UAHuntsville Propulsion Research Center
Overview

Dr. Robert A. Frederick,Jr.
Interim Director, UAH Propulsion Research Center
Robert.Frederick@uah.edu
http://prc.uah.edu

Date: March 9, 2012

for

Raytheon Missile Systems

UAH Propulsion Research Center

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UAH Contact Information

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  - **Dr. David Lineberry, Research Engineer**
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  - **Dr. James Blackmon**
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  - **Mr. Anthony Edmondson, Research Program Coordinator**
    - **256-824-7209, Anthony.edmondson@uah.edu**
- **UAH Department of Mechanical and Aerospace Engineering**
  - **Dr. Robert Frederick, Interim Chairman, Professor**
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  - **Dr. Jason Cassibry, Assistant Professor**
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Agenda

- PRC Background
- Example
- Future Collaborations

UAHuntsville Propulsion Research Center

Mission

PRC connects the Academic Research Community with Industry & Government to advance basic science and technology development related to propulsion and energy.

PRC Strategic Vision 2015

The PRC will be a major generator of talent and innovative solutions in propulsion and energy related technologies.

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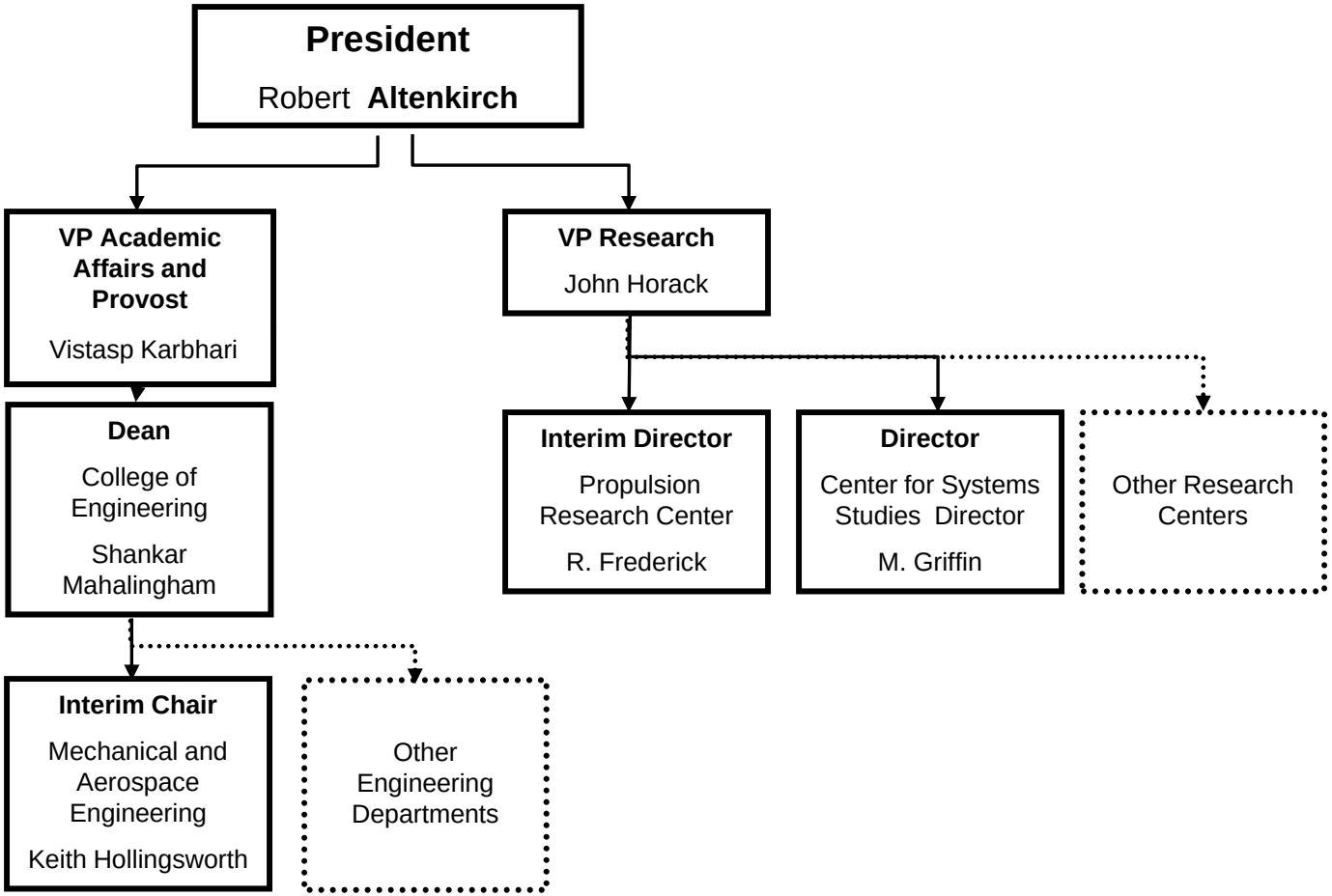
UAHuntsville Organization Chart



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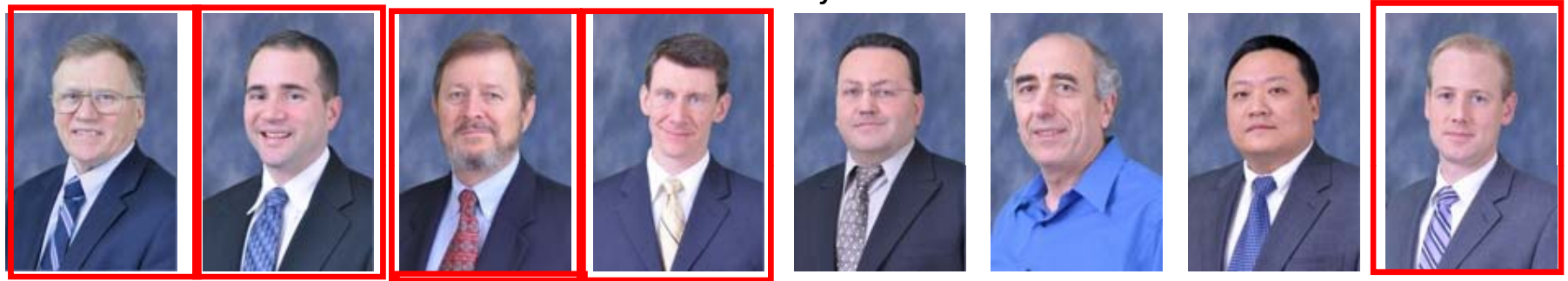
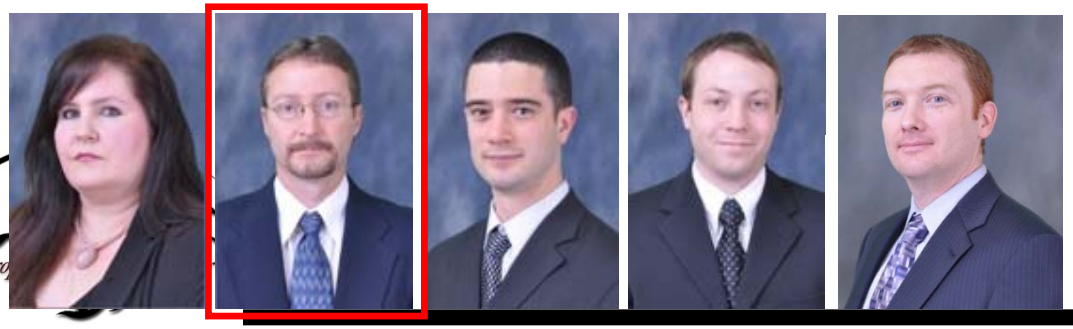
UAH Department of Mechanical and Aerospace Engineering

MAE Faculty/Administration

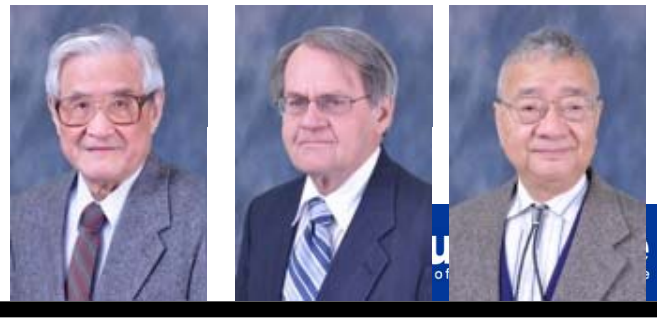
MAE Faculty



MAE Lecturers



Emeritus Faculty



UAH NIRPS University Consortium

National Institute of Rocket Propulsion Systems

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Grand Challenges in Propulsion Research
Workshop Chairs

Dr. Robert Frederick, Jr.
Int. Dir. Propulsion Res. Center
Professor MAE
Robert.Frederick@uah.edu

Dr. Shankar Mahalingam
Dean. College of Engineering
Professor, MAE
Shankar.Mahalingam@uah.edu

Back Row: Robert Frederick, UAHuntsville, Mark Brandyberry, University of Illinois; Robert Santoro, Penn State, Alan Wilhite, Georgia Tech.; Vadim Smelyanskiy, NASA Ames; Shankar Mahalingam, UAHuntsville.
Front Row: Ken Yu, University of Maryland; Roy Hartfield; Auburn ; C.P. Chen; UAH; Mitchell Walker; Georgia Tech; and Bill Anderson, Purdue University.
Brian Cantwell; Stanford to present on October 28th at UAH.

October 14, 2010,
Huntsville, AL

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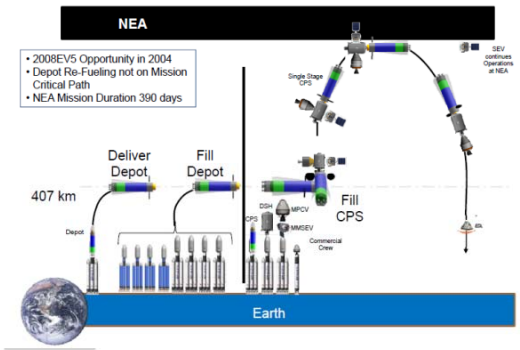
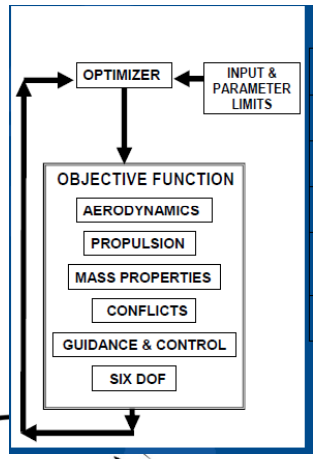
Current State of Academia in Propulsion

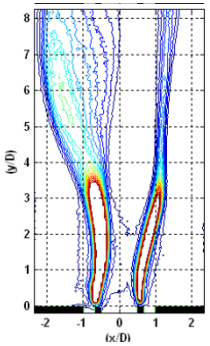
UAH NIRPS Worship Report

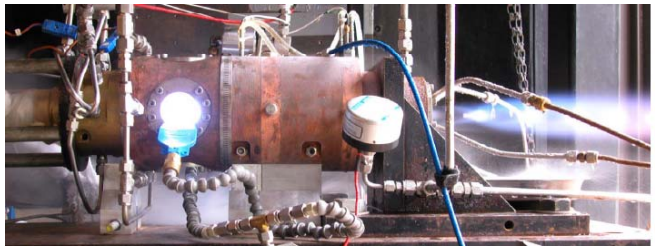
System Architecture and Cost

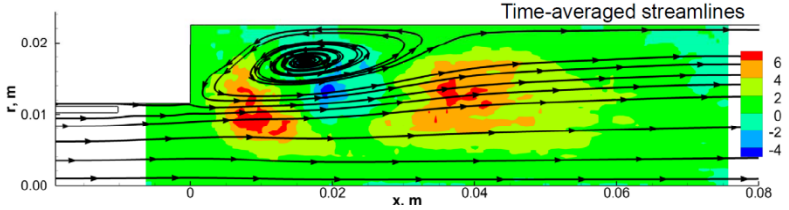




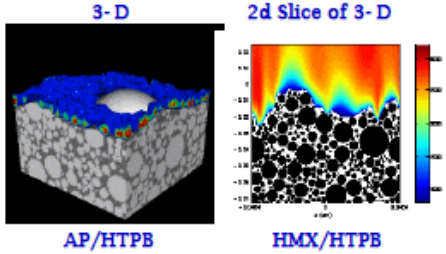
Fundamental Processes

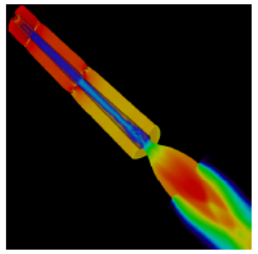


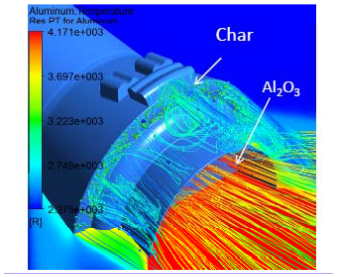




Multi-Physics Modeling







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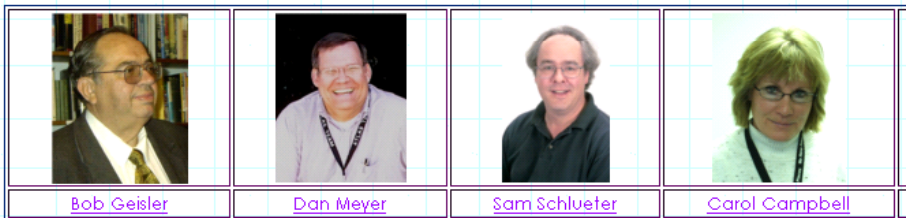
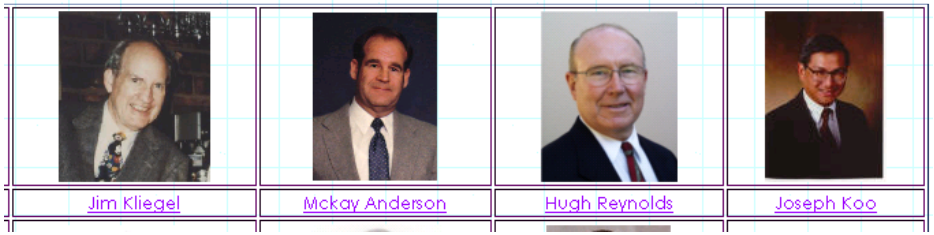
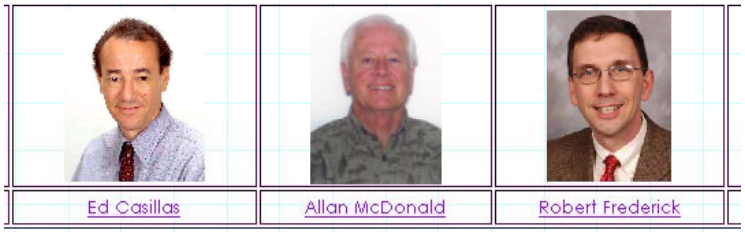
Example Class - Adv. Solid Rocket Propulsion

Developed by Robert Geisler and Dr. Robert Frederick, Jr.

ITAR Cleared, UAH Graduate Course, UAH Professional Development Course, and AIAA Short Course







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Nationally Recognized Student Launch Initiative

National First-Place Design-Fab.-Build – R. Frederick, UAH Faculty Advisor

POPSCI THE FUTURE NOW

PHOTO GALLERIES

FACEBOOK DIGG STUMBLEUPON REDDIT PRINT

Gallery: 30 Awesome College Labs

Posted 8.9.00 at 1:12 pm 0 Comments

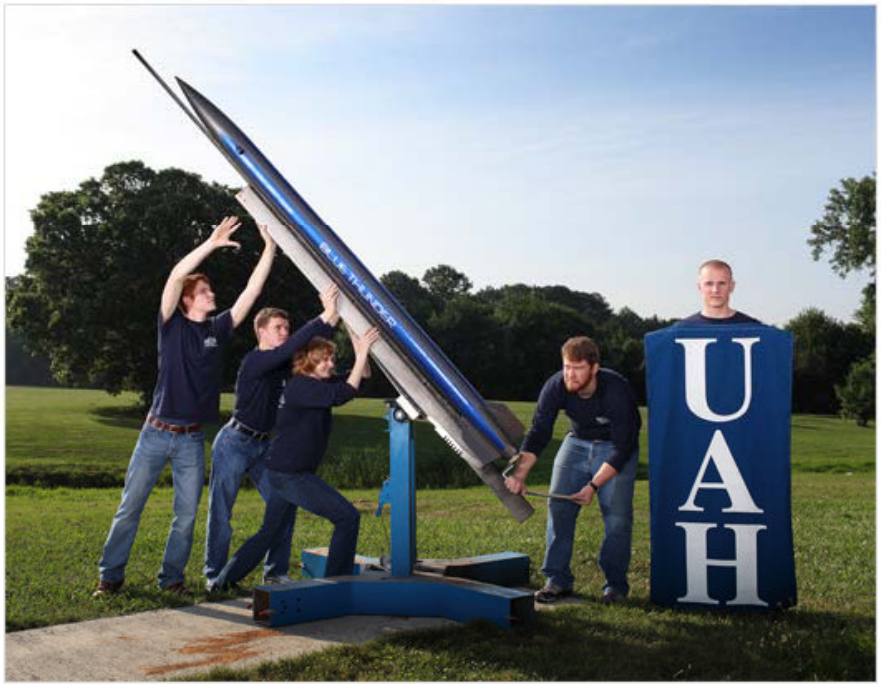


IMAGE 3 OF 30

University of Alabama at Huntsville: Propulsion Research Center

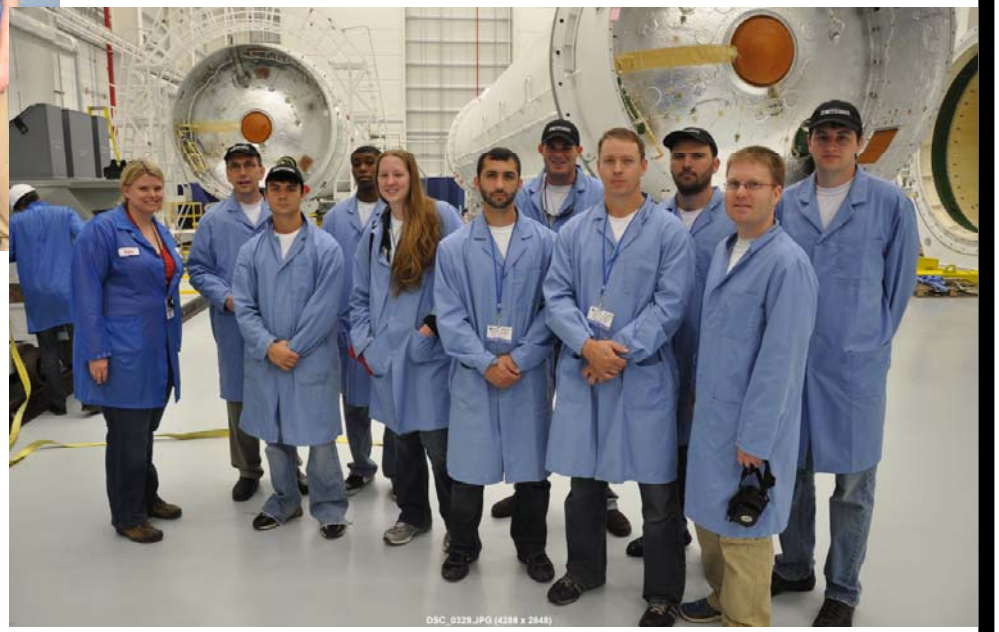
John B. Carnett

Career: Rocket scientist
Learn to: Make things that go very fast and very far

Each year, 20 aeronautical- and mechanical-engineering students get eight months to design, construct, and fly a rocket to a height of exactly 5,280 feet. These aren't hobby rockets, which typically fly to less than 1,000 feet (any higher requires an FAA permit). "Consider that an 'A' engine is half as strong as a 'B' engine, and so on," says engineering professor Marlow Moser. "The rockets you shoot off in the park: A and B engines. Our rockets: L engines."

Last year's class built a 37-pound, 8.5-foot-long carbon-fiber projectile with advanced data-collection systems onboard. The nosecone carried a video camera and avionics to record the rocket's flight path and other information; the aft end, temperature and strain sensors. Students enter their rocket in a NASA-

UAH University Student Launch Initiative



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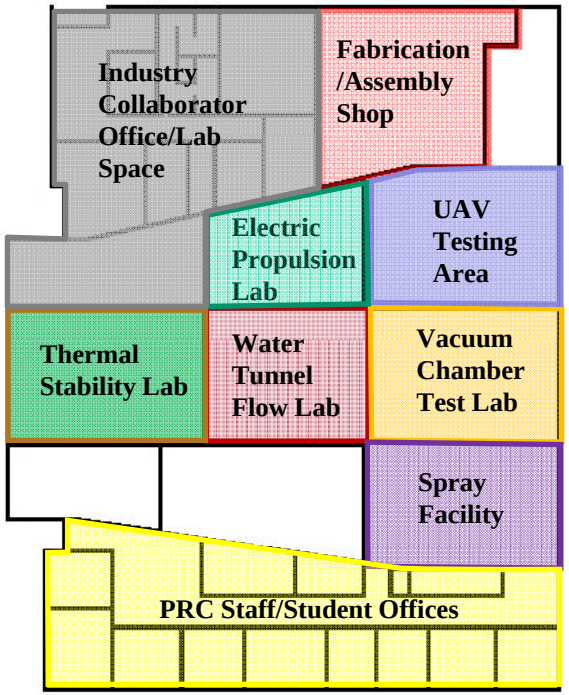
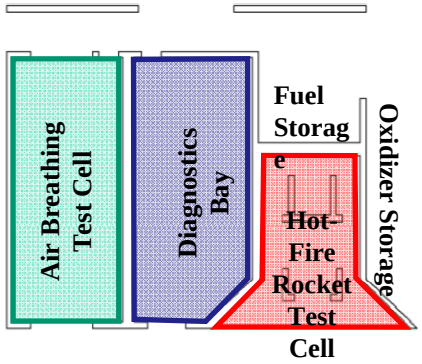
State of the Art Laboratories



PRC Labs at the Johnson Research Center

Approximately 15,000 ft² of Laboratory Space

- Air-breathing Test Cell
- Hot-Fire Rocket Test Cell
- Thermal Stability Test Lab
- Solar Thermal Lab (not Shown)
- High-Pressure Solid Propellant Lab (not shown)
- Electric Propulsion Lab
- Gaseous Cold Flow Lab
- Water Tunnel Flow Lab
- Vacuum Chamber Test Lab



PRC's Propulsion Test Facility

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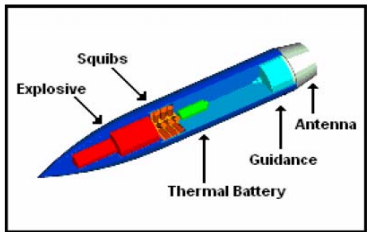
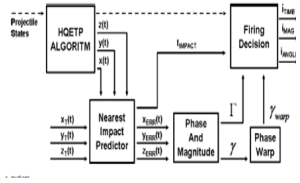
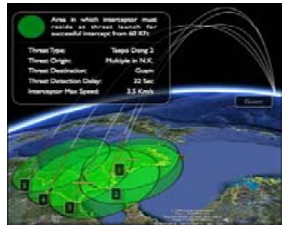
PRC Core Competencies

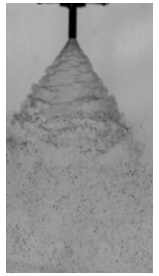
- **Aerospace System Design**
  - Systems Requirements
  - Technology /Assessment Integration
  - System Modeling/Evaluation

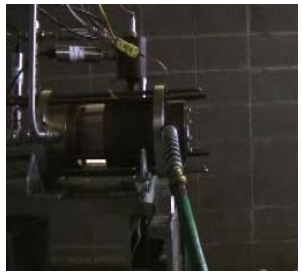






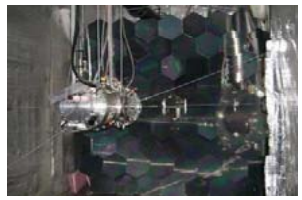
- **Liquid Propulsion**
  - Integrated Methodology
  - Combustion Efficiency/Instability
  - Laboratory-Scale Rocket Engine
  - Advanced Diagnostics



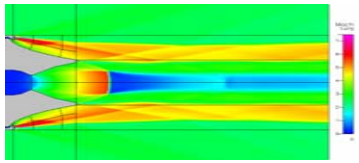


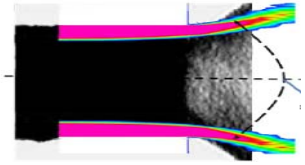
- **Solid Propulsion**
  - Propellant Formulation
  - Burn Rate Determination
  - Motor Testing

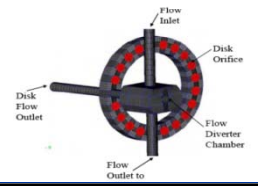
- **Advanced Propulsion**
  - Plasma Modeling
  - Plume Characterization
  - Solar Propulsion



- **Numerical Analysis**
  - Sprays
  - Acoustics

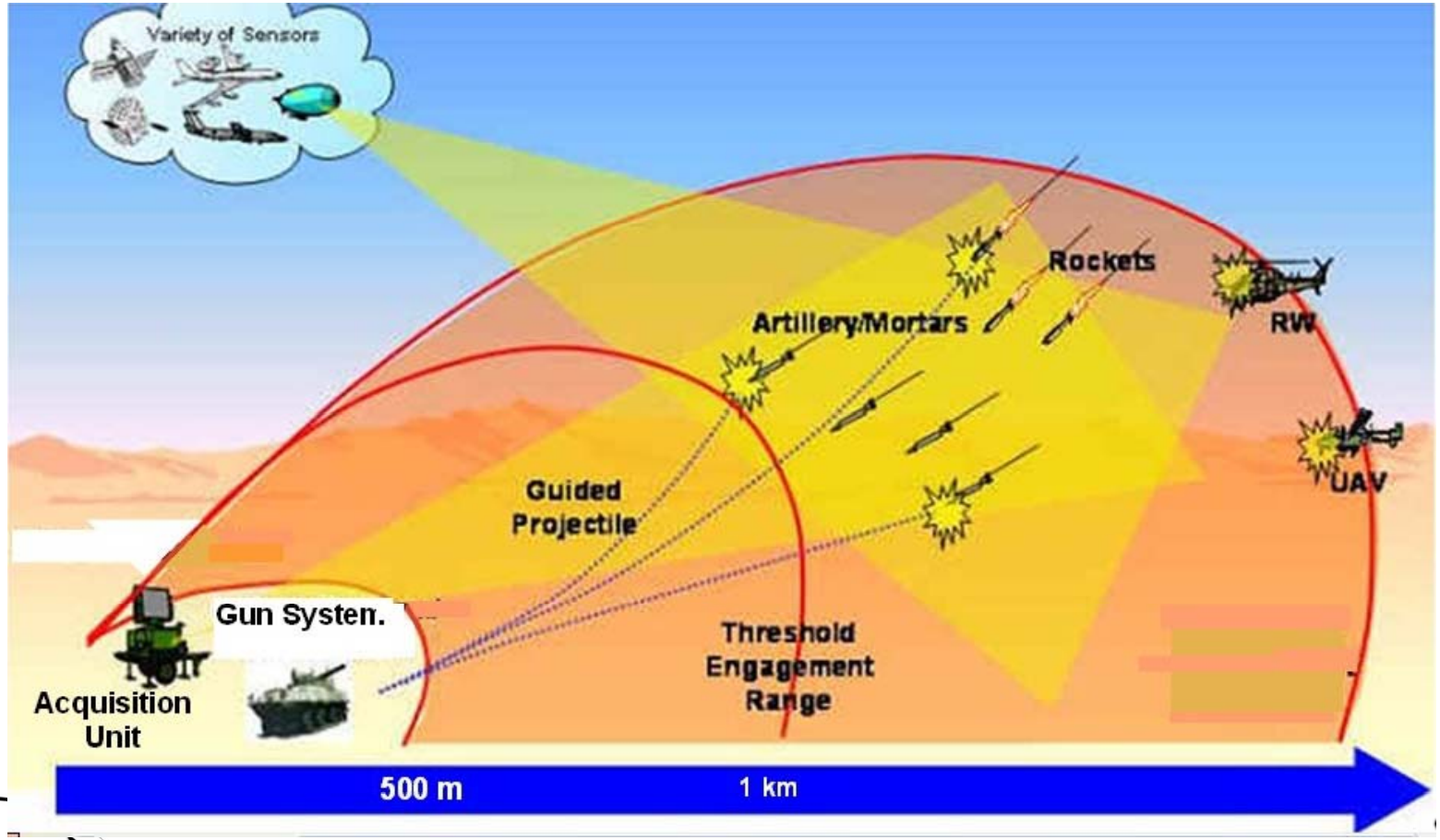






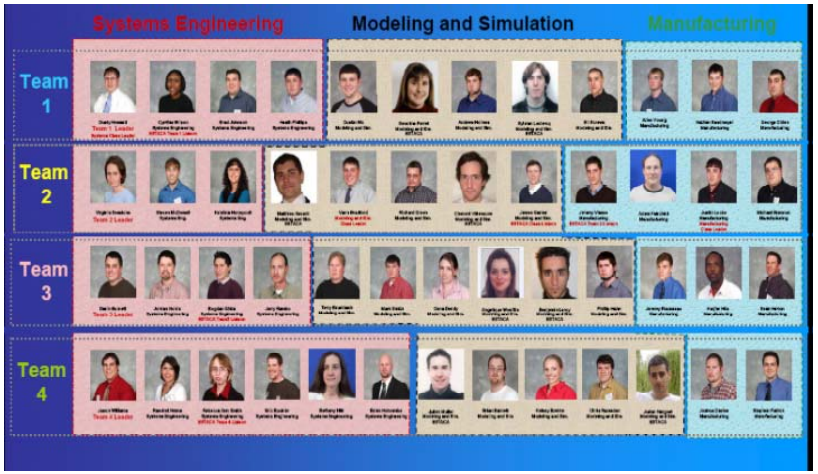
Aerospace Systems Design

Guided Bullet Study

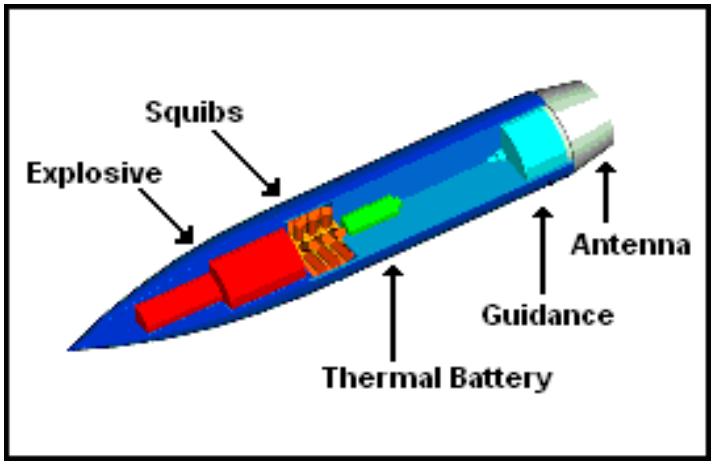


Guided Bullet Study

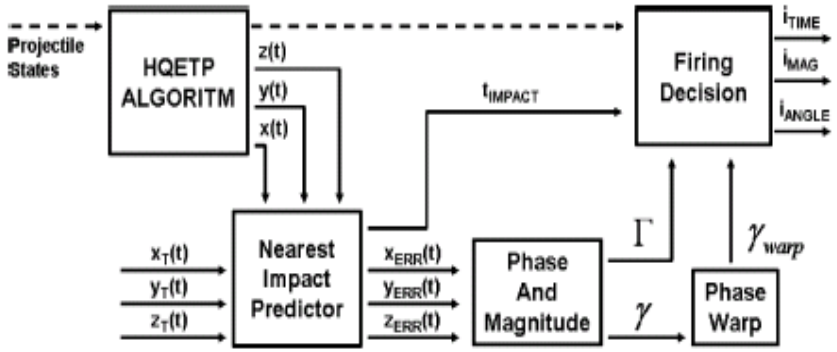
Student IPTs. – Competing Concepts



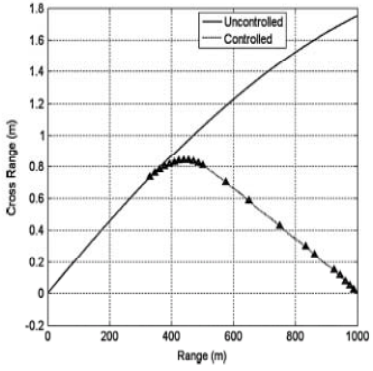
Selected Design – Army Contract.

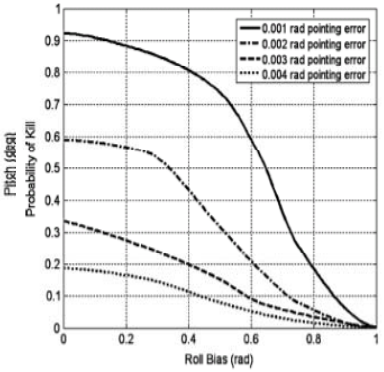


Additional Research - Autopilot



System Analysis – Journal Article





Hahn, P.V., Frederick, R.A., Jr., and Slegers, N., "Predictive Guidance of a Projectile for Hit-to-Kill Intercept," IEEE Transactions on Control System Technology, Vol. 17, No. 4, 2009.

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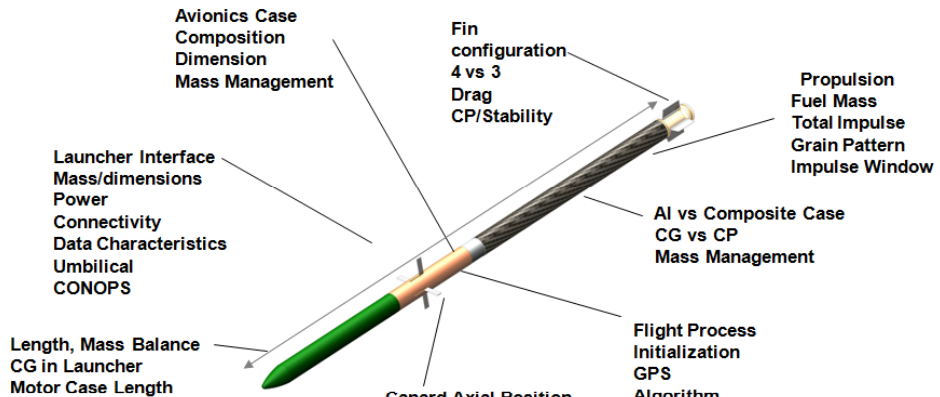
Guided 2.75 Rocket – Graduate Class

ADVANCED TACTICAL MISSILE II

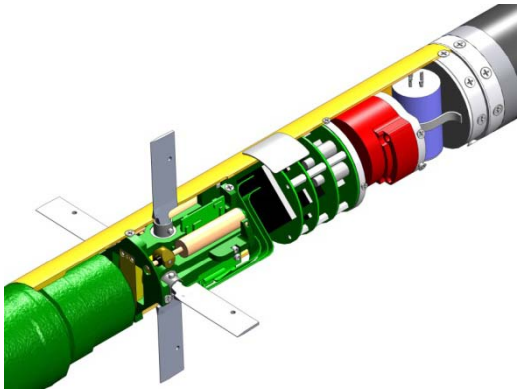
Systems Engineering Trade Considerations During Development

Cerberus



Mass/Range, CONOPS -Air/Ground

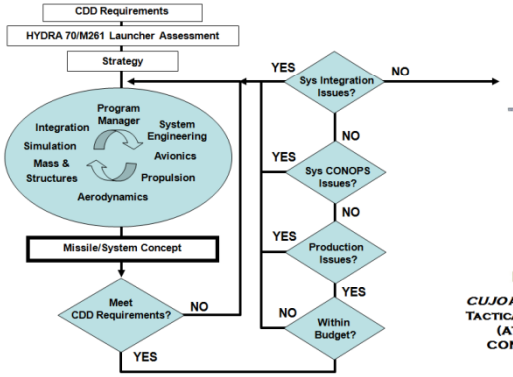
Component Performance/Availability/Produceability/Cost
Software Commonality/ Compatibility

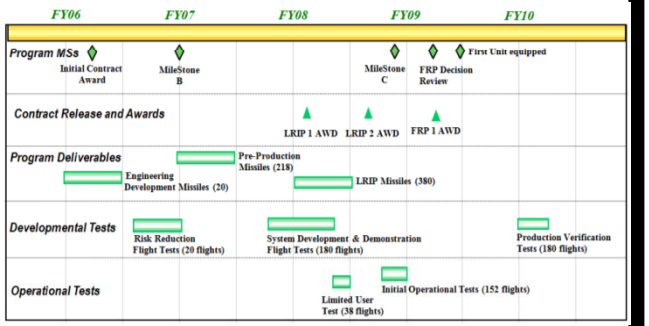


ADVANCED TACTICAL MISSILE II

Systems Engineering Process

Cerberus





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MDA – Innovative Propulsion Technology Support

UAH/MDA Charter

- Identify, Assess, and Prioritize Promising Technologies
- Establish Consortium of Propulsion Technical Experts
- Conduct Analytic and Laboratory-Scale Assessments of Promising Technologies as Independent Verification of Characterization
- Synthesize, Document, and Maintain Propulsion Technology Investment Strategy

Technology gap summary of high temperature materials

(Couchman, Cassibry)

Technology Gap Addressed	Technology Subcategory	Proposed Technology	Technology Limitations	SME
1. Long Duration Operating Time	e and f	Refractory Ceramics	Addresses high temperature, durability in question	Ken Zuo Gang Wang
1. Long Duration Operating Time	e and f	Superalloys	Limited temperature range but tolerates corrosive envir.	Jeff Evans
1. Long Duration Operating Time	e and f	HVOF	Limited temperature range but long duration	Mahesh, R.A. [9]
1. Long Duration Operating Time	e and f	UHTC	Addresses high temperature, durability in question	Ken Zuo Gang Wang
1. Long Duration Operating Time	e and f	rhenium-tungsten inserts	Limited long-term survivablity	

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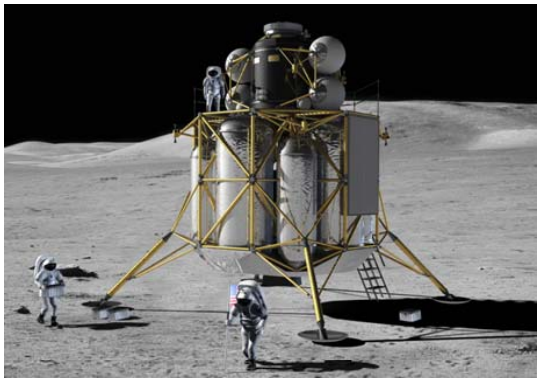
Example – UAH Integrated Methodology

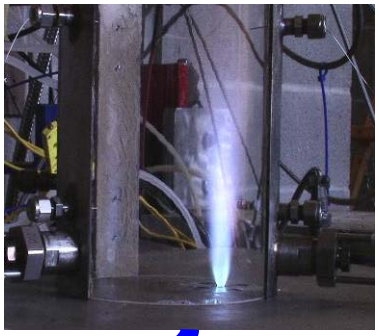
System Engineering



New Component Technology

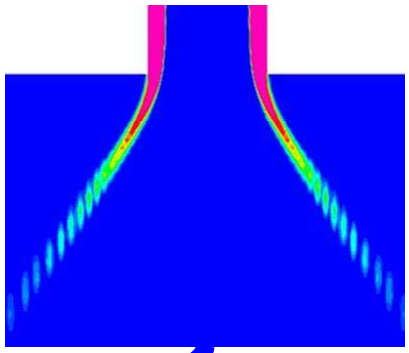
Cold-Flow
Spray Facility

Low-Pressure
Combustion Stability



High-Pressure
Combustion
Performance

Modeling and
Verification



Digital Database

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Laboratory-Scale Methodology for Injector Element Combustion Response *(TCA-24)*

TASK SUMMARY

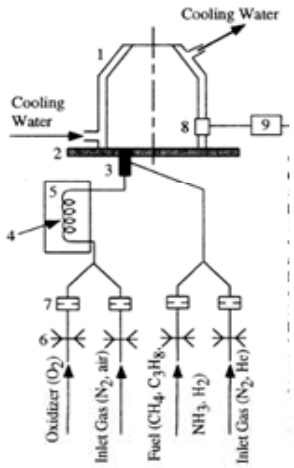
Objective: To evaluate and improve a laboratory-scale injector test facility that provides fundamental combustion data and maps the stability boundaries of practical injectors.

Team: UAH Propulsion Research Center

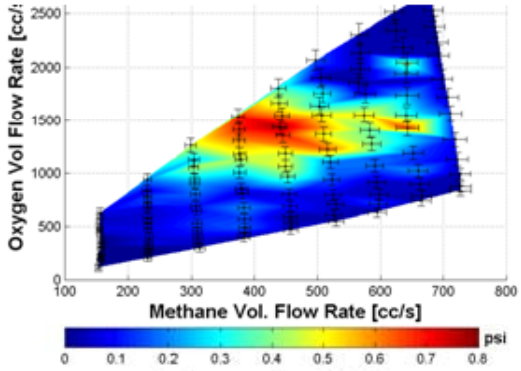
- Dr. R. A. Frederick, PI; Dr. David Lineberry
- Numerous Graduate Students
- Mr. James Hulka; Jacobs [Technical Monitor]

CONTENT

Burner Schematic



Results showing Regions of Spontaneous Radial and Combined Mode Instability.



a) Average Amplitudes

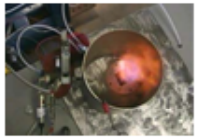
APPROACH

- Evaluate single, full-scale liquid rocket injectors with method from Russia
- Simulate key scaling parameters (such as momentum ratio) using atmospheric gases
- Measure the spontaneous oscillations in the atmospheric resonance chamber
- Correlate the amplitude and mode of observed instabilities with scaling parameters
- Verify Scaling Criteria with instabilities observed in high pressure motor firings

ACCOMPLISHMENTS

Year 1 – Demonstrated Spontaneous Instability
AIAA Paper 2006-4528

Year 2 – Mapped Stability of Three Injectors
AIAA Paper 2007-5587



Year 3 - Mode Analysis
AIAA Paper 2008-4655

Year 4 - Comparisons with Engines
AIAA Paper No. 2009-5493

Year 5 - Optical Diagnostics
(AIAA Paper 2010-6668, AIAA Paper 2010-6737)

Year 6 - Digital Analysis of Modes

UAH Propulsion Research Center

UAHuntsville
The University of Alabama in Huntsville

PRC Statistics

PRC History

- Founded in 1991
- 30 Million in External Funding to Date
- 75 Refereed Publications to Date
- Over 25 Ph.D. degrees Advised
- Over 120 Masters Degrees Advised
- Over 125 Undergraduate Students Supported
- Numerous Government, Academia, and Industry Partners

FY10 Statistics

- 14 Active Research Projects
- 5 Full time Staff
- 8 Faculty Collaborators
- 5 Ph.D. Students
- 20 Masters Degree Students
- 5 Undergraduate Students Researchers
- 1.2 Million in Expenditures

Sponsors and Collaborators

UAH Propulsion Research Center

UAHuntsville The University of Alabama in Huntsville

UAH PRC Affiliations

- AIAA Hypersonic Technical Committee
- AIAA Joint Propulsion Conference Organizing Committee [Propulsion Education]
- AIAA Solid Rocket Technical Committee
- Aerospace Consortium of Alabama (ACA), [UAH, Auburn, and Alabama]
- Air Force Educational Partnership Agreement, AFRL Edwards
- AMRDEC Standing Contracts
- ASEE Propulsion Education
- JANNAF Journal of Propulsion and Energy
- JANNAF Solid Performance Committee
- NASA Constellation University Institute Program (CUIP)
- NASA Educational Partnership Agreement, MSFC
- NASA MSFC Cooperative Agreement
- NASA Glenn RTAPS [Research and Technologies for Aerospace Propulsion Systems]
- ONERA France