Air Force Research Laboratory

AFRL Game Changing Technology:
The Self-Protect High Energy Laser Demonstrator (SHiELD) ATD

26 June 2017

Dr. Rich Bagnell
SHiELD ATD Program Manager
Directed Energy Directorate
Air Force Research Laboratory

America's Air Force:
A Call To The Future

Strategic Vectors for the Future

- Provide effective 21st century deterrence
- Maintain robust and flexible Global Integrated ISR
- Ensure full-spectrum capable, high-end focused force
- Pursue a multi-domain approach to our Five Core Missions
- Continue pursuit of Game-Changing technologies
  - Hypersonics
  - Nanotechnology
  - Directed Energy
  - Unmanned Systems
  - Autonomous Systems

AFRL HERITAGE | 1917–2017

Directed Energy Directorate

Mission: Lead the discovery, development and delivery of directed energy science and technology for National Security

Core Technical Competencies

High Power Electromagnetics

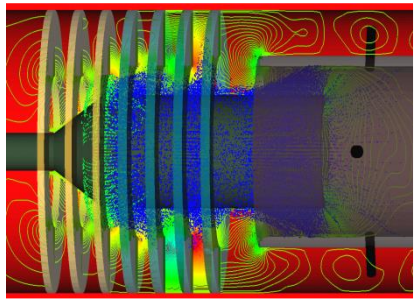
- Non-lethal counter-electronics technology (disrupt critical electronic systems)
- Advanced pulsed power sources
- High power electromagnetic effects and predictive modeling

Laser Systems

- Future offensive and defensive laser concepts
- Advanced Beam Control
- Gas, solid state, and fiber laser sources
- Laser effects and predictive modeling

Directed Energy and Electro-Optics for Space Superiority

- Space Situational Awareness
- Track and image space objects from ground-based telescopes
- Adaptive optic technologies to compensate for atmospheric distortions



Weapons Modeling and Simulation

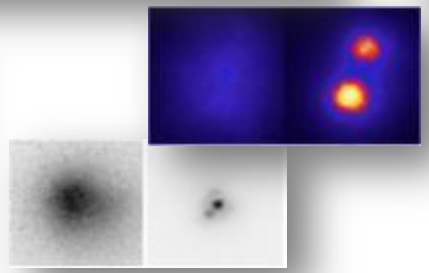
- Concept analysis
- Model synergy of directed energy and kinetic weapons at mission level
- Computer modeling saves time, lowers costs, and provides warfighter with predictive capabilities

Vision: Speed of Light to the Fight by 2020

AFRL/Directed Energy Directorate
Technology Heritage

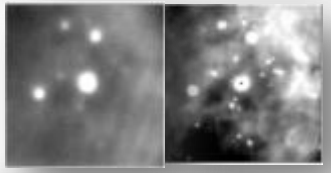
COIL Laser

Rayleigh Laser
Guidestar



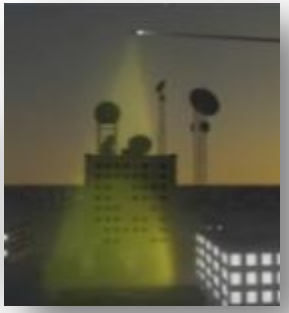
Guidestar Closed-loop
Adaptive Optics
Generations I and II

3.6m AEOS
Telescope



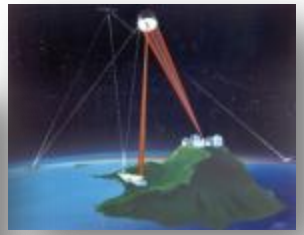
Guidestar
Rayleigh vs
Sodium

Sodium Laser
Guidestar



CHAMP

Mobile HPM



Relay Mirror
Experiment

3.5 m SOR
Telescope

Millimeter Wave Active Denial Technology

1980 | 1990 | 2000 | 2010 | 2017

AF High Power Laser System History

Gas Laser Era

Electric Laser Era

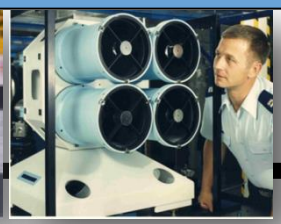
What Did We Learn?

- Ability to engage/destroy targets at range
- Non-laser subsystems must be matured
- Aero-optics must be addressed
- Gas laser weapons systems are large, logistically hard to support, expensive

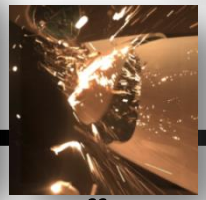
What We Are Learning

- Multiple approaches for laser source
- Further maturation of other key subsystems
- Addressing aero-optics for complex flow
- Design cycles with increased power & BQ

COIL Laser

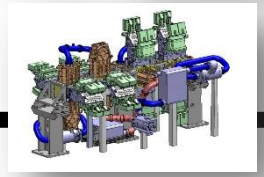


Phased Arrays



Effects

Beam Combining



High Power Bulk Media

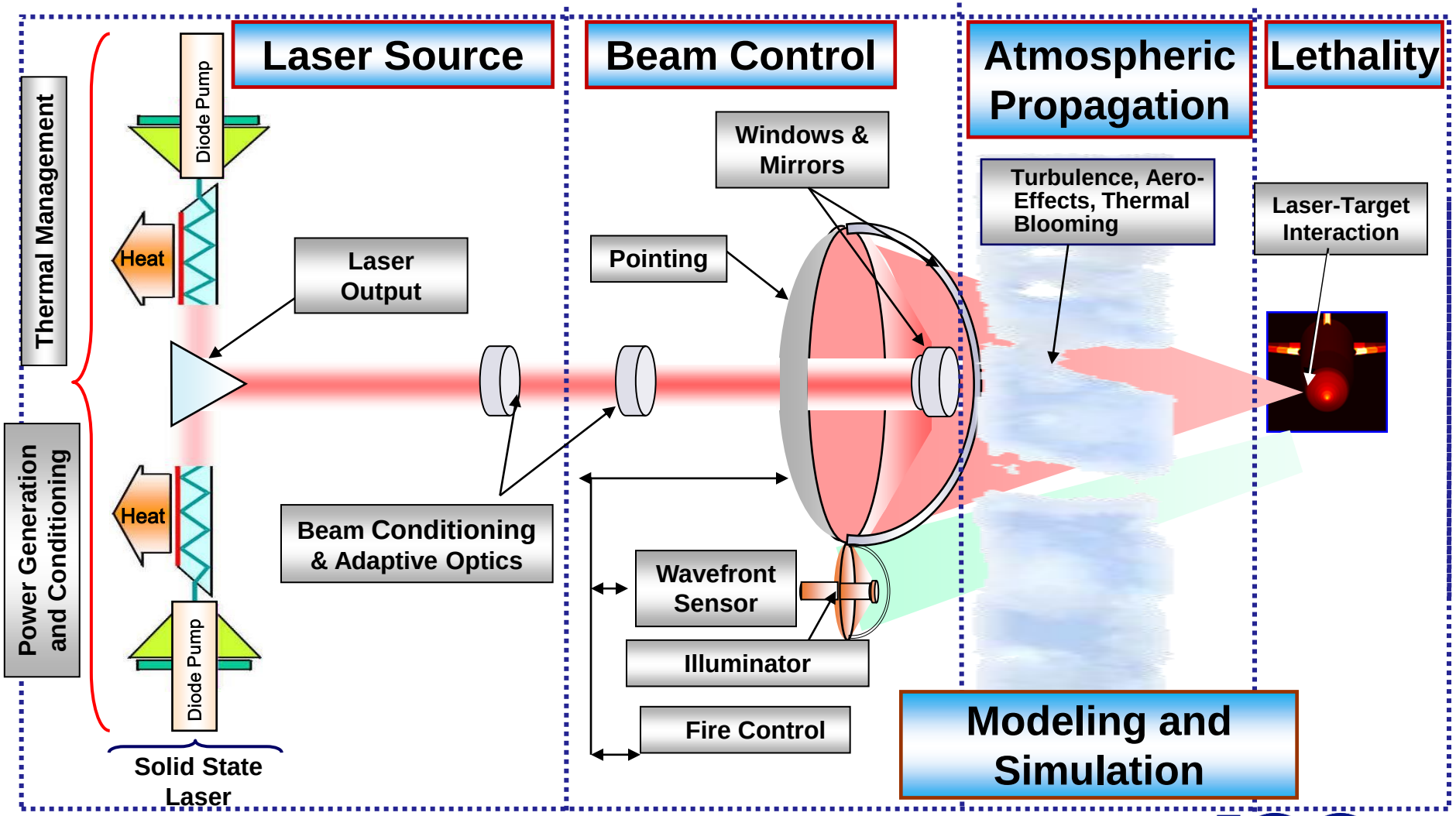
1980 1990 2000 2010 2020

10's kW Chemical

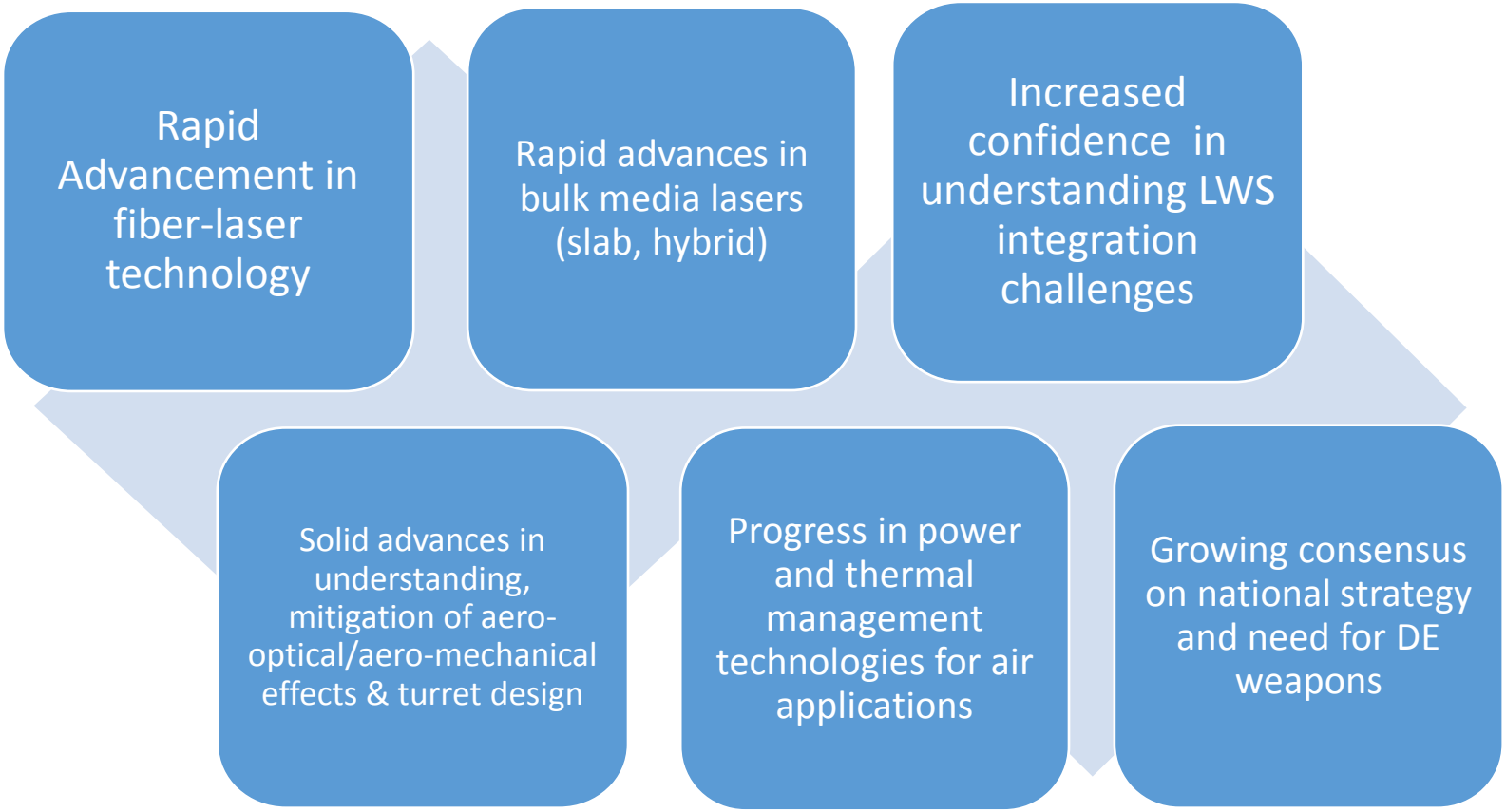
MW level Chemical

100's kW Electrical & better SWaP

Laser Weapon System Overview



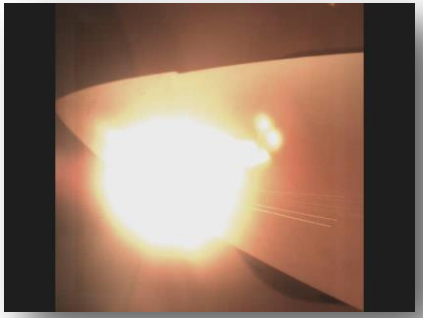
Laser Technical Strategy Drivers



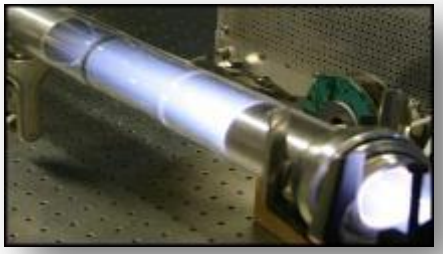
Multiple Laser Technology Advances Support a Wide Range of Applications

Enabling Technologies: Lasers System Technologies

Laser Effects

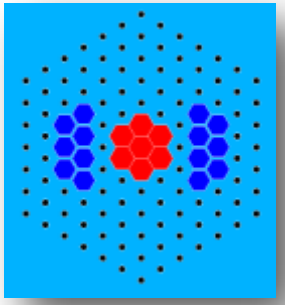


Gas Lasers

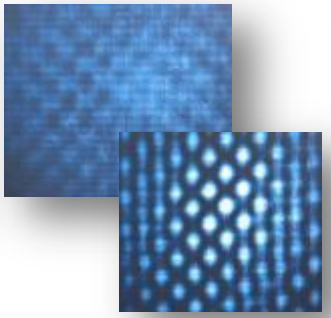


Solid State Lasers

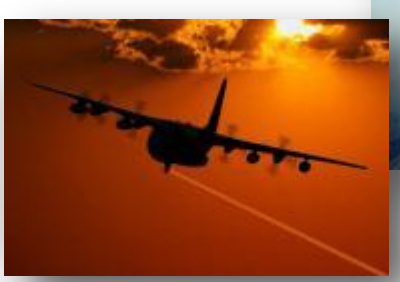
Fiber Lasers



Beam Combining



Acquisition, Tracking, Pointing Power and Thermal

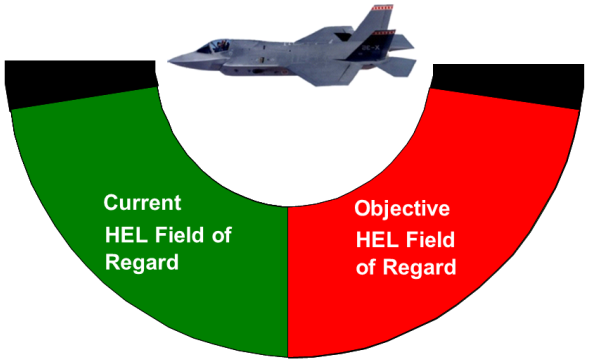


Laser System Integration

Enabling Technologies: Aero-optic/Aero-adaptive Beam Control (ABC)

Program Goals and Objectives

- Develop an aero-optic/aero-adaptive beam control (ABC) capability to increase lethality of airborne High Energy Laser (HEL) systems in the aft field of regard



Technical Approach

- Optimize flow control strategies for pointing angles through wake turbulence
- Explore the ability of the flow control system to complement adaptive optics

Military Utility

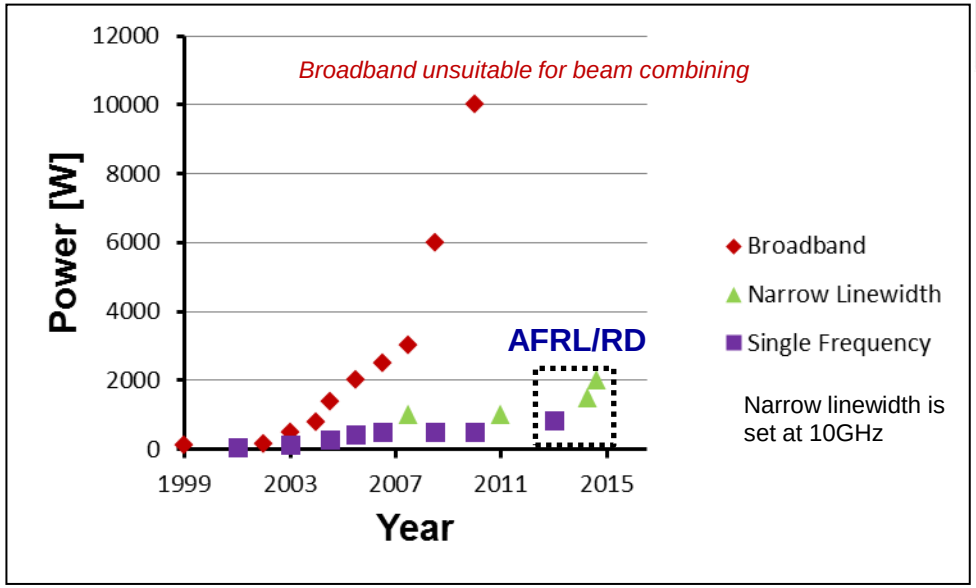
- Order of magnitude improvement in fluence in the aft field of regard enables efficient integration onto tactical platforms for self defense

Enabling Technologies: Fiber Laser Advantages & Challenges

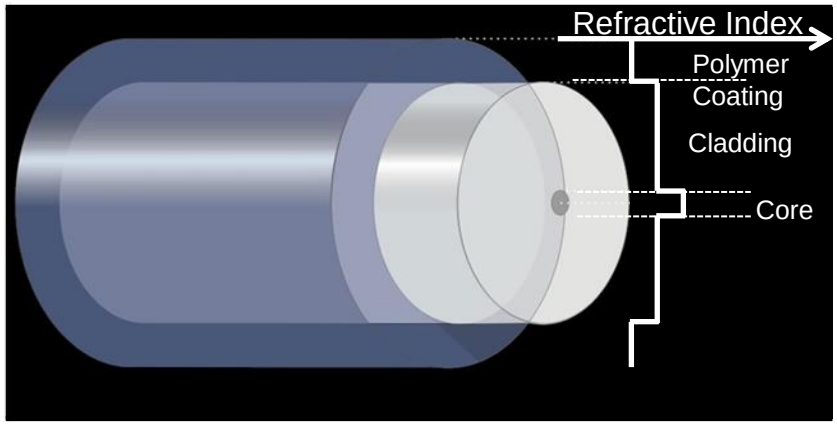
Fiber laser systems offer advantages over other solid-state devices

- Compact; Small size/low weight (SWaP favorable)
- Simple architecture (monolithic)
  - Reduction in free space optics
- High efficiency
  - ~35-40% wall plug efficiency, Yb-doped fibers
  - ~90% optical-to-optical efficiency
- Diffraction limited beam quality
- Excellent thermal management
- Spectral or coherent combining for power scaling

Yb-Doped Fiber Laser Power Scaling Trends

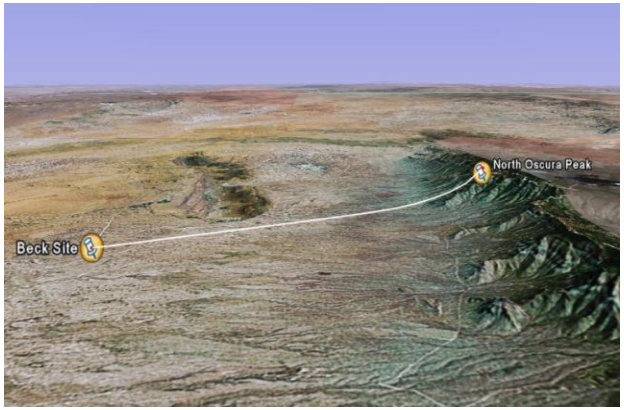


Double Clad Fiber



Challenges to scaling linewidth fiber laser amplifiers to high power: Stimulated Brillouin Scattering and Modal Instabilities

Enabling Technologies: HELLADS Demonstrator Laser Weapon System (DLWS)



Demo configuration for missile engagement

Integrated System

Program

- Joint AF/DARPA program
- First demo of fully integrated, 150kW class solid state laser (SSL) weapon system
- Significant breakthroughs in SSL power and beam quality
- Laser delivery late summer 2015
- Integrated high power tests complete
- Will be used for early SHiELD concept proofs

Status & Impact

- Field lethality data, M&S tool, and integration lessons learned
- Speed of light action can engage extremely fast targets
- Laser precision enables targeting swarms
- Safety protocols ensure safe laser operations in field

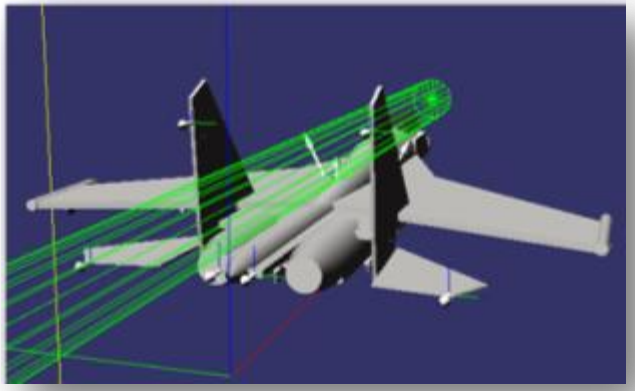
Existence Proof for 150kW Class Electric Laser Weapon

Distribution A: Approved for Public Release

Enabling Technologies: Weapons Modeling & Simulation

DE and DE/Kinetic Energy Concept and Mission Effectiveness Analysis

Systems and Missions Modeling and Simulation



Self-Protect High Energy Laser Demonstrator (SHiELD) Advanced Technology Demonstration (ATD)

Description

- SHiELD was commissioned by the Air Combat Command Applied Technology Council as an Advanced Technology Demonstration (ATD)
- SHiELD is an effort to integrate a high energy laser system onto a tactical aircraft to demonstrate self-protection from threats

Purpose

- Retire Science and Technology risks associated with integrating high energy lasers on fighter aircraft
- Demonstrate maturity of integrated laser systems in a complex flight environment

Approach

- 2-Phased approach
- Phase 1: Low power system demonstrating aero-effects mitigation
  - Aircraft and laser system compatibility and concept of employment
  - Acquisition, tracking, and pointing performance on threats
  - Characterization of aero-effects to develop concepts to expand operational envelop
  - Improved performance through aero-effects mitigation
- Phase 2: High power system demonstrating performance in flight against threats
  - Aircraft & high power laser system compatibility & concept of employment
  - Provides initial data for reliability, maintainability, availability
  - Anchors system models with flight data
  - Informs follow-on science and technology investments

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SHiELD Industrial Partners

- STRAFE (SHiELD Turret Research in Aero-effects)
  - Awarded 16 Aug 2016: Northrop Grumman Corporation
  - Beam Control subsystem which acquires the target, tracks it and delivers the laser output beam to the target aimpoint
- LPRD (Laser Pod Research and Development)
  - Awarded 14 Dec 2016: Boeing Corporation
  - Integrated aero-dynamic pod—contains the separately developed laser and beam control subsystems, and supplies them with power, cooling and overall system control
- LANCE (Laser Advancements for Next-Generation Compact Environments)
  - In evaluation
  - High Energy Laser subsystem

AF Roadmap: Laser Weapons

Entry level capability for self defense

- A-A Missions: Defeat incoming threats

Notional concept on 4th and 5th gen aircraft

- Aircraft self-defense: defeat moderate salvo of SAMs
- A-A missions: Defeat threats at moderate range
- A-G Missions: Ultra-precise weapon against moderately hard targets

Notional concept on 6th gen aircraft

- Defeat aircraft beyond visual range
- Defeat hard targets in flight at range
- Hard ground target defeat

Key Laser System S&T Disciplines

- Target effects
- Acquisition, Tracking, and Pointing
- Beam Control & Aero-effects
- Laser sources
- Power & thermal management
- Numerical design & analysis

2018-2021	2025	2029+

Reducing SWaP and Increasing Capability for A2/AD Environment