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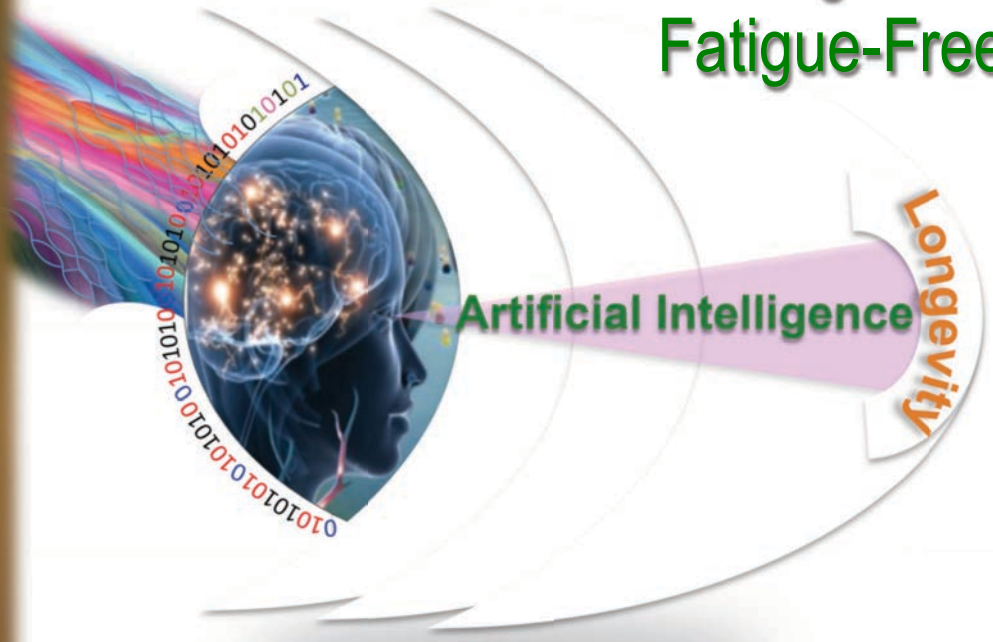
Intelligent State Awareness for Fatigue-Free Aviation Platforms



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

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Texas Tech University (TTU)
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Lubbock, Texas

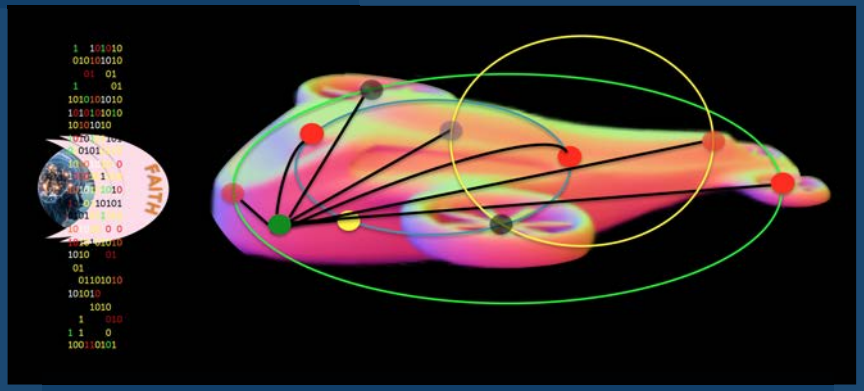
Presentation Outline

- 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

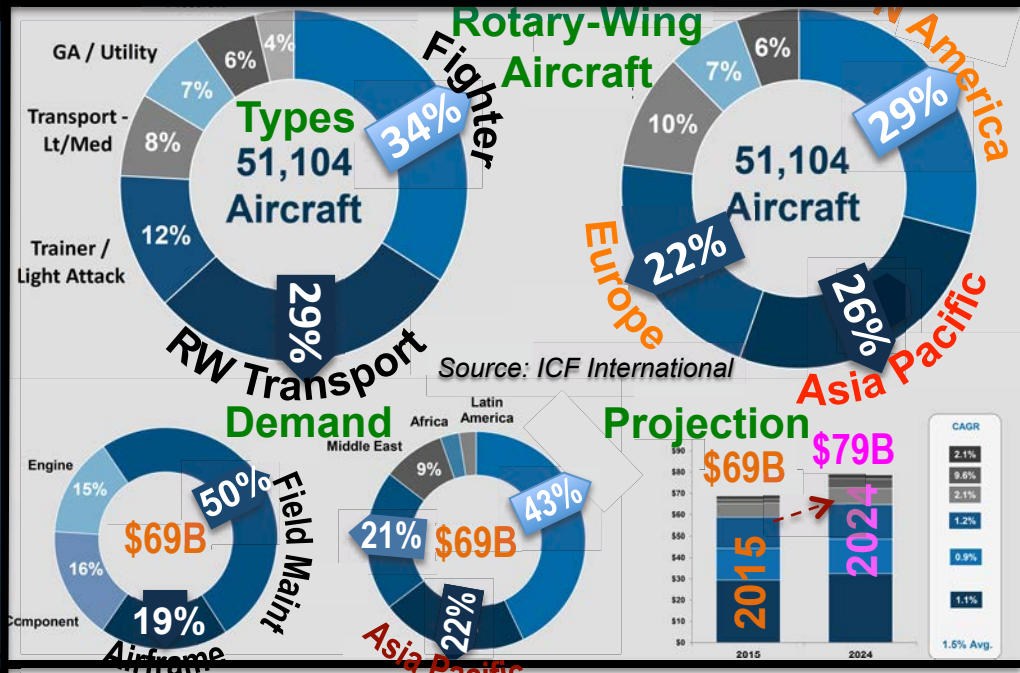


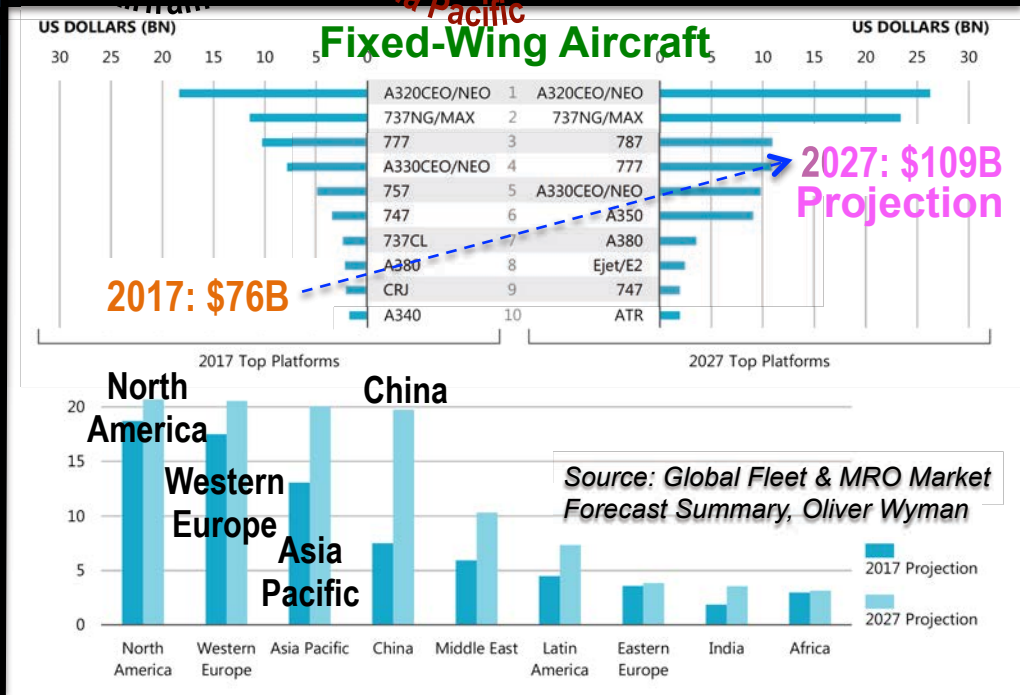
Revolutionary Capability

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

MRO: Maintenance, Repair, and Operation

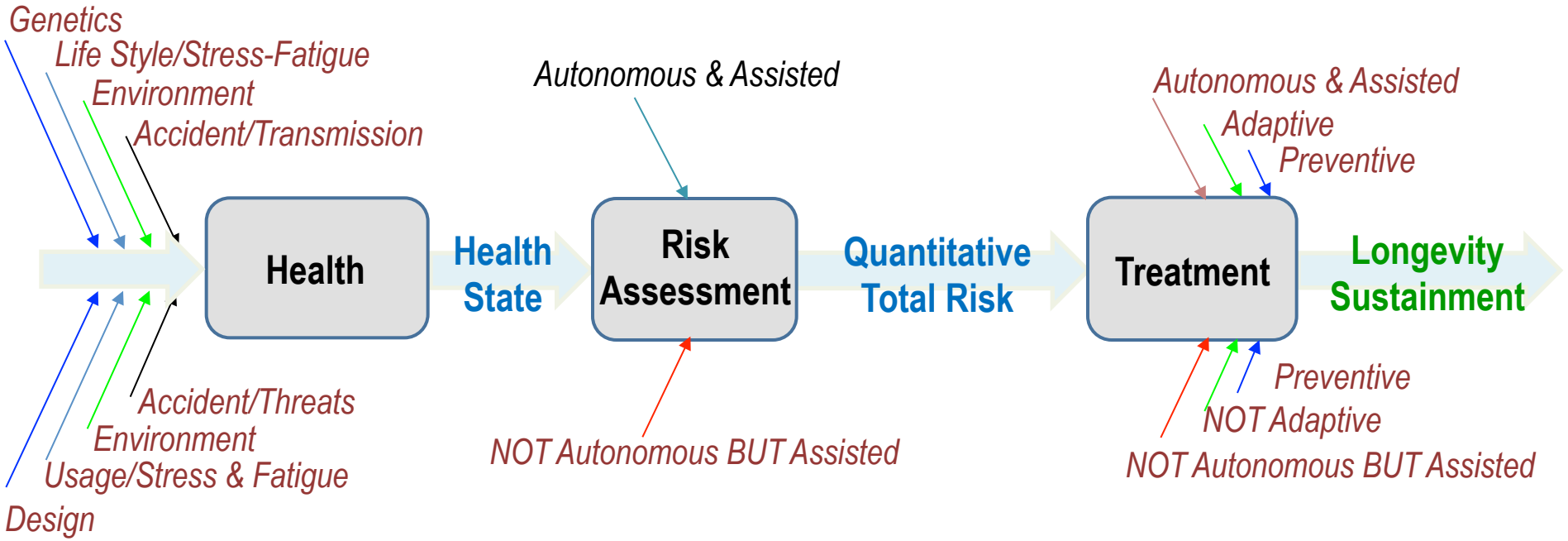
Aviation MRO Projections



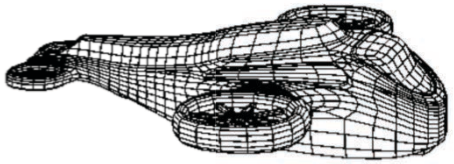


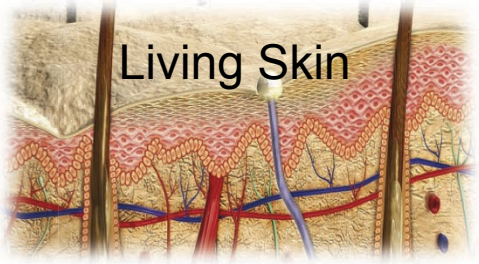
Human and Machine Longevity Perspectives
– Similarities and Differences –

Human-Machine Longevity Sustainment



Platform Design | **Multifunctional Structures** | **Intelligence** | **Next-Gen Platform**





Courtesy of photosearch

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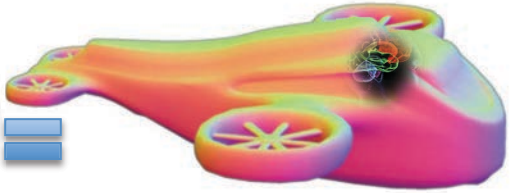
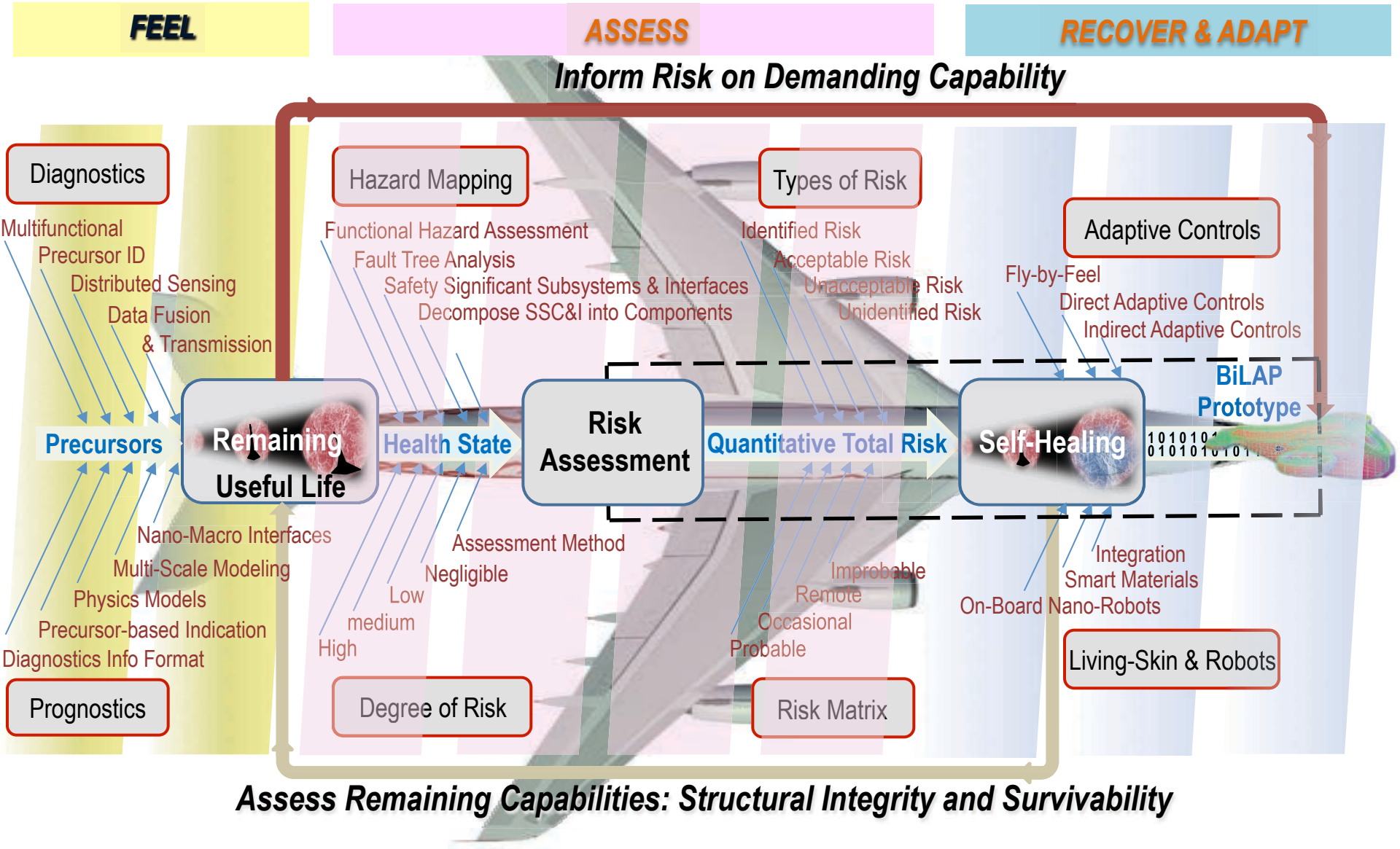
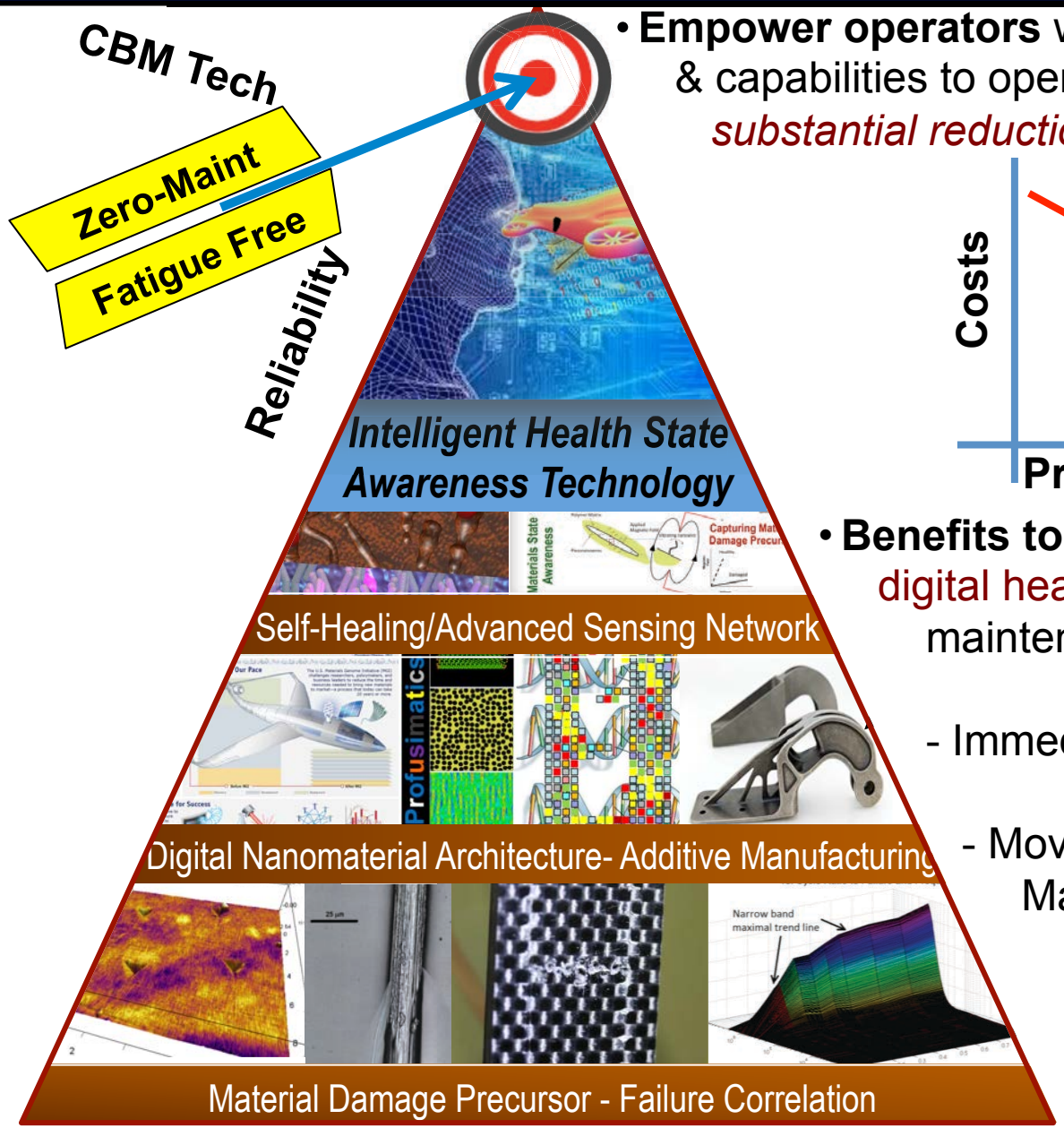


Bio-inspired Living Aerial Platform (BiLAP)

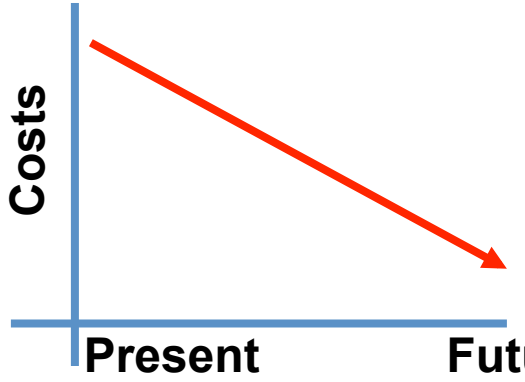
Science & Technology for "Bio-Inspired Living Aerial Platform - BiLAP



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



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



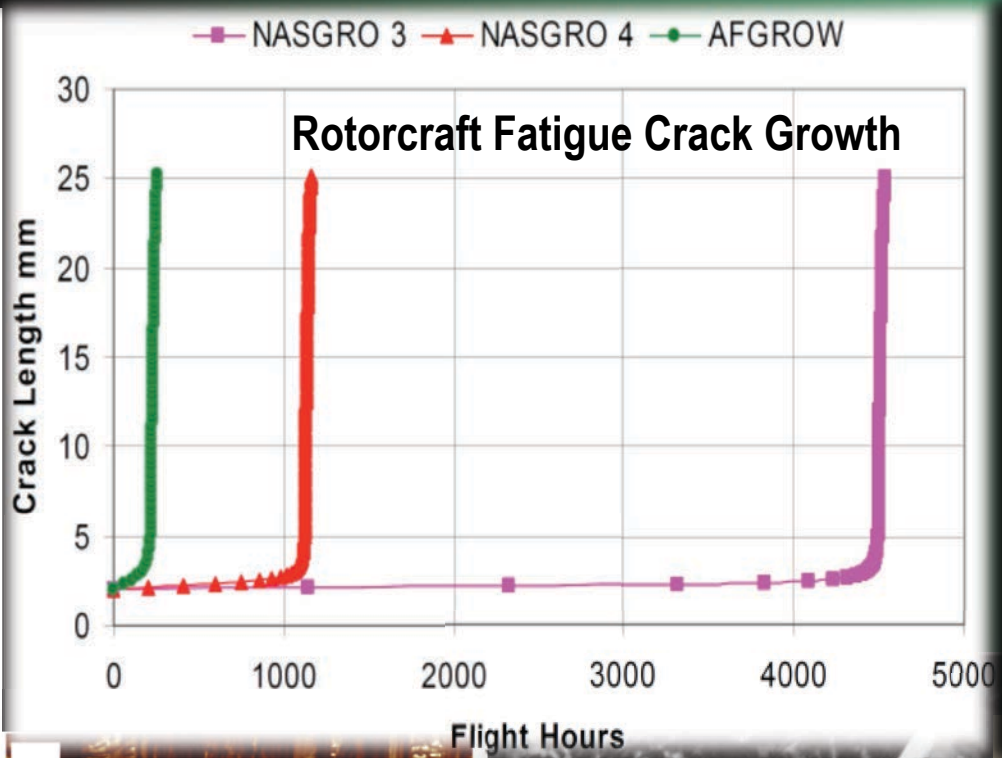
- **Benefits to operators:** Enable aviation digital health monitoring, effective maintenance "big data" management

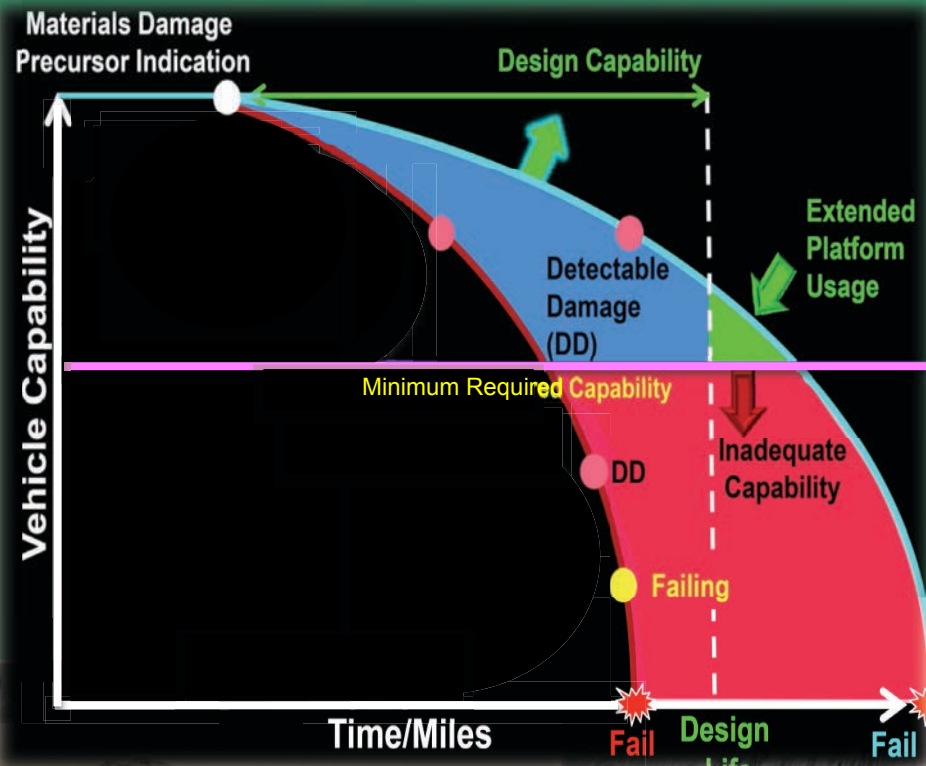
- Immediate vehicle health state

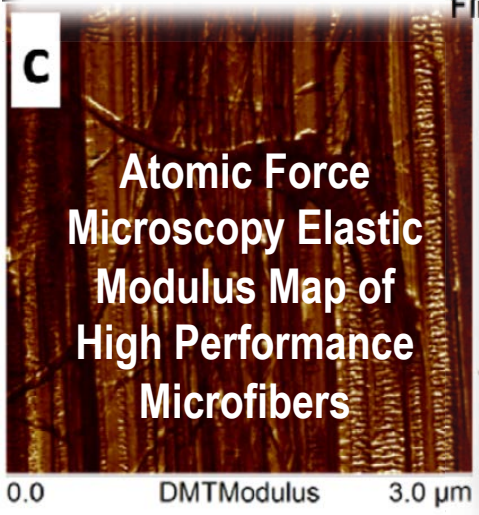
- Moving beyond Condition-based Maintenance (CBM) to informed material state-based awareness

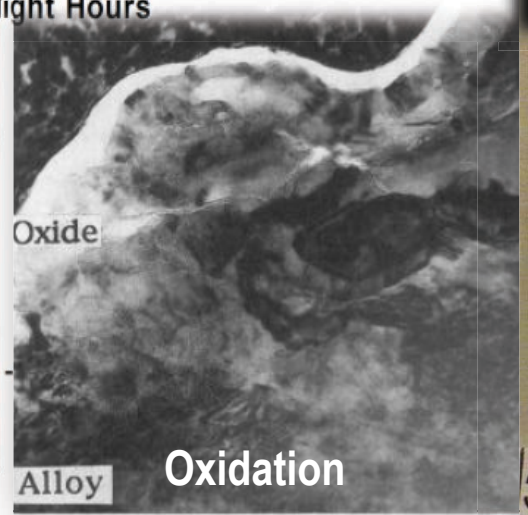
- Automated component health tracking

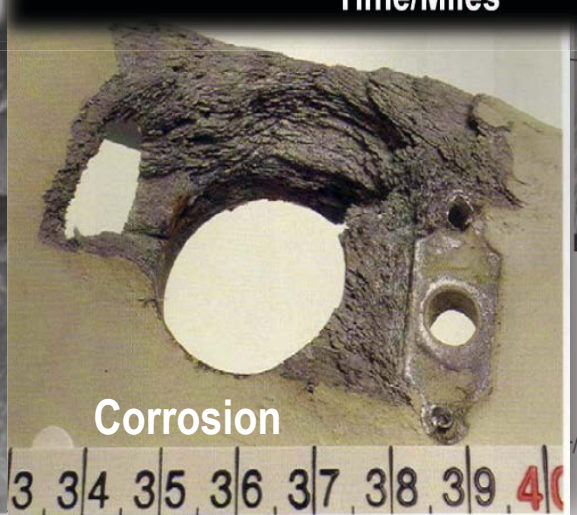
Finding and Catching "Materials Damage Precursors"
- Through Intelligent built-in Sensing Network & Multifunctional Materials

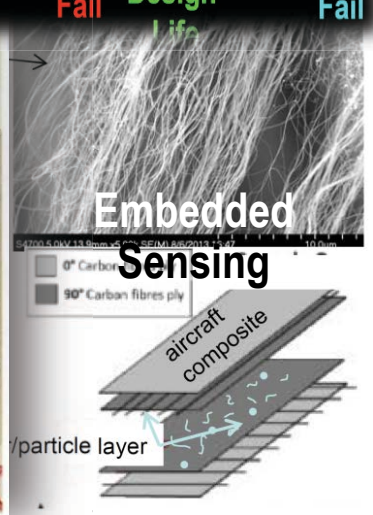




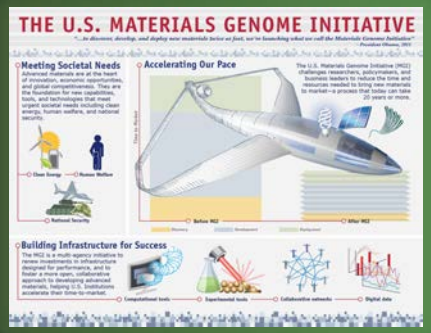






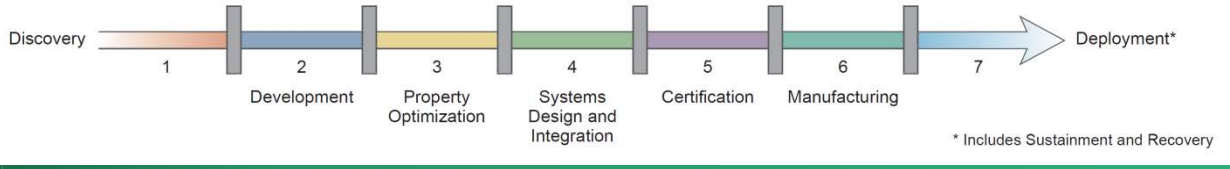


Cloning "Materials DNA"
- Producing Novel Materials Through Nanorestructuring -



Materials Development Continuum

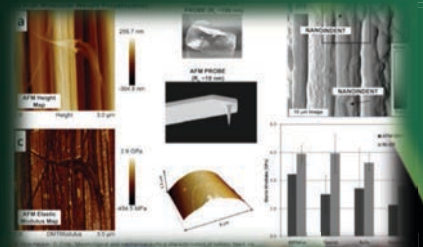
"Materials Genome Initiative for Global Competitiveness" – June 2011

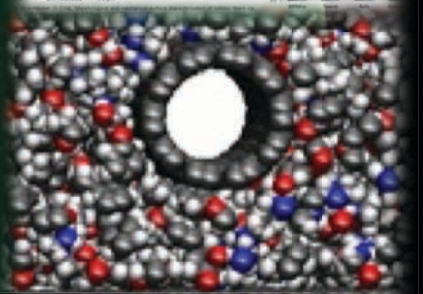


Materials Database – Computational M/S – Experimental & Digital Data

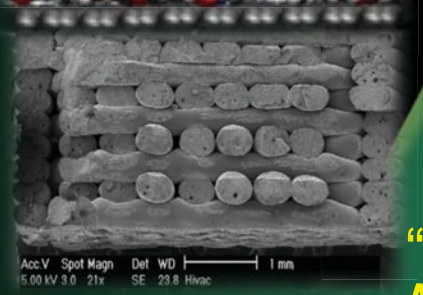
Materials Genome

Building Blocks **Characterization**

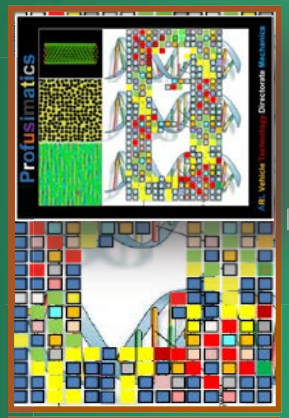


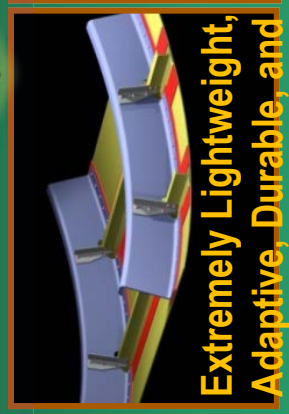


Engineering



Nanorestructuring

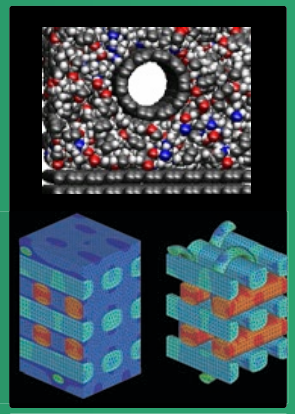


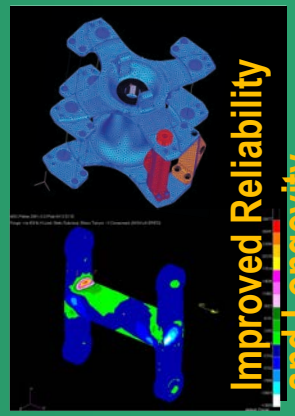


Extremely Lightweight, Adaptive, Durable, and Damage Tolerant

"Maintenance-Free" Aviation

Materials "DNA" Cloning

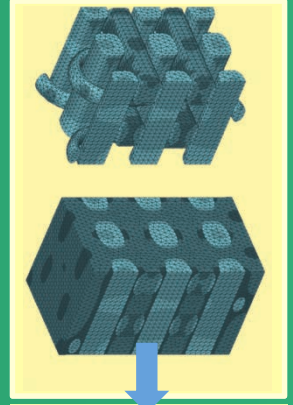


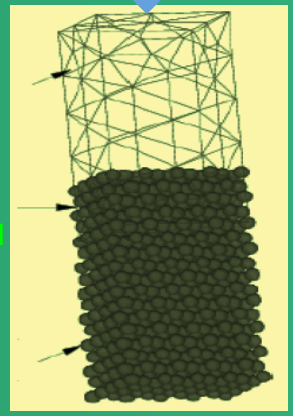


Improved Reliability and Longevity

"Fatigue-Free" Structures

Prototype





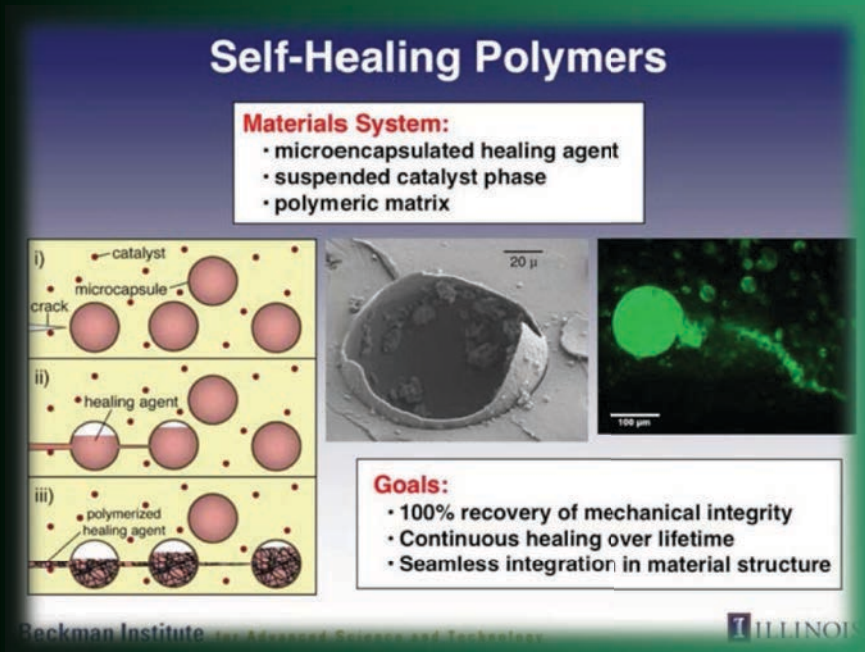
Materials by Design

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

Self-Healing

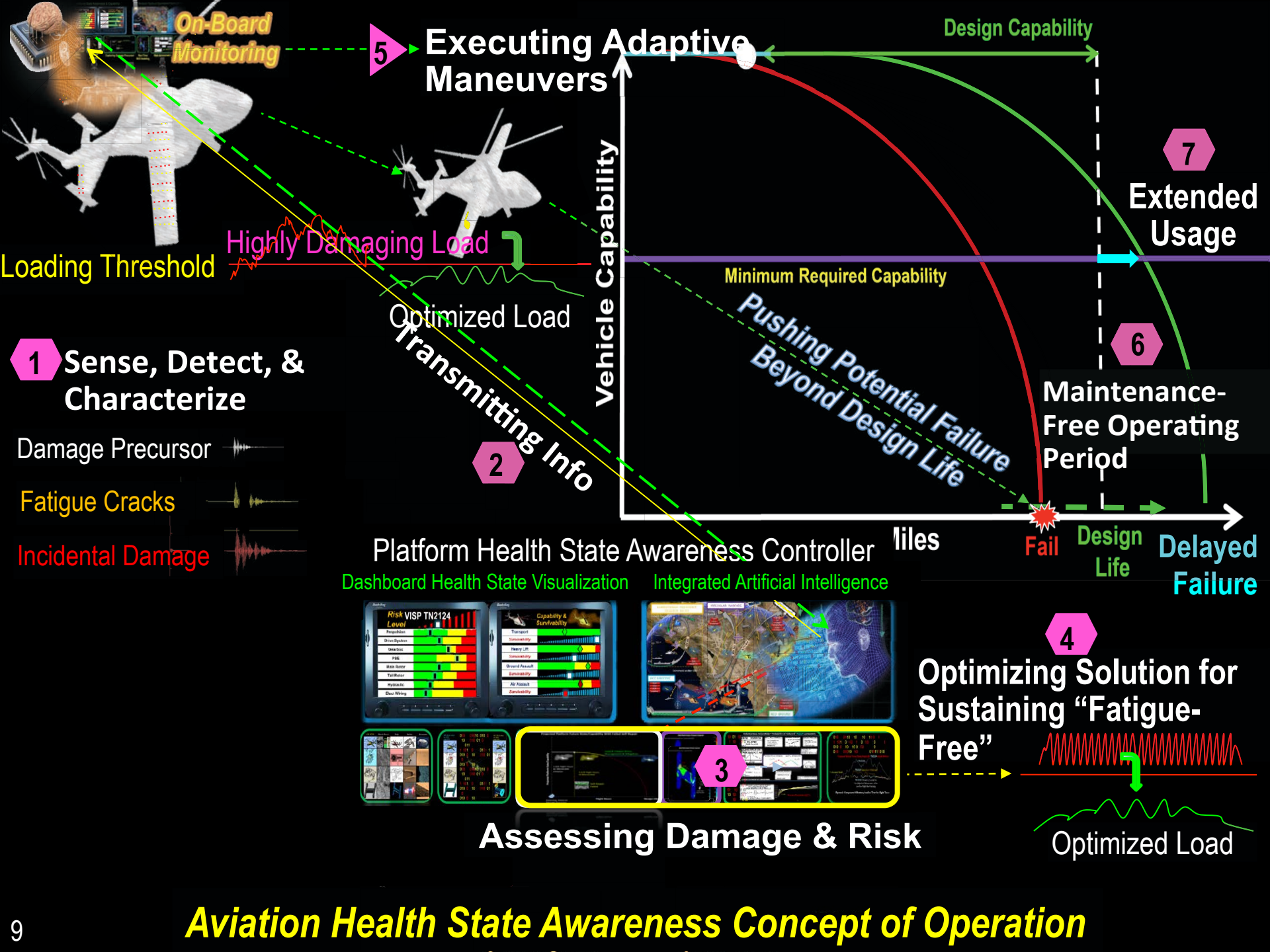


- Embedded microvascular networks within structural materials
- Continuous transport of healing agents throughout structural lifetime

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

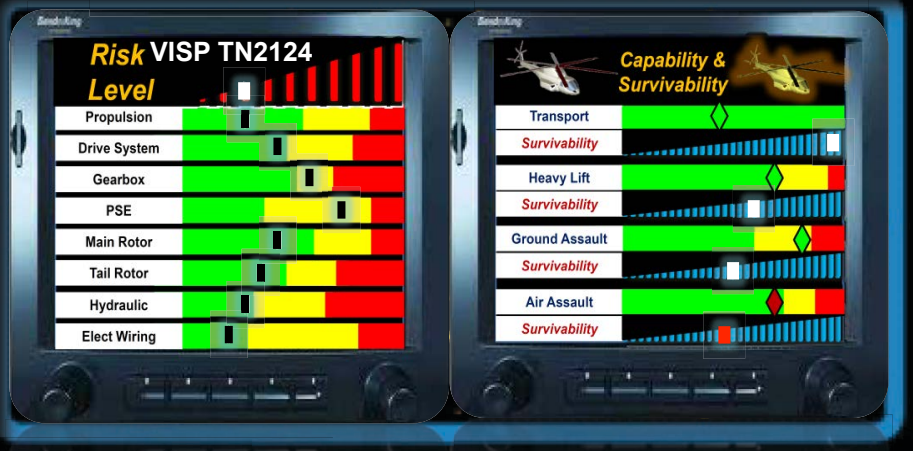
- Fire ants collectively entangle themselves to form an active structure capable of changing state from liquid to solid when subject to applied loads

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

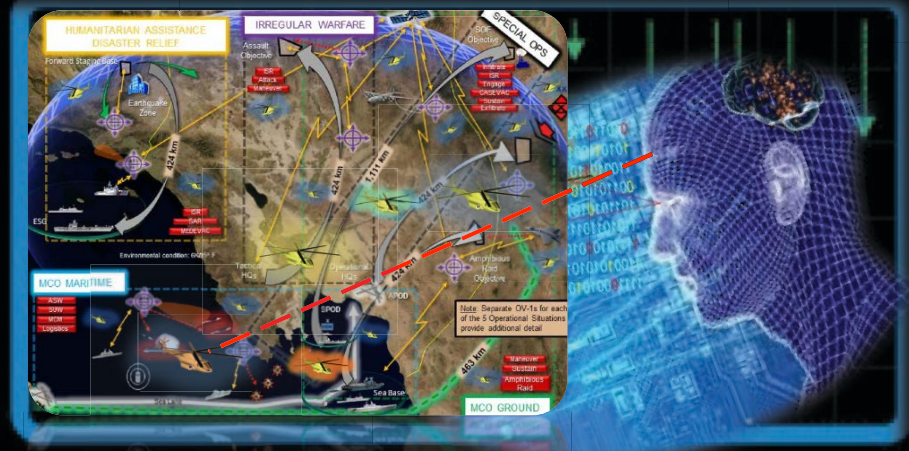


Aviation Health State Awareness Concept of Operation

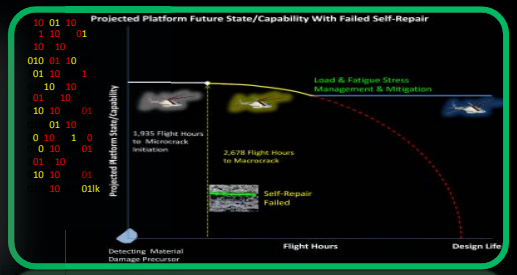
VEHICLE STATE AWARENESS & CAPABILITY



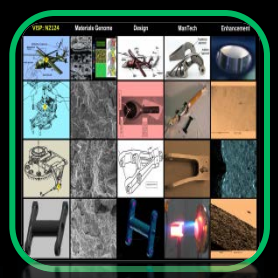
EXPEDITIONARY MANEUVERS



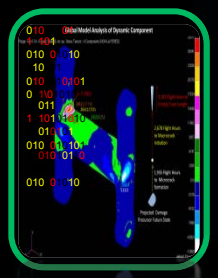
Record Maneuvers & Dynamics



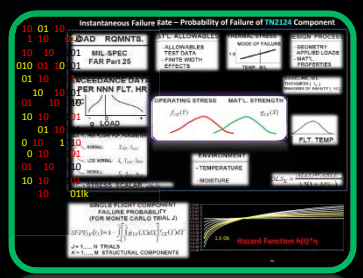
Capture Damage Precursor



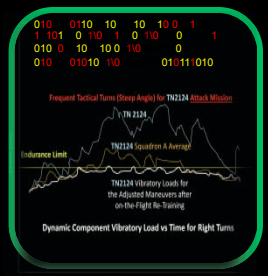
Access Baseline



Run M/S Modeling



Assess Risk



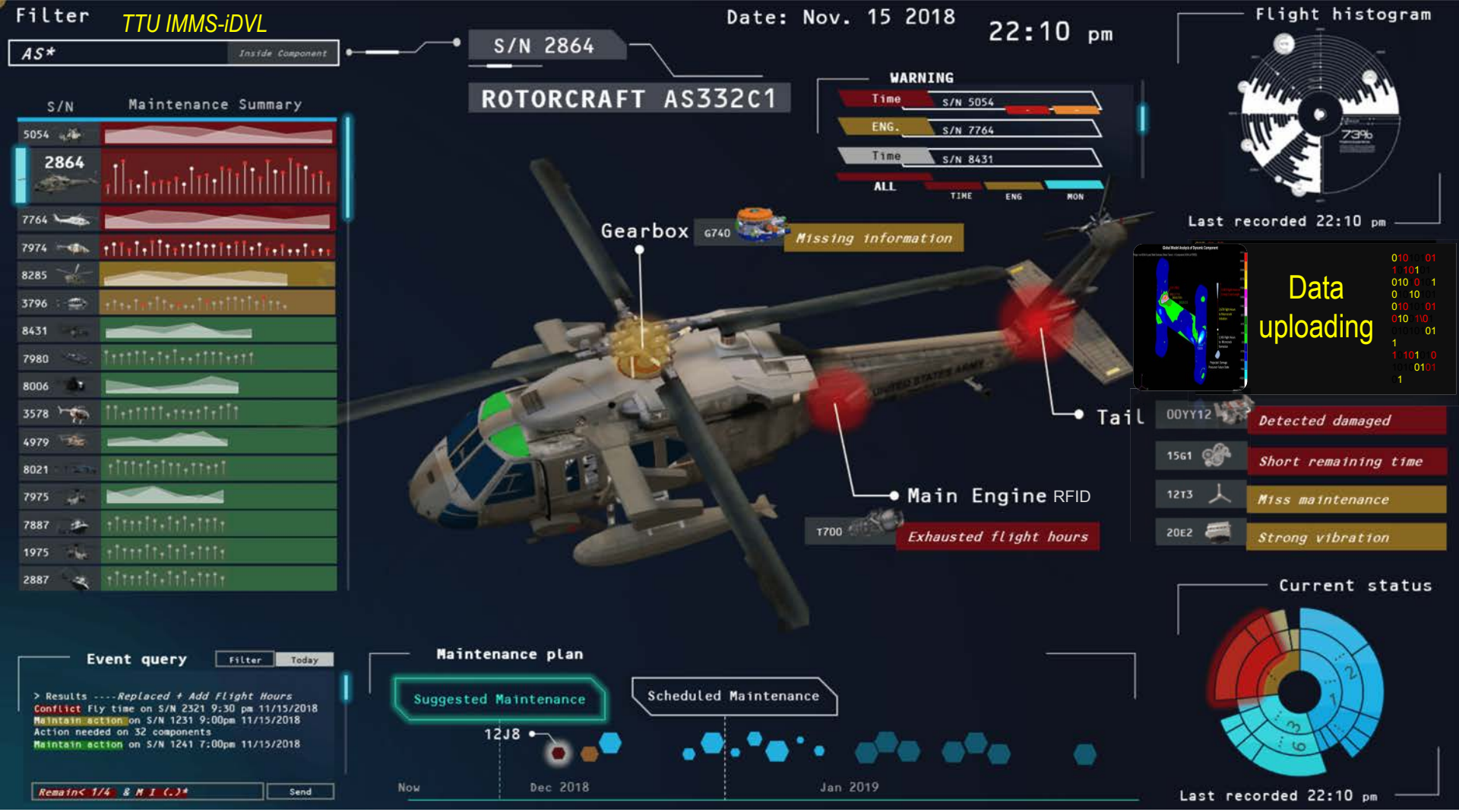
Configure Adaptive Maneuver

– Platform Health Management –

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

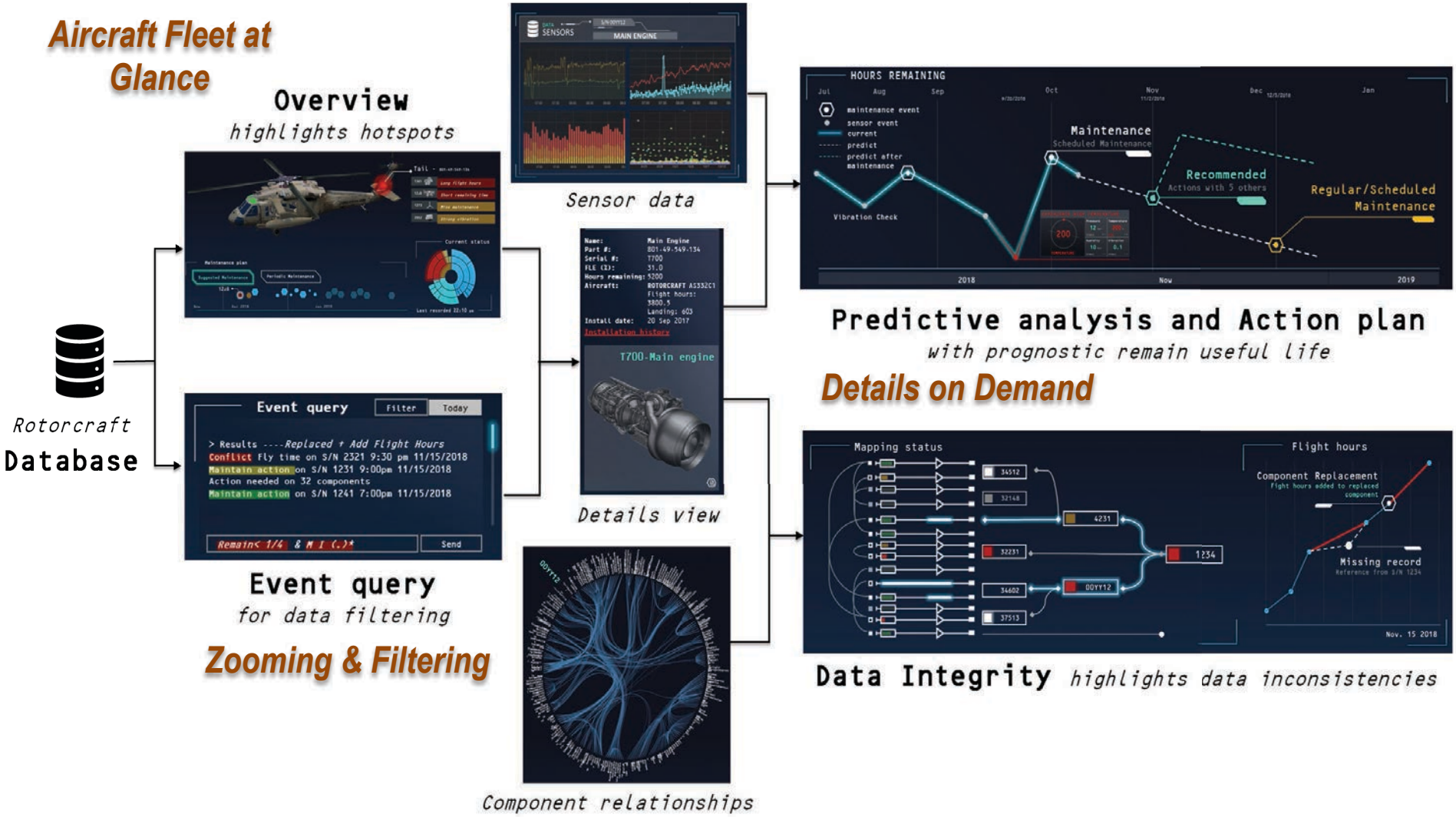
– Beyond Intelligent Health State Awareness –

- ✓ 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



– 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 -

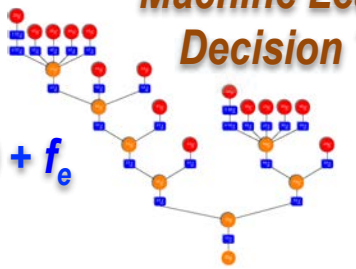
- ✓ Don't follow exact rules but based on statistical models of certain types of problems – Deal with uncertainty & probability
- ✓ Artificial Neural Network with different computation layers to process data
- ✓ Couldn't explain informed decision but could tell with level of probability
- ✓ *Difficult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

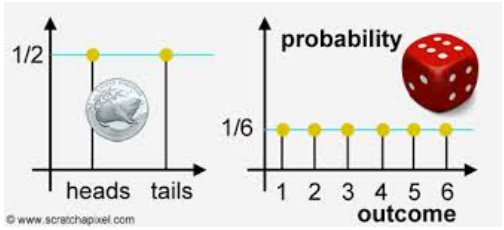
- Physics-Centric Model Based AI-

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

Machine Learning Decision Tree

$Y_d = f(V_i) + f_e$

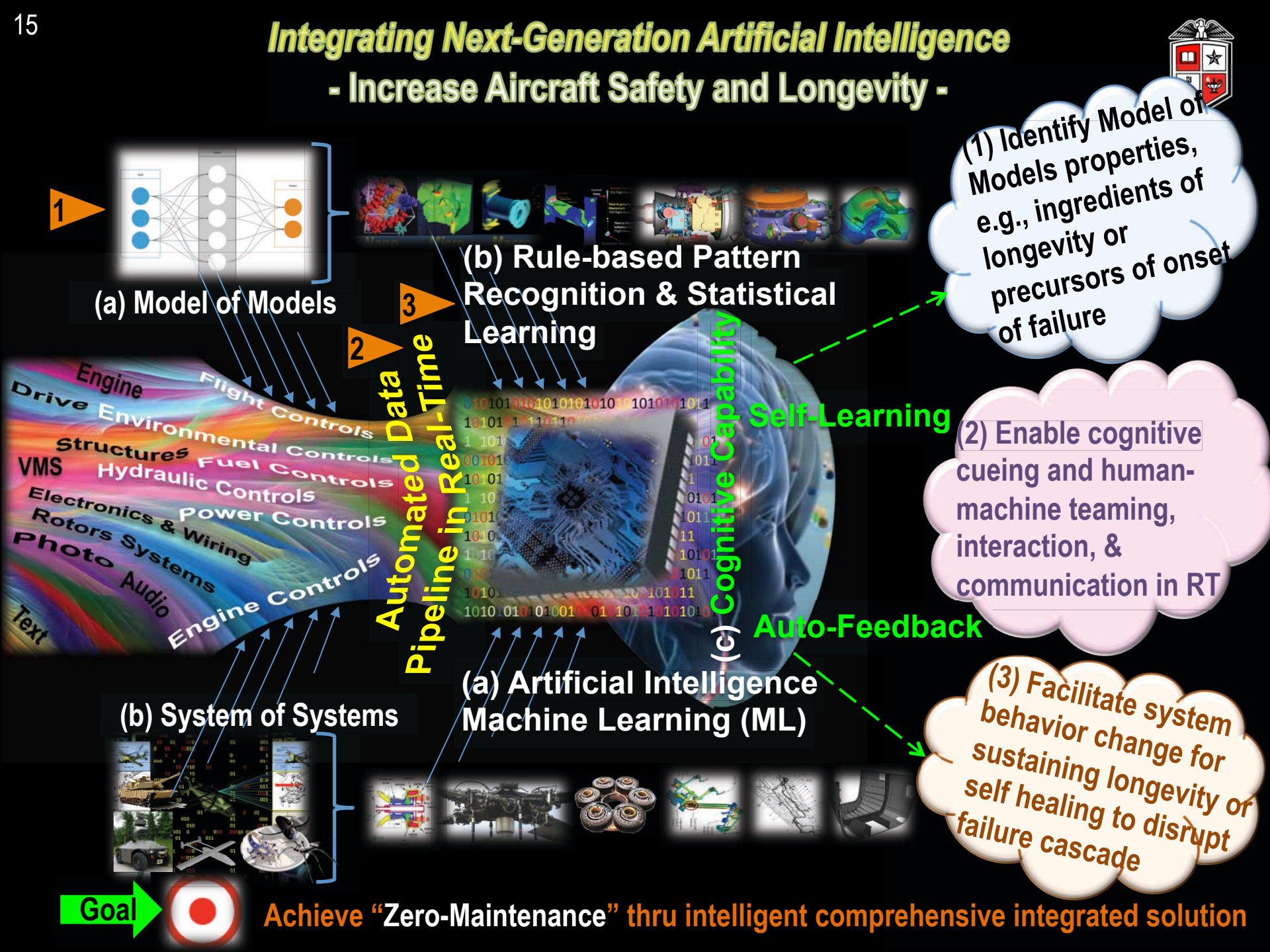




Probability of Outcomes

Cognitive capability with direct feedback and learning

Integrating Next-Generation Artificial Intelligence
- Increase Aircraft Safety and Longevity -



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?