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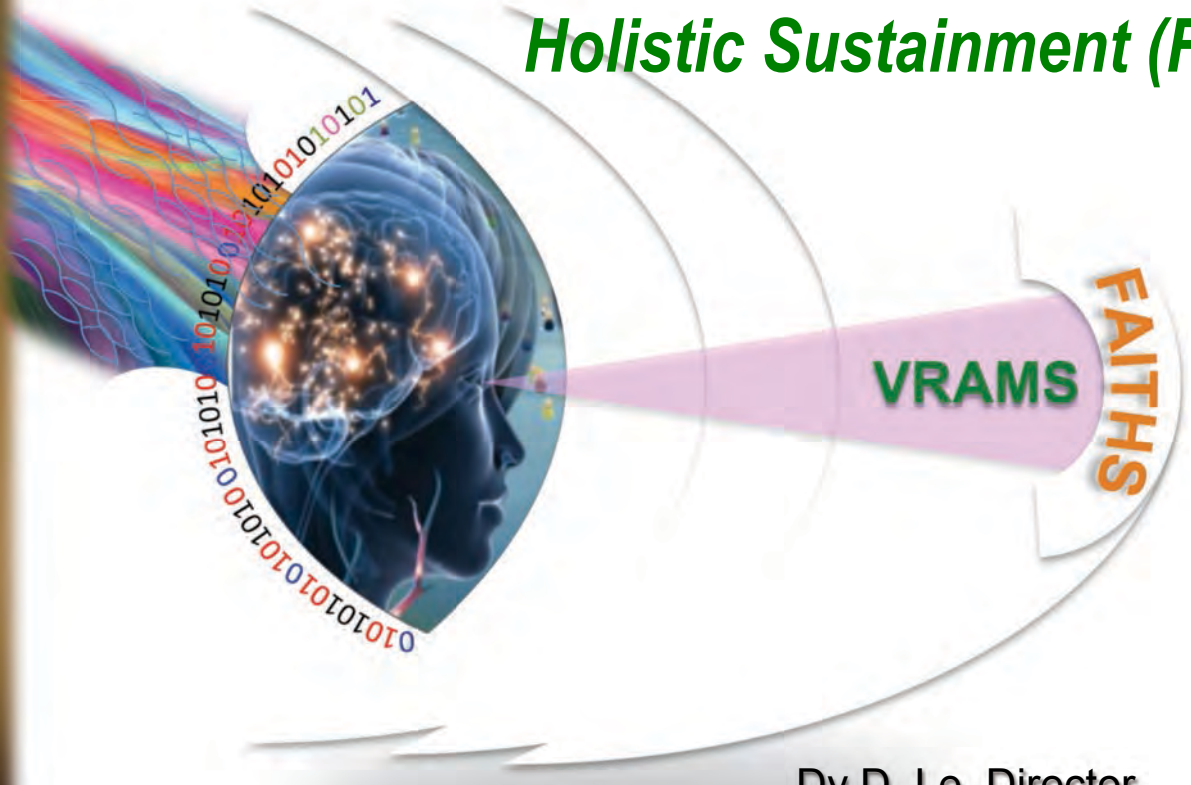
Virtual Risk-informed Agile Maneuver Sustainment (VRAMS) - *Fabrics of Artificial Intelligence-informed Technology for Holistic Sustainment (FAITHS)*



Presented to:
Defense Advanced Research Project Agency (DARPA)
Arlington, VA
March 24, 2017

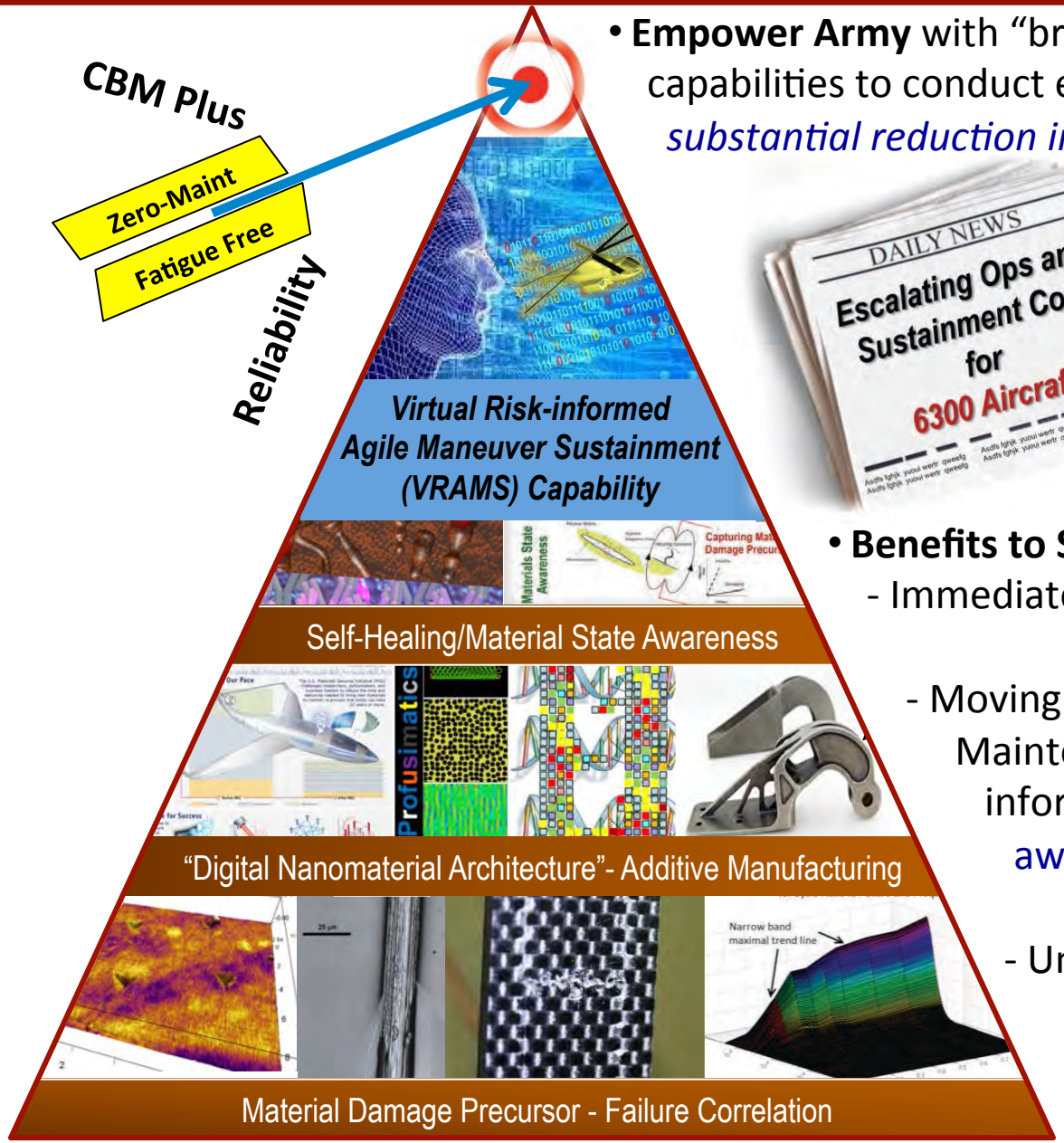
Dy D. Le, Director
Institute for Materials, Manufacturing, and Sustainment (IMMS)
Texas Tech University (TTU)

Defying "Impossibilities": U.S. Army Aviation Sustainment Vision

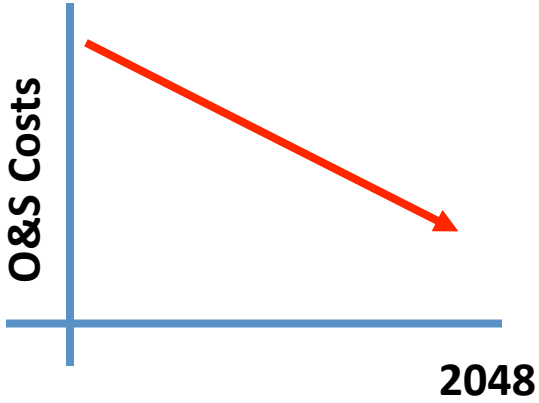
- "Leap-ahead" capabilities to sustain Next-Generation Aircraft with "little" or without maintenance, "Zero-Maintenance (ZM)"
- Evolutionary discoveries to enable the development of Next-Generation Air Platforms with "Fatigue-Free (FF)" characteristics

Support Sustainment Technology & Capability for Expeditionary Force 2025 & Beyond with Reduced Logistic Footprint

Envisioning Discoveries: A System Level Approach Perspective



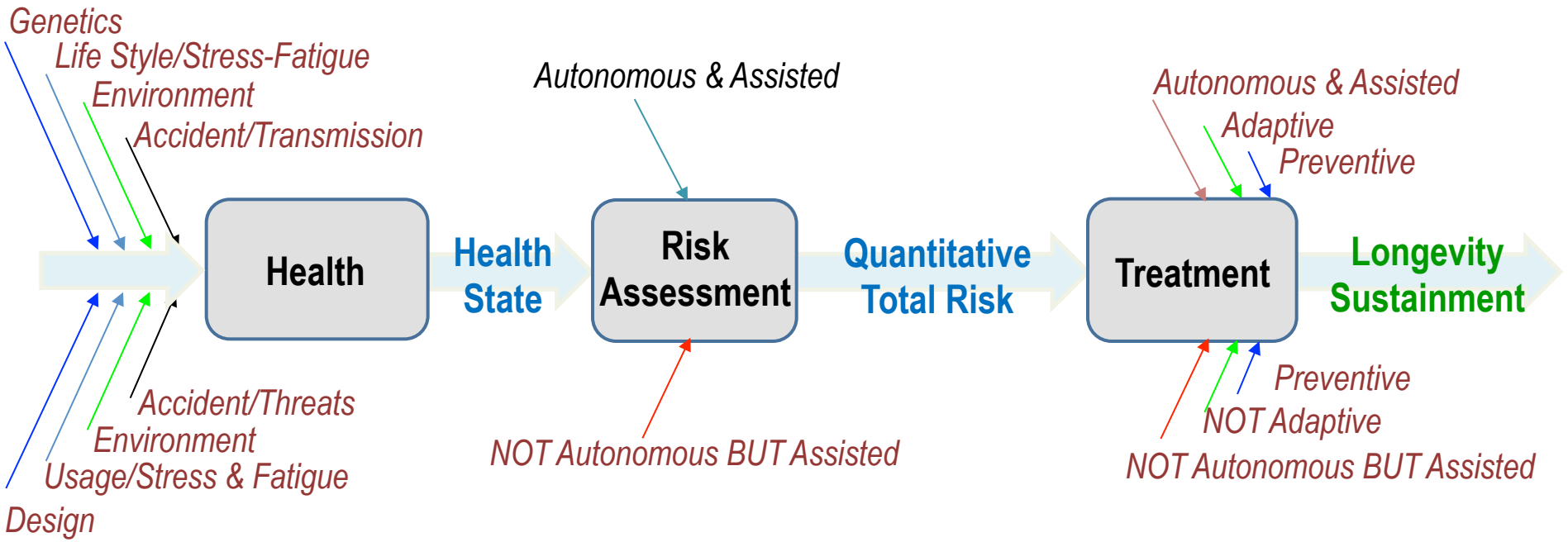
- **Empower Army** with "breakthrough" technologies & capabilities to conduct expeditionary maneuvers with *substantial reduction in operation & sustainment* costs



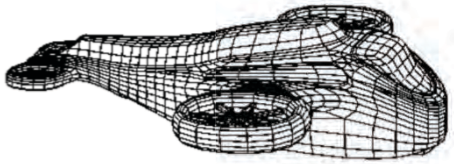
- **Benefits to Soldiers:**
  - Immediate vehicle health/capability state
  - Moving beyond Condition-based Maintenance (CBM) to mission-informed material state-based awareness
  - Unburden hardware-level concern focus on higher-level/mission-relevant operations

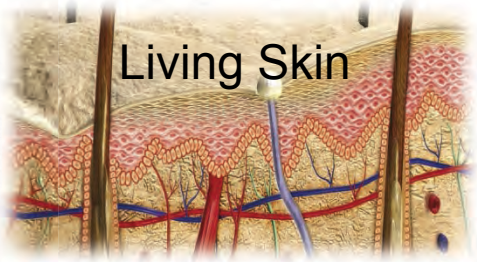
Science for Autonomous Prognosis and Healing for Longevity Sustainment

Human-Machine Longevity Sustainment



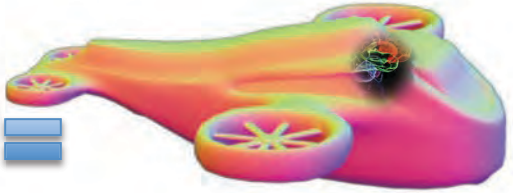
Platform Design | **Multifunctional Structures** | **Intelligence** | **Next-Gen Platform**





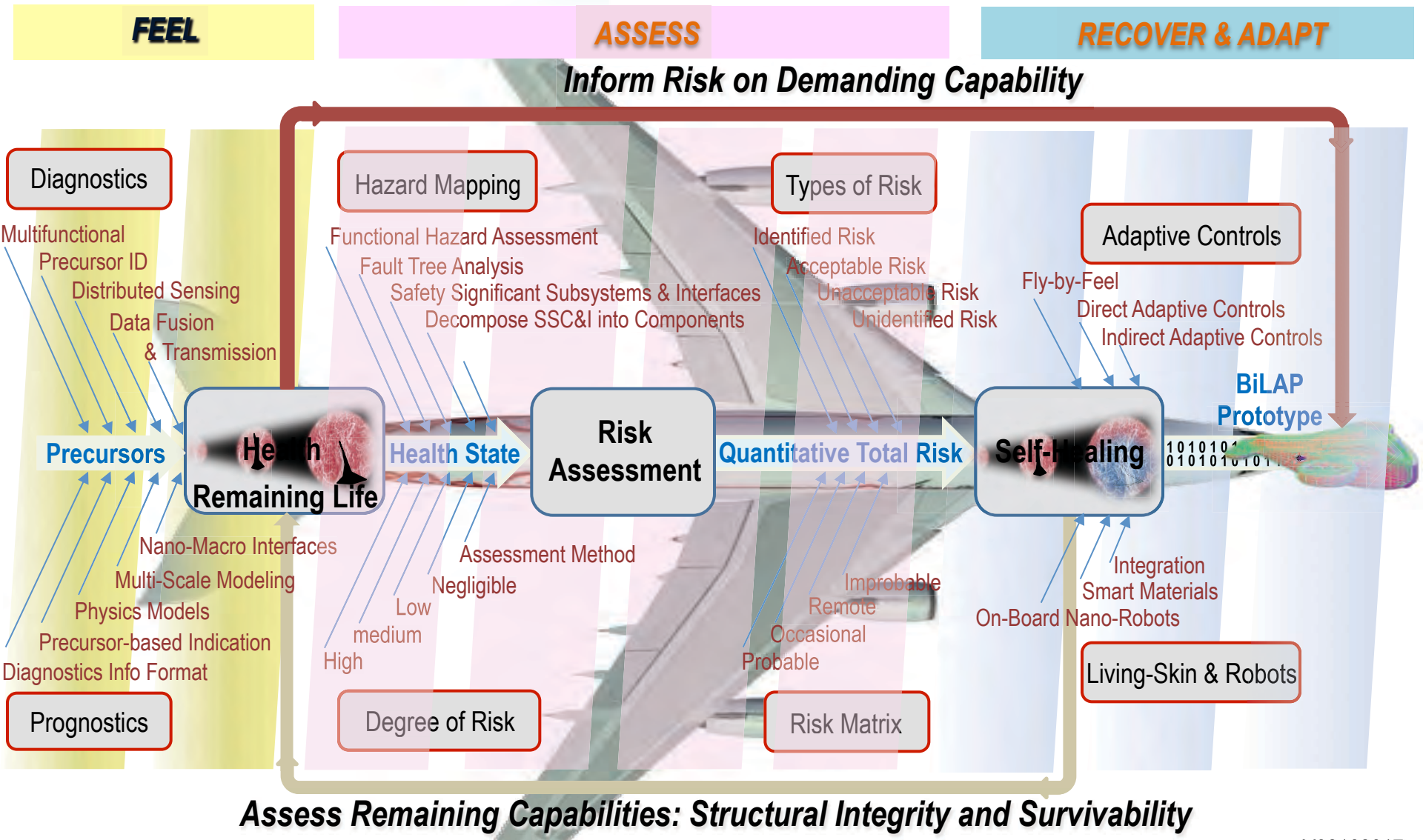
Courtesy of photosearch

cs.stanford.edu



Bio-inspired Living Aerial Platform (BiLAP)

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



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Cognitive Capability for Legacy-Future Aviation Platforms

VRAMS Concept

Platform Sustainment and Survivability

Conceptualized

AI Machine Learning Algorithm Suites

Need Developed

Real-Time Self-State Awareness

"Fatigue-Free & Zero-Maintenance

Concept & Tech Demonstrating

VRAMS Concept

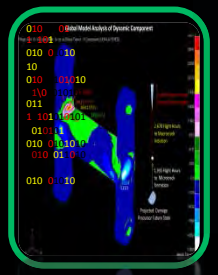
VEHICLE STATE AWARENESS & CAPABILITY

AVIATION TACTICAL OPERATION PANEL (ATOP)

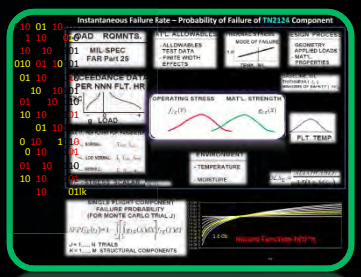
System Baseline

System Dynamics

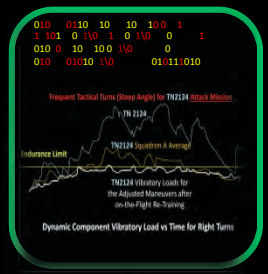
Capturing Damage Precursor



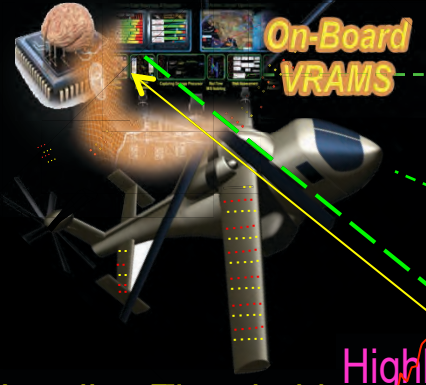
Real-Time M/S Modeling



Risk Assessment



Maneuver Adaptation



5 Executing Adaptive Maneuvers

Loading Threshold

Highly Damaging Load

Optimized Load

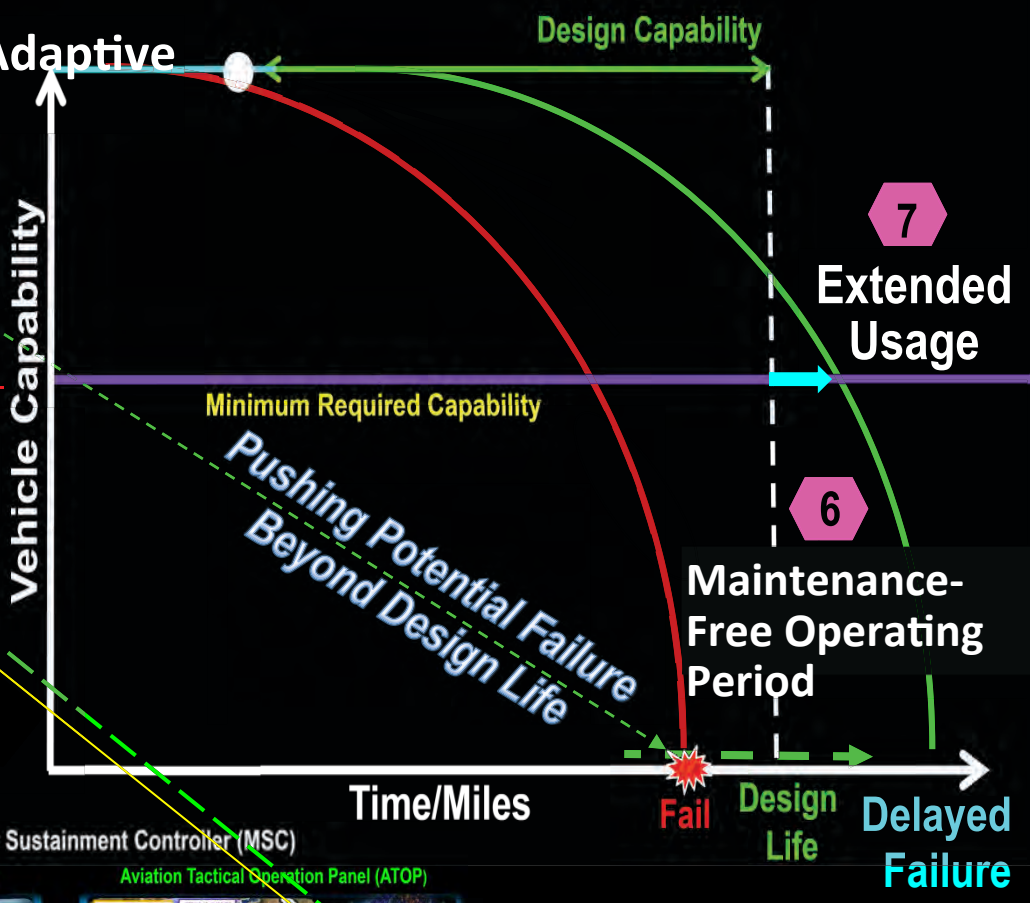
1 Sense, Detect, & Characterize

Damage Precursor

Fatigue Cracks

Combat Damage

2



7 Extended Usage

6 Maintenance-Free Operating Period

VRAMS Maneuver Sustainment Controller (MSC)

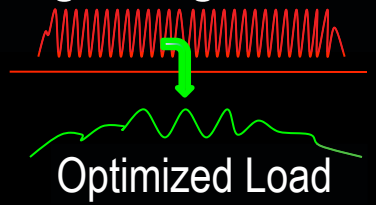
Platforms State Awareness & Capability

Aviation Tactical Operation Panel (ATOP)

3

Assessing Damage & Risk

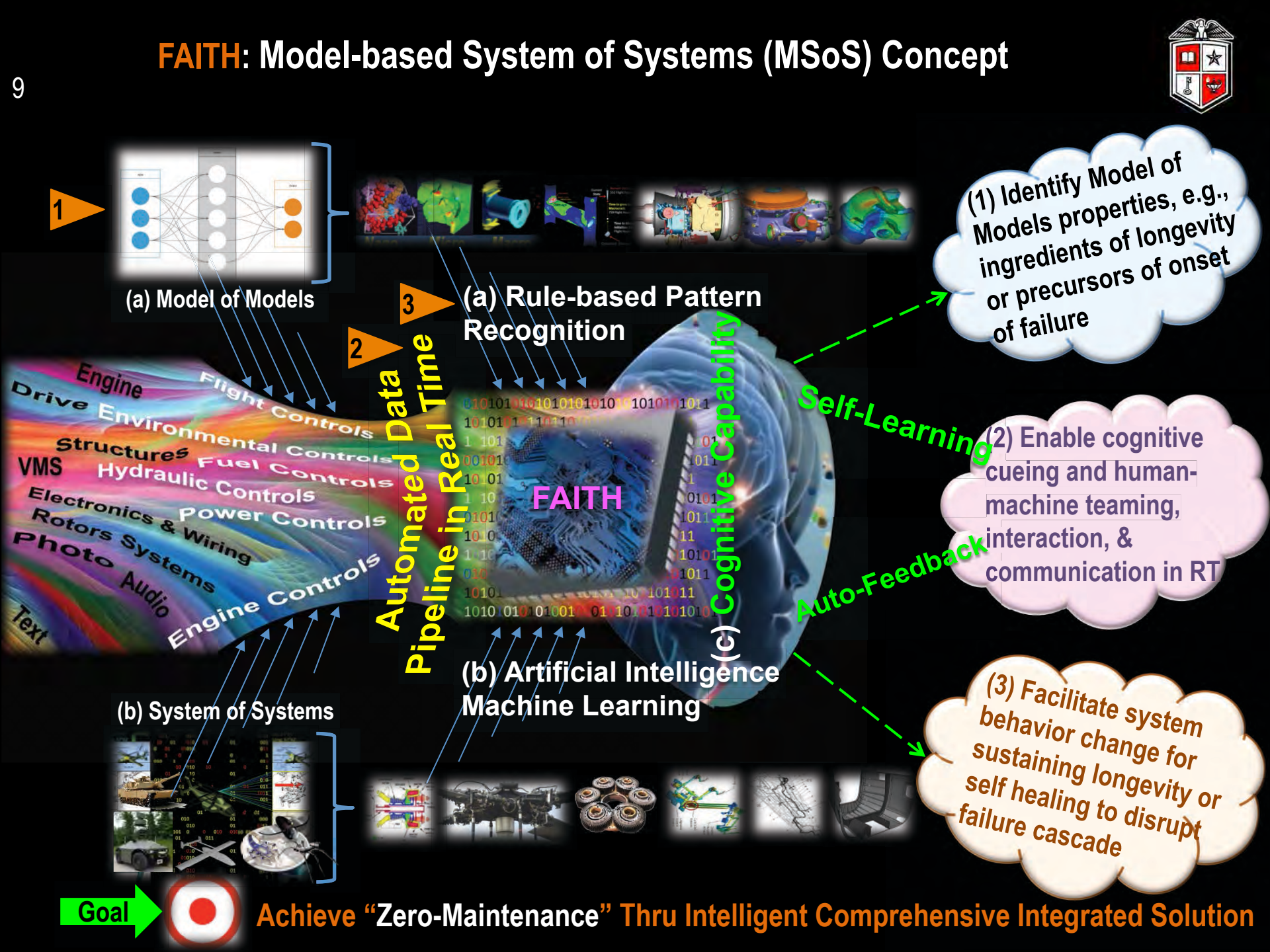
4 Optimizing Solution for Sustaining "Fatigue-Free"



Optimized Load

Core Engine: Virtual Risk-informed Agile Maneuver Sustainment (VRAMS)

FAITH: Model-based System of Systems (MSoS) Concept



FAITHS-VRAMS Core Engine Algorithm Architecture Modules

DESCRIPTIVE

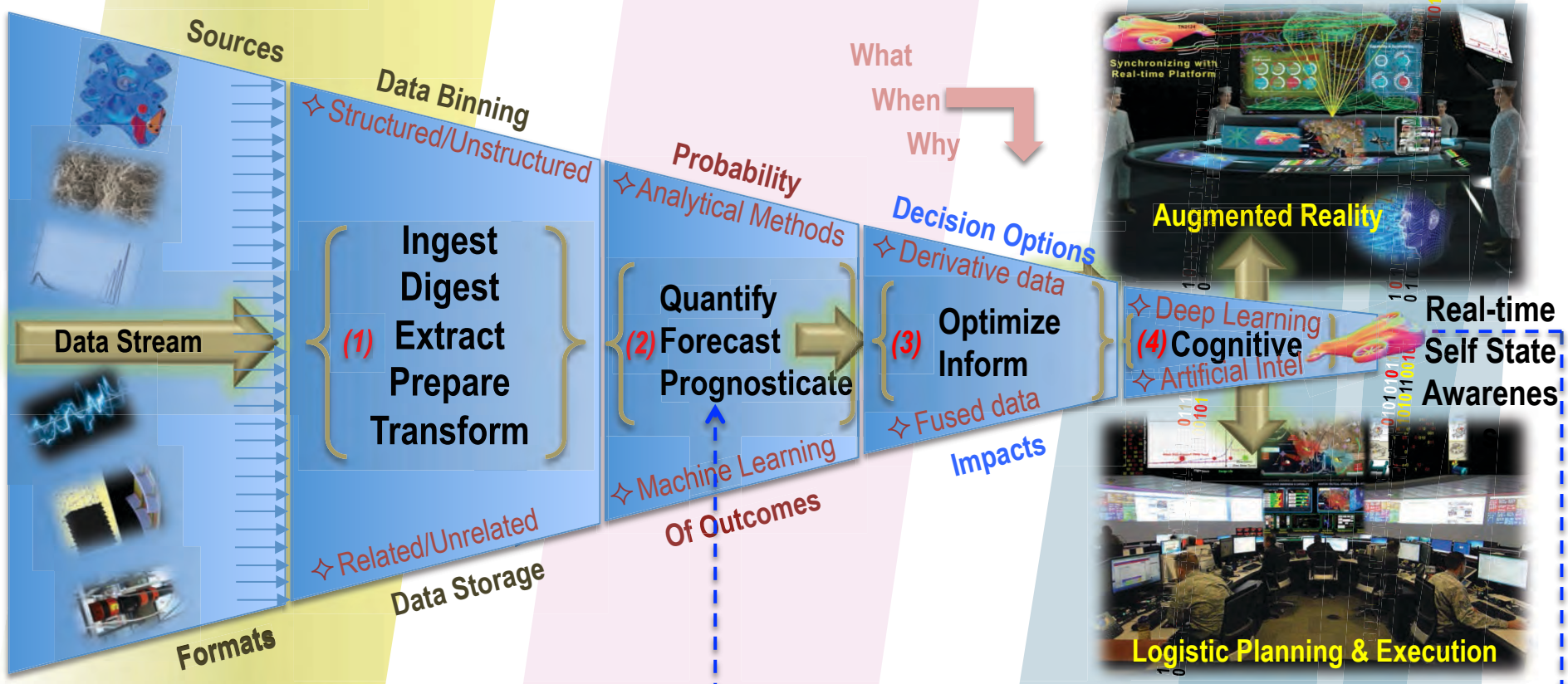
- Aggregate data in a way that relationships, meaningful patterns, and/or insights of anomaly might emerge

PREDICTIVE

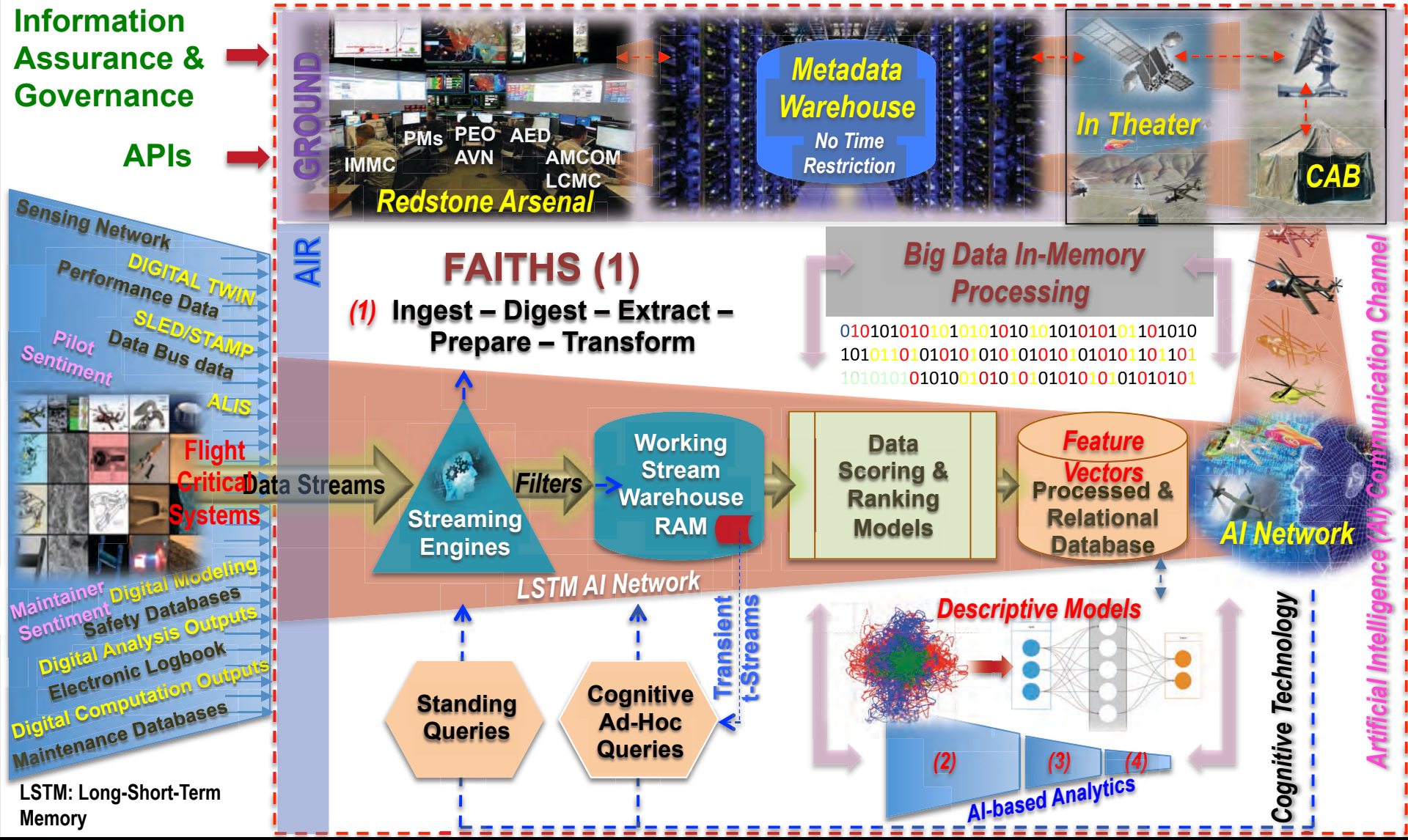
- Quantify, forecast, and prognosticate the likelihood of future events

PRESCRIPTIVE

- Optimize hindsight/insight into the past/future, assess effect of future decisions and projected outcomes, and inform course of actions



Complex Data Processing – Cognitive, Scalable, & Open Architecture
- Descriptive Module 1: Manage Automated Data Pipeline in Real Time -

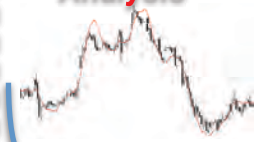


Transforming BIG DATA through DATA PIPELINE and Insight VISUALIZATION

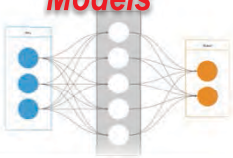
Complex Prognostic Processing – Cognitive, Scalable, & Open Architecture

12 Predictive Modules 2-3: Perform AI-based Predictive Analytics in Real Time

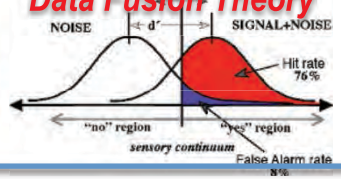
Regression Analysis



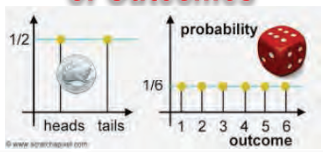
Regression Models



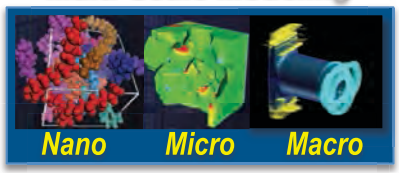
Signal Detection & Data Fusion Theory



Risk & Probability of Outcomes



Multi-Scale Modeling



Remaining Useful Life

FAITHS (1)

FAITHS (2-3)

Probability

Analytical Methods

Quantify

(2) Forecast

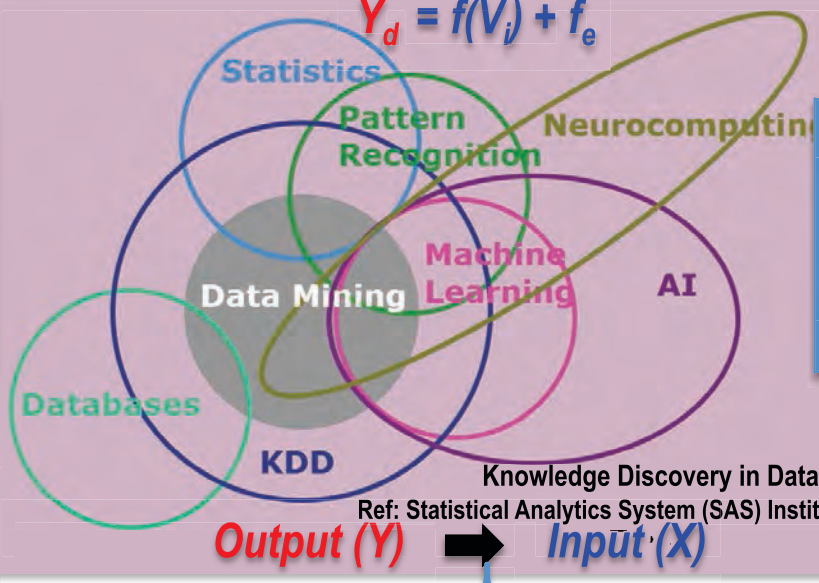
Prognosticate

Machine Learning

Of Outcomes

FAITHS (1)

$Y_d = f(V_i) + f_e$



Knowledge Discovery in Databases

Ref: Statistical Analytics System (SAS) Institute

Output (Y)

Input (X)

Decision Options

Derivative data

(3) Optimize

Inform

Fused data

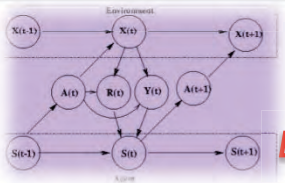
Impacts

(4) Cognitive

Discovered Knowledge

APIs

Machine Learning Algorithms



Reinforcement Learning For Dynamics Events

Enabling Autonomous Prognostics Via Machine Leaning

Complex Solution Processing – Cognitive, Scalable, & Open Architecture

Prescriptive Module 4: Learn Past, Aware Present, & Predict Future

Deep Learning Network

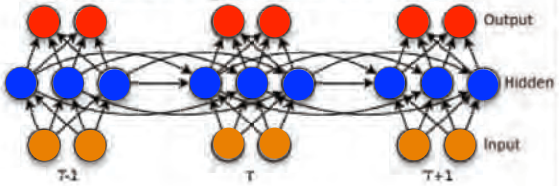
Training

Reduced Uncertainty

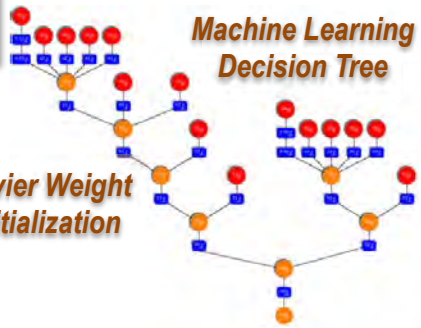
FAITHS (4)

(4) Cognitive

Recurring Neural Network

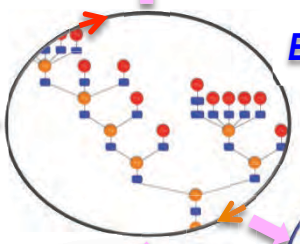


Machine Learning Decision Tree

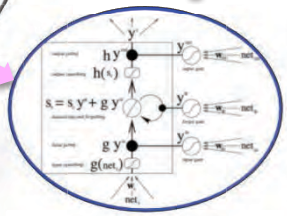


Xavier Weight Initialization

Network Error $f_c(e_r, b_j)$



Back-Propagation-Through-Time Training



Long-Short-Term Memory Units

Forward Training

Data & labels

Training dataset

Certain

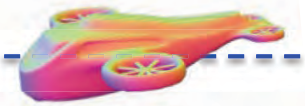
Uncertainty Entropy

$entropy(X) = -\sum p_i \log_2 p_i$

Cognitive

FAITHS (1-3)

(1) (2) (3)



FAITHS-VRAMS Technology

- Self-Sustaining -

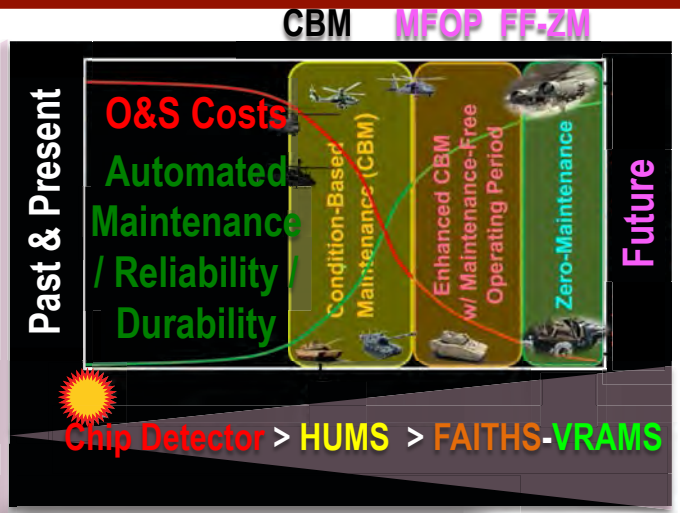
- ✓ "Fatigue-free" (FF) structures
- ✓ Maintenance-Free Operating Period (MFOB) – "Zero-Maintenance" (ZM)
- ✓ Self-maintenance and optimization of large data ("Big Data")
- ✓ Expeditionary missions with smaller logistic footprint

- Self-Maneuvering -

- ✓ Reconfigurable controls technologies
- ✓ Self-autorotation (rotary-wing)
- ✓ Autonomous systems (manned/ unmanned) teaming
- ✓ Fully autonomous missions

- Self-Adapting -

- ✓ Self-healing and repair
- ✓ Self-informed of parts replacement demands and schedules
- ✓ Self-informed of remaining capability to achieve demanding tasks or maneuvers



FAITHS: VRAMS Cognitive Capability for Legacy and Future Aviation Platforms

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QUESTIONS ?