DEPARTMENT SUMMARY

The research program of the Department of Mathematics seeks to advance the state of knowledge in the areas important to the Department of the Navy and Department of Defense, such as scientific and parallel computing, fluid flow, orbital mechanics, graph theory, and simulation and modeling.

The specific areas of our faculty and their students are reported in detail later in this book. Output in the form of student theses, technical reports, conference presentations, and refereed journal articles is listed.

Professors Borges and Mansager continued their work on mine countermeasures. Part of this work was presented at the 65th MORS conference and has been nominated for the Barchi prize. Professor Borges also worked on tactical image compression with Professor Fredricksen. This project involved an investigation of some current DoN capabilities, in particular, the radiant TIN algorithm. As part of this work Professor Borges developed a number of improvements to the *histogram* method of estimating the parameters of a Gibbs distribution. These improvements include an MMSE estimator for the local interaction sums of an auto-binomial Markov Random Field, and a direct solution for the field parameters following the generation of the histogram.

Professor Canright continued his work on thermocapillary convection in welding, particularly trying to determine the scaling and structure of the "cold-corner singularity" in thermocapillary flow in weld pools. His current efforts involve extending the working simulation code through the development, implementation, and testing of two additional components: the moving phase-change boundary and the Eulerian-Lagrangian Method (ELM) for the nonlinear convective terms. The details of discretization and implementation for these two components were fully worked out, and most of the programming was completed and partly debugged.

Professor Danielson continued to investigate the mechanical behavior of stiffened plates, basic structural components of ships and submarines. He is also a collaborator on a research project to study vibration/structural dynamics of the RAH66 Comanche helicopter.

Professor Franke continued his research into the approximation of scattered data using radial basis function methods, in particular multiquadric functions in a least squares setting. Professor Franke also worked on developing methods for more rigorous modeling of the three-dimensional spatial covariance function for the error in numerical weather forecasts, with the goal of improving data assimilation methods. This effort also involved applying methods derived in the first part to real data. In addition, Professor Franke worked extensively on developing algorithms for segmented data, in particular, computationally simple algorithms for constructing a surface that separates the various classes of data and the volumes that contain only data of one of the various classes.

Professor Fahroo worked extensively on applying Optimal Periodic Control theory to determine the optimal reboosting strategy for a Low-Earth-orbiting or LEO spacecraft to achieve minimum consumption of fuel. This research, which is a joint effort with Professor I.M. Ross of the Department of Aeronautics and Astronautics, involved the development of both analytical and numerical solutions for this complex optimization problem. Professor Fahroo also worked on the optimal design of damping and control mechanisms for distributed parameter systems. This work focuses on examining different damping designs for achieving exponential stability of flexible structures. Professor Fahroo also continued her study of the exponential stability of several acoustic-structure models by numerical approximation of these models. The focus of the work was on establishing uniform exponential stability for the model using the multiplier technique that has been used successfully in establishing exponential decay rates for wave equations with boundary feedback damping.

Professor Fahroo was also involved in a joint research project with Professor Y. Kanayama of the Department of Computer Science whose focus was developing an algorithm for the movement of a vehicle under the nonholonomic constraint to track a given directed line without allowing any spinning motion. This effort led to a new principle of computing the derivative of path curvature as a linear combination of the current vehicle path curvature, vehicle orientation, and positional difference. Numerous simulation results as well as experimental results were obtained on the autonomous robot Yamabico at the Naval Postgraduate School that showed the effectiveness of this method.

Professors Frenzen and Scandrett worked jointly to investigate the behavior of Scholte/Rayleigh-Lamb surface wave propagation along the interface of a elastic/poro-elastic solid underlying a fluid layer. In this effort the bi-orthogonality relationships developed for a porous/elastic-fluid layered system were implemented to determine the interfacial wave scattering from a vertical discontinuity in the medium. The dispersion relationship was found and used to determine wavenumbers for the discrete eigenfunctions of the media.

Professor Gragg set out to implement, rigorously test, and prove numerical stability of, new algorithms for executing the second phase of Pisarenko's signal processing algorithm, now reformulated so as to solve a well-conditioned problem. The new algorithms, stabilized forms of the unitary Hessenberg QR (uhqr) algorithm, permit fast, O(n^2), solution of problems of (essentially) arbitrarily high order. Together, these provide algorithms for fast adaptive recursive least squares modeling of stationary time series by trigonometric polynomials (spectral estimation).

Professors Russak and Jayachandran collaborated in an effort to improve the accuracy of damage calculations to an area target by removing certain non-real world assumptions used in its model. In particular, analysts who do computation of damage aggregation to an area target from a salvo of weapons sometimes use the simplifying assumption of a target consisting of cells. This often leads to the implicit assumption of weapons hits to the target always being at the center of a cell. The removal of this assumption provides a more accurate model with more accurate calculations of damage aggregation.

Professor Jayachandran also worked on developing probability models for the reliability of concurrent software modules used to build redundancy to increase reliability. Unlike hardware, failures of redundant software are correlated and, therefore, the determination of the improvement in reliability is difficult. An algorithm to compute the probability of failure for one of the models proposed in the literature was developed. Work to develop alternative models is in progress.

Professor Kang's work focused on developing a stabilization feedback design methodology for nonlinear control systems near bifurcation points. Two problems of immediate practical interest to the Department of the Navy are control of rotating stall and surge in gas engine compressors, and the design of feedbacks for depth control in the dive plane of submarines near the critical Froude number where pitchfork bifurcation occurs. This exceptional research effort led to four journal publications, several conference presentations, and one PhD thesis this year alone.

Professor Neta worked on a linear analysis of the shallow water equations in spherical coordinates for the Turkel-Zwas explicit large time-step scheme. The analysis suggests that the Turkel-Zwas scheme must be staggered in a certain way in order to get eigenvalues and eigenfunctions approaching those of the continuous case. This is joint work with Frank Giraldo of the Naval Research Laboratory. Professor Neta also investigated a control decomposition approach for parallelizing a numerical orbit propagator.

Professor Owen continued his collaborative work with Professor McCormick, Special Operations Curriculum Committee, targeting sub-state political groups. The goal of this research is to develop a formal framework for evaluating the dynamics of sub-state conflict and to employ this framework to improve our ability to target terrorist and other sub-state politico-military organizations.

Professor Rasmussen continued his efforts to develop and evaluate heuristics for finding approximate solutions to hard combinatorial optimization problems, such as graph coloring, that arise in diverse problems such as scheduling and frequency assignment. These problems are generally NP-complete, but typically are easily solved on certain families of highly structured problem instances. These families themselves possess more internal structure than was previously known, and the idea is to exploit this structure to obtain useful approximate solutions to the hard instances. Professor Rasmussen also continued his work on characterizing competition graphs and p-competition graphs of various highly structured families of graphs and digraphs.