This paper contains forward-looking statements concerning future business opportunities technology advances. Actual results may differ materially from those described as a result of certain risks and uncertainties, including challenges in the design, development, production and support of advanced technologies; as well as other risks and uncertainties, including but not limited to those detailed from time to time in United Technologies Corporation's Securities and Exchange Commission filings.
Agenda

Topics of Discussion:

• Engine Life Management Plan (ELMP) Overview
• F100 Engine Rotor Life Extension Program
• F100-PW-229 Engine Enhancement Program
• Prognostic Health Management and Usage Base Lifing Initiative
ELMP Proactively Identifies Activities to Improve Cost of Ownership and Safety Metrics

**Configuration**
- Retirement for Cause
- Common Engine Configuration
- CEMS Maintenance
- IPB Update
- ERLE
- EEP

**Engine Operation**
- Pacer
- PHM

**Maintenance**
- RFC Closed loop process
- TO Update
- ACI / Trending

**Spheres Of Influence**

**Supporting Initiatives**

**Parallel Improvement Programs**

**Growth / Study Initiatives**

**Component Improvement Program (CIP)**

**GSE Tasks**

**P-SAR Initiatives**

PRATT & WHITNEY PROPRIETARY INFORMATION
An Engine Life Management Plan (ELMP) is a comprehensive methodology for managing and sustaining systems throughout the F100 design life. Goals of enhanced system safety, reliability, and supportability, while reducing the cost per flying hour.
The Lifing Philosophy of the F100 Engine has Gone Through Many Iterations Since Initial Service Release.

**Probabilistic Life**

F100-PW-229 Utilized ENSIP and Probabilistics from Design Conception

ERLE and EEP Programs employed to increase usage

Thrust Constant for all Models

**LCF**

- PW-200
  - Development
  - Production

- PW-100
  - Development
  - Production

**Total Life**

-220 Production

**Probabilistic Life**

-220E Upgrade

Development

PRATT & WHITNEY PROPRIETARY INFORMATION
Lifing Methodology Progression

Evolution of Lifing Philosophy Allowed Parts to Safely Remain on Wing Longer

- Initial parts designed for 1800 TAC usage
- Requirement for 4000 TAC engine drove redesign and lifing approach
  - ENSIP design philosophy introduced for new parts
  - Retirement For Cause extended current part usage
    - Operation beyond LCF limit
    - Enhanced ECI inspections
- Life Limit (LCF & F/M) employed during 1993 lifing update
  - Enhanced ECI inspection coupled with LCF lives
- Probabilistic design approach used to supplement Engine Structural Integrity Plan (ENSIP)
Lifing Methodology Progression

Evolution of Lifing Philosophy Allowed Parts to Safely Remain on Wing Longer Cont.

- ERLE program introduced – 3rd interval usage
  - Successful field experience leveraged
  - Enhanced ECI inspection utilized
  - Use of Probabilistic design methodology expanded
- EEP program introduced – 6K inspection interval
  - Draws on success of ERLE program
  - Local feature redesigned to allow extension
- Usage Based Lifing – Next step
  - Subset of PHM
  - Employs actual engine performance data to calculate fatigue damage
  - Significant increase in on-wing time possible
Rotating Hardware Extensions to a Third Interval by Utilizing Lifing Methodology Changes

- Ground rules established using deterministic and probabilistic methods
- F100 rotating hardware selected based upon ROI of extending hardware for 3rd interval
- Hardware was analyzed using the latest inputs
- Expected completion date of Feb 2011
- Initial results have been reviewed with USAF
F100-PW-229
Engine Enhancement Package (EEP)

EEP Builds On Lifing Advancements Along with Robust Configuration of Current CIP Tasks

- Engine Enhancement Program
  - Usage Based Lifing & Health Monitoring
  - Focused Low Risk Technology Insertion
  - Interval Extension
  - Robust Fixes for Current Issues
  - ERLE Analysis & Extensions
    - Focused Wear Tasks
    - LLP Design Enhancements
    - Repair Development

- Current CIP Activities

- APHM
  - Anomaly Detection
  - Fault Isolation

- Turbine Durability Improvements
- Turbine Cooling Enhancements
- FOD Tolerance
Prognostic Health Monitoring

Substantial improvement possible in all ELMP categories with EHM

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<th>Fleet Metric (-220/-229)</th>
<th>Usage Based Lifing (life limited parts)</th>
<th>Anomaly Detection</th>
<th>HCF Airfoil UBL</th>
<th>Turbine Durability UBL</th>
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**EHM Tools Benefits**

- **Usage Based Lifing**: Extends scheduled service intervals through improved fatigue damage tracking.
- **HCF Airfoil UBL**: Predicts crack propagation from HCF.
- **Turbine Durability UBL**: Hot part damage models enable on-condition borescope inspections.
- **Anomaly Detection**: Reduce inspections, enhanced RCM, improved engine efficiency, oil system monitoring, reduced IFSD & UER.

**G6 DEEC Advanced PHM Board**: Streaming engine data enables EHM tools.
Usage Based Lifing Extends Time Between Scheduled Depot Visits

- Conventional TAC or cycle based lifing estimates the life used by comparison to conservative design missions
- Usage Based Lifing calculates the life used for each engine, each LLP, based on actual usage (“TACu”)

Studies have shown that the majority of engines are flown “easier” than design missions
- Actual TACs (“TACu’s”) were less damaging than the conservative design mission TACs
- On average, engines could have flown 50% longer to reach design mission damage
Definition of TACU - LCF

Continuous Data
Continuous data from engine control system and engine model

USAGE ALGORITHMS
Convert Continuous Data to Stress and Temp

LCF SYSTEM
Converts T, \( \sigma \) to LCF Life

\[ D_n = \frac{1}{N_f} \]
\[ D_{cum} = \int_0^n D_n \]
\[ TACU = TAC_{DESIGN} \times D_{cum} \]

\( N_f \) - Cycles to Failure, \( D_n \) - Damage Cycle n, \( D_{cum} \) - Damage Cumulative, \( TAC_{DESIGN} \) - Design life in TACS

TACU will have equivalent damage as a TAC as defined by the deterministic design for a location / mode (LCF / FCGR).
Definition of TACU
Fatigue Crack Growth (FCGR)

In Crack Growth, unlike LCF, a prior flights starting flaw size is required to calculation the current flights crack growth.
Focus On Development Of Oxidation/Erosion Algorithms

OXIDATION/EROSION
• Dominant distress mode for HPT airfoils
• Empirical correlations based on burner rig testing

CREEP
• Empirically derived

TMF
• Not a driver in F100 fleets
Recorded data shows potential to streamline the troubleshooting procedure, save cost and time, avoid engine events.

- Temperature Sensor Fault
- Compression System Bleed Anomaly
- Anti-Ice System Anomaly
- Variable Compressor Vane Anomaly

1) Fault detected
2) Performance trends analyzed
3) Symptoms analyzed, pattern matched

![Graphs showing trend analysis]

4) Isolate source
5) Direct Maintenance

Continuous Improvement in Anomaly Detection and Fault Isolation
Summary

The F100 Engine Life Management Plan (ELMP) activities continue to extend the engine design life (bathtub curve)

P&W continues to evolve lifing strategies to extend useful part lives

EHM scheduled for field demonstration leading to incorporation of an advanced PHM system
F100
Powering Freedom