U.S. AIR FORCE

USSF

AFRL

Power/Thermal 2030 Vision

Air Platform Electrification

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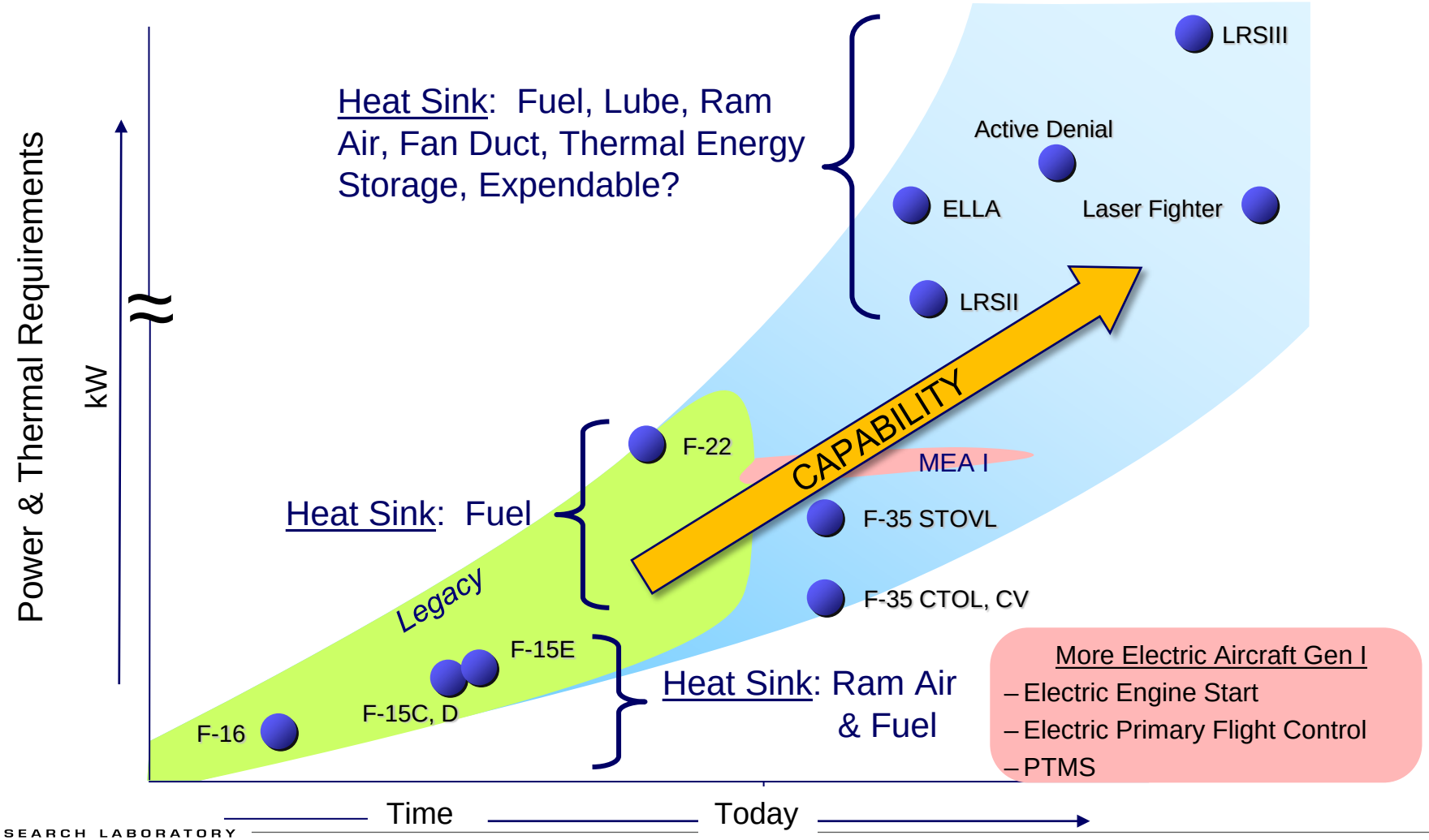
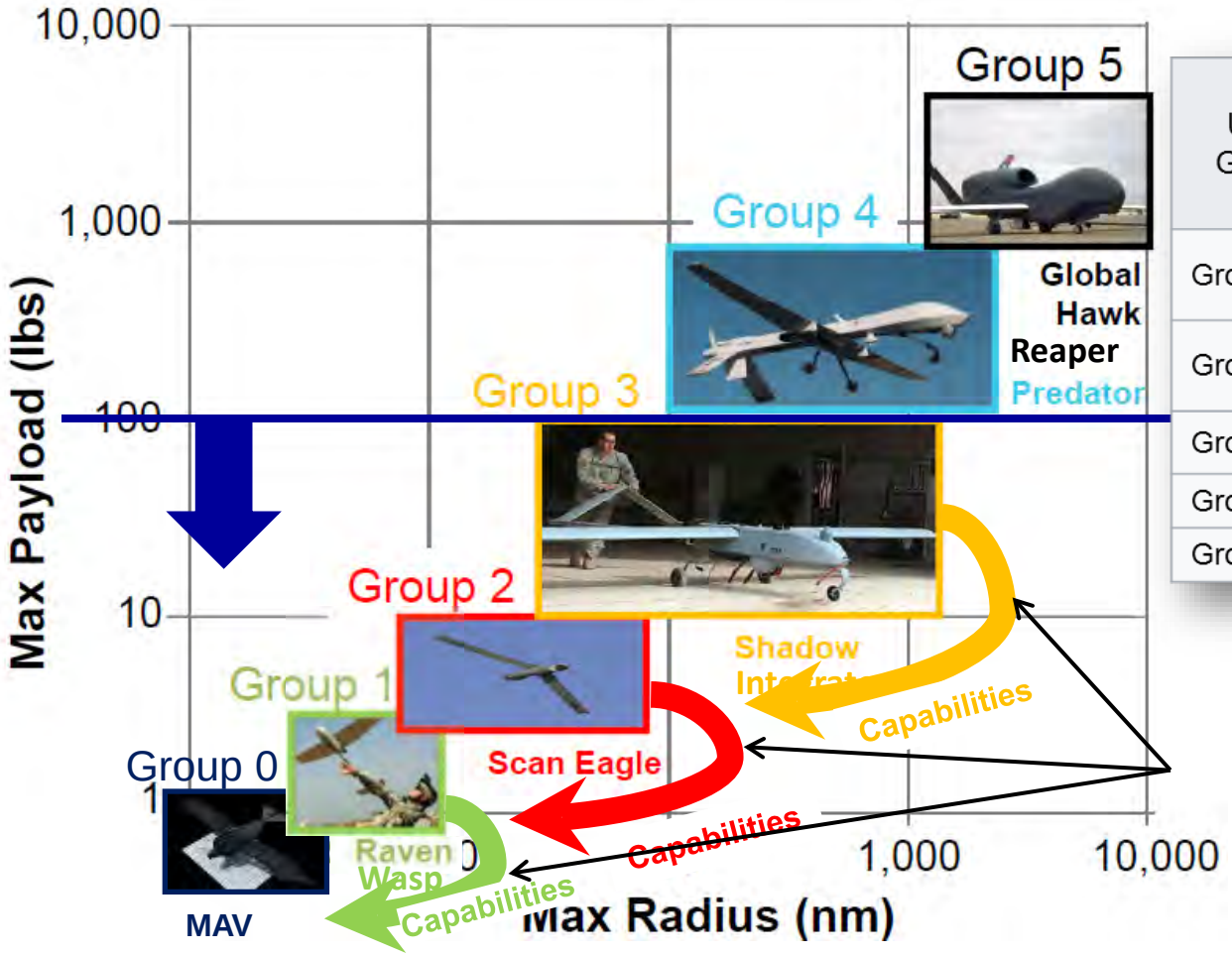
Increased Capability Drives Onboard Energy Requirements

Power & Thermal Management Requirements



Legacy UAS Power/Propulsion: Key Challenges



UAS Group	Maximum weight (lb) (MGTOW)	Nominal operating altitude (ft)	Speed (kn)
Group 1	0–20	< 1,200 AGL	100
Group 2	21–55	< 3,500 AGL	< 250
Group 3	< 1,320	< FL 180	
Group 4	> 1,320		Any
Group 5		> FL 180	

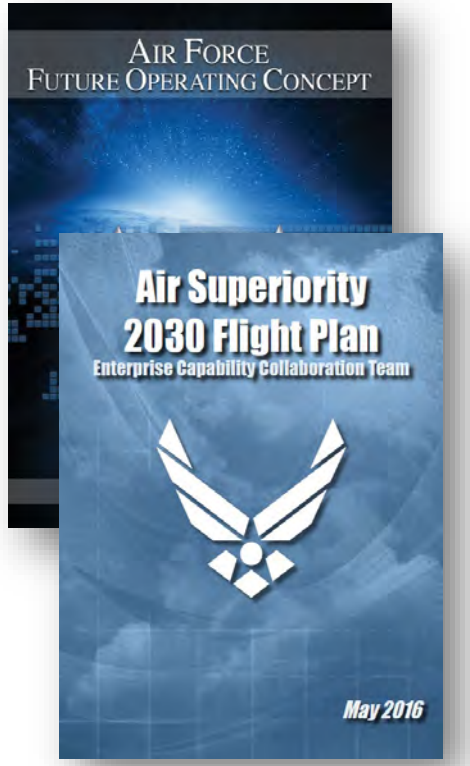
Enhanced Hybrid Electric Power/Propulsion Systems
- Increased Endurance/Range
- Excess Payload Power
- Quiet Operation
- Increased System Reliability

Small UAV / RPA Systems

Strategic Guidance

The Future Environment

- Wide range of intensifying threats (NSS)
- Military advantage is eroding…strategic competition creating complex and volatile environment (NDS)
- Many of our adversaries have developed advanced technology to counter our air dominance (AF SMP)
- Increasing speed/proliferation of technology change … adversaries' acquisition and development of capabilities to challenge the U.S. (AF FOC)
- AF will leverage operational agility to adapt swiftly to any situation or enemy action (AF FOC)
- Integrated/networked capabilities as part of A2/AD strategy in highly contested environment. (AS 2030)



DoD Priorities/Requirements

- Prioritize emerging/game changing tech (NSS)
- Gaining freedom of action for the joint force in the high end conflict is our highest priority (AF SMP)
- Access remains the key challenge to US & allies as they negotiate contested global commons (AF FOC)
- Employ mix of manned, remotely operated, and autonomous assets to support ops in contested & uncontested environments. (AF FOC)

Strategic Guidance: S&T 2030

TIME – Operate at unrivaled speed
SPACE – Unparalleled global awareness, reach, and effect
COMPLEXITY – Present adversary with ever-growing number of challenges

- Three Primary Objectives
  - Develop and Deliver Transformational Strategic Capabilities
  - Reform the Way Science and Technology is Led and Managed
  - Deepen and Expand the Scientific and Technical Enterprise
- AF S&T Portfolio
  - Broad-based, Enabling Enduring Component
  - Focused Transformational Component
    - Five Strategic Capabilities, Vanguard Programs
- Five Strategic Capabilities
  - Global Persistent Awareness
  - Resilient Information Sharing
  - Rapid, Effective Decision Making
  - Complexity, Unpredictability, and Mass
  - Speed and Reach of Disruption and Lethality
- Vanguard Programs – Demo viability of leap-ahead capabilities

AFRL redefining/learning its new role within USAF & Industry

- USAF S&T 2030 Strategy Report released April 2019
  - https://afresearchlab.com/events/2030/
- AFWERX → Agility Prime – eVTOL Electric Air Taxi

AF 2030 strategy vision to dominate:
TIME – Operate at unrivaled speed
SPACE – Unparalleled global awareness, reach, and effect
COMPLEXITY – Present adversary with ever-growing number of challenges

- AFRL Power & Thermal direction:
  - Focus towards Group 5 Autonomous Collaborative Platforms
    - "Affordable" systems —secondary power & thermal
    - Electrified Aircraft Propulsion —primary power

Leveraging Innovation — Collaboration

Enabling Future Military Capabilities

Future Military Capabilities

- Greater Efficiency = More Capability
  - Increases to range/loiter
  - Increased power for mission systems
- Reduced acoustics
  - Mission and basing flexibility
- Flexible system architectures
  - Support high-power payloads while maintaining range/loiter capability
- Reduced carbon emissions
  - Future requirements in EUCOM AOR

Enabling Future Military Capabilities

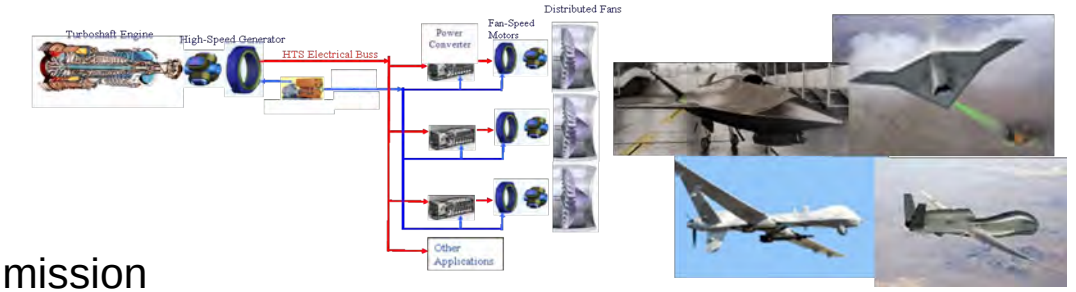
Future Military Capabilities

Air Platforms Capability Challenge Areas

PRODUCTS	MegaWatt Tactical Aircraft (MWTA) Med Scale Integr Prop/Power/Thermal (MSIPPT) Compact Power Generation (CPG) Silicon Carbide (SiC) Power Semiconductors
FOCUS AREAS	Aircraft Electrification/Electrified Propulsion (AEEP) Affordable Power/Thermal/Mechanical for Auton Sys Power/Thermal Tech for Hypersonic Sys Integrated Experimental Hardware-in-the-Loop (xHIL) Computational Engineering (CE) Air Vehicle Energy Management (AVEM) Advanced Thermal Lift

Power/Thermal 2030 Vision

- Autonomous ISR/Strike
  - Requirements for next gen large-class autonomous systems will stress currently available propulsion/power/thermal management solutions
  - AFRL Autonomous Collaborative Enabling Technologies (ACET) program pulling tech together to enable integr, layered networks of uncrewed sys
  - S&T Focus on integration of power/thermal mgmt tech with medium-scale engines to enable ACET relevant autonomous systems

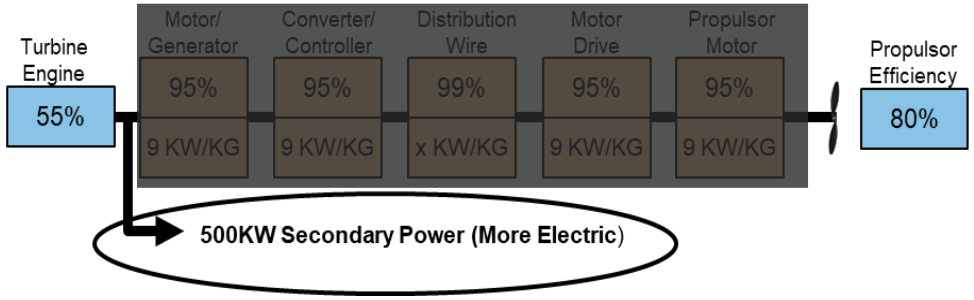


- Expendable/Reusable Hypersonic
  - Future high speed weapons and vehicles will extend mission duration/range, speed and/or payload capabilities
  - Alignment with AFRL Hypersonic Strategy
  - Active S&T programs will provide continuous system power for long duration hypersonic missions

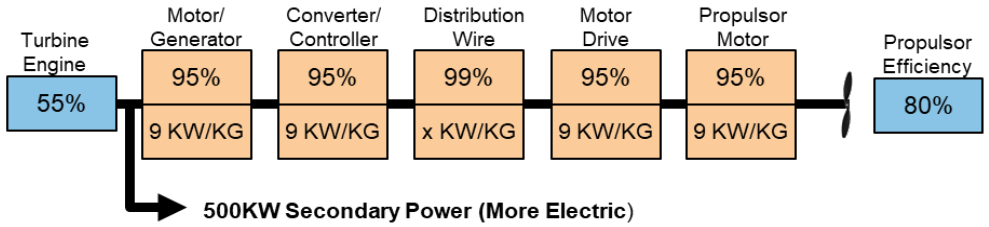
Powering Autonomous Systems and Hypersonics

Pivot to 2030 Power & Thermal

Megawatt Tactical Aircraft (MWTA)



Medium-Scale Integrated Propulsion, Power, Thermal

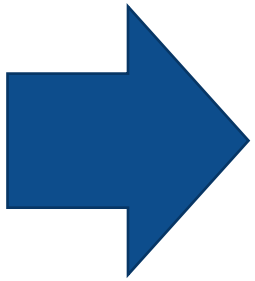


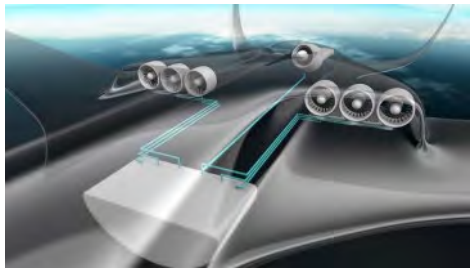
Group 5 Uncrewed Air Systems (UAS)

2030+ More Electric Aircraft

- **Turbine Engine Primary Propulsion or Power ??**
  - Near-term advances… adaptive engine fans, hybrid PTMS and dual-spool power extraction
  - Mid-term concepts…include MW power systems, adaptive engine cores, and wide-temperature PTMS (250kW modules)
  - Far-term concepts?...Trending toward continued electrification, distributed propulsion, and high-speed concepts (MW modules)

2010 **2025** **2030+**





Autonomous ISR/Strike

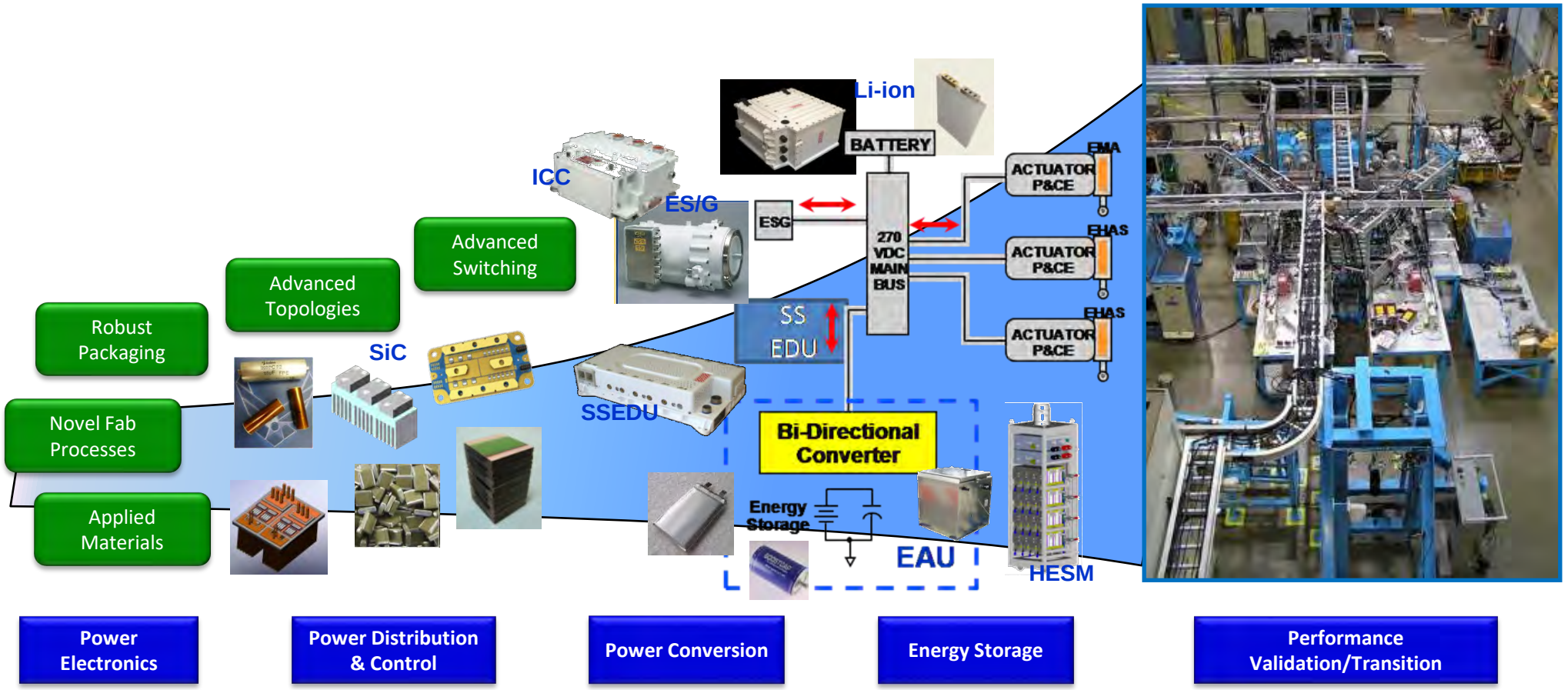
- Strategic focus on speed, operational agility
  - Mix of assets to support contested and uncontested environ.
  - Ability to present adversaries with varied options

- Current efforts across RQ/AFRL/Industry exploring this space
  - Low Cost Attritable Systems, Cost-Optimized/Limited Life Engines, Small/Medium-Scale Propulsion, Distributed Propulsion
  - AFRL Autonomous Collaborative Enabling Technology (ACET) program pulling technology together to enable integrated, layered networks of unmanned systems

- Power/Thermal management key to maximizing platform capabilities
  - Power/Thermal considerations need to be considered up-front
  - Electrified aircraft architectures have potential to revolutionize capabilities

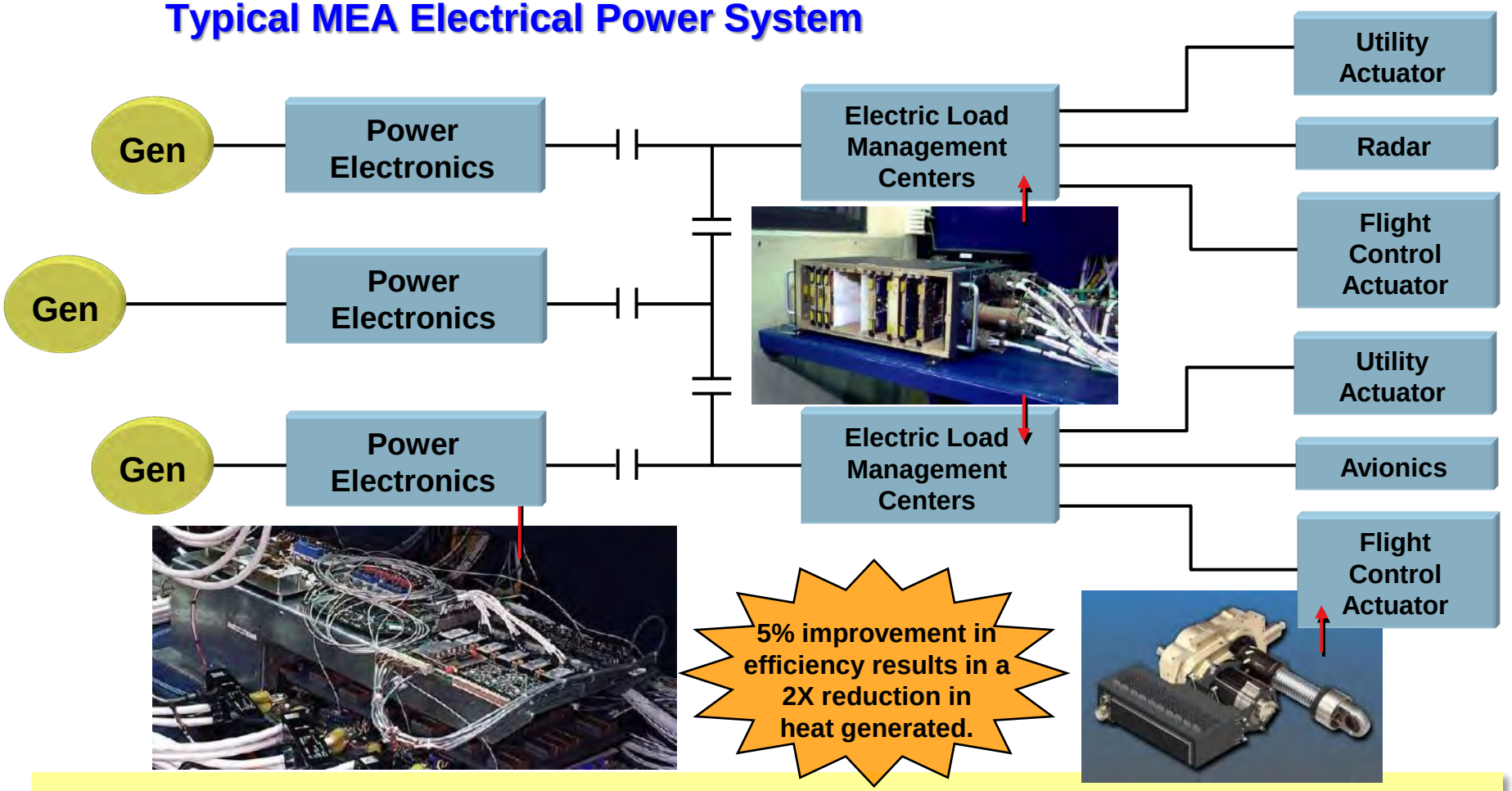
Electrical Power Systems (EPS)

AFRL/RQQ Works the Full Spectrum of Electrical Power Technology



MEA Power System for a Generic Fighter Aircraft

Typical MEA Electrical Power System



- **Every watt is processed 3 times by power conditioning before being used**
- **500 to 1000 switches involved in the typical airframe configuration shown**

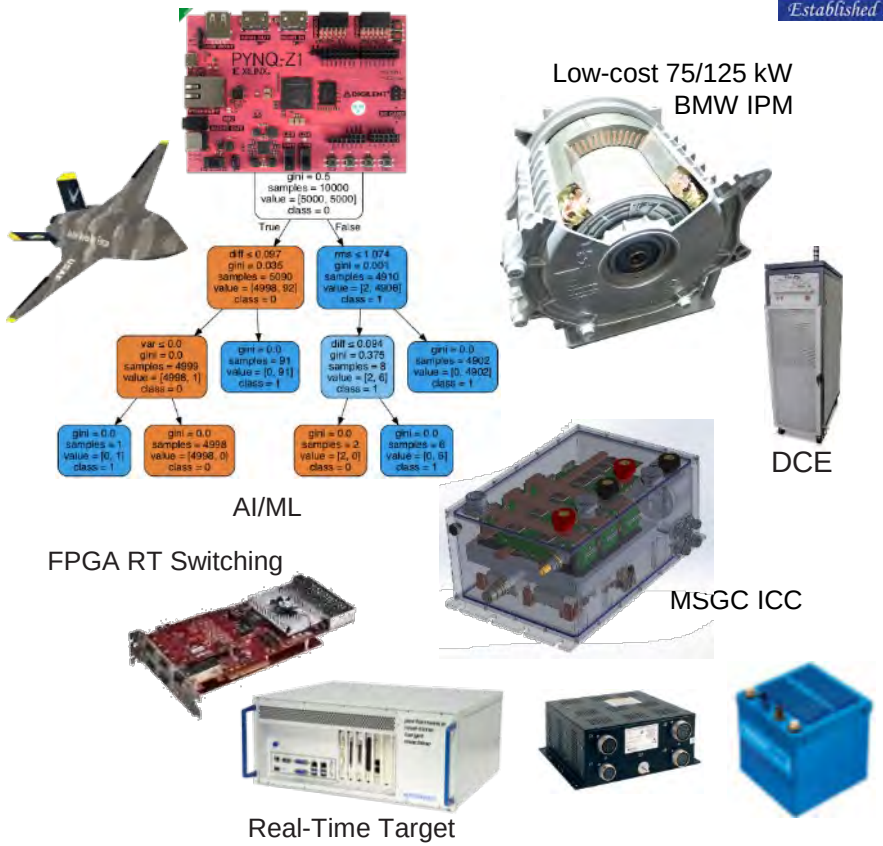
Affordable Power/Thermal/Mechanical for Autonomous Systems

Description:

- Study, develop, and test affordable technologies for affordable aircraft

High-level approach:

- Buy or develop, and test technologies with affordability being a primary consideration
  - Must meet performance, weight, volume, etc metrics
  - Demonstrate the potential of approaches too risky or novel for industry
    - Leverage COTS tech in unique or novel ways
    - Novel manufacturing, non-traditional vendors
    - Combining LRUs into a single tech solution
    - Consider 2nd order effects of the cost of the integrated system
  - Reduce component failures, reduce mission failure
  - Increase safety, stability, robustness, and general applicability (one size fits more)
  - Leverage In-house testing capabilities and expertise for home grown solutions



Technologies:

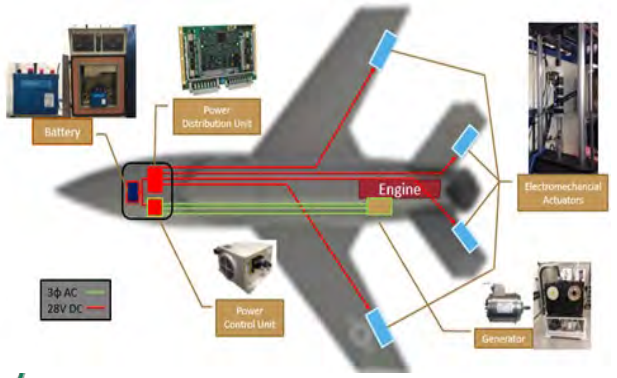
- AC/DC and DC/DC converters
- WBG Technologies
- Energy Storage and Management, Reconfiguration
- Digital Engineering, M&S, HIL and Testbeds
- Accurate, Dynamic Torque measurement
- Controls, AI/ML

Leveraging lower cost sources to put capable technologies On-the-Shelf

Experimental Hardware-in-the-Loop

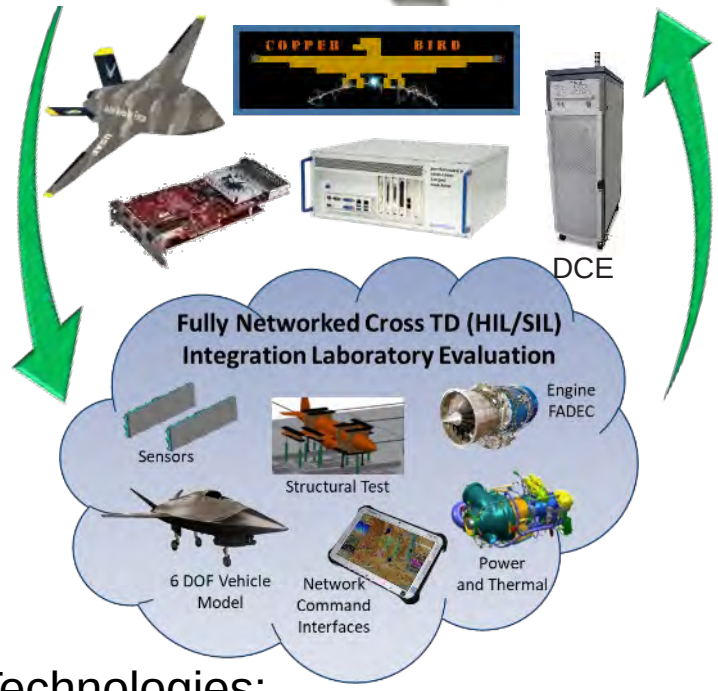
Description:

xHIL optimally leverages, integrates, and develops both physical and digital representations to virtually “fly” a vehicle configuration before it’s built



High-level approach:

- Faithfully integrate physical hardware where available (true response)
- Emulate boundary conditions around UUT as accurately as possible (High-Bandwidth)
- When possible, utilize models informed by hardware
- Push TRL, testing is a conduit from the lab to commercial tech.
  - Demonstrate feasibility of high risk approaches
- Generate air worthiness artifacts, evidence based advice for lower-risk flight test
  - Test it before you fly it.
- Use in-house capabilities to integrated and test home-grown approaches, components, and capabilities
  - Architectures, LRUs, Controls, etc.

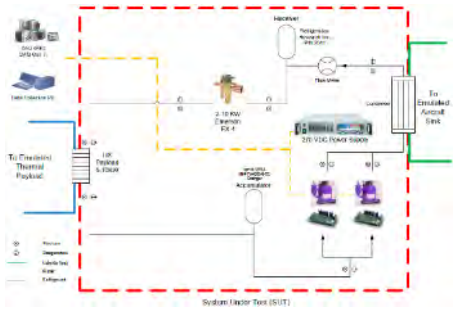


- Utilize M&S & xHIL to fly-it before you build-it
- Identify Power and Thermal Technology Gaps in an integrated digital/analog environment

Technologies:

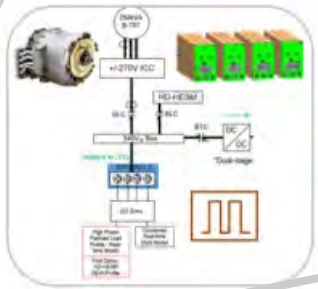
- HIL representation of study platforms
- Experimental Digital Twin for Aerospace Utility Subsystems
- Integrated, Detailed Emulation
- Real-Time Switching

Experimental Hardware-in-the-Loop & Digital Twin

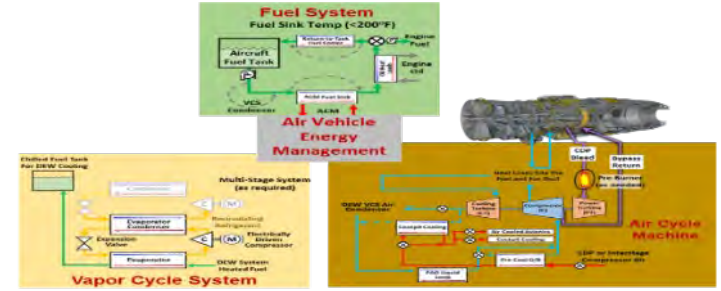


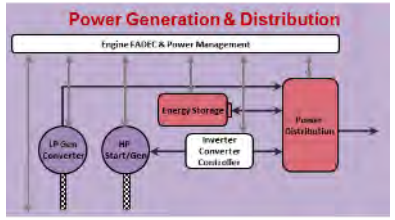
TMS

Turbines Collaboration

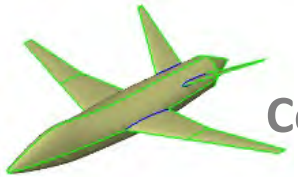


EPS





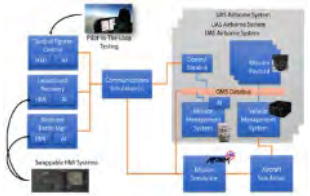
Computational Engineering



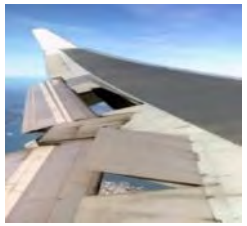
Vehicles Collaboration

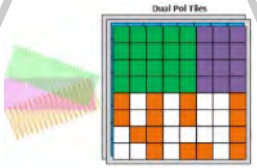
xHIL

Autonomy Collaboration (SIL)



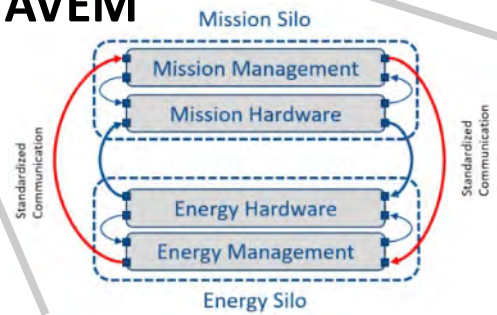
Iron Bird





Mission Payload Collaboration

AVEM



Leverage hardware where possible, parallel to M&S, to move better tech out faster to integrated systems.

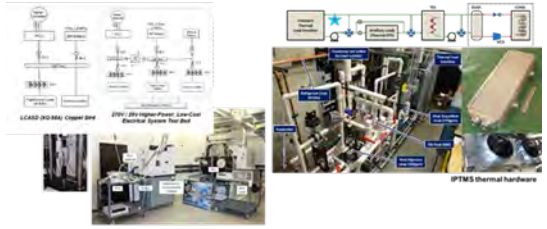
Aircraft Electrification/Electrified Propulsion

(Current)

Partner Investments

Long Endurance UAS

MegaWatt Power/Thermal

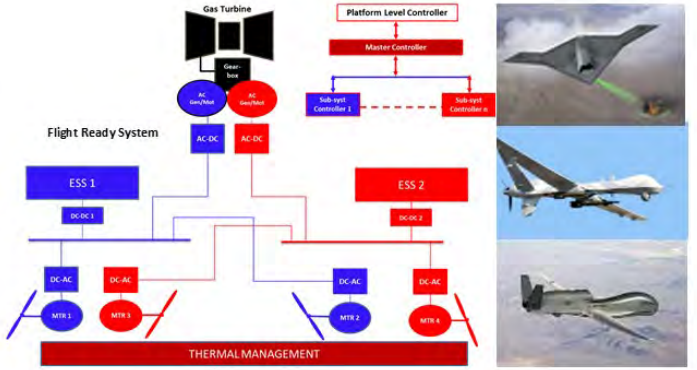


(2024 - 2026)

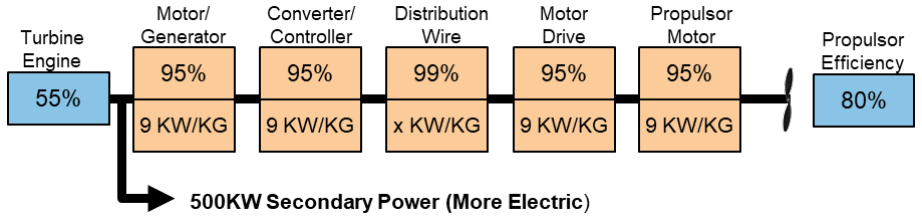
- **Engine/Power/Thermal Integration**
- **Mature Electrical Comp Tech**
  - Electrical Machines, High-V Distribution
- **Integrated TMS Approaches**
  - Conformal, Additive HTX
- **Scaled Hybrid Demo**
  - Controls, Operability, Alt Flight Modes
  - Scaled Grp-5 Relevant Architectures

(2027 - 2030)

- **Targeted Application Focus**
- **Integrated Architecture Demo**



Medium-Scale Integrated Propulsion, Power, Thermal (MSIPPT)



On High Electric Power, Electrified Aircraft Propulsion Systems

Challenges

- Better Mission/Segment Requirements
  - More than designs and claims for just one power at one speed
  - System-level design—e.g. thermal systems, EMI/EMC, PD, etc.
- Understanding component life – beyond just insulation temperature — and reliability
- Exhaustive testing – more than checkout, then claim success. Test, fix, fund/develop some more, repeat.
- *Available* facilities suitable for relevant power, speed, altitude/environment, voltage, etc.
- A broader understanding/appreciation of motor/generator nameplate ratings and their true capabilities
- How to distribute findings to broader audience?

Opportunity

- Upcoming “Affordable Power Generation” (name is TBD) AFWERX Challenge Program
  - Process to crowd source ideas, solutions, requirements with key stakeholders for secondary power (with electrified aircraft propulsion relevance & secondary benefits)
  - Contracting to ease burden for non-traditional government contractors (Commercial Solutions Offering)
    - Result of challenge is AFRL contract
  - To be announced before end of year

QUESTIONS?