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IDC Reengineering Phase 2 & 3 Rough Order of Magnitude (ROM) Cost Estimate Summary (Leveraged NDC Case)

Version 1.2

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Abstract

Sandia National Laboratories has prepared a ROM cost estimate for budgetary planning for the IDC Reengineering Phase 2 & 3 effort, based on leveraging a fully funded, Sandia executed NDC Modernization project. This report provides the ROM cost estimate and describes the methodology, assumptions, and cost model details used to create the ROM cost estimate.

ROM Cost Estimate Disclaimer

Contained herein is a Rough Order of Magnitude (ROM) cost estimate that has been provided to enable initial planning for this proposed project. This ROM cost estimate is submitted to facilitate informal discussions in relation to this project and is NOT intended to commit Sandia National Laboratories (Sandia) or its resources.

Furthermore, as a Federally Funded Research and Development Center (FFRDC), Sandia must be compliant with the Anti-Deficiency Act and operate on a full-cost recovery basis. Therefore, while Sandia, in conjunction with the Sponsor, will use best judgment to execute work and to address the highest risks and most important issues in order to effectively manage within cost constraints, this ROM estimate and any subsequent approved cost estimates are on a 'full-cost recovery' basis. Thus, work can neither commence nor continue unless adequate funding has been accepted and certified by DOE.

CONTENTS

REVISIONS

Version	Date	Author/Team	Revision Description	Authorized by
1.0	8/7/2014	SNL IDC Reengineering Team	OUO Release for I1	Bob Huelskamp
1.2	11/24/2014	SNL IDC Reengineering Team	UUR Release for I2	Bob Huelskamp

1 PROJECT BACKGROUND

The CTBTO's International Data Centre (IDC) has recognized the need to reengineer their waveform data processing software system. In the 16 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activities is an increasingly fragmented software landscape with little software reuse, code duplication, and outdated technologies.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 reengineering effort. Phase 1 focused on enhancements to individual components of the system and is near completion. Moving forward, Reengineering Phase 2 (RP2) & 3 (RP3) will address development of a modern, model-based component architecture as the foundation for 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 RP2 & RP3 ROM cost estimate assumes a combined reengineering project addressing both the IDC and US NDC systems ('Leveraging US NDC Modernization' figures in Table 1). To support budgetary planning for an IDC Reengineering effort leveraged off the National Data Center modernization project, the SNL project team has developed an initial ROM cost estimate for RP2 & RP3.

The purpose of a Sandia ROM cost estimate is to enable customer evaluation and initial planning for a proposed project. Providing an approved ROM cost estimate allows Sandia Management to participate in planning discussions related to the project, but does not commit Sandia National Laboratories or its resources. A typical ROM cost estimate lacks rigorous definition of project scope and requirements and is considered to be within -30% to +50% of actual costs. Based on the maturity and understanding of IDC scope and requirements, this ROM cost estimate is more narrowly bound at 80% confidence. 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 ROM cost estimate assumes that RP2 & 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 Rational Unified Process (RUP) framework (http://en.wikipedia.org/wiki/RUP). This current version of the ROM cost estimate is v1.2 (released November 2014). Updated estimates will be produced periodically to account for refinements in project knowledge, and to address evolution of project scope, assumptions, requirements, and constraints.

Consistent with Sandia's approach to the USNDC modernization project, the ROM cost estimate for a leveraged IDC reengineering 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). Table 1 summarizes cost information for RP2 & RP3 in then-year dollars. At 80% confidence, the total estimated cost for RP2 & RP3 based on leveraging **a *fully-funded, Sandia executed,* US NDC reengineering effort** is $44.9M. The costs showed here account for IDC-unique extensions to the shared system.

Cost sources in the estimate include labor as well as purchases & travel. Purchase estimates account for hardware and 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.

IDC Reengineering Phase 2 & 3	*Leveraging fully-funded US NDC Modernization*
	80% Confidence
RP2 - Inception	$1,081 K
RP2 - Elaboration	$4,933 K
RP3 - Development & Transition	$38,904 K
Total Cost	**$44,918 K**
Current Investment in RP2 - Inception	$1,081 K
Balance Due	**$43,837 K**

Table 1. IDC RP2 & RP3 Cost Summary

Figure 1 shows the cost profile for RP2 & RP3.The standard Rational Unified Process (RUP) funding profile for the Inception & Elaboration phases (RP2) has been scaled to lower initial funding based on known budgetary constraints. This approach defers significant Elaboration effort to the Development phase (RP3).

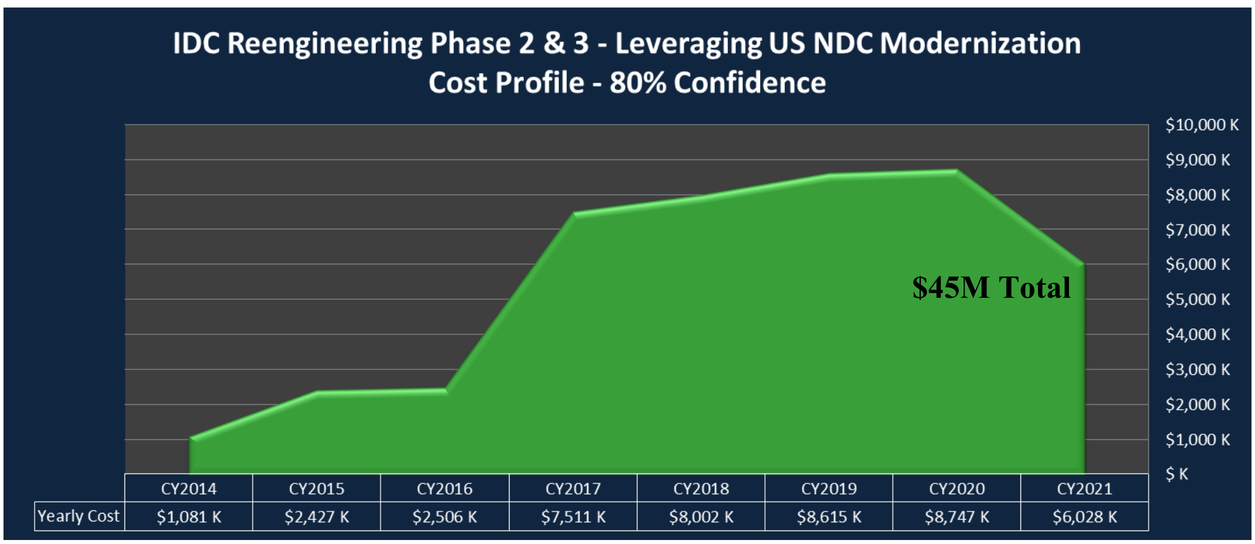

Figure 1. IDC Reengineering Project Cost Profile -
Leveraging a ***Fully-Funded, Sandia executed*** **US NDC Modernization Project**

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 Reengineering cost estimate, a staffing profile based on the Rational Unified Process (RUP)[2] was applied using Sandia-specific rates for the labor bands appropriate for the effort in each RUP 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. Existing SLOC were scaled to account for anticipated reductions in code size resulting from the elimination of duplicative and dormant code.

Future estimates will be provided in 6-month intervals throughout the project lifecycle to reflect current IDC code counts.

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

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[1] www.galorath.com

[2] The staffing profile used for the US NDC Modernization cost estimate is based on the RUP-based framework available at www.scribd.com/doc/7183531/Project-Planning-Best-Practices

such as NDC Modernization and IDC Reengineering, 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. It is typically used as an industry standard for fixed-price contract budgets, and accounts for the margin needed to mitigate cost risk.

4 KEY ASSUMPTIONS

The assumptions detailed in the following sections were used to develop the initial IDC Reengineering project ROM cost estimate for RP2 and RP3.

4.1 Scope Assumptions

The cost estimate includes RP2 & RP3. Together, these two phases account for all four of the RUP phases (see *Section 4.3* for more on RUP). The Reengineering 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 Reengineering 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 ROM estimate for the leveraged IDC project assumes that 75% of the software in each system is common. The recently created and released IDC Systems Requirements Document (SRD) lends credence to this assumption. ***Nearly 85% of the IDC requirements were found to be common with the US NDC requirements.***

4.3 Development Process Assumptions

This estimate assumes that RP2 & 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 RUP framework (http://en.wikipedia.org/wiki/RUP).

In keeping with the Rational Unified Process, the project will be organized into four high-level phases: *Inception*, *Elaboration*, *Development* and *Transition*.

1) RP2 will execute the Inception & Elaboration phases; RP3 will execute the Development and Transition phases.
2) The underlying project schedule accounting for these phases will be divided *iterations*, each of which will encompass a complete development cycle, including requirements analysis, architecture analysis & design, implementation, integration, and test as applicable based on the project phase.
3) During RP3, each iteration will produce a functional version of the system.

4.4 Schedule Assumptions

The RP2 & RP3 project schedule is assumed to span the 8-year period CY2014 – CY2021. The schedule for the project phases is as follows:

RP2

a. *Inception* (Q1 CY2014 – Q4 CY2014) **Fully funded**
   This fully funded phase focuses on definition of system requirements and use cases. Funding was provided by the US Department of State (DOS) with project oversight provided by the National Nuclear Security Agency (NNSA).

b. *Elaboration* (Q1 CY2015 – Q4 CY2016) **Unfunded**
   This phase will focus on definition of system architecture and prototyping of core system components.

RP3

a. *Development* (Q1 CY2017 – Q4 CY2020) **Unfunded**
   This phase will focus on incremental implementation, integration and deployment of system software and hardware components.

b. *Transition* (Q1 FY2021 – Q4 FY2021) **Unfunded**
   This phase will focus on verification, validation & delivery of the complete operational capability, as well as delivery of system documentation and user training.

Figure 2 shows the leveraged overlap between the IDC Reengineering Phases 2 & 3 and the US NDC Modernization project phases.

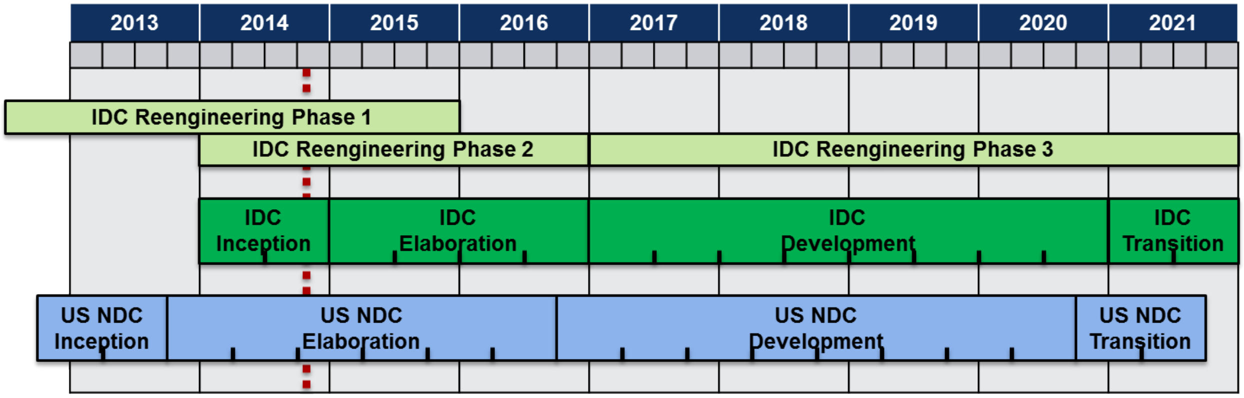

Figure 2. Schedule of RUP phases.

4.5 Deployment Assumptions

Mission operations must be maintained during the transition to the reengineered system. To meet this requirement:

1) Mission capabilities will be transferred incrementally from legacy to new system components as they are integrated, verified and validated.
2) This incremental capability transfer will occur during RP3.
3) 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 ROM cost estimate is based on the assumption that the IDC RP2 and RP3 projects will be executed through a collaborative effort between the PTS & Sandia project teams.

- The PTS team will be responsible for development of the system requirements, and will provide review and oversight of system specifications, use cases, and architecture products developed by the SNL project team.
- The SNL project team will be responsible for development 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 RP2 & RP3.

The organization(s) responsible for implementation and delivery of the reengineered system components during RP3 have yet to be determined. 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 ROM cost estimate is for Sandia participation only. Costs for non-Sandia participants are not included in the ROM cost estimate.

APPENDIX A. ESTIMATED LINES OF CODE (LOC) BY WORK BREAKDOWN STRUCTURE (WBS) MODEL ELEMENT

WBS Element Description	Effective Lines of Code	Total Lines of Code	New Lines of Code	Existing Lines of Code
IDC Reengineering Phase 2-3 - Sandia v2.3.0	**509708**	**823646**	**85000**	**717500**
Core System Software	**377679**	**642146**	**60000**	**573750**
SW Infrastructure Frameworks	**60833**	**60833**	**60000**	**0**
UI Framework	15000	15000	15000	0
Processing Control Framework	15000	15000	15000	0
COI Framework	30833	30833	30000	0
Core Services	**73207**	**100396**	**0**	**98750**
Earth Model	11120	15250	0	15000
Signal Processing	22240	30500	0	30000
Signal Detection	11120	15250	0	15000
Event Detection	13900	19063	0	18750
Location	5560	7625	0	7500
Magnitude	3707	5083	0	5000
Identification	5560	7625	0	7500
Core Applications	**222593**	**340583**	**0**	**335000**
Data Management	9026	15250	0	15000
Data Services	11524	76250	0	75000
Pipeline Processing	12370	15250	0	15000
Analyst Tools	123700	152500	0	150000
Reporting	6185	7625	0	7500
Monitoring	18555	22875	0	22500
Tuning	6185	7625	0	7500
Workflow	4123	5083	0	5000
Configuration	30925	38125	0	37500
Core Components	**21046**	**140333**	**0**	**140000**
Common Libraries	21046	140333	0	140000
IDC-Unique Software	**132030**	**181500**	**25000**	**143750**
IDC Services	**26505**	**36000**	**0**	**33750**
Earth Model	3927	5333	0	5000
Signal Processing	7853	10667	0	10000
Signal Detection	3927	5333	0	5000
Event Detection	4908	6667	0	6250

Location	1963	2667	0	2500
Magnitude	1963	2667	0	2500
Identification	1963	2667	0	2500
IDC Applications	**77358**	**117333**	**0**	**110000**
Data Management	3253	5333	0	5000
Data Services	4131	26667	0	25000
Pipeline Processing	4373	5333	0	5000
Analyst Tools	43733	53333	0	50000
Reporting	2187	2667	0	2500
Monitoring	6560	8000	0	7500
Tuning	2187	2667	0	2500
Configuration	10933	13333	0	12500
IDC Components	**11500**	**11500**	**10000**	**0**
Common Libraries	11500	11500	10000	0
IDC Distributions	**16667**	**16667**	**15000**	**0**
IDC Ops	10833	10833	10000	0
IDC Training	5833	5833	5000	0

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	*RUP Full*
Development Standard	*IEEE-EIA 12207*
Class (Custom)	*IDC Reengineering KBase Overrides* Includes parameter overrides specific to the IDC Reengineering 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 Reengineering 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	Nominal	High -	High +
Programmer Capabilities	Nominal	High -	High
Programmer's Language Experience	Nominal +	High +	Very High
Development System Experience	***	***	***
Target System Experience	***	***	***
Practices & Methods Experience	***	***	***
DEVELOPMENT SUPPORT ENVIRONMENT			
Development Practices Use	***	***	***
Automated Tools Use	***	***	***
Turnaround Time	***	***	***
Response Time	***	***	***
Multiple Site Development	Very High +	Extra High	Extra High
Resource Dedication	***	***	***
Resource and Support Location	Nominal	Nominal	Nominal +
Development System Volatility	Nominal	Nominal	Nominal +
Process Volatility	Low	Low +	Nominal -
PRODUCT DEVELOPMENT REQUIREMENTS			
Requirements Volatility (Change)	***	***	***
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	Nominal	High -	High +
TARGET ENVIRONMENT			
Special Display Requirements	***	***	***
Memory Constraints	***	***	***
Time Constraints	***	***	***
Real Time Code	Nominal	Nominal +	High -
Target System Complexity	***	***	***
Target System Volatility	***	***	***
Security Requirements	***	***	***
SCHEDULE & STAFFING CONSIDERATIONS			
Required Schedule (Calendar Mos)		0	
Start Date		10/01/2012	
Complexity (Staffing)	***	***	***
Staff Loading	***		
Min Time vs. Opt Effort		Optimal Effort	
REQUIREMENTS			
Requirements Complete at Start		Nominal	
Requirements Definition Formality	***	***	***
Requirements Effort After Baseline		YES	
SYSTEM INTEGRATION			
Concurrency of I&T Schedule	***		
Hardware Integration Level	***	***	***
Software Integration Level	***	***	***

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