

Joseph George Caldwell, Ph.D. (Statistics)
Consultant in Strategic Studies; System Simulation, Modeling, Analysis, and Development; and Test and Evaluation. Professor of Statistics

1432 N. Camino Mateo, Tucson, AZ 85745-3311 USA
Tel. (001)(520)222-3446, e-mail jcaldwell9@yahoo.com

Education...

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

Consultant...

to government agencies, international agencies and corporations

Director/Supervisor of major projects in...

- o strategy and tactics (national security, ballistic missile defense, theater-level operations; game theory; statistical decision theory; optimal allocation of resources; constrained optimization; nonzero sum games; resource-constrained games; asymmetric warfare (terrorism / counterterrorism; guerrilla warfare; nuclear attack by rogue nation); conflict and negotiation; Bayesian statistics; forecasting and control)
- o artificial intelligence / expert systems (automated scenario generation)
- o data fusion (sensor fusion, multisensor fusion, multisource multisensor fusion, information fusion); situation assessment; estimation, prediction, and control; correlation/tracking; satellite surveillance systems
- o simulation and modeling (ocean surveillance, ballistic missile defense, communications-electronics)
- o systems and software engineering (structured analysis / design; object-oriented design)
- o system development (requirements specification / analysis, design, implementation and test)
- o test and evaluation (communications-electronics, C⁴IEW)
- o statistical applications (test design, experimental design, fast algorithms, data analysis, data mining, statistical methodology, sample survey design and analysis)
- o scientific programming (statistics, optimization, graphics; expert systems, spatial analysis)
- o operations research and statistics
- o geographic information systems, mapping information systems
- o programming languages / development environments / tools / mathematical software packages: C, Visual Basic, MS Windows, UNIX, Stata, SAS, SPSS, MS Access, SQL, ArcView GIS, Fortran, Numerical Recipes, many others
- o standards: ISO 9000 Quality Management; ISO 12207 Information Technology; DOD-STD-2167A, MIL-STD-498 Software Development; Carnegie Mellon University Software Engineering Institute Capability Maturity Model (CMU SEI CMM)

Manager of contract research / system development firm (seven years); successful bidder on numerous technical contracts, including four Small Business Innovation Research (SBIR) contracts. Manager of R&D department of major US Army test and evaluation center. Director of more than twenty projects.

Director of Management Systems ("chief information officer" of the central bank of Botswana. Set IT vision, strategy, policy, procedures; supervised all IT operations. Supervised Year 2000 project and bankwide disaster recovery project.

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

Developer of technical seminars and computer program packages in defense applications, sample survey, causal analysis, small area estimation, forecasting, and geographic information systems

Languages: Native in English; working knowledge of Spanish and French; limited German, Portuguese,

Arabic

Summary of Experience. Dr. Caldwell's professional career in systems analysis, system development, research and management has centered on the use of modern analysis techniques to solve practical problems in government, commercial, industrial, and defense applications. His career includes founder and manager of Vista Research Corporation, manager of the R&D Department and Principal Scientist of the US Army Electronic Proving Ground's Electromagnetic Environmental Test Facility, and consultant or employee to major contract firms (Bell Technical Operations, SINGER Systems and Software Engineering, General Research Corporation, Planning Research Corporation, Research Triangle Institute).

CAREER SUMMARY

Served as independent consultant to numerous consulting firms and other organizations, including The Mitchell Group (2016), National Opinion Research Corporation of the University of Chicago (2007-2015), Inter-American Development Bank (2014), United Nations Development Program (2006), Academy for Educational Development (2002-2005), Bank of Botswana (1999-2001), Chemonics, Western Research Company, Bell Technical Operations, Planning Research Corporation and General Research Corporation in systems and software engineering, system development, project management, project and program monitoring and evaluation, management information systems, statistics, operations research, research design, and strategy and policy analysis in defense and other application areas.

MILITARY APPLICATIONS

Terrorism / Counterterrorism.

Education (PhD, statistics) and experience (constrained optimization, statistics, game theory, strategy development, policy analysis) has included all of the major tools now in wide use in counterterrorism, including data mining, game theory, biometric authentication, statistical decision theory, psychometric profiling, Bayesian estimation and decisions, constrained optimization (determination of optimal strategies, optimal allocation of resources), and modeling and simulation.

Many publications on global politics and warfare (analysis, strategies, tactics) posted at Internet website <http://www.foundationwebsite.org> . Book on population, energy and the environment (<http://www.foundationwebsite.org/canam4x.htm>) includes assessment of global military/political situation in the "Peak Oil" era, and the development of strategies for planetary management in a post-industrial, post-petroleum setting. Recent work includes efforts to develop an Automated Bayesian Data Fusion Analysis System (ABDFAS) based on statistical causal analysis (Bayesian networks; see <http://www.foundationwebsite.org/SBIRABDFAS.docx>).

Developed an approach ("Asymmetric Adversary Tactics and Strategy Generation") for automated generation of strategies and tactics for conducting asymmetric warfare (e.g., US vs. terrorists, rogue nations). The strategies and tactics are developed by formulating conflict as a resource-constrained nonzero-sum game, and solving the game using the generalized lagrange multiplier (GLM) method. The solution to the game, in the form of randomized strategies, constitutes the desired strategies (theater echelon) and tactics (below-theater echelon).

As unclassified examples of the application of lagrangian optimization to determine optimal strategies in resource-constrained applications, see "Conflict, Negotiation, and General-Sum Game Theory" at <http://www.foundationwebsite.org/Conflict.htm> or "Lagrangian Approach to Customer Relationship Management" at <http://www.foundationwebsite.org/LagrangianApproachToCRM.htm> . The GLM methodology is particularly relevant to the development of optimal strategies for allocation of resources to search and detection of terrorist cells, since it is designed for applications in which the "payoff" or

“objective” function may be represented as a sum of payoffs from independent “cells.”

President, Director, Vista Research Corporation (1977-81, 1988-91)

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. Major projects include the following:

Research in Artificial Intelligence for Noncommunications Electronic Warfare Systems; Geographic Information Systems; Expert Systems. 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 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 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 incorporates the US Army Corps of Engineers' C-Language Integrated Production System (CLIPS) expert system.

Tactical Theater Air Warfare Methodologies. 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. 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, even using the fastest computers. Under this project, a new estimation algorithm was developed and analyzed. The algorithm, a type of "structured neural network," 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).

Manager, R&D Department, US Army Electronic Proving Ground's Electromagnetic Environmental Test Facility (Bell Technical Operations, 1982-88)

Test and Evaluation in Communications-Electronics. Served as Manager of Research and Development and Principal Scientist of the US Army Electronic Proving Ground's (EPG's) Electromagnetic Environmental Test Facility (EMETF). Supervised the design and analysis of development tests of defense communications-electronics (C-E) systems. Directed the following projects:

- o 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.
- o 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.

- o 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.
- o Statistical Analysis of Voice Scoring Data. Conducted a components-of-variance analysis of data from voice scoring of data from noisy voice communications.
- o 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.

Summary of Work in Missile Defense. The following paragraphs summarize work in ballistic missile defense and related areas.

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.

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 a practical solution to John Nash's bargaining solution to a non zero-sum game). (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.

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.

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).

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 G Lucas and Hugh Everett III. (Cassandra is not only appropriate for tracking maneuvering missiles, but for identifying "turning points" in financial markets.)

NONMILITARY APPLICATIONS

Management and Scientific Consultant (1974-present)

Management Consulting / Information Technology / Senior Management. Recent work has been in the area of impact evaluation of US foreign assistance projects. Developed analytical sample survey designs for impact evaluations of economic development projects in the US, Jamaica, Honduras, Ghana, Burkina Faso, Namibia, Benin, Malawi, Zambia, and Côte d'Ivoire:

- Impact Evaluation of the Programme of Advancement through Health and Education (PATH), Jamaica (a conditional cash transfer program)
- 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)
- Community-Based Rangeland and Livestock Management Household Income and Expenditure Surveys, Namibia (Millennium Challenge Corporation)
- Conservancy Support and Indigenous Natural Products Household and Organisational Surveys, Namibia (Millennium Challenge Corporation)
- Impact Evaluation of Water Supply Activity, Ghana (Millennium Challenge Corporation)
- 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))
- 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 Investitions und Entwicklungsgesellschaft (DEG))
- Impact of Feeder Roads Activity, Ghana (Millennium Challenge Corporation)
- Farmer Training and Development Activity, Honduras (Millennium Challenge Corporation)
- Transportation Project, Honduras (Millennium Challenge Corporation)

Consultant to the Inter-American Development Bank to provide technical training in small-area estimation to the Bahamas Department of Statistics (2014). Consultant to the United Nations Development Program (UNDP) in East Timor (2006), to advise on the selection of a personnel management information system for the East Timor civil service. Served (2002-2005) as technical advisor to the Zambian Ministry of Education, to develop a management information system to store and retrieve data collected in the annual school census (US Agency for International Development / Academy for Educational Development). Prior to that (1999-2001), served as Director of Management Systems (chief information officer) of the Bank of Botswana (Botswana's central bank). Applied standards-based quality management (ISO 9000 Quality Management standard, ISO 12207 Information Technology standard, DOD-STD-498 Software Development and Documentation standard, Carnegie Mellon University Software Engineering Institute Capability Maturity Model (CMM)) to direct all Bank computer operations. Introduced the use of systems and software engineering tools, including the Popkin System Architect and the Computer Associates (CA) Entity Relationship for Windows (ERwin) and Business Process for Windows (BPwin) products. Acquired the CA Unicenter TNG system management software package for monitoring and control of the bank's 300-computer system. Managed a staff of 16 information-technology (IT) professionals and 30 IT projects (annual budget \$3 million, exclusive of personnel, training, and facility). Set IT vision, mission, strategy, policy and procedures, and supervised all IT operations. Supervised Year 2000 project, IT disaster recovery project, bankwide disaster recovery project. Other recent assignments in banking include development of a system for positioning automatic teller machines (ATMs) using lagrangian optimization and the ESRI ArcView Geographic Information System (GIS) (First Union National Bank), and development of an optimal variable-rate pricing strategies for Canada Trust Bank.

Automated Receiver Operating Characteristic System; Diagnostic Imaging Systems. Conducted requirements analysis and specification for the statistical system of an automated receiver operating characteristic (ROC) system. The goal of the development effort was to develop an easy-to-use, microcomputer-based system for facilitating the design, implementation and analysis of receiver operating characteristic experiments. (A ROC experiment is an experiment designed to determine and describe the accuracy of a diagnostic system, such as a computer imaging system. The system is to make a decision about what alternative state of nature is true, based on an (image) observation. The ROC methodology lends itself well to graphical presentations on microcomputer screens, e.g., in medical diagnostic imaging systems or military multisensor fusion applications.)

Personnel Management Information System for the Government of Malawi. Developed the computer Personnel Management Information System for the Government of Malawi civil service. The system includes a variety of demographic and employment-related data for all 60,000 Malawian civil servants, and offers the users (personnel officers) a wide range of data entry and query/report capabilities. The software includes a 30,000-line graphical user interface (GUI) to enable the user to generate a large selection of queries and reports by making point-and-click selections from a menu with a mouse. The software development was conducted in compliance with DOD-STD-2167A Software Development and Documentation standard (superseded by MIL-STD-498 and ISO 12207).

Monitoring and Evaluation of Development Projects; Management Information Systems; Geographic Information Systems. In Egypt, served as Manager of Monitoring and Evaluation for the Local Development Project, the largest local-level infrastructure development project in the world. Developed management information systems to assist the identification, monitoring, and evaluation of local infrastructure development projects. Designed and implemented a national-level sample survey to evaluate the implementation, operating, and service status of the projects. Evaluation systems made extensive use of the dBASE database management system and the SPSS statistical analysis program package. Supervised training of local planners in the use of the PC ARC/INFO geographic information system (GIS).

OTHER EXPERIENCE. In addition to the preceding positions, served as a consultant or senior employee to a number of other firms. Projects supervised, directed, or contributed to include the following:

Simulation and Modeling. Directed or consulted to the development and application of numerous simulation models, including:

- o National Military Command System Support Center's QUICK General War Game Simulation Model (general wargaming model used for strategic analysis of ballistic missile defense)
- o US Navy's Systems Simulation Program (to evaluate alternative satellite surveillance systems)
- o MICROSIM Microsimulation Forecasting Model for Human Development Service Programs
- o Simulation Model to Perform Economic Evaluation of Alternative Modes of Chemical Manufacturing

Intelligence Fusion; Correlation/Tracking Developed algorithms for correlating and tracking ocean vessels using data from satellites and other sources. Algorithms involved use of statistical models to estimate parameters of interest (e.g., location, direction, speed of ocean vessels), by combining spatial and temporal multisensor data. Developed simulation models to compare performance of alternative correlation / tracking methodologies. Methodology took into account the temporal and spatial irregularity of the data-capture technology.

Strategic Studies, Optimal Allocation, Game Theory. Directed the following studies:

- o Analysis of Hardsite Defense (Office of Assistant Secretary of Defense for Systems Analysis)
- o Nonzero Sum Game Analysis of Defense Systems (Office of Naval Research)
- o Analysis of Subtractive Overlapping-Island Ballistic Missile Defense System with Imperfect Interceptors (US Arms Control and Disarmament Agency)

The preceding studies involved the development of new theory for analysis of complex optimization problems involving two-sided, nonlinear, nonconvex, discontinuous objective functions in both the sequential-move and simultaneous-move (game) contexts.

Scientific Programming. Much career work has involved the sophisticated use of the computer to solve difficult estimation and optimization problems. In the field of weapon systems analysis, developed a computer program which could automatically select the optimal solution from the multiple set of generalized Lagrangian solutions, in the case of a discontinuous, non-convex payoff function. Developed new optimization and estimation components for some of the largest defense-system simulation programs, including the US Navy's Systems Simulation Program and the Department of Defense QUICK war game model.

Statistical Software Development. Developed the first commercially available computer program package for implementation of the Box-Jenkins time series methodology. The Box-Jenkins (autoregressive-moving average) models are useful in system identification problems, such as time series analysis, forecasting, control, digital signal processing (DSP) and linear predictive coding of speech. The software analyzes spatial or temporal data in both the time and frequency domains (correlation and spectral analysis), and uses nonlinear statistical algorithms to estimate model parameters.

Sample Survey Design. Developed the sampling plans for a number of national and state sample surveys.

Communication Theory. In doctoral dissertation, developed the best known class of codes for correcting both additive and synchronization errors in noisy communications channels.

Experimental Design and Quality Control. Developed statistical experimental designs for test and evaluation, simulation model run-sets, chemical and physical experimentation, and industrial quality control applications.

Technical Training. Developed the popular short course, "Sample Survey Design and Analysis," which has been conducted on both a public (advertised) and private (in-house) basis. Has lectured government and contractor organizations on sample survey, time series analysis, statistical forecasting methods, and microsimulation. Served as professor of statistics at the University of Arizona.

Computer Languages, Packages, and Systems. Heavy experience in applications programming in FORTRAN, C, Visual Basic, database (dBASE/FoxPro/Access), SAS, and GIS on mainframe computers, minicomputers and microcomputers under a variety of operating systems (MS-DOS/Windows/NT, UNIX, IBM, CDC, UNISYS, and others); experienced in application of statistical program packages, including SAS, SPSS and BMDP. 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, presentation, data base, groupware, desktop publishing, accounting).

Publications. Over fifty publications in the areas described above, and books on global population, energy and the environment, and tax reform. Examples (unclassified):

Can America Survive? <http://www.foundationwebsite.org/canam4x.htm>

The End of the World <http://www.foundationwebsite.org/TheEndOfTheWorld.htm>

How to Win the War in Iraq <http://www.foundationwebsite.org/HowToWinTheWarInIraq.htm>

Some Mathematical Theory of Global Nuclear War:

Optimal Attack in the Case of No Defense (suitcase-bomb attacks, missile attacks against an undefended enemy) <http://www.foundationwebsite.org/OptStratNoDefense.htm>

Optimal Attack and Defense in the Case of Terminal Interceptors

<http://www.foundationwebsite.org/OptStratTerminalDefense.htm>

Optimal Attack and Defense in the Case of Area Interceptors

<http://www.foundationwebsite.org/SubtractiveOverlappingIslandDefense.htm>

Conflict, Negotiation and General-Sum Game Theory (General-Sum Game-Theoretic Approach to Warfare) <http://www.foundationwebsite.org/Conflict.htm>

Honors. Tau Beta Pi National Engineering Honorary Society

General Motors Scholarship (Carnegie-Mellon University, Pittsburgh)

NASA Fellowship (University of North Carolina at Chapel Hill)

Positions.

Consultant, 1974-present (various organizations, including The Mitchell Group (2016), National Opinion Research Corporation of the University of Chicago (2007-2015), Inter-American Development Bank (2014), United Nations Development Program (2006), Academy for Educational Development (2002-05, 1994-95), Bank of Botswana (1999-2001), Wachovia National Bank (1996-97), Chemonics (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

Director of Research and Development and Principal Scientist of US Army Electronic Proving Ground's Electromagnetic Environmental Test Facility, Bell Technical Operations, 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-

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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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