Next Generation Aerospace Systems

Integrity ★ Service ★ Excellence
MISSION/VISION: Leading discovery and development of world class integrated Aerospace Systems S&T for national security
Next Gen Aerospace Systems
Core Technical Competencies (CTCs)

Basic Research

Turbine Engines
$215 M

Structural Materials & Applications
$31 M

Aerospace Vehicles
$79 M

Control, Power, & Thermal Management
$83 M

High Speed Systems
**Mission/Vision Statement**

**Mission:** We discover, shape, and champion basic science that profoundly impacts the future Air Force.

**Vision:** The U.S. Air Force dominates air, space, and cyber through revolutionary basic research.

**Goals/Objectives**

**Goals:** Develop the fundamental scientific knowledge required for revolutionary advancements in a broad variety of future AF capabilities for energetically-efficient air and space systems.

**Objectives:** Enable rapid global and regional response, create new materials and structures, and develop a framework for control of uncertain, information-rich, dynamic environments.

**Technical Approach/Ideas**

Fundamental science to support AF needs in multiple applications:

- Explore canonical problems that capture the behavior of representative mechanisms and build a cohesive understanding of the energy transfer processes.
- Analyze and predict physical phenomena of aerospace systems via computational mathematics.
- Integrate theoretical, analytical, numerical, and experimental approaches to understand fundamental flow physics.
- Generate understanding required to design and manufacture new aerospace materials and structures.

**Motivation**

- Understand foundation of energy transfer in multi-physics flow phenomena.
- Understand complex physical phenomena crucial to the design and control of future AF systems.
- Advance fundamental understanding of complex, time-dependent flow interactions.
- Develop new and revolutionary flight structures.
Aerospace Vehicles CTC

Mission Statement
- Discover, develop, demonstrate, and deliver aerospace vehicle-focused technologies to assure warfighter air dominance.

Goals/Objectives
- 4-10% efficiency improvements on legacy fleet A/C
- Deliver mature sustainment technologies to the fleet
- Deliver tools and technologies for affordable sustainment and A/C life extension
- 2X improvement in range for next generation mobility aircraft over C-17 baseline
- Enable extended range and capability for FAD.

Motivation
- A2AD—Operate from minimal basing locations and at extended ranges by enabling efficient, lightweight, and sustainable vehicle technologies for FAD and mobility A/C
- Air Force Energy Plan—Reduce fuel demand by increasing the energy efficiency of legacy fleet and future aircraft
- Airframe Lifecycle Management- Optimized lifecycle management for capability, availability, and cost
- Nat’l Aerospace R&D Plan – Certify composites, demonstrate multifunctional structures, and reduce A/C drag

Technical Approach/Ideas
- Global Mobility . . . right effects, right place, right time
  - Efficient propulsion integration
  - Drag reduction (high span wings, laminar flow)
  - Lightweight composite structures
- Future Air Dominance . . . trade space and tech mat
  - Conceptual designs and technology trades to support AFLCMC and ACC in AoA activities
  - Develop multi-disciplinary design methods
- Sustainment . . . near to far
  - Re-engineering structure
  - Structural Health Monitoring
  - Fleet Health Management
  - Affordable A/C Life Extensions

$79M / year
## Aerospace Vehicles CTC

<table>
<thead>
<tr>
<th>Near-Term</th>
<th>Mid-Term</th>
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<td>FY14-19</td>
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**Legacy Energy Efficiency Upgrades, Adv. Design Methods, and Sustainment Retrofits**

- C-130 Drag Reduction
- C-17 Formation Flight
- B-2 Windshields
- Re-engineering obsolete structures (C-5,C-130,F-15)
- FAD Design Methods
  - >10M Gal/yr Fuel Savings
  - >$Ms Logistic Savings

**Major Legacy Upgrades**

- C-17 Re-engine/Re-wing Feasibility
- Laminar Flow Designs
- High Bypass Efficient Propulsion Integration
- Composite Structure Life Assmt
- Structural Health Monitoring
- Per A/C Sustainment Tracking
- Physics-based Design methods
- Structurally Integrated Antenna Demonstration
  - >100M Gal/yr Fuel Savings
  - Service Life Extension Program
  - >$10M Logistic Savings

**Revolutionary Configurations**

- New Mobility Aircraft Designs - 60% fuel burn reduction
- Optimized Future Air Dominance
- Certified Primary Composite Structures
- Per A/C Sustainment and Life Extensions
  - Rapid Global Mobility
  - Future Air Dominance
High Speed Systems CTC

Mission/Vision Statement

- CTC MISSION: Develop technology options for high speed strike and penetrating regional ISR platforms
- VISION: Hypersonic platform technologies to produce revolutionary warfighting capabilities

Goals/Objectives

- Develop hydrocarbon-fueled scramjet, Mach 4-7 flight
- Develop reusable hydrocarbon-fueled scramjet and combined cycle engines
- Develop aerodynamic, aero-heating, and propulsion/weapon integration technologies for sustained high speed cruise
- Develop and exploit new structural concepts and physics-based methods to enable optimized high speed aircraft

Motivation

- Current capabilities are missile-scale, hydrocarbon-fueled scramjets, expendable structures, and load-superposition-based structural life prediction tools
- Current limitations are physical scale; expendable structures; and operability range (delta Mach)
- New capabilities will enable reusable, high Mach air-platforms at appropriate scale for strike and ISR

Technical Approach/Ideas

- Develop endothermic fuel cooled hardware that maintains positive thermal balance throughout mission
- Develop advanced materials/structures that operate at high temperatures and support reusable high Mach aircraft
- Develop life prediction tools for aircraft/engine structures operating in harsh environment based on accurately modeling load interactions
- Develop ground test and analysis-based methods to evaluate and mature large hypersonic engines and aircraft structures

$103M / year
# High Speed Systems CTC

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**Small-Scale Scramjet Engines and Hypersonic Flight Research**
- 1st Gen Hypersonic Cruise Missile Propulsion using conventional jet fuels
- X-51A flights in 2010-2013
- Flight Tested Hypersonic Research Vehicles Atop Sounding Rockets (HIFiRE)

**Medium-Scale Hypersonic Propulsion and High Speed Strike Weapon (HSSW)**
- Extended life, performance, operability of scramjets
- High Speed Strike Weapon (HSSW) integrated weapon demo in 2017

**Large-Scale Combined Cycle Propulsion Systems**
- Highly reusable, very wide operating range scramjets
- Integration of scramjets with turbines and/or rockets
- High temperature structures for reusable Mach 5-7 ISR/Strike aircraft

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- Global Precision Attack
- Global Precision Attack Global Integrated ISR
- Global Precision Attack Global Integrated ISR
Mission/Vision Statement

- Focused on 10x improvement in affordable capability
- Improving fuel efficiency and thrust/weight ratio
- Reducing development, production, and maintenance costs

Goals/Objectives

**Propulsion System Class**

- **Turbofan/Turbojet**
  - Large: (CCI) Goal = 4X, 6X, 10X
  - Small**: (CCI) Goal = 3X, 5X, 8X
- **Turboshaft/prop**
  - (CCI) Goal = 3X, 4X, 5X

**Expendable**

- (CCI) Goal = 4X, 6X, 10X

* **CCI** = Capability Cost Index
  
**Baseline FY2000 State-of-the-art**

Technical Approach/Ideas

- **Adaptive Versatile Engine Tech (ADVENT) & Adaptive Engine Tech Development (AETD)**
  - Objective: Fully mature fuel efficient (+25%) adaptive component technologies for low-risk accelerated engine development for future combat aircraft

- **Highly Energy Efficient Turbine Engine**
  - Objective: Improve fuel efficiency (+35%) through demo of ultra high bypass ratio; integrated inlets, exhaust, & thermal management; and high temperature, high strength materials

- **Advanced Energy & Sustainment Technologies for Propulsion (AESTP); Emerging & Fielded Systems**
  - Objective: Safely reduce Propulsion O&S cost through S&T

- **Aerospace Fuels**
  - Objective: Understand effects of fuels composition & spec tolerance to advanced engines performance & emissions.

**Motivation**

- A2AD and Pivot to Pacific – ADVENT, AETD, HEETE, STELR programs to provide highly-efficient turbine engines for long-range requirements
- Air Force Energy Horizons – Highly efficient engines & alternative fuels improve US energy position
- Nat’l Aerospace R&D Plan – Develop knowledge base to link emissions (and mitigation) to fuel composition
- Primary TFA: NGenAS; Leveraged: Afd&Sus, ISR, Wpns

<table>
<thead>
<tr>
<th>Turbomachinery Type</th>
<th>VAATE I 2009</th>
<th>VAATE II 2013</th>
<th>VAATE III 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbofan/Turbojet</td>
<td>4X</td>
<td>6X</td>
<td>10X</td>
</tr>
<tr>
<td></td>
<td>3X</td>
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## Turbine Engines CTC

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<tr>
<td>• Engine demos in 2013</td>
<td>• Could Save 1.4B Gallons of Fuel by 2040</td>
<td>• 35% SFC improvement for existing and future mobility, tanker and ISR platforms</td>
</tr>
<tr>
<td>• 25% SFC improvement</td>
<td></td>
<td>• High overall pressure ratio</td>
</tr>
<tr>
<td>• Increased range, speed, &amp; persistence</td>
<td></td>
<td>Supports Rapid Global Mobility</td>
</tr>
</tbody>
</table>

**Supersonic Turbine Engine for Long Range (STELR)**
- Mach 3+ operations
- 1 Hour at max Mach

**Targeted for 2020+ Combat Air Force**
- Future Air Superiority & Strike Aircraft

**Advanced Energy & Sustainment Technologies for Propulsion (AESTP)**
- Emerging and Fielded Systems

**Aerospace Fuels (AF)**
- Understand effects of fuels composition & spec tolerance to advanced engines performance & emissions.

**Supports AF Energy Horizons**

**Supports LRSO/ALCM, RPAs, & Adv Cruise Missiles**

**Supports Rapid Global Mobility**
Control, Power, and Thermal Management CTC

Mission/Vision Statement

Lead the nation’s S&T in integrated aircraft systems (controls, power, thermal management) for autonomous flight control and energy optimized aircraft

Goals/Objectives

Realize new mission and operational capabilities by:
- Enabling robust, safe, high-functioning automation for manned systems and autonomous UAS
- Removing power and thermal limitations for existing and new special mission systems

Technical Approach/Ideas

- Seamless integration of unmanned aircraft into airbase and airspace operations
- Cooperation and teaming of unmanned and manned aircraft
- Enhanced awareness of and real-time response to state of system, mission and environment
- Model-based design of integrated propulsion, power and thermal systems
- Verification and validation technologies to allow cost effective certification of new capabilities

Motivation

Current capabilities limited by:
- Ability to seamlessly integrate unmanned aircraft into training and operational environments
- Automation brittleness in uncertain, complex and contested environments
- Ability to model, design and assess integrated power and thermal system performance

$83M / year
## Control, Power, and Thermal Management CTC

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<tr>
<td>Safety, Robustness for Current Operations</td>
<td>Operations in Complex, Contested Environments</td>
<td>New Operational Capabilities</td>
</tr>
<tr>
<td>- Sense &amp; Avoid (SAA) for UAS Airspace Integration</td>
<td>- Tactical Off-Board Sensing - teaming behaviors (TOBS)</td>
<td>- Robust autonomous system response to mission, environment, power, thermal needs</td>
</tr>
<tr>
<td>- Electrical, Power and Thermal component technologies - Generators, Accumulators, Solid State Elect Distribution</td>
<td>- INVENT – Integrated power and thermal management</td>
<td>- Integration and certification through design</td>
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</table>

### SAA – Global Hawk, GIISR
Auto-GCAS transitions
INVENT – F-35, Air Sup.

### UAS Airspace Integration - GIISR
TOBS – AFSOC
INVENT – NGAD, AS
Mission/Vision Statement

• Delivering paradigm changing materials, processes, and NDE prototypes to enable new structural design concepts and their life-cycle management

Goals/Objectives

• Develop materials that can operate at much higher temperatures with comparable or better durability, weight, and affordability
  ➢ Includes subsonic, supersonic, and hypersonic structures and propulsion systems
• Develop sensing capabilities for NDE and real time condition based maintenance

Motivation

• Next Generation Aerospace Systems are fundamentally limited by the capabilities and affordability of current materials and materials processing, design, validation, & certification

Technical Approach/Ideas

• Shift from standardized to designed materials tailored for the applications
• Lighter weight materials that do much more than carry load
• Higher temp materials enabling faster, cheaper, more durable systems
  ➢ Enhanced performance and increased fuel efficiency
• Material and damage state assessment & prediction of component life
• Materials & processing as integrated variables in component design
• More capable, reliable, efficient inspections to reduce maintenance burden

$31M / year
## Structural Materials & Applications CTC

### Near-Term
**FY14-19**
- Hybrid Superalloy turbine engine compressor disk
- Ceramic Matrix Composite (CMC) components for engines and hot structures
- Modeling codes for integrating high temperature resin & fibers for organic matrix composites

### Mid-Term
**FY20-25**
- Integrated Ceramic Matrix Composite (CMC) components for engines and hot structures
- Multifunctional structural concepts for EM and HPM protection
- Integration of computational methodologies into standard industry design practices

### Far-Term
**FY26-30**
- Affordable & robust thermal protection systems
- Validated computational models for microstructure component performance
- On-site inspection of airframe & engine components
SUMMARY
Next Generation Aerospace Systems

• CTCs poised to provide technologies for future weapon systems
  - Basic Research
  - Turbine Engines
  - Aerospace Vehicles
  - High Speed Systems
  - Control, Power, and Thermal Management
  - Structural Materials & Applications

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