Intelligent Incorporation Of Advanced Technology Into Legacy Fighter Jet Engines To Increase Time On Wing And Reduce Maintenance

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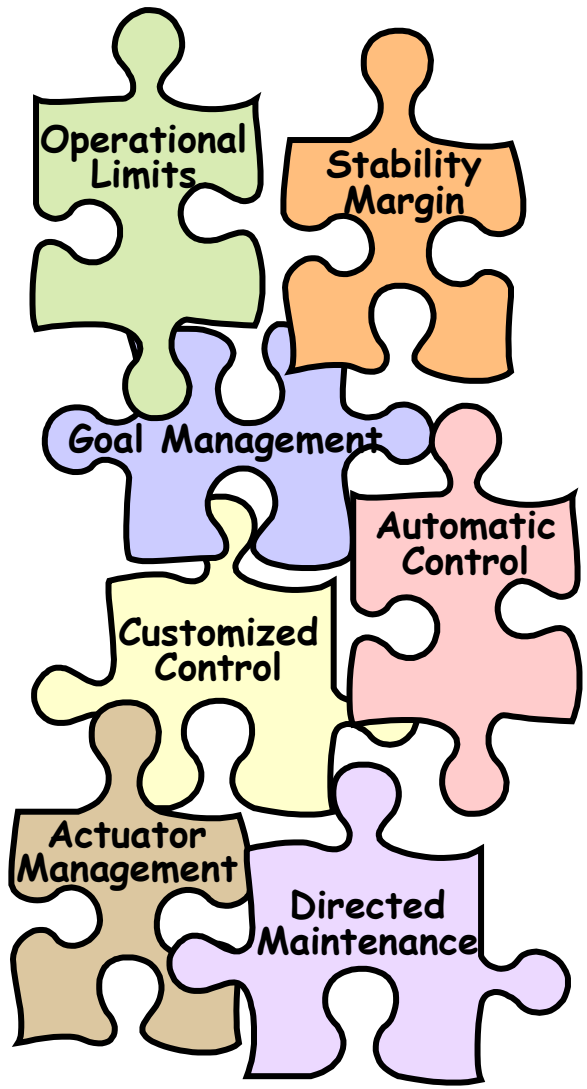
Agenda

- Objective: Talk About 4 Steps For Intelligent Technology Insertion
- Present Examples of P&W Technology Pull Process
- Show An Example Of Legacy Engine Technology Insertion Using F100-PW-229
- Summary

Four Steps For Intelligent Incorporation Of Technology

1. Identify Stakeholders, Common Goals And Critical Metrics
   - Example: USAF, P&W, Maintainers, Etc.
2. Review And Understand Engine Data
   - Performance, Safety, Affordability & Reliability
3. Select Proven Technologies Ready For Insertion Into A Legacy Engine
4. Balance Technology Selections With Customer Requirements

Integrating The "Puzzle"



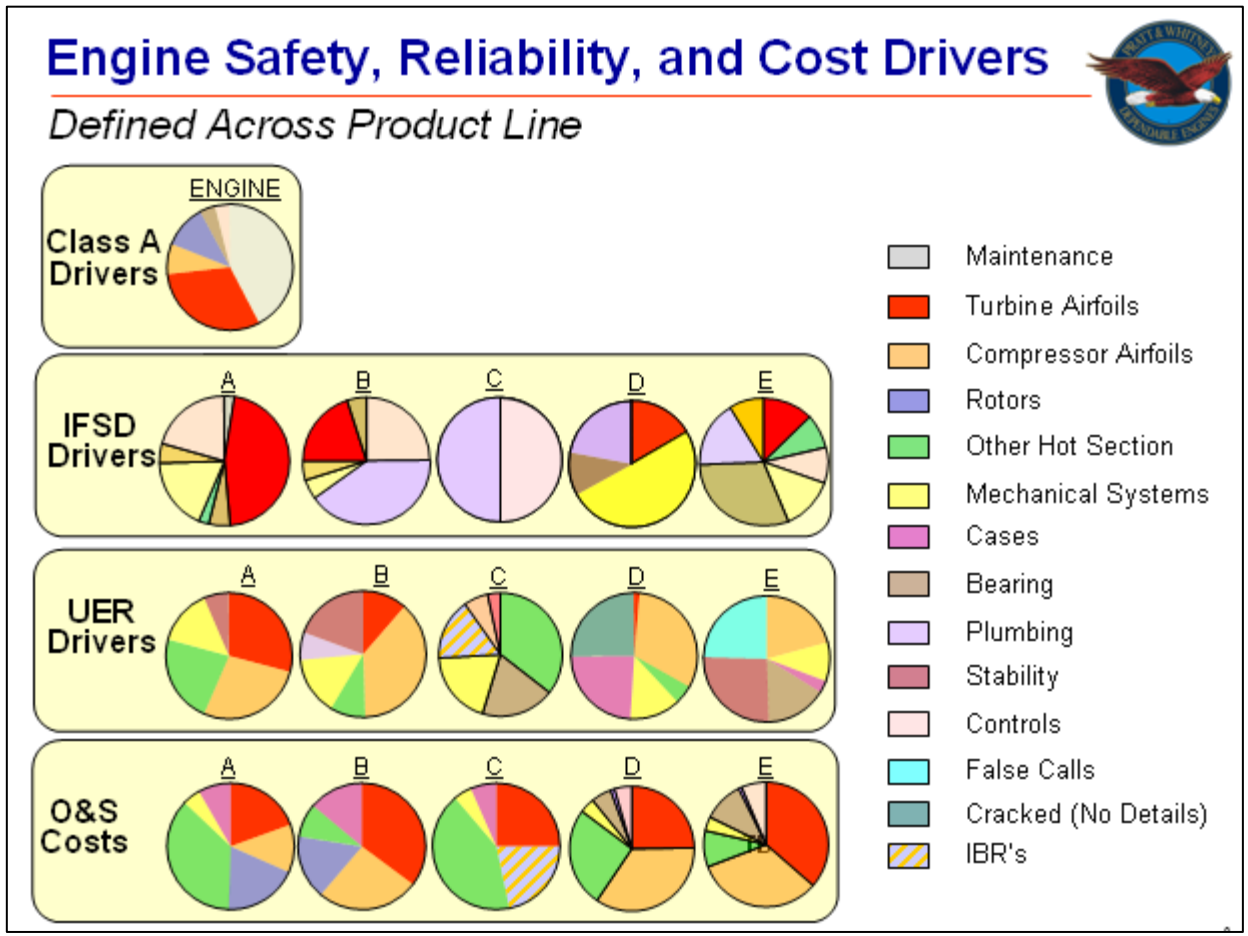
Step 1: Identify Stakeholders & Goals

Example: USAF F100-PW-229

- USAF Goals
  - Centralized Intermediate Repair
  - Reduced Maintenance Man-Hours
  - Increase Safety & Time On Wing; Reduce Maintenance Cost
- P&W Goal
  - Improve The F100-PW-229 Position For The Future
- USAF/P&W Common Goals
  - Focus On Safety & Reliability Through 2035+

Step 2: Review And Understand Engine Data

Example: F100-PW-229



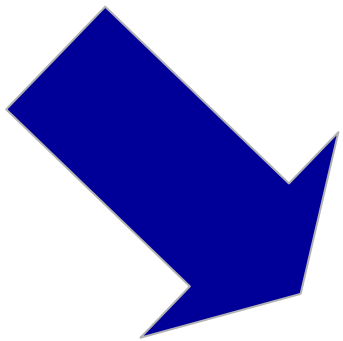
Understand Fleet

Step 3: Select Proven Technologies Ready For Insertion

Example: P&W Technology Development & Engineering Standard Work

Elements
1. Review closure of action items from prior TDR.
2. Evaluate a technology's development progress versus plan.
3. Concur and document status against key TRL validation requirements (e.g., test run, testing environment, analysis, tool calibration).
4. Concur and document achievement of technical parameters (e.g., efficiency, pressure ratio, temperature capability, life) at the current TRL.
5. Evaluate and concur on any updates to technical benefits projected at TRL-P6, if required.
6. Review Intellectual Property position/plan.
7. Review industrial plan, manufacturing producibility, and repairability.
8. Review applicable Green Engine and EH&S requirements and actions taken to ensure compliance.
9. Review product support and potential field issues.
10. Review and concur Level 2 plan for next 12 months, including significant milestones, funding requirements, manpower requirements, assets and/or capital needs, etc.
11. Review and concur Level 1 plan through achievement of TRL-P6.
12. Review status of ESW and MSW for the technology.
13. Recommend updating the TDP, if required (to be agreed to in reviewer caucus).
14. Assign TRL (to be discussed in reviewer caucus and agreed to by Chief Technologist).

Technology Review Steps



P&W Engineering Standard Work

Rigorous, Comprehensive and Continuously Improving

Established Processes Used To Assess And Advance Technology Maturity And Facilitate Transition To P&W Engineering Standard Work

Example: P&W Technology Pull Process

- Technologies Are Selected Based On Proven Track Records
  - Commercial Engines Technologies
    - » Output Of Development Engine Certification Process
  - 5th Generation Fighter Technologies
    - » F119/F135 Development And Field Exposed Technologies
- Technologies Must Meet Goals Of All Stakeholders To Be Cost Effective

P&W Example Of Technologies Evaluated For Incorporation

- **Turbine Airfoils**
  - Advanced Cooling Configurations
  - Thermal Barrier Coatings
  - TMF / Oxidation Lifing Systems
- **Disks**
  - Life Extension
  - Residual Stress Effects
- **Bearings**
  - Monitoring / Trending
  - Hybrid Bearings
- **Fan / Compressor Airfoils**
  - Foreign Object Damage
  - Surface Treatments
  - Probabilistic Assessments
  - Erosion
  - Repair (IBR's)
  - Mistuning (Field Effects)
  - HCF, Damping, etc.
- **System**
  - Usage-Based Fleet Management
  - Integrated Prognostics & Health Monitoring

Technologies Selected Based On Best Fit With Desired Outcome

Pull Process Guides Technology Development

2012

Engine Enhancement Package

USAF Component Improvement Program Activities

Usage Based Lifing & Health Monitoring

Focused Low Risk Technology Insertion

Interval Extension

Robust Fixes For Current Issues

Today

Logistics Technology
Anomaly Detection
Fault Isolation

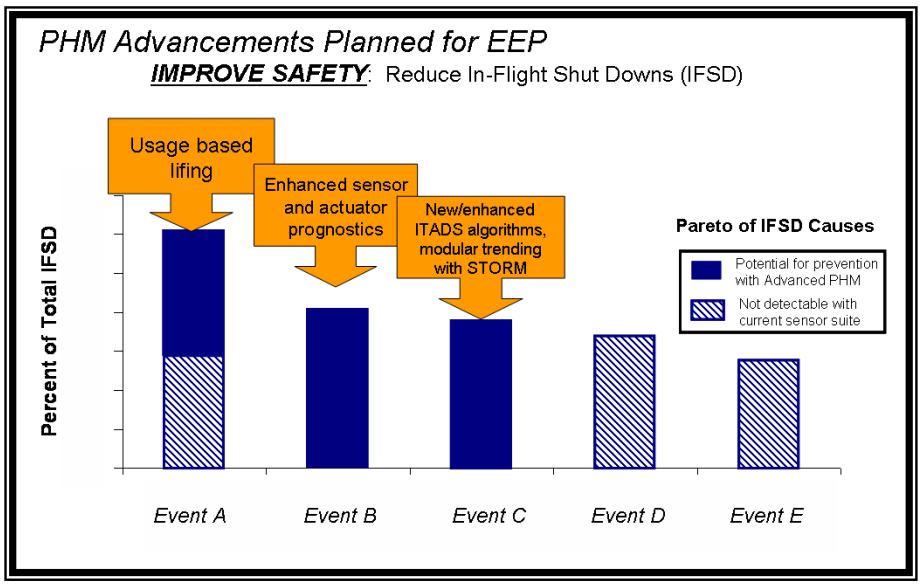
Turbine Technologies
- Improved Coatings
- Advanced Cooling Schemes

FOD Tolerance Technology

Advanced Life Analysis
Focused Wear Tasks
LLP Design Enhancements

Example: F100-PW-229 EEP Prognostic Health Monitoring

F100-PW-229 EEP Achieves Propulsion Safety, Affordability & Readiness Goals



- Historical F100 IFSD Causes From Last 5 Years Evaluated
- Early Identification Of Anomaly Can Avoid IFSD And Costly Secondary Damage
- Directed Maintenance Activity Significantly Decreases Cost And Mistakes Leading To Unwanted Consequences

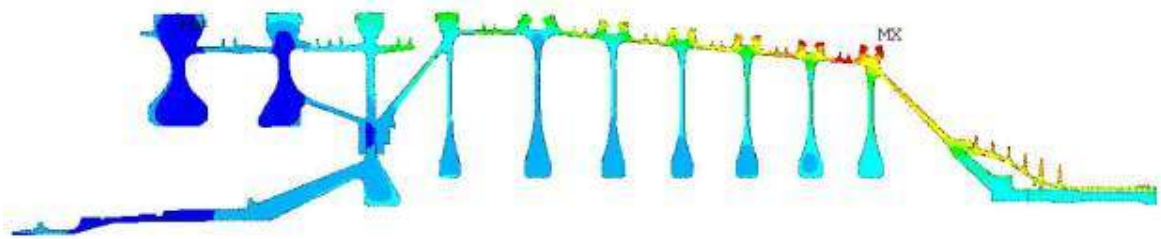
Example: F100-PW-229 EEP Advanced Lifing

Leverages Science & Technology Investment In Advanced Lifing And Prognosis

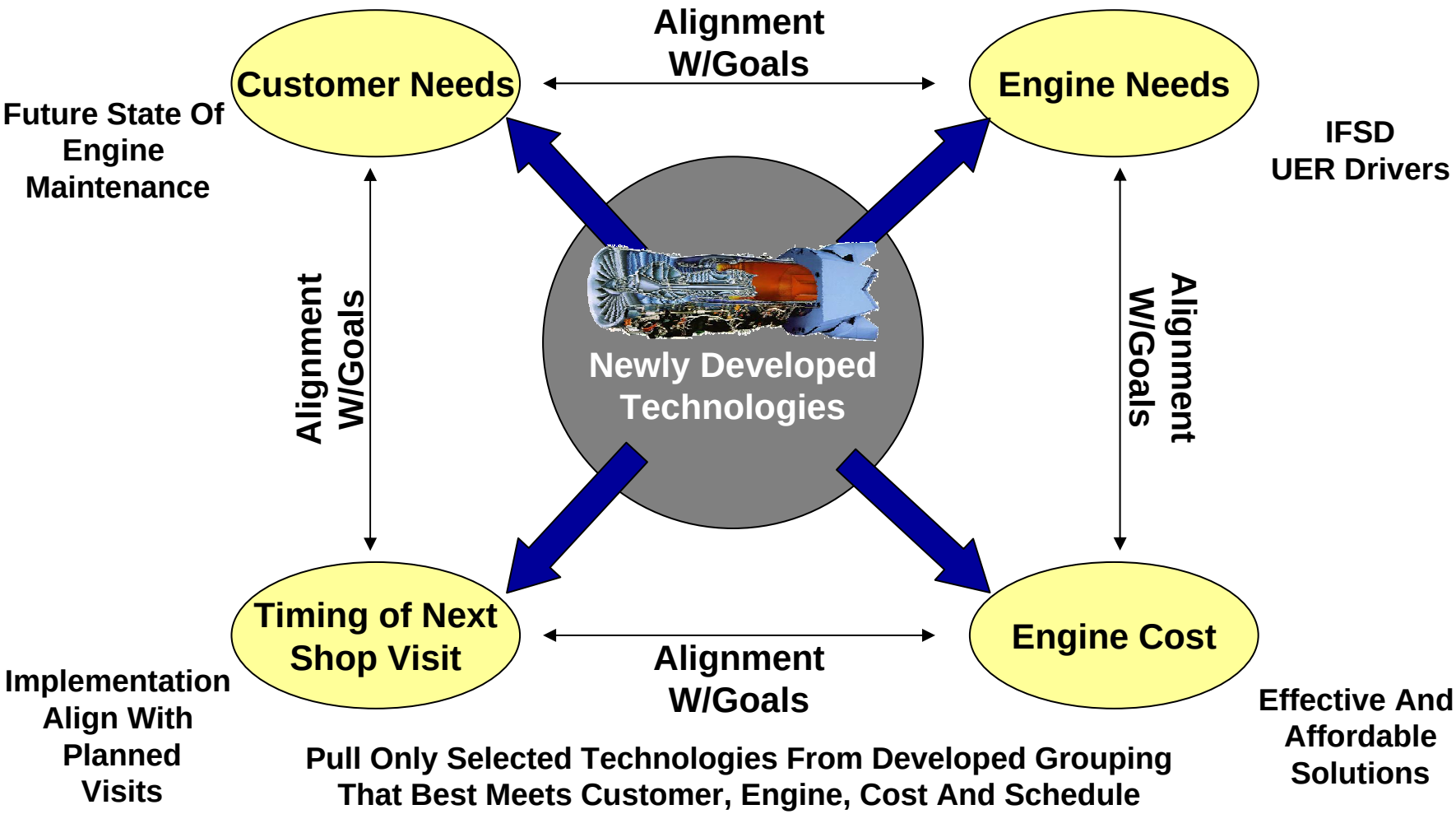
- Advanced Rotor Life Tools Developed & Implemented For F100

- Usage-Based Lifing Potential Demonstrated & To Be Implemented In F100

Usage Algorithm Feasibility Demonstrated For F100 Components Using Actual Continuous PW-229 Mission Data



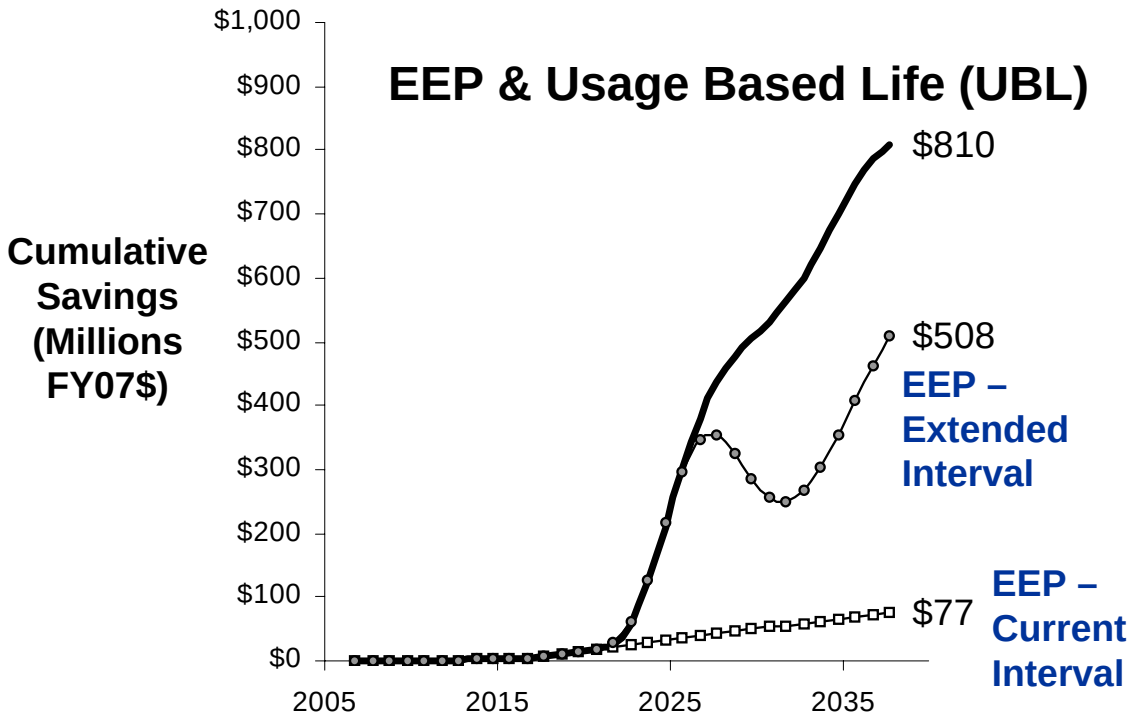
Step 4: Balancing Technology With Customer Requirements

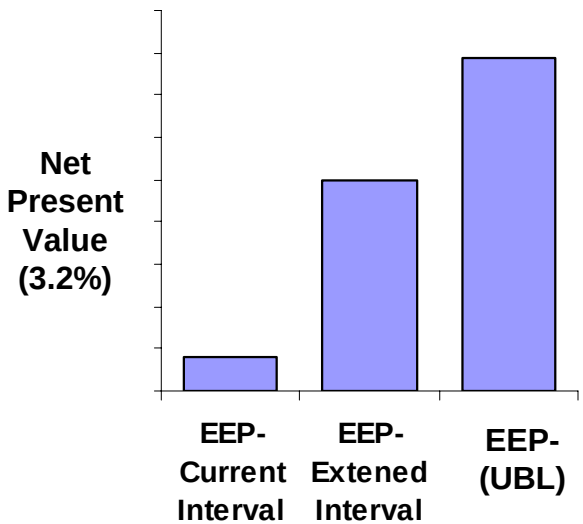


Example: Effect Of F100-PW-229 EEP Technology Insertion

Incorporated Technologies Reduce Maintenance Cost By 20%

- 975 Engine Removals Can Be Avoided
- Maintenance Cost Savings From Reduced UER And SER Removals





Summary: F100-PW-229 EEP Technology Insertion

F100-PW-229 Legacy Engine Safety, Affordability & Readiness Improved

PW-229 Engine Enhancement
Package Objectives

- Reduce IFSD Rate By 25%
- Double Mean Time Between Removal (MTBR)
- Reduce UER Rate By Half
- No Change In Depot Cost Per Engine
- Incorporate In Depot Build Standard By 2012

Safety:

- ☑ Goal: 75% Reduction In Propulsion Related Class A Mishaps

Affordability:

- ☑ Goal: 10% Reduction In Propulsion Related Material / Acquisition Costs

Readiness:

- ☑ Goal: ATOW Increased 2X

Summary

- P&W Is Committed To Product Performance, Safety, Affordability & Reliability
- Technology Pull Process Provides Cost Effective Development
- P&W Performs Extensive Testing To Mature Technologies & Selects Only Those With A Proven Track Record
- F100-PW-229 EEP Provides Example Of Technology Maturation And Insertion To Meet Stakeholder Goals