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Laptop Computers for Accuracy and Coverage Evaluation System Requirements Study

FINAL REPORT

This evaluation study reports the results of research and analysis undertaken by the U.S. Census Bureau. It is part of a broad program, the Census 2000 Testing, Experimentation, and Evaluation (TXE) Program, designed to assess Census 2000 and to inform 2010 Census planning. Findings from the Census 2000 TXE Program reports are integrated into topic reports that provide context and background for broader interpretation of results.

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PREFACE

Purpose of the System Requirements Study

The main objective of the System Requirements Study is to assess the efficacy of the requirements definition processes that were employed by the U.S. Census Bureau during the planning stages of the Census 2000 automated systems. Accordingly, the report's main focus is on the effectiveness of requirements methodologies, including processes for coordination, communication, and documentation, and their impact on overall system functionality. The report also addresses certain contract management issues and their effect on system development and/or operational considerations.

The System Requirements Study synthesizes the results from numerous interviews with a range of personnel--both U.S. Census Bureau staff and contractors--who were involved with the planning, development, operations, or management of Census 2000 systems. Our findings and recommendations in this report are qualitative in nature; they are based on the varied opinions and insights of those personnel who were interviewed. The intent is to use the results from this study to inform planning for similar future systems.

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EXECUTIVE SUMMARY

The use of laptop computers to collect respondent data was perceived as a highly successful platform for the Person Interview phase of the Accuracy and Coverage Evaluation program. A laptop-based automated questionnaire was used by interviewers to conduct personal and telephone interviews to assist with the determination of coverage error. In addition, laptops served as a platform for a case management system and provided remote mail services. This study presents information based on debriefings with personnel involved with the Laptops for Accuracy Coverage and Evaluation program.

There were two automated instruments for Computer Assisted Person Interviewing for Accuracy Coverage and Evaluation -- one for the Person Interview operation and another for the Person Interview Quality Assurance operation. The latter was used to confirm that the individual conducting the Person Interview had actually contacted the original respondent. For cases when the respondent had not been contacted, the Person Interview Quality Assurance instrument contained a complete version of the Person Interview thereby enabling the interviewer to collect the necessary information.

The U.S. Census Bureau built upon its experience base for using laptop computers for survey data collection that extended back as far as 1992. The laptop program for Census 2000 effectively utilized a customized version of an existing questionnaire authoring software package to develop the questionnaire for the Accuracy and Coverage Evaluation program. The laptops provided a hardware platform for a logic-based instrument that guided the interviewer through the data collection process. Interviewers liked using the laptop. A side benefit of the laptops was that they lent a professional appearance to the interviewers that may well have served to reduce concerns over the release of personal data by interviewees. Major results of the study include:

- **Extensive logistical support.** There were daunting logistical and support issues related to using laptops with automated survey instruments for data collection. Nevertheless, the U.S. Census Bureau opted to use them as the platform for the Accuracy and Coverage Evaluation data collection operations. Many of those issues were formidable. For example, Census had to acquire, configure and deploy over 9,000 laptops nationwide. Once deployed, there were major accountability, training, and maintenance issues. In spite of the costs and problems posed by these issues, the U.S. Census Bureau's decision to use the laptops proved to be a good one.

- **Right platform for the job.** The laptops were a very effective tool and perceived as the right platform for the job in that they greatly facilitated case management, accelerated the data collection process, and improved data quality. One unique facet of the laptop program was its ability to exchange data with Headquarters and Regional Offices via a remote dial-in telecommunications session. This method was very fast, secure, and reliable.

- **Off path data.** Off path data are generated when an interviewer needs to "back-up" to make a correction to the data entered. This action, in some cases, necessitates a shift into another logic "path" pertaining to the correct response. Off path data were identified as a requirement in the planning phase; the Computer Assisted Survey Execution Software software is designed to either globally keep off path data or to ignore it entirely. Off path data are important because these data are not always incorrect; instead, the data may be from a legitimate interview. Procedures to distinguish between the data that the U.S. Census Bureau wanted to keep and those data that were not important were established. However, these procedures were not correctly implemented. Since all off path data were captured, the U.S. Census Bureau is able to perform post-census processing edits to restore any missing values.

These and other findings have led to the following key recommendations:

- **Project planning - begin development early.** Development efforts must be initiated early enough so that fully tested, robust systems are available for Dress Rehearsal. Although requirements may change from the lessons learned in Dress Rehearsal and from external forces (e.g., Congress), there would be a higher chance that all requirements would be identified and implemented.

- **Laptop vendor - consider full and open competition.** An open competition among vendors may require substantial time and effort in the short run; however, the competitive process usually serves to mitigate risks in the long run by assuring that the vendor has the necessary capability and experience to meet project requirements. When making the evaluation, it is necessary to weigh technical capabilities heavily and conduct extensive reference checks.

- **Data transmission - identify data exchange requirements early.** The U.S. Census Bureau considered the requirements for transmitting data early in the laptops program. The early identification of the requirements helped to ensure the timeliness and accuracy of the information being transmitted and served to maximize network and machine resources by transmitting during off-hours.

1. BACKGROUND

The Titan Systems Corporation, System Resources Division (Titan/SRD) was tasked by the Planning, Research, and Evaluation Division (PRED) of the U.S. Census Bureau to conduct system requirements studies for 12 automated systems used in the decennial census. This report is a study of the Laptop Computers for the Accuracy and Coverage Evaluation (LC/A.C.E.) program. It addresses the extent to which the requirements definition process was successful in identifying the needed system functionality and offers one of several evaluation approaches for examining these automated systems. The report results are intended to assist in the planning of similar systems for the 2010 Census.

The Accuracy and Coverage Evaluation (A.C.E.) is a survey and coverage methodology designed to assess the size and characteristics of the population missed or erroneously enumerated in Census 2000. A.C.E. incorporates several interrelated field and processing operations; it is designed to develop an independent estimate of persons and housing units for use in evaluating the final census results. The concept was originally part of the Integrated Coverage Measurement (ICM) program.

A.C.E. identifies a listing sample of about 750,000 housing units. Field representatives systematically canvass block clusters during the A.C.E. Listing operation in order to create an address list that is independent of the census address list. After sample reduction, the A.C.E. universe is reduced to approximately 300,000 housing units to interview. A comparison is then made between the two lists to identify the housing units which are common (or match) between the two lists. Differences are resolved as part of the Housing Unit Followup (HUFU) operation. After HUFU, sample addresses are prepared and used to create input files for the Person Interview (PI). A comparison of the person files is made and differences between A.C.E. and census person data are then resolved in the Person Followup (PFU) operation. Activities include: conduct independent listing; key listing books; match and followup housing units; create enhanced list; conduct A.C.E. Person Interview (PI); conduct A.C.E. person matching and followup; and match and followup final housing units.

Laptop computers were used during the PI and Person Interview Quality Assurance (PIQA) operations to conduct personal visit and telephone interviews with sample households to assist with the determination of coverage error. Laptop computers were also used during other A.C.E. field operations to communicate with field staff using a custom mail application and through transmission of status reports. LC/A.C.E. provided an automated interview questionnaire and a case management system to control and manage work assignments. The design of the instrument replicated the survey and the principle of simplicity was applied. The design was intended to take the thought process away from the interviewer so that a person with no previous experience could be easily trained. LC/A.C.E. also provided mail services and a means of electronic case transmission. Interviewers retrieved their assigned cases and questionnaire input files when they connected their laptops via external modem to the A.C.E. telecommunications servers. Completed cases were uploaded to the A.C.E. telecommunications servers at the Bowie Computer Center and at headquarters; the case files were subject to quality checks. This system was critical for field control and kept field managers appraised of completion status and non-

interview rates during production. There were two LC/A.C.E. automated instruments for the Computer Assisted Personal Interview (CAPI)--one for PI and another for PIQA. Additionally, each instrument had both an English and Spanish version available to the interviewers.

2. METHODOLOGY

The Titan/SRD Team interviewed key personnel for each of the Census 2000 automated systems using a structured approach centered around four fundamental areas. A set of questions under each of those areas was designed to explore: (1) the effectiveness of the requirements definition process; (2) how well the systems were aligned with business processes; (3) identification of any deficiencies in functionality or performance relative to actual operational needs; and (4) how effective the agency contract management activities were in regards to contractor performance.

A similar, but separate set of questions, was designed for contractors who were identified as key personnel. The contractors were asked about the following areas: (1) the clarity of the statement of work and the impact of any changes to specifications; (2) their interactions with government personnel and the technical direction they received; (3) the timeline for the work; and (4) their impressions of the system's suitability and operational effectiveness.

The purpose of the system requirements study is to summarize the results of interviews with key personnel by system. A variety of related system documentation was reviewed in connection with the interviews. The assessments provided in Section 4., Results, reflect the opinions and insights of key personnel who were interviewed by the Titan/SRD Team in October and November 2000. Those personnel had varying levels of knowledge about the LC/A.C.E. system based on their involvement with system planning, development, implementation, or operational issues. Section 5., Recommendations, provides value added perspectives from the Titan/SRD Team that seek to illuminate issues for management consideration in the planning of future systems.

Quality assurance procedures were applied to the design, implementation, analysis, and preparation of this report. The procedures encompassed methodology, specification of project procedures and software, computer system design and review, development of clerical and computer procedures, and data analysis and report writing. A description of the procedures used is provided in the "Census 2000 Evaluation Program Quality Assurance Process."

Study participants reviewed the results of this system requirements study. Comments have been incorporated to the fullest possible extent.

3. LIMITS

The following limits may apply to this system requirements study:

- The perception of those persons participating in the interview process can significantly influence the quality of information gathered. For instance, if there is a lack of communication about the purpose of the review, less than optimal results will be obtained and the findings may lack depth. Each interview was prefaced with an explanation about its purpose in order to gain user understanding and commitment.

- In some cases, interviews were conducted several months, even years, after the participant had been involved in system development activities. This extended timeframe may cause certain issues to be overlooked or expressed in a different fashion (i.e., more positive or negative) than if the interviews had occurred just after system deployment.

- Each interview was completed within a one to two hour period, with some telephone followup to solicit clarification on interview results. Although a detailed questionnaire was devised to guide each interview and gather sufficient information for the study, it is not possible to review each aspect of a multi-year development cycle given the limited time available with each participant. Although this is a limitation, it is the opinion of the evaluators that sufficient information was gathered to support the objectives of the study.

- Every effort was made to identify key personnel and operational customers who actively participated in development efforts. In the case of LC/A.C.E., all government personnel who participated in the LC/A.C.E. are still with the Census Bureau. Contractors interviewed for the study are no longer active on the LC/A.C.E. program.

4. RESULTS

This section contains findings that relate to the effectiveness of the requirements definition process used during the development of LC/A.C.E. The requirements process establishes the foundation for a system and, as such, must be designed to thoroughly consider all technical and functional aspects of development and operation of the system.

4.1 Requirements definition

The development of the instrument was a team effort based on research that began shortly after the 1990 Census and continued through the Census 2000 Dress Rehearsal. The instrument design was changed a number of times during this period. Some survey staff have indicated that the A.C.E. instrument was very effective.

Laptop based survey questionnaire instruments had been used previously by the Census Bureau on many of their current survey programs, so there was an experience base on which to build extending back to 1992. The Census Bureau has previously used the Computer Assisted Survey Execution Software (CASES) developed by the University of California, Berkeley which is a questionnaire authoring software package. In 1995/1996, laptops with an automated instrument were used for the coverage survey tests. Given changes in data collection design for the survey, new instruments were designed and developed for the Census 2000 Dress Rehearsal conducted in 1998. The Census Bureau opted to use this off-the-shelf software which had been customized by Berkeley for earlier census surveys. Based on the dress rehearsal experience, the Census 2000 A.C.E. PI instrument was subsequently completed in November of 1999. The Decennial Statistical Studies Division (DSSD) was the sponsor for the requirements definition effort and was responsible for the design of the instrument. The Statistical Research Division (SRD) led the questionnaire design for the PI instrument and DSSD led the design of the PIQA instrument.

All changes to LC/A.C.E. requirements went through an orderly change control process where proposed changes were prioritized and documented. Once the instruments were finalized, any suggested changes were taken to an internal A.C.E. Change Control Board (CCB) for review. The A.C.E. CCB did not authorize changes to the A.C.E. instruments during operations. The A.C.E. CCB also reviewed and approved or disapproved any proposed changes to the laptop case management software during A.C.E. operations.

The LC/A.C.E. development process employed a team approach. Several teams were extensively involved including the Field Automation Team, Questionnaire Design Team, and Quality Assurance Team. These teams worked closely together to successfully develop the system. Smaller groups such as the System Test and Mini-Test Teams were also involved throughout the development effort.

4.2 Requirements issues

Nearly all requirements were met, but a few "work-arounds" were needed once LC/A.C.E. was in the production environment. Instructions were sent to the field describing steps needed for the work-arounds. The instrument was "stable" and there were very few modifications to the software.

4.2.1 All requirements were documented

Although there is no standard requirements documentation methodology or format, all LC/A.C.E. requirements were documented.

4.2.2 Several layers of software testing were implemented

Several layers of software testing were conducted on LC/A.C.E. Developers were responsible for unit testing their own code. Alpha testers exercised each software module to ensure the code functioned as intended and conducted regression testing to ensure that changes between versions

did not introduce problems in other parts of the system. Field testers conducted functionality testing to see if the software reflected the requirements and to determine whether the software would support the business process as it was defined. The Census Bureau Beta Test Site checked to see if laptop reports were produced at the appropriate time in ACE2000. Despite the many layers of testing, the process was not as thorough as it could or should have been. The number of changes that had to be implemented in a very short timeframe limited the testing process. Testing was prioritized based on resources, time available, and risk.

4.2.3 Laptop platform was well suited to task

The selected laptop model was very suitable for this project. In order to ensure that continuous operation would be assured during an interview, Census stipulated that the battery had to be hot-swappable (i.e., capable of being removed and quickly replaced with a new battery without losing data). The Hewlett-Packard Omnibook laptops met this requirement. Additionally, the laptops proved to be durable and had plenty of processing power. There was no requirement for color screen displays and this did not impact the usability of the instrument.

4.2.4 Quality control checks were used throughout data collection

A comprehensive quality control process was implemented for LC/A.C.E. that included quality checks at numerous points throughout the data collection process. The comprehensive checks were used to indicate the overall quality of the interviewer's work. Requirements for "clean" data were enforced by data edits built into the instrument. Data quality was also improved through the electronic transmission of captured data and quality assurance processing of the data at the host level upon receipt. This enabled statistical data to be provided daily to crew leaders so that supervisory decisions could be made to correct any problems, flaws, or errors in the collection process.

4.2.5 Instrument logic guided interview process

The interviewers were guided through the survey through a computer directed logic flow. The Census Bureau had knowledge of the interview methods and techniques, so this knowledge was a beneficial factor in terms of outlining the requirements for making the instrument "intelligent". The guiding principle when designing the instrument was to make it "bullet proof" (i.e., make it difficult for interviewers to make procedural mistakes or incorrect data entries).

4.3 Alignment with business processes

This section contains findings that relate to how well LC/A.C.E. supported the specific business processes that were associated with CAPI PI and PIQA operations. A goal of LC/A.C.E. was to streamline the process of case management through the application of remote access technology. LC/A.C.E. also was needed to improve the fundamental business processes of capturing data in the field and expeditiously transmitting it to allow sufficient time for timely progress and quality assessments. In short, LC/A.C.E. was designed to enhance collection of A.C.E. data, control of field operations, and to appraise managers about completion and non-interview rates. The laptop

survey instrument contained two paths for PI -- one for telephone interviews and another for an interview in person. The PIQA instrument was designed to verify that the PI interviews were completed with the respondents. Additionally, the PIQA instrument contained a complete version of the PI interview that initiated a full replacement interview for the original interview when needed.

4.3.1 Instrument was effective in supporting data collection

The instrument was "intelligent" in that it contained algorithms and logic that guided the interview depending upon the answers provided by interviewees. By and large, the instrument was a very effective tool in supporting data capture operations. However, the fact that it was built upon the CASES software, which had its own internal "conventions," led to some minor idiosyncrasies in the behavior of the instrument. This did not, however, have an appreciable impact on data collection or quality assurance operations. Currently, the Census Bureau is converting all survey laptops from DOS to Windows.

4.3.2 Assignments and case data were transmitted in same session

Downloads of assigned cases and uploads of completed case data occurred during the same session when the laptops dialed-in to the host computer at night. This feature allowed LC/A.C.E. to meet requirements for the timely transmission of data as well as current progress and quality assessments.

4.3.3 System captured every keystroke made by enumerator

For management purposes, the system captured every keystroke made by the enumerator during the interview in trace files, including "off-path" entries. Erroneous keystrokes were kept along with the corrected ones. All keystrokes were captured so that trends in mistakes could be identified. This capability facilitated improvements in the design/functioning of the survey.

4.3.4 Development status was shared with field

Laptop software undergoing development was made available on the network at headquarters and in the regional offices so that field personnel could see the instrument being developed and assess its evolving capabilities. This enabled the field to comment on LC/A.C.E. functionality with respect to its ability to support business processes relating to A.C.E. operations.

4.4 System deficiencies

This section contains findings that relate to any specific shortcomings that were identified with respect to the system's ability to accomplish what it was supposed to do. Recognizing that 100 percent success is rarely achievable, especially in the case of a completely new system, it is still worthwhile to assess deficiencies in the spirit of constructively identifying "lessons learned." Such insights can greatly contribute to improvements in future system development activities.

4.4.1 Software could have reinforced case close-out procedures

Some cases could not be closed out in LC/A.C.E. due to the user's uncertainty as to what kind of response was needed. This was primarily a training issue, but could well have been handled by the software. For example, in order to close out a case, two characteristics are needed and the instrument could have been designed to indicate exactly what type of response/information had to be entered in order to close out the case.

4.4.2 Edits were not included on the last name field

Some erroneous entries were accepted by the system as valid last names. For example, if a respondent refused to provide information to the field representative, and if "refused" was entered into the name field (i.e., answer block), the instrument accepted it as a valid name. This issue was discussed at length by the Questionnaire Design Team and it was decided that the edit checks on this field would not be included. One major reason for this decision was that it would be difficult to capture all possible invalid entries. While extensive edit checks would not have been easy to program, some editing capability for common errors could have been implemented. Items were added to the instrument name screen after dress rehearsal to prevent misuse of the name field when an interviewer did not know how to handle a refusal. There was a refusal option on the name screen for Census 2000.

4.4.3 PIQA instrument had some problems

There were several points in the PI instrument where the interviewer could indicate that a unit was vacant. These all functioned and resulted in correct outcomes and actions. However, the PIQA instrument was not able to handle "Did Not Exist" units properly. This was considered a minor shortcoming in the LC/A.C.E. instrument.

In the PIQA instrument, there was a problem with the interpretation of the flag that indicated if the original PI had been completed by phone or personal visit. This caused the PIQA instrument to ask about a phone interview at a household that was originally interviewed in person and vice versa. A work around was introduced but the automation could not be corrected while the survey was in the field.

4.5 Contract management practices

This section contains findings that relate to the effectiveness of contract administration activities. Even when system requirements are well-defined, ineffective management of contractors can lead to less than optimal results when the system is deployed. Consequently, it is beneficial to evaluate past practices in order to gain insights that can lead to improvements that will increase the likelihood of successful system development efforts. Contractors played a role in the design and development of LC/A.C.E. and were used to produce program flow charts and to test instrument logic.

4.5.1 Programming support augmented by contractors

Programming support for the design of the instrument was accomplished primarily by Census Bureau staff. Other programming, such as the development of the case management software, was done by contractors under the auspices of the Technologies Management Office (TMO).

4.5.2 Contractor turnover impacted development efforts

There was some turnover of contractor personnel during LC/A.C.E. development. Identifying replacement personnel was sometimes difficult due to the skill requirements of the position. Also, any new personnel, although technically qualified, were subject to a learning curve as they became familiar with the project goals and requirements and as they interacted with the other individuals assigned to the project.

4.5.3 In-house and contractor resources conducted path testing

Contractors were used for path testing as in-house resources were not sufficient to complete all of the path testing on schedule. Path testing was concluded in December of 1999. Contract labor was advantageous to the Census Bureau because of the enormous effort that was required to test every possible path/branch that a user could take during the interview. There also was a downside to using contractors because it required the time of Census personnel to constantly answer questions and give guidance to contractors. This was perceived as time consuming. Aside from contractors used by TMO, DSSD hired contractors for path testing and also had several DSSD staff members, with subject matter expertise, conducting the path testing. This interaction was very effective.

4.5.4 Existing vendor selected to provide laptop kits

The contract methodology for A.C.E. was not decided until March of 1999 when the sample size decision was made and the Hewlett Packard Omnibook 900 laptop was selected for the project. A sample size of approximately 300,000 cases enabled the Census Bureau to contract with a vendor that had been providing laptops since 1996 for other CAPI surveys within the Census Bureau. The resulting contract was a small business set aside with the option to purchase up to 15,000 laptops. A full competition was originally planned when the requirement was for 21,000

laptops. However, by using an existing contract, the Census Bureau had a decision on the laptop model in time to write training and to test the software on the production laptop. A project plan was jointly developed by the vendor and a Census Bureau team; however, once the contract was in place, another team of Census Bureau personnel assumed control over the integration, production, quality control, and shipping arrangements. (Only two people "carried over" from the original team.) The establishment of a detailed implementation plan brought to light the extensive logistical issues relating to a project of this scope; this became a source of stress between the Census Bureau and the vendor. The company's location in Chicago was also a complicating factor.

Equipment purchasing and integration of laptop kits was accomplished in four waves beginning in April of 1999 and ending in April of 2000. The 9,639 laptops kits had to be assembled before shipping and this required the contractor to make BIOS[1] configuration settings, load the software, and bundle the various accessories (adapters, manuals, batteries, etc.). The contractor had problems ensuring that each unit was configured exactly as required. As the vendor gained experience with the Census Bureau requirements, the quality improved. The promised laptop production rate was a very demanding 700 machines per week for each wave. The actual laptop production rate was 550 units per week during the final and largest integration/production wave. Census Bureau personnel quality checked a sample of laptop kits each week during the production period prior to the units' shipping to the regional locations. This slowed down the distribution process but increased quality (the return rate was only about 12 units out of 7,000). The vendor maintained a pool of extra laptops for immediate replacement of those that needed repair. The pool was established using a ten percent overage factor. The A.C.E. regional offices also retained a pool of spare laptops and parts to resupply the interviewers when they experienced hardware problems. Interviewers needing replacement machines received them via overnight express.

The laptop deployment schedule was clear; however, the destinations were not precisely identified up front. This caused some difficulties for the vendor. The vendor had recently implemented a new internal inventory and shipping control system and was not sufficiently prepared to track large quantities of shipments to so many places. These problems led to a strained relationship between the vendor and the Census Bureau, but that working relationship improved over time due to efforts on behalf of both parties.

[1] BIOS is an acronym for Basic Input/Output System and is the program that a personal computer's microprocessor uses to get the computer system started after its turned on. It also manages data flow between the computer's operating system and attached devices such as the hard disk, monitor, keyboard, mouse, and printer.

5. RECOMMENDATIONS

This section synthesizes the findings from above and highlights opportunities for improvement that may apply to the Census Bureau's future system development activities. The recommendations reflect insights from Titan/SRD analysts as well as opinions regarding "lessons learned" and internal "best practices" that were conveyed by Census Bureau personnel during interviews.

5.1 Project planning - begin development early.

The LC/A.C.E. program was affected by wholesale changes in census methodology (i.e., sampling versus full enumeration), technology (i.e., Oracle Forms to PowerBuilder), and business process (i.e., Paper Assisted Personal Interview (PAPI) versus CAPI). The census is not the time to try unproven approaches or to develop new systems without a sufficiently long lead time for development and without a sufficiently large staff of both subject matter and development personnel. The Census Bureau must plan well in advance to ensure that the necessary personnel resources are available to support the project and that those resources can devote a sufficient amount of time in requirement definition and testing without being diverted to other activities. The LC/A.C.E. development schedule was unrealistic because it did not allow for the full development of requirements, adequate testing, or the opportunity to accommodate virtually continuous program changes. Fully functional systems, based on well documented requirements baselines, must be available for the dress rehearsal so that necessary changes can be identified, implemented, and tested well before actual deployment.

Recommendation: Initiate development efforts early enough so that fully tested, robust systems are available for dress rehearsal. The purpose of the dress rehearsal should be to evaluate a fully functional system and fine tune system features, not to identify major changes in system functionality. Although some requirements may change from the lessons learned in dress rehearsal and from external forces (e.g., Congress), there would be a higher chance that all requirements would be identified and implemented for the actual census. In addition, establish realistic development timelines that incorporate sufficient time for requirements definition, development, testing, and enhancements.

5.2 Laptop vendor - consider full and open competition.

The selection of the HP laptops proved to be a wise one, however, the vendor selected to provide the laptops lacked experience as an integrator and had some difficulties procuring, configuring, and delivering the large quantity of laptops required for the program. Although the vendor had successfully provided laptops to the Census Bureau for other surveys, the nationwide deployment of over 9,000 "turn key" laptops in four waves proved to be a very demanding task for which the vendor was not well suited. Compounding this problem was the fact that the vendor had to contend with a transition from the original Census Bureau team that developed the project plan to the team that assumed control over the integration, production, quality control, and shipping arrangements. The vendor perceived that new requirements were being issued by the second team. This led to communication problems and strained relationships between the

vendor and the Census Bureau. A contracting officer was brought in by the Census Bureau to resolve any issues. Competing this contract may have been a better alternative had sufficient time been available.

Recommendation: It is recommended that, when extraordinary requirements will be placed on a vendor, Census Bureau consider a full and open competition to select a capable vendor. This may require time and effort in the short run, but will serve to minimize risks in the long run. That is the best route to follow when the need for an experienced vendor is paramount. It is also suggested that, when evaluating vendors, Census Bureau place heavy weighting on technical capabilities (as a ratio to costs) and ensure that reference checks are conducted so that past performance on similar contracts can be weighed.

It is recommended that the Census Bureau establish and maintain a consistent communications channel for providing technical direction to the vendor. This will help to minimize the potential for misunderstandings and avoid contract disputes.

5.3 Data transmission - identify data exchange requirements early.

The upload/download capabilities of LC/A.C.E. telecommunications system proved to be very effective. The requirements for this functionality improved both the quality and timeliness of data capture activities, and made good use of computing resources (telecommunications links, servers, etc.) during periods when their utilization levels would normally be low.

Recommendation: Continue to specify requirements for the electronic transfer and exchange of data as early as possible in the development process. This will help to ensure that management reports are generated from current information. When transmitted automatically during off-hours, as was the case with LC/A.C.E., it also has the ancillary benefit of minimizing server congestion and making good use of machine resources that might otherwise be idle.

5.4 Requirements process - develop and implement standardized guidelines.

There was no standard, systematized requirements definition process to provide guidance on how to perform the requirements analysis. Although some of the LC/A.C.E. staff had experience in requirements definition, other staff members were new to the process. The team believed that the quality of the specifications were high. If any problems were experienced, it was because the specifications were transitioned between multiple contractors.

One unique aspect of the requirements for LC/A.C.E. was that the system would be used by temporary personnel who lacked detailed knowledge of census operations; LC/A.C.E. addressed this need. The lesson learned in this case was that requirements should always be mindful of the "user base" to ensure usability of the application and to minimize the training effort.

Recommendation: Develop and implement standardized guidelines to assist agency personnel with performing requirements analysis according to a structured approach. Recognizing that a

well- defined set of requirements is an essential foundation for any system development effort, many agencies have such guidelines in place, usually through promulgated directives. People involved in the formulation of requirements should be trained on how to perform this function. Additionally, once developed, requirements should be frozen to the extent possible, with any proposed changes being subject to a CCB. Finally, the Census Bureau should ensure that the "user base" is considered for all system development projects.

5.5 Survey design/instrument logic - emulate in future survey instrument applications.

The requirements for the instrument design specified that the computer directed logic flow be such that it intuitively guided the interviewer. This allowed temporary personnel with no previous experience to use the instrument with minimal training. This also helped to reduce any procedural mistakes or incorrect data entries.

Recommendation: The alignment of the instrument design requirement with the business process of remote data collection was particularly well implemented and is a "best practice" that should be emulated in future applications involving laptop instruments.

5.6 Spanish language support - address and communicate requirements early.

The requirement for a Spanish language interview was accommodated later in the LC/A.C.E. development cycle. The requirements were defined by March of 1998 for the Census 2000 Dress Rehearsal with the necessary translations completed by March 1999 for Census 2000. The programming of the Spanish language translation was done at the point when the English version was reaching its final status. This delay was intentional in order to avoid reprogramming. This requirement was a planned addition to the survey.

Recommendation: Modifying existing software to accommodate another language is more difficult than it may appear. Because of differences in phraseology, changes to screen displays can sometimes require significant programming efforts. In view of the increasing need for foreign language support, this area needs to be carefully considered in all census applications that involve responses from the public. The requirements analysis phase should address such needs as early as possible. It is recommended that any requirements for foreign language support be communicated to developers so they can anticipate the complexities of incorporating such functionality.

5.7 Contractor turnover - ensure contract fully addresses this issue.

Skilled development contractors are in high demand throughout industry and government. Many developers have their choice of companies and even their choice of projects within the company. Aggressive salaries and benefits often lure developers to new jobs even when they have been with a company for only a short time. Frequent movement between projects and between companies is disruptive and sometimes detrimental to the success of a project.

Recommendation: Contractor turnover from “better offers” or extenuating personal

circumstances cannot be prevented, but it may be reduced if certain steps are taken during contract negotiations with the vendor. Skill requirements should be clearly specified for each labor category in the contract. Critical labor categories should be designated as "Key Personnel" so that the individuals proposed during negotiations are indeed the same individuals that support the project once it begins. Labor rates proposed for each category should be checked against other vendors and industry benchmarks to ensure that qualified personnel can be attracted and retained at the proposed rate. The government should request a minimum of 30 days notice from the vendor for any change in Key Personnel and resumes of any replacements should be provided for review as quickly as possible. Conversely, the government should specify a process to enable the immediate removal of any non-performing personnel.

For critical positions, both a primary and backup resource should be included on the project; the backup having sufficient skills and experience to function interchangeably with the primary resource. Cross-training should be encouraged throughout the project. Lastly, the Census Bureau has unique needs that must be addressed within a very short timeframe. Vendors and contractor personnel must be made aware of the importance of the Census Bureau mission, the intensity of the census environment, and the critical need for continuity of project personnel.

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