth Orbiter (examples: Earth , moon)
Prim B	Primitive Body Encounter (examples: comets, asteroids)

Sec numbering refers to the Section number in the paper



* SDC=Software Development Contractor, FFRDC=Federally Funded Research and Development Contractor

Basic Categories for SEER-SEM

- Software Systems Work Breakdown Structure: Identify software modules*
  - Decision Graph procedures apply to each module
- Software Size – in terms of new, reused, modified code
- Knowledge Bases (KB's) – set in Decision Box ***DO***
- Parameter Settings – all established by the KB's and a subset adjusted by Decision Graph procedures

* Frequently, decomposition into modules not possible

3.1 Initial SEER-SEM Input Data

D0

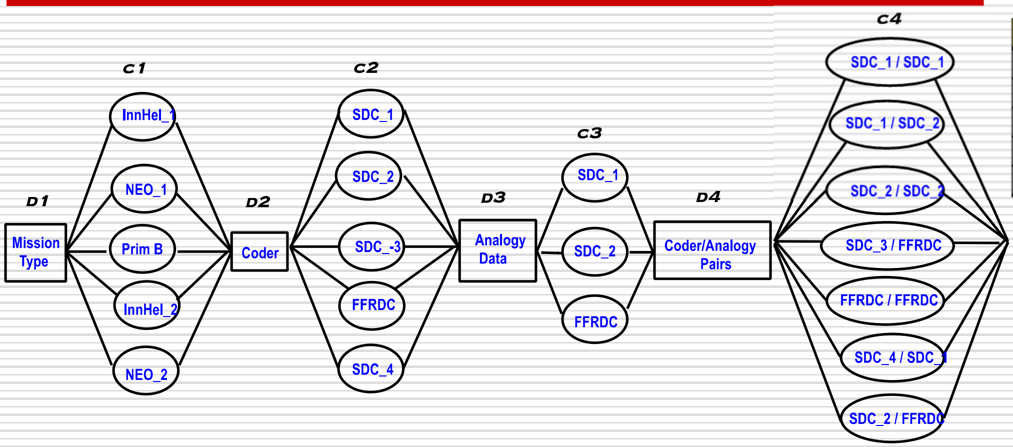
SEER -SEM Window:
Create/Modify
WBS Element
(1) Platform:
Unmanned Space
(2) Application:
Flight Systems
(3) Acquisition Method:
Gen'l – New and Pre-existing
(4) Develpment Method*:*
Incremental
(5) Develpment Standard*:*
DO-1788 Level B
(6) Class*: not used*

Knowledge Base	Definition	Selection
(1) Platform	Establishes a collection of input parameter settings that characterize a particular host environment.	Unmanned Space
(2) Application	Establishes a collection of input parameter settings that characterize an application or application technology type.	Flight Systems
(3) Acquisition Method	Establishes a collection of input parameter settings that characterize from where the software will come.	New and Reuse
(4) Development Method	Establishes a collection of input parameter settings that characterize the particular Software Development Life Cycle method that will be used.	Incremental Development
(5) Development Standard	Establishes a collection of input parameter settings that characterize the software development process standard that will be used.	DO-178B Level B
(6) Class	A knowledge base calibrated to a specific set of data or domain.	Not used

Knowledge Base Selections

- Trust your Knowledge Bases (KB’s)
- KB’s establish model parameter settings
- Make modifications cautiously
  - Focus on cost drivers
  - Be conservative
  - Use distribution to reflect uncertainty
- Document and reference adjustments

3.2 Mission Type, Developer, and Data Decision Dynamics



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- Determine mission type
- Identify spacecraft provider (contractor)
- Obtain relevant data for contractor
  - Repositories
  - Proposal documentation
- Specify contractor – data pair

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Mission Type

- Identify the nature of the mission
  - Inner Heliosphere e.g. Venus, Mars
  - Near Earth Orbiter e.g. Earth, Moon
  - Primitive Body Encounters e.g. comets, asteroids
- Determine source(s) for data of similar missions
  - Analogous historical projects
  - Project/proposal personnel
  - Industry data

Developer Identification

- Identify the organization developing the software, if possible
  - Helps determine best analogy data
  - Minimizes uncertainty
- If development organization is unknown
  - Use closest analogy data
  - Reflect different developer in risk range
- If organization is discovered during the estimate, update the estimate with new data

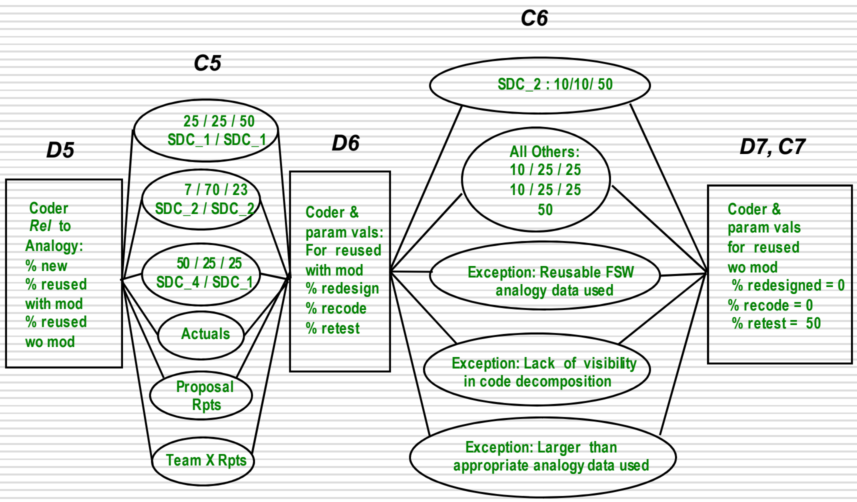
Data Sources

- CADRe (ONCE – One NASA Cost Engineering database)
  - Technical description from Part A
  - Measurement data from Part B, software tab
  - Cost data from Part C, software WBS elements mapped to the Project's WBS (for validation)
- SQI Software Repository (SMART)
  - Ground, flight, and instrument data
  - JPL Proprietary, ITAR restricted
- RedStar Library
- Project Personnel
- Other Projects (e.g. industry data)

Data Decision Dynamics

- Knowing the software development contractor (SDC) allows for selection of most appropriate analogy data
  - Does code exist from SDC for the same mission type
  - What adjustments need to be made to make it fit?
- Research the developer's experience
  - What is their track record with the type of mission?
  - How recent is their experience?
- If analogy data is from another contractor
  - Reflect in an uncertainty band
  - Update with better data as soon as possible

3.3 Quantitative Input Determination



SLOC value triplets

Vector 1 (v_1) : Applies to Total SLOC value

- v_1 = (%new, %reused with mods, %reused wo mods)
- Used from actuals, proposal reports and Team X reports, when possible
- Experience dictates predetermined set of values based on coder/analogy data pairs

Vector 2 (v_2) : Applies to %*reused* *(**with** mods)*

- v_2 = (%redesign, %recode, %retest)
- Experience dictates predetermined set of values based on coder
- Rare exceptions which cause a deviation from these values are noted and v_2 is altered accordingly

v2 is also related to %*reused* *(**without** mods)*

- *v2* = (0 , 0, 50) in all cases
- 0% redesign and 0% recode
- Base upon the equation used in SEER-SEM, a value of 50% represents pure testing and integration (discussed in subsequent slide)

Percentage Selections

- New code percentage is a function of contractor experience
- Reused code assumes 0% re-design, 0% re-code, 50% re-test

%Re-test = (.10*A + .04*B + .13*C + .25*D + .36*E + .12*F)*100

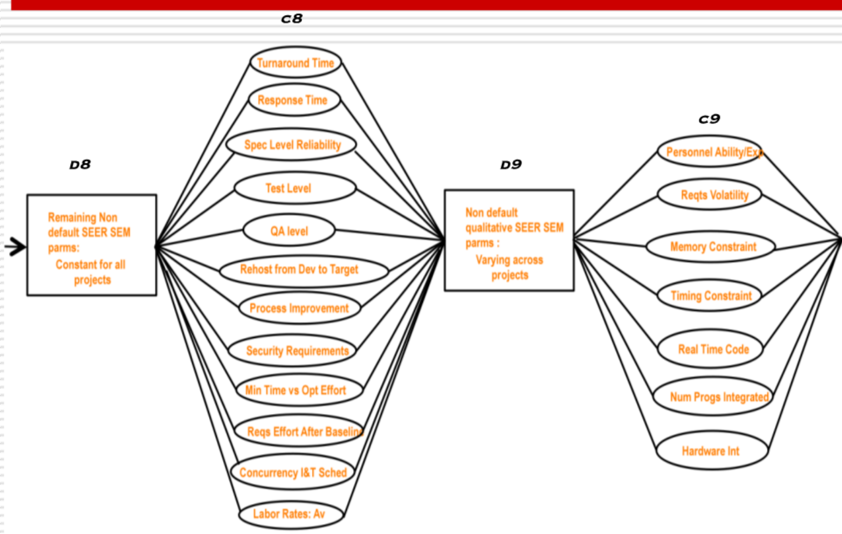
A	Test Plans Required	**Existing**
B	Test Procedures Required	**Existing**
C	Test Reports Required	**Existing**
D	Test Drivers Required	**Existing**
E	Integration Testing	
F	Formal Testing	

Values for A-F range from 0 to 1, continuous

In our reuse code case A-D = 0 and E-F = 1

- Modified code percentages are based on experience with contactor
  - Use a distribution
  - Always re-test 100% of the code (50% SEER parameter)

3.4 Non-Default Parameter Identification



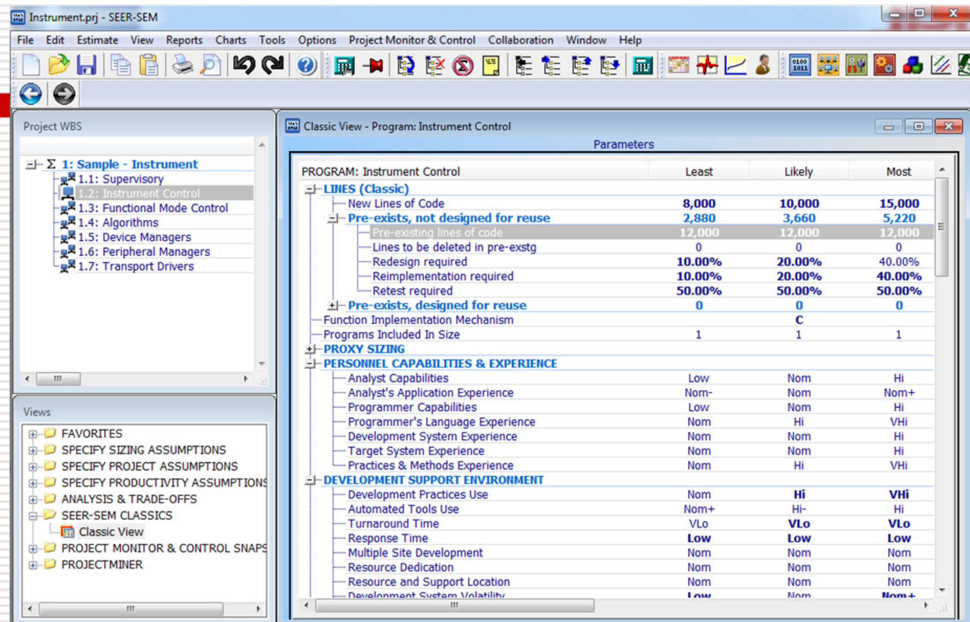
- **D9** represents decision that certain parameters were to have vals which varied across proposals (although for some proposals, the value could be a SEER-SEM default value)
  - **C9** represents these parameters

- **D8** represents the decision that certain parameters (parms) have values (vals) which:
  - (1) Differed from SEER-SEM KB and
  - (2) Were held constant for all missions of Type X
  - Knowledge base values for these parameters as designated by SEER-SEM were not appropriate
  - For each parameter, the same value was given across all proposals
  - **C8** represents these parameters

3.5 Program Output Mapping

D10

Run SEER - SEM Program : Use Automated Program to Map into JPL WBS V5 when appropriate Note: Done so far only for Independent Cost Estimates (ICE's).



Reports

Quick Estimate | Basic Estimate | **Person Hours by Labor Category**

Activity	Proj Mgr	Analyst	Design	Program	Data	Test/QA	CM/RM	QC Lead
System Requirements Design	27	117	31	0	13	27	4	4
S/W Requirements Analysis	79	303	92	40	40	79	13	13
Preliminary Design	176	160	656	192	128	224	32	32
Detailed Design	332	302	1,237	362	241	423	60	60
Code & Unit Test	337	145	289	2,651	289	723	193	193
Component Integrate & Test	365	91	182	1,778	365	1,322	228	228
Program Test	50	12	25	243	50	180	31	31
System Integrate Thru OT&E	467	117	233	1,108	58	3,441	292	117

Sample Data

Estimate Results – Mapping SEER Output

- Goal is to map the SEER model output into the Project’s WBS FSW elements
  - Total software activity cost
  - Individual WBS elements where possible
- Mapping Tool performs computations and row and column operations to parse the SEER output
  - Parses total software activity to get costs for Project’s WBS elements: *Management*, *Systems Engineering*, and *I&T*
  - Computes WBS element *Software Testbed* using 4% of total software cost

Estimate Results – Mapping SEER Output

- Mapping Tool performs computations and row and column operations to parse the SEER output
  - Uses CER to estimate cost of software equipment and facilities
  - Maps costs to a FSW summary template
- Saves a lot of time, effort and reduces the likelihood of error!
- Critical when there is a tight turnaround time!

SEER-SEM Mapping

Description	FY$08K Total System Cost	Basis of Estimate
Flight Software		**Roll-up**
Equipment		Factor based on number of computers
Facilities		Factor based on number of square feet
Flight Software		**Roll-up**
Software Management		SEER-SEM Mgmt total less System I&T
Software Systems Engineering		SEER-SEM SW Req and SW Design total less System I&T
C&DH		SEER-SEM Flight Systems Software less Engineering Models and Payload & Instrument Control (less portion og mgmt, se, i&t)
GN&C		
Engineering Models		SEER-SEM Flight Modeling and Simulation (less portion of mgmt, se, i&t)
Payload & Instrument Control Software		SEER-SEM Payload Code total less System I&T (less portion of mgmt, se, i&t)
Systems Services Software		SEER-SEM Services total less Modeling and Simulation (less portion of mgmt, se, i&t)
Software Testbed		4% added to the SEER-SEM Flight Software estimate to account for Testbed software
Software I&T		SEER-SEM I&T total for Flight Software

Estimated from historical data

Core Software development effort

50% of CM covered by SW developers

COST by LABOR Category

PROJECT - C:\Documents and Settings\sastokes\Local Settings\Temporary Internet Files\OLK2DB\JNS_SMAP_FSW 3-25-091.PRJ

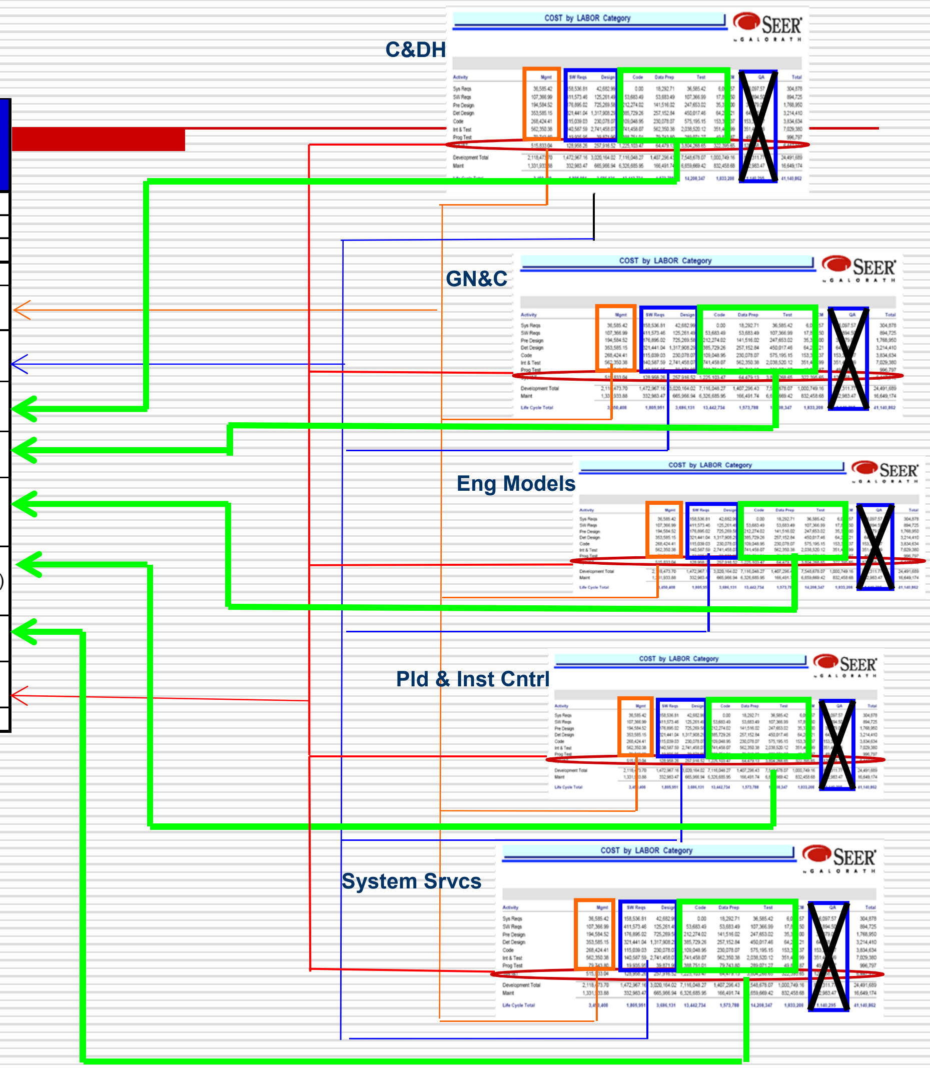
1 - Project - SMAP Flight Software - Phase A

Activity	Mgmt	SW Reqs	Design	Code	Data Prep	Test	CM	QA	Total
Sys Reqs	36,585.42	158,536.81	42,682.99	0.00	18,292.71	36,585.42	6,097.57	6,097.57	304,878
SW Reqs	107,366.99	411,573.46	125,261.49	53,683.49	53,683.49	107,366.99	17,894.50	17,894.50	894,725
Pre Design	194,584.52	176,895.02	725,269.58	212,274.02	141,516.02	247,653.02	35,379.00	35,379.00	1,768,950
Det Design	353,585.15	321,441.04	1,317,908.29	385,729.26	257,152.84	450,017.46	64,288.21	64,288.21	3,214,410
Code	268,424.41	115,039.03	230,078.07	2,109,048.95	230,078.07	575,195.15	153,385.37	153,385.37	3,834,634
Int & Test	562,350.38	140,587.59	2,741,458.07	2,741,458.07	562,350.38	2,038,520.12	351,468.99	351,468.99	7,029,380
Prog Test	79,743.80	19,935.95	39,871.90	388,751.01	79,743.80	289,071.27	49,839.87	49,839.87	996,797
Sys I&T	515,833.04	128,958.26	257,916.52	1,225,103.47	64,479.13	3,804,268.65	322,395.65	128,958.26	6,447,913
Development Total	2,118,473.70	1,472,967.16	3,020,164.02	7,116,048.27	1,407,296.43	7,548,678.07	1,000,749.16	807,311.77	24,491,689
Maint	1,331,933.88	332,983.47	665,966.94	6,326,685.95	166,491.74	6,659,669.42	832,458.68	332,983.47	16,649,174
Life Cycle Total	**3,450,408**	**1,805,951**	**3,686,131**	**13,442,734**	**1,573,788**	**14,208,347**	**1,833,208**	**1,140,295**	**41,140,862**

Covered by a non-Software organization

SEER-SEM Subsystem Mapping

WBS	Description	FY$08K Total System Cost	Basis of Estimate
6.12	**Flight Software**		**Roll-up**
	Equipment		Factor based on number of computers
	Facilities		Factor based on number of square feet
6.12	**Flight Software**		**Roll-up**
06.12.01	Software Management		SEER-SEM Mgmt total less System I&T
06.12.02	Software Systems Engineering		SEER-SEM SW Req and SW Design total less System I&T
06.12.03	C&DH		SEER-SEM C&DH (less portion of mgmt, se, i&t)
06.12.04	GN&C		SEER-SEM GN&C (less portion of mgmt, se, i&t)
06.12.05	Engineering Models		SEER-SEM Flight Modeling and Simulation (less portion of mgmt, se, i&t)
06.12.06	Payload & Instrument Control Software		SEER-SEM Payload Code (less portion of mgmt, se, i&t)
06.12.07	Systems Services Software		SEER-SEM Services total (less portion of mgmt, se, i&t)
06.12.08	Software Testbed		4% added to the SEER-SEM Flight Software estimate to account for Testbed software
06.12.09	Software I&T		SEER-SEM I&T total for Flight Software



Spreadsheet Summary

- Single source for compiling cost data for all proposals
- Consists of 3 major sections
  - Descriptive data
  - Size data
  - Attribute data
- Allows for quick relative comparison of all input data and output results
- Spreadsheet preceded and gave rise to the decision graph during the FSW cost estimating process

One picture is worth 1,000 words

Descriptive Data

Category	Inn_Hel_1			Inn_Hel_2	
Proposal Name	1	2	3	4	5
Cost Lead	A	B	C	D	D
Spacecraft Provider	SDC_1	SDC_1	SDC_2	SDC_3	FFRDC
Analogy Program(s) Used	from SDC_1	from FFRDC	from FFRDC	from FFRDC	from FFRDC
Contractor/Analogy Data	SDC_1/ SDC_1	SDC_1/ SDC_2	SDC_2/ SDC_2	SDC_3/ FFRDC	FFRDC/ FFRDC
Software Cost Estimates (SEER-SEM) (FY$10M) (excludes testbed, equip, facilities)	$XX	$XX	$XX	$XX	$XX
SEER-SEM (- ATLO, SQA, CM 50%)	$XX	$XX	$XX	$XX	$XX
Team X Estimate (for reconcilliation)	$XX	$XX	$XX	$XX	$XX
Software Duration (SEER-SEM) (mo)	27	30	23	30	26
Knowledge Bases					
SEER-SEM Window Name: (Create/Modify WSB Element)					
Platform (Operating Environment)	Unmanned Space	Unmanned Space	Unmanned Space	Unmanned Space	Unmanned Space
Application	Flight Systems	Flight Systems	Flight Systems	Flight Systems	Flight Systems
Acquisition Method	New/Reuse	New/Reuse	New/Reuse	New/Reuse	New/Reuse
Development Method	Incremental	Incremental	Incremental	Incremental	Incremental
Development Standard	DO-178B Level B	DO-178B Level B	DO-178B Level B	DO-178B Level B	DO-178B Level B

Sample Data

Size Data

Category	Inn_Hel_1			Inn_Hel_2	
Proposal Name	**1**	**2**	**3**	**4**	**5**
Software Size (SLOC)					
Size BoE	Used actual SLOC counts from SDC_1. Assumed 25% new, 25% reused "as is", and 50% reused modified.	Used an average actuals from FFRDC projects with the inheritance percentages fromFFRDC.	Used SDC_2-derived SLOC values for new, reused, reused modified. Added correction factor to convert code counts.	Used FFRDC TDP information.	Used FFRDC size estimates. Duplicated reasoning used for FFRDC estimate.
ESLOC	69,888	92,238	61,848	85,533	61,450
Delivered Software (SLOC) - most likely	153,812	202,000	204,990	221,664	180,000
Software Size (SLOC)					
New SLOC - most likely	38,453	60,600	25,000	46,404	30,000
% of new SLOC	**25%**	**30%**	**12%**	**21%**	**17%**
Reuse SLOC (as is - no mod) - most likely	38,453	35,350	97,700	117,424	70,000
% of reused (as is) SLOC	**25%**	**17%**	**48%**	**53%**	**39%**
% re-design	0	0	0	0	0
% re-implementation (Re-coding)	0	0	0	0	0
% re-test	50%	50%	50%	50%	50%
Reuse SLOC (modified) - most likely	76,906	106,050	82,290	57,836	80,000
% of reused (modified) SLOC	**50%**	**53%**	**40%**	**26%**	**44%**
% re-design	10%, 25%, 25%	10%	10%	10%, 25%, 25%	10%
% re-implementation (Re-coding)	10%, 25%, 25%	10%	10%	10%, 25%, 25%	10%
[illegible]	50%	50%	50%	50%	50%

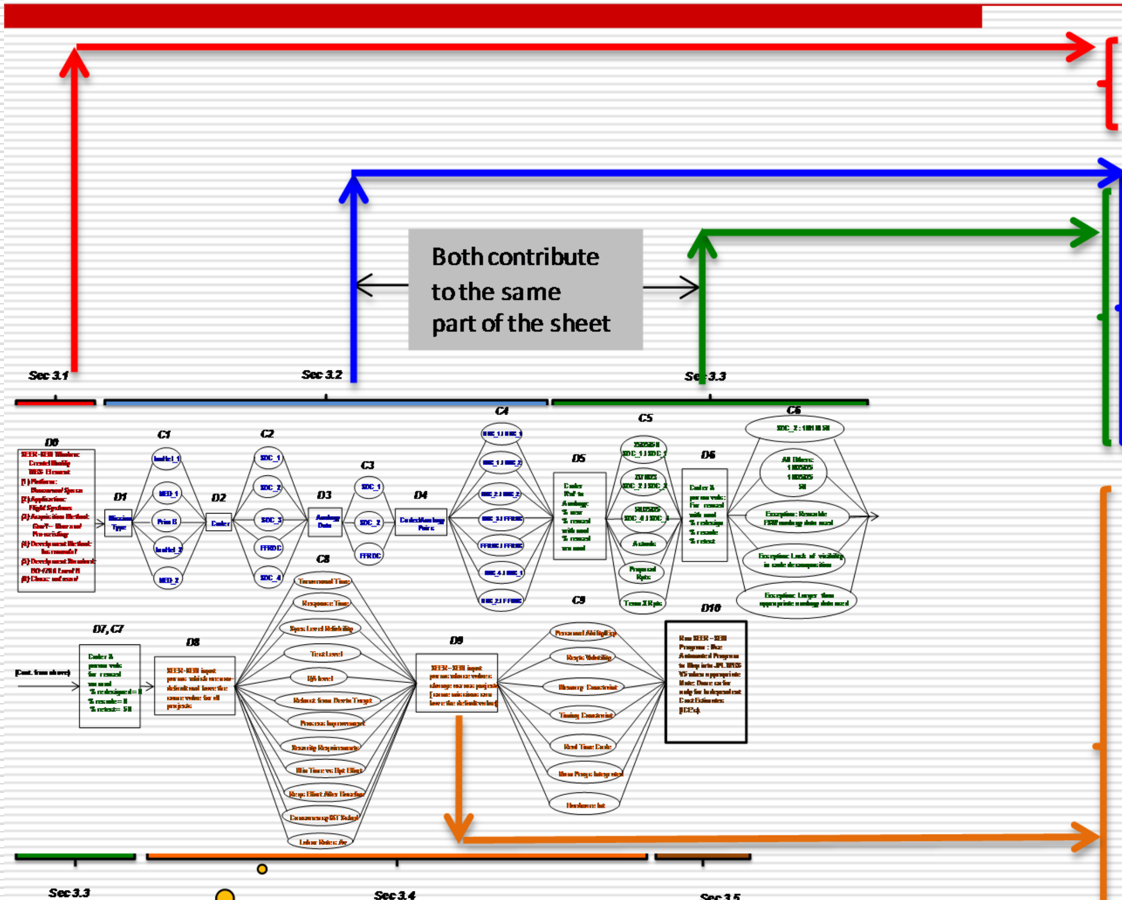
Sample Data

Attribute Data

Parmeter Settings Notes					
Personnel Capabilities & Experience (7 parameters)	Leave at KB setting. This reflects an industry average which is appropriate since we do not know the composition of the software development team so early in the proposal process.				
Analyst Capability					NOM-
Analyst's Application Experience					NOM
Programmer Capabilities					NOM-
Programmer's Language Experience					VHI
Developkent System Experience					HIGH
Target System Experience					VHI
Practices & Methods Experience					VHI
Development Support Environment	Leave at KB settings with the exception of:				
turnaround time	VLO	VLO	VLO	VLO	VLO
response time	LOW	LOW	LOW	LOW	LOW
Product Development Requirements	Leave at KB settings with the exception of:				
requirements volatility	HIGH	HIGH	HIGH	HIGH	HIGH
spec level - Reliability	HIGH-	HIGH-	HIGH-	HIGH-	HIGH-
test level	HIGH	HIGH	HIGH	HIGH	HIGH
quality assurance level	HIGH	HIGH	HIGH	HIGH	HIGH
rehost (development to target)	HIGH-	HIGH-	HIGH-	HIGH-	HIGH-
Product Reusability Requirements	Should always be NOM (no reusability required by the contract). If the parameter is set to NOM the percentage value is meaningless.				
Development Environment Complexity	Leave at KB settings with the exception of:				
process improvement	NOM	NOM	NOM	NOM	NOM
Target Environment	Leave at KB settings with the exception of:				
memory constraint	NOM	NOM	NOM	NOM	NOM
timing constraint	NOM+,NOM+,HIGH-	NOM+,NOM+,HIGH-	NOM+,NOM+,HIGH-	NOM+,NOM +,HIGH-	NOM+,NOM+,HIGH-
real time code	NOM, NOM, NOM+	NOM, NOM, NOM+	NOM, NOM, NOM+	NOM, NOM, NOM+	NOM, NOM, NOM+
security requirements	NOM	NOM	NOM	NOM	NOM
Schedule & Staffing Constraints	Leave at KB settings with the exception of:				
start date	11/25/2012	11/25/2012	11/25/2012	11/25/2012	11/25/2012
Min Time vs Optimal Effort	Always start with **Optimal Effort**. Where possible, verify that the schedule duration is achievable. If not, evaluate schedule constraints to accommodate the estimated schedule. If the software development time is less than the **Minimal Time**, the SEER-SEM model contends that it is not possible to complete the software. Identify this as a significant risk issue!				
Confidence Levels	Both effort and schedule should be run at 50% and 70% confidence. SQI recommends the 70%				
Requirements	Leave at KB settings with the exception of:				
requirements after baseline	YES	YES	YES	YES	YES
System Integration					
number of programs being integrated	5	5	7	5	5
concurrency of I&T	Hi	Hi	Hi	Hi	Hi
hardware integration	N-, N, N+	N-, N, N+	N-, N, N+	N-, N, N+	N-, N, N+
Ecomonic Factors	Labor rate based on NASA Center contractor developed software survery conducted in FY08. Escalated to FY$10 using the NASA New Start Inflation index (5.6%).				
cost base year	2010	2010	2010	2010	2010
labor rate (FY$2010) work months	$xx	$xx	$xx	$xx	$xx

Sample Data

Notional Retrospect



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% re-implementation (Re-coding)	0	0	0	0	0
% re-test	50%	50%	50%	50%	50%
Reuse SLOC (modified) - most likely	76,906	106,050	82,290	57,836	80,000
% of reused (modified) SLOC	50%	53%	40%	26%	44%
% re-design	10%, 25%, 25%	10%	10%	10%, 25%, 25%	10%
% re-implementation (Re-coding)	10%, 25%, 25%	10%	10%	10%, 25%, 25%	10%
% re-test	50%	50%	50%	50%	50%
Parmeter Settings Notes					
Personnel Capabilities & Experience (7 parameters)	Leave at KB setting. This reflects an industry average which is appropriate since we do not know the composition of the software development team so early in the proposal process.				
Analyst Capability					NOM-
Analyst's Application Experience					NOM
Programmer Capabilities					NOM-
Programmer's Language Experience					VHI
Developkent System Experience					HIGH
Target System Experience					VHI
Practices & Methods Experience					VHI
Development Support Environment	Leave at KB settings with the exception of:				
turnaround time	VLO	VLO	VLO	VLO	VLO
response time	LOW	LOW	LOW	LOW	LOW
Product Development Requirements	Leave at KB settings with the exception of:				
requirements volatility	HIGH	HIGH	HIGH	HIGH	HIGH
spec level - Reliability	HIGH-	HIGH-	HIGH-	HIGH-	HIGH-
test level	HIGH	HIGH	HIGH	HIGH	HIGH
quality assurance level	HIGH	HIGH	HIGH	HIGH	HIGH
rehost (development to target)	HIGH-	HIGH-	HIGH-	HIGH-	HIGH-
Product Reusability Requirements	Should always be NOM (no reusability required by the contract). If the parameter is set to NOM				
Development Environment Complexity	Leave at KB settings with the exception of:				
process improvement	NOM	NOM	NOM	NOM	NOM
Target Environment	Leave at KB settings with the exception of:				
memory constraint	NOM	NOM	NOM	NOM	NOM
timing constraint	NOM+,NOM+,HIGH-	NOM+,NOM+,HIGH-	NOM+,NOM+,HIGH-	NOM+,NOM+,HIGH-	NOM+,NOM+,HIGH-
real time code	NOM, NOM, NOM+	NOM, NOM, NOM+	NOM, NOM, NOM+	NOM, NOM, NOM+	NOM, NOM, NOM+
security requirements	NOM	NOM	NOM	NOM	NOM
Schedule & Staffing Constraints	Leave at KB settings with the exception of:				
start date	11/25/2012	11/25/2012	11/25/2012	11/25/2012	11/25/2012
Min Time vs Optimal Effort	Always start with Optimal Effort. Where possible, verify that the schedule duration is achievable. If not, evaluate schedule constraints to accommodate the estimated schedule. If the software development time is less than the Minimal Time, the SEER-SEM model contends that it is not possible to complete the software. Identify this as a significant risk issue!				
Confidence Levels	Both effort and schedule should be run at 50% and 70% confidence. SQI recommends the 70%				
Requirements	Leave at KB settings with the exception of:				
requirements after baseline	YES	YES	YES	YES	YES
System Integration					
number of programs being integrated	5	5	7	5	5
concurrency of I&T	Hi	Hi	Hi	Hi	Hi

Sample Data

Summary and Future Work:
The Evolution of the Graph

- Efficient and Effective Methodologies for Consistency Checking had to be established
  - Due to time constraints quick visual comparisons between proposal parameters were needed
  - Developed a comprehensive worksheet which served as a blueprint for FSW estimates
  - Started with inputs to SEER-SEM
  - Needed mission data that gave rise to these SEER-SEM inputs
- There evolved a Dynamic : An Interplay of Data/Reason for Data
  - Document mission information that gave rise to SEER-SEM parameter value selection
  - Forced a progressively exacting analysis with respect to:
    - The FSW costing exercise and
    - An examination of the thinking processes behind it

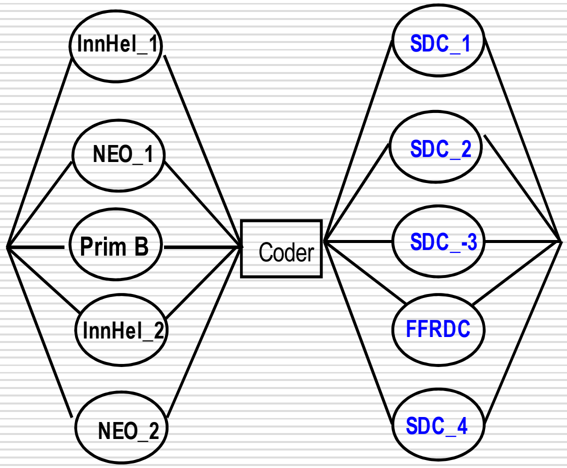
Summary and Future Work:
The Evolution of the Graph

- Thinking Process is Compartmentalized and Formalized
  - Key decisions had to be made in sequential order
  - Each decision was followed by several possibilities
  - Above sequence' type' : repeated several times
  - Resulted in a Decision Graph
  - "Necessity is the Mother of Invention"
- Decision Graph represents the expert knowledge
  - Convenient way of compressing the knowledge for discussion
  - Retains the content of what was needed for FSW estimates
  - Representative of an underlying decision tree
  - Decision tree gives rise to an expert system*

**An expert system is a computer program based upon an expert's knowledge powered by rules and an engine which determines how to manipulate those rules.*

Summary and Future Work:

From Decision Graph to Expert System



Portion of Decision Graph
with underlying Decision Tree

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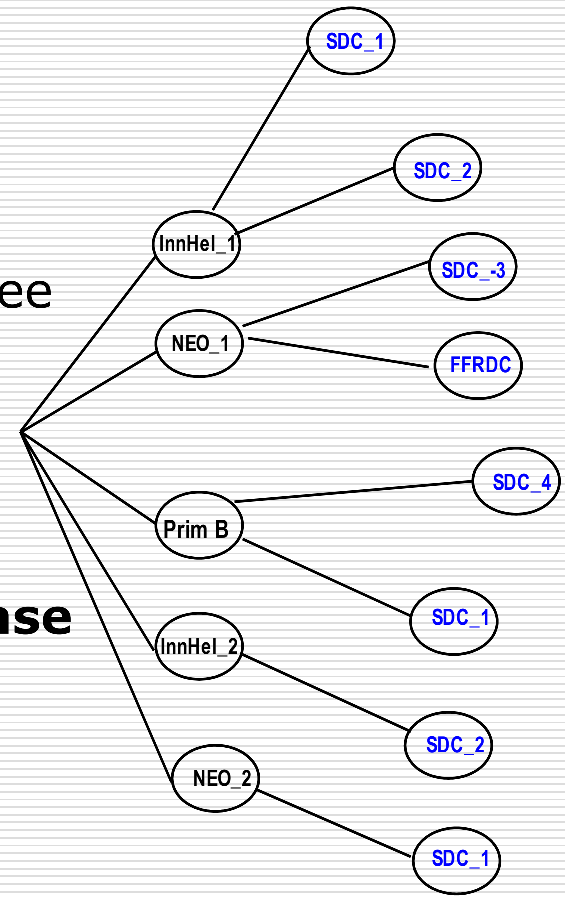


Decision Tree implies a expert system rule-base

- Use to determine cost of a proposal of interest
- Computer explains reasoning for costs
- Rule-base design facilitates expert modification
- Increased robustness can be obtained without extensive redesign : JUST ADD RULES !

Useful Resources and Web Sites

- “*Software Cost Estimation Using a Decision Graph Process: A Knowledge Engineering Approach*”, Sherry Stukes and Dr. John Spagnuolo, Jr., ISPA SCEA Joint Annual Conference & Training Workshop, June 2011
- SEER-SEM, v8.0.14, Galorath Inc., El Segundo, CA, 2011
- CADRe data – Eric Plummer, NASA Headquarters, (202) 358-5178
- RedStar Library – Mary Ellen Harris, SAIC,

  (256) 971-6425
- NASA Cost Estimating Handbook (2004 and 2008) (http://nasa.ceh.gov)

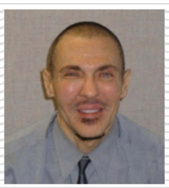
Biographies

Sherry Stukes

Ms. Stukes is a Software Systems Engineer/Cognizant Engineer at The Jet Propulsion Laboratory in Pasadena, California. She specializes in software estimating and software data collection in support of JPL Independent Cost Estimates, proposals, and CADRe development. Ms. Stukes manages a research project that will provide a software estimating tool for NASA Headquarters, which is not dependant on software lines of code.

Some of Ms. Stukes prior accomplishments include: development and maintenance of two large databases for the Air Force Space and Missile Systems Center (AF SMC): the Software Database (SWDB) and the Operations and Support Database (OSDB); instructor for the Army Logistics Management College (ASDC_2C) Software Estimating Models course; and advisor to Air Force Institute of Technology (AFIT) students conducting thesis projects in the area of software model calibration. Ms. Stukes was the 1997 International Society of Parametric Analysts (ISPA) Parametrician of the year.

Ms. Stukes holds a BS degree in Business Administration from California State University, Long Beach and an MBA from California Lutheran University.



Dr. John Spagnuolo, Jr.

Dr. Spagnuolo is presently serving as an Engineering Cost Analyst in the Engineering Cost Estimation Group at The Jet Propulsion Laboratory in Pasadena, California. He specializes in the preparation of Cost Estimation Data Requirements (CADRes), Cost Estimating relationships (CERs) and software cost estimation and analysis. He holds degrees in mathematics from Clarkson College of Technology, University of California at Los Angeles, and the Doctor's degree from Rensselaer Polytechnic Institute.

In the past, Dr. Spagnuolo has received several awards and certificates of recognition relating to his work in neural networks and solar physics. He received the Space Act Award for his paper on the Computation and Visualization of Archimedean spirals in 3 dimensions. Along with numerous conference and journal articles, he has published several abstracts in the NASA Tech Briefs Journal. He also developed an architecture for a hierarchical planning system for computerized military war gaming and an expert system for use in automated decision making in a computer war game for which he won best session paper at the Military Operations Research Society (MORS) Conference.

Presently, Dr. Spagnuolo is studying Newton's Principia from a mathematical perspective and doing research in mapping cognition onto an artificial neural network

List of Terms

ATLO	Assembly, Test, Launch Operations
CADRe	Cost Analysis Data Requirement
C&DH	Command and Data Handling
CEH	Cost Estimating Handbook
CER	Cost Estimating Relationship
EM	Engineering Model
ESLOC	Equivalent (new) Source Lines of Code
FFRDC	Federally Funded Research and Development Center
FSW	Flight Software
FY	Fiscal Year

List of Terms

GN&C	Guidance, Navigation and Control
GSW	Ground Software
ICE	Independent Cost Estimate
I&T	Integration and Test
ITAR	International Traffic in Arms Regulations
LCC	Life Cycle Cost
Mgmt	Management
NPR	NASA Procedural Requirement
ONCE	One NASA Repository

List of Terms

SDC	Software Development Contactor
SE	Systems Engineering
SEER-SEM	System Evaluation and Estimation Review – Software Estimation Model
SLiC	Software Line Counter (code counter)
SLOC	Source Lines of Code
SMART	Software Measurement Analysis Repository Tool
SQI	Software Quality Improvement
SW	Software
WBS	Work Breakdown Structure