

Comprehensive Digital Transformation

ED MCLARNEY
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The Problem

- **Situation:**

- Digital Age technologies are rapidly accelerating worldwide ability to work, think, invent, create, and solve problems of accelerating complexity
- Potential partners, and competitors, are embracing new tools

- **Problem:**

- NASA must acceptance of 21st Century technology, tools and methods to successfully incorporate into our programs and projects
- We must transform to execute NASA's future missions

A Possible Future

A globally-connected, virtually-enabled Agency

- Space Exploration, Aeronautics, and Science are all propelled by digital age advances
 - Modeling and simulation integrated across all disciplines (e.g., Digital Twin)
 - Integration of ground testing, flight testing, modeling & simulation and more (e.g., Virtual Flight Test and High Fidelity EDL)
 - Emerging capabilities supporting mod-sim: Exascale Computing, Uncertainty Quantification, Multiscale / Multifidelity Simulation, Integrated Verification & Validation
- Global partnerships: worldwide collective intelligence & collaboration
 - Remote work becomes commonplace; harnessing intellect worldwide
 - Collaboration technologies leverage NASA's workforce
- Emerging methods and techniques/capabilities
 - Fourth research paradigm via Big Data
 - Robots & automation: ubiquitous & ever-more capable
 - Virtual education: anytime/anywhere access to training and advanced education resulting in constant workforce intellectual currency
 - Computer-assisted idea generation and analysis

Comprehensive Digital Transformation

Worldwide Technology Trends

NASA & Langley Roadmaps

Required Capabilities

Workforce

VITAL

CDT

Expertise
Software
Algorithms
Partnerships
Hardware

Modeling,
Simulation &
Systems Analysis

Big Data Analytics
& Machine
Intelligence

High Performance
Computing

Advanced IT
Infrastructure

Phase 1

Pilot Projects

Phase 2

Digital
Capabilities

A Phased Strategy for Digital Transformation

- Phase 1: Lay the foundation
 - Institutionalize CDT
 - Staff and resource CDT implementation
 - Identify workforce implications
 - Pilot projects: Quick wins supporting LaRC initiatives and priorities
 - Beginning planning for Virtual capabilities 
 - Select capabilities to advance
 - Identify champion and secure broad-based advocacy and funding
 - Identify partners
- Phase 2: Begin to Implement Virtual Capabilities (Collaborate across NASA, DoE, DoD, and More)
 - Begin sequenced projects for selected virtual capabilities
 - Demonstrate tangible results
 - Align CDT foundation with virtual capabilities

Possible Virtual Capabilities

Virtual Flight Test
Vehicle Digital Twin
Materials by Design
National Airspace
Simulation
EDL Simulation
Coupled Earth
System Data &
Models

Virtual Capability Example #1: *Virtual Flight Test*

By 2035 ***Virtual Flight Test*** (VFT) will enable simulated testing of turbulence, separated flow and flutter

- Real-time for entire aircraft/spacecraft model
- Develop high speed, multi-scale, multi-disciplinary simulation

Benefits:

- Reduced time & cost for vehicle development and certification
- Rapid design/test iterations lead to virtual flight certification
- Minimize use of physical wind tunnels

Technology/Capability Gaps and Opportunities:

☐ Disciplines and Algorithms

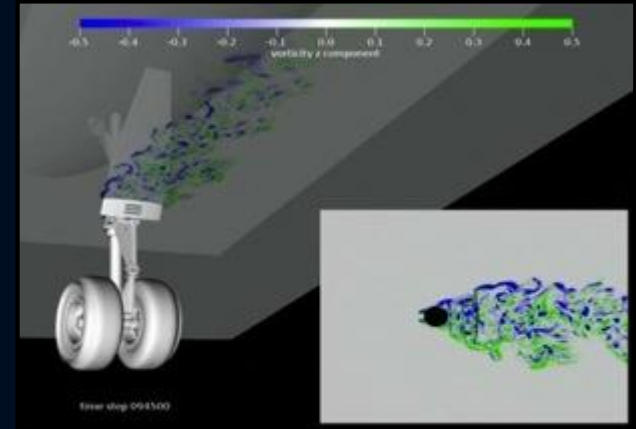
- ☐ High-fidelity aero, structures, materials, aero-elasticity, thermo models and their integration
- ☐ Unsteady flow, viscous flow, turbulence, large-eddy sim, high order approximation & adaptation schemes
- ☐ Revision of algorithms to work on future paradigms

☐ HPC: 10^6 - 10^9 x increase in computational speed

☐ Expertise: Aero, structures, materials experts, computational scientists, mathematicians, systems

☐ Transformation Foundation:

- ☐ Virtual research, design to enable remote utilization of Virtual Flight Test
- ☐ Cyber-physical instrumentation, verification & validation, uncertainty quantification
- ☐ Advanced analytics and machine intelligence for analysis and knowledgeability
- ☐ Connectivity and collaboration to enable partnership on Virtual Flight Test



**Virtual Flight Test:
Hi-Fidelity, Multidiscipline Simulation**

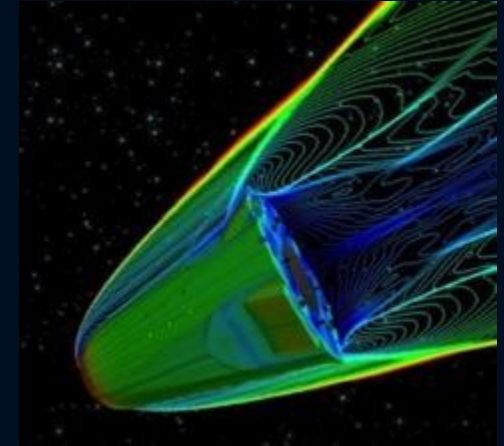
VC Example #2: *Vehicle Digital Twin*

By 2035 **Vehicle Digital Twin** provides high-fidelity lifecycle simulation of as-built critical systems

- Manage entire product lifecycle (concept - flight – retirement)
- Evaluate the effects of actual flight parameters by vehicle “tail number”
- Forecast life of flying twin using sensor data to continuously update simulations

Benefits:

- Proactively activate self-repair / load alleviation to mitigate degradation
- Eliminate excess margins - minimize vehicle weight; continually-optimize system performance & reliability
- Certification by analysis for NASA's extreme missions – conditions that can not be reproduced in a laboratory



**Digital Twin:
Ultra-High Fidelity Representation**

Technology/Capability Gaps (What is Missing?):

- ☐ Disciplines and Algorithms
 - ☐ Integrate modeling and simulation capabilities across disciplines
 - ☐ High fidelity measurement and instrumentation for continuous data collection
 - ☐ Unprecedented integration of simulation, data processing, computational capabilities
 - ☐ Revision of algorithms to work on future compute paradigms (ground and flight)
- ☐ HPC: Need 10^6 - 10^9 x computational speed; similar for on-board computation
- ☐ Expertise: Systems experts, materials, structures, aero, etc., computational scientists, mathematicians
- ☐ Transformation Foundation:
 - ☐ Collaboration and interoperability to leverage DoD progress
 - ☐ Advanced Verification & Validation and Uncertainty Quantification
 - ☐ Advanced analytics, & machine intelligence for analysis and knowledge synthesis

At LaRC in FY14: Establishing Foundation for High-Impact Virtual Capabilities

- Began modernization of Modeling & Simulation capabilities across all disciplines
 - Highly-capable CFD capability; working to enhance other disciplines beyond commodity mod-sim
 - Developing partnerships with leading external organizations: e.g., with DoE & DoD
 - Beginning to grow high-fidelity, system of systems capability
 - Continuing work to scale codes to exploit emerging HPC paradigms
- Big Data prototypes for Mission problems
 - Scientific literature analysis
 - Signal processing for NDE & flutter
- High Performance Computing – preparing for next paradigms
 - Next Gen HPC education from Intel & Nvidia ~45 personnel trained
 - Expanded HP partnering with NAS and DoE (ORNL)
- Advanced IT: Getting the basics right to enable missions
 - Began optimizing large data network flows: Science & OCIO partnership
 - Co-led creation of IT innovation strategy as Agency CIO begins modernizing core IT infrastructure

Comprehensive Digital Transformation Summary

- Agency priority: Gaining acceptance of 21st Century technology, tools and methods to successfully incorporate into our programs and projects
- Digital Age transformation and investment are required to maintain relevance and maximize technology force multipliers
- Now: Begin investing in transformation foundation:
 - Modeling & Simulation for Systems and Disciplines
 - High Performance Computing
 - Big Data Analytics and Machine Intelligence
 - Advanced IT
- Near Horizon: Select, plan, and develop grand challenge level virtual / digital capabilities for NASA's hardest problems
 - Solve NASA Program / Mission problems by leveraging digital age capabilities and know-how