Developing Interdisciplinary Workforce to Meet Future Aerospace Challenges

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Outline

• Definition and Drivers for interdisciplinary research

• Examples of interdisciplinary research

• Enablers for interdisciplinary research and implication for universities

• Concluding remarks
Multidisciplinary and Interdisciplinary Research - Definition

**Multidisciplinary:**
- Multiple disciplines coming together to study a complex problem, but each working primarily with their own framings and methods (interaction)

**Interdisciplinary:**
- Study of complex issue, problem, or question by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline
Drivers for Interdisciplinary Research

• Grand challenges that cannot be addressed by a single discipline

• Complex problems with interaction between multiple elements

• Scientific and engineering discovery at the interface between various disciplines
NASA Aeronautics Vision for Aviation in the 21st Century

3 Mega-Drivers

- Global
- Sustainable
- Transformative

3 Strategic Thrusts

- Safe, Efficient Growth in Global Operations
  Enable full NextGen and develop technologies to substantially reduce aircraft safety risks

- Innovation in Commercial Supersonic Aircraft
  Achieve a low-boom standard

- Ultra-Efficient Commercial Vehicles
  Pioneer technologies for big leaps in efficiency and environmental performance

- Transition to Low-Carbon Propulsion
  Characterize drop-in alternative fuels and pioneer low-carbon propulsion technology

- Real-Time System-Wide Safety Assurance
  Develop an integrated prototype of a real-time safety monitoring and assurance system

- Assured Autonomy for Aviation Transformation
  Develop high impact aviation autonomy applications
Electrified Aircraft Propulsion

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Challenges:
- >3X increase in power density of electrical machines and power converters
- Lightweight power transmission system
- Power-propulsion and aircraft integration
- Lightweight thermal management
- 5X increase in energy density of energy storage system
Interdisciplinary Approach for Defining Architecture of Electrified Aircraft Propulsion

The solutions will be SYSTEMS-level
Interdisciplinary Approach for 3-5X Increase in Power Density of Electric Motors

New Designs Enabled by Additive Manufacturing

- Direct Printed Coils for Stators
- Innovative Design and Fabrication of Other Motor Components
- Embedded Wires for Stators

Advanced Manufacturing
Advanced Materials
Structural Design
Computational Modeling
Electromagnetic Design
Advanced Cooling
High Power Density Motors

Conventional Design
After many years of research, energy storage potential of Li-air battery has not been realized.
Interdisciplinary Approach for Design of Li-Air Battery Cathode

Need a combination of:
- Large active surface area
- Micro/nano porous structure to optimize transport of oxygen, lithium ion
- Catalyst materials for charge and discharge
- Volume to store reaction products
- Affordable manufacturing process

Need system thinking
Multifunctional Structures for Lightweight Load-bearing Energy Storage

Replace battery with multifunctional structural element

Battery Pack

Electric motor

Battery Pack

Electric motor
Interdisciplinary Research to Develop Multifunctional Structures With Energy Storage Capability

Materials/Electrochemistry
- Electrode & Material Synthesis
- Electrochemical Testing
- Structural Electrochemical Component Synthesis/Design
  - Combined Electrochemical/Mechanical Testing
- Structural Design
  - Design/Fabrication
- Mechanical Testing
  - Atomistic
  - Mechanical/Electrochemical
    - Systems Analysis
      - Demo Vehicle Trade Study
      - Down-select Vehicle
- Modeling
  - Optimization/Scale-up
    - Component Integration
      - Vehicle Integration
      - Flight Demo
      - Demo Vehicle
      - Optimization/Scale-up
Smart Grid Universe

Evolves with the integration of all these elements and more

Application for intelligent aircraft power management
Interdisciplinary Nature of Autonomous System Development

Nanotechnology

Embedded Computing

Sensors

Computing

Communication

Autonomous System

Propulsion

Power

Mechanical System/Structures

Wireless Technology
Integration of Computing Sciences With Engineering Disciplines

- Machine Learning
- Artificial Intelligence
- Data Analytics

Discovery of New Material Chemistries

Cognitive Aerospace Communication
Enablers for Interdisciplinary Research

• Major challenge or grand challenge
• System level thinking
• Communication among team members from different disciplines
• Ability of team members to explain their discipline content in such a way that it can be clearly understood by other team members
• Prototypes to gain team experience
• Frequent experimental campaigns to quickly explore system alternatives
• Risk taking
• Strong leadership
Implications for Universities

- Early introduction of interdisciplinary thinking through coursework and various team projects
- Emphasis on system level thinking
- Coursework in multiple disciplines as part of curriculum
- Teambuilding and communication skills as part of the curriculum
- Recognition and reward system for faculty members engaged in interdisciplinary research
Interdisciplinary research is becoming the norm:

- To create new knowledge
- To develop advanced concepts
- To develop new products