2010 ESMD Faculty Fellowship Project

Christina L. Carmen — UAHuntsville, The University of Alabama in Huntsville

Tommy Morris — Mississippi State University

Peter Schmidt — UNC Charlotte, The William States Lee College of Engineering

Paul van Susante — Colorado School of Mines, engineering the way

Janusz Zalewski — Florida Gulf Coast University

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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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Project Goal

2010 Faculty Fellowship Solicitation

- 8 weeks on a selected ESMD project
- at Kennedy Space Center (KSC) for one week
- Incorporate project into an existing senior design course or capstone course 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 during the 2010/2011 academic year
- Use a systems engineering approach

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

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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

Ground Operations

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

Propulsion

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

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

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
- 600 students exposed this year alone

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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.

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 Project

Dr. Christina L. Carmen, Ph.D.

Midwest Regional Space Grant Meeting, Minneapolis, MN

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UAHuntsville
The University of Alabama in Huntsville

Overview

1. X-TOOLSS Project
2. X-TOOLSS Optimization Using Nastran
3. Lunar Wormbot Design Project
4. Systems Engineering Design
5. Summary

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

NASA ESMD X-TOOLSS Project

- X-TOOLSS project history began with NEVOT (Nuclear Exploration Vehicle Optimization Team)
- Today, the development and use of X-TOOLSS continues with the following:
  - North Carolina A&T State University (Computer Science dept.)
  - Marshall Space Flight Center
  - Oak Ridge National Laboratory
  - Arnold Engineering Development Center
  - And now…The University of Alabama in Huntsville (UAH)
    - First use of X-TOOLSS in a senior capstone design class

NASA ESMD X-TOOLSS Project

- X-TOOLSS requires a code file (java script or an executable application file)
- X-TOOLSS can be used with MATLAB, COMSOL, Nastran, etc.
- The use of X-TOOLSS at UAH will focus upon the optimization of the design via FEA using Nastran
- All MAE students at UAH learn MATLAB and all mechanical engineering students learn Patran/Nastran

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.

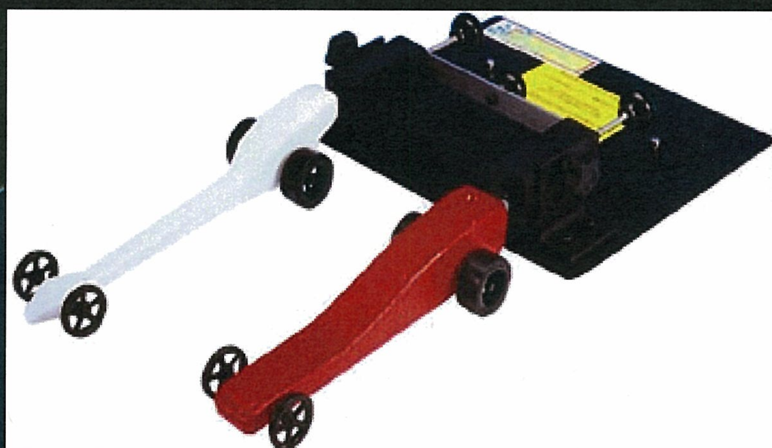

Figure 1: HotShot Raceway™ CO2 Dragster Launcher

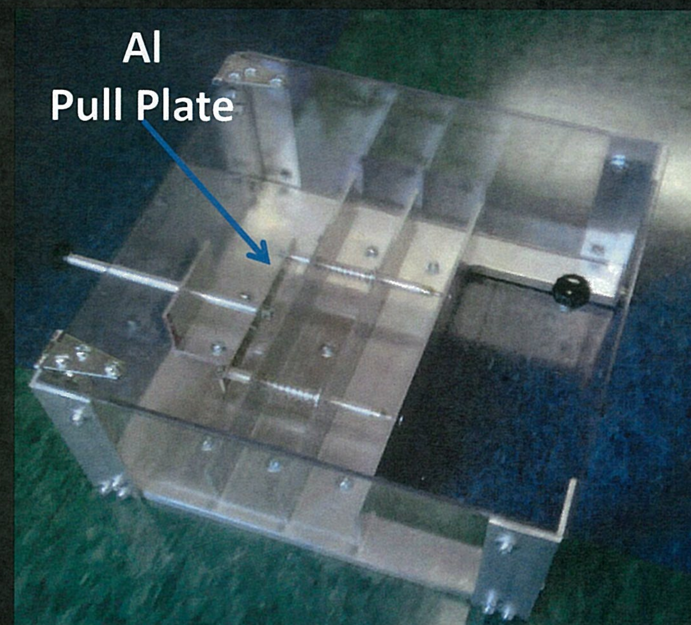

Figure 2: MAE Team 10 Final Product

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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.

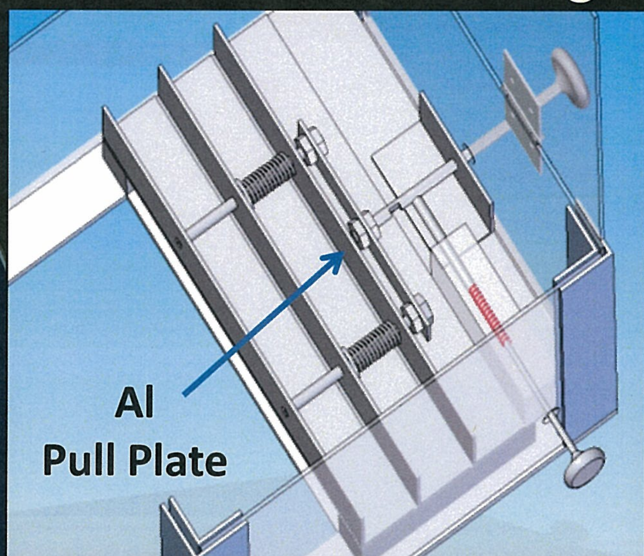

Figure 3: MAE Team 10 CAD Model

Figure 4: MAE Team 10 FEA

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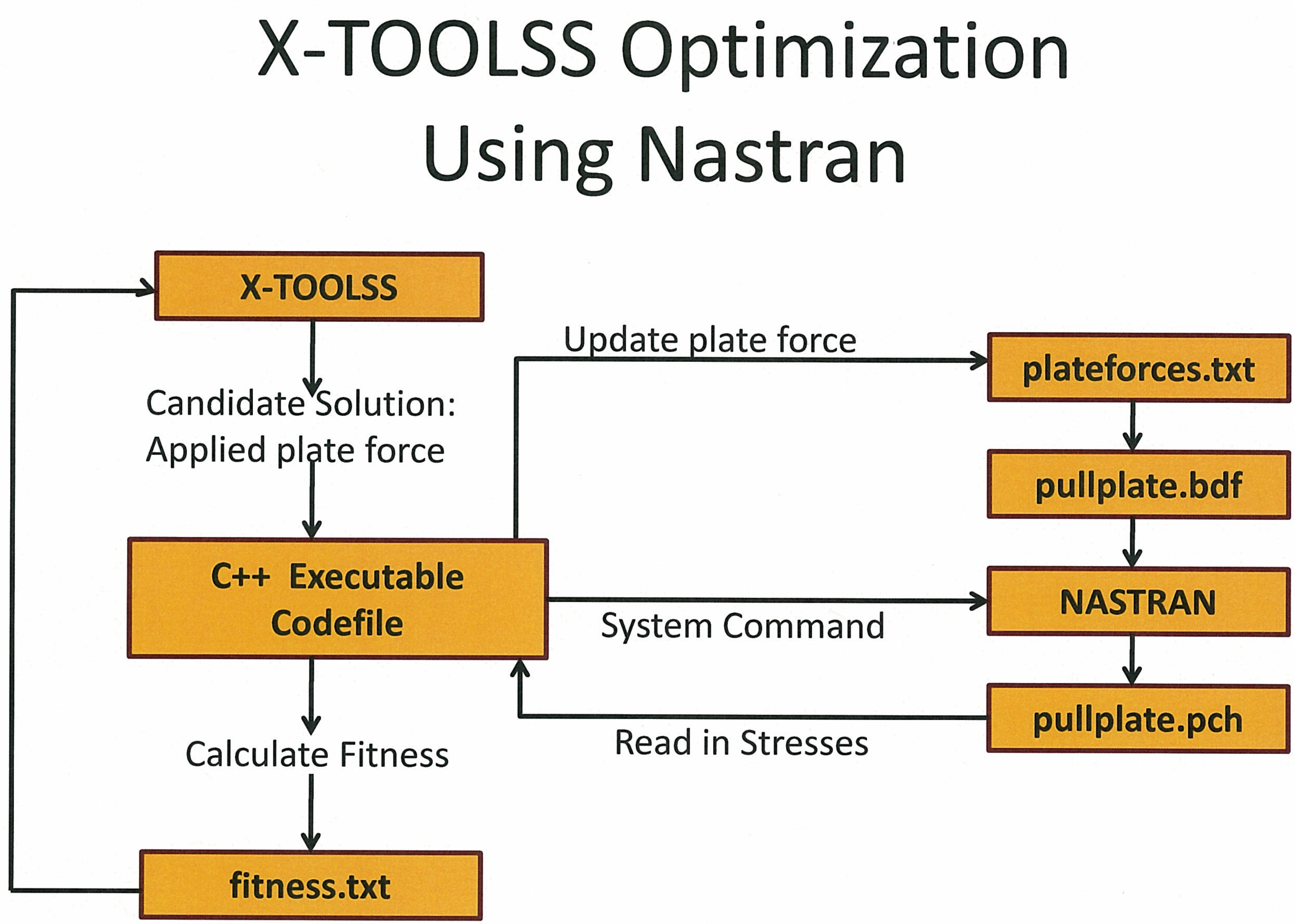

Figure 5: The X-TOOLSS/Nastran Optimization Loop

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.

Lunar Wormbot Design Project

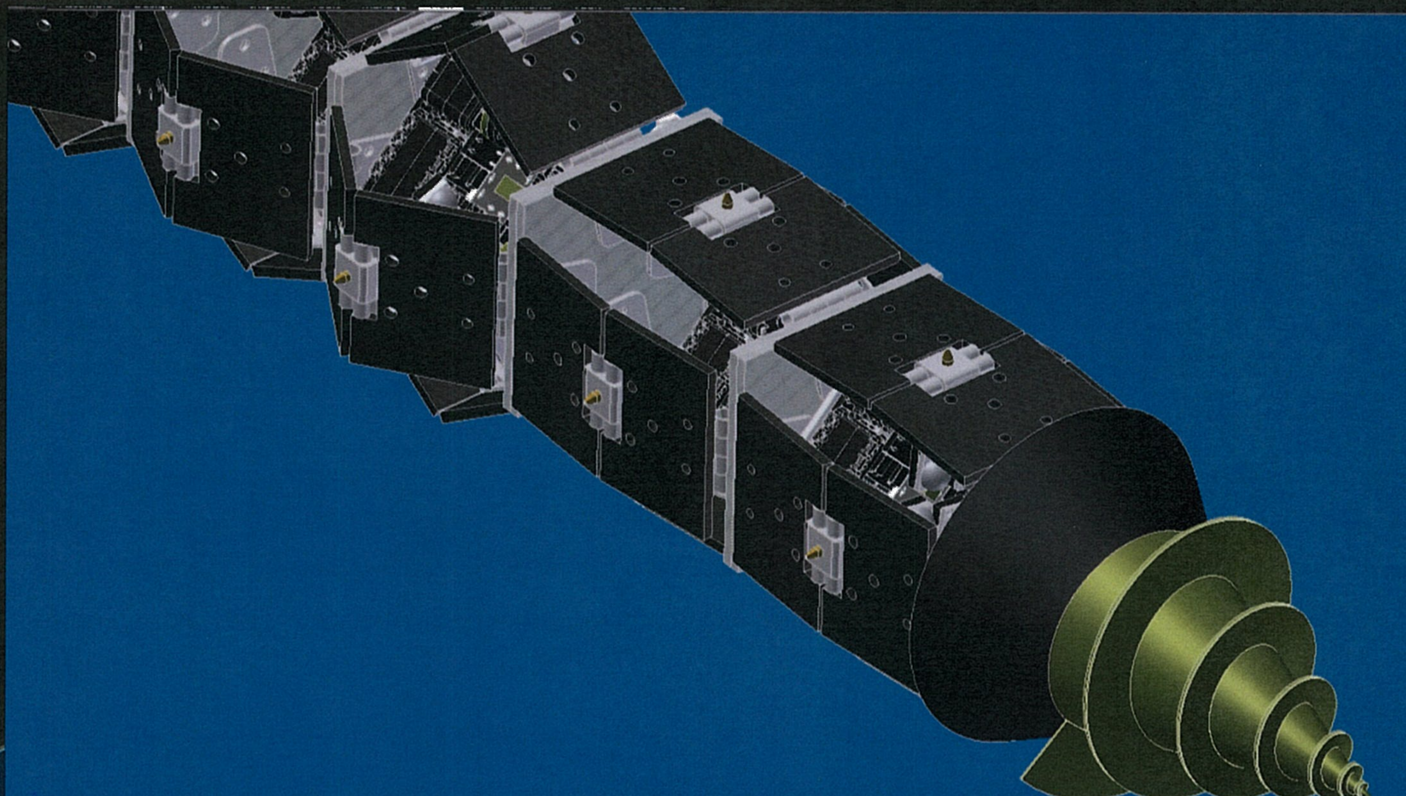

Figure 6: NSSTC Conceptual Design of the Lunar Wormbot

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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.

MISSISSIPPI STATE UNIVERSITY™

ESMD-Faculty Fellowship Report

Tommy Morris, Ph.D.

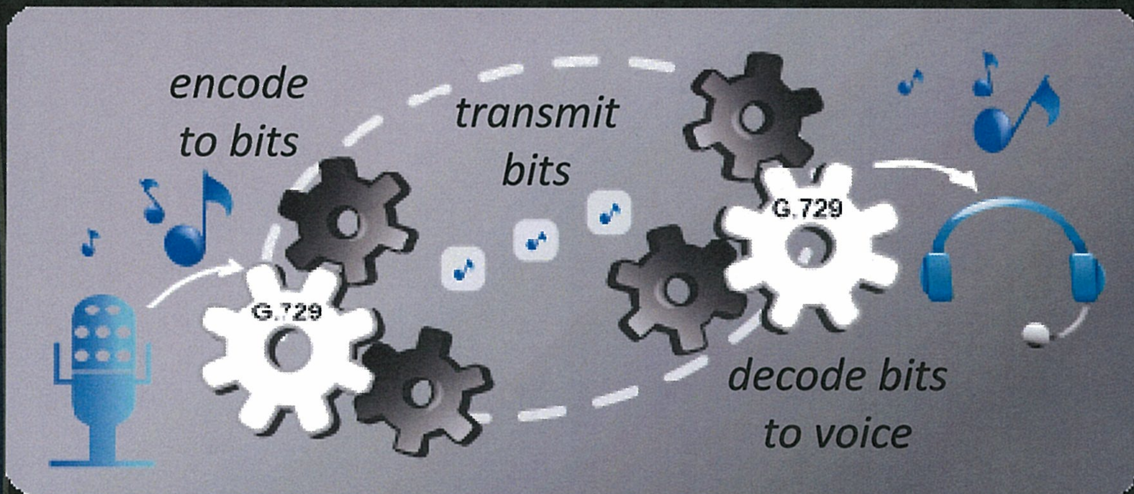
Northeast Regional Space Grant Meeting, New Port, RI

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.

Background



ITU G.729 is a voice CODEC (aka VOCODER).

Field Programmable Gate Array (FPGA) = Programmable microchip.

Hardware Description Language (HDL) = language used to describe digital circuits

- Concurrency
- Support for bits, bytes, etc.
- Event triggered processes

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.

Circuit Power

$$P \propto \frac{1}{2} C V^2 f$$

P = Power.
c = Capacitance.
v = Voltage.
f = Frequency.

The Hardware implementation of the CODEC will meet NASA and ITU G.729 function requirements at much lower frequency (f) than software version, leading to significantly lower power.

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.

Knowledge Gained

JSC4-36-SD Implement CODECs on FPGAs

- NASA Labs
  - Common configuration to simulate flight
  - Ground station electronics, Latency to simulate distance, flight side electronics
- NASA Processes
  - Chip design process at NASA.
  - Lots of FPGA work.
- NASA Research Needs
- NASA Research Funding Opportunities

Incorporation into Classroom

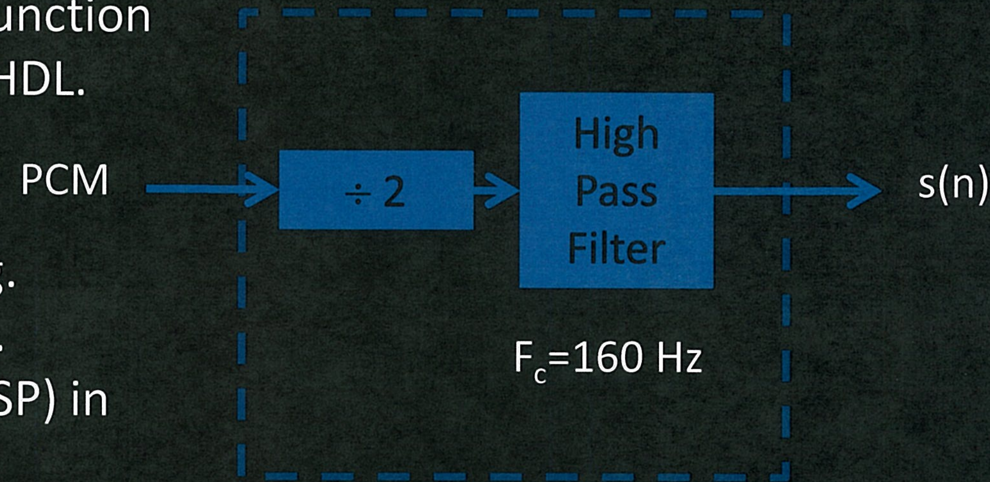
JSC4-36-SD Implement CODECs on FPGAs

- Integration of project into Digital Systems Design class.
  - 3-4 in class lectures + 1 lab exercise
  - Fixed point arithmetic.
  - Shared function unit scheduling.
  - Conversion of C to HDL.
  - System Engineering Design.
  - DSP in hardware.
  - Lab Exercise: FIR Filter implementation in HDL.

Lab Exercise: ITU G.729 FIR Filter implementation in HDL

- Lab exercise developed to implement pre-processing function on Xilinx FPGA with Verilog HDL.

- Fixed point arithmetic.
- Shared resource scheduling.
- Finite State Machine (FSM).
- Digital Signal Processing (DSP) in Hardware.

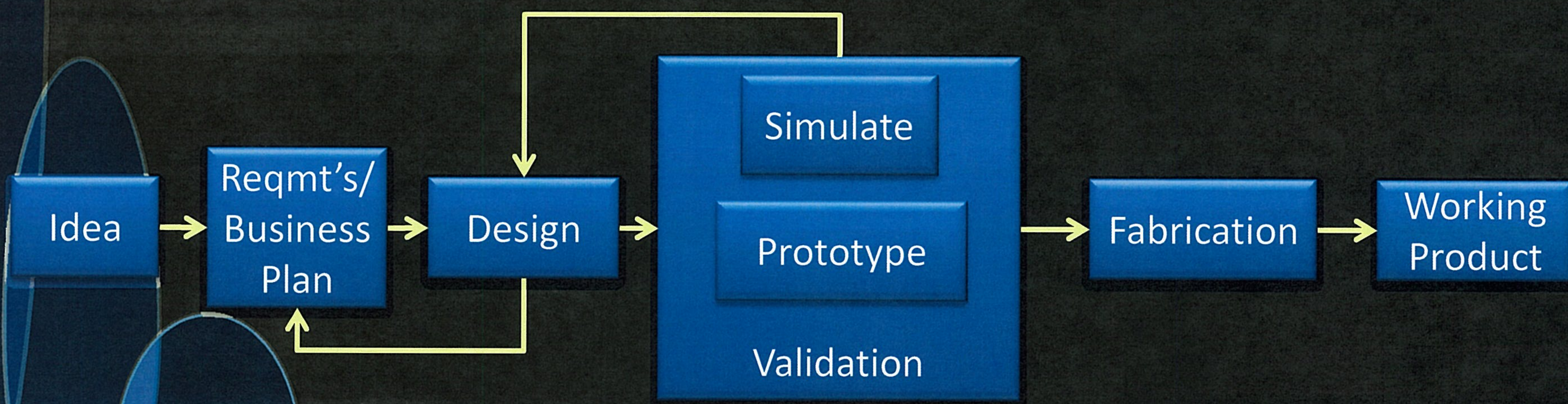


$$H_{h1}(z) = \frac{0.46363718 - 0.92724705z^{-1} + 0.46363718z^{-2}}{1 - 1.905946465z^{-1} + 0.9114024z^{-2}}$$

$$y[n] = 7807y[n-1] - 3733y[n-2] + 1899x[n] - 3798x[n-1] + 1899x[n-2]$$

MSU Electrical and Computer Engineering Senior Design

- 2 semester course sequence
- Capstone design experience
- Teams of 2-4 students



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Senior Design Project

- 2-3 student team.
- Implement ITU G.729 encoder in Verilog HDL.
- Validate in simulation and on Xilinx XUPV5-LX110T evaluation board.
- Managed with processes from NASA System Engineering Handbook.
- Deliver Verilog HDL to NASA EV2 Electronic Design Branch in May 2011.

UNC CHARLOTTE

The WILLIAM STATES LEE COLLEGE *of* ENGINEERING

ESMD-Faculty Fellowship Report

Peter L. Schmidt

Southeastern Regional Space Grant Meeting, Charleston, SC

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The WILLIAM STATES LEE COLLEGE *of* ENGINEERING

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

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.

Project Definition (ctd) - Cryogenic Fluid and Electrical Quick Connect System

- The system shall also include an installation tool to overcome large mating forces
- The system shall feature geometry to assure correct connector alignment for engagement
- The system shall have a dust exclusion system to minimize, if not eliminate, any dust that could impinge or collect on the connector interface surfaces.
  - This design effort will include a standardization effort, such that three distinct sizes of connector systems result.

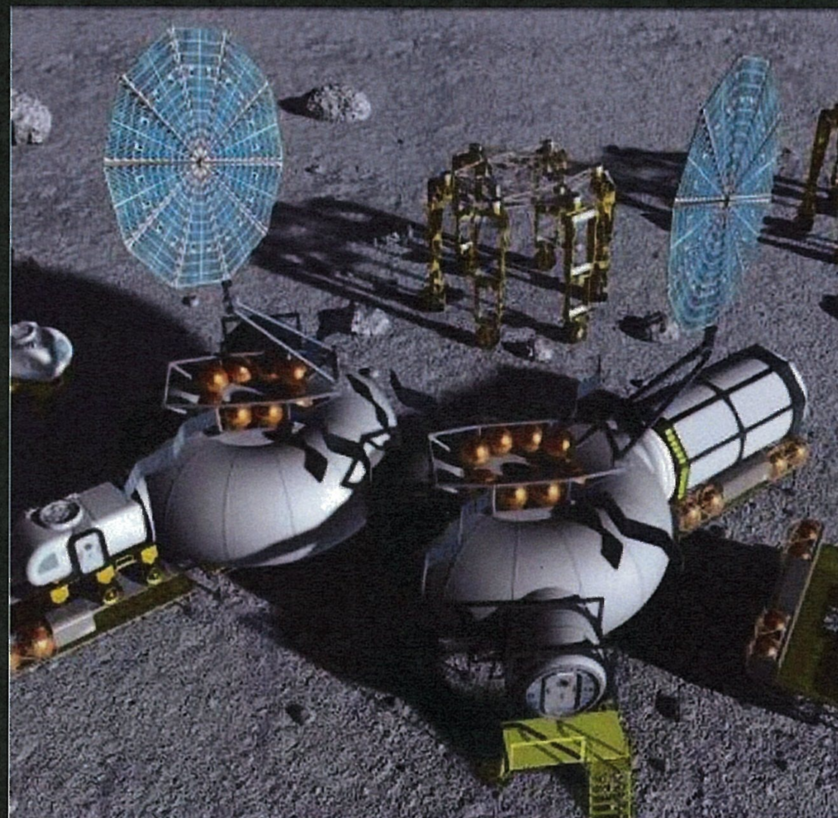
Lunar Regolith Design Case

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

Outpost Infrastructure

- Modular Layout
- Water
- Atmosphere
- Fuel
- Process Fluids
- Electric Power (High Voltage)
- Electric Signals (Low Voltage)

Proposed Outpost Layout



Complementary Technologies

- Consumables Scavenging
- Consumables Transport
- Consumables Production
- Suit Exterior Interface Station
- Construction Equipment
- Desert Operations

Use of Existing Standards / COTS

- Mil-C-24231
- Mil-C-24217
- Mil-DTL-26482
- ISO 7241

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Paul J. van Susante

Mid-Alantic Regional Space Grant Meeting, Delaware

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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

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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 O_2 Prod/Outpost Emplace

Description: Landing pad Installation and support for O_2 production. This project will investigate concepts for Lunar Regolith excavation equipment and propose solutions in the form of completed designs and prototypes.

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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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Landing Pad Project

- Go to other planetary bodies with humans and robots
- First thing you do: land on surface
- Sustainable, repeatable
- Safety, risk mitigation
- Use local resources
- Gather feedstock for O_2 production while building a landing pad

Apollo Lunar Landing

Apollo Landing video

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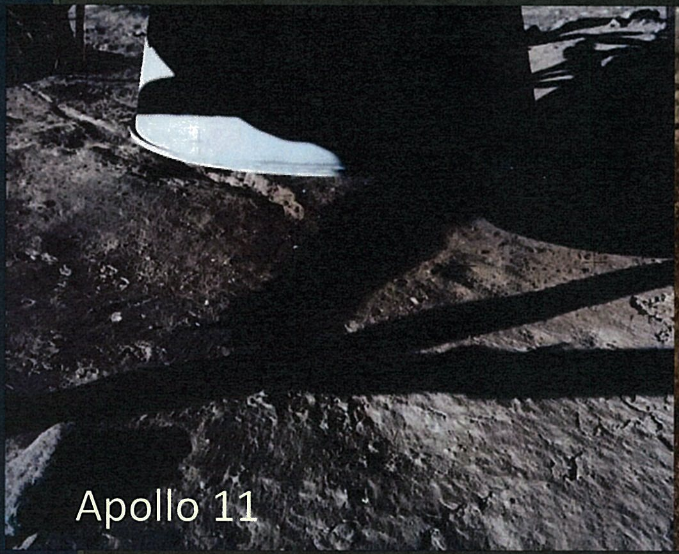
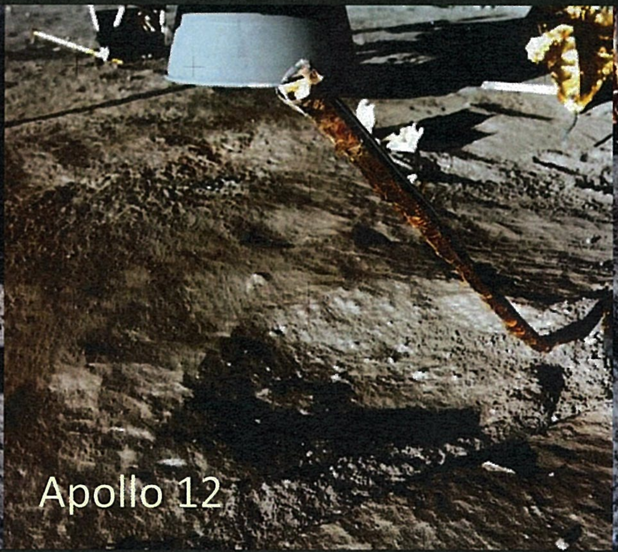
engineering the way

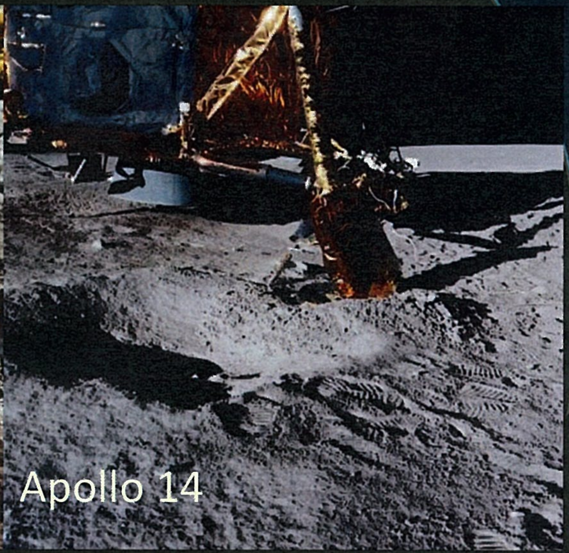
Need for landing pads

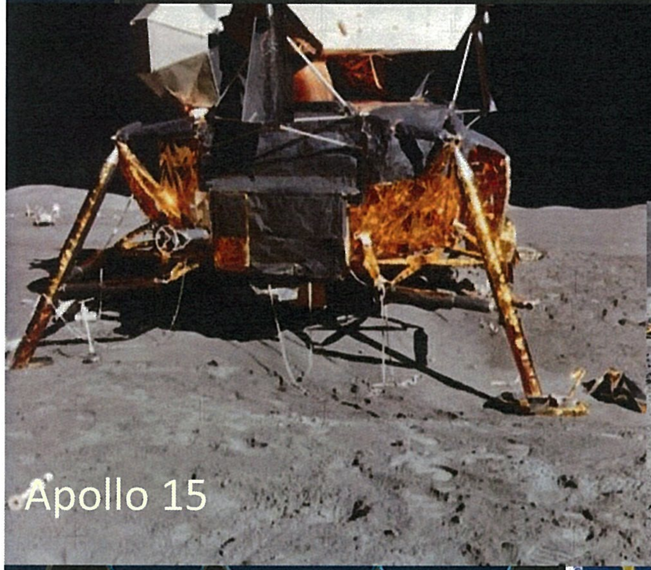
- blast streak (or 'plume') small particles (10-60 microns)
- speeds between 1.0-2.5 kilometers per second
- exhaust gases powerful enough to move rocks up to 15 cm in size.
- 1 to 3 degree elevation angle in all missions
- Apollo 15 anomaly
- Mars case, deep cratering (several feet) will occur underneath lander. Could tip over lander

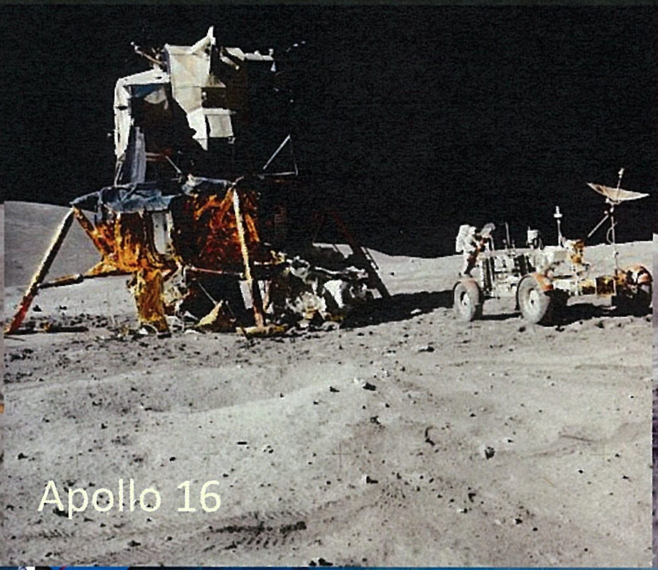
Need for landing pads











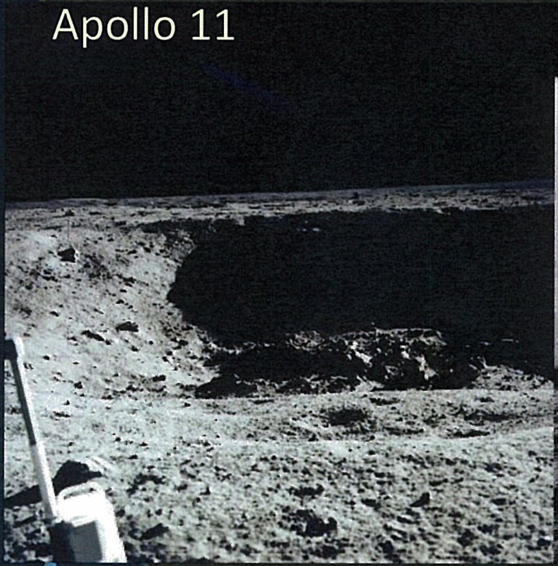
Need for landing pads

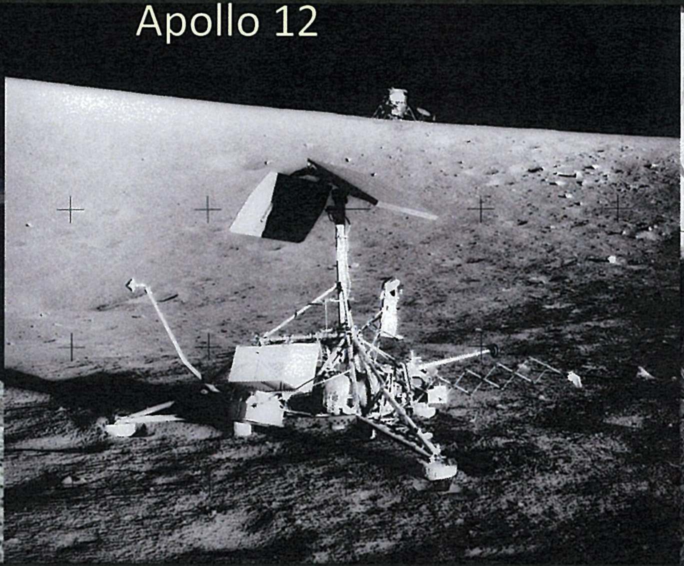
- Ejecta hits surrounding hardware
- Ejecta hits landing spacecraft
- Regolith instability after landing
- Loss of visibility during landing
- Spoofing of landing sensors
- Dust deposition on hardware
- Crew exposed to plume chemicals in soil

Requirements for Landing Pads

- -frequency of use
- -size
- -local geography
- -different zones with different loading requirements
  - -mechanical
  - -thermal
  - -chemical
  - -radiation
  - -meteoroids
- -variety of methods to use to stabilize top layer of regolith
- -surface quality of landingpad
- -environment
- -durability
- -ease of maintenance / repair / replacement

Landing Pad Preparation


Apollo 11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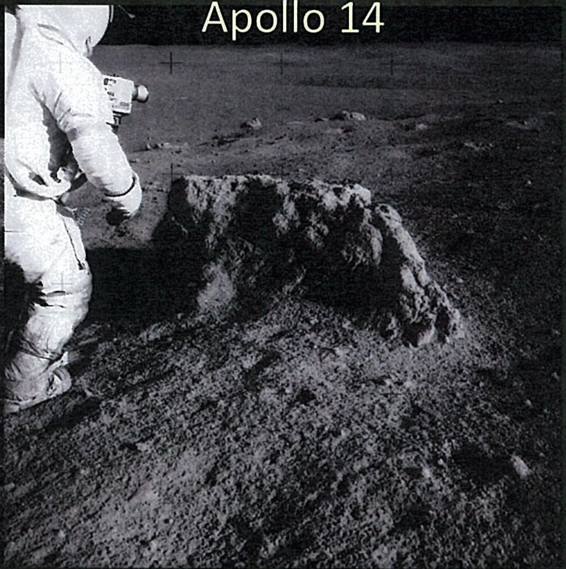
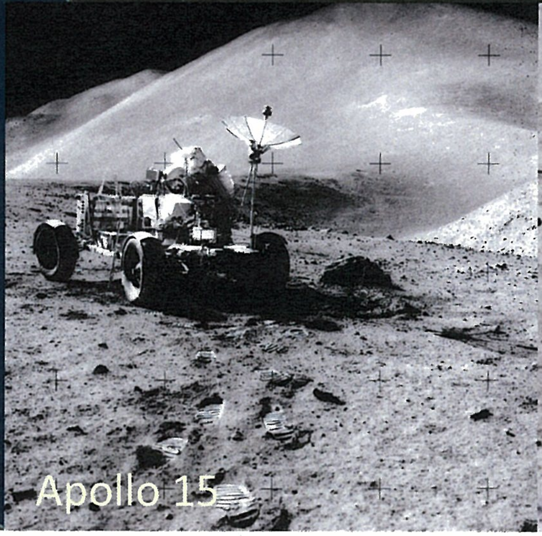
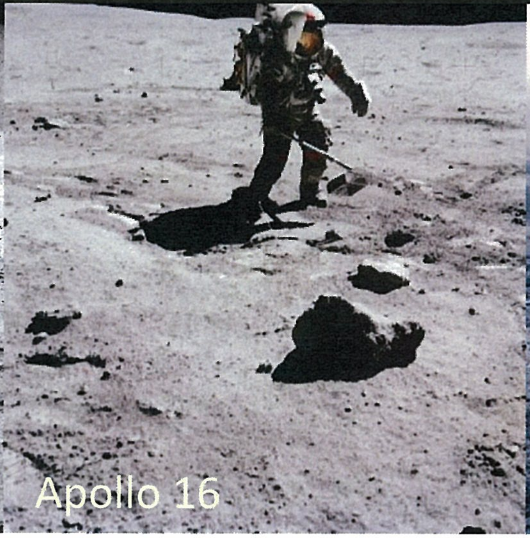
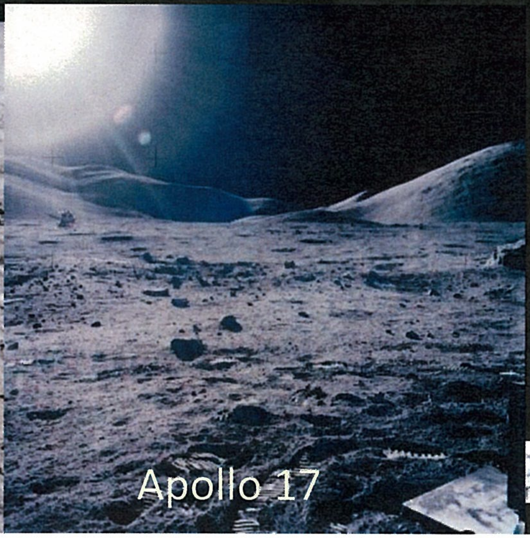

Apollo 14

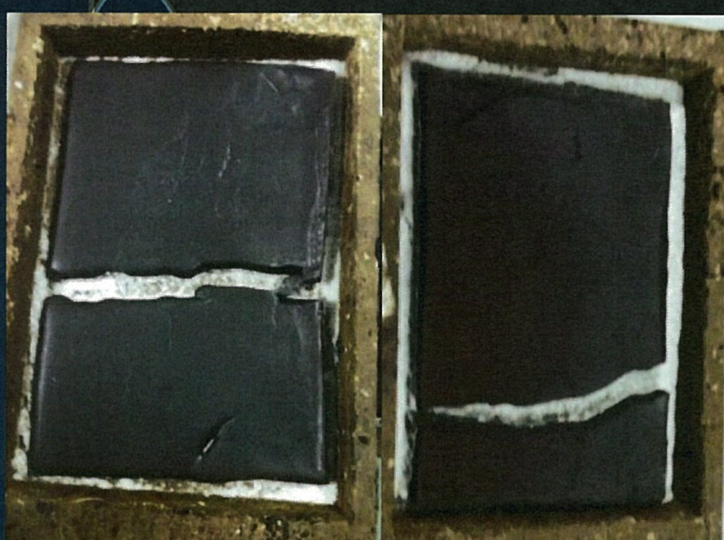

Apollo 15


Apollo 16


Apollo 17

Landing pad stabilization options

Testing in Progress



Landing Pad Testing at KSC

Requirements for Soil Stabilization Tool

-mass

-power

-communication/control

-volume

-budget

-schedule

-interfaces (Chariot Quick attach or CAT-MTL)

Conclusion

- 15 or more students in 3 senior design projects during AY 2011 (fall 2010, spring 2011)
- System Engineering Special Topic Seminar for 40-200 students
- Collaboration with KSC-NE-S on landing pad technology development
- Evaluation of knowledge of SE before and after course
- White paper with feedback to ESMD-education
- Still involved in ongoing landing pad material performance evaluation tests at KSC
- Tentatively 3 journal papers will be written on the results of the work performed over the summer

ESMD-Faculty Fellowship Report

Janusz Zalewski

Western Regional Space Grant Meeting, Omaha, Ne

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Florida Gulf Coast University


Janusz Zalewski
Florida Gulf Coast University
Project Topic:
Prognostics for Complex Systems
Project Sponsor:
Dr. Kai Goebel, NASA Ames
FLORIDA GULF COAST UNIVERSITY

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*

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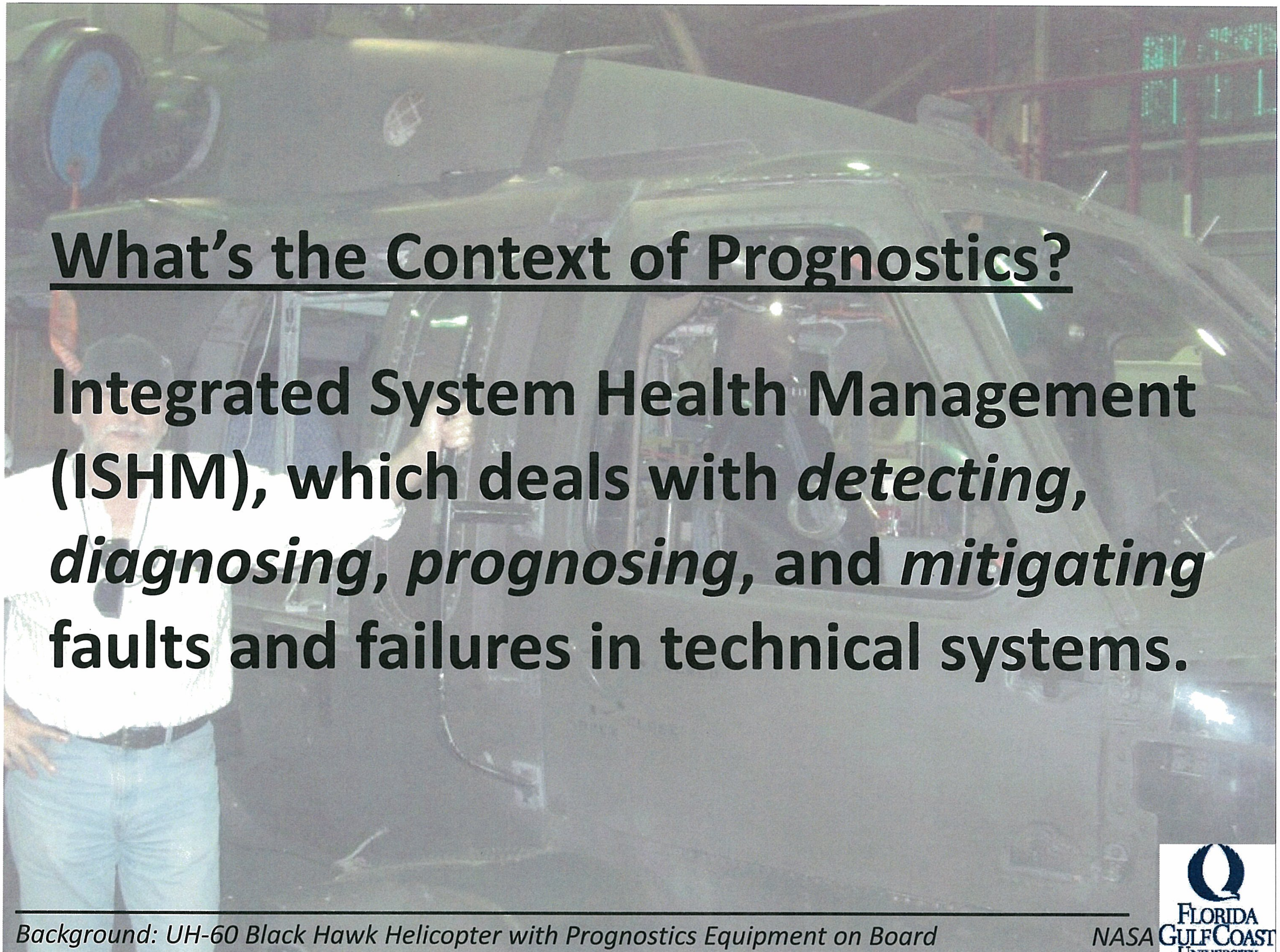

What's the Context of Prognostics?

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

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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.

Background: Behind the Control Panel of the Boeing 747 Flight Simulator *NASA Ames*

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

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]

Acknowledgements

- NASA
- ESMD Space Grant
- Gloria Murphy
- Diane Ingraham
- Rob Mueller
- Dr. Michael Tinker
- Gregory Hall
- Kai Goebel

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QUESTIONS?

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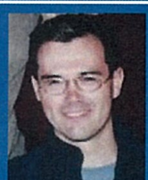
Senior Design Projects Selected

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 Sytems

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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 J. 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