TECHNICAL DESIGN PACKAGE

EventBus Architecture Enchancements: DataStax Cassandra

PR00014969

Project Overview:

Project calls for standing up DataStax Enterprise (DSE) build on Apache Cassandra at DFS. Apache Cassandra is an open source NoSQL distributed database that provides a non-single point of failure system with ability to be active-active in multiple data centers. Cassandra runs on commodity hardware, provides continuous availability, predictable scalability and ease of management. DataStax provides a platform built on top of Cassandra with tools to manage, operate and also has indexing and search capabilities.

DataStax Cassandra was piloted with Event Bus use case and worked well to prove out the test cases defined for the pilot. Key test case scenarios included high availability, active-active, one node down in data center, all nodes down in one data center, management and monitoring of the cluster. Initial setup was not straight forward and can be alleviated by scripting.

Event loader and repository service in PCF will be configured to connect to the Cassandra operational cluster in the respective data centers. The operational Cassandra cluster will be populated with events going through the current Events platform as a start.

Key Project Benefits:

- Continuous availability with redundancy in both data and functionality across SSB and BDC.
- Extreme write speed and low latency query speed.
- Seamless scalability with built-in replication of data across all Data Centers, Nodes.
- Cassandra runs on commodity hardware.
- DataStax provides additional drivers, tooling like SPARK, SOLR, DSE Graph and management/monitoring.

Design Overview:

Project calls for standing up Production environment with Cassandra cluster consisting of an operational datacenter with 7 nodes each in BDC and SSB. BDC will also host an analytical datacenter with 7 nodes. Cassandra DB Infrastructure will be stood up in IS-1 zone. Dell physical servers with 16 cores, 128 GB of memory and SSD for data will be utilized as per the best practices for Cassandra. Similar infrastructure will be stood up for Pre-Production Cassandra cluster with 4 nodes for each of the operational/analytical datacenters. Lab cluster will be setup with 3 nodes each.

Key Impacts to Infrastructure Services:

- Physical servers will used for Cassandra DB and virtual server for visual management and monitoring for DataStax Cassandra.

Risks / Issues / Gaps:

- Support and ownership of Cassandra database is tbd.

Service Catalog/Governance Req. #s: REQ0211463/000000
Clarity Project Number: PR00014969
Project Sponsor: [Joel Suchomel / Andrew Duckett]

TDP Version: 1.4
Date: Aug 8th 2017
Author: Firasath Ali

Governance

Revision History

Version 1.0 - 06/20/2017
•Initial version.

Version 1.1 - 07/11/2017
•Updated project#, pricing.

Version 1.2 - 07/12/2017
•Updated approver, nwg, removed development environment and fixed diagram.

Version 1.3 - 07/18/2017
•Added some details from test results.

Version 1.4 - 08/8/2017
•Updated pricing based on latest schedule.

Version 1.5 - 01/28/2018
•Updated hostname in diagram.

Natural Work Group

Technical Lead Name / Team	
Kavita Chekuri/Steve Kohn	BT / ISPO – Database Architect.
Erwin Veranga	BT / ISPO Domain and Hardware Arch.
Dominic Jeanbaptiste	BT / ISB – Unix Engineering.
Srikanth Srinivasan	BT / Architect of Cybersecurity Strategic Solutions.
Andrew Duckett	BT / AD – Digital Development Application Architecture.

Approvers

Name	Team	Title
Nick Kotzamanis	BT / ISPO – Solutions Architecture.	Sr. Manager
Kimberly Moder	BT / ISPO – Domain Architecture.	Sr. Manager
Dean Parke	BT / AD – Digital Development.	Sr. Manager

FYI Only

A copy of the approved TDP will be sent to the names listed below	
Bill Verzal / Unix Ops	[Name / Team]
Kyle Kruszewski / Database Ops	[Name / Team]
Sam Gerald / Unix Eng	[Name / Team]

TDP

Analysis

BUSINESS CASE / APPLICATION-SYSTEM FUNCTIONAL OVERVIEW

DFS completed a production pilot of DataStax Cassandra database with Event Loader Application and Event Repository Services in PCF. Functional and performance test criteria was successfully met and documented: (https://discoverfinancial.sharepoint.com/sites/BTIDDC/admn/Rsch/dataStx/_layouts/15/WopiFrame.aspx?sourcedoc=%7B61aade69-71e6-4950-8011-4d05c1c24909%7D&action=default)

DFS is now looking to stand up DataStax Cassandra Operational and Analytical datacenters to initially support Event Bus and Event Platform Analytics. Other potential uses cases that can share the Event bus infrastructure will also be looked at.

Currently DFS has applications that are active-active but the underlying database is only active in one data center. With Cassandra's ability to be active-active, the entire application stack can be truly active-active.

Event bus consist of Event Repository Service, Event Repository Loader, Event Publisher Service, App Event processors and subscribers. Application pulls the events from EventBus and loads them into the Event Repository database. Event Repository service is used by applications to retrieve the events from the Event Repository database. Currently both Event Loader Application and Event Repository service points to the active database instance.

With Cassandra, application services in a data center (DFS data centers) will point to the local Cassandra Operational data center. Cassandra uses "data center" terminology to mean a collection of related nodes. A Cassandra cluster will consists of an operational Cassandra data center ring at each of DFS's two data centers and an analytics Cassandra data center ring at one data center. Replication will be setup to write data to multiple Cassandra "data centers". This will allow Event Loader application and Event Repository service in each of DFS's data center to talk to the Cassandra Operational data center in their respective data centers.

Cassandra is a proven NoSQL database with ability to process big data workloads in active-active configuration. It has no single point of failure and applies peer-to-peer gossip communication protocol between the cluster nodes. Data is sharded on multiple nodes and each shard can be replicated to avoid data loss in case of a hardware failure. With Cassandra cluster there is no need for an ETL process to move the data from Cassandra operational data center to Cassandra analytic data center.

APPLICATION REQUIREMENTS

DataStax Cassandra provides the following key capabilities:

- Standard DML, DDL like capabilities.
- High write/read performance for application across both of DFS's data centers.
- Ease of management and operations; be able to add, remove nodes in cluster without impact to service, backup and restore ability, be able to monitor the nodes etc.
- Meets DFS security standards for user authentication and authorizations.
- Provide secure connections to database.

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User / Transaction Data

Initial scope of data requirement is estimated to be 2 TB. Below are metrics from existing database on Exadata

Current transactions per second on exiting Exadata:
- Avg. – 80
- Max. - 160

Current database connections on existing Exadata:
- Average DB connections. – 60

Availability

The Availability requirements for this proposed function/application service is defined as **99.9%** based on the requirements from the team. This percentage is based on uptime minus scheduled outages and maintenance.

Based on discussion with the team, architecture of Cassandra database and the infrastructure being stood up, it is expected to achieve an RTO of **5 – 60 minutes,** RPO of **1-15 minutes** and the team plans to classify this as a Recover Tier 5.

The environment supports a business process which is classified as **Support**.

During the Datastax Cassandra pilot, test were performed to prove availability by bringing one, two nodes down. There was no performance impacts when one node was brought down. All nodes in one data center were brought down and the application continued to function as Cassandra nodes from the other data center serviced the requests. Cassandra can also be designed to service local data center requests to reduce response times over WAN.

System Architecture

Cassandra is an open source NoSQL database with ability to handle big data workloads across multiple nodes and data centers with no single point of failure. It uses peer-to-peer distributed system across homogeneous nodes where data is distributed among all nodes in the cluster. Nodes exchange state information with other nodes using the gossip communication protocol. Data is partitioned on different nodes and also replicated to account for hardware failures. Cassandra scales very well for the application use cases that works with Cassandra data model and has been proven to scale almost linearly.

Cassandra has excellent write performance and is able to ingest lot of data and has good read performance as well. One key feature of Cassandra is its built in time-to-live feature that allows data to be removed when it's time has expired without having to do a manual deletes/clean up. Data can be inserted into Cassandra tables without having to previously model the query. Cassandra does not support the standard RDBMS functionality like joins, subqueries, normalization.

Cassandra uses a storage structure similar to Log-Structured Merge Tree unlike a typical relational database that uses B-Tree. Cassandra writes are written to ensure data durability. Writes first go to a commit log sequentially then indexed and written to a memory structure called memtable. Once the amount of data in memtable reaches a threshold it is flushed to a disk file called SSTable asynchronously. SSTable is an immutable data file and are append only and stored on disk sequentially and maintained for each Cassandra table. All writes are automatically partitioned and replicated throughout the cluster. Cassandra periodically consolidates SSTable using a process called compaction, discarding obsolete data marked for deletion with a tombstone. Cassandra has repair mechanism to ensure all data across the cluster stays consistent. Over time SSTable needs to be compacted which merges SSTables and discards old data.

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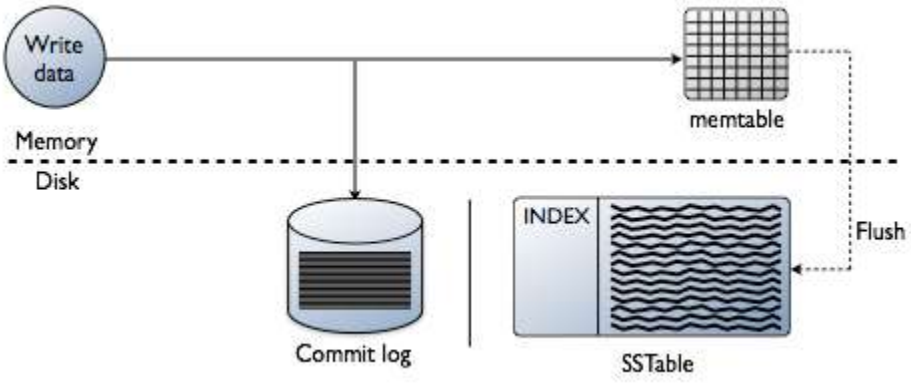

Ref: http://docs.datastax.com/en/cassandra/3.0/cassandra/dml/dmlHowDataWritten.html

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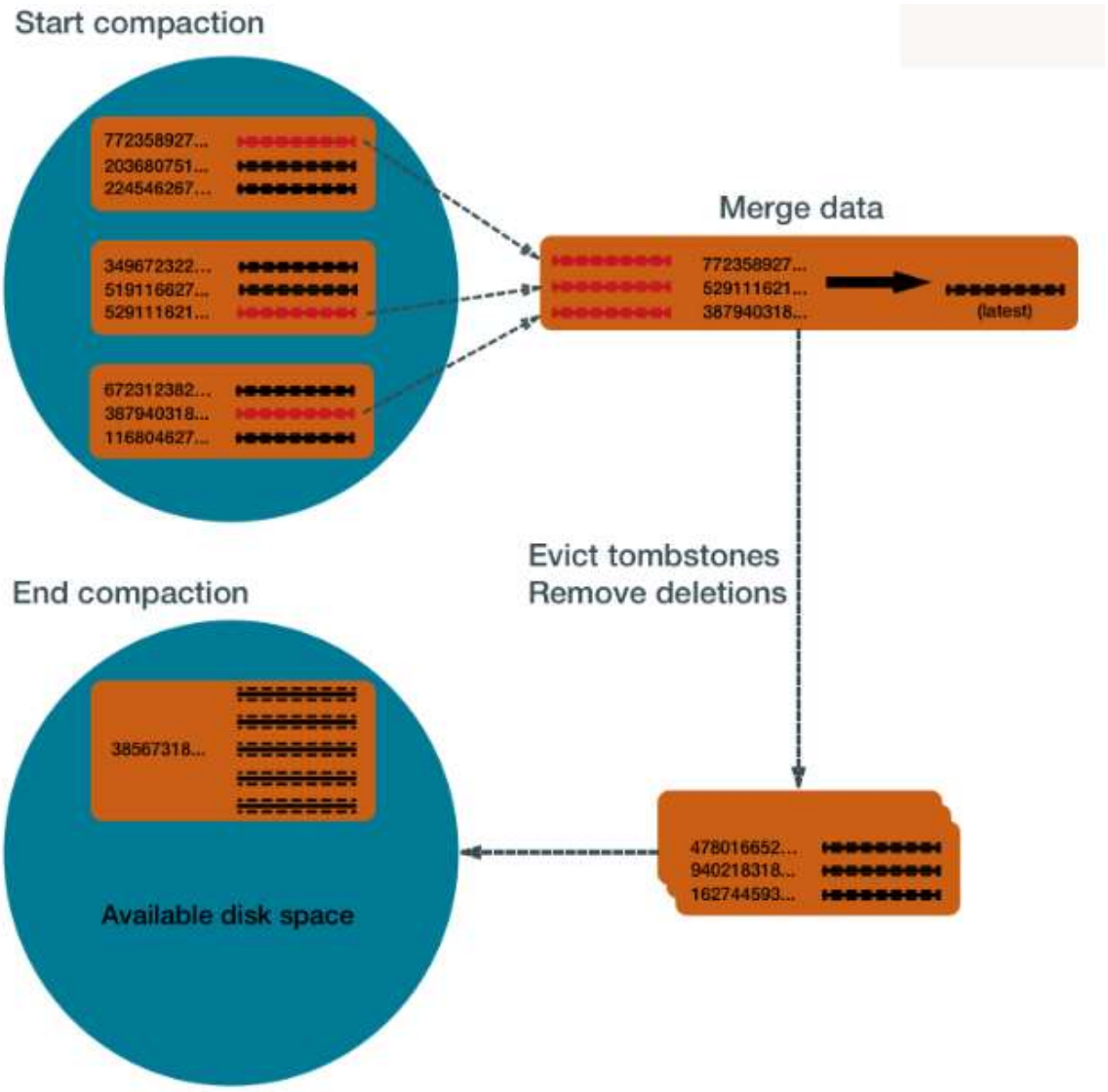

Ref: http://docs.datastax.com/en/cassandra/3.0/cassandra/dml/dmlHowDataMaintain.html

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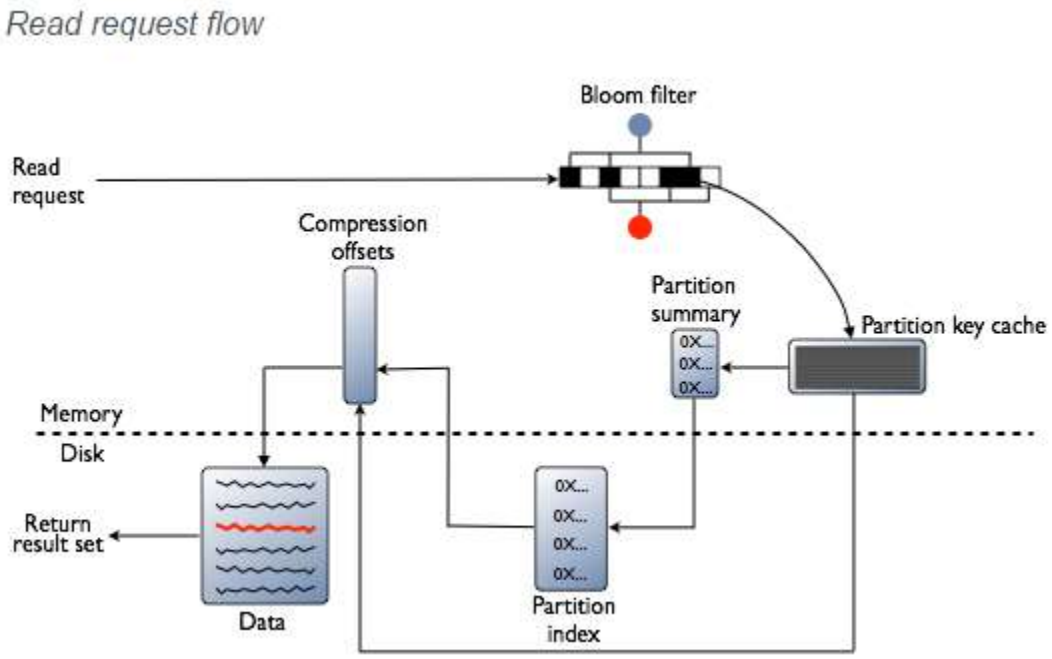
Cassandra reads data from the node and combines results from the active memtable and potentially multiple SSTables. Cassandra processes data at several stages on the read path to discover where the data is stored, starting with the data in the memtable and finishing with SSTables.



Ref: http://docs.datastax.com/en/cassandra/3.0/cassandra/dml/dmlAboutReads.html

Event Loader and Event Repository Service in PCF will interface with Operational Cassandra cluster with the services in a data center connecting/inserting/querying the Operational Cassandra data center in the respective DFS data center.

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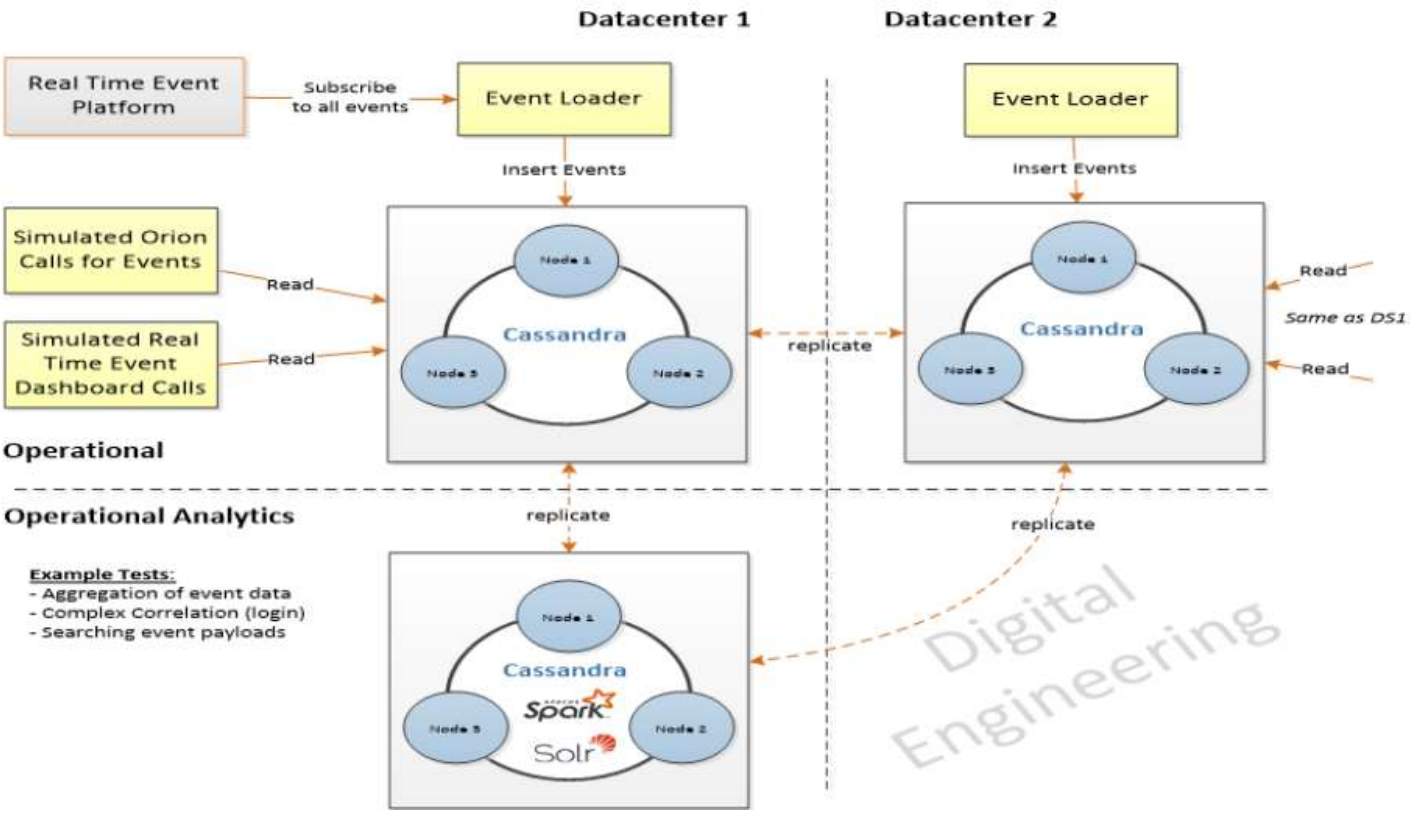

Ref:
https://discoverfinancial.sharepoint.com/sites/BTIDDC/admn/Rsch/dataStx/_layouts/15/WopiFrame.aspx?sourcedoc=%7BCE0E3D19-A9B6-467F-80F9-970B9D5DEC84%7D&file=DSEPilotResultsSummary.pptx&action=default&DefaultItemOpen=1

DataStax Enterprise System also comes with an OpsCenter that allows visual management and monitoring for the Cassandra cluster. OpsCenter provides administrators and operations team to manage the database cluster. OpsCenter manages the cluster by using the agents that are installed by the DataStax Enterprise. It also collect metrics from the cluster and issues various node administration commands, such as flushing SSTables, repairs etc.

Desktop / System Requirements

Server / Desktop Software	Application Version
Server – LINUX RHEL 7.X	DataStax Enterprise 5.1 Apache Cassandra 3.10 CQL 3.4 OpsCenter 6.1 Requires Java 8 DataStax Enterprise Java Driver 1.2

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INFRASTRUCTURE REQUIREMENTS / DESIGN / SIZING

A key requirement for project with Cassandra is to use servers with SSD to gain advantage with writes and reads on disks. Cassandra database cluster will be setup in IS1 zone as a standard practice for placement of databases. OpsCenter will be setup on a virtual server in PSN zone.

Servers / Storage

Project calls for using the standard KIT0916G NET/SSD kit for database cluster. KIT0916GP consists of Dell servers with 16 cores, 128 GB memory, 4 300 GB HDD for OS and 10 800 GB SSD's. OpsCenter center will be setup on a virtual server with 2 vcpu and 16 GB memory.

DataStax Cassandra Cluster configuration:

Location	Environment	Tier	Zone	Phy Server count	Compute (core count)	Memory (GB)	Storage
BDC	Production	DB	IS1	14	16	128	10 x 800 GB SSD 4 x 300 GB HDD
SSB	Production	DB	IS1	7	16	128	10 x 800 GB SSD 4 x 300 GB HDD
BDC	Pre-Production	DB	IS1	8	16	128	10 x 800 GB SSD 4 x 300 GB HDD
SSB	Pre-Production	DB	IS1	4	16	128	10 x 800 GB SSD 4 x 300 GB HDD
SSB	RLAB	DB	rlab	3	16	128	10 x 800 GB SSD 4 x 300 GB HDD
Total Counts				36	576	4608	

OpsCenter configuration:

Location	Environment	Tier	Zone	Virtual Server count	Compute (core count)	Memory (GB)	Storage (GB)
BDC	Production	Web	PSN	2	2	16	100
SSB	Production	Web	PSN	2	2	16	100
BDC	Pre-Production	Web	PSN	1	2	16	100
SSB	RLAB	Web	rlab	1	2	8	100
Total Counts				6	12	88	600

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Security

Inter node peer-peer communication of Cassandra cluster is secured using SSL. Traffic between Cassandra data center is also encrypted using SSL certificates. Client communication is also SSL encrypted. In DFS case application traffic will be initiated in PCF and then traverse into IS1 to talk to Cassandra Operational cluster. Application like Tableau will talk to Cassandra Analytic cluster.

Users will connect to OpsCenter web using two-factor authentication.

FIREWALLS

Firewalls will need to be opened by the team to allow traffic to come into DFS IS1 zone from PCF and then between IS1 zone in SSB and IS1 zone in BDC. OpsCenter will be located in PSN and firewalls will need be open between the OpsCenter vm and Cassandra cluster in IS1 (#7, 8).

Ref	Src Zone	Src Host / IP	Dest Zone	Dest Host / IP	Port / (TCP/UDP)	Comment
1	Zone3	cfp2 BDC 10.15.185.1	IS1	DB Host - tbd	9042, 9142 (tcp)	Application traffic
2	Zone3	cfp22 SSB 10.15.69.1	IS1	DB Host - tbd	9042, 9142 (tcp)	Application traffic
3	Zone3	cfd2 BDC 10.15.184.1	IS1	DB Host - tbd	9042, 9142 (tcp)	Application traffic
4	Zone3	cfd22 SSB 10.15.67.1	IS1	DB Host - tbd	9042, 9142 (tcp)	Application traffic
5	IS1(BDC)	DB Host - tbd	IS1(SSB)	DB Host - tbd	7000,7001,7199	Inter cluster communication
6	IS1(SSB)	DB Host - tbd	IS1(BDC)	DB Host - tbd	7000,7001,7199	Inter cluster communication
7	IS1(BDC)	DB Host - tbd	PSN	DB Host - tbd	61620	OpsCenter monitoring port for tcp traffic from the agents.
8	IS1(SSB)	DB Host - tbd	PSN	DB Host - tbd	61620	OpsCenter monitoring port for tcp traffic from the agents.

Database

Domain Architecture is in discussion with Database Engineering and Operations teams with regards to Cassandra database on install/configuration/management of the database. Operational and support details will need to be worked out for support and maintenance of Cassandra database environment.

Middleware

N/A.

Voice / Data Services

N/A.

BT - AD

Centrify zones for Datastax Cassandra is already setup for production and non-production environments.

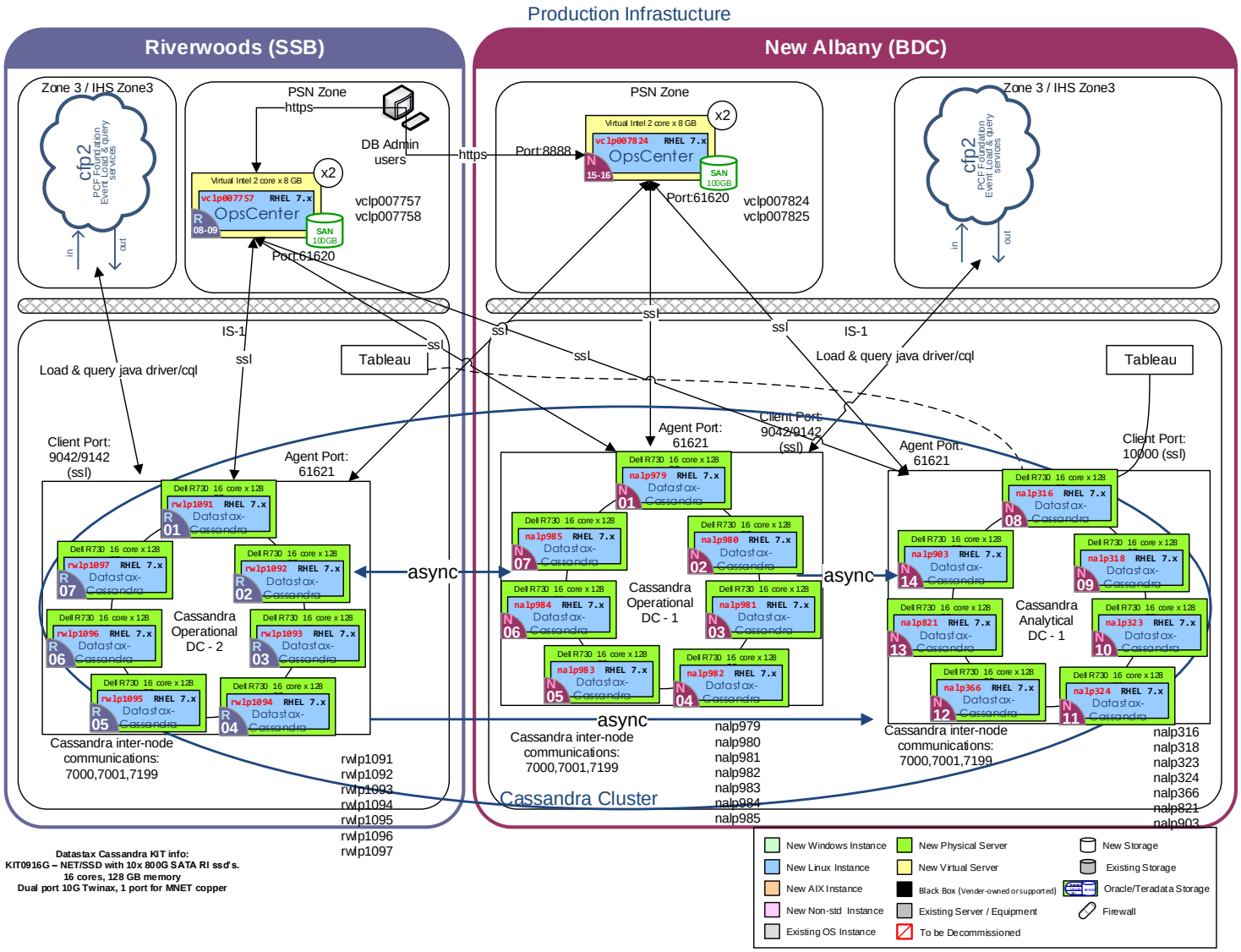
PRODUCTION ASSURANCE

N/A.

RISK / ISSUES / GAPS

- Support and owner ship of Cassandra database is still being worked out.
- Initial chef scripts for the build has been tested and more detailed chef scripts are in the works for automation.

Infrastructure Diagram for Production:



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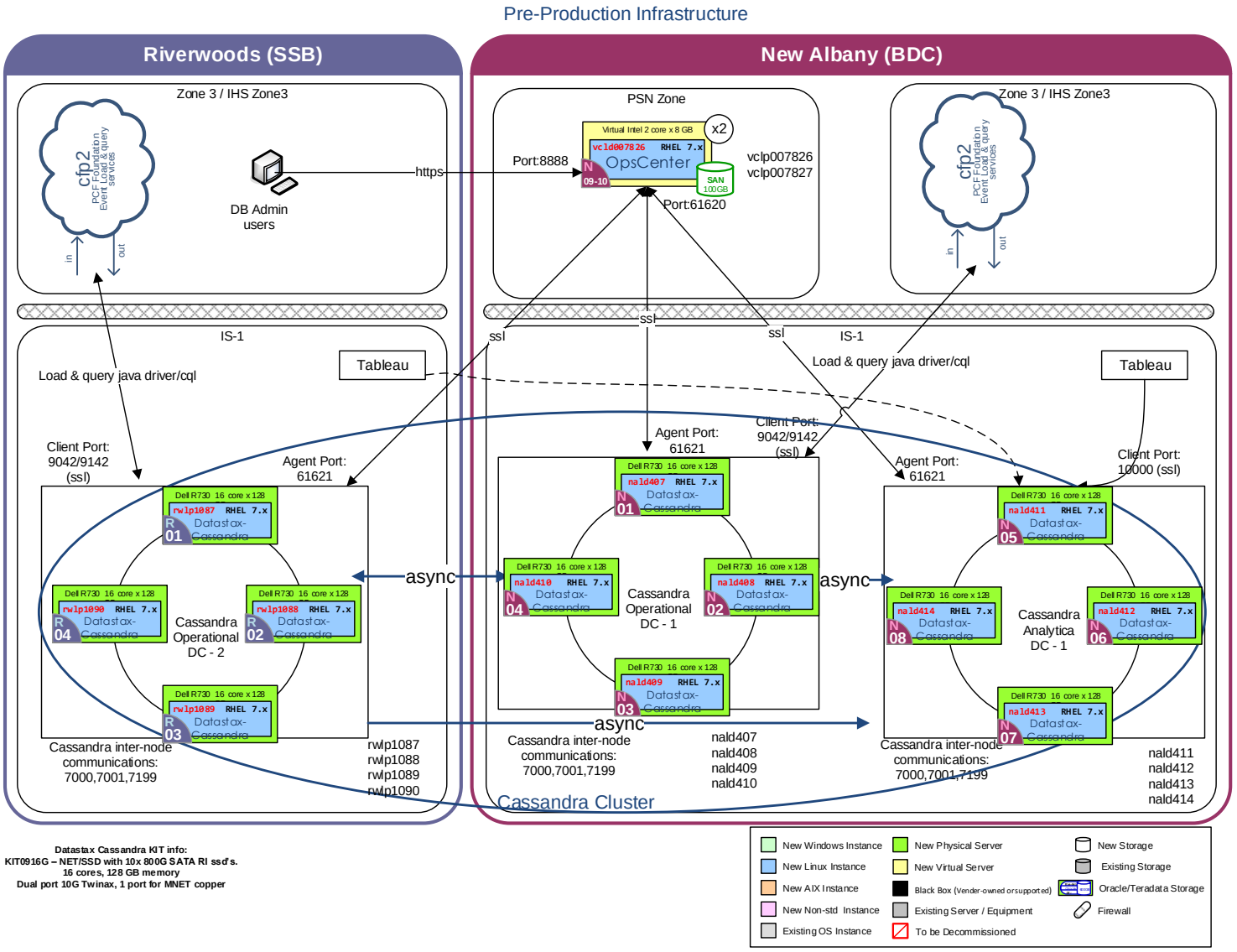
EventBus Architecture Enchancements: DataStax Cassandra

PR00014969

Infrastructure Diagram for Pre-Production:



Datastax Cassandra KIT info:
KIT0916G – NET/SSD with 10x 800G SATA RI ssd's.
16 cores, 128 GB memory
Dual port 10G Twinax, 1 port for MNET copper

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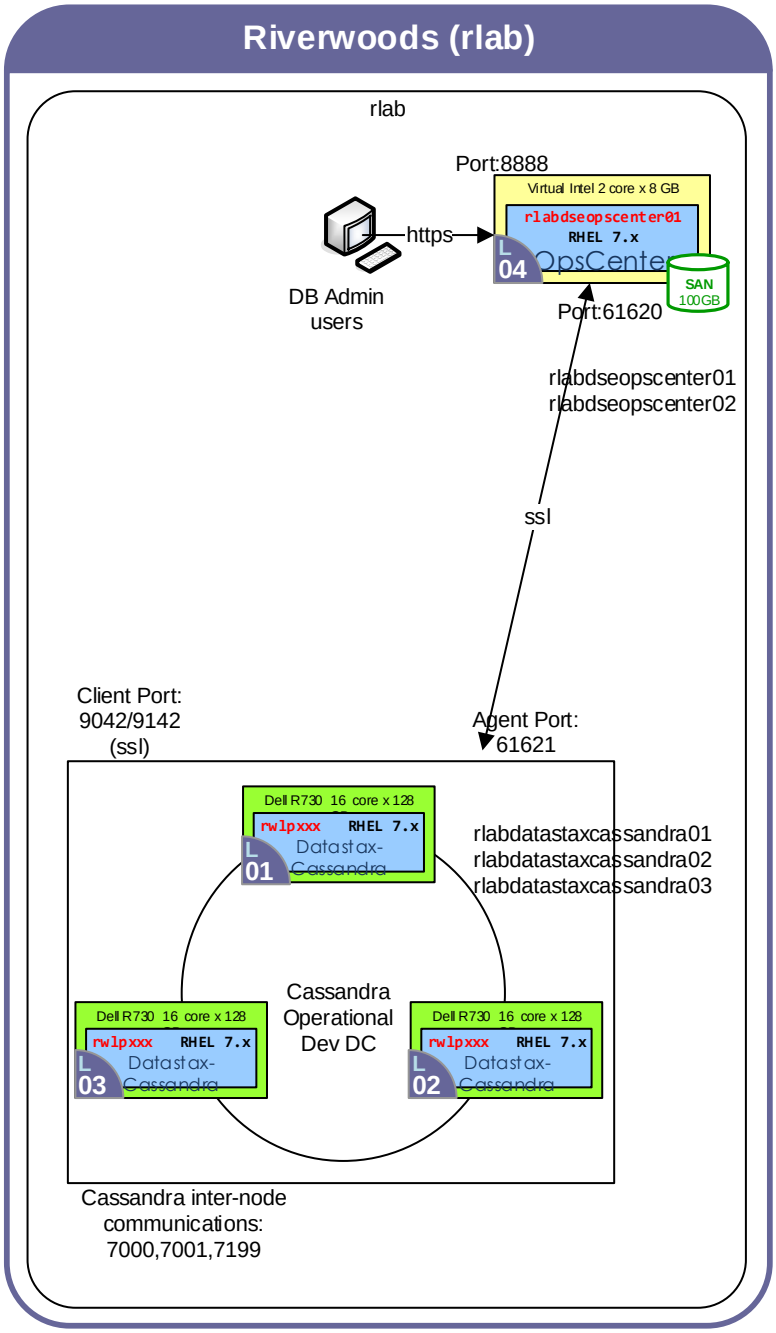
Infrastructure Diagram for rLab



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Implementation Details

This section will list out the details for each system, to allow for easy implementation by operations. Information will include all host capacity requirements, software needs, storage needs, file system information, and user / group requirements.

Production - New Albany (BDC)			
#	Short Desc. Name	Implementation Details	Svc Cat #
N 01-07	Database – Operational Cassandra DC-1	RHEL 7.x 64 bit Oracle Java Platform, Standard Edition 8 (JDK) or OpenJDK 7	nalp979 nalp980 nalp981 nalp982 nalp983 nalp984 nalp985
		4 300 GB HDD to be used for OS configured as raid 5. 10 800 GB SSD configuration – tbd based on engineering build with vendor input. Each of the seven servers should be rack mounted in a different rack.	
		DataStax Enterprise uses a plethora of open source software – please see the link below: http://docs.datastax.com/en/landing_page/doc/landing_page/thirdPartySoftware.html	
N 08-14	Database – Analytical Cassandra DC-2	RHEL 7.x 64 bit Oracle Java Platform, Standard Edition 8 (JDK) or OpenJDK 7	nalp316 nalp318 nalp323 nalp324 nalp366 nalp821 nalp903
		4 300 GB HDD to be used for OS configured as raid 5. 10 800 GB SSD configuration – tbd based on engineering build with vendor input. Each of the seven servers should be rack mounted in a different rack.	
		DataStax Enterprise uses a plethora of open source software – please see the link below: http://docs.datastax.com/en/landing_page/doc/landing_page/thirdPartySoftware.html	
N 15-16	OpsCenter	RHEL 7.X 64 bit Oracle Java Platform, Standard Edition 8 (JDK) or OpenJDK 7 Python 2.6+	vclp007824 vclp007825
		/opt/app – 100 GB	

Production - Riverwoods (SSB)			
#	Short Desc. Name	Implementation Details	Svc Cat #
R 01-07	Database – Operational Cassandra DC-1	RHEL 7.x 64 bit Oracle Java Platform, Standard Edition 8 (JDK) or OpenJDK 7	rwlp1091 rwlp1092 rwlp1093 rwlp1094 rwlp1095 rwlp1096 rwlp1097

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Production - Riverwoods (SSB)			
#	Short Desc. Name	Implementation Details	Svc Cat #
		4 300 GB HDD to be used for OS configured as raid 5. 10 800 GB SSD configuration – tbd based on engineering build with vendor input. Each of the seven servers should be rack mounted in a different rack.	
		DataStax Enterprise uses a plethora of open source software – please see the link below: http://docs.datastax.com/en/landing_page/doc/landing_page/thirdPartySoftware.html	
R 08-09	OpsCenter	RHEL 7.X 64 bit Oracle Java Platform, Standard Edition 8 (JDK) or OpenJDK 7 Python 2.6+	vclp007757 vclp007758
		/opt/app – 100 GB	

Pre-Production - New Albany (BDC)			
#	Short Desc. Name	Implementation Details	Svc Cat #
N 01-04	Database – Operational Cassandra DC-1	RHEL 7.x 64 bit Oracle Java Platform, Standard Edition 8 (JDK) or OpenJDK 7	nald407 nald408 nald409 nald410
		4 300 GB HDD to be used for OS configured as raid 5. 10 800 GB SSD configuration – tbd based on engineering build with vendor input. Each of the four servers should be rack mounted in a different rack.	
		DataStax Enterprise uses a plethora of open source software – please see the link below: http://docs.datastax.com/en/landing_page/doc/landing_page/thirdPartySoftware.html	
N 05-08	Database – Analytical Cassandra DC-2	RHEL 7.x 64 bit Oracle Java Platform, Standard Edition 8 (JDK) or OpenJDK 7	nald411 nald412 nald413 nald414
		4 300 GB HDD to be used for OS configured as raid 5. 10 800 GB SSD configuration – tbd based on engineering build with vendor input. Each of the four servers should be rack mounted in a different rack.	
		DataStax Enterprise uses a plethora of open source software – please see the link below: http://docs.datastax.com/en/landing_page/doc/landing_page/thirdPartySoftware.html	
N 09-10	OpsCenter	RHEL 7.X 64 bit Oracle Java Platform, Standard Edition 8 (JDK) or OpenJDK 7 Python 2.6+	vclp007824 vclp007825
		/opt/app – 100 GB	

TDP

Pre-Production - Riverwoods (SSB)			
#	Short Desc. Name	Implementation Details	Svc Cat #
R 01-04	Database – Operational Cassandra DC-1	RHEL 7.x 64 bit Oracle Java Platform, Standard Edition 8 (JDK) or OpenJDK 7	rwlp1087 rwlp1088 rwlp1089 rwlp1090
		4 300 GB HDD to be used for OS configured as raid 5. 10 800 GB SSD configuration – tbd based on engineering build with vendor input. Each of the four servers should be rack mounted in a different rack.	
		DataStax Enterprise uses a plethora of open source software – please see the link below: http://docs.datastax.com/en/landing_page/doc/landing_page/thirdPartySoftware.html	

rLab - Riverwoods (SSB)			
#	Short Desc. Name	Implementation Details	Svc Cat #
L 01-03	Database – Operational Cassandra DC-1	RHEL 7.x 64 bit Oracle Java Platform, Standard Edition 8 (JDK) or OpenJDK 7	rlabdatastaxcassandra01 rlabdatastaxcassandra02 rlabdatastaxcassandra03
		4 300 GB HDD to be used for OS configured as raid 5. 10 800 GB SSD configuration – tbd based on engineering build with vendor input.	
		DataStax Enterprise uses a plethora of open source software – please see the link below: http://docs.datastax.com/en/landing_page/doc/landing_page/thirdPartySoftware.html	
L04	OpsCenter	RHEL 7.X 64 bit Oracle Java Platform, Standard Edition 8 (JDK) or OpenJDK 7 Python 2.6+	rlabdseopscenter01 rlabdseopscenter02
		/opt/app – 50 GB	

TDP

DataStax Cassandra

PR00013914

Pricing

New Albany (BDC) - Production

Item	Ref. #	Qty	Unit Cost Capital	Unit Cost Expense	Extended Cost Capital	Extended Cost Expense
Hardware			HW / SW	HW / SW		
KIT0916c-Cassandra	N01-N07	7	$ 23,390.63	$ 9,184.07	$ 163,734.41	$ 64,288.51
KIT0916G-Net/SSD- 10x 800G	N08-N14	7	$ 19,790.03	$ 5,538.94	$ 138,530.24	$ 38,772.61
Internal Windows VM 2 x 16	N15-N16	2	$ 3,067.75	$ 2,262.71	$ 6,135.50	$ 4,525.43
Storage						
General SAN	N15-N16	100	$ 5.36	$ 1.66	$ 536.00	$ 166.00
Flatfile Standard Backup (per GB)	N01-N16	4300	$ 2.34	$ 0.57	$ 10,062.00	$ 2,451.00
Software						
PHY-LINUX OS + common	N01-N07	7	$ 502.61	$ 3,819.09	$ 3,518.26	$ 26,733.63
PHY-LINUX OS + common	N08-N14	7	$ 502.61	$ 3,819.09	$ 3,518.26	$ 26,733.63
DSE License - Prod - 10 servers	N01-N14	10	$ -	$ 73,220.71	$ -	$ 732,207.06
DSE License - Prod - 11+ servers	N01-N14	4	$ -	$ 64,429.51	$ -	$ 257,718.02
DSE Professional Service & training	N00-N99	1	$ -	$ 268,800.00	$ -	$ 268,800.00
DFS 2017 Offshore contractors	N00-N99	1	$ -	$ 160,000.00	$ -	$ 160,000.00
DFS 2018 Offshore contractors	N00-N99	1	$ -	$ 200,000.00	$ -	$ 200,000.00
New Albany Subtotal					**$ 326,034.66**	**$ 1,782,395.89**
New Albany Grand Total						**$ 2,108,430.55**

Riverwoods (SSB) - Production/DR

Item	Ref. #	Qty	Unit Cost Capital	Unit Cost Expense	Extended Cost Capital	Extended Cost Expense
Hardware			HW / SW	HW / SW		
KIT0916c-Cassandra	R01-R07	7	$ 23,390.63	$ 9,184.07	$ 163,734.41	$ 64,288.51
Internal Linux VM 2 x 16	R08-R09	2	$ 2,711.75	$ 2,662.71	$ 5,423.50	$ 5,325.43
Storage						
General SAN	R08-R09	100	$ 5.36	$ 1.66	$ 536.00	$ 166.00
Flatfile Standard Backup (per GB)	R01-R09	2200	$ 2.34	$ 0.57	$ 5,148.00	$ 1,254.00
Software						
PHY-LINUX OS + common	R01-R07	7	$ 502.61	$ 3,819.09	$ 3,518.26	$ 26,733.63
DSE License - Prod - 11+ servers	R01-R07	7	$ -	$ 64,429.51	$ -	$ 451,006.54
SSB Subtotal					**$ 178,360.16**	**$ 548,774.11**
SSB Grand Total						**$ 727,134.27**

New Albany (BDC) - Pre-Production

Item	Ref. #	Qty	Unit Cost Capital	Unit Cost Expense	Extended Cost Capital	Extended Cost Expense
Hardware			HW / SW	HW / SW		
KIT0916c-Cassandra	N01-N04	4	$ 23,390.63	$ 9,184.07	$ 93,562.52	$ 36,736.29
KIT0916c-Cassandra	N05-N08	4	$ 23,390.63	$ 9,184.07	$ 93,562.52	$ 36,736.29
Internal Windows VM 2 x 16	N09-N10	2	$ 3,067.75	$ 2,262.71	$ 6,135.50	$ 4,525.43
Storage						
General SAN	N09-N10	100	$ 5.36	$ 1.66	$ 536.00	$ 166.00
Flatfile Standard Backup (per GB)	N01-N10	2500	$ 2.34	$ 0.57	$ 5,850.00	$ 1,425.00
Software						
PHY-LINUX OS + common	N01-N04	4	$ 502.61	$ 3,819.09	$ 2,010.43	$ 15,276.36
PHY-LINUX OS + common	N05-N08	4	$ 502.61	$ 3,819.09	$ 2,010.43	$ 15,276.36
DSE License - nonProd - 10 servers	N01-N08	8	$ -	$ 55,500.00	$ -	$ 444,000.00
New Albany Subtotal					**$ 203,667.40**	**$ 554,141.73**
New Albany Grand Total						**$ 757,809.13**

Riverwoods (SSB) - Pre-Production

Item	Ref. #	Qty	Unit Cost Capital	Unit Cost Expense	Extended Cost Capital	Extended Cost Expense
Hardware			HW / SW	HW / SW		
KIT0916c-Cassandra	R01-R04	4	$ 23,390.63	$ 9,184.07	$ 93,562.52	$ 36,736.29
Storage						
Flatfile Standard Backup (per GB)	R01-R04	1200	$ 2.34	$ 0.57	$ 2,808.00	$ 684.00
Software						
PHY-LINUX OS + common	R01-R04	4	$ 502.61	$ 3,819.09	$ 2,010.43	$ 15,276.36
DSE License - nonProd - 10 servers	R01-R04	2	$ -	$ 55,500.00	$ -	$ 111,000.00
DSE License - nonProd - 11+ servers	R00-R99	2	$ -	$ 22,199.78	$ -	$ 44,399.56
SSB Subtotal					**$ 98,380.95**	**$ 208,096.21**
SSB Grand Total						**$ 306,477.16**

Riverwoods (SSB) - RLAB

Item	Ref. #	Qty	Unit Cost Capital	Unit Cost Expense	Extended Cost Capital	Extended Cost Expense
Hardware			HW / SW	HW / SW		
KIT0916c-Cassandra	L01-L03	3	$ 23,390.63	$ 9,184.07	$ 70,171.89	$ 27,552.22
Internal Linux VM 2 x 8	L04	1	$ 2,364.28	$ 2,138.29	$ 2,364.28	$ 2,138.29
Storage						
General SAN	L04	100	$ 5.36	$ 1.66	$ 536.00	$ 166.00
Flatfile Standard Backup (per GB)	L01-L04	950	$ 2.34	$ 0.57	$ 2,223.00	$ 541.50
Software						
PHY-LINUX OS + common	L01-L03	3	$ 502.61	$ 3,819.09	$ 1,507.82	$ 11,457.27
DSE License - nonProd - 11+ servers	L01-L03	6	$ -	$ 22,199.78	$ -	$ 133,198.67
SSB Subtotal					**$ 76,803.00**	**$ 175,053.95**
SSB Grand Total						**$ 251,856.94**

TOTAL PRICING

	Capital	Expense
Unit & Extended Cost Total	**$ 883,246**	**$ 3,268,462**
Grand Total Capacity Cost	**$**	**4,151,708**

Server pricing based on EIS standard capacity pricing and/or vendor quotes.

Server hosting fees consist of software, network, and facilities costs.

Server expense costs include 5 years of hardware and Operating System software maintenance.

DataStax Cassandra subscription costs include estimates out through Year 5.

Exadata and Storage costs are for 4 years.

Laptops depreciates over a 3 year period.

Costs include 11% for tax and shipping and are intended to assess 5-year total cost of acquisition.