

Electronic Schedule Dissemination 3.0

ESD 3.0 Independent Cost Estimate

**Presentation to
AFSPC SMC/SN Sponsor and Aerospace Corporation**

**Prepared by
Sherry Stukes**

Software Systems Engineer

Jet Propulsion Laboratory/California Institute of Technology

818.393.7517

sherry.a.stukes@jpl.nasa.gov

4 March 2011

**Copyright 2011 California Institute of Technology, Government Sponsorship Acknowledged.
All rights reserved.**



ESD 3.0 Topics

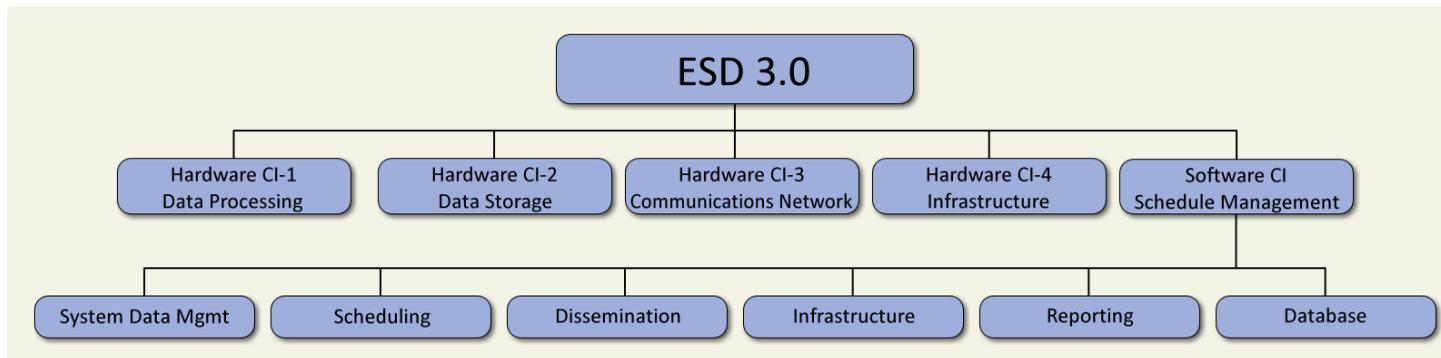
- **Scope of the ICE**
- **Description – ESD 3.0**
- **Estimate Results**
- **Estimating Methodology**
- **Ground Rules and Assumptions**
- **Estimate Cross-Check**
- **Follow-on Efforts**
- **Back-up Material**

Scope of the ICE

- **Includes cost-to-complete effort for ESD 3.0 development**
- **Covers the period of 9 June 2011 to 28 August 2014 (~39 months)**
- **WBS for cost estimate is based on 11 November 2010 ESD 3.0 contractor organization chart**
- **No Government, FFRDC, or SETA contractor costs are included**
- **Cross-checked estimates using a secondary estimating methodology**

ESD 3.0 Description – ESD 3.0

- The ESD 3.0 system includes the hardware and software required to support the Air Force Satellite Control Network (AFSCN). The ESD 3.0 provides the tools to facilitate the daily scheduling of the 400+ satellites.
- Provides support and status of all AFSCN resources at each operational location. Communicates the schedule and resource status information in a timely manner.
- ESD 3.0 is comprised of 5 Configuration Items, plus supporting functions (PM, CM/DM, QA, ILS, I&T)



Estimate Results

Most Likely Cost Estimate (FY\$11M)

Element	Primary Estimate	Cross-Check Estimate
Total Cost Estimate	\$ 62.0	\$ 59.1
Program Management	\$ 6.9	\$ 8.4
Configuration Management/ Data Management (CM/DM)	\$ 1.0	\$ 0.8
Quality Assurance	\$ 1.4	\$ 1.3
Hardware	\$ 8.2	\$ 8.2
Integrated Logistics Support (ILS)	\$ 6.7	\$ 2.5
Software	\$ 26.5	\$ 25.3
Integration & Test	\$ 11.3	\$ 12.6

- **Uncertainty in estimate due to data found to be incorrect and incomplete**
- **Estimate based on data provided by SMC and the contractor**
 - Hardware quantities may be incomplete
 - Operating locations may be missing items
 - Software size (SLOC) factored from exiting code
- **Factored cost elements will increase proportionately to changes in hardware and software costs**
 - Contractor management structure looks high
 - ILS appears understated
 - Testing activities are not fully described

Estimate Summary

Most Likely Cost Estimate (FY\$11M)

Key Cost Drivers of Cost Contributors

- ◆ Number of program management staff
- ◆ Use of “old technology” hardware items
- ◆ Initial spares requirement
- ◆ Training requirement (numbers of personnel and train-the-trainer)
- ◆ Software code size (integrating the new software with the existing code)
- ◆ System integration complexity

Most Likely Cost Summary

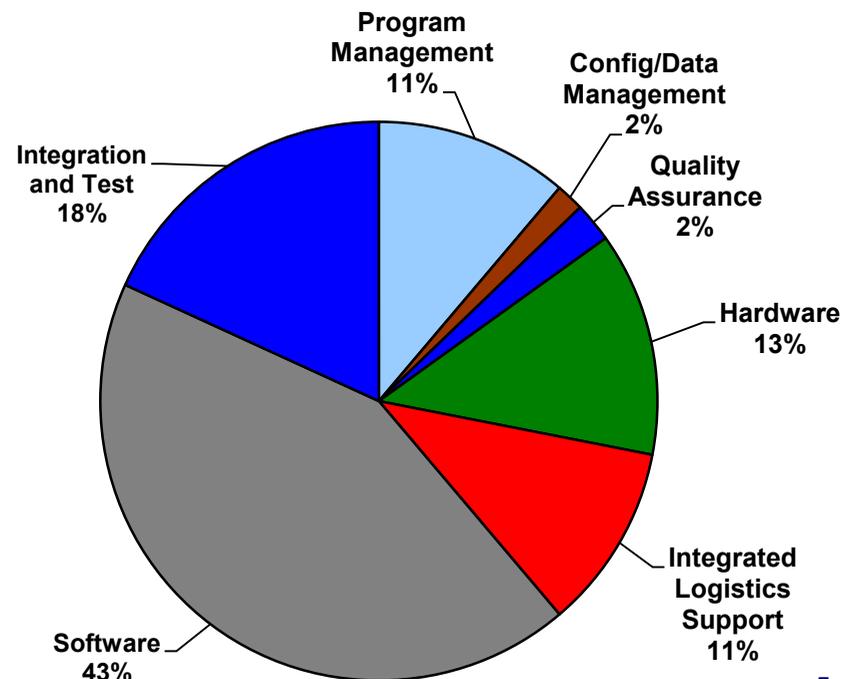
Cost Elements	FY\$11M
Program Management	6.9
Configuration/Data Management	1.0
Quality Assurance	1.4
Hardware	8.2
Integrated Logistics Support	6.6
Software	26.5
Integration and Test	11.2

Cost Risk Items

- ◆ M-H - System requirements volatility
- ◆ H - Software code integration (new to existing)
- ◆ M-H - Missing hardware elements
- ◆ M - Hardware item compatibility (technology)
- ◆ M - Number of operational sites
- ◆ M - Software size-to-complete may be understated
- ◆ M - Training requirements are not fully addressed

L=low M=medium H=high

Development (FY11\$M) = \$61.6



ESD 3.0 Estimating Methodology

Element	Primary Estimating Methodology	Cross-Check Estimating Methodology
Program Management	Planning Factor APO-98-4	Contractor Level of Effort
Configuration Management/ Data Management (CM/DM)	Planning Factor APO-98-4	Contractor Level of Effort
Quality Assurance	Planning Factor APO-98-4	Contractor Level of Effort
Hardware	Equipment List, plus Contractor Level of Effort	Contractor Level of Effort, plus Hardware costs
Integrated Logistics Support (ILS)	Planning Factor APO-98-4	Contractor Level of Effort
Software	SEER-SEM	Industry Productivity Factors
Integration & Test	Planning Factor APO-98-4	Contractor Level of Effort



ESD 3.0 Ground Rules and Assumptions (1)

- **Point estimate in FY 2011 dollars (FY\$11)**
- **Labor Rate**
 - Composite labor rate provided by Honeywell is stated as "current" and assumed to be FY 2011 dollars
 - \$21,588/WM
- **Software development contractor, Northrop Grumman, does not have a CMMI rating, but is self-assessed as a Level 4-5**
- **Honeywell ESD team is ISO 9001 certified and operates using these practices**



- **Assume firm requirements are established, minimal volatility**
- **Assume target and host environments are the same (no re-hosting of software code)**
- **Assume that there is no (or negligible) COTS software cost**
- **Used hardware quantities provided by program office**
- **Assume no hardware refresh during program duration**
- **Assume FAA planning factors (APO-98-4) are similar in criticality and appropriate for the ESD 3.0 system**

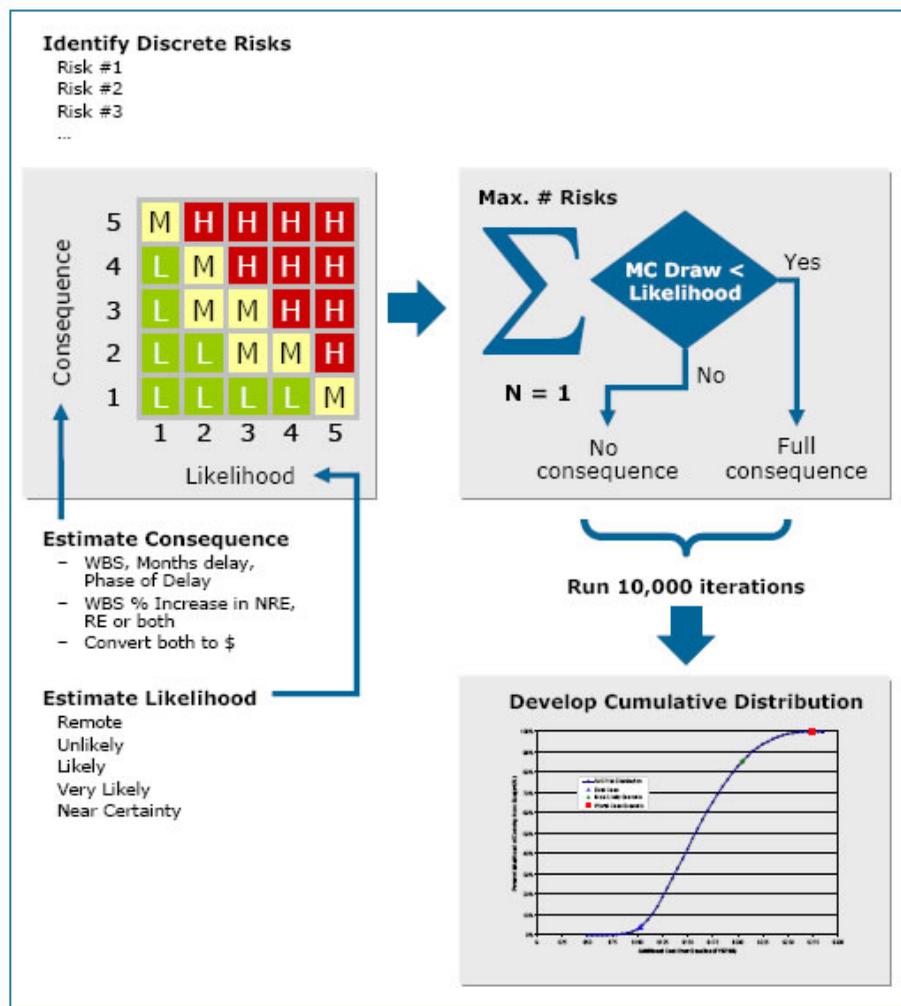


ESD 3.0 Estimate Cross-Check

- **Cross-check estimate based on ESD 3.0 contractor program organization chart dated 11 November 2010**
- **Obtained FTE levels from contractor briefing and discussion with Jim Pomerleau**
- **Assumed contractor work force is level loaded across the period of performance to ensure stable workforce**

ESD 3.0 Follow-on Efforts (1)

- Improve fidelity of estimate by becoming more engaged with the program
 - Validate factored cost elements



- Provide risk adjusted estimate with associated confidence level
 - Need application software such as CrystalBall, approximate cost \$1,500
 - Will provide improved confidence in estimate
- Evaluate risk in terms of cost, technical, and programmatic functions
- Sample NASA process*

*reference 2008 NASA Cost Estimating Handbook

ESD 3.0 Follow-on Efforts (2)

- **Assist with reconciliation of JPL ICE to estimates created by the program office and contractor**
 - Ensure consistency of cost category definitions, input data, and estimate results
- **Research, reconcile, and update documentation of hardware items required for sites**
- **Perform independent quarterly cost review estimates to monitor contractor progress**
 - Obtain current code counts
 - Project code-to-complete estimate

Back-up Material

WBS Description

Element	Description
Program Management	Management, direction and control of all effort contributing to the development and integration of the ESD 3.0. Includes administration, project controls, product effectiveness, subcontract management and security management.
Configuration Management/ Data Management (CM/DM)	Detailed recording and updating of information that describes the ESD 3.0 hardware and software. Includes the versions and updates that have been applied to installed software packages and the locations and network addresses of hardware devices. Data management includes the development, execution and supervision of plans, policies, programs and practices that control, protect, deliver and enhance the value of data and information assets.
Quality Assurance	The systematic monitoring and evaluation of the various aspects of ESD 3.0 that maximizes the probability that minimum standards of quality are being attained by the production process. QA cannot absolutely guarantee the production of quality products.
Hardware	Hardware items identified in the "Hardware Requirements Specification document. Associated labor to procure, configure, assemble, and maintain the hardware items throughout the development phase of the program.
Integrated Logistics Support (ILS)	Analysis, evaluation, and procurement of initial spares. Includes course and curriculum development for initial training and train-the-trainer sessions.
Software	Software requirements analysis, preliminary design, detailed design, code and unit test of the software modules. Includes the software portions of system-level requirements analysis.
Integration & Test	Contains all of the I&T resources specifically related to the ESD 3.0 system. It includes all resources necessary to perform segment verification test, integrated system test and verification and validation of the ESD 3.0 system. It includes requirements definition, planning and scheduling; development of test plans and procedures; test preparations, conduct and teardown; and review, analysis and documentation of test results.



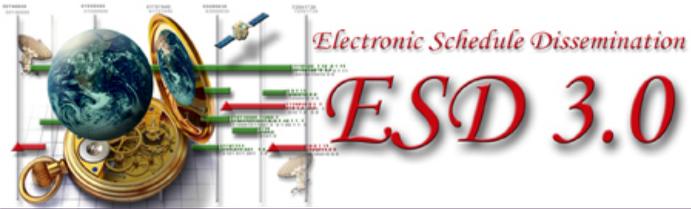
ESD 3.0 Hardware Estimate Details

- **Selected products based on technical description from the ESD 3.0 Hardware Requirements Specification dated 10 August 2010**
- **Quantities extracted from “*ESD3.0_Hardware_By_Site*” Excel spreadsheet provided by Capt Laura Boston 14 February 2011 (update)**
- **Cost estimates based on catalog prices**
 - Used non-discounted values
 - Added tax (10%) and shipping (5%) nominal values

ESD 3.0 Hardware Estimate

Hardware Elements	Total Cost (FY\$11)
Total Cost Estimate	\$3,957,573
HWCI-1 Data Processing	\$ 2,034,503
HWCI-2 Data Storage	\$ 306,190
HWCI-3 Communications	\$ 775,374
HWCI-4 Hardware Infrastructure	\$ 841,507

- **Description of hardware based on the ESD 3.0 “*Hardware Requirements Specification*” dated 10 August 2010**
- **Hardware items and quantities should be reviewed to ensure that they satisfy the requirements**
- **Quantities may be insufficient to cover location and number of sites**



Hardware Estimate Detail Sample

Hardware Elements	Description	Qty	Unit Cost (FY\$11)	Tax & Shipping (@15%)	Total Cost (FY\$11)	Source
Total Cost Estimate					\$3,957,573	
HWCI-1 Data Processing					\$ 2,034,503	
HWCI-2 Data Storage					\$ 306,190	
Database Admin Control (DBAC) Server	The DBAC Server provides multi-processor computing power, redundant network interfaces, and highly available RAID array for efficient database operations. The DBAC provides centralized database administration, management, configuration, monitoring capabilities, disk to disk backup, and restore capability.	35	\$ 5,800	\$ 6,670	\$ 233,450	Dell R610 2-socket/1U
Database Server	The Database Server provides multi-processor computing power, redundant network interfaces, and highly available RAID array for efficient database operations. The Database Server interfaces directly with the Network Attached Storage Device through a fiber channel interface bus card providing direct access to data storage.	10	\$ 5,500	\$ 6,325	\$ 63,250	Dell R610 2-socket/1U
Network Attached Storage (NAS) Device	The Network Attached Storage Device provides a high performance, high availability, and redundant network storage device with direct attachment capabilities through fiber channel bus interfaces. The Network Attached Storage Device directly supports the Database Server through a set of redundant fiber channel storage controllers and specialized set of software tools.	7	\$ 500	\$ 575	\$ 4,025	4TB Gigabit Ethernet ShareSpace Network Attached Storage Manufacturer Part# WDA4NC40000N Dell Part# A2029012
Removable Media Backup Device	The Removable Media Backup Device is a high-density magnetic media tape autoloader device that provides long-term storage of data for retrieval and disaster recovery. The drive is attached to a server via a high-speed interface and is compatible with industry leading backup management software.	8	\$ 594	\$ 683	\$ 5,465	Ultra2 SCSI DAT72 Tape Drive from Quantum® delivers compressed capacities of 72GB with backup speeds of up to 25.2GB/hr

Software Estimate SEER-SEM

- **System Evaluation and Estimation of Resources - Software Estimating Model (SEER-SEM), version 8.0.14**
- **Parametric cost estimating model**
 - Software effort as a function of size
 - Adjusted for complexity and complicating factors
- **Developed by Galorath Incorporated in 1987**
- **Widely accepted in Government and industry**
- **SEER-SEM is based on approximately 6,700 historical data points that are used to create the internal model equations**
 - 70% of the data points are defense related programs
 - 30% are based on commercial environments

ESD 3 ICE.prj - SEER-SEM

File Edit Estimate View Reports Charts Tools Options PPMC Window Help

Project WBS

- 1 ∑ Electronic Schedule Dissemination -
 - 1.1 Business Facade
 - 1.2 Business Rules
 - 1.3 System Frameworks
 - 1.4 Data Access Layer
 - 1.5 Instrumentation
 - 1.6 Web Services
 - 1.7 Win User Interface
 - 1.8 Tools

Parameters - Program: Business Facade

- LINES (Classic)

New Lines of Code	9,831	10,224	11,797
- Pre-exists, not designed for reuse	0	0	0
Pre-existing lines of code	0	0	0
Lines to be deleted in pre-exstg	0	0	0
Redesign required	5.00%	10.00%	40.00%
Reimplementation required	1.00%	5.00%	10.00%
Retest required	10.00%	40.00%	100.00%
- Pre-exists, designed for reuse	4,817	4,817	4,817
Pre-existing lines of code	27,526	27,526	27,526
Lines to be deleted in pre-exstg	0	0	0
Redesign required	0.00%	0.00%	0.00%
Reimplementation required	0.00%	0.00%	0.00%
Retest required	50.00%	50.00%	50.00%
Function Implementation Mechanism		3rd Generation Languages	
Programs Included In Size	13	13	13
- PROXY SIZING			

Quick Estimate

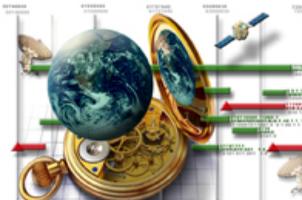
Program: Business Facade

Estimate	
Development Schedule Months	7.74
Development Effort Months	48.60
Development Effort Hours	7,388
Development Base Year Cost	1,049,244
Defect Prediction	8
Total Lines	37,946
Effective Lines	15,237
constraints	OPT EFFORT

Size Allocation

Business Facade

Category	Percentage
New	68.39%
ExistsNDR	0.00%
ExistsDR	31.61%



ESD 3.0 SEER-SEM Knowledge Bases

Knowledge Base Category	Knowledge Base Selection	Definition
Platform	Ground-Based Mission Critical	Aerospace/Defense specific Knowledge Base used to describe software to run ground-based (fixed location) environments serving a critical function.
Application	Mission Planning Analysis	Aerospace/Defense specific Knowledge Base used to describe software for mission planning (including space mission planning).
Acquisition Method	General, new and preexisting	Allows for both new and reused code to be included (new code is expected to be < 90% of effort). All code is re-integrated and tested.
Development Method	Incremental	A linear model of the software development process which allows the software developer to iterate among the activities within each of their life cycle phases for each increment of the system.
Development Standard	ISO 9001	Matches ESD Software Development Team practices and environment.

ESD 3.0 SEER-SEM Attributes

- **Established by the Knowledge Bases selected with the exception of software size – see next slide**
- **37 Parameters are grouped by:**
 - Personnel Capabilities and Experience
 - Development Environment
 - Product Requirements
 - Reusability Requirements
 - Development Environment Complexity
 - Target Environment
- **Adjustments made to “fine tune” the model for ESD 3.0 include:**
 - Software composite labor rate provided by Northrop Grumman
 - Optimal Effort solution – not schedule constrained
 - Minimized Requirements Volatility
 - Minimized Turnaround Time
 - Nominal Languages
 - Eliminated Rehosting

ESD 3.0 SEER-SEM Input - SLOC

- Software size is characterized as Logical Lines of Code
- Previously developed code is assumed to be reused code and is being reused “as is”, no additional design or code is required, however, all code is integrated and fully tested
- Existing code counted using the USC CodeCount tool
 - Represents the industry standard for counting code
 - Documented and maintained by USC PhD students with support from Industry
 - Available at no cost from the USC web site
- Code counts obtained from Honeywell 16 December 2011 are assumed to be 70% of the software development effort

Dec 2010 - Aug 2011	45 mo	30%	Highest Likely code-to-complete
Jun 2011 - Aug 2011	39 mo	26%	Most Likely code-to-complete
Jun 2011 - Aug 2011	39 mo	25%	Lowest Likely code-to-complete

ESD 3.0 SEER-SEM Size (SLOC)

Code Files	Current Code Count @70%				@30%	TOTAL	# of Modules	@25%	@26%
	PSLOC	LSLOC	PData	Comment	LSLOC			LSLOC	LSLOC
SEER Sizing Estimates					Highest Likely			Least Likely	Most Likely
Subtotal Business Façade	47885	27526	87	14363	11,797	39,323	13	9,831	10,224
Subtotal Business Rules	152779	87288	32277	38979	37,409	124,697	19	31,174	32,421
Subtotal Data Access Layer	93314	57871	0	33140	24,802	82,673	14	20,668	21,495
Subtotal System Frameworks	353536	212857	0	43233	91,224	304,081	4	76,020	79,061
Subtotal Instrumentation	1024	677	64	270	290	967	1	242	251
Subtotal Web Services	97137	57221	3028	22586	24,523	81,744	18	20,436	21,254
Subtotal User Interface	368141	245626	1475	104429	105,268	350,894	13	87,724	91,233
Subtotal Tools	55061	34630	2095	11307	14,841	49,471	4	12,368	12,863
TOTALS	1,168,877	723,696	39,026	268,307	310,155	1,033,851	86	258,463	268,801

SEER-SEM

Software Cost Estimates

◆ Activities

- ◆ Sys Requirements Design
- ◆ SW Requirements Analysis
- ◆ Preliminary Design
- ◆ Detailed Design
- ◆ Code & Unit Test
- ◆ Component Integrate & Test
- ◆ Sys Integrate through OT&E
- ◆ Program Test

◆ Labor Categories

- ◆ SW Mgmt
- ◆ SW Requirements
- ◆ SW Design
- ◆ SW Programming
- ◆ Data Preparation
- ◆ SW Testing
- ◆ Configuration Mgmt
- ◆ Quality Assurance

◆ Calculates Metrics

- ◆ Productivity
- ◆ Defect Density

Software Metrics				
Metric	Lines	Functions	Effort Units	Est. Delivered
Effective Size	400,616			
Total Size	997,666			
New Size	273,970			
Reuse Benefit		59%		
Cost Per Size Unit		103		
Effective Defect Density		0.59		
Total Defect Density		0.24		
Total Defects		238		
Development Productivity Measures - Lines/Person Month				
Activities	Labor Categories	Effective	Total	
Pre Design - Prog Test	All	299	744	
Code & Unit Test	All	906	2,257	
All	All	208	518	
Pre Design - Prog Test	Design & Code	587	1,462	
Code & Unit Test	Design & Code	1,486	3,701	
All	Design & Code	466	1,160	
Pre Design - Prog Test	Code	775	1,930	
Code & Unit Test	Code	1,648	4,104	
All	Code	660	1,644	

COST by LABOR Category

PROJECT - C:\Users\sastukes\Desktop\ESD 3 ICE.PRJ



1 - Project - Electronic Schedule Dissemination - ESD 3.0

Activity	Mgmt	SW Reqs	Design	Code	Data Prep	Test	CM	QA	Total
Sys Reqs	67,721.94	293,461.75	79,008.93	0.00	33,860.97	67,721.94	11,286.99	11,286.99	564,350
SW Reqs	198,743.15	761,848.73	231,867.00	99,371.57	99,371.57	198,743.15	33,123.86	33,123.86	1,656,193
Pre Design	356,677.86	324,252.60	1,329,435.68	389,103.12	259,402.08	453,953.64	64,850.52	64,850.52	3,242,526
Det Design	653,034.60	593,667.82	2,434,038.09	712,401.40	474,934.27	831,134.95	118,733.57	118,733.57	5,936,678
Code	667,852.76	286,222.62	572,445.23	5,247,414.58	572,445.23	1,431,113.02	381,630.15	381,630.15	9,540,754
Int & Test	961,042.99	240,260.75	4,685,084.39	4,685,084.39	961,042.99	3,483,780.76	600,651.85	600,651.85	12,013,037
Prog Test	132,277.09	33,069.27	66,138.55	644,850.83	132,277.09	479,504.45	82,673.18	82,673.18	1,653,464
Sys I&T	556,106.83	139,026.71	278,053.42	1,320,753.70	69,513.35	4,101,287.64	347,566.76	139,026.71	6,951,335
Development Total	3,593,457.22	2,671,810.25	5,471,508.40	13,098,979.60	2,602,847.57	11,047,239.55	1,640,516.87	1,431,976.82	41,558,336

ESD 3.0 SEER-SEM Results (FY\$11)

COST by LABOR Category



PROJECT - C:\Users\sastukes\Desktop\ESD 3 ICE.PRJ

1 - Project - Electronic Schedule Dissemination - ESD 3.0

Activity	Mgmt	SW Reqs	Design	Code	Data Prep	Test	CM	QA	Total
Sys Reqs	67,722	293,462	79,009	0	33,861	67,722	11,287	11,287	564,350
SW Reqs	198,743	761,849	231,867	99,372	99,372	198,743	33,124	33,124	1,656,193
Pre Design	356,678	324,253	1,329,436	389,103	259,402	453,954	64,851	64,851	3,242,526
Det Design	653,035	593,668	2,434,038	712,401	474,934	831,135	118,734	118,734	5,936,678
Code	667,853	286,223	572,445	5,247,415	572,445	1,431,113	381,630	381,630	9,540,754
Int & Test	961,043	240,261	4,685,084	4,685,084	961,043	3,483,781	600,652	600,652	12,013,037
Prog Test	132,277	33,069	66,139	644,851	132,277	479,504	82,673	82,673	1,653,464
Sys I&T	556,107	139,027	278,053	1,320,754	69,513	4,101,288	347,567	139,027	6,951,335
Development	3,593,457	2,671,810	9,676,071	13,098,980	2,602,848	11,047,240	1,640,517	1,431,977	41,558,336
									\$ 26,450,416

SEER-SEM (TM) Software Estimation - Planning - Project Control. Version 7.3.13

Monday February 7, 2011

NASA JPL sn: 03375. License Expires: 01/15/2011

9:31:40 AM

Copyright © 1988-2008 Galorath Incorporated. ALL RIGHTS RESERVED.

Page -1 of 1

Note: Highlighted items removed from software estimate and allocated to other cost elements

ESD 3.0 Estimate Factors

Element	APO-88-2* %	Definition
Program Management	20.0%	This element indicates the technical control as well as the business management of particular projects. (Note that, if the program management can be associated with a specific subsystem or piece of software, it is typically included in the subsystem cost.)
Config/Data Management	3.0%	This cost element indicates the effort required to maintain the system configuration and records, and preserve information concerning the system. It includes technical publications, engineering data, management data, and support data.
Quality Assurance	4.0%	This element includes the effort associated with the systematic monitoring and evaluation of the various aspects of the program to ensure that standards of quality are being met.
Integrated Logistics Support	19.2%	This element consists of the spare components, assemblies, subassemblies, and materials to be used for replacement purposes in major end items. This element excludes test spares and spares provided specifically for use during system installation, assembly, and checkout on site. Also includes training services, devices, accessories, aids, equipment, and parts used to facilitate instruction through which personnel acquire concepts and skills to operate and maintain the system. It encompasses all costs of designing, developing, and producing training programs, and training the initial instructors as well as the first generation of personnel who will maintain and operate the system.
Integration and Test	32.6%	This element indicates the detailed planning, conduct, support, data reduction, and reporting on the use of prototype or production hardware/software to obtain or validate engineering data on the performance of the system. (Note that, if the test can be associated with a specific subsystem or piece of hardware/software, the test is not systems test, but is a subsystem test and is included as part of the subsystem cost. Acceptance testing during production and/or installation is not part of this element. This element also includes System Assembly, Installation and Checkout.

*APO-98-4, "Economic Analysis of Investment and Regulatory Decisions", Table 4-2, January 1998.

- "Composite System" percentages for development phase
- Factors apply to hardware and software costs, prime mission product (PMP)