Air Force
Power Requirements

January 24, 2006

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Power Division

Propulsion Directorate

Air Force Research Laboratory

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Outline

- Our Recent Heritage – MEA

- Our Plan – HiPAC

- HiPAC Technologies

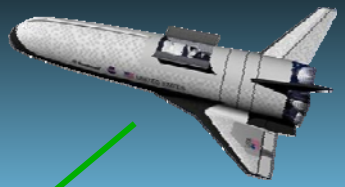
- Summary

Powering the United States Air Force

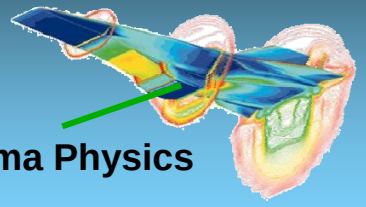
Air Force Research Lab
Power Technology Program

Internal Starter/
Generator (IS/G)

Low Spool
Power
Generator



Space Power and
Thermal Management

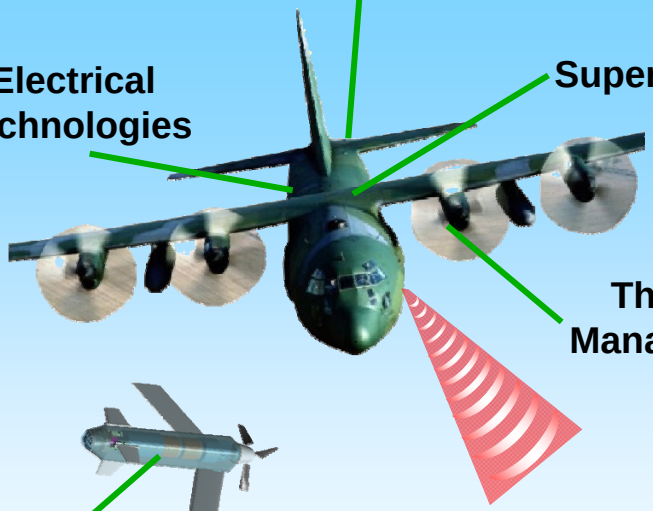


Plasma Physics

Electromagnetic Effects

Electrical
Technologies

Superconductivity



Thermal
Management

Fuel Cells

Electrical
Technologies

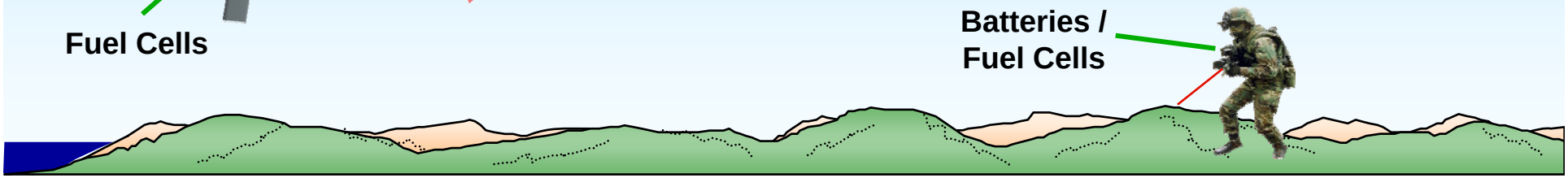
Electromagnetic
Effects

Batteries

Electromechanical/
Magnetic

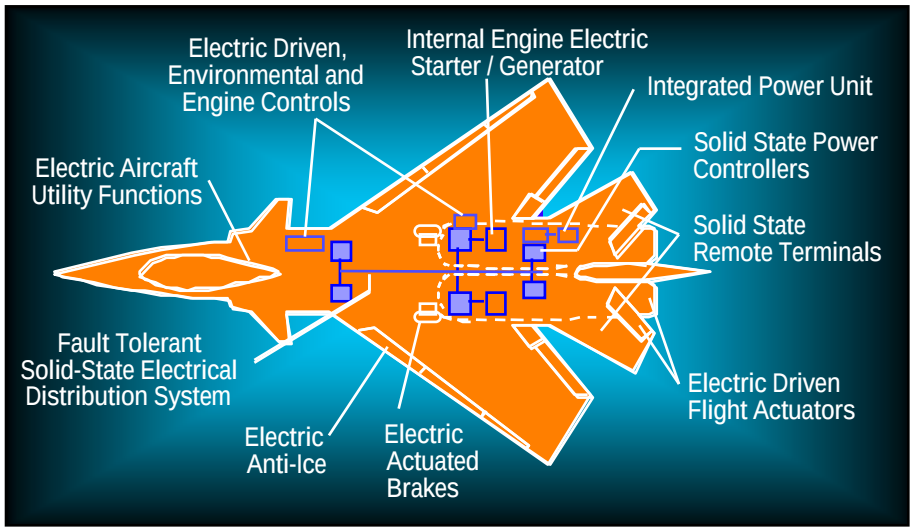
Thermal
Management

Batteries /
Fuel Cells



Our History:
The More Electric Aircraft

THE VISION → THE IMPACT



All-electric aircraft eliminates complex, inefficient, maintenance intensive…

- **Hydraulics**
- **Bleed Air Pneumatics**
- **Mechanical (gearbox) Subsystems**

Savings in $B's with improved warfighting

Enables mission available power for lethal airborne directed energy weapon

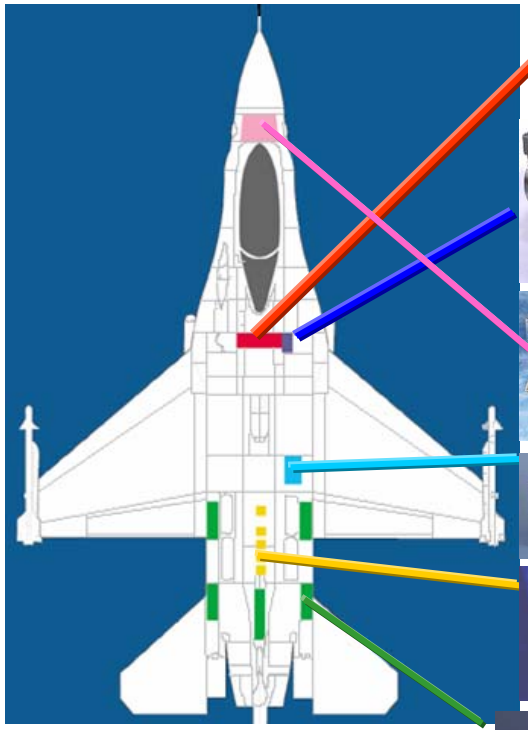
MEA Generation I Concept Transition to Lockheed F-35

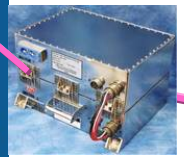
Affordable, High-Performance Baseline for F-35

AFTI/F-16 Demonstration Validates More-Electric Aircraft Technologies

Common Components

F-35 Subsystems Suite Identical to J/IST





Inverter/Converter/Controller (2) – Provides Conditioned 270-VDC Power to Flight Critical Actuation System

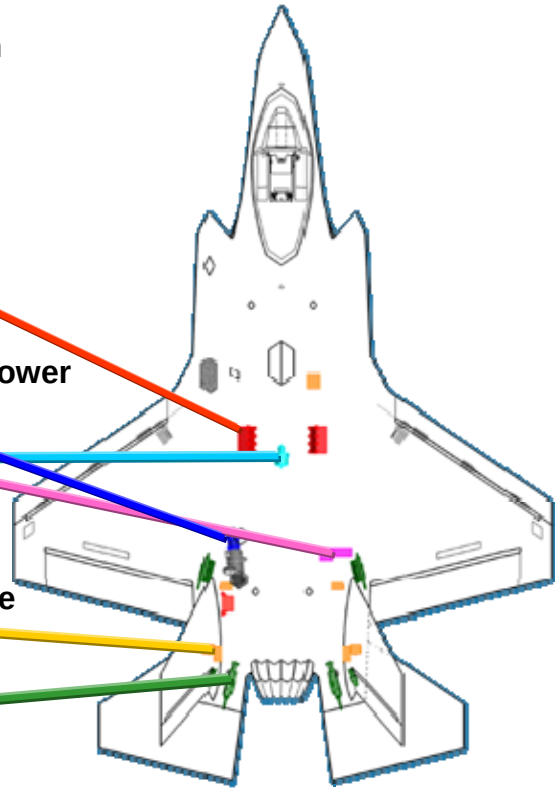
270-VDC Emergency Generator – Provides Independent Source of Electrical Power

270-VDC Battery – Provides Uninterruptible, Flight-Critical Power

Starter/Generator – Source for Redundant, Flight-Critical Power

Power Drive Electronics – Provide Modulated 270-VDC Power to Flight Control Actuators

Electro-hydrostatic Actuators – Provide Redundant Control Power at Each Control Surface



From Vision to Reality

F-35 IS THE FIRST TRULY "MORE ELECTRIC" AIRPLANE

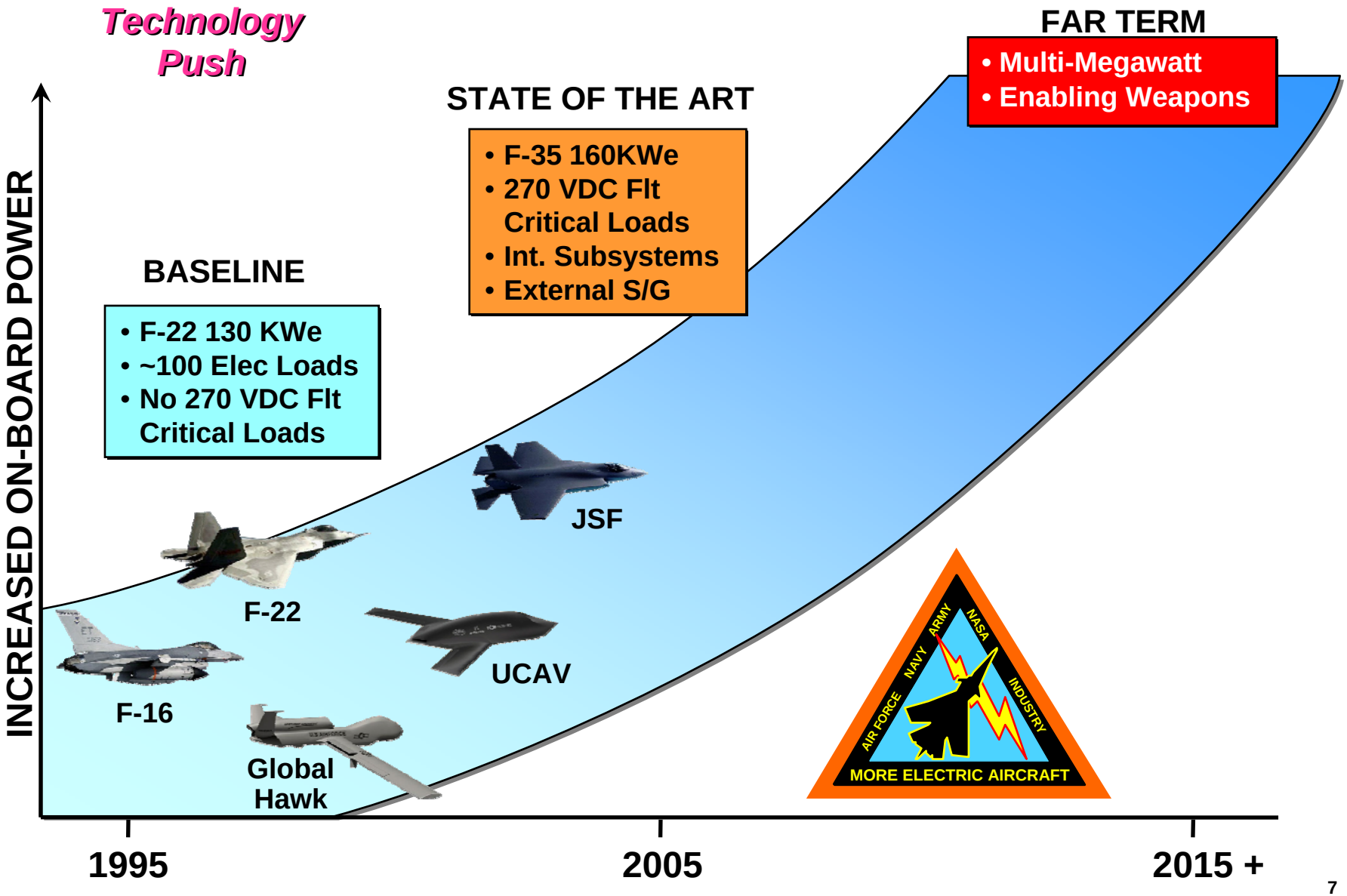
- Electric Engine Start
- Electric Power & Thermal Mgt System
- Electric Flight Control Actuation
- Electric Flight Control Power Systems

Electric Engine Start Ground Demo

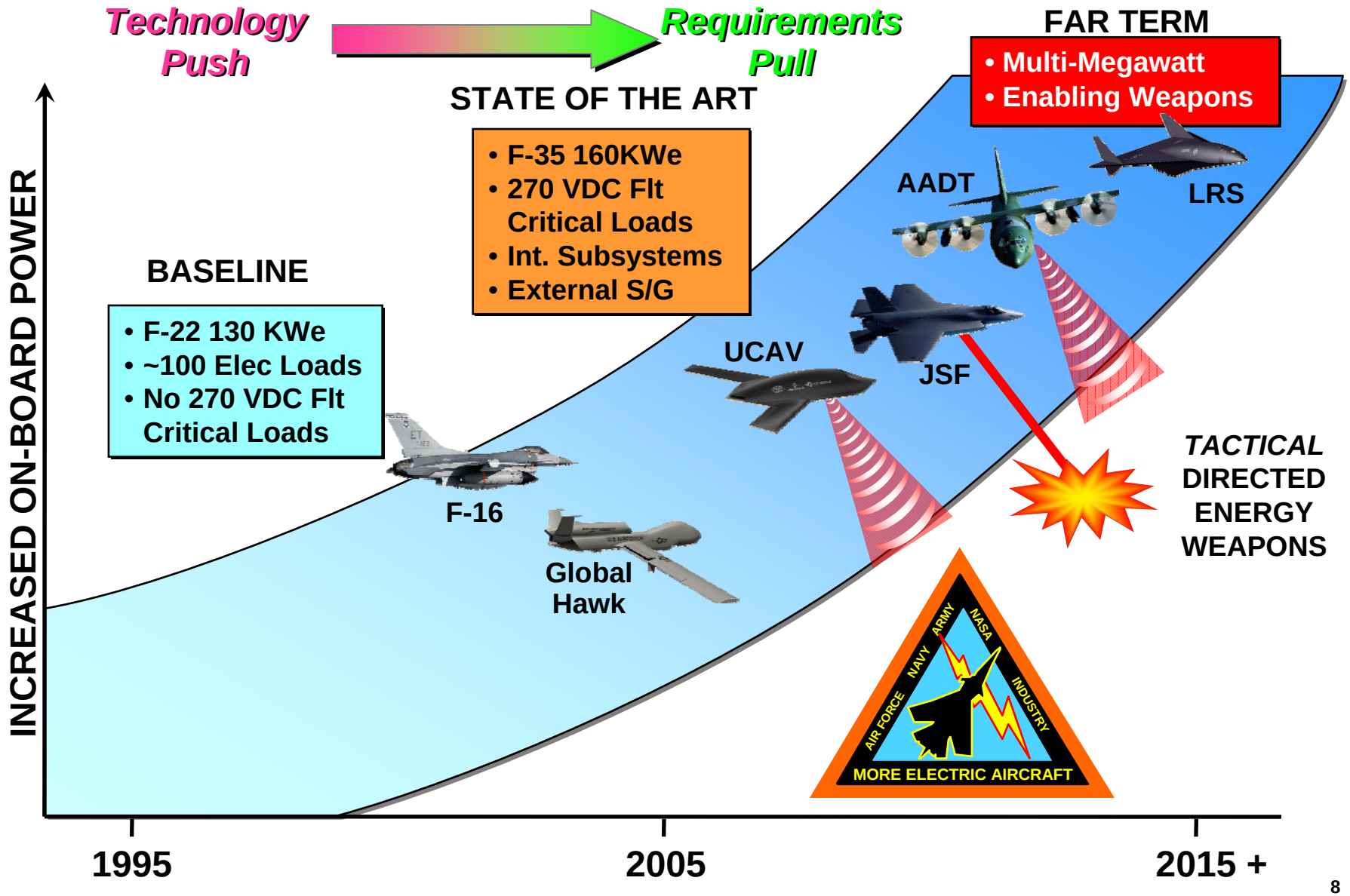
Starter/Generator / Electric Flight Control Actuation Flight Demo

MEA Thrust Initiated In 1987

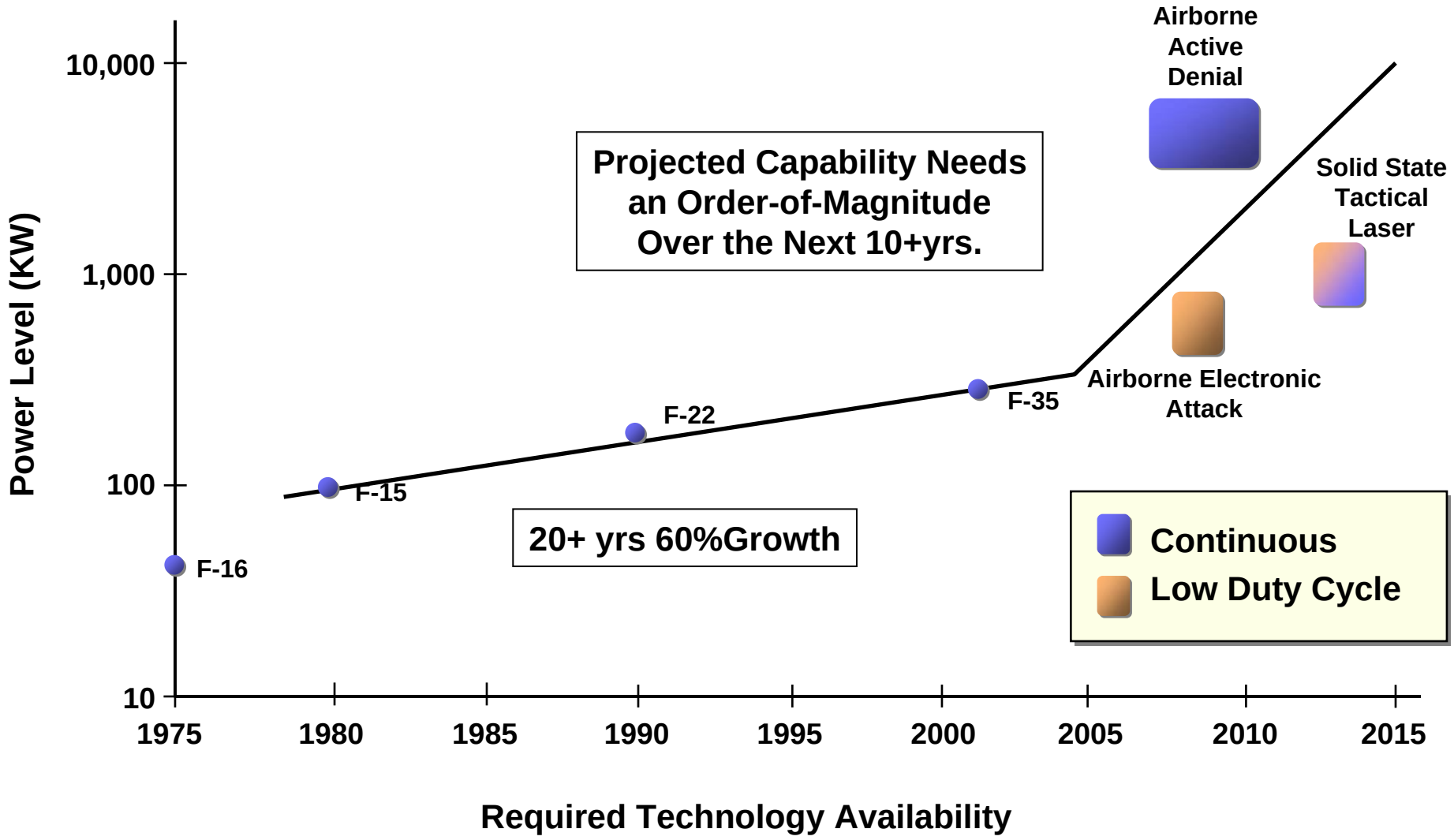
Exponential Growth for Power and Thermal Technology



Exponential Growth for Power and Thermal Technology



DE Weapons Need Unprecedented Power & Thermal Management



HiPAC Technical Program Areas

Micro-Mini Platforms

Munitions / UAV

Tactical Aircraft

Large Platforms

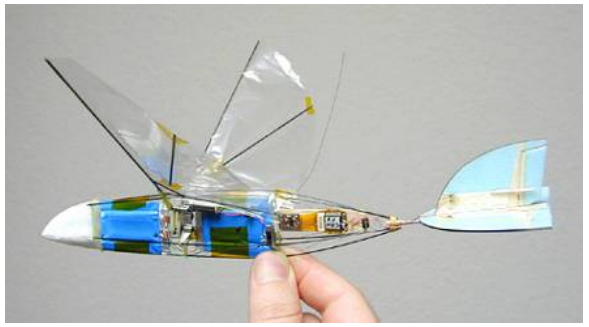
Directed Energy

- High Temperature Power System Components
- High Temperature Thermal Control Systems
- EMI Immunity
- Integrated Engine / Power Extraction
- Smart Power: Prognostics & Health Management
- MW Power Generation
- MMW Power Generation
- Active High Flux Thermal Control System
- Lightweight Compact Power Conditioning
- Energy Storage
- Electrochemical Power Generation
- MEMS Power Generation
- MEMS Thermal Management
- Pulse Power Components
- Subsystem Integration

Micro-Mini Platforms

CAPABILITY FOCUSED

Small Platforms with sub kW Power Requirements



Technologies:

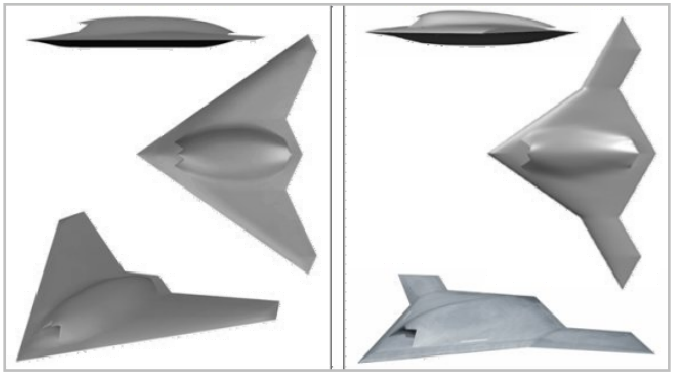
- **MEMS Power Generation**
- **MEMS Thermal Management**
- **Batteries**
- **Fuel Cells**

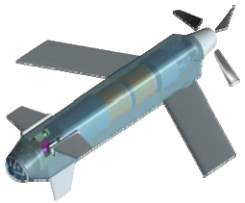
TECHNOLOGY ENABLED

Munitions / Small UAVs

CAPABILITY FOCUSED

Munitions / Small UAVs with 1-100 kW Power Requirements



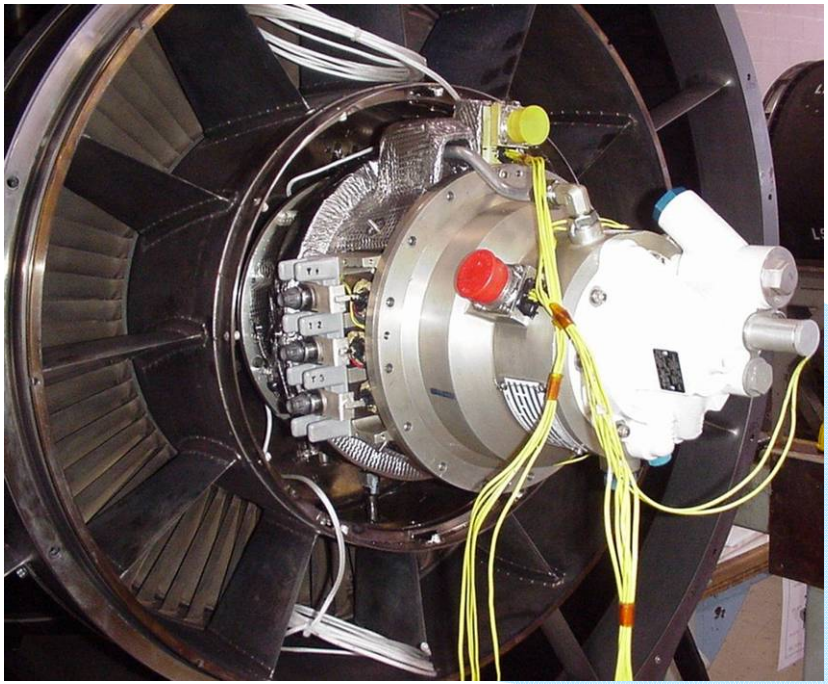


Technologies:

- EMI Immunity
- Integrated Engine / Power Extraction
- Smart Power – Prognostics and Health Management
- Electrochemical Power Generation
- Light Compact Power Conditioning
- Energy Storage

TECHNOLOGY ENABLED

Low Spool Generator for Global Hawk



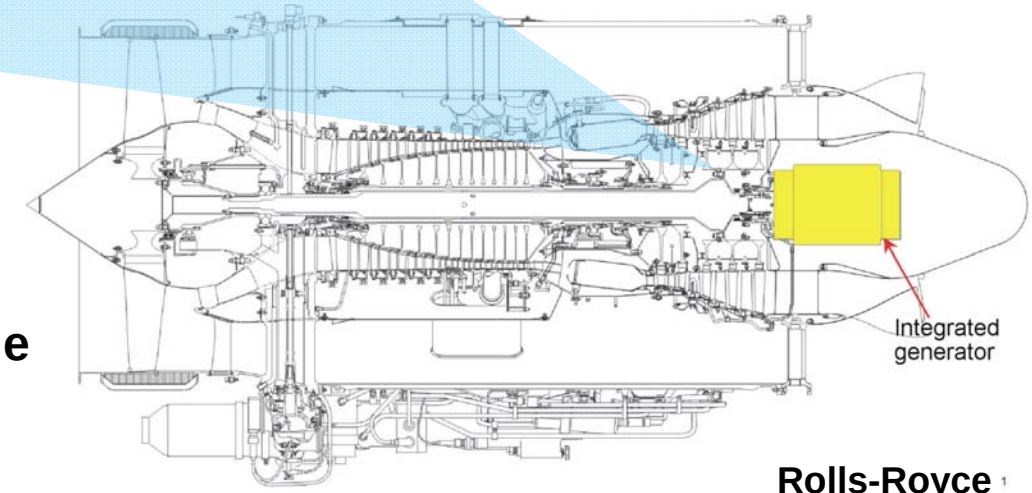
GLOBAL HAWK CAPABILITIES

NOW:
- 2000 lb Payload
- 24 Hour on Station
- 1200 NM range/ 60K ft altitude
- 10 KVA Payload Power

FUTURE:
- 3000lb Payload
- 20 Hour on Station
- 1200 NM range/ 60K ft altitude hold
- 25 KVA(Near-term); 75 KVA(Far-term)

Enables Advanced Sensor Upgrades for Global Hawk

AE3007 ENGINE - GLOBAL HAWK PROPULSION



Power Technologies Benefits :

- 15% Thrust Improvement at Altitude
- 7.5X Increase in Power Generated

Rolls-Royce

Tactical Aircraft

CAPABILITY FOCUSED

Tactical Aircraft with 100-500 kW Power Requirements

Technologies:

- High Temperature Power System Components
- High Temperature Thermal Control Systems
- Energy Storage
- Integrated Engine / Power Extraction
- EMI Immunity
- Smart Power: Prognostics & Health Management
- Lightweight Compact Power Conditioning
- Electrochemical Power Generation

TECHNOLOGY ENABLED

Li Ion Battery

- **Lithium Ion Technology Developed Under Joint AFRL/NASA/JPL Program Transitioned to B-2, F-35, and Mars Rovers**

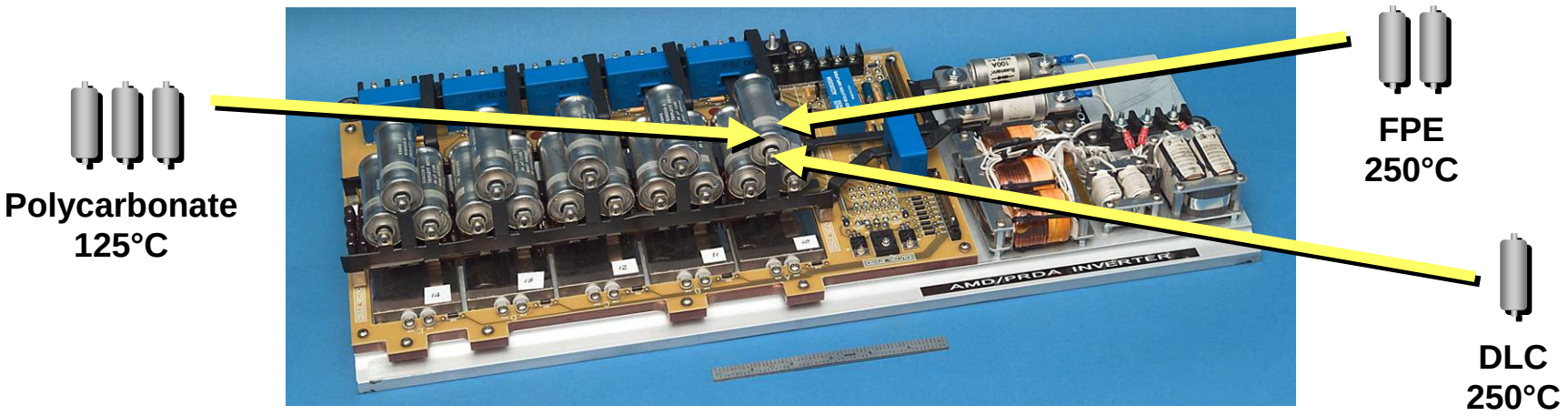
- **B-2 Batteries >350 Flight Test Hours Logged**
- **Mars Rover Batteries Fully Operational After 7 Month Cruise Through Space**

Revolutionary Capacitor Development

DIELECTRIC	DIELECTRIC CONSTANT	FILM THICKNESS	BREAKDOWN STRENGTH	UPPER-LIMIT TEMPERATURE	ENERGY DENSITY
POLYCARBONATE	3.2	3 m	5 KV/mil	125°C	> 1.0 J/g
FLUORENE POLYESTER (FPE)	3.4	3 m	10 KV/mil	250°C	> 2.0 J/g
DIAMOND-LIKE CARBON (DLC)	3.5	0.5 m	25 KV/mil	250°C	> 4.0 J/g

- **Low cost DLC thin film in-house process scale-up (Mar 01); Commercialization by FY04 (energy density)**

- **Enables DEW - - 2X increase in energy density**
- **Reduces size, weight & volume**



Large Platforms

CAPABILITY FOCUSED

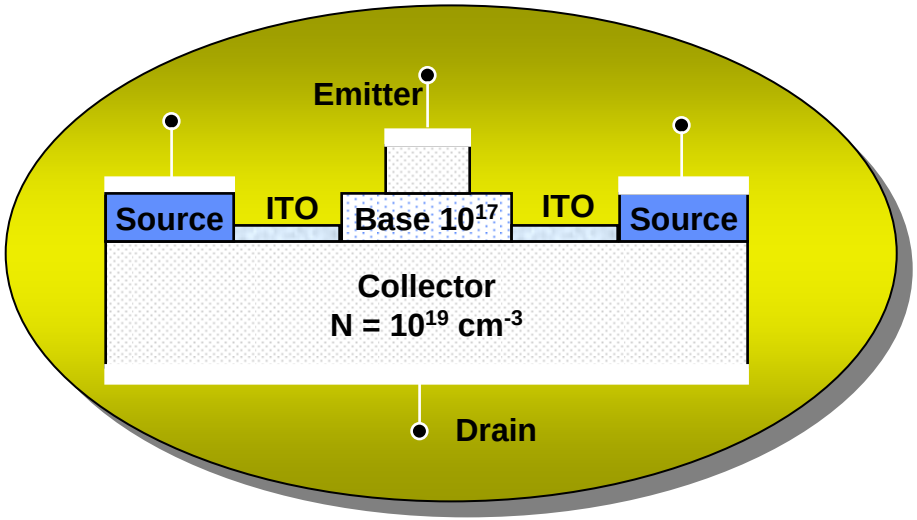
Large Platforms with 250 kW - 2+ MW Power Requirements

Technologies:

- MW-MMW Power Generation
- Integrated Engine / Power Extraction
- High Temperature Power System Components
- High Temperature Thermal Control Systems
- EMI Immunity
- Smart Power: Prognostics & Health Management
- Lightweight Compact Power Conditioning
- Energy Storage
- Electrochemical Power Generation

TECHNOLOGY ENABLED

Optically Triggered SiC Switch



TECHNICAL CHALLENGES:

Device design is foundational. Carrier transport and optical generation not quantified.

APPROACH:

- **Develop key fabrication components**
  - **SiC photo-transistors (600V, 60-150A)**
  - **SiC "PGBT"-based switches**
  - **2-D modeling in parallel with fab.**
- **Demo devices in electric actuator drive controllers or I-H motor drive**

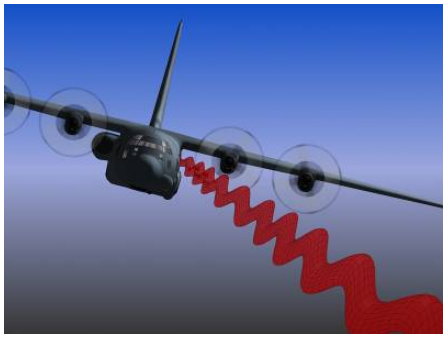
OBJECTIVE & PAYOFF:

Reduce actuator weight while providing photonic switching device to satisfy the robust actuator switching requirements for an EMI invulnerable FBL/PBW airframe concept.

Directed Energy

CAPABILITY FOCUSED

Directed Energy Concepts with 250 kW - MMW Power Requirements



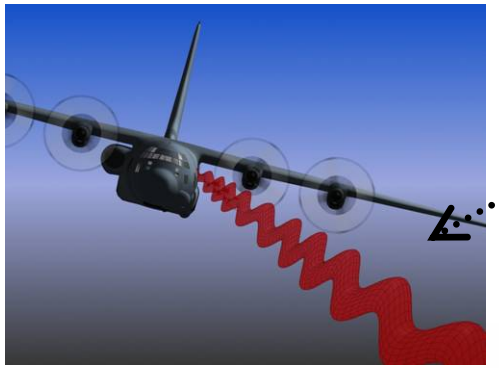
Technologies:

- Integrated Engine / Power Extraction
- MW-MMW Power Generation
- Active High Flux Thermal Control System
- Lightweight Compact Power Conditioning
- Energy Storage
- Pulse Power Components
- EMI Immunity
- High Temp. Power System Comp.
- High Temperature Thermal Control Systems
- Smart Power: Prognostics & Health Management

TECHNOLOGY ENABLED

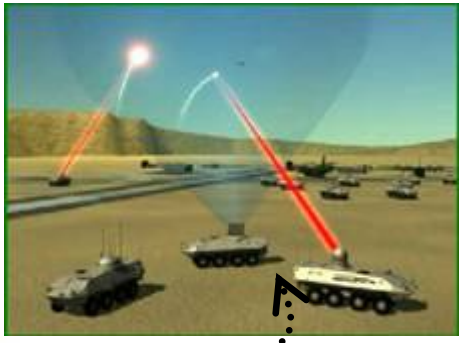
Multimegawatt Electric Power System

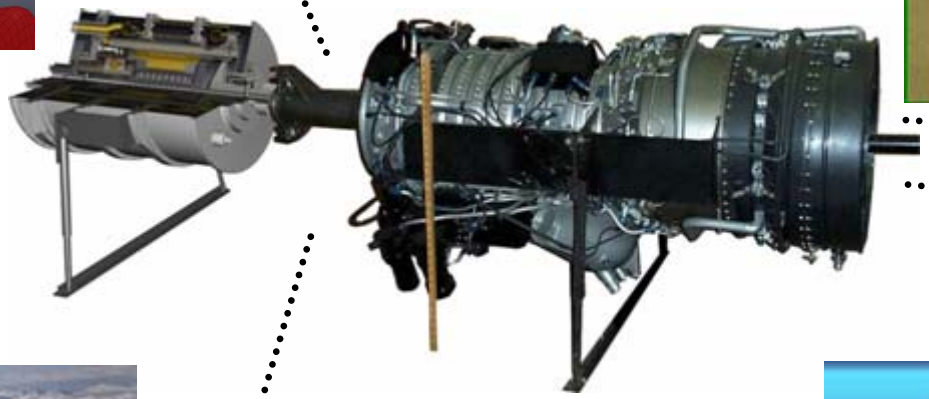
1-5 MW Capability Needed for Multiple Applications



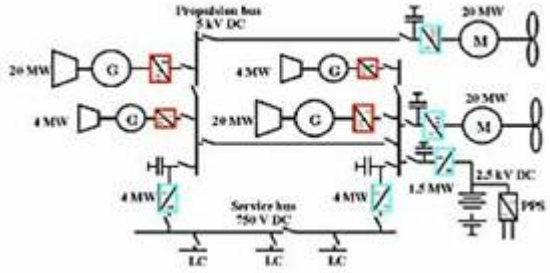
Directed Energy Weapons

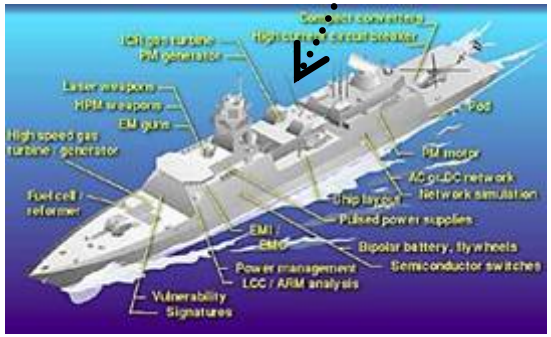
Army Future Combat Systems Electric Weapons





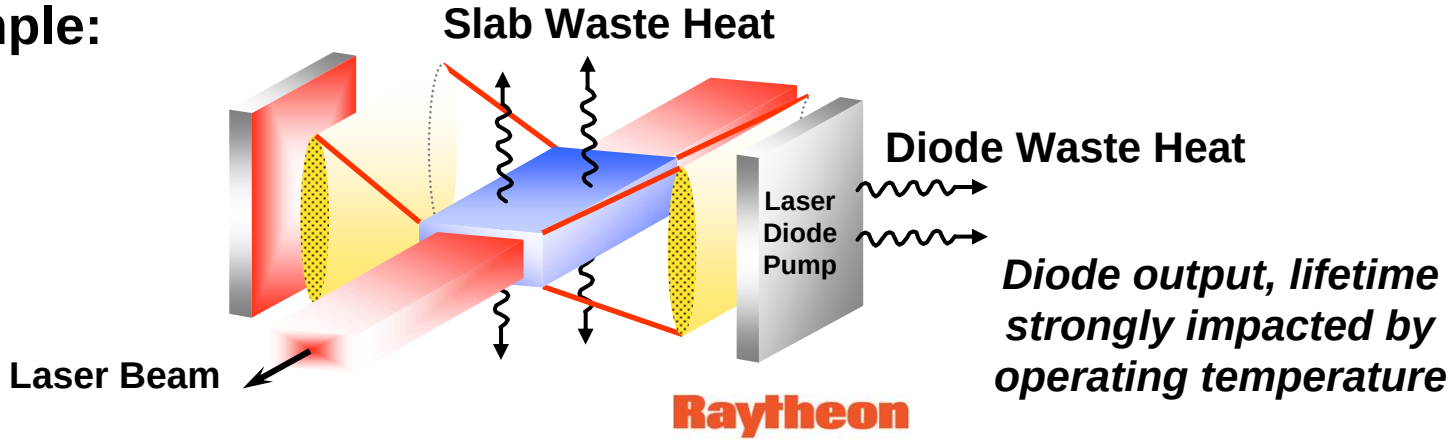
Navy Distributed Power





Power & Thermal Management ... Critical to DEW System Success

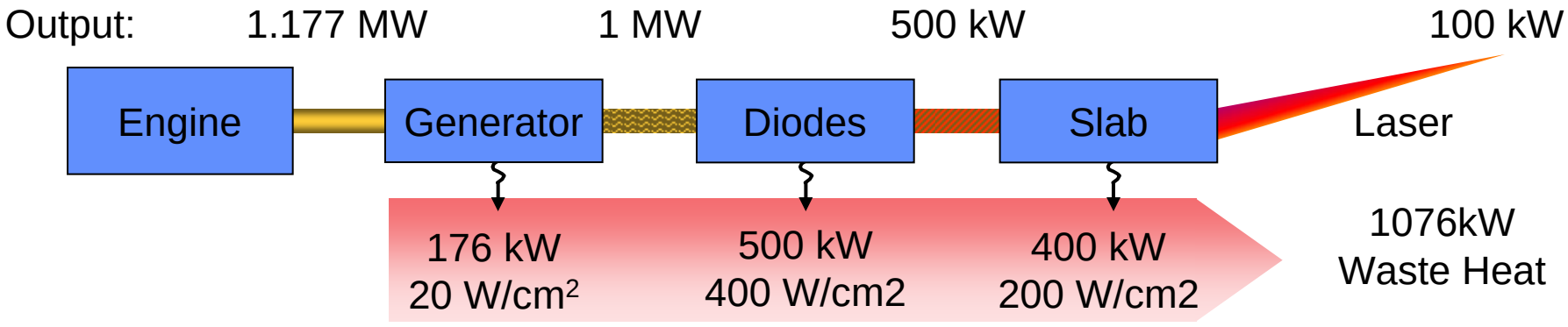
HEL Example:



Diode output, lifetime strongly impacted by operating temperature

The overall efficiency of solid state lasers vary from 10% to 30%, thus large amounts of waste heat must be managed

- As an example, for a 10% efficient laser



High Power for Aircraft Initiative

Five Power Regimes from Watts to Multi-Megawatts

Meet Today's and Tomorrow's Need for Unprecedented Power and Thermal Management

System Approach to Integrated and Optimized Weapons Power and Thermal Management

Powering the United States Air Force!