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 Mobility

- 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

<table>
<thead>
<tr>
<th>Year</th>
<th>Non-cryogenic</th>
<th>Largest Electrical Machine on Aircraft</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>100 kW</td>
<td>1 MW</td>
</tr>
<tr>
<td>2020</td>
<td>0.5 MW Total Propulsive Power</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50-250 kW Electric Machines</td>
<td></td>
</tr>
<tr>
<td></td>
<td>19 Seat 2 MW Total Propulsive Power</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.1-.1 MW Electric Machines</td>
<td></td>
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<tr>
<td>2025</td>
<td>3 MW</td>
<td>10 MW</td>
</tr>
<tr>
<td></td>
<td>50 Seat Turboprop 3 MW Total Propulsive Power</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.3-.6 MW Electric Machines</td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>30 MW</td>
<td>Superconducting</td>
</tr>
<tr>
<td></td>
<td>50 Seat Jet 12 MW Total Propulsive Power</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.3-.6 MW Electric Machines</td>
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<tr>
<td>2035</td>
<td>60 MW</td>
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</tr>
<tr>
<td></td>
<td>150 Seat 22 MW Total Propulsive Power</td>
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</tr>
<tr>
<td></td>
<td>1-11 MW Electric Machines</td>
<td></td>
</tr>
<tr>
<td></td>
<td>300 Seat 60 MW Total Propulsive Power</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3-30 MW Electric Machines</td>
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</tr>
</tbody>
</table>

**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

Conventional Design

New Designs Enabled by Additive Manufacturing

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

Advanced Materials

Structural Design

Advanced Manufacturing

Advanced Cooling

Computational Modeling

Electromagnetic Design

High Power Density Motors
Li – Air Battery

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
Interdisciplinary Research to Develop Multifunctional Structures With Energy Storage Capability

Materials/Electrochemistry
- Electrode & Material Synthesis
- Electrochemical Testing
- Combined Electrochemical/Mechanical Testing

Structural Design
- Structural Electrochemical Component Synthesis/Design
- Mechanical Testing
- Design/Fabrication

Modeling
- Atomistic
- Mechanical/Electrochemical
- Systems Analysis
- Demo Vehicle Trade Study
- Down-select Vehicle

Optimization/Scale-up
- Component Integration

Vehicle Integration

Flight Demo
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
- Propulsion
- Power
- Mechanical System/Structures
- Wireless Technology

Autonomous System
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