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MEMORANDUM FOR The Distribution List

From: Burton Reist *[signed]*
Acting Chief, Decennial Management Division

Subject: Final Report for the 2010 Census Evaluation of Automation in Field Data Collection in Address Canvassing

Attached is the 2010 Census Evaluation of Automation in Field Data Collection in Address Canvassing Report. The Quality Process for the 2010 Census Evaluations, Experiments, and Assessments was applied to the methodology development and the review process. The report is sound and appropriate for completeness and accuracy.

If you have questions about this report, please contact Jonathan P. Holland at (301) 763-7235 or Kevin Shaw, Chief, Census Evaluations Branch, at (301) 763-1851.

Attachment

2010 Census Evaluation of Automation in Field Data Collection in Address Canvassing Report

U.S. Census Bureau standards and quality process procedures were applied throughout the creation of this report.

Final

Jonathan Holland
Decennial Statistical Studies Division

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Executive Summary

The purpose of this evaluation is to measure operational improvements, efficiencies, and cost savings achieved through increased automation in the 2010 Census Address Canvassing operation. Address Canvassing was the primary method for updating the Census Master Address File during the 2010 Census; where over 100,000 listers verified, updated, or deleted addresses already on the list, added addresses missing from the list, and also validated addresses supplied by participating local governments. The results of this evaluation will provide input for future automation decisions regarding field data collection efforts.

The research questions for this evaluation are:

What was the impact of adding expanded automation to field data collection for Address Canvassing?

1. *Did automation contribute to operational improvements?*
2. *Did the Census Bureau gain in efficiency?*
3. *Did the Census Bureau see cost savings?*

In Census 2000, there was not an Address Canvassing operation. Instead, the Census Bureau conducted Block Canvassing in urban areas and Address Listing in rural areas. Some of the areas covered by Address Canvassing in the 2010 Census were also covered by a List/Enumerate operation in Census 2000 (very rural areas). Block Canvassing and Address Canvassing were dependent listing operations where listers began their work from a predetermined list of units or addresses for each block. Address Listing was an independent listing where listers created their own list of residential units or addresses for each block without aid from a predetermined list.

The first test of automated listing for decennial census operations occurred during the 2004 Census Test. This test included a feasibility study of Global Positioning System (GPS) technology. This GPS study occurred as part of the NonResponse FollowUp test. Subsequently, Address Canvassing automation occurred for the first time in the 2006 Census Test. Due to difficulties implementing the automation in-house, the Census Bureau decided to contract out the development of the automated listing for the 2008 Dress Rehearsal and the 2010 Census. The troubles in the 2006 Census Test were believed to be caused primarily by system integration difficulties. The demand the applications as a group placed on the available Random Access Memory (RAM) of the automation device proved too great. The Field Data Collection Automation contract was awarded to Harris Corporation, which provided the automated listing instrument for both the 2008 Census Dress Rehearsal and 2010 Address Canvassing operation; as well as all of the Information Technology Infrastructure to accomplish these operations. Harris provided a handheld computer with listing software, GPS capability, Time and Expense Reporting, text messaging, and Workload Management capabilities. The handheld computer experienced some performance problems in early testing for large blocks, those with 1,000 or more units. As a result, a contingency plan was developed for the 2010 Address Canvassing operation. Large blocks were listed via slightly modified Demographic Area Address Listing procedures using the Automated Listing and Mapping Instrument.

The 2010 Census Update/Leave operation, where enumerators manually updated the address list and left Census questionnaires for residents to mail back, occurred later and shared many of the same listing activities as Address Canvassing. Both operations systematically updated address lists and maps for given census blocks. Unlike Address Canvassing, however, Update/Leave was a paper operation.

In the 2010 Census operations, Time and Motion studies were conducted for both Address Canvassing and Update/Leave. For the Time and Motion studies, an observer followed a lister to record the duration of specific tasks. These studies can be used to measure efficiency. Personal Digital Assistants (PDAs) were used to record the results in the field. The Time and Motion implementers chose the 2010 geographic sites in the study for both Address Canvassing and Update/Leave to overlap with previously conducted Time and Motion Studies. By controlling for geography, the longitudinal results are more comparable.

To complete this evaluation, it was necessary to compare operations across censuses. When reading this report, please remember the 2010 Address Canvassing operation was not conducted in the same manner as the 2000 Address Listing or Block Canvassing operations. However, these Census 2000 operations provide the best source of comparison for large scale paper listing of addresses. That said, some key differences should be noted:

1. Census 2000 Address Listing was an independent listing of addresses. This means listers visited blocks and recorded and map spotted every address from scratch, as opposed to starting with an existing, dependent, list as was done in the 2010 Address Canvassing,
2. Map spots were not collected for existing units in Census 2000 Block Canvassing and only every third living quarter was visited,
3. Update/Leave occurred after Address Canvassing in the 2010 Census, so Address Canvassing had already improved the listing in those areas.

With this background information, a summary of the findings of this report categorized by the three evaluation research questions follows:

Operational Improvements and Impacts

One of the substantial operational improvements achieved through automation in the 2010 Census was the collection of GPS coordinates. GPS coordinates were captured for 98.8 percent of the 105,298,999 attempted structure collections. It is anticipated that the utility of these GPS data for boundary changes, unduplication, and future re-designed Census operations will prove invaluable. Another improvement was the increased security for the listing device. Binders in a paper operation have no intrinsic security. However, the handheld computer contained multiple security features; including data encryption and biometric access via a finger swipe (two-factor-authentication).

Automated edits were another operational improvement. Automated edits correct some errors as the listers enter information into the handheld computer, whereas those errors require manual

correction if they occur in paper operations. For example, listers sometimes fail to provide a valid action code when listing with paper. Automated edits prevented a lister from completing an address without an action code. In a paper operation, missing action codes persist until/unless detected and corrected later in the operation. This use of automated edits results in less rework, reducing how often listers are required to return to specific blocks to correct problems. DSSD used information from the 2010 Update/Leave Office Review Checklist to measure how often these errors occurred. Overall, DSSD found that about 0.73 percent of housing units had critical errors, errors in listing that could not be fixed in the Local Census Office, for the universe that passed office review. In a paper operation, these critical errors would be accepted and would likely propagate into the Master Address File. Using automated edits prevents these errors from occurring. Assuming a paper Address Canvassing operation would have a similar error rate to the Update/Leave operation, a paper Address Canvassing operation in 2010 could have introduced over one million critical errors into the Master Address File (159,494,710 housing units x 0.0073 rate of critical errors). These critical errors were prevented by automated edits in 2010.

In 2010, the automated payroll system was a substantial improvement over paper payroll for field staff. Address Canvassing listers keyed and transmitted their timesheets electronically via their handheld computer. In general, field staff preferred the use of the automated instrument over paper, and thought it worked fairly well overall. They had specific issues related to handheld computer use and implementation, but felt those could be overcome before the 2020 Census, and even recommended increased automation for the 2020 Census. This general result was observed in all the Regional Census Center, Lister, and Crew Leader debriefings.

Efficiency

Efficiency was measured by three methods:

1. Execution Cost per Case
2. Time and Motion Studies
3. Master Address File Update Times

Table ES-1 provides the first efficiency measure – a summary of the execution cost per case for the paper-based Census 2000 Address Listing and Block Canvassing operations, compared to the 2010 Census Address Canvassing operation; adjusted to reflect 2009 dollars. These costs reflect direct field costs such as mileage and salaries to conduct the listing. These figures do not include the contract, infrastructure or development costs. The cost per case figures show listing is more expensive in rural areas (Address Listing) than in urban areas (Block Canvassing); primarily due to the additional travel time. Combining Address Listing and Block Canvassing gives an approximation of the cost of a paper Address Canvassing operation. However, recall some geographies of the 2010 Address Canvassing workload were not included in the workloads of Address Listing and Block Canvassing during Census 2000. These excluded areas tend to be very rural, most of which are in the Rocky Mountain States. Also, Address Canvassing as depicted in this table does not include the 2010 Census Large Block Address Canvassing operation. The results indicate that Address Canvassing was slightly more expensive by about

$0.23 per case. The increased costs were partly due to increases in the length and cost of training as a result of new mandates and hiring/training procedures. The cost per case is a measure of the efficiency of the listing operation.

Table ES-1. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Execution Cost Per Case Efficiency Comparison in 2009 Dollars[1]

	Block Canvassing (BC) 2000[2]	Address Listing (AL) 2000[2]	Combined AL and BC 2000[2]	Address Canvassing (AC) 2010[3]
Universe Size (workload)	94,346,049	24,023,043	118,369,092	159,494,710
Total Execution Cost (in millions of 2009 dollars)	$138.3	$162.9	$301.3	$443.6
Dependent Listing (D) / Independent Listing (I) / Mixed (M)	D	I	M	D
Paper Operation (P) / Automated Operation (A)	P	P	P	A
Rural (R) / Urban (U) / Both (B)	U	R	B	B
Execution Cost Per Case	**$1.47**	**$6.78**	**$2.55**	**$2.78**

[1] This comparison only includes 'Execution Costs' such as training, listing and mileage; and does not include costs for 'Contracts/Infrastructure,' 'Equipment,' etc.
[2] Universe size for Census 2000 operations does not reflect a w orkload adjustment.
[3] Address Canvassing does not include the 2010 Census Large Block Address Canvassing operation.
This table excludes 'Provide OCS/HHC Technical Support' for BC, AL, and AC.
Some geographies of the Address Canvassing w orkload w ere not included in the w orkloads of Address Listing and Block Canvassing.
These excluded areas tend to be very rural, most of w hich are in the Rocky Mountain States.
Source: 2010 Cost and Progress system and 2000 Draft Assessment of AL and BC. See Section 3.2.3.1 for methods and calculations.

A second measure of efficiency was taken from the Time and Motion studies. The 2010 Census Address Canvassing and Update/Leave Time and Motion analyses correct for urban and rural differences and other problems by removing travel time, delay time (non-handheld computer), and respondent contact time. The analyses of both production and Quality Control work show Address Canvassing Quality Control was the most efficient at 1.04 minutes per case, followed by Update/Leave production at 1.53 minutes per case; which is not statistically significantly different from Update/Leave production and Quality Control at 1.63 minutes per case. Address Canvassing production was the least efficient at 1.81 minutes per case. However, these differences do not explain all of the variability in the data. Also, map spotting using GPS-enabled handheld computers was conducted for all structures in the Address Canvassing workload, but the map spot was only verified in Update/Leave and Address Canvassing Quality Control. This difference in operational requirements likely contributed to the reduced efficiency.

Another measure of efficiency is Master Address File update time, i.e. how long until the Master Address File is updated with field work results. For the listing operations compared here, all the updates started during the operation. For this evaluation, update times were determined by calculating the number of days between the end of the operation and completion of the Master Address File update. On average, Address Canvassing updated the Master Address File 43 days after the end of the operation, whereas Block Canvassing and Address Listing took 110 days. In 2010, automation allowed for quicker address file updates, at greater than 2.5 times that of paper.

Cost

One way to evaluate how well automation performed is to investigate the dollar cost of an automated operation compared with a paper operation.

Table ES-2. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Summary Cost Comparison of Paper and Automated Listing Operations in Millions of 2009 Dollars

Cost Category	Paper Operation[1]		Automated Operation[2]		Automated/ Paper Operation Cost Ratio*
	Estimated Cost	Percent of total+	Estimated Cost	Percent of total+	
Total	**$562.4**	**100.00**	**$845.0**	**100.00**	**1.50**
Procedures[3]	2.6	0.47	20.9	2.47	7.91
Materials/Equipment[3]	41.5	7.38	109.1	12.91	2.63
Infrastructure and Contract Costs[3]	59.7	10.62	253.1	29.95	4.24
Distribution	6.2	1.11	2.1	0.25	0.34
Execution	414.1	73.63	458.9	54.31	1.11
Results/Closeout	38.2	6.79	0.9	0.11	0.02

+Percentages may not sum to 100 due to rounding.

* All Ratios were calculated from exact figures, and may not represent the ratio calculated using the rounded figures in this table.

[1]Paper Operation refers to the Census 2000 Address Listing and Block Canvassing operations, adjusted to simulate both 2009 workload and dollars.

[2]Automated Operation refers to the 2010 Census Address Cancassing operation.

[3]Costs for an Automated Operation are part of the Field Data Collection Automation (FDCA) contract costs. Not all FDCA contract costs are available separately by operation. Some of the figures provided here are estimates. FDCA costs include some of the cost of Group Quarters Validation (GQV), since this could not be separated from Address Canvassing (AC). The original FDCA contract cost award was $596 million. The final FDCA contract cost was approximately $790 million after descoping, of which $662 million occurred before Fiscal Year 2010. Of the $662 million, $390 million was attributed to AC and is included in the table in the Procedures, Materials/Equipment and Infrastructure and Contract Costs categories. When a cost was not solely attributable to AC, a 50 percent allocation for each AC and Nonresponse Follow up (NRFU)/other operation(s) was used. These allocated costs were substantial.

Source: 2010 Cost and Progress system, 2000 Draft Assessment of AL and BC, and Census Bureau internal e-mails about cost See Section 3.2.4 and Appendix D for methods and calculations.

Table ES-2 shows the cost comparison, by category, for automated and paper listing operations. All figures were adjusted to both 2009 workloads and dollars, given that the 2010 Census Address Canvassing operation occurred in 2009. DSSD estimates that a simulated paper operation, of the same magnitude of Address Canvassing, conducted in 2009, would have cost about 562 million dollars, while the actual automated Address Canvassing operation cost over 1.5 times as much at about 845 million dollars. The Execution category costs are nearly entirely comprised of the training, listing and mileage costs. In previous studies, the most visible costs were the Execution costs. Table ES-2 shows this view is incomplete in that it does not account for other substantial costs incurred in both paper and automated listing operations. Here, the majority of the increase in dollar costs for an automated Address Canvassing operation is attributed to the Infrastructure and Contract Costs category -- total costs of 253 million dollars; an increase of about 193 million dollars, or about 4.2 times more, over a paper operation. The largest percent increase is observed in the Procedures category which increased by about 7.9 times. In 2010, the Field Data Collection Automation contract was the predominant source of costs for the Infrastructure and Contract Costs, and Procedures cost categories. Some categories showed cost reductions in an automated environment, e.g., about 37 million dollars were saved by not having to key address listing updates. However, these savings were more than offset by the increased Infrastructure and Contract, and Materials/Equipment costs. Originally, the Field Data Collection Automation contract included Address Canvassing, NonResponse FollowUp, and other smaller operations. Efforts were made to account for and remove non-AC operations from the figures in this Automated Operation column. However, where financial information was not available by operation, allocations were made.

Automation did not result in the expected cost savings, and in fact cost more throughout its census operation lifecycle – 845 million dollars as compared with 562 million dollars for a similar paper operation. However, noteworthy is the economy of scale that could have been realized should the same device and similar procedures been used in the Nonresponse Followup and subsequent operations. While additional costs would have been incurred to operationalize automation for subsequent operations, there stood potential to lessen some of the dollar cost gap measured in Table ES-2 by widening the cost base that the Infrastructure and Contract, and Materials/Equipment cost categories could have been attributed to. Also, as noted earlier, the handheld computers did improve some of the data quality: allowing for automated edits and the collection of GPS coordinates. Handheld computers also allowed for the operation to be completed more rapidly, and directly reduced the time from operation end to Master Address File update completion by over 60 percent. In 2010, this provided the necessary window for the Group Quarters Validation operation to be successfully implemented.

Based on these findings and the collective experiences of all conducting this research, the Decennial Statistical Studies Division recommends vigorous and careful pursuit of increased automation in the 2020 Census, and provides the following recommendations:

- **Contract Cost Evaluation and Containment:** Given the largest divergence of costs between automated and paper operations in this study was contract expenditures, with a difference of approximately 279 million dollars (observed in cost categories Procedures, Materials/Equipment, and Infrastructure and Contract Costs in Table ES-2), one of the highest intercensal priorities should be evaluating and modeling expected contract costs both pre- and post-award, and developing and implementing methods for cost monitoring and containment both pre- and post-award. Also, with such a deep and wide pool of technical and managerial expertise, wherever possible, a great deal of *documented* consideration and deliberation should be given to in-house solutions.
- **Operation Cost Estimation and Tracking:** During the course of this evaluation, for certain items, DSSD was unable to obtain documented, thorough, reliable, auditable pre- and post-operation cost estimates. Much careful, deliberate attention should be made to evaluate and *document* multiple competing pre-operation cost estimation strategies and outputs leading up to the 2020 Census. Also, in order to perform cost benefit analyses on operations, it is critical that all costs be tracked by operation. For this study, DSSD was not able to comprehensively obtain contract, control system, headquarters personnel, operational design, and printing/shipping/supply costs separately by operation. Additionally, DSSD recommends pursuing an earned value approach to track costs within operations. Assigning costs to Work Breakdown Structure (WBS) tasks by operation (as opposed to by process) will provide more relevant and informative cost benefit and earned value analyses. Shared operations costs should be consistently allocated and tracked by both an equally-distributed method (e.g., five operations benefiting from a shared process would each share one-fifth of the cost) and an estimated workload method (e.g., operation A with a 1 million housing units workload and operation B with a 2 million housing units workload would share the total cost of a shared process at one-third and two-thirds respectively).

- **Technology:** Given the 2010 Census handheld devices were one-time-use devices, at a total cost of over 80 million dollars, high consideration should be given to two alternative strategies: (a) conduct operations via applications (apps) designed to run on multiple operating systems and on numerous commercially-available, *personally-owned devices* (e.g., smart phones, tablet computers), or (b) conduct all survey and census listing and enumeration operations on a *single Census Bureau device* capable of a lifecycle to adequately absorb the initial acquisition and development costs, and semi-regular maintenance. Under strategy (a), to mitigate the risk of insufficient personally-owned device availability, the Census Bureau may elect to subsidize the purchase of personally-owned devices in select geographies; still resulting in overall cost savings to the agency.
- **Device Features:** If the Census Bureau elects to purchase, lease or build its own device as it did for the 2010 Census, consideration should be given to some key features requested by the 2009 user community: (a) acquire anti-glare display screens or offer a separate film or shield to reduce glare, (b) study the costs and benefits of adding weatherproofing to the device, (c) load the device manual and help facility onto the device itself and/or make available a centrally-administered crowd-sourced help website, accessible via the device, (d) ensure reliable real-time communication with other field staff, and (e) consider using cloud computing instead of loading data or software.

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1 Introduction

1.1 Purpose of Study

The objective of this evaluation is to measure operational improvements, efficiencies, and cost savings achieved through increased automation in field data collection for Address Canvassing (AC). This will provide input to automation decisions regarding future field data collection efforts.

1.2 Intended Audience

The intended audience for this report is anyone trying to understand the impacts of automating Census Bureau field data collection.

2 Background

The U.S. Census Bureau has a history of employing new technologies to improve operations and results. In the 1890 Census, the Hollerith machine, patented as An Electronic Tabulating System (1889), was used to automate tallying various statistical items; separately and in combination. This system produced Census results (for the 1890 Census) seven years quicker than the previous Census; an enormous improvement. The inventor's, Herman Hollerith's, corporation would merge with three others in 1911, to be later renamed as International Business Machines Corporation (IBM) in 1924.

Figure 1. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Hollerith Tabulator (left) and Sorter (right)
Photo Credit: U.S. Census Bureau, Public Information Office

The Census Bureau introduced computerized tabulations in the early 1950s, which were used to expand automation for the 1960 Census. This included a large investment in the late 1940s in the development of the UNIVersal Automatic Computer I (UNIVAC I), which was available for Census Bureau use in 1951, shipped to headquarters in 1952, and a copy soon thereafter delivered to the Pentagon. The UNIVAC I was the first commercial computer produced in the U.S. It used 5,200 vacuum tubes, weighed 29,000 pounds, consumed 36 square meters of floor space, had 12,000 characters of main memory, and could perform about 2,000 operations per

second (compared to today's commonplace personal computers with upwards of $32x10^9$ bytes of memory and 3.2×10^9 cycles per second processors).

To fully take advantage of the speed of UNIVAC I, the Census Bureau and National Bureau of Standards developed the Film Optical Sensing Device for Input to Computers (FOSDIC). FOSDIC was capable of transferring certain questionnaires to magnetic computer tape.

Figure 2. 2010 CPEX Evaluation of Automation in Field Data Collectionin AC: UNIVAC I
Photo Credit: U.S. Census Bureau, Public Information Office

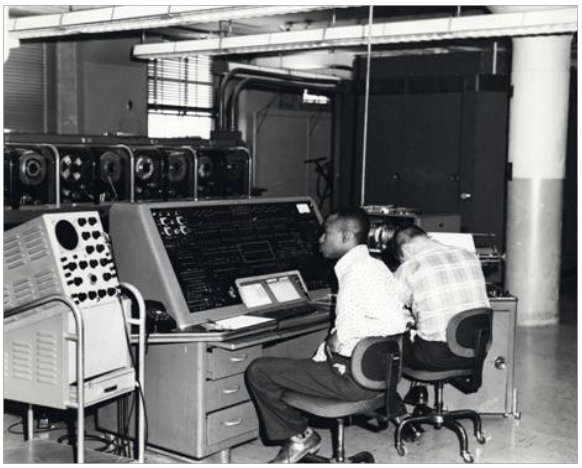


Figure 3. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: FOSDIC
Photo Credit: U.S. Census Bureau, Public Information Office

More recently, the Census Bureau allowed Internet responses to census questionnaires during Census 2000. Also between Census 2000 and the 2010 Census, the Census Bureau created the Statistical Administrative Records System (StARS). StARS is an Administrative Records (AR) database that was created annually, to represent as much of the U.S. population and housing inventory as possible. StARS includes Federal Government AR data from the Internal Revenue Service (IRS), Centers for Medicare and Medicaid Services, Department of Housing and Urban Development, Indian Health Service, and Selective Service System. This alternate source of low cost population and housing data has great potential to contain and reduce future decennial census costs. This innovative solution to reuse government data is only just beginning to be introduced into future decennial census operation plans. These and other efforts in the recent past have been aimed at reducing cost, and improving the quality and timeliness of census data.

It was largely believed that automating AC field data collection would help listers operate more efficiently and reduce errors. It was also believed automation would help:

- prevent loss of materials/data,
- alleviate some of the problems associated with having paper maps and records transferred between operations,
- reduce post-operational processing of the data (e.g., keying).

However, the development and use of automation carries a cost. The resources needed to develop and test the software and systems, as well as the cost of acquiring and maintaining the hardware can be high. There is also an associated training cost, since listers may not be familiar with the automated tools. Despite the start-up costs, the expectation was that in the long term, increased automation would improve operations and results.

Subsequent portions of this background section present many of the listing operations from Census 2000 through the 2010 Census. These operations are:

- Address Listing (Census 2000)
- Block Canvassing (Census 2000)
- Update/Leave (Census 2000)
- Address Canvassing (2004 Census Test)
- Address Canvassing (2006 Census Test)
- Address Canvassing (2008 Census Dress Rehearsal (DR))
- Address Canvassing (2010 Census)
- Update/Leave (2010 Census)

AC replaced the Address Listing (AL) and Block Canvassing (BC) operations that occurred in Census 2000. AL, BC, AC 2004, 2000 Update/Leave (U/L), and 2010 U/L were all paper-based operations, whereas AC in 2006, 2008, and 2010 were all automated operations. As part of the 2008 and 2010 AC operations, the Census Bureau chose to contract out the development of the automated listing and mapping instrument, as well as the Operations Control System (OCS) for the Stateside and Puerto Rico (PR) listing and enumeration operations. The Harris Corporation was selected for the development of the instrument, and the infrastructure support needed in the Local Census Offices (LCOs). The Harris contract is described in more detail in sections 2.7 and 2.8.

The following sections highlight Census operations and tests from 2000 to the present; sections 2.1, 2.2, and 2.4 through 2.7 are largely extracted from the "2008 Census Dress Rehearsal (DR) Address Canvassing Assessment Report" (Dixon et al, 2008).

2.1 Census 2000 Address Listing Operation

AL was used to create the initial Master Address File (MAF) for U/L areas for both the Census 2000 Dress Rehearsal and Census 2000. U/L and AL were conducted in areas where it was believed mail delivery would be inadequate for contacting the respondents. United States Postal Service (USPS) data, primarily the USPS Delivery Sequence Files, were assumed to be inadequate in areas that were not served by the USPS and so the address list was created from scratch in those areas using AL.

During the AL operation, which occurred from July 1998 to May 1999, listers systematically canvassed each block in their Assignment Area (AA) to build a paper list of addresses or physical location descriptions of the Housing Units (HUs) they found on the ground. The Census Bureau defines canvassing as traveling clockwise around a block, listing only addresses to the lister's right side, in the order found by walking. They also updated existing paper maps with map spots and map features to make the paper map reflect ground truth. Addresses and map changes from AL were captured and used to update the MAF and Topologically Integrated Geographic Encoding and Referencing (TIGER) databases. The Census 2000 AL operation differed from BC in that listers created the address list from scratch instead of updating an existing list. The AL workload was 24,023,043 including negative actions. The 114,905 listers conducted the operation.

2.2 Census 2000 Block Canvassing Operation

In Census 2000, the Census Bureau conducted the BC operation to update and improve the content and accuracy of the existing MAF and TIGER databases. Implemented during winter and spring 1999, the operation required field listers to conduct a 100-percent canvass of blocks within areas that were "inside the blue-line." Areas "inside the blue-line" were areas that contained predominantly city-style (house number and street name) addresses.

Listers canvassed blocks and then verified addresses printed in their [paper] address registers and used [paper] maps as aids in locating blocks and structures within the blocks that contained living quarters. The listers compared each address found on the ground with those in the address registers for the blocks included in their AA. They then recorded all corrections, additions, and deletions on the listing pages within the address register. The listers also updated census maps to show additions, corrections, and deletions to road features.

The listers stopped at approximately every third HU (as indicated in their address register), every multi-unit structure, and every added HU to inquire about the addresses on either side of that address as well as to identify any "hidden" units. ["Hidden" units are separate HUs that exist as part of another HU, but are not immediately visible (e.g., garage or basement apartments).] The BC workload was 94,346,049 including negative actions. The 140,688 listers conducted the operation.

2.3 Census 2000 Update/Leave Operation

In Census 2000, the Census Bureau conducted the U/L operation to update and improve the content and accuracy of the existing MAF and TIGER databases. In addition to updating the address list, the Census Bureau distributed the Census 2000 questionnaire to all the HUs in U/L and Urban Update/Leave (UU/L) enumeration areas. This section uses information from the "Evaluation of the Update/Leave Operation" (Pennington 2003) and "Urban Update /Leave" (Rosenthal 2002).

Both U/L and UU/L operations were implemented in the spring of 2000. In both operations, listers canvassed the blocks they were assigned. Most of U/L took place in rural areas. UU/L is a special subcategory of U/L and, as the name implies, occurred in more urban areas. The UU/L operation targeted urban areas with drop-point deliveries (usually multi-unit structures) and communities that are urban but pick up mail at Post Office (PO) boxes. The U/L workload for the operation was 23,525,257 addresses stateside and 1,471,225 in PR. UU/L had 238,216 addresses enumerated in Census 2000, including those addresses that were enumerated as vacant. Both the U/L and the UU/L numbers include addresses added during the operations.

U/L is one of the Types of Enumeration Areas (TEAs). These are designations as to how the Census Bureau enumerates people for a particular geographic area. The primary method in Census 2000 was Mailout/Mailback (MO/MB). The second largest enumeration operation, by number of questionnaires, was U/L. U/L occurred in most states and was used to enumerate all of PR.

U/L occurred after the BC and AL operations. U/L was similar to BC in that a dependent list was used when updating and verifying the address list.

2.4 2004 Census Test Address Canvassing Operation

A 100-percent AC operation was conducted in the Queens, NY test site during the 2004 Census Test. This new AC operation was a dependent listing operation that was designed to replace both the BC and AL operations. The address list from Census 2000 was used as a base for the dependent listing and updates could be made to the address list regardless of what types of addresses existed. The operation was originally intended to be tested in two 2004 Census Test sites, the other site being a mix of small urban, suburban, and rural areas in three counties in Southern Georgia. However, AC was canceled in the Georgia site in the 2004 Census Test due to budget limitations.

Listers for the 2004 Census Test canvassed each block in their AAs and verified addresses by contacting *every* structure, which was a change from Census 2000 BC, where listers contacted approximately every third structure. As with the Census 2000 BC operation, listers compared addresses found in the blocks they were canvassing to the information in their address registers and maps and made required changes/updates on paper. They added addresses missing from the address list, deleted addresses on the address list that duplicated other addresses or did not exist on the ground, and ensured all addresses were assigned to the correct geographic location.

The listers classified each living quarters in their assigned area as either a HU or Other Living Quarters (OLQs) which also was a change from the Census 2000 BC operation. OLQs are structures where there are more likely to be large groups of unrelated individuals living together such as prisons or dormitories at a college. Any addresses identified as OLQs were later validated during the Group Quarters Validation (GQV) operation. The listers also updated paper maps with information about the location and names of features (roads and streets). Address and map changes from AC were captured and used to update the MAF and TIGER geographic databases.

The Census Bureau used a Hand-Held Computer (HHC) for the NonResponse FollowUp (NRFU) operation in the 2004 Census Test. During NRFU, enumerators used HCCs to collect Global Positioning System (GPS) coordinates for all HUs contacted for followup. These coordinates were captured using procedures developed by a multi-divisional GPS Application Strategy Group. This was the first time enumerators captured GPS coordinates in the field using HHCs. After NRFU, an evaluation study examined the procedures for the capture of GPS coordinates during fieldwork, and data from this study informed the 2006 Census Test AC operation. The study found that although the enumerators did not attempt to capture coordinates for many of the structures, the functionality of the HHC GPS capture was a success.

2.5 2006 Census Test Address Canvassing Operation

For the first time in the 2006 Census Test, the AC operation was conducted using a HHC with the Listing and Mapping Instrument (LAMI)[1] software, instead of paper listings and maps. The test was conducted in Travis County, Texas and the Cheyenne River Indian Reservation in South Dakota. The Census Bureau developed the LAMI to allow listers to verify, update, add, and delete address records in each census block, to collect/update map spots, and to capture coordinate data where the GPS was available. The updates from canvassing were applied to the MAF and TIGER for use in subsequent operations. This was also the first time the Census Bureau tested an electronic payroll system for AC field listers.

The Office of Inspector General (OIG) summarized some of the problems seen in 2006: "As in 2004, the HHCs suffered from frequent crashes, data loss, slow performance, and problems associated with collecting global positioning system [GPS] coordinates." These problems led to a delayed completion of the AC operation. The reliability of the GPS coordinates was also in doubt (OIG 2006).

Many of these problems occurred due to the insufficient Random Access Memory (RAM) of the HHCs used in 2006. The applications used needed more RAM than available on the HHCs.

In the 2006 Census Test, there were no evaluation studies of the AC operation or HHCs due to schedule and budget constraints, but there was a 2006 Census Test AC Operational Assessment (Schneider et al, 2006) that documented what occurred during the operation. This assessment included the results of a Time and Motion (T&M) study.

In the T&M Study, observers recorded the amount of time it took a sample of listers to perform each element of the AC procedures (e.g., driving, getting out of the car, walking to the front door, knocking on the door, and waiting for an answer). Data from the T&M Study provided estimates of the listers' productivity through every step of the procedures and presented information about problems the listers encountered in the field (e.g., time spent troubleshooting the HHC and receiving technical support for the HHC).

[1] An instrument in survey work is the questionnaire or software used to collect the information.

The 2006 Census Test AC Operational Assessment also provided results on some issues that were being researched, and results of a new Delete Verification process that was being tested. Additionally, there was a section on lessons learned that was used in planning the 2008 Census Dress Rehearsal. In general, these lessons learned dealt with software and requirements issues, as automation of this operation was being tested for the first time.

2.6 2008 Census Dress Rehearsal Address Canvassing Operation

The 2008 Census Dress Rehearsal (DR) AC operation was conducted in San Joaquin County, California, and in Fayetteville and eastern North Carolina. The AC production work and quality control (QC) were managed out of LCOs, and was conducted from early May to late June 2007. In an effort to compile the most accurate and comprehensive residential address list possible of HUs and Group Quarters (GQs), the Census Bureau and the Field Data Collection Automation (FDCA) contractor, Harris Corporation, developed and tested new data collection technologies for AC during the 2008 DR. This was the first time the Census Bureau used a contractor-provided system to conduct field operations. Some of the new elements for the 2008 Census DR technologies included:

Figure 4. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: HHC
Photo Credit: U.S. Census Bureau, Public Information Office

- Establishment of interfaces between several different Census Bureau systems such as the MAF/TIGER System, Decennial Applicant, Personnel and Payroll System (DAPPS), Cost and Progress (C&P), and Census Experiments and Evaluations (CEE) to exchange input and output data,
- Establishment of a data processing center,
- Contractor development of software, hardware, telecommunications, and an office environment,
- Use of Computer-Based Training on the HHCs,
- Use of wireless transmission of data,
- Use of text messaging for field staff.

2.7 Field Data Collection Automation (FDCA)

For the 2008 DR, Harris developed the AC hardware and software to be used in the Regional Census Centers (RCCs), LCOs, and on the HHCs in the field. All were developed with requirements provided by the Census Bureau.

The design for automating field data collection consisted of three primary components:

- Operations Control System (OCS) – a collection of control and tracking software used to make assignments, reassign work already in the field, check in completed work, and track the status of assignments and listers. The OCS was intended to be used for more operations than just AC.
- Hand-Held Computers (HHCs) – including a GPS unit, a modem, storage media, and data collection software.
- Telecommunications Infrastructure – a combination of secure networked servers, modem banks, and software needed to authenticate users and transfer encrypted data.

The OCS and telecommunications infrastructure was intended for all operations, and the HHCs were intended for AC and NRFU. Some operations were cut from the DR, and the Harris contract was rescoped.

More specifically, for AC, the FDCA contractor was responsible for:

- Purchasing all HHCs, office telecommunications, and data processing hardware,
- Integrating all the different hardware,
- Developing software for all components of the AC operation, including software for the office staff and the HHC software used by field staff,
- Developing the software for all components of the AC QC operations including Delete Verification and Final Delete Verification,
- Establishing the two Dress Rehearsal Local Census Offices,
- Establishing interfaces between several different Census Bureau systems such as MAF/TIGER, DAPPS, C&P, and CEE to exchange input and output data,
- Establishing a data processing center required to execute the telecommunications infrastructure,
- Ensuring all software and hardware met security guidelines established by the Census Bureau,
- Loading the OCS with AA and map data files supplied by the MAF/TIGER database (MTdb),
- Loading the HHC with the address list and map files for the operation, supplied by MTdb,
- Integrating all the different software required for the entire AC operation,
- Testing the entire system to ensure that the software functioned as expected and the data captured were accurate, and
- Providing a help desk to assist with the use of the HHCs in the field.

2.7.1 Address Canvassing Software

The 2008 Census DR AC operation required listers to canvass (systematically travel throughout) assigned census blocks looking for all potential living quarters. The lister compared these living quarters on the ground to what was displayed on the HHC. By design, this was a dependent listing operation. The AC software resident on the HHC displayed an address record from the MTdb for each known living quarters.

During the AC operation, HHCs were used at both test sites by Census Bureau field listers to collect address and map information. Each HHC was equipped with:

- FDCA software to capture the address and map data and display Census-generated information,
- Assignment management system software to control the workload assigned to a particular lister,
- A GPS receiver to assist in the collection of GPS information and to provide a "You Are Here" display on the Census-generated maps, and
- A modem for listers to electronically transmit collected data and receive new work assignments daily, when wireless transmission was unavailable. The HHC had both wireless and wired transmission capability.

The AC instrument allowed listers to perform AC activities for each address in each block within their AA, and allowed Crew Leaders, production listers, and QC listers to:

- Update location and mailing address information,
- Verify or correct location and mailing address information,
- Add addresses,
- Delete addresses,
- Code a living quarters as a HU or an OLQ,
- Link duplicate addresses when identified,
- Collect structure type data,
- Capture map spots and GPS coordinates for all structures,
- Identify a QC workload for a dependent quality check,
- Conduct a dependent QC check of the lister's original work,
- Verify all address record deletes and duplicate records.

The software in the HHCs allowed listers to conduct the functions listed above in each census block within their AA, while the QC program allowed completed assignments to be reviewed and validated by separate QC listers.

The LCOs assigned staff to districts: Field Operations Supervisor (FOS) Districts and Crew Leader Districts (CLD). Then, before the operation, the OCS transmitted the work assignments to Crew Leaders (CLs). The CLs used the Assignment Management software on their HHCs to make assignments to listers in their CLD at the conclusion of training and on an ongoing basis as the listers completed AAs.

The OCS checked in the work and transferred completed AAs to the QC operation, where that AA was assigned to QC listers using a process similar to production AC. QC listers used the AC QC software on their HHCs to perform the various stages of QC -- Dependent Quality Control (DQC)[2], Delete Verification[3], etc. The AC QC software used QC algorithms to determine whether an AA passed or failed the QC checks. AAs that did not pass the DQC check were recanvassed. AAs that passed QC and Delete Verification process were considered complete and ultimately were transferred to the Geography Division (GEO) for processing and updating the MTdb.

Production and status reports were generated daily for the LCO and field staff to monitor the progress of the field work. These reports were also available on the laptops supplied to FOSs.

To assess the use of the HHCs in the field training and production, the Administrative Management Services Division staff conducted a T&M Study.

2.7.2 Electronic Maps

In the 2008 Census DR, HHC electronic maps were used to locate work assignments and to update block level maps with structure locations. This was consistent with the process followed for the 2006 Census test using the LAMI. However, this was a significant departure from the use of paper maps in the Census 2000 address list development operations.

In Census 2000 and for the 2004 Census Test, field staff updated paper maps with new street features, corrected street names, and deleted streets that did not exist. In areas outside the "blue line," they also added, deleted, or made corrections to map spots showing the location of structures.

These paper maps were then sent to a processing center where, for most operations, each map was scanned and the new street features and map spots were digitized. Digitizing is the conversion from paper into an electronic format. At this time, corrections to street names also were made and nonexistent features were deleted. Since the address registers and the maps were on different processing paths, it was possible to create mismatched information, such as correcting a street name from the map while the old name was maintained in the address register.

[2] For Dependent Quality Control (DQC), a QC lister verifies a production lister's work by relisting part of the AA, ensuring an acceptable threshold of quality (observing few or no errors as a percentage of the total AA work). If the quality threshold is not met, the QC lister relists the entire AA.
[3] For Delete Verification, a QC lister confirms the deletes identified in the production work.

For the 2006 Census Test, HHCs were used to conduct AC. Field staff in the AC operation used electronic maps on their HHCs to locate their block assignments. On these block maps, listers collected structure locations manually (by tapping on the screen) and via GPS, when available. Listers updated the maps associated with specific address records. For the 2006 AC operation, these maps and tools were included in the mapping component of the LAMI. Note that structure map spots were collected everywhere (a change from the Census 2000 model), which led to more uniform procedures.

In the 2008 Census DR, HHC electronic maps were used to locate work assignments and to update maps with structure locations in roughly the same manner as for 2006.

2.7.3 GPS Structure Coordinate Collection

For both the 2006 and the 2008 AC operations, the HHC included GPS hardware/software to support the display of the "You Are Here" indicator for navigation and structure coordinates capture. This allowed the listers to view where they were, spatially, in their AA. The mapping function allowed the listers to zoom in and out to achieve an accurate view from the block level out to a wider view of their AA.

The primary reason to include the functionality of the "You Are Here" indicator was to help listers orient their location and to identify the location of each structure. However, GPS was also used to capture GPS coordinates in a manner that was not observable to the listers. In both the 2006 and 2008 AC operations, two sets of coordinates were attempted at every structure, one set of manually-identified coordinates and one set of GPS coordinates.

When a lister completed updating an address record, the software presented a block map on the HHC and prompted the lister to capture the location of the address. The lister then identified the location on the map by tapping the screen, thereby placing a map spot on the map (the manual coordinates). After the manual map spot collection occurred, the software automatically attempted to capture the GPS coordinates of the HHC at that time. If the GPS collection was unsuccessful, only the manual coordinates were saved and associated with the listed address. If the GPS collection was successful, the software then associated both sets of coordinates with the listed address. For a multi-unit structure, the software allowed the lister to simply associate each individual address with one, previously collected, map spot for the entire structure.

2.7.4 Post Operation Processing

The post operational processing changed with automation. In paper listing operations such as AL and BC, the address data were shipped to a data keying facility such as the National Processing Center (NPC), and then keyed into electronic information that could be used to update databases such as the MAF. This keying process, although very accurate, does produce a small percentage of errors. When applying small percentages of errors to the entire MAF, the result can be large quantities of HUs with errors. By automating AC, these errors are avoided.

2.8 Challenges and Testing of Automation including the Operational Field Test of Address Canvassing

This was Harris Corporation's first contract with the Census Bureau for a large-scale field operation. The scale of the contract, combined with the contractor's first exposure to an operation of this magnitude contributed to the difficulties that were witnessed.

The following information on problems with HHCs is extracted from the Government Accountability Office's (GAO's) "2010 Census: Census Bureau's Decision to continue with Handheld Computers for Address Canvassing Makes Planning and Testing Critical" in July 2008 (Scirè and Powner 2008).

> For the 2008 Dress Rehearsal and the 2010 Census, the [Census] Bureau awarded the development of the hardware and software for a HHC to a contractor. In March 2006, the Bureau awarded a 5-year contract of $595,667,000 to support the FDCA project.
>
> Listers experienced multiple problems using the HHCs. For example, we observed and the listers told us that they experienced slow and inconsistent data transmissions from the HHCs to the central data processing center. The listers reported the device was slow to process addresses that were part of a large assignment area. [A large block, not a large assignment area, was the cause of processing degradation.]
>
> Productivity results were mixed when Census [Bureau] listers used the HHC for address canvassing activities. A comparison of planned versus reported productivity reveals lister productivity exceeded the Bureau's target by almost two housing units per hour in rural areas, but missed the target by almost two housing units per hour in urban/suburban areas.
>
> The [Census] Bureau took some steps to collect data, but did not fully evaluate the performance of the HHCs. For instance, the contractor provided the Bureau with data such as average transmission times collected from the transmission logs on the HHC, as required in the contract. But the Bureau has not used these data to analyze the full range of transmission times . . . Also, the Bureau had few benchmarks (the level of performance it (HHC) is expected to attain) to help evaluate the performance of HHCs throughout the operation.
>
> The Census Bureau's final assessment of dress rehearsal address canvassing indicated that unacceptable help desk response times and insufficient answers severely affected productivity in the field.

In response to the faults of the HHCs, Harris continued working to improve HHC functionalities. The Census Bureau examined the results and decided what role the HHCs and Harris would have in later operations. Many tests were conducted for the HHCs after the 2008 Census DR AC:

- Assembly Testing
- Production Integration Testing (PIT)
- Validated Systems Testing (VST)
- Interface Testing
- Dialup Testing
- User Testing
- Performance Testing
- AC Operational Field Test.

The Census Bureau organized the AC Operational Field Test (OFT) which took place in Fayetteville, North Carolina from December 4-11, 2008. The OFT field staff followed the AC procedures but did not make contact with respondents or enter multi-unit structures. Staff from Census Headquarters, all twelve Regional Offices (ROs), and external oversight groups volunteered to act as observers by accompanying listers and recording any errors on the HHCs using Investigation Logs. Overall, the OFT was successful: debriefing results pointed to significant improvements since the 2008 Census DR, and feedback was provided on Investigation Logs. The OFT provided considerations for the future (Chapin 2008).

The OFT also provided Census Bureau stakeholders a chance to ask listers what they thought about the HHC. The listers generally felt that the HHC helped them to complete their work. The maps helped the listers find their assigned blocks. The main complaint logged was the glare on the screen of the HHC. At least one lister, who had previous paper listing experience, felt that the HHC was a big improvement over paper operations. The HHC was not an apparent hindrance to the efficiency of the listers.

The additional testing identified and corrected problems[4], or at minimum significantly reduced potential impacts of the reported issues. In at least one case, this led to decreased functionality. The Census Bureau dropped the requirement that all multi-unit living quarters be linked to a map spot. There were frequent difficulties with collecting GPS map spots in 2004 and 2006, but GPS map spots were collected for 95 percent of the structures in the 2008 Census DR AC (Dixon et al, 2008). Also in the OFT, fewer computers froze and the block size that caused performance degradation had improved from the original threshold of 700 HUs.

2.9 2010 Census Address Canvassing Operation

The 2010 AC operation was managed from 151 Early-Opening Local Census Offices (ELCOs) and occurred in waves. The field work for the operation began on March 30, 2009 and ran through July 10, 2009.

Geographically, AC was conducted everywhere except remote areas of Alaska (areas in two boroughs that were not part of the Remote Alaska enumeration) and Maine (areas in three counties). Due to the remote location of these areas, they were visited and updated only once for the 2010 Census, which was during enumeration. In the remote areas of Alaska, the enumeration operation was called Remote Alaska. The areas in Maine and two non-remote Alaska boroughs used an enumeration methodology called Remote Update/Enumerate.

AC was not conducted in the Island Areas, which were covered by the List/Enumerate operation. AC was conducted in PR, with the HHC software adapted with Spanish language translations and the type of addressing specific to PR. Field manuals and training materials were adapted and translated specifically for AC in PR.

[4] Some solutions to problems involved reducing the scope or functionality of the HHCs.

The AC workload was 159,494,710 including negative actions. The 170,610 listers (126,798 production listers and 43,812 QC listers) conducted the operation

2.9.1 Time and Motion Study for Address Canvassing

A T&M study was conducted for AC. T&M studies involve an observer following a lister to record the duration of specific tasks. They can be used to measure efficiency. For 2010 AC, Personal Digital Assistants (PDAs) were used to conduct the T&M studies. Since AC was completed ahead of schedule, there was some difficulty planning the T&M studies.

2.9.2 Large Block Canvassing

Due to concerns about HHC-processing of blocks with large numbers of HUs, the Census Bureau conducted an additional operation for these "large blocks." This operation used laptops with Automated Listing and Mapping Instrument (ALMI) software following slightly modified Demographic Areas Address Listing (DAAL) procedures.

The Large Block AC (LBAC) operation was used in blocks that GEO identified as having 1,000 or more Living Quarters (LQs). The LCOs could also move blocks into LBAC once AC had begun for any blocks with 2,000 or more LQs. The LBAC operation was run entirely out of the ROs and RCCs, using Census Bureau current survey personnel and new hires.

Due to improvements made by the FDCA contractor, blocks containing 2,000 or more HUs during AC (that were not pre-identified as being large prior to the start of AC) were separated from remaining blocks in the large block AAs, put into a newly formed suffixed AA, and sent back to GEO through the OCS. After some additional processing by GEO, these large blocks were then sent to the current survey staff for the alternative listing work. Canvassing results from these large blocks were then sent back to GEO for MTdb updating.

Approximately 400 currently employed Field Representatives (FRs) had these blocks added to their regular DAAL workload. The Census Bureau also hired about 700 additional FRs to be trained specifically to conduct LBAC. The Census Bureau did not equip the ALMI laptops with GPS, although the software had the capability.

The LBAC operation was not used for large blocks in PR. Because all of PR was enumerated using U/L methodology, the Census Bureau relied on AC and U/L to update the address lists in PR. Depending on HHC performance, large blocks may have been canvassed at a slower than desired production rate in PR.

2.10 2010 Census Update/Leave Operation

The Census Bureau conducted the 2010 Census U/L operation in locations where it was known that the USPS could not deliver mail to most physical addresses (e.g., post office box delivery and drop point delivery). There were two types of U/L: basic U/L, which occurs in mostly rural

areas, and UU/L, which occurs mostly in urban areas or areas recovering from a natural disaster. Both operations were managed out of the LCOs.

The following information comes from the "2010 Census Operational Plan for Update/Leave" (Address List Development Operations Implementation Team, 2008):

> The expected production workload for U/L and UU/L (Urban U/L) is approximately 11.8 million housing units plus 1.4 million for Puerto Rico. The expected Quality Control (QC) workload for U/L and UU/L is approximately 930,043 housing units. The operation will be managed out of Local Census Offices (LCOs).
>
> During the U/L operation, enumerators canvass the blocks in their assignment areas, update the address lists and census maps, determine if the housing unit exists and is residential, and deliver addressed census questionnaires to each valid unit.
>
> The universe of units in the U/L operation workload is the set of addresses appearing on the U/L address listing pages and those added during the operation. Addresses designated as good addresses for the Census during the creation of the initial Universe Control and Management (UCM) file or in the supplemental universe delivered in the subsequent enumeration extract will be included in the printing of questionnaire labels. These addresses will appear on the listing pages for the U/L operation and are designated to receive a preprinted questionnaire.
>
> Housing units located in the field but not appearing on the listing pages are added to the Housing Unit Add Page. Address and geographic information, as well as the blank add questionnaire's preprinted processing identification number, are entered onto the add page. Then the enumerator will complete the hand-addressable questionnaire label on the add questionnaire and drop it off.
>
> After the assignment is complete through quality control, the address register (including all add pages and maps) is sent to the National Processing Center for keying and map digitizing. All listing pages and add pages are keyed and the processing ID from the add page is keyed and associated with the added address.
>
> Meanwhile, these "add" questionnaires, dropped off at the added housing unit, are returned by mail to the data capture center, where the results of the processing are maintained by the processing identification number captured from the add questionnaire. Geography division receives the results of the keying and digitizing of address registers and maps and processes all address updates as well as added addresses and adds them to the MTdb…

2.10.1 Time and Motion Study for Update/Leave

A T&M study was also conducted for U/L. T&M studies involve having an observer follow a lister to record the duration of specific tasks. They can be used to measure efficiency. For 2010 U/L, PDAs were used to conduct the T&M studies. The T&M implementers chose the 2010 geographic sites in the study to overlap with previously conducted T&M studies. By isolating geography, the longitudinal results are more comparable.

3 Methodology

3.1 Questions to be Answered

What was the impact of adding expanded automation to field data collection for AC?

1. *Did automation contribute to operational improvements?*
2. *Did the Census Bureau gain in efficiency?*
3. *Did the Census Bureau see cost savings?*

3.2 Evaluation Methodology

The methodology employed for this evaluation consists of four components:

- Listing Operational Comparisons
- Operational Improvements and Impacts
- Efficiencies
- Costs

The first component is a comparison of the various listing operations. This is meant to highlight the differences between the operations, making the results more understandable. For example, knowing that AL is more rural than BC helps the reader better understand the analytical results. The other three components simply address the research questions in the order they were presented in the study plan.

3.2.1 Census Methodology for Listing Operations

A solid understanding of the differences in the various listing operations is critical for the reader to fully appreciate the research and conclusions reached in this report. Ideally, the analyses conducted here would, for the same exact operation conducted at the exact same time, compare an automated implementation to a paper-based implementation. This was not feasible for this evaluation. The analyses here compare 2010 Census AC (automated) to the most similar operations in Census 2000: AL and BC (both paper-based). In addition, since some information is unavailable from 2000, the analysis sometimes compares 2010 Census AC (automated) to 2010 Census U/L (paper-based). Table 1 provides a summary of the differences between AC, AL, BC, and U/L.

Geographically, the areas of the nation covered by AC are vastly different from the areas covered by AL and BC (see Figure 5 and Figure 6). For Census 2000, BC primarily occurred in the MO/MB areas shown in salmon, and AL occurred mostly in the U/L areas shown in blue. The remaining geography, displayed in tan, was not covered by AL and BC. For the 2010 Census, AC was conducted in the entire nation, except for Remote Alaska and Remote Update

Enumerate, shown as dark green in Figure 6. The 2010 AC operation had increases in the length and cost of training due to new mandates and hiring/training procedures, compared to BC and AL from Census 2000.

Table 1. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Operational Comparison of Paper Operations to an Automated Address Canvassing Operation

	Paper Operations			Automated Operation
	2000 Address Listing	**2000 Block Canvassing**	**2010 Update/Leave**	**2010 Address Canvassing**
General	Conducted in **rural** areas.	Conducted in **urban** (MO/MB) areas.	Conducted mostly in **rural** areas. Some urban areas and areas recovering from disaster.	Conducted **Nationwide**, except in remote Alaska and some areas in Maine.
	Independent listing	**Dependent listing**	**Dependent listing / enumeration of HUs**	**Dependent listing**
	Up to two telephone **call backs**	No **call backs**	No **call backs**	No **call backs**
	Map spotted all LQs	No **map spot**ting	Verify existing **map spots** and **map spot** adds	**Map spot** all LQs, except units at multi-unit structures where only the first unit listed were map spotted. All units at the multi-unit structures were identified as being part of a multi-unit, but not linked to one another.
	No collection of **structure type**.	No collection of **structure type**.	No collection of **structure type**.	Collect **structure type** for all LQs.
	Three, six-week **waves**	Three, six-week **waves**	One month	Five start dates with multiple end dates within each.
	One **CLA** per CL.	Two **CLAs** per CL.	One **CLA** per CL.	One **CLA** per CL.
	Lister Training: 3 days (includes the practice field work).	**Lister Training**: 3 days (includes the practice field work).	**Lister Training**: 3.38 days Enumerator 4.25 days CL	**Lister Training**: 4 days (includes the practice field work, administrative and fingerprinting time).
	Production rates: Expected - 5.5 Actual - 4 Per Hour	**Production rates**: Expected - 27 Actual - 24 Per Hour	**Production rates:** Expected - 5.5 Actual - 5.3 Per Hour	**Production rates**: Urban / Suburban / Rural Expected - 19.2, 7.8, 2.9 Actual - 18.3, 11, 6.3 Per Hour
Coverage	Collect **location address by observation**.	Attempt an **interview at every 3rd HU** and ask about that unit and those on either side.	**Interview at every** HU while dropping off the 2010 Census form	**Only interview** at HUs where the house number is not posted.
	Attempt an **interview at every LQ** to collect mailing address by contact.	An **address** was collected either by **observation or interview**, but no distinction was made between location and mailing address.	A **location address** was collected for every house and an attempt to collect a **non-city style mailing** address.	For HUs where the house number is posted, no attempt was made to collect the **mailing address**. **However**, asked about additional LQs when contact made.
	Ask about **additional LQs** at every address.	Ask about **additional LQs** at every address.	Ask about **additional LQs** at every address.	Will ask about **additional LQs** only when contact is made. (No callbacks)
	No **duplicates** since it was an independent listing.	Identified **duplicates** and linked to the survivor, but linkage **was not data captured**.	Identified **duplicates** and linked to the survivor, but linkage **was data captured**.	Identify **duplicates**, but not linked to the survivor.
	No **deletes** since it was an independent listing.	**Deletes** were verified in subsequent operations.	**Deletes** were verified in subsequent operations.	**Deletes** were verified during AC QC part of the operation.
	Production staff conducted **QC**.	Production staff conducted **QC**.	**Separate QC** staff verifies the work of the production staff.	**Separate QC** staff verifies the work of the production staff.

MO/MB - Mailout Mailback, HU - Housing Unit, LQ - Living Quarters, CLA - Crew Leader Assistant, CL - Crew Leader, QC - Quality Control
Source: Operational Comparison and 2010 Update/Leave Assessment.

Figure 5. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Census 2000 Type of Enumeration Areas

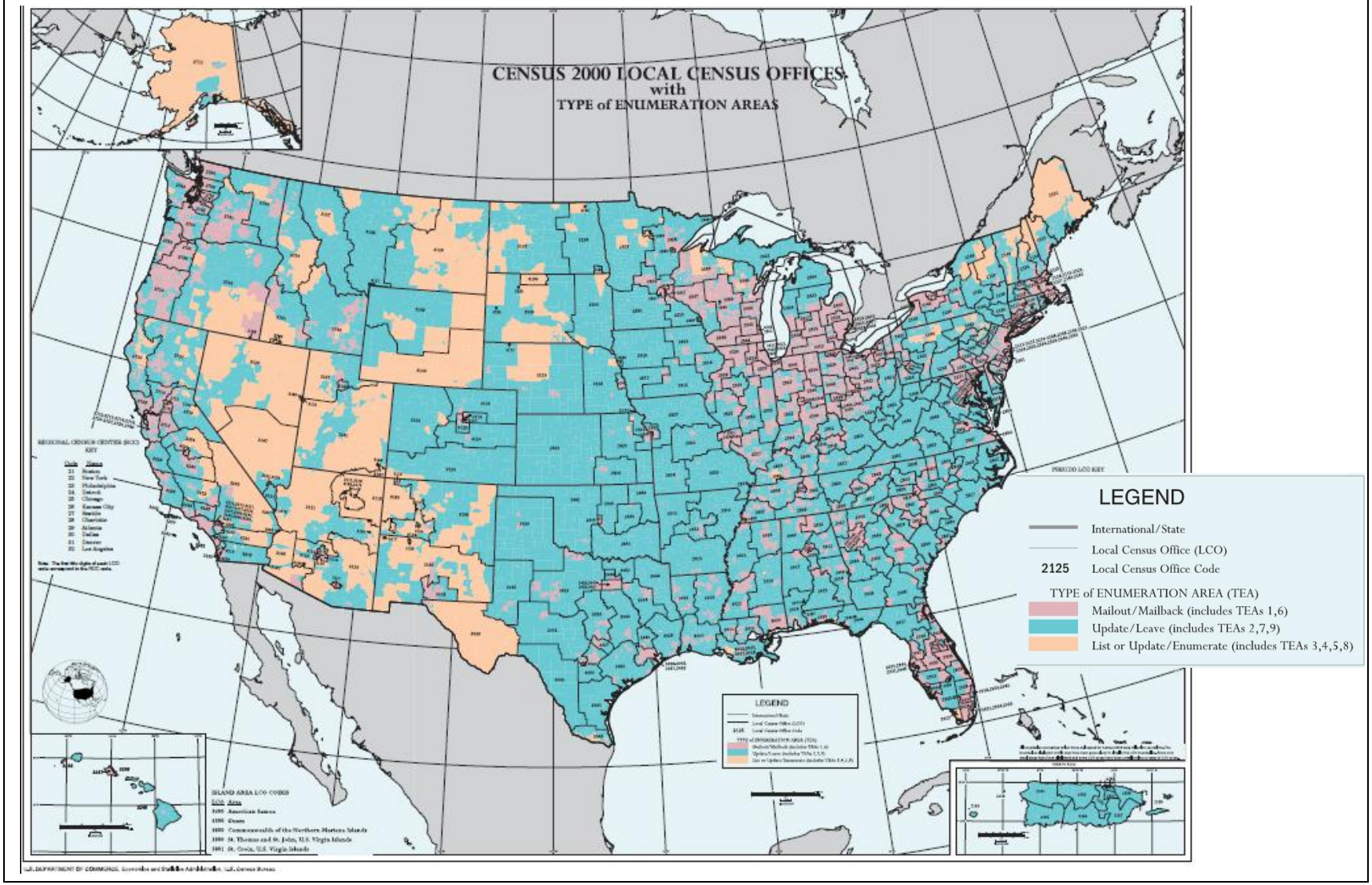
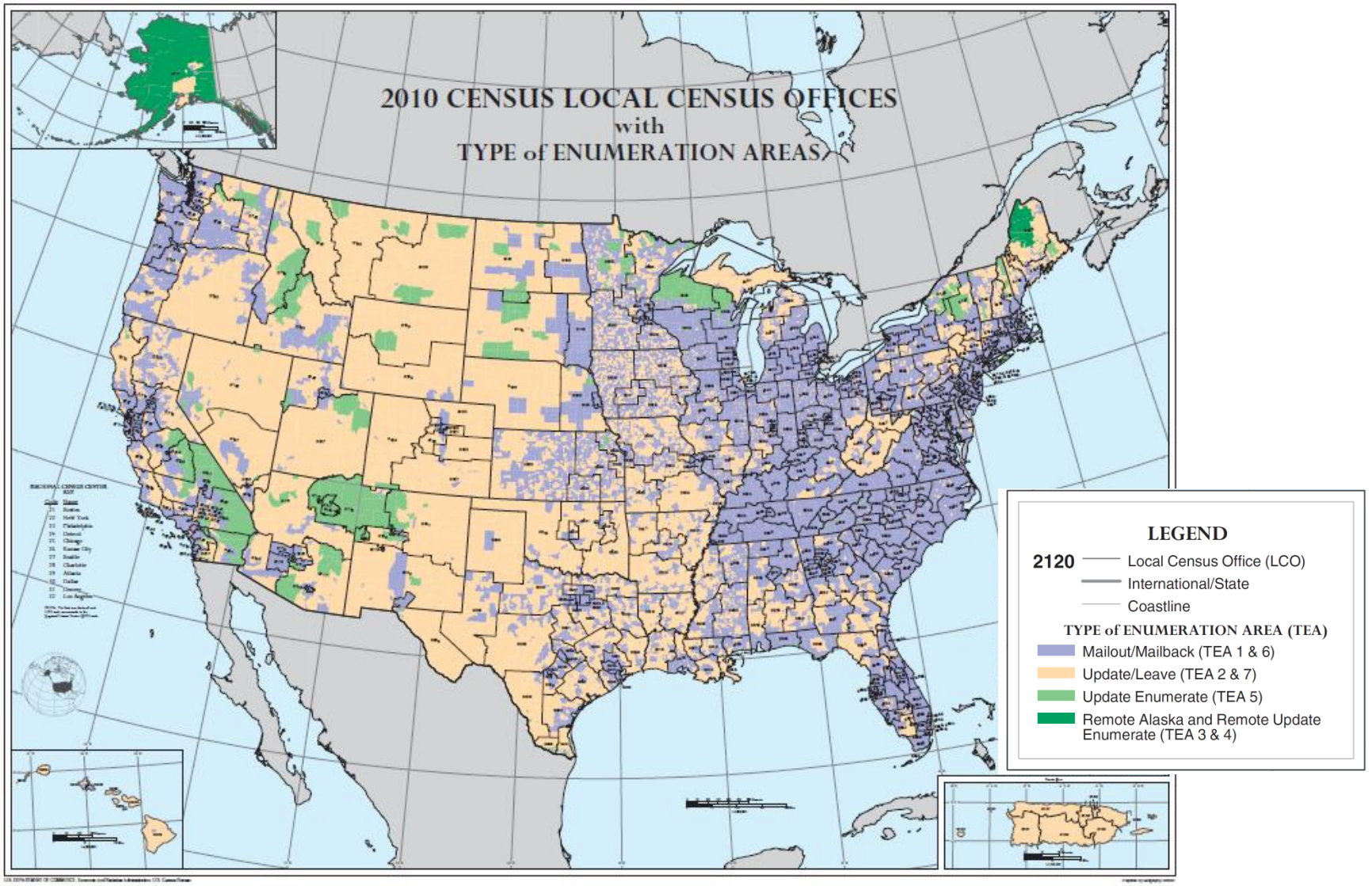


Figure 6. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: 2010 Census Type of Enumeration Areas



3.2.2 Methods Used to Measure Operational Improvements and Impacts

There are several ways to measure operational improvements and impacts of automation. Decennial Statistical Studies Division (DSSD) measured operational improvements and impacts using three methods:

1. Personnel feedback
2. 2010 Census U/L Office Review Checklist results
3. 2010 Census AC and U/L Quality Profile reports.

3.2.2.1 Personnel Feedback

Personnel feedback was collected via direct solicitations, debriefings, and a questionnaire. These were communications and exchanges with Headquarters (HQ), RCCs, and Listing staff. Personal interviews and emails with HQ staff in the decennial directorate and members of Field Division (FLD), and debriefings with RCC staff were all used as input. Listing staff, both Listers and CL, all provided input on the impact of automation via a post-GQV solicitation[5]. Some debriefings and lessons learned can appear overly negative since it is sometimes common for people to focus on problems they would like to avoid in the future. When reviewing some statements in this section, it is recommended that one pair the broader picture with many of the specific problems that are stated. The term issue that is referenced in the results sections for debriefings does not indicate problems. Instead, this term is used to indicate a topic related to automation.

3.2.2.2 2010 Census Update/Leave Office Review Checklist

The Office Review Checklist (ORC) is a quality tool used by clerks in the LCO to ensure listers properly complete listing pages. The National Processing Center (NPC) in Jeffersonville, IN captured the U/L ORC after the U/L operation. DSSD tabulated the forms, and calculated derived values for questions. Derived variables were made using intelligence from other questions on the form. These derived values did not replace the clerk-provided data. The derived values provided a consistency check. In some instances, the derived value provided a value for a question that the clerk did not complete.

Derived values were calculated for total critical errors, total noncritical errors, percent of critical errors, and the pass or fail outcome of the ORC. Total critical errors were calculated by summing all critical errors, or by using the total housing units and percent of critical errors. Total noncritical errors were calculated by summing all noncritical errors. Percent of critical

[5] Approximately 2,424 field staff completed the debriefing questionnaire after GQV, of the 170,610 field staff who worked AC. This provides for a lister sample of about 1.4 percent. For the analyses in this report, we assume the nonresponse bias is negligible.

errors were calculated from total critical errors and total housing units. The threshold of greater than five percent critical errors was used to indicate failure.

Some errors occurred when filling out and capturing the forms. For example, when calculating the percent of critical errors, some entries were transposed so that a 3 percent error rate was recorded as a 97 percent error rate. In addition, if the sum of critical error questions totalled the total critical errors, DSSD imputed each unanswered critical error as zero. This imputation was repeated for the noncritical errors. The process for NPC-capture did not require keying the zero values on the form, but these populated values were necessary for the consistency checks and analyses conducted for this evaluation. DSSD also removed any forms with total housing units greater than 9,000, since the U/L team informed DSSD that all U/L blocks contained fewer than 9,000 HUs. In general, DSSD edited values in a consistent, repeatable manner to glean the most value from the information provided on the checklist.

3.2.2.3 2010 Census Address Canvassing and Update/Leave Quality Profile Comparison

A quality profile is created for 2010 Census operations that have a QC plan. The profiles help measure the quality of each operation. DSSD compared some of the results from the AC Quality Profile to the U/L Quality Profile. Even though different operations, this allows for a comparison of quality in an automated operation, AC, with a paper-based operation, U/L. Being different operations, there are certainly some limitations to this comparison:

- U/L is a dependent listing based on the AC listing, so the contributions of AC might directly affect U/L (and thus U/L may have fewer errors);
- Some AC staff also worked on U/L, introducing the potential for a more experienced U/L staff (the more experienced staff should thus be more likely to list properly);
- U/L and AC tracked slightly different errors;
- U/L addresses may have been more difficult to list given that U/L areas are more rural;
- AC and U/L had some differences in error definitions, especially for observations.

In addition, the DQC had more stringent thresholds for U/L than for AC. See Table 2 for sample sizes and thresholds for critical and noncritical errors.

AC had a Weighted Average Outgoing Quality Limit (WAOQL) of 8.1 percent for critical errors; U/L had a WAOQL of 5.5 percent for critical errors. Taking into account these differences and limitations, DSSD compared observation checklist and AA pass/fail rates. For the observation checklists, the analytical universe was identical to that of the Quality Profiles.

Table 2. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: 2010 Census AC and U/L Dependant Quality Control Algorithm Comparison

Total Units in AA	AC DQC Sample Size	U/L DQC Sample Size	AC Allowable Critical Errors	U/L Allowable Critical Errors	AC Allowable Noncritical Errors	U/L Allowable Noncritical Errors
x <= 50	2	3	0	0	1	1
50 < x <= 100	3	5	0	0	1	1
100 < x <= 150	5	8	0	0	1	1
150 < x <= 175	5	9	0	0	1	1
175 < x <= 200	6	10	0	0	1	1
200 < x <= 275	8	14	0	0	1	1
275 < x <= 500	15	25	0	1	3	3
500 < x <= 1000	30	50	1	2	5	5
1000 < x <= 1500	45	75	2	4	8	8

AA - Assignment Area, AC - Address Canvassing, U/L - Update/Leave, DQC - Dependent Quality Control
Source: 2010 Census AC and U/L Quality Profiles.

3.2.3 Methods Used to Measure Efficiencies

DSSD measured efficiencies by three methods:

1. Execution Cost per Case
2. Time and Motion Studies
3. MAF Update Times

3.2.3.1 Execution Cost per Case

Execution cost per case directly measures the efficiency of the listers. More efficient operations have a lower execution cost per cost.

The cost results presented in this evaluation were generated by program office staff using methods predating the US Census Bureau's commitment to comply with GAO's cost estimating guidelines and the Society of Cost Estimating and Analysis best practices. Hence, while the Census Bureau believes these cost results are accurate and will meet the needs for which they will be used, the methods used for estimating costs of 2010 Census operations may not meet all of these guidelines and best practices. The Census Bureau will adhere to these guidelines in producing 2020 Census cost estimates.

DSSD applied inflation and workload adjustments to make comparisons over time. The inflation adjustments are described in Section 3.2.4.1. Once AL and BC values were adjusted for inflation, DSSD divided by the workload of each operation, including AC, to calculate the final cost per case. All cost per case values include both the production and QC portions of the operations, without increasing the workload. So, if two operations directed differing amounts of their workload to QC, that additional QC workload disparity was not adjusted for in the cost per case calculation. Additionally, there is a limitation in interpreting the cost per case when

comparing AC to AL and BC. The 2010 AC operation covered some very rural areas that were not covered by the Census 2000 AL and BC operations (this difference is covered in section 3.2.1), and the 2010 AC operation costs do not reflect the LBAC costs.

3.2.3.2 Time and Motion Studies

T&M studies provide information about operational efficiency. They allow for a micro-analysis of the various component tasks within a listing operation. T&M production rates, excluding travel, were compared for several operations and Census Tests between 2000 and 2010. In addition to the basic production rates, DSSD performed an analysis of the T&M data from the 2010 AC and U/L operations.

In this analysis, DSSD calculated the time from the start of the study to an activity group (performed at every living quarter), or the amount of time of an activity group to the time of the same activity group at the next living quarter. This measures the amount of time that lapsed between performing the same action in sequentially-assigned living quarters, which roughly equates to the listing time of each living quarter. To adjust for differences in operations and locations, travel time (excluding walking), non-work delays, and contact time were removed. Travel time included driving to or within an AA. Delay time was any time marked as a delay, but not caused by work activities. Contact time was the amount of time expended trying to contact a respondent, or speaking with the respondents directly. Each study's elements and classifications are in Appendix C. DSSD removed any duration that exceeded three hours, as well as all activities associated with AC QC delete verification.

After calculating these listing durations, DSSD transformed them using a natural log transformation to address the right skewness. DSSD then performed a generalized linear model on the transformed data.

3.2.3.3 MAF Update Times

To measure the pace of MAF updating, DSSD used the dates recorded in the Master Activity Schedules (MAS) and the Census 2000 Assessments. Note, dates recorded in the MAS sometimes do not reflect the actual start and finish dates, since error is certainly observed when a system/process is dependant upon numerous users to report information. Recall bias and incentives to depict positive schedule performance, although likely occurring very infrequent, would skew the analyses in this report. That said, DSSD believes the MAS dates are nearly always a reasonable approximation to what actually occurred

In the MAS, activities may be described differently between operations. So, since the process to find comparable activities from which to measure durations possesses some subjectivity, it could introduce error. An example might be a schedule item labeled "received dataset." In one schedule, this may depict only taking receipt, and in another it may reflect taking receipt and also validating its content. See Appendix D for detailed MAS schedule dates. Once the comparable activities were selected, DSSD calculated the time from the beginning of an operation's wave to

when the MAF was updated, and the time from the end of an operation's wave to when the MAF was updated. DSSD also created an average update time across waves.

3.2.4 Methods Used to Measure Costs

There are always factors that affect the cost of operations. When comparing operations that occurred ten years earlier, an inflation adjustment must be utilized. Due to inflation, certain items cost more in 2009 than they did ten years prior.

Another factor affecting cost of operations is workload. Since more living quarters, primarily HUs for the operations of interest, existed in 2009 than in 1999, it was necessary to conduct more listing work in 2009. This increased workload needs to be factored into analyses when comparing Census 2000 operations to the 2010 Census operations.

The cost results presented in this evaluation were generated by program office staff using methods predating the U.S. Census Bureau's commitment to comply with GAO's cost estimating guidelines and the Society of Cost Estimating and Analysis best practices. Hence, while the Census Bureau believes these cost results are accurate and will meet the needs for which they will be used, the methods used for estimating costs of 2010 Census operations may not meet all of these guidelines and best practices. The Census Bureau will adhere to these guidelines in producing 2020 Census cost estimates.

3.2.4.1 Inflation Adjustment

Since this evaluation compares costs that occurred about ten years apart, DSSD needed to account for the fact that the value of the dollar has changed during that time. Inflation methodology was developed for increases in labor costs, mileage costs, and an 'other cost' category. All costs were adjusted to 2009 dollars.

3.2.4.1.1 Wage Inflation Adjustment

Wages increased between 1999 and 2009, the approximate timing of the Census 2000 and 2010 Census listings respectively. For this report, DSSD selected a wage inflation adjustment based on the Bureau of Labor Statistics Employment Cost Index for wages of all workers in all occupations. Census 2000 AL occurred in 1998 and 1999, whereas Census 2000 BC occurred in 1999. DSSD created separate wage inflation adjustment factors for AL and BC because of this operational scheduling difference. DSSD used the wage inflation adjustment factor of 1.37 for AL and 1.35 for BC, to adjust AL and BC wage costs to 2009 dollars. Holland (2012), an internal memorandum, describes other candidate wage inflation adjustments that were considered.

3.2.4.1.2 Mileage Inflation Adjustment

The methodology to determine an inflation adjustment factor for mileage was straightforward. The Census Bureau provides reimbursement to listers using the privately-owned vehicle reimbursement rate set by the General Services Administration (GSA). To account for mileage inflation, DSSD applied the ratio of the 2009 GSA mileage rate to the GSA mileage rate in 1998 and 1999. The GSA mileage rate fluctuated during 1998 and 1999. To account for the work conducted in each year, and during different times of the year, DSSD used Census 2000 C&P data to determine cut-offs to group incurred mileage costs, to apply the appropriate GSA mileage rate for the time period. This process yielded a mileage inflation adjustment factor of 1.70 for AL and 1.72 for BC, to adjust Census 2000 AL and BC mileage costs to 2009 dollars.

3.2.4.1.3 Other Cost Inflation Adjustment

All non-wage and non-mileage inflation adjustments were made using a general measure. For this inflation adjustment, DSSD used the Consumer Price Index (CPI). As with wages, the difference in operations led to a small difference in the adjustment for AL and BC. The other cost inflation adjustment factor was 1.38 for AL and 1.36 for BC, to adjust other AL and BC costs to 2009 dollars.

3.2.4.2 Workload Adjustment

The number of living quarters, primarily HUs for the operations of interest, in the listing workloads for these operations significantly increased between 1999 and 2009. When comparing Census 2000 AL and BC to the 2010 Census AC, DSSD needed to account for the difference in the number of HUs. The address workloads for the related operations, which includes units that were added as well as units that were deleted within the operation, were:

- 2010 Census AC 159,494,710 addresses
- 2010 Census LBAC 4,096,642 addresses
- Census 2000 AL 24,023,043 addresses
- Census 2000 BC 94,346,049 addresses

3.2.4.2.1 Address Listing and Block Canvassing Combined Workload Adjustment

Comparing the 2010 Census AC to the combined Census 2000 AL and BC required a separate workload adjustment factor. DSSD calculated an adjustment factor using the number of HUs in AC divided by the total number of HUs from AL and BC combined. This gave a workload adjustment factor of 1.35 [159,494,710 / (24,023,043+94,346,049)] when comparing 2010 Census AC to Census 2000 AL and BC combined.

3.2.4.2.2 Block Canvassing Workload Adjustment

Similar to the combined AL and BC workload adjustment above, when comparing Census 2000 BC independently to the 2010 Census AC, DSSD applied a workload adjustment factor of 1.69 (159,494,710 / 94,346,049), to adjust the Census 2000 BC workload to the 2010 Census AC workload.

4 Limitations

There are limitations to the analyses, results and conclusions in this evaluation.

- Operational procedures are different for AL, BC, U/L, and AC.
- Operational scopes are different for AL, BC, U/L, and AC.
- Cost analyses are limited to the level at which the historical costs were tracked, which in some instances of insufficient granularity, resulted in the need to estimate some costs.
- Some loss of information and knowledge occurred as time elapsed since the completion of the operations analyzed.
- Costs may be tracked differently over time, thereby affecting the relevance of those cost comparisons.

One example of insufficient granularity is the costs of the FDCA contract, which were only available at the Work Breakdown Structure (WBS) level. Sometimes these levels contained costs for different operations, making it difficult if not impossible to disaggregate. Another example is the Census 2000 NPC data capture costs, where costs were not available by operation but rather only by activity.

5 Results

The results of this evaluation are systematically organized to address the study plan research questions; presenting the impact of adding expanded automation to AC field data collection, in three areas:

1. Operational Improvements and Impacts
2. Efficiencies
3. Costs

5.1 Operational Improvements and Impacts

Operational improvements and impacts were collected and analyzed from three sources:

1. Personnel Feedback
2. The 2010 Census U/L Office Review Checklist Results
3. The 2010 Census AC and U/L Quality Profile Reports

5.1.1 Personnel Feedback

There were three sources of personnel feedback: communication and exchanges with HQ staff, RCC staff and Listing staff. The solicitation of feedback from HQ staff largely occurred via personal emails and one-on-one exchanges. The feedback of the latter two were obtained via debriefings. The debriefing of the RCC staff occurred after the 2010 AC, on July 27-31, 2009. Because the 2010 AC ended earlier than expected, the debriefing was not deployed immediately after AC. Since staff was often rehired for later operations, the Census Bureau chose to send the debriefing questionnaire to GQV listers and crew leaders, anticipating most of them had also worked AC. This does bias the universe of questionnaire participants to only those who worked both operations.

Some debriefings and lessons learned can appear overly negative since it is sometimes common for people to focus on problems they would like to avoid in the future. When reviewing some statements in this section, it is recommended that one pair the broader picture with many of the specific problems that are stated. The term "issue" that is referenced in the results sections for debriefings does not indicate problems. Instead, this term is used to indicate a topic related to automation.

5.1.1.1 Headquarters Personnel Feedback

Table 3 summarizes the perceived improvements and impacts from the perspective of HQ personnel. Table 3 generally shows automation to have been an improvement for such things as security, quicker processing times, and GPS capture. The only favorable aspect of a paper

operation identified was field staff linking duplicates for QC. This could be reversed in future improvements to automation.

Table 3. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Operational Changes Moving from a Paper Operation (BC + AL) to an Automated Operation (AC)

Description	Advantage		
	Paper Operaton[1]	Automated Operation[2]	Mixed
Security		X	
Finger swiping protection and device security		X	
Fewer HHCs were lost than expected		X	
Data Availability			X
GPS capture of structures		X	
Field linked duplicate data available to listers	X		
Data Quality		X	
Automated edits of lister entered data		X	
Legible lister data		X	
Quality control processes automation		X	
Quicker data processing times		X	
Transmission problems (for some listers/locations)			X
Public perception of technology use			X

BC - Block Canvassing, AL - Address Listing, AC - Address Canvassing, GPS -- Global Positioning System, HHC -- Handheld Computer

[1]Paper Operation refers to Census 2000 Address Listing and Block Canvassing.

[2]Automated Operation refers to Census 2010 Address Cancassing.

Source: Meetings and discussions betw een DSSD, GEO, and DMD

5.1.1.1.1 Finger Swiping Protection and Device Security

Paper operation listing binders have no intrinsic security. Should one become lost, it can be read by anyone. The HHCs, however, were finger-swipe and password protected. Therefore, accessing the Title 13 data required either the lister's fingerprint and password or a system hack. Obtaining physical access to the listing instrument was not sufficient on its own to obtain the data contained therein.

Having an automated listing device also allows for the possibility of electronic security measures. A paper operation listing binder has few security protections beyond being physically secured in a safe location. With automation, fingerprint scanning, password protection, and data encryption are all possible. Other biometrics could also be utilized, including but not limited to retinal scanning and voice recognition. Note that finger swiping security may have at least one drawback given some seniors are more likely to lack readable fingerprints. For example, from the Federal Bureau of Investigation (FBI) at http://www.fbi.gov/about-us/cjis/ fingerprints_ biometrics/recording-legible-fingerprints/takingfps: "An individual, by the nature of their work or age, may have very thin or worn ridges in the pattern area." This may open the Census Bureau to charges of age discrimination if someone without readable fingerprints is refused work.

5.1.1.1.2 Fewer HHCs Were Lost Than Expected

Planners expected to lose approximately one percent of the equipment during the 2010 AC. A total of 110 HHCs, or 0.0007 percent of the about 150,000 HHCs, were lost. A total of 190 Secure Digital (SD) cards, or 0.0005 percent of the about 300,000 SD cards were lost. These 2010 AC equipment loss rates were significantly lower than expected.

5.1.1.1.3 GPS Capture of Structures

In the 2010 AC, GPS coordinates capture was attempted for 105,298,999 structures, of which about 98.8 percent were captured successfully. Further, 94.1 percent of structures were found in the correct block for the structures where collection was attempted. Collection was only attempted for the first unit of a multi-unit structure. The collection of highly accurate spatial data, i.e., GPS coordinates, allows for improved absolute accuracy in TIGER. This can improve the accuracy of tabulation. This accuracy also assists with drawing political boundaries more precisely, and more definitively determines whether a unit is inside or outside the boundaries drawn. These coordinates may also help later operations with locating or verifying HUs and with unduplication. It would not have been feasible to collect these data via a paper operation.

5.1.1.1.4 Field Linked Duplicate Data Available to Listers

In paper operations, a lister records an identification number of the surviving MAF address record next to the established duplicate record. In the 2010 AC, the HHC software did not permit listers to indicate these duplicate associations, even though this function was originally requested for the HHC. In the 2000 BC, this duplicate information was captured, but not keyed.

5.1.1.1.5 Automated Edits of Lister Entered Data

The HHCs deployed automated edits or processes to ensure information was completed. For example, an address could not be listed unless an action code was created (e.g., non-residential, uninhabitable, or HU). In addition, listers were required to provide what was deemed to be complete address information (sufficient city-style address information or a house description). In this regard, these automated edits can prevent return visits to the listing site to make corrections. This feature cannot be implemented in a paper operation. In a paper operation, these types of checks can only be performed after the listings are returned to the office upon completion of the assignment. Overall, about 1.6 percent of HUs listed by paper contain an error after returning from the field (see Table 4) for U/L. Section 5.1.2 provides additional detail on the expected value of automated edits.

5.1.1.1.6 Legible Lister Data

All entries are electronic in an automated listing, and should therefore be legible. Conversely, some entries on paper listings are illegible. Careless work, poor handwriting, smudging, and beverage spills can all cause illegible entries. Illegible entries occur in about 0.05 percent of HUs. See Section 5.1.2 and Table 4 for more details.

5.1.1.1.7 Quality Control Process Automation

Automation enabled a software program to systematically determine both the quantity and the precise HUs in the QC listing universe. Without automation, a clerk conducted these tasks in the LCO, after production binders were checked in. Automation also reduced the chance of losing the paper work, a problem that occurred in the 2010 U/L.

5.1.1.1.8 Quicker Data Processing Times

By using an automated instrument, data processing times are reduced. Previously, in order to capture the data from a paper listing, listings were mailed to a data capture center, unpackaged, checked in, and captured; all before any post-capture data processing could begin. The automated instrument skips the shipping and data capture center steps of the process, and allows post-capture data processing to begin much sooner. Quantitative results of these increases in data processing times are presented in Section 5.2.3 and in Table 9. Also noteworthy, these improved capture times allow changes to both HUs and maps to be used in operations immediately following the listing. This might also, in a more timely manner, remove duplicates and deletes from later operations; which could result in avoiding unnecessary costs.

5.1.1.1.9 Transmission Problems (for Some Listers/Locations)

Below is a quote from the 2010 Address Canvassing Assessment (2012) which explains the transmission problems.

> Sprint was the national wireless carrier selected by the FDCA contractor for AC. On March 18, 2009, it was discovered that some HHCs deployed to areas without Sprint cellular coverage could not transmit in dial-up mode due to incompatible data sequencing on the Secure Digital (SD) card and HHCs.
>
> All HHCs shipped from the provisioning center were hard reset prior to being shipped to the ELCOs. This hard reset set a null value in the signal strength registry key value. The HHC software did not handle the null value when the users were outside a Sprint coverage area. If a null value was present when the transmission was initiated, a blank yellow screen banner was displayed on the HHC and the HHC froze. The result meant users outside of a Sprint area were not able to do any type of transmission (dial-up or wireless).
>
> Two solutions were implemented for this problem.
>
> - Listers traveled to a Sprint coverage area to perform a wireless transmission. The HHC initiated a connection with Sprint and the cell tower sent down a valid value into the signal strength registry key field. The user was able to perform dial-up or wireless transmissions once the valid value was populated in the HHC.
>
> - In non-Sprint coverage areas, a new SD card needed to be burned, shipped, and installed. The new SD card contained the software fix. Because the software change involved the transmission program, a software patch could not be sent remotely to the HHCs. A total of 54,079 SD cards were re-burned and distributed for this effort. Special instructions were developed at HQ, transmitted to the RCCs, and implemented within the ELCOs to replace problematic cards. Additional instructions were prepared for the Help Desk to assist Listers when needed. These additional instructions were instituted systematically resulting in a successful replacement of the "bad" SD cards.

5.1.1.1.10 Public Perception of Technology Use

Using paper for census operations portrays an image of the Census Bureau which is not consistent with its prior technological accomplishments, but rather shows a lack of innovation. Using HHCs showed our respondents, the American public, serious efforts were taken to use new tools to capture their valuable information more efficiently. Unfortunately, by the time the tool was used, the HHC looked out-of-date, and frankly was reminiscent of the first cellular "brick" phones of the 1980s. In part, this can be attributed to design goals of making the HHC less appealing to would-be thieves. When the 2010 AC operation began in 2009, the HHC with a 3.5 inch touch screen, a 320 x 240 resolution display, and under a dozen buttons was a distant competitor to the publically-available smart phones and GPS units. To a large extent, the lead time necessary for contract award and device manufacturing, coupled with the ever rapidly changing world of electronic devices, was responsible. Additionally, the collection of GPS coordinates led to backlash in some communities. Some parties felt this data collection was overly intrusive and beyond the mandates of the agency.

5.1.1.2 Regional Census Center Address Canvassing Debriefing Results

DSSD divided the results of the RCC debriefing into nine categories.

1. Transmission/finger swiping issues
2. Other hardware issues
3. Real time reporting issues
4. Management/support issues
5. Easily rectifiable software issues
6. More complex software issues
7. You Are Here (YAH)/map change issues
8. Other map use issues
9. General issues

5.1.1.2.1 Transmission/Finger Swiping Issues

Generally, the transmission/finger swiping issues show what problems occurred during implementation of automation. Overall, the operation did not encounter major problems. Recommendations from the RCC debriefing include the following quotes:

- Investigate cell coverage in rural areas to ensure we are prepared to use the HHCs in these areas. The regions had to come up with workaround methods for wireless transmissions in rural areas, which was very time-consuming.
- Although the HHCs were equipped with dial-up capabilities, wireless capability was needed to effectively teach the part of training on wireless transmissions. Trying to teach trainees how to do

wireless transmissions, when the training site lacked wireless reception, created difficulties for the trainers and trainees.

- Sprint server outages simultaneously affected signal strength in many areas of the country. The regions recommended that this could be remedied if they got quicker notification of these planned outages so they could work around them.
- Across all regions, the debriefing participants reported that early into the operation they discovered several areas where the HHCs could not transmit. The solution was to replace all SD cards and it was recommended that the regions place "purple dots" on the new SD cards so they could be easily recognized as the new replacement SD card. The regions felt the distribution and return of HHCs for SD card replacement was difficult and costly, especially in rural areas. Conflicting and rapidly changing instructions for replacing SD cards from the contractor also complicated the situation. All regions reported, however, that while the replacement of the SD cards had the potential to become a much bigger issue, once it was identified, it was promptly addressed and the impact minimized.

5.1.1.2.2 Other Hardware Issues

The RCC staff raised other hardware issues in addition to the transmission/finger swiping issues. Similarly, the quoted recommendations below provide input for improving the hardware in the future:

- The HHC's battery charge could not drop below 30% or there were processing issues. Through experience, Listers learned to check this frequently and keep the battery charged to avoid this issue.
- Put stickers on HHCs that say "If lost, please call or return to…"
- Provide cell phones to supervisors in the field or enable the phone capabilities on the HHC.
- Make the HHC screens glare-free.
- Make the HHCs waterproof.

5.1.1.2.3 Real Time Reporting Issues

Near real time reporting was a valuable improvement to timeliness of information, made possible by automation. Even though there was some confusion over the vintages of certain reports, the improved timeliness helped the operation. Below are some quotes from the debriefing:

- As it turned out, the regions reported that the HHC proved to be a great addition to the AC operation. It simplified some administrative activities (e.g., payroll) as well as some operational aspects of the job (e.g., making assignments). The HHC also allowed for a shorter assignment preparation time because there was much less printing involved (e.g., the ELCOs did not have to print paper maps or address listing books).
- The electronic payroll form, Form E-308, had a very positive overall impact on the AC operation.
- The debriefing participants also thought the real-time reports were very useful and that the electronic payroll form, the E-308, had a very positive impact on the operation.
- Update the OCS reporting system so OCS reports reflect a truer picture of what is happening during the operation, and include real time reports that both HQ and the regions can see.

5.1.1.2.4 Management/Support Issues

The following field staff management/support issues are quoted.

- Property management procedures were very effective. Very few HHCs were lost/missing/stolen.
- Property management of the HHCS was a struggle for the ELCOs. The regions reported that the ELCOs were not prepared to deal with the volume of property they had to account for, and the process of registering and reassigning the HHCs was very cumbersome.
- In some ELCOs, the HHC room was not always easy to keep secure because of its location in the office.
- Test software patches in a variety of geographical areas and multiple ELCOs before pushing them out nationwide.
- HHC registration was an unexpected problem. If DAPPS and the OCS did not have a person listed in exactly the same position [job/title], the person could not register his/her HHC. Once this was discovered, however, this was one of the first things they checked when there was a registration issue.
- Provide Help Desk clerks with HHCs in production mode so they can better troubleshoot problems.
- Provide ELCO managers, FOS, and RCC geography staff an HHC in production mode that can be used throughout the operation to provide better support to the field staff.
- Management training did not contain enough HHC hands-on training.

5.1.1.2.5 Easily Rectifiable Software Issues

The RCC staff recommended many software changes quoted below. The following were perceived as easily rectifiable:

- Add a zip code drop down menu.
- Develop a better/easier way to switch the HHC from training to production mode.
- Some of the regions recommended putting the Lister manual on the HHC in the future.
- Add an electronic version of the INFO-COMM to the HHC.
- Automate INFO-COMM notes so that they flow between production and QA.

5.1.1.2.6 More Complex Software Issues

Below are some of the software changes recommended by the RCC staff that would likely be more difficult to implement:

- Make the HHC system more flexible, so QA Listers could go back in and change things, e.g., during Delete Verification they did not have the capability of adding missed living quarters.
- The debriefing participants reported that the QC HHCs had a recurring software glitch that came to be known as the "spinning" Beach Ball. [The spinning beach ball indicated the HHC was busy processing, similar to the hour-glass in the Windows operating system. Sometimes the HHC locked-up during the time a person experienced the spinning beach ball.] This glitch caused the HHC to lock-up, which rendered the affected HHC useless. According to the debriefing participants, this problem was promptly reported to Harris and HQ, but it took quite some time for it to be completely fixed. The regions reported, however, that when a patch was sent out to correct the issue, the patch fixed the spinning beach ball problem.
- The spinning beach ball problem was a huge unexpected problem, and the time it took for problems like this to be resolved was surprising.
- The regions recommended that the address list on the HHC be arranged in the order of canvassing a block, which would make working from the ground to the HHC easier. They also recommended that

future HHCs allow Listers to see adjacent AAs on the map, and that the regions should have the capability to print the HHC map. [The sequential ordering of addresses on the HHC was by street name and house number, not the order listers would observe while walking the assignment.]

- Add the ability to view [and/or] complete … adjacent AAs on the HHC. [Current training dictates listers only update their own AA, relying on the lister in the adjacent area to properly add units in their AA. Listers have no assurance this will happen and sometimes the other lister does not add the unit.]

5.1.1.2.7 You Are Here/Map Change Issues

Below are series of recommendations from the RCC staff regarding You Are Here (YAH) problems and some simple map changes:

- Have more colors on the HHC screen so Listers could distinguish between water and blocks.
- Make the blocks on the HHC change colors when they are completed.
- Add block numbers on the screen.
- The biggest challenge the Listers had with the HHC maps, was that some features on the maps were sometimes positionally inaccurate, which caused the You-Are-Here (YAH) indicator to be several blocks off from the true location. Some debriefing participants stated that their Listers also reported that some of the major highways were not detailed on the HHC maps. In addition, Listers reported that it was difficult to manually add roads or other block boundaries on the HHC.
- They reported that the biggest challenge they faced in the field was updating the maps using the GPS when the YAH was in a different location than it appeared on the map. In these situations, the user needed to manually place the map-spots. The regions felt there was not enough details presented during training to ensure the Listers would know what to do if the map was off. They recommended that more training be provided on the GPS and YAH.
- The features on the maps were sometimes positionally inaccurate, which caused the You-Are-Here (YAH) indicator to be several blocks off from the true location, making it difficult to map spot and use the maps effectively.

5.1.1.2.8 Other Map Use Issues

Other map use issues are defined as difficulties with the HHC maps other than 'You Are Here/Map Change Issues' and are quoted below.

- Using the HHC maps to locate AAs was difficult for many Listers. To accommodate, Listers sometimes relied on paper maps or other methods to find the assignment area.
- All regions agreed that even though there were some problems with the GPS training, and using the GPS, overall, training was acceptable and having GPS was much better than having to use paper maps.
- For both production and QC, the debriefing participants reported that Listers sometimes had problems with map-spotting due to recurring issues with the GPS and maps. According to the debriefing participants, it would sometimes take too long for the HHC to complete the map-spotting task, so their workaround was to manually map-spot.
- The regions reported that the QC procedures allowed almost no room for error between the original map spots and the QC map spots.
- All debriefing participants agreed that within their regions, most Listers used other sources, such as paper maps, car GPS, etc., to get to the AA because the maps on the HHC were too difficult to use for determining an efficient route to the AA.

- Once a Lister got to the AA, however, the HHC maps were very useful and accurate for listing the units and moving around within the AA. According to the debriefing participants, the Listers also reported that the HHC maps were especially useful for identifying houses that were not in numerical order.

5.1.1.2.9 General Issues

The following statements express general, overall impressions of how well the HHC performed, and how respondents reacted to them.

- The HHC proved to be a great addition to the Address Canvassing operation.
- Use an HHC in 2020 for all operations.
- Another challenge related to the HHC was the negative public perception of the GPS. The regions felt that people were uncomfortable with someone standing outside their house and pointing a device at it. They felt residents were not sure what the device was collecting about them, e.g., some thought the Lister was taking pictures of their house and/or were spying on them.

5.1.1.3 Address Canvassing Debriefing Results after Group Quarters Validation

The subsequent two sections provide summarized training and HHC-use results from the AC-related questions on the debriefing questionnaire. Of the 2,424 NPC-captured forms, about 2,150 employees completed the 2010 AC-related questions. Forms were completed in about three to seven months after the completion of the 2010 AC operation. For the questions that required prior paper listing experience, such as Census 2000 BC or AL, only about 440 employees answered those questions. Given the small sample size and possible bias, the results here may not be indicative of the entire AC workforce. See Appendix A for the full table of questionnaire responses.

5.1.1.3.1 Training

Overall, 60 percent of employees felt very prepared to use the HHC and 31 percent felt somewhat prepared (or 91 percent felt prepared to use the HHC). The areas where the training prepared them the least were:

1. Transmitting in areas where wireless technology was not available (66 percent felt prepared)
2. Using the HHC maps and GPS to add streets to the map (79 percent felt prepared)

The areas where training prepared them the most were:

1. Filling out the electronic time sheet (97 percent felt prepared)
2. Entering data in the HHC using the stylus (96 percent felt prepared)

Areas where they were less satisfied with the training include:

1. Making transmissions in areas where wireless was not available (61 percent were satisfied)
2. Adding streets to the maps on the HHC (80 percent were satisfied)

5.1.1.3.2 Working with the HHC

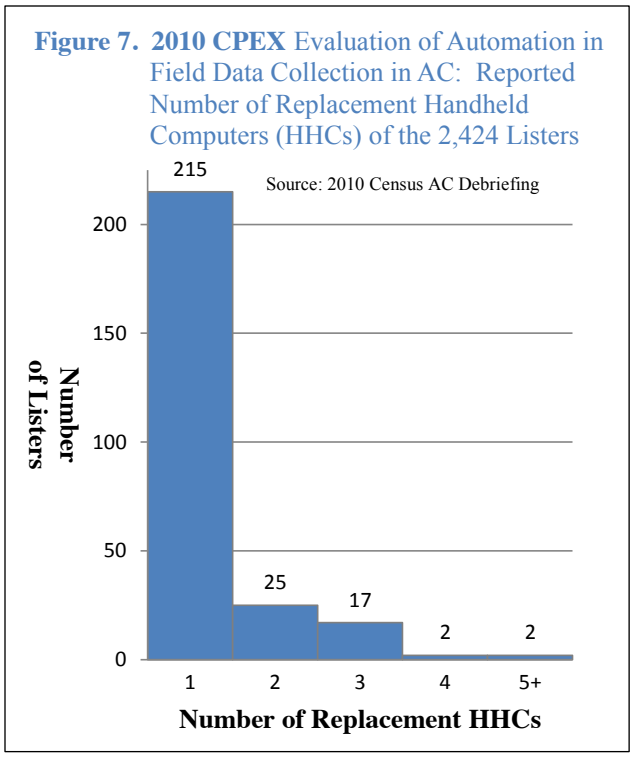


Figure 7. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Reported Number of Replacement Handheld Computers (HHCs) of the 2,424 Listers

Only 46 percent of listers thought it easy to transmit in areas where wireless technology was not available. And 94 percent of listers found the task of completing their electronic timesheets easy. The most frequently experienced listing problems were:

1. Glare on the HHC (49 percent reported the problem occurring more often than once a week)
2. The HHC freezing up (49 percent reported the problem occurring more often than once a week)
3. Reading the information on the screen due to lighting conditions (44 percent reported the problem occurring more often than once a week).

Most listers found the task to collect GPS coordinates for HUs very easy (45 percent) or somewhat easy (33 percent). Also most listers overall found the HHC either very easy (59 percent) to use or somewhat easy to use (31 percent). However, the listers indicated that 20 percent had to spend time solving HHC problems at least once a day, and 36 percent had to spend time solving HHC problems less than once a day but more than once a week. Also 13 percent reported needing to replace the HHC at least once during the operation. Many of these HHCs were probably functional, but required a quick check or modification before use. Of those listers who had prior paper listing experience, 84 percent preferred using the HHC to paper listing methods overall.

Figure 7 shows that, of the 2,424 respondents, about 11 percent required replacement HHCs. Of that 11 percent, nearly all required only one replacement.

In the additional comments section on the questionnaire, there was a variety of responses. Many people praised the HHC and would have liked to use them for GQV. Others strongly disliked the HHC. Some gave specific information about how the HHC performed for them and those around them. Below is a sample of comments.

- The HHCs were a great time saver, especially for administrative paperwork type tasks.
- AC QC HHC transmissions weren't adequately tested for the non-wireless (phone line) option prior to deployment. Also, why a one-carrier (Sprint) option? A multi-carrier i.e. free roaming option would have allowed for coverage in most of this region. A lot of time wasted in training due to extensive trouble shooting for HHC errors that should have appeared in testing and been fixed before rolling out the devices to the field.
- Biggest problem with the HHC was when an address was listed and should have been listed in the block but the HHC would not mapspot in the correct block registered as out of the block.
- HHC great idea need better viewing in light.
- HHCs for GQV would have been very helpful.
- Handhel[d]s were a joke-never worked.
- Using the HHC during AC was much more convenient than the papers used during GQV. I think GQV would have been more organized and easier with the HHC.
- Please use the HHCs again, they were great!
- …We experienced a great deal of headaches and unnecessary time spinning wheels to get the equipment to work. It was very frustrating.
- The main problem with the HHCs was how quickly they timed out/shutdown and the finger swiping process was too finicky.

5.1.2 Update/Leave Office Review Checklist

There is no direct measure of how many errors automated edits prevented. However, the number of errors that occurred in 2010 U/L for a paper operation gives a measure of errors preventable by automated edits. Table 4 provides the number of errors that occurred in 2010 U/L. Keep in mind U/L occurred after the 2010 AC, and therefore AC should have updated and improved the address frame, so the number of errors committed in U/L may be lower than what would have been seen in AC. Overall, there were 161 critical errors and 38 noncritical errors for every 10,000 HUs. Of those, there were about 73 critical errors and 35 noncritical errors for every 10,000 HUs that passed office review. Errors in assignments that passed office review would not have been corrected. Noncritical errors (e.g., illegible, but usable, entries) can be fixed in the office, but critical errors (e.g., missing action codes) cannot. So, about 88 critical errors per 10,000 HUs (the critical errors in assignments that failed review) were sent back to the field to be corrected. If the 2010 AC had a similar rate of errors and a similar pass/fail rate for office review, there would have been over 1,000,000 critical errors that would have required additional field work for correction. Although the universes for AC and U/L differ significantly, and DSSD does not have direct evidence that this U/L error rate is similar to AC, this provides an initial estimate of the quantity of errors that could propagate into the MAF as a result of a paper-based AC operation. For U/L, this rework was ordered when there were more than five percent critical errors for the number of HUs in an AA. Conversely, automated edits do not result in rework after a lister's assignment is complete. In effect, automated edits prevent all of these critical

errors, whereas in a paper listing operation only a certain percent of these errors could be reworked due to the cost constraints.

5.1.3 Address Canvassing and Update/Leave Quality Profile Comparison

The Quality Profiles document the quality control procedures and outcomes for each operation. The 2010 AC and U/L Quality Profiles measure how well procedures were followed, and can be compared to expected outcomes. Here, it is important to note some of the previously mentioned limitations:

- U/L is a dependent listing completed using the 2010 AC listing, so DSSD expects the U/L Quality Profile will show fewer errors in U/L than AC.
- Some of the staff who conducted the 2010 AC also participated in 2010 U/L.
- U/L and AC tracked slightly different errors.
- U/L addresses may be more difficult to list given the type of areas/addresses that comprise the 2010 U/L operation (generally more rural).
- AC and U/L had some differences in error definitions especially for the field observations.
- The DQC was more stringent for U/L than for AC.

5.1.3.1 Initial Field Observation Outcome

In Table 5, DSSD compares the initial field observation outcomes for 2010 AC and 2010 U/L. Keep in mind that not all observations were captured perfectly. Some forms had errors; others may have been lost. For the details about these losses see the appropriate 2010 Census Quality Profile report. For this analysis, DSSD assumes the captured initial observations are representative of all initial observations.

The satisfactory rates for the first field observation consistently approach 97 to 98 percent. With the exception of U/L QC enumerators, the second observation is constant at about 94 percent. The quantity of U/L QC observations were the smallest at 217. This introduces more uncertainty in the results. Overall, during the initial field observation, there is little difference in how often listers/enumerators correctly conducted their listing. This suggests that following procedures is likely more impacted by the listers' ability to follow training than by the listing device.

Table 4. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: 2010 Census Update/Leave Office Review Checklist Results

Quality Check	Total Occurances on Forms	Prevalence of Occurances by Housing Unit	Total Occurances on Forms that Pass First Office Review [1]	Prevalence of Occurances by Housing Unit that Pass First Review [1]
Question — Number of Forms or Housing Units	160,334	9,156,160	144,197	8,347,971
1 Action Code in is missing or invalid	30,995	0.34	13,542	0.16
2 Action Code does not have the follow ing corresponding entries	23,511	0.26	10,387	0.12
C – Corrections or additions are entered in address fields				
D2 – Line number of duplicate address is entered				
3 Address and Location Description are Incomplete	4,800	0.05	1,430	0.02
4 Map Spot Number is blank (unless unit has a preprinted 'Z' in action code)	17,475	0.19	6,975	0.08
5 Required fields are not completed on the Add Pages	20,106	0.22	8,080	0.10
6 House Identifier and Location Description are both blank	3,382	0.04	1,373	0.02
7 Non-city style mailing address including ZIP Code is blank w ithout housing identifiers	2,200	0.02	919	0.01
9 Entry on the Address Listing Pages or Add Pages do not have a corresponding map spot and map spot number entered on the Block Map	28,026	0.31	13,967	0.17
10 Map spot is deleted on the Block Map w ithout a corresponding deleted address on the Address Listing Page	14,121	0.15	7,726	0.09
12 Entries are not legible on the Address Listing Page, Add Pages, or Block Maps and cannot be fixed in the office	1,737	0.02	523	0.01
Total Critical	**147,370**	**1.61**	**61,324**	**0.73**
8 RCC, LCO, AA, State Code, County Code, and/or Page _ of _ are blank	7,408	0.08	5,769	0.07
11 Updated street/road name does not have corresponding updates reflected on the Address Listing Pages or Add Pages	5,673	0.06	4,403	0.05
13 Entries are not legible on the Address Listing Page, Add Pages, or Block Maps and can be fixed in the office	3,193	0.03	2,523	0.03
Total Noncritical	**35,242**	**0.38**	**29,066**	**0.35**

Note: There were a total of 160,334 forms processed, of which 144,197 passed the edited first office review.
[1]The number that passed first review was edited by the responses to other questions on the review form.
Source: National Processing Center Captured Office Review Checklist Forms

Table 5. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Initial Observation Outcome for Address Canvassing Listers and Update/Leave

Type of Lister	1st Observation		2nd Observation	
	Number*	Percent*+	Number*	Percent*+
AC Production Listers				
Satisfactory	61,978	97.91	5,932	93.54
Unsatisfactory	459	0.73	222	3.50
Other	861	1.36	188	2.96
Total	**63,298**	**100.00**	**6,342**	**100.00**
U/L Production Enumerators				
Satisfactory	13,508	97.41	986	93.99
Unsatisfactory	187	1.35	54	5.15
Other	172	1.24	9	0.86
Total	**13,867**	**100.00**	**1,049**	**100.00**
AC QC Listers				
Satisfactory	16,396	97.29	1,244	93.60
Unsatisfactory	186	1.10	70	5.27
Other	269	1.60	15	1.13
Total	**16,852**	**100.00**	**1,329**	**100.00**
U/L QC Enumerators				
Satisfactory	3,736	98.29	210	96.77
Unsatisfactory	31	0.82	7	3.23
Other	34	0.89	0	0.00
Total	**3,801**	**100.00**	**217**	**100.00**

AC - Address Canvassing, U/L - Update/Leave, QC - Quality Control
*Counts and percentages are unweighted.
+Percentages may not sum to 100 due to rounding.
Source: 2010 Address Canvassing and Update/Leave Quality Profiles.

5.1.3.2 Dependent Quality Control Results for Address Canvassing and Update/Leave

Table 6. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Address Canvassing and Update/Leave Dependent Quality Control

	Count*		Percent*+	
	AC	U/L	AC	U/L
Satisfactory AAs	671,793	190,648	91.57	93.97
Unsatisfactory AAs	61,843	12,241	8.43	6.03
Total AAs	733,636	202,889	100.00	100.00

AC - Address Canvassing, U/L - Update/Leave, AA - Assignment Area
*Counts and percentages are unweighted.
+Percentages may not sum to 100 due to rounding.
Source: 2010 Address Canvassing and Update/Leave Quality Profiles.

Table 6 summarizes the comparison of 2010 AC and U/L DQC results. The satisfactory rates only differ by at most 2.4 percentage points. These are favorable rates. However, they do not offer any substantial comparison among them other than that it is likely the updates in the 2010 AC had a positive impact on the U/L areas.

5.2 Efficiency

The results of our three efficiency analyses are presented below:

1. Execution Cost per Case
2. Time and Motion (T&M) Studies
3. MAF Update Times

5.2.1 Execution Cost per Case

One way to measure efficiency is to measure how much on average it costs to list an HU, where the execution cost (training, listing, mileage) is divided by the total number of HUs. Other studies[6] have used different methodologies to report 2010 AC cost per case data. Table 7 summarizes these calculations for AL, BC, combined AL and BC, and AC.

Table 7. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Execution Cost Per Case Efficiency Comparison in 2009 Dollars[1]

	Block Canvassing (BC) 2000[2]	Address Listing (AL) 2000[2]	Combined AL and BC 2000[2]	Address Canvassing (AC) 2010[3]
Universe Size (workload)	94,346,049	24,023,043	118,369,092	159,494,710
Total Execution Cost (in millions of 2009 dollars)	$138.3	$162.9	$301.3	$443.6
Dependent Listing (D) / Independent Listing (I) / Mixed (M)	D	I	M	D
Paper Operation (P) / Automated Operation (A)	P	P	P	A
Rural (R) / Urban (U) / Both (B)	U	R	B	B
Execution Cost Per Case				
Production Salary	$0.90	$3.90	$1.51	$1.77
Training Salary	$0.23	$0.64	$0.32	$0.51
Mileage Costs	$0.23	$1.79	$0.55	$0.47
Other Objects	$0.10	$0.45	$0.17	$0.02
Total	**$1.47**	**$6.78**	**$2.55**	**$2.78**

[1] This comparison only includes execution costs such as training, listing and mileage; and does not include costs for contracts/infrastructure, equipment, etc.
[2] Universe size for 2000 operations does not reflect a workload adjustment.
[3] Address Canvassing does not include the Census 2010 Large Block Address Canvassing operation.
This table excludes Provide OCS/HHC Technical Support for BC, AL, and AC.
Some geographies of the Address Canvassing workload were not included in the workloads of Address Listing and Block Canvassing.
These excluded areas tend to be very rural, most of which are in the Rocky Mountain States.
Source: 2010 Cost and Progress system and 2000 Draft Assessment of AL and BC. See Section 3.2.3.1 for methods and calculations.

The most expensive operation was Census 2000 AL at $6.78 per case. The least expensive was Census 2000 BC at $1.47 per case. The combination of AL and BC was similar to the 2010 AC, although smaller by $0.23. Here, it should be stated that AC covered more of the country in 2009 than the combination of AL and BC did a decade prior. Listing operations tend to be more

[6] One source of cost per case values is the 2010 Address Canvassing Operational Assessment (ACOA), which reported separately production and QC cost per case data. The execution cost per case in the ACOA is $2.07 for 2010 AC production work ($329,700,900/159,494,710) and $2.48 ($110,016,505/44,323,317) for 2010 AC quality control work. See Address List Operations Implementation Team (2012) for additional cost per case data.

expensive in rural areas, those covered by AL. As shown in Table 7, mileage costs per case are much higher for rural areas. Indeed, all cost per case areas were higher in rural AL than in urban BC. In addition, since there are fewer cases, elevated training costs areas are expected.

AC had higher production and training costs per case than the combined AL and BC; however, mileage and other costs were lower. While not a large contributor, one of the reasons for these differences is that some of the costs included in "other costs" in 2000, were included in production salary costs in 2010. Mileage costs per case may have been lower because the U.S. had a higher population density in 2010, or perhaps because technology led to more efficient routing of the assignments. Another explanation might be that listers were hired strategically closer to the areas they listed due to the increased labor pool.

Increased total execution costs per case may have been caused by:

- The Census Bureau's more comprehensive initial listing of rural America in 2010
- Technical difficulties or otherwise efficiency degradation from HHCs
- Increased requirements: GPS capture, fingerprinting, required training.

Uncertainty may be introduced by the inflation adjustment and pay rate changes above normal inflation.

5.2.2 Time and Motion Studies

One way to measure efficiency is by measuring productivity. T&M studies provide an estimate of listers' productivity based on observations made during their field work. Unfortunately, there are a few flaws to these studies. One problem is listers and assignment areas are not chosen randomly. This can create problems if the listers chosen are the most or least efficient, or the areas being listed are different in nature from a typical listing. The T&M design team attempted to match the geographic areas from prior studies with the 2010 operations to reduce some of this variability between listing areas. Essentially T&M studies are non-probabilistic, convenience samples. Table 8 provides a list of the T&M study results for listing operations between 2000 and 2010. Excluding travel time makes AC more comparable to U/L since, in general, U/L occurs in more rural areas that are likely to require longer travel times.

Table 8. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Time and Motion Study Results for Listing Operations Between Census 2000 and 2010 Census, Excluding Travel Time

Listing Operation	Minutes per Case	Cases per Hour+
2000 Update/Leave	3.5	17.2
2006 Address Canvassing in Travis County, TX	4.3	14.0
2008 Address Canvassing in Fayetteville, NC	7.0	8.0
2008 Address Canvassing in Stockton, CA	5.0	12.0
2010 Update/Leave without QC	6.1	9.8
2010 Address Canvassing without QC	2.8	21.0
2010 Address Canvassing	2.1	28.0

+Cases per hour may not equal to 60 divided by minutes per case due to rounding.
Update/Leave operations are paper operations.
Address Canvassing operations are automated operations.
Source: Time and Motion Study results, reports and internal emails.

From Table 8, it is observed that U/L increased from 3.5 minutes per case in 2000 (with QC) to 6.1 minutes per case in 2010 (without QC), and the efficiency of AC improved throughout the development of the listing device during the Census Tests, resulting in 2.1 minutes per case in 2010 (with QC). Another limitation of this comparison is the definitions of tasks, and the observers' understanding of tasks, which vary between operations and observers. This can lead to differences in whether time is considered travel or working time. Statistical measures of uncertainty have not been reported for these previously calculated results, so caution should be taken when making comparisons.

Table 9. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Micro Data Analysis of Time and Motion Study Results for Address Canvasing and Update/Leave

Operation and Work Type	Minutes per Case	Statistically Significant Groups
2010 Address Canvassing Production	1.81	A
2010 Address Canvassing Quality Control	1.04	B
2010 Update/Leave Production	1.53	C
2010 Update/Leave Quality Control	1.63	C

Update/Leave operations are paper operations.
Address Canvassing operations are automated operations.
Source: Time and Motion Study Microdata

In addition to Table 8, DSSD conducted an additional T&M analysis, correcting for differences in urban/rural and operational differences by removing the travel time, (non-HHC) delay time, and contact time. These results are in Table 9. In Table 9, DSSD established three artifical groups (A, B and C) to represent the values in the table that exhibit a statistically significant difference among the others. The analysis of the T&M data, from 2010 AC and U/L for both production work and QC work, showed AC QC (B) was the most efficient (1.04 minutes per case). This is followed by U/L production (C) (1.53 minutes per case) and U/L QC (C) (1.63 minutes per case) which was not statistically significantly different from U/L production. AC production (A) was the least efficient at 1.81 minutes per case. In contrast to the Table 8 results,

this analysis contains an uncertainty measure. However, these differences do not explain all of the variability in the data. Also, map spotting using GPS-enabled handheld computers was conducted for all structures in the 2010 AC workload, but the map spot was only verified in U/L and AC QC. This difference in operational requirements likely contributed to the reduced efficiency.

5.2.3 Master Address File Update Times

Another measure of efficiency is the amount of time it takes for the MAF to be updated with the results of the field work. To measure the update times from when an operation occurred until the MAF was updated, DSSD used dates from the 2010 Census MAS and Census 2000 Assessment Reports. Table 10 presents the average time, and the time of each wave of each operation. DSSD calculated two time measurements: the time from when the operation started until the MAF was updated, and the time from when the operation ended until the MAF was updated.

Table 10. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Update Times for the Master Address File (MAF) and Topologically Integrated Geographic Encoding and Referencing (TIGER) Databases

Operation	Days From Operation Start to Database Update Finished	Days From Operation End to Database Update Finished
2010 Address Canvassing	127	43
Wave 1	137	36
Wave 2	116	50
2000 Block Canvassing	155	110
Wave 1	195	151
Wave 2	164	105
Wave 3	107	75
2000 Address Listing	192	110
Wave 1	256	184
Wave 2	207	124
Wave 3	188	98
Wave 4	117	33

Source: 2010 Census and Census 2000 MAS and Draft Assessment for Address Listing and Block Canvassing.

For operation start to database update completion, 2010 AC had a duration of 127 days, 2000 BC had a duration of 155 days, and 2000 AL had a duration of 192 days. For operation end to database update completion, AC had a duration of 43 days, BC had a duration of 110 days, and AL had a duration of 110 days. Clearly, the introduction of automation for the 2010 AC operation had a significant positive impact on the timeliness of MAF updating. This positive impact also made it possible to successfully implement the GQV operation.

5.3 Cost

One of the most reasonable approaches to evaluate performance is to conduct a cost-benefit analysis. This final section of the report estimates the dollar cost for conducting a paper listing operation in 2009, as similar as possible to the 2010 Census AC operation. Table 11 details six cost categories, from listing operation inception (design listing procedures or software), to conducting the listing, and finally concluding with operation closeout. The result is the closest approximation of the cost of conducting a paper-based 2010 Census AC operation in 2009. In summary, the 2010 AC operation cost over 1.5 times as much as a paper operation would have cost, approximately 845 million dollars as compared with 562 million dollars. For reference, the total cost of the 2000 and 2010 Census were about 8 billion dollars (adjusted for inflation) and 12 billion dollars respectively.

The Execution costs are essentially the direct field costs of the operation – training, lister salaries, mileage, etc. In previous studies, Execution costs have been the most visible costs associated with an operation. Table 11 shows this view is incomplete, failing to account for several other substantial costs. The majority of the dollar cost increase of an automated AC was recorded in the Infrastructure and Contract Costs category. Here, the total costs incurred during the 2010 AC operation were about 253 million dollars; about 193 million dollars more than a simulated paper operation of the same magnitude conducted in 2009. The largest percent increase was in the Procedures cost category, which grew by nearly 7.9 times the cost of conducting a paper operation. For AC, both Infrastructure and Contract Costs, and Procedures cost categories, are primarily attributed to costs from the FDCA contract. It is observed that in an automated environment, there is some cost savings in the Results/Closeout cost category; primarily due to the realized savings from eliminating keying and data capture. However, these savings were not nearly large enough to offset the increases in all five of the other cost categories.

Below are some of the assumptions and limitations to this cost analysis:

- FDCA costs are not set up by operation and the provided numbers are estimates. Some FDCA costs include the cost of GQV since this could not be separated from AC. Some FDCA costs assume other shared tasks should be split 50 percent to AC/GQV and 50 percent to NRFU or other operations.
- The same number of LCOs are required for a paper operation (151 offices).
- Certain FDCA lifecycle costs that were attributable to implementing any listing operation were utilized for both paper and automated operation costs[7].

Additionally, the FDCA contract involved many new tasks, which required a greater financial commitment to accomplish due to inefficiencies since few or no examples could be followed. Also, some costs could not be separated from other operations, and subsequent allocations introduce uncertainty. The total FDCA contract cost was about 790 million dollars, of which 390 million dollars is represented in Table 11. For other assumptions and limitations, see Appendix D. Appendix D provides the precise calculations for each cell in Table 11.

[7] Nearly entirely representative of this are the OCS or LCO creation/support costs.

The total cost per HHC, including software and memory cards, was approximately $714 (HHC + designed software + purchased software + SD cards = $501+$136+$45+$32). The Census Bureau purchased two SD memory cards per HHC, allowing for one backup.

Table 11. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Cost Comparison of Paper and Automated Listing Operations in Millions of 2009 Dollars

Cost Category	Paper Operation[1]		Automated Operation[2]	
	Estimated Cost	Percent of total[+]	Estimated Cost	Percent of total[+]
Total	**$562.4**	**100.00**	**$845.0**	**100.00**
Procedures	**2.6**	**0.47**	**20.9**	**2.47**
Design Field Procedures	2.6	0.47	0.3	0.03
Design HHC Software (MCE $136 per unit)[3]	n/a	n/a	20.6	2.44
Materials/Equipment	**41.5**	**7.38**	**109.1**	**12.91**
Purchase Paper, Ink, Binders	19.5	3.47	n/a	n/a
Purchase HHCs ($501 per unit)[3]	n/a	n/a	75.7	8.96
Purchase SD cards ($32 per unit)[3]	n/a	n/a	4.7	0.55
Purchase HHC Software ($45 per unit)[3]	n/a	n/a	6.8	0.80
Lease ELCO Equipment[3]	10.6	1.89	10.6	1.26
Lease RCC Equipment[3]	11.3	2.01	11.3	1.34
Infrastructure and Contract Costs	**59.7**	**10.62**	**253.1**	**29.95**
Software and Security Infrastructure (OCS, etc.)[3]	27.1	4.82	89.7	10.62
Program Management/Largo Facilities[3]	8.7	1.55	43.0	5.09
Operational and Office Support[3]	23.9	4.24	100.0	11.83
Contract Fees and Incentives[3]	n/a	n/a	20.4	2.42
Distribution	**6.2**	**1.11**	**2.1**	**0.25**
Print/Assemble Address Binders, Small Maps	5.4	0.97	n/a	n/a
Ship Address Binders, Small Maps	0.8	0.14	n/a	n/a
Ship HHCs	n/a	n/a	1.8	0.22
Ship SD Cards	n/a	n/a	0.3	0.03
Execution	**414.1**	**73.63**	**458.9**	**54.31**
Conduct Training/Finger Printing	56.3	10.02	81.4	9.64
Conduct Listing and Update Addresses/Maps	240.5	42.77	282.7	33.46
Mileage	87.7	15.59	75.6	8.94
Large Block Canvassing	n/a	n/a	10.3	1.22
Other Field Costs	27.4	4.88	3.9	0.46
Provide OCS/HHC Technical Support	2.1	0.37	5.1	0.60
Results/Closeout	**38.2**	**6.79**	**0.9**	**0.11**
Ship Address Binders, Small Maps	unk	unk	n/a	n/a
Key/Capture Address/Map Updates	37.0	6.59	n/a	n/a
Archive/Dispose Paper	1.2	0.21	n/a	n/a
Ship HHCs	n/a	n/a	unk	unk
Decommission HHCs	n/a	n/a	0.8	0.09
Store HHCs	n/a	n/a	0.1	0.01

HHC - Handheld Computer, MCE - Mobile Computing Environment SD - Secure Digital, ELCO - Early Local Census Office, RCC - Regional Census Centers, OCS - Operations Control System

[+]Percentages may not sum to 100 due to rounding.

[*]n/a denotes costs that are not applicable for a specific type of operation (paper or automated).

[**]unk denotes costs that were not tracked seperately, but rather as part of a group of costs. For the purposes of completing this table, these costs were wholly placed in the Distribution category and excluded from the Results/Closeout category.

[1]Paper Operation refers to the Census 2000 Address Listing and Block Canvassing operations, adjusted to simulate both 2009 workload and dollars.

[2]Automated Operation refers to the 2010 Census Address Cancassing operation.

[3]Costs for an Automated Operation are part of the Field Data Collection Automation (FDCA) contract costs. Not all FDCA contract costs are available separately by operation. Some of the figures provided here are estimates. FDCA costs include some of the cost of Group Quarters Validation (GQV), since this could not be separated from Address Canvassing (AC). The original FDCA contract cost award was $596 million. The final FDCA contract cost was approximately $790 million after descoping, of which $662 million occurred before Fiscal Year 2010. Of the $662 million, $390 million was attributed to AC and is included in the table in the Procedures, Materials/Equipment and Infrastructure and Contract Costs categories. When a cost was not solely attributable to AC, a 50 percent allocation for each AC and Nonresponse Follow up (NRFU)/other operation(s) was used. These allocated costs were substantial.

Source: 2010 Cost and Progress system, 2000 Draft Assessment of AL and BC, and Census internal e-mails about cost See Section 3.2.4 and Appendix D for methods and calculations.

6 Related Evaluations and Assessments

There are many 2010 Census Evaluations and Assessments that are related to the work done here:

- Address Canvassing Assessment Report
- Update Leave Assessment Report
- Evaluation of Address Frame Accuracy and Quality
- Address Canvassing Quality Profile
- Update/Leave Quality Profile

7 Conclusions and Recommendations

7.1 Conclusions

Automation did not result in the expected cost savings, and in fact cost more throughout its census operation lifecycle – 845 million dollars as compared with 562 million dollars. However, noteworthy is the economy of scale that could have been realized if the same device and similar procedures had been used in NRFU and subsequent operations. While additional costs would have been incurred to operationalize automation for those operations and in procuring a sufficient number of devices, there stood great potential to lessen the dollar cost gap measured in Table 11; by widening the cost base to which the Infrastructure and Contract, and Materials/Equipment cost categories could have been attributed. Also, as noted earlier, the HHCs did provide for improvements in data quality: allowing for automated edits and the collection of GPS coordinates. HHCs also allowed for the operation to be completed more rapidly, and directly reduced the time from operation end to MAF update completion by over 60 percent. In 2010, this provided the necessary window for successful implementation of the GQV operation. Additionally, while not measured here, the HHC allowed for an automated payroll, which is believed to be a significant cost savings over paper payroll processes.

If procedures, materials/equipment, and infrastructure/contract costs can be managed more effectively, automation could be a cost effective means of obtaining higher quality results from a listing operation -- about 104 million dollars (3+41+60 from Table 11) for a paper operation as compared with 384 million dollars (21+109+253 from Table 11) for an automated operation. Reusing hardware or software for other operations would help to spread these costs over several operations and could also make automation more cost effective. AC, U/L, and Update/Enumerate are all operations with similar listing procedures. A listing device that is used for all three could share development and equipment costs.

Another way to control hardware costs is to consider the possibility of using hardware readily available to the listers. The realized per unit cost of the 2010 HHC was about $714, of which $501 was for the HHC itself. The Census Bureau could require listers to provide a smart phone,

tablet computer, or similar technology to complete their listing work. In a similar manner, the Census Bureau currently requires listers to provide their own vehicle. Rather than purchasing hardware for an entire workforce, an alternative solution could be to simply subsidize the purchase and operational expenses of personally-owned devices. Using reasonable assumptions for 2009 costs, subsidizing listers at $100 per month for operational expenses (most listers in the 2010 AC worked one month), $100 for hardware (smart phone or tablet computer), and estimating multiple operating system software development per unit cost of $272, the total unit cost of a personally owned device could be approximately $472. This alternative would reduce the per unit cost by about one-third, which could have saved almost $37 million in 2009. This also avoids the issue of what to do with the devices at the end of decennial census operations. Also, listers will tend to have devices with favorable reception in their AAs; directly addressing some of the transmission problems reported in 2010.

Today, typically, off-the-shelf mobile phones are less expensive than the $501 HHC per unit cost realized in 2009. Low-end tablet computers are also less expensive than the $501 HHC per unit cost; however, high-end tablets can be more expensive. Many of these devices, including almost all tablets, match or exceed the specifications of the HHCs used in 2009 – for memory, processing performance, and screen size. In addition, most individual data plans today are under or near $100 per month. Hopefully, the trend that new computer and mobile technologies like this continue to become more affordable, which will contribute to a more affordable outlook for automated decennial census operations. If mobile coverage and transmission speeds improve, it might be possible to implement a cloud computing solution for our field work. However, in 2009, some large geographic areas lacked coverage during AC; one of which was in southwestern Wyoming. It will be important to closely monitor improvements in mobile coverage and transmission speeds leading up to the next decennial census. Allowing multiple carriers may also alleviate coverage and transmission concerns.

Lastly, per the debriefing results, providing electronic lister manuals and materials will increase efficiency, lister satisfaction, and reduce printing and shipping costs.

7.2 Recommendations

Based on these findings and the collective experiences of those conducting this research, DSSD recommends vigorous and careful pursuit of increased automation in the 2020 Census, and provides the following recommendations:

- **Contract Cost Evaluation and Containment:** Given the largest divergence of costs of automated and paper operations in this study was contract expenditures, with a difference of approximately 279 million dollars (observed in the cost categories of Procedures, Materials/Equipment, and Infrastructure and Contract Costs in Table ES-2), one of the highest intercensal priorities should be evaluating and modeling expected contract costs both pre- and post-award, and developing and implementing methods for cost monitoring and containment both pre- and post-award. Also, with such a deep and wide pool of technical and managerial expertise, wherever possible, a great deal of *documented* consideration and deliberation should be given to in-house solutions.

- **Operation Cost Estimation and Tracking:** During the course of this evaluation, for certain items, DSSD was unable to obtain documented, thorough, reliable, auditable pre- and post-operation cost estimates. Much careful, deliberate attention should be made to evaluate and *document* multiple competing pre-operation cost estimation strategies and outputs leading up to the 2020 Census. Also, in order to perform cost-benefit analyses on operations, it is critical that all costs be tracked by operation. For this study, DSSD was not able to comprehensively obtain contract, control system, headquarters personnel, operational design, and printing/shipping/supply costs separately by operation. Additionally, DSSD recommends pursuing an earned value approach to track costs within operations. Assigning costs to WBS tasks by operation (as opposed to by process) will provide more relevant and informative cost-benefit and earned value analyses. Shared operation costs should be consistently allocated and tracked by both an equally-distributed method (e.g., five operations benefiting from a shared process would each share one-fifth of the cost) and an estimated workload method (e.g., operation A with a 1 million HU workload and operation B with a 2 million HU workload would share the total cost of a shared process at one-third and two-thirds respectively).
- **Technology:** Given the 2010 Census handheld devices were one-time-use devices, at a total cost of over 80 million dollars, high consideration should be given to two alternative strategies: (a) conduct operations via applications (apps) designed to run on multiple operating systems and on numerous commercially-available, *personally-owned devices* (e.g., smart phones, tablet computers), or (b) conduct all survey and decennial census listing and enumeration operations on a *single Census Bureau device* capable of a lifecycle to adequately absorb the initial acquisition and development costs, and semi-regular maintenance. Under strategy (a), to mitigate the risk of insufficient personally-owned device availability, the Census Bureau may elect to subsidize the purchase of personally-owned devices in select geographies; still resulting in overall cost savings to the agency.
- **Device Features:** If the Census Bureau elects to purchase, lease or build its own device as it did for the 2010 Census, consideration should be given to some key features requested by the 2009 user community: (a) acquire anti-glare display screens or offer a separate film or shield to reduce glare, (b) study the costs and benefits of adding weatherproofing to the device, (c) load the device manual and help facility onto the device itself and/or make available a centrally-administered crowd-sourced help website, accessible via the device, (d) ensure reliable real-time communication with other field staff, and (e) consider using cloud computing instead of loading data or software.

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Appendix A. 2010 Census Address Canvassing Debriefing Questionnaire Results for the Group Quarters Validation (GQV) Listers and Crew Leaders (questionnaire distributed after GQV)

Table A.
2010 CPEX Evaluation of Automation in Field Data Collection in AC:
Address Canvassing Debriefing Question Results After Group Quarters Validation (GQV) for Listers of GQV

Question	Response								
	Lister	**QC Lister**	**CLA**	**QC CLA**	**CL**	**QC CL**	**Other**		**Total**
Position for 2010 Address Canvassing (multiple response or no response possible)	1,321	412	192	38	243	54	89		2,349
	Very Prepared	**Somewhat Prepared**	**Unsure**	**Somewhat Unprepared**	**Very Unprepared**	**Do Not Remember**	**Did Not Respond**		**Total**
How well prepared did you feel you were to use the HHC	1,304	665	122	44	31	4	254		2,424
After working in the field for a while, how well did you think your Address Canvassing training had prepared you to do the following tasks that you needed to perform while working out in the field?	**Totally Prepared**	**Adequately Prepared**	**Somewhat Prepared**	**NOT Prepared**	**Do Not Remember**	**Did Not Respond**			**Total**
Use the maps on the HHC to find the blocks in your assignment	1,157	781	195	23	6	262			2,424
Use the HHC map to determine a travel route	1,021	766	284	68	21	264			2,424
Use the HHC when conducting interviews to verify address information	1,303	676	127	15	26	277			2,424
Use the HHC maps and GPS to add streets to your map	956	749	339	46	58	276			2,424
Get respondents to cooperate	904	885	276	44	45	270			2,424
Enter data into the HHC using the pop-up keyboard	1,345	637	115	12	45	270			2,424
Fill out your electronic time sheet	1,604	478	56	7	11	268			2,424
Perform tasks such as answering respondents' questions, etc	1,044	818	202	38	55	267			2,424
Perform the social tasks required such as meeting strangers	1,025	762	231	63	74	269			2,424
Meet production goals for the number of cases completed each hour that you worked	1,152	693	190	51	63	275			2,424
Enter data in the HHC using the stylus	1,547	529	64	7	8	269			2,424
Transmit in areas where wireless technology was not available	775	639	379	144	206	281			2,424
For each of the Address Canvassing job tasks listed below, please tell us how satisfied or dissatisfied you were with the guidance and training you received to perform the following tasks using the HHC	**Very Satisfied**	**Somewhat Satisfied**	**Neither Satisfied Nor Dissatisfied**	**Somewhat Dissatisfied**	**Very Dissatisfied**	**Do Not Remember**	**Did Not Respond**		**Total**
Locate a block	1,599	428	83	31	14	3	266		2,424
Make transmissions in areas where wireless technology was not available	765	542	348	164	110	210	285		2,424
Canvass a block	1,617	423	79	28	7	3	267		2,424
Update address information for living quarters	1,529	490	85	30	12	10	268		2,424
Add streets to the maps on the HHC	1,093	630	187	131	44	63	276		2,424
Thinking back to your experiences while working Address Canvassing, in an average week, how often did you	**Several Times a Day**	**At Least Once a Day**	**Several Times a Week**	**At Least Once a Week**	**Less Than Once a Week**	**Never**	**Do Not Remember**	**Did Not Respond**	**Total**
Encounter problems entering your payroll on the HHC	25	58	92	141	527	1,286	22	273	2,424
Have problems transmitting your payroll data	41	76	205	304	681	824	20	273	2,424
Use a paper D-308 to record your hours/miles worked	13	73	22	34	317	1,577	111	277	2,424

Table A (cont).

2010 CPEX Evaluation of Automation in Field Data Collection in AC:
Address Canvassing Debriefing Question Results After Group Quarters Validation (GQV) for Listers of GQV[1]

Question	Response								
While working Address Canvassing in the field, how difficult or easy was it for you to perform the following Address Canvassing job tasks?	**Very Difficult**	**Somewhat Difficult**	**Neither Easy Nor Difficult**	**Somewhat Easy**	**Very Easy**	**Do Not Remember**	**Did Not Respond**		**Total**
Use the maps on the HHC to find the blocks in your assignment	26	112	185	504	1,309	9	279		2,424
Use the HHC map to determine a travel route	50	162	271	542	1,093	25	281		2,424
Use the HHC when conducting interviews to verify address information	15	18	172	445	1,458	30	286		2,424
Use the HHC maps and GPS to add streets to your map	51	213	267	576	919	101	297		2,424
Get respondents to cooperate	17	65	311	651	1,039	56	285		2,424
Enter data into the HHC using the pop-up keyboard	16	45	140	423	1,451	61	288		2,424
Fill out your electronic time sheet	13	19	86	314	1,699	13	280		2,424
Perform tasks such as answering respondents' questions, etc	14	31	227	597	1,205	67	283		2,424
Perform the social tasks required such as meeting strangers	15	24	244	496	1,281	77	287		2,424
Meet production goals for the number of cases completed each hour that you worked	22	56	230	474	1,267	90	285		2,424
Enter data in the HHC using the stylus	16	18	100	323	1,672	13	282		2,424
Transmit in areas where wireless technology was not available	146	299	367	395	579	333	305		2,424
While using the HHC to conduct Address Canvassing, how often did you have trouble with the following activities?	**Several Times a Day**	**At Least Once a Day**	**Several Times a Week**	**At Least Once a Week**	**Less Than Once a Week**	**Never**	**Do Not Remember**	**Did Not Respond**	**Total**
Reading the information on the screen due to lighting conditions	283	227	239	207	394	745	55	274	2,424
Reading the information on the screen due to font size	68	70	61	91	205	1,607	46	276	2,424
Reading the information on the screen due to font style	32	31	23	46	143	1,818	55	276	2,424
Reading the information on the screen due to the color of the print	35	43	50	69	141	1,712	88	286	2,424
The screen going blank too frequently	129	106	219	256	456	866	103	289	2,424
Glare on the HHC screen	318	197	284	254	394	637	57	283	2,424
Using the maps on the HHC	63	73	132	205	444	1,188	29	290	2,424
Using the map tools (zoom, pan, etc.) on the HHC	76	87	138	200	424	1,202	17	280	2,424
Using the stylus to input information into the computer	39	26	38	64	237	1,723	17	280	2,424
Using the pop-up keyboard	26	29	31	70	263	1,648	73	284	2,424
Transmitting in areas where wireless technology was not available	106	88	212	277	441	692	306	302	2,424
Getting locked out of the HHC	106	90	300	314	612	682	38	282	2,424
HHC freezing up	134	118	376	425	693	364	37	277	2,424
Using the "You-Are-Here" feature on the maps	121	94	207	240	389	998	96	279	2,424
For each Address Canvassing job task listed, please tell us how often, while either planning your day and/or listing addresses, you…?	**Always**	**Most of the Time**	**Sometimes**	**Seldom**	**Never**	**Do Not Remember**	**Did Not Respond**		**Total**
Used the HHC maps to find the blocks in your assignment	1,417	502	147	50	23	9	276		2,424
Used the HHC map to determine a travel route	921	595	365	157	100	8	278		2,424
Used the HHC maps (and GPS) to add streets to your map	969	221	366	300	196	89	283		2,424
Uses the HHC when conducting interviews to verify and update address information	1,476	297	198	93	50	35	275		2,424
When you were conducting Address Canvassing, how helpful was the HHC map to you for each listed task?	**Very Helpful**	**Somewhat Helpful**	**Neither Helpful Nor Unhelpful**	**Somewhat Unhelpful**	**Very Unhelpful**	**Do Not Remember**	**Did Not Respond**		**Total**
Finding the blocks in your assignment when you were planning your day	1,622	386	76	23	24	12	281		2,424
Determining a travel route when you were planning your day	1,234	573	193	75	46	19	284		2,424
Adding streets to your map	1,194	437	207	83	38	168	297		2,424

Table A (cont).

2010 CPEX Evaluation of Automation in Field Data Collection in AC:
Address Canvassing Debriefing Question Results After Group Quarters Validation (GQV) for Listers of GQV

Question	Response								
While in the field working Address Canvassing, how useful did you find the "You-Are-Here" function in helping to correctly identify whether a unit was within your "active block"?	**Very Useful** 1,269	**Somewhat Useful** 418	**More useful than useless** 210	**Somewhat Useless** 79	**Very Useless** 46	**I did not use this function** 64	**Do Not Remember** 59	**Did Not Respond** 279	**Total** 2,424
While in the field working Address Canvassing, how often did the "You-Are-Here" function prevent you from adding units outside of the correct "active block?"	**Several Times a Day** 171	**At Least Once a Day** 189	**Several Times a Week** 240	**At Least Once a Week** 310	**Less Than Once a Week** 359	**N/A, Never needed to add units outside of the correct "active block?"** 586	**Do Not Remember** 289	**Did Not Respond** 280	**Total** 2,424
While in the field working Address Canvassing, how easy or difficult was it for you to collect GPS coordinates for housing units?	**Very Easy** 958	**Somewhat Easy** 706	**Neither easy nor difficult** 219	**Somewhat Difficult** 147	**Very Difficult** 28	**Do Not Remember** 84	**Did Not Respond** 282		**Total** 2,424
While in the field working Address Canvassing, how often did you need to update any addresses on the HHC?	**Several Times a Day** 454	**At Least Once a Day** 346	**Several Times a Week** 423	**At Least Once a Week** 332	**Less Than Once a Week** 311	**Never** 81	**Do Not Remember** 198	**Did Not Respond** 279	**Total** 2,424
Overall, how easy or difficult was the HHC to use?	**Very Easy** 1,270	**Somewhat Easy** 658	**Neither easy nor difficult** 106	**Somewhat difficult** 90	**Very difficult** 19	**Do Not Remember** 5	**Did Not Respond** 276		**Total** 2,424
In an average week, how often did you spend time resolving HHC problems?	**Several Times a Day** 173	**At Least Once a Day** 254	**Several Times a Week** 363	**At Least Once a Week** 420	**Less Than Once a Week** 719	**Never** 183	**Do Not Remember** 36	**Did Not Respond** 276	**Total** 2,424
Did you ever have to replace you HHC at any point during the operation?	**Yes** 282	**No** 1,866	**Did Not Respond** 276						**Total** 2,424
How often did you have problems entering data using the HHC stylus?	**Several Times a Day** 43	**At Least Once a Day** 70	**Several Times a Week** 72	**At Least Once a Week** 122	**Less Than Once a Week** 396	**Never** 1,394	**Do Not Remember** 49	**Did Not Respond** 278	**Total** 2,424
Which method did you prefer for recording listing information on the HHC, the stylus or keyboard?	**Strongly prefer the stylus with the HHC** 1,061	**Prefer the stylus with HHC** 686	**Prefer the keyboard with the HHC** 66	**Strongly prefer the keyboard with the HHC** 17	**No preference** 310	**Did Not Respond** 284			**Total** 2,424
How often did you experience difficulty using the text messaging on the HHC?	**At least once a day** 39	**Several times a week** 88	**Once a week** 99	**Less than once a week** 392	**Never** 1,356	**Do Not Remember** 168	**Did Not Respond** 282		**Total** 2,424
While working on Address Canvassing, did you ever use the following maps to assist you in locating an Assignment Area?	**Yes**	**No**	**Do Not Remember**	**Did Not Respond**					**Total**
Commercial (store bought) maps	695	1,396	24	309					2,424
Personal GPS	496	1,579	26	323					2,424
Computer generated maps such as Mapquest or Google maps	782	1,299	37	306					2,424

Table A (cont).

2010 CPEX Evaluation of Automation in Field Data Collection in AC:
Address Canvassing Debriefing Question Results After Group Quarters Validation (GQV) for Listers of GQV

Question	Response								
While working on Address Canvassing, did you ever use the following maps to assist you in locating a specific address?	**Yes**	**No**	**Do Not Remember**	**Did Not Respond**					**Total**
Commercial (store bought) maps	358	1,729	23	314					2,424
Personal GPS	459	1,623	24	318					2,424
Computer generated maps such as Mapquest or Google maps	609	1,470	37	308					2,424
	Strongly preferred the maps on the HHC	**Preferred the maps on the HHC**	**Strongly preferred commercial maps**	**Preferred commercial maps**	**Strongly preferred personal GPS**	**Preferred personal GPS**	**No preference**	**Did Not Respond**	**Total**
Looking back to your Address Canvassing experiences, which type of maps did you prefer to use for locating your assignment area, the HHC maps, commercial maps, or your personal GPS?	704	725	94	146	156	98	212	289	2,424
	Strongly preferred the maps on the HHC	**Preferred the maps on the HHC**	**Strongly preferred commercial maps**	**Preferred commercial maps**	**Strongly preferred personal GPS**	**Preferred personal GPS**	**No preference**	**Did Not Respond**	**Total**
Looking back to your Address Canvassing experiences, which type of maps did you prefer to use for locating a specific address, the HHC maps, commercial maps, or your personal GPS?	791	751	51	75	157	132	176	291	2,424
	Yes	**No**	**Did Not Respond**						**Total**
Prior to working on the 2010 Address Canvassing operation, did you work any previous Census paper-listing operations (e.g. 2000 Block Canvassing, 2000 Address Listing, or 2004 Census Test Address Canvassing operations)?	293	1,853	278						2,424
	Strongly prefer the HHC	**Prefer the HHC**	**Prefer paper**	**Strongly prefer paper**	**No preference**	**Did Not Respond**			**Total**
Comparing your previous paper-listing experiences and your 2010 Address Canvassing HHC experiences, which tool do you prefer for completing the Address Canvassing operation, the HHC or paper?	256	108	25	15	28	1,992			2,424
	Strongly prefer the HHC	**Prefer the HHC**	**Prefer pen or pencil with paper lists**	**Strongly prefer pen or pencil with paper lists**	**No preference**	**Did Not Respond**			**Total**
Which method do you prefer for recording listing information, the HHC or pen/pencil with paper lists?	270	127	25	11	23	1,968			2,424

Source: SAS Output from read_cl_output.sas and read_lister_output.sas by Jonathan Holland

Appendix B. 2010 Census Time and Motion Study Results for Address Canvassing and Update/Leave

Table B-1.
2010 CPEX Evaluation of Automation in Field Data Collection in AC:
Time and Motion Study's Activity List for Address Canvassing Production Work

Activity	Number of Occurances	Total Minutes	Analysis Category
Update Address	8,511	5,862.8	Work
Collect Mapspot	7,303	3,904.5	Map
Back to AL	5,606	1,447.1	Work
Walking	5,314	4,757.5	Walk
Drive Address to Address	1,857	4,513.4	Travel
Locate Address	1,701	2,131.5	Work
Address List Appears	562	447.3	Work
Other Delays	506	2,123.1	Delay
Map Update	494	1,163.6	Map
Travel to AA	416	1,149.9	Travel
AA Block Appears	275	258.3	Work
** START OF THE STUDY	234	-	
Power UP	188	379.7	Work
HHC Delay	165	500.7	Delay
Idle	141	477.1	Break
Crtsy ontact/Interview	81	79.4	Contact
Break	71	658.3	Break
Lunch	69	2,306.8	Break
Gated	60	94.3	Work

** Start of study takes no time just indicates a new study has started
Crtsy ontact/Interview = Courtesy Contact/Interview
AL -- Address List AA -- Assignment Area HHC -- Handheld Computer
Source: Micro data from AMSD

Table B-2.
2010 CPEX Evaluation of Automation in Field Data Collection in AC:
Time and Motion Study's Activity List for Address Canvassing Quality Control Work

Activity	Number of Occurances	Total Minutes	Analysis Category
Accept Address	3,642	2,024.9	Work
Walking	2,297	1,849.3	Walk
GPS	1,937	1,005.9	Map
Back to AL	1,932	337.8	Work
Locate Address	1,568	1,335.3	Work
Drive Address to Address	751	1,862.8	Travel
Reject Address	520	716.8	Work
AL Appears	404	254.5	Work
Travel to AA	298	1,477.0	Travel
Add	293	263.2	Work
Other Delays	194	771.9	Delay
AA Block Screen	154	139.1	Work
** START OF THE STUDY	149	-	
Power UP	115	1,505.5	Work
Idle	104	238.3	Break
Map Update	82	125.3	Map
HHC Delay	78	395.9	Delay
Break	44	168.9	Break
Lunch	34	922.3	Break
Crtsy Contact/Interview	6	12.1	Contact
Suspend Time	1	-	Work

** Start of study takes no time just indicates a new study has started
Crtsy Contact/Interview = Courtesy Contact/Interview
GPS -- Global Positioning System AL -- Address List AA -- Assignment Area HHC -- Handheld Computer
Source: Micro data from AMSD

Table B-3.
2010 CPEX Evaluation of Automation in Field Data Collection in AC:
Time and Motion Study's Activity List for Update/Leave Production Work

Activity	Number of Occurances	Total Minutes	Analysis Category
Walking	1,038	1,291.7	Walk
Attempt to Contact?	968	245.2	Work
Addressed Questionaires	869	1,047.7	Work
Interview?	662	67.4	Contact
Drive Address to Address	423	1,628.5	Travel
Locate Address	416	1,206.4	Work
Prepare Work	399	1,108.4	Work
Verify Mapspot?	372	185.1	Map
Interview	149	26.0	Contact
Update Maps	125	117.0	Map
Drive to AA	118	1,296.0	Travel
Update Mapspot	113	272.0	Map
** START OF THE STUDY	110	-	
Other Delays	102	636.7	Delay
Unaddressed Questionaires	98	285.6	Work
Complete Block Review	70	131.7	Work
Personal Time	56	901.1	Break
Gated Community	13	15.7	Work
Review completed block	11	30.3	Work
Suspend Time	3	6.5	Work

** Start of study takes no time just indicates a new study has started
Interview ? and Interview were combined during analysis
AA -- Assignment Area
Source: Micro data from AMSD

Table B-4.
2010 CPEX Evaluation of Automation in Field Data Collection in AC:
Time and Motion Study's Activity List for Update/Leave Quality Control Work

Activity	Number of Occurances	Total Minutes	Analysis Category
Attempt to Contact?	1,158	224.7	Contact
Interview?	1,041	86.1	Contact
Verify Mapspot	650	182.2	Map
Walking	631	617.8	Walk
Drive Address to Address	559	1,650.1	Travel
Locate Address	544	1,747.9	Work
Recanvass	517	462.3	Work
Review D-1190	510	420.9	Work
Verify DQC Address	463	753.9	Work
Prepare Work	324	3,620.8	Work
Drive to AA	198	2,355.0	Travel
Other Delays	173	790.8	Delay
Update Mapspot	169	180.6	Map
** START OF THE STUDY	151	-	
DQC Address	111	109.1	Work
LQ Add	110	289.5	Work
Complete Block Review	99	178.0	Work
Interview	69	12.3	Contact
Personal Time	68	634.0	Break
Update Maps	46	202.0	Map
Gated Community	17	20.4	Work
Repair	9	28.5	Work
Suspend Time	2	0.6	Work
Unaddressed Questionnaire	1	11.5	Work

** Start of study takes no time just indicates a new study has started
Interview ? and Interview were combined during analysis
D-1190 is a form from DQC -- Dependent Quality Control AA -- Assignment Area LQ -- Living Quarters
Source: Micro data from AMSD

Appendix C. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Census 2000 and 2010 Census Schedule Analysis

Table C. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Census 2000 and 2010 Census Schedule Analysis

Activity ID	Activity Description	Actual Start Date	Actual Finish Date	Source
	Census 2000			
	Conduct Address Listing Wave 1	7/20/1998	9/30/1998	-Draft- Address Listing Assessment
	Conduct Address Listing Wave 2	10/8/1998	12/30/1998	-Draft- Address Listing Assessment
	Conduct Address Listing Wave 3	11/5/1998	2/3/1999	-Draft- Address Listing Assessment
	Conduct Address Listing Wave 4	3/4/1999	5/27/1999	-Draft- Address Listing Assessment
06-04C1240	Add addresses from Wave 1 Address Listing to the MAF	12/10/1998	4/2/1999	Census 2000 Master Activity Schedule
06-04C2240	Add addresses from Wave 2 Address Listing to the MAF	2/9/1999	5/3/1999	Census 2000 Master Activity Schedule
06-04C3240	Add addresses from Wave 3 Address Listing to the MAF	2/24/1999	5/12/1999	Census 2000 Master Activity Schedule
06-04C4525	Add addresses from Wave 4 Address Listing	6/1/1999	6/29/1999	Census 2000 Master Activity Schedule
	Conduct Block Canvassing Wave 1	1/16/1999	3/1/1999	-Draft- Block Canvassing Assessment
	Conduct Block Canvassing Wave 2	2/16/1999	4/16/1999	-Draft- Block Canvassing Assessment
	Conduct Block Canvassing Wave 3	4/14/1999	5/16/1999	-Draft- Block Canvassing Assessment
06-03C6340	Update the MAF with Block Canvassing Results - all waves	4/21/1999	7/30/1999	Census 2000 Master Activity Schedule
	2010 Census			
10ADC-05510	Conduct Address Canvassing Production Field Work Wave 1	3/30/2009	7/9/2009	2010 Census Master Activity Schedule
10ADC-05520	Conduct Address Canvassing Production Field Work Wave 2	4/20/2009	6/25/2009	2010 Census Master Activity Schedule
10MTS-18950	Update M/T With AC Spatial Updates - All Waves	4/27/2009	8/14/2009	2010 Census Master Activity Schedule
10MTS-18910	Update M/T With AC Address Updates (incl. loading and assessing files) - Wave 2	5/6/2009	8/7/2009	2010 Census Master Activity Schedule
10MTS-18920	Update M/T With AC Address Updates (incl. loading and assessing files) - Wave 1	5/6/2009	8/7/2009	2010 Census Master Activity Schedule

Source: Master Activity Schedule for Census 2000 and 2010 Census -Draft- Address Listing and -Draft- Block Canvassing Assessment

Appendix D. Cost Sources and Detailed Methods

Totals and Subtotals (Rows A, B, E, L, Q, V, and AC of Cost Table Shell)

The Total A1 is the sum of the subtotal values B1, E1, L1, Q1, V1 and AC1. The Total in A2 is the sum of the subtotal values B2, E2, L2, Q2, V2 and AC2. Similarly, the subtotals are the sum of the detail items in that group. For example, V1 is the sum of W1, X1, Y1, AA1, and AB1. Percentages are calculated based on the Total in A1 for Paper Operation calculations in column 1 and Total in A2 for Automated Operation calculations. Values in Table 11 are rounded to tenths of millions.

Table D.
2010 CPEX Evaluation of Automation in Field Data Collection in AC:
Cost Comparison Shell of Paper and Automated Listing Operations

Cost Source	Paper Operation[1]		Automated Operation[2]	
	Estimated Cost	Percent of total[+]	Estimated Cost	Percent of total[+]
Total	***A1***		***A2***	
Procedures	**B1**		**B2**	
Design Field Procedures	C1		C2	
Design HHC Software (MCE $136 per unit)[3]	n/a	n/a	D2	
Materials/Equipment	**E1**		**E2**	
Purchase Paper, Ink, Binders	F1		n/a	n/a
Purchase HHCs ($501 per unit)[3]	n/a	n/a	G2	
Purchase SD cards ($32 per unit)[3]	n/a	n/a	H2	
Purchase HHC Software ($45 per unit)[3]	n/a	n/a	I2	
Lease ELCO Equipment[3]	J1		J2	
Lease RCC Equipment[3]	K1		K2	
Contract/Infrastructure Costs	**L1**		**L2**	
Software and Security Infrastructure (OCS, etc.)[3]	M1		M2	
Program Management/Largo Facilities[3]	N1		N2	
Operational and Office Support[3]	O1		O2	
Contract Fees and Incentives[3]	n/a	n/a	P2	n/a
Distribution	**Q1**		**Q2**	
Print/Assemble Address Binders, Small Maps	R1		n/a	n/a
Ship Address Binders, Small Maps	S1		n/a	n/a
Ship HHCs	n/a	n/a	T2	
Ship SD Cards	n/a	n/a	U2	
Execution	**V1**		**V2**	
Conduct Training/Finger Printing	W1		W2	
Conduct Listing and Update Addresses/Maps	X1		X2	
Mileage	Y1		Y2	
Large Block Canvassing	n/a	n/a	Z2	
Other Field Costs	AA1		AA2	
Provide OCS/HHC Technical Support	AB1		AB2	
Results/Closeout	**AC1**		**AC2**	
Ship Address Binders, Small Maps	AD1	unk	n/a	n/a
Key/Capture Address/Map Updates	AE1		n/a	n/a
Archive/Dispose Paper	AF1		n/a	
Ship HHCs	n/a	n/a	AG2	unk
Decommission HHCs	n/a	n/a	AH2	
Store HHCs	n/a	n/a	AI2	

HHC - Handheld Computer, MCE - Mobile Computing Environment SD - Secure Digital, ELCO - Early Local Census Office, RCC - Regional Census Centers, OCS - Operations Control System

[+]Percentages may not sum to 100 due to rounding.

[*]n/a denotes costs that are not applicable for a specific type of operation (paper or automated).

these costs were wholly placed in the Distribution category and excluded from the Results/Closeout category.

[1]Paper Operation refers to the Census 2000 Address Listing and Block Canvassing operations, adjusted to simulate both 2009 workl

[2]Automated Operation refers to the 2010 Census Address Cancassing operation.

[3]Costs for an Automated Operation are part of the Field Data Collection Automation (FDCA) contract costs. Not all FDCA contract costs are available separately by operation. Some of the figures provided here are estimates. FDCA costs include some of the cost of Group Quarters Validation (GQV), since this could not be separated from Address Canvassing (AC). The original FDCA contract cost award was $596 million. The final FDCA contract cost was approximately $790 million after descoping, of which $662 million occurred before Fiscal Year 2010. Of the $662 million, $390 million was attributed to AC and is included in the table in the Procedures, Materials/Equipment and Infrastructure and Contract Costs categories. When a cost was not solely attributable to AC, a 50 percent allocation for each AC and Nonresponse Follow up (NRFU)/other operation(s) was used. These allocated costs were substantial.

Procedures

Cell C1

The cell C1, design of field procedures (paper), is sourced from the 2000 Census Block Canvassing Costs Breakdown.xls document from Field Division (FLD). This was adjusted by the FLD provided estimate of 5 of the 8.3 Full Time Equivalents (FTEs) working on Block Canvassing (BC) design in 1998. The cost for 8.3 FTEs is $1,202,145. Reducing by 5/8.3, DSSD arrived at $724,184. Sourced from a FLD/DMD/DSSD meeting, it was estimated that Address Listing (AL) had about the same amount of FTEs, for a combined total of $1,448,367. This figure was then adjusted for wage inflation (1.35) and workload (1.35) as seen in the methods section for Block Canvassing (BC) only. Using these adjustments, DSSD arrived at $2,636,449.

Cell C2

The cell C2, design of field procedures (automated), is sourced from a meeting with FLD and DMD staff, where it was estimated approximately 30 FTEs worked on the requirements for FDCA for about one month. DSSD estimated this as 30 FTEs working 20 days, 8 hours a day, at GS-14, step 5 wages of 53.24 dollars an hour, arriving at a total of $255,552.

Cell D2

The cell D2, design HHC software costs is sourced from FDCA contract costs from the 110113_LCCE.xls and 071015_LCCE.xls files provided by DACMO. The WBS elements, 01-02-03-02, Software- Mobile Computing Environment (MCE) from starting in 2006 through 2008, and 02-03-02-02, Decennial AC MCE Development from Fiscal Years (FYs) 2008-2009, are those directly involved in the development of the MCE, the software created to conduct the listings. The sum of these two WBS elements was $20,608,876.

Materials/Equipment

Cell F1

The cell F1, purchase of paper, ink, and binders (paper), is sourced from the 2000 Census Block Canvassing Costs Breakdown.xls document from FLD. Original value is $8,500,000 for these supplies. The BC only adjustment to workload (1.65) and wage inflation (1.35) is appropriate. After adjustments DSSD calculated the value as $19,542,513.

Cell G2

The cell G2, the purchase of HHCs (automated), is sourced from a 4/12/2010 e-mail from DACMO. The value was $75,695,209. There were 151,056 HHCs purchased for a per unit cost of $501.

Cell H2

The cell H2, the purchase SD cards (automated), is from a 4/12/2010 e-mail from DACMO. The value was $4,657,734. There were 299,148 SD cards for a per SD card price of $16; however, there were about twice as many SD cards as HHCs so the per HHC unit cost was $32.

Cell I2

The cell I2, software costs in the FDCA contract (automated), is sourced from a 4/12/2010 e-mail from DACMO. The value was $6,767,762. The151,056 HHC software packages were purchased for a per unit cost of $45.

Cell J1

DACMO supplied the LCO and ELCO Equipment cost (paper). For comparability, it was assumed the same number of LCOs would be required if conducting a paper AC. The source is the 110113_LCCE.xls document WBS 03-04, ELCO Lease Equipment FFP, for FYs 2008-2009. The $21,291,587 was reduced by half since this is considered to be a shared cost. The resulting value was $10,645,794.

Cell J2

DACMO supplied the LCO and ELCO Equipment cost (paper). For comparability, it was assumed the same number of LCOs would be required if conducting a paper AC. The source is the 110113_LCCE.xls document WBS 03-04, ELCO Lease Equipment FFP, for FYs 2008-2009. The $21,291,587 was reduced by half since this is considered to be a shared cost. The resulting value was $10,645,794.

Cell K1

DACMO supplied the RCC Equipment cost (paper), the source is the 110113_LCCE.xls document WBS 03-01, EP1 Lease Equipment FFP, for FYs 2008-2009. These costs were assumed to be the same as an automated operation, with the limitation that these costs were calculated using a 50 percent AC/50 percent NRFU allocation. The value was $11,331,692.

Cell K2

DACMO supplied the RCC Equipment cost (automation), the source is the 110113_LCCE.xls document WBS 03-01, EP1 Lease Equipment FFP, for FYs 2008-2009. These costs were assumed to be the same as an automated operation, with the limitation that these costs were calculated using a 50 percent AC/50 percent NRFU allocation. The value was $11,331,692.

Cell M1

Cell M1, Software and Security Infrastructure (paper), is sourced from Census 2000 OCS costs adjusted for inflation. The OCS costs were provided by FLD. The OCS costs were $27,122,393 after inflation. Mileage, Wage and Other inflation adjustment factor tables are included.

	Adjustment into 2009 Dollars for OCS		
Reference Year	Mileage	Wages	Other Costs
2000	1.69	1.27	1.31
1999	1.75	1.34	1.36
1998	1.75	1.41	1.39
1997	1.77	1.48	1.41
1996	-	1.57	1.44
1995	-	-	1.48

Cell M2

Cell M2, Software and Security Infrastructure (automated), is sourced from FDCA contract costs from the 110113_LCCE.xls and 071015_LCCE.xls files provided by DACMO. Shared software development was split 50 percent to AC and 50 percent to NRFU or other operations. The sum of all WBS elements gave an estimate of $89,711,638.

Software and Security Infrastructure Sources			
071015_LCCE WBS Elements 2006-2008		110113_LCCE WBS Elements FYs 2008-2009	
01-02-01-02	Support Engineering	02-01-01-02	Support Engineering
01-02-02-01	Support Engineering Management	02-02-01-01	System Engineering Management
01-02-02-03	External Interfaces	02-02-01-02	External Interfaces[1]
01-02-02-04	System Security	02-02-02-01	Systems Management[1]
01-02-02-06	Systems Test	02-02-02-02	Systems Architecture Engineering
01-02-02-07	System Integration	02-02-02-03	Systems Security Engineering
01-02-03-01	Software Management	02-03-01-02	Decennial Operations System Integration Test[1]
01-02-03-03	Office Computing Environment	02-03-02-01	Decennial AC/GQV Office Computing Environment[1]
01-02-03-04	Interface Mobile/Office Environment	02-03-03-01	Decennial AC/GQV Integration[1]
		02-03-03-02	Decennial AC/GQV Test[1]
		02-03-08-01	Framework Development[1]
		02-03-09-01	Framework Integration[1]
		02-03-09-02	Framework Test

[1] 100 percent of costs for these WBS elements were attributed to AC. All other WBS elements listed were allocated to AC at a rate of 50 percent.

Cell N1

Cell N1, Program Management/Largo Facilities (paper), assumes paper AC would have some of the same management costs of an automated AC, but not all of them. Our paper estimate excludes all Largo facility costs. DSSD assumed half of the WBS element 02-01-01-01, program controls for FYs 2008 and 2009, would apply to a paper operation. The estimate for Program Management is $8,738,999.

Cell N2

Cell N2, Program Management/Largo Facilities (automated), is sourced from FDCA contract costs from the 110113_LCCE.xls and 071015_LCCE.xls files provided by DACMO. Shared program management was split 50 percent to AC and 50 percent to NRFU or other operations. The sum of all WBS elements gave an estimate of $43,013,015.

Program Management/Largo Facilities			
071015_LCCE WBS Elements 2006-2008		110113_LCCE WBS Elements FYs 2008-2009	
01-01-01-01	Baseline Planning	02-01-01-01	Program Management
01-01-02-01	Early Development	02-01-01-03	Change Management
01-02-01-01	Program Office	02-01-01-04	Largo Facilities
01-02-01-03	Change Management	02-02-01-03	Requirements Management
01-02-02-02	Requirements Definition		
01-02-06-03	Largo Operations		
01-02-07-01	Next Phase Planning		

Cell O1

Cell O1, Operational and Office Support (paper), assumes paper AC would have costs associated with any contract cost from 110113_LCCE.xls that had similar values from 2008-2009 and 2010-2011. The table includes the WBS elements and descriptions. Some WBS elements were considered shared and only 50 percent of the cost was associated. Note for telecommunication cost DSSD adjusted on a per LCO basis which reduced the estimate by about half. The estimate for Operational and Office Support is $23,858,096.

Operational and Office Support (paper)	
110113_LCCE WBS Elements FYs 2008-2009	
02-02-03-01	Deployment Management
02-02-03-02	LCO/ELCO Deployment
02-02-03-05	Asset Management and Maintenance
02-02-03-06	Telecommunication Services
02-02-04-02	Operations Environments
02-02-04-04	Enterprise Management System

Cell O2

Cell O2, Operational and Office Support (automated), is sourced from FDCA contract costs from the 110113_LCCE.xls and 071015_LCCE.xls files provided by DACMO. Shared operational and office support was split 50 percent to AC and 50 percent to NRFU or other operations. The sum of all WBS elements gave an estimate of $99,953,396.

Operational and Office Support (automated)			
071015_LCCE WBS Elements 2006-2008		110113_LCCE WBS Elements FYs 2008-2009	
01-02-02-05	Architecture/Telecommunications	02-02-02-04	Infrastructure
01-02-03-05	Training	02-02-02-05	TSS Architecture
01-02-05-01	Deployment Management	02-02-03-01	Deployment Management
01-02-05-02	Deployment	02-02-03-02	LCO/ELCO Deployment
01-02-05-03	Deployed Assets	02-02-03-03	HHC deployment[1]
01-02-06-01	Operations Management	02-02-03-04	RCC deinstall
01-02-06-02	Census Operations	02-02-03-05	Asset Management Maintenance
01-02-06-04	Field Services	02-02-03-06	Telecommunication Services
		02-02-04-01	Operations Management
		02-02-04-02	Operations Environment
		02-02-04-03	Census Training Materials
		02-02-04-04	Enterprise Management Systems
		02-02-04-06	TSS Field Service
		02-02-04-07	TSS Training Materials
		02-03-01-01	Decennial Operations Management
		02-03-01-02	TSS test
		03-07	Other Leased Equipment
		04-01-01-01-20	Accenture Award Fee Support
		04-01-01-01-50	Unisys Award Fee Support
		04-01-01-01-90	Project Control Support
		04-02-01-01	Systems Support
		04-02-02-01	Security Support
		04-02-03-01	Field Deployment Support
		04-02-04-01	Field Operations Support

[1] 100 percent of costs for these WBS elements were attributed to AC. All other WBS elements listed were allocated to AC at a rate of 50 percent.

Cell P2

Cell P2, Contract Fees and Incentives (automated), is sourced from FDCA contract costs from the 110113_LCCE.xls, total fee for FYs 2008-2009, and 071015_LCCE.xls files, total fee for 2006-2008, provided by DACMO. Contract fees and incentives were shared and split 50 percent to AC and 50 percent to NRFU or other operations. The total is $20,439,522.

Distribution

Cell R1

The cell R1, print and assemble both address binders and small maps (paper), is sourced from the Census Block Canvassing Costs Breakdown.xls document from FLD. This source detailed printing costs as $2,300,000 and total assembly costs as $66,373. Both used the BC workload adjustment factor 1.69. The printing cost was adjusted using the CPI inflation adjustment 1.36, and the assembly costs were adjusted using the wage inflation adjustment of 1.35. The final inflation and wage adjusted prices were as follows: printing $5,015,799 ($2,300,000*1.69*1.36) and assembly $151,627 ($66,373*1.69*1.35). This totals $5,439,556.

Cell S1

The cell S1, ship address binders and small maps (paper), is sourced from the Census Block Canvassing Costs Breakdown.xls document from FLD. The shipping costs used the BC-only workload adjustment factor, and the CPI inflation adjustment factor. The original value was $350,000. The final workload and inflation adjusted value is $804,692 ($350,000*1.69*1.36). Note, shipping costs include both shipping to and from the local offices so S1 contains the value for AD1 as well.

Cell T2

The cell T2, Ship HHCs (automated), is sourced from a 1/25/11 e-mail from DACMO. Note that shipping costs include both shipping to and from the local offices so T2 contains the value for AG2 as well. The value was $1,848,925.

Cell U2

The cell U2, Ship SD Cards (automated), is sourced from a 1/25/11 e-mail from DACMO. Note that shipping costs include both shipping to and from the local offices. The value was $269,235.

Execution

Cell W1

The cell W1, Conduct training (paper), is from the draft Census 2000 BC and AL Assessments, increased by the estimated fingerprinting costs incurred in the 2010 Census. The combined workload adjustment factor is 1.35. The wage adjustment for BC and AL were applied to each operation. The unadjusted figures are $16,220,070 for BC and $11,286,069 for AL. With workload and inflation adjustments, the final 2009 dollar values are $29,525,233 ($11,286,069*1.35*1.35) for BC and $20,810,432 ($11,286,069*1.37*1.35) for AL. The final training cost estimate for a paper operation is $50,335,664.

The fingerprinting costs were sourced from the GAO report: “Efforts to Build an Accurate Address List Are Making Progress, but Face Software and Other Challenges.” This fingerprinting cost of $6,000,000 in 2010 was not incurred in Census 2000. This cost would have been required of a 2010 paper Address Canvassing operation, so it was included this cost category. Including fingerprinting, the estimated training costs are $56,335,664.

Cell W2

The cell W2, Conduct training (automated), was obtained directly from the 2010 Cost and Progress (C&P) system. The value was $81,430,297.

Cell X1

The cell X1, Conduct Listing and Update Addresses and Maps (paper), is from the draft Census 2000 BC and AL Assessments. The combined workload adjustment factor of 1.35 was applied. The wage adjustment factor for BC of 1.35 was applied to BC wages. Using the same method for AL, the AL adjustment factor was 1.37. The unadjusted figures were $62,830,260 for BC and $68,408,012 for AL. Adjusted for workload and inflation, the final 2009 dollar values are $114,369,300 ($62,830,260*1.35*1.35) for BC and $126,137,831 ($68,408,012*1.37*1.35) for AL. The final training cost estimate for a paper operation is $240,507,131.

Cell X2

The cell X2, Conduct listing and update addresses and maps (automated), is directly sourced from the 2010 Census C&P system. The value was $282,724,290.

Cell Y1

The cell Y1, Mileage (paper), is from the draft Census 2000 BC and AL Assessments. The workload adjustment factor of 1.35 was applied. The mileage inflation adjustment factor was derived from the GSA reimbursement rates: http://www.gsa.gov/portal/content/103969. The reimbursement rates changed throughout BC and AL. DSSD used the current reimbursement rates along with the C&P data, to determine the reimbursement for miles driven. This assumes Census 2000 reimbursements occurred exactly according to the GSA rates, at exactly when any rate changes transpired. Below, the final reimbursement rate is highlighted in yellow for BC and AL.

AL before	9/7/1998		2,261,569	$701,086.39	$0.31
cum from 2000 CP	3/31/1999		62,889,697		
	5/12/1999		62,889,697		
	9/5/1999		69,943,251		
		reimburse	part cum miles	part cum cost	
	9/7/1998	$ 0.310	2,261,569	$ 701,086	
	3/31/1999	$ 0.325	60,628,128	$ 19,704,142	
	5/12/1999	$ 0.310	-	$ -	
	9/5/1999	$ 0.310	7,053,554	$ 2,186,602	
					miles cost AL
			69,943,251	$ 22,591,830	$ 0.32
			AL mileage adjust		$ 1.70
BC before			full cum miles		
cum from 2000 CP	3/31/1999		20,180,620		
	7/24/1999		22,548,879		
	9/20/1999		33,924,370		
		reimburse	part cum miles	part cum cost	
	3/31/1999	$ 0.325	20,180,620	$ 6,558,701.50	
	7/24/1999	$ 0.310	2,368,259	$ 734,160.29	
	9/20/1999	$ 0.310	11,375,491	$ 3,526,402.21	
					miles cost BC
			33,924,370	$ 10,819,264.00	$ 0.32
			BC milage Adjustment		$ 1.72

The unadjusted figures were $12,757,052 for BC and $25,300,082 for AL. Adjusting for workload and inflation, the final 2009 dollar values were $29,643,881 ($12,757,052*1.72*1.35) for BC and $58,047,964 ($25,300,082*1.70*1.35) for AL. The final training cost estimate for a paper operation is $87,691,845.

Cell Y2

The Cell Y2, Mileage (automated), is sourced from the 2010 Cost and Progress (C&P) data for AC. The value was $75,562,818.

Cell Z2

The cell Z2, Large Block Canvassing (automated), is the total cost of conducting the Large Block Address Canvassing (LBAC) operation. This figure was directly obtained from the 2010 Census Program for Evaluations and Experiments AC Assessment. The value was $10,275,874.

Cell AA1

The cell AA1, Other Field Costs (paper), is from the Census 2000 draft BC and AL assessments. The combined workload adjustment factor was 1.35. The CPI inflation adjustment factor for BC of 1.35 was applied to BC other costs. Using the same method, the AL adjustment factor was 1.37. The unadjusted figures are $7,023,342 for BC and $7,862,347 for AL. After workload and inflation adjustments, the final 2009 dollar values are $12,870,360 ($7,023,342 *1.35*1.35) for BC and $14,566,757 ($7,862,347*1.37*1.35) for AL. The final other cost estimate for a paper operation is $27,437,117. Note that some of the costs included in other costs for 2000 are included in wages in 2010 cost distributions since they were extra payroll costs.

Cell AA2

The cell AA2, Other Field Costs (automated), was directly obtained from the 2010 C&P system. The value was $3,873,894.

Cell AB1

The cell AB1, Provide OCS Technical Support (paper), is an estimate from the AutomationStaffComparisons2000 to 2010_102108.xls document provided by FLD, as well as a 1/20/11 email from FLD. The email contained the costs of the 2010 AC technical support. The xls document contained a technical support staffing resource comparison between Census 2000 and the 2010 Census. DSSD estimated the 2000 cost by multiplying by the 2000/2010 staffing ratio, or $5,055,165 * (664/1,594) = $2,105,790.

Cell AB2

The cell AB2, Provide OCS/HHC Technical Support (automated), is sourced from a 1/20/11 email from FLD. The FDCA help desk cost was removed since it was already included in the Contract/Infrastructure category. The final cost was $5,055,165.

Results/Closeout

Cell AD1

The cell AD1, Ship Address Binders and Small Maps (paper), was already grouped into cell S1. DSSD did not have a reliable method to disaggregate these costs.

Cell AE1

The cell AE1, Key/Capture Address/Map Updates (paper), was obtained from two sources: one source for addresses capture and updates, and another source for map updates. The address information is sourced from the DOC000.pdf document provided by NPC. Specifically, the value was obtained from The Assignment Number 6405 "Address List Data" from the NPC Performance Review of Operating programs from October 1, 1998 through September 30, 1999. This assumes the address listing data capture done during this time was BC or AL, and any non-BC or AL costs would be offset by the missed AL costs in the prior fiscal year. Using this source, the unadjusted figure is $18,186,620. This cost was adjusted using the wage inflation factor of 1.35 and workload adjustment factor of 1.35. Adjusting for inflation and workload, the final estimated 2009 dollar value is $33,104,924. The map update costs are from the Census 2000 Geog Operations (2).xls document provided by NPC. The unadjusted cost estimate for AL was $1,372,425 and $769,192 for BC. Adjusted for inflation and workload, the final estimated 2009 dollar values are $2,530,620 ($1,372,425*1.35*1.37) for AL and $1,400,153 ($769,192*1.35*1.35) for BC. The final cost estimate was $37,035,697.

Cell AF1

For the cell AF1, Archive/Dispose Paper (paper), little direct documentation exists. Using the assumptions, one sheet per unit (159,494,710), 1,000 sheets per hour can be disposed, and the person disposing can be paid minimum wage ($7.25/hour), the final cost estimated is $1,156,337. Typically, there are about eight units to a page but there are header sheets and miscellaneous paper processing sheets that once factored in, result in the one sheet per unit average. On a personal shredder, it is reasonable to shred 200 sheets in about 12 minutes.

Cell AG2

The cell AG2, Ship HHCs (automated), was included in cell T2. The shipping to and from ELCOs was not available separately.

Cell AH2

The cell AH2, Decommission HHCs (automated), is sourced from an 1/25/2011email from DACMO. The value given was $791,093 for decommission costs. .

Cell AI2

The cell AI2, Store HHCs (automated), is sourced from DSSD. At the sourced value of $50,000 per year, storing the HHCs for 2 years, 5 months, the total cost is about $120,000. The devices are currently being stored at a NOAA facility.

Appendix E. Handheld Computer Pictures and Specifications

Figure E-1. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Picture of Handheld Computer from Various Angles

Figure E-2. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: GPS Chip

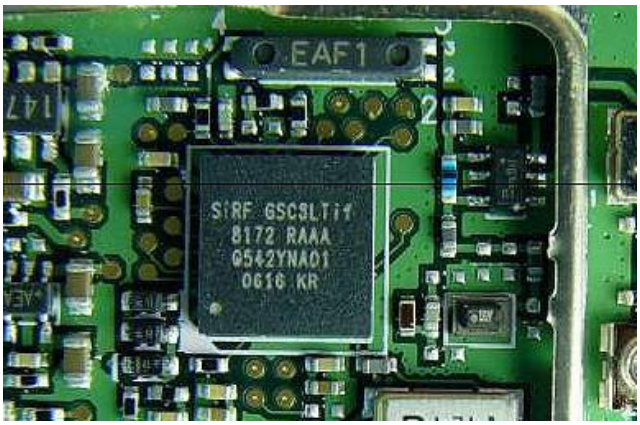

Figure E-3. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Lister Handheld Computer Kit

Figure E-4. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Handheld Computer Front and Bottom

Figure E-5. 2010 CPEX Evaluation of Automation in Field Data Collection in AC: Handheld Computer Back and Top

Handheld Computer Specifications according to Nanko R. at
http://www.phonearena.com/news/HTC-Census-is-data-only-PPC-for-Sprint-PCS_id1852

HTC Census Specifications:

- Dual-band CDMA/EV-DO device
- WiFi; Phone Connector; miniUSB; Bluetooth
- No microphone or speakerphone built-in
- 6.1 x 3.1 x 1.4 inches (154 x 79 x 29 mm); 12.3 oz (350 g)
- QVGA touch display (240x320); 3.5 Inches
- Windows Mobile 5 OS for PPC
- Intel Bulverde 416MHz processor
- GPS with Sirf Star III chip
- SD slot for memory

Handheld Computer Specifications according to Jonathan Angel at
http://www.windowsfordevices.com/c/a/News/2010-Census-kicks-off-with-Windows-Mobile/

Features and specifications listed for the HTC Census by PhoneArena.com include the following:

- Processor -- Marvell "Bulverde" clocked at 416MHz
- Memory -- n/s, but includes SD card for memory expansion
- Display -- 3.5-inch touchscreen display with 320 x 240 resolution
- Keys -- Six dedicated keys, five-way controller, and fingerprint sensor
- Wireless:
    - Dual-band CDMA/EV-DO data modem (no voice capability)
    - Bluetooth
    - WiFi
    - GPS
- Other I/O:
    - Phone jack
    - miniUSB
- Expansion -- SD slot
- Dimensions -- 6.1 x 3.1 x 1.4 inches (154 x 79 x 29mm)
- Weight -- 12.3 ounces (350g)