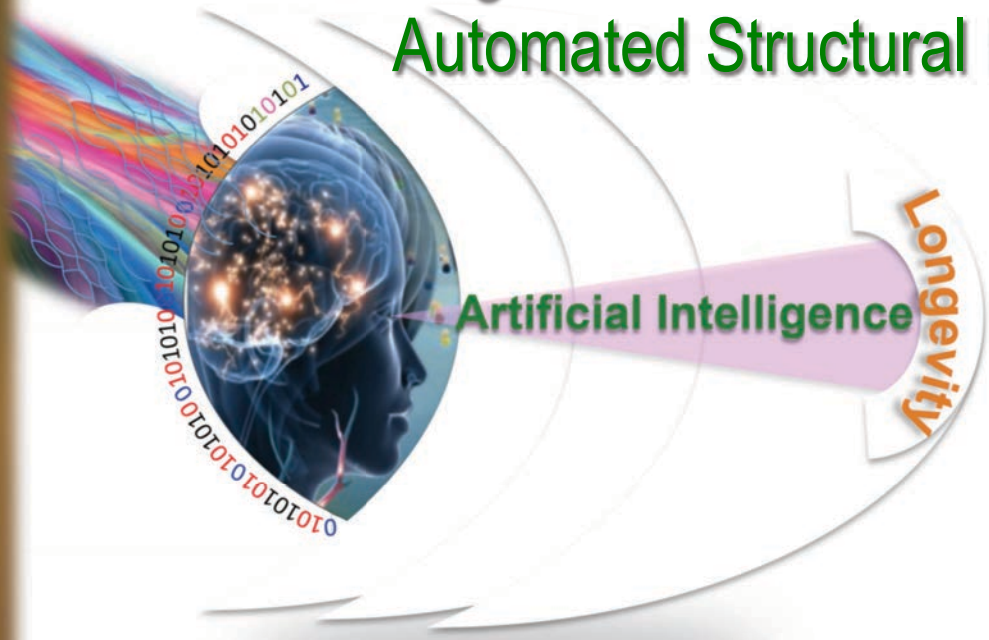
TEXAS TECH UNIVERSITY™

Intelligent Health State Awareness Vision for Automated Structural Health Monitoring



Presented to:
4th International Conference on Structural Health Monitoring and Integrity Management
Hangzhou, China
Oct 21-23, 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 - USA

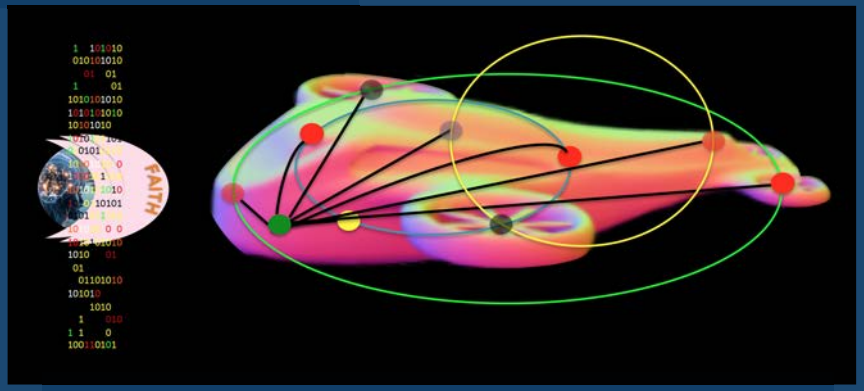
Presentation Outline

- Why "Automated SHM" for *"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

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

Unleashing

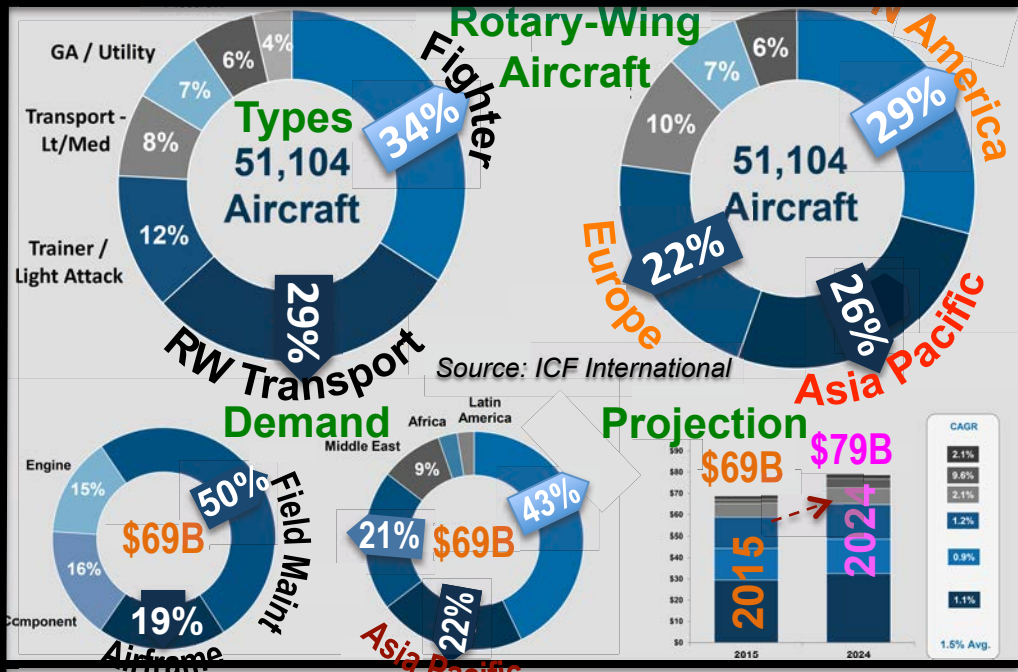


Revolutionary Capability

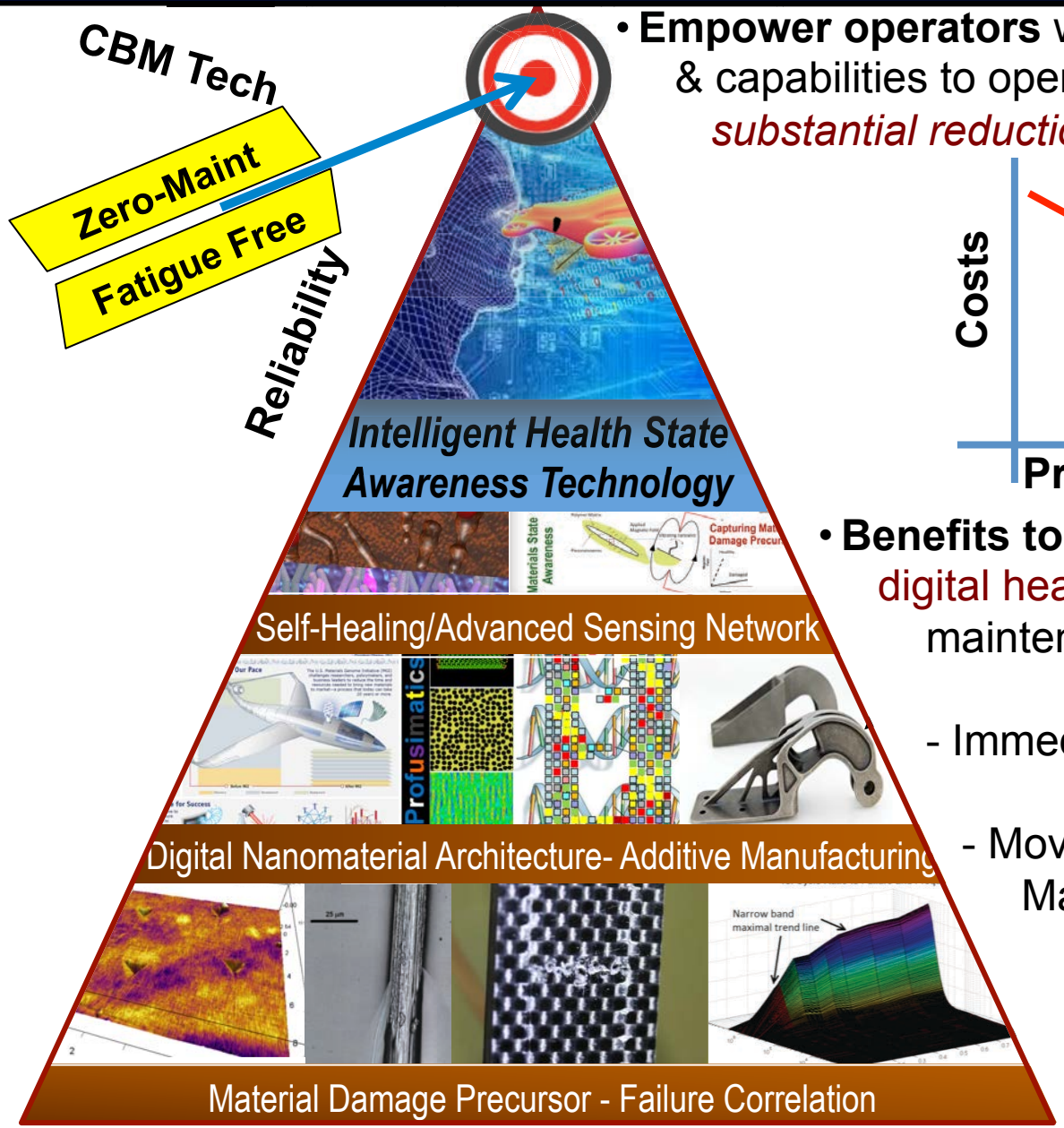
- ***Reduce sustainment costs***
- ***Increase safety and availability***

MRO: Maintenance, Repair, and Operation

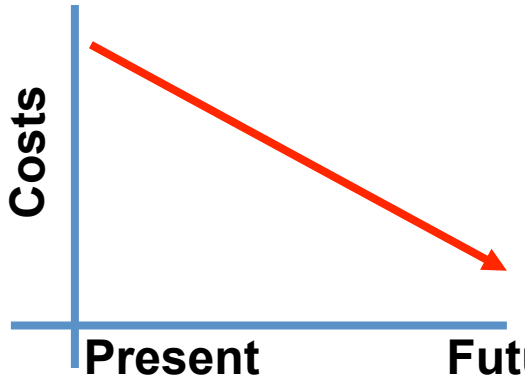
Aviation MRO Projections



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



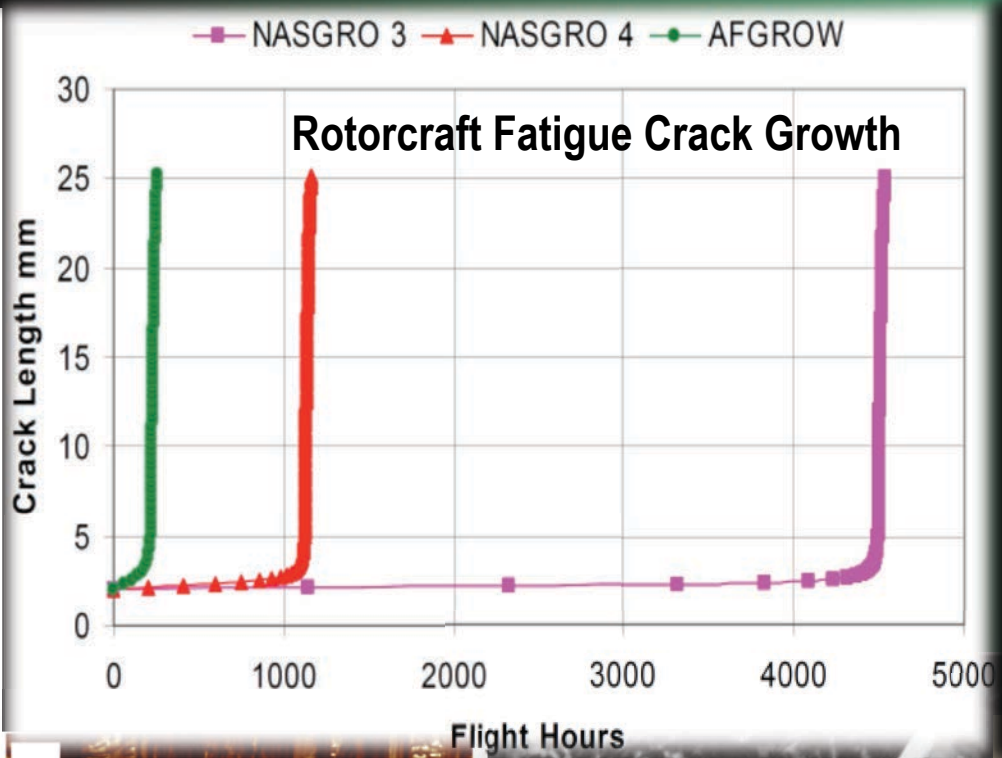
- **Benefits to operators:** Enable aviation digital health monitoring, effective maintenance "big data" management

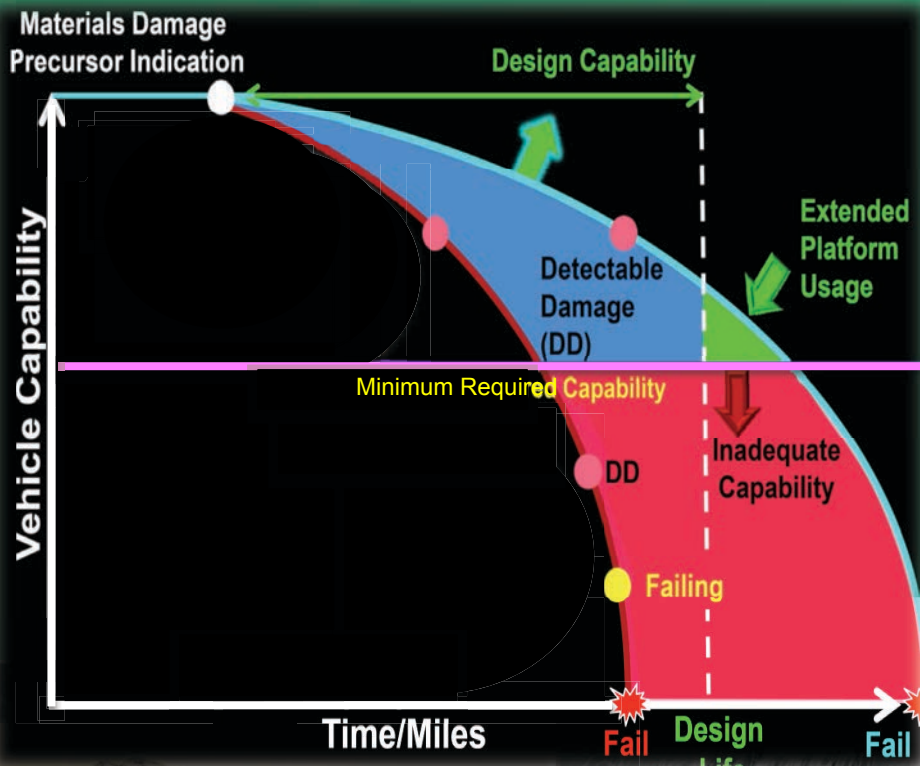
  - Immediate vehicle health state

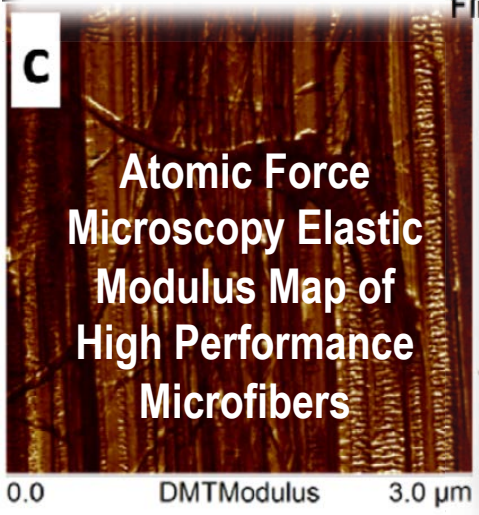
  - Moving beyond Condition-based Maintenance (CBM) to informed material state-based awareness

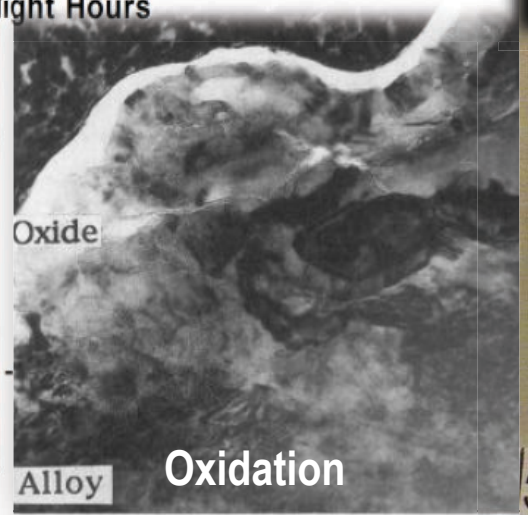
  - Automated component health tracking

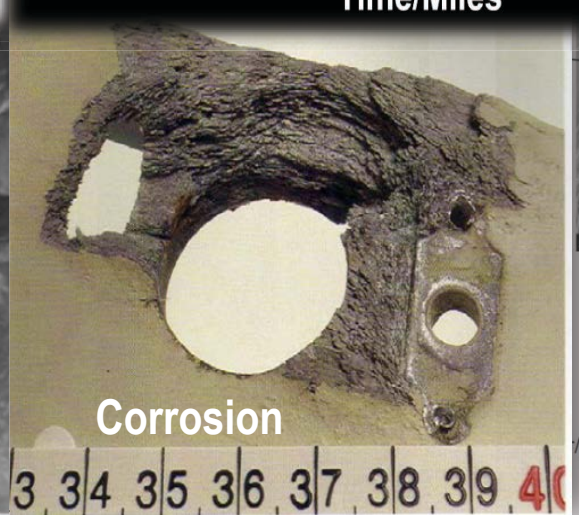
Finding and Catching "Materials Damage Precursors"
- Through Intelligent built-in Sensing Network & Multifunctional Materials

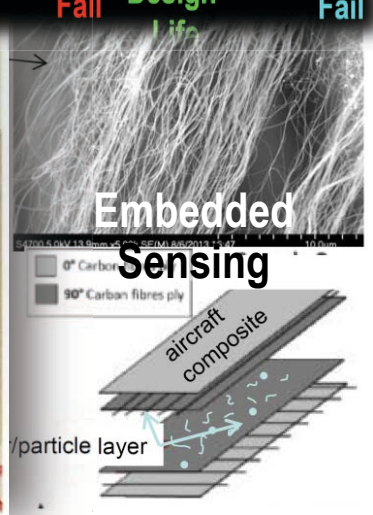




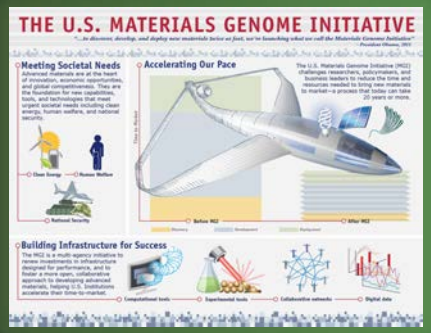






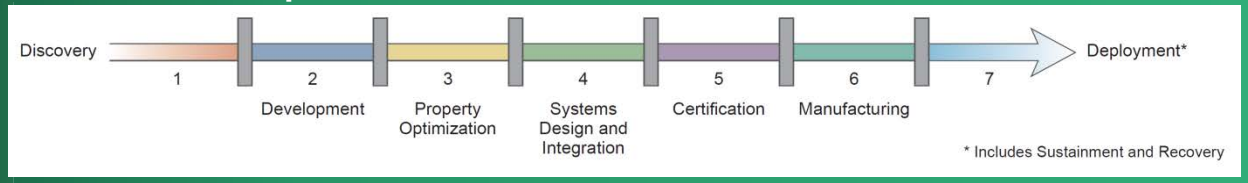


Cloning "Materials DNA"
- Producing Novel Materials Through Nanorestructuring -



Materials Development Continuum

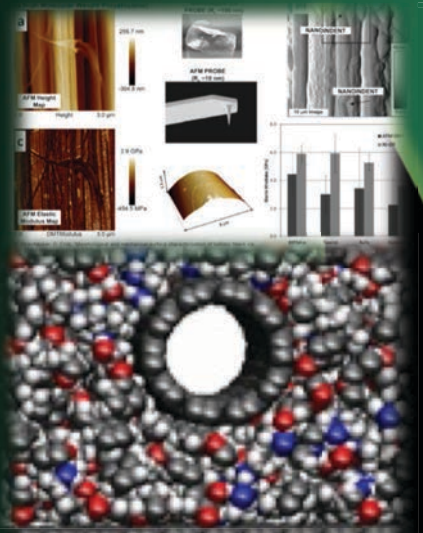
"Materials Genome Initiative for Global Competitiveness" – June 2011



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

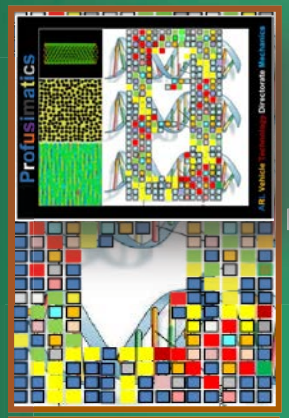
Materials Genome

Building Blocks **Characterization**

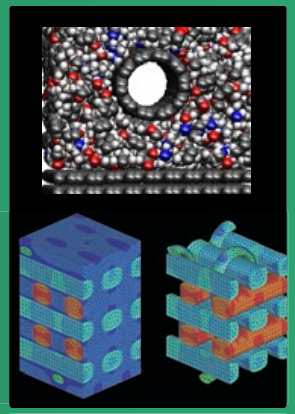


Engineering

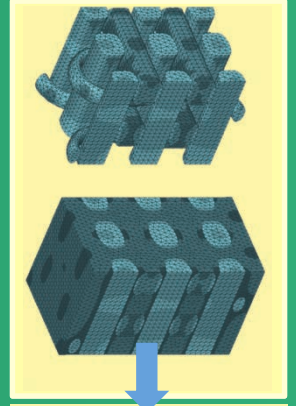
Nanorestructuring

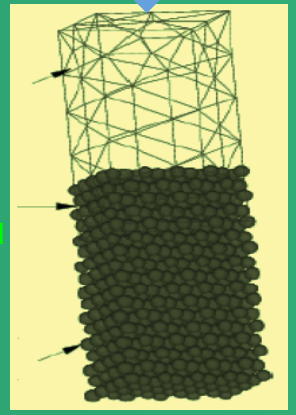


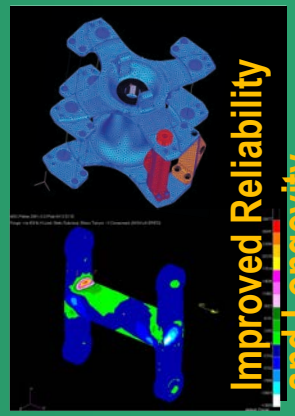
Materials "DNA" Cloning

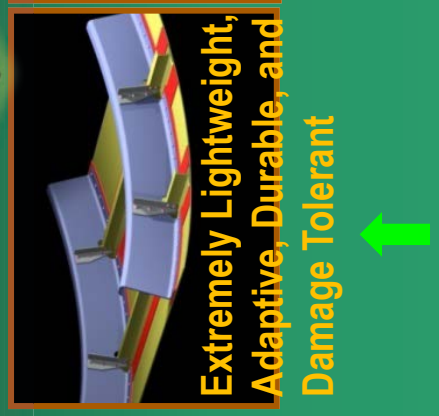


Prototype









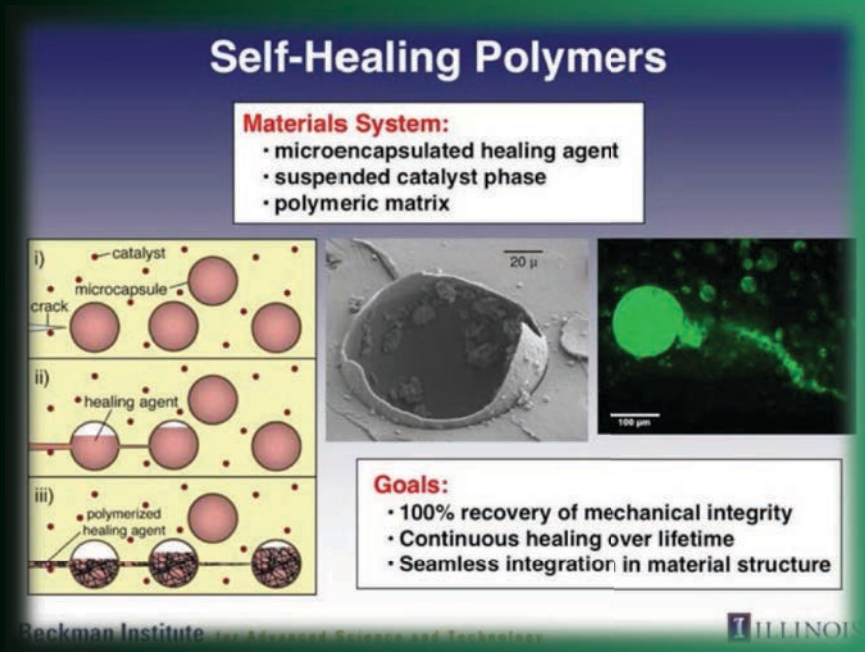
"Maintenance-Free" Aviation **"Fatigue-Free" Structures** **Materials by Design**

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

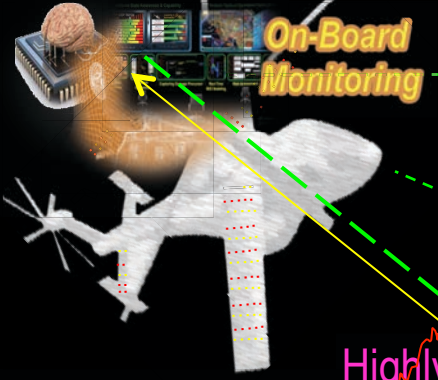


- Embedded microvascular networks within structural materials
- Continuous transport of healing agents throughout structural lifetime

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?



5 Executing Adaptive Maneuvers

Loading Threshold

Highly Damaging Load

Optimized Load

Transmitting Info

2

1 Sense, Detect, & Characterize

Damage Precursor

Fatigue Cracks

Incidental Damage

Design Capability

Vehicle Capability

Minimum Required Capability

Pushing Potential Failure Beyond Design Life

7 Extended Usage

6 Maintenance-Free Operating Period

Fail

Design Life

Delayed Failure

Intelligent Health State Awareness Controller

Dashboard Health State Visualization

Integrated Artificial Intelligence

3

Assessing Damage & Risk

4 Optimizing Solution for Sustaining "Fatigue-Free"

Optimized Load

Aviation Health State Awareness Vision

Developing Next-Generation Artificial Intelligence
- Physics-Centric Model Based AI -

- Rule-Based AI –

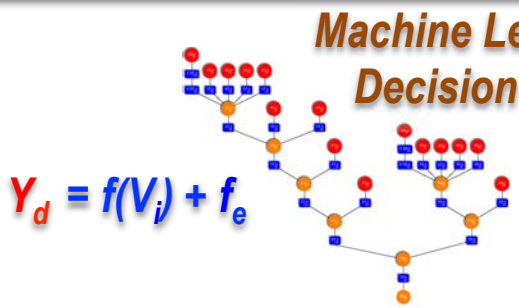
- ✓ Good for well-defined problems and system parameters with good known certainty
- ✓ *Incapable of training and difficult to address new hidden states and uncertainty*

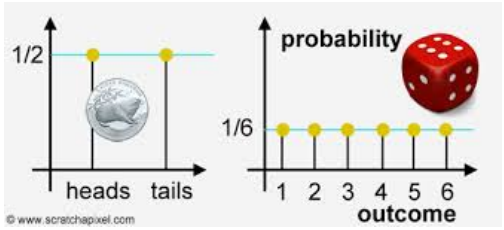
- Statistical Learning AI -

- ✓ 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*

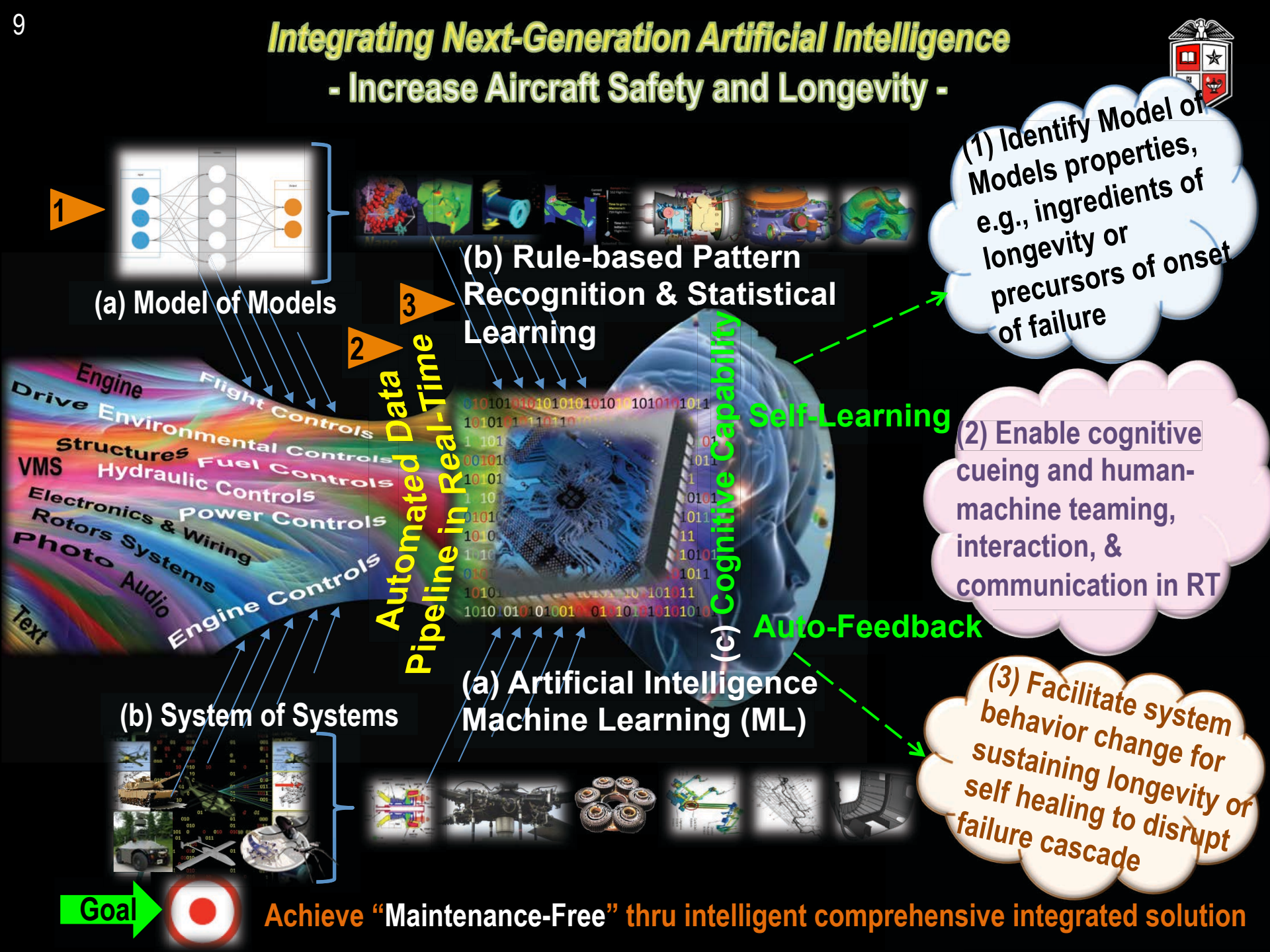




Probability of Outcomes

Cognitive capability with direct feedback and learning

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



Conclusions

- ✓ Extensive human-manual maintenance labor presents substantial cost burden for aviation stakeholders
- ✓ Condition based maintenance 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
- ✓ 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
- ✓ AI-ML integrated health state awareness technology enables automated SHM to achieve structural fatigue-free and maintenance-free vision

TEXAS TECH UNIVERSITY™

Dy D. Le, Director
IMMS, Texas Tech University, Lubbock, TX
dy.d.le@ttu.edu

THANK YOU AND QUESTIONS?