Structures, Propulsion, And Control Engineering (SPACE) Center

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SPACE Center Director

NASA Ames

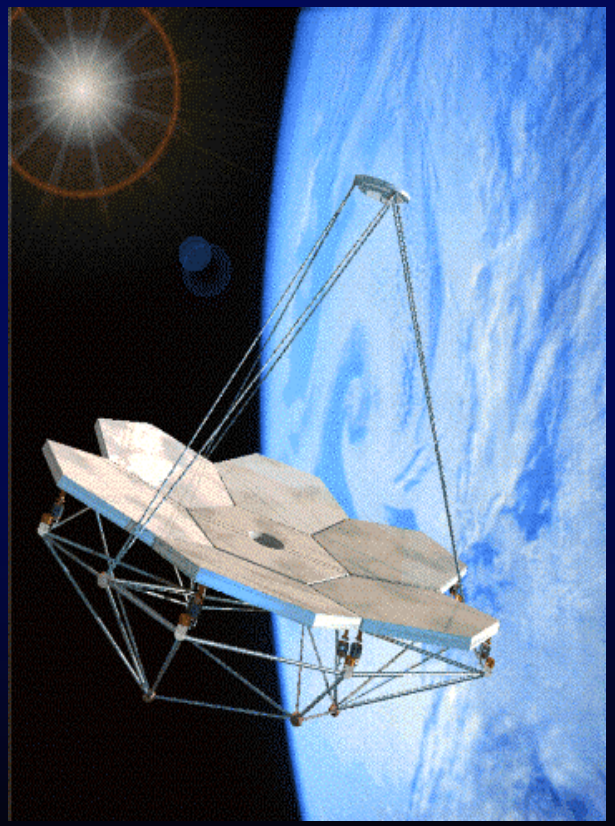
October 24, 2009

www.calstatela.edu/space

NASA Grant URC NNX08BA44A

California State University, Los Angeles

Structures, Pointing, And Control Engineering (SPACE) Laboratory



Multidisciplinary Flight Dynamics & Control Laboratory
(MFDC Lab)

- **The SPACE University Research Center (URC) works in partnership with Dryden Flight Research Center (DFRC) as the lead NASA center, and JPL (Jet Propulsion Laboratory) as the secondary NASA center.**

- **In addition, the URC has a close collaboration with Boeing Company and Northrop Grumman Corporation.**

- **The major areas of research in the URC are directly related to the missions of:**
  - Aeronautics Research Mission Directorate (Uninhabited Aerial Vehicles (UAVs) and Combustion)
  - Exploration Systems Mission Directorate (James Webb Space Telescope), addressing and supporting some of these missions' key challenges.

RESEARCH AREAS

To address the technology challenges of both Directorates, the SPACE center conducts research and development in the following Research Areas:

- Intelligent Flight Control, Autonomous Control, Formation Flying
- Uninhabited Air Vehicles (UAV) Development
- Wind-Tunnel Testing and Validations
- Optimization of Combustion and Propulsion Systems
- Bio-derived Liquid Fuel and Solid Propellant Development
- Thermal Analysis of Space Systems
- Space Telescope Technology, Precision Pointing, System Identification
- Decentralized Control, Failure Analysis and Reconfigurable Control
- Ubiquitous Computing and Embedded Architectures.

NASA's Educational Objectives

SPACE Center MISSION

Aligning with NASA's Educational Objectives, the SPACE Center Mission is to:

- **Develop state-of-the-art computing tools and techniques for modeling, control and simulation of high-performance and unusual aircraft of the future such as:**
  - Airbreathing hypersonic flight vehicle
  - Variable geometry aircraft
  - Reusable launch vehicles
  - Uninhabited aerial vehicles
- **Design a testbed resembling the complex dynamic behavior of a space telescope (James Webb Telescope)**
- **To prepare the U.S. future workforce, train students to a NASA research development environment to prepare them for a future employment, and motivate them towards graduate studies**

INVESTIGATORS

Dr. Helen Ryaciotaki-Boussalis
Center Director Responsible for
Control Systems

Dr. Pol Spanos
Chair of Technical Advisory Board

Dr. Chivey Wu
Assistant Director
Responsible for UAV

Dr. Darrell Guillaume
Assistant Director Responsible for
Propulsion Systems

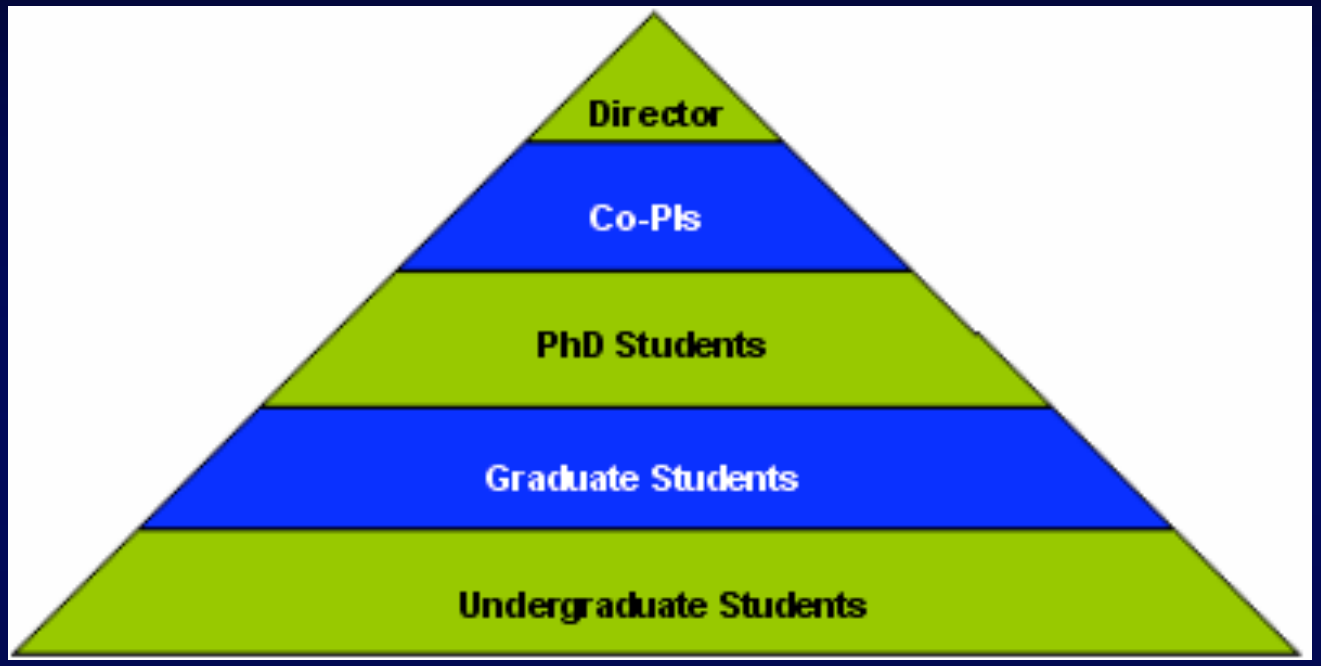
Dr. Charles Liu
Assistant Director
Responsible for Embedded Systems

Dr. Trinh Pham
Co-Investigator

Dr. Derek Dunn-Rankin
Faculty Advisor

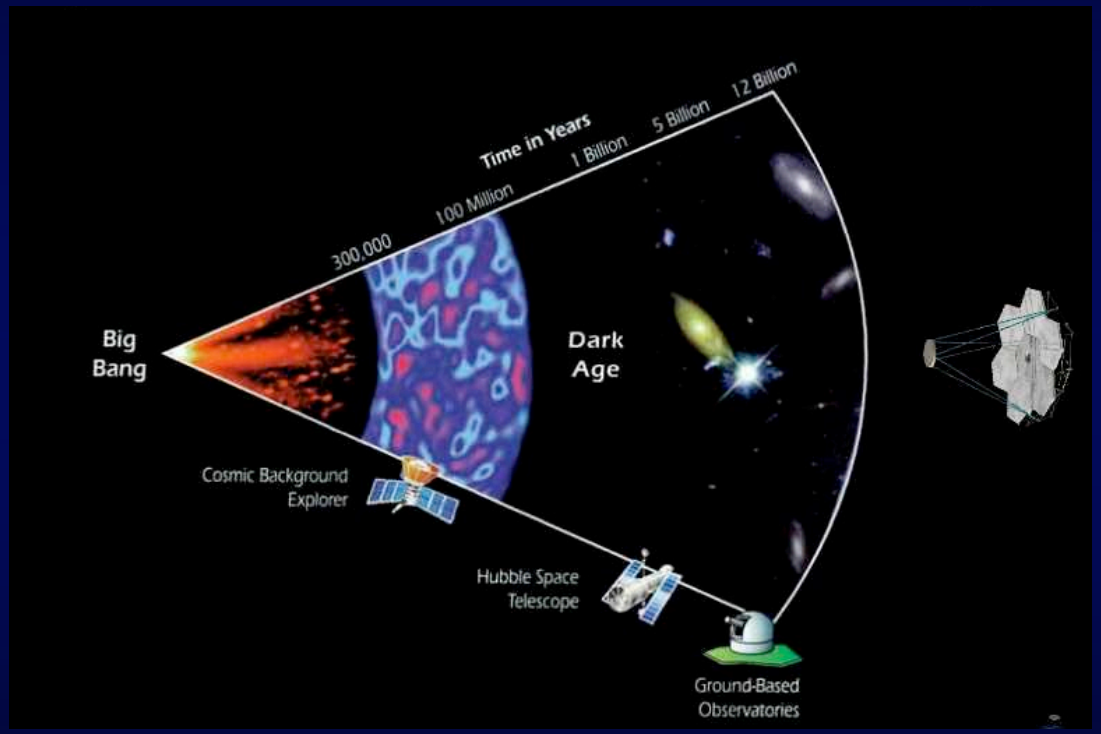
Dr. Kenneth D. Mease
Faculty Advisor

MANAGEMENT STRUCTURE



Pyramid Structure of Training

NEXT GENERATION SPACE TELESCOPE (NGST)



- Understand the Universe.
- Explain galaxy evolution
- Understand the birth and formation of stars
- Determine how planetary systems form and interact.
- Determine how the Universe built up its present chemical/elemental composition.
- Probe the nature and abundance of Dark Matter

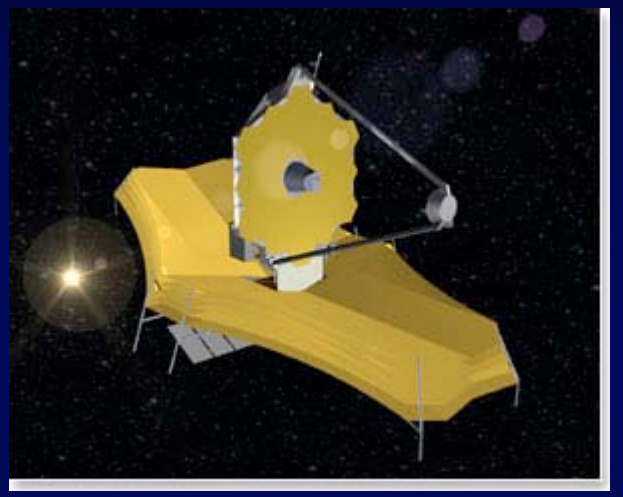
NEED FOR SEGMENTED REFLECTOR

- Travel to Space with Space Shuttle
- Manufacturing Limitations

Credit: Northrop Grumman Space Technology

JAMES WEB SPACE TELESCOPE

- JWST will reside in an L2 orbit, about 1.5 million km (1 million miles) from the Earth.
- Mission Duration: 5 - 10 years
- JWST is projected to cost one-fourth to one-third the cost of Hubble
- Total payload mass: Approx 6200 kg, including observatory, on-orbit consumables and launch vehicle adaptor
- JWST will have a large mirror, 6.5 meters (20 feet) in diameter
- Expected to be launched in 2013
- Northrop Grumman is building the actual telescope



SPACE TESTBED

- In 1994, the NASA Institutional Research Award (IRA) program established the SPACE Laboratory at CSULA for the design and fabrication/assembly of a testbed resembling the complex dynamic behavior of a space segmented reflector telescope ($5.3 million)
- Effective 2003, the SPACE Laboratory is part of a NASA University Research Center ($6 million)
- $5 million have been allocated by NASA to support the research activities at the SPACE Center until February 2013

Testbed Control Requirements

Testbed

- Design and fabricate a testbed that emulates a Cassegrain telescope with performance comparable to an actual space-borne system (James Webb Space Telescope)

Figure Control

- Hold to within 1 micron RMS

Pointing Control

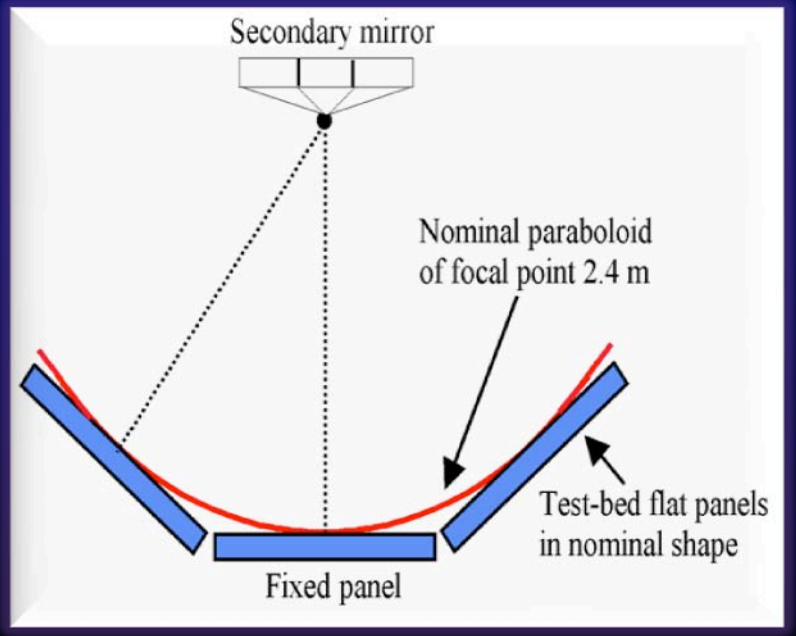
- Accuracy of 2 arc second

Vibration Suppression

- 100:1

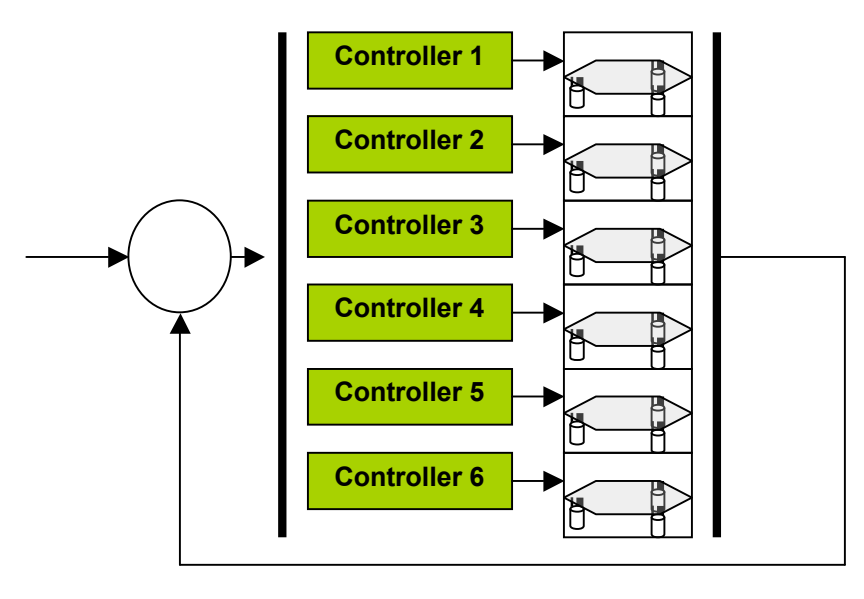
Control Bandwidth

- 30HZ



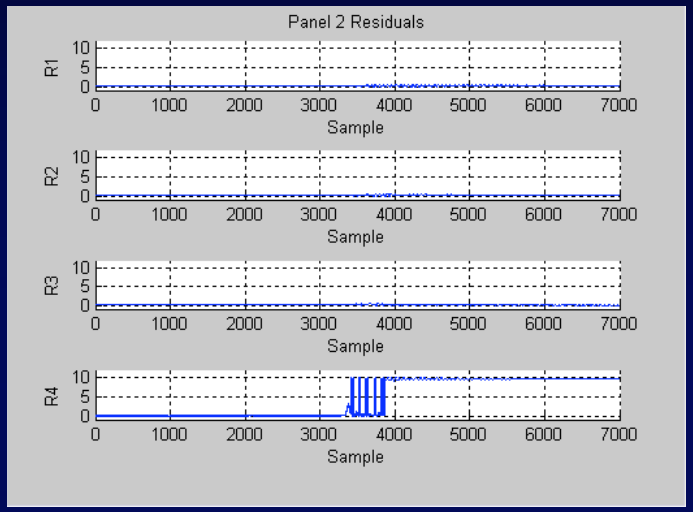
Decentralized Control

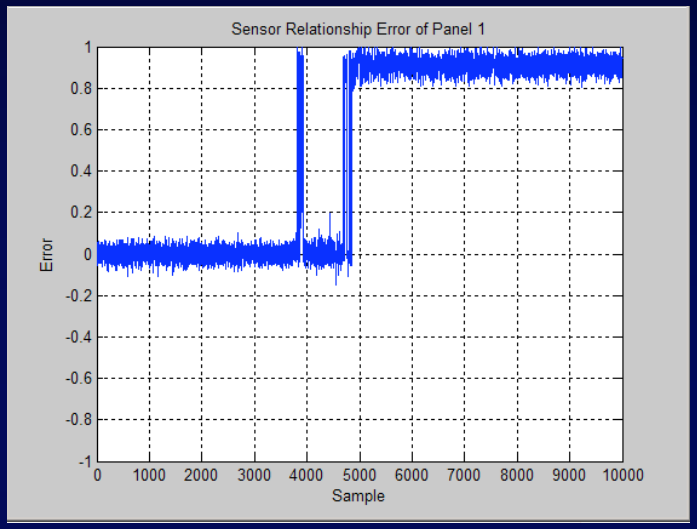
- Symmetry in the system
- Weak interconnections
- Physical Decentralization
  - 6 subsystems
- Mathematical Decentralization
  - 3 subsystems
- Developed PID, Adaptive, H-Infinity Controllers

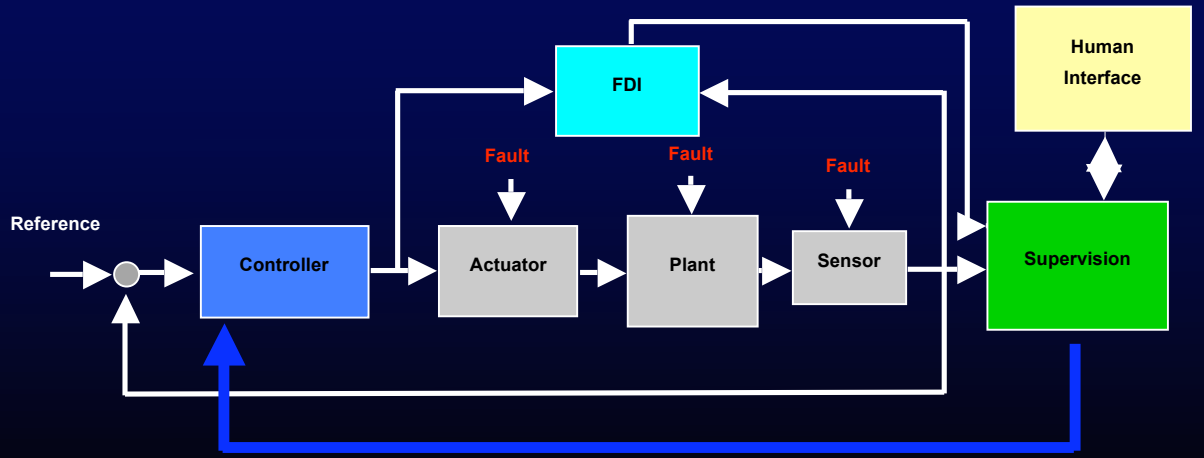


Reconfigurable Control

- Actuator and sensor fault detection and isolation

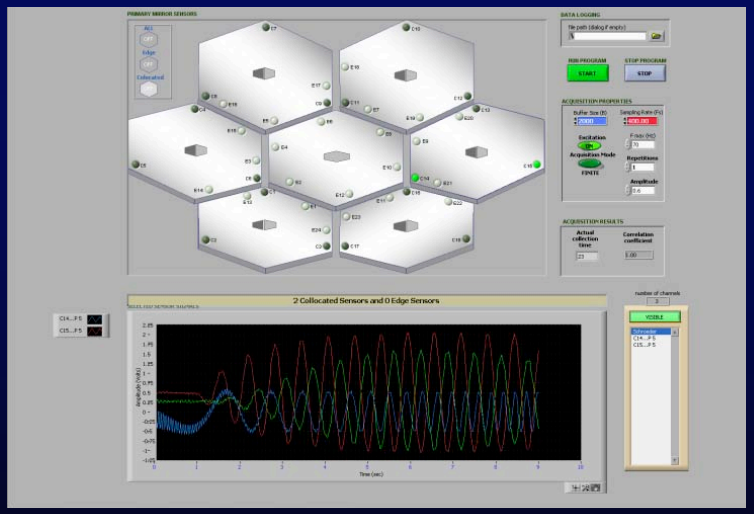


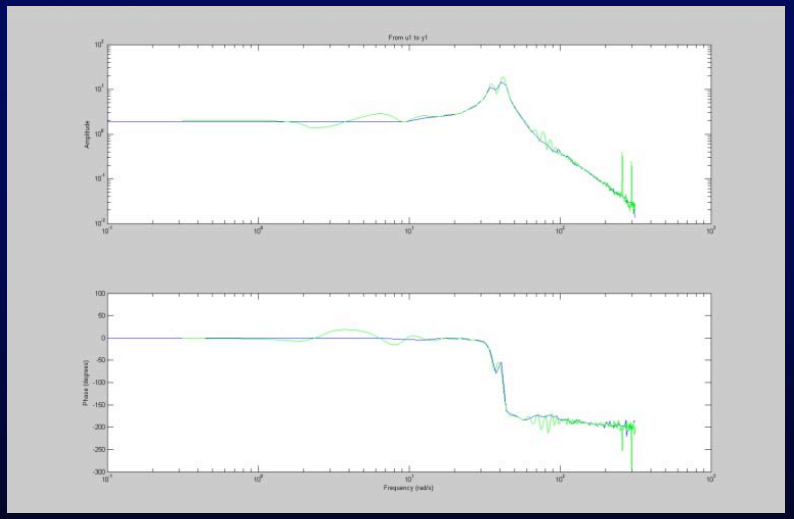




System Identification

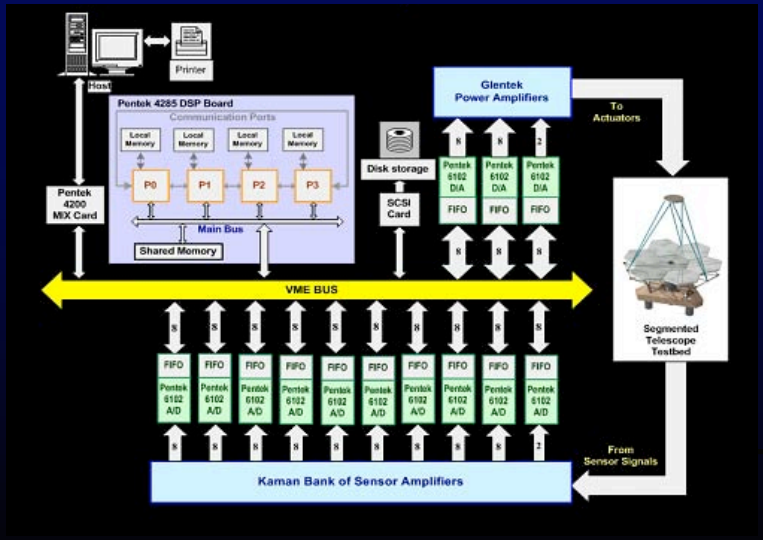
- **Objective**
  - Validate the mathematical model derived from finite element analysis using experimental data and frequency domain system identification techniques
- **Results**
  - Developed and implemented LabVIEW interfaces for real-time data collection, signal generation, and signal analysis.
  - Developed MATLAB algorithms for preprocessing and analysis of experimental data.

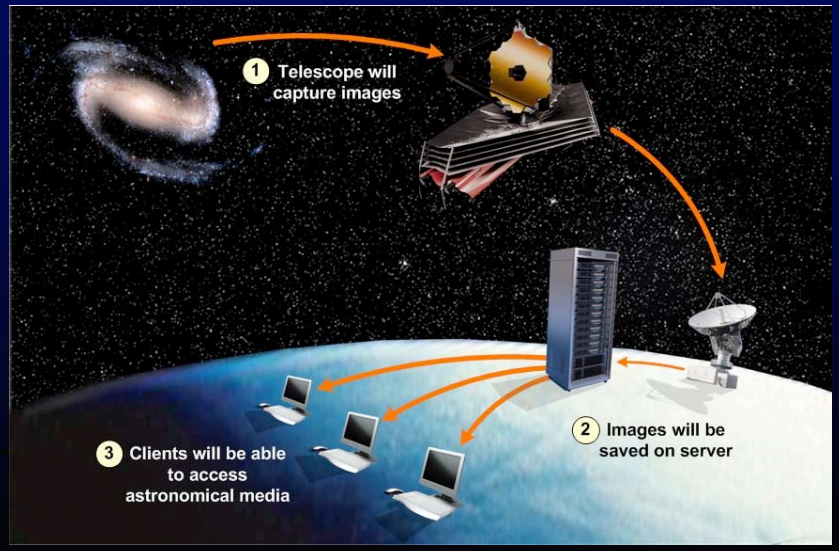




Computer Systems

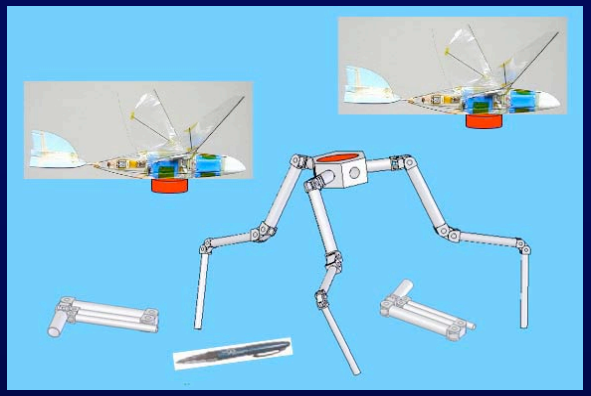
- **Objective: To develop and implement an Aerospace Information Server to:**
  - Collect, manage, and disseminate aerospace information
  - Allow collected media to be available to the aerospace community and the general public
- **Results:**
  - Completion of component Integration
  - Conducting system performance analysis and optimization
- **NASA Relevance:**
  - Adheres to NASA's mission to encourage space exploration and research through education



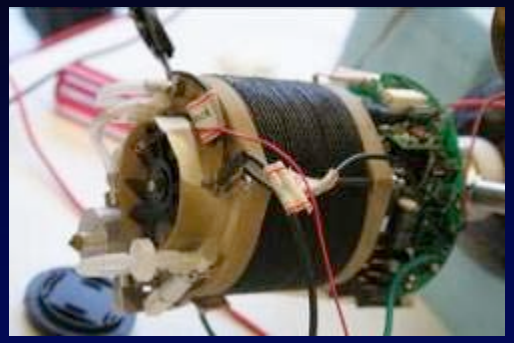


UAV DEVELOPMENT

- **Objectives**
  - Design and build unusual/innovative unmanned aerial vehicles (UAVs)
  - Develop a technology foundation which:
    - Enable the application of electric and fuel cell powered propulsion
    - Develop technologies and know how for design and fabrication of ultra light-weight airframe
  - Investigate feasible transition for commercial product development
- **Results: Successful flight of the fuel cell UAV on August 26, 2006**
- **NASA and DoD Relevance:**



Fuel Cell Powered UAVs



1st Fuel Cell System

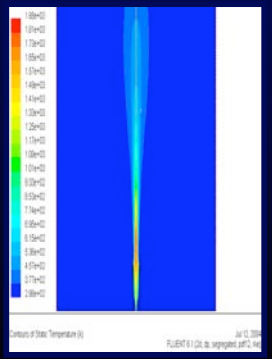
- **Power :** **460 to 670 Watts**
- **Type:** **PEM**
- **Weight:** **10 lbs (4.54 kg)**
- **Metal Hydride Tank**
  - Weight 6.85 lbs (3.1 kg)

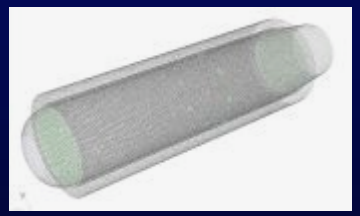
2st Fuel Cell System

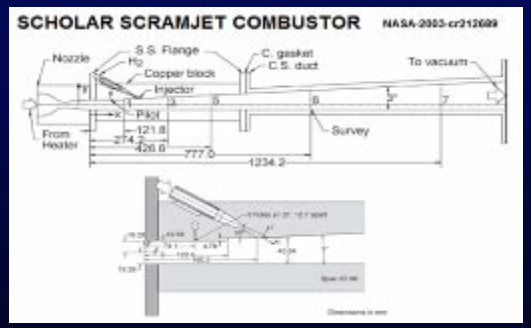
- **Power** **150 Watts**
- **Type** **PEM**
- **Storage Tank**
  Carbon Fiber Wrapped with Aluminum Lining

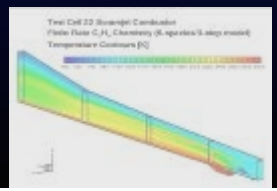
COMBUSTION / PROPULSION

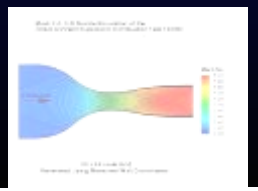
- **Objectives**
  - Develop analytic, numerical, and simulation models for combustion processes; test and validate
  - Develop methods for combustion processes optimization
  - Develop ramjet / scramjet, multi-cycle propulsion system models models
  - Validate multi-physics software such as Fluent
- **Results**
  - A 2-D model of a simple combustor simulation model
  - A 3-D combustor simulation and physical model
  - A swirled air combustion chamber simulation and physical model
  - A supersonic combustion chamber simulation model
  - Model validation tests
- **NASA Relevance: Reducing NOX & CO2 emissions of future aircraft, Renewed interest in airbreathing hypersonic vehicles for inexpensive access to space**







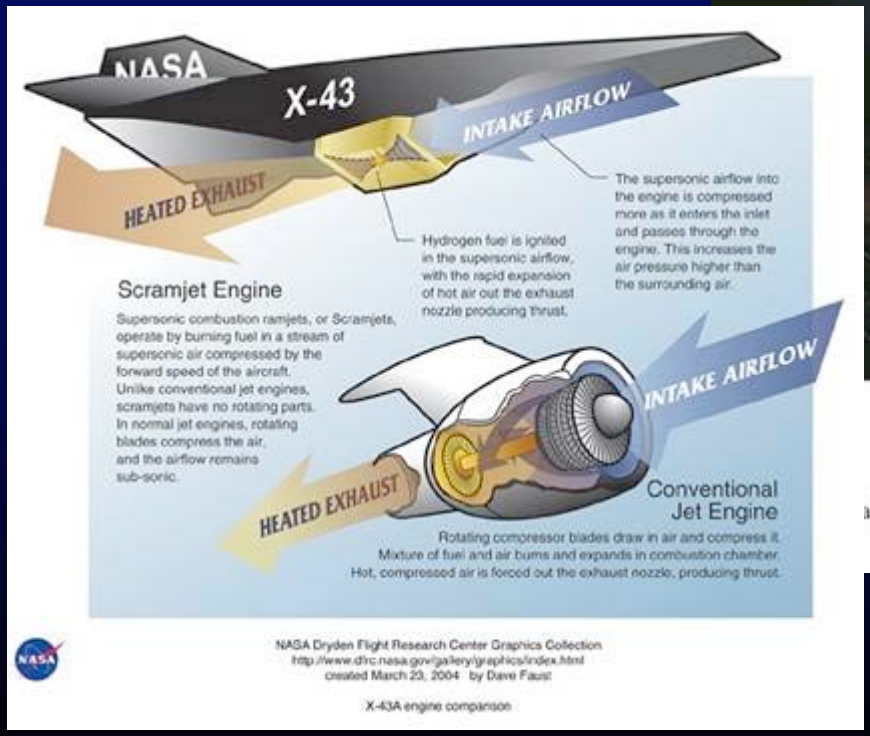




Combustion and Propulsion

NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/Gallery/Photo/index.html
NASA Photo: ED04-0082-2

ach 7 wind tunnel test of the full-scale X-43A model with spare flight engine in Langley's 8-Foot High Temperature Tunnel.



NASA Dryden Flight Research Center Graphics Collection
http://www.dfrc.nasa.gov/gallery/graphics/index.html
created March 23, 2004 by Dave Faust

X-43A engine comparison

INTELLIGENT FLIGHT CONTROL

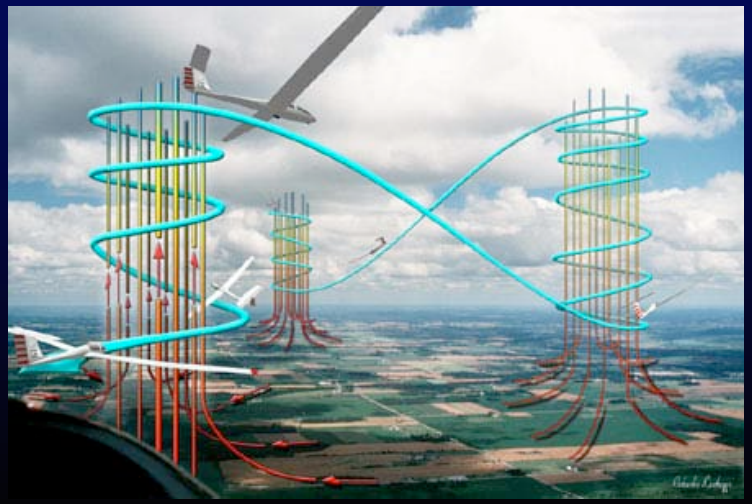
Objectives

- Design, analyze, and test intelligent flight control systems for the next generation of atmospheric and space access flight vehicles such as high-performance fighter planes, reusable launch vehicles, single stage-to-orbit vehicles, reentry vehicles, airbreathing hypersonic vehicles, UAVs
  - An onboard failure identification scheme Measures/identifies, isolate failure
  - An adaptive inner loop maintains attitude stability, reestablish guidance command following performance to the extent possible
  - An adaptive guidance system recognizes the inner-loop performance degradation, maintains flight path stability, and recovers the trajectory command following performance
  - An onboard algorithm modifies mission/retarget trajectory – optimum-path-to-go, maximizes chance of survival

Results

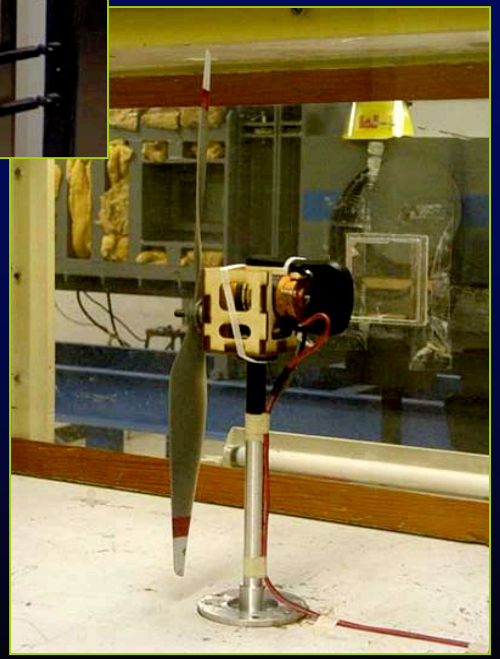
- Adaptive sliding mode, adaptive linear quadratic control for hypersonic flight, adaptive fault tolerant LQR with trajectory optimization for F-16, adaptive LQR for UAV thermal soaring

NASA Relevance: Gen I, Gen II, and Gen III, IFCS F-15, C-17; UAVs and UCAVs, RLVs

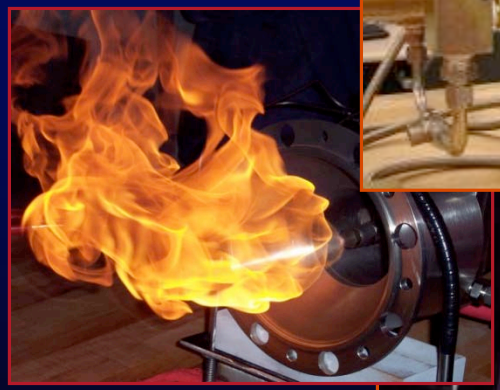


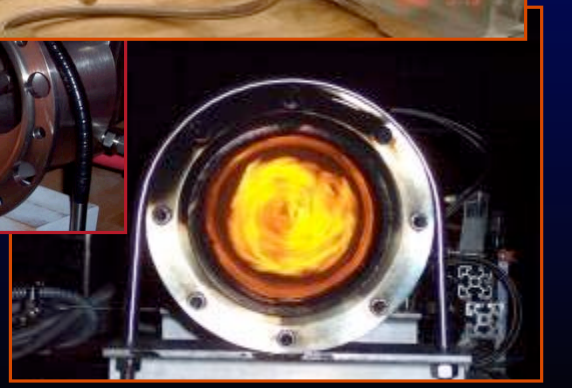
TESTING & VALIDATION
(2 SUBSONIC + 1 SUPERSONIC WIND TUNNELS)

Wind Tunnel Test



Physical Combustor and Test





RECRUITMENT OF STUDENT RESEARCH ASSISTANTS

❑ Developing Enrollment Prospects

- Faculty recommendations
- Department chairs advising structure
- SPACE students contacts
- Through the SPACE website

RECRUITMENT OF STUDENT RESEARCH ASSISTANTS

- **Developing Enrollment Prospects**
  - SPACE students visit community colleges
  - Collaborate with the MEP and MESA programs at CSULA
  - Advertise openings to other student organizations (IEEE, TBP, HKN, SWE…)

RECRUITMENT OF STUDENT RESEARCH ASSISTANTS

❑ Selection Process

- Recommendation letters are submitted to the center director
- Student's academic standing

RECRUITMENT OF STUDENT RESEARCH ASSISTANTS

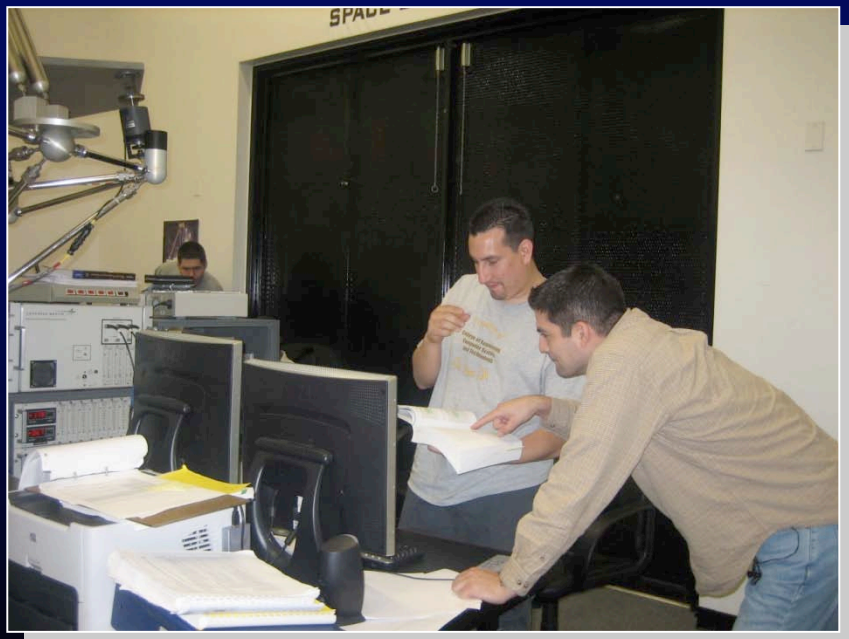
Selection Process

- Meeting with the faculty who does research in the area of interest
- An interview with the faculty and the SPACE center director

RETENTION OF STUDENTS

Work in groups

Have a mentor for every incoming student



RETENTION OF STUDENTS

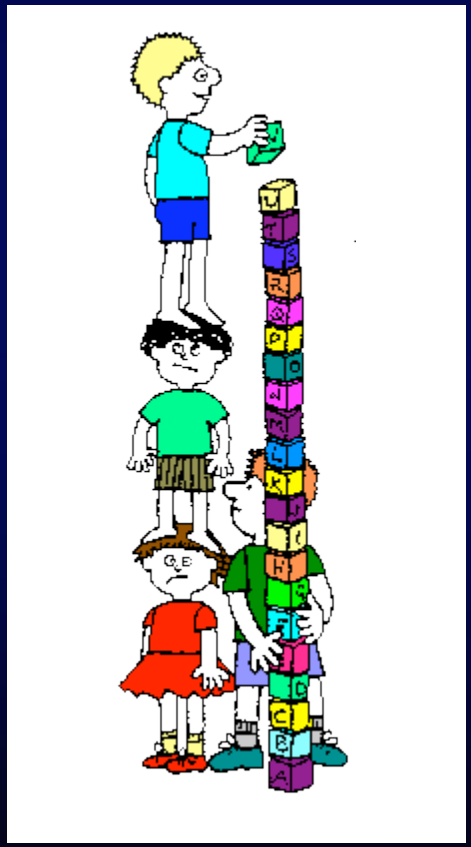
Have a student council for professional and social activities

RETENTION OF STUDENTS

Assign students to the faculty related to the subject of their expertise/interest

RESPONSIBILITIES OF STUDENTS

Perform Research



Work close with the faculty

RESPONSIBILITIES OF STUDENTS

- Report via email every Wednesday on the progress of their research
- Give formal presentation every week during the project status meeting

RESPONSIBILITIES OF STUDENTS

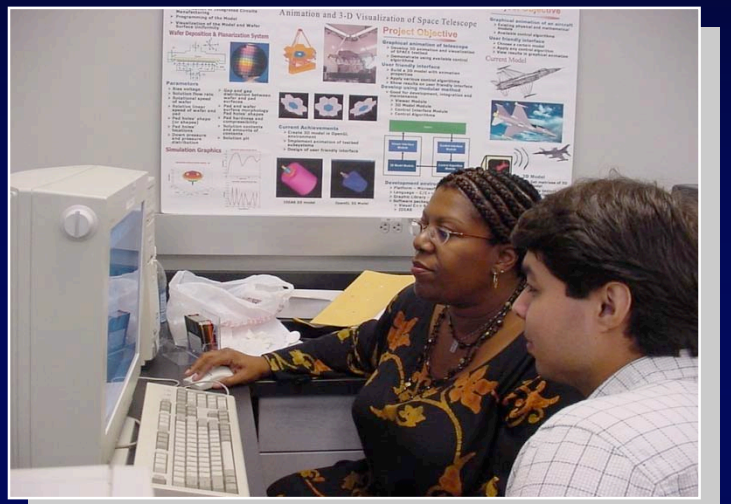
- Participate in the preparation of reports to be submitted to NASA
- Present the performed research during the NASA project review visit
- Present during the Industry Advisory Board meeting

RESPONSIBILITIES OF STUDENTS

- Participate in technical paper preparation
- Present papers during conferences
- Participate in educational exhibitions and meetings

RESPONSIBILITIES OF STUDENTS

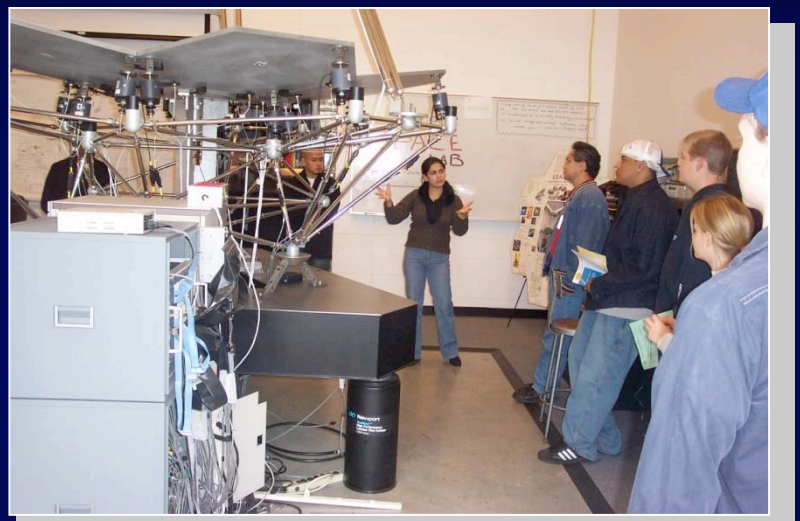
- Work close with high school and community college teachers who are sponsored by NASA



- Train high school/community college teachers and students

RESPONSIBILITIES OF STUDENTS

- Train newcomers
- Participate in all university and college open houses



RESPONSIBILITIES OF STUDENTS

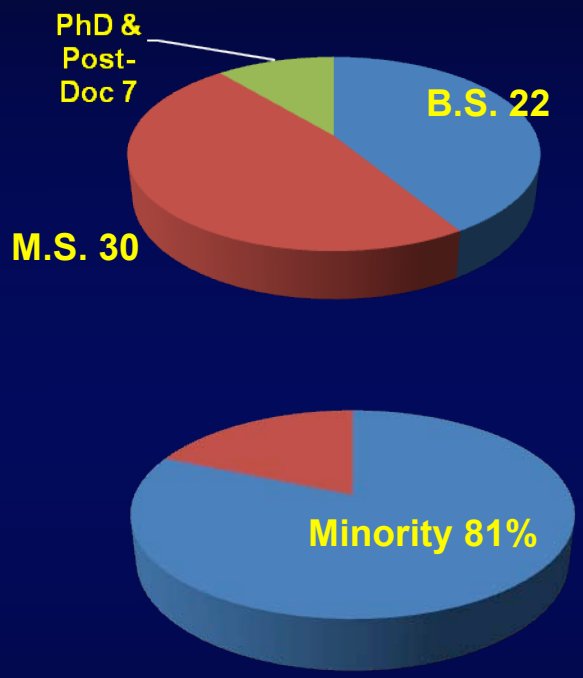
Work well with everybody in the Center; be part of the “SPACE family”

IMPACT ON CURRICULUM

- **Curriculum Development**
  - Senior Design Projects
  - Master Theses
  - Ph.D. Dissertations

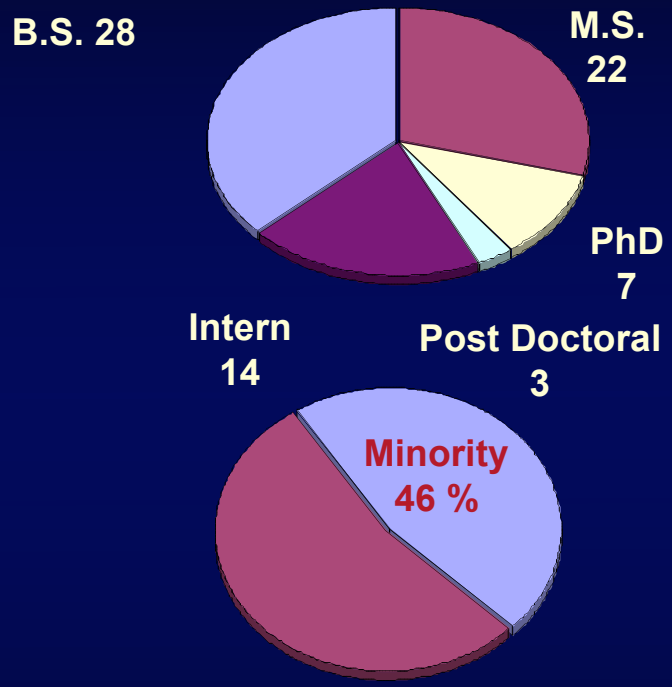
STUDENT DATA

- **Students Supported by SPACE Lab (2003-2008): 59**



- **Currently supporting 12 Research Assistants**
  - 6 Undergraduate, CSULA
  - 6 Graduate, CSULA
  - 9 Minority, Female

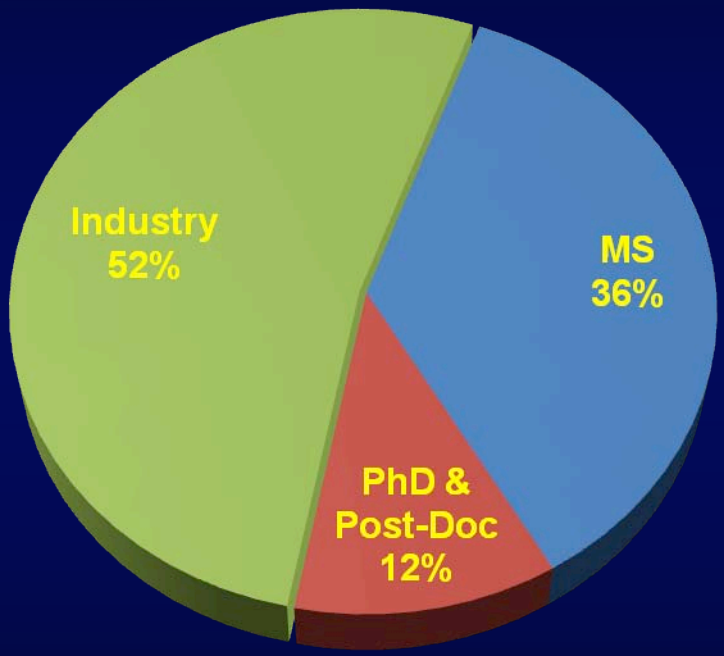
- **Students Supported by MFDC Lab (2003-2008): 42**



- **Currently supporting 13 Research Assistants**
  - 8 Undergraduate, CSULA
  - 3 Graduate, CSULA
  - 3 PhD Candidates, USC
  - 6 Minority, Female

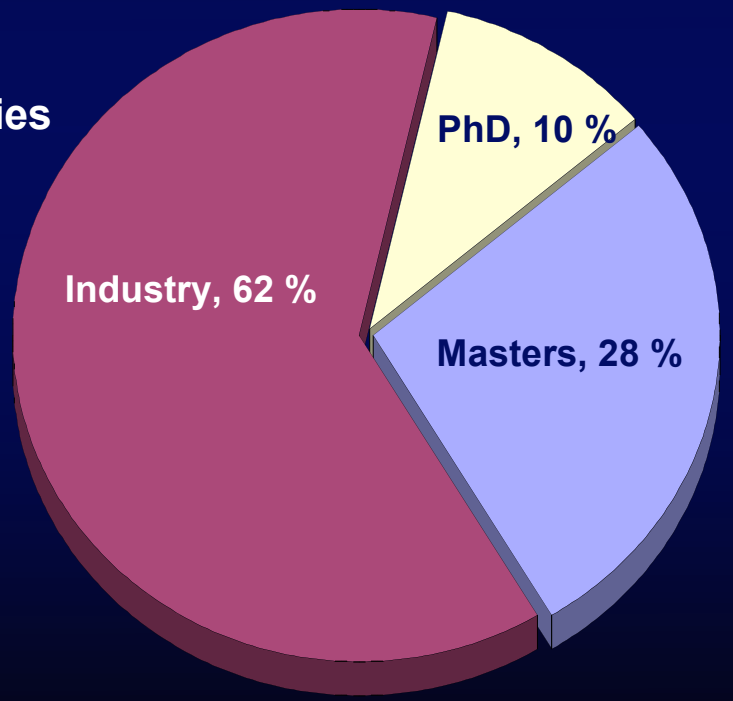
POST GRADUATE DATA (2003-2008)

- **21 undergraduate members have entered Master program at CSULA**
- **3 graduates have entered a PhD Program**
  - University of Idaho
  - Claremont Graduate University
  - Johns Hopkins University
- **32 graduates have found employment in industry**
  - NASA Dryden
  - Northrop Grumman
  - Boeing Company
  - Bechtel
  - Southern California Edison
  - DWP
  - Honeywell



POST GRADUATE DATA (2003-2008)

- **8 Undergraduate Members have entered Master program at CSULA and USC**
- **4 Graduates have entered a PhD Program**
  - University of Southern California
  - University of California, Riverside
  - University of Kansas
- **18 Graduates have found employment at industries**
  - NASA Langley
  - Boeing Company
  - Lockheed Martin



PUBLICATIONS

1. [I.1.1] USC Student Research Conference, "Pointing Control of Segmented Reflector Testbed." Alex Khoshafian, Los Angeles, CA March 26,2004
2. [I.1.2] USC Student Research Conference, "Frequency-Domain System Identification of aLarge Segmented Space Reflector." Efain Velazquez Los Angeles, CA March 26,2004
3. [I.1.3] USC Student Research Conference "Fault-tolerant Parallel Processing for the SPACETestbed." Salvador Fallorina Los Angeles, CA March 26,2004
4. [I.1.4] 5th Ukranian Conference on Design and Construction in Seismic Areas, —SeismicPerformance, Control, and Protection of Reinforced Concrete Structures.‖ A.Chassiakos, E. Kosmatopoulos, V. Levtehitch, Yalta, Crimea, Ukraine, May 24-29,2004
5. [I.1.5] Fidan, B., Mirmirani, M. D., and Ioannou, P. A.,"Air-breathing hypersonic flightcontrol." submitted to 16th IFAC Symposium on Automatic Control in Aerospace, June2004.
6. [I.1.6] International Multiconference in Computer Science and Computer Engineering,"Integrated 3-D Animation System for Decentralized Controlled Space Telescope Testbed"Dr. Jane Dong Las Vegas, NV June 21-24, 2004
7. [I.1.7] iNEER Conference for Engineering Education and Research (iCEER 2004) "TITLE"Dr. Charles Liu Czech Republic June 27-30, 2004
8. [I.1.8] Fidan, B., Mirmirani, M. D., and Ioannou, P. A.,"Air-breathing hypersonic flightcontrol." submitted to 16th IFAC Symposium on Automatic Control in Aerospace, June2004.
9. [I.1.9] IEEE International Midwest Symposium on Circuits and Systems, —DecentralizedControl of a Segmented Reflector Testbed.‖ A. Khoshafian, H. Boussalis, S. Fallorina,E. Velazquez, K. Rad, C. Liu, D. Cantzos, Hiroshima, Japan, Jul 2004.

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SYNERGETIC ACTIVITIES

- **Collaboration**

Industry and NASA Research Centers

- NASA Dryden Research Center
- Jet Propulsion Laboratory
- NASA Ames Research Center
- Northrop Grumman Corporation
- Boeing Company
- Bechtel Corporation
- Southern California Edison

Universities

- University of California Irvine (UCI)
- Claremont Graduate University (CGU)
- Rice University

CHALLENGES FOR ENHANCED RESEARCH INTERACTION BETWEEN DOCTORATE GRANTING UNIVERSITIES (DGU) AND MINORITY SERVING UNIVERSITIES (MSI)

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Challenges

- The administration of Minority Serving Universities (MSI's) must provide a robust infrastructure for supporting research activities within their domain, and to facilitate the procurement of subcontracts to Doctorate Granting Universities (DGU'S); issues such as cascade of overhead charges must be addressed.

- Every effort should be made to ensure that the teaching loads of faculty members at MSI's do not become prohibitive for undertaking appealing and rewarding research projects. The existing scheme of additional compensation to the faculty is helpful, but additional steps can perhaps be taken.

Challenges

- Creative approaches must be introduced to convince the extremely-sought-after by the industry BS level minority students to continue towards a doctoral program. The real challenge, in this regard, would be to identify individuals who perhaps can pursue a program of alternating presence in an industrial company, and in a DGU campus.

- Caution should be exercised to ensure that the agency expectations do not set the threshold of success at the standards of exclusively-research-seeking funded programs, and simultaneously define significant levels of effort from the faculty of MSI faculty for diversity-supporting/enhancing activities.

QUESTIONS?

THANK YOU