Geotechnical Engineering, Software Development

Expertise	Numerical Modeling of Geotechnical Processes
Education	Ph.D. (Rock Mechanics), 1971 B.Sc. (Electrical Engineering), 1966 Imperial College, London
Recent Honors & Awards	Elected Member of the National Academy of Engineering, 2008 Elected Fellow of the Royal Academy of Engineering, 2005 2003 Award for Outstanding Contributions to Rock Mechanics American Rock Mechanics Association 2003 Rock Mechanics Award Society for Mining, Metallurgy and Exploration, Coal & Energy Division, Mining & Exploration Division

Professional Experience

	Itasca Consulting Group, Inc., Minneapolis, Minnesota
2000 - Present	*Principal*
1989 - Present	*Senior Consultant*
1990 - Present	*University of Minnesota, Department of Civil Engineering* *Adjunct Professor*
1987 – 1990	*University of Southampton, Department of Civil Engineering, England* *Visiting Professor*
1986 – 1994	*University of Minnesota, Underground Space Center* *Senior Research Associate*
1982 – 1986	*University of Minnesota, Department of Civil & Mineral Engineering* *Associate Professor*
1980 – 1982	*Geognosis Limited, London, Technical Leader & Managing Director*
1974 – 1979	*Dames & Moore, London, Principal Engineer/Senior Engineer*
1972 – 1974	*University of Minnesota, Department of Civil & Mineral Engineering* *Assistant Professor*
1971 – 1972	*Empresa Nacional ADARO, Madrid, Geotechnical Engineer*
1971	*Turkish National Coal Board, Zonguldak, Consultant*

Project Experience

Computer Code Development: Developed (or was the primary developer for) the following computer codes.

Un-named, 1974 — A distinct element code, written mainly in assembly language, allowed the user to "draw" lines on a graphics terminal to represent joints and faults in a rock mass. The program automatically identified closed areas as discrete blocks, and calculated their resulting interaction and motion, displaying the movements and forces dynamically on the screen. This code was possibly the first in geomechanics to use a completely graphical interface.

QUAKE & DAMSEL, 1975-1978 — These codes were used primarily for dynamic soil-structure interaction in one and two dimensions, respectively, and modeled arbitrary non-linear soil or rock in the time domain under large strain. Very large problems could be simulated on a small minicomputer.

BALL & TRUBAL, 1979-1980 — The distinct element method was applied to disks and spheres. The codes were mainly used for element tests on granular material, in order to study micromechanisms. *TRUBAL* was distributed freely for 15 years, used by many research groups, and has been the basis for many published papers.

NESSI, 1980 — A code for soil-structure interaction, written for the Norwegian Geotechnical Institute for modeling mainly offshore structures acted on by water waves and seismic waves.

UDEC, 1980 — This code uses the distinct element method applied to a mixture of rigid, simply deformable and fully deformable blocks. Some novel ideas were embodied, such as rounded corners and a canonical data structure. Subsequent developments included fluid flow in joints, dynamics and generalized material models. The code is probably the most widely used model for jointed rock.

FRIP, 1982 — A fluid-rock interaction code developed for modeling hot, dry rock geothermal sites. This program was one of the first to include the full, non-linear interaction between deformable rock blocks and the fluid flowing in the discontinuities.

FLAC, 1986 — This general continuum-mechanics code was originally intended to exploit the power of newly available microcomputers. It is now widely used internationally to model problems in soil and rock. Users are attracted by its open nature (access to most internal variables and methods), versatility and the range of physical mechanisms that can be modeled.

3DEC, 1988 — Developed originally in collaboration with José Lemos, this code is a three-dimensional extension of UDEC. It is probably the most powerful 3D code for modeling assemblies of arbitrary discrete blocks.

PFC, 1994 — *PFC* models two- and three-dimensional circular particles, and is a development of BALL and TRUBAL that allows much more flexibility in the set-up of simulation conditions and material laws.

WAVE, 1994 — A three-dimensional elastodynamic code that exploits the large increase in efficiency when using a regular grid. The code handles interfaces and absorbing boundaries. It was developed for MiningTek of South Africa; it has been extended by their own personnel.

REBOP, 2000 — A simplified solution for the flow of broken material from multiple drawpoints in a caving operation. The code operates semi-analytically and is based on generalizations of mechanisms observed in full simulations, with PFC3D, of the granular flow process.

Research Developments: Originated or developed several novel techniques in numerical modeling: the distinct element method (DEM), the mixed-discretization scheme, an incompressible fluid flow algorithm, static and dynamic damping schemes, the continuously yielding joint model, a phreatic-surface algorithm for porous media flow, a fracture mechanics formulation for discontinuous media, the recognition of "mode-1 compression" cracks, a methodology for numerical modeling in geomechanics, the design and development of the FISH language, and schemes for coupled fluid flow in discrete media.

Applied Numerical Modeling. Numerical modeling techniques have been applied to specific problems in the following fields: dynamic soil/structure interaction and liquefaction; wave propagation in heterogeneous and non-linear materials; failure of jointed rock masses: tunnels and slopes; rock/fluid interaction in a jointed rock mass; backfill stability; investigation of micromechanisms in deforming granular material; various phenomena of localization; bearing capacity of footings in soil; dynamic instabilities of faults, joints and pillars; borehole breakout and sand production; instability and production of proppant particles in a fracture; wormhole development in bonded proppant packs; mechanisms of fiber reinforcement in proppant packs; fracture development in brittle, heterogeneous materials; notch formation in tunnels and boreholes; response of mixed viscous and frictional material; mechanisms of caving: initiation, propagation and flow of broken material

Teaching, Lecturing and Student Advising: Instructor of courses in rock mechanics numerical modeling, University of Minnesota; service as Advisor for seven Ph.D. students and one M.S. student, University of Minnesota; Invited Lecturer for many universities and companies world-wide; Instructor and Presenter of many short courses and seminars in a number of countries.