Joseph George Caldwell, Ph.D. (Statistics)
Consultant in Statistics, Economics, Demography, Information Technology and Operations Research
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Education...

Ph.D., Statistics, University of North Carolina at Chapel Hill, 1966
B.S., Mathematics, Carnegie-Mellon University, 1962

Consultant...

to US government agencies, state governments, corporations, and foreign governments

Director/Supervisor of projects in the areas of...

o statistical experimental design and data analysis (Stata, SAS, SPSS, R)
o sample survey design for major national program evaluations and monitoring systems
o causal inference (causal modeling and analysis of experimental and observational data); Neyman-Rubin Causal Model; potential outcomes / counterfactuals; Judea Pearl Bayesian networks (directed acyclic graphs); Rosenbaum-Rubin (statistical, matching) approach; Heckman (econometric) approach)
o demographic analysis (population projection, synthetic estimation, demographic forecasting)
o computer models, software and management information systems (C, Microsoft Access)
o artificial intelligence systems / geographic information systems (ArcView)
o systems and software engineering (C, Visual Basic, Fortran, DOD-STD-2167A, ISO12207)

o operations research / management science and statistics in industrial and defense applications
o monitoring and evaluation, planning and policy analysis of government programs in health, education, human services, urban problems, rural development, agriculture, tax policy analysis, and public finance
o optimization and game theory (zero-sum and non-zero-sum, resource-constrained games)
o international development applications in many countries, including Barbados, Bahamas, Jamaica, Honduras, Haiti, Timor-Leste. the Philippines, Zambia, Botswana, Malawi, Egypt, Bangladesh and Ghana

Manager of contract research firm (seven years); successful bidder on numerous technical contracts, including four Small Business Innovation Research (SBIR) contracts. Manager of Research and Development at US Army Electronic Proving Ground Electromagnetic Environmental Test Facility. Director of Management Systems at the Bank of Botswana (Botswana's central bank). Director of more than twenty projects.

Adjunct Professor of Statistics at the University of Arizona, Tucson, Arizona

Developer of technical seminars and computer program packages in experimental design, sample survey design, time series analysis, forecasting, small area estimation, demographic projection, and geographic information systems

Languages: Native in English; working knowledge of Spanish and French

Summary of Experience. Dr. Caldwell's professional career in research and research management has centered on the use of modern analysis techniques to solve practical problems in government, commercial, industrial, and military applications. He has directed major technical projects; developed technical training seminars; accomplished significant research results in statistics; developed statistical, demographic, and geographic-information-system computer program packages; designed statistical reporting and management information systems; and served as professor of statistics, consultant, and manager of a contract research firm.

Significant Scientific Accomplishments:

- In doctoral dissertation, developed the best known codes for correcting additive and synchronization errors in noisy communication channels. Summary of dissertation is Bose, R. C. and J. G. Caldwell, "*Synchronizable Error Correcting Codes*," Information and Control, 10, 1967. Posted at http://www.foundationwebsite.org/SynchronizableErrorCorrectingCodes.pdf.

- Developed a practical way of obtaining approximate, but explicit, solutions to John Nash's bargaining solution to a non-zero-sum game (Nash's theory presented only an existence proof, not a constructive proof, of the bargaining solution). (Article *Conflict, Negotiation, and General-Sum Game Theory* posted at http://www.foundationwebsite.org/Conflict.htm.)

Significant Technical Accomplishments:

- Developed *TIMES*, the first commercially-available general-purpose Box-Jenkins computer-forecasting package (described at http://www.foundationwebsite.org/BoxJenkins.htm, http://www.foundationwebsite.org/TIMESVol1TechnicalBackground.htm).

- Developed the *DESTINY* microcomputer software for making population projections and population-based forecasts (similar to USAID's *RAPID* population-projection program, but extended to handle multiple regions and ethnic groups; described at http://www.foundationwebsite.org/DestCapINTL.htm and http://foundationwebsite.org/DestUserManINTL.htm)). The *DESTINY* system uses the cohort-component method of population projection to produce estimates of population by age, sex, race and region, and applies the method of synthetic estimation to determine forecasts of variables related to population.

- Applied the methods of Generalized Lagrange Multipliers (GLM) (for solving ill-conditioned (nonlinear, discontinuous, nonconvex) resource-constrained optimization problems and game theory to obtain optimal solutions to a variety of resource-constrained optimization problems in national defense (ballistic missile defense, general-purpose naval forces) and finance (variable-rate pricing of loans). (See, for example, the articles *Subtractive Overlapping Island Defense with Imperfect Interceptors* at http://www.foundationwebsite.org/SubtractiveOverlappingIslandDefense.htm and *A Lagrangian Approach to Customer Relationship Management: Variable-Rate*

Pricing Strategy at http://www.foundationwebsite.org/LagrangianApproachToCRM.htm.)

- Applied the methodologies of artificial intelligence (expert systems) and geographic information systems (GIS) to automate the generation of military scenarios for use in operational test and evaluation (project *Research in Artificial Intelligence for Non-Communications Electronic Warfare Systems*). See materials at http://www.foundationwebsite.org/index16-artificial-intelligence.htm.

- Applied the methodology of systems engineering to develop a systematic approach to developing tax systems (described in the book *The Value-Added Tax: A New Tax System for the United States* posted at Internet web site http://www.foundationwebsite.org/VAT.htm.

- Developed a comprehensive methodology for constructing analytical sample survey designs to estimate the impact of projects and programs using causal inference. Described in the article *Sample Survey Design for Evaluation (The Design of Analytical Surveys)* posted at http://www.foundationwebsite.org/SampleSurveyDesignForEvaluation.htm. Related material posted at http://www.foundationwebsite.org/index12-design-of-analytical-sample-surveys.htm.

- Identified a population strategy that is sustainable in the long term the human species and has low impact on the

planet's biodiversity (book *Can America Survive?* posted at http://www.foundationwebsite.org/CanAmericaSurvive.htm.)

- Identified a practical system for providing basic health care to all Americans at low cost (article *A New Health-Care System for America: Free Basic Health Care* at http://www.foundationwebsite.org/ANewHealthCareSystemForAmerica.htm.)

Management Approach. Utilizes modern management and software engineering practices based on standards-based quality management (ISO 9000 Quality Management standard, ISO 12207 Information Technology standard, Carnegie Mellon University Software Engineering Institute Capability Maturity Model (CMM), DOD-STD-498 Software Development and Documentation).

Management Experience:

- Director of Management Systems, Central Bank of Botswana (managed 20 IT professionals; two years)
- Principal Scientist and Manager of Research and Development, US Army Electronic Proving Ground Electromagnetic Environmental Test Facility (managed 20 scientists, engineers, statisticians, computer scientists; two years)
- Adjunct Professor, University of Arizona (taught largest core statistics course, 500 students per semester, five teaching assistants, four years)
- Founder and President, Vista Research Corporation (contract research firm; seven years)

- Vice President, JWK International Corporation (contract research firm; from inception to about 30 technical staff; four years)
- Supervised or directed many research projects, from one to ten team members

Education. Dr. Caldwell holds a PhD degree in mathematical statistics from the University of North Carolina at Chapel Hill. In his graduate studies, he specialized in the theory of experimental design and algebraic coding theory. His doctoral dissertation advisor was Prof. R. C. Bose, regarded as the "father" of the mathematical theory of experimental design, and developer of the Bose-Chaudhuri-Hocquenghem (BCH) codes, the best known class of codes for correcting random errors in noisy communication channels. In his doctoral dissertation, Dr. Caldwell developed the best-known class of codes for correcting additive and synchronization errors in noisy communication channels.

CAPABILITIES AND EXPERIENCE IN STATISTICS

Summary of Experience in Statistics. Dr. Caldwell has over thirty years' experience as a consultant and teacher of statistics. He has provided statistical consultation in a wide variety of fields, including causal inference, experimental design and sample survey design and analysis; statistical analysis of data; time series analysis and forecasting; management information systems; demographic modeling and analysis; simulation and modeling of industrial and military systems; operational test and evaluation of military electronic systems; industrial quality control; process control and product improvement; and planning, policy analysis, and program evaluation in health, education, social services, and economic development.

Experience in selected technical areas is summarized below, followed by a list of project summaries.

Experimental Design / Sample Survey Design. Specialized in experimental design in PhD program. Developed statistical experimental designs for test and evaluation, simulation model run-sets, chemical and physical experimentation, and industrial quality control applications. Developed an approach to analytical survey design that incorporated principles of experimental design. Developed computer software programs to implement the approach, and applied it to develop analytical survey designs for many applications. Developed computer program to determine sample size for experimental designs using statistical power analysis.

Causal Inference. Experienced in applying the theory of causal modeling and analysis to estimate causal impact in applications in which data are available from other than a randomized experiment (experimental design / randomized controlled trial), i.e., from observational study or a design in which randomized assignment to treatment was imperfectly implemented. The methodology of causal inference includes the Neyman-Rubin Causal Model (potential outcomes / counterfactuals) approach; Judea Pearl's Bayesian networks (directed acyclic graphs); the Rosenbaum-Rubin (statistical, matching) approach; and the James Heckman (econometric) approach). The two Honduras program evaluations described later utilized this approach. The approach is described in the lecture on causal inference cited below.

Econometrics. Used statistical sample survey and causal inference to assess the economic impact of farmer training and roads improvement projects in Honduras.

Computer Software for Time Series Analysis, Forecasting and Control. Dr. Caldwell developed the first commercially-available general-purpose Box-Jenkins computer-forecasting package (*TIMES*, described at http://www.foundationwebsite.org/BoxJenkins.htm , http://www.foundationwebsite.org/TIMESVol1TechnicalBackground.htm). The Box-Jenkins (autoregressive integrated moving average) models are useful in system identification problems, such as forecasting, control, and linear predictive coding of speech. A computer program for developing the most common Box-Jenkins models is posted at http://www.foundationwebsite.org/BoxJenkinsForecastingProgram.exe.

Population-Based Forecasting. Dr. Caldwell developed the *DESTINY* microcomputer software for making demographic projections (cohort-component, synthetic estimation) (described at http://www.foundationwebsite.org/DestCapINTL.htm and http://foundationwebsite.org/DestUserManINTL.htm) similar to USAID's *RAPID* population-projection program, but extended to handle multiple regions and ethnic groups). The *DESTINY* system uses the cohort-component method of population projection to produce estimates of population by age, sex, race and region, and applies the method of synthetic estimation to determine forecasts of variables related to population. Lecture notes for a short course on demographic analysis are posted at http://foundationwebsite.org/StatCourse13DemographicAnalysis.htm .

Microsimulation Forecasting. For the US Department of Health and Human Services, he directed the project to develop a prototype microsimulation forecasting model and a statistical reporting system to provide the data required by the model. The

model -- called MICROSIM -- was developed to forecast caseloads and expenditures for HHS programs under various policy assumptions. He has developed numerous "custom" programs to construct survey designs, conduct sampling, analyze survey data, determine optimal allocations, and conduct cost-benefit analysis.

Teaching. Dr. Caldwell served as an adjunct professor of statistics at the University of Arizona. He taught the graduate course, Sampling Theory and Methods, and the undergraduate course, Statistical Methods in Management (for all students of business, public administration, and management information systems).

Technical Training. Dr. Caldwell has developed and presented a number of statistics courses relating to monitoring and evaluation (*Statistical Methods for Monitoring and Evaluation: A Comprehensive Survey Course*). These courses have been presented on an advertised basis and as in-house courses at client facilities (US Bureau of Labor Statistics; National Opinion Research Center; Bahamas Department of Statistics). Course notes and materials for these courses are posted at Internet websites

http://www.foundationwebsite.org/StatCourse1and2SampleSurvey3DayCourse.htm
http://www.foundationwebsite.org/StatCourse3ReviewOfStatisticalInference.htm
http://www.foundationwebsite.org/StatCourse4and5CausalInferenceAndMatching.htm
http://www.foundationwebsite.org/StatCourse6and7StatisticalDesignAndAnalysisForEvaluation2DayCourse.htm
http://www.foundationwebsite.org/StatCourse8SampleSizeDetermination.htm
http://www.foundationwebsite.org/StatCourse9MissingData.htm

http://www.foundationwebsite.org/StatCourse10SmallAreaEstimation.htm
http://foundationwebsite.org/StatCourse11ContinuousMultivariateAnalysis.htm
http://foundationwebsite.org/StatCourse12MultivariateTimeSeriesAnalysis.htm
http://foundationwebsite.org/ASurveyOfMethodsForForecastingAndPolicyAnalysis.htm
http://foundationwebsite.org/StatCourse13DemographicAnalysis.htm

Statistical Methodology for Evaluation. An article describing Dr. Caldwell's approach to the design of analytical surveys (e.g., for impact evaluation of economic and social development programs) is posted at http://www.foundationwebsite.org/SampleSurveyDesignForEvaluation.htm, and a computer program for determining sample sizes for complex surveys is posted at http://www.foundationwebsite.org/SampleSize.exe. An illustrative example of use of this program is presented in the article *Determination of Sample Size for Analytical Surveys, Using a Pretest-Posttest-Comparison-Group Design*, posted at http://www.foundationwebsite.org/SampleSizeEstimationAnalyticalSurveysGeneric.htm. This sample-size program is useful in determining sample sizes for Phase III clinical trials, which address the issue of assessment of the performance of alternative treatments.

Monitoring and Evaluation. Dr. Caldwell developed the design for many important national sample surveys and statistical reporting systems. He specializes in the development of analytical survey designs to collect data for model development. He developed analytical sample survey designs for impact evaluations in the US,

Jamaica, Honduras, Ghana, Burkina Faso, Namibia, Benin, Malawi, Zambia, and Côte d'Ivoire, including the following.

Impact Evaluations:

- o Impact Evaluation of the Programme of Advancement through Health and Education (PATH), Jamaica (a conditional cash transfer program)
- o Evaluation of Performance and Impact of Rehabilitation and Intensification of Olive Plantations in Rain-fed Zones, Morocco (Millennium Challenge Corporation)

Agricultural Data Collection in the Sourou Valley and Comoé Valley, Burkina Faso (Millennium Challenge Corporation)

- o Community-Based Rangeland and Livestock Management Household Income and Expenditure Surveys, Namibia (Millennium Challenge Corporation)
- o Conservancy Support and Indigenous Natural Products Household and Organisational Surveys, Namibia (Millennium Challenge Corporation)
- o Impact Evaluation of Water Supply Activity, Ghana (Millennium Challenge Corporation)
- o Monitoring and Evaluation of the Competitive African Cashew Value Chains for Pro-Poor Growth Program in Benin, Burkina Faso, Côte d'Ivoire, Ghana and Mozambique (Deutsche Gesellschaft für Zusammenarbeit (GTZ))
- o Monitoring and Evaluation of the Competitive Action Cotton for Pro-Poor Growth Program in Benin, Burkina Faso, Côte d'Ivoire, Zambia, Ghana and Malawi (Deutsche Investions und Entwicklungsgesellschaft (DEG))
- o Farmer Training and Development Activity, Honduras (Millennium Challenge Corporation)

Transportation Project, Honduras (Millennium Challenge Corporation)

- o Ghana Trade and Investment Program Survey
- o National survey of local development projects in Egypt

- o Study of the Impact of National Health Insurance on Bureau of Community Health Service Users

Program Monitoring Surveys:

- o National Center for Health Services Research (NCHSR) Hospital Cost Data Study
- o Professional Standards Review Organization (PSRO) Data Base Development Study
- o Malawi Annual Primary School Enrollment Survey
- o 1976 Survey of Institutionalized Persons
- o Housing and Urban Development (HUD) Housing Market Practices Survey
- o Research Design for the Urban Arterials Section of the Highway Capacity Manual
- o Elementary and Secondary School Civil Rights Survey

Statistical Program Monitoring Systems:

- o Sampling Manual for Utilization Review of Medicaid
- o Sampling Manual for Social Services Reporting Requirements (Title XX)
- o Sampling Manual for Office of Child Support Enforcement Reporting Requirements

Data Analysis. He has applied statistical software to analyze sample survey data, including for a number of the sample surveys listed earlier. He is an expert in the analysis of time series data, and has analyzed data collected in accordance with statistical experimental designs. He has applied the full range of statistical analysis procedures, including experimental design and sample survey analysis, multiple regression analysis, multivariate analysis of variance, components-of-variance analysis, factor analysis, and nonparametric analysis.

He is expert in the use of modern commercial statistical analysis software (e.g., Stata, SAS, SPSS, R) and the use of related

microcomputer software (e.g., Microsoft Access database management system).

CAPABILITIES AND EXPERIENCE IN OTHER FIELDS

Economics / Program Financial Management / Cost-Benefit Analysis / Tax Policy Analysis. Developed a financial planning computer-program model to estimate the effect of alternative tax policies in Barbados. Conducted cost-benefit analysis of alternative day-care systems and alcoholism treatment centers. Developed alternatives to the Federal Medical Assistance Percentage (FMAP) formula, which is used to reimburse state Medicaid and Aid to Families with Dependent Children (AFDC) expenses. Directed the Medicaid Standards Impact Assessment Study to assess the cost and effectiveness of federal standards for nursing home costs and performance. Conducted study to analyze the allocation formula used by the federal government to allocate federal vocational-rehabilitation funds to the states. Author of a book on tax policy analysis and the value-added tax.

Health, Education and Social Welfare. Developed the survey design and instrumentation for the 1976 Survey of Persons in Institutions. Developed the survey design for a national vocational rehabilitation follow-up study. Developed sample designs for a number of US national health studies. Developed the Education Management Information System for the Government of Zambia. Served as consulting statistician to the National Center for Education Statistics Statistical Analysis Group in Education (SAGE).

Systems and Software Engineering. Developer of computer systems (including commercial program packages) for statistical analysis, forecasting, optimization, simulation and modeling,

management information systems, geographic information systems. Based development on the principles of modern software engineering (structured analysis and design), using US and international standards (DoD STD 2167A Defense Systems Software Development, ISO 12207 Systems and Software Engineering, Carnegie Mellon University Software Engineering Institute Capability Maturity Model (CMM),

Management Information Systems. Developed the national Personnel Management Information System (PMIS) for the Government of Malawi and the national Education Management Information System for the Government of Zambia.

Geographic Information Systems (GIS). Developed a system to identify good locations for automated teller machines (ATMs) for First Union National Bank (now Wells Fargo) (ArcView GIS). Used GIS input to support economic impact estimation of a roads improvement project in Honduras. Used GIS technology as part of the project, Research in Artificial Intelligence for Non-Communications Electronic Warfare Systems, to develop an automated system for generating military scenarios for use in operational test and evaluation (GRASS GIS).

Information Technology Management. Served as Director of Management Systems for the Central Bank of Botswana, responsible for all of the Bank's information technology (IT) operations. Directed the Bank's Year 2000 date-change program and the development of the Bank's Disaster Recovery / Business Continuity Plan. In this role, made heavy use of international standards for quality management, such as ISO 9000 Quality Management, ISO 12207 Systems Engineering, Carnegie Mellon University Software Engineering Institute Capability Maturity Model (CMM), Year 2000 guidelines from the Bank for International

Settlements and the US Government, and disaster-planning guidelines of the State of Texas.

Optimization and Game Theory. Applied the methodology of Generalized Lagrange Multipliers (GLM) to obtain solutions to constrained optimization problems in defense and finance. The GLM method is useful for finding solutions to ill-conditioned constrained optimization problems, for which the objective function (payoff function) is nonlinear, discontinuous and non-convex. Use the GLM approach to develop a variable-rate loan pricing model for Canada Trust Bank (now Toronto Dominion Bank) and to solve a variety of problems in defense (optimal allocation of missiles and interceptors in ballistic missile defense; deployment of Naval general-purpose forces; solutions to non-general sum resource-constrained games (Nash Bargaining Solution).

Operations Research / Systems Analysis / Management Science. Utilized the methodologies of operations research (optimization, statistics, simulation and modeling) to determine solutions to operations research problems in industry and government (application areas: textile manufacturing, pharmaceutical manufacturing, finance (banking loans and credit cards), defense systems (ballistic missile defense, naval general purpose forces, satellite ocean surveillance, tactical air support, operational test and evaluation of military electronic systems and equipment, electronic warfare systems).

Simulation and Modeling. Developed the following mathematical models, implemented as general-purpose computer programs:

- *Financial Simulation Model for Tax Policy Analysis* (used to evaluate alternative tax policies in Barbados; autoregressive integrated moving average (ARIMA,

"Box-Jenkins") models used for forecasting; economic cost-benefit analysis; Microsoft Access)
- *Variable-Rate Pricing Model* (used to determine optimal terms for loans, taking into account customer characteristics, risk, and loan resources; Generalized Lagrange Multipliers; Visual Basic)
- *Temporal-Projection Tracking Model* (Visual Basic; Visual Studio)
- Program for determining good locations for automated teller machines (ATMs) (ArcView GIS; Spatial Analyst; SAS)
- Program for credit-card marketing (logistic regression; SAS)
- *SurvDes* program for designing analytical surveys (Microsoft Access)
- Computer program for determining sample sizes for pretest-posttest-comparison-group designs using statistical power analysis (Microsoft Access)
- *SCENARIST*, automated scenario-generation system, used to generate scenarios for placing electronic-warfare systems in operational test and evaluation (GRASS GIS; expert systems; C)
- *Education Management Information System* (EMIS) for Government of Zambia (Microsoft Access, ESRI GIS)
- *Personnel Management Information System* (PMIS) for Government of Malawi (dBASE)
- *DESCEM Dynamic Electromagnetic Combat Effectiveness Model*
- *TIMES* computer-program package for developing autoregressive integrated moving average (ARIMA) models (Fortran; Visual Basic; Microsoft Visual Studio)
- *DESTINY* demographic analysis computer-program package for constructing population-based forecasts

using the cohort-component population-projection method and the method of synthetic estimation (Fortran; Microsoft Access).

- *MICROSIM Microsimulation Forecasting Model*, used to forecast caseloads and budgets for social welfare programs
- Model for analyzing the allocation formula used by the federal government to allocate federal vocational rehabilitation funds to the states (Fortran)
- Model for analyzing alternatives for the Federal Medical Assistance Percentage (FMAP) formula, which is used to reimburse state Medicaid and Aid to Families with Dependent Children (AFDC) expenses (Fortran)
- Subtractive Overlapping-Island Defense Model (ballistic missile defense; Fortran)
- Naval General-Purpose Forces Combat Model (Fortran)
- Tactical Air Warfare Combat Model (Fortran)
- Hardsite Defense Model (Fortran)
- Satellite Ocean Surveillance Correlation-Tracking Model (Fortran)
- Many application-specific statistical and econometric models used to analyze experimental-design data and sample-survey data, and to conduct causal modeling and analysis of development projects (IBM Scientific Programming Package, BMD, BMDP, SPSS, SAS, Stata)

PROJECT SUMMARIES

Dr. Caldwell's recent work has centered mainly in the areas of social and economic development, evaluation and monitoring, institutional development, and management information systems

development, in international-development applications. Following are summaries of projects in these areas.

August - December, 2018. Statistical Consultant, National Opinion Research Center of the University of Chicago (NORC). Sample survey design and analysis consulting services for the USAID Kenya Project, Feed the Future Zone of Influence Survey

May – July, 2017, Economist / Statistician, EUROPE, Ltd. Consultant to the European Union (EU) -funded project, Consultancy to Undertake a Domestic Resource Mobilisation Programme Aimed at Modernising the Informal Economy in Barbados (EuropeAid/132633/C/SER/multi Lot 11, Request number 2017/384-889-1). The purpose of the project was to conduct an economic analysis of the informal economy and means by which the sector can be modernized, with an eye to increasing domestic tax revenues and decreasing the government deficit. I was responsible for the following activities / deliverables: (1) development of a Financial Simulation Model (FSM) to assess the cost/benefit characteristics of alternative tax policies; and (2) production of a comprehensive cost-benefit analysis report to determine the effectiveness of modernizing the informal sector. The FSM was a causal model that estimated the effect of making changes in three policy control variables: (1) Enforcement Strength Index; (2) Tax Burden Index; and (3) Expenditure Restraint Index. Model parameters were estimated from historical data, using autoregressive integrated moving average (ARIMA, Box-Jenkins) models based on the causal model. The FSM was used to make five-year forecasts of policy variables of interest (including the cost/benefit indicators) for a range of values of the policy control variables. The FSM was developed in Microsoft Access. A detailed FSM user's manual was developed, so that government officials could examine alternatives in addition to those considered

during the course of the project. I produced three project deliverables: (1) *Financial Simulation Model for Tax Policy Analysis: User's Guide*; (2) *Cost-Benefit Analysis of Tax Policy Analysis Alternatives*; and (3) Briefing: *Financial Simulation Model for Tax Policy Analysis and Cost-Benefit Analysis* (PowerPoint slides).

May – August, 2016, Statistical Consultant, The Mitchell Group. Expert consultant in statistics; sample weighting specialist. SAREL project (USAID). The Sahel Resilience Learning Project (SAREL) and the Resilience in the Sahel Enhanced (RISE) Initiative Baseline Survey are efforts to increase the resilience of chronically vulnerable populations in the agro-pastoral and marginal areas of Burkina Faso and Niger. The RISE survey was a probabilistic household survey o 2,500 households across villages in the Sahel. The survey was a complex sample survey consisting of a stratified first-stage sample of 100 villages and a second-stage sample of 25 households in each selected village. Advised on specification of proper statistical procedures for analyzing the collected survey data, using Stata (*svy* module).

2015, Statistical Consultant, National Opinion Research Center of the University of Chicago (NORC). Sample survey design consulting services (statistical power analysis for sample size determination; sample allocation and selection; calculation of survey weights) to proposals and projects in international development (USAID Burundi Village Savings and Loan Association (VSLA) child welfare project; IADB Honduras Bono 10 Mil conditional cash transfer project; USAID Liberia Electoral Access and Participation (LEAP) project).

March 2014 – July 2014. Statistical Consultant, Inter-American Development Bank / Bahamas Department of Statistics.

Development and presentation on a training course on small-area estimation, for the Bahamas Department of Statistics. The purpose of the course is to describe statistical methodology for making estimates of unemployment for the Bahamas Labour Force Survey (conducted in May and November of each year), for small islands or island groups for which the sample size for a particular survey round is small or zero.

June 2011 – November 2012. Economist and Statistical Analyst, Impact Evaluation of the Programme of Advancement through Health and Education (PATH), Jamaica. Government of Jamaica / Sanigest, Costa Rica. Responsible for evaluation and sample survey design used to collect household data to evaluate Jamaica's PATH conditional cash transfer (CCT) program. Adopted the Neyman-Rubin ("potential outcomes," "counterfactuals") conceptual framework for the evaluation design, and constructed a sample survey design to support this approach. The sample design was an "analytical" sample design intended to provide data useful for estimating program impact and the relationship of impact to explanatory variables. The sample design was a "matched pairs" design that included matching of eligible households on a number of socio-economic characteristics, prior to selection of probability samples of treated and untreated households. Statistical power analysis was used to determine a sample size sufficient to provide a high level of power for detecting impacts of specified magnitude ("minimum detectable effects"). The precision of impact estimates and the power of statistical tests about those impacts were increased by the use of marginal stratification to assure adequate variability on explanatory variables related to outcomes of interest. The marginal stratification was implemented by setting variable probabilities of selection for each household of the population.

September 2010 – September 2012. Evaluation Expert and Statistician to the project, "Evaluation des performances et de l'impact de l'activité de rehabilitation et d'intensification des plantations d'oliviers au niveau des zones pluviales," Agence du Partenariat pour le Progrès, Millennium Challenge Account – Maroc, Project Arboriculture Fruitière, National Opinion Research Center of the University of Chicago (NORC). Responsible for sample survey design and selection of samples for an impact evaluation of an olive development project in Morocco.

August 2010 – July 2012. Evaluation Expert and Statistician to the project, "Agriculture Data Collection in the Sourou Valley and Comoé Basin." Millennium Challenge Account – Burkina Faso (MCA-BF), National Opinion Research Center of the University of Chicago (NORC). Responsible for construction of sample survey design and selection of samples for an impact evaluation of two agricultural development projects in Burkina Faso.

August 2010 – November 2011. Evaluation Expert and Statistician to the project, "Community-Based Rangeland and Livestock Management Household Income and Expenditure Surveys." Millennium Challenge Account – Namibia (MCA-N), National Opinion Research Center of the University of Chicago (NORC). Responsible for construction of sample survey design and selection of samples for an impact evaluation of a rangeland management project in Namibia.

August 2010 – March 2012. Evaluation Expert and Statistician to the project, "Conservancy
Support and Indigenous Natural Products Household and Organisational Surveys." Millennium Challenge Account – Namibia (MCA-N), National Opinion Research Center of the University of Chicago (NORC). Responsible for construction of

sample survey design and selection of samples for an impact evaluation of an indigenous natural products project in Namibia.

July 2010 – September 2010. Evaluation Expert and Statistician to the project, "Impact Evaluation of Water Supply Activity." Millennium Development Authority—Ghana (MiDA), National Opinion Research Center of the University of Chicago (NORC). The Water Supply Activity project was undertaken by the Millennium Development Authority – Ghana (MiDA) as part of its Compact with the US Millennium Challenge Corporation (MCC) to improve infrastructure in selected agricultural areas in Ghana. The goal of the water supply activity improvements was to improve the quantity and quality of water in MiDA program areas, and thereby improve the health and economic status of communities in those areas. Of particular interest were effects on household health outcomes, time savings, and income levels. The purpose of the evaluation project was to conduct a rigorous impact evaluation of the program to assess the extent to which it achieved its goals. The evaluation design was a pretest-posttest-comparison-group design, and the basic measure of program impact was a double-difference estimate based on this design. Dr. Caldwell constructed the evaluation and survey design for the evaluation project.

November 2009 – October 2010. Evaluation Expert and Statistician to the project, "Monitoring and Evaluation of the Competitive African Cashew Value Chains for Pro-Poor Growth Program", Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, National Opinion Research Center of the University of Chicago (NORC). Here follows a brief summary of the project, taken from the project grant proposal: "The project will contribute to sustainably reducing rural poverty in five African countries (Benin, Burkina Faso, Côte d'Ivoire, Ghana and Mozambique). An estimated 2.5 million mainly smallholder farmers grow cashew in

Africa. Annually production of almost 750,000MT they supply about 40% of the world's cashew crop. But only about 12% of cashew nuts are processed into cashew kernels in Africa. The cashew project aims to improve the quality of raw cashew nut cultivation, increase farmer productivity, improve linkages between smallholder farmers and the marketplace, build African processing capacity and promote a sustainable global market for African cashews. The project's goal is to help 150,000 smallholder cashew farming households in Benin, Burkina Faso, Côte d'Ivoire, Ghana and Mozambique increase their incomes by 50 percent by 2012." The goal of the program was to increase income and employment for cashew farmers. The purpose of the evaluation project was to conduct an economic impact evaluation of the program to assess the extent to which it is achieving its goals. For the evaluation, surveys were conducted in all five countries of the program. Dr. Caldwell constructed the evaluation and sample survey designs for all program countries except Mozambique. The measures of program impact were double-difference estimates based on pretest-posttest-comparison-group evaluation designs. Sample sizes were determined by statistical power analysis to assure high power for detecting impact effects of specified size. A two-stage sample design was employed, with selection of a first-stage sample of villages and a second-stage sample of farmers within sample villages. The sample design used matching to increase precision of estimates and power of tests of hypotheses. Marginal stratification, implemented through the use of variable probabilities of selection, was used to assure adequate variation in explanatory variables.

<u>March 2009 – March 2013. Evaluation Expert and Statistician to the project, Monitoring and Evaluation of the Competitive African Cotton for Pro-Poor Growth Program ("COMPACI"), Deutsche Investitions und Entwicklungsgesellschaft GmbH (DEG), NORC.</u>

The purpose of the project was to conduct an economic impact evaluation of the "Cotton Made in Africa" initiative. For the evaluation, surveys were conducted in six countries: Benin, Burkina Faso, Côte d'Ivoire, Zambia, Ghana and Malaŵi. Under the program, cotton farmers were provided training and services so that their cotton may be certified as having been produced under the "Cotton Made in Africa" (CMiA) program. The goal of the program was to increase income and employment for cotton farmers. Dr. Caldwell constructed the evaluation and sample survey designs for all program countries. The measures of program impact were double-difference estimates based on pretest-posttest-comparison-group evaluation designs. The sample designs for the cotton project were similar to those described above for the cashew program (statistical power analysis, matching, marginal stratification, variable probabilities of selection).

February, 2009 – February 2011. Lead Statistician, Impact Evaluation of Feeder Roads Activity, Millennium Development Authority - Ghana (MiDA), NORC. The purpose of the project is to conduct an impact evaluation of the MiDA Feeder Roads Activity in eight of its 23 program districts. The evaluation will determine the impact of feeder roads improvements on input costs, product prices, and passenger fares and goods' tariffs that are associated with reduced travel time and vehicle operating cost. The primary data for the impact evaluation will consist of three market surveys, similar in scope to the Consumer Price Index (CPI) survey, examining changes in price over time in localities different distances from the improved road segments. The sample design involved matching of treatment and control localities using a "nearest neighbor" technique with a data set enhanced with GIS methods. The impact of the roads improvements will be determined employing a double-difference estimator applied to

changes in prices over the next two years. Dr. Caldwell was responsible for providing advice on the strengths and weaknesses of particular evaluation designs, devising sampling strategies and designs, estimating sample sizes, drawing the sample for data collection activities, preparing weights to apply to the price and fare observations, and assisting with analysis plans to ensure statistical robustness of results.

May 2007 – September 2013. Evaluation Expert and Statistician, Millennium Challenge Account - Honduras Program Impact Evaluation, National Opinion Research Center (NORC), Honduras. Technical advisor to provide evaluation research design and analysis services in support of an economic impact evaluation of roads-improvement and farmer-development projects funded by the Millennium Challenge Corporation in Honduras. Dr. Caldwell developed the evaluation and sample survey designs for the two projects.

For both projects, statistical power analysis was used to determine sample size. Using this approach, the sample size was determined so that the probability (power) of detecting an effect (impact) of a specified size was high. Both projects involved a "panel" sample design in which the survey was administered before and after the program intervention, i.e., the basic design was a "pretest-posttest" design. The conceptual framework for the impact analysis was the "Neyman-Rubin causal model", or "potential outcomes model," or "counterfactuals model."

For the farmer assistance project, eligible villages ("*aldeas*") were classified into sets of "matched pairs," and one member of each pair was randomly selected to receive program services. The matching was done on a number of variables believed to affect outcomes of interest, and available prior to the survey. The

matching was done prior to randomized selection for treatment, to increase the precision of impact estimates and the power of tests of hypothesis about them. A probability sample of matched pairs was selected using the technique of "marginal stratification," to ensure adequate variation (spread, balance) in the design variables. The randomized-assignment-to-treatment sample was supplemented by a sample selected for treatment in the usual fashion (by the program implementer). The data analysis included development of a "two-step" model, in which the first step was a binary "selection" (propensity-score) model and the second step was an "outcome" model that included the selection probability estimated in the first step. The principal impact estimate of interest was the Average Treatment Effect (ATE), or average effect of the program intervention on an eligible farmer. The ATE was a "regression adjusted" or "covariate adjusted" double-difference estimate.

The survey design for the transportation project included selection of a probability sample of *caserios* (administrative units generally smaller than villages), where marginal stratification was once again used to assure adequate variation in variables believed to affect outcome. In particular, the selection probabilities were set to assure adequate variation in the estimated change in travel time to be caused by the program intervention (road improvements). The estimated change in travel time was calculated from a GIS road-network model that included all official roads in Honduras. The survey data were used to develop an estimate of the Partial Treatment Effect (PTE) (relationship of impact to travel-time variables) and, from the PTE, the Average Treatment Effect.

<u>May – June 2008. Statistical Consultant, Analysis of Poverty and Social Impact of Education Sector Reforms in Mozambique, World Bank / KPMG / Manitou Incorporated.</u> Developed the data-entry

program to be used for a national sample survey of households, to assess the economic and social impact of education sector reforms. The US Bureau of the Census CSPro software system was used for this application. The questionnaire and corresponding data-entry forms were in Portuguese.

Dec 2007 – Feb 2008. Systems Integration Consultant, Governance and Economic Management Assistance Program (GEMAP), USAID / Segura Consulting, Liberia. Technical advisor to a project funded by the US Agency for International Development to develop a computer system to automate tax payments. The goal of the project is to establish a "One-Stop Shop" at the National Port, where importers can settle their tax obligations quickly. Developed system requirements specifications and procurement documents. The system includes radio communication links among the National Port, the Ministry of Finance, and the Central Bank.

June 2007. Consultant in Information Technology and Statistics, Guinea Baseline Survey, Indefinite Quantity Contract (IQC) for Democracy and Governance Analytical, Support and Implementation Services, US Agency for International Development / Management Systems International, Guinea. Technical advisor to develop a design for a database to store data required in support of USAID's Performance Monitoring Plan (PMP) reporting and management needs, and for a statistical sample survey to collect data to be stored in the database. Advised on the database design (e.g., static Word files, static HTML files, standalone Microsoft Access database, networked database, web-based dynamic system (e.g., MS ASP.net, Adobe ColdFusion, Sun Java Server Pages, Linux operating system / Apache web server , MySQL database, PHP web page (LAMP)), selection of sample survey data-entry software (e.g., Epi Info,

CSPro, Viking, SPSS), and sample survey design (a two-stage sample survey design using Census enumeration districts as primary sampling units (PSUs) was recommended, to provide data in support of a pretest-posttest comparison-group quasi-experimental design). Statistical power analysis was used to determine the survey sample sizes (number of sample PSUs, number of sample households within PSUs).

Mar 2006 – Sept 2006. Technical Advisor in Personnel Management Information Systems, United Nations Development Program, East Timor and Portugal. Source Selection for Civil Service Personnel Management Information System. Technical advisor to advise the Government of Timor-Leste on the selection of a software developer to develop a civil-service Personnel Management Information System (PMIS). The software developer was selected and the system was successfully implemented. (In early 2012 this system was selected by UNDP as third best of all of UNDP's projects.)

Feb 2002 – April 2005. Technical Advisor in Educational Management Information Systems, Academy for Educational Development, Zambia. Technical advisor to a project funded by the US Agency for International Development, to develop an Educational Management Information System (EMIS) for the Zambia Ministry of Education. The purpose of the EMIS is to collect, store, and retrieve data (produce reports) from the Annual School Census, in support of program planning and analysis by the Ministry and donor agencies. Applications developed in Microsoft Access database development system, the Academy for Educational Development's EdAssist system, and the ArcView geographic information system (GIS).

Jan 1999 – Jan 2001. Director of Management Systems, Bank of

Botswana, Botswana. Responsible for management of all information technology operations for the Bank of Botswana, Botswana's central (reserve) bank (IT vision, strategy, policy, procedures, operations, acquisition, training, staff development). The Bank's computer system is comprised of over 300 networked microcomputers running under Windows NT/95/98/2000, Novell 4.1 and UNIX operating systems. Managed a group of 16 information technology specialists to operate and support the Bank's computer hardware and software applications (network management; Microsoft Office Suite; Internet/intranet; banking operations; accounting; investment portfolio / foreign reserve management; financial data services; economic analysis; human-resources management; and asset management. Introduced modern management and software engineering practices based on standards-based quality management (ISO 9000 Quality Management standard, ISO 12207 Information Technology standard, Carnegie Mellon University Software Engineering Institute Capability Maturity Model (CMM), DOD-STD-498 Software Development and Documentation). Responsible for system development (design, implementation), procurement, training, operations and maintenance (annual budget approximately USD3 million, exclusive of staff salaries, training, and noncomputer facilities and equipment). Responsible for setting Bank's IT vision, strategy, policy, procedures, security. Supervised approximately 30 IT projects. Directed the Bank's Year-2000 date-change ("Y2K") program, in accordance with international standards (Bank for International Settlements and US government) (no date-change problems encountered after the century date change). Directed preparation of the Bank's first disaster-recovery plan. Directed preparation of the Bank's first disaster-recovery plan. Supervised the development of the Bank's first web page, and acquisition of the country's first "code-line clearing" system (for magnetic-ink character recognition

(MICR) of bank checks). Participated in all meetings of the Bank's Executive Committee and Board of Directors; reported to the Governor and Deputy Governor.

Apr – Oct 1998. IT Specialist, Educational Management Information System Design for Secondary Education Sector Development Project, Asian Development Bank / Academy for Educational Development, Bangladesh. Developed top-level requirements for the Educational Management Information System (EMIS) to be developed under a multi-year development program funded by the Asian Development Bank. Assignment included review of current systems, identification of user information needs, and identification and comparative evaluation of alternative systems.

Sep 1997 – Mar 1998. Consultant in Risk Management, Strategic Sourcing Inc., / Canada Trust Bank, Bank Risk Management, Canada. Consultant in risk management to Canada Trust Bank. Responsible for the development of analytical models for risk management of the Bank's loan products. Developed a model for risk-based variable-rate pricing of loans, using the techniques of Generalized Lagrange Multipliers (GLM) and mathematical simulation. The methodology determines pricing strategies that are optimal with respect to the allocation of capital to the Bank's investment opportunities, taking customer, market, and policy factors into account. The computer simulation approach is used as an efficient framework for exploring alternative pricing strategies; the GLM method is used to determine pricing strategies that maximize stockholder value added (profitability) subject to constraints (on capital reserve requirements, probability of exceeding loss provisions, and other factors). Windows NT, UNIX, SAS, VB5.

May 1996 – Jul 1997. Statistical Consultant to Strategic Sourcing Inc. / Wachovia Bank, Statistical and Optimization Computer Models in Banking, USA. Consultant to First Union National Bank (US sixth largest bank, later Wachovia Bank, now Wells Fargo Bank), conducting statistical analysis to develop customer segmentation models in support of bankcard marketing initiatives. Developed optimization model for identifying profitable locations for automatic teller machines (ATMs). Used SAS statistical analysis software and ArcView 3.0 geographic information system (spatial analyst) to develop logistic regression and discriminant analysis models to identify likely customers for PC banking. Models used a wide range of economic and demographic data at the block group and ZIP-code levels (population, income, employment, sales, shopping centers, crime statistics, traffic counts, ATM locations and characteristics). Windows 95 and UNIX (Sun Solaris SPARCcenter).

Nov 1995 – May 1996. Survey Statistician, Income and Employment Survey for Ghana Trade and Investment Program, Sigma One Corporation / USAID, Ghana. As part of the US Agency for International Development's Trade and Investment Program in Ghana, Dr. Caldwell designed and analyzed the survey to estimate the employment and income associated with every $1,000 of exports in non-traditional areas. The survey was designed to produce national estimates and estimates for selected product sectors (pineapples, pineapple juice, tuna loins / canned tuna, and cashew nuts). The sampling plan involved a probability sample of 300 exporting firms selected with probabilities proportional to a measure of size (export value) without replacement.

May – Jun 1995. Sample Survey Design and Sampling Statistician, Academy for Educational Development / USAID,

Malawi. For the Malawi Ministry of Education, Dr. Caldwell developed the sample design for the Annual Primary School Survey. Previously, the annual school survey was a census of all 3,400 schools and three million students; the amount of time and effort required to collect and process all of these data was placing a serious burden on the Planning Unit resources. The sampling plan involves a probability sample of 500 schools selected with probabilities proportional to a measure of size (the previous year's enrollment) using the Rao-Hartley-Cochran method. With the probability sampling approach, all of the information required by the Planning Unit will be available for a fraction of the effort required by the previous approach.

Jun 1993 – Dec 1994. Personnel Management Information System Developer, Civil Servant Personnel Management Information System, Academy for Educational Development / USAID, Malawi. For the Malawi Department of Human Resources Management and Development, Dr. Caldwell designed and implemented the Malawi Civil Service Personnel Management Information System. The system was developed using the dBASE database management information system, for use on microcomputers (standalone or networked) using the MS-DOS operating system. The system includes a variety of demographic and employment-related data for Malawian civil servants, and offers the users (personnel officers) a wide range of easy-to-use data entry and query/report capabilities. Experienced database users may generate queries and reports using SQL (Structured Query Language) commands or any of dBASE's automated query and report-generation features, but the system is designed with a powerful graphical user interface (GUI) so that a nontechnical user may generate all standard queries and reports without the need for any programming or entering of complicated commands, simply by making selections from a suite of menus. Data entry is facilitated

by a series of easy-to-use data entry screens, with ample on-line help and validation of all entered data. Employee records may be displayed on the screen or printed.

The system development effort was conducted in full compliance with the DOD-STD-2167A software development standard, and included the production of almost 1,000 pages of detailed system documentation, including a System Design Document, Software Requirements Specification, Software Design Document, Software Programmer's Manual, Software Product Specification, and Software User's Manual. The project included on-the-job training of members of the Department's Management Information Systems Unit (systems analysts, programmers) in systems engineering (requirements analysis, technology assessment, synthesis of alternatives, specification of evaluation criteria, selection of a preferred alternative, top-level design, detailed design (optimization), implementation, and test), the modern software engineering discipline (structured, top-down design), management information system design, dBASE, software development project management, and basic microcomputer upgrading and repair; and classroom instruction for system users (personnel officers) in use of the system for data entry and retrieval (queries and report generation).

Mar 1991 – Oct 1992. Manager of Monitoring and Evaluation, Chemonics International / USAID, Egypt. Served as manager of Monitoring and Evaluation for the USAID-funded Local Development II - Provincial (LDII-P) project, which provided technical assistance in the development and maintenance of USAID-funded infrastructure projects in Egypt (potable water, waste water, roads, buildings, rolling stock, environment, and information systems). The LDII-P project was the largest USAID local development project in the world, having funded the

development of over 16,000 local-level projects. In addition to infrastructure development, a major goal of the project was to promote government decentralization and increase the capacity of local governments to plan, finance, implement, and maintain local projects. Principal activities included: (1) the design and implementation of a nationwide project monitoring survey to assess the implementation, operating, and service status of projects; (2) the development of an indicators system to assist local officials in the assessment of need for public services, the availability of services, and the identification and prioritization of local development projects; (3) the design and implementation of a governorate project monitoring system to assist governorate detection and follow-up of implementation and operational problems. On this project, Dr. Caldwell made heavy use of automated management information system tools (dBASE, SPSS) to store, process, and retrieve data on project status and needs assessment (including continuous monitoring of project status indicators), and applied the techniques of sample survey (questionnaire development, stratified random sampling) and rapid appraisal techniques (focus group interviews) to assist end-of-project evaluation, as well as continuous monitoring of indicators. Dr. Caldwell lectured on the use of geographic information systems (GISs) in development planning, and supervised training of development planners in use of the PC-ARC/INFO GIS.

1988 – Mar 1991. President, Vista Research Corporation, Sierra Vista and Tucson, Arizona. Founded and operated contract research firm specializing in strategic and tactical analysis, simulation and modeling, program monitoring and evaluation, artificial intelligence applications, and software systems development. Winner of four Small Business Innovation Research (SBIR) contracts. Projects included the following:

Research in Artificial Intelligence for Noncommunications Electronic Warfare Systems; Geographic Information Systems; Expert Systems (1989-1991). Directed project for the Electronic Warfare / Reconnaissance, Surveillance, and Target Acquisition (EW/RSTA) division of the US Army Communications-Electronics Command (CECOM), to develop the Scenarist, a prototype knowledge-based system to generate scenarios for use in evaluating electronic warfare systems and concepts. The Scenarist positions military units and equipment on maps using rules that take into account tactical doctrine, geographic features, friendly mission, and enemy threat. The system uses digital mapping data and is based on an object-oriented parametric representation of military units. The system, coded in C (50,000 lines) and operating on MS-DOS or UNIX-based microcomputers, contains an easy-to-use graphical user interface. The system used digital terrain data extracted from the US Army's Geographic Resources and Services (GRASS) geographic information system (GIS), and incorporated the US Army Corps of Engineers' C-Language Integrated Production System (CLIPS) expert system. (The GRASS GIS is a free, open-source geographic information system originally introduced in 1982 by the US Army Construction-Engineering Research Laboratory (USA-CERL), a branch of the US Army Corps of Engineers.)

Tactical Theater Air Warfare Methodologies (1988-1989). Directed project for the Air Force Aeronautical System Division / Wright Aeronautical Laboratories (ASD/AFWAL) at Wright-Patterson Air Force Base, to develop an analytical theory for the generation of tactical air warfare scenarios to be used as a basis for evaluation of air warfare tactical systems and concepts. The approach involved the development of a rigorous mathematical framework for tactical combat; it incorporated elements of game theory (resource-constrained nonzero-sum games) and artificial

intelligence (knowledge-based simulation).

Fast Algorithms for Real Time Estimation, Prediction and Control (1985-1986). Directed project for the Office of Naval Research to investigate improved algorithms for real time estimation, prediction and control. Improved algorithms are needed to provide a solution to a critical problem faced in both industrial and defense applications the fact that the algorithms used to implement state of the art statistical estimation, prediction and control techniques are too slow and failure-prone for many real time or near real time applications of high interest (such as correlation / tracking of missiles), even using the fastest computers. Under this project, a new estimation algorithm was developed and analyzed. The algorithm was demonstrated by applying it to solve multiple linear regression problems in "ill-conditioned" situations, such as the case of a singular or near-singular design matrix (multicollinearity).

Sep 1982 – May 1986 Adjunct Professor of Statistics, University of Arizona. Taught the graduate course, Sampling Theory and Methods, and the required basic undergraduate statistics course for all students of business, public administration and management information systems. This class was very large, with about 500 students per semester. Presented lectures to two classes of 250 and supervised five graduate teaching assistants, who conducted homework-review and test-review sessions in small classes (about 30 students per class).

1982 – 1986, 1986 – 1988. Manager of Research and Development and Principal Scientist of United States Army Electronic Proving Ground (EPG) Electromagnetic Environmental Test Facility (EMETF), Tucson and Sierra Vista, Arizona. Responsible for design and analysis of operational operational test and evaluation of military electronic equipment. Managed staff of

about 16 (mostly PhDs in engineering, science and mathematics). Supervised the design and analysis of development tests of defense communications electronics (C-E) systems. Directed the following projects:

- Dynamic Electromagnetic Systems Combat Effectiveness Model. Directed project to develop measures of effectiveness for defense C-E systems and explore means of linking large scale C-E models to large scale tactical combat models. The project made use of queuing models to estimate message delay as a function of system characteristics.
- Simulation of Realistic Electromagnetic Environment for Stress Load Testing. Directed project to demonstrate the feasibility of simulating a realistic C-E signal environment for loading the EPG Stress Loading Facility.
- Simulation Model Architecture / Intelligence Electronic Warfare (IEW) Model Extension. Directed project to develop a dynamic event driven simulation model architecture for C-E test and evaluation.
- Statistical Analysis of Voice Scoring Data. Conducted a components-of-variance analysis of data from voice scoring of data from noisy voice communications.
- Requirements Specification for Computer-Graphics Deployment Analysis System. Supervised a systems engineering effort to develop a modern computer graphics system to interface existing EMETF communication system simulation programs.

1986. Principal Engineer, Singer Systems and Software Engineering, Tucson, Arizona. Systems and software engineering in defense applications.

1982. Consulting Statistician. Provided statistical consulting to a law firm pursuing a case involving the prices that Mexican growers received for produce in Arizona markets. (Data analysis, legal

testimony at trial).

1977-1991. Founder and President, Vista Research Corporation, Alexandria, Virginia and Tucson, Arizona. President and manager of contract research firm. Contracts included the following.

Microsimulation Forecasting Model for Human Development Services Programs (1979-1981). Dr. Caldwell directed the project to develop the MICROSIM microsimulation forecasting model for the US Department of Health and Human Services. The purpose of this contract was to assist the Division of Forecasting and Analysis of the Office of Planning, Research, and Evaluation of the US Department of Health and Human Services (DHHS) Office of Human Development Services, in formulating and implementing a prototype microsimulation forecasting model and developing a prototype statistical reporting system which provides the data required for the forecasting model. The model called MICROSIM was developed to forecast caseload and expenditures for the following HDS programs under various policy assumptions: Rehabilitation Services Administration, Title XX Social Services (Administration for Public Services), the Administration for Children, Youths, and Families (Child Welfare, Headstart, Runaway Youths), the Administration on Aging, and the Administration for Native Americans. The MICROSIM model simulated future demographic changes to individuals in a large population of individuals (drawn from the US Current Population Survey), simulated the incidence of human-service-related problems for each of the individuals in the simulated population, and estimated caseloads and budgets for the simulated population (corresponding to program and policy assumptions) by direct computation. The system was pilot-tested in Utah.

Economic and Social Impact Analysis / Women in Development

(ESIA/WID) Project (1979-1981). The purpose of this project, sponsored jointly by the Philippines National Economic and Development Authority (NEDA) and the US Agency for International Development, was to help improve the capability of the Government of the Philippines to monitor and measure economic progress, social change, and the impact of development projects, including the effects on women in their dual role as agents and beneficiaries of development. The contract provided technical services to assist the Philippines Institute of Development Studies (PIDS) to develop and validate analytical frameworks and indicators for analyzing and measuring progress and the impact of development projects on selected areas of concern; to design and field test efficient means for measuring and monitoring project progress and impact indicators; and to determine a better understanding of the mechanisms by which development projects achieve their goals. The development projects included a wide variety of substantive fields -- health, nutrition, and family planning; education; integrated agricultural production and marketing, aquaculture production, and agro-reforestation; integrated area development; feeder roads; ports; local water systems; electrification; small-scale industries, and tourism. The ESIA/WID project identified and evaluated the use of a variety of statistical design and analysis techniques to assist project impact assessment: quasi-experimental designs, sample survey, analysis of variance, multiple regression analysis, questionnaire design, indicator development. For the Philippines Ministry of Health, Dr. Caldwell developed alternative management information system (MIS) designs to support both agency operations and program monitoring. Dr. Caldwell served as chief of party and directed a team of eleven Ph.D. consultants on the ESIA/WID project.

Social Services Effectiveness Evaluation (1975-1978). The purpose of this project, funded by a three-year grant from the US

Department of Health and Human Services Administration for Public Services to the State of West Virginia was to develop systems for assessing the effectiveness of social service programs in West Virginia. This effort involved interaction with program staff to define social service objectives, develop measures of effectiveness, develop instrumentation and sampling plans, conduct training sessions, analyze data report formats. Dr. Caldwell was director of this project.

Evaluation of the Economic and Social Consequences of the Extension Education Program (1978). For the Office of the Deputy Director for Extension of the US Department of Agriculture (USDA), conducted (supervised) a mail-survey evaluation of all of the USDA agricultural extension programs in the United States.

Sampling Manual for Office of Child Support Enforcement Reporting Requirements (1978). For the Office of Child Support Enforcement of the Office of Human Development (US Department of Health and Human Services), this project developed the sampling manual to be used by state agencies that elect to submit the OCSE quarterly and annual reports on the basis of statistical sampling. These reports are required by Title IV D of the Social Security Act. The manual presents a number of alternative sampling plans, to take into account administrative differences (county administered, state administered) in the state IV D programs. Dr. Caldwell directed this project (subcontract to JWK International Corporation).

Statistical Analysis Group in Education (SAGE) Project (1977). Under a contract to Killalea Associates, funded by the National Center for Education Statistics, Dr. Caldwell provided statistical consulting services to the Statistical Analysis Group in Education. Tasks included identification of future NCES research agenda

topics and research on subsampling of nonrespondents in longitudinal studies.

Elementary and Secondary School Civil Rights Survey (1977). Under a contract to Killalea Associates funded by the US Department of Health and Human Services Office of Civil Rights, Dr. Caldwell constructed the sample design for the biennial civil rights survey of elementary and secondary public schools.

Bossangoa Integrated Rural Development Project, Central African Republic (1977). For the African Development Bank / US Agency for International Development, conducted (supervised) an assessment of the rural sector of the Bossangoa region of the Central African Republic, for the purpose of identifying studies and projects that are suitable for Bank group financing.

1974-1978. Independent Statistical Consultant, Alexandria, Virginia, and Fairfax, Virginia. Statistical Consultant to various organizations, primarily in the design of analytical surveys (for the purpose of developing model-based estimates of program impact. Projects included the following.

Housing Market Practices Survey (1978). Constructed the sample design for the 1977 Housing Market Practices survey for the National Committee Against Discrimination in Housing, funded by the US Department of Housing and Urban Development. Survey results are presented in Measuring Racial Discrimination in American Housing Markets: The Housing Market Practices Survey, US Department of Housing and Urban Development, Office of Policy Research and Development, April 1979.

PSRO Data Base Development Study (1977). As a consultant to SysteMetrics, Inc. and General Research Corporation, developed

the sample design for the PSRO Data Base Development Study. For the Office of Planning, Evaluation, and Legislation of the Health Services Administration, this study was funded to develop a data base that would permit analysis of the impact of Professional Standards Review Organizations (PSRO) concurrent review on hospital utilization. The principal objective of the analysis is to assess the impact of concurrent review on length of stay by diagnostic category. This study was implemented through collection of data from patient record abstracts from a sample of short stay hospitals.

Hospital Cost Data Study (1976). As a consultant to SysteMetrics, Inc., for a contract funded by the National Center for Health Services Research (NCHSR), developed the sample design for the NCHSR Hospital Cost Data Study. The purpose of this study was to collect a wide spectrum of data from patient record abstracts to form a data base that could be used to conduct econometric investigations of the relationship of hospital cost to various patient, physician, hospital, and demographic characteristics. An analytical sample survey design was used as a basis for the data collection.

Developing Measures of Productivity for the U.S. Employment Service (1976). The purpose of this study, for the Manpower Administration of the U.S. Department of Labor, was to develop procedures for constructing an overall measure of productivity for the Employment Service. The approach adopted was to identify State Employment Service Agency (SESA) missions, goals, and objectives; to develop a production model of SESA; to synthesize and evaluate alternative productivity measures; and to validate the productivity measures. Consulting services in the area of developing the analytical approach to the study were provided to this project under an agreement with the Analytic Systems Division of Mauchly Wood Systems Corporation.

Workload Reporting Validation Guidelines (1976). The objective of this study for the Commonwealth of Pennsylvania Bureau of Employment Security was to establish validation guidelines that would permit consistent counting of workload budget items among states. The effectiveness of the administration's Cost Model system is dependent on the accuracy of workload reporting. Where inconsistent reporting of workload items exists among states, corresponding inequities will be present in the budget amounts provided to the states for program administration. This study analyzed initial claims, weeks claimed, nonmonetary determinations, appeals, wage records, and subject employers, and developed revised reporting definitions, workload validation guidelines, and sampling guidelines. The sample design for the Unemployment Insurance (UI) validation surveys was developed under an agreement with Analytic Systems Division of Mauchly Wood Systems Corporation.

Survey Design for Study of Impact of National Health Insurance on Bureau of Community Health Service (BCHS) Users (1975). As a consultant to SysteMetrics, Inc., directed the project to develop the sample design for a nationwide survey of users of BCHS facilities, to determine the impact of alternative national health insurance plans on the users. A multistage sampling plan, stratified by the major BCHS programs and state Medicaid status, was adopted. The survey questionnaires collected the health, employment, family, and demographic characteristics necessary to determine eligibility and benefit levels under alternative plans.

Design Task for Survey of Persons in Institutions (1975). As consultant to General Research Corporation funded by the Assistant Secretary for Planning and Evaluation (ASPE) of the US Department of Health and Human Services, directed the project to

develop questionnaires and a statistical survey design for the nationwide Survey of Institutionalized Persons. This survey, implemented by the US Bureau of the Census, addressed a broad range of issues associated with institutionalization, including appropriateness of placement, quality and effect of care, and patient rights. The survey instruments included staff, family, and patient questionnaires. The survey design was stratified by institution size and type. The survey for which the questionnaires and sample design were constructed was conducted by the Bureau of the Census, and documented in the reports, 1976 Survey of Institutionalized Persons: Methods and Procedures, Technical Paper 42, US Department of Commerce, Bureau of the Census, 1978; and 1976 *Survey of Institutionalized Persons: A Study of Persons Receiving Long-Term Care*, Current Population Reports, Special Studies Series P-23, No. 69, US Department of Commerce, Bureau of the Census, 1978.

Study of Discrimination in Salaries in Academia (1974). The objective of this study was to conduct a thorough analysis of the American Council on Education (ACE) survey data concerning salaries in academia. The survey data had been collected in two different years (1967 and 1973). The analysis centered on the development of parametric models that related salary level to number of years' experience, degree, quality of degree program, field of study, age, sex, race, and other variables. Separate models were developed for blacks, whites, males, and females. The data analysis produced estimates of the residual salary differential between blacks and whites, after accounting for all other major explanatory variables. Dr. Caldwell coordinated the data analysis under an arrangement with the Urban Institute and The Hendrickson Corporation.

Assessment of Recreational Benefits Accruing from the Clean

Water Act (1974). Under a contract to the Bureau of Outdoor Recreation, this study was an in-depth analysis of the benefits deriving from PL 92 500, the Federal Water Pollution Control Act. The study assessed the impact of the act on boating, swimming, and fishing, through the development of national and regional econometric models. The models related benefits to a wide range of socioeconomic, demographic, and geographic variables (water quality indices, facilities indices, mode of transportation, age, sex, race, income, family size, occupation, marital status, season, ownership of recreational vehicle, travel distance). Dr. Caldwell supervised the data analysis of the National Recreation Survey under an agreement with the National Planning Association and the Hendrickson Corporation.

Budget Justification Model for Federal Energy Administration (1974). For the Federal Energy Administration, this project was directed toward the development of an analytical model to be used to assist the process of allocating funds between competing solar energy programs (wind, ocean thermal, solar electric, solar thermal). Development of a stronger analytical framework for budget allocation was required by the Office of Management and Budget, subsequent to a General Accounting Office analysis of the previous budget justification. Dr. Caldwell provided consulting in the area of decision analysis, under an agreement with Planning Research Corporation.

Research Design for the Urban Arterials Section of the Highway Capacity Manual (1974). As consultant to Alan M. Voorhees Company of Planning Research Corporation, constructed an experimental design to specify computer simulation runs for a large-scale highway traffic simulation model. This effort was one of the earliest applications of the use of experimental design to specify “run sets” for large-scale computer simulation models.

1974-1978. Vice President, JWK International Corporation, Annandale, Virginia. Served as Vice President of firm from inception to size of about 30 technical staff. Responsible for all technical projects (supervised all, directed many). Projects included the following.

Analysis of Federal Medicaid Matching Percentage Formula (1978). For the Social and Rehabilitation Service, directed the study to develop alternatives to the Federal Medical Assistance Percentage (FMAP) formula, which is used to reimburse state Medicaid and Aid to Families with Dependent Children (AFDC) expenses. The analysis effort considered factors such as ability to pay, cost of services, incidence of the target population, and program effort. The analysis was implemented through a time-shared computer program.

Economic Policy Analysis for the Government of Haiti (1975-76). Under a contract funded by the US Agency for International Development, this study determined agricultural and tax policy changes that the government of Haiti could employ to increase foreign exchange and increase the income of the small farmer. The study addressed five commodities -- coffee, cotton, sisal, mangoes, and meat (major emphasis on coffee). The project included the use of rapid-assessment sample surveys to collect up-to-date data on commodity prices. A major goal of the project was the transfer of policy analysis capabilities to members of the Haitian Ministry of Agriculture. Dr. Caldwell supervised a team of four Ph.D. consultants (economists) on this project, and conducted the statistical analysis of survey data (surveys of current prices). For a number of years, the coffee study was the definitive work on the economics of coffee in Haiti.

Medicaid Standards Impact Assessment (1975-76). For the Health Care Financing Administration, Dr. Caldwell directed the Medicaid Standards Impact Assessment Study, the objective of which was to assess the cost and effectiveness of federal standards for nursing home costs and performance. Under the first year's effort, a computer model was developed to estimate the residual cost impact of requiring full compliance with standards in the State of Minnesota. Data were collected from all Medicaid survey and cost reports for all Skilled Nursing Facility (SNF) and Intermediate Care Facility (ICF) nursing homes in Minnesota. The second year's effort centered on the development of instrumentation to assess the impact of standards on quality of care.

Sampling Manual for Social Services (Title XX) Reporting Requirements (1976). For the Office of Information Sciences of the Social and Rehabilitation Services, developed the Sampling Manual that is used by states which elect to use statistical sampling as a basis for completing the eight Social Service Reporting Requirements (SSRR) forms. These quarterly and annual forms are required to be submitted by all states to document their social service program activities funded by Title XX of the Social Security Act.

Vocational Rehabilitation Performance Evaluation Standards Study (1976). For the Rehabilitation Services Administration, directed project to conduct statistical analysis of vocational rehabilitation (VR) program data submitted by the states as part of their respective VR programs. The objectives of the study were to review and validate the submitted state agency data, to develop performance limits for each of the federal VR evaluation standards, to analyze changes that have occurred (over time) in national and state performance, to develop an analytical paradigm to enable use of the standards data for management purposes to suggest

and outline evaluative research or demonstrations, and to develop guidance material for use by states in making future evaluation standards data submissions.

Cost Benefit Analysis of NIAAA Alcoholism Treatment Centers (1976). For the National Institute for Alcohol Abuse and Alcoholism, supervised the study to determine the benefit-cost ratio associated with 43 alcoholism treatment centers located in communities across the country. Benefits and costs were calculated from three points of view the economy, the federal government budget, and the local community. The study revealed a high benefit-cost ratio from all three perspectives.

NASA Technology Transfer Programs (1975). For the National Aeronautics and Space Administration, supervised several cost benefit studies of technology transfer for several NASA programs. These analyses were used as input to NASA's budget justification for the Office of Management and Budget (OMB). The first such study concerned an assessment of the desirability of developing a mass spectrometer for analysis of destruction to the earth's ozone layer, reputedly caused by fluorocarbons. The purpose of the study was to conduct an economic assessment of the mass spectrometer, from a cost benefit standpoint. Apart from the economic analysis of the mass spectrometer, the study asserted that from a cost benefit standpoint, it was absurd to allow the continuation of widespread release of fluorocarbons into the atmosphere, as long as they were suspected of significant damage.

A second analysis was concerned with the terra forming of Venus through the injection of blue green algae into the Venusian atmosphere, while a third study concerned a cost benefit assessment of a highly reliable airborne computer.

Day Care Cost Benefit Study (1974). Directed study for the Department of Health, Education and Welfare (HEW) Social and Rehabilitation Service (SRS) to perform cost benefit analysis of day care services provided under Title IV A of the Social Security Act. This model determined benefit/cost ratios from the societal, government budget, and individual viewpoints, as a function of type of day care (center care, family day care, and in-home care), family size, ages of family members, and family income. The model was applied to example data to determine "breakeven" curves, i.e., the family size, income, and age characteristics for which the dollar benefits of various types of care exceed the cost. The project was implemented by constructing a time-shared computer model.

Vocational Rehabilitation Program Administration Review (1974). For the Rehabilitation Services Administration, directed project to conduct a program administration review, or PAR, of state vocational rehabilitation agencies. The objective of the PAR was to analyze state progress in complying with recent changes in the VR program, the Individualized Written Rehabilitation Program (IWRP) and Post Employment (Post Closure) services.

Vocational Rehabilitation Follow-up Study (1974-76). This nationwide follow-up study of former clients of the vocational rehabilitation program sought to determine the extent to which clients retain program benefits. The project was implemented as a statistical sample survey of 6,000 former clients of vocational rehabilitation. The objective of the study was to assess benefit retention in the areas of earnings and employment, health, and family relationships. The effort included a full range of survey methodologies, issue identification, questionnaire development, preparation of the Office of Management and Budget (OMB)

clearance package required by the Paperwork Reduction Act, monitoring of the data collection effort (conducted by Opinion Research Corporation), and analysis of the collected data. Dr. Caldwell directed the VR Follow-up Study in its initial phases, prior to field data collection.

Vocational Rehabilitation State Allocation Study (1974). For the Social and Rehabilitation Service, conducted study to analyze the allocation formula used by the federal government to allocate approximately $700 million in federal funds to the states. The previous formula was adopted from the Hill Burton hospital construction program of the 1950s, and had never been subjected to a formal economic analysis. The Hill Burton formula was analyzed in detail, to determine the extent to which it adequately implemented the intent of the Vocational Rehabilitation program; the formula was found to have serious deficiencies. The analysis took into account each state's need for services (i.e., the target population), the ability of a state to pay for services, cost of services, program effort, willingness to pay, maintenance of effort, and transitionary provisions. A basic measure, the equity index, was developed to compare the performance of alternative matching formulas. The Hill Burton formula was shown to be seriously deficient, based on a comparison of alternatives using the equity index. Two new formulas were developed that allocated funds in a much more equitable fashion. The results of this study were used by Congress to determine the allocation formula used in legislation.

1972-1974. Principal, Planning Research Corporation Systems Sciences Division (PRC/SSD). Principal of world’s largest non-legal non-medical contract research firm. Primarily engaged in the development of correlation / tracking algorithms for satellite ocean surveillance systems.

US Navy Systems Simulation Program. As part of the effort to design the Naval Satellite Ocean Surveillance System, determined methods for performing correlation/tracking and multisensor fusion of surveillance data. This work is described in the reports, Correlation/Tracking Performance Study and Improvements to the Systems Simulation Program, Navy Space Systems Activity (NAVELEX).

1967-1972. Member of the Technical Staff, Lambda Corporation, Arlington, Virginia. Member of the technical staff of Lambda Corporation (later General Research Corporation), a contract research firm specializing in solving optimization and game-theory problems in defense and industrial applications. Lambda Corporation was founded by Hugh Everett III, the American physicist who developed the Parallel Universe (Many Worlds) interpretation of quantum mechanics and the Generalized Lagrange Multiplier (GLM) method for solving large constrained optimization problems, such as resource-allocation problems and games. The GLM method is useful for solving problems in which the objective function is nonlinear, nonconvex, and noncontinous. The GLM optimization method was used in many of the projects conducted by the firm. The GLM method is an iterative methodology, implemented using digital computers. Most of the models described below were developed on a Control Data Corporation CDC 1604 48-bit computer (developed by Seymour Cray), one of the first commercial transistor-based computers, and one of the fastest machines on the market. Later models were developed on the CDC 6400 60-bit computer.

TIMES Box-Jenkins Time Series Analysis Software Package. Dr. Caldwell developed TIMES, the first commercially available general purpose statistical program package for analyzing time

series data using the Box-Jenkins (Autoregressive Integrated Moving Average, ARIMA) models.

Economic Analysis of Alternative Manufacturing Facilities. For Merck and Company, Lambda Corporation conducted a study to assess the economic feasibility of constructing a very large scale modular chemical manufacturing facility. A pilot plant had demonstrated the technical feasibility of the concept. A large-scale microsimulation model was developed to examine the economic returns associated with alternative plants, and alternative phase-in schedules. The analysis indicated that, although the modular procedure outperformed the traditional (line-plant) approach, serious economic difficulties were associated with transitioning from the current mode of manufacturing to the new mode. The analysis made heavy use of the Generalized Lagrange Multiplier method. Dr. Caldwell was in charge of the simulation of product demand. Box-Jenkins time series models were developed from historical data, and used as a basis for developing alternative future demand scenarios. At the time, this contract was the largest non-military operations research contract ever conducted.

Derivation of Optimal Ballistic Missile Area Defense. Derived the optimal solution to the problem of allocating imperfect (less than perfect reliability) area interceptors to defense sites. This problem is technically referred to as "subtractive overlapping-island defense with imperfect interceptors." It is technically difficult because it is a two-sided optimization problem (a resource-constrained game) involving a nonlinear, noncontinuous, nonconvex payoff function. The solution to this problem is necessary to compare alternative ballistic missile defense system configurations, and to make decisions about sizing and allocation of interceptor stockpiles. This work is described in the report, Subtractive Overlapping-Island Defense with Imperfect Interceptors, US Arms Control and

Disarmament Agency Report ACDA/ST-166.

Derivation of Optimal Ballistic Missile Point (Local) Defense. Derived the optimal solution to the problem of allocating imperfect point-defense (hardsite defense) interceptors to local defense sites. As in the case of area interceptors, this problem is technically difficult to solve, since it involves nonconvex, noncontinuous payoff functions. This solution is needed to compare alternative defense configurations in the case of point defense (e.g., defense of an isolated radar facility, or a target of such importance that its interceptors would not be used to defend alternative targets). This work is described in the report, Some Problems in Ballistic Missile Defense Involving Radar Attacks and Imperfect Interceptors, US Arms Control and Disarmament Agency Report ACDA/ST-145.

HARDSITE Defense Model. Developed the HARDSITE computer model to analyze ballistic missile defense systems. The model included treatment of imperfect interceptors, reprogramming of interceptors, decoy silos and sites, redundant radars, local (modular) and area defense, multiple reentry vehicles (RVs), decoy RVs, and multiple weapon types. The model determines the optimal preallocated, randomized, (min-max) defense-offense strategies, taking radars into account, and can also be used to determine the value of simple nonoptimal strategies. This work is described in the report, HARDSITE Defense Model, Office of the Assistant Secretary of Defense Contract DAHC15-68-C-0187.

Naval Combat Damage Model; Multiple Resource-Constrained Game Solution. As part of a project to determine a model to assess the value of naval general-purpose forces, methods were determined for solving matrix games having multiple resource constraints. A solution was determined by combining the method

of Generalized Lagrange Multipliers and the Brown-Robinson method of fictitious play. This work is described in the papers, Naval Combat Damage Model, ONR Contract N00014-69-C-0282 and Multiple Resource-Constrained Game Solution, ONR Contract N00014-69-C-0282.

Evaluation of Alternative Missile Tracking Systems. For the Advanced Ballistic Missile Defense Agency, conducted a study to compare the performance of alternative missile tracking algorithms. The study centered on analysis of the performance of autoregressive integrated moving average (ARIMA, or "Box-Jenkins") models compared to the Kalman filter and alpha-beta trackers. The work is described in the report, Box-Jenkins Filter Feasibility Study, Advanced Ballistic Missile Defense Agency, Contract DAHC 60-71-C-0048. This work laid the groundwork for the development of the “Cassandra” tracker, a Bayesian, nonlinear missile tracker subsequently developed by Gary Lucas and Hugh Everett III. (Cassandra is appropriate not only for tracking maneuvering missiles, but for identifying “turning points” in financial markets.)

Conflict, Negotiation, and General-Sum Game Theory. Developed a computationally tractable general-sum (non zero-sum) game-theoretic solution to war, taking into account the effect of the threat of war on negotiations. This work found approximate, but explicit, solution to John Nash’s bargaining solution to a non zero-sum game (Nash’s theory presented only an existence proof, not a constructive proof, of the bargaining solution). Game-theoretic formulations arise in the evaluation of weapon systems since it is important to evaluate all systems when optimally deployed. Most war gaming, weapons allocation, and force procurement models have been developed using either zero-sum payoffs (one player's loss is the other's gain), or ignoring the relationship of conflict to

negotiation. This work shows how optimal strategies for the difficult mathematical problem of solving a general-sum game (which represents war better than the zero-sum formulation) can be approximated by the solution to a particular zero-sum game derived from the general-sum game. This work is described in the report, *Conflict, Negotiation, and General-Sum Game Theory*, Office of Naval Research Contract N00014-69-C-0282.

This work involved basic research in game theory. A reprint of the original report is posted at Internet website http://www.foundationwebsite.org/Conflict.htm

A note on Lambda Corporation is posted at http://www.foundationwebsite.org/HistoricalNote1.htm. A brief biography of Hugh Everett III is posted at http://en.wikipedia.org/wiki/Hugh_Everett.

1966-1967. Senior Operations Research Analyst, Deering Milliken Research Corporation, Spartanburg, South Carolina. Conducted operations research studies in textile applications. Primarily engaged in the design of experiments to improve the efficiency of production operations and the quality of products. Statistical analysis was done on a second-generation transistor-based IBM 7094 computer with double-precision arithmetic based on a 36-bit word length, using the IBM Scientific Subroutine Package (FORTRAN) for mathematical and statistical processing (regression analysis, analysis of variance, principal components analysis, factor analysis).

1964-1966. Operations Research Analyst, Research Triangle Institute, Durham, North Carolina. Conducted operations research studies in civil defense applications. Participated in national sample survey of fallout shelters (field survey work, data analysis

and reporting), analysis of radiological defense, post-nuclear attack health and medical issues, vulnerability of the national electric power system to nuclear attack, and post-attack countermeasures.

1962-1966. Graduate Student, Department of Statistics, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina. Completed PhD degree in mathematical statistics at the University of North Carolina at Chapel Hill, North Carolina. The Statistics Department at UNC Chapel Hill was founded in 1948. In 1962, it was the oldest and largest comprehensive statistics department in the United States, and one of the three world-wide Institutes of Statistics. For his PhD work, he studied under Professor Raj Chandra Bose, the "father" of the mathematical theory of experimental design. (Raj Chandra Bose (1901-1987) was an Indian-American mathematician and statistician best known for his work in design theory and the theory of error-correcting codes in which the class of Bose-Chaudhuri Hocquenguem (BCH) codes is partly named after him. He was notable for his work along with S. S. Shrikhande and E. T. Parker in their disproof of the famous conjecture made by Leonhard Euler dated 1782 that there do not exist two mutually orthogonal Latin squares of order 4n + 2 for every n. A brief biography of R. C Bose is posted at Internet web site http://en.wikipedia.org/wiki/Raj_Chandra_Bose.) In PhD dissertation, *Synchronizable Error-Correcting Codes*, developed the best known class of codes for correcting both additive and synchronization errors in noisy communication channels. National Aeronautics and Space Administration (NASA) Fellowship. Invited to International Conference on Coding Theory in Royan, France, 1965. Worked summers at Research Triangle Institute (Operations Research Department).

Computer Languages, Packages, and Systems. Heavy

experience in applications programming in C, Visual C, Visual Basic, dBASE/FoxPro, Microsoft Access, SQL and Fortran on mainframe computers, minicomputers and microcomputers under a variety of operating systems (MS-DOS, Microsoft Windows, UNIX, IBM, CDC, UNIVAC, Sun Solaris SPARCcenter and others); experienced in application of statistical program packages, such as Stata, SAS, SPSS and R. Strong microcomputer experience, including the development of graphics-based microcomputer software for geographic information systems applications. Familiar with a variety of commercial microcomputer software (e.g., word processing, electronic spreadsheet, data base, desktop publishing, accounting). Experience working in a Microsoft Windows / UNIX network environment (VB, SAS, Oracle). Familiar with Microsoft Office suite of products (Word, Access, Excel, PowerPoint, FrontPage) on Windows 95/NT/XP or UNIX client/server system.

Publications. Author of articles and books on divers topics (e.g., population, energy, environment, economics, politics, tax reform, health care, defense music, guitar, defense, religion / spirituality / philosophy, and science fiction), including *Statistical Methods for Monitoring and Evaluation: A Comprehensive Survey Course* (2016); *A New Health-Care System for America: Free Basic Health Care (2017*); *The Value-Added Tax: A New Tax System for the United States* (1987); *The Late Great United States* (2008); *Can America Survive?* (1999); *Mathematical Theory of Global Nuclear War* (2001); *A Lagrangian Approach to Customer Relationship Management: Variable-Rate Pricing Strategy* (2006); *How to Play the Guitar by Ear (for mathematicians and physicists)* (2000). See Internet website http://www.foundationwebsite.org to view these and other publications (over 80).

Honors / Awards. Tau Beta Pi National Engineering Honorary Society, General Motors Scholarship (Carnegie-Mellon University,

Pittsburgh), NASA Fellowship (University of North Carolina at Chapel Hill)

Professional Affiliations. Institute for Management Sciences and Operations Research (INFORMS), American Statistical Association, Institute of Mathematical Statistics

Positions

Consultant in Statistics, Optimization and Information Technology, 1974-present (various organizations, including National Opinion Research Center at the University of Chicago (NORC), The Mitchell Group, Sanigest, Academy for Educational Development (AED), Chemonics, Wells Fargo Bank, Bank of Botswana, United Nations Development Program (UNDP), contractors of United States Agency for International Development (USAID), Millennium Challenge Corporation (MCC), Inter-American Development Bank (IDB),African Development Bank (AfDB), Asian Development Bank (ADB))

Software Engineer (Developer of Education Management Information System (EMIS)), Academy for Educational Development, Lusaka, Zambia, 2002-05

Director, Management Systems Department, Bank of Botswana, 1999-2001

Software Engineer (Developer of national civil service Personnel Management Information System (PMIS)), Academy for Educational Development, Lilongwe, Malawi, 1993-94

Manager of Monitoring and Evaluation, Chemonics International, Cairo, Egypt, 1991-92

President and Manager, Vista Research Corporation, Tucson and Sierra Vista, AZ, 1988-91

Adjunct Professor of Statistics, University of Arizona, Tucson, AZ, 1982-86 (taught the graduate course in sample survey design

and analysis and the core statistics course for students in business, public administration and management information systems)

Director of Research and Development and Principal Scientist of US Army Electronic Proving Ground's Electromagnetic Environmental Test Facility, Bell Technical Operations and Combustion Engineering, Tucson and Sierra Vista, AZ, 1982-86, 1986-88

Principal Engineer, SINGER Systems and Software Engineering, Tucson, AZ, 1986

President and Manager, Vista Research Corporation, Alexandria, VA, and Tucson, AZ, 1977-81

Vice President, JWK International Corporation, Annandale, VA, 1974-76

Principal, Planning Research Corporation, McLean, VA, 1972-74

Member of the Technical Staff, Lambda Corporation / General Research Corporation, McLean, VA, 1967-72

Senior Operations Research Analyst, Deering Milliken Research Corporation, Spartanburg, SC, 1966-67

Operations Research Analyst, Research Triangle Institute, Research Triangle Park, NC, 1964-66

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