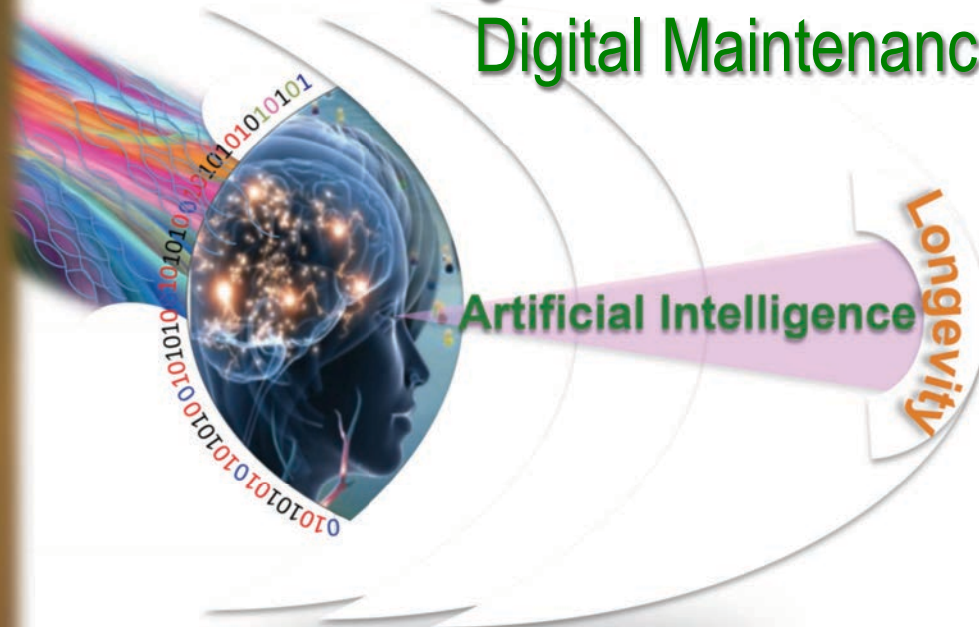




TEXAS TECH UNIVERSITY™



Intelligent Health State Awareness Vision for Digital Maintenance-Free Aviation



Presented to:
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Health Management
Xiamen University
Xiamen, China
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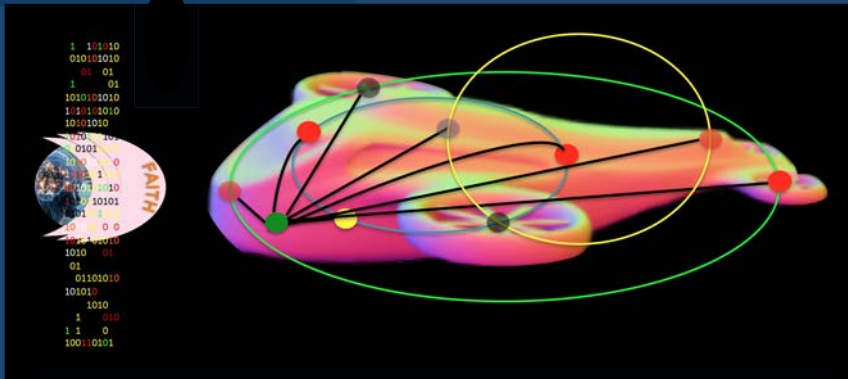
Presentation Outline

- Why “*Maintenance-Free Aviation*” ?
- Defying “*Impossibilities*”
- Envisioning “*Discoveries*”
 - Finding & catching “*Materials Damage Precursors*”
 - Cloning “*Materials Digital Nanomaterials Architecture (DNA)*”
 - Enabling “*Reconfigurable & Self-Healing Elements*” and “*Intelligent Sensing Network*”
- Demonstrating “*Intelligent Health State Awareness*” concept of operation for achieving “*Fatigue and Maintenance-Free Aircraft*”
- Developing and integrating “*Next-Generation of Artificial Intelligence*” to increase aircraft safety and longevity
- Conclusions

Value Proposition – Aviation MRO Projections

Intelligent Health State Awareness
Vision for Digital Maintenance and
Fatigue-Free Aviation

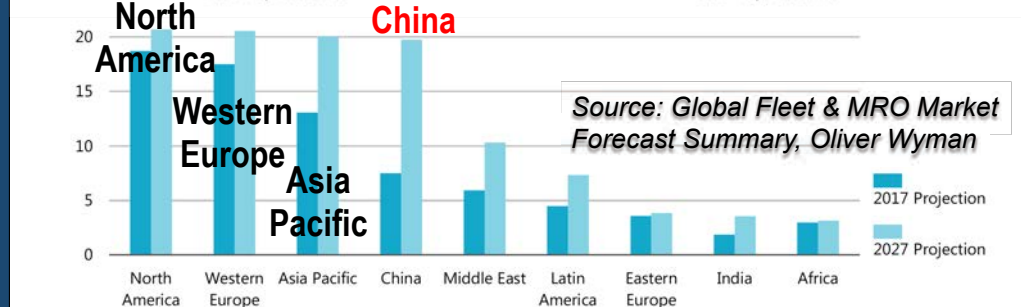
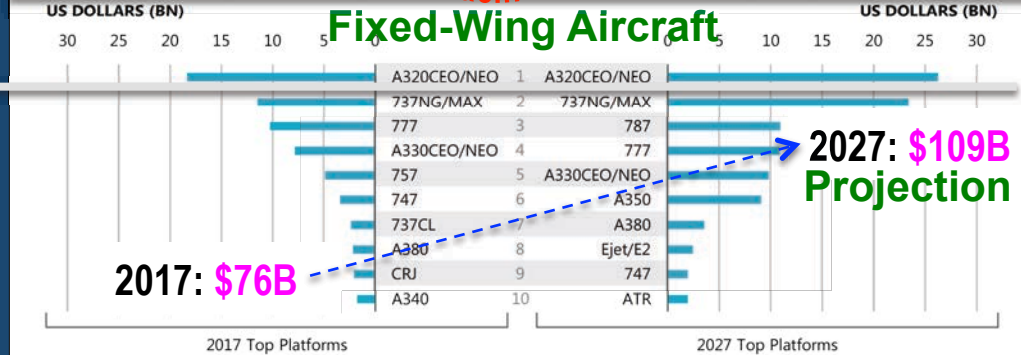
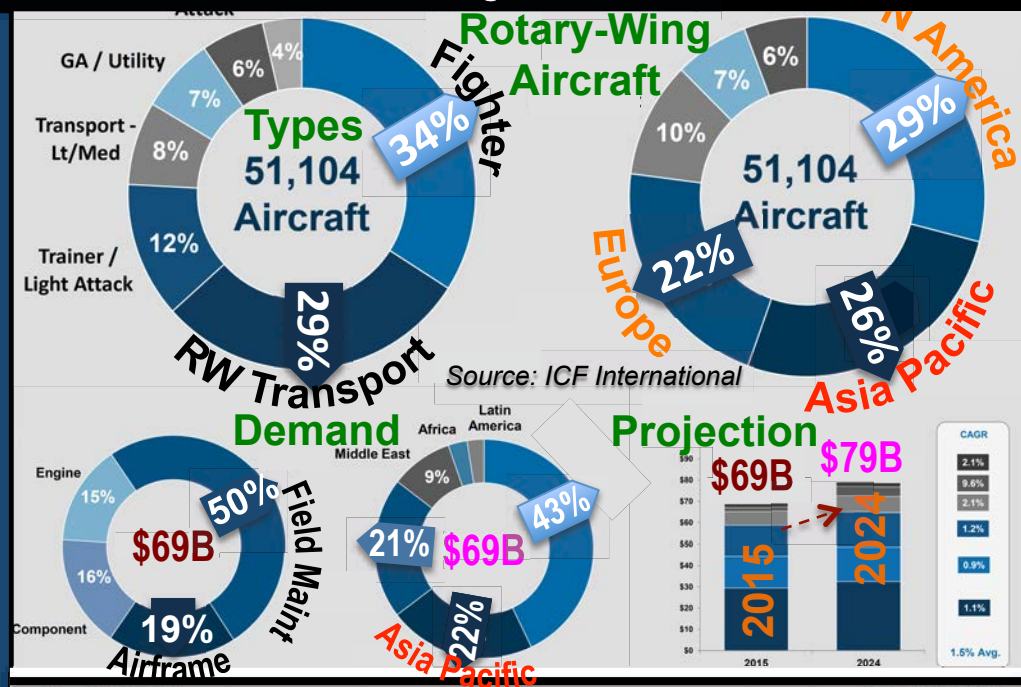
Unleashing



Revolutionary Capability

- Reduce sustainment costs
- Increase safety and availability

MRO: Maintenance, Repair, and Operation



Defying Impossibilities and Envisioning Discoveries - A System Level Approach: Structures Perspective -

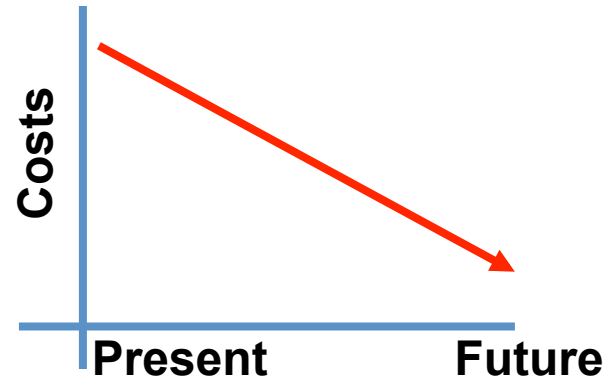


CBM Tech
Zero-Maint
Fatigue Free

Reliability



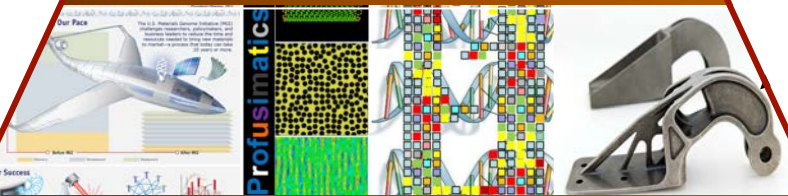
• Empower operators with “breakthrough” technologies & capabilities to operate vertical lift aircraft with *substantial reduction in maintenance costs*



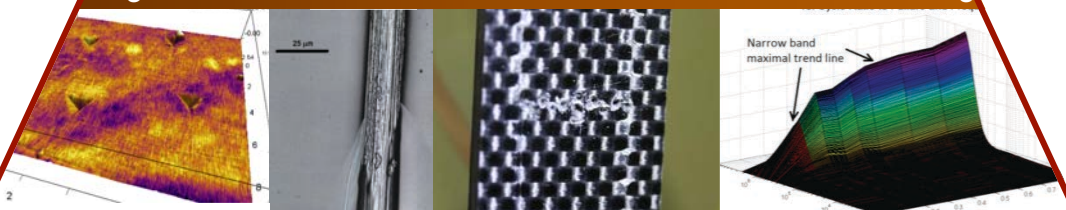
Intelligent Health State Awareness Technology



Self-Healing/Advanced Sensing Network



Digital Nanomaterial Architecture- Additive Manufacturing

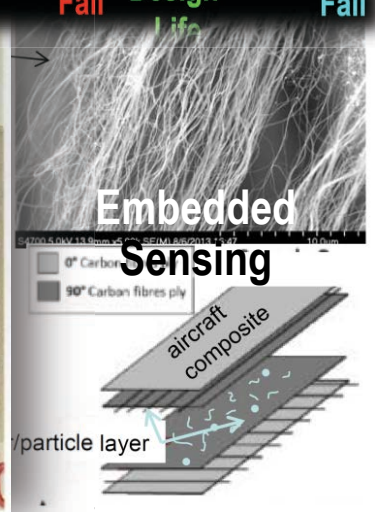
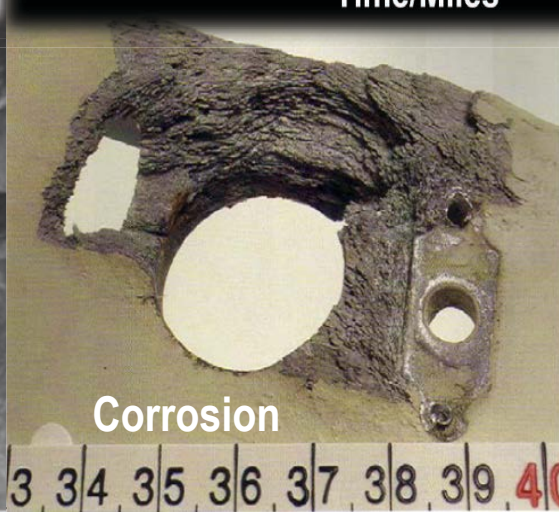
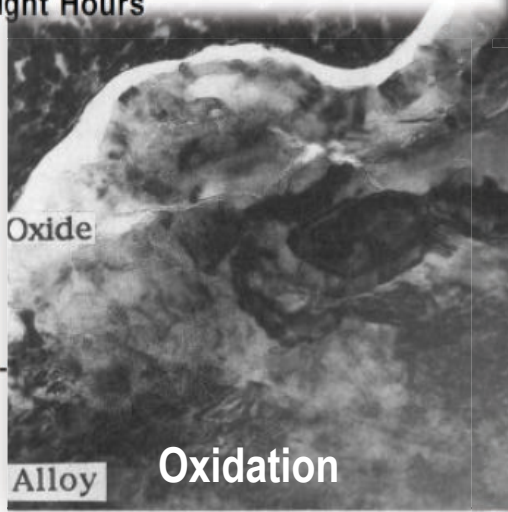
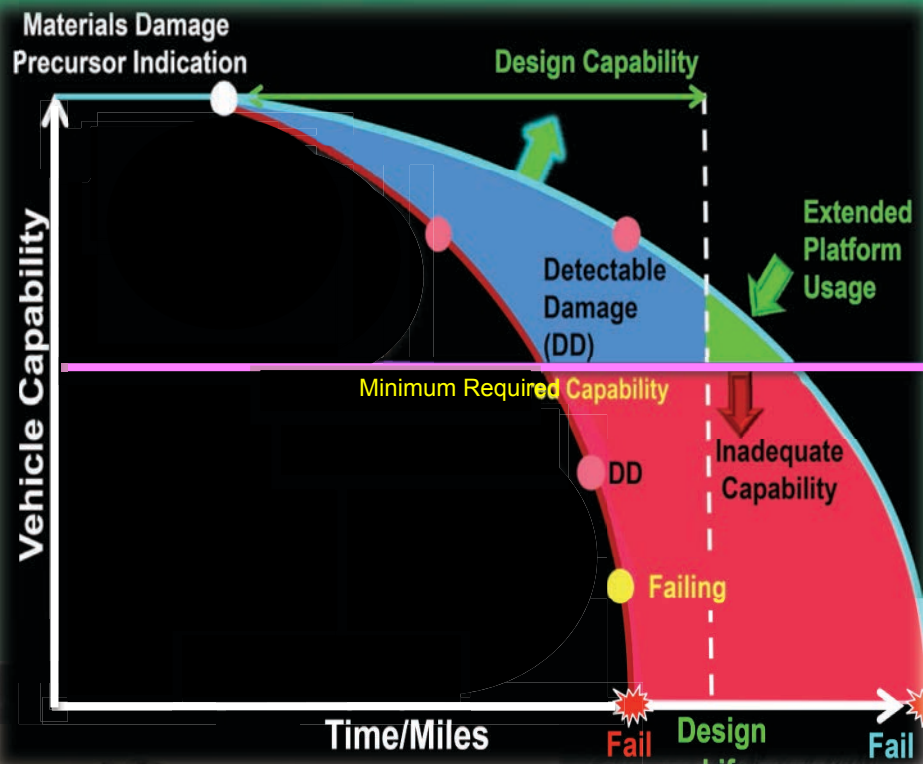
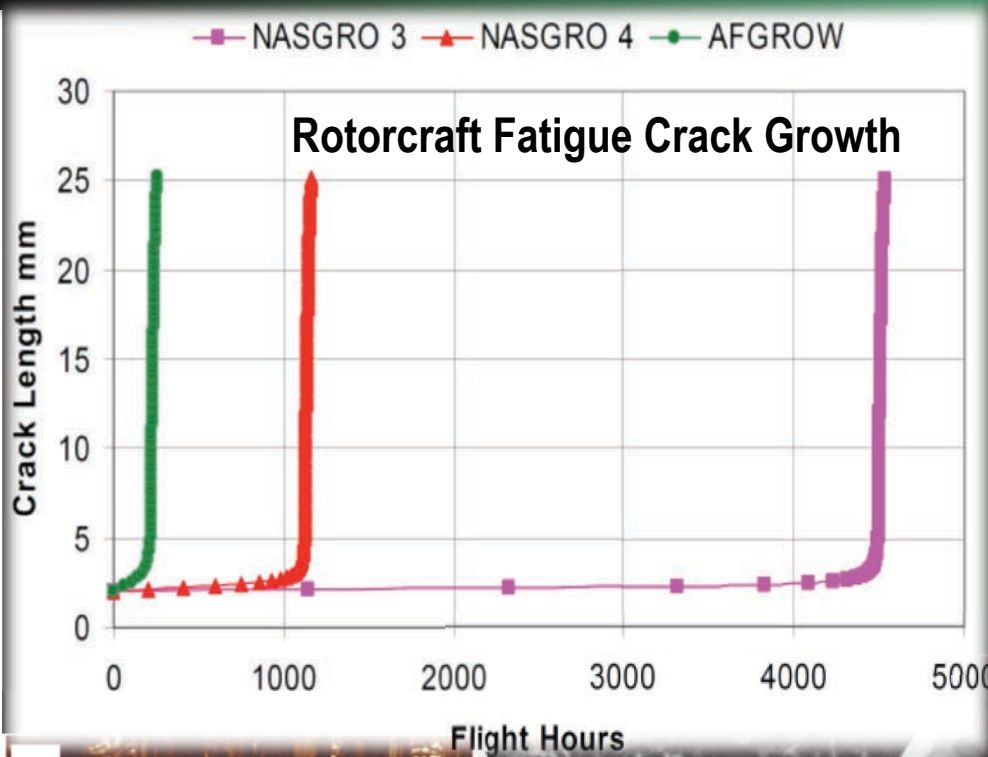


Material Damage Precursor - Failure Correlation

- **Benefits to operators:** Enable aviation *digital health monitoring*, effective maintenance “big data” management
- Immediate vehicle *health state*
- Moving beyond Condition-based Maintenance (CBM) to informed *material state-based awareness*
- *Automated* component health tracking

Finding and Catching "Materials Damage Precursors"

- Through Intelligent built-in Sensing Network & Multifunctional Materials





Cloning "Materials DNA" - Producing Novel Materials Through Nanorestructuring -

Materials Genome
Engineering Building Blocks Characterization

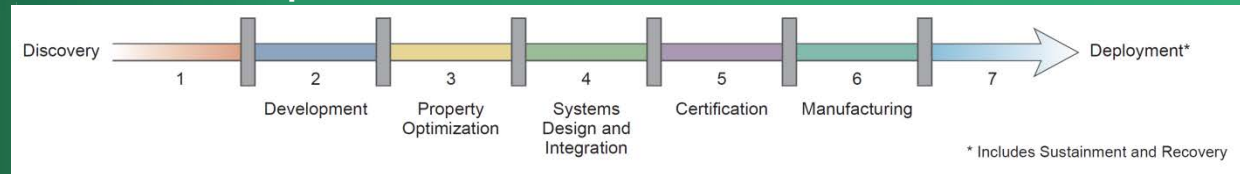
THE U.S. MATERIALS GENOME INITIATIVE

Meeting Societal Needs: Accelerating Our Pace

Building Infrastructure for Success

Materials Development Continuum

"Materials Genome Initiative for Global Competitiveness" - June 2011



Materials Database - Computational M/S - Experimental & Digital Data

Nanorestructuring Materials "DNA" Cloning Prototype

Acc.V 5.00 kV 3.0 21x Det SE WD 23.8 Hvac

Extremely Lightweight, Adaptive, Durable, and Damage Tolerant

Improved Reliability and Longevity

"Maintenance-Free" "Fatigue-Free" Structures Materials by Design

Aviation

DNA: Digital Nanomaterial Architecture

Enabling "Reconfigurable & Self-Healing Elements"



- Bio-Inspired with Multifunctional & Self-Adaptable Capabilities -

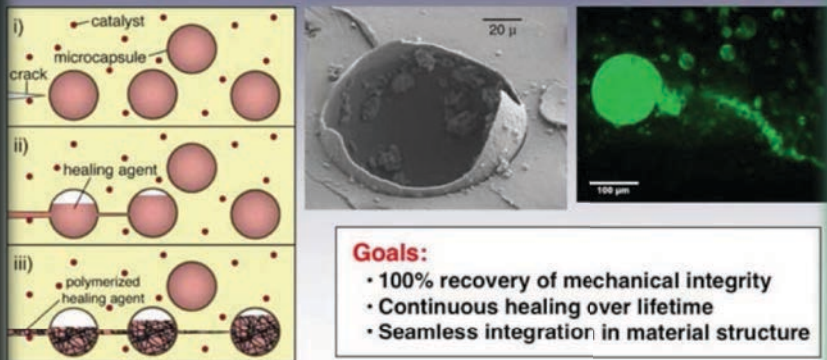
Potential new process for new types of active, reconfigurable materials for structural morphing & healing, vibration attenuation, and dynamic load mitigation

- Fire ants collectively entangle themselves to form an active structure capable of changing state from liquid to solid when subject to applied loads

Self-Healing Polymers

Materials System:

- microencapsulated healing agent
- suspended catalyst phase
- polymeric matrix



Goals:

- 100% recovery of mechanical integrity
- Continuous healing over lifetime
- Seamless integration in material structure

Self-Healing

- Embedded microvascular networks within structural materials
- Continuous transport of healing agents throughout structural lifetime

Can this technology be applied to composites materials with fiber reinforcement in the resin?



Can we dynamically alter interconnections among subsystems to direct the flow of energy and entropy within networks to achieve desired macroscopic properties?



Aviation Health State Awareness Vision

Developing Next-Generation Artificial Intelligence

- Physics-Centric Model Based AI -



- Rule-Based AI -

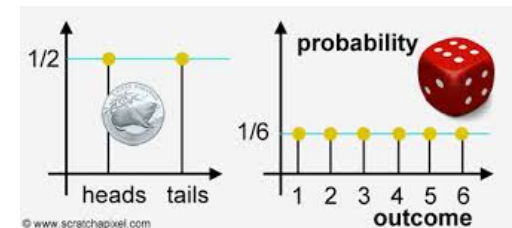
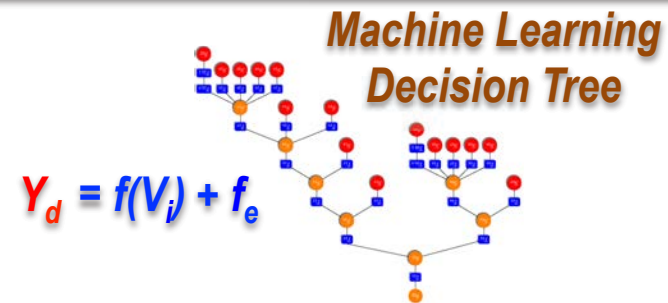
- ✓ Good for well-defined problems and system parameters with good known certainty
- ✓ *Incapable of training and difficult to address new hidden states and uncertainty*

- Statistical Learning AI -

- ✓ Don't follow exact rules but based on statistical models of certain types of problems – Deal with uncertainty & Probability
- ✓ Artificial Neural Network with different computation layers to process data
- ✓ Couldn't explain informed decision but could tell with level of probability
- ✓ *Difficult to train/address new hidden states*

- Physics-Centric Model Based AI-

- ✓ Construct and/or update models in real environment & address new hidden states
- ✓ Enable self training
- ✓ *Capable of perceiving, learning, abstracting, and reasoning*



Probability of Outcomes



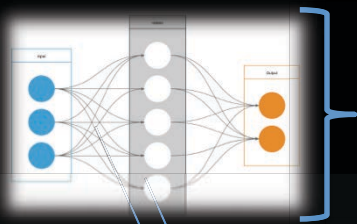
**Cognitive
capability with
direct feedback
and learning**

Integrating Next-Generation Artificial Intelligence

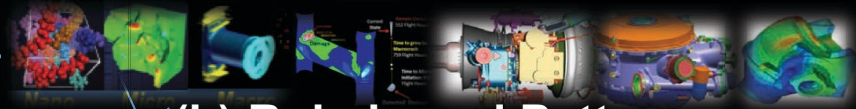
- Increase Aircraft Safety and Longevity -



1



(a) Model of Models



(b) Rule-based Pattern Recognition & Statistical Learning

2

Automated Data Pipeline in Real-Time

- Engine
- Drive Environmental Controls
- Structures Fuel Controls
- VMS Hydraulic Controls
- Electronics & Wiring Power Controls
- Rotors Systems Engine Controls
- Photo Audio
- Text



(c) Cognitive Capability

Self-Learning

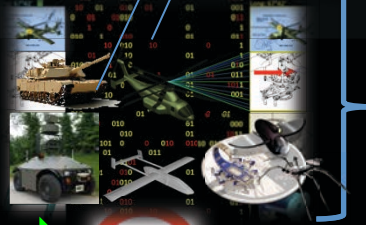
Auto-Feedback

(1) Identify Model of Models properties, e.g., ingredients of longevity or precursors of onset of failure

(2) Enable cognitive cueing and human-machine teaming, interaction, & communication in RT

(3) Facilitate system behavior change for sustaining longevity or self healing to disrupt failure cascade

(b) System of Systems



(a) Artificial Intelligence Machine Learning (ML)



Goal



Achieve "Maintenance-Free" thru intelligent comprehensive integrated solution

Conclusions

- ✓ Extensive human-manual maintenance labor presents **substantial cost burden for aviation stakeholders**
- ✓ Condition based maintenance lack automation capability – **not a perfect solution**
- ✓ **Advanced discoveries** in materials damage precursor detection and characterization, materials genome, and self-healing are possible to help ease some poor reliability concerns
- ✓ Fatigue and maintenance-free vision can be achieved via comprehensive **AI-ML integrated health state awareness** technology
- ✓ In addition to rule-based and statistic learning, next generation of artificial intelligence will include **physics-models to provide cognitive capability** including direct feedback and learning



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THANK YOU AND QUESTIONS?