

CENSUS 2000 DRESS REHEARSAL METHODOLOGY AND INITIAL RESULTS

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1 Introduction

The U.S. Bureau of the Census conducts a census of population and housing units every ten years. Counting every person is important as the census is used to apportion the seats in Congress among the states, to allocate billions of dollars of federal funds, and for future planning by federal and private agencies. Yet the census has been afflicted by two serious problems in recent decades. First the price of the census has increased markedly. The 1990 Census cost \$2.6 billion; in constant 1990 dollars, the four censuses from 1960 to 1990 cost \$9, \$11, \$20, and \$25 per household, respectively (National Research Council 1995). The 2000 Census is projected to cost much more. As will be discussed in the next section, much of this increase is due to the fact that fewer people have been returning their census questionnaires.

The second problem involves the census counts themselves. For the past six censuses, the Bureau has evaluated errors in census counts--measuring people who were missed and others who were enumerated erroneously. The evaluations have shown a net undercount for the total population, and a differential net undercount among demographic groups. For example, the Bureau estimated that in the 1990 Census 1.6 percent of all people were missed, but that 4.4 percent of all Blacks were missed, as well as 5.0 percent of all Hispanics.

To address these problems, during the 1990's the Bureau of the Census developed methods for conducting the census that rely on sampling and estimation procedures. First, instead of visiting all housing units that did not respond, our plan was to select a large sample of them and visit only those in the sample. A second component of the new procedures was called the Integrated Coverage Measurement (ICM). This quality check survey and operation, similar to the Post Enumeration Survey conducted after the 1990 Census but larger in scope, would allow us to estimate the net undercount for various demographic groups and to adjust the census counts--thereby eliminating or greatly reducing the differential net undercount among the groups.

In 1998 the Census Bureau conducted a dress rehearsal in three sites. According to an agreement

between the Congress and the Department of Commerce, we applied the planned sampling techniques in two of the sites--Sacramento, California, and Menominee County, Wisconsin. In the third site, the city of Columbia, South Carolina and eleven surrounding counties, sampling procedures were not used. However, a post-enumeration survey was conducted there to measure the net undercount. This paper discusses the methodology used in the Dress Rehearsal and presents a brief summary of selected results in the three dress rehearsal sites.

On January 25, 1999, the Supreme Court ruled against the use of sampling in the 2000 Census for the apportionment counts, but left open its use for all other purposes. Thus, the Census Bureau will follow up all nonresponding households in 2000, but will conduct a quality check survey to estimate and adjust for the undercount--for purposes other than apportionment.

In Section 2 we present the methodology and results for the initial phase of the census--including sampling for nonresponse follow-up. Section 3 provides a discussion and some results from the ICM phase.

2 The Initial Phase

Since the 1970 census, most people have been mailed or given a questionnaire, and asked to mail it back. To each household that does not return a questionnaire by mail, the Bureau sends an interviewer to collect the information. This 100% follow-up of the nonresponding households has been a major factor in the increase in census cost as more and more households require follow-up with a personal visit. The response rate for the mail questionnaire declined from 78% in the 1970 Census, to 75% in 1980, to 65% in 1990 (National Research Council 1995). To address the issue of declining response rates and increased costs, the Bureau developed a plan to sample the nonresponding households.

To begin the initial phase of the Dress Rehearsal the Census Bureau prepared a list of addresses in the three sites and delivered census questionnaires by mail or in person to all housing units on the list. The U.S. Postal Service returned some of the questionnaires as "undeliverable as addressed." In addition, we did not receive questionnaires back from many of the remaining housing units. The Bureau conducted a field follow-up of nonresponding housing units and postal returns. As is seen below, the procedures differed according to the site.

2.1 Sampling for Nonresponse Follow-up (NRFU)

In Sacramento, California, from those households that did not return a census form, we selected a sample and conducted a personal interview. Although the Bureau applied sampling techniques in Menominee County, Wisconsin, during the Dress Rehearsal, most of the Menominee site is an Indian reservation. On Indian reservations our sampling plans called for personal follow-up visits to *all* the nonresponding housing units. In South Carolina, we also conducted follow-up with all nonresponding units--as is the general rule under a traditional census.

In Sacramento, the sample of nonresponding housing units was selected separately in each census tract. The goal was to achieve a completion rate of 90% or higher in each tract. For example, if the initial response rate in a tract was 70%, then the sampling rate among nonrespondents would be 2 in 3. In general, if the initial response rate was 85% or higher, we sampled 1 in 3. Thus the sampling rate depended on the initial response rate, and varied by tract; as the response rate increased, our sampling rate in that tract generally decreased. Note, however, that we followed up all nonrespondents in blocks selected for the Integrated Coverage Measurement sample. (See Section 3.1.)

Immediately after the cut-off for mail returns, the nonresponding housing units were sorted within the tract by geography and form type (long vs. short form). Then a systematic sample was selected. This ensured that the sample was distributed evenly across the tract.

The population characteristics of the remaining nonresponding households--those not selected in the sample--were imputed using a hot-deck procedure based on information collected from sampled nonrespondents in the same census tract. (This was also true for housing units selected in the NRFU sample that were nonrespondents again in the follow-up.) The procedure was designed to reduce bias in estimation and to ensure that the hot-deck population estimates agree in expectation with simple weighted estimates at the tract and higher levels of geography. Occasionally a census form was returned after NRFU sample selection. The information from these forms was not discarded; rather an appropriate adjustment to the estimation methodology was made to accommodate late forms.

2.2 Sampling the Undeliverable-As-Addressed (UAA) Vacant Returns

In the Sacramento site, we selected a sample of the UAA vacant housing units for personal visits to check whether the housing unit was actually vacant. As was the case with nonresponse follow-up, there was no UAA

sampling operation in Menominee or South Carolina. In Menominee, Census Bureau staff initially left questionnaires at all existing housing units; because the U.S. Postal Service did not deliver questionnaires, there were no UAA vacant returns there. As was mentioned earlier, in South Carolina we conducted a traditional census.

The Bureau selected a systematic sample of UAA vacant units as identified by the U.S. Postal Service at a 3-in-10 rate. This rate was the same in each tract, regardless of the number of returns. Before selecting the sample, the vacant returns were sorted by geography and form type (long vs. short) within an eligible tract. The sampling for NRFU and UAA vacants was done simultaneously but independently within separate sampling strata for NRFU units and UAA vacants. The characteristics for UAA vacant units not selected into the sample were imputed based on sample cases in the same census tract.

2.3 Results of Sampling for NRFU and UAA in Sacramento

Table 1 below presents some results for the initial phase in the collection blocks in Sacramento (Memo. [1]).

Table 1. Sacramento, CA: Housing Unit Frequencies in Collection Blocks

Occupied Housing Units	Total	% of Total
Total	151,732	100.00%
Total respondents	138,271	91.1%
By mail	90,156	59.4%
In NRFU sample	48,115	31.7%
Imputed	13,461	8.9%

On a person basis, in Sacramento 24,930 people were imputed into nonresponding housing units based on the NRFU sampling and estimation operations. Similarly, 2,409 people were imputed into UAA addresses. As noted earlier, we followed up all nonresponding units in the Menominee and Columbia sites.

3 Integrated Coverage Measurement (ICM) and Post Enumeration Survey (PES)

To reduce the differential net undercount, the Bureau conducted the ICM in Sacramento and Menominee and

adjusted the initial-phase counts. Essentially the same design was implemented in South Carolina in what was called the Post Enumeration Survey (PES). The goal in South Carolina, however, was to measure the net and differential net undercount without making adjustments to the counts. *Unless otherwise specified*, whenever we refer to the ICM, our statements refer to the ICM conducted in Sacramento and Menominee *as well as* the PES in South Carolina.

3.1 Sampling in the ICM (PES)

The ICM sample was a stratified systematic sample of clusters of geographically contiguous housing units. To select the sample, we first formed block clusters by combining adjacent blocks with at least three housing units but no more than 79. All other blocks were defined as block clusters by themselves.

Next we formed sampling strata by grouping block clusters into homogeneous groups based on the 1990 Census demographic characteristics of the block clusters. The stratum definitions corresponded to major demographic groups such as the proportion of certain race or ethnic groups and the proportion of renters--known to be traditionally undercounted. These strata were formed within each group of clusters based on their sizes--small (0-2 housing units), medium (3-79 housing units), and large (80 or more housing units) clusters. In the third step we selected sample clusters using proportional allocation and systematic sampling.

In the fourth step Census Bureau field staff listed the sample block clusters independently, that is, without the use of any census address lists. If a selected cluster had fewer than 80 housing units in the independent listing, all were retained for ICM interviewing. If the cluster had 80 or more housing units it was divided into segments and one or more of these segments were selected randomly. This was done to make the interviewer work load more efficient and to improve the efficiency of the design by reducing the clustering effect. Other adjustments to the sample were also applied to bring field listing workloads in line with expectation. A sample of block clusters was selected for each site. The summary statistics of the ICM samples by site are given in Table 2.

3.2 Interviewing Results

Census Day in the Dress Rehearsal was April 18, 1998. ICM telephone interviewing started May 15, and the personal visit (door-to-door) interviewing started on June 2; interviewing was completed on September 3, 1998. Computer Assisted Personal Interviewing (CAPI) was used for the ICM sample households.

The "Census-day" noninterview rate for the P sample

Table 2. Summary of the ICM (PES) Sample: Clusters, Housing Units, and People

	Sacramento	Menominee	South Carolina
No. of Clusters	390	21	674
No. of P-sample HUs ¹	16,419	794	17,677
Interviewed	14,322	409	14,972
Nonint'v'd	765	7	822
Vacant or deleted HUs	1,332	378	1,883
No. of P-sample people ¹	35,509	1,233	35,018

¹ See section 3.3 for a definition of the P sample.

is defined as the number of noninterviewed housing units--based on the Census-day status of the housing unit--divided by the number of P-sample housing units. These rates were 4.7% in Sacramento, 0.9% in Menominee, and 4.7% in South Carolina.

To evaluate the procedures for households that moved into P-sample housing units *after* Census day, we define "interview day" noninterview rates. The numerator here is the number of noninterviewed units based on the status of the housing unit *on the day of the ICM interview*. These rates were 2.0% in Sacramento, 0.1% on Menominee, and 1.6% South Carolina.

3.3 Dual System Estimation in the ICM (PES)

Estimation in the ICM entailed three major steps--dual system estimation, post-stratification, and raking. A brief description of each is given in the following subsections. Dual system estimation (DSE) is based on capture-recapture methodology. Consider only those housing units contained in the sample block clusters selected for the ICM. Within these clusters we define the units enumerated in the initial phase as the E sample, and those enumerated in the ICM as the P sample. After the ICM field work was completed, the Census Bureau tried to match all P-sample persons to E-sample persons. Each person is classified in one of three ways, according to whether he or she is matched (included in both enumerations), included in only the census enumeration (only in the E sample), or included in only the ICM enumeration (only in the P sample). Table 3 demonstrates the possibilities.

Table 3. Enumeration in the Census and in the ICM

ICM Enumeration (P Sample)	Census Enumeration (E Sample)		Total
	In	Out	
In	N_{11}	N_{12}	N_{1+}
Out	N_{21}	(N_{22})	(N_{2+})
Total	N_{+1}	(N_{+2})	(N_{++})

Note that N_{11} , N_{12} , and N_{21} , and thus also the marginals N_{1+} and N_{+1} , are observed after we match the P and E samples. The cell entry N_{22} and all sums derived using N_{22} are unobserved (and placed in parentheses). If we assume that the two enumerations are conducted independently, then the interior frequency N_{11} / N_{++} should be approximately equal to the product of the marginal frequencies $(N_{+1} / N_{++}) \times (N_{1+} / N_{++})$. In that case, we can estimate the unknown total as $N_{++} = N_{+1} \times N_{1+} / N_{11}$. Note that, for any person, the probabilities of enumeration in the initial phase and in the ICM need not be the same. However, the enumerations must be conducted independently.

To this point, the numbers in Table 3 refer to counts or estimates in the ICM sample block clusters. But because the ICM clusters are a representative sample of the appropriate site, we apply the sample weights to get an estimate of the total population of the site. In the DSE model above, N_{1+} represents the number of people enumerated in the ICM (the number of P-sample people). N_{11} is the number of people enumerated in the initial phase and in the ICM, that is, the number of matches between the P and E samples. Then the ratio of weighted totals N_{1+} / N_{11} is the inverse of the weighted match probability among P-sample people.

The weighted estimate N_{+1} is the number of distinct and identifiable census persons (E-sample people), also called the official census count. The official count, however, includes imputed persons and people who are erroneously enumerated. People are imputed when a census enumerator confirms that a certain number of people live at an eligible address, but insufficient additional information can be gathered. Erroneous enumerations include people who should not be counted at that address, for example, because they should be counted elsewhere, such as in a college dormitory, or because their residence is actually at a different address. To correct for these situations, in place of N_{+1} in the formula above, the Bureau subtracts the number of whole-person imputations and multiplies by the proportion of correct enumerations (1 minus the rate of

erroneous enumerations, as estimated in the E sample).

In Table 4, for matches, imputed persons, and erroneous enumerations, we display the aggregate rates as measured across each site.

Table 4. Rates Used in the Dual System Estimate

	Sacra- mento	Meno- minee	South Carolina
Rate of matches	78.1%	82.9%	74.1%
Rate of imputed persons	7.4%	7.6%	5.6%
Rate or erroneous enumerations ¹	10.5%	9.7%	13.7%

¹ Duplicates, geocoding errors, fictitious persons, illegible names, etc.

It should be noted, however, that the rates are applied at more detailed levels in the actual estimator. In the Dress Rehearsal, these rates were estimated at the site level from information gathered *within the ICM clusters*. For example, follow-up operations were used to determine erroneous enumerations by identifying duplicates, geocoding errors, fictitious persons, and illegible names. Other adjustments are made to the estimator above to account for specific aspects of the ICM operations. For example, different procedures must be applied in the case of households where the census-day residents moved out before the ICM enumeration. This allows us to obtain a more precise estimate of the number of P-sample people and matches in the ICM.

Because capture probabilities are not equal for all members of the population, we try to partition the population into groups (post-strata) such that coverage probabilities are similar for all members in a post-stratum but different in different post-strata. The dual system estimates are then calculated separately in each post-stratum. In the Dress Rehearsal we formed post-strata based on combinations of tenure, race, ethnicity, age, and sex--all done separately within each of the three sites.

For a given post-stratum, the coverage factor is defined as the ratio of the dual system estimate divided by the census count. This coverage factor allows us to compute small-area estimates at the block level using an approach called synthetic estimation. For people satisfying the characteristics of the post-stratum, the block-level estimate (for these people) is obtained by multiplying the corresponding census count by the post-stratum coverage factor. A controlled rounding procedure is then applied to obtain integer person

estimates. For information on these and other more intricate aspects of the dual system estimator as applied to the 1990 Post Enumeration Survey, see Hogan (1993).

3.4 Post-strata and Raking

As mentioned in section 3.3, dual system estimates were to be computed for 84 predefined groups, or post-strata, as given by cross-classifying the following:

Race-ethnicity (6 groups): Hispanic; and non-Hispanic groups of the races black, Asian, American Indian, Hawaiian or Pacific Islander, and white and all others.

Age-sex (7 groups): male or female, 0 - 17; male, 18 - 29; female, 18 - 29; male, 30 - 49; female, 30 - 49; male, 50 and over; female, 50 and over.

Tenure (2 groups): owner, renter.

These post-strata were required to have a minimum population size; if not, groups were collapsed according to predefined criteria. Because of differing racial and ethnic compositions in the dress rehearsal sites, some post-strata were collapsed in each of the three sites. (See Memorandum [3].) However, the two tenure groups--owner and renter--were never collapsed together.

In Sacramento, American Indians, Hawaiian and Pacific Islanders, and Hispanics were placed in one group, but all age-sex and tenure categories were retained throughout the site. This produced 56 (rather than 84) final post-strata in Sacramento. In South Carolina, whites and others formed one race-ethnicity group, but the other five were collapsed into a second group. Retaining all age-sex and tenure categories, the site used 28 post-strata for estimation. The post-stratification was a little more complex in Menominee. There, blacks, Asians, American Indians, and Hawaiian and Pacific Islanders were combined. For this group we retained the age-sex and tenure breakdowns. For the white-and-other group, we collapsed the first four age-sex categories above; the other three stood on their own. For the Hispanic group, we collapsed all age-sex categories, and ended with two post-strata--one each for owners and renters. This produced 24 post-strata in Menominee.

To reduce the variance of the dual system estimates (DSEs), we employed raking procedures using several steps. (1) We assigned the race-ethnicity \times age-sex groups (after collapsing groups as necessary) to the rows of the raking matrix, and the two tenure groups to the columns. (2) The internal cells of the raking matrix were filled with the DSEs corresponding to the row and column categories. (3) The marginals were then obtained by adding the DSEs across rows and down columns of the

matrix. (4) The initial interior cells were then replaced with the *unadjusted population counts*. (5) The interior cells were raked to the marginal totals until convergence. For more details on the post-stratification and on the effect of the raking procedure, see Schindler (1999).

3.5 The Summary of Estimates and Undercounts

In Table 5 the apportionment count for each site is given and divided into its several components. These components include the use of sampling for nonresponse follow-up and UAA vacant returns and multiplicity estimation in Sacramento, and the adjustment for the net undercount in Sacramento and Menominee.

Table 5. Census Counts and Their Components

Components	Sacramento	Menominee	South Carolina
Actual count for GQs ¹ and SBE	7,066	45	33,524
Actual count for NonGQ persons	334,952	4,490	612,962
Actual count for unclassified HUs	7,143	60	15,654
Added sampling for NRFU	24,930	NA ²	NA
Added UAA vacant	2,409	NA	NA
Added SBE	1241	NA	NA
Added ICM	25,572	143	NA ³
Total Count for Apportionment	403,313	4,738	662,140

¹ GQs: group quarters; SBE: service-based enumeration.

² Not applicable.

³ Although no persons were added to the apportionment count in South Carolina, the PES estimated a net undercount of 65,108 people.

The estimated net undercount for a group or geographic area is defined as the difference between the group's census counts after (adjusted) and before (unadjusted) applying the ICM (PES) coverage factors. The net undercount rate is simply this difference divided by the adjusted count. Over the entire site, including people enumerated in group quarters and services such as

shelters and soup kitchens, the net undercount rates (with standard errors in parentheses) were estimated as 6.3% (1.1%) in Sacramento, 3.0% (1.8%) in Menominee, and 9.0% (1.6%) in South Carolina.

Finally, Table 6 provides estimated net undercount rates for the Dress Rehearsal computed for specific race-ethnicity groups retained in the post-stratification for that site (Memos. [2], [3], and [4]). It should be noted that the rates in Table 6 are based only on the housing unit population; group quarters and people enumerated at services are not included in the rate's denominator.

Table 6. Net Undercount Rates for Race-Ethnicity Groups (Housing Unit Population Only)¹

2000 Census Dress Rehearsal	Net Undercount Rate (SEs in parentheses)
Sacramento, CA	
Non-Hispanic White ²	4.7% (1.2%)
Non-Hispanic Black	8.7% (2.4%)
Non-Hispanic Asian	6.0% (1.9%)
Non-Hispanic American Indian	8.5% (1.7%)
Non-Hispanic Hawaiian	8.0% (1.6%)
Hispanic	8.3% (1.5%)
Total	6.5% (1.1%)
Menominee	
Non-Hispanic Amer. Indian on Reservation	4.1% (2.0%)
Total	3.0% (1.8%)
South Carolina	
Non-Hispanic White ²	6.3% (1.3%)
Hispanic, Black, Asian, Am. Ind., Hawaiian	13.2% (2.6%)
Total	9.4% (1.6%)

¹ These undercount rates do not include people in Group Quarters and Service Based Enumerations in the denominator.

² This group includes Non-Hispanics of all races other than Black, American Indian, Asian, and Hawaiian and Pacific Islanders.

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- [2] Memorandum from Rajendra P. Singh to Howard Hogan, "Some Results from the Census 2000 Dress Rehearsal," February 26, 1999, DSSD Census 2000 Dress Rehearsal Memorandum Series, #A-76.
- [3] Memorandum from Donna L. Kostanich to Dennis W. Stoudt, "Approval of 2000 Dress Rehearsal Site Level Estimation," March 15, 1999, DSSD Census 2000 Dress Rehearsal Memorandum Series, #A-80.
- [4] Memorandum from Donna L. Kostanich to Howard Hogan, "Preliminary Investigation of South Carolina Post Enumeration Survey Results," April 5, 1999, DSSD Census 2000 Dress Rehearsal Memorandum Series, #A-83.

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**This paper reports the results of research and analysis undertaken by Census Bureau staff. It has undergone a more limited review than official Census Bureau publications. This report is released to inform interested parties of research and to encourage discussion.*