ESMD Faculty Fellowship Project

Christina L. Carmen, U. Alabama, Huntsville
Tommy Morris, Mississippi State University
Peter Schmidt, U. North Carolina, Charlotte
Paul van Susante, Colorado School of Mines
Janusz Zalewski, Florida Gulf Coast Univ.

NASA Space Grant Western Regional Meeting
Omaha, Nebraska, September 17, 2010

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Project Goal

2010 Faculty Fellowship Solicitation

- Exploration Systems Mission Directorate (ESMD) is funding a Faculty Fellowship Project to prepare faculty to enable their students to complete senior design projects with potential contribution to NASA ESMD objectives.
- work for eight weeks on a selected ESMD project
- convene at Kennedy Space Center (KSC) for one week
- incorporate the ESMD project into an existing senior design course or capstone course at their university in the 2010/2011 academic year.
- work side-by-side with a NASA technical expert.
- gain extensive knowledge on the ESMD project and associated requirements, interfaces and issues affecting the design and potential solution(s).
- develop materials for use at their university during the 2010/2011 academic year in support of the completion of senior design project(s) using a systems engineering approach.

Overview of ESMD projects

Spacecraft

Guidance, navigation, and control; Thermal; Electrical; Avionics; Power systems; High-speed reentry; Interoperability/ Commonality; Advanced spacecraft materials; Crew/Vehicle health monitoring; Life-support systems; Command/ Communication software; Modeling and simulation

Propulsion

Methods that utilize materials found on the Moon and Mars; On-orbit propellant storage; Methods for soft-landing

Ground Operations

Pre-launch; Launch; Mission operations; Command, control, and communications; Landing and recovery operations

Lunar & Planetary Surface Systems

Precision landing software; In-situ resource utilization; Navigation systems; Extended surface operations; Robotics; Environmental sensors and analysis; Radiation protection; Life-support systems; Electrical power and efficient power management systems

Senior Design Projects Selected

	Christina Carmen (**MSFC)** University of Alabama at Huntsville MSFC1-20-SD NASA Exploration Toolset for Optimization of Launch and Space Systems (XTOOLSS)
	Thomas Morris (**JSC)** Mississippi State University JSC4-36-SD Implement Codecs on FPGA's
	Peter Schmidt (**KSC)** University of North Carolina at Charlotte KSC1-06-SD Umbilicals and Quick Disconnect Couplings
	Paul van Susante (**KSC)** Colorado School of Mines KSC1-05-SD Lunar Regolith Excavation 02 Prod/Outpost Emplace
	Janusz Zalewski (**ARC)** Florida Gulf Coast University ARC2-07-SD Prognostics for Complex Systems

Purpose of the NASA ESMD Faculty Fellowship

- Prepares 5 selected university faculty to enable senior design students to complete projects during the 2010-2011 academic year with potential contribution to NASA ESMD objectives.

  - The faculty gain extensive knowledge on the ESMD project and develop materials for use by their senior design students using a systems engineering approach.

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NASA ESMD
2010 Faculty Fellowship Schedule

Date	Task
June 2- July 23, 2010	Report to NASA facility for 8 weeks to work on ESMD project
July 26-30, 2010	ESMD Faculty Fellows convene at KSC
Sept. 17-18, 2010	Present at regional Space Grant Conference
Fall 2010-Spring 2011	Implement Senior Design Project

NASA ESMD
Space Grant Meeting Assignments

Faculty	Space Grant Meeting	Dates	KSC Attendee
Christina L. Carmen	Great Midwest Minneapolis, MN	9/17/10-9/18/10	Diane Ingraham
Tommy Morris	Northeast Newport, RI	9/10/10-9/11/10	Susan Sawyer
Peter Schmidt	Southeast South Carolina	TBA	Gloria Murphy
Paul van Susante	Mid-Atlantic Delaware	9/16/10-9/18/10	Mandi Falconer
Janusz Zalewski	**Western Omaha, NE**	**9/16/10-9/18/10**	**Luis Rabelo**

Individual Plans for Incorporation

- Overview of faculty plans to incorporate their selected ESMD project and developed materials into a specific existing senior design or capstone course at their respective university

ESMD-Faculty Fellowship Report

Christina L. Carmen, Ph.D.

NASA Exploration Toolset for Optimization of Launch and Space Systems (XTOOLSS)

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NASA ESMD X-TOOLSS Project

- Marshall Space Flight Center (MSFC)
- X-TOOLSS (e**X**ploration **T**oolset for **O**ptimization **O**f **L**aunch and **S**pace **S**ystems)
- Software package developed at North Carolina A & T (NCAT) via a grant from NASA
- Developed for scientists and engineers to solve optimization problems

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X-TOOLSS Optimization Using Nastran
Example Application

- Typical application of X-TOOLSS within the UAH Mechanical and Aerospace Engineering senior capstone design class.
- CO_2 Launching Mechanism, Team 10, Spring 2010.

Figure 1: HotShot Raceway™ CO2 Dragster Launcher

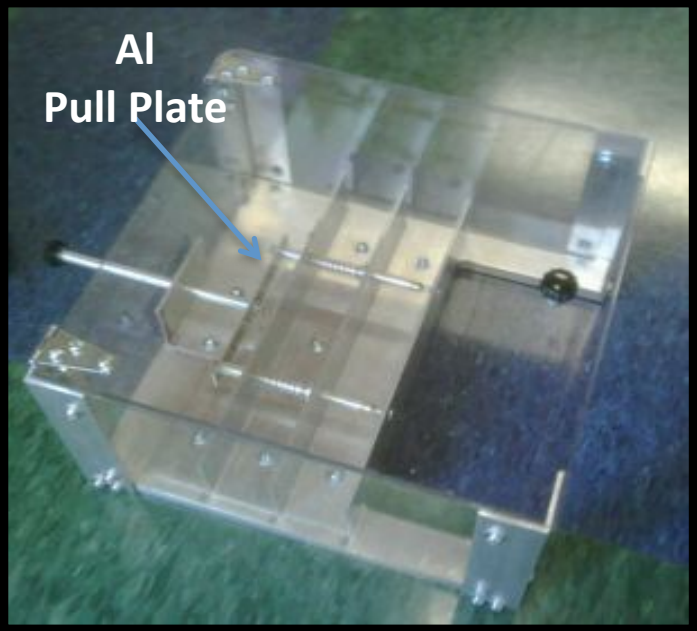

Figure 2: MAE Team 10 Final Product

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X-TOOLSS Optimization Using Nastran
Example Application

- Visualization of the Finite Element Analysis (FEA) results via computer graphics and animation provides a critical understanding of a model's behavior, how the model/part will move and how the design can be improved.

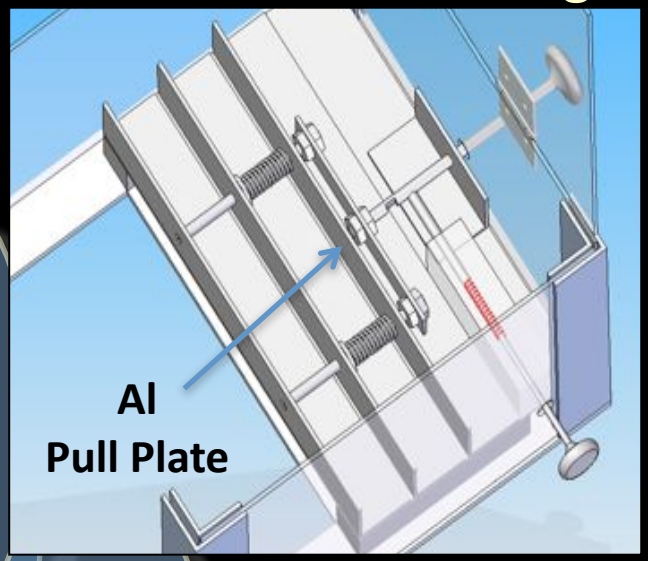

Figure 4: MAE Team 10 CAD Model

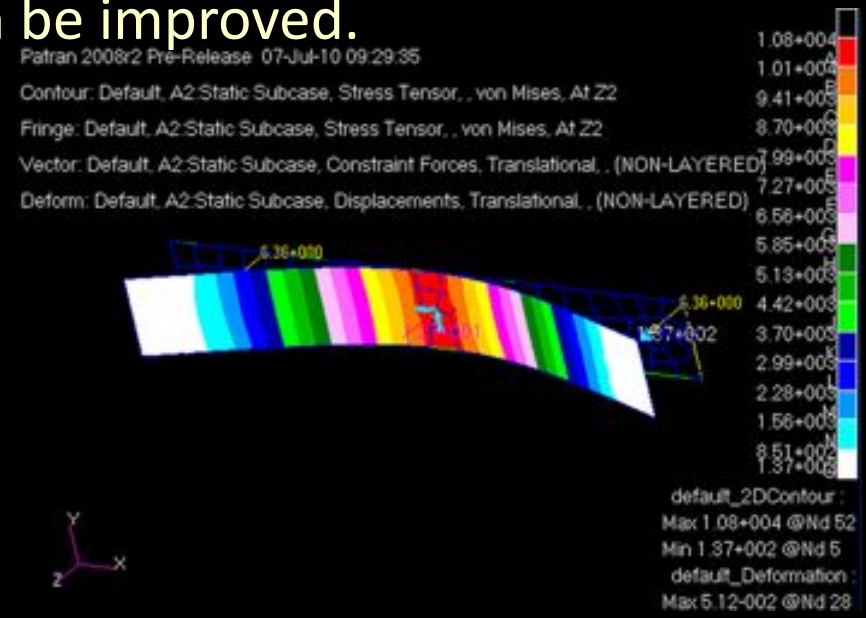

Figure 5: MAE Team 10 FEA

Lunar Wormbot Design Project

- Engineers at the National Space Science and Technology Center (NSSTC) in Huntsville, AL have developed conceptual designs of a “Lunar Wormbot “– a device to burrow into lunar regolith.
- UAH MAE design teams will refine the design and fabricate the hardware.
- X-TOOLSS will be utilized during the conceptual design phase.

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Systems Engineering Design

- NASA ESMD website:
  http://education.ksc.nasa.gov/esmdspacegrant/
- Apply SE design process to senior design projects at UAH
- Integrate lectures available at the ESMD Space Grant website in the senior Mechanical and Aerospace Engineering product realization design class at UAH.

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Tommy Morris, Ph.D.

Implement Codecs on FPGA's

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Overview of Project

JSC4-36-SD Implement CODECs on FPGAs

- NASA desires HDL realization of ITU G.729 CODEC with for implementation on FPGA
- No VHDL or Verilog HDL implementations found
- Resulting Project
  - Incorporate aspects on implementing ITU G.729 CODEC in HDL into Digital Systems Design class.
  - Implement ITU G.729 encoder prototype as 2 semester senior design project during Fall 2010-Spring 2011.

Significance to NASA's Mission

JSC4-36-SD Implement CODECs on FPGAs

- Orion Crew Exploration Vehicle (CEV)
- HDL implementation of ITU G.729 CODEC
  - Lower power than software version.
    - Power is at a premium on space vehicles and extra planetary rovers.
  - Faster computation than software version.
    - Reduces communication latency between astronauts and ground.
  - Supports use with reconfigurable computing algorithms.
    - Potential to reduce space craft weight by reducing number of separate electronic devices in vehicle.

Significance to NASA's Mission

JSC4-36-SD Implement CODECs on FPGAs

- Digital Signal Processing
  - Common in many areas important to NASA mission
  - communications, robotics, image processing, speech recognition, weather forecasting, RADAR, biomedicine, etc.
- HDL Design
  - NASA Avionics System Division Electronic Design Branch (EV2) current HDL projects include
    - Camera interface, voice processing, networking, space station telephony, robotics.
  - NASA contractors have many more active HDL based projects.

Knowledge Gained

JSC4-36-SD Implement CODECs on FPGAs

- Worked with NASA engineers to understand project requirements.
  - Honeywell contracted to implement software version on embedded Xilinx MicroBlaze microcontroller.
  - Software version latency target 15 mS algorithmic delay + 6-10mS computational delay.
  - HDL version should meet or exceed this version. Latency target 15 mS algorithmic delay + 1-3 mS computational delay.
  - NASA reconfigurable computing goals.
- ITU G.729 CODEC
  - Hi intelligibility. Important to be able to understand astronauts.
  - Good compression score. Limits communication bandwidth required between vehicle and ground. Potential to lower power.
- NASA Systems
  - In flight communications and networking capabilities.
  - In flight cyber security requirements.

Incorporation into Classroom

JSC4-36-SD Implement CODECs on FPGAs

- Integration of project into Digital Systems Design class.
  - Fixed point arithmetic.
  - Shared function unit scheduling.
  - Conversion of C to HDL.
  - System Design.
  - DSP in hardware.
  - Lab Exercise: FIR Filter implementation in HDL.
- Senior Design Project
  - 2 student team.
  - Implement ITU G.729 encoder in HDL
  - Validate in simulation and on Xilinx XUPV5-LX110T evaluation board.
  - Managed with processes from NASA System Engineering Handbook.

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Peter L. Schmidt

Umbilicals and Quick Disconnect Couplings

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Overview of knowledge gained during summer experience

- System Engineering
- On-center and NASA procedures
- Great space-flight immersion
- Specific Project Knowledge
  - Lunar Regolith Physical Properties
  - Current Design Work and Philosophy
  - Stakeholder Meetings
  - Embedded with current design team, working with design engineers tasked with the current project

Project Definition - Cryogenic Fluid and Electrical Quick Connect System

- Quick connect functionality for both electrical and fluid connectors used in extraterrestrial
- Use of commercial off the shelf (COTS) electrical and fluid connectors as a design basis will help in minimizing system costs.
- The project's goals are to create quick connect/disconnect hardware that is operable by an astronaut wearing a space suit, in any gravity condition.
  - The hardware shall operate in zero gravity and near perfect vacuum and be adaptable to non-terrestrial locations with aggressive atmospheres and unusual contaminants.

Lunar Regolith Design Case

- Particle Shape
- Particle Size Distribution
- Composition
- Lessons Learned
- Simulants
- Hard Vacuum
- Other Planets / Bodies

Proposed Outpost Layout

Course Integration

- Material covering the basics of System Engineering will be incorporated into the course at UNC Charlotte via lecture
- A specific lecture will be given detailing the System Engineering process
- An additional lecture on documentation maintenance and configuration control is also scheduled

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Paul J. van Susante

Lunar Regolith Excavation 02 Prod/
Outpost Emplace

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engineering the way

ESMD Project

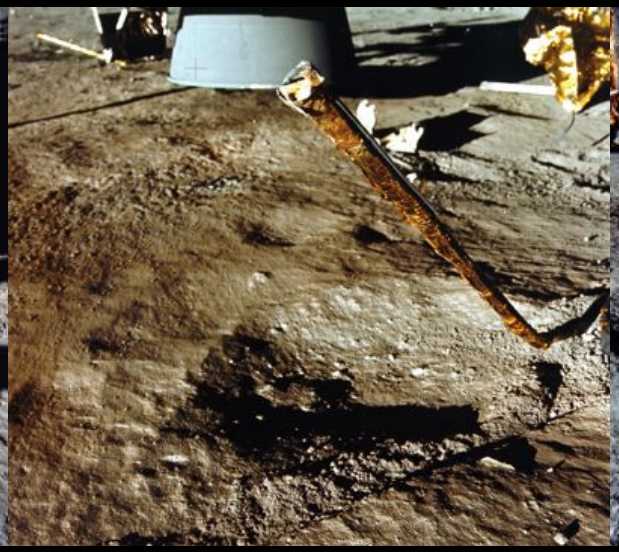
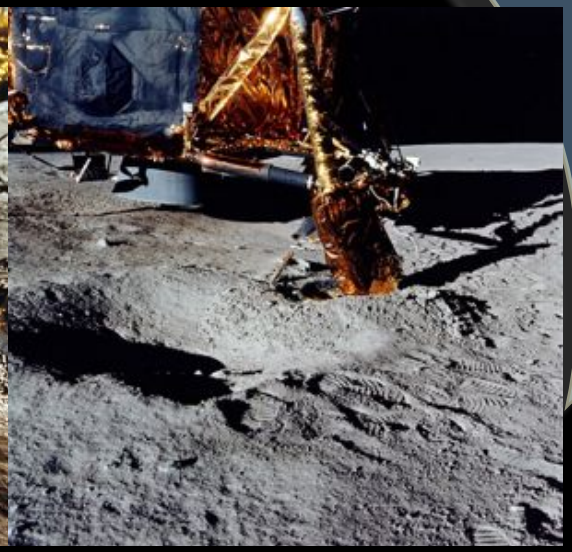
NASA Field Center: Kennedy Space Center

ESMD Related Area: Lunar and Planetary Surface Systems

Project Title: Lunar Regolith Excavation O2 Prod/Outpost Emplace

Description: The feedstock required for O2 production on the moon is Lunar Regolith (soil). 100 metric tonnes (MT) of Lunar Regolith will be required each year for Oxygen Production of 1 MT. In addition up to 2,000 MT of regolith excavation will be required per year in the initial stages of Outpost construction. This project will investigate concepts for Lunar Regolith excavation equipment and propose solutions in the form of completed designs and prototypes.

Need for landing pads


CSM ESMD Senior Design Projects

- Robotic Excavator, Grader, Dumper integration for lunar O2 production, feedstock gathering and lunar outpost site preparation

- Robotic Attachment for interplanetary landing pad surface stabilization
  - Lunabotics Mining Competition 2011 team

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Overview of knowledge gained during summer experience

- System Engineering
- On-center and NASA procedures
- Great space-flight immersion
- Specific Project Knowledge
  - Landing pad requirements
  - Landing pad materials and production
  - Test setup
  - Coached an Excavator design group (co-ops & interns)
  - Safety experimental procedures

Definition of senior design projects associated with each ESMD project

- "Robotic Excavator, Grader, Dumper integration for lunar O2 production, feedstock gathering and lunar outpost site preparation"
-
- Design challenge
- The design challenge to the students would consist of studying and reverse engineering previously built lunar excavation systems. Sources would include prototype CSM excavators, centennial challenge rovers, the lunabotics competition as well as designs used in the desert rats campaigns and on the PISCES test site. Then, based on the reverse engineering results, the group of students will design and build a prototype of a rover that can excavate, dump and grade regolith such that it could perform all operations required by the concept of operations based on the latest lunar surface architecture envisioned. Lastly, a field test demonstrating the capabilities of the design will be performed.

Janusz Zalewski
Florida Gulf Coast University

Project Topic:

Prognostics for Complex Systems

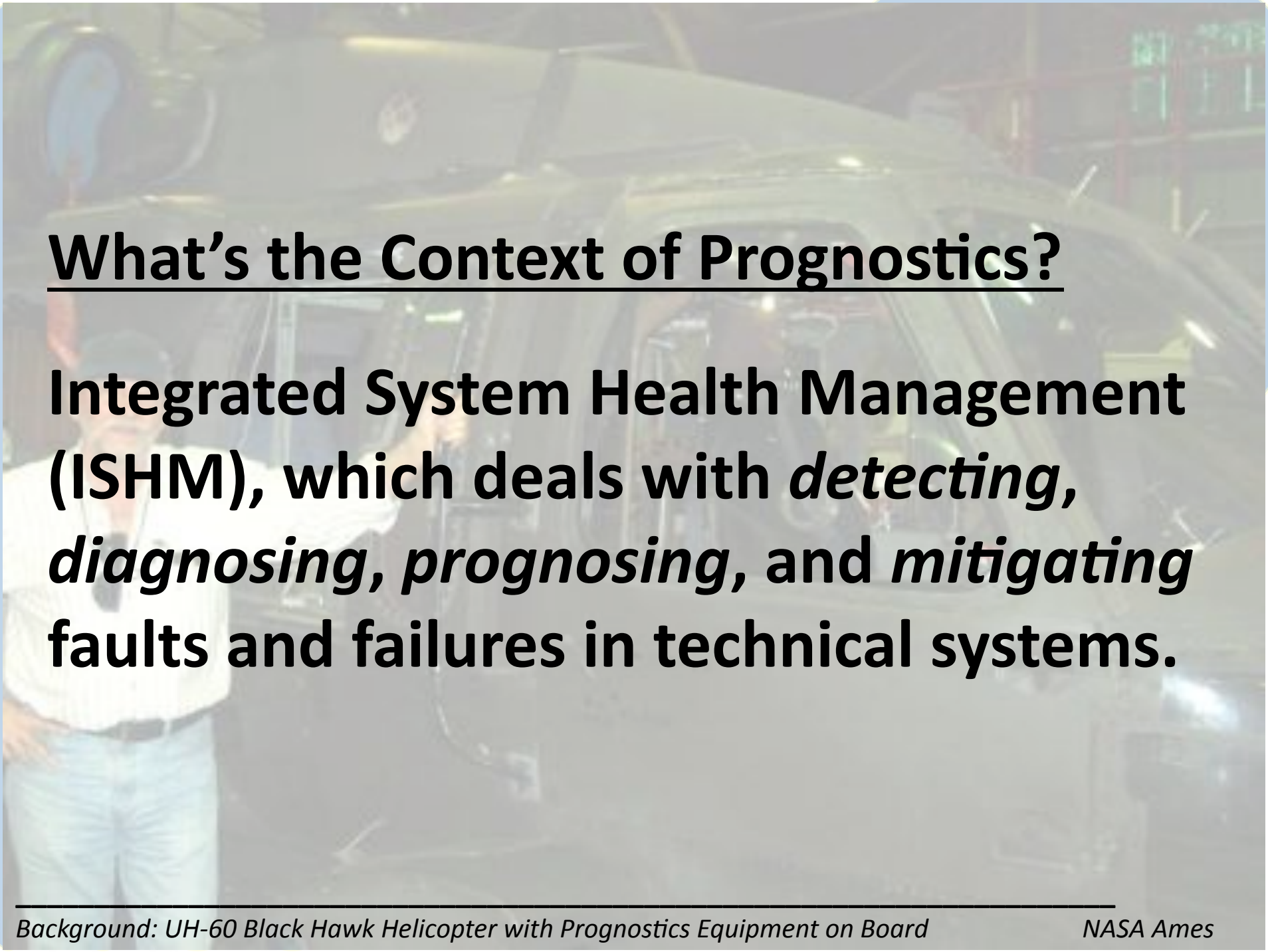
Project Sponsor:

Dr. Kai Goebel, NASA Ames

What is Prognostics?

A field of engineering, which deals with detecting and predicting faults and failures in technical systems.

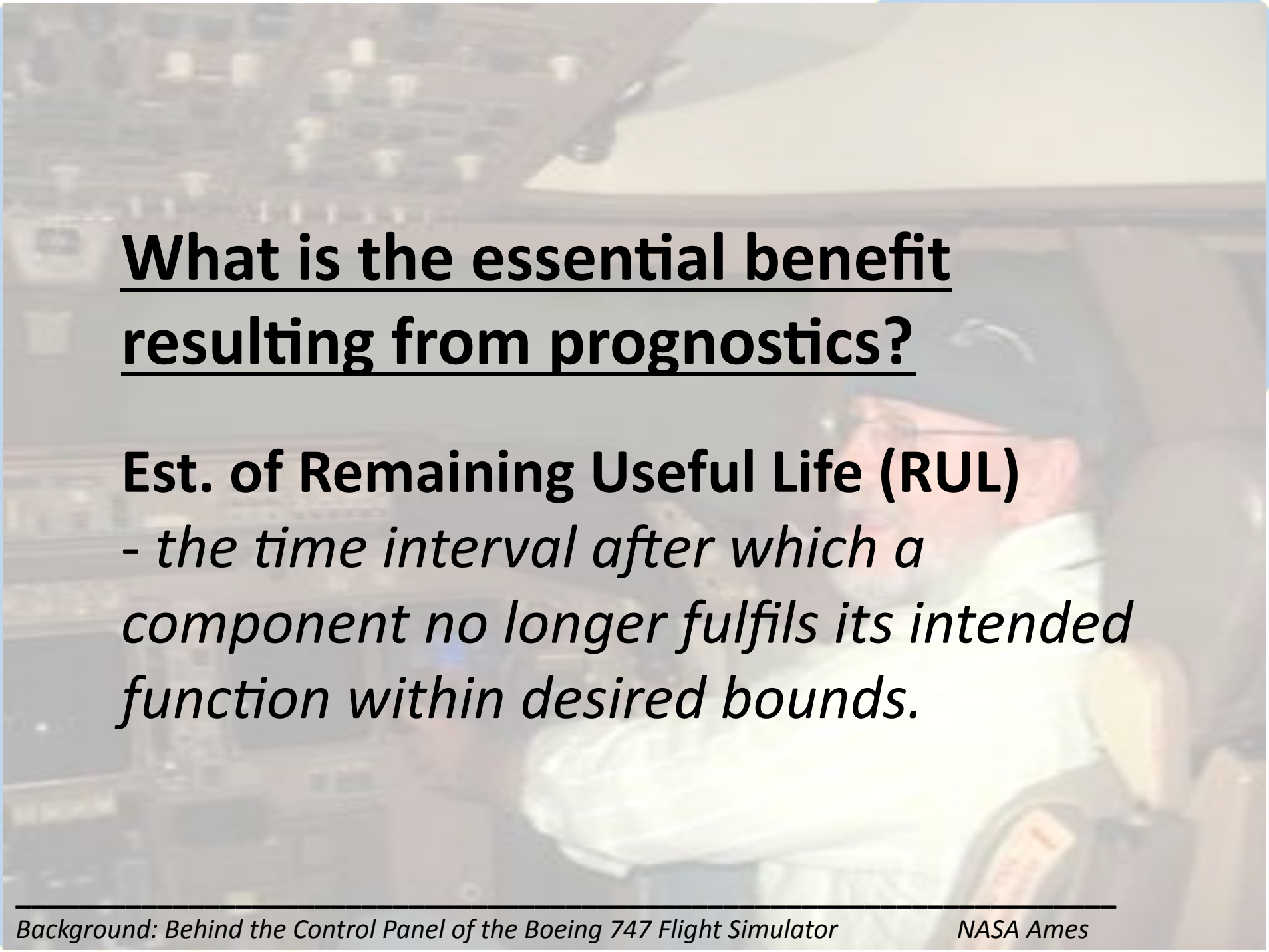
Background: Supercomputer Simulation of Space Shuttle Flight Conditions *NASA Ames*



What's the Context of Prognostics?

Integrated System Health Management (ISHM), which deals with *detecting*, *diagnosing*, *prognosing*, and *mitigating* faults and failures in technical systems.

Background: UH-60 Black Hawk Helicopter with Prognostics Equipment on Board *NASA Ames*



What is the essential benefit resulting from prognostics?

Est. of Remaining Useful Life (RUL)

- the time interval after which a component no longer fulfils its intended function within desired bounds.

2010 Summer Accomplishments (1)

- 5+ Educ. Modules on Prognostics
  http://satnet.fgcu.edu/~zal/prognostics
- Definition of a Senior Design Project
- Review Paper on Recent Methods in Prognostics (in the works)
- Educational Paper on Experiences at NASA Ames (with 2 other faculty)

2010 Summer Accomplishments (2)

- Innovative way of engaging domain experts in interacting with students via Q&A exchange on the Bulletin Bd
  - Kai Goebel
  - Abhinav Saxena
  - Sankalita Saha
  - Bhaskar Saha
  - [Ole Mengshoel & Wojtek Przytula]

Summary

Significance of ESMD projects to NASA's mission and ESMD objectives

- Education and outreach of ESMD
- Gathering ideas while creating experience
- Create long lasting experience that translates to students for many years
- Create translation to lower level students for further development of workforce

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Conclusions

Bridges the gap between academia and the NASA vision and mission. Students connect to real world space-related work.

Exposes students to new and novel approaches to space exploration that better prepare them for future space-related careers.

Creates greater awareness of current NASA research to new faculty who have never been previously associated with or exposed to the NASA vision and mission.

- Motivates incorporation of Systems Engineering curriculum to enrich the experience and increase the knowledge base of participants.

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