SAND2007-3134P

Sandia National Laboratories

Briefing to VADM Venlet

NAVAIR

21 May 2007

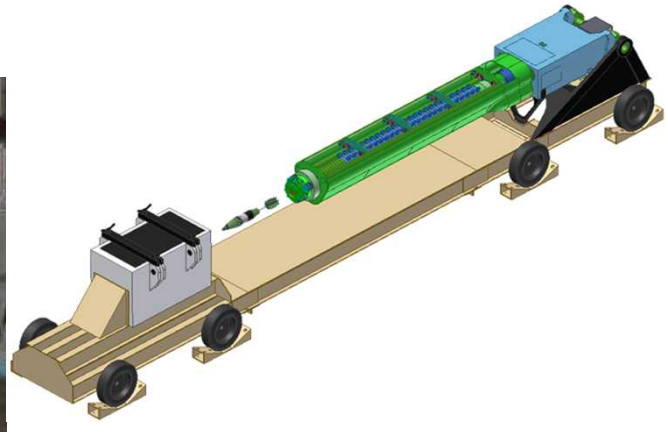
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy under contract DE-AC04-94AL85000.

Overview

- Discuss Sandia's extensive experience with linear motor launchers, power systems, and modeling and simulation directly related to the Navy EMALS system
- Discuss history of advanced non-destructive testing, advanced materials, and formal process development and deployment in aviation and other
- Discuss Bob C input. Bullet(s) starting with a verb
- Wrap up and questions

Electromagnetic Launcher Technology

Bob Turman
Sandia National Laboratories
Manager, Directed Energy Systems
(505) 845-7119, bnturma@sandia.gov



Sandia National Laboratories

Sandia Research Centers Related to Navy Systems Solutions

Engineering Sciences Center
Structural Mechanics
Thermal Management
Mechanical Modeling

Integrated Military Systems Center
Magnetic Propulsion
Advanced Power Systems

Energy Infrastructure Center

Pulsed Power Sciences Center
Power Systems Design and Development

Energetic Components Realization Center

Government / Industry Partnerships

Intelligent Systems
Systems Sustainability and Readiness
Reliability & Risk Management

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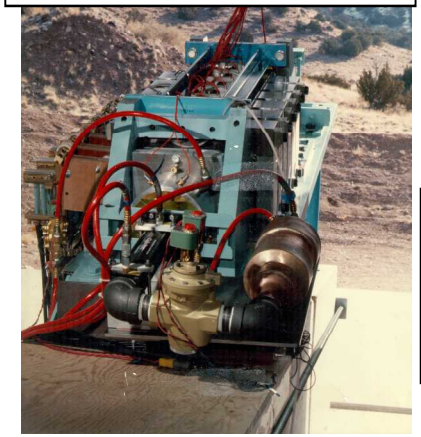
Sandia Experience Relevant to EMALS Development

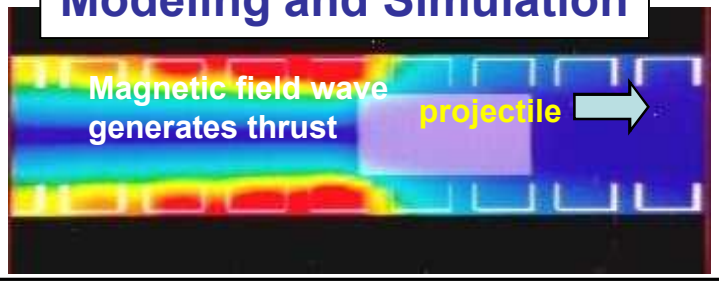
	Technical Expertise	Application to EMALS
Linear Motors & Launchers	Low speed launchers, High speed guns, Design, Modeling, Testing	Catapult performance, Trade Analysis, Design, Testing
EM Modeling and Simulations	EM interference, EM fields, Power flow in pulsed power systems, Electromechanical wear and lifetime issues	High voltage breakdown, Field management, Component requirements
Pulsed Power Systems	High voltage, High current components and systems	Energy storage, Power conditioning, Thermal management
Power Management	Power modulators, Power switching, High rep rate pulsed power	Power systems design, Testing, Switching components

Magnetic Propulsion for Launcher Applications

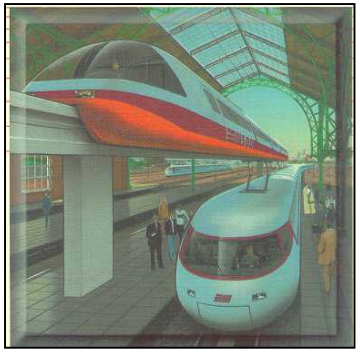
Short-Range Gun



Modeling and Simulation

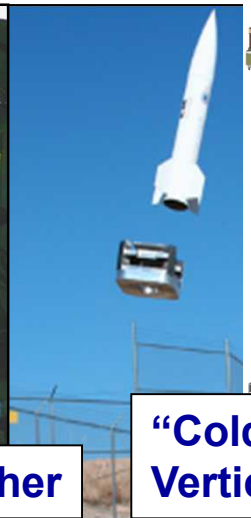


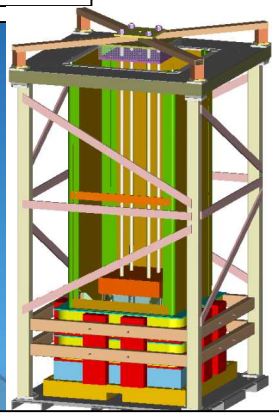
High Speed Ground Transportation



EM launcher applications are based on linear motor technology and advanced power systems

Missile & Canister Launchers

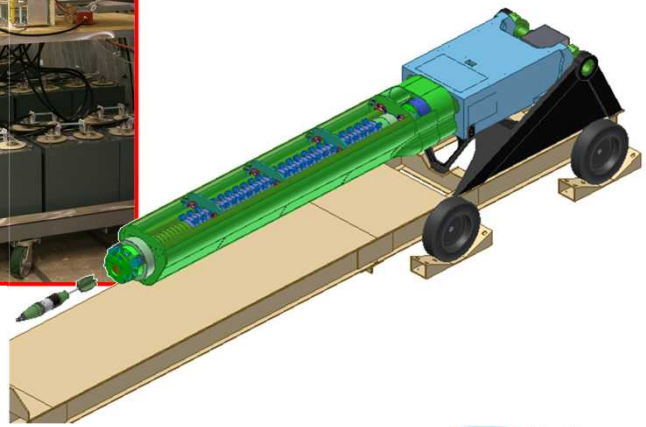




Countermeasures Launcher

"Cold Launch" for Vertical Launch Systems

DARPA EM Coilgun



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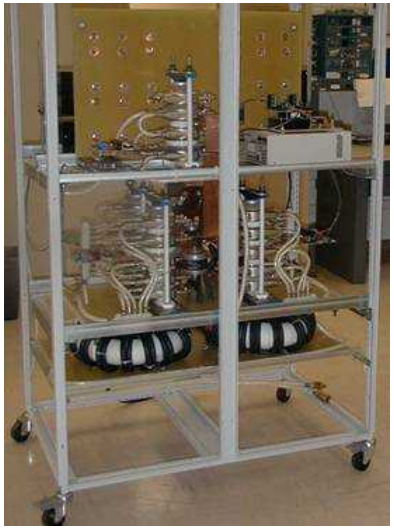
High Power Systems Development

World-leader in high average power repetitive pulsed power systems

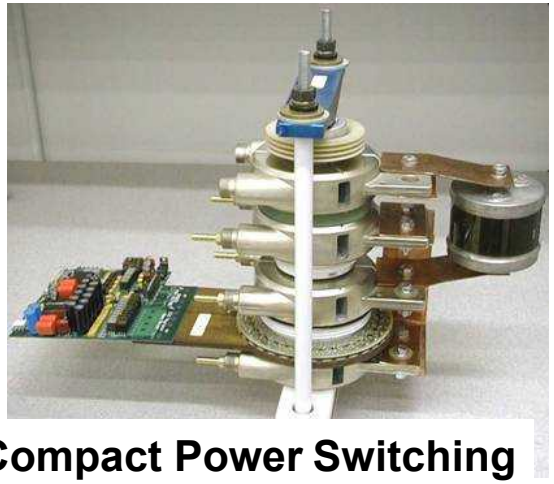
5-MVA ETO-based electric Utility applications



Power Electronics

3.2 MW Solid-state Inductive Load Driver

High Power X-ray Simulators



Compact Power Switching

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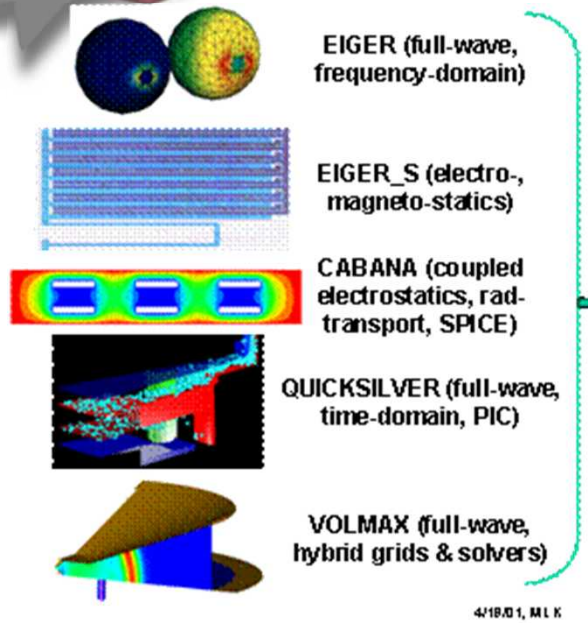
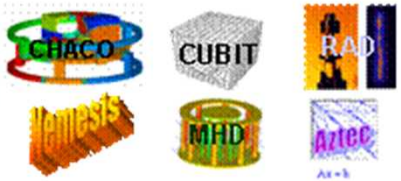
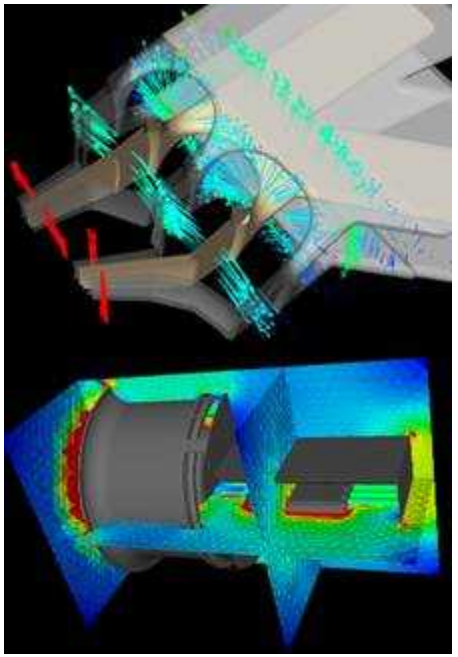
World-Class Electro-Magnetic Modeling

EM Modeling of Complex Structures

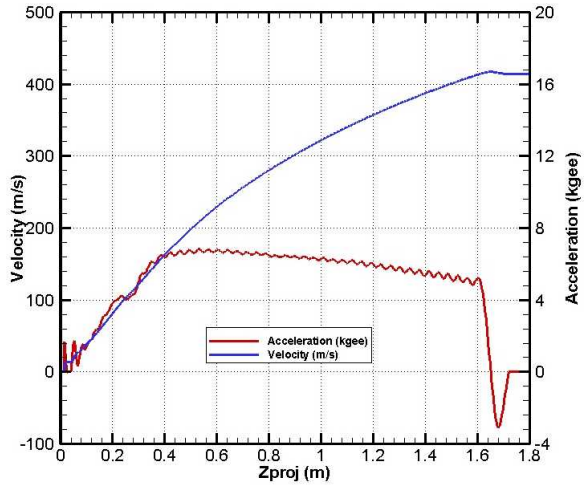


NEVADA *Electrical* Framework (integrates all code capabilities, couples codes, object-oriented development framework)

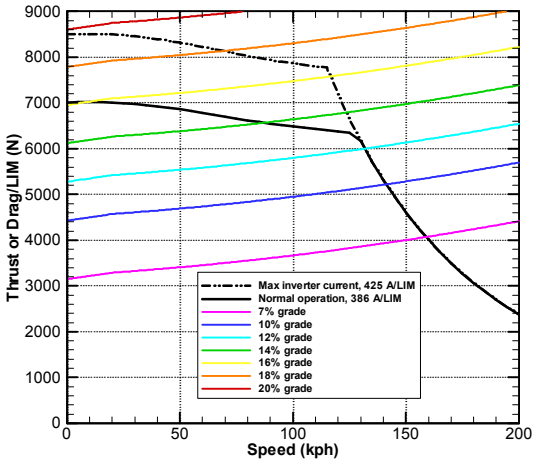




Modeling & Simulations for Navy long-range EM guns



Linear Motor Modeling



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Navy Related Projects with Electromagnetic Launch

Vertical Launch EM system for Navy VLS cold launch

Technology demonstrator designed, built, and tested jointly with Lockheed Martin (Shared Vision program)
Feasibility study for Kinetic Energy Interceptor mission, for ONR
Proposed study and demonstration for CGX Analysis of Alternatives

Navy Countermeasures Launch for improved accuracy, range, and rate of fire

Inventory countermeasure canister launch demonstrated under Shared Vision
Demonstrated reliable operation, ability to launch fuzed energetics in EM environment

Concept design and analysis for Naval Fire Support Gun

Sponsored by Office of Naval Research to scope systems requirements for EM gun
Linear induction launcher concept developed for high-velocity gun

Modeling and Simulation for EM Railgun Launch Tube Environment

High Current Contact environment modeling with the ONR Bore Life Consortium
Extending EM models developed for DOE applications

Sandia National Laboratories

FAA Airworthiness Assurance NDI Validation Center (AANC)

Infrastructure Assurance and Non-Destructive Inspection Department

Roger Hartman, Manager 505-844-9968 rdhartm@sandia.gov

- **Following Aloha accident in 1988, FAA initiated the Aging Aircraft Program**

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- **Following Aloha accident in 1988, FAA initiated the Aging Aircraft Program**
- **In 1990, Sandia was tasked to open the Center and operate for the FAA**
- **Operate under an Interagency Agreement that covers virtually all aspects of *continued airworthiness assurance***
- **Immediate access to the entire Sandia technology base**
- **Develop, evaluate, validate, & bring new technologies to market**
- **Formal test & validation process accepted by FAA for rule-making and fully supported by international aviation community**
- **Nearly 100% work-for-others (not DOE-funded)**
- **Support all US Armed Forces, Coast Guard, Forrest Service, major airlines, major manufacturers, and others**
- **Partner with industry, academia, and government, foreign and domestic**
- **Key Expertise: Metallic structures, advanced materials (composites) both as stand-alone and to repair metals, advanced non-destructive inspection (NDI), formal process development and validation, aircraft ops and maintenance, structural health monitoring**

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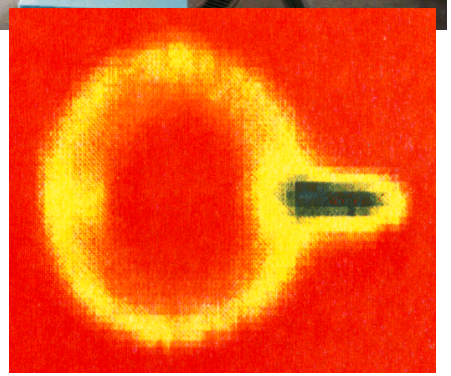
Sandia/AANC – Some Applicable History

- **Eddy current reliability study evaluated eddy current devices' performance at aircraft maintenance depots to detect fuselage cracks. Identified need for and led to developing improved imaging techniques**



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Sandia/AANC – Some Applicable History

- Eddy current reliability study evaluated eddy current devices' performance at aircraft maintenance depots to detect fuselage cracks. Identified need for and led to developing improved imaging techniques
- DC-9 Wing Tee Cap inspection procedure reduced time from 800 to 80 hours, increased probability of detection, and eliminated confined space entry

Before **- 800 hours Visual Inspection**

After **- 80 hours**

Sandia National Laboratories

Sandia/AANC – Some Applicable History

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- DC-9 Wing Tee Cap inspection procedure reduced time from 800 to 80 hours, increased probability of detection, and eliminated confined space entry
- Supported Air Force Research Lab and maintenance depots (Air Logistics Centers), quantified probabilities of detection and false call rates for field inspection activities (e.g. B-2, KC-135, F-15, C-141, C-130)
- Resulted in numerous FAA rule-making documents and changes to AF ops/maintenance
- Supported NAVAIR on applying phased-array ultrasonics to inspect EA-6B wing skins
- Identified 12 potential projects to assist NAVAIR on other programs

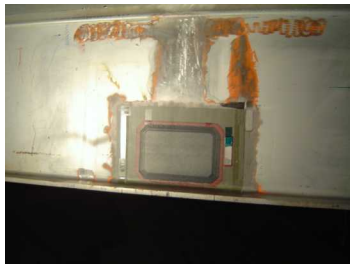
Advanced Materials (Composites) As Stand-Alone and to Repair Metal Structures

- Sandia pioneered composite doubler repairs for transport aircraft; installed the first after getting FAA approval

L-1011 Composite Doubler

- Sandia has extensive experience in material strength of composites and repairs (to metals and composites)

- We've migrated composite technologies to mining, highway bridges; investigating pipelines, reactors. Ships next?



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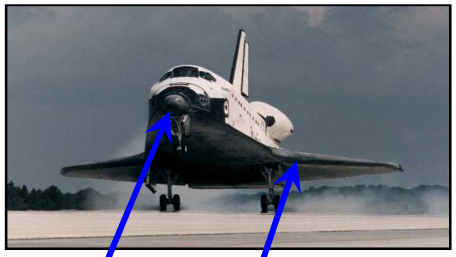
Sandia-AANC Processes and Procedures Accepted by FAA, Industry, Other US Gov't

- Sandia's formal, approved test and validation procedures support FAA rule-making
  - Address technical, operational, and human factors considerations, in the lab and in the field
  - Industry strongly supports and accepts, e.g. Boeing, Airbus
- Sandia develops some technologies and also tests and provides reports on others' technologies
- Sandia has no profit motive in any particular technology or process; industry accepts us as an *honest broker*
- Support other nationally important projects



Sandia provided only non-NASA-developed NDI technique for inspecting critical reinforced carbon-carbon orbiter leading edges. Now used for all mission-ready certifications

Advanced Non-Destructive Inspection (NDI) Techniques Can Monitor System Health and Find System Flaws Early

- Deploy them
  - Hand-held, Automated, Robotically
  - In-situ: Structural Health Monitoring -- the future of NDI, first approved use for transport aircraft approved by Boeing in March 2007 following AANC test/validation
- Enhance knowledge of systems' condition to improve knowledge of system's states
- Properly implemented, these techniques have a proven record of creating knowledge to allow safely operating critical systems
  - Required: high probability of detection with low false-call rate
  - Sandia has extensive experience developing and implementing for civil and military aircraft
  - Moving those technologies to other critical infrastructure
- Along with material science, enable condition-based maintenance
- Provide opportunity to increase operational availability and lower logistics support costs – lower life-cycle cost if systems are properly designed and implemented
- Allow Predictive Health Monitoring models to be optimally useful

Robert M. Cranwell, Manager
System Sustainment & Readiness Technologies
Center for Systems Reliability
Sandia National Laboratories (SNL)
Albuquerque, NM 87185

Phone: (505)844-8368 Fax: (505)844-3321
Email: rmcranw@sandia.gov
Web Site: reliability.sandia.gov

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CVN-21 Navy Airwing Manning Study

Results and Discussion from Phase I

3-Month "*Quick-Look Analysis*"

Not enough time to **fully** understand and analyze a complex, dynamic, multifaceted system,

Preliminary impressions:

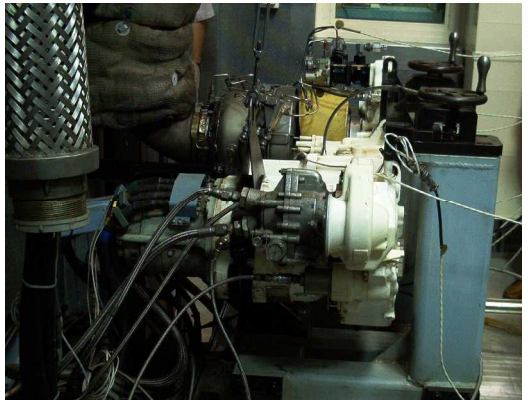
- Technology-insertion opportunities
- Spatial opportunities
- Cultural/organizational issues

Sample Technology insertion opportunity – Prognostics & Health Management (PHM)

F-16 ADG Prognostics & Health Management (PHM)

Objectives and Approach

- Introduce JSF proposed Prognostics & Health Management (PHM) technologies into F-16 hardware.
- F-16 Accessory Drive Gearbox (ADG) is currently under a Scheduled Based Maintenance (SBM).
- PHM will maximize the operational life while mitigating premature catastrophic failures.
- Approach is to model, analyze and test PHM technologies for effective integration into ADG hardware.
- Were Working with Kirtland National Guard unit for oil and vibration analysis.



ADG Test Stand at Hill AFB

On-aircraft ground test at Kirtland

Savings of $27M/Year in unnecessary maintenance costs

LCAC Readiness M&S

- **Primary Objective: Capability to place $$ value on readiness**
  - **Optimal component upgrade options**
  - **Best repair/sparing strategies**
  - **Maintenance procedure changes**

- **Phase I: Unit-level LCAC fleet characterization**
  - Steady-state model to ascertain readiness of the fleet
  - Operator chosen scenarios for given postulated situations
  - Address component upgrades, supply system, maintenance resources, organizational changes, etc.
- **Phase II: Enterprise-level readiness strategies**
  - Dynamic model for the LCAC community
  - Treat LCAC community as a System-of-Systems

Organic Capability to Relate Cost to Readiness

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Phase 1 – Benefits to LCAC Program

- **Fully trained LCAC personnel**
  - Software/model use, data requirements, etc.
  - Gap & sensitivity analyses
  - Assessment of changes in R&M, scenario, improvement options, etc.
  - Full software documentation and consultation
- **Flexible modeling of the LCAC fleet**
  - Fleet, unit, model, system, subsystem, LRU
  - Multiple scenarios, budgets, etc.
- **Capability to maximize fleet readiness based on budget**
  - Best component upgrade, maintenance, sparing and labor cost strategies
  - Impact of no improvement, not enough spares, etc.
  - Optimized selection of components to buy now to maximize readiness later
- **Results of Analyses**
  - Sensitivity/uncertainty analyses
  - Optimization analyses

} ***For Multiple Scenarios***

Capability to answer: A budget increase of $1M would…

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F/A-18E/F & F414-GE-400 Readiness

Program Objective: **Perform Modeling, Simulation & Optimization of the F414 Enterprise to determine the best use of funds that will optimize the number of Ready For Issue engines and Mission Capable aircraft.**

- **M&S of F/A-18E/F and F414-GE-400 aircraft/engine combination to forecast reliability, readiness and cost impacts for a series of improvements**

How much will readiness & reliability be impacted by a defined budget increase or decrease

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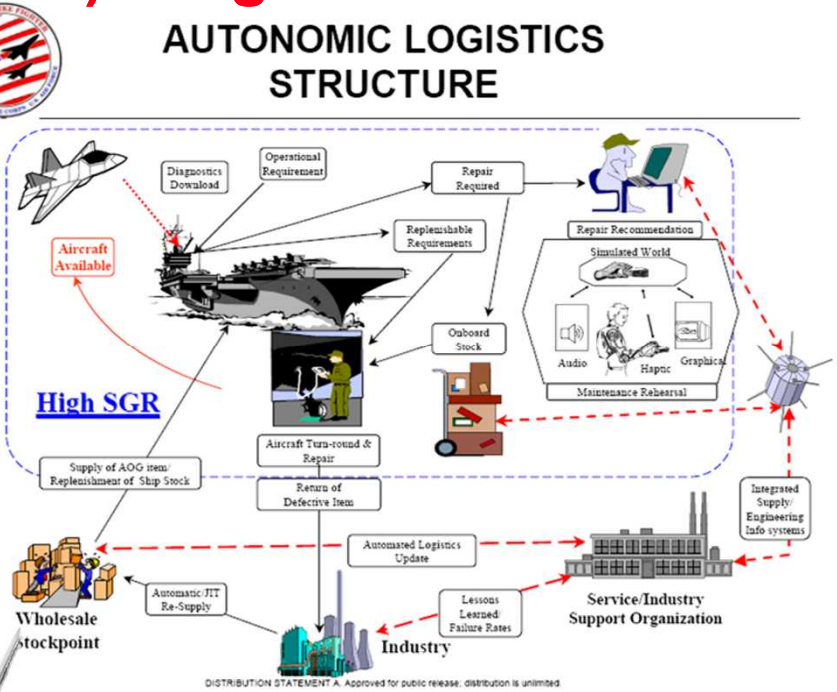
JSF Autonomic Logistics Support

Providing Autonomic Logistics (AL) Support to Joint Strike Fighter (JSF) Program:

- Design for Reliability, Maintainability, Supportability
- On-board/Off-board Prognostics & Health Management (PHM)
- Tech Refresh/Parts Obsolescence
- Support Enterprise Modeling (SEM)



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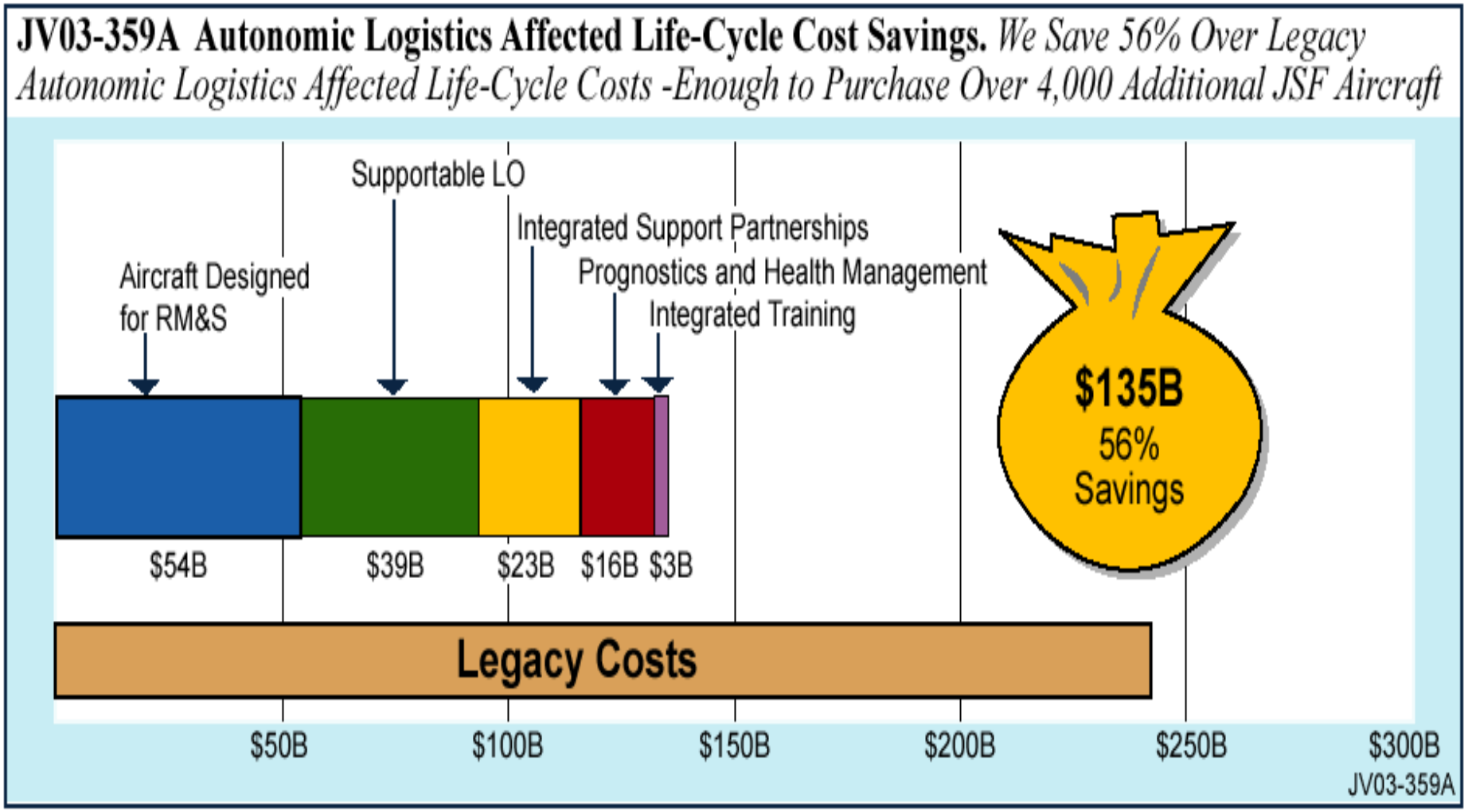
Benefits of PHM to JSF LCC



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AH-64 RECAP Program

Supported Army's Recapitalization (RECAP) Program by analyzing Apache AH-64 RECAP Objectives:

Through upgrades & rebuilds of selected components:

- Achieve 20% Reduction in O&S costs
- Achieve 20% Increase in Availability

Results of Study

- **RECAP Investment Cost Savings**
  - Analyses showed potential savings of over 50% of expected RECAP investment cost (~$400M in savings)
- **Use Model to Evaluate "What If's"**
  - What will it take to get to Army Aviation's 90% readiness goal?
    - RECAP alone will only get less than 3% improvement
    - Also need optimal improvements in maintenance, spares, etc.,
    - Possible use of PHM
- **Analysis projected 15-20% reduction in MR (observing ~30%)**

"The Apache RECAP program will:

Incorporate the Sandia National Laboratories Analysis … This action ensures that RECAP resources are focused on the highest payoff components."

Source: *Apache Recapitalization Program Baseline (RPB) Approval,* 10 April 2002

Signed by: Secretary Bolton, Army Acquisition Executive, John M. Keane, General, U.S. Army Vice Chief of Staff