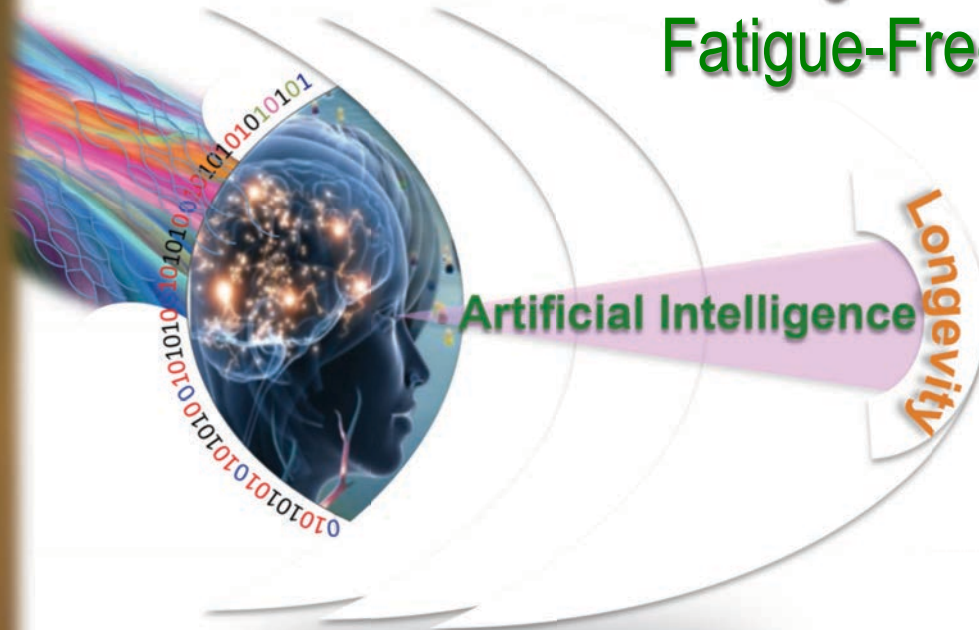




TEXAS TECH UNIVERSITY™



Intelligent State Awareness for Fatigue-Free Aviation Platforms



Presented to:
Rensselaer Polytechnic Institute (RPI)
Troy, NY
Dec 5, 2018

Dy D. Le, Director
Texas Tech University (TTU)
Office of the Vice President for Research
Institute for Materials, Manufacturing, and Sustainment (IMMS)
Lubbock, Texas

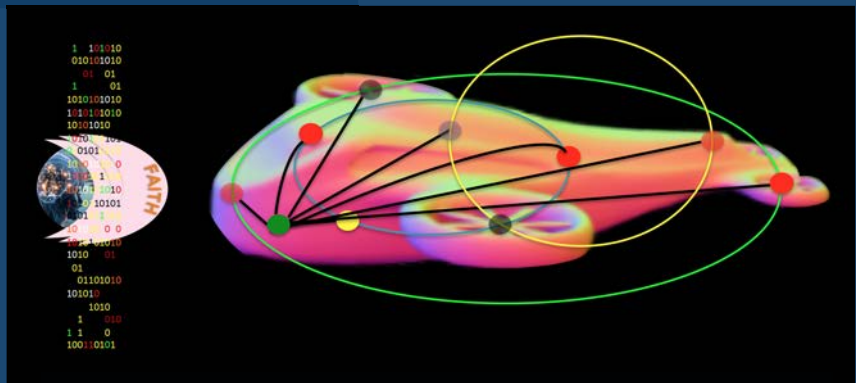
Presentation Outline

- Why “*Fatigue-Free Aviation Platforms*” ?
- Machine versus human “*Longevity Perspective*” and the search for “*Bio-Inspired Living Aerial Platform*”
- Defying “*Impossibilities*” and envisioning “*Discoveries*”
 - Finding & catching “*Materials Damage Precursors*”
 - Cloning “*Digital Nanomaterials Architecture (DNA)*”
 - Enabling “*Reconfigurable & Self-Healing Elements*” and “*Intelligent Sensing Network*”
- Demonstrating “*Health State Awareness*” concept of operation for achieving “*Fatigue and Maintenance-Free Aircraft*”
- Enabling “*Digital Twin*” and “*Autonomous Component Tracking*” to increase aircraft safety and fleet health management
- Highlighting “*Artificial Intelligence*” perspectives
- Presenting “*Intelligent State Awareness*” hypothesis
- Summary

Value Proposition

**Intelligent Health State Awareness
Vision for Automated Structural
Health Monitoring and Fatigue-Free
Aviation Platforms**

Unleashing

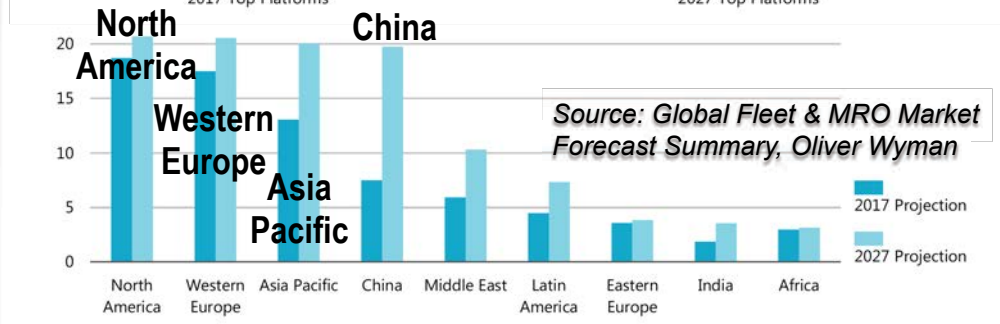
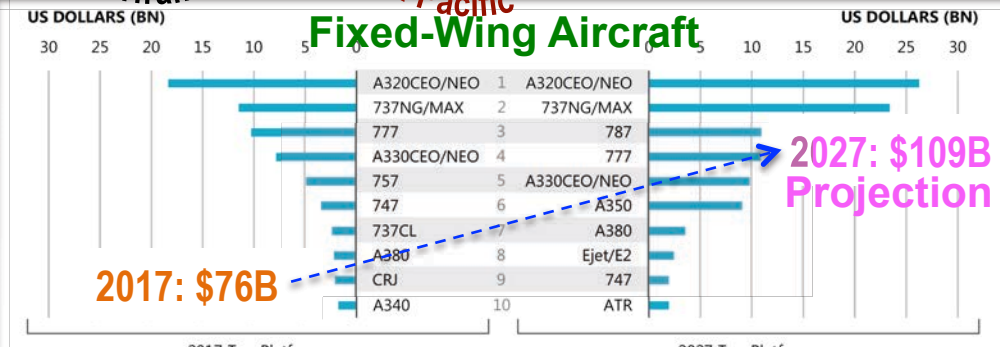
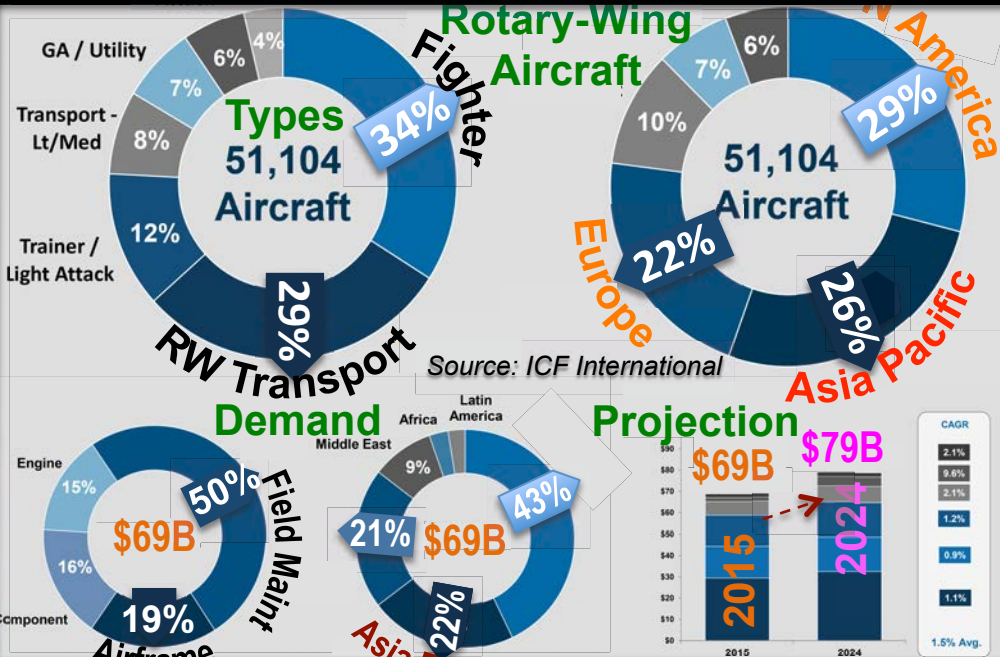


Revolutionary Capability

- **Achieve “zero-maintenance” to reduce sustainment costs**
- **Increase safety and availability**

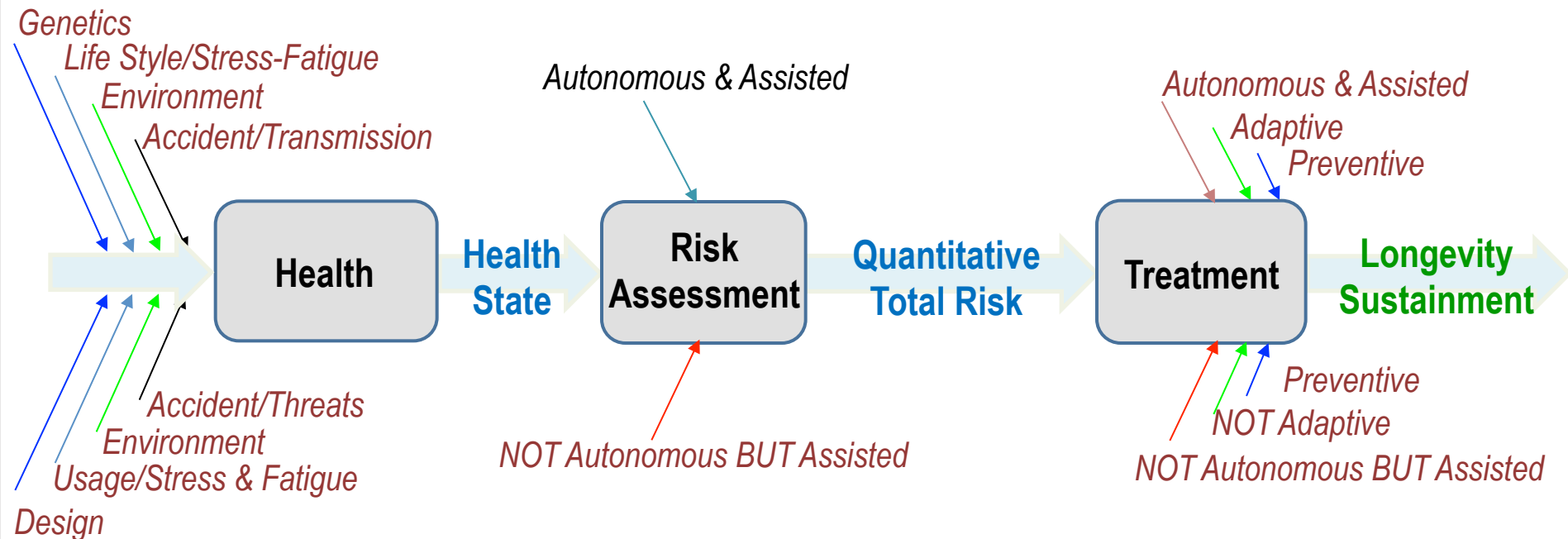
MRO: Maintenance, Repair, and Operation

Aviation MRO Projections

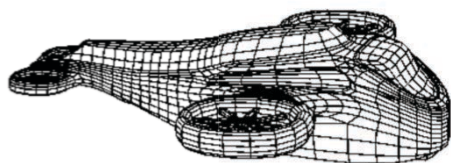




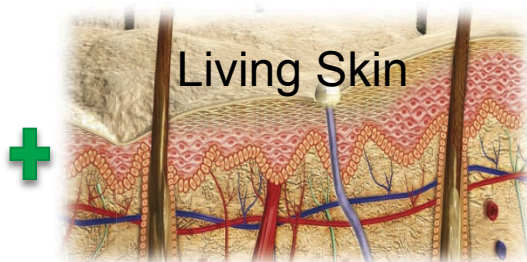
Human-Machine Longevity Sustainment



Platform Design



Multifunctional Structures



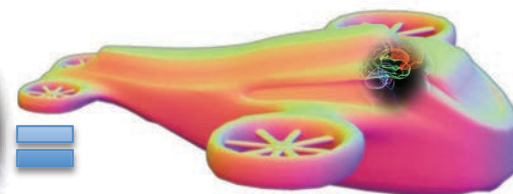
Courtesy of photosearch

Intelligence



cs.stanford.edu

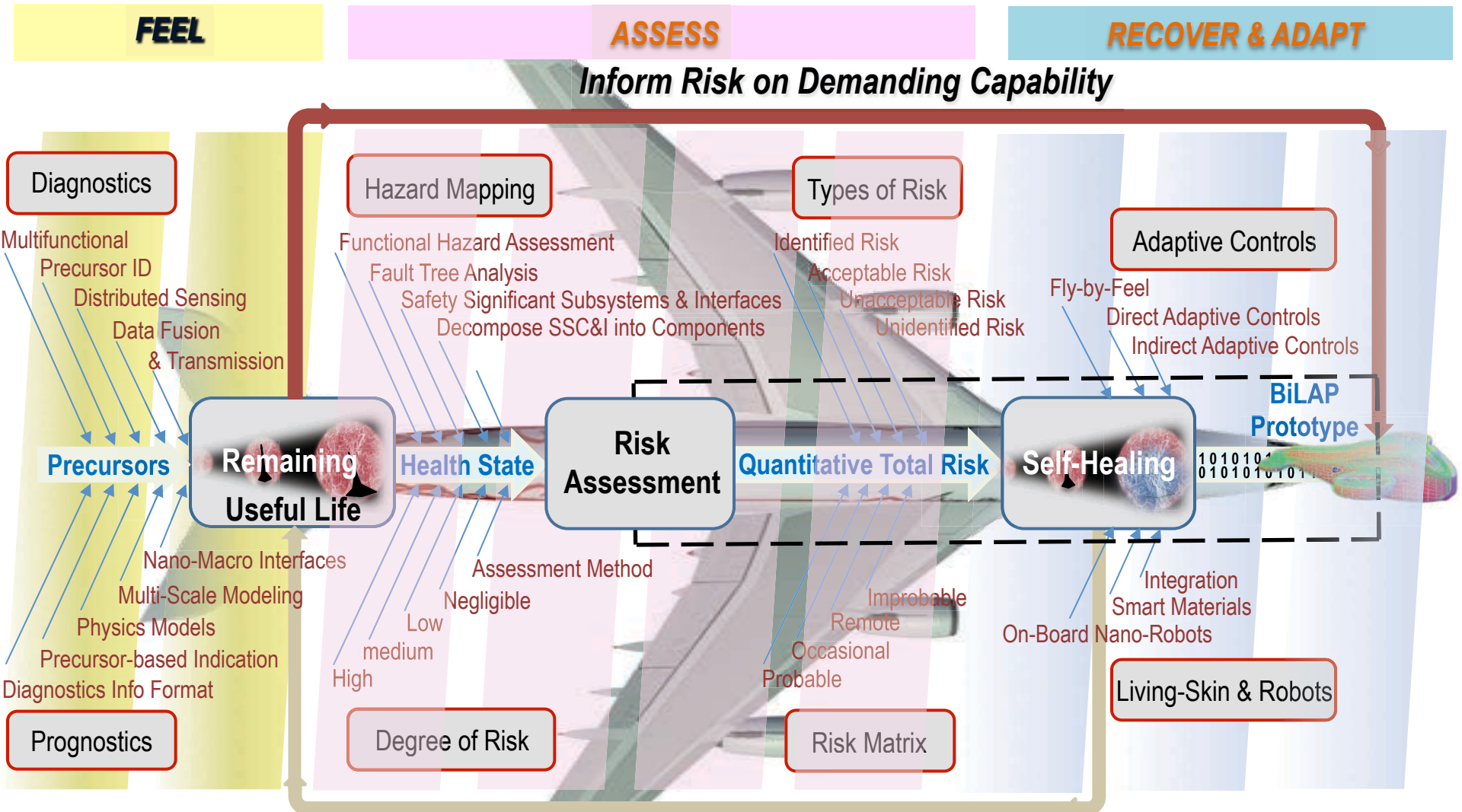
Next-Gen Platform



Bio-inspired Living Aerial Platform (BiLAP)



Science & Technology for "Bio-Inspired Living Aerial Platform - BiLAP"



Assess Remaining Capabilities: Structural Integrity and Survivability

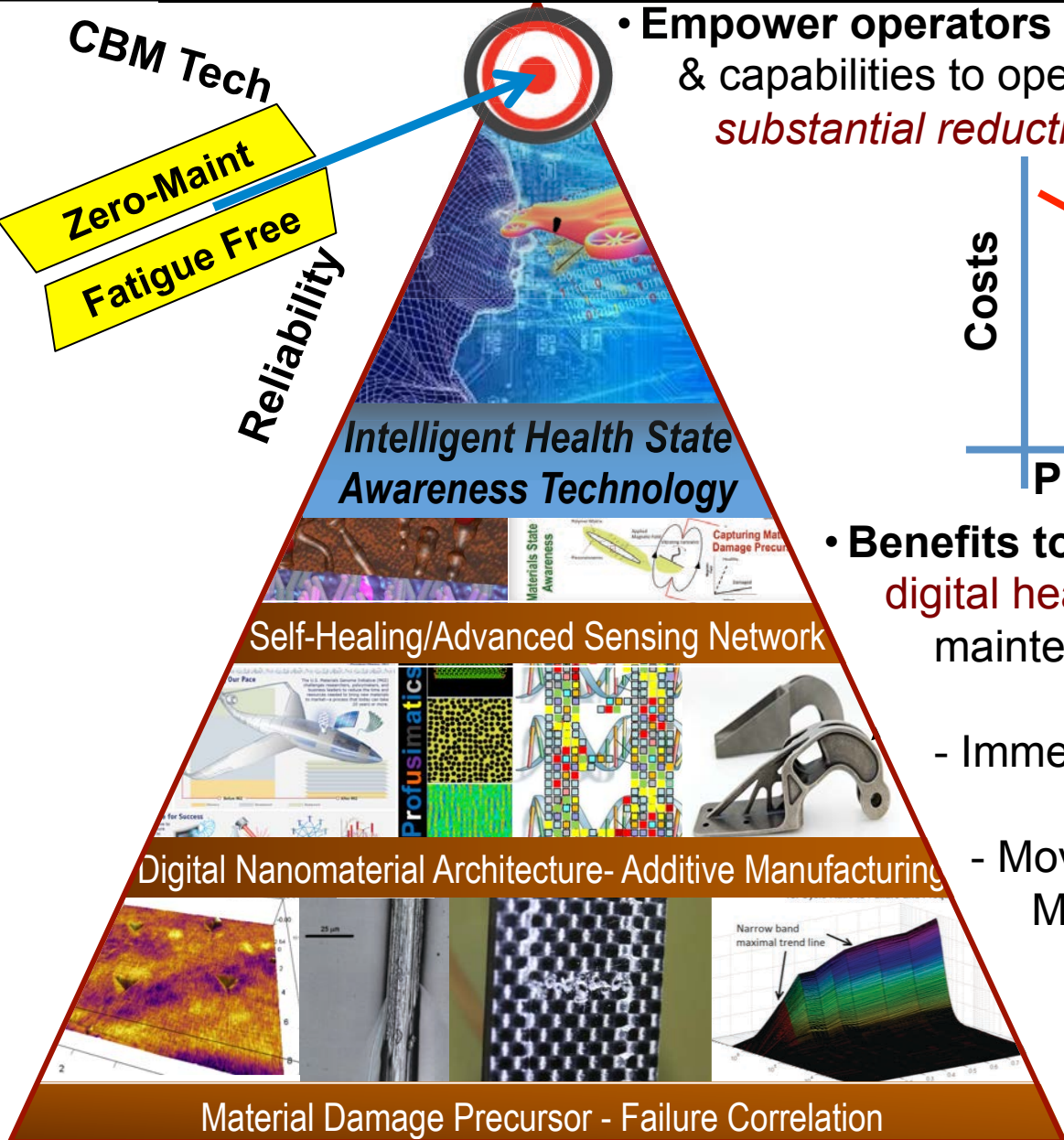
Defying Impossibilities and Envisioning Discoveries



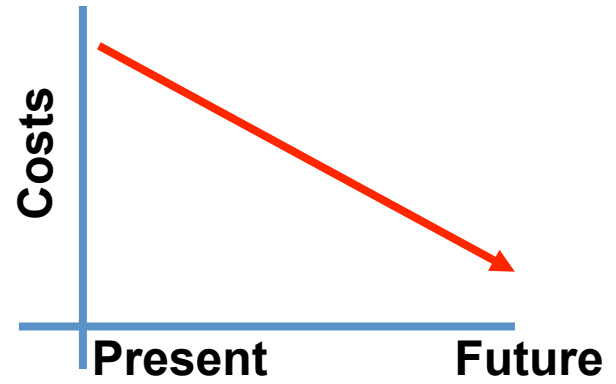
- A System Level Approach: Structures Perspective -

CBM Tech
 Zero-Maint
 Fatigue Free

Reliability



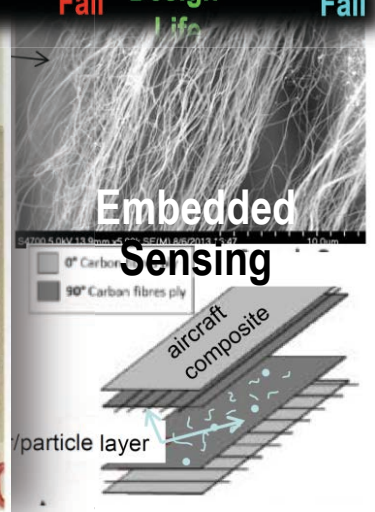
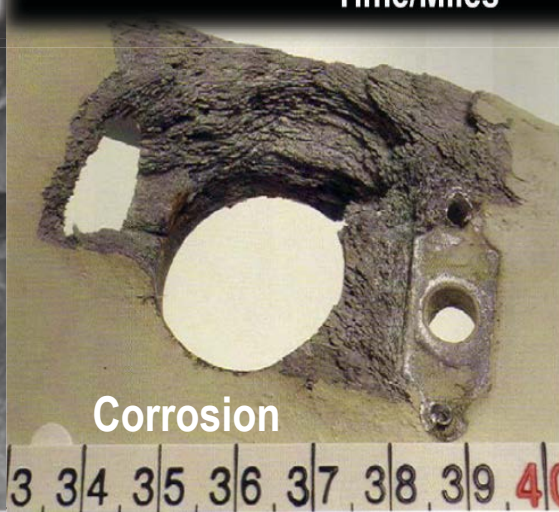
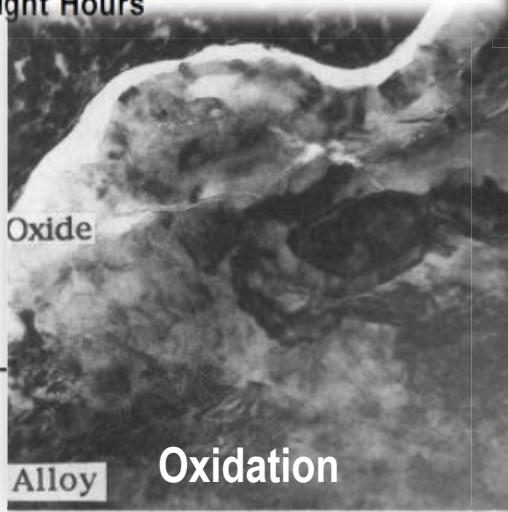
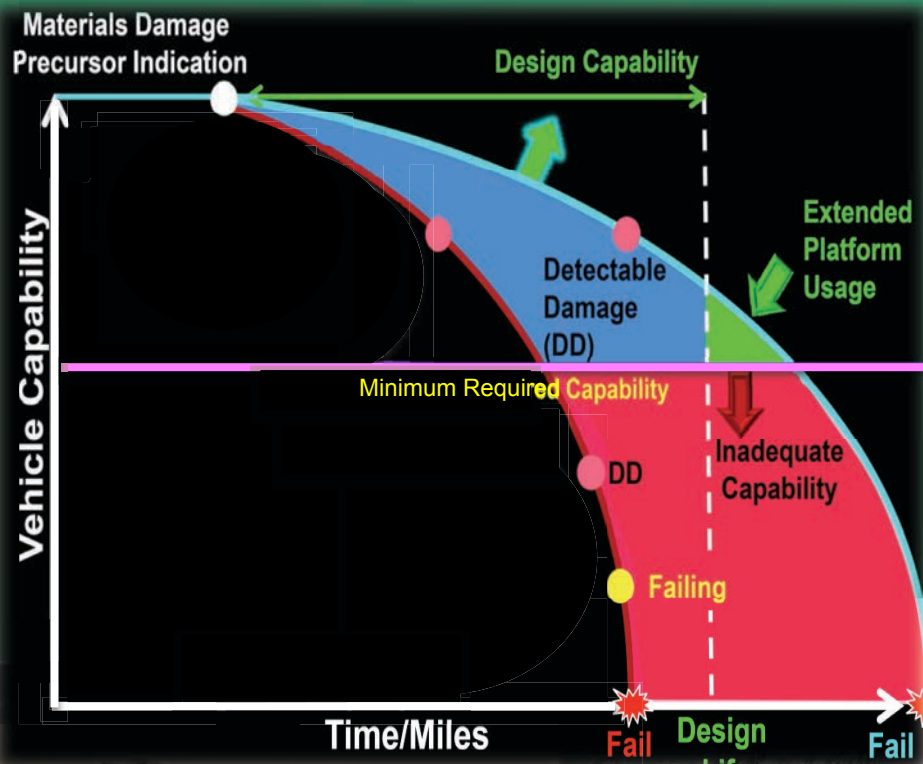
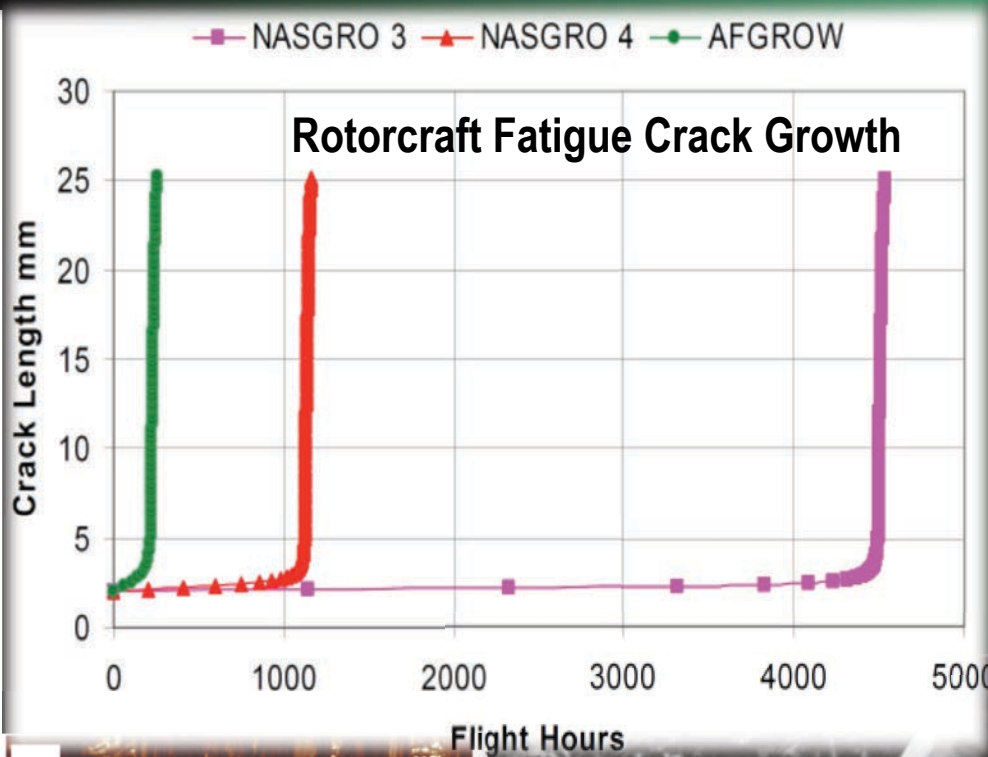
- Empower operators with “breakthrough” technologies & capabilities to operate vertical lift aircraft with *substantial reduction in maintenance costs*



- **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

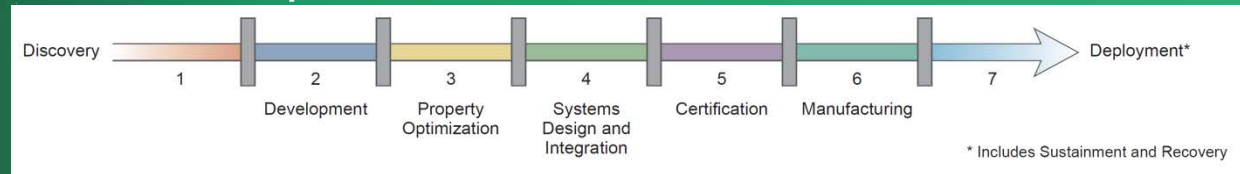
THE U.S. MATERIALS GENOME INITIATIVE

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 Spot Magn Det WD | 1 mm
5.00 KV 3.0 21x SE 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 -

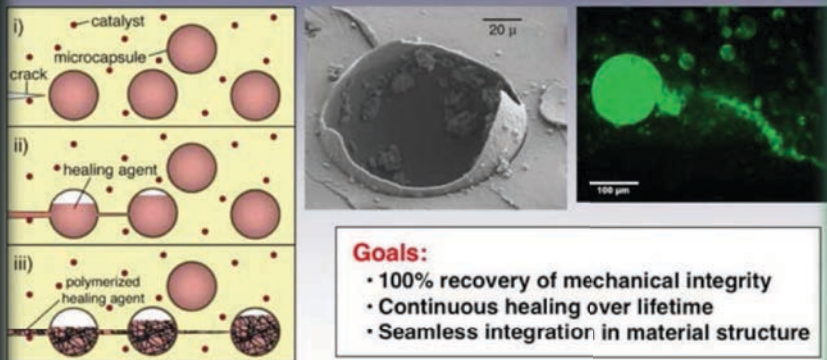
Potential new process for new types of active, reconfigurable materials for structural morphing & healing, vibration attenuation, and dynamic load mitigation

- 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

Reckman Institute

ILLINOIS

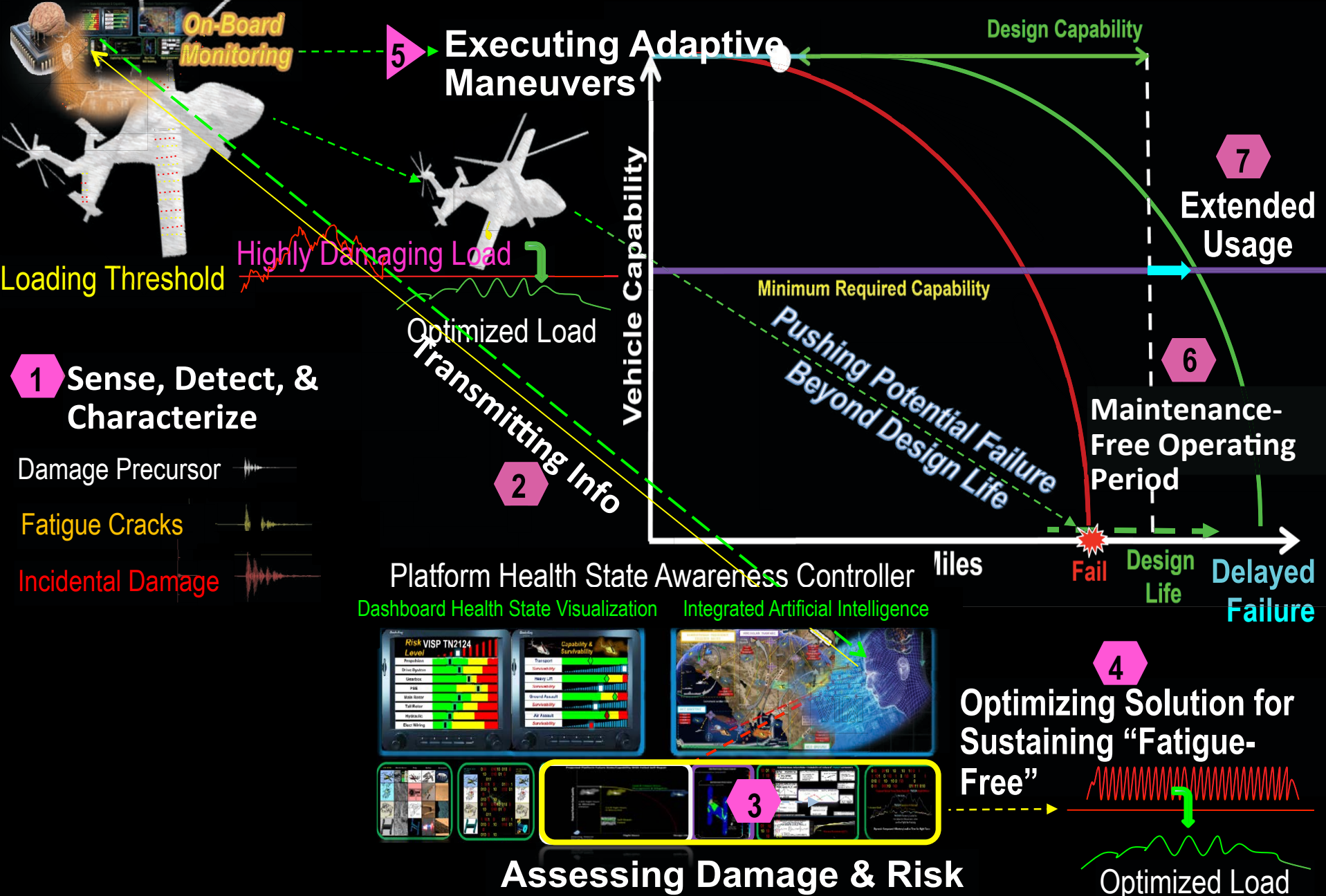
Self-Healing

- 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?

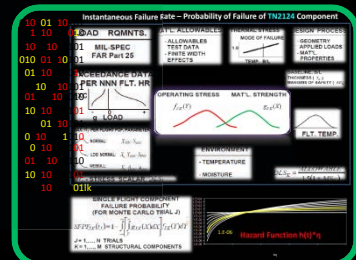
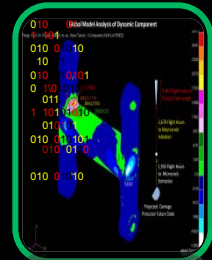
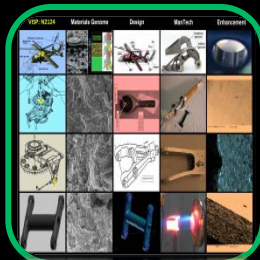
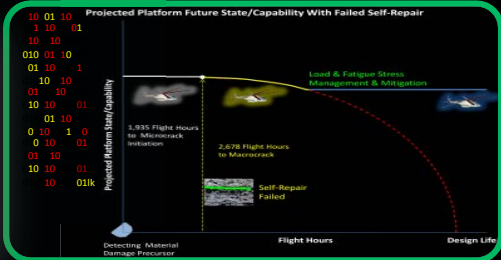
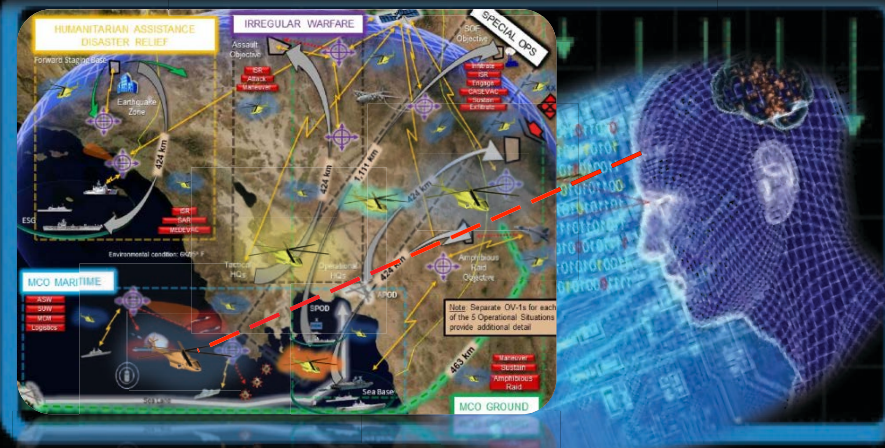
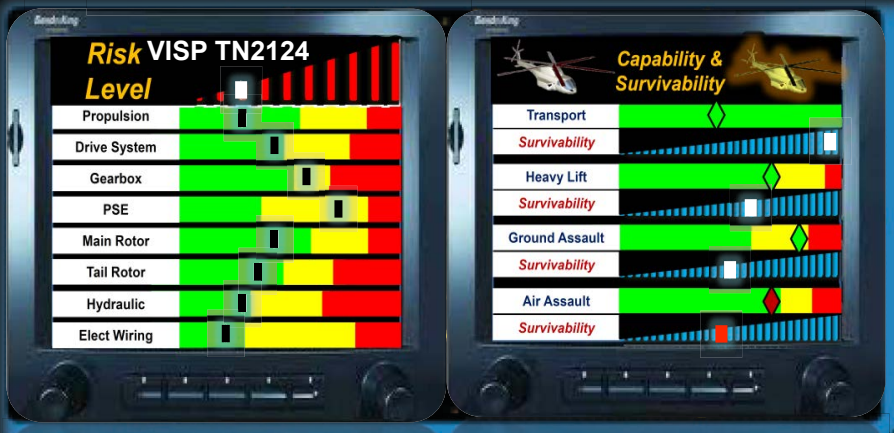


Aviation Health State Awareness Concept of Operation



VEHICLE STATE AWARENESS & CAPABILITY

EXPEDITIONARY MANEUVERS



Record Maneuvers & Dynamics

Capture Damage Precursor

Access Baseline

Run M/S Modeling

Assess Risk

Configure Adaptive Maneuver

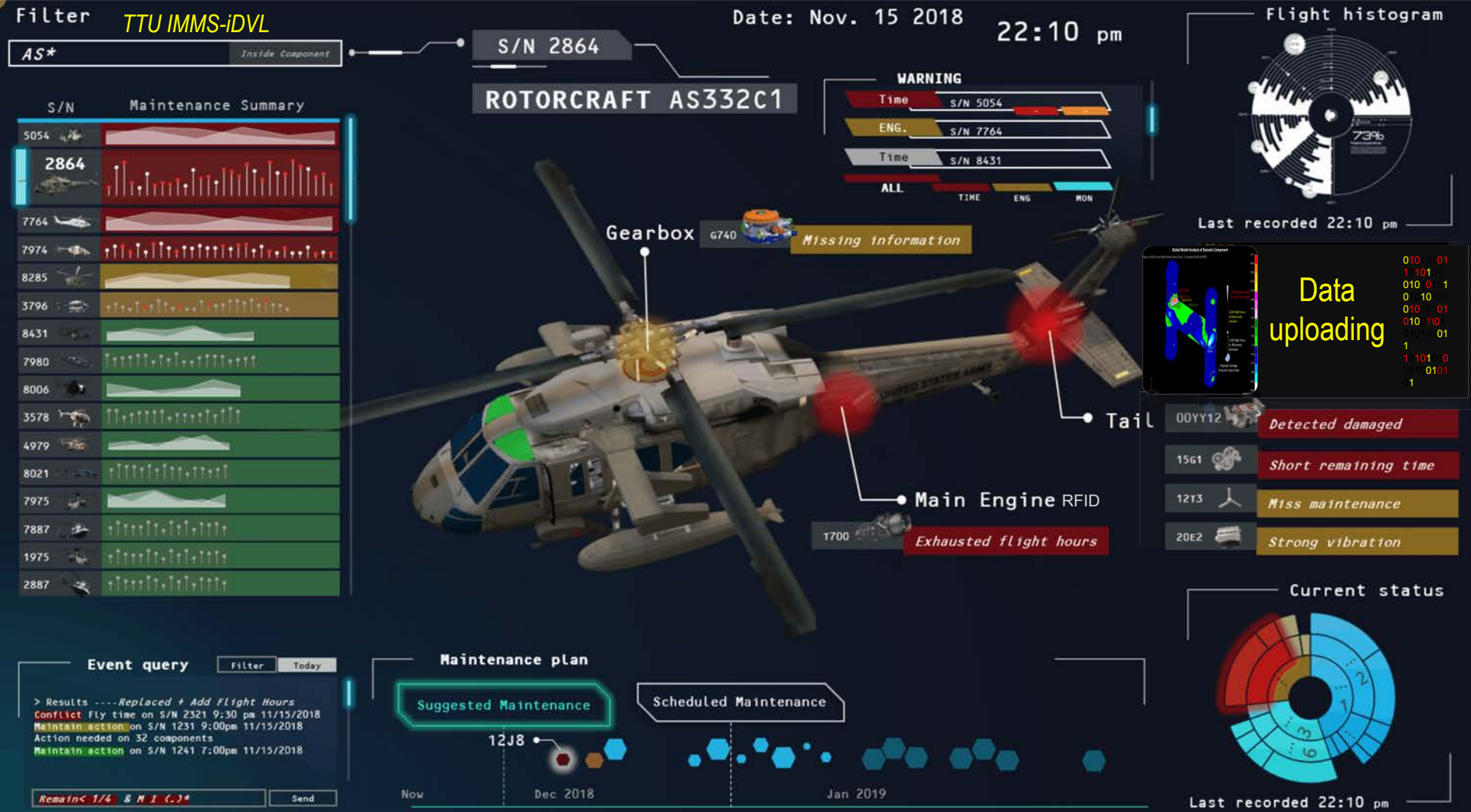
- Platform Health Management -

- ✓ Digital health monitoring
- ✓ Beyond CBM to informed health state-based awareness



– Beyond Intelligent Health State Awareness –

- ✓ Enable digital twin technology in near or real-time
- ✓ Allow autonomous component tracking



- Enable Digital Twin Concept -

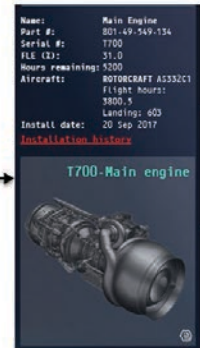
- ✓ Update virtual life-limited components augmented with incoming data in real-time or near RT
- ✓ Determine remaining useful life based on actual usage and characterized damage

Aircraft Fleet at Glance

Overview
highlights hotspots



Sensor data



Details view

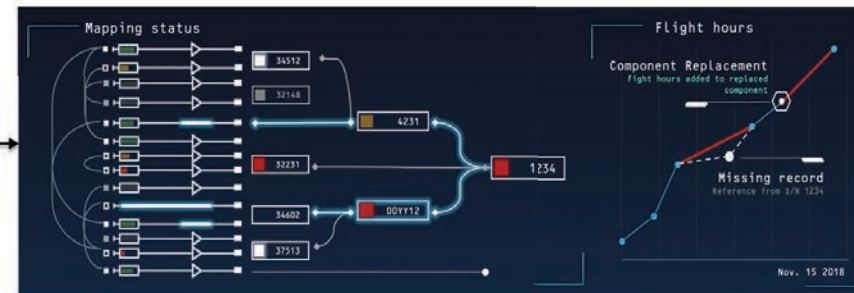


Component relationships



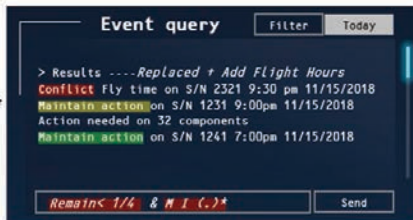
Predictive analysis and Action plan
with prognostic remain useful life

Details on Demand



Data Integrity *highlights data inconsistencies*

Rotorcraft Database



Event query
for data filtering
Zooming & Filtering

– Allow Autonomous Component Tracking –

- ✓ Aggregate “big data” to highlight patterns and trends from individual aircraft and fleet by serial numbers – enable autonomous tracking of critical components

Developing Next-Generation Artificial Intelligence

- Physics-Centric Model Based AI -



- Rule-Based AI -

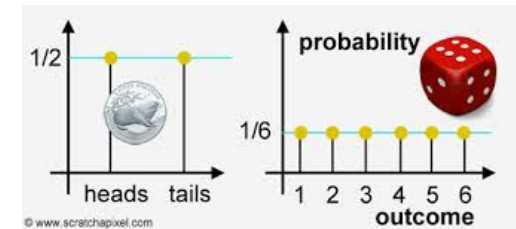
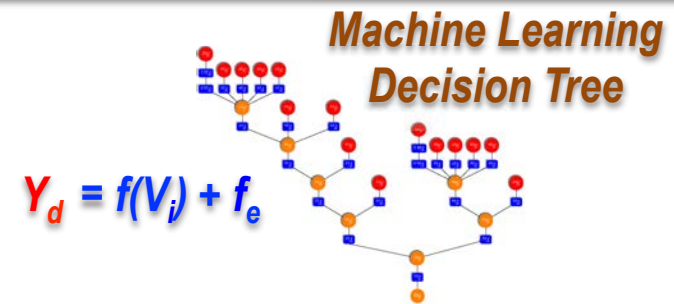
- ✓ Good for well-defined problems and system parameters with good known certainty
- ✓ *Incapable of training and difficult to address new hidden states and uncertainty*

- 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



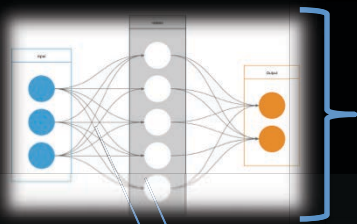
**Cognitive
capability with
direct feedback
and learning**

Integrating Next-Generation Artificial Intelligence

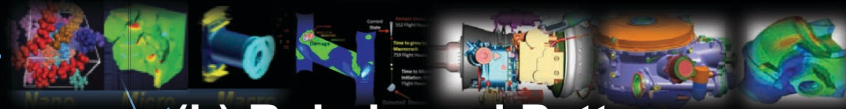
- Increase Aircraft Safety and Longevity -



1



(a) Model of Models



(b) Rule-based Pattern Recognition & Statistical Learning

Automated Data Pipeline in Real-Time

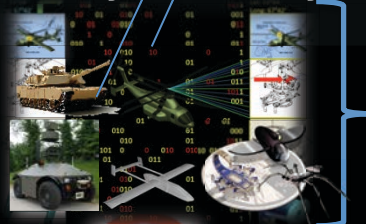
- Engine
- Drive Environmental Controls
- Structures Fuel Controls
- VMS Hydraulic Controls
- Electronics & Wiring Power Controls
- Rotors Systems
- Photo Audio Engine Controls
- Text



(c) Cognitive Capability

(a) Artificial Intelligence Machine Learning (ML)

(b) System of Systems



(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

Self-Learning

Auto-Feedback

Goal



Achieve "Zero-Maintenance" thru intelligent comprehensive integrated solution

Summary

- ✓ Next-generation aviation platform needs **multifunctional** and **intelligence** capabilities to achieve “**zero-maintenance**” and “**fatigue-free**” vision
- ✓ Extensive human-manual maintenance labor presents **substantial cost burden for aviation stakeholders**
- ✓ CBM **lack automation capability** – and improving reliability - **not a total solution**
- ✓ **Advanced discoveries** in materials damage precursor detection and characterization, materials genome, and self-healing are possible to help ease some poor reliability concerns
- ✓ **Health state awareness** technology also enables **Digital Twin** concept and **automated SHM** and **component tracking**
- ✓ In addition to rule-based and statistic learning, next generation of AI will include **physics-models to provide cognitive capability** including direct feedback and learning for Bio-inspired Living Living Platform



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THANK YOU AND QUESTIONS?