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IDC Re-engineering Phase 3 Budgetary Cost Estimate Summary (Leveraged NDC Case)

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Abstract

Sandia National Laboratories has prepared a budgetary cost estimate for planning for the IDC Re-engineering Phase 3 effort, based on leveraging a fully funded, Sandia executed NDC Modernization project. This report provides the budgetary cost estimate and describes the methodology, assumptions, and cost model details used to create the budgetary cost estimate.

Budgetary Cost Estimate Disclaimer

This cost estimate is based upon a documented work scope that may not be complete at this time. This *estimate* may be used to develop budgets, includes a contingency appropriate for a budget estimate and *does not represent a commitment to the estimate*. If the project proceeds and the scope becomes better defined, a *definitive estimate* will be developed.

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REVISIONS

Version	Date	Author/Team	Revision Description	Authorized by
1.0	01/13/2017	SNL IDC Re-engineering Team	UUR Release for E3	Mary Clare Stoddard

1 PROJECT BACKGROUND

The CTBTO's International Data Centre (IDC) has recognized the need to reengineer their waveform data processing software system. In the 18 years since the delivery of the first version of IDC software, major components of the system have been replaced in response to advances in monitoring technologies leading to new functional requirements and infrastructure changes. In the absence of an up-to-date, overarching architecture, the result of these development activities is an increasingly fragmented software landscape with little software reuse, code duplication, and outdated technologies. Such a system is increasingly difficult to maintain and enhance as new technologies become available.

In response, the Provisional Technical Secretariat (PTS) has established a three-phase re-engineering effort. Phase 1 focused on enhancements to individual components of the system and is near completion. Phase 2 focused on the production of requirement artifacts for the re-engineered system including a system requirements document, a system specification, a set of use cases, a set of user-interface storyboards, a set of architectural reports, and this cost estimate for the development of the re-engineered system. Moving forward, Phase 3 (RP3) will comprise the development of a cost-effective, maintainable, and extensible system that will allow the CTBTO to meet its treaty monitoring requirements for the next 20+ years.

2 COST ESTIMATE OVERVIEW

The US Air Force Technical Applications Center (AFTAC) has begun a modernization project for the US National Data Center (NDC) system that can be leveraged to realize substantial cost savings for the IDC. This IDC Re-engineering Phase 3 (RP3) budgetary cost estimate assumes a combined effort addressing both the IDC and US NDC systems. To support budgetary planning for an IDC Re-engineering effort leveraged off the National Data Center modernization project, the SNL project team has developed a budgetary cost estimate for RP3.

The purpose of a Sandia budgetary cost estimate is to refine the scope and cost drivers from an initial rough order-of-magnitude (ROM) estimate. Budgetary cost estimates are meant for planning, but do not commit Sandia National Laboratories or its resources. Planning for long lead-time purchases of equipment may begin based on these estimates. Typically, the goal of a budgetary estimate is to be within a range of -15% to +30% of the actual costs. Budgetary estimates contain an explicit contingency in order for costs to be bound.

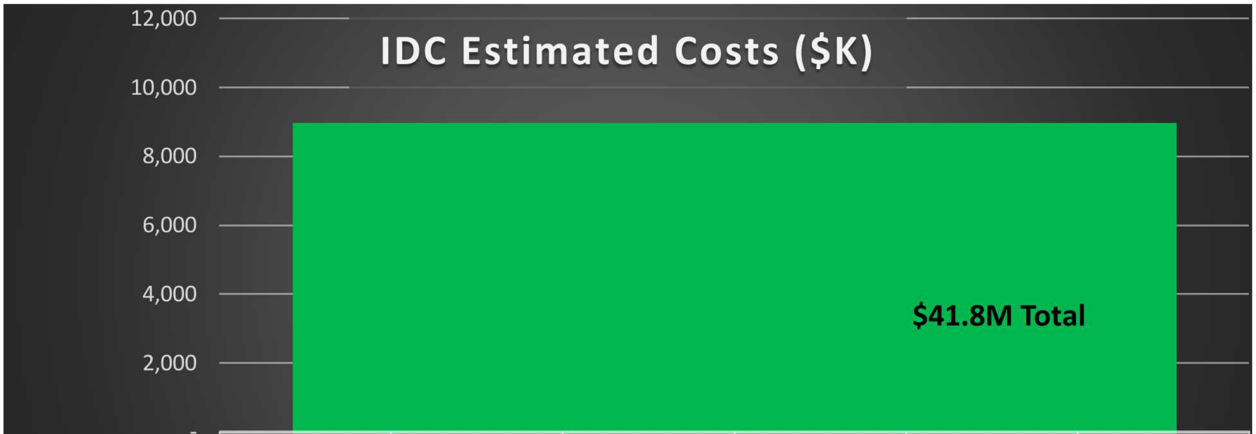
At the request of the funding agency, Sandia is prepared to provide a definitive cost estimate based on detailed scope of work and clearly defined requirements. An approved definitive cost estimate commits both Sandia and its resources.

This budgetary cost estimate assumes that RP3 will be executed using an incremental, iterative software development methodology leveraging best practices developed at Sandia National Laboratories for similar systems based on the Scaled Agile Framework (SAFe) framework (http://www.scaledagileframework.com/). This current version of the budgetary cost estimate is v1.0 (released January 2017).

Consistent with Sandia's approach to the USNDC modernization project, the budgetary cost estimate for a leveraged IDC re-engineering effort is provided at the 80% confidence level based on Monte Carlo analysis of cost uncertainty (see *Section 3.2* for more information on cost-risk analysis methodology). At 80% confidence, the total estimated cost for RP3 based on leveraging **a *fully-funded, Sandia executed,* US NDC re-engineering effort** is $41.8M. The costs showed here account for IDC-unique extensions to the shared system.

Cost sources in the estimate include labor as well as purchases and travel. Purchase estimates account for software acquisition and recurring licensing costs required for the project development environment. Delivered system hardware & software purchases are assumed to be funded by other elements of the PTS, and are excluded from this estimate.

Figure 1 shows the cost profile for RP3, assuming a mid-FY17 start.



	FY17	FY18	FY19	FY20	FY21	FY22
IDC	2,479	7,936	8,232	8,470	8,725	5,959
IDC Cumulative	2,479	10,415	18,647	27,117	35,842	41,801

Figure 1. IDC Re-engineering Project Cost Profile -
Leveraging a *Fully-Funded, Sandia executed* **US NDC Modernization Project**

3 METHODOLOGY

The cost estimate presented here was developed using a combination of parametric models and engineering judgment, informed by experience with similar projects at Sandia.

Software engineering costs were estimated using parametric cost models based on project assumptions regarding scope, staffing, development processes, and schedule. The Sandia project team used the *SEER for Software*[1] (SEER) cost estimation product to develop these parametric models. SEER is an industry standard cost estimation tool. SEER parametric models were used to produce estimates of the software engineering labor effort, and that effort was then converted to cost through the application of Sandia-specific staffing profiles with applicable labor rates and inflation factors.

For the IDC RP3 cost estimate, a staffing profile based on using an agile process framework was applied using Sandia-specific rates for the labor bands appropriate for the effort in each discipline. The SEER model was calibrated for Sandia staff productivity factors so should be used with Sandia labor rates only. Standard Sandia forward pricing factors were applied to account for inflation.

Purchases and travel costs for the modernized system were estimated using engineering judgment based on actual costs from similar projects.

3.1 Software Sizing

As is common practice at Sandia and in US industry, Logical Source Lines of Code (SLOC) were used as the initial measure of system size for this cost estimate; function points were used to a limited degree to model Commercial Off-The-Shelf (COTS) components, following the default SEER modeling approach. SLOC estimates for the reengineered IDC system were derived from code counts provided for the current US NDC system, scaled to account for anticipated reductions in code size resulting from the elimination of duplicative and dormant code.

3.2 Cost Risk Analysis

The SEER parametric modeling tool supports Monte Carlo analysis of total cost, accounting for uncertainty model parameters. Inputs to the tool, including SLOC and project assumptions, were modeled as three-point distributions representing least, likely and greatest values. The distributions were sampled within the SEER model to produce a cumulative frequency distribution representing software engineering effort as a function of confidence. For projects such as NDC Modernization and IDC Re-engineering, Sandia uses an 80% confidence estimate of the software engineering effort. This estimate translates into an 80% chance that the total cost of the system will be at or under the estimated cost. This is typically used as an industry standard for fixed-price contract budgets, and accounts for the margin needed to mitigate cost risk.

[1] www.galorath.com

3.3 IDC Cost Calculation

Using the independent US NDC cost model as a basis, the total size for the combined US NDC and IDC development effort was estimated by adding SLOC for unique IDC features (see Appendix A). The independent US NDC cost model and the combined total cost model were then differenced to obtain the additional labor effort for IDC development. IDC specific non-development, purchases, and travel are added for the total IDC cost estimate.

4 KEY ASSUMPTIONS

The assumptions detailed in the following sections were used to develop the initial IDC Re-engineering project budgetary cost estimate for RP3.

4.1 Scope Assumptions

The scope of this cost estimate is the development of the Re-engineered system as well as its incremental deployment to an IDC testbed. The Re-engineering project will address all IDC deployments and subsystems, including:

- Operational (OPS) & alternate (ALT) processing deployments
- Standalone system
- Testing and Training subsystems

An all-new modular, service-based software architecture will be developed for the reengineered system, accommodating expanded sensor networks and facilitating the integration of new computational modeling techniques, computer network technologies, and geophysical data analysis processes. It is assumed that:

1) Most of the legacy software will not be compatible with the modernized system architecture and design. Exceptions to the software replacement rule include the data acquisition software and common libraries.
2) Most of the existing IDC system software (~80%) is expected to be replaced.
3) Most of the data acquisition software is expected to be reused with moderate changes. This area of the system is considered to be more robust and maintainable than others and has not been identified as a priority for the modernization effort.
4) The common libraries are not expected to be heavily impacted by the changes in system architecture.
5) The overall size of the reengineered system software is expected to decrease by 20-30% percent as a result of duplicate/dormant code elimination and reorganization of the code in the new architecture.

4.2 IDC / US NDC Commonality Assumptions

For the purposes of the leveraged IDC /US NDC Re-engineering project scenario, the IDC and US NDC systems are assumed to overlap significantly in requirements, architecture and software components.

As mentioned previously, AFTAC has begun a modernization project for the US NDC system that can be leveraged to realize substantial cost savings for the IDC. The budgetary estimate for the leveraged IDC project assumes that 75% of the software in each system is common. The requirements artifacts created during the earlier phases of the US NDC Modernization and IDC Re-engineering projects lends credence to this assumption. Approximately 75% of the IDC requirements were found to be common with the US NDC requirements.

4.3 Development Process Assumptions

This estimate assumes that RP3 will be executed using an incremental, iterative software development approach leveraging best practices developed at Sandia National Laboratories for similar systems based on the Scaled Agile Framework (http://www.scaledagileframework.com/).

The project execution schedule for RP3 will be organized into quarterly program increments (PIs), each of which encompasses a complete development cycle including integration and test. Each PI begins with a planning event in which all members meet to coordinate the development of features. Each team decomposes features into user stories which the teams work during the six two-week iterations. The PI concludes with the system being in a shippable state. It is demonstrated and validated before being made available for deployment to an IDC testbed for acceptance testing.

4.4 Schedule Assumptions

The RP3 project schedule is assumed to span the 5-year period CY2017 – CY2022. Figure 2 shows the leveraged overlap between the IDC Re-engineering Phase 3 and the US NDC Modernization project phases.

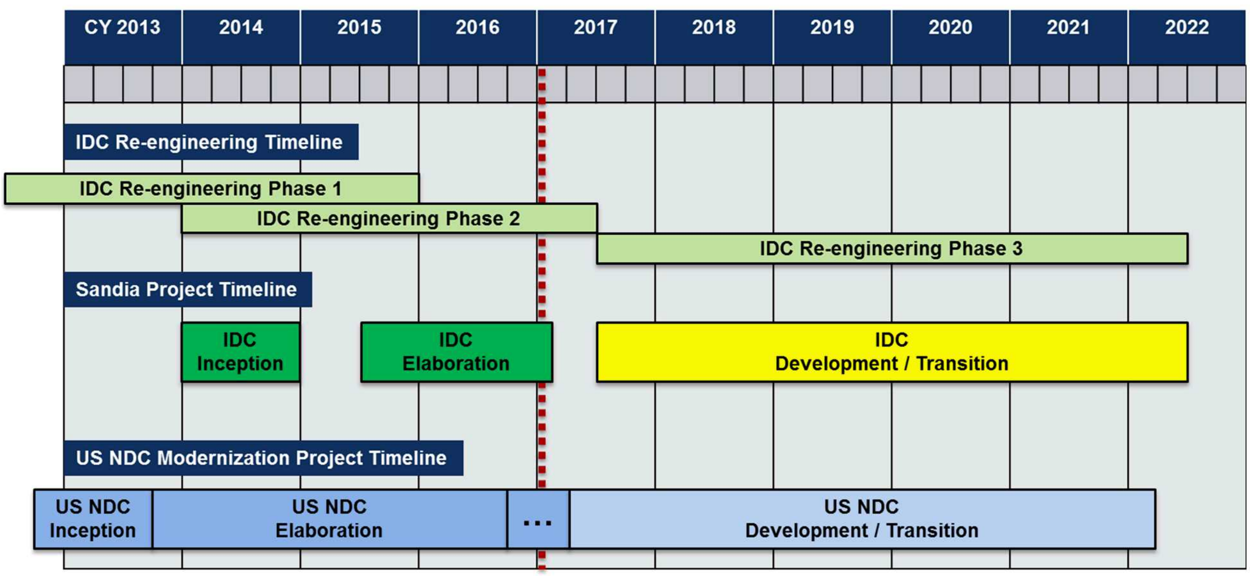


Figure 2. Schedule of Re-engineering Phases.

4.5 Deployment Assumptions

Mission capabilities will be delivered incrementally as they are integrated, verified and validated. Operations and Maintenance (O&M) of the reengineered system following the end of RP3 are expected to be managed separately within the PTS, and have not been included in the estimate.

4.6 Staffing Assumptions

This budgetary cost estimate is based on the assumption that the IDC RP3 projects will be executed through a collaborative effort between the PTS & Sandia project teams.

- The PTS team will provide review and oversight of system specifications, use cases, and architecture products as they are refined by the SNL project team.
- The SNL project team will be responsible for continued refinement of the system specification, use cases, architecture definition, and supporting prototypes.
- The PTS project team will serve as the system integrator for incremental deliveries of the reengineered IDC system components during the RP3.
- SNL will provide on-site support, as necessary, at the IDC in Vienna during RP3.

For the purposes of cost estimation, it is assumed that

- All team members performing this work will be comparable to the Sandia project team in terms of overall productivity.
- The Sandia project team will retain responsibility for architecture definition during RP3 and integration of software components provided by other contributors.

Finally, this budgetary cost estimate is for Sandia participation only. Costs for non-Sandia participants are not included in this estimate.

APPENDIX A. ESTIMATED SOURCE LINES OF CODE (SLOC) BY WORK BREAKDOWN STRUCTURE (WBS) ELEMENT

	WBS Element	COMMON SLOC	IDC SLOC
6	**Software Development**		
6.1	**System Frameworks**		
6.1.1	Develop System Control Framework	10000	
6.1.2	Develop Data Persistence Framework	20000	
6.1.3	Develop Automated Processing Framework	10000	
6.1.4	Develop Interactive Processing Framework	10000	
6.1.5	Common Libraries	200000	
6.2	**Data Management Components**		
6.2.1	Develop Station Data Acquisition	15000	1000
6.2.2	Develop Bulletin Data Acquisition	10000	1000
6.2.3	Develop Meteorological Data Acquisition	10000	
6.2.4	Develop Data Forwarding	8000	
6.2.5	Develop Data Synchronization Software Components	8000	
6.3	**Automated Processing Components**		
6.3.1	Waveform QC	5000	
6.3.2	Waveform Enhancement	20000	
6.3.3	Signal Detection	10000	2000
6.3.4	Signal Measure	20000	2000
6.3.5	Signal Prediction	10000	2000
6.3.7	Event Build	25000	
6.3.8	Event Correlation	5000	
6.3.9	Event Deconflict	8000	2000
6.3.10	Event Location	8000	
6.3.11	Event Magnitude	5000	1000
6.3.12	Event Moment Tensor	10000	
6.4	**Analysis Components**		
6.4.1	Analyst Workspace	10000	2000
6.4.2	Data Selection	10000	
6.4.3	Search	5000	
6.4.4	Map	10000	
6.4.5	Event Analysis	50000	5000
6.4.7	Event Location	5000	
6.4.8	Event Magnitude	5000	
6.4.9	Event Moment Tensor	10000	

6.4.12	Event Comparison	10000	
6.4.13	Event History	10000	
6.5	**Data Product Distribution Components**		
6.5.1	Develop Data Request Application	10000	2000
6.5.3	Develop Event Portal	15000	2000
6.6	**Configuration Components**		
6.6.1	Data Acquisition Config	10000	1000
6.6.2	Data Acquisition Control	5000	1000
6.6.3	Station Usage Config	5000	
6.6.4	Processing Sequence Config	10000	
6.6.5	Processing Component Config	10000	1000
6.6.7	Analysis Interface Config	2000	
6.6.8	System Permission Config	2000	
6.6.9	Configuration History Viewer	10000	
6.7	**Monitoring Components**		
6.7.1	Mission Performance Analysis	10000	
6.7.2	System Performance Monitoring	5000	1000
6.7.3	Station SOH Monitoring	5000	1000
6.7.4	System Processing Monitoring	10000	
6.8	**Operational Support Components**		
6.8.1	Access Control	5000	
6.8.2	System Control	10000	1000
6.8.3	Operations Log	5000	
6.8.4	Analyst Feedback and Performance	10000	1000
6.8.5	Security Monitoring	5000	
6.8.6	User Messages	2000	
6.9	**System Maintenance Components**		
6.9.1	Backup and Restore	2000	
6.9.2	Software Update	2000	
6.1	**Research Support Components**		
6.10.1	Research Event Analysis	2000	1000
6.10.2	Component Development Support	2000	1000
6.10.3	Tuning	10000	
6.10.4	Multiple Event Location	5000	
6.11	**System Testing Components**		
6.11.1	Data Replay	5000	
6.11.2	Analyst Replay	10000	
6.11.3	Component Testing	5000	1000
6.12	**Training Support Components**		
6.12.1	Training Configuration	2000	

6.13	**System Distributions**		
6.13.1	Host Analysis System	5000	2000
6.13.2	Standalone Analysis System	5000	
6.13.3	Field Survey Laptop System	5000	
6.13	**IDC Unique**		
6.13.1	Event Consistency		5000
6.13.2	Event Screening		5000
6.13.3	Station Control		2000
6.13.4	Expert Technical Analysis		10000
	TOTAL	**758000**	**56000**

APPENDIX B. SEER MODEL KNOWLEDGE BASES APPLIED

A SEER knowledge base is a set of parameter values applied to the project WBS in the cost model. SEER provides knowledge bases based on research of actual industry projects, categorized so they may be applied as initial values for similar projects. SEER includes a set of knowledge bases organized into six standard categories, plus a category to capture custom project overrides:

- Platform knowledge bases describe the primary mission or environment of the software.
- Application knowledge bases describe the primary function of the software.
- Acquisition Method knowledge bases describe the scope and type of project being developed or maintained.
- Development Method knowledge bases describe the methods or paradigm used to develop software.
- Development Standard knowledge bases describe the standards to be followed during development. They generally include values for the specification, test, and quality assurance level parameters.
- Test Rigor knowledge bases are parameters for COTS elements that are only tested. A Test Rigor knowledge base is not used here.
- The Class knowledge base category contains custom settings.

SEER Knowledge Base Type	**Knowledge Base Applied**
Platform	*Ground-Based Mission Critical*
Application	Set for each model WBS element, including: • *Signal Processing* • *Mathematical and Complex Algorithm* • *Graphical User Interface* • *Process Control* • *Data Warehousing* • *System & Device Utilities*
Acquisition Method	Custom, based on *Re-engineering, Major*: Increased *Redesign*, *Reimplementation* and *Retest* factors above the knowledge base to account for modernized architecture and significant software replacement
Development Method	*Agile Novice*
Development Standard	*Commercial High*
Class (Custom)	*IDC Re-engineering KBase Overrides* Includes parameter overrides specific to the IDC Re-engineering project. See Appendix C for the list of parameter overrides.

APPENDIX C. US NDC/IDC CUSTOM KNOWLEDGE BASE

This table contains the custom settings applied to the IDC Re-engineering cost estimate. SEER defines qualitative rating values for many parameters using terms such as Extra High, Very High, High, Nominal, Low, Very Low. A description of each rating for each parameter is provided in the "SEER for Software User Guide" to guide selection. Items marked with *** are unchanged from the standard SEER Knowledge Bases applied to the project.

Parameter	*Least* Value	*Likely* Value	*Most* Value
PERSONNEL CAPABILITIES & EXPERIENCE			
Analyst Capabilities	Nominal -	Nominal +	High -
Analyst's Application Experience	High -	High	High +
Programmer Capabilities	Nominal	High -	High
Programmer's Language Experience	Very High -	Very High	Very High +
Development System Experience	***	***	***
Target System Experience	***	***	***
Practices & Methods Experience	Nominal	High	Very High
DEVELOPMENT SUPPORT ENVIRONMENT			
Development Practices Use	High -	High	High +
Automated Tools Use	High	High +	Very High -
Turnaround Time	Very Low	Low -	Nominal
Response Time	***	***	***
Multiple Site Development	Nominal	High	Very High
Resource Dedication	***	***	***
Resource and Support Location	***	***	***
Development System Volatility	***	***	***
Process Volatility	***	***	***
PRODUCT DEVELOPMENT REQUIREMENTS			
Requirements Volatility (Change)	Nominal	Nominal	High
Specification Level - Reliability	***	***	***
Test Level	***	***	***
Quality Assurance Level	***	***	***
Rehost from Development to Target	Nominal	Nominal	Nominal
PRODUCT REUSABILITY REQUIREMENTS			
Reusability Level Required	***	***	***
DEVELOPMENT ENVIRONMENT COMPLEXITY			
Language Type (complexity)	***	***	***
Development System Complexity	***	***	***

Application Class Complexity	***	***	***
Process Improvement	High -	High	High +
TARGET ENVIRONMENT			
Special Display Requirements	High -	High	High +
Memory Constraints	***	***	***
Time Constraints	High -	High	High +
Real Time Code	Nominal	Nominal +	High -
Target System Complexity	***	***	***
Target System Volatility	***	***	***
Security Requirements	***	***	***
SCHEDULE & STAFFING CONSIDERATIONS			
Required Schedule (Calendar Mos)		0	
Start Date		3/11/2017	
Complexity (Staffing)	High -	High	High +
Staff Loading	***		
Min Time vs. Opt Effort		Optimal Effort	
REQUIREMENTS			
Requirements Complete at Start		High	
Requirements Definition Formality	***	***	***
Requirements Effort After Baseline		YES	
SYSTEM INTEGRATION			
Concurrency of I&T Schedule	Extra High		
Hardware Integration Level	***	***	***
Software Integration Level	***	***	***

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