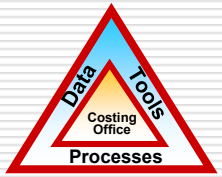



# Modeling SEER-SEM Using a Decision Graph: A Knowledge Engineering Approach

## SEER Users Workshop
## El Segundo CA

Sherry Stukes
Software Systems Engineer
Jet Propulsion Laboratory/
California Institute of Technology
818.393.7517
sherry.a.stukes@jpl.nasa.gov

John Spagnuolo, Jr., PhD
Cost Engineer
Jet Propulsion Laboratory/
California Institute of Technology
818.354-8266
john.s.spagnuolo@jpl.nasa.gov

22 February 2011

# Outline

- Background
- Approach - Decision Graph
- Data Sources
- Data Sheet
  - Descriptive
  - Size
  - Attributes
- Mapping
- Lessons Learned
- References

# Background
# Types of Software Cost Activities

- Across the board estimates done for Discovery proposals (14 missions)
  - Main focus of this presentation
  - Strove for consistency in analysis
  - Had to be done quickly and in parallel
- Independent Cost Estimates (ICE)
  - Requested by the project
  - Initiated by the Costing Office
  - Required at milestone reviews
  - Performed separately from the project
- Cost Analysis Data Requirements (CADRes)
  - SW metrics page – 48 columns displayed for each SW element
  - Up to 40 rows of SW elements
  - Required at milestone reviews

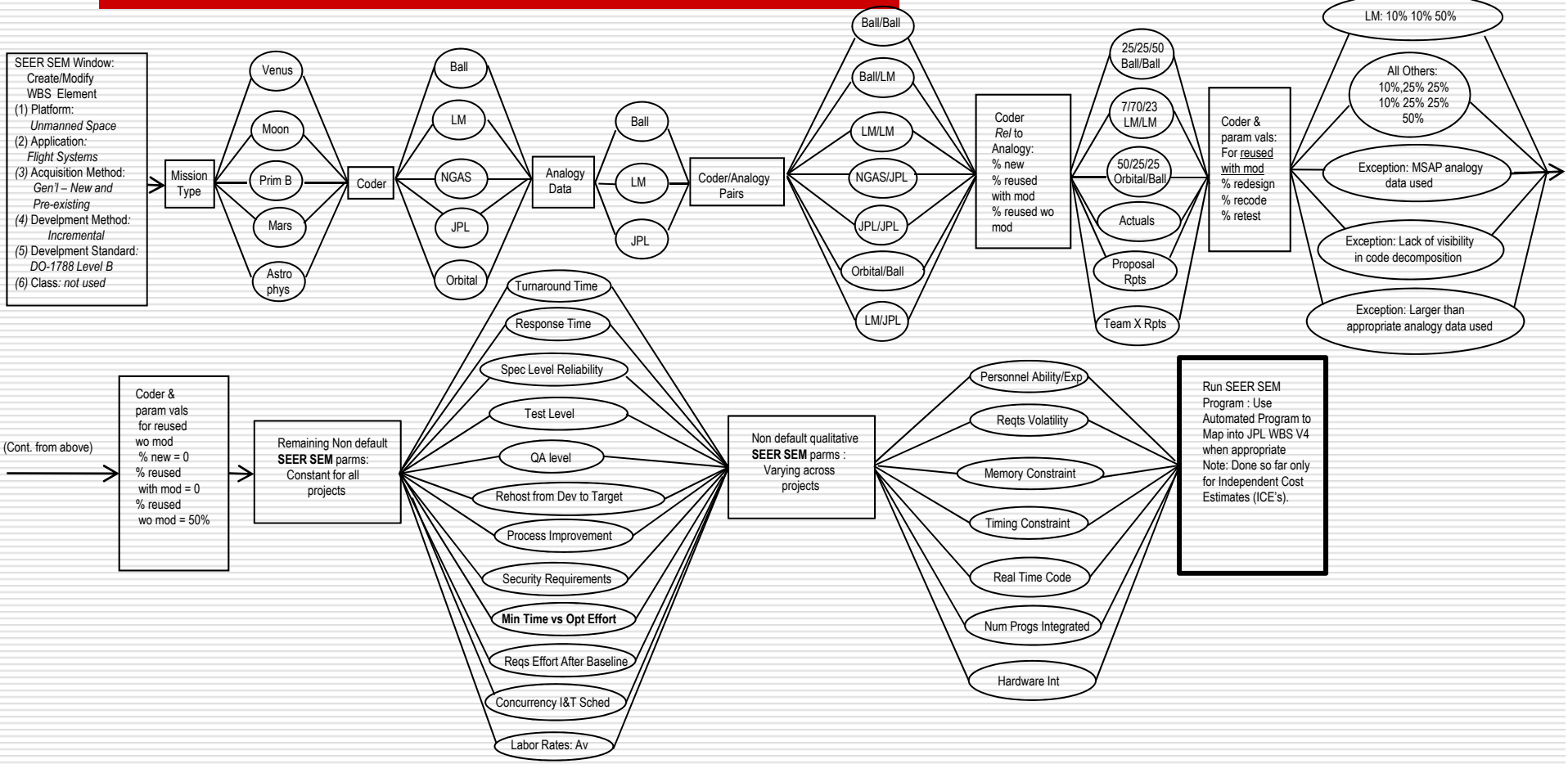
# Background
# Specific Application

- Needed to provide software estimates for 14 Discovery Class proposals
- Tight schedule constraint
- Limited resources
  - 3 analysts (reduced to 2)
  - Funding for less than half time
- Provided results to individual proposal Cost Engineers
  - Follow-up with additional data
  - Respond to questions
  - Support proposal meetings

# Knowledge Engineering Approach

- Experienced Software Cost Estimator
  - > 30 years in the business
  - Successfully engaged at many different technical facilities
  - Developing a SW estimating Tool for NASA
- Experienced Knowledge Engineer
  - Published and experienced in expert systems work
  - Brings a new perspective to the cost estimating business
  - Organizes, makes consistent, and represents expert's analysis
- Build Decision Graph
  - More compact and intuitively palatable than decision tree
  - Sufficiently expresses high level relationships and concepts

# Decision Graph



# 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 JPL standard WBS (for validation)
- SQI Software Repository (SMART)
  - Ground, flight, and instrument data
  - JPL Proprietary, ITAR restricted
- RedStar Library
- Project Personnel
- Other Projects for software data not captured anywhere else

# Data Sheet (1) – Descriptive Data

| Category | Venus | | | Moon | |
|---|---|---|---|---|---|
| Proposal Name | 1 | 2 | 3 | 4 | 5 |
| Cost Lead | Patrick | Mike F. | Eric | Mike D. | Mike D. |
| Spacecraft Provider | Ball | Ball | LMA | TBD - costed as in-house via Team X | JPL |
| Analogy Program(s) Used | DI SQI Actuals | MRO | Vesper Step 2 report | MSAP | MSAP |
| Contractor/Analogy Data | Ball/Ball | Ball/LM | LM/LM | NGAS/JPL | JPL/JPL |
| Software Cost Estimates (SEER-SEM) (FY$10M) (excludes testbed, equip, facilities) | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| SEER-SEM (- ATLO, SQA, CM 50%) | | | | | |
| Team X Estimate (for reconcilliation) | | | | | |
| Software Cost Estimates (SEER-SEM) (WY) | 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

# Descriptive Data

- Identify spacecraft provider (contractor)
- Obtain relevant data for contractor
  - Repositories
  - Proposal documentation
- Specify contractor – data pair
- Select appropriate Knowledge Bases

# Data Sheet (2) – Size Data

| Category | Venus | | | Moon | |
|---|---|---|---|---|---|
| **Proposal Name** | **1** | **2** | **3** | **4** | **5** |
| **Software Size (SLOC)** | | | | | |
| Size BoE | Used **Deep Impact actual** SLOC counts. Assumed 25% new, 25% reused "as is", and 50% reused modified. | Used an average of **MRO actual** code and **Odyssey actual** with the inheritance percentages from Team X. | Used LMA **derived** SLOC Values from **Step 2** report: new, reused, reused modified. Added correction factor to convert LMA code counts to JPL code counts. | Used **LSO TDP** (Team X report) information. | Used **MSAP** (reuseable flight software) size **estimates**. Duplicated reasoning used for SMAP 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%, 25%, 25% | 10%, 10%, 10% | 10%, 25%, 25% | 10%, 25%, 25% |
| % re-implementation (Re-coding) | 10%, 25%, 25% | 10%, 25%, 25% | 10%, 10%, 10% | 10%, 25%, 25% | 10%, 25%, 25% |
| % re-test | 50% | 50% | 50% | 50% | 50% |

Sample Data

# Software Size (1)

- Software size defined as Logical Lines of code
- Reused code assumes that the code is being reused "as is", no additional design or code is required, all code is integrated and fully tested
- Modified code requires additional design and coding
  - Requires % re-design, %re-code, %re-test
  - Objective equations containing cost drivers are used to calculate the percentages
- Auto-generated and ported code
- Using the USC Code Counter

# 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

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

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

# Software Size (2)

- Not changed often
  - Different ways of enumeration (counting) or deriving the SLOC value
  - Differing values (e.g. project vs. developing contractor)
  - Different work content (e.g. giving total pre-existing GSW count as opposed to count for the project of interest )
  - Differing assumptions on new, reused and modified code
- Probabilistic input values

  (e.g. least likely, most likely, highest likely)

# Data Sheet (3) – Attribute Data

| Category | Venus | | | Moon | |
|---|---|---|---|---|---|
| **Proposal Name** | **1** | **2** | **3** | **4** | **5** |
| **Software Size (SLOC)** | | | | | |
| **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. | | | | |
| **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** | | | | | |
| 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 | | | | |
| **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+ |
| real time contraint | 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** | | | | |
| **Confidence Levels** | Both effort and schedule should be run at 50% and 70% confidence. SQI recommends the 70% confidence estimate. | | | | |
| **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 | 5 | 5 | 5 |
| concurrency of I&T | Hi | Hi | Hi | Hi | Hi |
| hardware integration | N-, N, N+ | N-, N, N+ | L, N, N+ | N-, N, N+ | N-, N, N+ |
| **Ecomonic Factors** | Labor rate based on NASA Center contractor developed software survery conducted in FY08 ($24,887/wm). Escalated to | | | | |
| cost base year | 2010 | 2010 | 2010 | 2010 | 2010 |

Sample Data

# Attribute Selection

- Trust your Knowledge Base
- Make modifications cautiously
  - Focus on cost drivers
  - Be conservative
  - Use distribution to reflect uncertainty

# Estimate Results – Mapping SEER Output

- Goal is to map the SEER model output into the JPL Standard 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 JPL WBS elements: Management, Systems Engineering, and Integration and Test
  - Computes WBS element SW 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

**SMAP Software ICE - Based on JPL Parameter Settings and Adjusted Size @ 50% Confidence**

| 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 sw 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

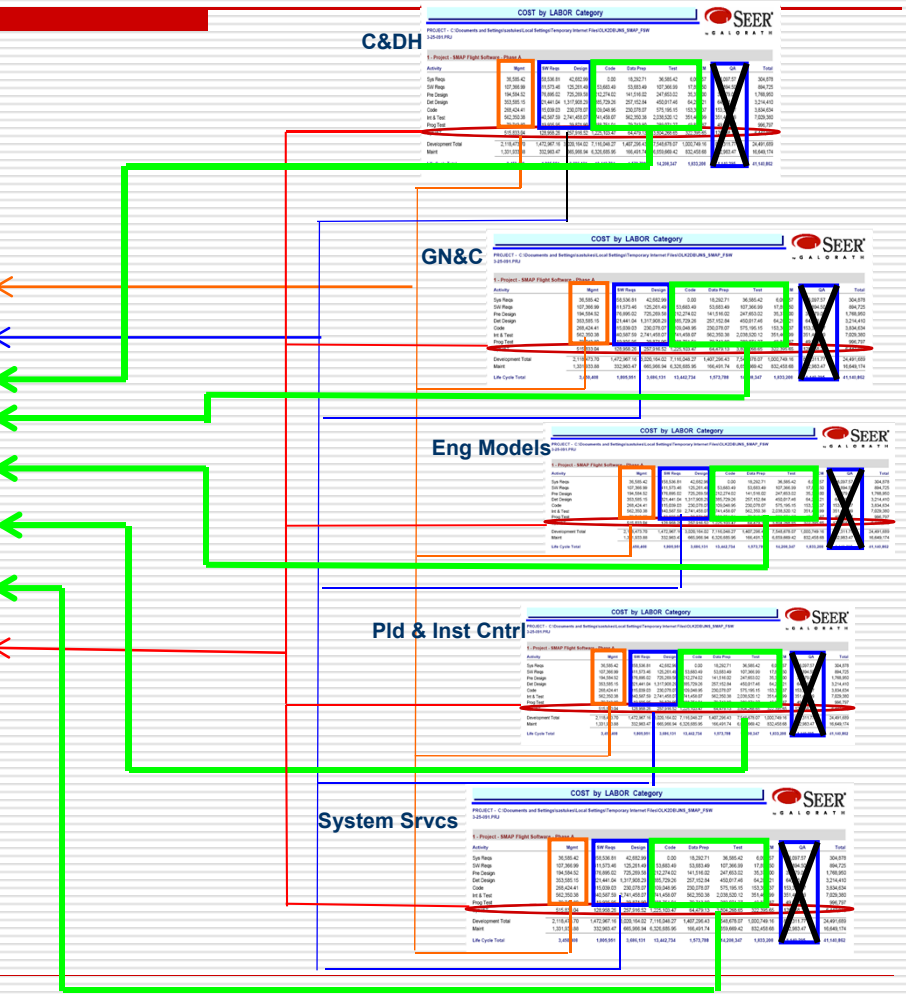
| Activity | Mgmt | SW Reqs | Design | Code | Data Prep | Test | CM | QA | Total |
|---|---|---|---|---|---|---|---|---|---|
| Sys Reqs | 36,585.42 | 158,536.81 | 42,682.99 | 0.00 | 18,292.71 | 36,585.42 | 6,097.57 | 6,097.57 | 304,878 |
| SW Reqs | 107,366.99 | 411,573.46 | 125,261.49 | 53,683.49 | 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 | 1,741,458.07 | 562,350.38 | 2,038,520.12 | 351,469.99 | 351,469.99 | 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 | 803,311.77 | 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 5x

# SEER-SEM Subsystem Mapping

**SMAP Software ICE - Based on JPL Parameter Settings and Adjusted Size @ 50% Confidence**

| 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 C&DH (less portion of mgmt, se, i&t) |
| GN&C | | SEER-SEM GN&C (less portion of mgmt, se, i&t) |
| Engineering Models | | SEER-SEM Flight Modeling and Simulation (less portion of mgmt, se, i&t) |
| Payload & Instrument Control Software | | SEER-SEM Payload Code (less portion of mgmt, se, i&t) |
| Systems Services Software | | SEER-SEM Services total (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 |



# Lessons Learned

- Use a consistent and objective approach when creating multiple estimates that will be compared
- Use relevant historical data to support your estimates
  - Use expert input whenever possible
- Don’t second guess the data or the tool
- Use expert input whenever possible

# Useful Resources and Web Sites

- CADRe data – Eric Plummer, NASA Headquarters, (202) 358-5178
- RedStar Library – Mary Ellen Harris, SAIC, (256) 971-6425
- NASA Cost Estimating Handbook (http://nasa.ceh.gov)

# 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 |
| 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

| | |
|---|---|
| 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 |