Plans for Measuring Coverage of the 2010 U.S. Census

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Abstract: Coverage evaluation of the two previous United States censuses focused mainly on providing estimates of the net undercount. The initial coverage estimates of Census 2000, based on the Accuracy and Coverage Evaluation Survey, were unacceptable because the survey failed to measure significant numbers of erroneous census enumerations. Research efforts aimed at correcting for these measurement errors have provided ground-breaking information on the source and magnitude of coverage error components. These prompted us to expand the coverage measurement goals for 2010 beyond estimating net error to include estimating individual components of coverage error. Based on our 2000 coverage measurement experience and our new goals for 2010 coverage measurement, we have identified major research issues. We believe these are the most important challenges we face to improve coverage measurement in 2010. This paper briefly summarizes the goals and objectives for coverage measurement in 2010, discusses the motivation for the major research topics and also provides a broad overview of its anticipated design features.[1]

1. Introduction

This paper discusses our current plans for coverage measurement of the 2010 census. We discuss our goals for 2010 coverage measurement and how these differ from the main objective of previous coverage measurement programs. We also discuss plans for how we will begin to address some of our coverage measurement goals in the 2006 census test.

Coverage measurement programs for recent censuses have gone by different names: in 1980 it was called the Post-Enumeration Program (PEP), in 1990 it was called the Post-Enumeration Survey (PES), and in 2000 it was called the Accuracy and Coverage Evaluation Survey (A.C.E.) A major purpose of all these previous coverage measurement efforts was to provide results that could potentially be used to improve the census counts. To this end, the PEP, PES and the A.C.E. programs were designed primarily to provide estimates of the net coverage error in the census. A main purpose for coverage measurement in 2010, however, is to understand how cover error relates to specific census operations, to understand how the operations might be improved to reduce coverage error in the subsequent census. This change in purpose implies a need to provide estimates of components of coverage error, rather than just the net effect of the coverage errors.

To estimate net error, the dual system estimation (DSE) methodology was used by the PEP, PES, and A.C.E. In using DSE we have relied on strict definitions of what information had to be reported for a census enumeration to be considered correct, and on what it meant to be "counted in the right place." Analogous definitions applied to coverage survey cases in regard to whether they had sufficient information and whether a matching census enumeration was in the same area. These strict definitions were suitable for estimation of net coverage error, but led to inflated estimates of the components of coverage error (census omissions and erroneous enumerations). Therefore, expanding the scope of 2010 coverage measurement to include providing estimates of components of coverage errors, as well as the net coverage error, raises new methodological issues. In work for coverage measurement of the 2010 census, we will thus need to develop better methodology for estimating these coverage error components. (Section 4.3 below elaborates on this issue.)

This paper first summarizes what we learned from coverage measurement in 2000. We then turn our attention towards 2010 coverage measurement by outlining the Census Bureau's goals, discussing major research issues, and describing plans for a 2006 test.

2. The 2000 A.C.E. Experience

Coverage estimates of Census 2000 based on the A.C.E. were first produced in March 2001, but there were major concerns with these original results. Evaluations ultimately showed that the March 2001 A.C.E. results failed to identify large numbers of erroneous census enumerations, particularly duplicates. Thus, the March 2001 A.C.E. results substantially overstated the net undercount (ESCAP II, 2001). The reasons behind this and the magnitude of the errors found provide the prime motivation behind our current research plans.

The first indications of problems with the original March 2001 A.C.E. estimates came from comparisons with Demographic Analysis (DA) results. These comparisons showed large discrepancies, with the March 2001 A.C.E. estimating a 3.3 million net undercount and DA estimating a 1.8 million net overcount. These results raised concerns that there was some undiscovered error in either the March 2001 A.C.E. estimates or the DA estimates or both. These concerns could not be resolved before the date the redistricting files had to be released (March 31, 2001), therefore, the census counts were not adjusted for the redistricting files (ESCAP 2001).

Extensive evaluations were conducted over the next six months to examine the reasons for the discrepancy and to determine if other Census 2000 data products, to be released after the redistricting data, should be coverage adjusted. Two planned A.C.E. evaluation programs, the Matching Error Study (MES) (Bean 2001) and the Evaluation Followup (EFU) (Raglin and Krejsa 2001), identified some but not all of the errors in the A.C.E. An

[1]This report is released to inform interested parties of ongoing research and to encourage discussion of work in progress. The views expressed on statistical, methodological, technical, or operational issues are those of the author(s) and not necessarily those of the U.S. Census Bureau.

additional evaluation that was not originally planned, the Person Duplication Study, used computer matching techniques to identify significant numbers of duplicate census enumerations that were not identified by the A.C.E. or by its evaluation studies (Mule 2000; Fay 2001, 2002). Some additional evaluations were conducted to address some other specific concerns, but these studies did not find evidence of further problems. In addition to the A.C.E. evaluations, research was done on the components of the DA estimates, resulting in some significant revisions to the components (particularly to the migration estimates), and a new set of DA estimates (Robinson 2001b). While the revisions to the DA estimates explained some of the discrepancy between the A.C.E. and DA results, the A.C.E. evaluations also revealed that the A.C.E. had failed to measure large numbers of erroneous census enumerations, particularly duplicates. Thus, in October 2001, the ESCAP decided not to adjust the census counts for other Census 2000 data products (ESCAP II, 2001).

The Census Bureau then did further evaluations of the A.C.E., in an effort known as A.C.E. Revision II, which resulted in new Census 2000 coverage estimates. One aspect to this effort involved correcting errors using information from the A.C.E. evaluation data. Combining information from various evaluations, a subsample of the A.C.E. data was recoded, leading to revised estimates via double sampling adjustments. This increased the estimates of erroneous enumerations, reducing the estimated net undercount by 2.4 million persons. Another aspect to the effort involved a Further Study of Person Duplication (Mule 2002b) that provided more detailed results on census duplicates. The DSE methodology was modified to incorporate these results, which also increased the estimates of erroneous enumerations, reducing the estimated net undercount by an additional 2.8 million persons. The duplicate results also lowered the estimate of census omissions, further reducing the estimated net undercount by 1.1 million, while correlation bias adjustments to the estimates (for adult males only) increased the estimate of omissions, raising the estimated net undercount by 1.7 million. Other changes made in A.C.E. Revision II had relatively minor effects. These results and the methodology used for A.C.E. Revision II are discussed in U.S. Census Bureau (2003a).

Although the A.C.E. Revision II results provide the best available estimates of coverage error in Census 2000, it was decided not to use these results to adjust the base for intercensal population estimates. This decision was made due to concerns about limitations of the methodology for correcting the errors in the A.C.E. estimates (U.S. Census Bureau 2003b).

While the A.C.E. Revision II results were not used to adjust the 2000 census, they nonetheless provided ground-breaking information about census coverage error. While A.C.E. Revision II estimated a small overall net overcount, the net overcount was clearly composed of large numbers of erroneous enumerations and omissions. For reasons discussed in Section 4.3, the separate estimates of erroneous enumerations and omissions obtained from the DSE approach as implemented in the 1980 PEP, the 1990 PES, and the 2000 A.C.E, somewhat overstate actual erroneous enumerations and omissions. This occurs, though in an offsetting way that provides reasonable estimates of net error. This situation has prompted us to expand the goals of coverage measurement for the 2010 census beyond just estimating net error to include improving the estimates of the components of coverage error (erroneous enumerations and omissions).

Another major conclusion from the A.C.E. evaluations was that the data collection in Census 2000, the 2000 A.C.E., and even the A.C.E Evaluation Follow-up, did not necessarily produce definitive results about Census Day residence of persons enumerated. We concluded that our interviewing approach to discerning true Census Day residence needs to be researched and revamped. This has implications for both the 2010 census and 2010 CCM.

3. 2010 Coverage Measurement Goals

The focus of coverage measurement of the 2010 census will be considerably different from that of the previous two censuses. Rather than concentrating our efforts on the potential use of coverage measurement results to adjust the census counts, our emphasis will be on evaluating the sources and magnitudes of coverage error components. The general goal is to provide useful information which can be used to improve the quality of future censuses. In brief, specific goals for the 2010 Census Coverage Measurement (CCM) program are:

- to produce improved measures of coverage error components,
- to provide measures of coverage error components for key census operations,
- to again provide measures of net coverage error,
- to provide measures of net error and coverage error components for certain demographic groups and geographic areas, and
- to strengthen the evaluation of the coverage error estimates.

Our most important goal for the 2010 CCM program will be to improve the estimates of coverage error components, that is, the estimates of erroneous census inclusions and census omissions. Based on our 2000 experience, estimates of net error alone do not provide adequate insight into the sources of errors in the census. A.C.E. Revision II showed that a very small net overcount in Census 2000 resulted from large numbers of erroneous census inclusions that were offset by an almost equally large number of census omissions. As discussed elsewhere, however, the estimates of erroneous inclusions and omissions from A.C.E. Revision II were not very precise, being somewhat inflated in a way that did not adversely affect the main objective, the estimation of net error. This was also essentially true of estimates of erroneous inclusions and omissions from the 1990 PES and 1980 PEP. Thus, we feel that additional work is needed to improve the estimation of erroneous inclusions and omissions, to provide more direct information on components of census coverage errors in 2010.

Estimates of detailed types of components of coverage error should help answer questions such as the following:

- How many persons and housing units were missed?
- How many persons were missed because their housing unit was missed?
- How many persons were missed in housing units that were included?
- How many housing units were counted in the wrong location?
- How many persons were included at the wrong residence?
- How many persons were counted in the wrong place because their housing unit was referenced to the wrong geographic location?
- How many persons and housing units were counted more than once; i.e., duplicated?
- How many housing units were counted erroneously for other reasons, such as newly constructed units completed after Census Day?
- How many fictitious persons were included?
- How many persons should not have been included for other reasons, such as born after April 1st, died before April 1st, or moved in after April 1st?
- How many housing units were counted with incorrect occupied or vacant status?

Additionally, as noted above, we would like to understand the relationship between measured components of census coverage error and particular census operations. For example, we would like to determine to what extent duplicated housing units result from a particular address list construction operation and to what extent they result from a combination of address list building operations that overlap. We would also like to measure how successful, in terms of coverage, the census was in following up on persons who did not mail back their census form, that is, how many people who did not mail back their census form were also missed by census nonresponse followup?

Producing estimates of net error in 2010 will continue to be an important goal. Our plans include providing measures of the net coverage error and the differential net coverage error with respect to demographic characteristics. We are also interested in understanding the components of coverage error for these same demographic groups. Estimates of coverage error (net and components) for geographic areas are important to the extent that these would be informative about how a census operation might be improved. Note, however, that we do not view estimating net error for small geographic areas to be as important as in previous censuses because our emphasis will not be on producing results for possible adjustment of census counts.

We anticipate that the estimation of coverage error components by census operations will be a somewhat complex effort. Therefore, it will be critical to develop a comprehensive program to assess and evaluate the coverage error estimates resulting from the 2010 CCM. This will be of particular importance since the production of plausible estimates of the coverage error components will be something new. We also expect that Demographic Analysis will continue to play a major role in the evaluation efforts, both of the 2010 census and the 2010 CCM. Specific goals for the 2010 CCM evaluation program will be developed as plans for the 2010 CCM become more definitive.

Although coverage measurement faces new challenges in meeting its new goals for 2010, one aspect of coverage measurement will become easier: the 2010 CCM program will not be subject to the sort of strict deadlines that prevailed in the last two decades. In 1990 and 2000, because of the potential use of coverage measurement results for adjustment of the censuses, both the 1990 and the 2000 coverage measurement programs had to produce results within legally mandated time periods. The 1990 Post Enumeration Survey was required to have results available by July 1991, just over a year after Census Day. In 2000, the timing became even tighter as the A.C.E. had to produce results by March 2001. The latter date corresponded to release of data for legislative redistricting. It was subsequently concluded, however, that although such a time frame was adequate to conduct and produce coverage results, it was not nearly enough time to fully evaluate the coverage measurement results. Therefore, the 2010 CCM will not be forced to meet such tight deadlines. We will strive to conduct the 2010 CCM and fully evaluate its results in a timely manner so that the results can be used to inform early planning for the next census. This relaxing of the coverage measurement schedule does not, however, preclude adjustment for any purpose. Depending on assessments and evaluations of the accuracy of the 2010 CCM estimates and the 2010 census results, consideration may be given to using the CCM results to adjust the base for the intercensal population estimates.

CCM goals outlined in Singh (2003) mention measurement of the coverage of persons in group quarters facilities, the coverage of the group quarters facilities themselves, and assessment of errors from misclassifications of group quarters facilities as housing units or vice versa. Due to resource limitations, however, it is uncertain at this time what, if anything, we will be able to do to measure coverage error for this segment of the population.

More details concerning the goals discussed here can be found in Singh (2003). These goals were developed without regard to resource, timing, or budget constraints. As we further develop a research agenda and produce a comprehensive plan for 2010 CCM, these goals will likely be revised.

4. Research Issues for 2010 Coverage Measurement

Based on the problems identified with the 2000 A.C.E., and on the new goals we would like to achieve for 2010 CCM, we have identified four broad areas for research:

- improving determination of Census Day residence,
- improving techniques to detect and resolve duplicate enumerations,
- improving methods for measuring the components of coverage error, and
- improving techniques to estimate net coverage error.

These topics are discussed below.

4.1 Improving determination of Census Day residence

The most serious limitation with the 2000 A.C.E. was the ineffectiveness of its person and follow-up interviews in

establishing a person's Census Day residence. In situations where a respondent's true Census Day residence was a place other than the A.C.E. sample address, the A.C.E. interviews often incorrectly indicated that the A.C.E. sample address was the Census Day residence. As a consequence, the A.C.E. failed to detect a large proportion of persons erroneously included in the census because they were a duplicate of another census enumeration. (Note that the A.C.E. could not directly identify such cases as duplicates, but rather had to identify them as erroneous enumerations because their correct Census Day residence was elsewhere.) The difficulties in determining Census Day residence also engendered false P-sample non-matches since such persons were often enumerated–perhaps correctly–at their other residences. The problems with determining Census Day residence led the A.C.E. to underestimate the number of erroneous enumerations and to overestimate the number of census omissions.

In part, these problems stemmed from the difficulty of applying complex residence rules requiring detailed knowledge that some respondents, especially proxy respondents, may lack. The Census Bureau attempts to enumerate each person at his or her "usual residence" on April 1. A person's "usual residence" is defined as the place where a person lives or sleeps most of the time, but no reference period is defined, so "most of the time" has no fixed meaning. Over the years, the usual residence principle has been modified by thirty-one rules which apply to special circumstances. Thus, the rules that determine where a person should be enumerated in the census are complex, and respondents often find them confusing and counter-intuitive, or they have their own ideas regarding who should be considered a resident at a given address. In addition, the rules may not fit certain complex residence situations. Another specific problem was that questions asking respondents about possible alternative residences did not uncover alternative residences sufficiently often.

It is not the role of the coverage measurement program to change the Census residence rules, but rather to implement enhanced data collection efforts to obtain higher quality data on residence. Since coverage measurement will be based on a sample, there is the potential for using more highly qualified and better trained interviewers, and having an interview process that can be more easily controlled. To support accurate estimates of census coverage errors, research is needed to develop improved interview questions about residence, and to study errors inherent in this process–such as recall error and other reporting error.

In addition, because of the difficulties involved in obtaining accurate responses about a person's residence, we do not want to rely solely on the interview results. Instead, a national computer match and followup may be useful for uncovering and resolving potential erroneous enumerations due to duplication. This topic is discussed next.

4.2 Improving techniques to detect and resolve duplicates

Duplication in Census 2000 led to errors in both Census 2000 counts and the March 2001 A.C.E. estimates. Many of these duplicates were likely a result of our inability to collect accurate data on residence in the census or the A.C.E. Some of the duplicates were due to addresses being inadvertently included in the census Master Address File multiple times. Work on A.C.E. Revision II developed methods to identify and estimate the number of duplicates in the census. These methods serve as a starting point for developing a census process to identify and remove duplicates from the census in real-time before the coverage measurement process has begun. For 2010 CCM this implies not only identifying and estimating the number of duplicates remaining in the census, but also evaluating the success that census operations had in identifying and removing duplications.

It must be realized that simply detecting the duplicates is not enough. Methods of correcting for duplicates will need to deal with the issue that it is typically not obvious which member of a duplicate pair of census records corresponds to the person's actual Census Day residence (and is thus a correct enumeration). Enough duplicate records refer to sufficiently different geographic areas to make this a serious issue. Options such as arbitrarily tossing out one member of a duplicate pair at random, or calling both members of the pair one-half of a correct enumeration, also produce errors. Therefore, in regard to evaluating census duplicate removal operations, we should address questions such as, "Was the correct enumeration in a pair of duplicates retained?"

CCM will also face the issue of which record from a census duplicate pair to treat as the correct census enumeration for purposes of coverage estimation. This issue also arises for P-sample records that match census records outside the Dual System Estimation (DSE) search area, leading to uncertainties about how to treat these cases in DSE. These were some of the limitations in the A.C.E. Revision II results noted in U.S. Census Bureau (2003b). Research is needed on methods for reducing this uncertainty.

4.3 Improving methods for measuring the components of coverage error

Another major challenge is to design a coverage measurement survey that accurately measures the components of coverage error as well as the net coverage error. This refers to obtaining accurate estimates of census omissions and erroneous enumerations (EEs). In estimating net census error, the 2000 A.C.E., 1990 PES, and 1980 PEP nominally provided estimates of census omissions and EEs. However, as discussed below, some enumerations whose statuses were uncertain were classified as EEs, though some amount of these surely were correct. And these were balanced in the DSEs by some number of P-sample nonmatches (reflecting census omissions) for which there probably was a corresponding census enumeration, though such matches could not be determined with the available information. The restrictive definitions used in determining omissions and EEs were

appropriate for, and probably improved, estimates of net error. The resulting estimates overstated both census omissions and EEs, though, making these definitions of limited use for estimating the coverage error components.

There are two important situations contributing to the difficulties in estimating coverage error components. First, there were 4.8 million weighted data-defined census records that the 2000 A.C.E. removed from its matching process because they did not meet the A.C.E. criterion of sufficient information for matching and follow up (Feldpausch, 2001). Usually these records had a missing or deficient name. Presumably, many of them corresponded to people who lived at the given address on Census Day and were not counted elsewhere, that is, they actually were correctly enumerated. (Technically, these cases were considered "insufficient information for matching" rather than EEs, but their effects on the DSEs were essentially similar to those of EEs.) Logically, many of these cases also corresponded to P-sample non-matches. In computing net error, little is lost by treating insufficient information cases this way, because the excess EEs and excess nonmatches balance each other. But this causes serious bias in estimates of the components of coverage error.

The second important situation involves the definition of people being enumerated in the "wrong place." For DSE, people found to be enumerated in the wrong place are defined as omissions in the (right) place where they should have been enumerated and as EEs in the (wrong) place where they actually were enumerated. The 2000 A.C.E. and 1990 PES used very restrictive definitions that considered people enumerated in the "right place" only if it was determined that they should have been enumerated in the sample block or in a small "search area" around the sample block (including, for example, one ring of blocks surrounding the sample block). Again, these definitions were appropriate for estimating net error but they exaggerated estimates of omissions and EEs in ways that balanced out. For estimating components of coverage error the definition of "counted in the wrong place" should ideally correspond to the geographic areas for which the errors are being estimated. Thus, for estimating erroneous inclusions in state census counts, "counted in the wrong place" should mean "counted in the wrong state." For estimating erroneous inclusions in county census counts it should mean "counted in the wrong county," and so forth.

In seeking to estimate the components of coverage error, coverage measurement for 2010 faces challenges in dealing with these two situations. In regard to "counted in the wrong place" we must determine not just whether E-sample persons should have been counted in the sample block or a surrounding block, but where they actually should have been counted (except for those who should not have been counted anywhere, that is, non-U.S. residents on Census Day). This information will be needed to develop estimates of EEs and omissions under the alternative geographic definitions of "counted in the wrong place." Assessing the quality of this information will be important. For cases previously considered to have "insufficient information for matching," particularly cases with missing or deficient names, we must investigate procedures and estimation routines that will allow P-sample cases to be matched to them to avoid exaggerating estimates of omissions and EEs. Assessing the quality of the data resulting from these expanded matching procedures will also be important.

4.4 Improving techniques to estimate net coverage error

The post-stratification approach to DSE used to date has some significant limitations. It limits the number of factors or stratification variables that can be included because each factor added to the post-stratification can crudely be thought of as cutting the post-stratum sample sizes in half. (This is due to the implicit estimation of many high-order interactions across factors or stratification variables in the post-stratification.) Fairly standard statistical modeling techniques (for example, logistic regression) offer more flexibility and possibilities for reducing sampling error, synthetic error, and correlation bias in the estimates. Another limitation of post-stratification when coupled with synthetic estimation is that this approach yields uncertainty measures for the estimates that ignore synthetic error, and thus significantly understate the uncertainty in small area estimates. Extensions of statistical models may permit use of detailed data to quantify synthetic error as a variance component to address this problem.

Two other estimation problems surfaced in connection with the 2000 A.C.E. Revision II results. One estimation problem is related to the occurrence of large estimated overcounts for some small places and counties. Research revealed that these could reflect an increase rather than a decrease in synthetic error from the use of certain factors (particularly proxy status) in the E-sample post-stratification that were not used and could not even be tested in the P-sample post-stratification. The empirical question for the A.C.E. Revision II results involves trying to assess, particularly for those persons that were included by proxy responses, how their chances of being missed in the census compared to their census erroneous enumeration rates? Looking ahead, relevant questions involve how to assess these issues generally for factors that might be used in the E- but not the P-sample poststratifications, and the analogous question for variables that might be used in E- but not P-sample logistic regressions or related models.

The other estimation issue involves concerns about uncertainty in the correlation bias adjustments. Correlation bias exists if (within P-Sample post-strata) people missed in the census were more likely (or less likely) to also be missed in the coverage measurement survey. In the "more likely to be missed" scenario, correlation bias results in a downward bias on estimates of census omissions, and hence on the DSEs. In the 1990 PES and 2000 A.C.E. (original results), correlation bias adjustments were avoided out of concerns related to uncertainty about the exact nature of correlation bias (i.e., which post-strata were affected and how much). These decisions were made, however, under an assumption that the number of EEs was much smaller than the number of omissions. In such a setting, not adjusting estimates for correlation bias has the effect of understating the net

undercount. In the presence of overcounts, however, it is possible that without a correlation bias adjustment, the estimate of net error might not even be in the right direction. This was a prime motivation for making a correlation bias adjustment in A.C.E. Revision II. Looking towards the 2010 CCM, with greater emphasis placed on producing estimates of coverage error components, we note that without some type of correlation bias adjustment, estimates of omissions will likely be too low.

For A.C.E. Revision II, correlation bias adjustments were made to DSEs for adult males by age and Black and non-Black race groups based on sex ratios obtained from DA results. Different correlation bias models could have been used that provided identical fits to the available data, but that produced different sub-national results. The demographic detail of the adjustments for males was limited (by that of the DA data used) to Black versus non-Black race groups by age. While it is possible that correlation bias differs according to race/Hispanic origin beyond the Black versus non-Black distinction of DA, or according to other factors (for example, renter versus owner), we had no data to detect such differentials in correlation bias. While some uncertainties about correlation bias are likely to remain empirically unresolvable, others can perhaps be addressed. This includes concerns about correlation bias in estimates for children, as these might be addressed by using DA totals for children rather than sex ratios.

5. Other Issues for 2010 Coverage Measurement

In addition to the four broad research issues just discussed, coverage measurement in 2010 faces further challenges due to potential improvements under consideration for the census and for coverage measurement. This has resulted in two additional general issues to address:

- issues with the timing of the CCM interview, and
- improving techniques for the treatment of movers.

5.1 Issues with the timing of the CCM interview

In the 1990 PES and the 2000 A.C.E., interviewing was scheduled so that it was not in the field in an area at the same time as the census was following up on those cases that had not responded. This was done to maintain independence between the census and coverage measurement operations, this being an important requirement for the DSE methodology. The independence assumption underlying DSE fails if a person's inclusion or exclusion from the census is affected by the coverage measurement interview. This type of failure of the independence assumption is referred to as contamination. Although the 2000 A.C.E. postponed it's personal interviewing until the Census Nonresponse Follow-up was very nearly completed, it did overlap some with the Census's field operation for Coverage Improvement Follow-up and it's centralized telephone Coverage Edit Follow-up. An evaluation was conducted in 2000 to assess any potential contamination of census data that might have arisen from any overlap between the A.C.E. and census operations. This study, by Bench (2002), did not detect any such contamination.

A new coverage improvement effort being investigated for the 2010 Census has implications for the timing of the CCM interview. Research is underway to develop a census process to identify, follow-up, and remove duplicates from the census in real time. This would include a computerized search to identify duplicate enumerations, as well as field follow-up of the duplicates to attempt to determine which record from any duplicate pair corresponds to the person's correct Census Day residence. The erroneous member of the duplicate pair would then be removed from the census.

The timing of this new duplicate detection and removal operation is tentatively scheduled for a July through September timeframe. This raises a major issue for coverage measurement in 2010 in regard to maintaining independence of the census and the coverage measurement operations. The issue is whether coverage measurement interviewing should be postponed until September or later when the field work for this census unduplication operation is finished? Doing so would help to avoid contamination by preventing overlap of the census unduplication operatrions and the CCM Person Interview, but it could increase reporting errors for CCM due to the longer elapsed time between Census Day and the CCM interview. Conversely, while beginning CCM interviewing earlier should reduce reporting errors, it would raise concerns about potential contamination from overlap of the census unduplication operations and CCM interviewing. The question is how much will conducting a CCM interview at a given address before the census conducts its coverage improvement interview at that address affect the responses provided to the census coverage improvement questions? The actual effect on tabulated census results should be very small since, (1) only census duplicates would be affected, which should be a small percentage of the population, and (2) the CCM interviewing is done for only a sample that is also a small percentage of the population. The concern about contamination is more for the CCM results, since they depend on tabulations from the CCM sample cases (E-and P-samples). The DSE methodology fundamentally assumes that probabilities of being included in the census for persons covered by the CCM sample (residents of the CCM sample block clusters) are the same as for persons outside the CCM sample, an assumption that would be violated by contamination.

5.2 Improving techniques for the treatment of movers

The 1990 PES used a procedure referred to as PES-B for its treatment of persons who moved between Census Day and the PES interview. (PES-B was also used in the 1980 PEP.) This mover procedure asked respondents who was living at the sample address at the time of the interview and where they lived on Census Day. No special treatment was needed for persons who lived at the same address on both PES Interview Day and Census Day (nonmovers). For persons who moved from another address (outside the sample block) on Census Day to the sample address on PES Interview Day (inmovers), the matching operations attempted to find the inmovers in the census at their reported Census Day address (or surrounding search

area.)

Another mover procedure, that has been used mainly in tests, is referred to as PES-A. This mover procedure asks respondents who was living at the sample address on Census Day. With PES-A no P-sample cases require special treatment in matching since all are reported as being Census Day residents. The difficulty here involves data collection for those persons who moved from the sample address on Census Day to some address (outside the sample block) by Interview Day. For these cases, known as outmovers, data must often be collected from proxy respondents, such as neighbors or landlords (except for individuals who moved out of a household some members of which remain at the address on Interview Day).

There are advantages and disadvantages associated with either of these procedures for handling movers. A disadvantage with PES-B in 1990 involved difficulties in obtaining accurate address information for some inmover's Census Day residences. This led to difficulties in trying to locate these addresses geographically, and consequently to difficulties in trying to match these cases to the census. The geocoding operation in 1990 was extremely cumbersome, leading to quite a few inmovers with unresolved match status. This led to uncertainty about whether nonmatched inmovers were actually missed by the census or whether they were not matched only because their reported Census Day address could not be correctly located so that the correct geographic area could be searched for a matching census record. A major disadvantage with the PES-A mover procedure is the need to rely on proxy data for outmovers, since proxy reports are notoriously error-prone. It also leads to a larger amount of missing data both because knowledgable proxy respondents cannot always be found (leading to noninterviews), and because other times proxy respondents cannot provide sufficient information on persons so that they can be matched to the census. The main advantage of PES-B is the greatly reduced reliance on proxy data. The main advantage of PES-A is the less error-prone operations involved with the matching of outmovers compared to inmovers.

The 2000 A.C.E. used a mover procedure referred to as PES-C that was a hybrid of the PES-B and PES-A procedures. The PES-C procedure asked who was living at the sample address at the time of the A.C.E. interview and who was living at the sample address on Census Day. Match rates were then estimated separately for P-sample nonmovers and P-sample outmovers. As with PES-A, data collection for outmovers often had to rely on proxy respondents. (In the 2000 A.C.E. outmovers had a proxy respondent rate of 75 percent and an unresolved rate of 18.5 percent, compared to much lower rates for nonmovers of 3.1 percent proxy and 1.7 percent unresolved (Liu, 2001).) PES-C did not have to match the inmovers as did PES-B. Instead, for estimation, PES-C multiplied the estimated outmover match rate by the weighted number of inmovers to obtain an estimate of the number of mover matches. The theory behind this approach was that the inmover data provided a better estimate of the number of movers than did the outmover data, and that the outmover match rate was, despite the number of proxy responses and the amount of missing data, a valid estimate of the true outmover match rate.

PES-C was used in the 2000 A.C.E. not so much because it was believed to be better than PES-B, but for some practical reasons. The Census Bureau's initial plans for Census 2000 included sampling for nonresponse follow-up (NRFU) – following-up only a sample of cases for which a questionnaire was not received by mail. Sampling for NRFU created some matching challenges for coverage measurement. If a P-sample person did not match to a census enumeration this could be because the census missed that person, or it could be because that person was not reported in the mail response and their housing unit was not included in the NRFU sample. This problem could be addressed for nonmovers by doing 100 percent NRFU in the coverage measurement sample blocks, but it could not be addressed for inmovers, who could have been resident anywhere in the country on Census Day. This caused complications for PES-B, and PES-C was chosen as the solution to this problem. In 1999 the Supreme Court ruled that sampling for NRFU violated the census act, so sampling for NRFU was dropped. However, at this point it was too late to change the mover procedure, and so PES-C was used in the 2000 A.C.E.

In general, we believe that the reliance on proxy data under PES-A or PES-C is more of a problem than the difficulties in matching inmovers under PES-B. Therefore, for the 2010 CCM, we plan to go back to the PES-B procedure. Additionally, advances made in computerized geocoding of addresses and in computerized matching should allow us to improve the matching of inmovers relative to what was done in the 1990 PES.

5.3 Other research issues

Other general areas of research for 2010 coverage measurement which could prove beneficial but are not discussed here include research on the use of administrative records data in coverage measurement, and research on improvements to the DA estimates.

6. Plans for the 2006 Coverage Measurement Test

Historically, each decade, the Census Bureau conducts a series of test censuses to examine the efficacy of census methodological innovations. In the 2006 test we will undertake a coverage measurement program that addresses the goals that have been set for the decade-long program.

The purpose for including coverage measurement in the 2006 Census Test is not to evaluate the effectiveness of the census methodology being tested in 2006, but rather to begin testing and figuring out how to implement improved methods for measuring coverage in 2010.

Additionally, we will not be addressing all of our research goals in the 2006 test. We need to concentrate on issues that demand relatively long-term periods of research. For instance, we need to test any major changes to our residency questions as more lead time is needed to incorporate new questions into an automated interviewing instrument.

For the 2006 CCM Test we will address the first three research issues: concentrating on a person's Census Day residence, duplicates and components of coverage error. For the components of coverage error this means addressing our ability to match persons with insufficient information and also to collect address information for persons that are not a resident at the sample address on Census Day. For purposes of estimating net error in 2000, it was only necessary to determine whether the sampled address was the person's correct residence and not where the person should have been counted. This plan addresses these issues but only for persons in housing units, thereby excluding coverage of housing units. (As mentioned above current plans do not address coverage error for the group quarters population.) The focus is only on persons in housing units because of budget and other resource constraints and because the motivation behind the first two challenges was a direct consequence of problems identified with the person coverage estimates in 2000. Note that there were no major problems identified with the 2000 A.C.E. estimates for housing unit coverage. Even without the budget constraints, resources and timing do not allow us to address coverage of the group quarters.

Estimating the components of coverage error is a new feature for 2010 and it will require new methods. This will be a first attempt to collect additional information to determine where a person should have been counted and to match to census enumerations having a missing or deficient name or not enough data characteristics.

This plan also addresses two important design questions: 1) when, with respect to other census operations, the CCM interview should be conducted and 2) how to deal with persons who have moved since Census Day. It is important to concentrate on these issues in 2006 because they have major implications on the overall design of the coverage measurement survey. If there are any changes needed, we would like the opportunity to test them first in 2008.

These challenges for the 2006 test have major implications for data collection and for the matching operations. Developing these two aspects of the survey process are two of the main objectives. We need to address improvements in the data collection and matching effort that will allow for a more accurate determination of a person's census day residence, determination of the address of the person's residence if it is not at the sampled address, a more accurate identification of persons that are duplicated in the census, and additional data to determine if inmovers are included in the census. For the CCM test we will collect data for inmovers at the sample address and attempt to match them to where they were living on Census Day. (For the 2000 A.C.E., we collected data for outmovers and attempted to match them to the sample block and surrounding area.) The third objective is to address the timing of the CCM interview. This requires assessing the potential contamination that could arise from an early CCM Person Interview. These objectives and their implications on the 2006 CCM design are discussed next.

Objective 1: Design and test data collection methods

This entails designing data collection methods for the Person Interview and Person Followup interviews. The interviews must allow us to determine whether census enumerations and omissions were counted correctly at various levels of geography. This new geographically-oriented information is needed to support sufficiently accurate estimation of coverage error components as well as the net coverage error. The data collection effort will also be designed to support the treatment of movers in estimation which will use the persons who have moved into the sampled address. For the 2006 CCM we will test changes in data collection methods to:

- ask additional questions in the rostering to probe for persons who might not be included to help identify omissions
- collect additional information about other possible places where a person may have been counted to improve the determination of the person's true Census Day residence–especially for inmovers and for people with multiple addresses
- collect information on the addresses of other potential residences and where the address is located such as state, county or even cross streets.
- automate the Person Followup interview to improve ease of interview and resulting data quality, including potential automated coding of interview results

The data collection effort will involve changes to both the Person Interview and the Person Followup interview that is conducted after the initial matching effort. We anticipate highly complex data collection instruments that will include additional batteries of questions dealing with establishing Census Day residency and complicated skip patterns. Data collection will need to address complex living situations, account for alternative living arrangements/locations, and probe for address information for persons who might have moved since Census Day. For these reasons, the data collection instruments will be automated for both the Person Interview and the Person Followup interview. The automation of the Person Follow interview is a new feature. It is important to test the functionality of such a complex instrument in a field environment.

Objective 2: Design and test matching methods

This involves designing computer and clerical matching methods to match CCM person data to census person data to measure the coverage of the census. For CCM persons who have moved-in, their coverage will be measured by matching to their Census Day address. For the 2006 CCM we will test changes to the matching methods to:

- incorporate the additional information, such as alternative addresses or previous addresses for inmovers collected in the Person Interview and Person Followup interview to identify census omissions, erroneous inclusions and correct Census Day residence. This will involve attempting to match and find persons at many different locations. The matching in 2000 was only in the sampled block or surrounding area.

- determine the correct vs. erroneous enumeration status for more of the "insufficient information" persons, e.g., persons with a missing or incomplete name for purposes of estimating more accurate coverage error components.
- extend the automated match and duplicate search from the local area (block and surrounding block) to the site level also for purposes of improving estimates of the coverage error components
- incorporate/examine duplicates identified by the census real-time unduplication operation to determine if the census is removing the appropriate person
- extend the automated and clerical match to search for persons that the census may have mistakenly deleted to begin to gain an understanding of how coverage errors relate to the census operations.

The matching will need to be expanded to the national (site) level to identify person duplicates, people enumerated at the wrong place, and to help match movers to their Census Day residence. The automated national matching is the first step of this process. Some of the (possibly) matched cases will be complemented by a computer-assisted clerical match to allow for greater accuracy. In the case of people with a missing or incomplete name, the clerical component is particularly critical to determine if a person corresponds to a census enumeration with.

Objective 3: Determine if conducting the CCM Person Interview as soon as Census nonresponse followup is complete in a sample area adversely affects the census data.

This objective is to assess the potential contamination of census data that could arise from conducting the CCM Person Interview under the same timing that was used by A.C.E. in 2000. Although no contamination was detected in 2000, there is a new coverage improvement operation under consideration for the 2010 Census that needs to be reflected in the evaluation. This is important because the new census operation includes a field followup of potential duplicate enumerations to obtain their correct Census Day residence which may be influenced by CCM. The question is how much will conducting a CCM interview before the census conducts its coverage improvement interview affect the responses provided to the census coverage improvement questions and the subsequent census results. The 2006 CCM Test will begin interviewing after the census nonresponse followup is completed in a sample area but before the census completes its coverage improvement followup. We will then be able to conduct a study to determine if the census results were contaminated.

One aspect of the study may compare census results between the CCM sample blocks and neighboring nonsample blocks. There are discussions of other approaches for evaluating contamination. The precision of such a study is dependent on the sample design, the number of sample blocks and the extent of census coverage follow up in the CCM sample blocks and the neighboring blocks.

Additional Plans for the 2006 CCM

Although not a key objective for the 2006 CCM Test, an important aspect of our plan is to form pseudo-estimates of person coverage error including the net error and the components. This will serve two main purposes. First, this will be our attempt at trying to collect data on where persons should have been counted and also our first attempt for estimation purposes of using any matches to census enumerations which have inadequate name information.

Developing pseudo-estimates of coverage error components will allow us to examine whether sufficient and consistent data are being obtained. Second, this will allows us to test the estimation requirements for census data. For 2010, one of the new coverage measurement goals is to provide information that can be used to improve future censuses. This will require obtaining more data about specific census processes that we have not traditionally dealt with. It will be particularly important to develop estimation models with this data in mind. Since it is not the purpose of the 2006 CCM Test to actually evaluate the census test, we are not requiring that these pseudo-estimates be representative of the site. The sample design and any adjustments for missing data will likely be very simple. There are no plans to even attempt estimating variances.

A critical aspect of the 2006 CCM Test will focus on the effectiveness of integrating the operations needed to carry out the above objectives. Besides coordinating the matching and data collection requirements and software, these all need to be integrated with the typical activities necessary for managing and implementing a large sample survey. These activities include control and transmission of data from one operation to the next. It is also extremely important that the CCM operations are compatible with the actual census taking operations. We will need to analyze and assess the performance of these operations.

References

Bean, Susanne L. (2001), "ESCAP II: Accuracy and Coverage Evaluation Matching Error." Executive Steering Committee For A.C.E. Policy II, Report No. 7., October 12, 2001. Census Bureau, Washington, DC.

Bench, Katie (2002), "Contamination of Census 2000 Data Collected in A.C.E. Blocks," PRED Accuracy and Coverage Survey Evaluations #N1, U.S. Bureau of the Census, October ??, 2001.

ESCAP (2001), "Report of the Executive Steering Committee for Accuracy and Coverage Evaluation Policy," March 1, 2001.

ESCAP II (2001), "Report of the Executive Steering Committee for Accuracy and Coverage Evaluation Policy on Adjustment for Non-Redistricting Uses," October 17, 2001.

Fay, Robert E. (2001), "ESCAP II: Evidence of Additional Erroneous Enumerations from the Person Duplication Study," Executive Steering Committee for A.C.E. Policy II, Report 9, Preliminary Version, October 26, 2001.

Fay, Robert E. (2002), "ESCAP II: Evidence of Additional Erroneous Enumerations from the Person Duplication Study," Executive Steering Committee for A.C.E. Policy II, Report 9, Revised Version, March 27, 2002.

Feldpausch, Roxanne, (2001), "E-Sample Erroneous Enumerations Analysis," ESCAP II Report #5, U.S. Bureau of the Census, October 14, 2001.

Hogan, Howard (2002), "Five Challenges in Preparing Improved Post-Censal Population Estimates," DSSD A.C.E. REVISION II MEMORANDUM SERIES PP-1, January 25, 2002. Census Bureau, Washington, DC.

Hogan, H., Kostanich, D., Whitford, D., and Singh, R. (2002), "Research Findings of the Accuracy and Coverage Evaluation and Census 2000 Accuracy," American Statistical Association Joint Statistical Meetings, 2002 Proceedings of the Section on Survey Research Methods.

Kostanich, D. (2003a), "A.C.E. Revision II: Design and Methodology," DSSD A.C.E. REVISION II MEMORANDUM SERIES #PP-30, U.S. Bureau of the Census, Washington, DC.

Kostanich, D. (2003b), "A.C.E. Revision II: Summary of Methodology," DSSD A.C.E. REVISION II MEMORANDUM SERIES #PP-35, U.S. Bureau of the Census, Washington, DC.

Kostanich, Donna L., and Dawn E. Haines, (2003), "Census 2000 Accuracy and Coverage Evaluation Revision II," American Statistical Association Joint Statistical Meetings, 2003 Proceedings of the Section on Survey Research Methods

Liu, Xijian Jim, (2001), "Analysis of Movers," ESCAP II Report #15, U.S. Bureau of the Census, October 2, 2001.

Mule, Thomas (2001), "ESCAP II: Person Duplication in Census 2000," Executive Steering Committee For A.C.E. Policy II, Report No. 20., October 11, 2001. Census Bureau, Washington, DC.

Mule, Thomas (2002a), "Revised Preliminary Estimates of Net Undercounts for Seven Race/Ethnicity Groupings," DSSD A.C.E. REVISION II MEMORANDUM SERIES PP-2; U.S. Bureau of the Census; April 4, 2002.

Mule, Thomas (2002b), "Accuracy and Coverage Evaluation Revision II: Further Study of Person Duplication," DSSD A.C.E. REVISION II MEMORANDUM SERIES PP-51, U.S. Bureau of the Census, December 31, 2002.

Mule, Thomas (2003), "A.C.E. Revision II Results: Change in Estimated Net Undercount," DSSD A.C.E. REVISION II MEMORANDUM SERIES PP-58, U.S. Bureau of the Census, March 4, 2003.

Mulry, M. and Petroni, R. (2002), "Error Profile for PES-C as Implemented in the 2000 A.C.E.," American Statistical Association Joint Statistical Meetings, 2002 Proceedings of the Section on Survey Research Methods.

Raglin, David A. and Krejsa, Elizabeth A. (2001) "ESCAP II: Evaluation Results for Changes in Mover and Residence Status in the A.C.E." Executive Steering Committee For A.C.E. Policy II, Report No. 16., October 15, 2001, Census Bureau, Washington, DC.

Robinson, J. Gregory (2001a), "Accuracy and Coverage Evaluation Survey: Demographic Analysis Results," DSSD Census 2000 Procedures and Operations Memorandum Series B-4*, March 2, 2001.

Robinson, J. Gregory (2001b), "ESCAP II: Demographic Analysis Results," Executive Steering Committee for A.C.E. Policy II, U.S. Bureau of the Census, Report 1, October 13, 2001.

Shores, Roger (2003), "A.C.E. Revision II: Adjustment for Correlation Bias," DSSD A.C.E. REVISION II MEMORANDUM SERIES PP-53, U.S. Bureau of the Census, March 4, 2003.

Singh, Rajendra P., (2003), "2010 Census Coverage Measurement – Goals and Objectives (Executive Brief)," DSSD 2010 CENSUS COVERAGE MEASUREMENT MEMORANDUM SERIES #A-1, U.S. Bureau of the Census, October 1, 2003.

U.S. Census Bureau (2003) "Technical Assessment of A.C.E. Revision II," available at http://www.census.gov/dmd/www/pdf/ACETechAssess.pdf, March 12, 2003.

U.S. Census Bureau (2003) "Decision on Intercensal Population Estimates," available at http://www.census.gov/dmd/www/dipe.html, March 12, 2003.