Summary of Research and Development Programs

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Outline

• Primary Technology and Application Areas

• New Projects

• Integrated Damage Modeling Adaptive Control System (IDMACS)
Primary Technology and Application Areas

TECHNOLOGIES

• Intelligent and Autonomous Control Systems
• Signal and Image Processing Systems
• Information and Communication systems
• System Integration

APPLICATIONS

• Collaborative Control, Autonomy and Situational Awareness for Manned and Unmanned Vehicles (Air, Surface, Underwater).
• Autonomous Space Systems (Formation Flying, Rendezvous and Docking).
• C4ISR and Network-Centric Warfare
• Automatic Target Recognition and Tracking
• Sensor Fusion and Sensor Management
• Information Assurance and Network Security
New Projects

• Connectivity Technologies for Mobile AD-Hoc Networks Formed by Heterogeneous Nodes. (Air Force) – Phase II

• EVASE: Extensible Video Analysis of Symbology Events. (Air Force) – Phase II

• CMARS Genetic Algorithm Auto Router Software Module - Phase III SBIR

• Visual Collision Detection and Avoidance for a Micro Air Vehicle. (Air Force)

• Robust Machine Learning for UXO Detection. (Army) – Phase II

• Pilot-Directed Computer Assisted Helicopter Formation Flying (ARO Phase II STTR with UC Berkeley, UTRC and Sikorsky)

New Projects (Cont.)

• *Integrated Damage-Adaptive Control System (IDACS)* (NASA Langley Phase II SBIR)

• Distributed Formation State Estimation Algorithms with Multi-Tasking Constraints. (NASA-JPL) – Phase I

• Dynamic Sensor Management of Dispersed & Disparate EO/IR Sensors. (Air Force) – Phase II

• Ballistic Debris Coherent Discrimination and Modeling. (MDA)

• *VAMAV: Visual Collision Detection and Avoidance for a Micro Air Vehicle.* (Air Force)
NASA Langley Research Center Phase II SBIR (Contract No. NNL07AA02C)
(December 2006 to November 2008)

Integrated Damage Modeling and Adaptive Control System (IDMACS)
Introduction

- Aircraft structural damage is highly complex both in terms of its effect on aircraft dynamics and in terms of its modeling for analysis and control design.

- Aircraft dynamics immediately after damage can be very different from the nominal pre-damage dynamics.

- In general, a fixed robust controller cannot achieve acceptable post-damage performance for all cases of damage.

- A single model-based adaptive controller may be too slow to bring the closed-loop system into a new, stable operating regime, and may result in unacceptably large transients.

- We propose to develop an approach that integrates damage modeling & simulation, with model-set reduction and multiple-model based control design.

- The proposed system is referred to as the Integrated Damage Modeling and Adaptive Control System (IDMACS)
Phase II Objectives and Deliverables

- Develop modeling, simulation and adaptive control techniques for aircraft structural damage accommodation
- Develop integrated damage modeling and adaptive control (IDMAC) software toolbox that will contain the following:
  - Model Set Reduction software
  - Multiple observer design software
  - Multiple adaptive controller design software
- Identify opportunities to transition technology
  - Piloted simulation at NASA Langley
  - Integration with Integrated Vehicle Health Management (IVHM).
Phase II Work Areas and Tasks

- **Modeling and Simulation (M&S)**
  
  Task 1. Select transport aircraft model and obtain nominal system data
  
  Task 2. Develop quasi-steady solver for damage effects simulation
  
  Task 3. Develop flight simulation test bed

- **Model Set Reduction (MSR)**
  
  Task 4. Select model structures for damage effects
  
  Task 5. Formulate control-oriented model set reduction problem
  
  Task 6. Develop algorithms and software for aircraft damage MSR
Phase II Work Areas and Tasks (continued)

- Integrated Damage Adaptive Control System (IDACS) Design
  
  Task 7: Extend damage adaptive control algorithms and architecture
  
  Task 8: Implement algorithms in a flight simulation test bed
  
  Task 9: Evaluate controller design under various damage conditions

- Software Development and Deliverables Tasks
  
  Task 10: Develop IDMAC system software toolbox
  
  Task 11: Meetings, progress reports and final report
**Damage Adaptive Controller Terminology**

- A switching controller consists of
  - a finite set \( \{1, 2, \cdots, N\} \) of observers based on distinct modes of operation,
  - a set \( \{C_1, C_2, \cdots, C_N\} \) of controllers,
  - a switching law \( \sigma \) that maps measurement \( y \) to modes

such that the control input is given by: \( u = C_{\sigma(y)}(y) \)

- Multiple Models, Switching & Tuning (MMST)
Block Diagram of the Proposed ASE Modeling & Control Testbed

- Lumped Forces and Moments
- A/C Rigid Body Dynamics
- Dryden Turbulence and Wind Effects
- Engine Dynamics
- Structural Dynamics
- Distributed Forces and Moments
- Structural Modes
- Aerodynamics
- Sensor Damage
- Rigid Body States
- Sensor Noise
- Engine Control Settings
- Damage Adaptive Control System
- Control Surface & Actuator Dynamics
- Control Effector Damage
- Pilot inputs
- Measurements from Aiding Sources (EGI)
- Modeled using a simplified ASE Solver
Structural Diagram of the Proposed Integrated Damage Modeling & Adaptive Control System (IDMACS)