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This memorandum releases the final version of the 2020 Census Evaluation: Reengineered Address Canvassing Study Plan, which is part of the 2020 Census Program for Evaluations and Experiments (CPEX). For specific content related questions, you may also contact the authors:

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2020 Census Evaluation:

Reengineered Address Canvassing Operation Study Plan

Final

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I. Introduction

In an effort to reduce costs, the U.S. Census Bureau has reengineered address canvassing for the 2020 Census to include a suite of In-Office and In-Field Address Canvassing operations (U.S. Census Bureau, 2018b). Because these operations include new or revised methods, evaluating their accuracy and effectiveness is important when considering either improvements for the 2030 Census or new approaches to conducting the census (JASON, 2016).

This evaluation will focus on selected components of the reengineered Address Canvassing operation. Specifically, it will estimate certain types of errors that can occur during In-Field Address Canvassing and will compare these estimates to results from previous studies. In addition, the evaluation will investigate the effectiveness of the Interactive Review and of the In-Office Address Canvassing operation as a whole.

II. Background

To conduct and tabulate the decennial census, the Census Bureau needs the address and physical location of each living quarters in the United States and Puerto Rico. A complete and accurate list ensures residents will be invited to participate in the census and that the census will count residents in their correct locations. The Address Canvassing operations are key components in the creation of an accurate address list.

Historically, Address Canvassing field staff, referred to as listers, traversed almost every block in the United States and Puerto Rico, comparing their observations on the ground with the Census Bureau's address list. Listers verified or corrected addresses that were on the list, added new addresses to the list, and deleted addresses that no longer existed. Listers also collected map spot (coordinate) locations for each structure and added new streets. However, this method is expensive. During the full In-Field Address Canvassing operation for the 2010 Census, 8,213 crew leaders managed 111,105 listers during production listing and 3,083 crew leaders managed 37,784 listers during quality control listing (U.S. Census Bureau, 2012) for a field execution cost of about $445 million. Additional costs were incurred for field infrastructure and information technology infrastructure support for a total cost of about $845 million (Holland, 2012).

As part of the revised design for the 2020 Census, the Census Bureau identified four major innovation areas. The reengineered Address Canvassing operation is one of those innovation areas. While Address Canvassing will cover the entire nation in 2020, the Census Bureau has determined that a full In-Field Address Canvassing is no longer necessary (U.S. Census Bureau, 2017). Address Canvassing now includes a suite of operations, conducted both in the field and in the office, that will update the address list and map data for the 2020 Census enumeration.

A. Address Canvassing

Overview

In-Office Address Canvassing is the process of using empirical geographic evidence (e.g., imagery, and comparison of the Census Bureau's address list to partner-provided lists) to assess the current address list. This process detects and identifies change using high quality imagery, administrative data, and third-party data sources to reduce the In-Field Address Canvassing workload. In-Office Address Canvassing includes five components: Interactive Review (IR); Active Block Resolution (ABR); Ungeocoded Resolution; In-Office Address Canvassing Group Quarters/Transitory Locations; and Local Update of Census Addresses (LUCA) Address Validation. An additional process monitors potential change through "triggers" as described in the section on Change Monitoring. Each component includes a Quality Control (QC) process. All of these components update the address list prior to enumeration operations.

Master Address File Updates

The Master Address File (MAF) serves as the base of the census frame and was first used to support the 2000 Census operations. Each address in the MAF is designed to be linked to a geographic location in the Topologically Integrated Geographic Encoding and Referencing (TIGER) database, the Census Bureau's spatial feature database. This linkage ensures that the census data are processed and tabulated in the correct geographic location. After 2009, when the decennial census conducted a large In-Field Address Canvassing operation to update the MAF/TIGER systems, the Geographic Support System (GSS) was developed to provide current, accurate, and complete address, feature, and boundary data. The Census Bureau currently conducts several operations to validate and update the census address list in preparation for the 2020 Census. One of the operations uses the United States Postal Service's Delivery Sequence File (DSF), which contains a list of all updated address information and is used to update the MAF twice a year (U.S. Census Bureau, 2017).

Interactive Review

In-Office Address Canvassing began in September 2015 with the Interactive Review (IR) of blocks to identify coverage issues that exist in the MAF (where the MAF counts do not reflect the housing units observed in current imagery) and to identify stability, growth, or decline in housing compared to the 2010 Census residential landscape. During IR, staff reviewed blocks by comparing baseline satellite images from the time of 2010 Census operations to current images to assess the extent to which the number of addresses in the census address list—both housing units (HUs) and group quarters (GQs)—was consistent with the number of addresses visible in current imagery. The staff identified blocks that contain residential growth and decline, blocks that contain MAF overcoverage and undercoverage[1], and the capacity of blocks to contain additional living quarters in the future. After IR, each block received one of three high-level statuses:

[1] Overcoverage occurs when the address list contains an address that does not exist on the ground or when there are multiple instances of an address for the same residential structure (that is, duplicates). Undercoverage occurs when the address list is missing residential addresses that exist on the ground.

1. *Passive* – A passive status indicates that staff did not see any change in housing between the baseline image and the current image. In addition, the number of housing units observed in imagery matched the number of addresses in the MAF; staff detected no overcoverage or undercoverage.
2. *On Hold* – A block may be placed on hold for one of several reasons (e.g., poor imagery, cloud cover, or detected future growth).
3. *Active* – An active block has some indication of residential growth or decline since the 2010 Census, or coverage differences identified in IR. That is, the IR staff set one or more electronic markers, or pins, during their review to indicate that the MAF/TIGER System data are inconsistent with imagery. Therefore, the block requires further assessment to either fix the coverage concerns with a MAF/TIGER System update or to assign the block to In-Field Address Canvassing.

Blocks placed on hold may be triggered into re-review when new imagery becomes available. Blocks designated as active were sent to ABR, where some were resolved, and some remained in an active status.

Active Block Resolution

Active Block Resolution (ABR) seeks to research and update areas identified with growth, decline, undercoverage of addresses, or overcoverage of addresses in the MAF. The ABR staff use several data sources to update the MAF and to resolve IR Active blocks. The ABR program was in place beginning in April 2016 and was discontinued in February 2017 because of funding uncertainty and reprioritization of critical components of the 2020 Census. Because this program was performed leading up to the 2020 Census Address Canvassing operation as a part of the In-Office Address Canvassing activities that began in 2015, it is considered part of the 2020 Census Address Canvassing operational design.

Ungeocoded Resolution

Ungeocoded Resolution is an activity designed to resolve ungeocoded records (addresses that are not assigned to a block) by adding or editing spatial features and address ranges in the MAF/TIGER System.

In-Office Address Canvassing Group Quarters/Transitory Locations

In-Office Address Canvassing Group Quarters[2]/Transitory Locations[3] is an activity designed to identify, validate, and update living quarters that the Census Bureau classified as a group quarters or transitory location. Staff conduct research using administrative data, local Geographic Information System data, public and commercial information, and, in some cases, phone calls that are made to administrative contacts. Although this activity began in 2017, the Census Bureau decided to suspend this component of In-Office Address Canvassing from March 2018 through September 2018 because of budget constraints.

Local Update of Census Addresses Address Validation

Local Update of Census Address (LUCA) Validation is an In-Office Address Canvassing activity that reviews address lists from outside partners. The LUCA program provides the opportunity for tribal, state, and local governments to review and comment on the Census Bureau's address list to ensure an accurate and complete enumeration of their communities. The LUCA Validation is designed to use office research to validate submissions provided by these entities.

Change Monitoring

A "trigger" is an automated process or event that provides information or data that suggests a block should be re-reviewed through IR or sent for canvassing in the field. The temporal difference between In-Field Address Canvassing for the 2020 Census and the first IR was the reason behind the development of "trigger" events; In-Field Address Canvassing for the 2020 Census will occur several years after the first IR was completed. In an attempt to record changes that occur within blocks after the latest IR review or ABR review, and to re-review blocks that at some point cause uncertainty regarding their latest In-Office Address Canvassing status, some blocks get "triggered" for re-review to determine whether the status of the block has changed.

In-Field Address Canvassing

In-Field Address Canvassing is an operation in which listers visit specific geographic areas—Basic Collection Units (BCUs)—to identify every place where people could live or stay. Using the Listing and Mapping Application (LiMA[4]), listers compare what they see on the ground to the existing census address list and either verify or correct the address and location information. Listers knock on every door to verify address information, collect associated mailing address

[2] Group quarters are places where people live or stay, in a group living arrangement, which is owned or managed by an entity or organization providing housing and/or services for the residents. This is not a typical household-type living arrangement. These services may include custodial or medical care as well as other types of assistance, and residency is commonly restricted to those receiving these services. People living in group quarters are usually not related to each other. Group quarters include such places as college residence halls, residential treatment centers, skilled nursing facilities, group homes, military barracks, correctional facilities, and workers' dormitories.
[3] Transitory locations are recreational vehicle parks, campgrounds, hotels, motels, marinas, racetracks, circuses, and carnivals.
[4] The LiMA is an application that aids listers with constructing or updating address lists. It contains map information that helps listers to find their canvassing assignments and provides a means to collect coordinate information for each address.

information, and collect information about any additional housing units present at the address. Listers also classify each living quarter as a housing unit, group quarter, or transitory location.

Quality Control

Quality Control (QC) is the process of reviewing the work of office and field staff. For the operational design of 2020 Census Address Canvassing, QC is an integrated part of each of the components that make up the Address Canvassing operation. The QC program for Address Canvassing is responsible for devising a plan to ensure quality of the In-Office Address Canvassing and In-Field Address Canvassing work. For the QC of In-Field Address Canvassing, this means ensuring proper execution of duties by field staff. For In-Office Address Canvassing, QC strategies include additional review and adjudication of work. It also includes a process for informing individual analysts of errors that is intended to reduce their future error rate.

B. Filters

The decennial census operations[5] use snapshots of the MAF, known as extracts, to retrieve the latest information on the nation's addresses. A set of rules, called a filter, is applied to the MAF in an attempt to maximize the number of valid MAF units, while minimizing the number of invalid units on the MAF extracts. These extracts provide the basis for the address frames used in census operations. The In-Field Address Canvassing Extract is sent to the Listing and Mapping Application (LiMA) and forms the basis for the dependent address list, which the listers update as they canvass the BCUs. In general, the In-Field Address Canvassing filter rules rely on categorical variables such as when a unit was added to the MAF, the source of data that added the unit, its residential status, and outcomes from past field operations to determine whether or not an address is valid for its operation. Some components of the In-Office Address Canvassing also use filters either in the creation of an address list or in producing counts of addresses in blocks.

C. Post-Enumeration Survey

Because several of the evaluation research questions use data from the Post-Enumeration Survey (PES), this section provides background on the PES operations.

Overview

To measure the coverage of the 2020 Census, the U.S. Census Bureau will conduct the PES. The 2020 PES will provide estimates of census net coverage error and components of census coverage for housing units[6] and people living in housing units in each state, the District of Columbia, and Puerto Rico, excluding remote Alaska. The components of census coverage include correct enumerations, omissions, and erroneous enumerations, including duplicates.

[5] The Census Bureau surveys and other estimate programs also use extracts from the MAF that are produced from filters as defined by the needs of the surveys or programs.
[6] Group quarters are out-of-scope for the PES.

The 2020 PES is a large, complex survey that collects housing unit and person information (independent from the 2020 Census operations) for a sample of housing units in selected areas across the country. The survey has two separate samples: 1) the Population sample (P sample) and 2) the Enumeration sample (E sample). The P sample consists of independently listed housing units within an area-based sample of BCUs. The source of the E sample is the census housing units and census person enumerations in housing units geocoded to the sample of BCUs selected for the P sample.

The PES includes several activities, such as:

- Selecting the BCU sample.
- Conducting the Independent Listing (IL).
- Subsampling small BCUs.
- Conducting the Initial Housing Unit (IHU) Matching and Followup (IHUFU).
- Identifying the P sample.
- Identifying the Person Interview (PI) Sample.
- Conducting the Person Interview.
- Identifying the E sample.
- Conducting Person Matching and Followup.
- Conducting Final Housing Unit (FHU) Matching and Followup (FHUFU).
- Estimation.

The next sections summarize the activities listed above. The majority of the description is a summary from Kennel, 2019. For details on the PES sample design, see Hill et.al, 2019.

Selecting the BCU Sample

The first production operation will be the selection of the BCUs from the BCU frame, which includes all BCUs for the 50 states, D.C., and Puerto Rico[7]. (Note: For the remainder of this document, references to state also include D.C. unless otherwise specified.) The BCU frame will exclude BCUs that are in remote areas of Alaska determined by the census type of enumeration areas (TEAs) and BCUs that are fully covered by water. The eligible BCUs will be stratified by state, size, percent of homeowners, and an American Indian Reservation indicator.

Conducting the Independent Listing

Listers will canvass the sample BCUs and construct a list of housing units. Using the LiMA, listers will identify the location of all housing units by collecting GPS coordinates. Group Quarters are out of scope, but housing units within transitory locations will be listed. Approximately 564,500 housing units are expected to be listed (541,000 housing units in the U.S. and 23,500 housing units in Puerto Rico) in approximately 10,400 BCUs (10,000 in the U.S. and 400 in Puerto Rico).

[7] Puerto Rico is in the Update Leave Type of Enumeration Area and will not be listed by In-Field Address Canvassing.

Subsampling Small BCUs

The Independent Listing results and preliminary census housing unit counts are used to stratify and determine the subsampling rates for small BCUs. Small BCUs are subsampled using variable rates to minimize variance on the coverage estimates and to increase field efficiency.

Initial Housing Unit Matching and Followup

The matching starts with a computer match of the independent listings against the census records on the Enumeration Extract within each sample BCU and one ring of surrounding BCUs. A match results in four possible outcomes for each address:

1) Matched
2) Possibly matched
3) Not matched
4) Potential duplicate

The possibly matched addresses, not matched addresses, and potential duplicates go to the Initial Housing Unit Before Followup Clerical Matching. The National Processing Center (NPC) matching staff will use computer-assisted clerical matching techniques, along with maps, to review and attempt to resolve the match status of the possibly matched addresses and the not matched addresses. In addition, the matching staff search for duplicate census addresses. Cases that remain unresolved after the clerical matching will go to the Initial Housing Unit Followup.

In the Initial Housing Unit Followup, the interviewers will collect additional information that may allow resolution of the match status, and they attempt to resolve the potential duplicates. This field operation will include a QC component.

The NPC staff will use the information from the Initial Housing Unit Followup to match the unresolved cases. The result of this operation is a file containing match codes for listed housing units and census housing units in the sample BCUs.

Identifying the P Sample

The source of the P sample housing units are the IL units that are determined to be housing units or potential housing units after the IHU Matching and Followup operations. In BCUs containing 57 or fewer IL housing units, all the IL units are in the P sample. For BCUs having 58 or more IL housing units, a subsample of IL units is selected for the P sample. In the American Indian Reservation stratum, all housing units are included in the P sample.

Identifying the Person Interview Sample

In this phase of sampling, the addresses that go to the Person Interview (PI) will be selected. For a BCU with 57 or fewer housing units observed, all of the housing units will be included in the PI sample. For a BCU with 58 or more housing units observed, a subsample of segments of contiguous housing units will be selected.

After selecting the addresses, the PI sample is expected to be approximately 171,500 housing units in the U.S. and 7,800 in Puerto Rico. The sample will be distributed among the states roughly proportional to the population size. However, states with small populations and American Indian Reservations will have slight increases in sample.

Person Interview

For each sample BCU, enumerators visit people in selected housing units. During the Person Interview (PI) operation, enumerators use an automated instrument to obtain information about the

- Current residents of the sample housing unit (name, sex, age, date of birth, race, relationship, and Hispanic origin).
- People who moved out of the sample housing unit between Census Day and the time of the PI (outmovers).

For QC purposes, the PI operation will include a reinterview.

Identifying the E sample

The E sample will be identified after the PI but before the Person Matching begins. A primary goal of E sample identification is to identify changes (primarily adds and deletes) to the census housing units in sample BCUs between In-Field Address Canvassing and the final census universe.

The sampling frame for the E sample is the final list of valid housing units on the Census Unedited File (CUF) that are in the same sample BCUs as the P sample. The CUF contains the final inventory of census housing unit addresses and will likely differ from the preliminary list of census addresses.

Person Matching and Followup

Before the Person Matching operations begin, an automated operation assigns a residence status code to all people listed in the PI. In addition, an automated operation assigns geocodes to alternate and inmover addresses collected during the PI. For addresses where the automated operations cannot assign codes, clerical operations attempt to make the code assignments.

The Person Computer Matching will attempt to search for matches between people rostered at the sample address during the PI and the people enumerated in the census in the sample BCU and the surrounding ring of BCUs. Alternate and inmover addresses collected in the PI and geocoded during automated or clerical geocoding provide other places to search for matches between the PI roster and census people. In addition, the computer matching will conduct a nationwide search for matches. However, matching people between Puerto Rico and the states is out of scope. The computer match includes a search for duplicate people.

During the Person Before Followup Clerical Matching, the matching staff assign the status of match, possible match, or nonmatch to the PI and census person records. In addition, the matching staff searches for duplicates. Cases with an unresolved match status, enumeration status, or residence status are eligible for the Person Followup (PFU).

During the PFU, interviewers contact cases to resolve issues. The PFU is sometimes conducted outside the sample BCUs to followup on links found during the nationwide search.

The Person After Followup Clerical matching uses the information from the PFU in an attempt to resolve the match, enumeration, or residence status.

Each component of the Person Matching and Followup includes QC checks.

Final Housing Unit Matching and Followup

The Final Housing Unit Computer Processing will determine which housing units will go to Final Housing Unit Clerical Matching. These housing units are:

- Housing units added to the census after the preliminary list (i.e., Enumeration Extract) was created.
- Listed housing units matched to a census unit that was deleted from the preliminary list.

In the Final Housing Unit Before Followup Clerical Matching, the NPC matching staff use computer-assisted matching techniques, along with the Independent Listing maps and census maps, to match, possibly match, or assign no matched codes to the addresses from the Final Housing Unit Computer Processing. Unresolved addresses go to the Final Housing Unit Followup.

In the Final Housing Unit Followup, interviewers collect information about the unresolved addresses. The information collected will vary depending on the reason for the case going to followup.

During the Final Housing Unit After Followup Matching, the NPC matching staff use the information collected by the interviewers to attempt to resolve the status of the addresses. This is the last step before PES estimation.

Each component of the Final Housing Unit Matching and Followup includes QC checks.

Post-Enumeration Survey Estimation for Housing Units

Note: Because this evaluation does not include any estimates for people, this section only summarizes the estimation methodology for housing units.

The PES Estimation process consists of several operations, which lead to estimates of coverage for both housing units and people in housing units. This process includes estimates of net

coverage and the components of census coverage. The estimation operations for housing units consist of:

- Imputing missing data for the P sample housing units.
- Imputing missing data for the E sample housing units.
- Using the dual system estimate methodology to determine the housing unit net coverage error.
- Computing the housing unit components of census coverage.
- Calculating uncertainty estimates (e.g., standard errors and mean squared errors).

D. Past Studies and Census Tests

This section describes past studies and census tests containing results relevant to this evaluation.

1990 Census Precanvass Suppression Study

For the 1990 Census Precanvass operation[8], a sample of addresses was suppressed from the Precanvass Address Registers. These registers contained the addresses sent to listers for verification and updating. The analysis then determined whether the listers added the suppressed addresses or missed them.

The findings were as follows:

- The overall miss rate was 30.0 percent with a standard error of 1.6 percent.
- The miss rate for housing units suppressed from multiunit addresses was significantly higher than for single unit addresses—45.2 percent and 24.3 percent, respectively. The estimated standard errors were 4.1 percent for multiunits and 1.5 percent for single units.
- Of the assignment areas sampled, 55.1 percent contained at most one miss.

Census 2000 and the 2010 Census

An evaluation in Census 2000 (Smith, et.al, 2003) estimated the addresses that were correctly added (and added-in-error) and correctly deleted or duplicated (and deleted-in-error[9]) by the enumeration operations[10]. An evaluation of the 2010 Census (U.S. Census Bureau, 2013) expanded on the Census 2000 evaluation by including a component to estimate the number and percent of addresses that the 2010 Census Address Canvassing operation correctly added (and added-in-error) and correctly deleted or duplicated (and deleted-in-error).

Using results from the 2000 Post-Enumeration Survey and the 2010 Census Coverage Measurement, these two studies yielded the following results:

[8] The 1990 Census Precanvass operation was a precensus activity that occurred in certain types of areas from May 1989 through July 1989. Field enumerators canvassed the areas to identify and add addresses missing from the precanvass registers and to update existing addresses on the registers. This Precanvass operation was an earlier form of the In-Field Address Canvassing operation.
[9] Deleted-in-error also includes duplicated-in-error.
[10] Examples of enumeration operations include Nonresponse Followup, Non-ID Processing, GQ Enumeration, etc.

- In Census 2000, enumeration operations correctly deleted about 85.6 percent of addresses, and in the 2010 Census, enumeration operations correctly deleted 74.2 percent of addresses.
- In Census 2000, enumeration operations correctly added 83.9 percent of addresses, and in the 2010 Census, the enumeration operations correctly added 79.6 percent of addresses.
- The 2010 Census Address Canvassing operation correctly deleted 95.7 percent of addresses and correctly added 83.6 percent of addresses.

2015 Census Address Validation Test

The purpose of the 2015 Address Validation Test (AVT) was to assess the performance of various methods to develop the 2020 Census address frame and to determine workloads for the 2020 canvassing operation; in other words, reengineering the address canvassing for the 2020 Census. The AVT occurred between September 2014 and February 2015. (U.S. Census Bureau, 2015)

One component, the MAF Model Validation Test (MMVT), consisted of a *full-block canvassing operation* intended to assess the ability of a set of statistical models to predict blocks that have experienced address changes that are not recorded in the MAF. If effective, the statistical models would offer an inexpensive solution to the problem of determining which census blocks require updates or which do not. To do this, the test collected address data in an address listing operation in a national sample of 10,100 blocks. The analysis compared the results of the fieldwork to the predictions from the statistical models.

Key observations from the MMVT include that the statistical models:
- Did a mediocre job of identifying specific blocks with many adds or deletes.
- Were not accurate for predicting national totals of MAF coverage errors.
- Could do reasonably well at initially screening or prioritizing blocks for in-office imagery review.

2016 Address Canvassing Test

The Address Canvassing Test occurred during the fall of 2016 in two sites: Buncombe County, NC, and a portion of St. Louis, MO. Both of these locations offered situations to gain insight on how they handled both in-office and in-field operations. All blocks in both sites were canvassed using both In-Field and In-Office Address Canvassing methods. (Snodgrass, et.al, 2018)

Two key findings from the Address Canvassing Test were as follows:
- In passive blocks, including ABR resolved blocks, there were inconsistencies when comparing In-Field Address Canvassing address actions and In-Office Address Canvassing.
- Of the actions taken by Active Block Resolution in active blocks, most were consistent with In-Field Address Canvassing. Of the blocks “identified for fieldwork,” most had either an add action or a negative action.

2016 Master Address File Coverage Study

The MAF Coverage Study (MAFCS) was a field activity intended to measure the coverage of the census address list, to validate the In-Office Address Canvassing operation, and to provide updates to the MAF. Based on funding uncertainty and reprioritization of critical 2020 Census components, the MAFCS was discontinued in fiscal year 2017. Consequently, the 2016 MAFCS report provided the only set of estimates generated from the MAFCS program. The coverage measures from the MAFCS were for 2016 and were likely not indicative of the address coverage for the 2020 Census because most of the frame updating procedures specific to the decennial census had yet to start. (Williams, 2018)

Two findings from the 2016 MAFCS were as follows:

- For 2016, the national estimate of overcoverage was about 5.5 percent, and the estimate of undercoverage was 6.6 percent.
- Blocks classified as Active in IR had an estimated 7.7 percent overcoverage and 9.8 percent undercoverage of addresses. In Passive blocks, however, the 2016 MAFCS estimated 4.3 percent overcoverage and 4.8 percent undercoverage.

2018 Census End-to-End Test: Evaluation of Address Canvassing

The Evaluation of Address Canvassing was conducted in Providence, RI, one of the 2018 Census End-to-End Test sites. The main objective of the evaluation was to quantify the extent to which In-Office Address Canvassing correctly assigned BCU statuses as either active or passive. (Johnson and McDougall, 2019)

The key findings were as follows:

- In-Office Address Canvassing correctly classified 71 percent of the active BCUs.
- Of all the passive BCUs in sample, an estimated 67 percent were correctly classified.
- An estimated 71 percent of the triggered BCUs were correctly identified as having a change to the inventory of residential addresses.

III. Assumptions

Below are assumptions that will enable successful completion of the design and methodology for this evaluation.

1. The project team will obtain adequate funding to implement the evaluation as described in this study plan.
2. The project team assumes that the Census Bureau will be able to obtain the services of a contractor to support the implementation of Virtual Canvassing.
3. The Census Data Lake will contain 2020 Census operational data required for analysis.
4. Costs are tracked at a level that allows comparisons between the 2010 Census Address Canvassing and the 2020 Census Reengineered Address Canvassing.
5. The PES design will provide enough sample in the evaluation domains of interest to calculate reliable estimates.

IV. Research Questions

Listed below are the research questions for this evaluation.

1. **Enumeration operations:** What percentage of the housing units added by the post-Address Canvassing operations (e.g., Non-ID processing, Nonresponse Followup, New Construction, etc.) combined were correctly added and added-in-error?
2. **In-Field Address Canvassing:** What percentage of the housing units added during In-Field Address Canvassing were correctly added (and added-in-error)? What percentage of the housing units identified as deleted or duplicated by the listers during In-Field Address Canvassing were correctly deleted or duplicated (and deleted-in-error)?
3. **In-Field Address Canvassing:** What percentage of the suppressed housing units did the listers add and miss adding? What percentage of the "salted" or false housing units did the listers delete and miss deleting?
4. **In-Office Address Canvassing:** What percentage of the BCUs did the In-Office Address Canvassing Interactive Review correctly classify as active and passive?
5. **In-Office Address Canvassing:** How accurate is the Virtual Canvassing?
6. **In-Office Address Canvassing:** Were the set of triggers sufficient for identifying instances in which housing unit change occurred?
    a. Were there instances of housing unit change that were not detected by triggers, and as a result, did not send a block (or BCU) back to Interactive Review for assessment or directly to an active status?
    b. Did the set of triggers result in unnecessary work in the Interactive Review and in-field?
    c. What is the effectiveness of specific trigger reasons?
7. **In-Office Address Canvassing:** What is the effect on the enumeration of addresses missed by In-Office Address Canvassing in the misclassified BCUs?
    a. Were the missed addresses in the BCUs, which the Interactive Review misclassified as passive, enumerated as valid, residential units?
    b. What is the cost of incorrectly classifying BCUs?
8. How effective was the filter in identifying valid living quarters for the In-Field Address Canvassing dependent address list?
9. What is the cost of the reengineered Address Canvassing operation compared to the cost of a 100 percent In-Field Address Canvassing?
10. Can unit level modeling support improved targeting for Address Canvassing, specifying filter criteria, estimating hidden units, or estimating recurring MAF coverage errors?

V. Methodology

This section describes the methodology for answering the research questions.

A. Evaluation Design

Question 1 - Enumeration operations: What percentage of the housing units added by the post-Address Canvassing operations (e.g., Non-ID, Nonresponse Followup, etc.) combined were correctly added and added-in-error?

Although this question is not about Address Canvassing, it was included, along with question 2 below, in the 2010 Census Evaluation of Address Frame Accuracy and Quality (U.S. Census Bureau, 2013). In addition, an evaluation in Census 2000 (Smith, et. al., 2003) provided these estimates. Because the data to answer this question are readily available from PES and complement question 2, it will be included in this evaluation and will provide a comparison to the percentages from Census 2000 and the 2010 Census.

Note that the evaluations from Census 2000 and the 2010 Census included estimates for the percentages of housing units correctly deleted or duplicated and deleted-in-error. However, unlike Census 2000 and the 2010 Census, PES will not match or conduct field followup for housing units deleted or duplicated by the enumeration operations.

The "Adds" will consist of the housing units that exist on the Census Unedited File (CUF) that did not exist on the Enumeration Extract[11]. These units are part of the PES E sample.

The PES will classify the **correctly added** housing units as "correct enumerations" and will have one of the following PES match codes[12] assigned:

- *Match* – The P sample and E sample housing units matched in the FHU operation.
- *Correct Enumeration* – The FHU Followup interview determined that the E sample housing unit existed as a housing unit on Census Day and was correctly geocoded in the BCU. The housing unit was not matched to a unit previously found by PES.
- *Possible match* - The code for a possible match was assigned when the E sample housing unit was a possible match to a P sample housing unit, but the FHU followup interview was inconclusive or incomplete.

The "Adds" **added-in-error** will consist of the housing units added to the census inventory that the FHU did not find as housing units existing on Census Day. These cases will have one of the following PES codes assigned to them:

- *Not a housing unit* – The FHU followup determined the E sample address was for a group quarters, a business, or the unit was demolished, burned down, uninhabitable, or could not be located.
- *Duplicates* – The E sample address was found to be a duplicate of another unit in the census.

[11] The Enumeration extract is a file that identifies the eligible addresses for the enumeration operations. It includes the results of In-Field Address Canvassing.

[12] When this study plan was drafted, the PES match codes were not final. Therefore, the PES match codes in question 1 and question 2 are examples and may not list all the match codes that will be classified as correct or incorrect enumerations.

- *Geocoding error* – The E sample housing unit existed as a housing unit at the time of the FHU followup interview but was incorrectly geocoded to the BCU. As a result, the PES analysis considers the housing unit to be erroneously enumerated in the BCU.

After the FHU operation, the match and enumeration status for some housing units may remain unresolved. The PES imputes an enumeration status for housing units missing a status. The analysis will either report the unresolved housing units in their own category or re-impute a match and enumeration status for these units.

The calculated estimates will use the PES weights or a modified version of the PES weights. The analysis may need to modify the weights because it will not use the match code results in exactly the same way as the PES analysis will use them. When possible, estimates will be provided for various characteristics (e.g., urban/rural, size of housing unit) to examine whether add errors are correlated with any characteristic.

Question 2 – In-Field Address Canvassing: What percentage of the housing units added during In-Field Address Canvassing were correctly added (and added-in-error)? What percentage of the housing units identified as deleted or duplicated by the listers during In-Field Address Canvassing were correctly deleted or duplicated (and deleted-in-error)?

Like question 1 above, the PES will have the data to provide estimates of the correctly added and added-in-error housing units for In-Field Address Canvassing. The 2010 Census evaluation provided estimates of the correctly deleted units and the housing units deleted-in-error by conducting matching and field followup on a sample of units identified during In-Field Address Canvassing as deletes and duplicates. For the 2020 Census, the In-Field Address Canvassing deleted units that pass the filter will go into the enumeration operations. This will give these units a second look to verify their deleted status. The PES will include these units in its match universe and follow up on questionable cases or potential matches. As a result, the evaluation analysis will use the PES match codes to determine whether the units are **correctly deleted** or **deleted-in-error**.

The universe for determining the correctly added addresses will consist of the housing units having "Add" action codes from In-Field Address Canvassing in the PES sample BCUs. The analysis will use the match codes from the PES Initial Housing Unit Matching and Followup operations to determine whether the added housing units were correctly added or add-in-error.

The **correctly added** housing units will have one of the following PES match codes from the Initial Housing Unit Matching and Followup operations:

- *Match* – The address having an "Add" action matched a P sample housing unit.
- *Geocoded correctly* – The address having an "Add" action matched a P sample housing unit and was found in the sample BCU during the Initial Housing Unit follow up search in the BCU and the surrounding BCU. It was correctly enumerated in the BCU. Note that the PES analysis considers addresses found in the surrounding BCU of the sample BCU as correct enumerations, the evaluation analysis will treat these as added-in-error.

- *Possible Match* - The code for a possible match was assigned when the address having an "Add" action was a possible match to a P sample housing unit, but the Initial Housing Unit follow up interview was inconclusive or incomplete.

The **added-in-error** housing units will have one of the following PES match codes from the Initial Housing Unit Matching and Followup operations:

- *Not a housing unit* – The Initial Housing Unit followup determined the address with an "Add" action was for a group quarters, a business, or the unit was demolished, burned down, uninhabitable, or could not be located.
- *Duplicates* – The address with an "Add" action was found to be a duplicate of another unit in the Census.
- *Geocoding error* – The address with an "Add" action existed as a housing unit at the time of the Initial Housing Unit followup interview but was incorrectly geocoded to the BCU. As a result, the PES analysis considers the housing unit to be erroneously enumerated in the BCU. As noted above, the analysis will treat any addresses found in the surrounding BCU of the sample BCU as a geocoding error instead of a PES match status of geocoded correctly. The evaluation analysis will need to identify and recode these addresses.

After the Initial Housing Unit Matching and Followup operations, some addresses may have an unresolved match status. The analysis will either report the unresolved housing units in their own category or impute a match status.

The calculated estimates will use the PES weights or a modified version of the PES weights. The analysis may need to modify the weights because it will not use the match code results in exactly the same way as the PES analysis will use them. When possible, estimates will be provided for various characteristics (e.g., urban/rural, size of housing unit) to examine whether add errors are correlated with any characteristic.

Question 3 – In-Field Address Canvassing: What percentage of the suppressed housing units did the listers add and miss adding? For a sample of "salted" or false housing units, what percentage of the housing units did the listers delete and miss deleting?

To answer these questions, a sample of addresses from the MAF that passed the filter will be suppressed from the dependent list that populates the LiMA for the 2019 production In-Field Address Canvassing. In addition, a sample of false addresses will be included in the LiMA's dependent address list for the production In-Field Address Canvassing. Suppressed addresses, even if listers do not add them, will still be in the Mailout operation, and the salted addresses will not be included in the Mailout.

It is possible that some of the suppressed addresses actually do not exist or are nonresidential or duplicates. Because these addresses will be in the Mailout, the analysis will check their status by using both the UAA codes and their status on the CUF. If a suppressed address has an UAA code, then the analysis will classify the address as not correctly added by the listers (i.e., lister error). Because it is possible for the U.S. Postal Service to successfully deliver mail to an ineligible unit (e.g., nonresidential address), the analysis will match the MAFIDs of the

suppressed addresses to the MAFIDs on the CUF. If the lister did not add a suppressed address, and it appears on the CUF as a valid, enumerated housing unit, then the analysis will classify the address as a missed add (i.e., lister error).

In addition, some of the false addresses may be actual addresses. These addresses will be matched—either by the Decennail Information Technology Division (DITD) or through Production Environment for Administrative Records Staging, Integration and Storage (PEARSIS)—to the enumerated addresses on the CUF to determine the validity of these addresses. If a lister did not delete a false address and it matches to a valid, enumerated address on the CUF, then the lister took the correct action. If the address does not match, then the lister missed deleting the address (i.e., lister error).

Sample Selection for Suppressed Addresses

The sample of suppressed addresses will be selected from the universe of addresses (MAFIDs) that pass the filter in blocks identified as active, triggered, or on hold at the time of sampling. The MAFIDs will be sorted by state, county, tract, BCU, and by address within the BCU.

The sample design will include 13 strata in four address categories and five Urban/Rural (U/R) Types as shown in Table 1 below. The U/R Type is collapsed for some of the categories.

Table 1: Sampling Strata and Sample Sizes for Suppressed Addresses

Stratum	Address Category	Urban/Rural Type	Minimum Sample Size	Oversample Size
1	Single unit	Central city	2,416	18,200
2	Single unit	Suburban	2,416	31,010
3	Single unit	Exurban	2,416	17,000
4	Single unit	Small town	2,416	5,000
5	Single unit	Rural	2,416	22,910
6	Multiunit	Central city	3,378	22,950
7	Multiunit	Suburban	3,378	14,350
8	Multiunit	Exurban	3,378	5,000
9	Multiunit	Small town	3,432	5,000
10	Multiunit	Rural	3,432	5,000
11	Mobile home or trailer	Central city, suburban, exurban, small town	3,432	6,300
12	Mobile home or trailer	Rural	3,432	5,680
13	Special units	Central city, suburban, exurban, small town, rural	3,432	1,600
Total Sample Size			41,790	160,000

The four address categories include the following:

1. Single unit addresses.
2. Addresses within multiunits.
3. Mobile homes or trailers.

4. Addresses with an indication that they may be special housing situations that are not group quarters or transitory locations, such as potential "hidden" housing units, hard-to-find units, and informally subdivided housing (e.g., location description has: basement apartment, apartment over garage, unit above store, share, alley, etc.).

The five U/R types include the following:

1. Central city.
2. Suburban.
3. Exurban.
4. Small town.
5. Rural.

The minimum sample size to detect differences between two strata is calculated using the following formula:

$$n \geq \frac{((Z_{\alpha^*/2} + Z_{\beta})^2 * (p_1(1-p_1) + (p_2(1-p_2)) * deff)}{\delta^2}$$

Where

δ	=	minimum detectible difference
$Z_{\alpha*/2}$	=	critical value for set alpha level assuming a two-sided test
Z_{β}	=	critical value for set beta level
p_1	=	proportion for stratum 1
p_2	=	proportion for stratum 2
deff	=	design effect due to unequal weighting
n	=	sample size

In a 1990 study, the Census Bureau ran a similar approach for the suppression of addresses and found the field listers' overall miss rate was 30 percent: with a 42.2 percent miss rate for multiunit addresses and a 24.3 percent miss rate for single units (Russell, 1992).

The minimum overall sample size for the 13 strata is 41,790. This assumes a minimum detectible difference = 0.03, the design effect = 1, and a two-sided Z-test with a power of 80 percent at an alpha level of 0.10. This formula uses the miss rates from the 1990 study for the single units (strata 1 to 5) for a minimum sample size of 2,416 per stratum and for multiunits (strata 6 to 10) for a minimum sample size of 3,378 per stratum. Because the 1990 study did not provide miss rates for mobile homes or special addresses, the formula uses a conservative miss rate of 51 percent for a minimum sample size of 3,432 each for strata 9 to 13.

The selected sample of 160,000 addresses will be an oversample for two reasons: 1) For Field Division (FLD) planning purposes, the Decennial Statistical Studies Division (DSSD) needs to select the sample before Geography Division (GEO) has identified the final set of BCUs going to In-Field Address Canvassing. The final number of BCUs going to In-Field Address Canvassing is expected to decrease by that time. Because some sample addresses may be in BCUs no longer going to In-Field Address Canvassing, an oversample will ensure statistical quality of the results.

2) The estimated coefficient of variation (CV) of the minimum sample size is above the Census Bureau's statistical standard of 0.30. The optimizer in Excel was used to obtain the stratum sample sizes. The optimizer estimated a CV of 0.13 assuming a minimum sample of 1,600 addresses in a stratum with a total oversample size of 160,000 addresses.

There is a risk that listers may add suppressed addresses in a manner that differs from the original addresses. The processing of these addresses in the MAF matching and updating system will result in introducing address duplication. Unfortunately, there is no time during production processing for either DSSD or DITD to identify these duplicate addresses and remove them from the production stream. As a result, both the original suppressed addresses and their duplicates will continue into the Mailout. Ultimately, the duplicate addresses could end up in the Nonresponse Followup (NRFU) workload.

Identifying Salted Addresses

As with the suppression sample design, the strata for the salted sample includes address categories and the U/R type. The address categories include four categories for single housing units and two categories where multiple addresses will be added to the sample. Two of the single housing unit categories will be selected from the MAF, two of the single unit categories will be based on existing addresses and the other two categories will be for multiple units in false, made-up addresses.

The sample of salted or false addresses will be sorted by state, county, tract, and BCU, then selected from the following six strata:

<u>Single units selected from the MAF</u>

1. Nonresidential addresses
2. Addresses that do not pass the filter (where the Unit Status variable equals demolished units or nonexistent addresses)

<u>Single unit, false addresses based on existing addresses</u>

3. Single housing unit
4. False hidden units

<u>Multiple, false addresses</u>

5. Add entire multiunit structures
6. Add a false street with one house number or a range of false house numbers

Table 2 shows the strata and sample sizes for the salted addresses. As indicated, there will be 30 strata, and the total size with oversampling will be 150,000. The sample of salted addresses going to In-Field Address Canvassing is expected to be less than 150,000 because the active or passive status of BCUs is not yet final. Some active BCUs are expected to change to a passive status.

Table 2: Sampling Strata and Sample Sizes for Salted Addresses

Stratum	Salted Category	Urban/Rural Type	Oversample Size
Single addresses:			

1	Nonresidential	Central city	14,672
2	Nonresidential	Suburban	14,672
3	Nonresidential	Exurban	5,000
4	Nonresidential	Small town	5,000
5	Nonresidential	Rural	5,000
6	Addresses that do not pass filter	Central city	9,854
7	Addresses that do not pass filter	Suburban	9,854
8	Addresses that do not pass filter	Exurban	5,000
9	Addresses that do not pass filter	Small town	5,000
10	Addresses that do not pass filter	Rural	5,948
11	Single unit address	Central city	8,000
12	Single unit address	Suburban	8,000
13	Single unit address	Exurban	8,000
14	Single unit address	Small town	8,000
15	Single unit address	Rural	8,000
16	Special units	Central city	2,000
17	Special units	Suburban	2,000
18	Special units	Exurban	2,000
19	Special units	Small town	2,000
20	Special units	Rural	2,000
Multiple addresses:			
21	Entire multiunit	Central city	4,000
22	Entire multiunit	Suburban	4,000
23	Entire multiunit	Exurban	4,000
24	Entire multiunit	Small town	4,000
25	Entire multiunit	Rural	4,000
26	Entire street	Central city	4,000
27	Entire street	Suburban	4,000
28	Entire street	Exurban	4,000
29	Entire street	Small town	4,000
30	Entire street	Rural	4,000
Total Addresses Salted			***150,000***

To be consistent with the suppressed sample, the minimum sample size is calculated using the same formula, detectable difference, power, and alpha as the suppressed addresses. Because there is no prior information on the miss rate for salted addresses, a conservative miss rate of 51 percent is used. Therefore, the minimum number of addresses to salt for each stratum is 3,432 for a total of 102,960.

The optimizer in Excel was used to determine the oversample sizes for strata 1 to10 (i.e., the strata for which the addresses are selected from the MAF) that would minimize the CV assuming a minimum size of 5,000 addresses in a stratum and a total size of 80,000 addresses for the 10 strata. This results in a CV of 0.16.

For the salted sample, the analysis will only provide unweighted numbers. As false addresses, the salted addresses represent just themselves. Even the addresses selected from the MAF, such

as the nonresidential units, do not represent all nonresidential addresses in the nation or in the active blocks. The MAF update process does not routinely add nonresidential units to the MAF. Typically, a field operation, such as a prior In-Field Address Canvassing operation, provides the information that these addresses are nonresidential.

Question 4 – In-Office Address Canvassing: What percentage of the BCUs did the In-Office Address Canvassing Interactive Review correctly classify as active and passive?

This question examines the effectiveness and accuracy of the In-Office Address Canvassing IR in identifying the BCUs that need In-Field Address Canvassing. Essentially, this question is asking whether the active and passive BCUs have change to the address inventory.

The analysis using PES results will examine the coverage components. For housing units, the PES computes separate estimates of correct enumerations, erroneous enumerations and omissions. The PES correct enumerations will be two types: 1) correctly enumerated in the BCU and 2) correctly enumerated in the surrounding BCU. The estimates for erroneous enumerations will have three parts: 1) structures enumerated in the census as housing units but do not exist or were not housing units, 2) housing units enumerated more than once (duplicates), and 3) geocoding errors.

For this evaluation, the second type of PES correct enumerations—the housing units correctly enumerated in the surrounding BCU—will be classified as erroneous enumerations. The analysis for the evaluation is changing this definition because the intent is to examine correct classification or incorrect classification for BCUs[13]. However, the PES staff estimates correct enumerations, erroneous enumerations, and omissions at higher levels of geography. Changing the definition requires the evaluation analysis to code its own variables for correct enumerations and erroneous enumerations based on the P sample and E sample matching and follow up results. Because the PES calculation for omissions is the Dual System Estimate minus the correct enumerations, the analysis will need to recalculate this estimate.

If an active BCU has one or more housing units that are erroneous enumerations or omissions, then IR correctly classified the BCU. If a passive BCU has only correct enumerations and no erroneous enumerations or omissions, then IR correctly classified the BCU.

The analysis will include distributions of addresses in the correctly and incorrectly assigned active and passive BCUs.

Question 5 – In-Office Address Canvassing: How accurate is the Virtual Canvassing?

The operation called “Virtual Canvassing” by this evaluation will use the ABR procedures that were revised just before the suspension of ABR. Therefore, this research question will essentially evaluate ABR if the operation had continued.

[13] The IR work unit is a block. So ideally, the analysis would examine correct and incorrect classification at the block-level. However, the fieldwork will use BCUs as the work unit. BCUs and blocks do not always have a one-to-one relationship, so the analysis cannot translate a BCU-level analysis to a block-level analysis.

The revised ABR procedures rely on the placement in IR of coverage "pins." (The IR staff will assign a "pin" to an area on the current imagery that appears to have additional housing units or less housing units when compared to the baseline image). As a result, a "second" or repeat IR will need to be conducted before the Virtual Canvassing. This repeat IR will occur in the 10,000 BCUs in the PES sample for the U.S.

In Virtual Canvassing, staff (contractors) will use in-office information to canvass the BCUs found to be active by the repeat IR. In-office information may include imagery, local geographic information and imagery, parcel data, local files, partner data, street-level imagery, MAF address information, TIGER street data, and DSF data. Staff will focus on resolving the coverage issues identified by the IR. To resolve the coverage issues, staff may have to canvass the entire BCU. However, only the addresses needing updating will receive action codes.

Because of resource constraints during census production, the repeat IR and Virtual Canvassing will be conducted from late August 2020-October 2020. To mitigate temporal differences, IR and Virtual Canvassing will use current imagery from around April 1, 2020—the PES reference day.

The analysis will use the PES results to determine the accuracy of the Virtual Canvassing—and thus of the revised ABR procedures. To use the PES results, the addresses added by Virtual Canvassing will need to be matched to the PES addresses. (The other addresses should already be in the PES match universe). Either the DSSD or the GEO will conduct this matching.

The calculated estimates will use the PES weights or a modified version of the PES weights. The analysis may need to modify the weights because it will not use the match code results in exactly the same way as the PES analysis will use them.

Question 6 – In-Office Address Canvassing: Were the set of triggers sufficient for identifying instances in which housing unit change occurred?

a. Were there instances of housing unit change that were not detected by triggers, and as a result, did not send a BCU back to IR for assessment or directly to an active status?
b. Did the set of triggers result in unnecessary work in the IR and in-field?
c. What is the effectiveness of specific trigger types?

The analysis for question 6a will examine the passive-never triggered BCUs and determine whether these BCUs have changes to the address list. When using the PES results, the analysis will determine whether the passive-never triggered BCUs have omissions or erroneous enumerations.

If the sample size allows, the analysis will examine the passive BCUs that were triggered for IR re-review and remained passive after the re-review. It is possible for change to occur after the re-review, but subsequent triggers did not detect the change. The analysis will use the Virtual Canvassing and PES results as described in the previous paragraph.

The analysis for the first part of question 6b will show a summary from the weekly Trigger Report. This report shows the number of blocks sent to IR for each trigger event, and as a result of the re-review, the number and percentage of blocks that become active, passive, or placed on hold. A trigger event with a relatively high percentage of passive blocks and low percentage of active blocks after the re-review may indicate an ineffective trigger that resulted in unnecessary work. (The weekly Trigger Report covers triggered blocks in the entire U.S. and Puerto Rico).

The analysis for the second part of question 6b will examine the PES results for the triggered BCUs that became active and went to In-Field Address Canvassing. Triggered BCUs without omissions or erroneous enumerations from PES may indicate BCUs that did not need to go to In-Field Address Canvassing.

The analysis for question 6c will examine the effectiveness of specific trigger types or reasons (e.g., a DSF update results in an increase or decrease to the housing unit count, a block has a large number of housing units without map spots, etc.). To date, there have been about 50 trigger types. A trigger type may have occurred on multiple dates or events. The analysis will examine both trigger types and trigger events. The PES sample size may not allow estimates for each trigger type or event. If necessary, the trigger types and events will be collapsed into smaller categories, but any trigger types or trigger events that stand out will be noted.

Note that "effectiveness" may be defined in different ways. For example, is a trigger type effective if it:

- Results in a "high" percentage of reviewed blocks becoming active?
- Results in a "high" percentage of changed addresses?
- Results in any changed addresses or active blocks?

The analysis will provide several tables to allow for an examination of differing meanings of the term "effectiveness."

Question 7 – In-Office Address Canvassing: What is the effect on the enumeration of addresses missed by In-Office Address Canvassing in the misclassified BCUs?

a. Were the missed addresses in the BCUs, which the IR misclassified as passive, enumerated as valid, residential units?
b. What is the cost of incorrectly classifying BCUs?

The analysis will use results from both the Virtual Canvassing and the PES to answer questions 7a and 7b.

The intent of question 7a is to determine whether the missed addresses in the BCUs incorrectly classified as passive are being added by enumeration operations, and as a result, the effect of the misclassification on the final enumeration is minimized. The BCUs misclassified as active and that should have been passive according to the Virtual Canvassing or PES results, will not have

added addresses from Virtual Canvassing or omissions from PES. Therefore, question 7a just examines the misclassified passive BCUs.

The addresses having add actions from Virtual Canvassing will need to be matched to the CUF (i.e., the final address list) to determine whether they are valid, enumerated units. If the match determines that any of the addresses are enumerated units, then the analysis will estimate the undercoverage rate in the misclassified passive BCUs.

The analysis will use the PES results in a similar way to answer question 7a. Because the PES matches to In-Field Address Canvassing results, which are on the Enumeration Extract, and the results from census enumerations, which are on the CUF, no additional matching will be needed. The analysis will calculate the omissions in the misclassified passive BCUs and estimate the undercoverage rate.

Question 7b examines the negative actions (deletes, duplicates, moves from one BCU to another BCU, and nonresidential) and the effect these records have on cost by potentially increasing the NRFU workload. Virtual Canvassing results will provide the negative actions in the sample BCUs that IR incorrectly classified. The DITD will match the addresses having negative actions to the CUF to minimize the potential of false negatives. The analysis will remove any addresses that match to valid, enumerated addresses.

The 2020 Census NRFU Operational Assessment report is expected to provide a cost per address (or a cost from which a cost per address can be derived). Multiplying the estimated, weighted number of addresses having negative actions by the NRFU cost per address will give the estimated cost impact of incorrectly classifying BCUs as passive.

In addition, the BCUs incorrectly classified as active may increase the cost of In-Field Address Canvassing. Using Virtual Canvassing and In-Field Address Canvassing results, the analysis will determine the number of BCUs that have no address inventory changes. The 2020 Census In-Field Address Canvassing Operational Assessment will provide a cost per BCU. Multiplying this cost by the estimated, weighted number of misclassified active BCUs will provide the estimated total cost impact for these BCUs.

Question 8 – How effective was the filter in identifying valid living quarters for the In-Field Address Canvassing dependent address list?

To evaluate how well the In-Field Address Canvassing filter identified housing units for the dependent address list, the results from the PES P sample will be used for part of the analysis. As mentioned in the background section, the P sample includes matching of the PES Independent Listing to the Enumeration Extract—which includes the results from In-Field Address Canvassing—and field follow up on questionable matches or unmatched housing units. (Note that PES does not include group quarters, so the research question can only be answered for housing units.)

The In-Field Address Canvassing Transaction File will show the added housing units that match back to existing addresses on the MAF that did not pass the filter (i.e., matched adds). The PES match codes will identify which of these matched adds were valid, residential addresses. In addition, the PES results will assist in identifying the existing MAF addresses that listers failed to add. The matched adds representing valid, residential housing units are addresses that ideally, should have be included on the In-Field Address Canvassing Extract. If possible, the analysis will attempt to find one or more common characteristics of these addresses that can define new filter rules, which will pass the addresses without substantially increasing the number of invalid addresses that pass. Examples of characteristics the analysis may examine include:

- The latest source that validated the addresses.
- The original source of the addresses.
- The length of time since operation validated the addresses.
- The geographic location of the addresses.

Because the PES does not match to the In-Field Address Canvassing addresses having negative actions (deletes, duplicates, and nonresidential), the analysis will use the results of matching these types of addresses to the CUF. This match will show the addresses with negative actions that are valid, enumerated housing units and were deleted-in-error. The PES match codes will identify the In-Field Address Canvassing addresses that listers failed to identify as invalid, or deleted, housing units. Based on the results from the CUF match and the PES match codes, the analysis will identify the address records that should have been excluded from the In-Field Address Canvassing Extract.

Question 9 - What is the cost of the reengineered Address Canvassing operation compared to the cost of a 100 percent In-Field Address Canvassing?

Note: The methodology for this question depends on cost information from the Decennial Budget Office.

Question 10 – Can unit level modeling support improved targeting for Address Canvassing, specifying filter criteria, estimating hidden units, or estimating recurring MAF coverage errors?

See the appendix for a description of the methodology for answering this question.

B. Interventions with the 2020 Census

The suppression and salting of addresses during the In-Field Address Canvassing operation requires interventions with the 2020 Census production solutions or systems.

The DITD will give the In-Field Address Canvassing Filter Flag variable a value that will cause the suppressed addresses to not pass. By not passing the filter, the addresses will not go to In-

Field Address Canvassing. After completion of In-Field Address Canvassing, all the suppressed addresses will be reinstated and have a value that passes the enumeration filter.

The DITD will add the salted addresses directly to the input file created for the LiMA. This will cause the salted addresses to go to In-Field Address Canvassing. After completion of In-Field Address Canvassing, the DITD will remove all the salted addresses before matching to the MAF/TIGER. This will keep the salted addresses from continuing on to the enumeration operations.

C. Implications for 2030 Census Design Decisions and Future Research and Testing

The Decennial Research Objectives and Methodology (DROM) Working Group removed the following proposed research question because of substantial limitations associated with acquiring results that are meaningful and not confounded:

If In-Office Address Canvassing Interactive Review was eliminated, what would be the effect on the decennial census? If In-Field Address Canvassing was eliminated, what would be the effect on the decennial census?

Stakeholders agreed that a more meaningful research focus for the early decade phase would involve testing alternative operational designs to strike an optimal balance between in-office and in-field operations for improved efficiency and accuracy.

VI. Data Requirements

The table below lists the data needed to answer the research questions along with the source of the data, how the evaluation will use the data (purpose), and the expected delivery date.

Data File/Report	Source	Purpose	Expected Delivery Date
August 2018 Block Characteristics File	Decennial Information Technology Division (DITD)	This file provides the preliminary active, passive, on hold status of blocks and will be used for selecting the sample of suppressed and salted addresses in the In-Field Address Canvassing.	08/03/2018
August 2018 MAF Extract	DITD	This MAF extract will be used for selecting the sample of suppressed and salted addresses in the In-Field Address Canvassing.	08/10/2018
January 2019 Block Characteristics File	DITD	This file provides the updated active, passive, and on hold status of blocks and will be used to check how status changes affect the suppressed and salted sample.	01/04/2019

Data File/Report	Source	Purpose	Expected Delivery Date
January 2019 MAF Extract	DITD	This MAF extract will be used to check how updates affect the sample of suppressed and salted addresses in the In-Field Address Canvassing.	01/11/2019
Dangerous Address File	FLD or DCMD	Dangerous addresses will be excluded from the suppressed sample.	04/24/2019
Block Characteristics File for In-Field Address Canvassing	DITD	This file will give the final status (active, passive, etc.) for blocks.	01/31/2020
BCU Table for In-Field Address Canvassing	DITD	This file will give the final status (active, passive, on hold) for BCUs.	01/31/2020
Address Canvassing Geographic Reference File – U.S.	DITD	This file will show the BCUs going to In-Field Address Canvassing.	06/28/2019
Address Canvassing MAF Extract –U.S.	DITD	This file provides all the addresses on the MAF prior to In-Field Address Canvassing and a flag will show the addresses that pass the filter for Address Canvassing.	06/28/2019
Trigger Status File	GEO-Address and Spatial Analysis Branch	This shows the final status of blocks or BCUs that were triggered and never triggered.	07/31/2019
Trigger Event File	GEO – Address and Spatial Analysis Branch	This file shows the trigger reasons and events and the results from IR for each event for each BCU.	07/31/2019
LiMA Output (Address Update) File from In-Field Address Canvassing	Applications Development and Services Division (ADSD)	This file shows the actions and updates made by the listers and QC listers. It will aid DSSD in resolving potential duplicates.	11/08/2019
In-Field Address Canvassing Transaction File	DITD	This file shows the lister actions and the updates to the MAF. For suppressed addresses, it will show the MAFIDs added by the listers. For salted addresses, it will show the addresses identified as deletes.	12/17/2019
Virtual Canvassing Transaction or Address Update File	DITD	This file shows the actions taken by staff doing the Virtual Canvassing operation.	11/20/2020
Undeliverable as Addressed File	Census Data Lake (CDL)	This file shows the addresses from Mailout that were undeliverable by the U.S. Post Office. The evaluation can use this file to check the validity of addresses after In-Field Address Canvassing.	05/01/2020
Cost Data	Decennial Budget Office and the Uniform Tracking System (UTS)	The data will allow a comparison of the 2020 Address Canvassing costs and the 2010 Address Canvassing costs.	09/30/2020
Census Unedited File	CDL	The CUF provides the final enumeration status of housing units in the census.	11/30/2020

Data File/Report	Source	Purpose	Expected Delivery Date
Match Files	DITD	The match files will indicate whether In-Field Address Canvassing added addresses and deleted addresses ended up being enumerated as valid, residential addresses.	12/30/2020
In-Field Address Canvassing Operational Assessment Report	DCMD	The assessment report will provide a cost per BCU and cost per address for the In-Field Address Canvassing operation.	12/2020
NRFU Operational Assessment Report	DCMD	The assessment report will provide a cost per address for the NRFU operation.	03/2021
PES Files	DITD	The PES results will provide benchmarks for evaluating the In-Field and In-Office Address Canvassing operations.	09/30/2021[1]
[1] To avoid interference with PES analysis, the evaluation will use PES files after the PES analysis is complete. The date shown is when PES analysis and reporting is scheduled to complete.			

VII. Risks

1. If adequate resources to conduct the evaluation activities are unavailable, then activities may be delayed or descoped.
2. If the Census Bureau cannot obtain a contractor for the Virtual Canvassing by August 29, 2019, then analysts will not be able to answer some research questions.
3. If a lister adds a suppressed sample address in a manner that differs from the original address, then the processing may not match the added address to the original MAF address, and a duplicate address may be created. This can result in an increase in the NRFU workload.
4. If resources are constrained because of competing work on 2020 Census production activities, then Virtual Canvassing may be delayed or canceled.
5. If information regarding triggers is not available, then the research question regarding triggers may not be fully answered.

VIII. Limitations

Limitations that may affect the results of this evaluation include:

1. **Differences between BCU and Block** – The In-Office Address Canvassing unit of geographic measure is a block, whereas the In-Field Address Canvassing and the PES unit of measure is a BCU. The results from the two operations need to be analyzed using the same geographic unit, which in the case of this evaluation, will be a BCU. The relationship of a block to a BCU is not always one-to-one. As a result, it is possible for a BCU to contain (all or part of) an active block and (all or part of) a passive block. When a BCU contains at least part of an active block, it becomes an active BCU and is sent for listing. Even if only the passive portion of the BCU has one or more address inventory actions, the analysis would consider the BCU as correctly classified. However, an analysis at the block-level would include the block in the misclassification estimate, causing a block misclassification rate to

be higher than a BCU misclassification rate. The same is true for other BCU status categories.

2. **Temporal differences between operations** - The timing of when each operation will be conducted, including the state of the MAF when the address lists or extracts will be created, may confound the analytic results.

IX. Issues That Need to be Resolved

Will the Experiments, Assessments, and Evaluations budget cover the cost of contractors to conduct the Virtual Canvassing operation?

X. Division Responsibilities

The table below lists the divisions and offices involved in the development and implementation of the evaluation and their responsibilities.

Division or Office	Responsibilities
ADSD	• Deliver LiMA output file from In-Field Address Canvassing to DSSD.
Contractors	• Conduct the Virtual Canvassing operation.
CSRM	• Conduct a cost-benefit analysis of the Address Canvassing operations. • Conduct analysis on modeling. • Review and provide comments on the evaluation methodology.
DCMD	• Provide overall management of experiments/evaluations, the budget, and schedule. • Review the evaluation study plan and report. • Provide cost data on the Address Canvassing operation.
DITD	• Deliver data files from census and PES operations. • Ensure suppressed addresses go into the Mailout operation and salted addresses do not move on. • Conduct additional matching of evaluation files to the final census.
DSSD	• Specify requirements for data products needed to implement to evaluation. • Design and select the suppressed and salted samples. • Conduct analysis to answer the research questions. • Report on the schedule status to DCMD. • Develop the study plan and write the report.
GEO	• Provide oversight and management of the Virtual Canvassing operation and the repeat IR. • Write software requirements for the requested data products. • Provide data on the status of blocks and BCUs for In-Field Address Canvassing. • Provide data on the triggered blocks and BCUs.
NPC	• Conduct a repeat IR for the BCUs in the PES sample.

XI. Milestone Schedule

Activity ID	Activity Name	Orig Duration	Start	Finish
2020 Census Evaluation of the Reengineered Address Canvassing Operation Study Plan				
Initial Draft				
	Prepare Initial Draft of 2020 Census Evaluation of the Reengineered Address Canvassing Operation Study Plan	**15**	05/11/2018	09/27/2018
	Distribute Initial Draft of 2020 Census Evaluation of the Reengineered Address Canvassing Operation Study Plan to the Author's Division Chief, Subject Matter Experts (SMEs) and Other Reviewers	**1**	09/28/2018	09/27/2018
	Incorporate Author's Division Chief, SMEs and Other Comments to 2020 Census Evaluation of the Reengineered Address Canvassing Operation Study Plan	**5**	10/10/2018	10/29/2018
Final Draft				
	Prepare Final Draft 2020 Census Evaluation of the Reengineered Address Canvassing Operation Study Plan	**5**	11/14/2018	01/30/2019
	Distribute Final Draft 2020 Census Evaluation of the Reengineered Address Canvassing Operation Study Plan to Evaluations & Experiments Coordination Brach (EXC)	**1**	01/31/2019	01/31/2019
	EXC Distributes Final Draft 2020 Census Evaluation of the Reengineered Address Canvassing Operation Study Plan to the DROM Working Group for Electronic Review	**1**	02/01/2019	02/01/2019
	Receive Comments from the DROM Working Group on the Final Draft 2020 Census Evaluation of the Reengineered Address Canvassing Operation Study Plan	**5**	02/02/2019	02/19/2019
	Schedule the 2020 Census Evaluation of the Reengineered Address Canvassing Operation Study Plan for the IPT Lead to Meet with the DROM Working Group	**17**	01/14/2019	02/05/2019
	Discuss DROM Comments on Final 2020 Census Evaluation of the Reengineered Address Canvassing Operation Study Plan	**1**	02/19/2019	02/19/2019
FINAL				
	Prepare FINAL 2020 Census Evaluation of the Reengineered Address Canvassing Operation Study Plan	**15**	02/20/2019	03/14/2019

Activity ID	Activity Name	Orig Duration	Start	Finish
	Distribute FINAL 2020 Census Evaluation of the Reengineered Address Canvassing Operation Study Plan to the EXC	**1**	03/15/2019	03/15/2019
	EXC Staff Distributes the 2020 Census Evaluation of the Reengineered Address Canvassing Operation Study Plan and 2020 Memorandum to the DCCO	**3**	03/18/2019	03/21/2019
	DCCO Staff Process the Draft 2020 Memorandum and the 2020 Census Evaluation of the Reengineered Address Canvassing Operation Study Plan to Obtain Editorial Clearance (Chief Editor)	**100**	03/22/2019	08/09/2019
	DCCO Staff Formally Release the 2020 Census Evaluation of the Reengineered Address Canvassing Operation Study Plan in the 2020 Memorandum Series	**1**	08/12/2019	08/12/2019
2020 Census Evaluation of the Reengineered Address Canvassing Operation Report				
Initial Draft of Report				
	Receive, Verify, and Validate 2020 Census Evaluation of the Reengineered Address Canvassing Operation Data for the Suppressed and Salted Addresses	**20**	12/16/2019	01/06/2020
	Examine Results and Conduct Preliminary Analysis for the 2020 Census Evaluation of the Reengineered Address Canvassing Operation Suppressed and Salted Addresses	**20**	01/07/2020	05/01/2020
	Brief DROM on the Preliminary Results for the 2020 Census Evaluation of the Reengineered Address Canvassing Operation Suppressed and Salted Addresses		05/21/2020	05/21/2020
	Conduct “Second” Interactive Review for the 2020 Census Evaluation of the Reengineered Address Canvassing Operation in PES Sample BCUs		08/17/2020	08/31/2020
	Conduct Virtual Canvassing for the 2020 Census Evaluation of the Reengineered Address Canvassing Operation in PES Sample BCUs		09/01/2020	10/30/2020
	Receive, Verify, and Validate 2020 Census Evaluation of the Reengineered Address Canvassing Operation Data	**20**	08/03/2018	09/30/2021
	Examine Results and Conduct Analysis	**20**	10/01/2021	04/29/2022
	Prepare Initial Draft of 2020 Census Evaluation of the Reengineered Address Canvassing Operation Report	**15**	04/29/2022	07/08/2022
	Distribute Initial Draft of 2020 Census Evaluation of the Reengineered Address Canvassing Operation Report to the Author’s Division Chief, SMEs and Other Reviewers	**1**	07/11/2022	07/11/2022

Activity ID	Activity Name	Orig Duration	Start	Finish
	Incorporate Author's Division Chief, SMEs and Other Comments 2020 Census Evaluation of the Reengineered Address Canvassing Operation Report	**7**	07/12/2022	07/29/2022
Final Draft of Report				
	Prepare Final Draft 2020 Census Evaluation of the Reengineered Address Canvassing Operation Report	**8**	08/01/2022	08/15/2022
	Distribute Final Draft 2020 Census Evaluation of the Reengineered Address Canvassing Operation Report to Evaluations & Experiments Coordination Br. (EXC)	**1**	08/16/2022	08/16/2022
	EXC Distributes Final Draft 2020 Census Evaluation of the Reengineered Address Canvassing Operation Report to the DROM Working Group for Electronic Review	**1**	08/17/2022	08/17/2022
	Receive Comments from the DROM Working Group on the Final Draft 2020 Census Evaluation of the Reengineered Address Canvassing Operation Report	**10**	08/18/2022	09/08/2022
	Schedule the 2020 Census Evaluation of the Reengineered Address Canvassing Operation Report for the IPT Lead to Meet with the DROM Working Group	**10**	09/09/2022	09/26/2022
	Discuss DROM Comments on Final Draft 2020 Census Evaluation of the Reengineered Address Canvassing Operation Report	**1**	09/27/2022	09/27/2022
FINAL Report				
	Prepare FINAL 2020 Census Evaluation of the Reengineered Address Canvassing Operation Report	**25**	09/28/2022	11/02/2022
	Deliver FINAL 2020 Census Evaluation of the Reengineered Address Canvassing Operation Report to the EXC	**1**	11/03/2022	11/03/2022
	EXC Staff Distribute the FINAL 2020 Census Evaluation of the Reengineered Address Canvassing Operation Report and 2020 Memorandum to the DCCO	**3**	11/04/2022	11/09/2022
	DCCO Staff Process the Draft 2020 Memorandum and the FINAL 2020 Census Evaluation of the Reengineered Address Canvassing Operation Report to Obtain Clearances (DCMD Chief, Assistant Director, and Associate Director)	**100**	11/10/2022	03/30/2023
	DCCO Staff Formally Release the FINAL 2020 Census Evaluation of the Reengineered Address Canvassing Operation Report in the 2020 Memorandum Series	**1**	03/31/2023	03/31/2023

Activity ID	Activity Name	Orig Duration	Start	Finish
	EXC Staff Capture Recommendations of the FINAL 2020 Census Evaluation of the Reengineered Address Canvassing Operation Report in the Census Knowledge Management Application	**1**	04/03/2023	04/03/2023

XII. Review/Approval Table

Role	Approval Date
Primary Author's Division Chief (or designee)	02/01/2019
Decennial Census Management Division (DCMD) ADC for Nonresponse, Evaluations, and Experiments	02/19/2019
Decennial Research Objectives and Methods (DROM) Working Group	02/19/2019
Decennial Census Communications Office (DCCO)	

XIII. Document Revision and Version Control History

Version/Editor	Date	Revision Description
0.1	08/29/2018	Initial draft for DSSD team review.
0.2	09/27/2018	Draft for DSSD Division Chief review.
0.3	10/25/2018	Draft for DROM review.
1.0	02/01/2019	Final draft for DROM.
1.1	03/15/2019	Final study plan.

XIV. Glossary of Acronyms

Below is a list of acronyms used in this study plan.

Acronym	Definition
ABR	Active Block Resolution
ADC	Assistant Division Chief
ADSD	Applications Development and Services Division
AVT	Address Validation Test
BCU	Basic Collection Unit
CSRM	Center for Statistical Research and Methodology
CUF	Census Unedited File
DCCO	Decennial Census Communications Office
DCMD	Decennial Census Management Division
DITD	Decennial Information Technology Division
DROM	Decennial Research Objectives and Methods Working Group
DSF	Delivery Sequence File
DSSD	Decennial Statistical Studies Division
EXC	Evaluations & Experiments Coordination Branch
FHU	Final Housing Unit
FLD	Field Division
GEO	Geography Division
GQ	Group Quarters
GSS	Geographic Support System
IHU	Initial Housing Unit
IL	Independent Listing
IPT	Integrated Project Team
IR	Interactive Review
LiMA	Listing and Mapping Application
LUCA	Local Update of Census Addresses
MAF	Master Address File
MAFID	Master Address File Identification Number
MMVT	MAF Model Validation Test
NPC	National Processing Center
NRFU	Nonresponse Followup
PEARSIS	Production Environment for Administrative Records Staging, Integration and Storage
PES	Post-Enumeration Survey
PI	Person Interview
QC	Quality Control
R&M	Research & Methodology Directorate
TEA	Type of Enumeration Area
TIGER	Topologically Integrated Geographic Encoding and Referencing
UAA	Undeliverable as Addressed
U/R	Urban/Rural
UTS	Uniform Tracking System

XV. References

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XVI. Appendix

Proposal for Unit-level Modeling of MAF Changes based on MAF History Files to Support a 2020 Census Evaluation Proposal on Reengineered Address Canvassing

Eric Slud, CSRM, US Census Bureau

October 19, 2018

Abstract: This document describes a proposal to perform unit level modeling of Master Address File (MAF) changes, with the goal of supporting research previously proposed in Johnson (2018) as part of the 2020 Census Evaluation research program. Predictive modeling of MAF adds and deletes has previously been undertaken at the block level in connection with the 2020 Targeted Address Canvassing program, but such models have been found insufficiently predictive to guide Reengineered Address Canvassing. It is argued that block-level modeling does not allow important distinctions to be drawn between MAF address changes that might or might not be detectable by remote sensing from those resulting from status changes within existing addresses. Such less-obvious changes could reflect 'hidden units' as discussed in recent Census Bureau evaluative reports, changes in occupancy or changes in residential versus commercial status, or corrections or new instances of geocoding errors. It is proposed to explore extensive MAF history data as a source of new predictive variables to identify basic housing-unit addresses at risk for MAF status changes, to support unit level MAF-change modeling. Such unit level models might hope to achieve the decennial-census objective of improved targeting for Address Canvassing, but might also serve a useful purpose in evaluating mid-decade in-office address canvassing and in estimating hidden-unit frequencies and other types of recurring MAF coverage errors.

1 Introduction

The 2020 Census Evaluation Research Proposal of Johnson (2018) describes a program of research aimed at assessing error rates of MAF changes of various types: post-Address Canvassing operation, in-field address canvassing and in-office address canvassing. Much of this work would be directly related to recent Decennial reengineered canvassing operations, but the proposal recognizes that many of the same techniques are relevant for continuing assessment of the efficacy of systems instituted in Geography Division for in-office canvassing for ongoing maintenance of MAF as the frame for all major Census Bureau surveys from now on.

Some of the assessment methodology proposed in Johnson (2018) is based on matching and coverage evaluations that might be undertaken with Coverage Measurement data from the independent listing and matching operations of the Post Enumeration Survey (PES). Other

suggested assessments would be undertaken from the application of listing and canvassing systems on geographies from which a sample of actual living quarters would be suppressed or to which a sample of 'salted' or false living quarters would be added. PES results and data from experiments of that sort would indeed provide useful information on gross error-rates in detecting incorrect MAF entries. The Johnson (2018) proposal aims to gain information about the rates of occurrence of types of errors known to be difficult to detect from post-office Delivery Sequence Files (DSF) and in-field listing, by stratifying the suppressed and seeded addresses according to address type (single- versus multiunit, mobile units, addresses with indicators associated with 'hidden units'). However, it seems unlikely that such a design could by itself give a sufficiently rich picture of geographical neighborhood variation of error types in terms of demographics, population density, and terrain from design-based analyses alone.

Therefore, some sort of modeling of error rates seems unavoidable. Past efforts to model MAF additions and deletions from address-canvassing data (Raim and Gargano 2015, Young et al. 2016) were based on national field-canvassing data and MAF variables and attempted to produce predictive models for block-level changes in MAF due to canvassing, Interactive Review, etc. These models were not highly predictive of block-level counts of MAF adds and deletes, and this may have been because the types of MAF errors that might be partially predictable from MAF variables are of several different types that would occur differently at different geographic locations and would be associated with different kinds of MAF variables. The errors necessarily arise at the level of individual units of living quarters, but when modeled at block level, only the aggregates of MAF variables to blocks can reasonably serve as predictors.

2 New Approaches

The direction of research suggested here is to model MAF adds and deletes at unit address level, in terms of MAF and DSF variables and auxiliary data sources. There are several reasons to prefer unit-level models, which not really to have been undertaken before, for lack of data and manpower resources. First of all, the MAF and DSF predictor variables primarily describe the residential and mail-delivery status of individual addresses, not blocks. The predictive value of address-level information is necessarily diluted if aggregated to block level, so one might expect better prediction accuracy for models at unit level. A second reason to model at unit level is that MAF errors can be distinguished by at least several different characteristics related to the origin and potential detection of the errors: new construction and demolitions can be ascertained either by street-level observation or remote sensing (satellite pictures); changes in residential status related to vacancy are opaque to remote sensing but detectable and possibly predictable through mail-delivery history; subdivision of apartments and other sorts of changes in hidden existing units with ambiguous addresses are again inaccessible to remote sensing but may have indicators from address-level DSF and MAF history; similarly, there may be MAF flags indicative of past and present address-geocoding errors histories. Thus, differences in address characteristics amenable to analysis from MAF history are likely associated with different types and sources of MAF errors. Some such errors may be particularly relevant to the success of specific procedures of in-office canvassing, so a third reason for resolving errors at address level, by type, is the possibility of improving the assessment of quality of those in-office canvassing procedures. This description of address and error types further suggests that MAF longitudinal data about

individual addresses, which has hardly been used in previous modeling approaches, may be a promising big-data resource to be mined for descriptive and predictive variables. This kind of data mining may also involve machine-learning ideas, since appropriately combined and recoded MAF-history variables developed from machine-learning strategies for classification of addresses. Addresses found to have been misrepresented in MAF might be classified in a number of carefully prescribed ways, for example, in terms of status changes (subdivided unit such as garage or basement becoming or ceasing to be living quarters); geocoding error initiation or correction; new construction or demolition; changes in accessibility (e.g., erection of a gate around a neighborhood area or development); protracted vacancy, etc.

The sources of predictor variables will build on the analyses done previously in Virgile (2010), Johnson and Kephart (2013), and Raim and Gargano (2015), relying primarily on MAF and DSF files. Variables used previously will have to be modified to unit-level variables in some cases. In addition, multi-year MAF files will be matched where possible, with the objective of extracting longitudinal histories of variables indicating: interruptions and changes of mail delivery, occupancy changes, indicators of change of accessibility (such as gates, or building locks in the case of multiunit structures), flags of new or corrected geocoding errors, indicators of changes in residency status (such as commercial use, or protracted vacancy), flags indicating new construction or condemned building, and indicators of 'hidden units' by way of changes in the residential status of subdivided units or basements or outbuildings such as sheds or garages.

Models of MAF changes in terms of predictor variables will build on previous work of Raim and Gargano (2015) and Young et al. (2016), incorporating new unit level predictors. Some potential models incorporating the unit-level change models, relevant to the estimation of frame coverage errors for censuses and surveys, will be investigated following ideas initiated in Slud (2014).

3 Timeline and Resources Required

The exploratory analysis and modeling activity suggested here will be heavily dependent on the access of CSRM staff to historical MAF files and help from DSSD staff concerning the meaning and continuity of variable designations over the years. This research would be maximally productive if staff with MAF data expertise in DSSD, GEO and possibly ACS could be consulted on multiple occasions to help develop indicators mirroring MAF errors of various types and could help in the definition of meaningful types. Once the data have been made available, the exploratory effort will be undertaken by 2 or 3 CSRM mathematical statisticians for a period likely running 6 months to 1 year. Deliverable products of this analysis would first include new MAF variable combinations found to be highly associated with errors of specified types: such variables might be developed either through modeling efforts or through mapping of outputs of Machine Learning classification to stand-alone variables. A further outcome of the exploratory analysis would be predictive models for counts of MAF adds and deletes at unit level that might be described and evaluated by aggregating unit-level predictions to block- and higher-level geographic domains.

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