Air Force Research Laboratory

Integrity ★ Service ★ Excellence

Systems Engineering & Basic Research

28 October 2015

Wednesday, 10:50 am – 11:25 am

Presentation 17856

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Program Manager

Air Force Office of Scientific Research

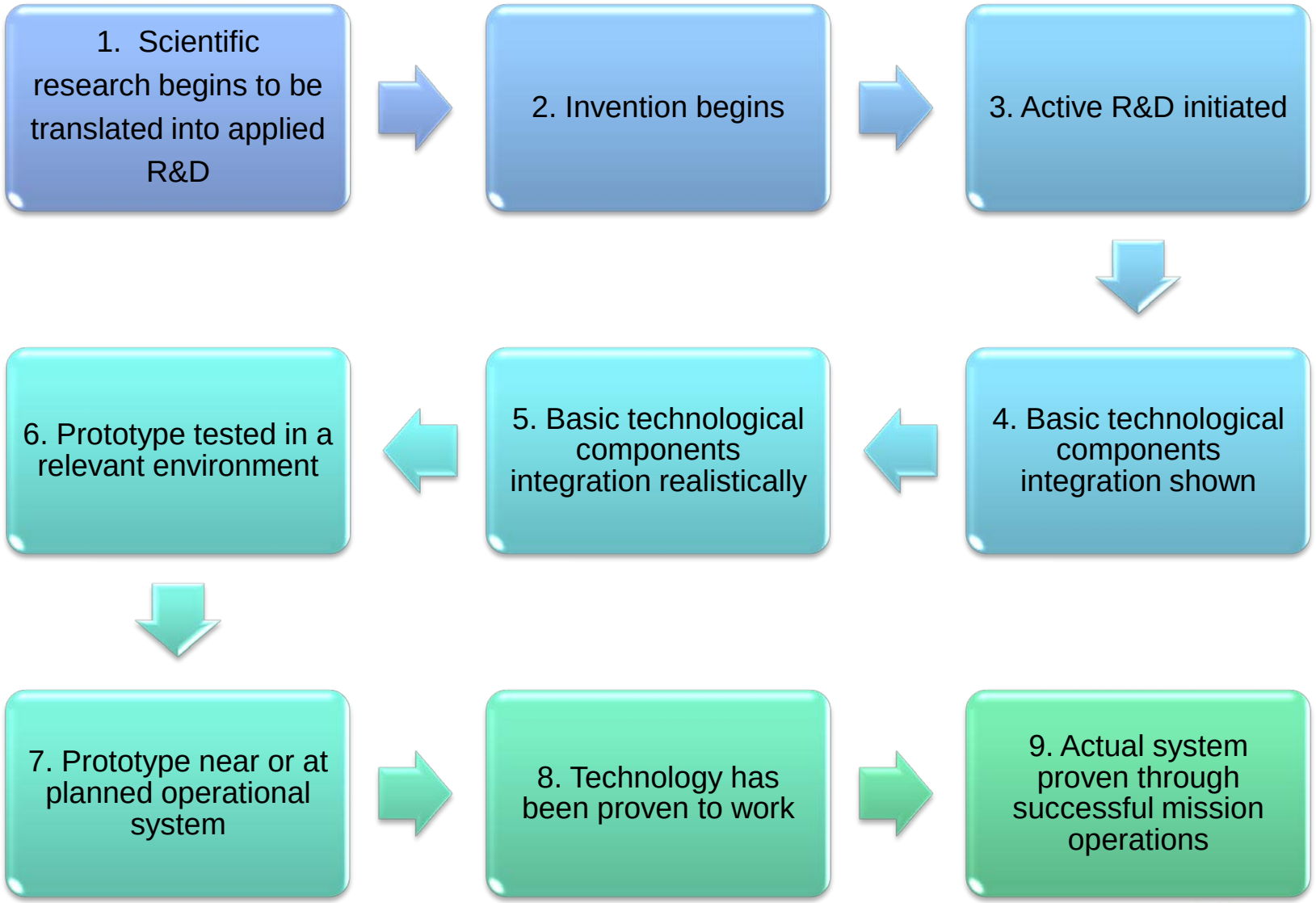
Overview

- **In a nutshell, the presentation will discuss the intersection of basic research and systems engineering**
- **Examples of current basic research will be discussed in juxtaposition of systems engineering principles**

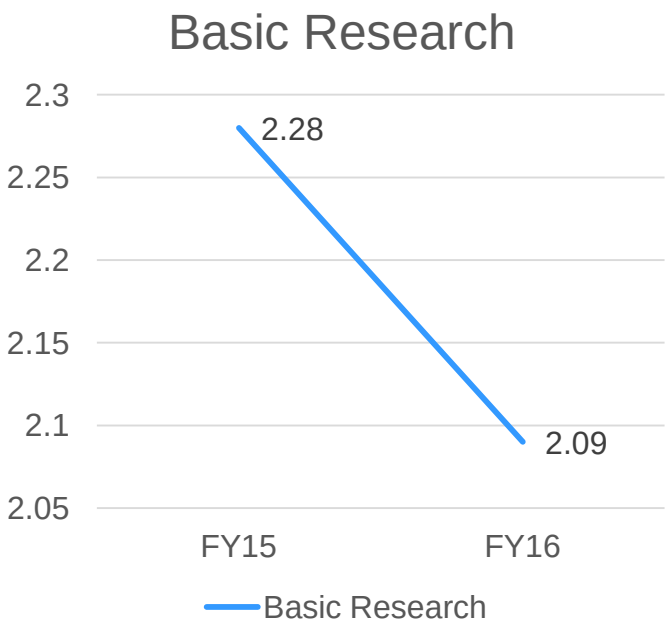
Systems Eng v. Basic Research

- **Systems engineering:**
  - **Very structured process in order to achieve highly defined objectives and requirements**
- **Basic research:**
  - **The fundamental step in the Research, Development, Test, and Evaluation (RDT&E) life cycle**
  - **Does not employ such a structured process, and instead favors creative discovery**

Technology Readiness Levels (TRLs)



President's Budget



FY16 President's budget:

- decrease basic research (6.1) funding (FY15 $2.28B to FY16 $2.09B)
- decrease ~ 8.3%

Basic research S&Es must utilize every resource in order to *"do more, without more"*

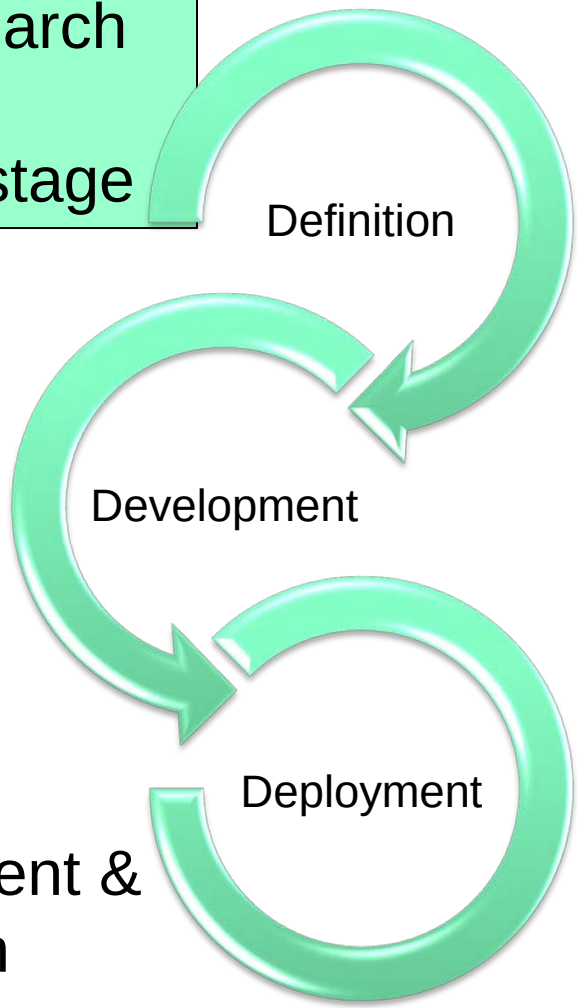
This is the battle cry of Systems Engineering, and in utilizing Systems Engineering principles, basic research S&Es will be able to maintain the balance required to improve performance while maintaining affordability

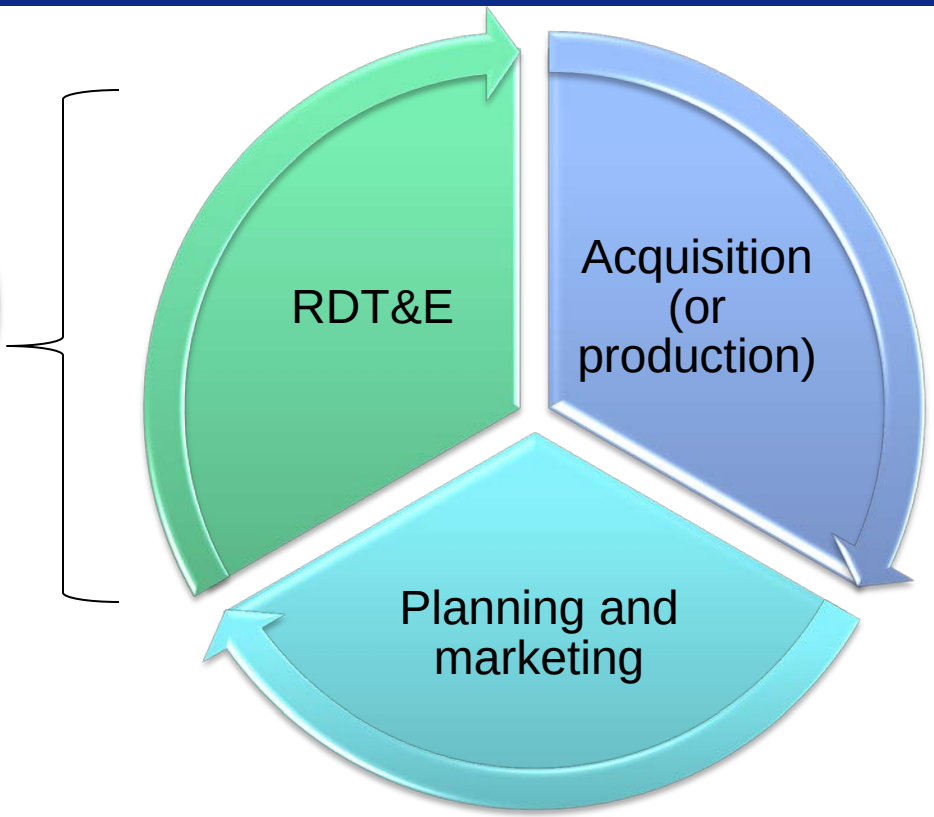
Systems Engineering & Basic Research

Basic research is in the definition stage

Applied Research & T&E

Full Scale Development & Production Support

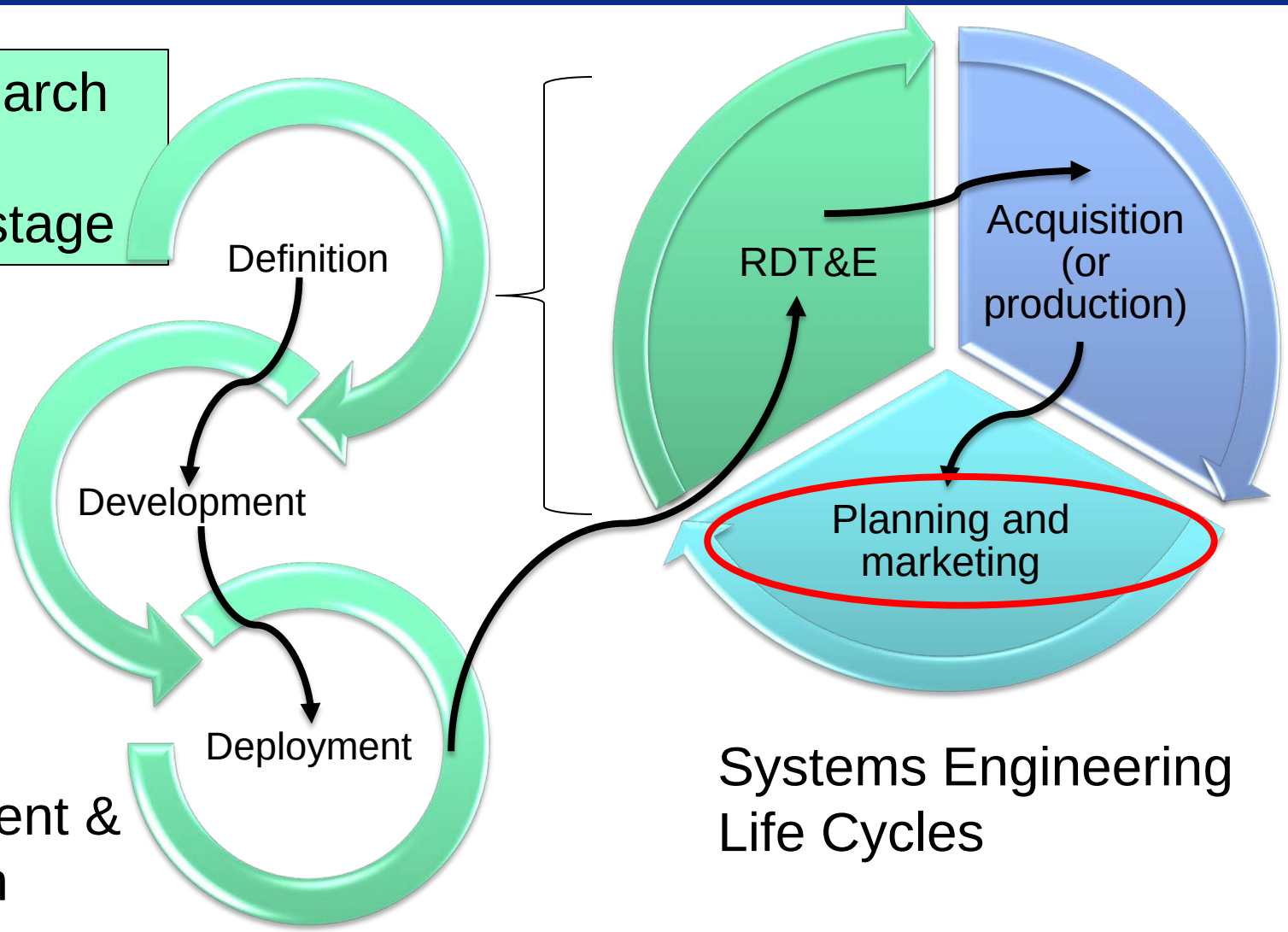




Systems Engineering Life Cycles

Systems Engineering & Basic Research GOAL

Basic research is in the definition stage



Applied Research & T&E

Full Scale Development & Production Support

Systems Engineering Life Cycles

United States Air Force Mission

The Mission of the United States Air Force is to

Fly, Fight, and Win…In *Air, Space, and Cyberspace*

"The first essential of air power necessary for our national security is preeminence in Research."

- General Henry "Hap" Arnold

"…innovation – fueled by intelligent, creative Airmen – will remain a key part of who we are and what we value as a service." Gen Welsh, CSAF

Air Force Leadership

President Barack H. Obama,
Commander-in-Chief

Secretary of Defense
Ashton B. Carter

Secretary of the Air Force
Deborah Lee James

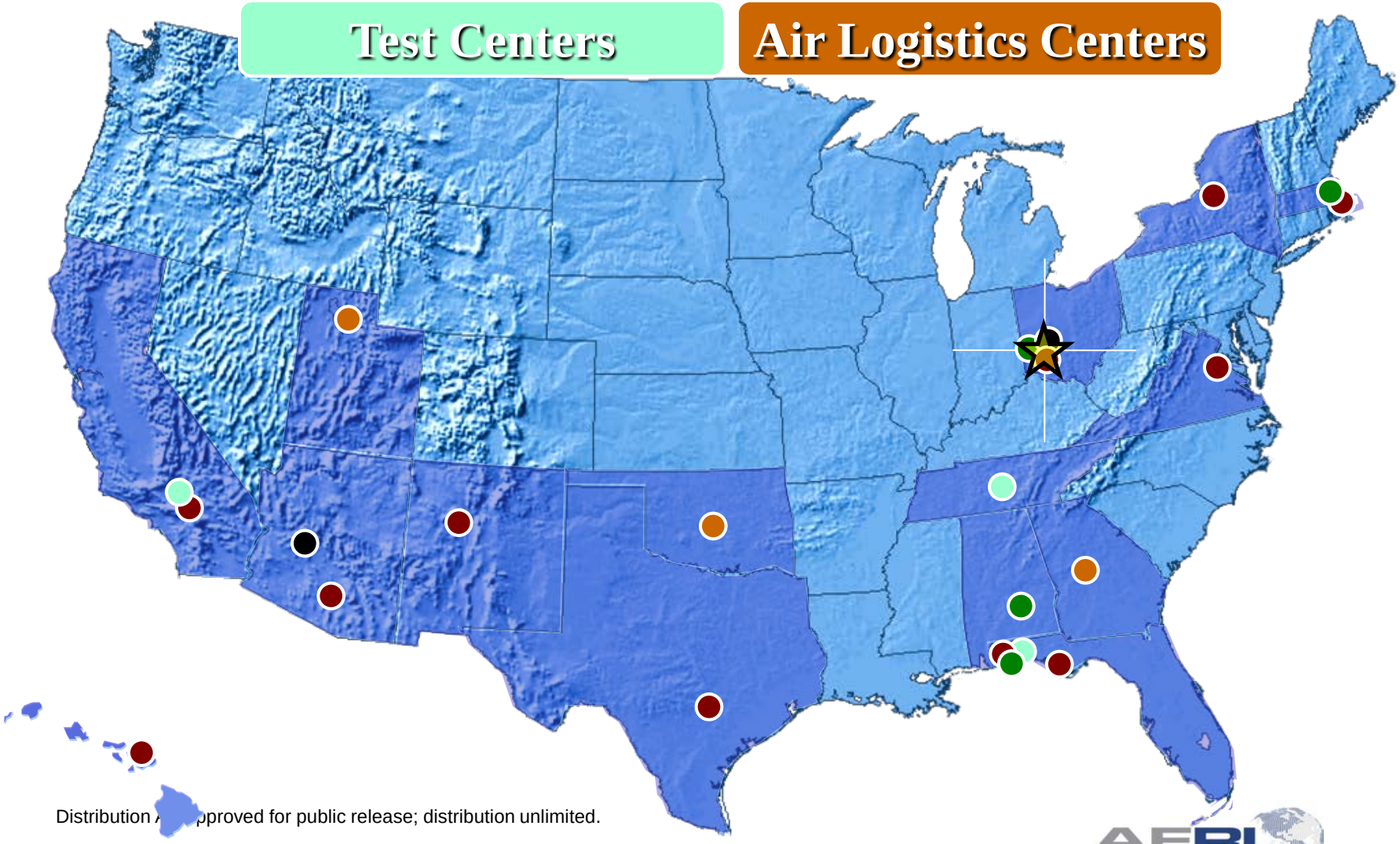
General Ellen M. Pawlikowski
AFMC Commander

Major General Thomas J. Masiello
AFMC Commander

AFMC - Who We Are

AF Research Lab | **Product Centers** | **Specialized Units**

Test Centers | **Air Logistics Centers**



AFRL

Air Force Research Laboratory (AFRL) Mission

LEADING the discovery, development, and integration of affordable warfighting technologies for our air, space, and cyberspace force.

Air Force Research Laboratory (AFRL) at a Glance

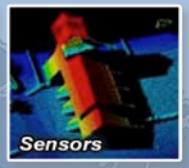
AFRL Headquarters

711th Human Performance Wing

Materials & Manufacturing

Aerospace Systems

Sensors

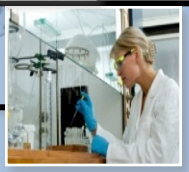


Information
Rome Research Site, NY

Rome Research Site, NY

Wright-Patterson AFB, OH

Arlington, VA



AF Office of Scientific Research

Edwards AFB, CA

Kirtland AFB, NM

Space Vehicles
Directed Energy

Ft. Sam, TX

Eglin AFB, FL

Munitions
Eglin Air Force Base, FL

International Sites

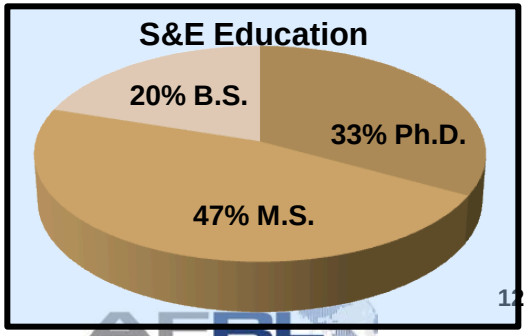
London, UK

Tokyo, Japan

Santiago, Chile

Maui Research Site, HI

	Employees	Civilian	Military
Total	5,827	79%	21%
S&Es	3,455	80%	20%



AFRL Technical Directorates and Core Competencies

AF Office of Scientific Research
- Aerospace, Chemical & Material Sciences
- Education & Outreach
- Mathematics, Information, & Life Sciences
- Physics & Electronics

Aerospace Systems
- Air Vehicles
- Control, Power & Thermal Management
- High Speed Systems
- Space & Missile Propulsion
- Turbine Engines

Directed Energy
- Directed Energy & EO for Space Superiority
- High Power Electromagnetics
- Laser Systems
- Weapons Modeling and Simulation

Information
- Autonomy, C2, & Decision Support
- Connectivity & Dissemination
- Cyber Science & Technology
- Processing & Exploitation

Human Performance
- Bio-effects
- Decision Making
- Human Centered ISR
- Training

Munitions
- Fuze Technology
- Munitions AGN&C
- Munitions System Effects Science
- Ordinance Sciences
- Terminal Seeker Sciences

Sensors
- Advanced Devices & Components
- Layered Sensing Exploitation
- Multi-Int Sensing (RF/EO)
- Spectrum Warfare

Space Vehicles
- Space Electronics
- Space Environmental Impacts & Mitigation
- Space OE/IR
- Space Experiments
- Platforms & Operations Technologies

Materials and Manufacturing
- Functional Materials & Applications
- Manufacturing & Industrial Technology
- Structural Materials & Applications
- Support for Operations

Turning Science Into Capability

Driven by Service Core Functions

Vectored by Air Force Strategy + S&T Vision/Horizons + Product Center Needs + MAJCOM Needs

6.1 Basic Research

6.2 Applied Research

6.3 Advanced Tech Demo

~ $5B

Science Knowledge

Technologies

Capability Concepts

Warfighter

Outputs: ***New Technologies***

Outputs: ***Mature Technologies***

Outputs: ***Flagship Capability Concepts***

25 Years | 10 Years | 5 Years | 1 Year

Initial Operating Capability Timeline

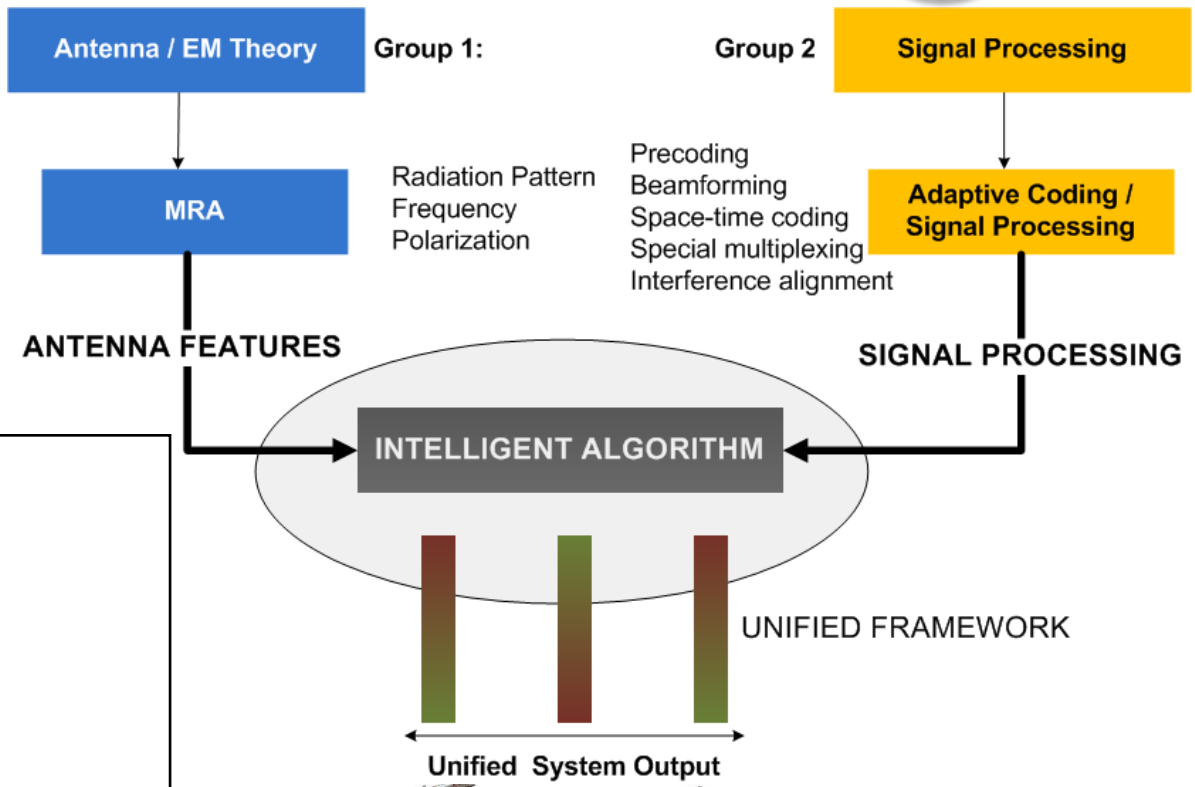
Systems & Software

1. Legacy System Research – Keep the current systems up-to-date
2. New Technology Research – AF must continue to be on the cutting-edge of technology; studying operating systems, compilers, virtual memory, multi/many-core platforms, etc. will drastically improve current AF systems and help to develop new S&T for the benefit of the nation

Efficient and Intelligent Algorithms for a New Class of Multifunctional Reconfigurable Antenna Systems

Dr. Bedri Cetiner, Utah State

Problem: Antenna Tech is old!
Approach: Development of efficient and intelligent control algorithms enabling the joint optimization of antenna and communication parameters



Smart skin technology

New class of conformal antenna arrays of reduced size & signature along with improved direction finding capabilities & radiation pattern control

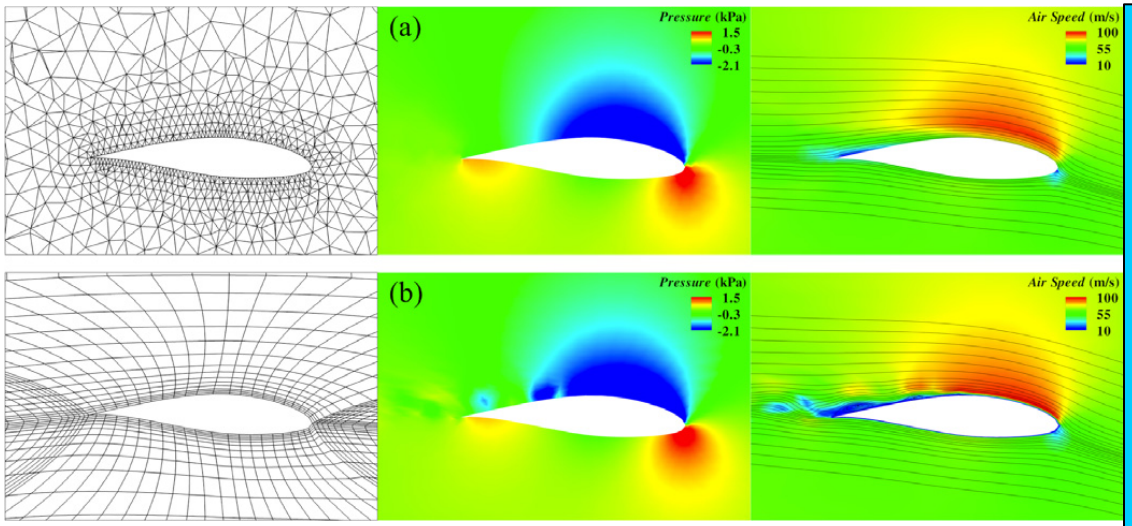
Integrated Isogeometric Approach to Engineering Design & Optimization of Aircraft Structures

Dr. Michael Scott, BYU

Collaborative project - BYU & CU Boulder

Problem: Major engineering bottleneck (> 80% of overall analysis time) wrt fixing CAD geometry and creating FEA models; FEA & CAD have incompatible geometric representations

Approach: Merge T-splines & Isogeometric analysis (IGA) to provide foundation for integrated design-through-analysis frameworks; this will enable: precise and efficient geometric modeling, simplified mesh refinement, smooth basis functions with compact support, superior approximation properties, integration of design and analysis

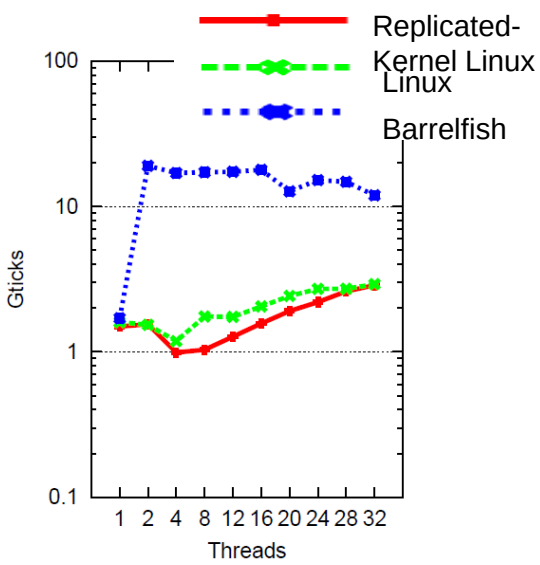


Status: Implemented a fully integrated isogeometric structural analysis capability; developing detailed structural aircraft wing, novel modeling approaches to enable rapid design space exploration & model updates; future includes coupling the structural model & CFD solver to compute the unsteady aerodynamic loads & implementation of a robust optimization framework

Scalable, Fault-Tolerant Operating System for Many-core and Multicore Platforms

Dr. Binoy Ravindran, Virginia Tech

Problem: Hardware failures are increasing with the increasing core count of multicore architectures; current OSs are not resilient to transient and fail-stop hardware failures, causing critical software infrastructure failures



Approach: Two-pronged approach to develop OS to tolerate hardware faults: 1) detect transient faults (e.g., memory bit-flips) and recover through replicated OS kernel design; and 2) detect fail-stop CPU failures and recover through transparent migration of OS services from stalled CPUs; Linux-based OS implementations so legacy applications will run unmodified

CPU fault injection analysis reveals that, in Linux, the entire system crashes 100% of the time!

Status: First version of replicated-kernel Linux built (scales as well as Linux); automated CPU fault injection framework; prototype GCC TM compiler for OS kernel function instrumentation

A Holistic Approach to Networked Information Systems Design & Analysis

Dr. P. R. Kumar, Texas A&M University

Problem: Fly-by-wireless; real-time wireless networks for connecting on-board sensors and actuators; communication and computational constraints; uncertainty at several layers; complex and interdependent systems

Approach: Design scheduling algorithms to operate under hard deadlines, guarantee timely throughput & minimize energy usage; also design methodology for precise characterization of performance

Conclusion

- **Basic research is an engineering process in that it solves the general problem of generating a higher R&D response**
  - **Basic research S&Es should always have this clearly defined exit strategy in mind**
- **With respect to technology readiness levels (TRLs), basic research has this requirement; TRL 1 states:**
  - **"Scientific research begins to be translated into applied research and development (R&D)"**
- **There must be:**
  - **Trade-offs in basic research that have been discussed, but not routinely placed in practice**
  - **A balance between innovative research and product development**

Questions?