ONR Basic Research (6.1)

- "DEFENSE RESEARCH SCIENCES"
  - "Core" funding
  - Typically single investigator, $150K/year

- "UNIVERSITY RESEARCH INITIATIVES" (URI)
  - URI funds limited to U.S. Institutions of Higher Education that award SEM degrees
  - Includes Multidisciplinary (MURI) research
  - High priority/high payoff topics published in BAA
  - Multi-investigator, frequently multi-university team
  - Typically $0.3M to $1.3M/year
  - Encourage collaboration with DoD labs and industry
  - Topics developed and grants managed by any ONR S&T Division

MURI on Integrated Predictive Diagnostics
1994 - 1999

Pennsylvania State University-Applied Research Laboratory

(+ RPI)

P.I.: David L. Hall

P.O.: Tom McKenna, ONR Code 342

OBJECTIVES

Explore the area of machinery diagnostics/prognostics and Condition Based Maintenance.

- **Apply to fleet safety and affordability.**
- **Develop fundamental understanding of failure mechanisms and ways of sensing/diagnosing failures**

APPROACH

- Conduct basic research necessary to understand complex degradation and failure processes in mechanical systems
- Provide technologies to provide real-time assessments of health and usage of mechanical systems.
- Research Areas Included:
  - Detection and Identification of Failures
  - Failure Prediction Methodology
  - Direct Sensing, Analysis and Real-Time Diagnosis
  - Sensors and Signal Processing

Scientific Accomplishments on Condition-Based Maintenance (CBM)

- **A formalization of the CBM problem**
- **A suite of test beds and toolkits to analyze transitional failure data**
- **CBM system advances**
  - **Implementation of advanced sensors and new sensing techniques (e.g. vibration, fluid condition/debris monitoring)**
  - **Robust signal processing & feature extraction methods**
  - **Fusion methods for multisensor CBM data**
  - **Hierarchical models for mechanical components and subsystems**
  - **Prognostic models at the observation and state-vector level**
  - **New architectures and hybrid methods for automated reasoning**

Transition of the CBM Open System Architecture (OSA) from MURI to DDX

- At ONR, MURI results transitioned via "Accelerated Capabilities Initiative" and "Dual-Use S&T" programs
- Standardized OSA for CBM accepted by Rockwell, Boeing, Newport News Shipbuilding and Caterpillar
- DDX will realize the full vision of the CBM concept in
  - propulsion system
  - auxiliary systems
  - electrical system
  - combat systems

MURI on Nonlinear Active Control of Dynamical Systems
1996 - 2001

Virginia Polytechnic Institute and State University

(+ U. Maryland, N.C. A.&T., Florida Atlantic U.)

P.I.: Ali Nayfeh

P.O.: Kam Ng, ONR Code 333

OBJECTIVES

Develop a unified control methodology and control strategy for nonlinear dynamical systems and processes

- **Model ship hydrodynamics and develop control methodologies that can be used to conceptualize advanced hull forms**

- **Develop controller architecture and control algorithms for both high- and low-level controls for undersea vehicles, shipboard crane operation, and large-scale power electronic systems**

Approach

- **Extend, strengthen, unify, and transition the recent important breakthroughs in the understanding of complex systems and their control**

- **Utilize nonlinear analysis and stability techniques from applied mathematics and nonlinear dynamics**

- **Develop comprehensive models**

Scientific Accomplishments on Modeling Ship Motion

- **Large-Amplitude Motions Program (LAMP) had been developed and enhanced by SAIC to address linear components**
  - **Time-domain simulation of large-amplitude motions of ships in waves**
  - **Platform for the development, evaluation, and design control approaches and systems**
- **MURI-based upgrade of LAMP to include non-linear effects**
  - **A new dynamic supervisor to improve the accuracy and extend the length of the simulations**
  - **A modified formulation to increase the speed of the simulations**
  - **Multi-body interactions**
- **Use enhanced LAMP to develop sets of finite-degree-of-freedom models of ships for real-time use in the Computer Automated Virtual Environment (CAVE) at VPI&SU Simulator**
- **For many sea conditions, calculate the individual as well as the relative motions of the vessels and store them for use by the controllers and the CAVE Simulator**

Transition of LAMP from MURI to DDX

Enhanced LAMP is very comprehensive nonlinear time-domain ship dynamic simulation program. Specific capabilities that are being applied by SAIC in design calculations for the DDX program include:

- **Nonlinear ship motion and loads predictions in both the vertical and horizontal planes**
- **Nonlinear dynamic stability evaluation including capsizing on various ship geometries including tumble home/wave piercer designs**
- **More accurate wave field description with a non-linear incident wave model. This unique approach makes it possible to model the wave field correctly for DDX dynamic stability evaluation**
- **Small Boat handling capability including side and stern launch and recovery and pendulation control**
- **A simulation platform for motion control system development**