Energy Efficient Cryogenics on Earth and in Space

Cryogenics Test Laboratory
NASA Kennedy Space Center

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KENNEDY SPACE CENTER

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ESC Engineering Services Contract
Partnering To Engineer the Future

NASA

Team QinetiQ North America

Objective

The Cryogenics Test Laboratory, NASA Kennedy Space Center, works to provide practical solutions to low-temperature problems while focusing on long-term technology targets for energy-efficient cryogenics on Earth and in space.

Space launch and exploration is an energy intensive endeavor; cryogenics is an energy intensive discipline.

Technology Focus Areas

KSC:

- ✓ Storage, Distribution, and Conservation of Fluids
- ✓ Materials for Life Cycle Optimization

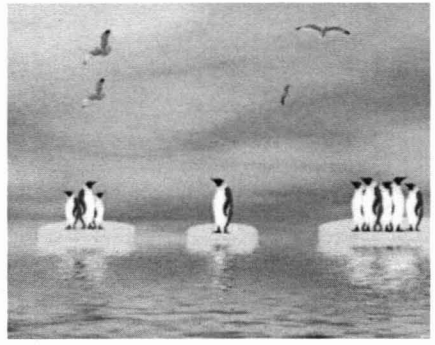
CryoTestLab:

- ✓ Thermal Management Systems
- ✓ Propellant Process Systems
- ✓ Advanced Materials & Components
- ✓ Low-Temperature Applications

Cryogenic engineering is about two things:
1) using low-temperatures to do something useful and
2) storing something in a small space (energy density).

Connections

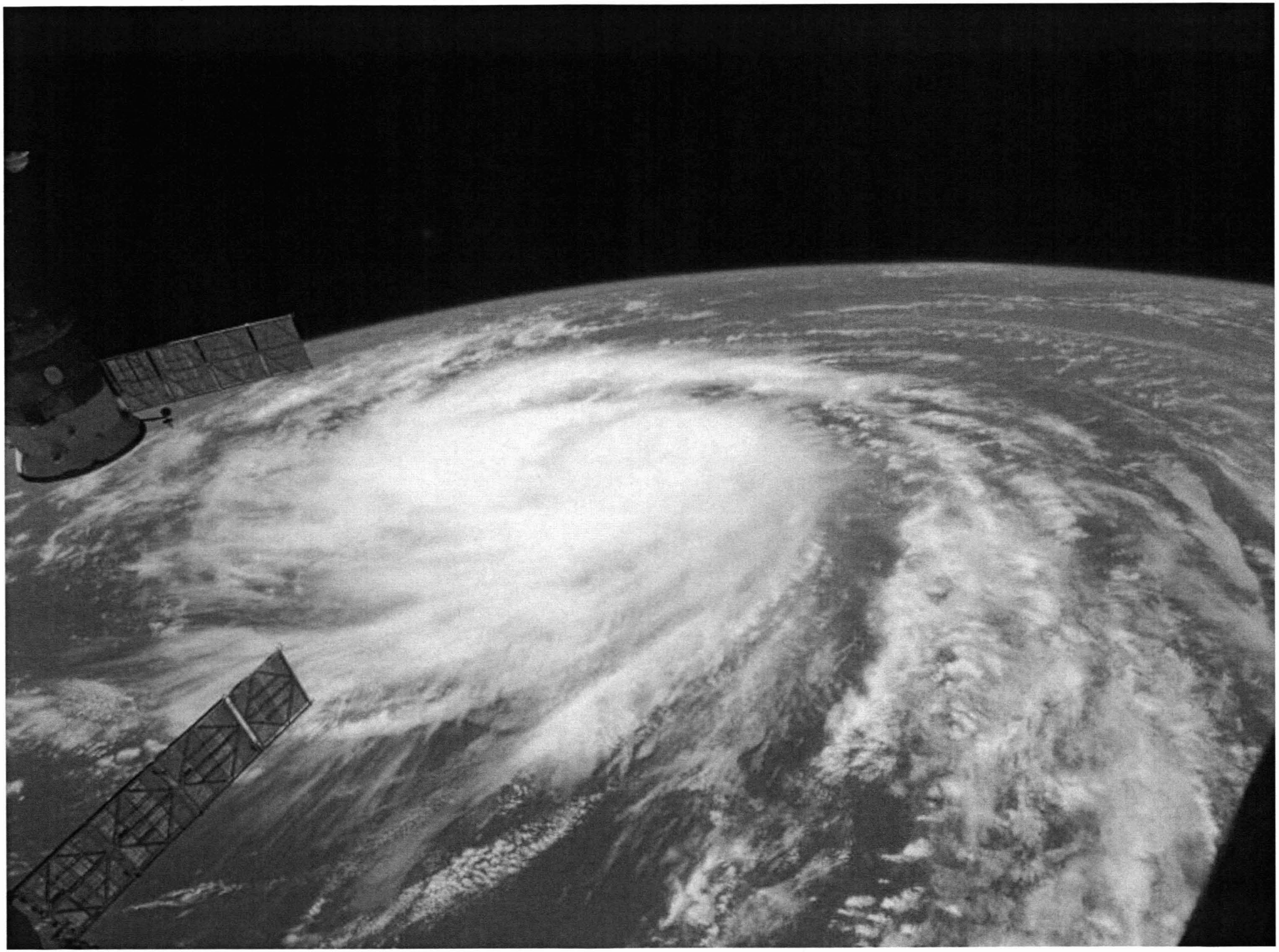
- ✓ Florida Academics: UCF, FTU, USF Poly, UF, FSU, and ERAU
- ✓ Federal Agencies: DoD, DoE, DHS
- ✓ National Institute of Standards (NIST): Boulder and Gaithersburg
- ✓ National Laboratories: Oak Ridge, Jefferson, Fermilab, Los Alamos, Livermore
- ✓ NASA Centers: MSFC, GRC, LaRC, GSFC, JSC, SSC, ARC, JPL, WSTF
- ✓ Industry Partners: Aerospace; General Industry; High Energy Physics
- ✓ Cryogenic Society of America (CSA)
- ✓ Cryogenic Engineering Conference (CEC) and International Cryogenics Materials Conference (ICMC)
- ✓ Space Cryogenics Workshop (SCW)
- ✓ International Cryogenic Engineering Conference (ICEC)
- ✓ International Institute of Refrigeration (IIR)
- ✓ American Institute of Aeronautics and Astronautics (AIAA)
- ✓ ASTM International (ASTM)

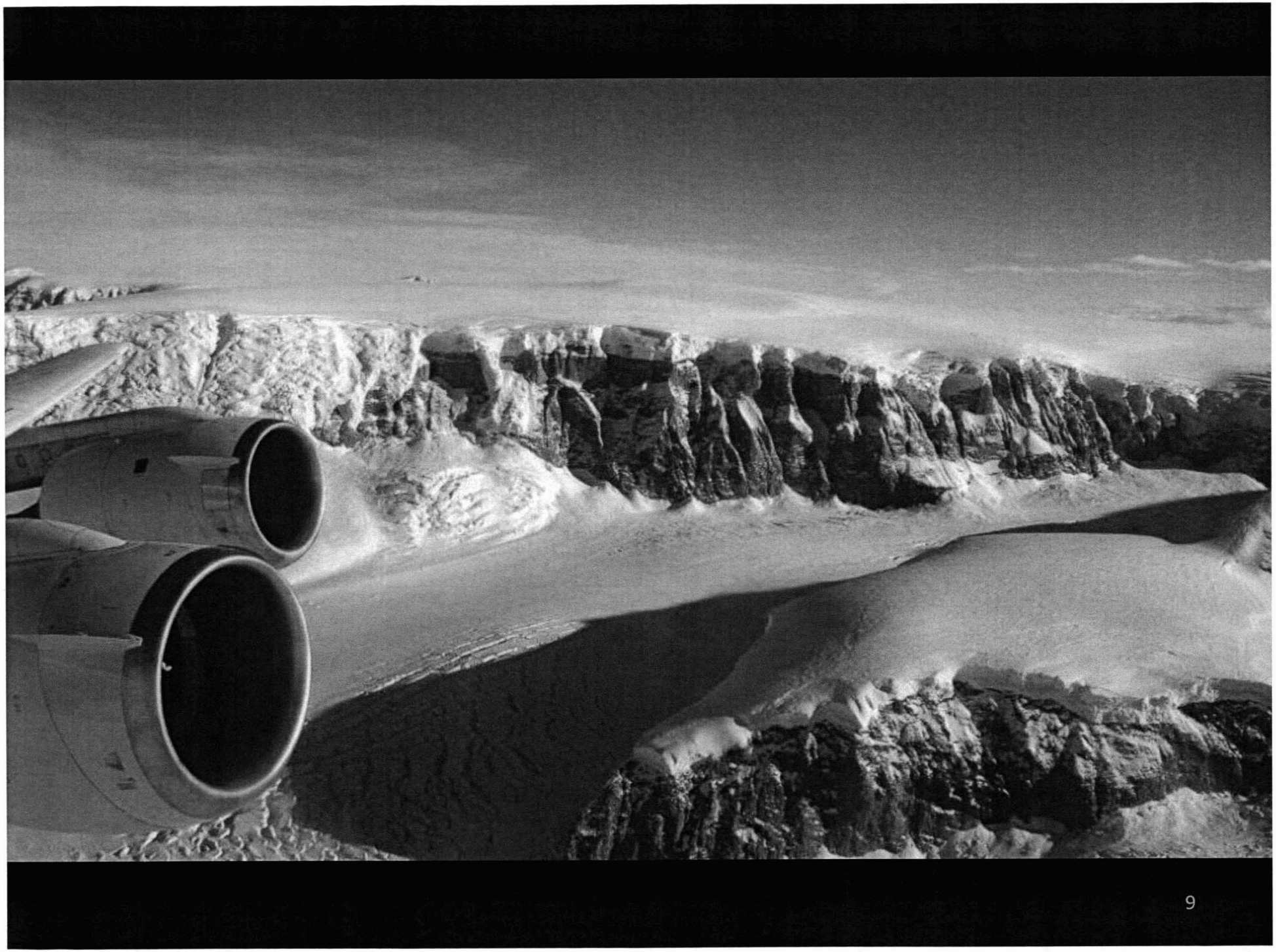


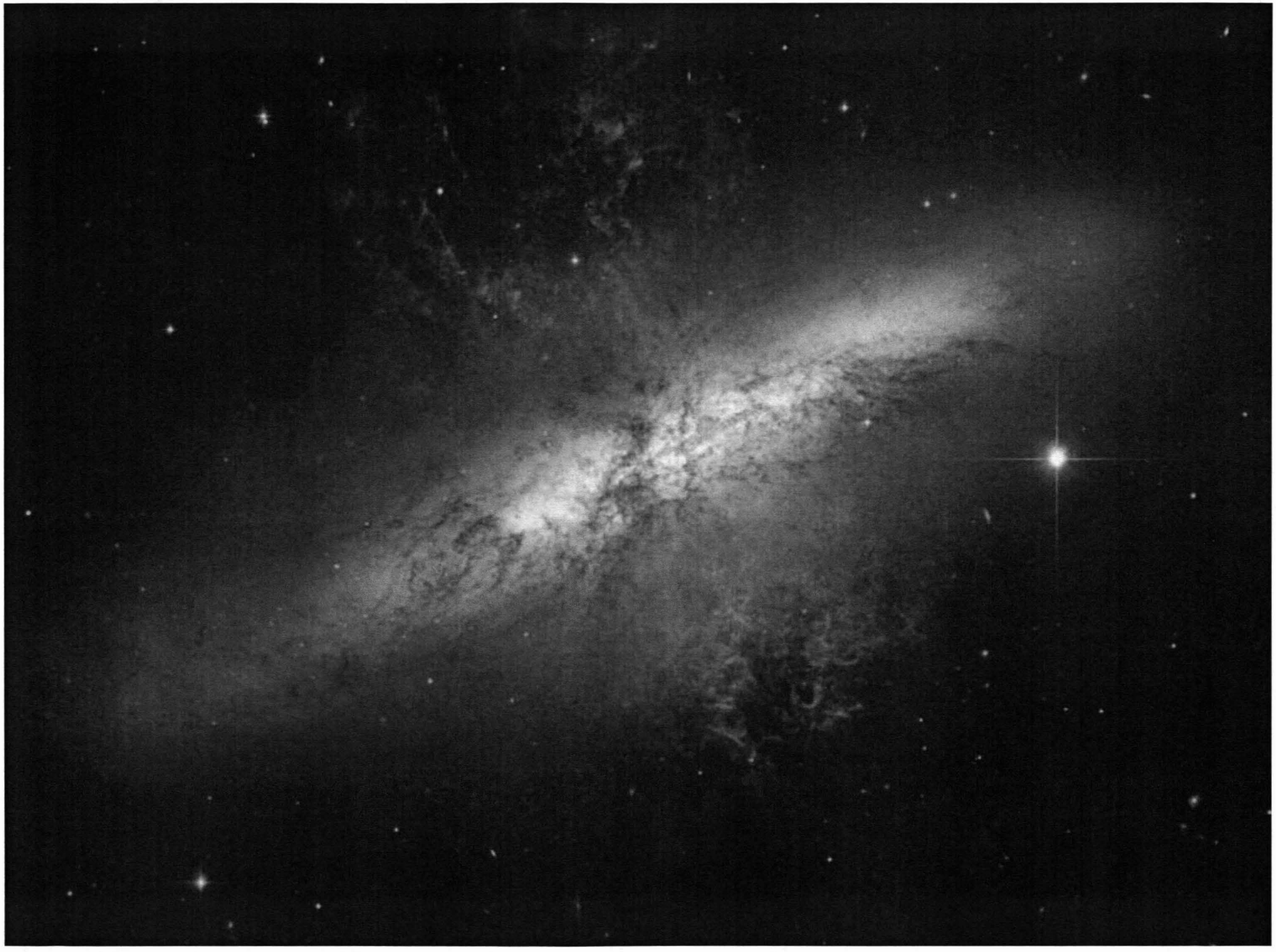
Success in cryogenics has always been defined as a healthy triangle of interaction among research, industry, and training.

Past Collaborations with UCF

- ✓ *Thermal switch using Shape Memory Alloys* – Vaidyanathan; Notardonato
- ✓ *Hydrogen liquefaction and zero boil-off storage* – Baik; Notardonato
- ✓ *Polyimide foam studies & hydrogen storage* – Hampton; Williams, Fesmire
- ✓ *Miniature recuperative heat exchanger* – Kapat, Chow; Notardonato
- ✓ *Cryocooler compressor development* – Kapat, Chow; Notardonato
- ✓ *Thermal insulation system modeling and analysis for liquid hydrogen storage* – Gu; Fesmire
- ✓ *Thermal performance of cryogenic multilayer insulation at various layer spacings* – Chow, Kapat, Kassab; Johnson
- ✓ *Experimental liquefaction and densification of liquid oxygen* – Chow, Kapat, Kassab; Partridge







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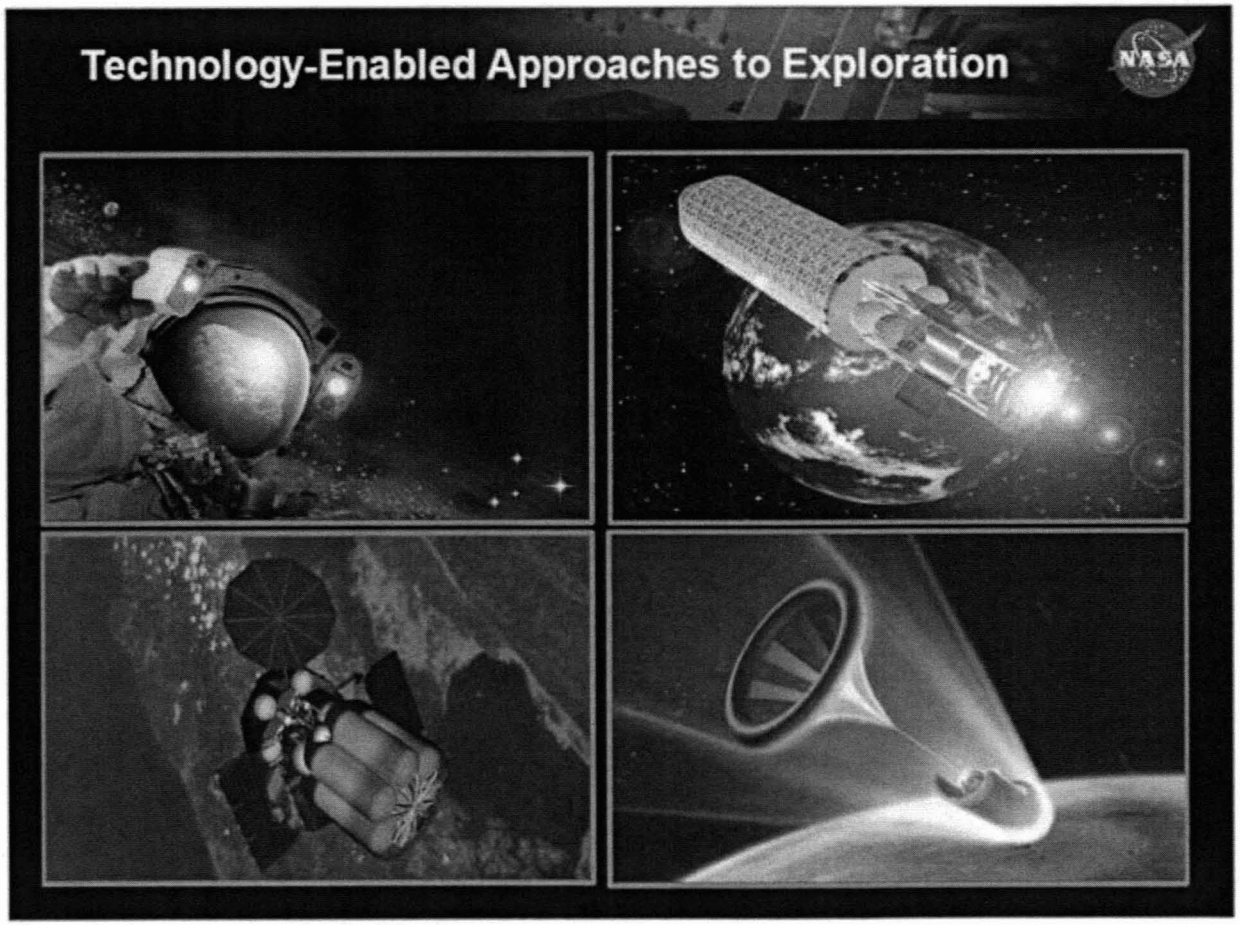


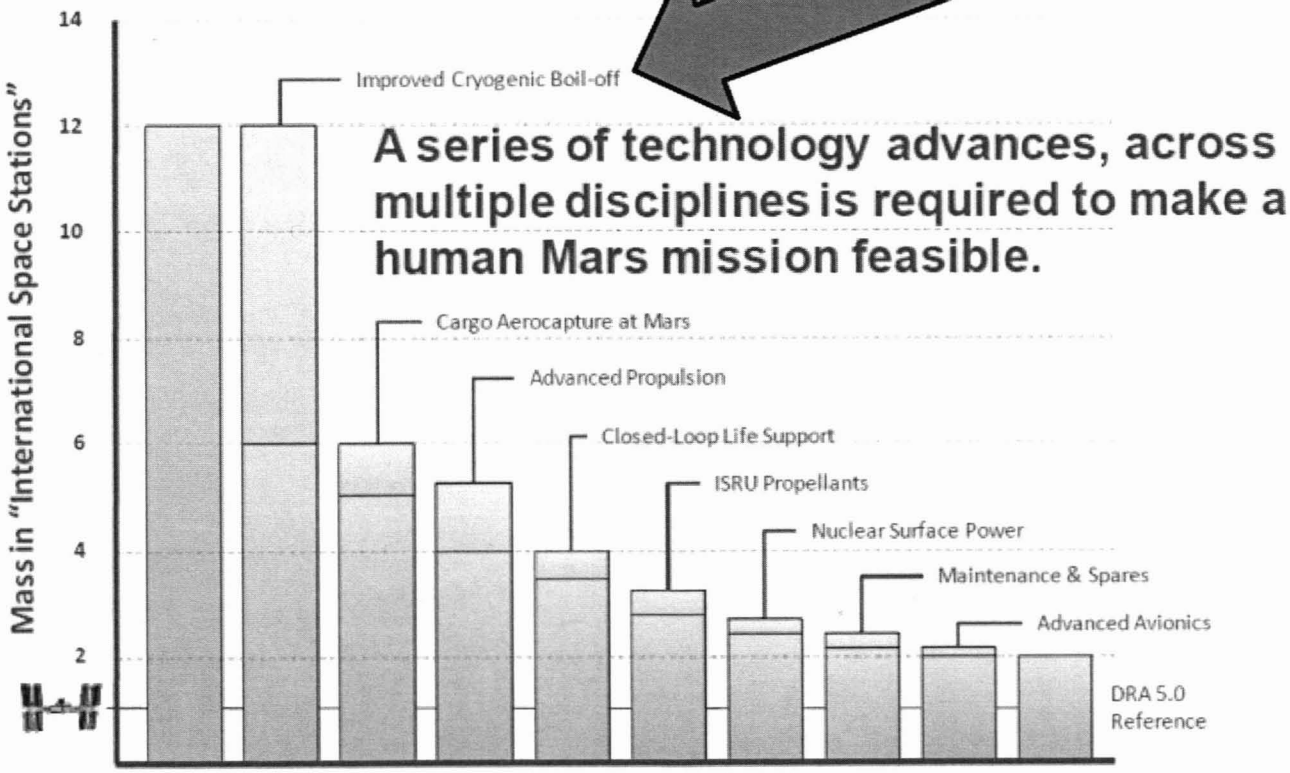
Cryogenics Enables:

- ✓Propulsion
- ✓Power
- ✓Life Support
- ✓Science
- ✓Manufacturing
- ✓Testing

Exploring Space Through Innovation & Technology, B. Braun, 5/25/2011
http://www.nasa.gov/offices/oct/home/index.html

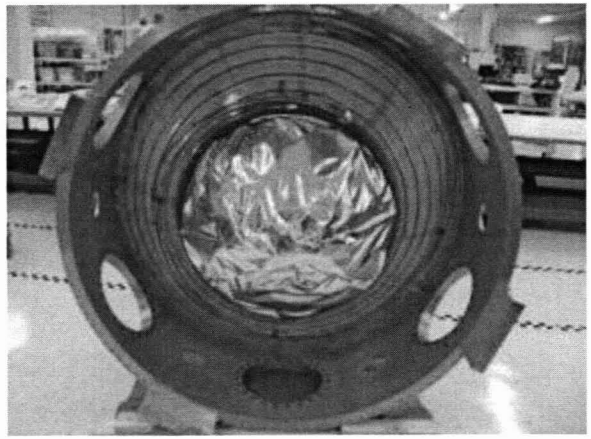
NASA OCT

The Impact of Technology Advancement

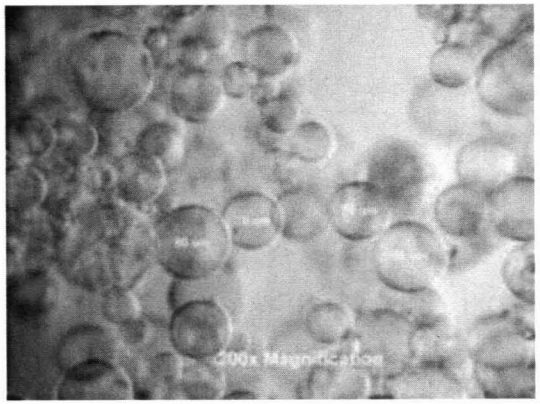


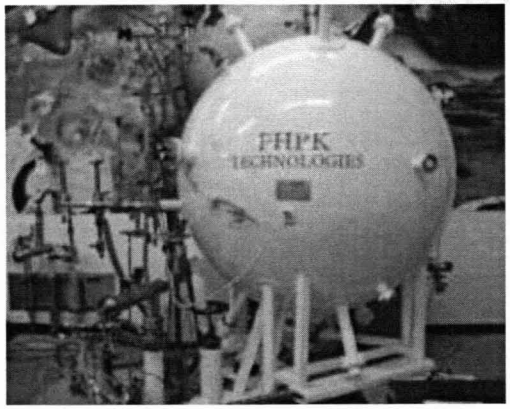
Mass-Efficient Storage & Transfer

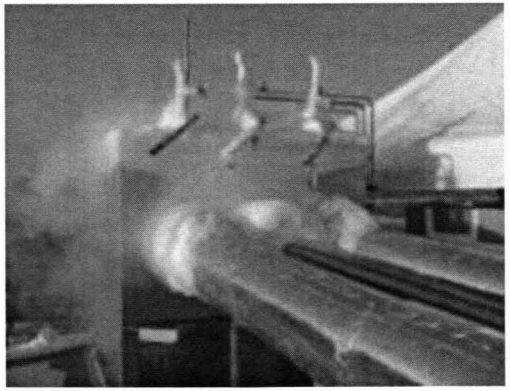
- ✓ Reduced Boil-off
  - Cryocoolers Integration
  - Structural Materials
  - Thermal Insulation Systems
- ✓ Zero-gravity Control
- ✓ Multilayer Insulation Systems
  - New materials characterization
  - Test methodologies
  - Thermal modeling and analysis
  - Micro-meteoroid Orbital Debris (MMOD) Shielding
  - Launch Pad Ground Hold Considerations
  - Launch Ascent Considerations

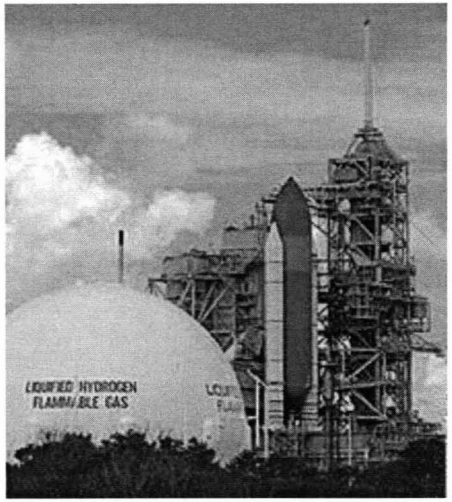


Cost-Efficient Storage & Transfer









Materials Research **Demonstration Testing** **System Studies**

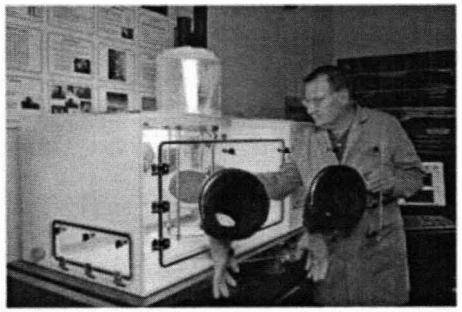
Global positive impact for energy efficiency and cost savings.

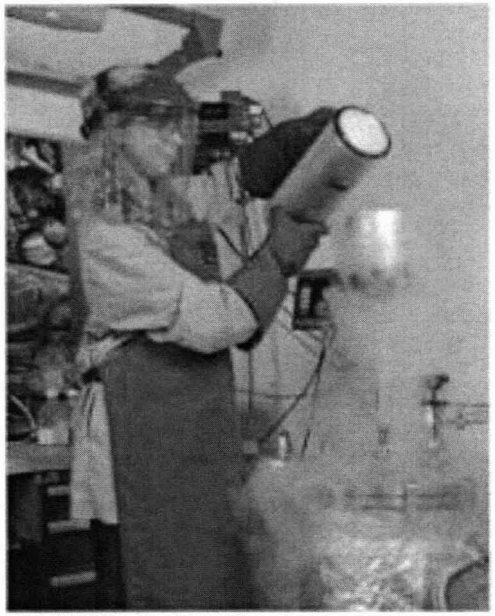
Novel Thermal Insulation Systems

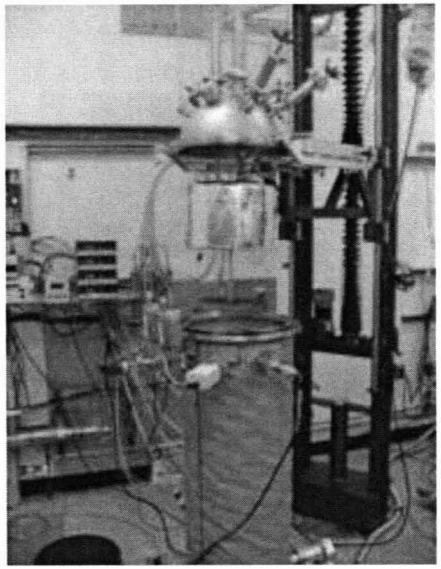
✓Materials
- Development of materials for engineered applications
- Pioneered aerogel blankets, AeroFoam, and AeroPlastic composites

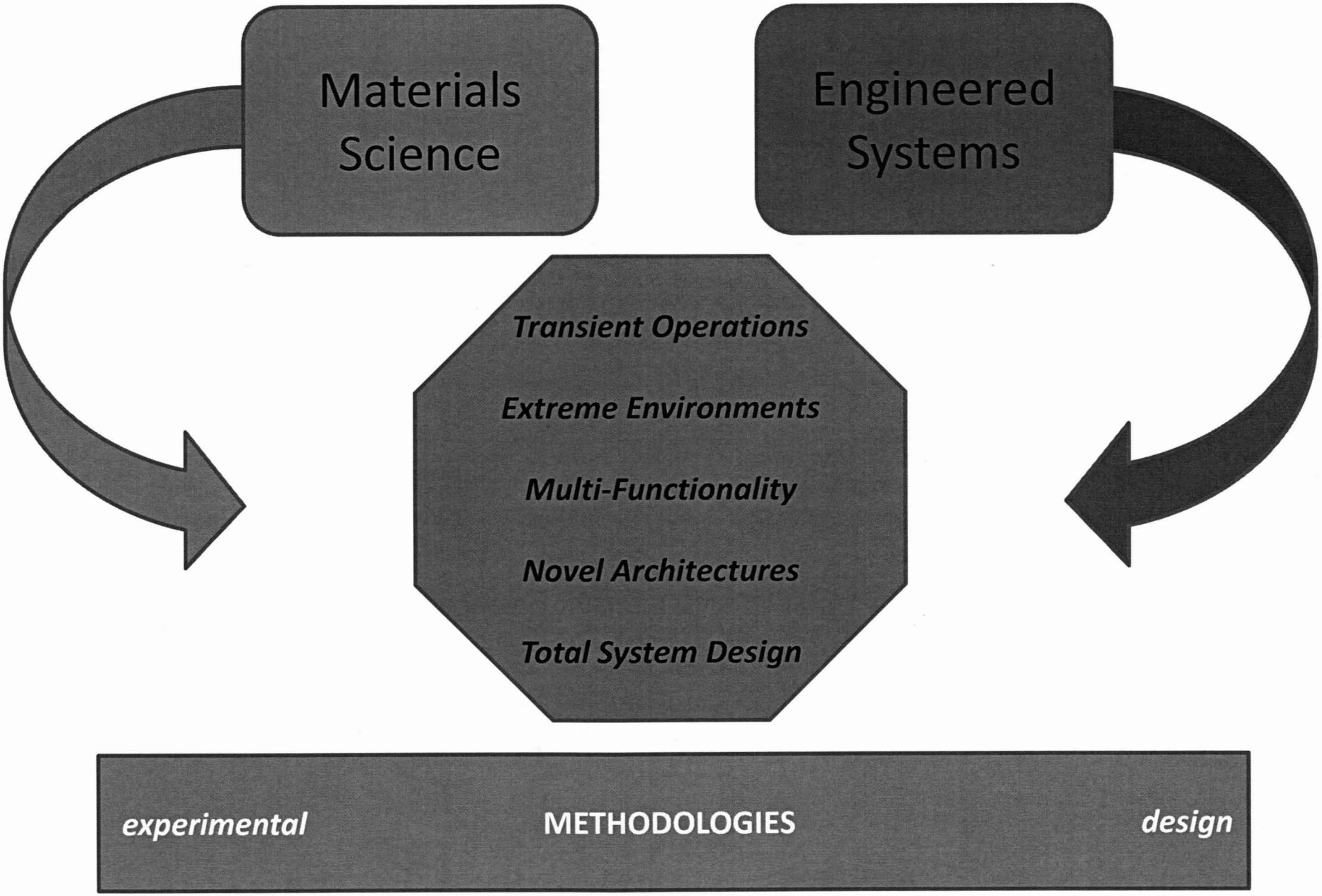
✓Testing/Methodologies
- Thermal conductivity testing of materials under real-world conditions
- Thermal performance testing of cryogenic piping systems and tanks
- Experimental methodologies and design approaches

✓Applications
- Engineering thermal analysis
- Standard Test Methods and Materials Practices (ASTM International)





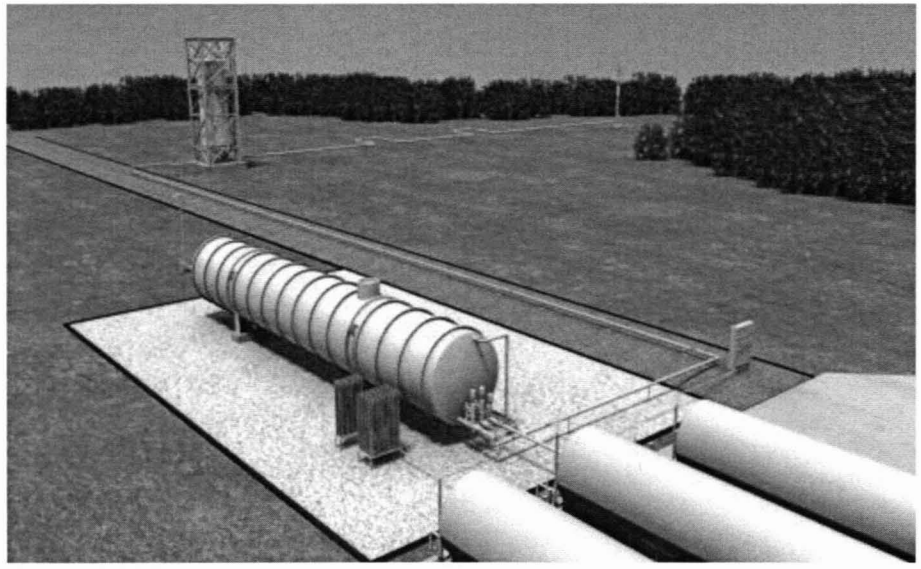



Materials Science
Engineered Systems
Transient Operations
Extreme Environments
Multi-Functionality
Novel Architectures
Total System Design
experimental
METHODOLOGIES
design

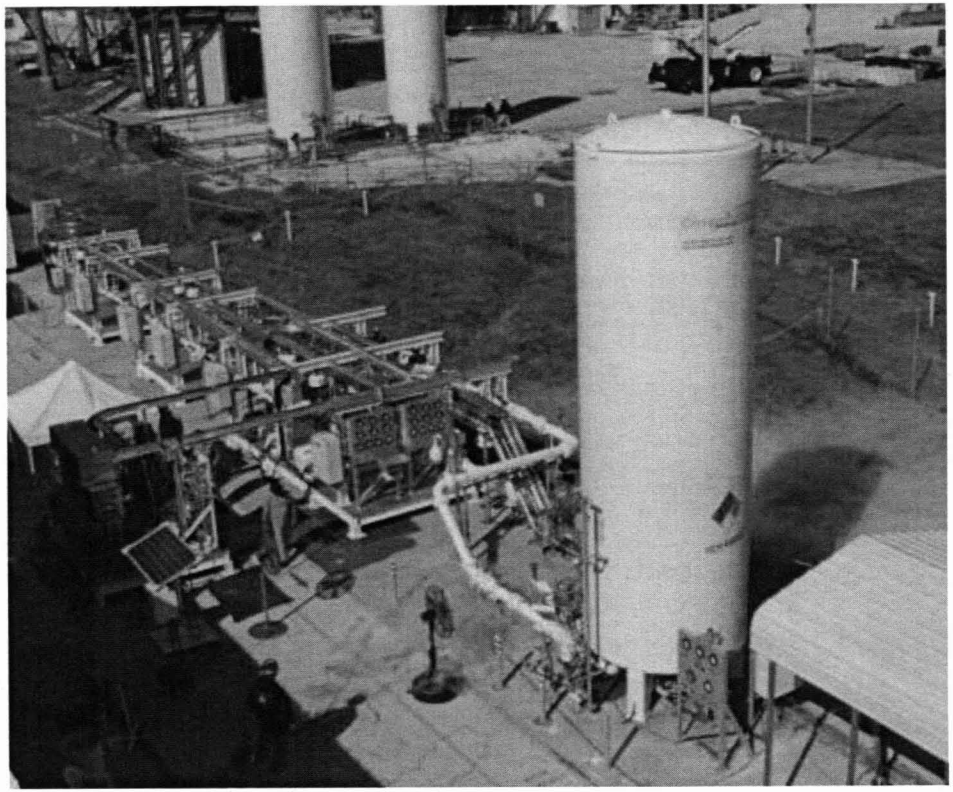
Liquid Hydrogen Ground Ops Demonstration

- **Purpose:** Validate operational concepts in a pad-like environment prior to upgrading KSC facilities
- Main Objectives:
  - Demonstrate zero loss storage and transfer of LH2 at a large scale
    - KSC loses 50% of the hydrogen purchased
  - Demonstrate hydrogen liquefaction using close cycle helium refrigeration
    - KSC currently purchases LH2 from New Orleans area (900 miles away)
  - Demonstrate hydrogen densification in storage tank and loading of flight tank
    - Increase payload mass fraction by up to 8%
- Further Objectives:
  - New densified hydrogen servicing capability
  - Demonstrate low-helium usage operations
  - Validate modern component technologies
- Partners: GRC, SSC, and ULA

New liquid hydrogen testbed facility will integrate cryogenic refrigeration inside the 33,000 gallon storage tank to control the propellant conditions



Liquid Oxygen Ground Ops Demonstration



Overall view of the Simulated Propellant Loading System located at the CryoTestLab

- Objectives:
  - Rapid propellant loading concept demonstrations.
  - Autonomous control and data monitoring system development.
  - Testbed for development of many technologies and innovations, such as:
    - Fault tolerance of failed control valves and sensors.
    - Software to monitor the overall health and status of the propellant loading system.
    - Globe valve seal designs.
- Features:
  - Up to 800 GPM flow rate and 225 PSI.
  - Four cryogenic pumps are fed from a 6,000 gallon liquid nitrogen supply tank.
  - Pumps have varying flow capacities from 25 up to 450 GPM.
  - Complexity and component count is comparable to full scale launch pad transfer system
  - Modular and re-configurable for a wide range of different vehicle or R&D requirements.

Energy Efficient Cryogenics

- Cost-Efficient Storage & Transfer of Cryogens on Earth
- Mass-Efficient Storage & Transfer of Cryogens in Space
- Low-Temperature Materials & Novel Applications

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