



Aviation Safety Program Integrated Vehicle Health Management Project

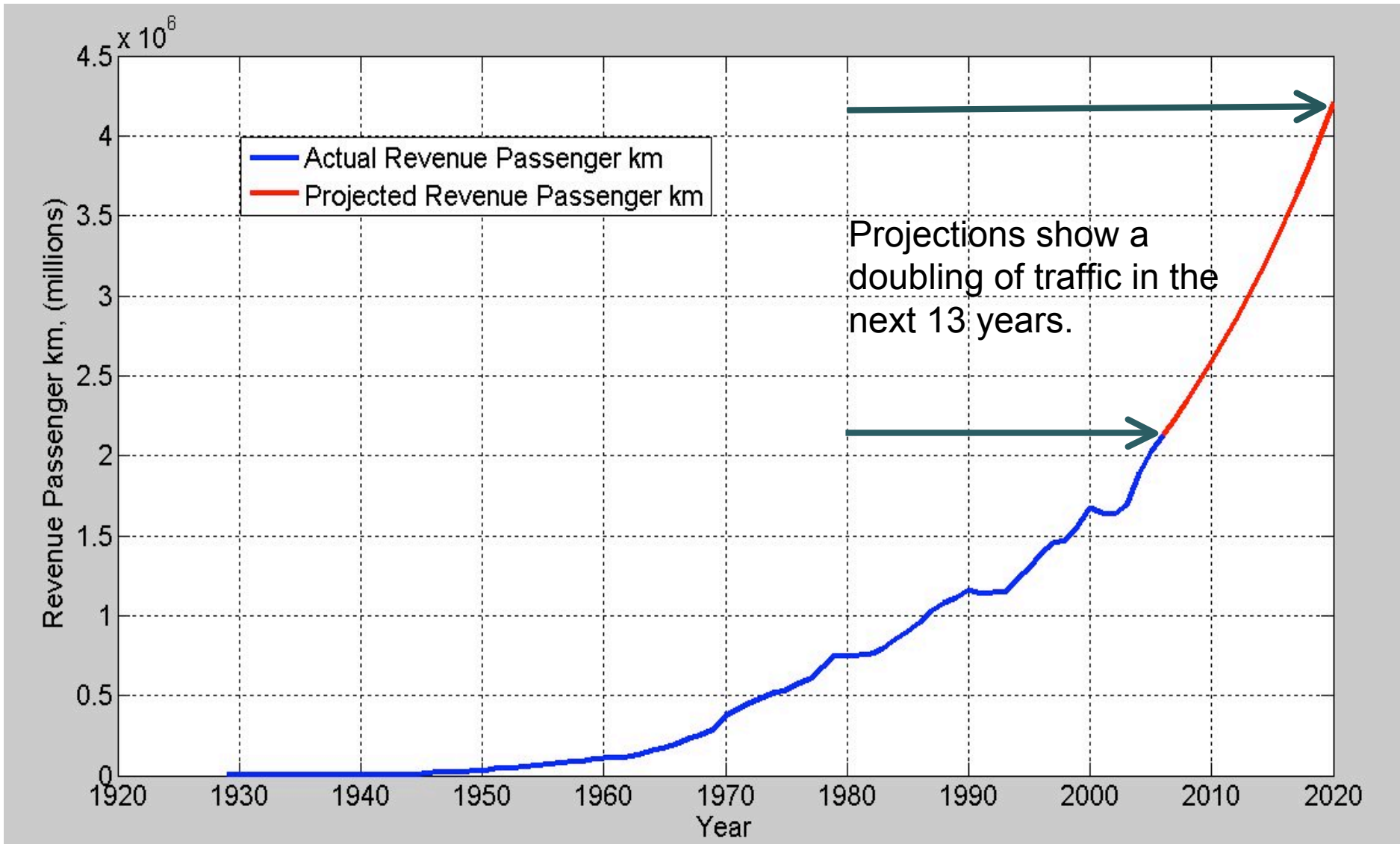
Project Overview ***Aviation Safety Technical Forum***

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Project Scientist: Robert Mah, Ph.D.
Project Manager: Joseph E. Grady, Ph.D.
Associate Project Manager: Susan Johnson, Ph.D.

October 10, 2007



Annual Worldwide Air Traffic





Fatal Airplane Crashes Drop 65%

September 28, 2007

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Twenty Years of Fatal Airline Accidents

Since a 1997 goal to reduce the rate of airline accidents by 80 percent, fatal accidents have fallen. Roll over the boxes for details.

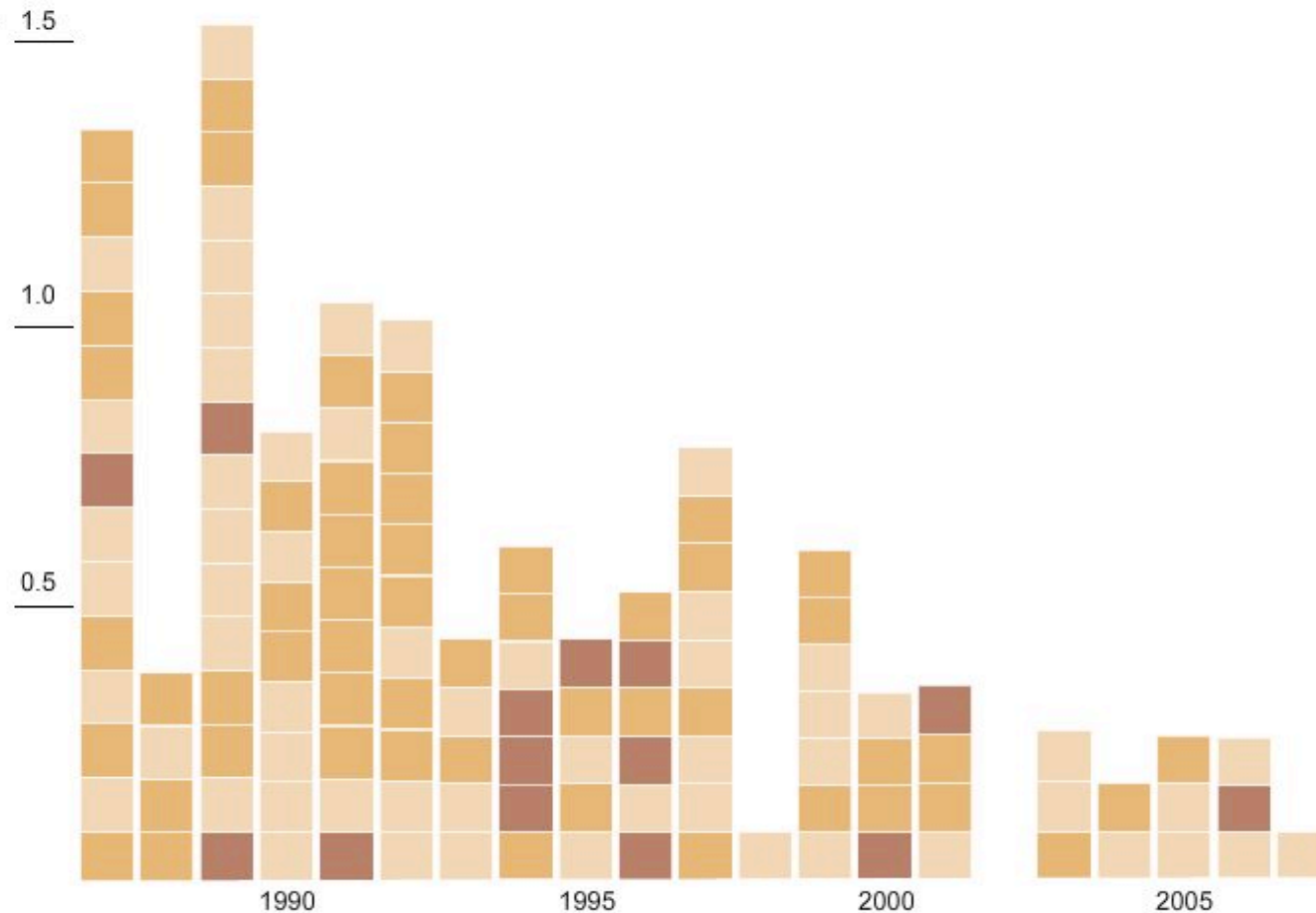
Number of fatal accidents per 1 million departures

Each box represents one fatal accident on a major airline or commuter plane.

Number of fatalities

- 1 or 2
- 3 to 30
- 30+

Note. Box heights have been scaled according to the number of departures each year. Accidents caused by terrorism or other criminal acts are not shown.



Source: National Transportation Safety Board

Amanda Cox



Top Challenges according to the National Research Council's Decadal Survey of Civil Aeronautics

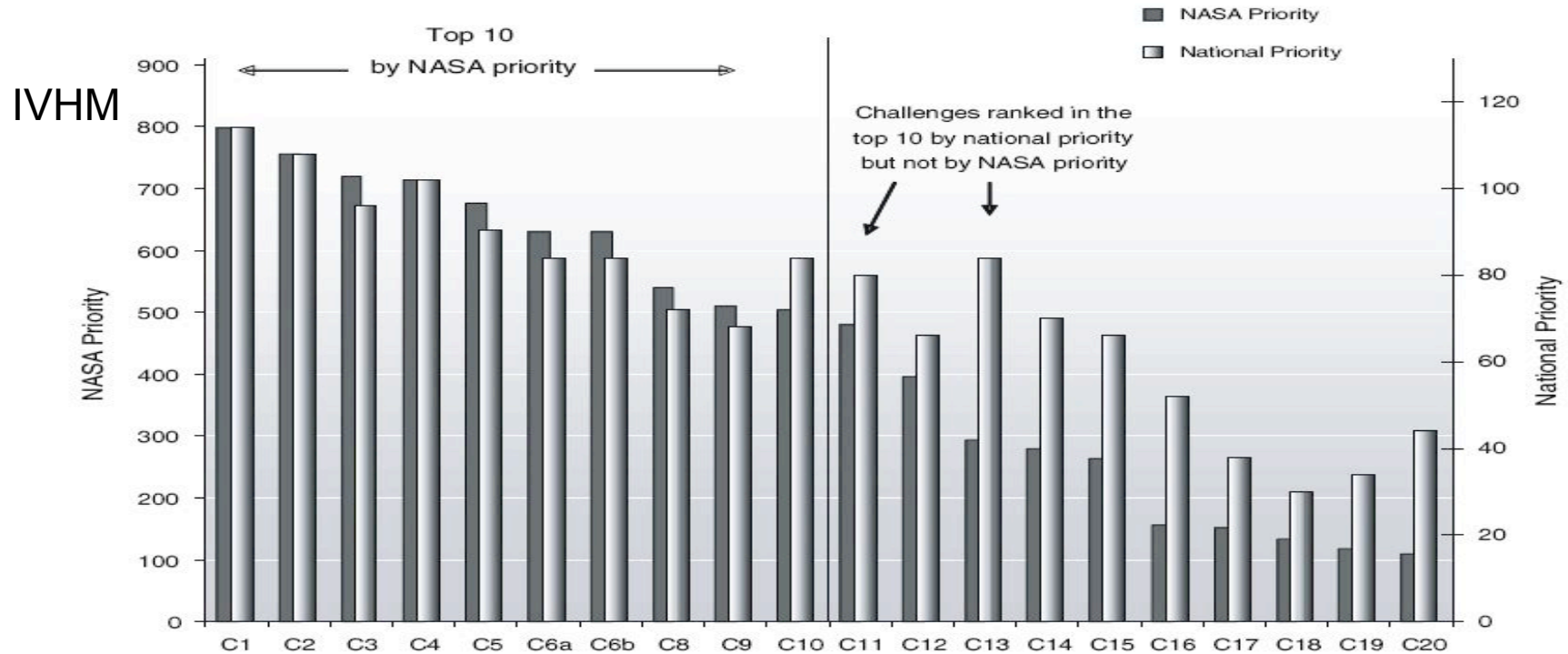


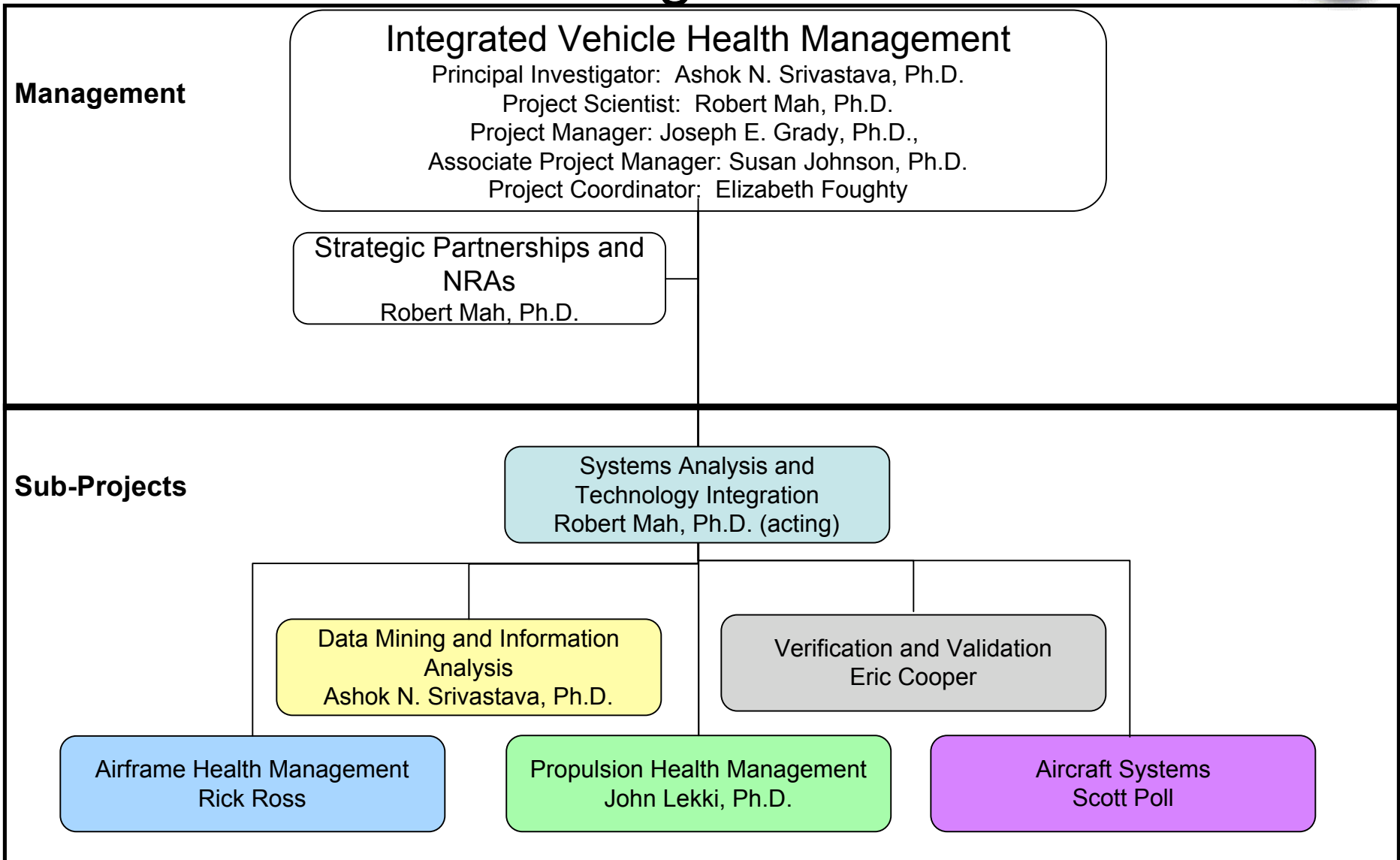
FIGURE 3-5 NASA and national priorities for Area C: materials and structures.

Element	Priority	Title
C1	798	IVHM
D5	630	Fault-tolerant and IVHM systems
E1	936	Modeling to design and evaluate complex interactive systems



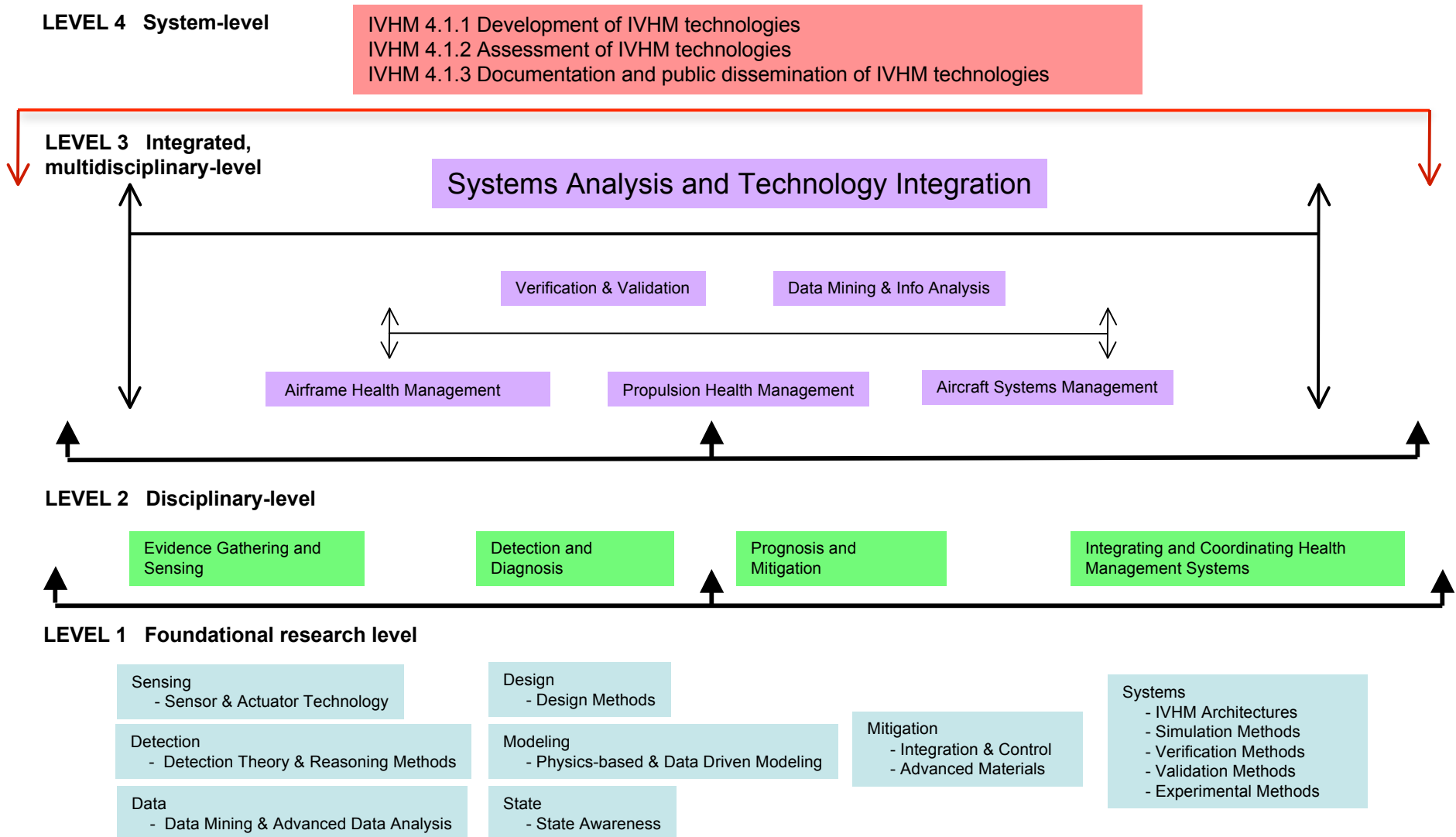


Management



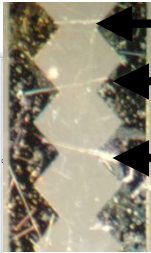
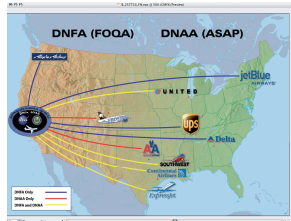


Work Flow



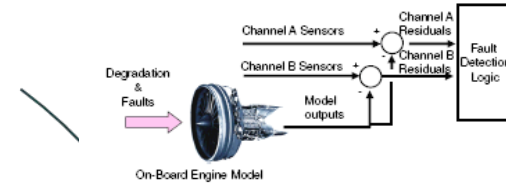


Technical Approach



SnO₂
ZnO
SnO₂

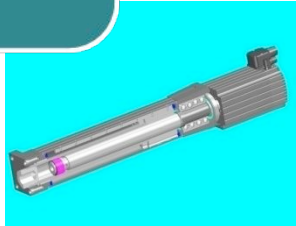
Evidence Gathering and Sensing



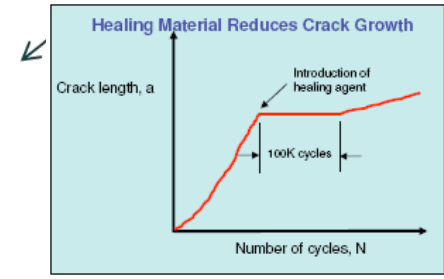
Integrating and Coordinating Health Management Systems

Goal: Validated multidisciplinary integrated vehicle health management tools and techniques to eliminate system failures in the presence of adverse conditions such as faults, damage, and degradation.

Detection and Diagnosis



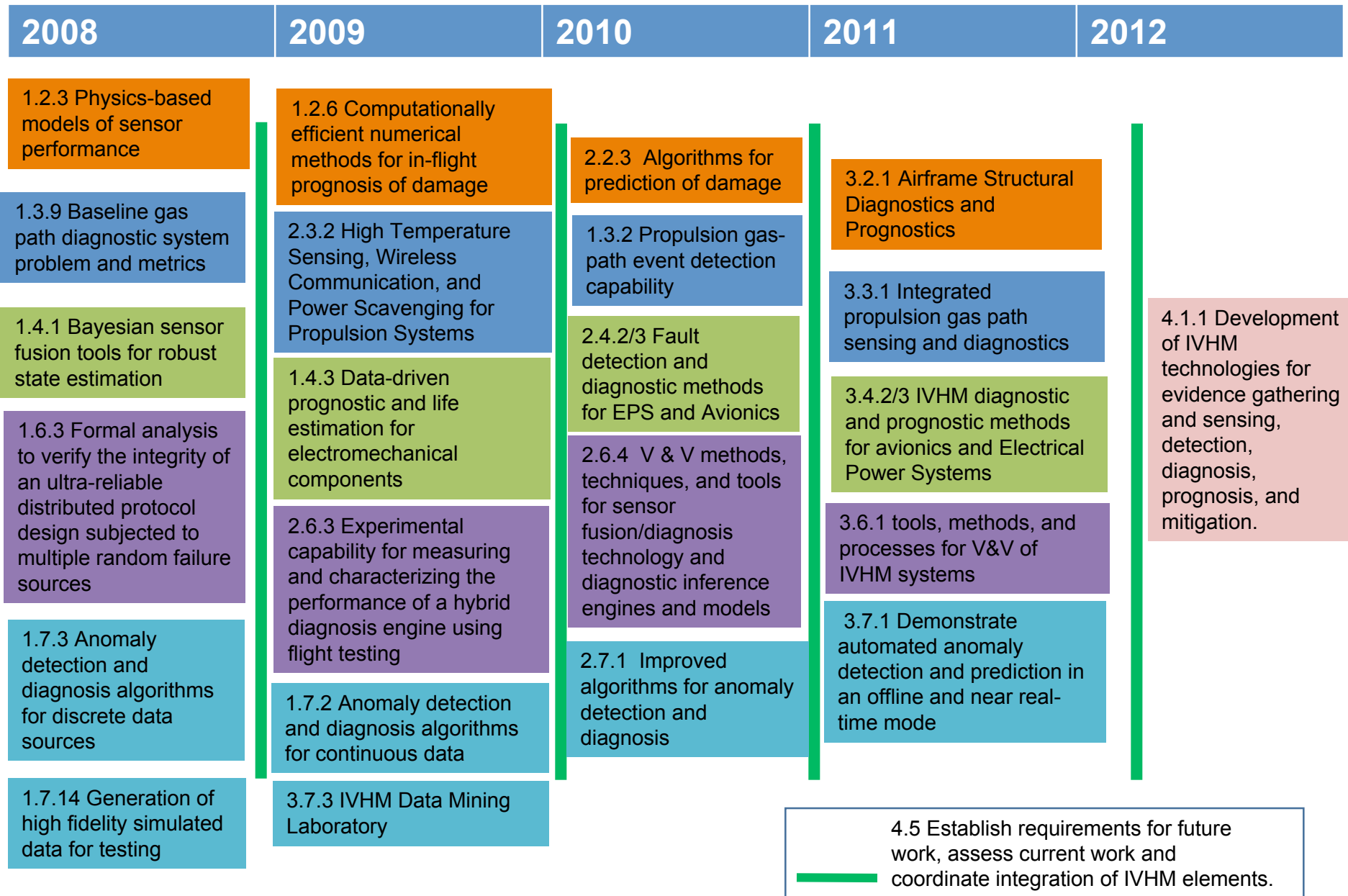
Prognostics and Mitigation



Interaction between IVHM Themes and Research Areas	Evidence Gathering and Sensing	Detection and Diagnosis	Prognosis and Mitigation	Integrating and Coordinating HMs
Airframe HM	<ul style="list-style-type: none"> • Development of structural damage sensing technologies • Self powered wireless sensors 	<ul style="list-style-type: none"> • Interpretation of sensor data for structural HM • Detecting electrical hazards 	<ul style="list-style-type: none"> • Computational methods to predict damage initiation and propagation. • Predict damage propagation & remaining useful life. • Self healing materials • Electronics robust to EMI 	
Propulsion HM	<ul style="list-style-type: none"> • High temperature sensing, wireless communication, power scavenging • High temp. microwave & optical sensors 	<ul style="list-style-type: none"> • On-board modeling to track gradual degradation and detection of abrupt or rapid changes in gas path 	<ul style="list-style-type: none"> • Physics-based prognostics for high temperature static structural components 	
Aircraft Systems HM		<ul style="list-style-type: none"> • Sensor fusion, detection, diagnosis, & isolation for actuators, electrical power systems and avionics. 	<ul style="list-style-type: none"> • Prognostic methods for actuators, avionics, and electronics. • Mitigation concepts for Single Event Effects caused by ionizing radiation. 	<ul style="list-style-type: none"> • Modeling interactions between hydraulics, structures, and electrical components to enable diagnostics and prognostics.

Interaction between IVHM Themes and Research Areas	Evidence Gathering and Sensing	Detection and Diagnosis	Prognosis and Mitigation	Integrating and Coordinating HMs
Systems Analysis and Technology Integration	<ul style="list-style-type: none"> • Generate requirements for sensor technology based on future aviation trends. 	<ul style="list-style-type: none"> • Generate requirements for detection and diagnosis techniques based on future aviation trends. 	<ul style="list-style-type: none"> • Generate requirements for prognosis and mitigation techniques based on future aviation trends. 	<ul style="list-style-type: none"> • Management and coordination of HM systems • Adaptive reconfiguration of subsystems (excluding effectors, engines, and control surfaces).
Verification and Validation		<ul style="list-style-type: none"> • Simulations to enable detection of non-robust elements in state space. 	<ul style="list-style-type: none"> • Simulations for automatic test case generation 	<ul style="list-style-type: none"> • Identification non-robust regions of complex state spaces. • Integration of flight, propulsion and airframe structure via simulations.
Data Mining and Information Analysis	<ul style="list-style-type: none"> • Integrated systems to gather and analyze large heterogeneous data repositories. 	<ul style="list-style-type: none"> • Advanced algorithms for anomaly detection and diagnosis using heterogeneous data. 	<ul style="list-style-type: none"> • Algorithms for aircraft level prognostics. • Algorithms for system level detection, diagnostics, and prognostics using complex data. 	<ul style="list-style-type: none"> • Algorithms for automated information integration. • Generation of prior distributions for IVHM

Schedule





Cross-Project and Program Coordination

Project or Program	Activity
IRAC	C-17/F/A-18/Airstar shared testbed Systems Analysis
IIFD	Architecture analysis Data mining for cockpit switching
AAD	Crack propagation, aging and durability tools, providing SHM data
Airspace Systems	Data mining for capacity planning
Hypersonics	Distributed control techniques
Space Operations Mission Directorate	Virtual Sensors and anomaly detection methods for ISS and Shuttle
Science Mission Directorate	Virtual Sensors for anomaly detection
Exploration Systems	Anomaly detection algorithms supp
Air Force	NASA-AF Executive Research Committee



Collaboration Through NRAs

Area	Description	Proposals Received / Recommended
Topic Area 1	Detection, Diagnostics, and Prognostics	60 / 9
Topic Area 2	Advanced Materials and Sensors	9 / 4
Topic Area 3	Environmental Hazards	1 / 1
Topic Area 4	Verification, Validation, and Predictive Capability	8 / 2
Topic Area 5	Data Mining and Information Analysis	13 / 2

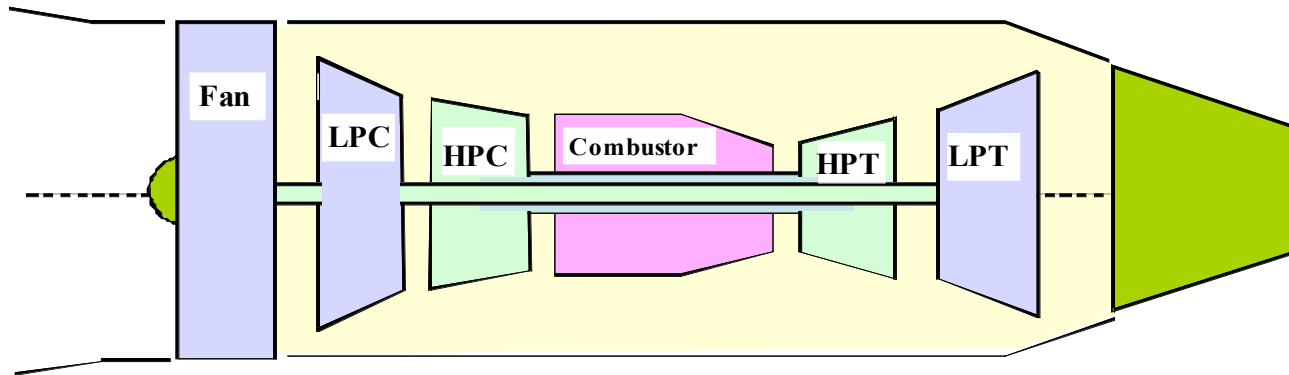
91 proposals received with 18 recommended for selection.
 8 Round 1 NRA proposals are underway.
 SBIR process is underway.



TECHNICAL ACCOMPLISHMENTS



Initial Characterization of Sensor Placement Methodology for Propulsion Systems



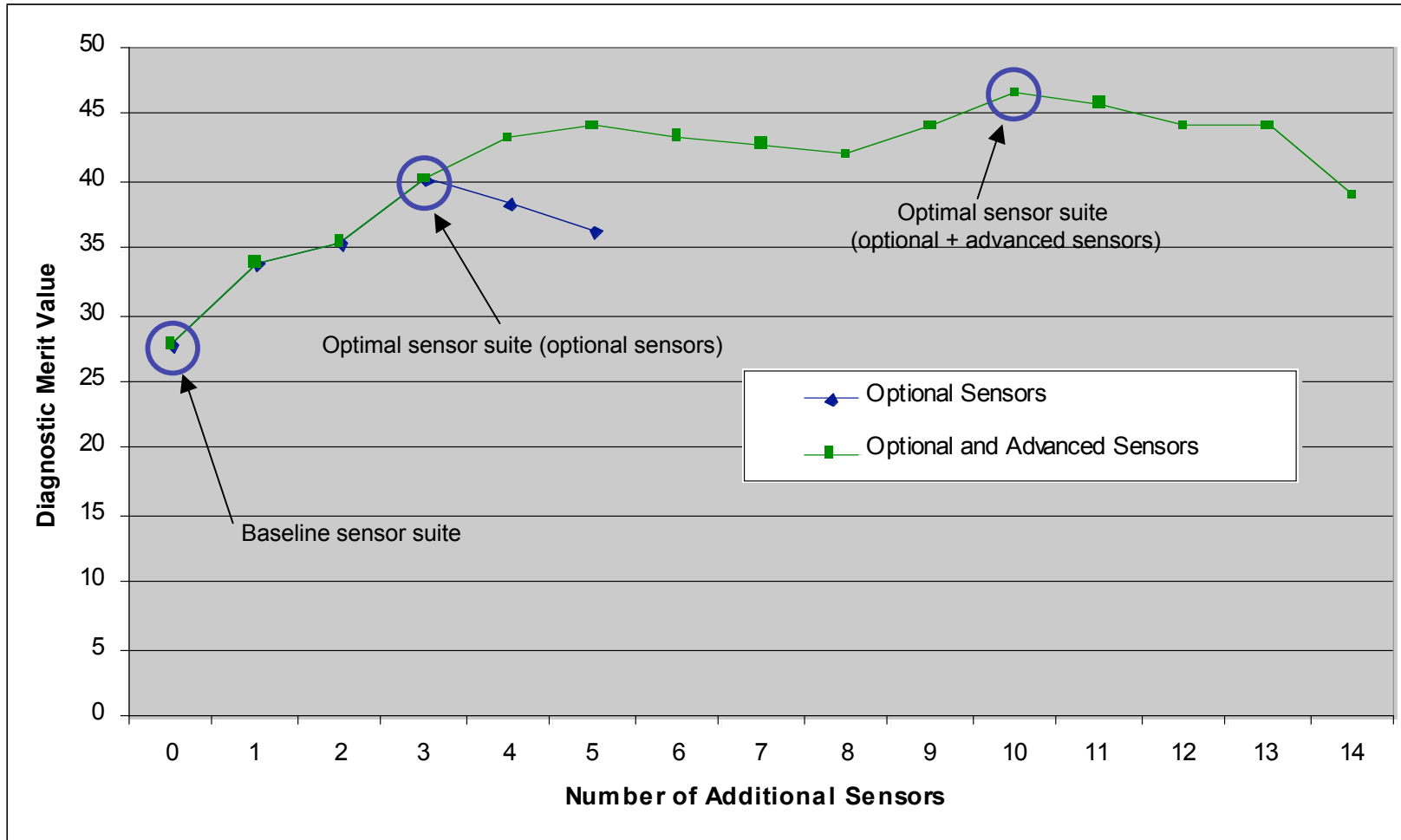
FADEC Control Sensors	T12 P0	T25	T3 PS3	WF N1 N2	T45	
Optional Sensors	T0 P2	PS 13 T13	P25		T5 P5	
Advanced Sensors		m2	m25	m3	T41 P41 m41	P45 m45
						m5

Black = typical
Green = optional
Red = advanced

Turbofan engine with sensor type and locations.



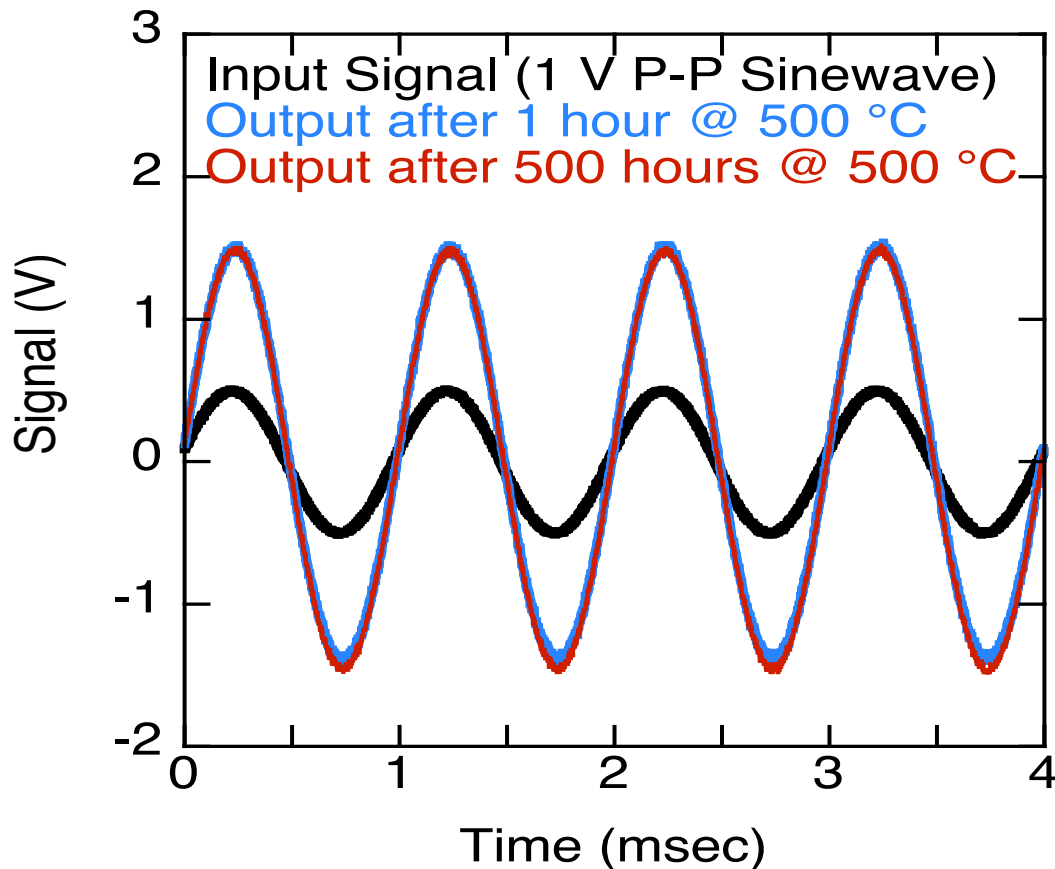
Performance of Sensor Placement Methodology



Diagnostic performance for optimum sensor suites increasing in size.



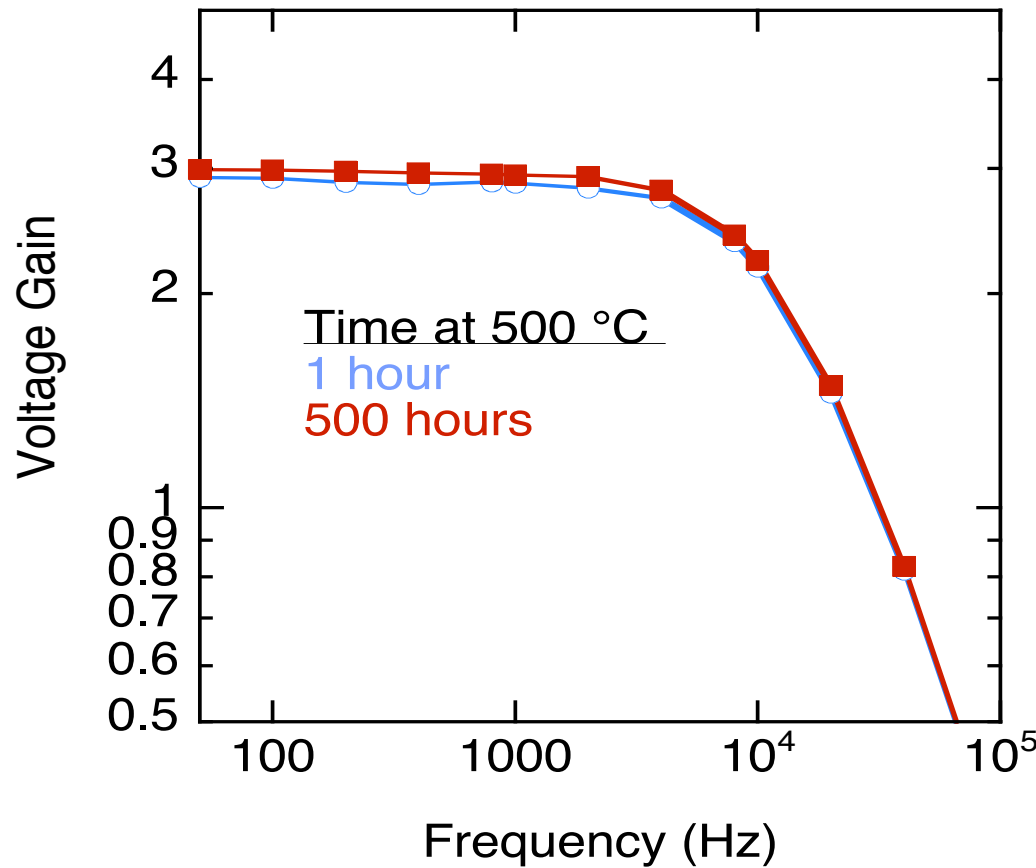
World Record Amplifier Operation at High Temperatures



Input sinewave (black) and amplified output test waveforms after 1 hour (blue) and 500 hours (red) of continuous SiC integrated circuit amplifier operation at 500 °C.



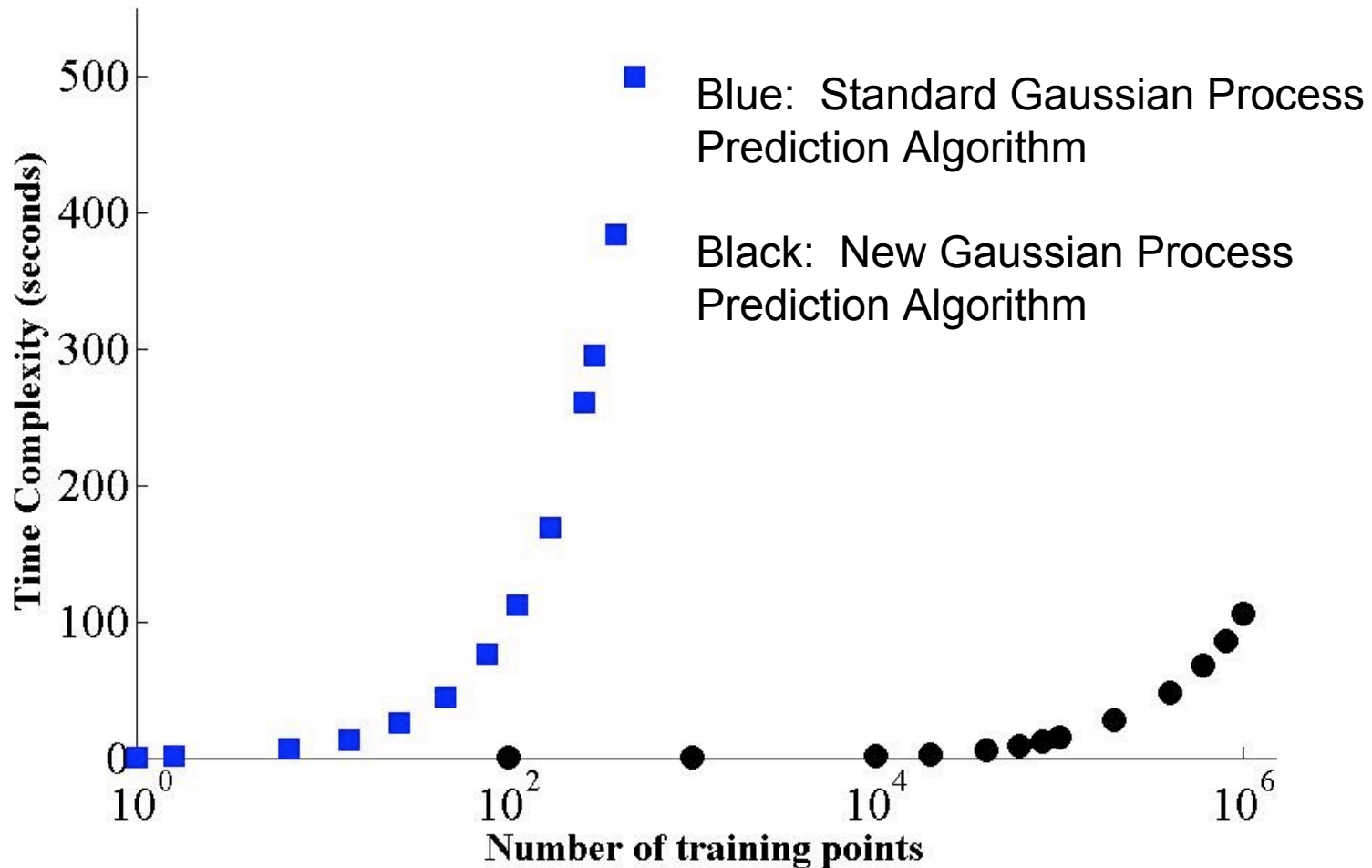
World Record Amplifier Operation at High Temperatures



SiC integrated circuit differential amplifier voltage gain measured as a function of frequency at after 1 hour (blue) and 500 hours (red) of continuous 500 °C electrical operation.



Fundamental Research into Fast and Accurate Predictions using Data Mining Techniques

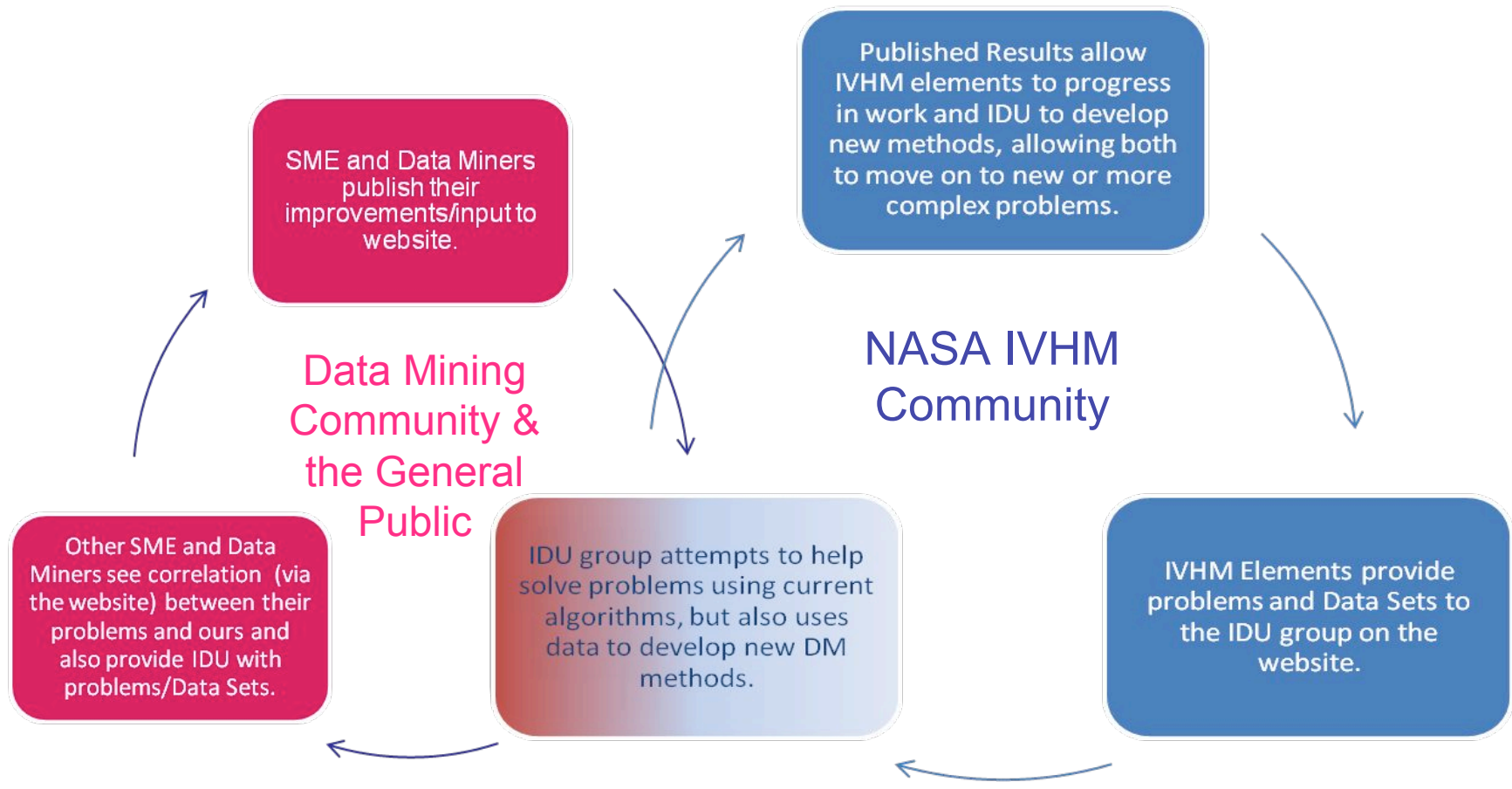




IVHM Data Mining Lab

Collaborate. Innovate. Disseminate.

Implement proof of concept website for dissemination of IVHM related papers, code, publicly available data, and algorithms.





Questions

