High Performance Computing in Support of Engineered Resilient Systems

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DoD HPC
MODERNIZATION PROGRAM

Presentation Outline

- **HPCMP Overview**

- **Progression of Analytics**

- **HPCMP CREATE**

- **Parallel Analytics**

- **Integrated HPC Analytics**
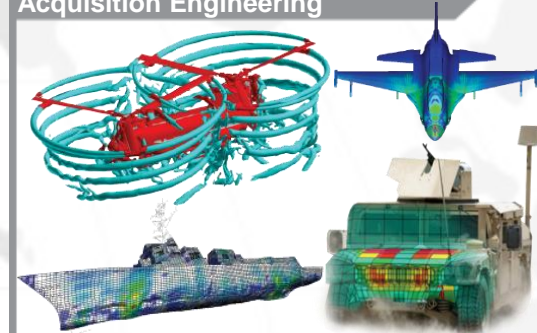
HPCMP High-Level Operational Concept

Users

A technology-led, innovation-focused program committed to extending HPC to address the DoD's most significant challenges

Results

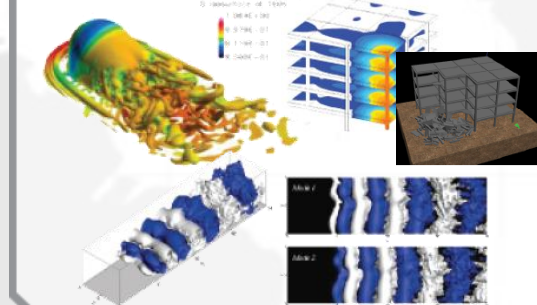### Acquisition Engineering

DoD Supercomputing Resource Centers (DSRCs)

- US Air Force Research Laboratory DSRC
- US Army Research Laboratory DSRC
- US Army Engineer Research and Development Center DSRC
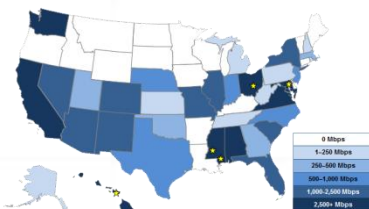- Maui High Performance Computing Center DSRC
- US Navy DSRC

Networking and Security

Defense Research & Engineering Network (DREN)

Connects DoD HPC Centers and Users

High-bandwidth, Low-latency Full-service Network

| 0 Mbps |
| 1–250 Mbps |
| 250–500 Mbps |
| 500–1,000 Mbps |
| 1,000–2,500 Mbps |
| 2,500+ Mbps |

Software Applications Support

Core Software

Computational Environments

Education and Training

Support

Decision Support

Science and Engineering Research
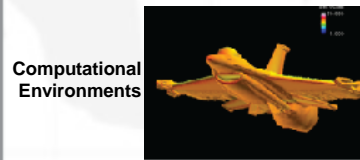
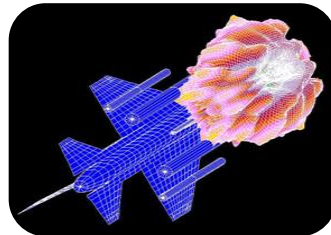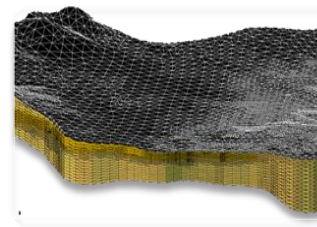# Science and Engineering Disciplines Supported by HPCMP

Innovative research and development, test and evaluation, and engineering is based on synergistic application of science-based software utilizing advanced computing and experiments
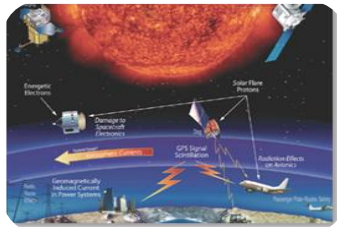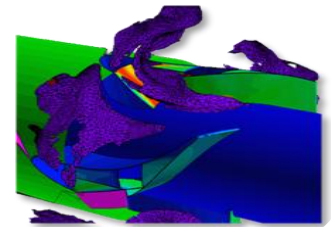
Space and Astrophysical Sciences

Computational Electromagnetics & Acoustics
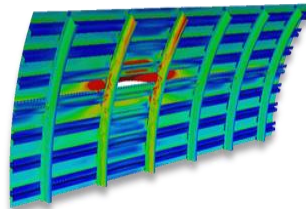
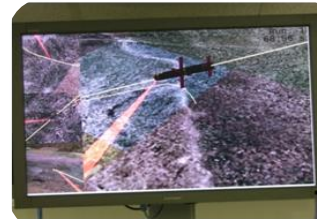**Environmental Quality Modeling & Simulation**
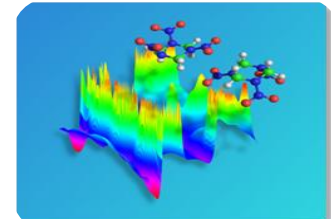
Computational Fluid Dynamics
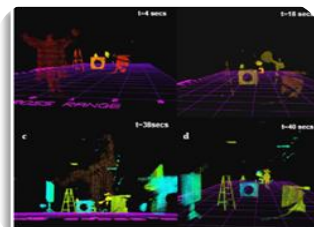
Forces Modeling & Simulation
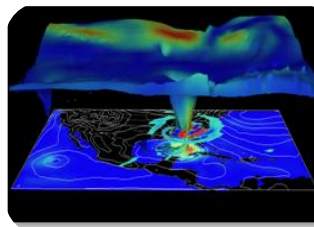
Computational Structural Mechanics

Integrated Modeling & Test Environments

Computational Chemistry, Biology & Materials Science

Signal/Image Processing

Climate/Weather/Ocean Modeling & Simulation

Electronics, Networking, and Systems/C4I

HPCMP Centers High-Level Operational Concept

DoD HIGH PERFORMANCE COMPUTING MODERNIZATION PROGRAM

DEPARTMENT OF DEFENSE
HIGH PERFORMANCE COMPUTING
MODERNIZATION PROGRAM

A technology-led, innovation-focused program committed to extending HPC to address the DoD's most significant challenges

DoD Supercomputing Resource Centers (DSRCs)

Each Center is a robust complement of HPC capabilities that include: large-scale HPC systems, high-speed networking, multi-petabyte archival mass storage systems, and customer support services.

DSRC Resources

Data Analysis and Assessment Center DAAC) Virtual Center

Consolidated Customer Assistance Center (CCAC)

Supercomputing

Data Recovery

Storage

Defense Research and Engineering Network (DREN)

US Air Force Research Laboratory (DSRC)

US Army Research Laboratory DSRC

Maui High Performance Computing Center DSRC

US Army Engineer Research And Development Center DSRC

US Navy DSRC

DOD Supercomputing Resource Centers (DSRCs) Systems

- **Lightning** – Cray XC30
- **Predator** – SGI UV
- **Spirit** – SGI ICE X
- **Thunder** – SGI ICE X

Air Force Research Laboratory (AFRL) DSRC

- **Pershing** – IBM iDataPlex
- **MRAP** (C) – Cray XT5
- **Hercules** (C) – IBM iDataPlex
- **Excalibur** – Cray XC40

Army Research Laboratory (ARL) DSRC

- **Garnet** – Cray XE6
- **Copper** (ORS) – Cray XE6
- **Topaz** – SGI ICE X

Engineer Research and Development Center (ERDC) DSRC

- **Riptide** – IBM iDataPlex

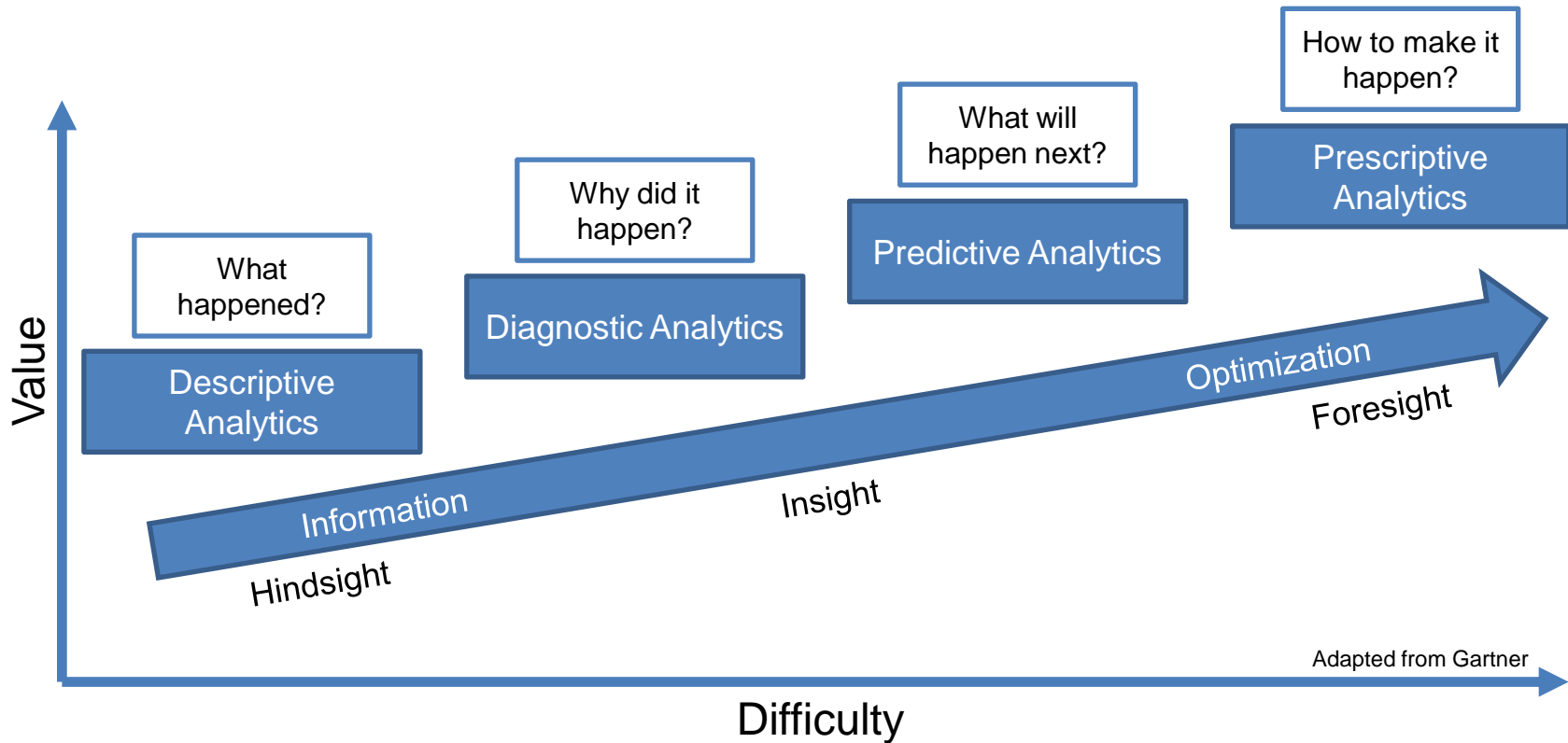**Maui High Performance Computing Center (MHPCC) DSRC**

- **Armstrong** – Cray XC30
- **Haise** – IBM iDataPlex
- **Kilrain** – IBM iDataPlex
- **Shepard** – Cray XC30
- **Cernan** (C) – IBM iDataPlex
- **Bean** – Cray XC40
- **Conrad** – Cray XC40

Navy DSRC

For additional information on each of the Centers and their capabilities, visit http://centers.hpc.mil/

Progression of Analytics

Value

Difficulty

Descriptive Analytics — What happened?

Diagnostic Analytics — Why did it happen?

Predictive Analytics — What will happen next?

Prescriptive Analytics — How to make it happen?

Hindsight

Information

Insight

Optimization

Foresight

Adapted from Gartner

RDT&E Process
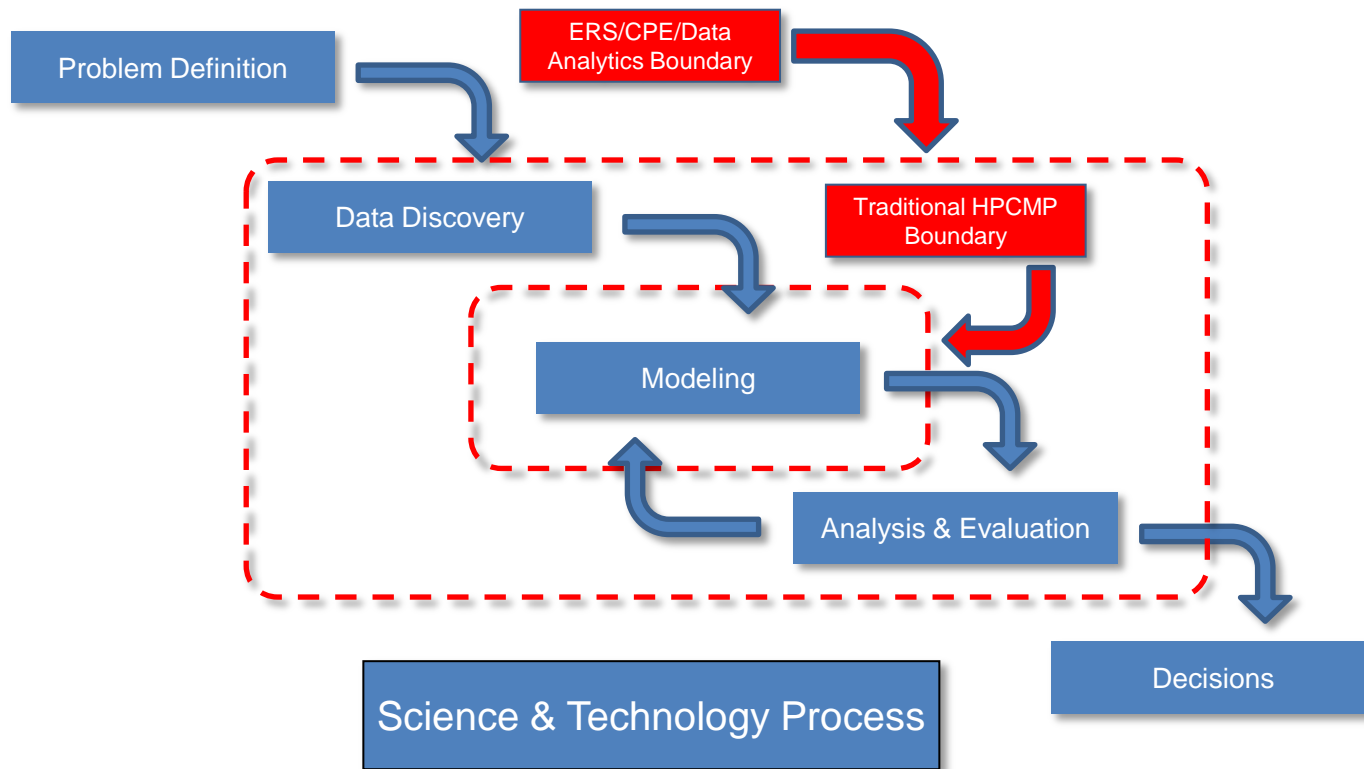
- HPCMP focused on "Modeling"
- ERS requires a new boundary

Computational Research and Engineering Acquisition Tools and Environments (CREATE)

CREATE is a multi-phase program that started in 2008, to develop and deploy four (now five) computational engineering tool sets for acquisition engineers

- **Aircraft (AV) Design Tools:** Fixed-wing aircraft, rotorcraft, conceptual design, trade-space exploration and operational testing and transition

- **Ship Design Tools:** Shock/damage, hydrodynamics, early-stage design & trade-space exploration, and operational testing and transition

- **Radio Frequency (RF) Antenna Design and Integration Tools:** Conceptual design and detailed analysis tools relevant to virtually all DoD platforms

- **Ground Vehicles (GV) Tools:** End-to-end mobility solver, provide rapid, physics-based data for design and trade-space analysis

- **Meshing and Geometry (MG) Support:** The geometry and meshing project improves the ease, speed, flexibility, and quality of geometry and mesh generation, and enables the generation of CAD-neutral digital representations and product models of weapons systems & platforms and operational terrains and environments

CREATE-AV

Aircraft (AV) Design Tools

CREATE-SHIPS

Ship Design Tools

CREATE-RF

Radio Frequency (RF) Antenna Design and Integration Tools

CREATE-GV

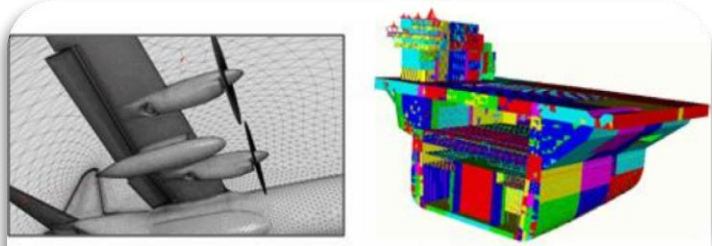Ground Vehicle Design Tools

CREATE-MG

Meshing and Geometry (MG) Support

CREATE: Suite of Physics-based HPC Tools for the design and analysis of DoD platforms:

- **Air Vehicles (AV)—Air Force, Army & Navy**
  - Concept design, High Fidelity Fixed-Wing and Rotary-Wing
- **Ships—Navy**
  - Concept design, Shock and Life Fire Vulnerability, Hydrodynamics
- **Radio Frequency (RF) Antennas—Air Force, Army & Navy**
  - RF Antenna electromagnetics & integration with platforms
- **Ground Vehicles (GV) — Army, Marine Corps**
  - Design and evaluation of tactical ground vehicles
- **Mesh and Geometry (MG) Generation**
  - Rapid generation of geometry representations and meshes
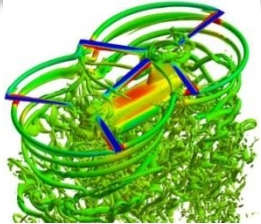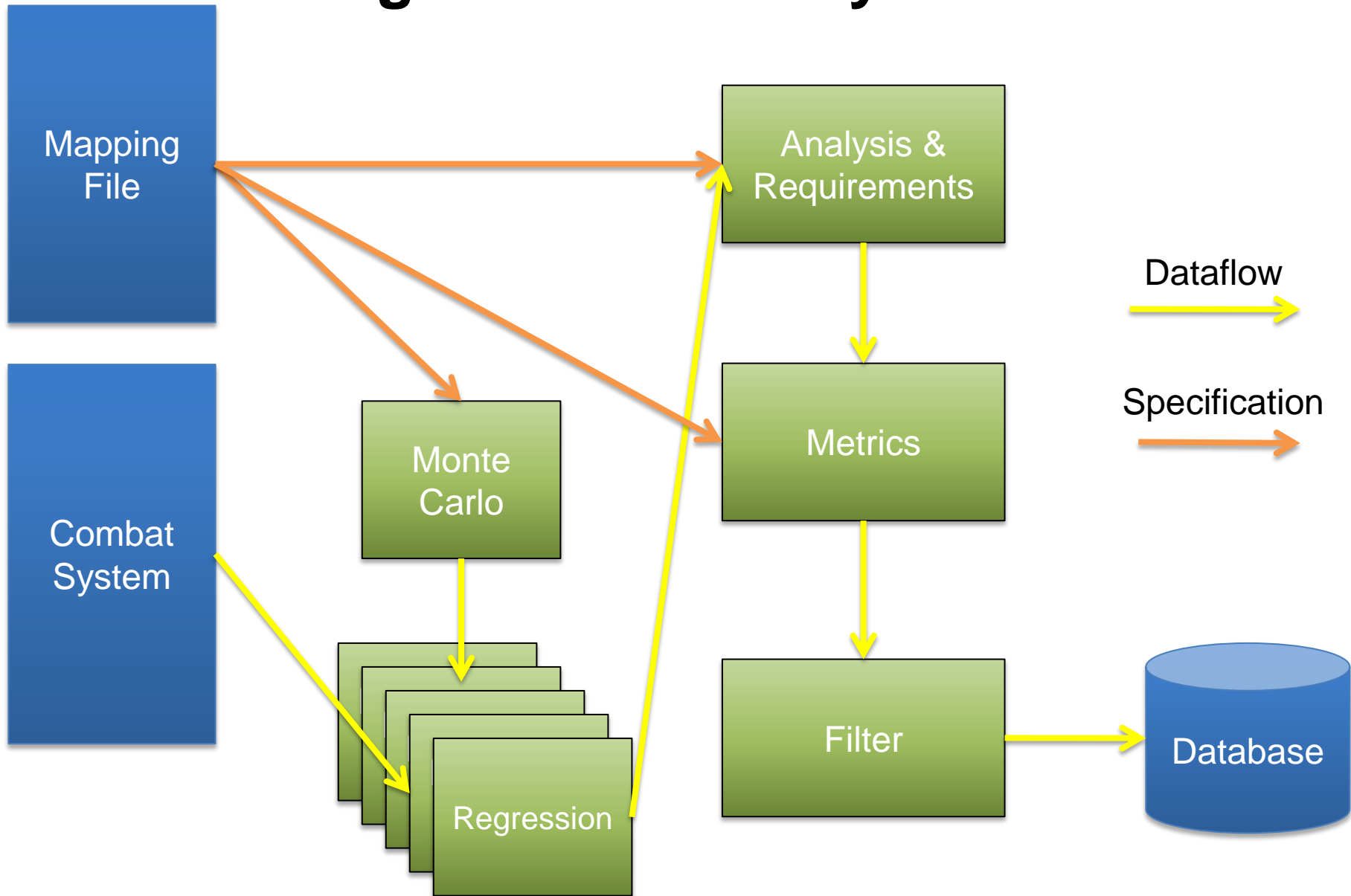
CREATE tools support all stages of acquisition from rapid early-stage design to full life-cycle sustainment and modifications

F-35

CH-47

Design concept

Seakeeping and resistance

Aircraft and aircraft carrier meshes

Military platforms with antennas

Shock vulnerability

Single Thread Analytics

Inputs

Mapping File

Combat System

Monte Carlo

Analysis & Requirements

Metrics

Regression

Filter

Database

Dataflow

Specification

Parallel Analytics

Inputs

MPI Processes

Mapping File

Combat System (process Indexed)

Execution

Execution

Execution

Database

Database

Database

Post-processing Spec files

Post-processing

Distributed Database
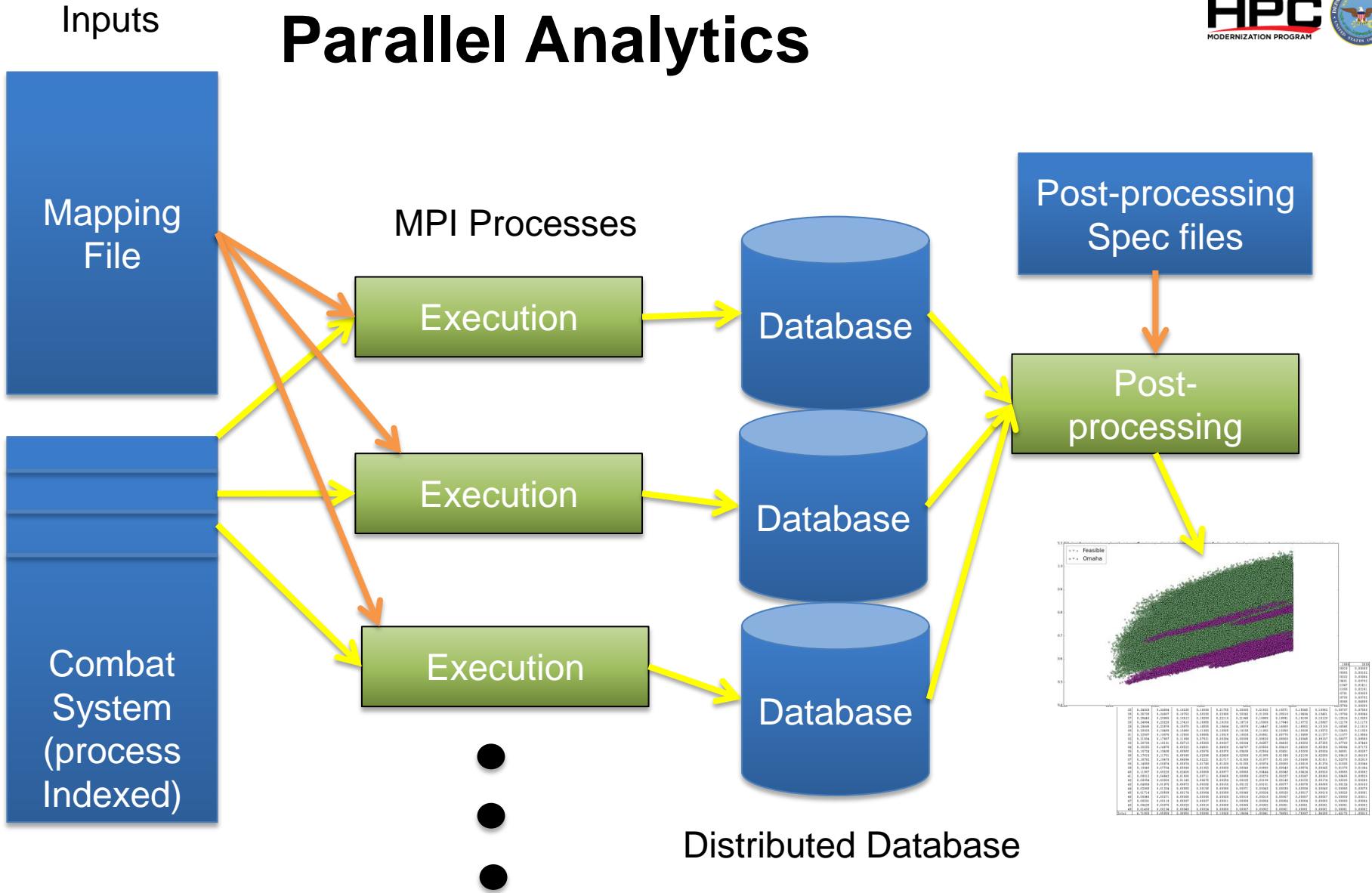
Number of Processes = 8 desktop, 16 cluster, 348 supercomputer

ERS HPC Turnaround For SSCTF Project

Code Adjustments + Processing Time

212 Variables
3.6 Million Designs

Turnaround = 27 Minutes

SSC Iteration - August 1st

Turnaround = 30 Hours

209 Variables
2.64 Million Designs

SSC Iteration - July 21st

Tradespace Size & Complexity

Turnaround = Three Days

74 Variables
185,000 Designs

SSC Iteration - June 24th

Turnaround = Three Weeks
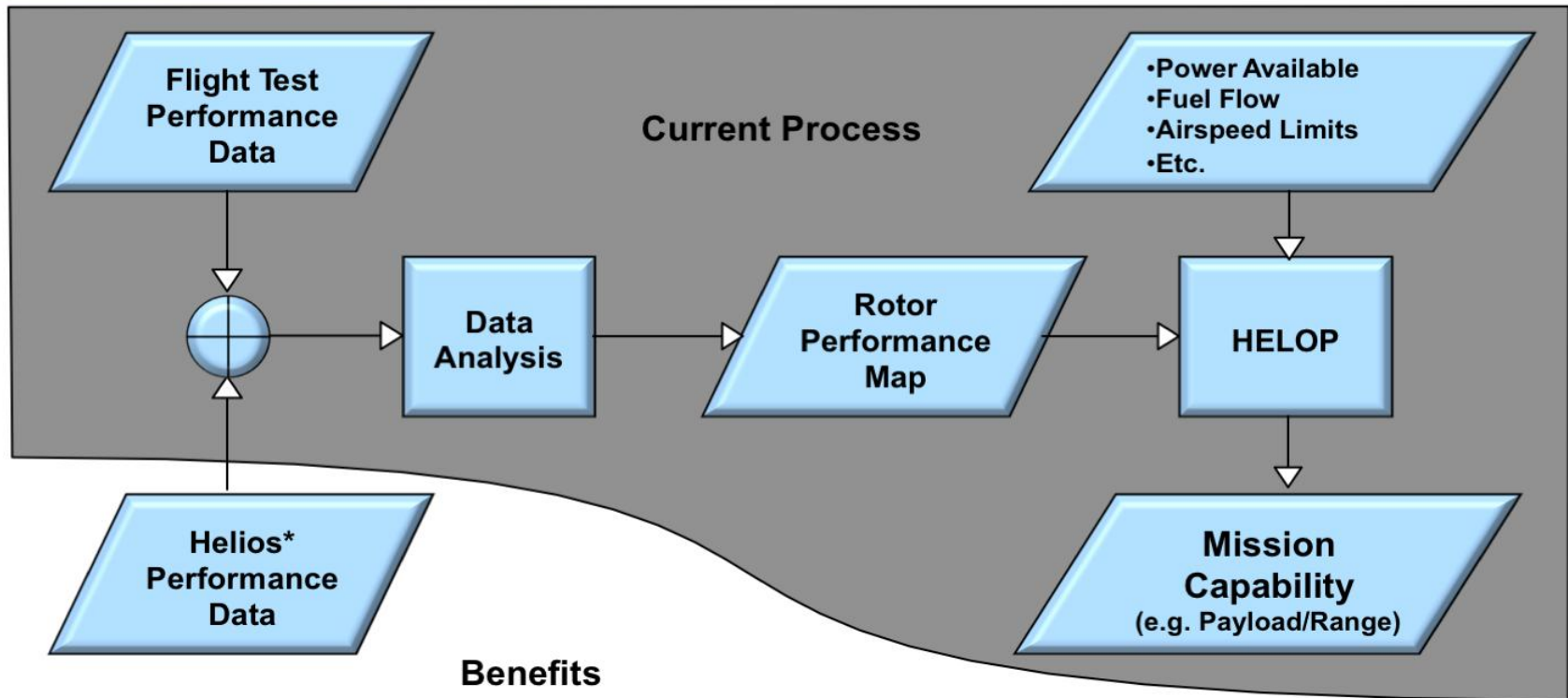
16 Variables
7,000 Designs

LX-R Exercise

40 Total Iterations each with changes in scope, variables, models, and post-processing

Turnaround Speed

Mission Capability Process

Current Process

- Flight Test Performance Data
- Helios* Performance Data
- Data Analysis
- Rotor Performance Map
- Power Available
- Fuel Flow
- Airspeed Limits
- Etc.
- HELOP
- Mission Capability (e.g. Payload/Range)

Benefits

- Basis for predicting impact of future modifications
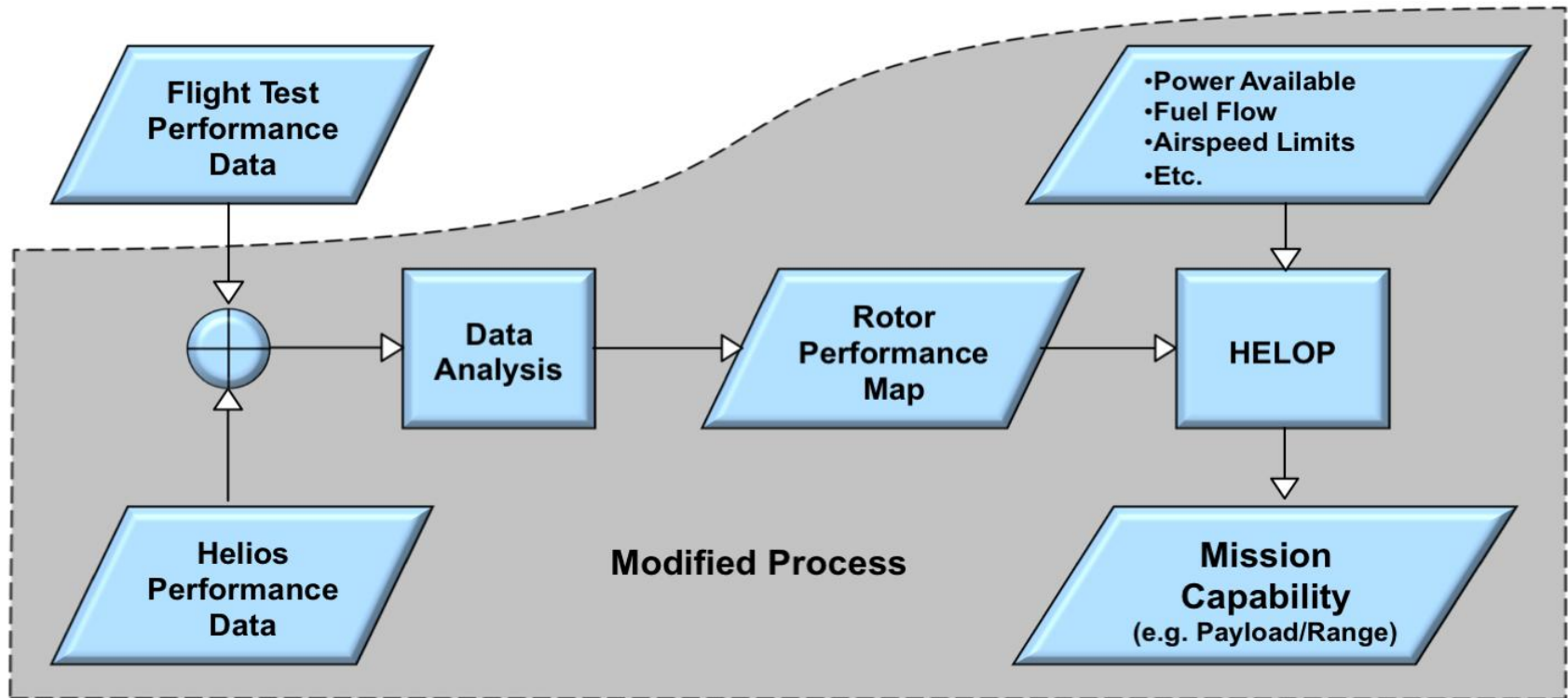- Supports Data Analysis
- Optimized flight test matrix

* High fidelity CFD codes accurately predict complex rotor blade performance

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Flight Test Performance Data

• Power Available
• Fuel Flow
• Airspeed Limits
• Etc.

Helios Performance Data

Data Analysis

Rotor Performance Map

HELOP

Modified Process

Mission Capability
(e.g. Payload/Range)

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Objective

Demonstrate accuracy in predicting mission capability for the Legacy CH-47 helicopter using Helios Engineering Model based rotor map.
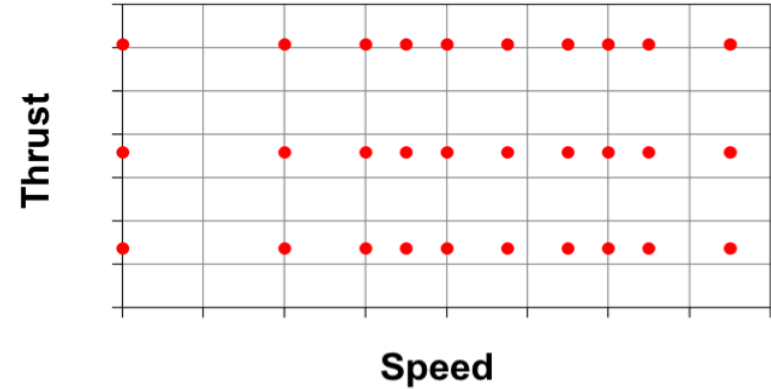
Software Basis

Helios v4.0

Evaluation Data

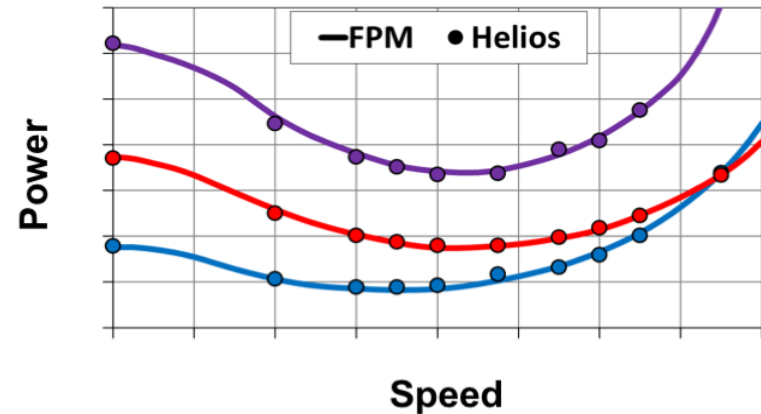Legacy CH-47 Flight Performance Model (FPM)

Run Matrix

Schedule

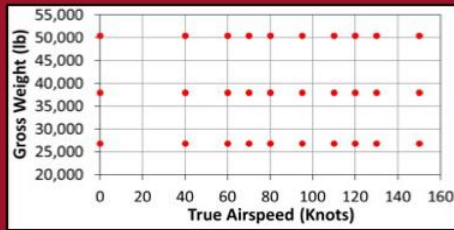| Task ID	Task Name	Q1 14 J F M	Q2 14 A M J	Q3 14 J A S	Q4 14 O N D	Q1 15 J F M	Q2 15 A M J
3	CH-47F Mission Analysis						
3.1	Thrust Sweep - Hover						
3.2	Thrust Sweep - 200 ft/min VROC						
3.3	Speed Sweep - High Gross Weight						
3.4	Speed Sweep - Mid Gross Weight						
3.5	Speed Sweep - Low Gross Weight						
3.6	Perform Mission Analysis						
3.7	Report						

Results

Updated ACRB Effort

CH-47 ACRB

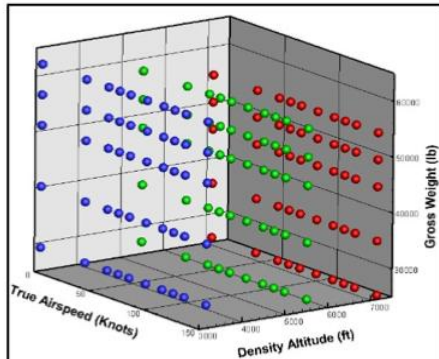Helios v4.0: 30 points, 5 million CPU hrs, 3 calendar months.
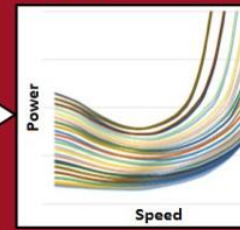
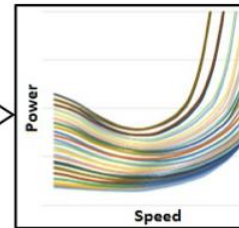Data Analysis: Carpet plot is dependent on extrapolation, interpolation and smoothing.

Impact

- **Predicted specification point performance to inform programmatic decision making.**

- **Defined and validated a new standard process for high fidelity mission assessments.**

Updated CH-47 ACRB

Helios v6.0: 150 points, 6 million CPU hrs, 3 calendar months.

Data Analysis: Carpet plot is less dependent on extrapolation, interpolation and smoothing.

Impact

- **Predicts specification point performance for updated ACRB design.**

- **Case runs will pre-populate entire flight envelope to evaluate performance and optimize ACRB flight test matrix (Jan 2017).**

- **Flight test data will enable ACRB model validation efforts which will lead to airworthiness assessments and additional PM support tasks.**

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

So What?

- **New DoD programs (such as ERS) are moving toward prescriptive analytics that require a change in how analytics are performed**

- **HPCMP provides computing resources that allow Integrated analytics that combine physics-based simulations to support mission critical analysis**