Census Enterprise Data Collection and Processing (CEDCaP)

COTS Capability Assessment & Analysis

Issued on May 25, 2016

United States Census Bureau

U.S. Department of Commerce
Economics and Statistics Administration
U.S. CENSUS BUREAU
census.gov

Revision History

Version	Date	Description of Changes
1.0	5/26/16	Original Document
2.0	6/1/16	Updated Table D-3 (previously duplicate of D-4, updated to reflect Mobile Data as titled and described)

Table of Contents

1. EXECUTIVE SUMMARY 7

1.1 Process **8**

1.2 Analysis of Alternatives Summary **11**

1.3 Recommendation **12**

2. BACKGROUND SUMMARY 14

2.1 COTS Capability Assessment & Analysis Scope **15**

2.2 CCAA Process Planning & Research **18**

2.3 Constraints/Assumptions **20**

3. COTS CAPABILITY ASSESSMENT & ANALYSIS (CCAA) APPROACH 22

3.1 CCAA Team **22**

3.2 CCAA Framework Summary **24**

4 CCAA ANALYSIS OF ALTERNATIVES 34

4.1 Business Functional Need Criteria **34**

4.2 System Design Criteria **38**

4.3 Cost (5-Year TCO) Criteria **56**

4.4 Schedule Criteria **59**

4.5 Vendor/Development Team Viability Criteria **63**

5 RECOMMENDATION 68

5.1 Process Summary **68**

5.2 Recommendation.....75

Appendix A – Acronym Guide 78

Appendix B – Phase II Challenge Question 81

Appendix C – CEDCaP Evaluation Questions 83

Appendix D – CCAA Assessment of Requirements 85

Appendix E – Survey & Listing Operational Control Requirements.....94

Appendix F – Centralized Operational and Control Capability Requirements.....96

Appendix G – Questionnaire Design & Metadata Capability Requirements.....100

Appendix H – Mobile Data Collection Capability Requirements.....103

Appendix I – Address Listing & Mapping Capability Requirements 108

Appendix J – Internet Data Collection Capability Requirements 110

Appendix K – Maintainability.....113

Appendix L – Portability.....114

Appendix M – Availability/Dependability.....115

Appendix N – Performance.....116

Appendix O – Security 117

Appendix P – Integrability/Interoperability 118

Appendix Q – Scalability/Elasticity 119

Appendix R – Testability.....120

Appendix S – Schedule 121

Appendix T – Vendor/Development Team Viability 122

[This page is intentionally left blank.]

1. EXECUTIVE SUMMARY

The mission of the U.S. Census Bureau (USCB) is to serve as the leading source of quality data about the Nation's people and economy. Measuring an ever-expanding, busy, and diverse American society and economy requires constant innovation of our data collection methods and dissemination activities. Costs are rising and data is becoming harder to collect, and the Census Bureau is adapting and innovating to continue meeting its mission. Collecting and processing data in the 21st century requires a streamlined, enterprise approach that is embodied in the Census Enterprise Data Collection and Processing (CEDCaP) initiative.

CEDCaP is a forward-thinking, bureau-wide initiative to create an integrated and standardized enterprise solution that will offer shared data collection and processing across all censuses and surveys. CEDCaP became a formal program in Fiscal Year (FY) 2015, and will consolidate costs by retiring unique, survey-specific systems and redundant capabilities and bring a much greater portion of the USCB's total IT expenditures under a single, integrated, and centrally managed program. CEDCaP will also halt the creation of program-specific systems and put in place a solution that will be mature and proven for the 2020 Census. CEDCaP focuses on minimizing redundancy, lowering complexity, and delivering significant savings for all censuses and surveys, with a current focus on the 2020 Census. This is an opportunity to reduce risks to the 2020 Census by implementing an integrated, proven solution of survey collection and processing capabilities well in advance that will result in our most automated and efficient decennial census ever. In addition, CEDCaP will position the USCB to implement capabilities, reengineered business processes, and new technologies more quickly across the enterprise.

The CEDCaP program is responsible for delivering an enterprise solution and enabling technologies for twelve capabilities that comprise enterprise data collection and processing. The USCB established IT guiding principles for implementing these enterprise solutions, including, but not limited to, reducing redundancies through shared services, emphasizing standards-based software, use of commercial off-the-shelf solutions (COTS) over custom development, and adopting new technology while maintaining secure systems and information.

Based on a CEDCaP business and technical solutions architecture, in-house development teams were formed who created initial system designs that leveraged existing USCB systems wherever practicable. The development teams provided innovative solutions that were tested and used for the 2020 Census Tests in 2014-2016, the CAPI Technology Refresh, and the Economic Directorate's Company Organizational Survey /Annual Survey of Manufacturers (COS/ASM). The research, testing, information and solutions provided by these teams were critical when we approached the analysis and decision phases to determine if the best approach to deliver the CEDCaP solution was to continue to build internal system or purchase an existing COTS solution. The work of these Census teams is the foundation on which CEDCaP builds to make well-informed recommendations and decisions on behalf of the enterprise. Additionally, the innovation and creativity shown by the in-house teams during this development effort has led to the development of the processes and business rules that have allowed the USCB to reengineer NRFU operations, which are projected to result in a cost savings of $2.6 billion during 2020 Census operations.

In addition to the work done by the Census development teams to date, the USCB has benefited from funding received during the past several budgetary cycles which demonstrated the priority that Congressional and other stakeholders placed on CEDCaP, and the importance of building the initial CEDCaP systems that became the standard to develop requirements and used to evaluate commercially available systems. We continue to receive support from stakeholder groups including Carnegie Mellon University's Software Engineering Institute, and the National Academy of Sciences, who provided their expertise as we developed our approach and analysis.

Based on the internal proof of concept work, the USCB developed a rigorous, iterative, and transparent process to conduct the systems analyses of commercially available solutions and in-house developed solutions as outlined in this COTS Capability Assessment & Analysis (CCAA) report. As a result of the CCAA, the CEDCaP team has recommended a hybrid approach, consisting of integrating the best COTS platforms with specific USCB in-house solutions developed by Census experts. The recommended approach will address the short-term goal of successfully deploying the 2020 Census while building the infrastructure to transition to the long-term goal of CEDCaP's future state that will support all surveys and censuses.

The hybrid approach includes buying a COTS solution to support six of the CEDCaP capabilities identified as part of market research during the CCAA process, and using in-house capabilities for the remaining six CEDCaP capabilities. All twelve CEDCaP capabilities are listed in Section 1.1: Background, and are further described throughout this CCAA report. Additionally, the in-house Internet and Mobile Data Collection system will continue to be tested alongside the capabilities delivered by the COTS solution, as part of a risk mitigation strategy in support of internet self-response, a key CEDCaP capability.

The recommended COTS solution resulting from the CCAA demonstrated overall superiority and led the majority of the individual CCAA evaluation criteria. These criteria are described in Section 4: Analysis of Alternatives Summary.

The remaining sections in the CCAA report provide details on the planning and research conducted, the transparent process more detailed information on the strengths and weaknesses of each alternative solution considered, and a listing of recommendations and next steps.

A listing of acronyms used in this report is available as Appendix A.

1.1 Process

As part of its implementation strategy, the CEDCaP program developed a multi-year strategy to design and test internally developed systems. This strategy included an analysis and comparison of in-house systems to commercially available ones. This analysis would determine the systems to provide CEDCaP capabilities on a long-term basis.

The USCB took a disciplined approach in conducting this analysis and comparison. The steps involved in the process included:

1. Identifying core and key business capabilities to be delivered by CEDCaP

2. Conducting extensive market research on which capabilities may be commercially available
3. Preparing a Request for Information (RFI) from industry
4. Conducting vendor demonstrations on commercially available solutions
5. Preparing a Request for Quotation (RFQ) based on USCB requirements
6. Completing vendor demonstrations and selection of qualified vendor solutions
7. Leveraging Carnegie Mellon University's Software Engineering Institute (CMU SEI) to assist with the COTS Capability Assessment and Analysis (CCAA)
8. Developing the CCAA process, including leveraging components from the CMU SEI Evolutionary Process for Integrating COTS-Based Systems (EPIC) process
9. Completing the CCAA Process, including three sub-components:
    a. Offline Product Development
    b. Physical Assessments (though prototype development)
    c. Analysis of Alternatives (AoA)
10. Completing analysis, including documentation of findings
11. Preparing overall recommendations and next steps

Market research confirmed the availability of COTS products for six of the twelve CEDCaP capabilities. These capabilities are listed later in this section. These COTS products fall into a services category called intelligent Business Process Management Systems (iBPMS). The iBPMS platforms are not like traditional COTS products where the business logic is installed directly from the application with business-specific custom application code. These platforms incorporate Business Process Modeling (BPM) and Business Rules Engines (BRE) into an integrated development and runtime platform allowing quick configuration to meet specific user's business cases with minimal to no application code changes. This style of platform incorporates user-friendly drag and drop user-interface (UI), which allows for a less skilled IT developer and more skilled business analyst to develop the user's specific business logic faster than a traditional COTS product or from an in-house developed solution.

As outlined above, and as part of the market research process, the USCB issued a Request for Information (RFI) on December 12, 2014 to solicit information about the experience and expertise of vendors to provide the identified CEDCaP capabilities through COTS Platforms and Software. The USCB garnered a great deal of interest and received approximately 29 responses. The vendors' responses enabled the USCB to learn about industry experience and capabilities and gain better clarity around our requirements.

The USCB then requested demonstrations from several vendors with COTS products that had the capabilities described in the RFI to demonstrate how the products could meet USCB needs.

The market research process (including the RFI as well as vendor demonstrations), enabled the USCB to learn even more about the vendors' COTS products, their ability to meet our capability needs, and view additional functionality that could help enable scalability and reduce risks for the 2020 Census. This thorough process resulted in well-defined requirements in the Request for Quotations (RFQ), issued on September 2, 2015.

The USCB awarded Purchase Orders on September 30, 2015 to purchase product licenses from the five vendors that submitted proposals in response to the RFQ. This allowed for further assessments (physical and engineering), software testing, and analysis of the vendors' tools. At the conclusion of the first evaluation phase for all five COTS products, the USCB was able to reduce the number of vendors down to two that met all programmatic requirements. Coincidently, these vendors were also the highest rated iBPMS and Dynamic Case Management (DCM) platforms by the independent IT research firms of Gartner and Forrester. To ensure that participants in the acquisition process are not identifiable, vendors will be referenced in this report by a randomly selected number.

The USCB engaged with the CMU SEI to assist with a CCAA. The USCB also leveraged components from the CMU SEI Evolutionary Process for Integrating COTS-Based Systems (EPIC), which outlines the key elements in building, fielding, and supporting COTS solutions. The CMU SEI framework has been used successfully in a variety of government COTS solutions and was used by the CCAA team. The CCAA process included establishing weighted evaluation criteria to assist in the analysis of how the proposed solutions would perform and what solution would be the best option for USCB required functionality.

Six of the 12 CEDCaP capabilities were chosen for this analysis because they comprise the needs of a digital data collection system. The digital data collection system capabilities were selected for this analysis because they encompass a large number of the requirements for the 2020 Census and are the key cost drivers for the 2020 Census data collection operations. The in-house solutions that map to the CEDCaP components that were part of the analysis included:

1. Centralized Operational Analysis and Control, also known internally as Multi-Mode Operational Control System (MOCS),
2. Survey (and Listing) Interview Operational Control, also known internally as MOJO/Mobile Case Management (MOJO/MCM),
3. Address Listing and Mapping, also known internally as Listing & Mapping (LiMA),
4. Questionnaire Design and Metadata, also known internally as Content Metadata (COMET),
5. Internet and Mobile Data Collection, also known internally as PRIMUS, and
6. Census Operations Mobile Platform for Adaptive Services and Solution (COMPASS).

The first two capabilities provide Operational Control System (OCS) functionality and are considered core CEDCaP capabilities. These are described in more detail in Section 4: Analysis of Alternatives Summary. The remaining four items (capabilities 3-6) are considered key CEDCaP capabilities. These will be described in more detail in Appendix D: Assessment of Business Requirements.

The remaining six CEDCaP capabilities that were not assessed during this analysis are:

7. Service Oriented Architecture
8. Centralized Development and Testing Environment
9. Decennial Scale-up (Architecture)
10. Survey Response Processing
11. Scanning Data Capture from Paper

12. Centralized Operational Analysis and Control and Adaptive Survey Design Capability, including statistical modeling and administrative records.

The CCAA included two aspects: 1) a proof of concept phase; and 2) Analysis of Alternatives (AoA). The 90-day Proof of Concept (POC) phase began in January 2016 and involved two selected vendors (referred to as Vendor One and Two throughout this CCAA report) configuring prototypes for the CCAA determined key capabilities, based on a subset of the 2020 Census requirements. Important to the 90-day POC were configuration sprints where the COTS vendors developed specific USCB requirements on their platforms. Prior to each sprint was a Joint Analysis Design (JAD) session, which is a typical Agile developmental activity where the business requirements staff and IT team collaborate prior to the sprint to develop a strategy. At the end of each sprint, there was a review session where the vendors demonstrated the agreed upon business requirements on their platforms.

The AoA was performed comparing Vendors One and Two with each of the in-house solutions that made up the two CEDCaP core OCS capabilities (1-2 above). A detailed explanation of this AoA is provided in Section Four: Analysis of Alternatives Summary. There was an additional assessment of the COTS platforms ability to deliver the remaining four capabilities (3-6 above). An explanation of this additional assessment is presented in Appendix D.

In addition to CMU SEI and CEDCaP staff, there was broad USCB stakeholder representation on the CCAA teams. The USCB Executive Guidance Group (EGG) was established to help provide the necessary stakeholder engagement and technical direction within the CEDCaP program and is comprised of the senior IT leadership from all directorates in the USCB. The EGG was a consistent presence throughout the CCAA effort, helping to problem-solve, set direction, work with the CEDCaP staff to establish evaluation criteria and document the analysis, and make the final recommendation for the CCAA decision to the CEDCaP Executive Steering Committee (ESC), comprised of senior Census Bureau leadership. The ESC evaluates, accepts, and takes action to oversee CEDCaP activities, resolves organizational issues and manages and reduces risks to the program. In addition, the ESC provides guidance in establishing timelines for program development, specifically when cross-directorate resources are required. The ESC will also adjust project objectives, resources, etc., as necessary, and resolve high-level issues.

1.2 Analysis of Alternatives Summary

The CCAA team identified five key criteria to use in the evaluation process:

1. Business Functional Need - the degree to which the alternative satisfies a set of defined business requirement and related quality attributes,
2. System Design – the degree to which the alternative satisfies an identified set of important architectural quality attributes,
3. Schedule Impacts – the ability of the alternative to be confidently deployed to meet the required timelines,
4. Cost (5-Year Total Cost of Ownership (TCO)) – the relative comparison of estimated five-year total cost of ownership for a given alternative, and
5. Vendor/Development Team Viability – indicator of vendor/development team and tool's stability and ability to meet the USCB's long term needs.

To calculate the weights, the EGG and CCAA team members held workshops for several days that focused on each of the evaluation criteria. These workshops were facilitated by CM SEI staff and were attended by all assessment teams and EGG. This allowed the group to identify and define the criteria, as well as sub-criterion. Then for each criterion and sub-criterion the teams discussed the level of criticality each carries in relation to other criteria or sub-criteria, came to an agreement and assigned weights accordingly. The weights reflected relative value to the USCB, the CEDCaP enterprise solution, and the 2020 Census. A quantitative scoring model was developed and used to provide an objective platform for comparison. See Figure 1: CCAA Criteria & Weights.

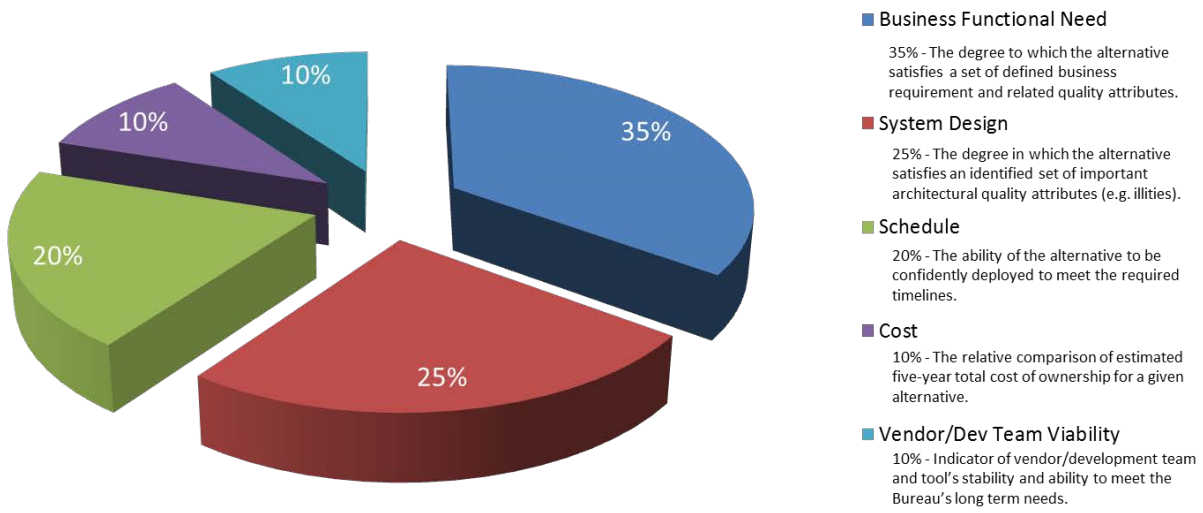


Figure 1: CCAA Criteria & Weights

Scores were then compiled for each solution alternative using the weights shown in Figure 1 to calculate the overall evaluation scoring results.

The CCAA team used this quantitative scoring model to assist in the overall evaluation. The higher an alternative scored, the better it aligned to the needs of the USCB. The scoring model then applied weights to the criteria based on perceived value relative to the success of the solution. These weights are shown in Figure 1 above. Ratings on the individual criterion as well as the overall scores are presented in Section 5.1: Process Summary.

1.3 Recommendation

The CEDCaP CCAA team and CEDCaP program recommend a hybrid approach to delivering the CEDCaP solution, where the best COTS platform is integrated with select USCB custom solutions that will optimally address the short-term goal of successfully deploying the 2020

Census while also building the infrastructure to transition to the long-term CEDCaP goal to support all surveys and censuses.

Specific recommendations from the CCAA effort include:

1. Use Vendor Two's platform as the core CEDCaP data collection operations platform, performing the capabilities currently being performed by the following systems: MOCS/MOJO/MCM, LiMA, COMET, PRIMUS, and COMPASS;
2. Supplement the platform with the Census Bureau developed optimizer and routing engine developed by the MOJO team;
3. Deploy Vendor Two as the CEDCaP data collection platform for the 2017 Census Test, including the internet self-response component; and
4. Develop a comprehensive performance-testing plan and initiate immediate performance testing of Vendor Two's platform.

The 2020 Census will be the first decennial census that will use the internet as the primary self-response mode. PRIMUS is the in-house solution built to address the key Internet Data Collection capability specific to the 2020 Census. It is not part of the OCS components (MOCS/MOJO/MCM) reviewed during the CCAA assessment. However, due to the importance of internet self-response the USCB has invested in this in-house solution focusing on system design and overall performance. As a result of this assessment, the team is confident that both PRIMUS and the selected COTS platform will scale; however, they recommend further performance testing be conducted to determine the most efficient scaling alternative for internet self-response.

As part of the 2020 Decennial internet self-response mode the USCB will include Real Time Non-Id Processing (RTNP), which is a non-CEDCaP solution for the 2020 Census. RTNP is a process that performs a look-up in the USCB master address file to find the Census ID for respondents completing their questionnaire online without a Census issued ID number. Understanding the importance of this integration and internet-self response to the 2020 Census the CEDCaP CCAA team recommends the following:

1. Use the internet data collection capability provided by the recommended COTS solution. This solution will be used for all future 2020 Census testing, beginning with the 2017 Census Tests. As a risk mitigation strategy, while the performance and scalability of the COTS solution is being tested, the in-house internet data collection solution (PRIMUS) will be equally tested.

2. Start integration testing of the recommended COTS solution internet data collection capability with RTNP and be ready to deploy it into USCB Infrastructure-as-a-Service (IaaS)/Platform-as-a-Service (PaaS) offering (e.g. cloud), when available, to conduct performance/load/stress/torture testing. RTNP allows the USCB to match incoming survey/census responses to addresses in the address file, without the respondent providing a USCB provided ID number with their response. IaaS/PaaS are cloud application services that use the web to deliver applications, which can usually be run directly from a web browser.

The continued testing outlined above will allow the USCB to determine which of the two solutions scales most easily and provides the most efficient solution for data integration for self-response during the 2020 Census.

2. BACKGROUND SUMMARY

The USCB is facing an increasing set of challenges, from declining survey participation to flat or declining budgets and increasing data collection costs. Each threatens the ability to deliver high-quality, timely, relevant and cost-effective information consistently. The USCB is in the process of transforming into a more functionally based, efficient, cost-effective and adaptive organization. The strategy to accomplish this transformation seeks to identify and implement large-scale and complex integrated enterprise solutions developed following very structured and consistent business and technical processes. One mitigation strategy to increase cost-effectiveness is to implement integrated enterprise solutions supporting business and technical processes to eliminate costly duplicative systems.

In examining operations across the enterprise, USCB leadership determined it needed to make transformational changes to succeed now and in the future in the way the Bureau collects and processes data. To this end, they created the Census Enterprise Data Collection and Processing (CEDCaP) initiative. The CEDCaP Program, which began in fiscal year 2015, is an initiative to create an integrated and standardized system of systems that will offer shared data collection and processing across all censuses and surveys. CEDCaP will consolidate costs by retiring unique, survey-specific systems and redundant capabilities and bring a much greater portion of the Census Bureau's total IT expenditures under a single, integrated and centrally-managed program. CEDCaP will also halt the creation of program-specific systems and put in place a solution that will be mature and proven for the 2020 Census. This enterprise solution will become a permanent enterprise data collection and processing environment at an estimated cost lower than the cost of 2010 Census systems alone. The current CEDCaP program is comprised of twelve projects responsible for delivering enterprise solutions that provide core capabilities and enabling technologies for enterprise data collection and processing. The USCB has established IT Guiding Principles for implementing these major IT initiatives, including, but not limited to, reducing enterprise redundancies through shared services, emphasizing standards-based, commercial off-the-shelf solutions (COTS) over custom development, and adopting new technology while maintaining secure systems and information.

CEDCaP's scope includes not only census and survey data collection operations, but also portions of survey design, instrument development, sample design, implementation, data editing, imputation and estimation. All included survey lifecycle segments have the potential to increase the efficiency of the overall data collection and processing. The architecture of this integrated solution resulted in twelve capabilities identified as part of the planning and budgeting process:

1. Centralized Operational Analysis and Control and Adaptive Survey Design, including statistical modeling and administrative records;
2. Survey (and Listing) Interview Operational Control;
3. Address Listing and Mapping;
4. Internet and Mobile Data Collection;

5. Dashboards for Monitoring Survey Cost, Progress, and Quality and Enterprise Paradata Repository;
6. Questionnaire Design and Metadata;
7. Service Oriented Architecture;
8. Centralized Development and Testing Environment;
9. Decennial Scale-up;
10. Survey Response Processing;
11. Scanning Data Capture from Paper; and
12. Electronic Correspondence Portal.

The CEDCaP Program office tasked the IT Directorate with delivering these capabilities via multiple IT projects.

2.1 COTS Capability Assessment & Analysis Scope

While CEDCaP is responsible for delivering future IT solutions to support survey and census data collection operations, all CEDCaP functionality could not be reviewed as a part of this assessment. The CCAA team had to limit the scope of requirements to be reviewed in this assessment. Once the scope was set, the assessment moved forward through a series of information gathering and evaluation phases that will be outlined in this section.

There are several USCB initiatives underway to support the goals of the CEDCaP program by transforming the way the USCB does business, rethinking our current business processes for data collection operations. The goal of CEDCaP is to provide the technical solutions that support the re-engineering of our current business processes to create more efficient data collection operations. Additional key Census Bureau initiatives that align with CEDCaP initiatives are the following:

- *The Center for Adaptive Design (CAD)* -- Research office launched in 2012 with the goal of using adaptive survey designs, allowing for real-time changes to how a survey is conducted based on incoming information (e.g., costs, fieldwork quality, and estimates of key variables) during the data collection process.
- *ROCkIT (ReOrganize Census with Integrated Technology)* -- Research prototype project launched in 2014 that successfully re-engineered 2020 Census field operations by developing a new management structure and associated business processes that significantly increases NRFU productivity.
- *The Office of Innovation and Implementation (OII)* -- Office launched in 2015 to lead the innovation of business process re-engineering efforts across the enterprise and the implementation of re-engineered business processes.

The CAD, ROCkIT & OII focus on business process re-engineering efforts. These projects align closely with the goals of CEDCaP initiatives by delivering re-engineered business processes (which do not exclude technology, but rather enables redesigned business processes and technology to mutually reinforce and influence each other). CEDCaP is responsible for delivering the integrated technology needed to successfully operationalize the re-engineered business processes defined by ROCkIT, CAD and OII.

The capabilities delivered by the ROCkIT and CAD systems have been added into the CEDCaP initiative. The systems developed by these initiatives deliver core data collection system capabilities internally known as an Operational Control System (OCS). The overall goal of an OCS is to create operational efficiencies in the distribution and management of a workable case. A workable case can be described as an activity that requires the collection of data, be it respondent data or data relating to a specific address or geographic composition. The more quickly the data are passed along and across tiers, the more efficient the overall data collection process. These CEDCaP capabilities areas and current in-house systems the OCS corresponds to are:

- Centralized Operational Analysis Control and Adaptive Survey Design – also known as Multi-Mode Operational Control System (MOCS):
    - **Tier 1:** MOCS makes case assignments at the mode-level (e.g.; paper, internet, Computer Assisted Personal Interviewing (CAPI) and Computer Assisted Telephone Interviewing (CATI) and includes real-time case status reports and data reconciliation.
- Survey (and Listing) Interview Operational Control - Field OCS:
    - **Tier 2:** MOJO. The management of field mode (CAPI and CATI) case data collection, providing optimum daily field case assignment, alerts and real-time management interfaces to automate field interaction.
    - **Tier 3:** Mobile Case Management (MCM). The management of assigned cases and interaction with field OCS by the individual field worker.

This CCAA effort provided an analysis to understand the relative comparison of solutions considering: 1) the status from an overall systems perspective (i.e., not only business capabilities but system design and architectural maturity); 2) the gap between system readiness and the target state required for the 2020 Census; and 3) the gap between current state and the ideal future state to realize the strategic long-term, enterprise-wide goal. As planned, the CCAA was the next step required for the USCB to move forward with plans to compare and select a solution able to best meet the comparison above as well as the business and system requirements. As discussed in Section 1.1, the CEDCaP capability areas and solutions identified to be part of the CCAA effort, based on the needs of a digital data collection component, were:

- **Core Capabilities:**
    1. Centralized Operational Analysis Control and Adaptive Survey Design – Known internally as Multi-Mode Operational Control System (MOCS)
    2. Survey (and Listing) Interview Operational Control – Known internally as MOJO/MCM
- **Key Capabilities:**
    1. Address Listing and Mapping – Known internally as LiMa (Listing & Mapping field instrument used for listing operations)
    2. Questionnaire Design/Metadata – Known internally as COMET (metadata repository of content used to create instrument)
    3. Internet Data Collection – Known internally as PRIMUS (high-performance self-response web instrument used by public to submit response)
    4. Mobile Data Collection – Known internally as COMPASS (field instrument used to conduct response interview)

The USCB issued a Request for Information (RFI) on December 12, 2014 to solicit information about the experience and expertise of vendors in the industry to provide these core and key capabilities through COTS Platforms and Software. The USCB garnered a great deal of interest from the vendor community in reference to the RFI and received approximately 29 responses. The USCB learned that some vendors had greater experience, capabilities, and understanding of our requirements than others.

The USCB then requested demonstrations from several COTS vendors with products that had the capabilities described in the RFI to demonstrate how the products could meet the defined needs.

The market research process, including but not limited to the RFI, as well as vendor demonstrations, enabled the USCB to learn more about the vendors' COTS products, and their ability to meet our requirements, and to view additional functionality that could help enable scalability and reduce risks for the 2020 Census. This process resulted in well-defined requirements in the Request for Quotations (RFQ), issued on September 2, 2015.

The USCB awarded Purchase Orders on September 30, 2015 to all five of the vendors that submitted proposals in response to the RFQ to purchase product licenses. This allowed for further assessments (physical and engineering), software testing, and analysis of the vendors' tools.

The first evaluation task order provided to these vendors included the following:

- Provide a response to a Challenge Question requiring the vendor to deliver a pragmatic implementation strategy and framework for an adaptable, secure, and resilient, loosely coupled, service-oriented solution that meets or exceeds performance requirements relative to the USCB data collection business needs. The challenge question can be found in Appendix B.

- Provide a response to twenty-eight questions relative to implementation, schedule, deployment history, technology, and vendor viability. The specific questions can be found in Appendix C.

- Perform a "Controlled Demo" against the data collection specifications provided by USCB.

At the conclusion of the first evaluation phase for all five COTS products, the USCB was able to reduce the number of vendors down to two (Vendors One and Two) that met all programmatic requirements. As mentioned previously in this report, vendors will be referenced in this report by a randomly selected number so that participants in the acquisition process are not identifiable. Importantly, these two vendors were also the highest rated iBPMS and DCM platforms by the independent IT research firms of Gartner and Forrester.

The rationale that Vendors Three, Four and Five were not awarded a subsequent task order was as follows: Vendor Three did not have an "on premise" solution offering that would allow the USCB to physically locate the solution at the physical site of its choosing. Vendor Three only had a Software-as-a-Service (e.g., Cloud) offering that was hosted on their physical environment,

which is not Federal Risk and Authorization Management Program (FedRAMP) Certified; Vendor Four was not included on the subsequent task order because they were planning to deploy a government off-the-shelf (GOTS) open-source product that has not been updated since 2012. Vendor Five is a Business Intelligence (BI) platform, and would only be considered as a potential sub-component of the overall solution (if that chosen solution did not meet the dashboard and reporting capabilities needed by the USCB).

To further assess platform capabilities, a new task order was issued for participation in an evaluation relative to our in-house solutions compared to their respective platforms. The two vendors that met all programmatic requirements were given the next task order, which consisted of the CCAA process.

2.2 CCAA Process Planning & Research

This section details the background planning process and research the CCAA team used as part of the CCAA process. As part of the planning and research phase, the CCAA team discovered the core OCS capabilities (one of the identified key capabilities for this analysis) is very similar to what is referenced in the private industry as Dynamic Case Management (DCM), the handling of case-related work through the use of technologies that automate and streamline aspects of each case. Current commercial products typically offer delivery DCM functionality as part of what is called an intelligent business process management suite (iBPMS) platform. Within the technology sphere today, iBPMS platforms have evolved as the preferred approach to building enterprise applications.

These platforms use DCM technology to analyze business processes, detect events, and guide people to respond accordingly. These systems help close process “gaps” with interconnected, adaptive cases and workflows, and streamline collaboration by facilitating real-time decision management.

When comparing USCB needs to these leading commercial iBPMS platforms, the following are key features to the CEDCaP technology vision:

- Dynamic Case Management, Process intelligence and Business Activity Monitoring - The platform uses dynamic case management technology to analyze business processes, detect events, and guide people to respond accordingly. This intelligent, adaptive case management engine is essential for OCS and workload management systems like MOCS and MOJO. This will be discussed further in the Business Functional Needs Section 4.1.

- Graphical Model-Driven Composition Environment - The platform provides a model based User Interface (UI) development environment where developers and business analysts collaborate to develop business functions by using process models. This declarative development method cuts down significantly on coding time, minimizes the skill-set needed for development, and improves the maintainability of the business functions. This will be discussed further in the System Design Section 4.2.

- Connectivity - Enterprise systems are often interconnected and the iBPMS platform provides out of box connectivity tools to other systems by supporting industry-leading protocols - HTTP, REST, SOAP, WSDL, and ODBC/JDBC. The incorporation of standards-based Application Program Interface (API) improves interoperability with systems external to the platform leading to seamless integration between different applications within the USCB. This will be discussed further in the System Design Section 4.2.

- On-Demand Analytics – Data-driven organizations (like the Census Bureau) require on-Demand Analytics capability within the iBPMS platform. Process data/metrics can be analyzed and actions/reports triggered automatically. These core technology features enrich adaptive design and field efficiencies. This will be discussed further in the Business Functional Needs Section 4.1.

- Configuration and Management - iBPMS platform can be configured to provide granular access to different parts of the application by User, Roles, Group, Department or function. Security features are built into the platform and are part of the development effort rather than being a separate process. This will be discussed further in the System Design Section 4.2.

- Management and Monitoring - Processes can be started, stopped, and monitored easily for issues. Having a diagnostic tool improves the system maintainability as performance bottlenecks can be easily identified and remediated. This will be discussed further in the System Design Section 4.2.

As part of the CCAA process, CEDCaP decided to put these iBPMS platforms through an internal analysis evaluating Vendors One and Two versus in-house solutions to determine which alternative is the best path to meet business and technical requirements required to conduct the 2020 Census.

The CEDCaP Team, the EGG, and Carnegie Mellon University's SEI, proposed that the CCAA follow this approach:

- Conduct an Analysis of Alternatives (AoA) of the USCB In-House OCS solutions of core capabilities MOCS, MOJO, and MCM versus the two COTS platform Vendors One and Two (discussed in section Four: Analysis of Alternatives Summary).
- Perform an assessment of the platforms' ability to effectively address the business requirements needed to meet the functional needs of the CCAA identified key capabilities currently performed in-house by COMET, COMPASS, LiMA, and PRIMUS as they relate to the specific needs of the 2020 Census (discussed in Appendix D: Assessment of Business Requirements).
- A key aspect of the evaluation of business requirements would include a 90-day prototype period for the COTS vendors to develop to USCB specific requirements while their platforms installed in the Census environment.

The rationale for this approach is as follows:

- The functionality embodied within the MOCS, MOJO and MCM solution is the overall core to CEDCaP data collection operations and is the major cost driver (approximately 88%) within data collection operations.
- This OCS functionality is core to the iBPMS platforms offered by the COTS vendors. The cost to develop in-house solutions would cover the entire cost of the COTS products (which include the OCS functionality plus additional key capabilities described above and assessed in Appendix D: the Assessment of Requirements, essentially at no additional cost).
- Carnegie Mellon initial review of the multiple in-house systems raised a concern related to the multiple integration points and data exchange between the current in-house systems: MOCS, MOJO, MCM, COMPASS, COMET, LiMA, and PRIMUS. This approach allows the USCB to evaluate the ability of the COTS platforms to reduce the current integration complexity.
- The 90-day prototype period will provide a real-life evaluation of the COTS products' ability to develop both the core capabilities and other key CEDCaP capabilities including Questionnaire Design/Metadata, Address Canvassing, Internet Data Collection and Enumeration/Mobile Data Collection. A sprint is a defined window of time during which development activities are completed and demonstrated. The defined 90-day prototype period represents six separate sprints. Based on the sprints, there would be no need to conduct a full AoA on each of the four key capabilities (once the AoA is completed on the critical capabilities), because the prototype sprints will allow the opportunity to ensure that needed business functionality of the four capability areas can be delivered by the COTS platform.

2.3 Constraints/Assumptions

Specific assumptions used during this CCAA included:

- Access to in-house development teams was limited due to their work on the 2016 Census Test or 2016 Company Organization Survey/Annual Survey of Manufacturing (COS/ASM; in preparation for the Economic Census).
- Focus on enterprise functionality (i.e., CEDCaP Objectives) with prioritization on 2020 Census delivery.
- Accept only out-of-the-box platform/solution functionality (in conjunction with configuration capabilities) that actually exists at the time of the specified CCAA sprints. Promises of functionality to be delivered after the 90-day POC will not be accepted.
- All solutions must adhere to Census Bureau standards, regulations, and pertinent federal laws (e.g., security, technology standards, etc.).
- The CCAA must be completed within a very tight timeframe for delivering the results of the overall evaluation, providing only 4 months to conclude and deliver a recommendation.
- Adjustments needed to the in-house cost estimates (e.g., removal of all USCB overheads) to allow for a relative cost comparison.

- Physical testing must be limited to COTS platform evaluation of business requirements and specific system design capabilities, and not include volume, load, or stress-based performance testing.
- All prototype sprints must conduct their planning sessions with both vendors and Census Business Subject Matter Experts (SME's) together, to ensure the same information and opportunities for clarifications were afforded to both vendors equitably and are discussed further in Section 3.2.
- Joint Analysis Design (JAD) methodology that involves the client as part of the design and development of an application, through a succession of collaborative workshops called JAD sessions. JAD sessions (before each sprint) limited to several hours. These sessions will be discussed further in Section 3.2.
- Minimal interaction with Business SMEs can occur during the actual 10-day development sprint
- No custom-code development and only platform configuration should be completed during prototype sprints, other than agreed upon disconnected mode enhancements. Any questions from either vendor during a sprint were addressed either in joint vendor sessions or through a joint response.

Additionally, each criterion for evaluation will be outlined further in Section 3.2. However, for the purposes of this analysis, there were four criteria considered "must have" elements for any potential solution. Even if a potential option had a perfect score on all other requirements, if it could not meet the "must have" elements, that solution would be deemed unacceptable. A list of the categories and must have requirements are listed in Table 1 below.

Security "must" criteria/requirements - Security requirements address the security needed to protect the system and data, and prescribe the audit trail, access, roles, and permissions
Solution shall be able to comply with Census IT Security Policies and Regulations.
Solution shall be Federal Information Security Management Act (FISMA) compliant.
Full-disconnected mode requirement "must" criteria/requirement (by Sprint 5) for USCB field operations – This is core requirement for Internet and Mobile Data Collection ("The COTS product(s) shall provide the ability to allow for the instrument to be used in both connected and disconnected mode.") This critical requirement addresses the overall business requirement that field workers must be able to conduct an interview and complete their uninterrupted even when there is no wireless connection.
Solution shall be able to run all field instruments in a fully disconnected mode on the mobile device as part of sprint 5. Any alternative that cannot meet this core requirement will have their business functional needs scores reduced to 0% for the following dependent relative system capabilities: MOCS/MCM, COMPASS, and LiMA. Scores will also be reduced for related system design quality attributes.
Section 508 "must" criteria/requirement - Requirements for compliance to Section 508 of the Rehabilitation Act of 1973, hereafter referred to as Section 508
Solution shall comply with Section 508 (29 U.S.C. 794d), which makes federal electronic and information technology accessible to people with disabilities.

Table 1: Must Have System Requirements

3. COTS CAPABILITY ASSESSMENT & ANALYSIS (CCAA) APPROACH

The CCAA approach is the procedure the CEDCaP PgMO would follow to conduct the AoA and an assessment of requirements feasibility needed to make a solution recommendation for the key data collection operation capabilities needed in support of censuses and surveys. Each portion of the approach will be outlined through the upcoming sections.

3.1 CCAA Team

The first step in the CCAA analysis was to construct a team that was representative of SMEs across the Census Bureau. The USCB wanted to utilize an objective third party as a partner in the overall analysis and to provide an objective critique of the process. Carnegie Mellon - Software Engineering Institute (CM SEI) was selected based on their leading role in system engineering processes. CM SEI is a federal research and development center sponsored by the Department of Defense, and based at Carnegie Mellon University, a global research university annually rated among the best for its programs in computer science and engineering.

Due to the level of analysis, the overall CCAA team was broken down into a core group, plus four support groups. The core group was responsible for leading the overall analysis effort and

coordinating with all support groups. The IT SME group provided directorate-specific IT subject matter expertise and/or industry specific IT SME expertise. The Business SME group led the JAD sessions as the USCB business subject matter experts and evaluated the alternatives' ability to meet USCB specific business needs. The Physical Assessment Group installed and/or assisted in the installation of the platforms within the USCB environments and ran specific tests against the platforms. Finally, the EGG members were active participants in the overall process and provided executive review.

- Core Group members:
    - CEDCaP Chief Architect
    - CEDCaP Chief Engineer
    - CEDCaP Lead Architect
    - Decennial Chief Engineer
    - Decennial Mobile Engineer
    - OII Chief
    - CEDCaP SEI Contract Support
    - CM SEI Lead Consultant, advisor to Core Group
    - CM – SEI IT Consultant, advisor to Core Group
- IT SME Group members:
    - Decennial Chief Architect
    - CEDCaP Lead Engineer
    - Demographic Directorate IT SME
    - Decennial Directorate IT SME
    - Economic Directorate IT SME
    - Decennial IT Division Solution Architect
    - Various Carnegie Mellon SEI SM, advisors to IT SME Group
- Business SME Group members:
    - OII Chief
    - OII Contract Support
    - Business SMEs from multiple directorates
- Physical Assessment Group members:
    - Decennial Mobile Engineer
    - CEDCaP Chief Engineer
    - CEDCaP SEI Contract Support
    - Senior Application Test Engineer
- Executive Guidance Group members:
    - Center of Adaptive Design (CAD) Chief
    - Decennial Senior Executive Service IT SME
    - Demographics Senior Executive Service IT SME
    - Field Operations Senior SME
    - Economic Senior IT Executive Service SME
    - USCB Chief Engineer

3.2 CCAA Framework Summary

This section describes the framework used in the CCAA process. A breakdown of the key high-level activities needed to complete the overall CCAA process is shown in Figure 2: CCAA Framework Summary, which highlights the simultaneous activities occurring over a four-month period that included the consolidation and evaluation of multiple data streams. The following sections will describe each the three activities that make up the three (dark green) segments of Figure 2.

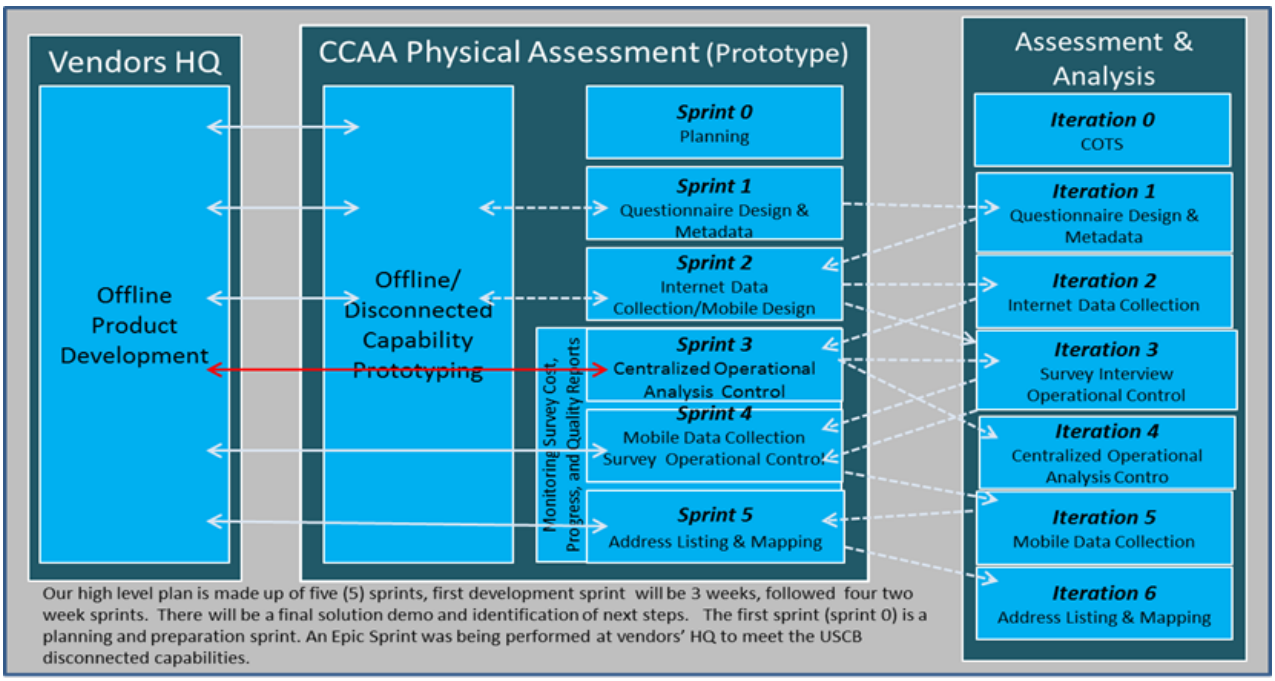


Figure 2: CCAA Framework Summary

Within each component, there may be several activities. For example, as described previously, there were six sprints in the overall 90-day prototype sprint period. Within each sprint pictured, a JAD session would be held prior to the sprint kickoff to review requirements. A JAD session is a typical Agile developmental activity where the business requirements staff and IT team collaborate prior to the sprint to guarantee that all uncertainties between parties are covered and to help prevent any miscommunication. Then a set number of days (typically 10) were provided for the vendor to work on developing a solution to the requirements. At the end of each sprint, there was a review session to assess how well the vendor was able to provide required functionality.

3.2.1 Vendors HQ: Offline Product Development

Offline product development is a demonstration by the COTS platforms of their disconnected mode capability state, such as a fully functional application for the collection of data via a mobile device not dependent on a connection to the Internet. This activity is depicted on the left side of Figure 2. Due to USCB field operations that require a field user to be able to run key

USCB capabilities relating to individual case management, mobile data collection via interview, and listing and mapping functionality to be used in a fully disconnected state, the RFQ contained a requirement that the COTS product(s) be able to provide the ability to allow the instrument(s) to be used in both connected and disconnected mode.

During the CEDCaP RFQ task order assessment (e.g., controlled demonstration and discussion with vendors), the USCB identified that Vendors One and Two required back-end server processing for their full-featured mobile data collection capability, which meant they could not perform the business processing functions needed by the USCB in a disconnected state. Both vendors agreed to satisfy and demonstrate this requirement was capable of being rolled-out in their base COTS offering before the end of the 90-day prototype/configuration activities. This capability is the key feature for operating all mobile instruments in disconnected mode. Without meeting this requirement, the vendors would not be able to ensure the field instrument could be used in all areas of the United States and/or prevent and interview session from being interrupted due to loss connectivity. They agreed to an "Epic Sprint" in Agile development terms, indicating this is a major developmental undertaking that normally includes multiple sprints. The "Epic Sprint" would be conducted at each vendor's headquarters and the results would be the delivery of an enhanced disconnected off-line capability as part of Sprint 5, pictured in Figure 2.

Note: The key result is that Vendors One and Two agreed to develop the disconnected feature improvements as part of their overall new package release, and not a special USCB package.

3.2.2 CCAA Physical Assessment (Prototype)

The on-site physical assessment activities are outlined in the middle box of Figure 2. Both vendors agreed to install their software in the Census Bureau's Center for Applied Technology (CAT) Laboratory and participate in a 90-day Agile prototype effort. The Agile approach optimizes the interaction of the CCAA Team with the COTS platform development team. The approach focuses on delivering fully tested, independent, valuable features. For the Census Proof of Concept (POC), these sprints will each focus on one of the CEDCAP capabilities as the theme for each sprint.

Sprint 0 was a 2-week planning sprint of various project initiation activities that included: establishing the development environment, acclimating the USCB business SME and COTS vendors to an agreed upon development cycle, planning for the first few sprints, and most importantly, creating a sprint backlog of implementable user stories (s a description consisting of one or more sentences in the everyday or business language of the USCB user that captures what a user does or needs to do as part of his or her job function). These were developed for the first 2 sprints based on USCB business requirements during Sprint 0.

Sprints 1-5 were configuration sprints where user stories are configured, tested, and demonstrated to the business stakeholder(s). The first sprint was three weeks while the remaining sprints were two weeks. Prior to each sprint a JAD session is led by the CCAA Business Functional SME team and OII to discuss the list of prioritized business requirements concentrating on the 2020 Census to be configured, tested, and demonstrated for the upcoming sprint.

Each set of requirements was developed based on the functionality of one of the in-house solutions under evaluation as part of this analysis. The requirements were the "in scope commitments" for evaluation. Upon the completion of each sprint, a 3-hour demonstration of these commitments was held that allowed the CCAA team to validate whether the requirements were successfully implemented. This is how the USCB assessed the platforms' (provided by Vendors One and Two) ability to meet business functional needs.

Note: The key aspect of the process is that the sprints did not include any application coding; the vendors were to only make configuration and business rules changes within their platform and verify that any future platform upgrades would not affect these configuration changes. This process allowed the evaluation of the COTS platform without specialized coding for USCB processes. The specialized coding could increase long-term costs in comparison to using features in an existing COTS product.

3.2.3 Analysis of Alternative (AoA)

The CCAA evaluation process consisted of two parts: 1) Assessment, and 2) Analysis. This process ran in parallel to the 90-day prototype sprint as depicted on the right side of Figure 2.

The team performed an assessment of the platforms' ability to effectively address the business requirements needed to meet the business functional needs of the CCAA identified key capabilities not covered in the CCAA Analysis of Alternatives. These key capabilities are currently performed in-house by COMET, COMPASS, LiMA, and PRIMUS. The findings of this assessment are discussed in Appendix D: CCAA Assessment of Business Requirements. To complete this work, the CCAA team relied heavily on the results obtained during the on-site physical assessment previously discussed.

The team then conducted an Analysis of Alternatives (AoA) of the USCB in-house OCS solutions versus the two COTS platforms. This is a full-scale AoA that takes into account the five major criteria pictured in Figure 1: Business Functional Need, System Design, Schedule Impacts, Cost, and Vendor/Development Team Viability.

In order to complete the AoA, the information needed involved not only the results of the on-site physical assessment, but additional information, gathered as part of the process including:

- Deep-dive and Q&A discussions with Vendors One and Two and in-house solution providers regarding system and architectural design;
- Sprint Demos;
- Additional market research and outreach;
- Cost proposals;
- Review of architectural/technical documentation, whitepapers, test strategy etc.; and
- On-site (e.g., USCB) software code installation and testing.

Note: A key point is that the USCB SMEs who assisted with the initial install of the platforms in the CAT Laboratory also installed the new code base of the platforms developed at the end of each sprint. The same staff conducted software application testing against the COTS platforms

in the CAT for independent assessments, without the vendor present. This allowed for independent IT testing and validation.

3.3 CCAA Evaluation Summary

This section describes the overall evaluation process which includes defining the key criteria that will be used to evaluate each alternative, and the scoring approach including how these criteria will be used in the evaluation process.

3.3.1 Defining Individual Evaluation Criteria, Criteria Importance and Evaluation Criteria Weights

A critical part of the evaluation process was to identify the criteria that would be used to evaluate the alternatives. In defining the evaluation criteria, considerations affecting overall system deployment (not just functional requirements) were identified and assigned relative degrees of importance via weights.

The evaluation criteria identified for this Analysis of Alternatives covered five areas: Business Functional Needs, Schedule, System Design & Technical Complexity, Cost, and Vendor/Team Viability.

The Criteria weights were derived from a Carnegie Mellon led workshop activity with the CCAA team and were finalized by the Executive Guidance Group. The purpose of qualitative scoring was to evaluate Vendors One and Two compared to in-house solutions.

The criteria descriptions and the initial weights that were collaboratively identified and agreed to were pictured in Figure 1. Those criteria are:

1. Business Functional Need (35%) – The degree to which the alternative satisfies a set of the defined business requirements and related quality attributes.
2. System Design (25%) – The degree to which the alternative satisfies an identified set of important architectural and engineering quality attributes.
3. Schedule (20%) – The ability of the alternative to be confidently deployed to meet the required timelines.
4. Cost (10%) – The relative comparison of the estimated five-year total cost of ownership for a given alternative
5. Vendor/Dev Team Viability (10%) – Indicator of the vendor/development team and solution stability and ability to meet the USCB's long-term needs.

3.3.2 Scoring Approach

After the sprints and AoA were complete, each vendor was scored based on predetermined criterion, including weights. The sum of the primary weighted criteria scores (its total score, ranging from 1 to 100) was computed for each alternative (Vendor One, Vendor Two, and in-house). In areas with substantial complexity, sub-criteria were also individually weighted and scored, and added to the weight percentage of the corresponding criteria. For example, within the "System Design" sets of defined quality attributes were identified, each of which was given a

weight within the overall criterion. The identified subcategory capabilities will be outlined in the following two sections.

3.3.2.1 Business Functional Need Criteria

Vendors One and Two were required to demonstrate their ability to meet USCB-specific business needs, via a practical, hands-on demonstration, as outlined in section 3.2.2, On-site Physical Assessment. The business requirements were prioritized prior to the beginning of the CCAA based on their 2020 Census criticality. Any business requirements determined not to be critical within the 90 day prototyping effort for delivering a capability (either in a given sprint or not practical for delivery within a ten-day sprint timeframe) were considered "out-of-scope."

The sprint development process made use of the vendors' drag and drop development platforms and excluded any underlying code (i.e., Java, Perl, C++, etc.) changes to the platform. Each sprint concluded with a three-hour demonstration of completed functionality by the vendors. These demonstrations were evaluated against the "in scope" requirements commitments made at the beginning of the sprint. The business requirements for each sprint were based on the following USCB capability areas.

- **Questionnaire Design & Metadata Capability (e.g., COMET)** -- reflects the ability of each vendor to meet 30 core requirements related to the design of questionnaires and the ability to manage the metadata repositories.
- **Internet Data Collection Capability (e.g., PRIMUS)** -- reflects the ability of each vendor to meet 64 core requirements related to the collection of data from the Internet.
- **Survey (& Listing) Operational Control Capability (e.g., MOJO/MCM)** -- reflects the ability of each vendor to meet 44 core requirements related to the ability of survey administrators to control the operational flow of surveys as well as monitor and administer the enumerated surveys.
- **Centralized Operational and Control Capability (e.g., MOCS)** -- reflects the ability of each vendor to meet 65 core requirements that allow systems administrators to control and monitor enumerated surveys at mode level.
- **Mobile Data Collection Capability (e.g., COMPASS)** -- reflects the ability of each vendor to meet 76 core requirements that allow enumerators to collect data through mobile devices, including in a primary disconnected mode state.
- **Address Listing & Mapping Capability (e.g., LiMA)** -- reflects the ability of each vendor to meet 31 core requirements related to collect address listing and mapping data for field workers, including in a primary disconnected mode state.

Analysis regarding the two core capabilities (Centralized Operational Analysis Control and Adaptive Survey Design, and Survey (and Listing) Interview Operational Control) will be discussed in the remainder of Sections 3-4. A CCAA assessment of the remaining four capabilities (Questionnaire Design/Metadata, Enumeration/Mobile Data Collection, Internet Data Collection, and Address Canvassing) is provided in Appendix D.

Requirements for all six capabilities listed above can be found in Appendixes E-J with the assessment scores (explained in further detail in Section 4.1). Each "in-scope" business

requirement was given a value of 1, 2, or 3, by the CCAA team members based on the team's assessment of the requirement during the platform demonstration after each sprint:

1 = Not adequate to the requirement
2 = Partially adequate to the requirement
3 = Meets the requirement

As part of the overall evaluation process, the team did a high-level assessment of the COTS vendors' ability to meet the "out-of-scope" requirements. The projected ability of the vendors to implement "out-of-scope" requirements was assessed based on factors including: were any of the requirements (1) a duplicate of any of an "in-scope" requirement, (2) not really specific to the capability area, (3) an "in-scope" requirement in another capability area, (4) requirements already demonstrated as part of a vendor's stretch goal, (5) deemed by the evaluator as meetable based on the understanding of the platform's capability, or (6) deemed a very minor requirement that can be easily be supported. If the team determined that the out-of-scope requirements could be met using standard platform capabilities given additional time, it was labeled "standard." If the team could not determine with a reasonable level of confidence that an "out-of-scope requirement" could be met via standard platform capabilities it was labeled "TBD".

Note: To be successfully deployed in the field to meet the need of the USCB three of the key capabilities (Mobile Data Collection (e.g., COMPASS), Address Listing & Mapping (e.g., LiMA), and the MCM subsystem in Survey (& Listing) Operational Control) require a core capability of disconnected mode, as discussed in Section 3.2.1. Without meeting this core capability, the vendor would not be able to successfully deploy the field instruments.

3.3.2.2 System Design Criteria

Within the AoA assessment, each vendor was required to demonstrate their ability to meet the needs of the future CEDCaP system architecture as well as 2020 Census requirements. The CCAA evaluation team followed industry standards to use Quality Attributes (QA) to evaluate system design qualities. As part of the refinement of System Design quality attributes for the AoA, CMU SEI led several days of QA workshops that decomposed USCB specific capabilities and requirements starting from the highest levels into quality attributes. These quality attributes were collectively examined to assign prioritization and weighting relative to USCB needs. The top eight attributes based on SME review (listed below) were then decomposed into measurable attributes that could be used to evaluate each system design. Approximately 40 measurable attributes (under the eight QAs), were finalized and prepared.

The eight key quality attributes were:

- **Maintainability (weighted 8%),** the ability of the system to undergo changes with a degree of ease. These changes could affect components, services, features, and interfaces when adding or changing the application's functionality in order to fix errors, or to meet new business requirements. Maintainability can also affect the time it takes to restore the system to its operational status following a failure, or removal from operation for an upgrade.

- **Portability (weighted 5%),** a measure of the level of effort required to deploy a computer system to an alternative operating system or runtime environment without loss of capability, functionality, or system dependencies.
- **Availability/Dependability (weighted 21%),** defines the proportion of time that the system is functional and working. It can be measured as a percentage of the total system downtime over a predefined period. Availability is affected by system errors, infrastructure problems, malicious attacks, and system load.
- **Integrability/Interoperability (weighted 9%),** the ability of a system or different systems to operate successfully by communicating and exchanging information with other systems written and run by external parties. An interoperable system makes it easier (through standard protocols) to exchange and reuse information internally as well as externally.
- **Performance (weighted 20%),** an indication of the responsiveness of a system to execute specific actions in a given time interval. It can be measured in terms of latency or throughput. Latency is the time taken to respond to any event. Throughput is the number of events that take place in a given amount of time.
- **Scalability/Elasticity (weighted 15%),** the ability of a system to handle increases in load without impact on the performance of the system, or the ability to be readily enlarged. To scale vertically, you add more resources such as CPU, memory, and disk to a single system. To scale horizontally, you add more machines to a farm that runs the application and shares the load. Elasticity is the degree to which a system dynamically adapts to capacity, e.g., by altering the use of computing resources, to meet a varying workload.
- **Security (weighted 16%),** the capability of a system to reduce the chance of malicious or accidental actions outside of the designed usage affecting the system, and prevent disclosure or loss of information. Improving security can also increase the availability of the system by reducing the chances of an attack succeeding and impairing system operation. Securing a system should protect assets and prevent unauthorized access to or modification of information. The factors affecting system security are confidentiality, integrity, and availability. The features used to secure systems are authentication, encryption, auditing, and logging.
- **Testability (weighted 6%),** a measure of how well a system or components allow you to create test criteria and execute tests to determine if the criteria are met. Testability allows faults in a system to be isolated in a timely and effective manner and faster turnaround time when making any code changes.

A set of measurable attributes was developed for each key quality attribute, in order to evaluate each solution. Each measurable attribute was expressed either as a single question or a group of related questions designed to address different aspects of a quality attribute used to measure the quality of the system design. Each measurable attribute (approximately 40 in total and provided in Appendixes K-R) was scored between 1 and 4, based on how well they met the requirement:

1 = Not adequate to the requirement
2 = Partially adequate to the requirement
3 = Meets the requirement
4 = Meets the requirement and is superior to other alternatives

Evaluators used the following to assess each alternative:

- Technical and functional documentation,
- Independent whitepapers,
- Market research and or references,
- "Deep Dive" Architecture presentations with Question & Answer periods, and
- Physical Testing Assessment and results performed in the CAT Lab.

CCAA team members conducted a physical testing assessment in the CAT Laboratory, where each COTS platform was configured in a manner typical for USCB deployment. After each sprint, the platforms were updated in the CAT lab for USCB staff to use, test, and explore.

3.3.2.3 5-Year Total Cost of Ownership (TCO) Criteria

The cost analysis for the CCAA was designed to allow the team to conduct a relative cost comparison between the COTS vendors and the in-house solutions over a 5-year period.

For this part of the CCAA, the vendors were asked to provide cost estimates for FY 2016 through FY 2021 using a cost element template provided by the USCB in Excel spreadsheet format The USCB utilized the Department of Homeland Security's (DHS) IT Work Breakdown Structure (WBS) for the cost elements in the template. This template was provided to CM SEI, who reviewed and made suggested changes to the form prior to distribution. Approximately 30 days into the 90-day sprint timeline, the USCB gave the vendors the cost element template and corresponding DHS WBS definitions, the CEDCaP Transition Plan, which shows the timeline for CEDCaP product releases, the CEDCaP requirements, and performance metrics spreadsheet. The cost elements focused labor and non-labor cost elements for planning, systems engineering and operations and maintenance. They were given 4 weeks to complete the cost element template to provide labor and non-labor costs for their base platform, the configuration of the platforms for the core and key capabilities included in the CCAA and the scale costs to handle the 2020 Census workload.

For the costs of the in-house solutions, to derive the cost for all of the in-house solutions, the CCAA team used data from the CEDCaP Independent Cost Estimate (ICE) created by the Office of Cost Estimation, Analysis, and Assessment (OCEAA) and the Office of Innovation and Implementation (OII) within the USCB. The ICE for CEDCaP was developed in FY 2015 for a review of CEDCaP by the Department of Commerce (DOC). It was developed in accordance with Department of Commerce's Acquisition Project Management policy and follow-on policy for Commerce Cost Estimation and Independent Cost Estimates for High-Priority Programs. All in-house systems involved in the CCAA were included in the ICE, with the exception of COMPASS. While COMPASS is an enumeration application being used for 2020 Census tests, it is not currently a CEDCaP solution. COMPASS began as a Proof of Concept (POC) product within the Decennial Directorate. For the CCAA cost comparison, the Decennial Directorate provided a rough order of magnitude (ROM) estimate for COMPASS since data specific to this system was not in the ICE.

There are some cost elements in the CEDCaP ICE that did not apply to the CCAA cost comparison with the vendor provided costs. To ensure the analysis was conducted with the same cost elements in each option, the following adjustments were made to in-house cost estimate:

- The ICE includes the costs of USCB subject matter experts (SMEs) in the software development costs. Since the vendors could not include costs for government SMEs in their estimates, the software costs for the in-house systems were reduced by 25% accounting for a 4:1 ration of SMEs to contractors supporting the project.
- The ICE also includes costs of government project management personnel for each system. Since the vendor did not include costs for government personnel, these costs were removed for the in-house estimates.
- USCB overhead costs were removed since the vendor estimates did not include those costs.
- Since any solution chosen would run on the USCB provided infrastructure, hardware and software maintenance and hardware procurement costs were removed from the in-house solution.

Once this normalization was completed, the team assessed the 5 year TCO for the core CEDCaP capabilities (Centralized Operational Analysis and Control/ Survey (and Listing) Interview Operational Control) for each vendor and the in-house solutions (MOCS/MOJO/MCM).

3.3.2.4 Schedule

Understanding and managing factors that can affect a deployment schedule will be critical in the USCB's success to deliver the needed systems for the 2020 Census, Economic programs and current surveys. To that end, the in-house solution team(s) and each COTS vendor were evaluated based on the two sub-criteria of, schedule management and schedule impact.

These sub-criteria assess the ability for each alternative to be implemented according to the schedule needed by USCB. This includes the duration of time needed to acquire, implement, integrate the solution, and if necessary, design, develop, and test upgrades to impacted systems to complete integration and achieve operational readiness.

The AoA used the following to analyze these attributes:

1. "Deep Dive" presentations & discussions;
2. Team/Vendor documentation & written responses to questions;
3. Historical scheduling documentation, and Level-Of-Effort (LOE) estimates, where applicable;

The CCAA team established sub-criteria and their measurable attributes as part of the analysis for scheduling:

- Schedule Impacts:
    - Hardware & Software procurement dependencies
    - Specific advantages that speed up deployment
    - Adaptability to a 'volatile' client business environment

    - Development methodology's ability to respond to late requirements of any type
    - Maturity of testing culture of the team/vendor, as it relates to enabling swift deployment
- Schedule Management:
    - Ability to estimate levels of effort for completion of solution deployment
    - Historical development & deployment record

Each measurable attribute was expressed either as a statement, a single question or a group of related questions designed to address different aspects of the sub-criteria. Each measurable attribute was scored between 1 and 4, based on how well the solution met the requirement:

1 = Not adequate to the requirement
2 = Partially adequate to the requirement
3 = Meets the requirement
4 = Meets the requirement and is superior to other alternatives

3.3.2.5 Vendor/Team Viability Criteria

As with any software product, the success of its deployment is more than meeting a scheduled deadline, it is about being able to use and support the product in the long-term. Understanding this, the CCAA determined that the USCB needs to ensure the long-term support of any chosen solution.

The Vendor/Team Viability criteria reflects the probability that the team deploying the solution will be properly organized, staffed, supported, and managed long-term. This score is an indication of the risk associated with the team being unable to effectively accomplish its mission in the proper timeframe of design, develop, and provide operation and maintenance support over the product's lifecycle. The viability criteria had two components: Team Viability and Solution Viability. For each component, a higher score indicates lower risk and identifies a candidate with a better chance of success to meet the requirements of the USCB.

Team Viability is determined by examining how the development team is structured (e.g., are there separate development and support components?), the experience level of the team (e.g., specifically with regard to USCB census and survey needs), the probable impact of key personnel changes, and the responsiveness of the team to operations and maintenance issues. Teams that have deeper experience, that are separated into support teams and development teams, and that show a resistance to loss of key personnel indicate higher levels of viability in this area.

Deeper experience is an indication that it will take less time to develop features and systems and implies higher quality levels of development (e.g., fewer bugs that result in less retesting). Resistance to the loss of key personnel is an indication of the potential impact to development timelines if someone on the development team with deep knowledge is no longer available. The more reliant a development team is on a given individual, the greater the impact to the timelines, and the higher the associated risk to the project.

Solution viability is determined by examining the extent and maturity of the documentation associated with the solution, and the length of time the product has been fielded in support of its clients. Longer periods of time indicate higher levels of maturity and therefore viability in this area. Higher levels of maturity indicate a broader field exposure, which means defects are more likely to have already been identified and resolved.

The maturity of the documentation is an indication of amount of time taken to properly communicate the details and understanding of the product to the people that will install, administer, and use the product. Higher levels of this type of maturity indicate lower risk to the success of the project. Product maturity is indicated by the length of time in the market and the number of successful releases of the product. More successful releases of a product indicate higher levels of institutional understanding of the product, which is related to lower levels of risk for using the product.

4 CCAA ANALYSIS OF ALTERNATIVES

The purpose of this portion of the evaluation was to compare the overall in-house solutions of MOCS/MOJO/MCM versus the solutions of Vendors One and Two. The MOCS, MOJO, and MCM systems currently support the delivery of CEDCaP's core components of all survey and census data collection operations, typically called an Operational Control System (OCS).

As described in Section 3.2.5, the team evaluated each alternative on five predefined criteria: Business Functional Needs, System Design, Cost (5-Year TCO), Schedule, and Vendor/Development Team Viability, as discussed in Section 1.2. An important note to the analysis was the breadth and depth of evaluation material that the team had collected. This enormous amount of data set the foundation for a thorough AoA.

4.1 Business Functional Need Criteria

Evaluation of business functional needs related to the CCAA analysis of alternative phase, consisted of data exclusively from the results of two 10-day development sprints for the Survey (& Listing) Operational Control and Centralized Operational Analysis Control capability areas. The key vehicles for evaluation of the COTS platforms ability to meet these criteria were the three to four hour sprint demos, which occurred after each sprint.
The COTS platforms were scored (per requirement) on the following scale:

1 = Did Not Meet
2 = Partially Met
3 = Met

For all business functional need criteria, the in-house solution was scored as 100%, as the platforms were developed and customized exclusively to meet the business requirements. Overall, both COTS Platforms scored well in meeting business functional needs and ability to develop a fully functional prototype equivalent to MOCS/MOJO/MCM in two 10-day sprints. However, when adjustments were made to account for Vendor One not being able to meet the

disconnected mode filtering criteria, only Vendor Two's overall score was good. Vendor One was able to complete this requirement at a 59.2% rate and Vendor Two as 98%, see Figure 3: Business Functional Need Criteria Assessment.

For a complete view of each of the in-scope requirements that were developed and the evaluation score for each in CCAA evaluation, refer to Appendixes E-F.

One of the most impressive results of the CCAA was illustrated during the 10-day development sprints where each of the COTS platform vendors demonstrated Census requirements by simply configuring their software to adhere to the business rules, business requirements and workflow processes the USCB SMEs provided to the vendor's professional services staff. The resulting functionality from a ten-day sprint was often comparable to the results of in-house custom development of approximately six months. This meant that in a 10-day period the COTS platforms were able to deliver a complete prototype application specific to USCB needs based on a three-hour meeting with a business SME. This rate of development was much faster than anticipated.

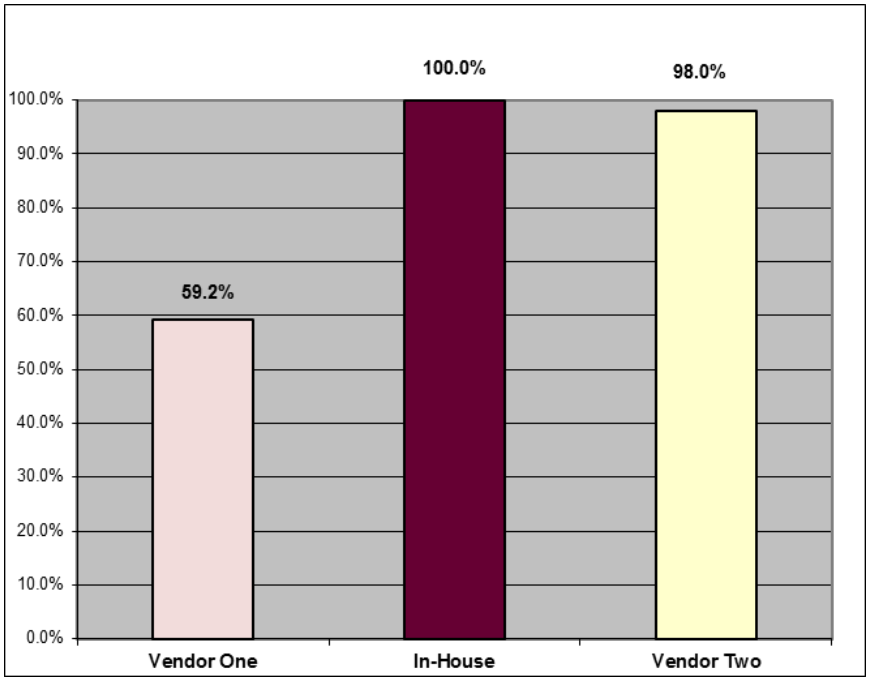


Figure 3: In-Scope Business Functional Need Assessment

Vendor One

Examining the business functional needs, Vendor One could not meet the business requirement to perform in disconnected mode. This functionality is essential as enumerators will often be out of wireless network range and will consequently need to perform survey interviews and/or listing and mapping data collection in disconnected mode. This was the principal objective of the Offline Product Development track of the CCAA. Vendor One's failure to complete this requirement affects overall field operations and in particular, the mobile case management

(MCM) component for this particular solution area. Their failure to meet this key non-functional capability was a critical missing component in the offered platform and as referenced in Section 2.3, this element was considered a "must have" for any platform to remain a viable option that could be considered. Therefore, overall, despite their ability to successfully perform other business functional needs, adjustments had to be made to the overall score as depicted in Figure 3, Vendor One's failure in providing disconnected mode removes this platform from consideration.

MOCS/MOJO/MCM

The purpose of evaluating each platform against the business functional need criteria is to assess the alternatives' ability to satisfy specific USCB business requirements. In the case of the COTS platforms, that assessment determines if the platform can be configured to meet the business requirements without the use of custom code. In the case of the in-house solutions, there is no need to provide configuration requirements because MOCS/MOJO/MCM are custom-coded applications designed specifically to meet the USCB business requirements. Due to the inherent nature of the in-house products (development designed specifically to meet all USCB business functional needs), the MOCS/MOJO/MCM solution was awarded the highest possible score (3) for all business functional need requirements.

As indicated previously, the work completed by the in-house teams became the foundation of USCB business re-engineering efforts for the 2020 Census. An integral sub-component to the MOJO system is the optimization algorithms that will synthesize mapping/geographical information. The geographical map system optimization of case assignments will eliminate unnecessary time and mileage needed to conduct in-person interviews. While the COTS platforms met the general prioritization requirements provided by the business stakeholders, the MOJO implementation takes these requirements to the next level of efficiency.

Vendor Two

Of the 109 total requirements that were part of the sprints, Vendor Two successfully completed 98% towards satisfying the USCB business requirements. To place the tasks in perspective, Vendor Two built a fully functioning prototype system comparable to three in-house systems (MOCS, MOJO, and MCM) in 20 days with two meetings with the business SMEs.

In addition, Vendor Two demonstrated a fully disconnected mode capability to support the Census' business functional needs. This functionality would allow Census Bureau field staff to operate in disconnected mode for the needed length of time as they complete interview and listing field operations. Additionally, Vendor Two was able to incorporate a third-party Map Management suite with enhanced listing and mapping requirements relative to the current in-house solutions ability (scheduled to be incorporated into LiMA, but has not yet been integrated), into their platform. This allowed for a fully functional geographic capability in a disconnected mode, something not completely implemented by any of the current in-house solutions.

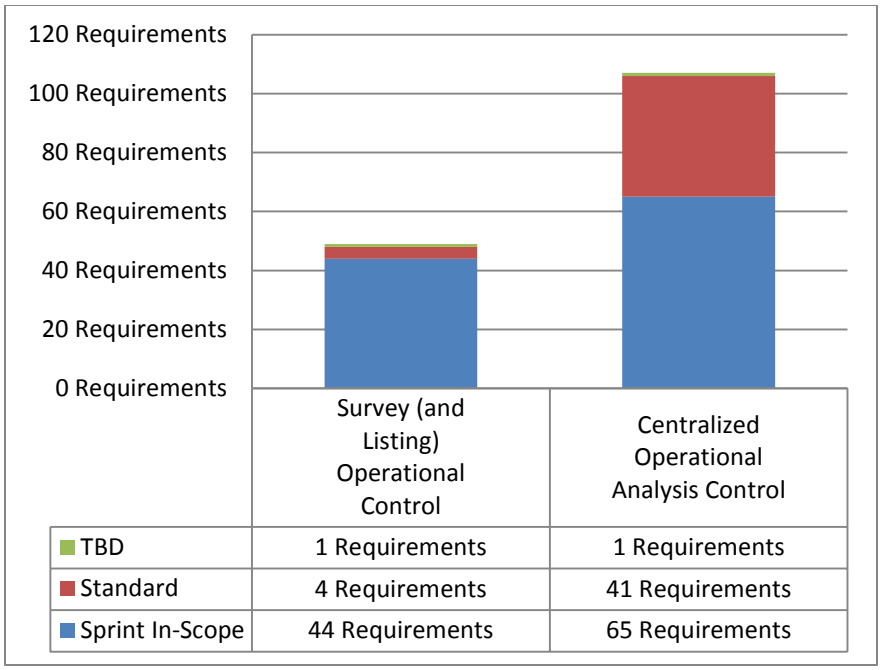
Out-of-Scope Requirements

Any business requirements determined to be not critical within the 90 day prototyping effort for delivering a capability (either in a given sprint or not practical for delivery within a ten-day sprint timeframe) were considered "out-of-scope." However, these requirements are still important, as discussed in Section 3. The "out-of-scope" assessment was designed to identify if there were any existing requirements the team could determine were critical but could not be configured within the COTS platforms at a future date without some customization. This is an important consideration because as increased levels of customization are required, costs typically increase accordingly.

The team completed an assessment of the COTS platforms' ability to implement "out-of-scope" requirements. This assessment involved reviewing those out-of-scope requirements (in both Survey & Listing and Centralized Operational Control requirements, listed in Appendixes E-F) and determining the likelihood that they could be met in the COTS platforms if given adequate time. Requirements fell into two categories "standard" if the CCAA team felt the requirement could be met if enough time was allotted or "TBD if the CCAA team could not determine if a platform could meet the requirement without a code change.

There were a total of five Survey (& Listing) Operational Control business requirements identified as "out-of-scope" prior to the CCAA AoA. Only Vendor Two's platform was assessed because the requirements in this capability area are impacted by disconnected mode, which Vendor One could not demonstrate. Based on the CCAA team assessment, four of the five requirements could have been demonstrated by Vendor Two if enough time had been allotted. There was one requirement the CCAA team could not asses if the COTS platforms had the ability to deliver the requirement without a code change. A snapshot of the assessment is pictured in Figure 4: "Out-of-Scope" Business Requirements Assessment demonstrating that the COTS products produced or were capable of producing 48 of our 49 requirements for Survey (& Listing) Operational Control.

There were forty-two Centralized Operational and Control Capabilities business requirements identified as "out-of-scope" prior to the CCAA AoA. Based on the CCAA team assessment, 41 of the 42 could have been delivered by the COTS platform if enough time had been allotted. There was one requirement the CCAA team could not assess if the COTS platforms had the ability to deliver the requirement without a code change, again pictured in Figure 4, demonstrating that the COTS products produced or were capable of producing 106 of our 107 requirements Centralized Operational and Control Capabilities.



	Survey (and Listing) Operational Control	Centralized Operational Analysis Control
TBD	1 Requirements	1 Requirements
Standard	4 Requirements	41 Requirements
Sprint In-Scope	44 Requirements	65 Requirements

Figure 4:"Out-of-Scope" Business Requirements Assessment

4.2 System Design Criteria

Developing systematic ways to relate the software quality attributes of a system to the system's architecture provides a sound basis for making objective decisions about design tradeoffs. The CCAA evaluation of system design took the form of both black box (examination of test results) and white box (architectural review). Black box assessments refer to the process of reviewing the product without any access to the inner workings of the platform. This would be a review that provides the perspective of an end-user. White box assessments refer to the process of reviewing the inner-workings of a product. The ultimate goal of using both approaches was the ability to quantitatively evaluate multiple software quality attributes to arrive at the best overall system.

In order to make the quantitative assessment, CEDCaP identified eight key quality attributes (outlined individually in section 4.2.1), to evaluate system design. Those attributes were: Maintainability, Portability, Availability/Dependability, Performance, Security, Integrability/Interoperability, Scalability/Elasticity and Testability. Based on these weighted attributes, the overall score for each vendor can be seen in Figure 5 below.

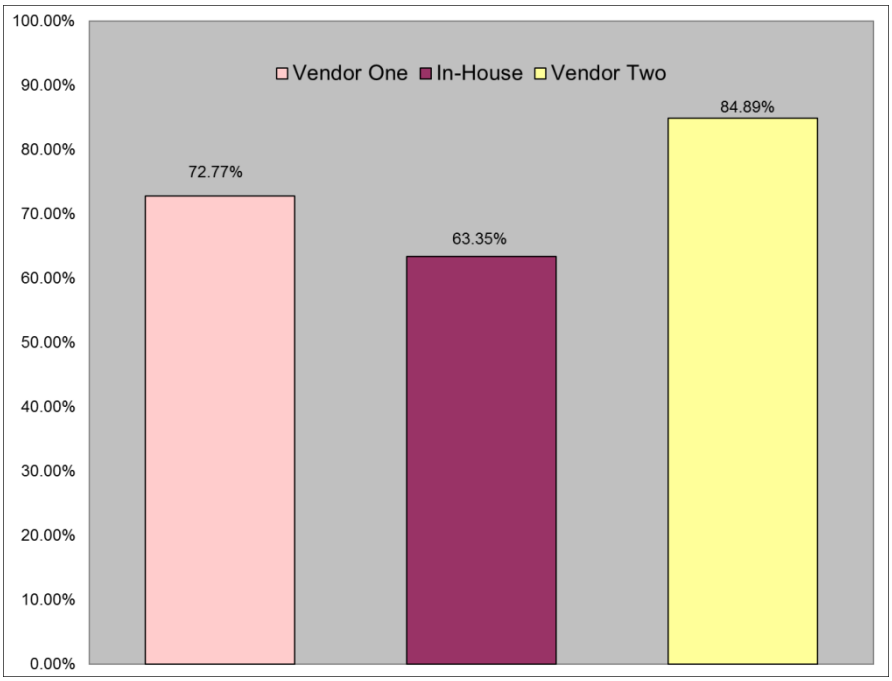


Figure 5: System Design At-A-Glance

4.2.1 USCB Quality Attributes

The Carnegie Mellon QA two-day workshop was held for the Census Bureau to identify and prioritize the key quality attributes the CCAA team would be using to evaluate the alternatives' system design. The workshop identified eight key quality attributes:

- Maintainability (weighted 8%)
- Portability (weighted 5%)
- Availability/dependability (weighted 21%)
- Performance (weighted 20%)
- Security (weighted 15%)
- Integrability/interoperability (weighted 9%)
- Scalability/elasticity (weighted 15%)
- Testability (weighted 6%).

A breakdown of how each alternative scored relative to each quality attribute and its value can be viewed in Figure 6: System Design Quality Attributes.

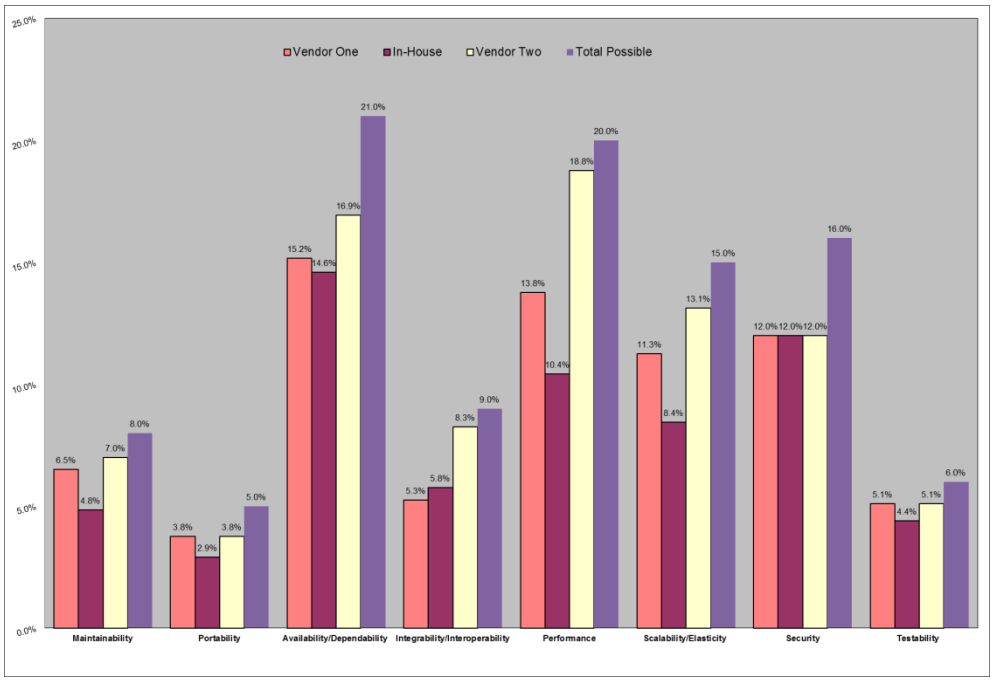


Figure 6: System Design Quality Attributes

Each measurable attribute was scored between 1 and 4, based on the how well the solution met the measurable attribute:

1 = Not adequate to the requirement
2 = Partially adequate to the requirement
3 = Meets the requirement
4 = Meets the requirement and is superior to the other alternatives

The strengths and weaknesses of the in-house solutions versus a COTS platform on the eight key quality attributes are discussed below, and a summary assessment is then given in section 4.2.2.

Maintainability

Maintainability is the ability of the system to undergo changes with a degree of ease. These changes could affect components, services, features, and interfaces when adding or changing the application's functionality in order to fix errors, or to meet new business requirements. Maintainability can also affect the time it takes to restore the system to its operational status following a failure or removal from operation for an upgrade.

Maintainability was determined to be a key quality attribute because this allows a system to quickly change business logic processing. Maintainability allows late requirements or last minute business changes to be deployed quickly with a minimum impact to the existing system logic. The USCB has devoted substantial time to developing requirements earlier than in previous decennial cycles in order to reduce the number of late requirements. However, no amount of planning will eliminate late requirements or last minute changes needed for a system. Therefore, it is important for the selected platform to score high in maintainability.

The four measurable attributes identified by the CCAA Team to evaluate maintainability, and how each alternative scored can be seen in Appendix K. A graphical view of the summary score of each alternative on the maintainability quality attribute is pictured in Figure 7.

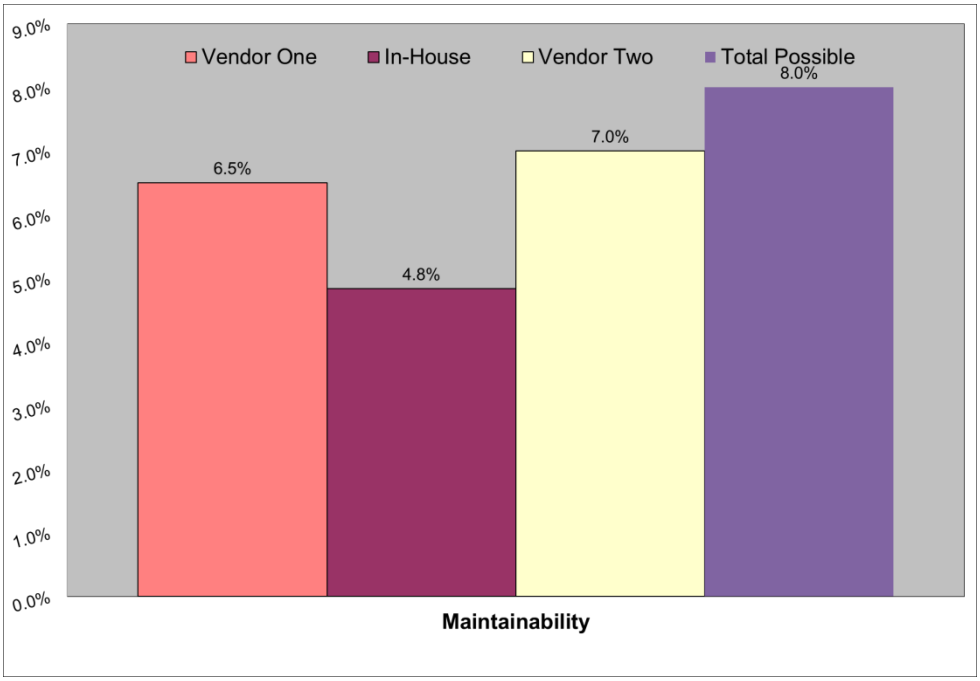


Figure 7: Maintainability Comparison Summary

All three alternatives have good layering and modularity in their architectures, which affect the maintainability score. The in-house solutions have a detailed design documentation that addresses interoperability, data flows, and overall structure of the system. In comparison to the COTS solutions, in-house solutions demonstrated two weaknesses. First, components of the in-house solution used stored procedures to initiate some of the business logic. The industry best practice for large applications is to have a separation of presentation, business and database logic. This separation allows for optimum code changes at the respective tiers with a minimum impact across tiers, which is limited in certain aspects of in the in-house solutions. Second, was the lack of Business Rules Engine (BRE), Event Stream Processing (ESP), or Business Activity Monitoring (BAM) technologies. These are key features in iBPMS platforms because they allow the system to be more flexible to change, allow for quicker development, and allow COE audits to be more efficient.

Vendors One and Two benefited from these design features, which allow for easier and more efficient changes to the business logic, which also streamlines the automated testing of changes. Vendor One provided an iBPM platform with BRE, BAM, and Complex Event Processing. This provides an environment where components can be built and re-used across the entire platform. Vendor One's monitoring and troubleshooting capabilities are consistent with a mature COTS product. They provide dozens of log files that can be used for monitoring performance and usage, analyzing data metrics, troubleshooting, and auditing operations. Vendor One provides automated reporting and communication logic that can be configured and customized based on the log files. Finally, Vendor One has mature documentation and its online forum provides

community with feedback, best practices and upcoming features. However, Vendor One's platform proved unable to ingest Census Business Process Modeling Notation (BPMN) models, which means that the BPM would have to be all written as requirements to be incorporated in Vendor One's platform. BPMN allows for a simplified entry of requirements that can be developed by BAs, without the need to develop specific written requirements, typically with the assistance of developers or advanced SMEs.

Vendor Two also provided an iBPM platform with BRE, BAM, and Complex Event Processing. Vendor Two's platform uses built-in diagnostic tools, which make monitoring and troubleshooting issues much easier. These tools allow for quicker code development and less technical development experience to utilize. This solution has an industry-grade business rules engine, where the business rules are imported from a Word file and are completely separate from the application logic. This allows business users to made changes to the business logic and test those changes without affecting the overall application code. With the help of these tools, maintenance issues can be turned around much faster. Vendor Two uses a layered approach when developing common components. This improves the re-usability and maintainability of these components. In contrast to Vendor One, Vendor Two's platform can ingest BPMN models already developed by USCB BPM staff. This has the potential to save significant time in writing and rewriting requirements. Finally, Vendor Two also has very good documentation and an active online forum.

Portability

Portability is a measure of the level of effort required to deploy a computer system to multiple operating systems or runtime environments without loss of capability, functionality, or system dependencies. A system with a low degree of portability could lock USCB into a particular platform either tightly (with no ability to transfer to another platform without significant rework), or loosely (requiring extensive time and effort to port to the different platform). A good example of a portability challenge are the new subsystems like LiMA and MCM designed to support field surveys which were built on a Windows platform. This was required in order to deploy them on the same physical device as the legacy Blaise instrument (currently in use for current survey field interviews). Blaise is a Windows-specific platform and cannot be ported to another Operating System. Therefore, our field users are limited to Windows-only devices, and our supporting systems are limited to the Windows platform.

Portability is also a good measure to determine how cloud-ready a system is because the system is less dependent upon specific operating systems and middleware products, which broadens the range of IaaS/PaaS providers to meet the USCB needs.

The two measurable attributes identified by the CCAA Team to evaluate portability, and how each alternative scored by quality attribute can be seen in Appendix L. A graphical view of the summary score of each alternative on the portability quality attribute is pictured in Figure 8.

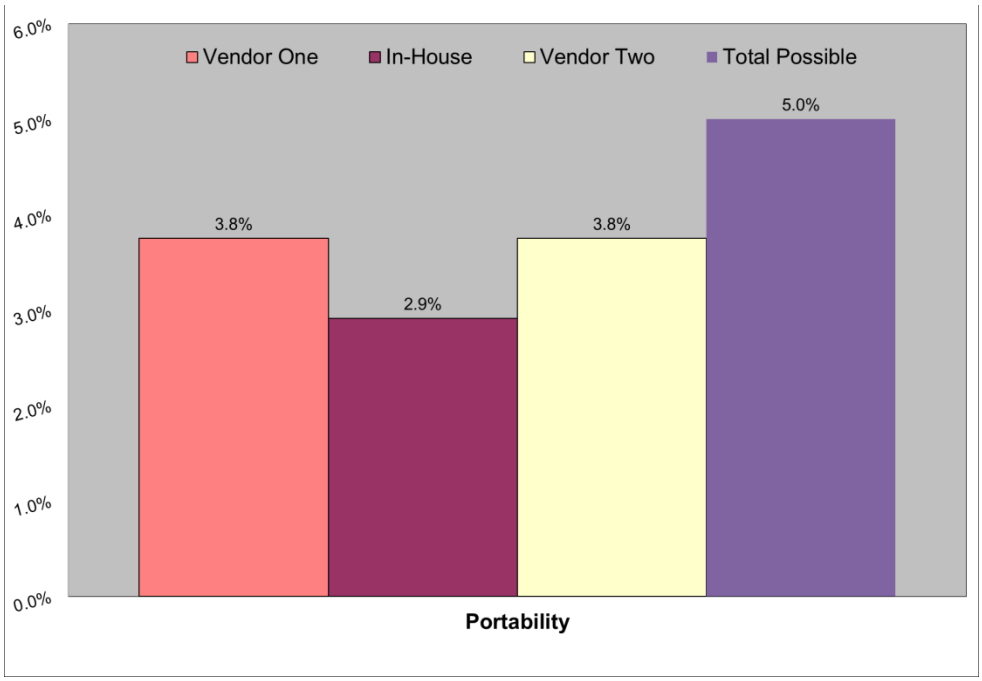


Figure 8: Portability Comparison Summary

The two COTS platforms scored relatively well for overall portability. It should be pointed out that while the in-house solution had some limitations when compared to the COTS, the limitations were not a technology issue, per se. The in-house solutions by definition, are building for a single client, which did not require the same degree of portability. The COTS platforms are building for multiple clients with varying operating systems, DB platform, browser, and middleware needs. Those varying client factors mean that the platforms developed by Vendor One and Two have to be portable. This is a benefit to all of its users, especially when it relates to cloud deployment.

The in-house solutions did demonstrate some strengths. MOJO is built on standard Java-based middleware architecture with Angular JS/Jquery UI and MOCS similarly is an N-tier J2EE platform that lend themselves to portability if there is no specific application logic tying it to a specific database. However, the MCM mobile solution does not currently run on either Apple iOS or Android OS. This is a concern due to the overwhelming use of Apple iOS and Android OS in comparison to Windows based mobile phones.

Neither of the COTS products offers native Windows API support on their mobile platforms. However, this does not appear to be a substantial concern because the Windows market share for mobile devices has declined to less than 1% of total mobile phones. Vendor One and Two are fully portable solutions with its middleware and database supported on all major platforms with very few exceptions. The mobile platform for both vendors runs on both Apple iOS and Android OS. These similarities are what caused Vendor One and Two to receive the same overall portability score.

Availability/Dependability

Availability and dependability are defined as the proportion of time that the system is functional and working. It can be measured as a percentage of the total system downtime over a predefined period. Availability will also be affected by system errors, infrastructure problems, malicious attacks, and system load.

The nine measurable attributes identified by the CCAA Team to evaluate availability/dependability, and how each alternative scored can be seen in Appendix M. A graphical view of the summary score of each alternative on the availability/dependability quality attribute is pictured in Figure 9.

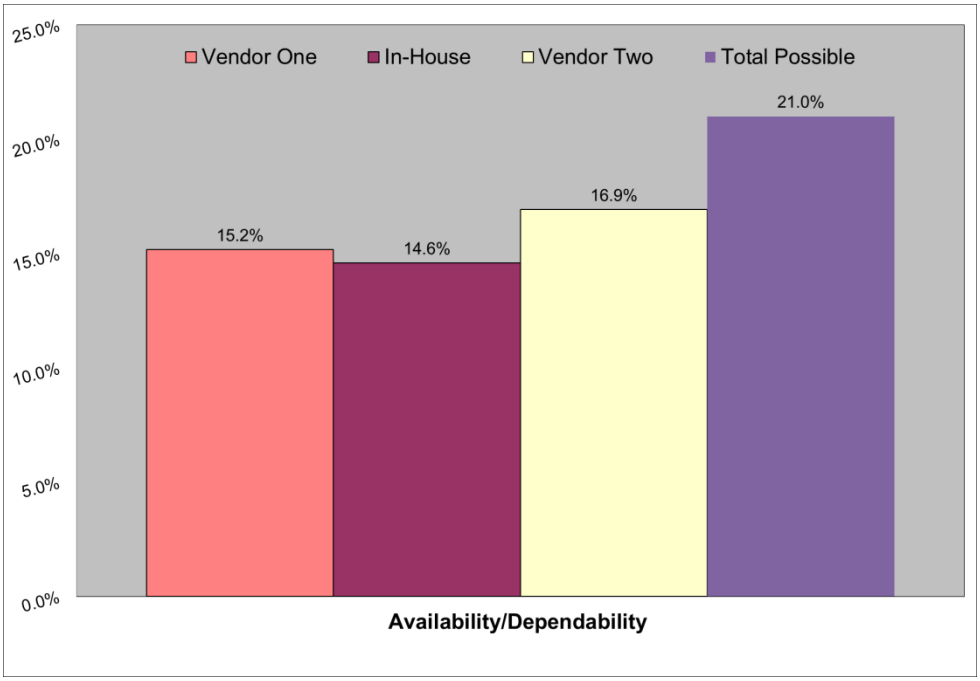


Figure 9: Availability/Dependability Comparison Summary

The underlying infrastructure platform is a very important component of system design when discussing availability. In the evaluation of the alternatives, the CCAA team looked for deficiencies in the system design that would affect the overall physical infrastructure.

Overall, all alternatives scored highly on dependability. Both COTS platforms have a history of use by private industry clients who rely on the availability and dependability of the platforms. Due to the maturity and the commercial nature of the platforms developed by Vendor One and Two, these solutions have undergone extensive levels of code testing both internally (through major revisions), and externally (by their clients). As noted previously in section 3.2.1, the absence of disconnected mode by Vendor One was the main differentiator between Vendor One and Two, ultimately disqualifying the scores for Vendor One. Within the scoring model, disconnected mode is a “must have,” as described in Section 2.3. If a system does not meet the “must have” requirements, it is automatically disqualified. Finally, the in-house solutions are in

an earlier stage of their lifecycle and therefore, have not fully proven their dependability as an overall integrated solution at the time of the assessment.

However, outside of the disconnected mode, Vendor One's platform has been well designed to provide and support redundancy features and clustering capabilities. The system deploys a high availability architecture, which eliminates single points of failure. Vendor One's platform can be deployed a number of ways (including in Active-Active, Active-Passive and Virtualized) based on requirements. Runtime upgrades can be applied to Vendor One's system without any downtime. Vendor One has unit tests, acceptance tests, non-functional tests and pre-production deployment tests built into their continuous integration tool. This means each release goes through a rigorous testing process. Vendor One's internal architecture allows it to scale both horizontally and vertically in order to manage multi-million transactions per day. However, as noted previously, Vendor One's mobile platform was not able to support offline capabilities. Overall impacts of disconnected mode have been addressed in a number of sections, and are most evident in the discussion of Business Functional Needs. Looking strictly within the availability criteria, this means that field support operators will be susceptible to network faults and unreliable network connections.

The in-house system architecture allows it to fully use the redundancy and clustering facilities of underlying technology platform. The solutions can recover from system faults by being deployed in High Available architecture. Unfortunately, any code release in the in-house solutions needs downtime, which affects system availability. The in-house solutions, have been individually tested, however, they have not been exposed to performance and load stress tests that would be required by Census operations. The in-house solutions have also not been exposed to the same level of independent performance, load and stress tests as the COTS platforms. The COTS platforms have an advantage of being in use and meeting the needs of multiple large scale clients, while the in-house systems have not be tested at the same level.

Vendor Two's mobile platform includes all the features described for Vendor One, plus the ability to support offline capabilities that would help field operations survive network outages and unreliable connections, while making available key capabilities like mobile data collection, mobile case management, and listing & mapping which cannot be fully featured on Vendor One's platform. Vendor Two's mobile platform supports offline capabilities that would help field operations survive network outages and unreliable connections. Additionally, Vendor Two's automated test coverage ranges from 80%-100% making it highly reliable. Vendor Two's platform can be deployed in multiple high-availability modes that would eliminate any single points of failures. As with Vendor One, this platform can support both Horizontal and Vertical scaling. Finally, code releases can be applied to the platform without any system downtime.

Performance

Performance is an indication of the responsiveness of a system to execute specific actions in a given time interval. It can be measured in terms of either latency or throughput. Latency is the time taken to respond to any event. Throughput is the number of events that take place in a given amount of time. An application's performance can directly affect its scalability, and a lack of scalability can affect performance.

The four measurable attributes identified by the CCAA Team to evaluate performance quality, and how each alternative scored can be seen in Appendix N. A graphical view of the summary score of each alternative on the performance quality attribute is pictured in Figure 10.

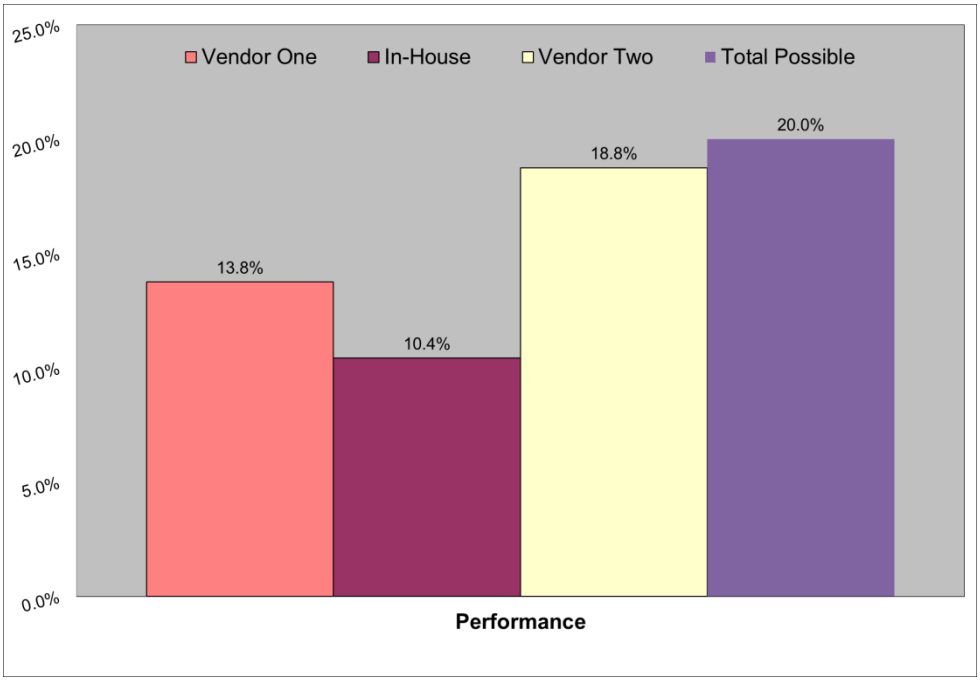


Figure 10: Performance Comparison Summary

Test and actual production (e.g., past performance) results are considered a better gauge of performance than a review of systems architecture and design. For new systems, testing is critical for gauging performance. Due to the timing of this assessment, the in-house solutions have been concentrating efforts to date on meeting the functional needs for the 2015 and 2016 Census Tests and have spent limited time on performance testing that was not directly related to the Census Tests. None of the in-house solutions have had independent testing completed for their overall systems.

Both COTS solutions were built with a very strong architecture relative to performance with proper layering, modular composition, and scalable design. Additionally, the COTS solutions have provided industry-leading clients, who are using their products in production, as references for performance. Vendor Two provided a wealth of documentation related to test results of system performance, including several different independent test results (e.g., IBM and Cisco) on different platforms. Vendor Two also provided documentation from multiple client deployments supporting multi-million transactions per day proving that it can survive severe load and stress conditions. Additionally, Vendor Two's platform includes system health modeling capabilities for real-time application production monitoring of performance, which factored favorably into the overall performance assessment. The in-house solutions do not have these types of tools currently deployed within their application.

As described above, Vendor One's platform has been deployed in multiple client environments with multi-million transactions per day. Vendor One's platform has been thoroughly

performance and stress tested in real-time environments. Vendor One's platform provides log files, which provide complete end-to-end monitoring of system health. The underlying log files are accessible through standard business process models enabling custom report development. However, Vendor One did not have any examples of performance metrics relative to key performance indicators performed by an independent testing authority to provide, and Vendor Two had several independent performance tests conducted and provided for review.

Evaluations of the in-house database server processing approach reveal the use of standard techniques in application development. However, the in-house solutions have been in production for a short time and have not been tested on a large scale. Additionally, there are no end-to-end systems monitoring tools that can provide a check on system health at any given time. Although logging exists for the in-house solutions, there is no access to these log files through standard applications in order to customize reports.

Vendor Two's platform provides diagnostic programs that provide a complete window into the health of system. Independent tests conducted by Cisco, conducted on Cisco Cloud provide performance metrics relative to key indicators under various stress test conditions. These results revealed no abnormality in the KPI even under high stress. Vendor Two also provided documentation from multiple client deployments supporting multi-million transactions per day proving that it can survive sever load and stress conditions.

Both vendors have been able to deliver the performance needs of their clients; therefore, the gap to scale needed to meet the 2020 Census OCS capability is much smaller than the in-house systems would need to reach the same level of scalability. The provided testing demonstrates that the platforms can scale in a linear fashion. This means that as more computer resources are added to the architecture the processing numbers climb in proportion. This important finding, along with the review of the overall system design, provides the closest estimation that a system could meet 2020 Census workloads. The fact that Vendor Two has independent testing results from multiple independent test providers adds more weight to their performance abilities than either alternative.

Security

Security is the capability of a system to reduce the chance of malicious or accidental actions outside of the designed usage affecting the system, as well as to prevent disclosure or loss of information. Improving security can increase the availability of the system by reducing the chances of an attack succeeding and impairing system operation. Securing a system should protect assets and prevent unauthorized access to or modification of information. The principal factors affecting system security are confidentiality, integrity, and availability. The features used to secure systems include authentication, encryption, auditing, and logging. Data security is of paramount importance and is routinely examined for all USCB systems.

The seven measurable attributes identified by the CCAA Team to evaluate security, and how each alternative scored can be seen in Appendix O. A graphical view of the summary score of each alternative on the security quality attribute is pictured in Figure 11.

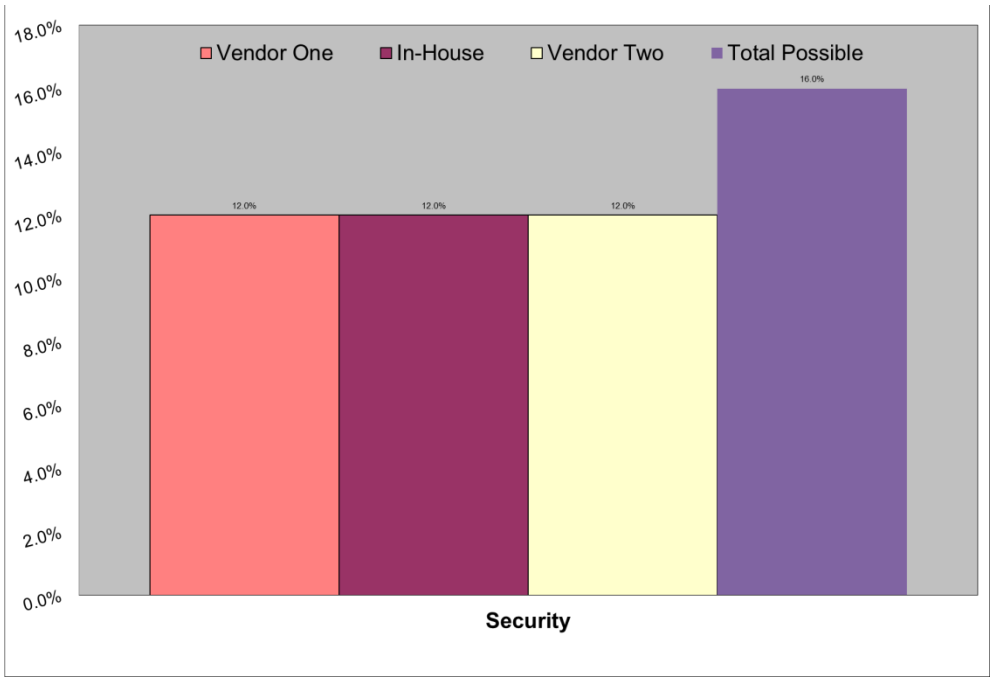


Figure 11: Security Comparison Summary

All three alternatives have ample security measures built in to meet strict USCB security requirements. All systems adhere to secure coding and testing practices, are Federal Information Security Management Act (FISMA) compliant, and provide data encryption in flight and at rest. All three options are very good, resulting in the even scoring. Each option meets sufficient levels of security and regularly logs, monitors and upgrades security functions. All three alternatives have been exposed to third-party security application scanning tools to identify code-based malicious attacks and other security flaws. In this assessment, no single alternative was found to be superior to the other. Because no one alternative was superior, no alternative received a score of "4" (that the option met the requirements and was superior to the other alternatives). Without being deemed superior to the other alternatives, no system could receive the full 16% possible for this quality attribute, instead they were all found to fully meet the requirements. The specific scoring on each subcomponent can be found in Appendix O. Either the in-house solution or the COTS platform solutions could be successfully deployed on a FedRAMP certified IaaS/PaaS offering.

Integrability/Interoperability

Integrability/interoperability refers to the ability of a system (or different systems) to operate successfully by communicating and exchanging information with systems written and run by external parties. An interoperable system makes it easier to exchange and reuse information internally as well as externally. How well-designed a solution is to integrate and interoperate with systems outside their domain will be critical for a CEDCaP solution because of the requirement to integrate new modernized systems with older technology (legacy) systems.

The three measurable attributes identified by the CCAA Team to evaluate integrability/interoperability, and how each alternative scored by attribute can be seen in

Appendix P. A graphical view of the summary score of each alternative on the integrability/interoperability quality attribute is pictured in Figure 12.

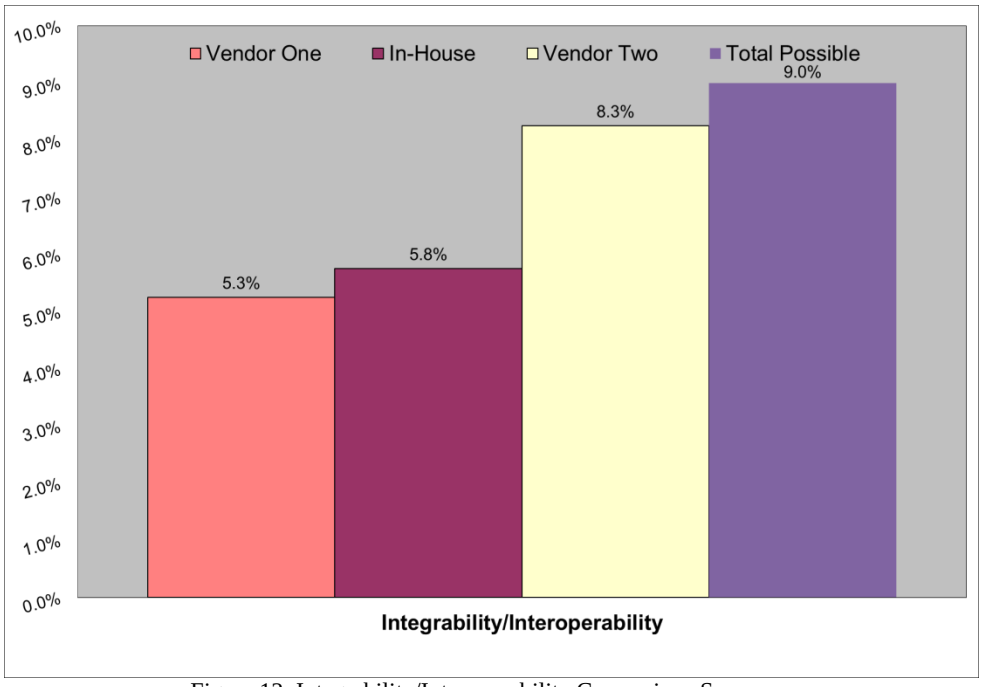


Figure 12: Integrability/Interoperability Comparison Summary

This quality attribute is about system integration and web services. Vendors One and Two use all the necessary open architecture standards for integration protocols. Both COTS Platforms were tested using SoapUI in the CAT Lab. Both the SOAP and REST APIs (standard industry styles that allows for system-to-system integration) services were examined for design features and to assess the solution's integrability quality. Each met similar standards for elements of interoperability, including granularity, extensibility, customizability, and security. However, Vendor Two exceeded Vendor One in that its platform fully implemented both SOAP and REST services, and offered additional authentication services to ensure systems are allowed to integrate with one another. Vendor One offered partial implementation of each of SOAP and REST APIs and has plans to remove the SOAP standards from their offering within their future releases

Assessments of in-house solutions (MOCS, MOJO, and MCM) were based on deep-dive information and available documentation. These in-house solutions utilize web services API (a standard industry style that allows for system and component integration) between the UI and backend and for inter-component communication internally within their systems. MOJO's service endpoints can be configured to produce JSON (for Javascript client-side consumption) or SOAP/XML (for Web Service consumption). This allows complete interoperability and reusability across external systems and internal components. They also did not include the levels of integration services provided by Vendor Two.

Scalability/Elasticity

Scalability is the ability of a system to either handle increases in load without impact on the performance of the system, or the ability to be readily enlarged or expanded. To achieve vertical scaling, one must add more resources such as CPU, memory, and disk space to a single system. To scale horizontally, one must add more machines (or 'nodes') to a farm that runs the application and shares the load. Elasticity refers to the ease of scaling up and back down by dynamically adapting to capacity (e.g., by altering the use of computing resources) to meet a varying workload. Both of these are critically important to the USCB for all survey and census work but is vital for the 2020 Census.

The five measurable attributes identified by the CCAA Team to evaluate scalability/elasticity, and how each alternative scored can be seen in Appendix Q. A graphical view of the summary score of each alternative on the scalability/elasticity quality attribute is pictured in Figure 13.

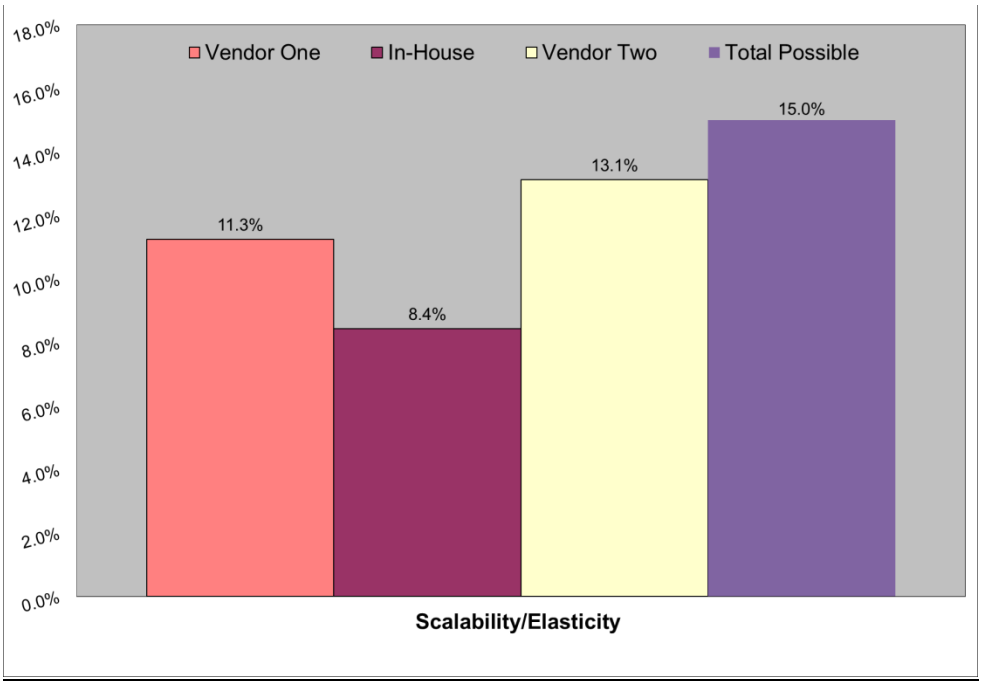


Figure 13: Scalability/Elasticity Comparison Summary

An application made of multiple tiers that performs different key functions is referred to as following n-tier architecture. For example, a 3-tier solution is the most common and would include a presentation tier (what you see on the screen), the application/business logic (based on requirements), and the database tier.

An examination of the COTS alternatives revealed that a great deal of effort had gone into planning for overall scaling. Vendor One's business rules engine uses a real-time, in-memory columnar database called Kx. This allows the BRE to scale up in a very efficient manner without Input/output (I/O) bottlenecks. Vendor One supports both horizontal and vertical scaling and provided several client deployments to prove its ability to scale. The business engine uses an in-memory (Kdb) database that allows it to scale with-out any I/O bottlenecks in case of

spikes in traffic. However, Vendor One's mobile platform does not implement the queuing type store-and-forward mechanism that would impact field operations' ability to handle communications, with the store-and-forward feature in the case of a disconnection of any kind the system would continue processing filling up a queue and once connection was restored it would forward the messaging from the queue.

In-house solutions (with the exception of PRIMUS discussed in the System Design Summary Section) use the clustering capability within their infrastructure platform for scaling. The in-house solutions do not have any custom scaling features built into their system. The absence of custom scaling features, as well as the fact that no large-scale performance and stress tests have not been carried out on the systems indicate higher levels of risk associated with the scaling of these in-house solutions.

Vendor Two also used a robust approach in the overall scaling design. The system uses "Layer Cake" where generalized business process models are built upon to create specialized business models layered on top. Business Process Models are not interpreted at runtime but instead are pre-compiled into JAVA classes and are loaded into Java Virtual Machine (JVM) using optimization techniques. The logical layers can then be on the same or different physical tiers. Data can be shared across multiple DB Servers. Session states can be migrated across different application servers. Finally, dynamic working memory and application caching with code and data are shared for optimization inside Vendor Two's BRE. Vendor Two's platform supports both horizontal and vertical scaling and has extensive documentation from current client deployments. Finally, Vendor Two's platform engine uses an in-memory clipboard feature that caches both cases and data that helps the engine to scale in case of spike in load.

While neither COTS solution has yet scaled to handle a workload at the anticipated size of the 2020 Census, this assessment indicates that both Vendor Two's solution, as well as PRIMUS would be capable of completing the required scaling. Based on the results of this assessment, the team made the overall recommendation to move forward testing both solutions to determine which option will scale the most efficiently and allow for the least risky data integration. Similar to performance assessment, test and actual production (e.g., historical) results are the best gauge of scalability and provide more accurate assessments than a review of systems architecture and design. The fact that the in-house solutions lack any measurable scaling numbers relating to their current production runs is of concern and risk for future scalability. Both COTS platforms can provide clients as references to show their systems are scalable and dependable at very high processing rates. Some of these clients are processing at a very high rate from a case management perspective relative to our targeted needs so the gap to meet 2020 Census would not represent a substantial change in volume. However, their internet application volumes are not close to the projected 2020 Census volumes.

Testability

Testability is a measure of how well a system or its components allow you to create test criteria and execute tests to determine if those criteria are met. Testability allows faults in a system to be identified and isolated in a timely and effective manner. This quality attribute is important because timely identification and isolation of system faults allows for their rapid remediation and

minimization (or even elimination) of down time, thereby improving the ability of USCB to keep the system running effectively.

The 12 measurable attributes identified by the CCAA Team to evaluate testing and how each alternative scored can be seen in Appendix R. A graphical view of the summary score of each alternative on the testability quality attribute is pictured in Figure 14.

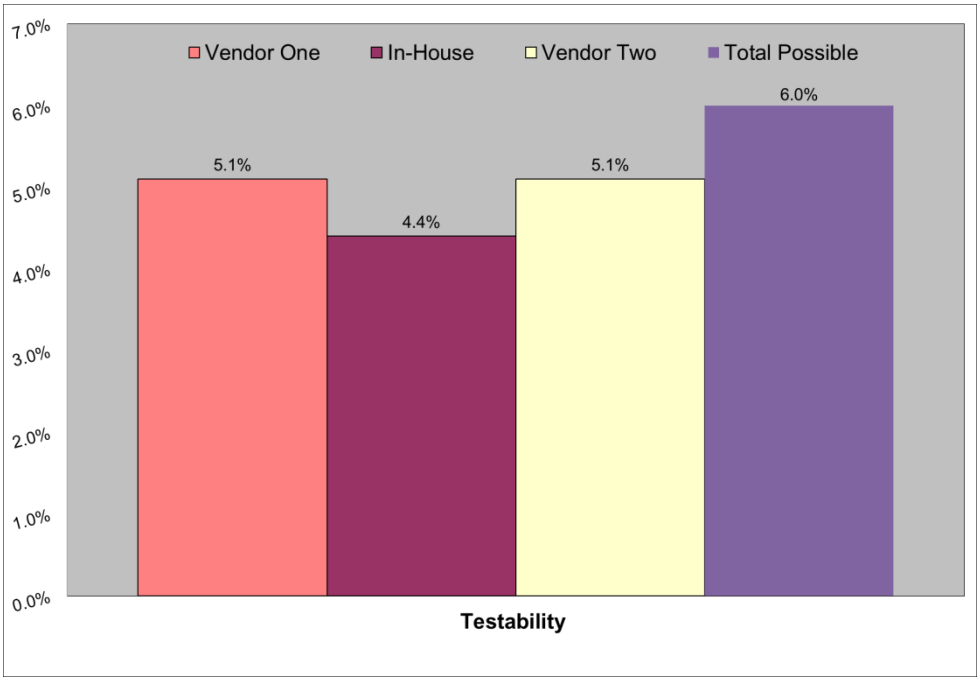


Figure 14: Testability Comparison Summary

Vendor One placed a high amount of rigor and energy into their testing efforts. Part of this evaluation included the COTS platforms being evaluated in the CAT lab using Selenium Firefox plug-in and Selenium Web Driver. This showed that the platform was reasonably easy to capture and test via the plug-in. Roughly 60% of elements strongly identified by “id” or “name”, making for test capture that would easily persist regardless of incidental modification to the UI element. This test displayed how easily changes made to the platform could be tested using automation tools.

Vendor One’s platform has test IDs built in that facilitates all automated end-to-end testing strategies and uses automated tools for testing their source code. The automated test scripts are detailed and extensive, which is included as part of their automated testing environment that is fully integrated to support their clients Further, their process follows a continuous delivery strategy, allowing tests to be defined in a way that allows everything to be in version control, automated, and executed as frequently as needed. Both REST and SOAP services provide for ease of testing, and clear generation of test input.

The team reviewed the documentation provided by the in-house teams and held meetings to take a deeper-dive in order to gather the needed information to evaluate these solutions. The in-house solution demonstrated a carefully designed test strategy and developed synthetic and mock test data for executing test plans. However, due to the timing of the assessment, these systems did not have the time to fully implement these strategies and plans. Their focus, as indicated previously, was on delivering the business requirements needed for the 2015 and 2016 Census Tests. All in-house systems use some degree of automated tools for testing code, however only MCM could provide the test coverage for its source code (less than 75%).

Vendor Two also places a high amount of rigor and energy into their testing efforts. Part of this evaluation included the COTS platforms being evaluated in the CAT lab using Selenium Firefox plug-in and Selenium Web Driver. This showed that the platform was also reasonably easy to capture and test via the plug-in. Roughly 60% of elements strongly identified by “id” or “name”, making for test capture that would easily persist regardless of incidental modification to the UI element. This test displayed how easily changes made to the platform could be tested using automation tools.

Vendor Two’s platform has test IDs built in that facilitates all automated end-to-end testing strategies, and it uses automated tools for testing their source code and the automated test scripts are detailed and extensive. These scripts are included as part of their automated testing environment that is fully integrated to support their clients. Further, their process follows a continuous delivery strategy, allowing tests to be defined in a way that allows everything to be in version control, automated, and executed as frequently as needed. Both REST and SOAP services provide for ease of testing, and clear generation of test input.

These approaches both simplify and improve testing overall. Both COTS platforms had well thought-out test strategies that included the development of synthetic and mock test data for executing test plans. Additionally, the source code of both products has been checked by external lab tools and found to be in conformance with widely accepted industry best practice coding standards. The coverage of unit testing in both products has been documented to be well over 90%. Which means before their code is propagated to an integration test environment well over 90% of their code is retested and approved. The testability quality attribute is another area where the COTS platforms consistently out scored the in-house solutions due to the robust nature of their development and implementation.

4.2.2 System Design Summary

As outlined in the previous section, both the in-house solutions and the COTS platforms were thoroughly examined to uncover their potential strengths and weaknesses. Specific components related to platform design are summarized for reference and understanding of the design nature of each solution.

Vendor One
An iBPMS platform would provide the USCB with a good development and run-time platform by offering features that facilitate the rapid development and deployment of enterprise level solutions.

Vendor One has compelling application monitoring tools to allow for real-time application diagnostics during production.

Vendor One uses an embedded Kdb technology (e.g., a non-standard in-memory database), with very high performance test documentation.

The USCB CCAA team performed a rigorous examination on Vendor One's platform against the key quality attributes. The system measured relatively strong overall, due to the underlying iBPMS structure. However, one notable item discovered in the assessment included Vendor One's inability to deliver the platform on a mobile device in disconnected mode, which limits the system's overall availability. This does not meet a critical requirement for the 2020 Census.

MOCS/MOJO/MCM In-House Solutions

MOCS is a service-based solution that serves as the primary mechanism for operational control across multiple survey modes. MOCS is a set of business processes implemented in a service-oriented architecture. The process uses business rule coding logic and the Enterprise Service Bus (ESB) to integrate with various external systems. Custom Java Development is the primary development tool for this application.

MOJO is built on standard Java based middleware architecture with Angular JS/Jquery UI and Oracle DB RAC in the backend. A unique feature of MOJO is the use of Spatial Server (ArcGIS) that runs the MOJO spatial server for executing route optimization and performing other geography processing tasks. The effort that has gone into developing the MOJO optimizer has created a high-quality product that meets the unique needs of the Census Bureau. MOJO also interfaces with external systems in a variety of ways through ESB, REST and ODBC. Although logging is implemented through Log4J, there is a lack of system-wide performance monitoring and troubleshooting tools that are essential for enterprise-level systems.

MCM services include a back-end component and a Windows based client. The back-end services include an ETL component based on Oracle DB packages and a RESTful web service interface developed on C#.NET. The front-end service uses standard HTML5/Javascript for UI rendering but relies on a wrapper for native device file system operation. The wrapper currently works only on Windows Clients. Plans are underway to develop web services in Java platform and support iOS and Android Clients in the future. MCM does not have a native scalability feature built into the application instead relying on the clustering capabilities of the underlying Oracle RAC and Windows servers.

The MOCS/MOJO/MCM solutions have been developed in an Agile development environment and have met Census Bureau's business needs. The in-house solutions have individual strengths, including delivering on all business functional needs. However, there is not enough evidence at this time to report that the systems can meet all of the complex system design attributes required to support of the 2020 Census as a single integrated unit.

PRIMUS In-House Solution

PRIMUS is not part of the in-house components that make up the OCS capabilities (MOCS/MOJO/MCM above). It is the in-house solution built to address the Internet Data Collection capability. Due to the importance of internet self-response, the USCB has spent a lot of time and effort building this solution from a system design and overall performance perspective. The CCAA team wanted to provide some information relating to this solution and its system design because of its inclusion in the overall recommendation.

PRIMUS is designed specifically to handle large volume processing. This is the performance version of the USCB current in-house self-response web application known as Centurion. Centurion has been used for USCB activities including the 2012 Economic Census, and the American Community Survey. The development team supporting PRIMUS/Centurion has separated operation & maintenance and development teams. Understanding the performance needs of the 2020 Census, the team designed an n-tier web application with overall performance in mind, which was designed to scale from the beginning of its design. This requirement led them to make specific functional decisions about requirements and development to provide the best ability to scale to 2020 Census requirements. Additionally, PRIMUS has completed multiple degrees of performance testing, including testing on the Noblis AWS cloud environment.

Presently, 18F (digital services agency based within GSA which runs in parallel with the Digital Government Strategy's Digital Services Innovation (DSI) Center) began working with the in-house team to ensure the team is well-aligned with foundational architecture, design, and software engineering practices. They have recently completed the following:

- Added support to the Primus team for 12 factor portability,
- Code refactoring and design,
- Added ability to much more easily test application on different database technologies,
- Redesigned server side code structure to better follow iterative development,
- Refactored application initialization and setup, to ease restarts,
- Reworked database migration and deploy processes to follow safer rollback practices,
- Double the amount of Primus' automated unit and integration tests,
- Extract Health Monitor code into several modules, and
- Migrate Access Control into a series of easily maintainable middleware modules.

Many of these improvements, building on PRIMUS' original design strengths and purpose bolster the overall quality of its system design.

Vendor Two

An iBPMS platform would provide the USCB with a good development and run-time platform by offering features that facilitate the rapid development and deployment of enterprise level solutions.

Vendor Two also has compelling application monitoring tools to allow for real-time application diagnostics during production.

Vendor Two follows a rigorous and highly automated end-to-end testing strategy and its critical engine functions have a coverage range between 80-100%, supporting the need to have thorough unit, system, and integration testing. This type of testing regiment has allowed the platform to mature into a highly dependable environment.

The USCB CCAA team performed a rigorous examination on Vendor Two against the key quality attributes. The system measured relatively strongly due to the underlying iBPMS structure.

In comparison to Vendor One and the in-house solutions, Vendor Two's overall design for scaling was found to be very well thought-out and completely integrated into their process. Based on the system design review and the independent testing, Vendor Two's platform supported both horizontal and vertical scaling and provided extensive documentation from scaled deployments.

Summary
The key results from the evaluation of system design are:

- Vendor Two consistently scored better than the other alternatives for each of the quality attributes.
- Both COTS vendors benefited from a large, established client base and a mature commercial product.
- In-House solutions consistently scored lower than the COTS vendors because:
  - The products have a shorter lifecycle of development, which limited testing and real-world results, and
  - Unlike the COTS platforms that must meet the needs of a large client base, the in-house solutions were developed for one client (USCB) and in some cases one Census Test which limited the scope of development on some attributes.

The findings of the overall system design comparison can be viewed in Figure 6, at the start of section 4.2.

4.3 Cost (5-Year TCO) Criteria

The CCAA team developed a five-year IT plan (an industry best practice) in combination with a Total Cost of Ownership (TCO) assessment to perform the cost evaluation component of the alternative analysis. TCO estimates adds to the initial purchase price other costs expected to be incurred during the life of the product such as lifecycle project management, software development and engineering, system deployment, operations and maintenance.

For the TCO comparison, the team used a framework recommended by the Office of Cost Estimation, Analysis, and Assessment (OCEAA) within the USCB. OCEAA provided a Cost Element Structure template for the vendors to organize their estimates. This structure is similar to what OCEAA used to perform a CEDCaP Independent Cost Estimate (ICE) of all twelve of the CEDCaP capability areas in 2015.

This analysis uses CEDCaP 2015 costs for all in-house solutions, with the exception of COMPASS. COMPASS is not a CEDCaP program. It began as a proof of concept program within the Decennial Directorate. Therefore, the Decennial Directorate business owner for COMPASS provided the best estimate available for inclusion in the ICE.

As part of their CCAA 90-day task, both vendors were required to provide a 5-year TCO proposal to the CCAA Team. To assist the vendor and provide consistency, the CCAA Team provided each vendor the CES provided by OCEAA, an inventory of CEDCaP requirements, and the CEDCaP Transition Plan, which captures the five-year deployment roadmap for the CEDCaP Program Management Office. The proposal was due in the middle of the 90-day development cycle to allow the vendors time to get acclimated with the USCB capabilities, requirements, and the USCB business SME support process overall. The idea was this would allow for a more informed estimate. Both vendors were given approximately four weeks to provide their cost estimates.

For the purpose of the analysis there were three basic cost elements examined:

- Planning Phase Program/Project Management - This cost element includes the direct activities of persons performing program management functions in the planning phase as defined in OMB Circular A-11. These costs include all personnel, TDY, indirect support and non-labor pre-milestone 2A program management costs, and software procurement cost.
- System Engineering - This cost element includes all resource expenditures required to develop and deliver the IT system to full operational capability (FOC). This element is a rollup of the Software Development, Data Development & Transition Planning, DB Standards/Dictionary, Training Development, Test and Evaluation, System Integration, and System Deployment.
- Operations & Maintenance -This major element includes all costs to operate and maintain the IT system after FOC at all sites. It includes the cost to manage and maintain the hardware and software, whether centrally or at each unit, to sustain operations throughout the remainder of the life cycle (i.e. post-FOC).

4.3.1 Cost Analysis summary - Vendor One

In general, the proposal provided by Vendor One lacked some details. Despite the fact that both vendors received the same exact cost estimation package, the lack of documentation did not allow the team to feel that the costs estimate was realistic. Given the lack of detailed documentation there were serious concerns that Vendor One would not be able to provide a solution for the cost they proposed. For example, when reviewing the contractor development team resources the LOE was significantly lower than the other two alternatives. When the team contacted Vendor One for clarification on how the hours needed to perform the designated work was derived, it took a number of follow-up conversations in order to receive the requested clarification.

Vendor One’s actual software cost based on the GSA schedule was estimated at $537 million. In their cost estimate, they provided a 90.50% discount, resulting in an approximate cost of approximately $45 million for the requested contract period. However, Vendor One did not

describe the basis of that discount or future cost implications in upcoming contract periods. The $45 million licensing cost also includes the O&M costs for the platform.

The 5-Year TCO for Vendor One was approximately $69 million; however, this estimate did not include required components to support the Economic Census. This estimate included only their costs to deliver the 2020 Census and the internet response option for the American Community Survey beginning in 2019. This included the $45 million in licensing fees outlined above (including O&M) as well as approximately $21 million in software design charges, $2.5 million in contracting services, and $135,000 for initial training.

4.3.2 Cost Analysis summary - In-House Solutions

For the estimated cost of the in-house solution, the CCAA team used the 2015 CEDCaP Independent Cost Estimate (ICE) created by OCEAA, which used a similar CES model provided to the vendors to determine the in-house capability cost of ownership. Within the CEDCaP ICE, there are USCB related costs that would be incurred regardless of whether the USCB used a COTS vendor or performed in-house custom development. The CCAA team looked to identify these major cost drivers and remove them from the in-house solutions' cost to allow for a good relative comparison. With this in mind, the following adjustments were made to the CEDCaP ICE for the in- house solutions: reduced Software Development Cost by 25% to account for USCB SMEs (as 25% is the approximate ratio of USCB SMEs to contract support on the current development team); removed all Project Management Government Personal; removed all Acquisition Phase costs for both Government and Contractor Personal; removed all Hardware and Software Maintenance – COTS, and System Hardware Procurement.

The estimates of a custom-built solution were 50% higher than COTS platforms. The 5-Year TCO for the MOCS/MOJO/MCM solution was estimated at $127 million. This included approximately $9.5 million in contracting services, $105 million in system design and $12.5 million in O&M. By including all capabilities and their supporting in-house solutions, the total TCO estimate was approximately $182 million. This included the MOCS/MOJO/MCM estimates above plus approximately $0.5 million in contracting services, $52 million in system design and $2 million in O&M.

4.3.3 Cost Analysis Summary - Vendor Two

Vendor Two was provided the same cost package as Vendor One; however, their presented cost model was significantly more complete, following a logical progression from the concept of equating requirements to user stories, to hours worked based on the work done as part of the 90-day sprint. They had some key assumptions to help drive their cost for example: CCAA POC experience to-date indicates that there is roughly a 1:1 or 1:2 correlation between the requirements and user stories depending on the business rules embedded in the system; and, given the business requirements do not reflect all of the business rules, the risk factor for business functionality was given a 1.25. The following two assumptions were key cost drivers to calculate the labor cost, (1) Level of effort in hours was determined by number and type of user stories, (2) Labor cost was based on their labor rate of $190/hour multiplied by the LOE hours and the 1.25 risk factor.

The 5-Year TCO for the Vendor Two platform included the costs to deliver the 2020 Census, the internet survey component of the American Community Survey beginning in the 2019 data year, and the 2022 Economic Census was approximately $84.5 million. This included approximately $42 million in licensing fees (including O&M) as well as approximately $33 million in software design charges, $9 million in contracting services, and $520,000 for initial training.

4.4 Schedule Criteria

The USCB has strict schedules to meet in order to conduct operations, including inflexible legal requirements for the 2020 Census. Understanding and managing related items that can affect a deployment schedule is a critical factor for success in delivering the needed systems.

Schedule management and schedule impact are the two sub-criteria used to measure overall scheduling. These sub-criteria assess the ability for each alternative to be implemented according to the needed schedule (i.e., the calendar duration needed to acquire, implement, integrate this solution, and if necessary, design, develop, and test upgrades to impacted systems to complete integration and achieve operational readiness).

The CCAA team assigned each sub-criterion a set of measurable attributes. Each measurable attribute was expressed either as a statement, a single question, or a group of related questions designed to address different aspects of the sub-criteria. Each measurable attribute was scored between 1 and 4, based on how well the alternative met the requirement:

1 = Not adequate to the requirement
2 = Partially adequate to the requirement
3 = Meets the requirement
4 = Meets the requirement and is superior to other alternatives

4.4.1 Schedule Impact

Once a schedule is established and baselined, unforeseen elements can force a schedule to change. Any change to a schedule will have an impact. Therefore, for the USCB to meet its schedules, any proposed solution must produce minimal impacts to existing schedules. While meeting the 2020 Census schedule was examined by the team as the end goal, the short-term need to meet the 2017 Census Test schedule was also considered.

Impacts to the schedule include internal processes that can delay deployment of resources and tools and increase deployment time; solution-specific elements that can reduce deployment time; changes in required or available resources; changes in requirements; testing; and development style. Impacts may be positive, resulting in less time to accomplish scheduled tasks, or negative, resulting in more time to accomplish scheduled tasks. The USCB seeks to maximize positive schedule impacts and minimize negative schedule impacts.

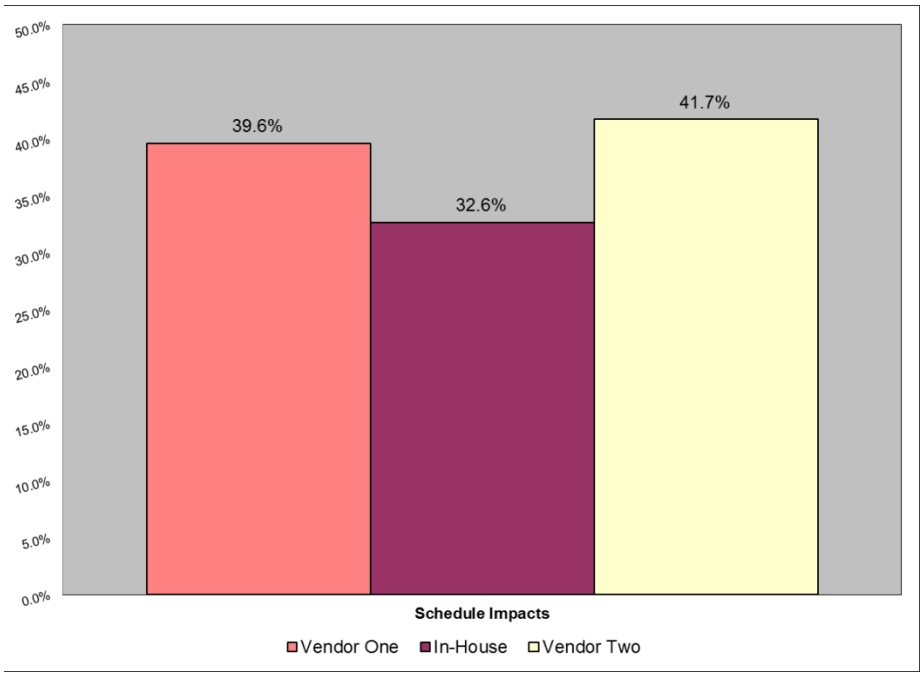


Figure 15: Schedule Impact Summary

The six measurable attributes identified by the CCAA team to evaluate schedule impact, and how each alternative scored can be seen in Appendix S. The overall summary of schedule impacts can be seen above in Figure 15.

Vendor One cited examples of their ability to support clients with rapidly evolving and volatile requirements and still deploy into production on schedule with high quality results. They have access to a resource pool beyond their direct employees (reaching out to subcontractors, etc.), which allows them to react quickly to changing resources demands. They are able to identify, acquire, and deploy resources as needed to satisfy requirements and to minimize schedule impacts. Vendor One adheres to established Agile methodology and associated best practices. This development methodology allows them to react quickly to changes in requirements with minimal impact to schedules. However, the Level of Effort (LOE) submitted by Vendor One did not explicitly address tasking levels, staffing effort, or resource estimates. They did not submit any information that would be required to estimate the amount and type of resources required to meet the requirements of the USCB leading up to the 2017 Decennial Test or the 2020 Census. Not understanding the resources required to fulfill a schedule can impact being able to meet the schedule.

The in-house custom solutions are currently deployed within the internal production environment, so there are no impediments to delay in the fielding of these systems to production. Each custom solution uses either Agile variants or full Agile methodologies for system development. However, the in-house solution teams are small with no or limited reach-back (depth of resource experience to call upon). We are witnessing cases where the need to support multiple efforts relating to O&M and new development (e.g. 2016 Census Test, 2016 COS/ASM, 2016 Address Canvassing Test, 2017 Census Test) are impacting what the team can deliver due to limited resources. Additionally, their development environments are not to the

point that would allow for full automation of the build to test cycles, which improve code delivery time.

Vendor Two provided examples of their ability to support clients with rapidly evolving and volatile requirements and still deploy into production on schedule with high quality results. They have access to a resource pool beyond their direct employees, which allows them to react quickly to changing resources demands. Vendor Two demonstrated they are able to identify, acquire, and deploy resources as needed to minimize schedule impacts. Vendor Two adheres to established Agile methodology and associated best practices. This development methodology allows them to react quickly to changes in requirements with minimal impact to schedules. Vendor Two integrated its methodology into its platform, which helps to facilitate collaboration, and overcome organizational roadblocks. Vendor Two uses a model-driven approach, where the configuration interface checks every application to follow a strict governance model. Testing can be highly automated and visually confirmed. Their ability to automate the testing results in shorter and more thorough testing and lowers possible schedule impacts. Vendor Two estimated labor costs by capability and provided details on the underlying assumptions for their estimates. This indicates a high level of confidence in their abilities to predict future schedules based on anticipated effort. However, they based their LOE on not reusing any of the materials developed in their Proof of Concept (POC). This would require Vendor Two to develop fully functional systems for the 2017 Decennial Test “from the ground up” in a compressed time frame.

Overall, the lowest potential impact on schedules over time was exhibited by Vendor Two. This was reflected in their higher score overall, based on better estimation, a dedicated and automated approach to Agile development, and the ability to minimize impacts associated with team resources.

4.4.2 Schedule Management

Schedule management is the ability to manage resources and meet the milestones associated with a schedule based on available resources. As outlined in section 4.3, the USCB operates on very specific schedules, many with immovable timelines. This criterion helps define the level of risk associated with meeting deadlines on a project with resources at hand – the higher the scores, the lower the associated risk. An overall summary of each option is presented in Figure 16 below.

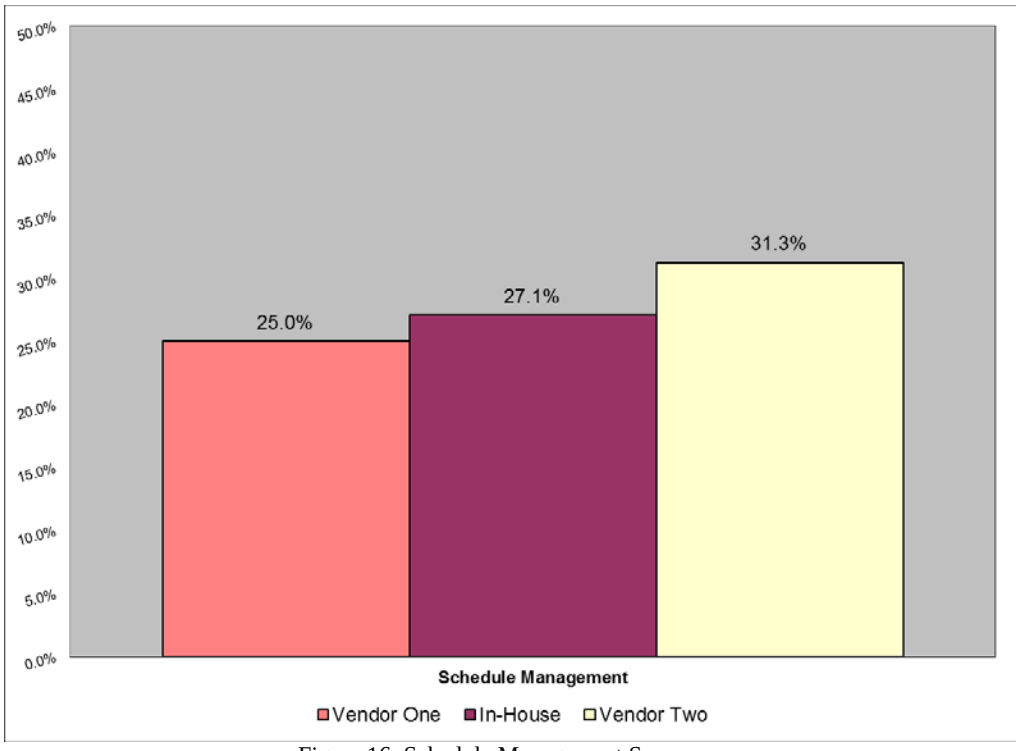


Figure 16: Schedule Management Summary

Vendor One provided numerous references and examples of how they have consistently hit deployment schedule for their clients – including clients that had extremely tight and volatile schedules. However, Vendor One failed to deliver a fully disconnected mode capability as agreed upon during the CCAA. This failure reflects poorly on their ability to manage schedule requirements. When the CCAA team requested a schedule for deploying for 2017 test, Vendor One provided an extremely high-level timeline for development, which contained minimum level of details for addressing schedules and deadlines associated with the 2017 Census Test.

In-house development teams are prepared to meet the existing schedule to deliver the needed functionality provided that funding is available and the requirements are unchanged.

Vendor Two also provided numerous references and examples of how they have consistently hit deployment schedule for their clients – including clients that had extremely tight and volatile schedules. Vendor Two's high-level Master Schedule and their cost proposal demonstrated an awareness of upcoming milestones, as well as a scheduling roadmap on how they would deliver for the 2020 Census, Economic programs, and current surveys that included required capabilities and multiple release schedules.

4.4.3 Schedule Summary

Overall, the ability to maximize positive impact, minimize negative impact, and effectively manage schedules was best demonstrated by Vendor Two. This is reflected in the schedule summary comparison, shown in Figure 17.

In summary, the in-house solutions demonstrated strong capabilities in terms of schedule management, based on their abilities to meet deadlines and provide working solutions that are in use. However, there were two sub-criteria (schedule impact and schedule management). The in-house solution did not score as well in schedule impact, which affected their overall schedule management summary.

Both COTS vendors scored well in the ability to respond to volatile resource demands. This was due to their providing use cases detailing instances where they were required to replace existing contractors and provide working solutions in a limited amount of time. COTS vendors also scored well based on their ability to configure their platforms to support the workflows and process models of the USCB. In addition to the requirements both COTS vendors demonstrated, Vendor Two demonstrated strong capabilities in their ability to respond to late changes, to provide reasonable estimates of Level of Effort (LOE), and to show historical abilities to meet deployment schedules.

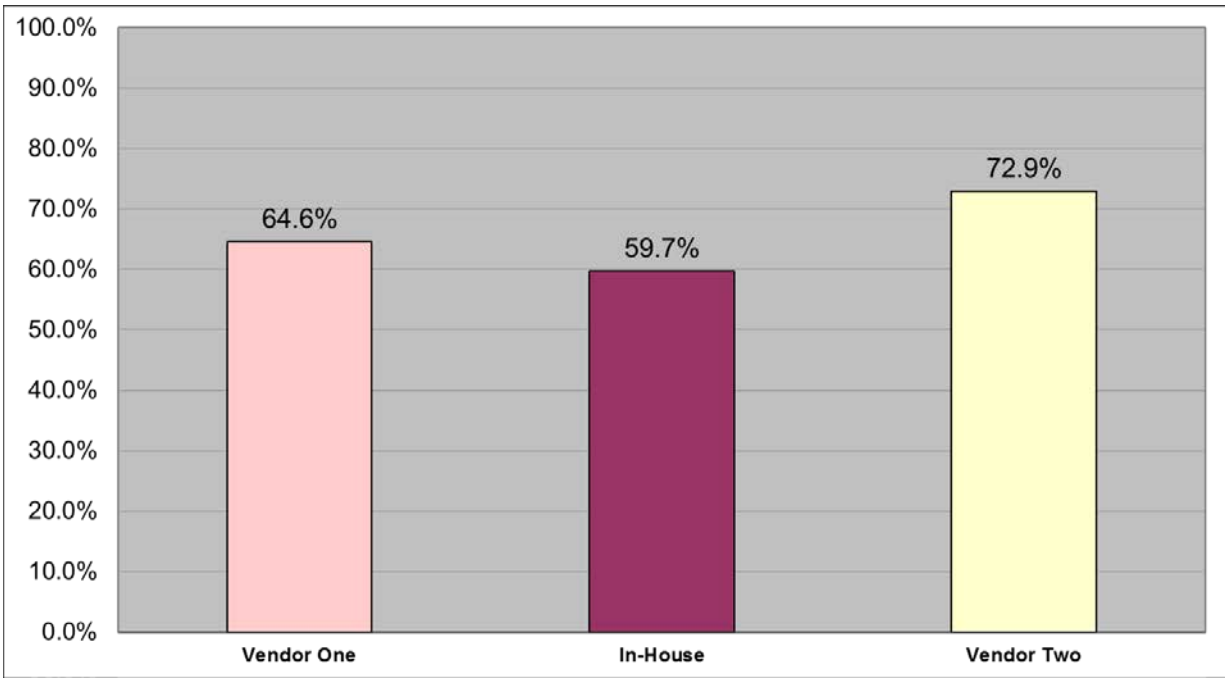


Figure 17 – Schedule Summary Comparison

4.5 Vendor/Development Team Viability Criteria

The success of a software deployment depends on the viability of the supporting team (from management through operations and maintenance). The strength and maturity of the supporting team must match USCB need for product delivery and support. This criterion examined the viability of both the vendor (including development teams) and the overall product/solution. This evaluation is based on five key measurable attributes composed as multiple questions separated into two distinct sub-criteria: Vendor/Development Team Viability and Solution

Component Viability. Requirements for both sub-criteria can be found in Appendix T. In this criteria area, the COTS vendors demonstrated considerable ability to meet USCB needs.

4.5.1 Vendor/ Development Team Viability

Both COTS vendors used team structures with both breadth and depth in their staff. Both proposed including staff familiar with the CEDCaP project and with the initial prototyping of the CCAA sprint efforts. While this strengthens the team, it does not rely solely on a single member for knowledge of the underlying business process or product, which greatly reduces risk. Both vendors benefit from the fact that it is easier to bring staff up to speed on configuration-based development, rather than code-based development.

Vendors One and Two are structured with a division of labor between support and development teams. This results in minimizing the impact on the development team of any high-priority issues requiring attention by O&M. Both Vendors One and Two exhibit strong team viability by dividing labor resources between support and development teams, offering 24x7x365 support with 1-hour response times for severity 1 issues, and by leveraging personnel with CEDCaP and USCB CCAA prototyping experience on their proposed staffing.

The in-house solution teams are small, requiring a “round-robin” style of support services. This has the potential to negatively affect development efforts if O&M requires resources assigned to development tasks. Due to the small team sizes staffed with highly skilled personnel with in-depth product and institutional knowledge level of support could potentially be limited by their availability. This can increase the time required to address high-priority issues that arise.

The structure and level of experience on the development team for the in-house solution reflects the reliance on a few key individuals who designed the custom solution and exposes the teams and the Census Bureau, to possible single points of failure. The scores reflect the understanding that the loss of a single key resource could have detrimental effects on the development, updates, operation, and maintenance of the custom solution.

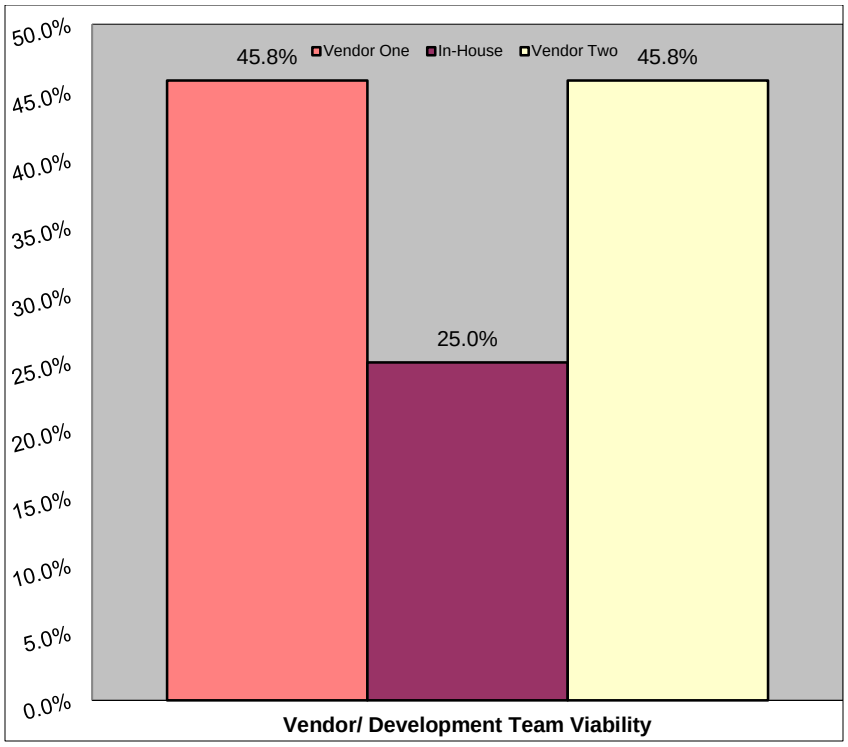


Figure 18: Vendor/Development Team Viability

The results shown in Figure 18 reflect the scores for team viability for the In-House and COTS vendors. Both Vendors One and Two scored well in this sub-criteria area, each receiving full marks for Team Viability. This was due to the separate development and support resources, being able to deploy sufficient development resources to avoid single points of failure due to the loss of key personnel, and being able to provide 24x7x365 support for severity 1 issues. The in-house solutions were scored lower because they use development resources for support, and rely heavily on critical resources (creating a single point of failure for development efforts).

4.5.2 Solution/Component Viability

The USCB requires a solution that is properly documented. This indicates that the solution is mature, providing sufficient information to users of the solution in order to install, update, and operate the system. Strong documentation allows for maintenance that is more effective and future upgrades by a different set of future resources.

Vendor One and Two both provide reasonable levels of documentation maturity, reflecting their longevity in the solution space and the maturity of their product offering. The in-house solutions also exhibit reasonable levels of documentation maturity, reflecting their adherence to the Census Enterprise System Development Life Cycle.

Solution maturity was evaluated because it is an indicator of the longevity and stability of a given product. The USCB performs certain activities on long lifecycles (up to 10 years), such as the Decennial Census. Any product offering needed to demonstrate their ability to remain a viable source. A solution that has produced multiple major releases over several years exhibits

the level of solution maturity associated with these criteria. Less mature solutions will score lower in this area.

Vendor One has been in the iBPMS marketplace for over a decade and has a user community of 3.5 million users globally. Vendor One ranks as one of the two highest products in the Gartner iBPMS Magic Quadrant, and is ranked as a Leader by Forrester in Dynamic Case Management. This resulted in Vendor One receiving a high score on these criteria.

Vendor Two has also been in the iBPMS marketplace for over a decade, and has in excess of 650 customers and over 1,000 installations of the product. They were named by Forbes Magazine as one of "America's Most Trustworthy Companies" based on their having one of the 100 highest scores for trustworthy behavior over the course of the previous fiscal year. Vendor Two also ranks as one of the two highest products in the Gartner iBPMS Magic Quadrant, and is ranked as a Leader by Forrester in Dynamic Case Management. This resulted in Vendor Two receiving a high score on these criteria.

The in-house products have been developed only within the past few years. The MCM product went live in 2015 for CAPI refresh for current surveys, the MOJO prototype was used for the 2015 and 2016 Census Tests and MOCS for the 2016 Census Test. The lack of solution maturity is not a reflection of the quality of the solutions but of their relative time in production.

The graph shown in Figure 19 reflects the scores for both COTS vendors and the in-house solution for solution viability.

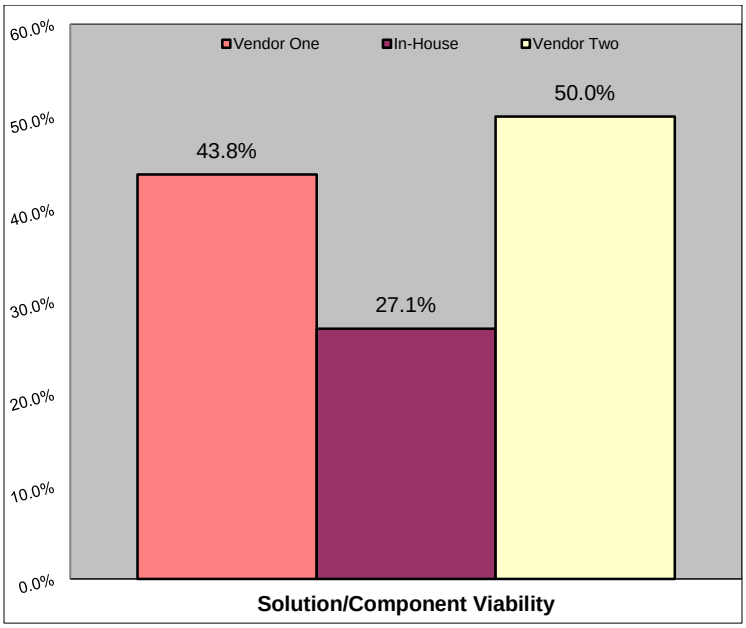


Figure 19: Solution/Component Viability

4.5.3 Vendor/Development Team Viability Summary

The high scores for team viability and solution viability for the COTS vendors reflect that both platform vendors are major companies with a long history in the market. They are both considered leaders in independent evaluations of the market space for iBPMS vendors. Both vendors also have extensive partner networks, which gives them the ability to reach back to existing and previous engagements, providing them the ability to obtain the right people with the right skills at the right time for USCB efforts. A summary of both solution/component viability as well as vendor/development team viability can be found in Figure 20.

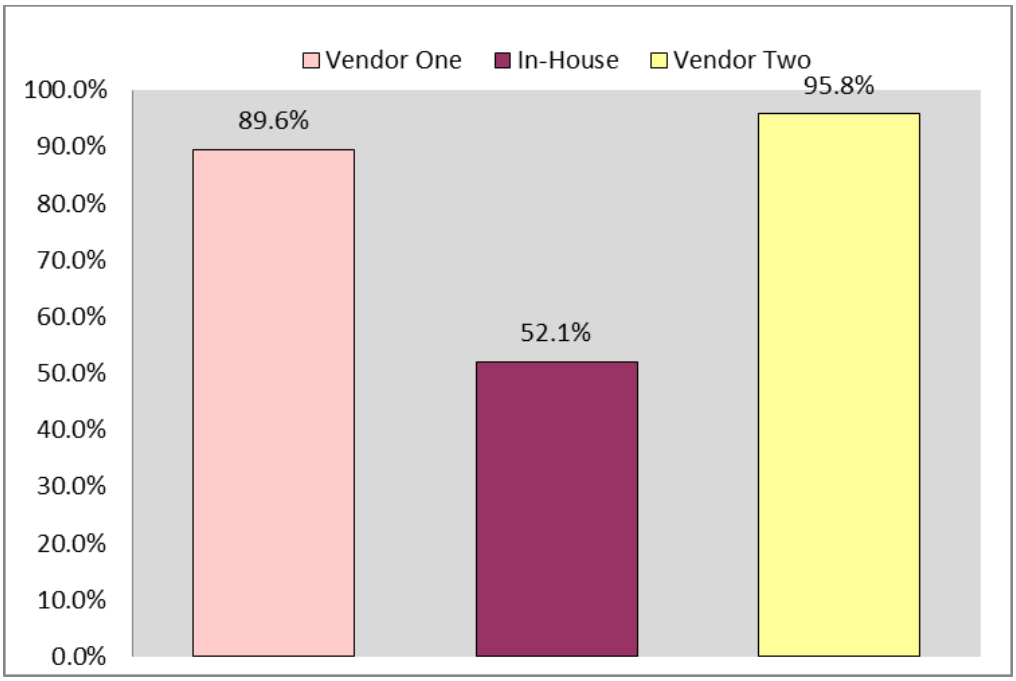


Figure 20: Overall Vendor/Development Team Viability Summary

Vendor One provides an extensive depth of documentation maturity, reflecting their longevity in the solution space and the maturity of their product offering. Vendor One has been in the iBPMS marketplace for over a decade and has a user community of 3.5 million users globally. They rank as one of the two highest products in the Gartner iBPMS Magic Quadrant, and is ranked as a Leader by Forrester in Dynamic Case Management.

The in-house solutions do not have the same depth of document maturity as the COTS platforms, due to the timing of the system development. This is reflected in their overall score.

Vendor Two also provides an extensive depth of documentation maturity, reflecting their longevity in the solution space and the maturity of their product offering**.** Vendor Two has also been in the iBPMS marketplace for over a decade, has over 650 customers with over 1,000 installations of the product. . Finally, Vendor Two was named by Forbes Magazine as one of "America's Most Trustworthy Companies" based on their scores for trustworthy behavior over the course of the previous fiscal year. Vendor Two scored the overall highest for this criterion.

5 RECOMMENDATION

5.1 Process Summary

The CCAA team identified five key criteria to use in the evaluation process:

1. Business Functional Need,
2. System Design,
3. Cost (5-Year TCO),
4. Schedule Impacts, and
5. Vendor/Development Team Viability.

The weights of these criteria were established by the EGG, prior to the start of actual analysis, in terms of where they saw value to the USCB, the CEDCaP enterprise solution, and the 2020 Census. Refer to Figure 1 to review the weights for each criterion. Within each of these criteria, a set of attributes was established and scored by the CEDCaP team and stakeholders.

For the final overall scoring rollup, the criteria weights assigned by the Executive Guidance Group were applied. The purpose of using a quantitative scoring model was to provide an objective platform for comparison. However, the scoring model results were never intended to stand-alone but rather to be supplemented with the strategic analysis outlined throughout this report.

As described throughout this report, each of the alternatives was evaluated using these five criteria and assigned a review score. Figure 21, Criterion Scoring Summary Breakdown, provides a summary of each COTS vendor and the in-house solution (for each of the five criteria).

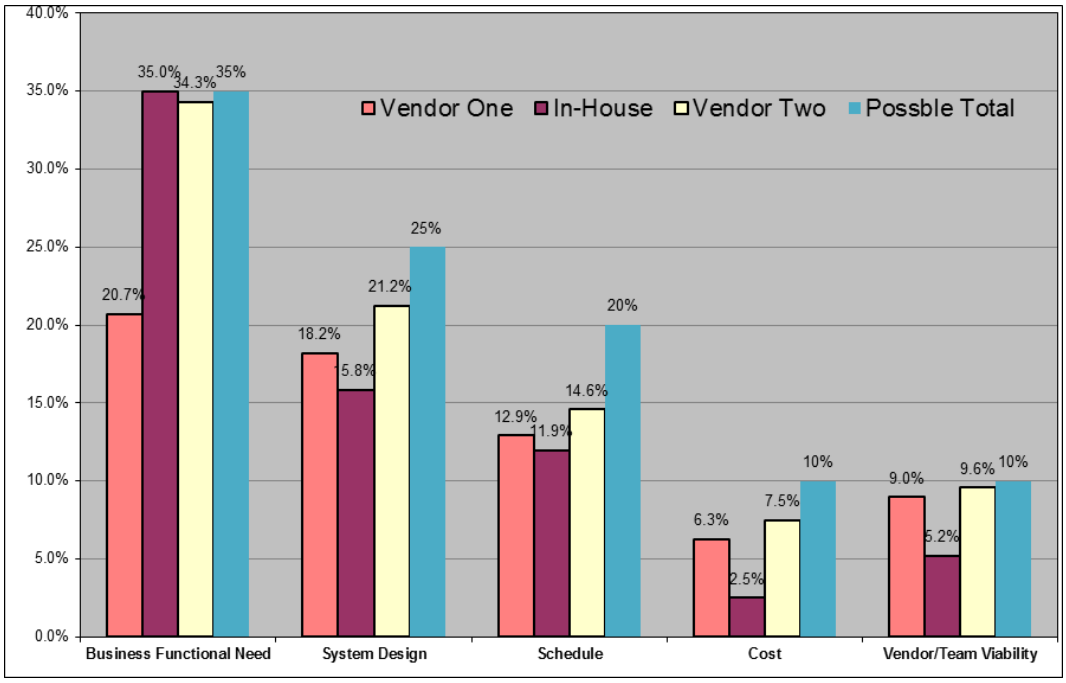


Figure 21: Criterion Scoring Summary Breakdown

Once the weights were applied to the results pictured in Figure 21, an overall evaluation score was determined for each company. Those results are listed in Figure 22: CCAA Overall Criteria Scoring and will be reviewed individually by option, in the following sections.

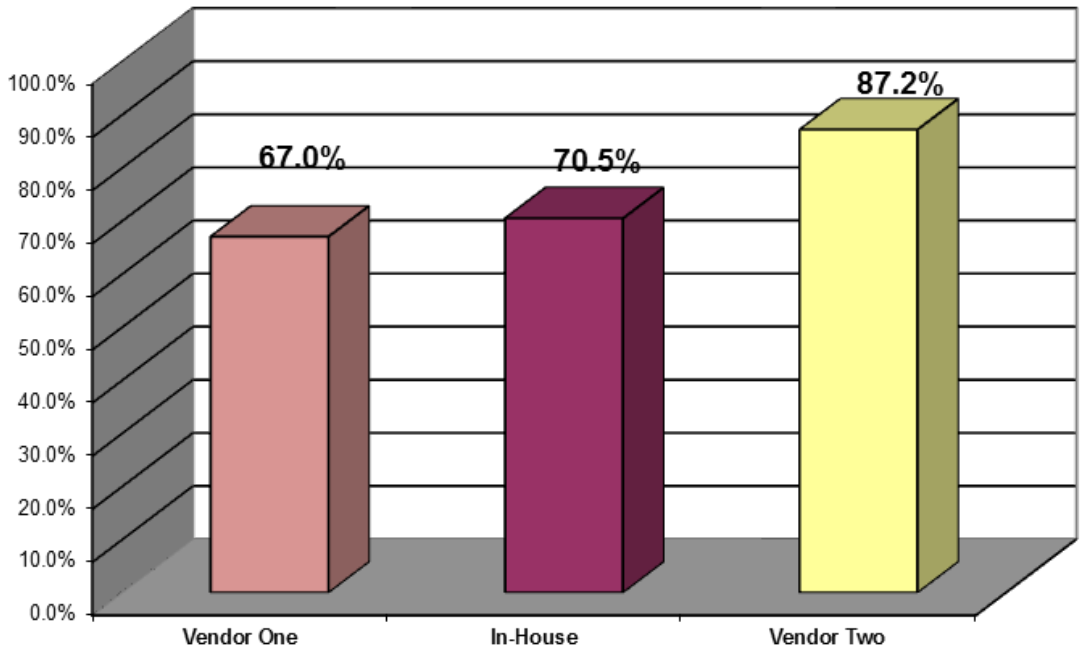


Figure 22: CCAA Overall Criteria Scoring

5.1.1 Vendor One Summary

As we learned through market research, Vendor One is a top industry leader in iBPMS platforms. It has a feature-rich ecosystem, meaning the product is easily capable of addressing multiple businesses and engineering needs.

Business Functional Need
Examining the business functional needs, Vendor One could not meet the non-functional requirement to perform in disconnected mode. While they met the functional requirements at a high rate, their failure to meet this key non-functional capability was a critical missing element in the offered platform, failing in a “must have” component, which affects the platforms ability to properly deliver the functional requirements.

System Design

- Maintainability – Vendor One’s platform allows for easy and efficient changes to the business logic of the iBPM platform and uses built-in diagnostic tools.
- Portability – Vendor One’s platform offered fully portable solutions with its middleware and database supported on all major platforms. The mobile platform runs on both Apple iOS and Android OS, however, there is no native Windows API support.
- Availability/dependability – Vendor One’s platform is well-designed to provide and support redundancy features and clustering capabilities. Vendor One has a history of

usage by mission critical private industry clients and supports both horizontal and vertical scaling. However, the lack of disconnected mode in Vendor One's platform automatically disqualifies the platform.

- Performance – Vendor One's platform is built on very strong architecture relative to performance with proper layering, modular composition, and scalable design with proper diagnostic programs.
- Security – Vendor One built ample security measures to meet strict USCB security requirements. All systems adhere to secure coding and testing practices and are Federal Information Security Management Act (FISMA) compliant. Integrability/interoperability – Vendor One's platform does use all necessary open architecture standards for integration protocols and met including granularity, extensibility, customizability, and security.
- Scalability/elasticity - Vendor One's platform supports both horizontal and vertical scaling and provided several client deployments to prove its ability to scale. However, the mobile platform does not implement the queuing type store and forward mechanism that will would impact field operations ability to handle communications
- Testability – Vendor One's platform demonstrates a high amount of rigor and energy into their testing efforts. The platform has test IDs built in that facilitate all automated end-to-end testing strategies and use automated tools for testing the source code.

Schedule

Vendor One provided evidence that they were able to support clients with rapidly evolving and volatile requirements and still deploy into production on schedule with high quality results. They have access to a resource pool beyond their direct employees, which allows them to react quickly to changing resources demands. They are able to identify, acquire, and deploy resources as needed to satisfy requirements and to minimize schedule impacts.

However, LOE submitted by Vendor One did not explicitly address tasking levels, staffing effort, or resource estimates. They did not submit any information that would be required to estimate the amount and type of resources required to meet the requirements of the USCB leading up to the 2017 Decennial Test or the 2020 Census. Additionally, Vendor One failed to deliver a fully disconnected mode capability as agreed upon during the CCAA, which reflects poorly on their ability to manage schedule requirements.

Cost

The five-year total cost of ownership for the platform offering from Vendor One was projected at approximately $68 million. However, as outlined in Section 4.4, we have concerns related to the level of detail provided in Vendor One's cost estimate for us to review. Of specific concern, the cost estimate reflected a large unexplained license discount with no documentation to describe how the discount would be realized. In addition, Vendor One did not meet the requirement of providing a cost estimate for the 2022 Economic Census support.

Vendor/Developmental Team Viability

The development team structure for Vendor One is mature and stable, leveraging a previous USCB contractor's background knowledge and experience to support their prototype efforts, exhibiting both breadth and depth in their staff. Vendor One's product offering is mature,

reliable, and stable. It has been deployed over multiple major releases to major clients with observed success. Vendor One supports this product with a mature support model that allows for separation between operations and maintenance and application development. This industry standard approach provides reach back when necessary without significant risk to production operations.

Summary
Based on these concerns, the team had severe reservations about the viability and sustainability of using Vendor One's platform. However, the fact that their mobile platform does not meet our requirement for a fully disconnected-mode capability, which would limit USCB data collection operations like NRFU and address listing to when internet connectivity is available, was a critical missing element in the platform. The inability to deploy the disconnected-mode onto Vendor One's platform within the agreed upon schedule timeframe (demonstrating an inability to manage commitments) presents an unacceptable risk at this point in preparations for the 2020 Census that we are not prepared to accept. This is why disconnected mode was listed as one of the four "must have" requirements for any potential system. Vendor One's inability to deliver this requirement as agreed upon, removed the system from further consideration.

5.1.2 In-House Solutions Summary

The in-house solutions are custom coded applications designed specifically to meet USCB business requirements. While the systems have not been in place for a long period of time, the systems have demonstrated the ability to meet the functional needs of the 2014, 2015 and 2016 Census Tests. The work performed by the in-house development teams provided the foundation for this analysis and for our 2020 Census reengineering efforts. These reengineering efforts are part of the cost saving approach that is projected to provide over $2.5 billion in savings.

Business Functional Need
The overall in-house solutions were designed to meet the specific business functional needs of the USCB and have shown great potential. USCB solution teams are well integrated across the different program areas and are extremely knowledgeable about business processes related to their individual projects. The MOJO optimizer/router in particular is an extremely successful application of business requirements for the 2020 Census. The MOJO optimizer/router demonstrated superior capabilities to the COTS products. The success of this component led the team to recommend that it be adopted within the chosen solution.

System Design

- Maintainability – The in-house solutions demonstrated two weaknesses by not having a separation of presentation, business and database logic. This separation allows for optimum code changes at the respective tiers with a minimum impact across tiers, which is not utilized in the in-house solutions. Additionally, the systems lack Business Rules Engine (BRE), Event Stream Processing (ESP), or Business Activity Monitoring (BAM) technologies. These are the necessary IT tools to increase overall application efficiency during continuous changes and improvements.
- Portability – The in-house solutions fully use the redundancy and clustering facilities of the underlying technology platform. MOCS is written on a BPM platform and can port to a compliant BPM platform. MCM has a native windows wrapper that works on

Windows Mobile platforms. However, the in-house solutions built a product for a single client, which did not require the same degree of portability as the COTS products.

- Availability/dependability – The in-house solutions use standard techniques in application development. However, they have been in production for a short time and have not been tested on a large scale.
- Performance - Due to the timing of this assessment, the in-house solutions have been concentrating efforts to date on meeting the functional needs for the 2015 and 2016 Census Tests and have spent a more limited time on performance testing that was not directly related to the Census Tests.
- Security – In-house solutions have ample security measures built in to meet strict USCB security requirements. All systems adhere to secure coding and testing practices and are Federal Information Security Management Act (FISMA) compliant.
- Integrability/interoperability - While the in-house systems are generally documented with good design principles for integrability and interoperability, the software is not mature enough for significant testing metrics to have yet been captured.
- Scalability/elasticity - None of the three critical in-house systems making up the OCS solution have proven the necessary scalability. They depend on their supporting platform's clustering capabilities, which could cause problems during the 2020 Census high volume periods. This is exacerbated by the fact that they lack End-to-End continuous integration test coverage; integrated system health checks, monitoring and diagnostic tools, and hence are not up to par with those of the COTS platforms. The exception to the scalability concerns is the PRIMUS system. PRIMUS was designed to scale from the initial development phase. Its demonstrated scalability is what led the CCAA team to recommend that PRIMUS continue to be tested alongside the commercial system, as part of a risk mitigation strategy for internet response.
- Testability – In-house solutions demonstrated carefully designed test strategy and developed synthetic and mock test data for executing test plans. However, due to the timing of the assessment, these systems did not have the time to fully implement these strategies and plans.

In general, the in-house teams develop products separately, which leads to serious concerns about the integration of components. The divisional separation of the teams is evident during integration testing by a lack of system design across the overall platform. There is currently zero automated integration testing across all three boundaries. As a result, none of these systems demonstrates an integrated solution. A number of other concerns and risks have been highlighted in this report, many due to the lack of time for each system to prove enterprise production abilities. The in-house solutions are extremely reliant on limited resources with specific skillsets, which provide single-points of failure and overall depth and breadth concerns.

Schedule

In-house development teams are prepared to meet the existing schedule to deliver the needed functionality provided that funding is available and the requirements are unchanged. However, the solution teams are small with no or limited reach-back to additional resources. The in-house solutions do exhibit instances of continuous integration testing, regression testing, and automated build processes. At this time, they are not able to fully automate the build cycle in software

development, which causes the build cycle to remain at least partially manual. This can cause build cycles to take longer and potentially introduce errors into the build process.

Cost
The five-year total cost of ownership for the MOCS/MOJO/MCM offering is approximately $127,236,000 (the highest of the three options).

Vendor/Developmental Team Viability
The in-house development teams are small, requiring a "round-robin" style of support services. This has the potential to negatively affect development efforts if O&M requires resources assigned to development tasks. The structure and level of experience on each development team reflects the reliance on a few key individuals who designed the custom solution. The lack of solution maturity is not a reflection of the quality of the solutions but of their relative time in production.

5.1.3 Vendor Two

As with Vendor One, Vendor Two is a top industry leader in iBPMS platforms, and their product provides a feature-rich ecosystem. However, Vendor Two consistently demonstrated top-level performance across the attributes. Their team quickly configured their product to all USCB specific requirements within the CCAA and their ability to add out-of-scope requirements as part of their stretch goals surpassed Vendor One.

Business Functional Needs
Importantly, Vendor Two demonstrated fully disconnected-mode functionality, which means they could fully address this USCB requirement for field operations, which Vendor One could not. They accomplished this by integrating a third-party tool (based on industry standards) seamlessly within their platform.

This functionality would allow Census Bureau field staff to operate in disconnected mode for the needed length of time as they complete interview and listing field operations. Additionally, Vendor Two was able to incorporate a third-party Map Management suite. This is an important capability for an OCS to demonstrate, something the in-house solutions have planned but have not yet accomplished. Finally, the Vendor Two platform also provides a very rich alert, dashboard, and reporting capability. The platform also provides the ability to have real-time alerts, which would augment both headquarters and field operations.

System Design

- Maintainability – Vendor Two's iBPM platform allows for easy and efficient changes to the business logic containing built-in diagnostic tools. With a true business rules engine (BRE) and business process model (BPM) technology, the vendor was able to quickly incorporate USCB specific business rules (requirements) within their overall platform. The platform provides innovative capabilities based on a broad customer base that will allow the USCB to quickly re-engineer some of our current business processes, making them more efficient. In particular, the real-time interactive help features have the potential to integrate with the Decennial Census Telephone Questionnaire Assistance (TQA) operations.

- Portability – Vendor Two provided fully portable solutions with its middleware and database supported on all major platform with very few exceptions. The mobile platform runs on both Apple iOS and Android OS, however, there is no native Windows API support.
- Availability/dependability – Vendor Two's mobile platform supports offline capabilities that would help field operations survive network outages and unreliable connections. Vendor Two provided evidence of a history of usage by mission critical private industry clients on a platform that supports both Horizontal and Vertical scaling.
- Performance – Vendor Two demonstrated a very strong architecture relative to performance with proper layering, modular composition, and scalable design. The platform has effective diagnostic programs built in.
- Security – Vendor Two's platform ample security measures built in to meet strict USCB security requirements. All systems adhere to secure coding and testing practices and are Federal Information Security Management Act (FISMA) compliant.
- Integrability/interoperability – Vendor Two uses all the necessary open architecture standards for integration protocols and met standards for elements of interoperability, including granularity, extensibility, customizability, and security. Additionally, Vendor Two offered full support for SOAP and REST, and offers "Basic", "NTLM", and OAuth 1.0/2.0 authentication that platform one could not.
- Scalability/elasticity – Vendor Two's system supports both horizontal and vertical scaling and has extensive documentation from current client deployments. As part of the scaling strategy, the platform engine uses an in-memory clipboard feature that caches both cases and data that helps the engine to scale in case of spike in load during high volume processing, and provides real-time application performance monitoring. Vendor Two uses "Layer Cake", which builds upon generalized business process models to create specialized business models. Those logical layers can be on the same or different physical tiers. This structure with these features, incorporated with a robust runtime platform of monitoring tools, contributes to the product's overall ability to provide high availability and strong scalability for USCB needs.
- Testability – Vendor Two demonstrated a high amount of rigor and energy in their testing efforts. Their platform products has test IDs built in that facilitates all automated end-to-end testing strategies and uses automated tools for testing their source code with detailed and extensive automated test scripts.

Schedule

Vendor Two also provided numerous references and examples of how they have consistently hit deployment schedule for their clients – including clients that had extremely tight and volatile schedules. They have access to a resource pool beyond their direct employees, which allows them to react quickly to changing resources demands. Vendor Two provided more thorough, complete schedule estimation, along with a dedicated and automated approach to Agile development, plus the demonstrated ability to minimize impacts associated with team resources. Vendor Two's high-level Master Schedule and their cost proposal demonstrated an awareness of upcoming milestones, as well as a scheduling roadmap on how they would deliver for the 2020 Census, Economic programs, and current surveys that included required capabilities and multiple release schedules, which far exceeded the level of detail provided by Vendor One.

Cost
Vendor Two provided a complete cost model, based on development requirements estimated on projected hours for specific components of the cost models. The five-year total cost of ownership for the platform offering from Vendor Two is approximately $84.5 million.

Vendor/Developmental Team Viability
Vendor Two's product offering is mature, reliable, and stable. It has been deployed over multiple major releases to multiple major clients with observed success. The team and solution are the most mature of the alternatives considered, with over 25 years in the IT industry with both breadth and depth of development staff. Their vast network of certified partners reduces reliance on individual personnel and the likelihood of a single point of failure issue. Vendor Two provides a division of labor between support and development teams. This results in minimizing the impact on the development team of any high-priority issues requiring attention by O&M. Additionally, Vendor Two proposed a CEDCaP specific support model.

5.2 Recommendation

Based on the results of the CCAA, Vendor Two stands out as the best solution for USCB, both for the core data collection capabilities of OCS (covering Dynamic Case Management and intelligent BPM Suite functionality) and for the non-core data collection capabilities (e.g., COMPASS, LiMA, CoMET). While the in-house solution of MCOS/MOJO/MCM was not selected, the optimization/routing engine component did prove superb, and can be easily integrated into Vendor Two's platform with RESTFul API. The team recommends its continued use.

The CCAA developed recommendation is based on the specific scores outlined in this report from the AoA as well as risks associated with each selection and the need to address both short-term and long-term CEDCaP objectives. To that end, we recommend a hybrid approach, where the best the COTS platforms and the USCB custom solutions can address not only the short-term goal of successfully deploying the 2020 Census but also building the infrastructure to transition to the long-term goal of CEDCaP's future state to incorporate all surveys and censuses.

The CCAA team recommends that the USCB implement Vendor Two's platform product, coupled with the MOJO team's optimizer/router to fulfill the core CEDCaP capabilities for dynamic case management functionality.

The use of Vendor Two's platform would remove artificial system boundaries (such as those inherent in the separate in-house systems), providing a documented ability to provide needed functionality. Additionally, this approach minimizes the concern (from USCB and CMU SEI advisors) related to the complications and risks associated with having multiple integration points within a single system, as discussed in Section 4.2.1 Integrability. The solution by Vendor Two will remove the many different integration layers and allow for a less complicated and risky architecture. Finally, the recommended approach also resolves the major architecture challenge the CEDCaP/Decennial System Engineering, Integration, & Testing (SEIT) team were examining related to the best way to manage data across the many systems boundaries currently in existence.

The team further recommends that Vendor Two be used to provide Internet self-response, with continued in-house testing of the overall capability and scalability. The 2020 Census will be the first Decennial Census that will include internet self-response as the primary self-response mode. Due to the importance of this response mode, its first time use at this scale, the unknown volume spikes relative to internet applications, and the public nature of the Census, the team believes it is prudent to continue the 18F assisted architecture improvements of PRIMUS and to devise a performance test plan for both PRIMUS and Vendor Two's internet offering to determine which scales the most efficiently to meet the needs of the 2020 Census before making a final decision on the internet self-response option.

Additionally, this approach would permit the USCB to start integration testing of Vendor Two's internet component with RTNP, which is a non-CEDCaP solution for the 2020 Census, as part of the 2017 Census Tests into the USCB IaaS/PaaS service provider offering. Simultaneously, the vendor's professional services integration team can be conducting performance testing. This provides the opportunity for the USCB to determine which internet solution to use in the 2018 End-to-End Census Test based on actual performance test results.

Finally, this approach would allow the Census Bureau to initiate immediate performance testing (e.g., immediately load all household records into the environment to start performance design and tuning) of the Vendor Two platform from a USCB perspective and provide time to devise a full-blown performance test plan.

5.3 Next Steps

In order to move forward with this approach, there are a series of actions that will be required. The following list is not all-inclusive, but outlines the next steps to move forward with the acquisition and integration of the Vendor Two platform into CEDCaP programs for implementation within the USCB:

- Acquisitions and CEDCaP Project Management Office (PgMO) must finalize funding reallocations and implement a new task order with Vendor Two.
- CEDCaP leadership, working with all project managers, must develop a comprehensive transitioning plan for CEDCaP current project support, which would include re-organization of current projects (focusing first on the 2020 Census program).
- CEDCaP project managers, in connection with senior leadership must quickly develop staffing transition plans to ensure all in-house project team members have a plan for their individual work within CEDCaP moving forward. Engaging the extensive knowledge and experience of all project members will be a critical aspect of moving forward integrating the solution in the upcoming development phase.
- CEDCaP leadership should form technical teams to manage the specific components related to the integration of the platform solution, leveraging the development and requirements expertise of existing members of the CEDCaP development teams and subject matter experts.

- CEDCaP leadership must develop a comprehensive load and stress testing plan of Vendor Two's product to address USCB volume needs for the 2020 Census.
- The CEDCaP PgMO and Bureau Senior Management should develop a clear communication plan to socialize the implementation of the recommendations.
- Acquisitions must review the recommendation to ensure no discontinuity between the current contract and any subsequent contract needs.
- CEDCaP and Decennial SEIT Teams will need to update all of their architecture and re-engineering documentation to address the new approach.
- CEDCaP leadership should coordinate with HR in order to ensure a smooth onboarding process for Vendor Two's contract staff.
- The CEDCaP PgMO should conduct a risk assessment of all AoA criteria to determine actual impacts to USCB and develop a Risk Mitigation plan to address all identified risks.

Appendix A – Acronym Guide

AoA	Analysis of Alternatives
API	Application Program Interface
BA	Business Analyst
BAM	Business Activity Monitoring
BFN	Business Functional Need
BI	Business Intelligence
BPM	Business Process Modeling
BPMN	Business Process Modeling Notation
BRE	Business Rules Engines
BRE	Business Rule Engine
CAD	Center for Adaptive Design (at the Census Bureau)
CAPI	Computer Assisted Personal Interviewing
CAT	Center for Applied Technology (Computer Laboratory at the Census Bureau)
CATI	Computer Assisted Telephone Interviewing
CCAA	COTS Capability Assessment and Analysis
CEDCaP	Census Enterprise Data Collection and Processing
CMU SEI	Carnegie Mellon University's Software Engineering Institute
COMET	Content Metadata or Questionnaire Design and Metadata (Census Bureau in-house developed application)
COMPASS	Census Operations Mobile Platform for Adaptive Services and Solution (Census Bureau in-house developed application)
COS/ASM	Company Organizational Survey /Annual Survey of Manufacturers
COTS	Commercial Off-the Shelf Solutions
DCM	Dynamic Case Management
DOC	Department of Commerce
EGG	CEDCaP Executive Guidance Group
EPIC	Evolutionary Process for Integrating COTS-Based Systems, developed by CMU SEI
ESB	Enterprise Service Bus
ESC	Executive Steering Committee (of the CEDCaP Project)
ESP	Event Stream Processing
FedRAMP	Federal Risk and Authorization Management Program
FISMA	Federal Information Security Management Act
FOC	Full Operational Capability
GOTS	Government Off the Shelf
GSA	Government Services Administration
HTTP	Hypertext Transfer Protocol
I/O	Input/Output
IaaS	Infrastructure as a Service

iBPMS	intelligent Business Process Management Systems
ICE	Independent Cost Estimate
IT	Information Technology
JAD	Joint Analysis Design
JDBC	Java Database Connectivity
JSON	JavaScript Object Notation
JVM	Java Virtual Machine
KPI	Key Performance Indicator
LiMA	Listing and Mapping or Address Listing and Mapping (Census Bureau in-house developed application)
LOE	Level of Effort
MCM	Mobile Case Management (Census Bureau in-house developed application)
MOCS	Multi-Mode Operational Control System (Census Bureau in-house developed application)
MOJO	Survey and Listing Interview Operational Control System (Census Bureau in-house developed application)
NRFU	Non-Response Follow-up
NTLM	NT LAN Manager
O&M	Operations and Maintenance
OCEAA	Office of Cost Estimation, Analysis, and Assessment (within the Census Bureau)
OCS	Operational Control System
ODBC	Open Database Connectivity
OII	Office of Innovation and Implementation
OII	Office of Innovation and Implementation
OMB	Office of Management and Budget
PaaS	Platform as a Service
PgMO	CEDCaP's Program Management Office
POC	Proof of Concept
PRIMUS	Internet and Mobile Data Collection (Census Bureau in-house developed application)
QA	Quality Attributes
REST	Representational State Transfer
RFI	Request for Information
RFQ	Request for Quotation
ROCkIT	ReOrganize Census with Integrated Technology
ROM	Rough Order of Magnitude
RTNP	Real Time Non-ID Processing
SME	Subject Matter Expert
SOAP	Simple Object Access Protocol
TBD	To Be Determined
TCO	Total Cost of Ownership
TQA	Telephone Questionnaire Assistance

UI	User Interface
USCB	U.S. Census Bureau
WBS	Work Breakdown Structure
WSDL	Web Service Definition Language
XML	Extensible Markup Language

Appendix B – Phase II Challenge Question

United States Bureau of the Census
RFQ1032579 (CENS15-COTS)

The Census Enterprise Data Collection and Processing (CEDCaP) program is responsible for the development and integration of an enterprise system of systems to improve the data collection and processing phases of the Bureau's Survey Life Cycle (SLC). Historically, the Bureau has built multiple, duplicative data collection and processing systems for each major organizational Directorate or program area (e.g., Decennial, Demographic, and Economic) instead of providing functional capabilities that meet standardized operational requirements across the enterprise. In addition, in an era of significant budget constraints, the Bureau has committed to delivering improved service to its customers, while providing new capabilities to deliver its mission more efficiently.

In light of the above, stakeholders across the Bureau have identified the following opportunities:

- Implementation of new and enhanced business capabilities to improve performance and reduce cost
- Implementation of integrated, data-driven designs and processes
- Simplification of processes and systems through reduction of complexity by leveraging shared services and service-oriented architecture
- Alignment of capabilities to the Survey Life Cycle (SLC) components to deliver mission-enabling and support functionality through shared services
- Consolidation of stove-piped, duplicative systems in order to eliminate redundancies, promote standardization, and increase efficiency

Leveraging the business process model(s) presented in *Appendix A* of the *Vendor Demonstration Agreement*, please propose a pragmatic implementation strategy and framework for delivering an *adaptable, secure, resilient, loosely coupled, service-oriented solution* that meets or exceeds performance requirements. For the purposes of this challenge question, assume the solution may utilize an *existing message-oriented middleware platform* and *service bus* infrastructure.
Assume further that the proposed solution shall be required to interface and/or interoperate with *commercial off-the-shelf (COTS) software*, *open source software (OSS)*, and *in-house custom-developed software systems*, all of which are *deployed on premise or across hybrid cloud infrastructure*.
Another key factor that should be considered within your response is to address the complexity of creating a system of systems that requires a unique elastic scaling characteristic caused by the Decennial Census, which introduces a major performance processing need every ten years that can equate to a multiplier of approximately 100x normal peak volume processing capacity in various areas of the overall solution.
In your response, please articulate your engagement strategy in collaborating with the government, the CEDCaP Program Management Office (PgMO), and the program's multiple service delivery partners. Citing examples of similar experience(s), discuss how such prior experience has prepared you to deliver the above successfully.

Lastly, what immediate risks do you identify in the scenario presented above, and how would you mitigate each identified risk?

Appendix C – CEDCaP Evaluation Questions

United States Bureau of the Census

RFQ1032579 (CENS15-COTS)

Implementation and Schedule

1. Describe the normal implementation chronological timeline to deploy your solution into a new client's environment? What activities need to take place from initial installation into a development environment to final deployment into a production environment? Explain the process and what variables exist that impact the timelines.

Deployment History

2. Can you provide examples of the most complex survey and the longest survey that were developed using your tool? For example, additional material/information that provides a real-life demonstration of the magnitude of complexity and length of which your tool can be used to develop an instrument (electronic questionnaire).
3. Can you provide examples of the average processing volumes for your internet solution and the greatest peak processing volume numbers (e.g., average file size and number of transaction per hour) and who was the client?
4. Can you provide the number for your largest single deployment of a mobile application and the make up of the volumes of data being passed from the mobile app to your backend systems (e.g., average file size and number of transaction per hour)?
5. Provide more information about the largest client you deployed your case management offering for, and some complexities related to that deployment.

Technical

6. Explain the overall physical architecture of your solution?
7. Please explain the specialized skill sets needed to develop within your solution and needed to provide ongoing O&M support of your solution.
8. What programming language (if applicable) and/or domain-specific BR language is used to create the business rules that define the skip logic, branching logic, etc. embedded in the instrument design portion of your solution? What skill set level is needed to create the electronic questionnaires in your development environment, the assumption is the skill set level varies depending on the complexity of the questionnaire, so please provide response based on the following levels of complexity; low, medium, and high.
9. What out of the box features relating to your product would you like for the Bureau to be aware of?
10. How do you differentiate customization versus configuration within your tool?
11. What tools are provided in your integrated development environment for validating complex business rules, skip logic, branching logic, etc. embedded in the instrument?

12. Can a set of specifications or other design documentation (e.g., business process models, flow diagrams) automatically be produced/generated using your integrated tool development environment?
13. Is any part of the application and/or architecture you are proposing offered as a software-as-a-service and/or platform-as-a-service? If yes, is any part of the application and/or architecture limited to software-as-a-service and/or platform-as-a-service?
14. If your product offering is limited to cloud services are you FedRamp certified and what is your proposed engagement model with the Bureau staff?
15. What is the approximate data size of the response data that is captured and uploaded for the specs that were provided for the demo, per respondent questionnaire? And, are there any vendor-specific variables and/or content that impact this size? If so, what are they?

Security

16. Are your systems subjected to penetration testing? Is testing performed by internal personnel or outsourced? When was the last penetration test? What were the results?
17. Does your company have a dedicated security team?
18. What is your patches and Service Packs installation policy and process?
19. What is your company's SLA terms with regard to security incidents, the reporting of them, and release of said data to the client?

Vendor Viability

20. Provide a chronological timeline related to when your company started and what was its targeted business to where the company is now?
21. How do you envision your company 10 years from now.
22. What is the current version release of the product you are proposing for the Census? What was the initial release version and what date?
23. What is your current release model/ cycle for your product/s? (e.g., What is the targeted EOL for the current version? How often do you release maintenance packages, upgrade releases, etc.)
24. Explain the process for upgrading from one release to the next of your product, and provide examples of previous upgrade complexities.
25. Provide us some insight into your operation and maintenance support model?
26. How long has your company been delivering products in the mobile data collection, electronic questionnaire/forms design, and/or dynamic case management areas, and what are your future plans in this particular area?
27. If your proposal includes a partnership of multiple vendors, how long has this partnership been in existence and what is the future of this partnership outside your proposal for this particular RFQ.
28. What is the number of employees currently working specifically in the solution area presented in your proposal and how long has your company been delivering a product in this particular solution area?

Appendix D – CCAA Assessment of Requirements

In addition to assessing each platform's ability to provide OCS functionality, the AoA also assessed each platform's ability to provide non-OCS functionality. Non-OCS functionality includes services such as address listing and mapping, questionnaire design and metadata, internet and mobile data collection. This functionality represents key components needed to implement a solution that would fully meet all needs of the USCB, but were not considered as critical as the OCS functionality during this assessment.

This portion of the assessment followed the same process described in Section 4 - Business Functional Needs. To recap, each vendor was required to demonstrate their ability to meet the needs of the USCB business requirements, via a practical, hands-on demonstration of deploying key Census business requirements onto their platforms. This demonstration was done through a 90-day prototype/configuration period that included a planning sprint, one fifteen-day sprint, followed by four focused ten-day Agile-based development sprints. Each of the five sprints covered one or more of the capability areas identified for evaluation. All capabilities were configured using user-friendly drag and drop development platforms and did not involve any underlining code (i.e., Java, Perl, C++, etc.) changes to the platform.

Through JAD sessions led by the CCAA Business Functional SME group, the team determined which set of the business requirements would be considered "in scope" for each individual sprint. The requirements deemed not critical for delivering the capability for that sprint or not practical for delivery within a ten-day period were considered "out-of-scope." Each sprint concluded with a three-hour demonstration of completed functionality by the vendor, after which the Business Functional SME group rated how well the "in-scope" requirements were implemented on the vendor's platform.

Each "in-scope" business requirement was given a value of 1, 2, or 3, by the CCAA team members based on the team visually seeing the requirement implemented on the platform during the Demo sprint:

1 = Not adequate to the requirement
2 = Partially adequate to the requirement
3 = Meets the requirement

The projected ability of the vendors to implement "out-of-scope" requirements was assessed by the CCAA Core Team by combining a review of in-scope deployed requirements with an assessment of architectural mechanisms. Applying those techniques resulted in categorizing "out-of-scope" requirements into 2 categories. If the team determined that the out-of-scope requirements could be met using standard platform capabilities given additional time, it was labeled "standard." If the team could not determine with a reasonable level of confidence that an "out-of-scope requirement" could be met via standard platform capabilities it was labeled "TBD".

The four CEDCaP capability areas that were assessed in this portion of the AoA were:

- **Questionnaire Design & Metadata Capability (e.g., COMET)** -- reflects the ability of each vendor to meet 31 core requirements related to the design of questionnaires and the ability to manage the metadata repositories.
- **Internet Data Collection Capability (e.g., PRIMUS)** -- reflects the ability of each vendor to meet 64 core requirements related to the collection of data from the Internet.
- **Mobile Data Collection Capability (e.g., COMPASS)** -- reflects the ability of each vendor to meet 75 core requirements that allow enumerators to collect data through mobile devices in both connected and disconnected mode.
- **Address Listing & Mapping Capability (e.g., LiMA)** -- reflects the ability of each vendor to meet 31 core requirements related to address listing and mapping for enumerators.

The assessment took into account the fact that Mobile Data Collection Capability (e.g., COMPASS), and Address Listing & Mapping Capability (e.g., LiMA) capabilities are fully reliant on the non-functional disconnected mode capability. That is, a vendor's inability to meet the non-functional requirement of disconnected mode would disqualify them from consideration as a provider of Mobile Data Collection and Address Listing & Mapping, even if they were able to meet all the functional requirements for these capabilities. At the time of this analysis, Vendor One was not able to deliver disconnected mode as part of its platform.

Questionnaire Design & Metadata

There were a total of 52 questionnaire design and metadata business requirements identified by the CCAA. All 52 business requirements are listed in Appendix G. 30 of the 52 were deemed in scope for the prototype sprints (listed in Appendix G). Of the 30 requirements, Vendors One and Two were able to deliver high percentages (90.9% and 91.9% respectively) of the requirements, see Figure D1: Questionnaire Design & Metadata "In-Scope" Requirements.

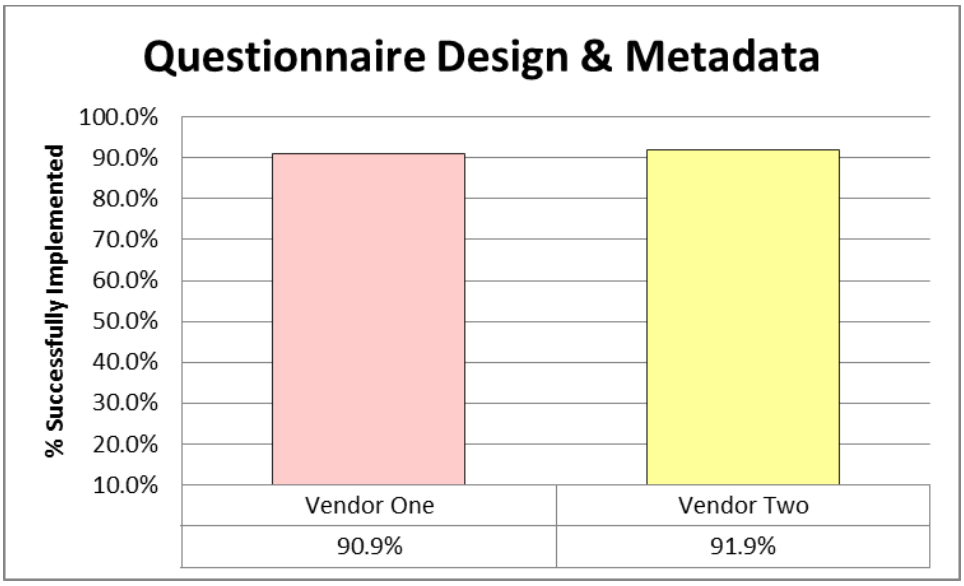


Figure D-1: Questionnaire Design & Metadata "In-Scope" Requirements

For the remaining 22 requirements that had been deemed "out-of-scope" (listed in Appendix G) the team assessed that 18 could have been delivered by the COTS platform if allotted enough time. Vendor One and Two were assessed to be at the same level in performance for the questionnaire design and metadata criteria. There were four remaining requirements for which the team felt they could not assess the COTS platforms' ability to deliver the requirement without code modifications to the platforms, see Figure D-2: Questionnaire Design & Metadata Requirement Assessment.

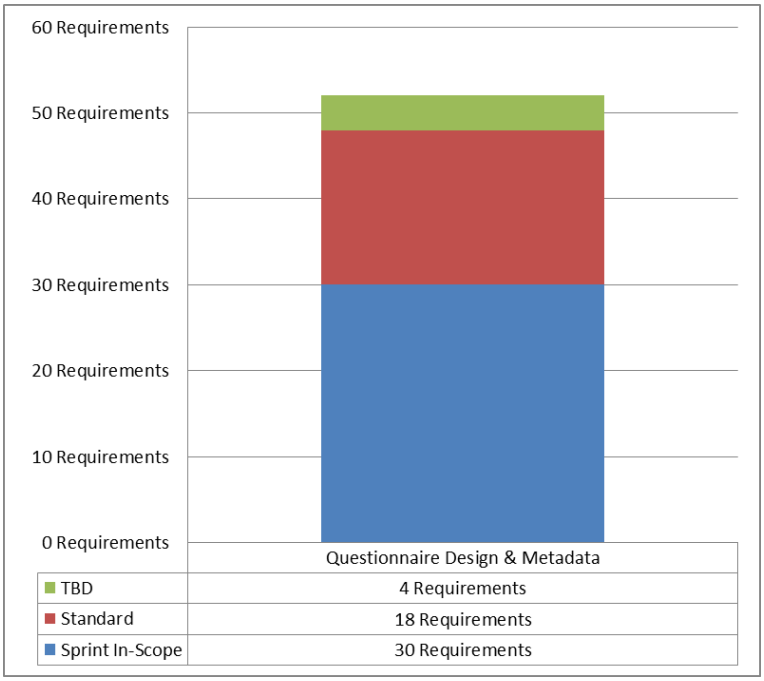


Figure D-2: Questionnaire Design & Metadata Requirement Assessment

Mobile Data Collection

There were a total of 143 mobile data collection business requirements identified by the CCAA. All 143 business requirements are listed in Appendix H. 76 were deemed in scope for the prototype sprints (listed in Appendix H). Of the 76 requirements, Vendor Two was able to deliver high percentages (91.0%) of the requirements, see Figure D-3: Mobile Data Collection "In-Scope" Requirements. However, Vendor One was disqualified from overall consideration due to their inability to deliver mobile data collection in disconnected mode. Vendor Two demonstrated the ability to apply a BPM model to disconnected mobile in real-time.

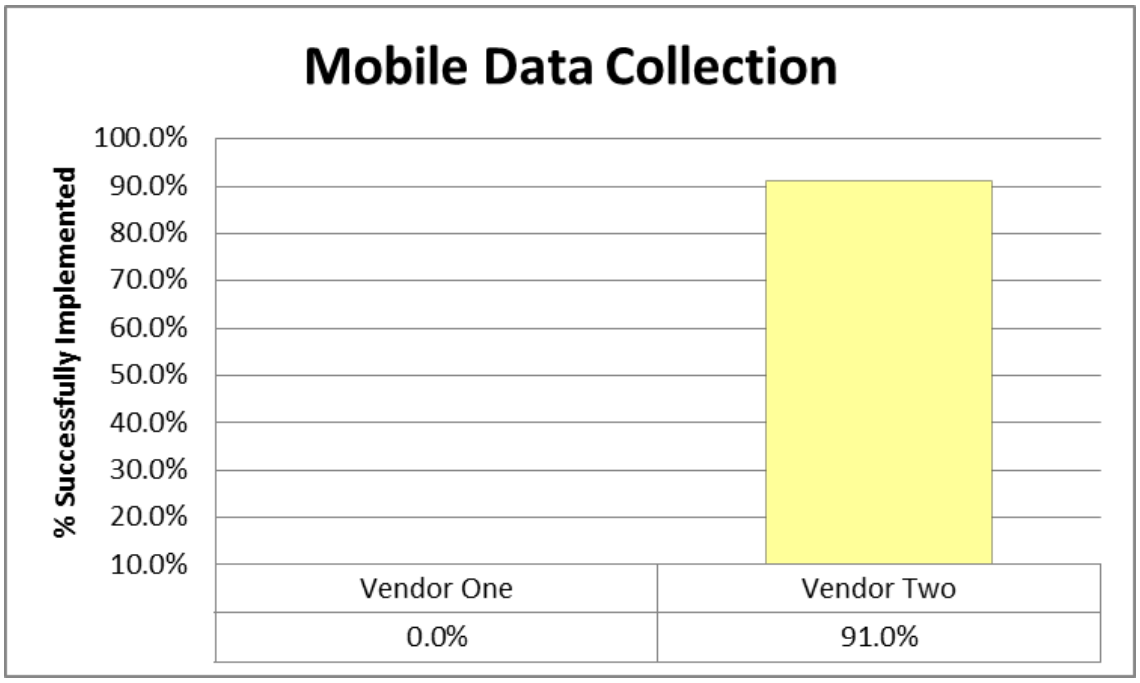


Figure D-3: Mobile Data Collection "In-Scope" Requirements

For the remaining 67 requirements that were deemed "out-of-scope" (listed in Appendix H) the team assessed that all could have been demonstrated to be delivered by Vendor Two's platform if provided enough time had been allotted and without code modifications to the platform, see Figure D-4: Mobile Data Collection Requirement Assessment.

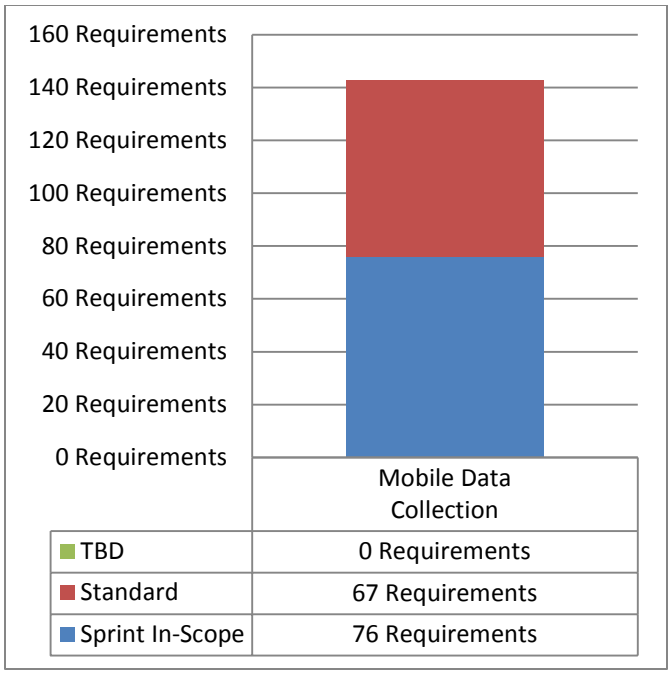


Figure D-4: Mobile Data Collection Requirement Assessment

Address Listing & Mapping

There were a total of 44 address listing and mapping business requirements identified by the CCAA. All 44 business requirements are listed in Appendix I. 31 were deemed in scope for the prototype sprints (listed in Appendix I). Of the 31 requirements, Vendor Two was able to deliver high percentages (95.1%) of the requirements, see Figure D-5: Address Listing and Mapping "In-Scope" Requirements. However, Vendor One did not meet a critical requirement (to deliver address listing and mapping in disconnected mode), needed to move forward.

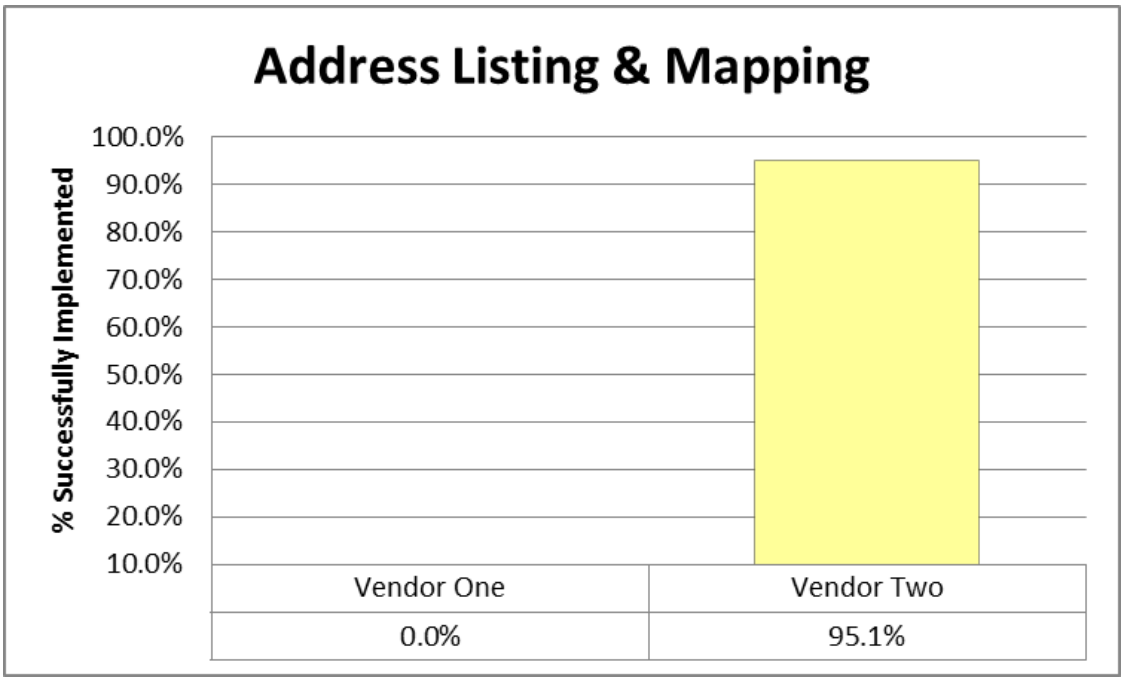


Figure D-5: Address & Listing Mapping "In-Scope" Requirements

For the remaining 13 requirements that were deemed "out-of-scope," (listed in Appendix I) the team assessed that all could have been delivered by Vendor Two's platform if allotted enough time, without code modifications to the platform, see Figure D-6: Address & Listing Mapping Requirement Assessment.

Additionally, Vendor Two demonstrated some of the "out-of-scope" requirements as stretch goals. They integrated a third-party map management suite which compresses and/or decompresses imagery to industry standard. USCB MAF data is presented successfully in the format Vendor Two used during a demonstration. The ESRI database can be updated in batch mode, which demonstrated that Vendor Two would be able to address all out-of-scope requirements from the prototyping sessions. Both vendors demonstrated GPS technology in their demonstrations.

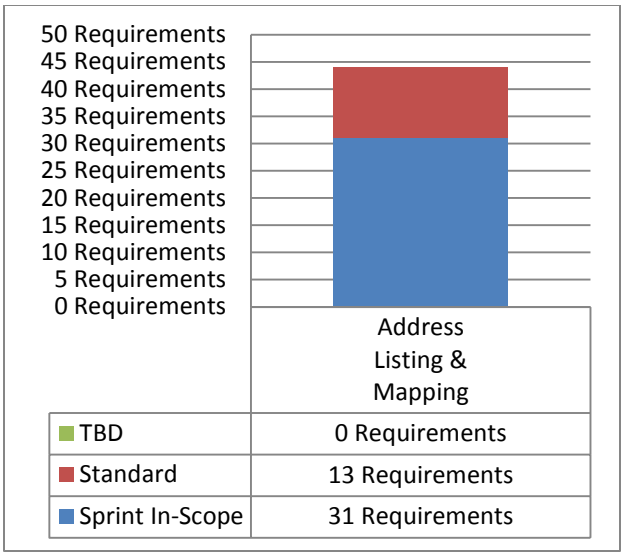


Figure D-6: Address & Listing Mapping Requirement Assessment

Internet Data Collection

There were a total of 73 business requirements identified by the CCAA. All 73 business requirements are listed in Appendix J. 64 were deemed in scope for the prototype sprints (listed in Appendix J). Of these 64 requirements, Vendors One and Two were able to deliver high percentages (90.9% and 93.4% respectively) of the requirements, see Figure D-7: Internet Data Collection "In-Scope" Requirements.

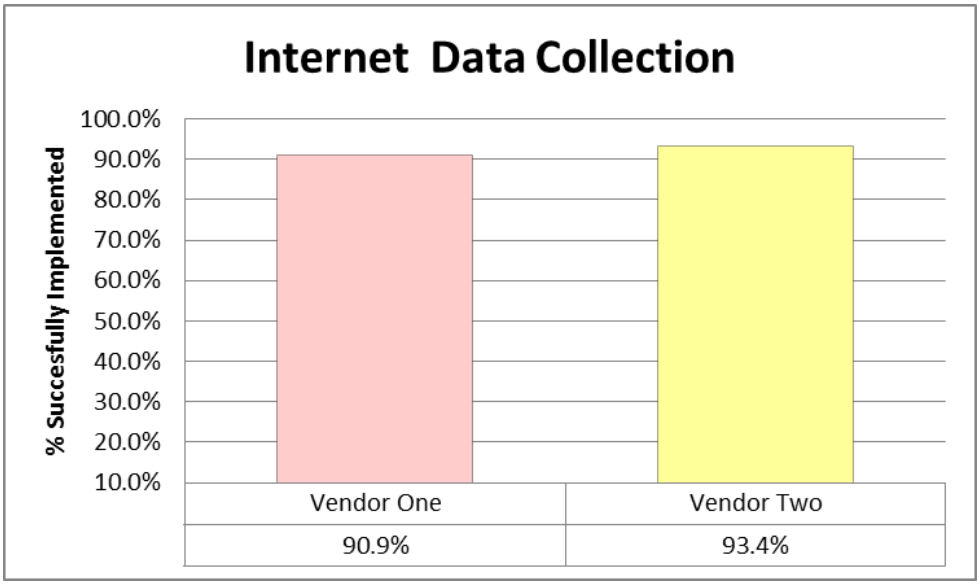


Figure D-7: Internet Data Collection "In-Scope" Requirements

For the remaining nine requirements that were deemed "out-of-scope" (listed in Appendix J), the team assessed that six could have been delivered by both vendors if enough time was allotted. There were three requirements for which the team was unable to assess the COTS platforms'

ability to deliver the requirement without any custom code, see Figure D-8: Internet Data Collection Requirement Assessment.

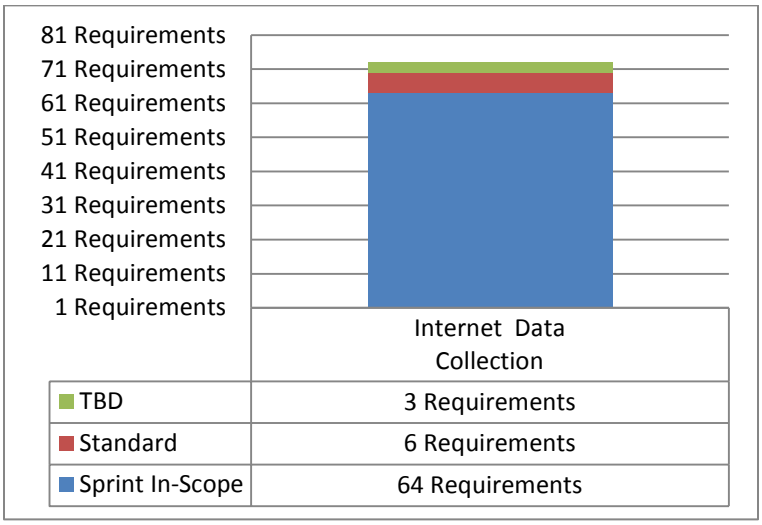


Figure D-8: Internet Data Collection Requirement Assessment

Assessment Summary

When assessing the COTS platforms' abilities to deliver the "in-scope" capabilities based on the business requirements, the iBPMS platforms scored favorably. By design, a business process platform (integrated with a business rules engine) lends itself to effectively adding user specific business processes. When looking at the overall scores for required capabilities that were in-scope and built on each platform in a 10-day sprint window the numbers for both COTS platforms are quite high, see Figure D-9: Assessment Capabilities "In-Scope" Requirements.

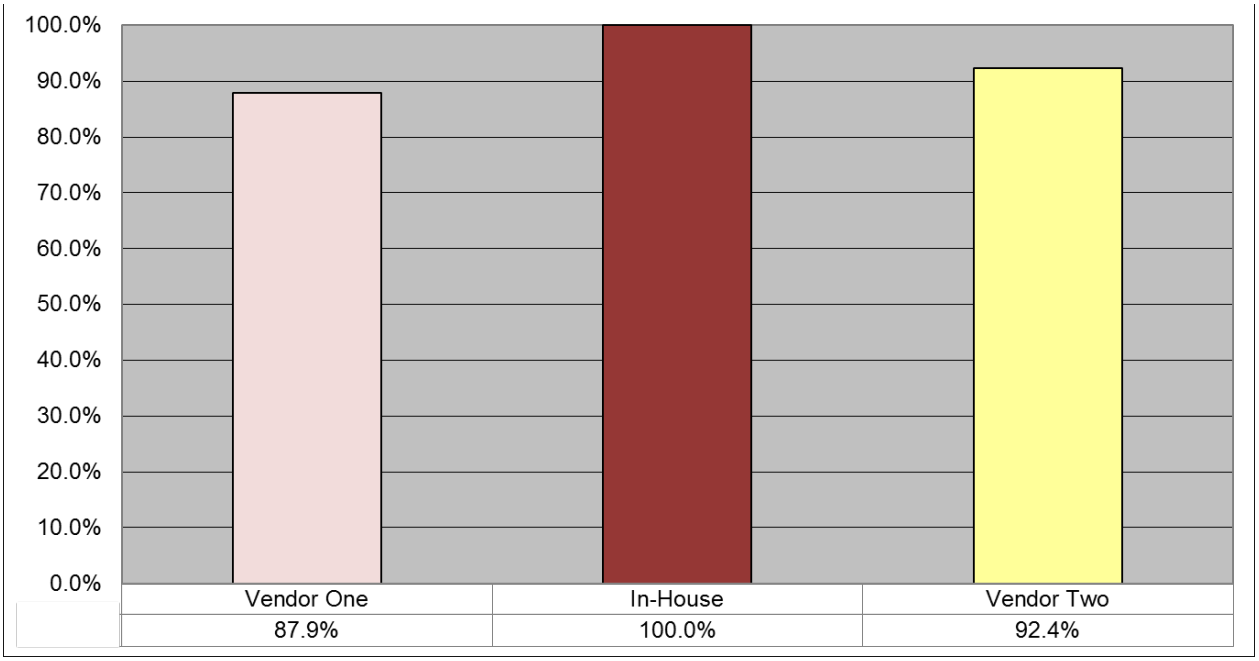
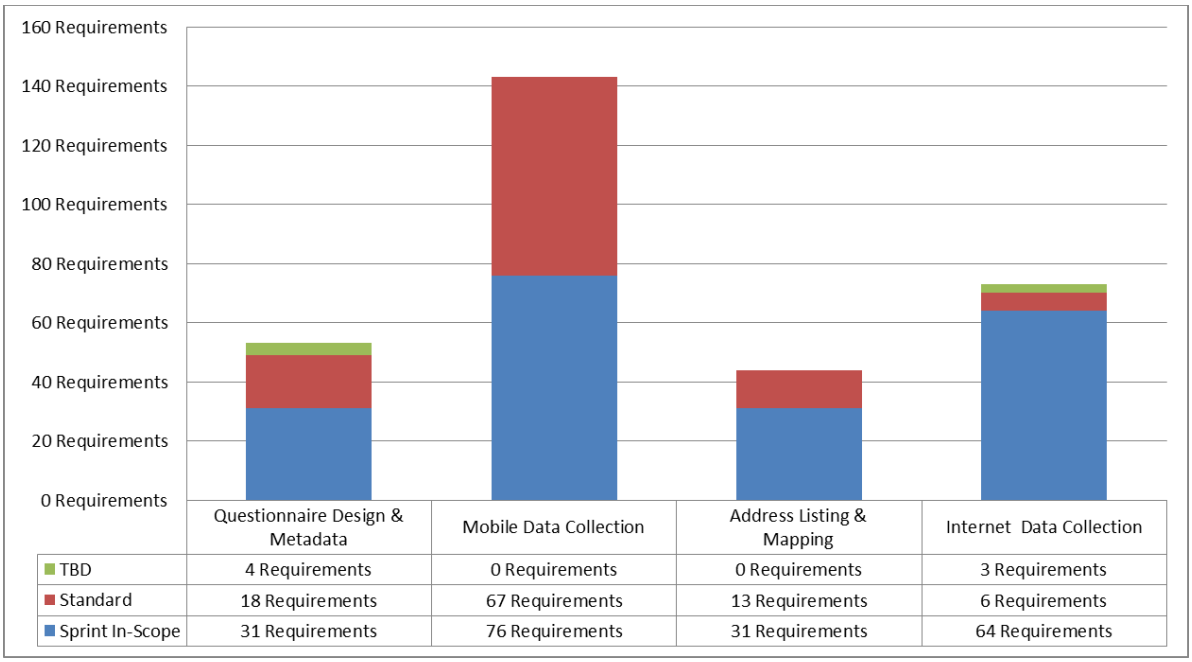


Figure D-9: Assessment Capabilities "In-Scope" Requirements

Of the requirements deemed out-of-scope for the prototype sessions, the team assessed that the majority of the requirements would be completed if the COTS vendors were provided more time than a 10-day sprint window, see Figure D-10: Capability Business Requirement Assessment.



	Questionnaire Design & Metadata	Mobile Data Collection	Address Listing & Mapping	Internet Data Collection
TBD	4 Requirements	0 Requirements	0 Requirements	3 Requirements
Standard	18 Requirements	67 Requirements	13 Requirements	6 Requirements
Sprint In-Scope	31 Requirements	76 Requirements	31 Requirements	64 Requirements

Figure D-10: Capability Business Requirement Assessment

As witnessed in the sprint demonstrations, the COTS platforms had the ability to surpass some of our business requirements. However, the in-house solutions were building to requirements provided, which were used as the evaluation point for this assessment, even if higher capabilities were achieved.

Based on a view of the overall requirements, Vendor Two would be able to meet USCB needs in mobile connected mode. The disconnected mode it would not be a viable single solution. Vendor Two outperformed Vendor One across the board, and their overall percentage score of 92.4% was the higher of the two platforms.

Appendix E – Survey & Listing Operational Control Requirements

In Scope

Survey (and Listing) Operational Control
Transmission successful, transmission unsuccessful
See in UI the launch of the instrument for each operation/survey
The solution shall manage the start, stop and restart of the systems for management of workloads and receipt of data.
The solution shall manage multiple surveys, censuses, and programs simultaneously.
The solution shall be able to manage multiple independent operations, simultaneously.
The solution shall provide the ability to manage workers workloads across multiple census/survey operations
The solution shall provide the ability to manage workforce (both individual and group members)
The solution shall provide the ability to view a field interviewer's work assignment
The solution shall provide the ability for field interviewers to manage (track, edit, complete) their assigned cases
The solution shall provide the ability to manage (control, track) workloads for field interviews
The solution shall maintain assignment type for each assignment.
The solution shall be able to receive, validate, upload and store a workload.
The solution shall be able to receive, validate, upload, and store a sample delivery
The solution shall be able to receive, validate, upload, and store workload update files for all operations.
The solution shall have the ability to ingest the "stop flag" from QC process in order to set staff not eligible in the optimizer so they will no longer receive cases.
The solution shall provide the ability to manage (control, track) workloads for field interviews
2-3 persons. 30-40 cases each. Explain how to extrapolate. Out-of-scope is a systematic solver and business rule optimization engine. This is an illustration of a route of cases in order based on key items (location, best time to contact, etc.) Vendor to illustrate how changes to these key variables change the route.
The solution shall provide the ability to plug in business rules to optimize case assignments
The solution shall provide the ability to automatically make case assignments based on pre-defined business rules
The solution shall provide the ability to create a work assignments in an optimized way to reduce the number of hours and miles driven.
The solution shall provide the ability to use route information to optimize case assignment for field interviewers.
The solution shall provide the ability to stop work based on executed business rules.
The solution shall provide the ability to order cases based on location and routes in order to optimize workload management.
Each of: real-time alert, overnight, based on events from others, and dependent data
The solution shall provide the ability to allow appropriate users to see the current set of alerts that need to be monitored and all of the progress and quality metrics reports used to derive the alerts being monitored.
Case list should include: operation name, address, status,
Map list should include: pins,
Case details should include: notes, contact attempts. Notes should be able to be updated and edited.
The solution shall provide the ability to allow appropriate users to reassign staff manually, to specify the enumerator, and/or timeframe required.
The solution shall provide the ability to allow appropriate users, based on role and field staff that are their assignees, the ability to manually assign work schedule items, such as tasks or additional items to the schedule, to their designated assignees.

Activity has already occurred on a case.
The solution shall provide the ability to view a field interviewer's work assignment
The solution shall provide the ability for field interviewers to manage (track, edit, complete) their assigned cases
The solution shall provide the capability to add, modify, and delete business rules for QC work assignments.
The QC work case must be conducted by a different staff member.
The solution shall create and assign NRFU work to appropriate personnel utilizing the following data and business rules from various sources including: 1) Field Worker Profile (including enumerator location) 2) Schedule (enumerator work schedule) 3) Geographic location (respondent location) 4) Case statuses from previous interviews 5) NRFU assignment rules 6) Re-Interview assignment rules 7) AdRec Modelling determinations of best time to contact.
The solution shall add, modify, and delete business rules for production work assignments.
The solution shall provide the ability to receive data from data the field operations.
The system shall include a GUI to display all user actions.
The system shall have the capability to audit user and system actions. From this, there will be a GUI that displays user actions, such as logins, log outs, all activities, etc. This GUI will only be visible to MOJO Admin users.
The solution shall display the approved system user notification before granting access to users.
The solution shall provide a schedule management to implement security features which regulate which users can view and edit the operations schedule.
The solution shall the ability to separate duties of roles.
The solution shall separate user functionality from system management (system administration) functionality.

Out-of- Scope

Survey (and Listing) Operational Control
Time Zones
Time and Expense collection and approval
Recruiting Activities and mobile dashboarding
Progress and Dashboarding
Messaging and emergency notification

Appendix F – Centralized Operational and Control Capability Requirements

In Scope

Centralized Operational Analysis Control
The solution shall be able to start, stop, and restart operations.
The solution shall manage the start, stop and restart of the systems for management of workloads and receipt of data.
The solution shall manage multiple surveys, censuses, and programs simultaneously.
The solution shall be able to manage multiple independent operations, simultaneously.
The solution shall be able to receive, validate, upload, and store a sample delivery file minimum of 145 million records (SDF).
The solution shall provide the capability to track the number of contacts received by a living quarter by all modes.
The solution shall provide the ability to receive sample updates, sample appends, and sample reductions.
The solution shall provide the ability to validate sample information received based on rules.
The solution shall receive the Universe Sample Delivery File.
The solution shall provide the ability to define, schedule, and manage workloads containing a collection of cases.
The solution shall provide the ability to enter the schedule through User Interface.
The solution shall execute the schedule for workload creation.
The solution shall provide the ability to enter the schedule for closeout through the User Interface.
The solution shall execute the schedule for survey closeout.
The solution shall communicate closeout complete from the modes and operational control system to customer.
The solution shall execute system closeout based on geographical areas, time zones or mode.
The solution shall provide the ability to create and route a workload (collection of cases) across data collection modes (i.e. Paper, Internet, Interview-Assisted, Telephone Interview)
The solution shall provide the ability to define a case consisting of a sample (address) and applicable data collection modes (i.e. Paper, Internet, Interview-Assisted, Telephone Interview)
The solution shall provide the ability to receive dependent data and pass only appropriate data to the appropriate mode via workloads.
The solution shall provide the ability to copy/duplicate rules, queries, and parameters for reuse by others.
The solution shall provide the ability to re-run response validations.
The solution shall create the Nonresponse Follow-up Universe of addresses designated as NRFU cases on a daily basis.
The solution shall provide the workload to Field Operational Control.
The solution shall have the ability to provide titled data securely to an external vendors.
The solution shall provide the Group Quarters Operation (GQO) workload to Field Operational Control.
The solution shall provide the ability to receive data from the modes (i.e. Paper, Internet, Interview-Assisted, Telephone Interview) for a survey/census
The solution shall provide the ability to receive and store response data, and initiate follow-up actions by invoking operational control rules.
The solution shall provide the capability to receive questionnaire responses from multiple operation types.
The solution shall update the Universe with the response data received from data capture operations.
The solution shall provide the capability to receive questionnaire responses submitted in Spanish.
The solution shall provide the capability to maintain Spanish characters submitted in questionnaire responses in their original form.

The solution shall provide the capability for business rules.
The solution shall provide the ability to define, execute, and manage business rules for operational control.
The solution shall manage business rules and data as a result of the business rules (present and historical).
The solution shall provide the ability to execute the automated and manual workflow interventions based on response data and status information.
The solution shall provide the ability to route a case to specified modes (i.e. Paper, Internet, Interview-Assisted, Telephone Interview)
The solution shall provide the ability to route a workload (collection of cases) to specified data collection modes (i.e. Paper, Internet, Interview-Assisted, Telephone Interview)
The solution shall provide a user interface for the entry of business rules by the customer.
The solution shall execute the "sufficiency edits" on data in order to close a case or re-enter it into a workload.
The solution shall perform reverse check-in on respondent questionnaires that do not meet the sufficient data checks.
The solution shall the ability to access the case management page by selecting a case in the search results grid and right clicking on a context menu item labeled "View Reporting Unit"
The solution shall provide the ability to run response validations on a list of cases, interactively, from the Case Management page.
The solution shall separate user functionality from system management (system administration) functionality.
The system shall provide a UI based Case Status Report to display the current status of all cases for a survey processing period (mode, site, number of cases per status type, current status code, description of the status code).
The system shall provide an error message in the UI if during the import/upload process if the format does not match that specified by MOCS.
The system shall provide the Sponsor with the ability to approve or disapprove the workload creation in the UI.
The system shall provide the "Mailout Approvers" a UI to review the output from workloads.
The system shall allow the Sponsor to reset the case to restart processing through the UI.
As a MOCS user, I need to be able to use the UI to update cases in a census or survey sample/universe.
The system shall allow for an export of sample delivery file errors in multiple formats (Excel, CSV, PDF, XML) or each failure at the validation level, in the UI.
The system shall allow drill down from highest level failure to SurveySponsorCaseID level in the report in UI.
The system shall create a high level report containing the total for each failure at the validation level in UI.
The system shall provide high level data containing the total cases for each sample delivery file in UI.
The system will provide file level data from the Sample File Load Process in UI.
The system shall create a validation status report for each sample file in UI.
The system shall store validation results and make them accessible from the Maestro UI.
Users shall be able to specify Operation repeat behaviors by using the Operations Detail UI and Scheduler UI.
Users shall be able to set an operations repeatability (Single occurrence vs. recurrable) using the Operations Detail UI
When a recurring operation is scheduled, the scheduler UI shall present the user with the input controls necessary to specify the repeat interval and duration of execution for the operation.
Create UI component for viewing operation and case status/tracking.
The system shall provide UI based reporting that enable survey progress and performance to be assessed.
The system shall provide the ability to provide information/ notes of why the label file creation was not approved via the UI.
Users shall have the ability to view the displayed reporting unit's by clicking on a control on the

reporting unit detail page
The system shall prepare a Survey Closeout Report that displays closeout status and timestamps
The system shall log information of the individual that passes or fails the workload and display it in a status report.

Out-of-scope

Centralized Operational Analysis Control -Out-of-scope
The solution shall provide the ability to process non-ID cases, including all interfaces.
The solution shall identify eligible Response Validation cases for Field Verification.
The solution shall provide the Quality Assurance workload to Field Operational Control for all modes.
The solution shall provide the Quality Assurance workload to Field Operational Control for all operations.
The solution shall provide the Address Canvassing workload to Field Operational Control.
The solution shall create the NON-ID Asynchronous workload.
The solution shall create the NRFU Reinterview case workload.
The solution shall provide the capability to send Asynchronous Non-ID cases to Non-ID processing for matching and geocoding.
The solution shall provide the capability to send Non-ID cases to Non-ID processing for matching and geocoding.
The solution shall identify eligible Non-ID cases for Field Verification.
The solution shall create the workload for deterministic modeling to determine contact strategy.
The solution shall create the workload for deterministic modeling to determine updated contact strategy.
The solution shall begin generation of the workload for AdRec Removals on the start date of NRFU Field operations.
The solution shall remove eligible cases from the NRFU workload based on the results of AdRec Modeling on a daily basis.
The solution shall create the workload for stop work based on edits, imputation, weighting, etc. resulting in updated contact strategies for data collection.
The solution shall provide the ability to review workloads.
The solution shall provide the ability to modify workloads.
The solution shall provide the ability to approve workloads.
The solution shall provide the ability to deliver workloads to external systems/interfaces.
The solution shall provide the ability to deliver cases to external systems/interfaces.
The solution shall provide the ability to deliver updated workloads to the external systems/interfaces.
The solution shall remove cases based on business rules in order to create updated workloads or removal of cases from workloads.
The solution shall provide the ability to automatically update workloads for active modes when sample adjustments (appends, updates, reductions) are received.
The solution shall provide the ability to switch modes for a case or set of cases.
The solution shall provide the ability to receive interventions from external sources, generate and execute mode interventions including switches, holds, stops, lifts, and propensity messaging.
The solution shall provide the ability to manage the execution of automated and manual workflow interventions based on response data and status information.
The solution shall provide the capability to set and track the status of a Reinterview case.
The solution shall provide the capability to receive results from the matching and geocoding of Non-ID cases.
The solution shall receive United States Postal Service (USPS) Intelligent Mailbarcode (IMB) data in near real time.
The IMB data should contain tracking and tracing data.
The solution shall receive data and paradata from external vendors.
The solution shall provide the capability to receive results from the matching and geocoding of Non-ID

cases.
The solution shall receive the results of deterministic modeling on a daily basis. (Administrative Records, modeling)
The solution shall provide the capability to receive Reinterview cases from the NRFU quality operation.
The solution shall provide the ability for users to define how Barcodes are to be constructed for mail out operations.
The system shall provide a review screen in the UI for Sponsor review before system applies the sample reduction updates to the database.
The system shall have a UI for the Sponsor to manually select the case(s) to set for sample reduction.
The system shall prepare a Survey Information Report via UI that displays the complete set of parameters for a survey processing period.
The system shall provide a UI for the Sponsor to query the IMB data.
The reporting unit detail page shall contain a grid which displays the current status of the case in each operation for the survey. The grid shall contain the following columns: - Operation ID - Operation Name - Current Status - Last Status Change - Operations History - Link to display the chronology of all status changes for the case within the operation The grid shall contain a row for each active operation defined for the survey For operations that have not been initialized for the case the operation ID and Operation Name Cells shall be populated but remaining cells shall be merged and contain the text "Not Initialized"
The reporting unit detail page shall contain a grid which chronicles each time the reporting unit was updated. The grid shall contain the following columns: * Update Date Time * Updated Version Number * Name of user/system that performed the change * A link that when clicked displays a gui that allows the user to compare the current version of the reporting unit's XML to the archived version of the XML.
The system shall only display queries of the Bond ID user in the dashboard.

Appendix G – Questionnaire Design & Metadata Capability Requirements

In Scope

Questionnaire Design & Metadata
The solution shall provide the ability to create documents used for approval.
The solution shall provide the ability to route census or survey content and/or metadata through a review and approval process.
Illustrate copying of questions and groups of questions as well as rollover of entire questionnaire content from Quarter to Quarter. (Instructions to questions, response categories, error messages (pop-ups within instrument), help text, soft/hard edits ("Are you sure you want to continue?"), branching)
The solution shall provide the ability to manage questions and content in a central library, or repository.
The solution shall provide the ability to store a individual question, response variable, and layout sections
The solution shall provide the ability to retrieve questions, response variables, and layout sections
The solution shall provide the ability to version control questions, response variables, and layout sections
The solution shall provide the ability to copy current version of a question, response variable, and layout section
The solution shall provide the ability to modify current version of a question, response variable, and layout section
The solution shall provide a library of data types and survey objects for the design layout (i.e. date type, time type, text, integer, pick list, drop-down box, etc.)
The solution shall provide the ability to create and manage a repository of questions, responses, and layouts (i.e. instrument).
The solution shall provide the ability to manage questions and response variables, including groups of questions and versions, for re-use across surveys.
The solution shall provide a mechanism to reuse questions across surveys
The solution shall provide the ability to allow a user to copy a survey and then modify the design and content of the new survey.
The solution shall provide the ability to maintain a central repository of all past, present, and future surveys.
The solution shall provide the ability to add tokens and fills when adding questions to the General Library, so that I can add new reusable content to the COMET General Library.
The solution shall create groups of questions within a General Library that may be used across surveys.
The solution shall provide the ability to create questions, response variables, and layout sections in multiple languages
The solution shall allow language translation (including 2-byte languages) from human translation to be entered into the system and linked to English translations for the question.
The solution shall provide the ability to define data collection details across modes and surveys/census.
The solution shall provide the ability to define the paradata to be captured for the survey instrument
The solution shall provide the ability to capture the metadata needed to data capture a paper form.
The solution shall provide the ability for users to assign modes of data collection (Paper, Internet, Interview-Assisted, Telephone Interview) to a layout.
The solution shall provide the ability for users to define modes of data collection (Paper, Internet, Interview-Assisted, Telephone Interview) for a survey/census.

The solution shall provide the ability to allow the user to add and edit survey initiation information to register and initialize a Census/Survey.
The solution shall provide the ability to rollover survey information from a previous reference period to the current reference period.
The solution shall provide the ability to allow complex rostering – for example, creating arrays of questions within arrays of people. Collect household roster information in either a person-based approach (all questions for one person at a time) or topic-based approach (one question at a time for all people).
The solution shall provide the ability to define the paradata to be captured for the survey instrument
The solution shall provide the ability to deliver data.
The solution shall provide the ability to deliver XML output of survey metadata (questions, response variable, layout) for each mode of data collection
The solution shall provide the ability to create a printable version of the layout metadata and schema in standard XML format

Out-of-scope

Questionnaire Design & Metadata - Out-of-scope
The solution shall provide the ability to retrieve a layout
The solution shall provide the ability to store a layout
The solution shall provide the ability to create a library of layouts
The solution shall provide the ability to version control a layout
The solution shall provide the ability to copy current version of a layout
The solution shall provide the ability to modify current version of a layout
The solution shall provide the ability to create metadata and schema of the layout in standard XML format
The solution shall provide the ability to design a view of the layout (e.g.,. survey design, instrument layout) via UI for paper and/or electronic mode formats
The solution shall provide the ability to create a form in the Federal Register notice format
The solution shall provide the ability to capture the metadata needed to data capture a paper form.
The solution shall provide the ability to support print functionality (including printing survey barcodes such as ‘dentils’)
The solution shall provide the ability to support print functionality (including printing survey barcodes such as ‘dentils’)
Instrument configuration management
The solution shall provide the ability to deliver XML output of survey metadata (questions, response variable, layout) for each mode of data collection
The solution shall provide the ability to export the metadata and schema of the layout
The solution shall provide the ability to preview the current layout being designed
The solution shall provide the ability to preview the current layout being designed
The solution shall provide the ability to create a printable screen capture of the layout
The solution shall provide a library of layout templates
The solution shall provide the ability to define a variety of data types and survey objects for the design layout (i.e. date type, time type, text, integer, pick list, drop-down box, etc.)
The solution shall provide the ability to navigate throughout the layout as defined by the survey designer (including use of auto-advance/skip patterns, when specified).

The solution shall provide to the ability to allow a user to copy an layout and then modify the design and content of the new layout

Appendix H – Mobile Data Collection Capability Requirements

In Scope

Mobile Data Collection
The solution shall have the ability to alert users.
The solution shall have the ability to define and display context sensitive error messages.
The solution shall provide the ability to notify enumerator that they are out of the expected geographic location.
The solutions shall provide the ability to execute on business logic
The solution shall provide the ability to define business logic to be used in field level validation.
The solution shall provide the ability to allow complex rostering – for example, creating arrays of questions within arrays of people. Collect household roster information in either a person-based approach (all questions for one person at a time) or topic-based approach (one question at a time for all people).
The solution shall provide the ability to edit instruments.
The solution shall provide the ability to update an instrument to correct certain defects/issues after data collection has already started.
The solution shall provide the ability to navigate intuitively within the instrument and among instruments in the case.
The solution shall provide the ability to allow a user to move to the next applicable question as defined by sponsor (including use of skip patterns, when specified).
The solution shall provide the ability to confirm and revise roster information
The solution shall provide the ability to allow the interviewers to return quickly to the “next question to ask” after backing up or when resuming an interview
The solution shall provide the ability to display in other languages.
The solution shall provide the ability to switch between languages at the start of and anytime within an interview or self-response questionnaire.
The solution shall provide the ability to manage data collection.
The solution shall provide the ability to allow multiple people to work on one case (e.g., for GQs - giant high-rise, soup kitchen, etc.).
The solution shall provide the ability to pick different address styles, based on location needs (e.g., PR address, RR, PO Box, Street, and physical description).
The solution shall provide the ability to injest a workload.
The solution shall provide the ability to replace an instrument to correct certain defects/issues after data collection has already started,
The solution shall provide the ability to sync data manually and automatically.
The solution shall provide the ability to transition screen-to-screen in a timely fashion.
The solution shall provide the ability to provide to integrate with a Census Bureau approved Mobile Application Manager
The solution shall provide the ability to automate updates without user intervention.
The solution shall provide the ability to allow the interviewers to display status, roster information, and other case data at any time during the interview
The solution shall automatically determine whether a proxy interview is allowed for each case in which the case status indicates that the respondent is unavailable or unable comply.
The solution shall provide the capability to collect response data during field operations.
The solution shall provide the ability to allow a user to record contact history data.
The solution shall provide the ability to allow for item level and case level remarks (notes) to be entered at any point in the interview that can be recalled and viewed.
The solution shall provide the ability to collect and send paradata.
The solution shall provide the ability to log and time stamp all application events and user actions during an interview.

The solution shall provide the ability to capture trace data
The solution shall provide the ability to render instruments and their associated media content.
The solution shall provide the ability to provide radio buttons, check boxes, and write-in boxes.
The solution shall provide the ability to allow complex fills, which is to create specialized question and/or answer text fills based on previous responses or data provided on input
The solution shall provide the ability to display Interviewer instructions near the question text. These instructions should be visually distinguished (e.g., bold, italics, color) them from the question text.
The solution shall provide the ability to securely, receive, store, and send data.
The solution shall provide the ability to require interviewers to log in, reset and maintain passwords.
The solution shall provide the ability to lock user out of application at any point.
The solution shall provide the ability to allow the user to exit the interview at any point, saving any data collected.
The solution shall provide the ability to restart the interview without the loss of no more than 1 screen of data, upon removal and replacement of the battery
The solution shall provide the ability to maintain response data while navigating forward and backwards between screens
The solution shall provide the ability to validate data.
The solution shall provide the ability to allow validations to a survey based on business logic as well as information in other fields.
The solution shall provide the flexibility to support multiple types of data validation: preventing inappropriate data being entered into the field (defensive validation); validating the data immediately upon exit of the field; and validation of the data at some predetermined event (for example, waiting to perform validation until a group of fields have been completed, or continuing to the next section of the questionnaire).
The solution shall provide the ability to allow for wireless device connectivity.
The solution shall provide the ability to allow for the instrument to be used in both connected and disconnected mode.
The solution shall provide the ability to attempt to sync after each contact attempt.
The solution shall provide the ability to attempt to sync when user logins into application.
The solution shall provide the ability to allow the user to attempt a manual sync.
The solution shall provide the capability for enumerators to receive and view NRFU work assignments.
The solution shall send verification that the NRFU enumerator successfully entered the work assignment status for each case.
The solution shall provide HU status data to Ops Control.
The solution shall create a contact record for each contact attempt.
The solution shall provide the capability for the enumerator to enter any special case statuses. Special case statuses include but are not limited to: 1) Unable to Locate 2) Does Not Exist 3) Demolished/ Burned Out 4) Non-residential 5) Uninhabitable 6) Empty Mobile Home 7) Multiunit, Missing Unit Designation 8) Restricted Access 9) Dangerous Address
The solution shall provide the capability to enter and update case notes.
The solution shall provide the capability to log additional contact information.
The solution shall provide the capability to track and update the number of contact attempts per case.
The solution shall provide the capability to schedule enumeration appointments for respondents.

The solution shall provide the ability to switch to multiple instruments within same address
The solution shall provide the ability to easily clear the instrument contents and restart an interview.
The solution shall provide the ability to restart the case.
The solution shall provide the ability for a field interviewer to see their case assignments on a mobile device (e.g., laptop, smart phone, tablet)
The solution shall provide the ability to allow for a user to use to a mobile device select a work assignment from the map or list, with associated information displayed for the assignment and the ability for the user to update this information
The solution shall provide the ability to use a mobile device to view work assignments in a list order.
The solution shall provide the ability to use a mobile device to manage individual case assignments across multiple census/survey operations
The solution shall provide the ability to use a mobile device to receive individual case assignments
The solution shall provide the ability to use a mobile device to collect case data from instrument application
The solution shall provide the ability to allow for numerous operations, running independently.
The solution shall provide the ability to close out a field survey data collection operation.
The solution shall provide the ability to use a mobile device to manage individual case assignments across multiple census/survey operations
The solution shall provide the ability to create and store notes.
The solution shall delete title data from the device following response submission and confirmation from OCS.
The solution shall provide the ability to wipe response data (with the exception of contact history) from device after confirmation from MOJO that MOJO has received previously sent response data.
The solution shall provide the ability to store case response data during data collection for a specific case.
The solution shall provide the ability to pull data (MOJO commands and work assignments) from server with each successful sync attempt.
The solution shall allow an option for Field Workers to enumerate via the phone.

Out-of-Scope

Mobile Data Collection
The solution shall provide the ability to allow for GPS-enabled capabilities.
The solution shall provide the ability to navigate to a specific geographic location.
The solution shall provide the ability to allow for map movement with a static indicator .
The solution shall provide the ability to open a case from within the map (highlight the case on the map, and the case will be highlighted on the list).
The solution shall provide the ability to allow clustering of units in balloon on the map for MUs.
The solution shall provide the capability to view assignments and status as points on a map.
The solution shall provide the ability to locate the device.
The solution shall provide the ability to adhere to hardware requirements.
The solution shall not consume more than 10% of CPU recourses on average for any 5 minute interval
The solution shall not consume more than 20% of RAM resources on average for any 5 minute interval
The solution professional services team shall provide baseline metrics for RAM and CPU usage during development
The solution shall provide the ability to support multiple interviewer navigation methods to provide flexibility while interviewing, including skipping to different sections of the interview.
The solution shall provide the ability to interface with other systems.
The solution shall provide the ability to receive content updates from the Content Metadata system after initial instrument creation and apply the updates to the instrument.

The solution shall provide the capability of reading Quick Response Codes and barcodes to prepopulate certain fields on the questionnaire.
The solution shall provide the ability to render instruments in multiple languages.
The solution shall provide the ability to take pictures of receipts and attach to an enumerators payroll.
The solution shall provide the ability to interface with the Content Metadata system to provide screen captures of all instrument pages for Office of Management and Budget package approval. .
The solution shall provide the ability to ingest lists containing hundreds to thousands of entries for use as pick-lists or validation in survey fields.
The solution shall provide the ability to provide a crash log for application send notification to HQ
The solution shall provide the ability to allow the interviewers to jump directly to a question with an item level note or a nonresponse (i.e., DK or REF).
The solution shall provide the ability to allow interviewers to freely navigate through questions – without enforcing field level validation until they are ready to complete the section.
The solution shall provide the ability to flag for removal.
The solution shall provide the ability to provide case ID's.
The solution shall provide the ability to provide panels within the survey.
The solution shall provide the ability to generate paper ID for GQs (e.g., respondents do not want to provide answers directly to device and prefer a paper questionnaire).
The solution shall provide the ability to combine individual cases to create GQ case.
The solution shall provide the ability to create a temporary ID and an ad-hoc case that interface with case management.
The solution shall allow for the near real time transfer of data.
The solution shall provide the ability to allow listing tables (couple thousand) – with complex edit checks, for listing large amounts of data (e.g., permit information)
The solution shall provide the ability to operate on multiple hardware and software systems.
The solution shall provide the ability to allow for desktop support for testing.
The solution shall provide the ability to run on multiple operating systems.
The solution shall provide the ability to record parts of the conversation between the interviewer and the respondent, associate it with a specific interview and question, and capture screen shots of responses entered.
The solution shall provide the ability to allow users to add general text notes to a field interviewer's schedule
The solution shall provide the ability to display images and play videos for the respondents to help collect accurate information.
The solution shall provide the ability to play sound files to respondents so that they can “self-respond” to sensitive questions that they may not want to discuss with an interviewer.
The solution shall provide the ability to render on a screen size no smaller than iPhone 6S and Samsung S6.
The solution shall provide the ability to randomize the answer choice list to help reduce any bias of first answer always being selected.
The solution shall provide the ability to randomize the order of questions/question-blocks asked to help get sufficient responses for questions.
The solution shall provide the ability to allow users to accurately and securely capture respondent data via electronic means (i.e. biomarkers, blood pressure, fingerprints, pulse, temperature).
The solution shall provide the ability to support prevention of early interviewing – don’t allow FR to open case before the start of the interview period (e.g., 1st of the month)
The solution shall provide the ability to verify and remove Title 13 data in XX amount of time.
The solution shall provide the ability to secure data in-flight and at rest.
The solution shall provide the ability to support special storage instruction – to help with post data processing (for example, the same information may be captured in multiple places of the instrument, based on interview path, then stored into one post processing variable).

The solution shall provide the ability to allow the interviewer to change respondents at any point in the interview without loss of previous collected information, so previous respondent's interview can be resumed later.
The solution shall provide the capability to provide data and functionality in "training mode" for enumerator training.
The solution shall provide the ability to support instrument validation and debugging capabilities for researching and solving production issues.
The solution shall provide the ability to execute a phone call and access the instrument at the same time.
The solution shall provide the ability to attempt to sync after user has attested their timesheet.
The solution shall provide the ability to attempt to sync after work availability has been updated.
The solution shall provide the ability to manage a mobile employee workforce.
The solution shall receive field worker availability via the mobile device application.
The solution shall electronically collect employee T&E through the mobile device application.
The solution shall allow entry/edit of employee T&E.
The solution shall provide the capability to receive emergency notifications from partnership staff.
The solution shall provide the capability for partnership staff to receive emergency notifications.
The business shall perform Reinterview activities in order to monitor staff performance.
The solution shall provide the capability for enumerator to enter the current work assignment status.
The solution shall provide the capability to perform supervisory reviews for all eligible cases.
The solution shall provide the ability to execute business rules.
The solution shall provide the ability for a field interviewer to see their case assignments on a mobile device (e.g. laptop, smart phone, tablet)
The solution shall provide the ability to allow for a user to use to a mobile device select a work assignment from the map or list, with associated information displayed for the assignment and the ability for the user to update this information
The solution shall provide the ability to toggle between language translations.
The solution shall provide the capability to send emergency notifications from field staff.
The solution shall provide the capability for field staff to receive emergency notifications.
The solution shall provide the capability to capture and submit time and expense data for all personnel.

Appendix I – Address Listing & Mapping Capability Requirements

In Scope

Address Listing & Mapping
The solution shall provide the ability to provide alerts about data collection elements and as well as disruptions in service.
The solution shall indicate/ID that features are missing e.g., A road and features
The solution shall provide the ability to collect, send, and store data and paradata.
The solution shall provide the ability to generate and store work assignment paradata, specifically data about the collection process, e.g., how long it takes between cases, how long it takes between screens, etc.
The solution shall collect and send paradata to enterprise paradata repository.
The solution shall ensure image compression/decompression follows industry standards when displaying visual map data.
The solution shall provide the capability to back-up all data received every 12 hours.
The solution shall provide the ability to enable field representatives to collect data that allows for updates to the spatial features of the TIGER database, e.g., to add new roads, to mark roads for deletion, and to name/rename roads.
The solution shall provide the ability to collect (verify and recommend to add, update, or delete) address data in order to have an update-to-date address listing.
The solution shall output data as specified by customer.
The solution shall send final In-Field Canvassing updates (address and spatial data) to operational control system.
The solution shall send all raw Production Data, raw QC Data, and raw Reconciled QC Data to operational control system.
The solution shall capture street and feature name updates.
The solution shall submit production assignment results to operational control system.
The solution shall capture street and feature name updates for QC assignment.
The solution shall provide the ability to manage workload assignments.
The solution shall provide the capability to add, modify, delete, or verify the addresses and MAF Structure Points (MSP) for the production assignment.
The solution shall provide the capability to status the production assignment as complete.
The solution shall provide the capability to add, modify, delete, or verify the addresses and MAF Structure Points (MSP) for the QC assignment.
The solution shall provide the capability to status the QC assignment as complete.
The solution shall conduct a full recanvas of the QC assignment when the QC sample does not meet pass criteria.
The solution shall provide the ability to allow for mapping and location functionality during data collection.
The solution shall include Global Positioning System/Global Navigation Satellite System (GPS/GNSS) functionality.
The solution shall manual mapspot and collect coordinate data to Geocode the address and fulfill GEO's requirements
The solution shall provide the ability to operate when GPS/GNSS functionality is unavailable.
The solution shall require the use of GPS/GNSS technology to collect map spots (H) when it is available.
The solution shall provide the ability to display geographic areas on the a map.
The solution shall provide the ability to be able to capture location paradata/ metadata from GPS/GNSS.
The solution will provide the ability to search for specific map features, including addresses, zip codes, and cities, with the resulting information displayed to the user in a map
The solution will provide a mapping interface, with tools available that allow a user to navigate within the map and turn on/off map layers
The solution will provide the ability for the map to display map information symbolized by work activity status, which will be automatically updated after a user completes an activity

Out-of-Scope

Address Listing & Mapping
The image compression/decompression follows industry standards.
The solution shall provide the ability to interface with external and internal systems.
The solution shall receive in batch mode the MAF Extract and reference files consisting of up to 200 million addresses and associated data.
The solution shall require the use of GPS/GNSS technology to collect roads (L) when it is available.
The business shall request adherence to Census Bureau and other applicable Security policies, including policies associated with Approved ISA's, Title 13, Title 26 & PII.
The solution shall provide the ability to adhere to Census usability and uptime requirements.
The solution shall provide subsecond transition in swipe to swipe screens.
The solution shall be available 8 AM to 11 PM EST to accommodate Address Canvassing processing activities.
The solution shall be available 99.9 % of the time during operational hours.
The business shall request the capability to meet Address Canvassing performance standards.
The business shall request the capability to ensure that Address Canvassing services can recover and continue should a incident occur.
The solution shall recover from an outage within one hour.
The solution shall provide the capability to continuously monitor Address Canvassing Test applications 24/7.

Appendix J – Internet Data Collection Capability Requirements

In Scope

Internet Data Collection
First six questions for Decennial instrument -- Languages: English, Spanish (incl special characters), Korean, Chinese (Simplified), Russian, and Arabic (Readable right to left)
First 6 questions agreed upon - Race write-in, name field, address field, DOB, sex, relationship
The solution shall provide the ability to provide a dashboard for respondent data entry.
As a Respondent, I need to be able to access the dashboard once successfully logged in and be presented with a selection of Navigation choices for me to respond to.
As a Respondent, accessing the dashboard after I have provided information about the people in the household, I need to be presented with Navigation selections allowing me to provide information on each Person.
As a Respondent, accessing the dashboard, I need to be able to review my current responses and determine the current status of the responses to the full set of survey items for the survey.
The system shall allow access to the dashboard, I need to be presented with a Navigation selection allowing me to provide Household information.
As a Respondent, I need to be able to identify remaining work to be done via form status indicators that display on the dashboard that update after initial responses are provided and on subsequent login sessions.
Help content from developed from Sprint 1 to be pulled into instrument
The solution shall provide the ability to issue alerts, errors, and help information.
As a Respondent, while completing an available survey form, I need to be able to access relevant help information without losing my place within the current survey response window.
The solution shall provide the ability to issue warnings to the respondent in the instrument during data collection.
The solution shall provide the ability to issue errors to the respondent in the instrument during data collection.
The solution shall provide the warning to the respondent in two different iterations provided by customer prior to allowing them to continue on in the data collection process.
The solution shall provide the ability to issue errors to the respondent in the instrument during data collection as well as corrective action required.
The solution shall have the ability to collect and store data.
The solution must validate Census ID on log-in.
The solution shall not allow a respondent to access the instrument once a response has been submitted.
The solution shall track screen data on where the respondent is within the instrument during data collection.
The solution shall allow the respondent to start, stop and leave the instrument to continue data collection until submission.
The solution shall allow respondent the ability for the respondent to start where they left off in previous session.
The solution shall not allow the user to see already submitted data (dependent on customer business rules)..
The solution shall allow for storage of on the client side during active data collection until log out of session (voluntary or mandatory) or submission.
As a Respondent, I need to be presented with an interactive set of response screens which guide me through the response process in order to allow me to complete the entry of required content requested by survey.
The solution shall provide the capability to validate the respondent's decennial census questionnaire entries.
The solution shall implement hard and soft edits as defined by survey customer.
The solution shall implement edits based on previously provided data in session

The solution shall provide the capability to store the respondent's internet Decennial census questionnaire responses.
The solution shall keep original data, as reported in original language.
The solution shall provide the capability to capture paradata about respondent's internet instrument entries and actions and output.
The solution shall provide that if there is a partial unsubmitted response, the response lives within the internet instrument as well as the operational control system for response processing.
The solution shall provide the capability for a respondent to save an incomplete internet response without submitting for final processing.
The solution shall provide the ability to track the partial responses not yet submitted, but given to the OCS, the continued responses of the respondent in the partial instrument and stacking of all data for each change.
The solution shall provide the capability for a respondent to retrieve the latest incomplete, not submitted internet response.
The solution shall provide the capability for a respondent to submit an incomplete internet response.
The solution shall provide the ability for a valid ID to do an incomplete submission
The solution shall provide the capability to capture response data during agent-assisted phone calls.
The solution shall provide the capability for internal census users to collect data from respondents
The solution shall provide the capability for Live Agents to modify unsubmitted responses providing respondents can supply their identification credentials (questionnaire not yet submitted).We agreed that the requirement here is that only one person can control the instrument in the circumstance of an unsubmitted case. (Example, Live Agent can be in instrument but not respondent.
The solution shall provide the ability to maintain respondent preference for supported language upon re-entry to the instrument.
The solution shall provide the capability to automatically save the internet questionnaire entries on a screen by screen progression.
The solution shall collect web analytics for Decennial Census Internet Self-Response.
The solution shall provide the capability to maintain Spanish characters submitted via Internet Self Response in their original form.
The solution shall provide the ability to capture special characters.
The solution shall provide the ability to pass special characters to include: emojis, links, foreign language special characters and pass in output.
The solution shall receive questionnaires from Internet Self Response submitted in languages other than English or Spanish for translation.
The solution shall provide the ability to adhere to Census security standards.
The solution shall end a user session if the respondent does not navigate between pages in XX minutes.
As a Respondent, I need to be informed of the need to exit my web browser for security purposes once I have logged out of the Survey Response web site.
The solution shall accept passwords with alphanumeric characters and length consistent with Census Policy.
As a Respondent, I need to be presented with a timeout warning pop-up prior to timeout occurring to allow me to acknowledge and continue my login session.
The solution shall be able to uniquely identify internal Census users.
The solution shall only allow 1 user in the system at a time to provide data.
The solution shall provide the capability for a respondent to access the internet instrument via the Census website.
The solution shall display the Decennial census questionnaire as specified in content and metadata repository and Language Services.
The solution shall allow for input flags to determine screen or versions of the same screen received by respondent.

The solution shall create the layouts from the metadata stored in the content and metadata repository.
The solution shall create the help text from the metadata stored in the content and metadata repository.
The solution shall provide the ability to render the survey instrument.
The solution shall be able to execute customer business rules
The solution shall provide for execution of customer business rules for an incomplete internet response acceptance. These are included in the PRIMUS specification.
The solution shall provide the ability to manage data collection.
The solution shall begin collecting internet responses at start date of data collection.
The solution shall provide the capability for Live Agents to retrieve a respondent's questionnaire data using a respondent provided pin number (questionnaire not yet submitted). We agreed that the requirement here is that only one person can control the instrument in the circumstance of an unsubmitted case. (Example, Live Agent can be in instrument but not respondent.

Out-of-scope

Internet Data Collection - Out-of-scope
Address standardization with inclusion of map requirements for respondent to place pin on map.
Spawn of new case ID for demo, decennial, or econ.
Spawn of new case ID for demo, decennial, or econ which includes the management of data for previous as well as new case ID.
Subcycle for validation and verification of ID and Non-ID cases
Interface with other systems
Live chat
Collection and flagging of an image as part of a response
Ability to support 2M concurrent users
Multi-structure spreadsheets

Appendix K – Maintainability

Maintainability	Vendor One	In-House	Vendor Two
Percentage of Overall Criteria 8%			
Evaluate system design to determine if there are well-defined layers, modules, or areas of concern, that clearly delineate the system's UI, business processes, and data access functionality. Look to see how teams addressed cross-layer dependencies did they use abstractions (such as abstract classes or interfaces) rather than concrete classes, and minimize dependencies between components and layers.	3	2.67	3
How are changes to use cases, business processes, and business rules managed? Is the solution built upon a configurable workflow management framework that supports interoperability with business rules engines (BREs), event stream processors (ESP), business activity monitoring (BAM) components, and other capabilities to provide a configurable and extensible ecosystem of capabilities?	3	1.67	4
Evaluate the applications use of troubleshooting tools (e.g., code to create a snapshot of the system's state to use for troubleshooting; custom instrumentation that can be enabled to provide detailed operational and functional reports; use of logging and auditing information for maintenance and debugging, such as request details or module outputs and calls to other systems and services; use of common components to provide tracing support in code; or use of Aspect Oriented Programming (AOP) techniques or dependency injection).	4	2.33	4
Evaluate the quality of the system documentation for communicating the overall structure of the system, interoperability, data flows and critical performance parameters, as well as the patch and upgrade process.	3	3	3

Appendix L – Portability

Portability	Vendor One	In-House	Vendor Two
Percentage of Overall Criteria 8%			
Platform agnostic - What specific operating systems (e.g., Windows, Mac OS, and Unix/), database platforms, and mobile where applicable (e.g., Window Mobile, Android, and IOS) has the solution been documented to run on, and what level of credibility exist to validate (e.g., independent assessment, user documentation, whitepaper, reference user).	3	2.33	3
Cross-Browser Compatibility (where applicable) What are the numbers of browsers that the solution's UI is certified to run on, and what level of testing has occurred to validate?	3	2.33	3

Appendix M – Availability/Dependability

Availability/Dependability	Vendor One	In-House	Vendor Two
Percentage of Overall Criteria 21%			
How and where does the solution take into account clustering and redundancy features within the current architecture (e.g., Load Balancing for Web servers, application clustering, use of a RAID mechanism). Are there any single-points of failure identified in the design relevant to DB design, presentation, and business logic?	3	3	3
Examine the system architecture to determine if there are design cues that complicate and/or restrict the solution's architecture from being deployed using dynamic failover with geographically dispersed redundant sites.	3	3	3
How is the system designed to be resilient in order to prevent, detect, and recover from both system and malicious faults? (We are interested in the Solution Design per se, i.e. not the external IDS and IPS devices).	3	3	3
To minimize the downtime related to updates (e.g., configuration changes, security patches, release upgrades, bug fixes) how is the application designed for run-time upgrades (e.g., is there redundancy and component replication that allows for partial takedown versus complete shutdown)?	3	2.67	3
Examine how the application addresses network faults and unreliable network connections (e.g., are the clients designed to provide full functionality in disconnected mode or with occasionally-connected capabilities).	1	2.67	3
Evaluate the design to determine if there are any restrictions and/or enhancements within the application that would support and/or restrict how the Census would incorporate end to end monitoring .	3	3.33	4
Within the solution's current documentation (e.g., testing documentation, design documentation, whitepapers, etc.) what metrics exist to display how the solution has addressed availability and are there any delimiting factors to prevent if from being available 24x7 with proper maintenance windows?	3	2	3
How extensive is the testing of the system's code? Has the code been tested over multiple major releases? Has the system undergone unit testing, integration testing, and regression testing? Is the code tested by a testing group separate and independent from the development team? Are the same levels of testing performed for minor and major releases of the system? What documentation exist to support.	4	2.67	4
Evaluate the scalability approach, what considerations relative to the design layers and tiers for scalability were taken into account, and how do they affect the system's capability to scale both horizontally and vertically at the application and/or database layer when required (e.g., did they consider to locate logical layers on the same physical tier to reduce the number of servers required while maximizing load sharing and failover capabilities; did they consider partitioning data across more than one database server to maximize scale-up opportunities and allow flexible location of data subsets; did they avoid stateful components and subsystems where possible to reduce server affinity).	3	2.67	3

Appendix N – Performance

Performance	Vendor One	In-House	Vendor Two
Percentage of Overall Criteria 20%			
What is the documented breadth and depth of performance tests, load tests, and stress tests conducted for comparable deployment types targeted in this evaluation.	3	1.67	4
Evaluate the database server processing approach and Database Transaction profile to ensure the system chooses effective types of transactions, locks, threading, and queuing approaches (e.g., use of efficient queries to minimize performance impact, avoidance of fetching all of the data when only a portion is displayed or needed).	3	3	3
Evaluate the application's documented performance metrics relative to key performance indicators (e.g., average CPU, disk and memory utilization) and compare the quality and validity of the documentation (i.e. independent test metrics, whitepaper, etc.)	2	2	4
Evaluate the existence and maturity of a system health model to monitor system activity and performance, as well as provide diagnostic information. Does the model leverage instrumentation to monitor system states and properties of the system, and expose the changes and underlying data via standard toolsets (e.g., event logs, trace files, etc.), to provide sufficient information for system maintenance?	3	1.67	4

Appendix O – Security

Security	Vendor One	In-House	Vendor Two
Percentage of Overall Criteria 16%			
Does the application address code-based malicious attacks (e.g., SQL injection and cross-site scripting; address data tampering, Denial of Service (DoS), including DDoS (Distributed Denial of Service) attacks)?	3	3	3
Examine how the application addresses and prevents access to, or exposure of sensitive system and application information (i.e., audits and logs all user system interaction.) To what degree does the solution adhere to secure coding and testing practices (i.e. identified coding standards, static code vulnerability scanning tools, etc.)	3	3	3
What type of security measures are in place to provide data protection (e.g., in-flight, at rest, and end-to-end (i.e., web application server))	3	3	3
What is the solution practice for detecting security vulnerabilities and providing/deploying security related patches and Service Packs.	3	3	3
Evaluate all security related documentation relative to implementation of documented security measures, security postures, and security access control models including data related to their security monitoring and reporting mechanisms; compare the quality and validity of the documentation (i.e., independent test metrics, whitepaper, etc.)	3	3	3
Review the solution Security Assessment and the overall scope of the assessment relative to Census performed assessments. Assess the typical threat scenarios used as part of the assessment and relevant accreditations where applicable Are there any restrictions preventing the use of Census Bureau enterprise technology (e.g., active directory) and/or prevents ability to pass Census Bureau Security Assessment process?	3	3	3

Appendix P – Integrability/Interoperability

Integrability/Interoperability	Vendor One	In-House	Vendor Two
Percentage of Overall Criteria 9%			
Assess how the overall design uses and follows open architecture standards to promote interoperability (i.e. web API, RESTFul, SOAP) of the overall solution. To what level does the system incorporate the use of fully defined and independent grain service components, allowing for component reuse without the use of the full solution?	3	2	4
Within the solution's current documentation (e.g., testing documentation, design documentation, whitepapers, etc.) what information is captured to display how the solution has addressed interoperability from a best-practices perspective? Does the architecture documentation clearly define the use of open standards, adapters, web API, and related services that align with the Bureaus API policy allowing for ease of integration with bureau enterprise systems and full access to the collected stored data.	3	2.67	4
Examine the structure of the application when communication must cross process or tier boundaries; is it using coarse-grained interfaces that require the minimum number of calls (preferably just one) to execute a specific task and using asynchronous communication to reduce wait times?	1	3	3

Appendix Q – Scalability/Elasticity

Scalability/Elasticity	Vendor One	In-House	Vendor Two
Percentage of Overall Criteria 15%			
Evaluate the documented scalability metrics and/or tests provided by the application team.	3	2	4
Examine how and/or if the application is designed to handle spikes in traffic and load (e.g., implementation of code that uses additional or alternative systems when it detects a predefined service load or a number of pending requests to an existing system).	3	2	3
Should and does the application implement queuing type store-and-forward or cached message-based component-base communication that allow requests to be stored when the target component/system is unavailable, and replayed when it is online allowing the application design to handle unreliable external systems, failed communications, and failed transactions. This also allows for component-base maintenance.	2	3	3
What design and/or architectural dependencies, which complicates its ability to be hosted or that would prevent/limit its ability to be fully serviced in IaaS/PaaS offering (i.e. specific DB and/or middleware dependencies), and has your application been deployed in such an architecture?	4	2	4

Appendix R – Testability

Testability	Vendor One	In-House	Vendor Two
Percentage of Overall Criteria 6%			
What rigor applies to system development in your platform solution and the configured system (i.e. Census specific) ? e.g., When the platform was being developed, was it designed to facilitate the construction of test cases? Was the system modular in design, did the development environment support the creation of input to the tests and analysis of output from the tests, and were the system components capable of being tested in isolation and in full regression tests? Has the system comprising your proposed solution been designed in such a way as to facilitate the testing of systems configured by customers of your product? Have the configurable capabilities of your platform solution been tested in combination with one another?	4	3	4
What is the team's development test strategy, and has it been fully implemented including customer specific configuration? What is the quality of the test plan - does testing occur in the development life cycle that can be tied to the test plan, are mock objects and other synthetic test data used during testing, and are simple structured test solutions constructed for testing?	3	3	3
Has the proposed solution's system been evaluated by tools designed to check conformance to coding standards? What were the results?	3	3	3
Does the system make use of one or more automated testing tools or suites designed to evaluate the amount of code covered by testing (code coverage)? Is the automated testing tool used internally to test the code of the core system? Is the automated testing tool used to test configured solutions built on top of the core system? Is the configured development automated testing performed internally, externally, or both? Are the automated tests designed to address changes in the tool/suite?	3	3	3
What is the quality and level of test cases/scripts and what are the minimum and maximum test coverage levels that have been met?	3	2.67	3
Is continuous integration supported – are tests automatically performed whenever the source code changes? If not, when are the tests performed on the source code - major release, minor release, et cetera? What is the level of documentation available to support this?	4	1.67	4

Appendix S – Schedule

Schedule Impact	Vendor One	In-House	Vendor Two
Percentage of Overall Criteria 50%			
Are there any impediments specific to the software or hardware that can delay the deployment into the current Census production environment (e.g., procurement process, SWG approval process, ATO approval)?	3	3	3
Are there any advantages specific to the software or hardware that can speed up the solution deployment (e.g., SaaS, IaaS, PaaS)?	4	3	4
Describe the team's ability to respond to "volatility" (i.e., unstable resource demands), as it relates to the team's ability to quickly adapt to decisions relative to changes in resource needs.	4	2	4
How does your team's development methodology address late changes in business, design & architecture requirements?	2	2.67	3
What is the level of established development processes as it relates to test and environment migration/propagation and how does the solution take advantage of these process to speed up development? (e.g., documented configuration and release notes, automated unit testing framework, use of static code analyzer)	3	2	3
What is the level of effort based on your development style (e.g., coding, configuration) required to deploy the 2017 Decennial Test functional requirements relative to the current functionality that exists and the additional functionality needed?	3	3	3

Schedule Management	Vendor One	In-House	Vendor Two
Percentage of Overall Criteria 50%			
Evaluate the Integrated Master Schedule at the capability level to deliver the 2017 Census Test solution (includes development tasks, procurement tasks and tasks of any other relevant Census functional organizations; include resourcing)?	2	2.33	2
Historical implementation schedule data (e.g. ability to meet target deployment schedule)	2	2	3

Appendix T – Vendor/Development Team Viability

Vendor/Development Team Viability	Vendor One	In-House	Vendor Two
Percentage of Overall Criteria 50%			
What will be the overall support model as it relates to new development versus O&M support?	4	2	4
What is/will be the structure of the development team, and the experience of key IT Team personnel supporting this effort? What is it's history? What is impact if key personnel departed.	3	1	3
Operations & Maintenance (O&M) Support History (e.g., responsiveness)	4	3	4

Solution/Component Viability	Vendor One	In-House	Vendor Two
Percentage of Overall Criteria 50%			
Documentation maturity (i.e., Solution design, development, O&M, Support)	4	3	4
Solution maturity (e.g., years in IT market)	3	1.33	4