RCM Applied to the CH-47 Chinook Heavy Lift Helicopter

For the Warfighter – With the Warfighter

Presentation Agenda

- Reliability Centered Maintenance (RCM) overview
- CH-47 Chinook Introduction
- Application of RCM Principles to the CH-47D:
  - Maintenance Program
  - Special Tools and Test Equipment (STTE)
  - Unique Identification (UID)
  - Condition Based Maintenance Plus (CBM+)

What is Reliability Centered Maintenance?

RCM

A zero-based, structured process used to identify the failure management strategies required to ensure an asset meets its mission requirements in its operational environment in the *most safe* and *cost effective* manner.

Real honest to goodness output that meets the needs of the organization

RCM

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Zero-Based

RCM

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Failure Management Strategies

RCM

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Operational Environment

The RCM Process

RCM

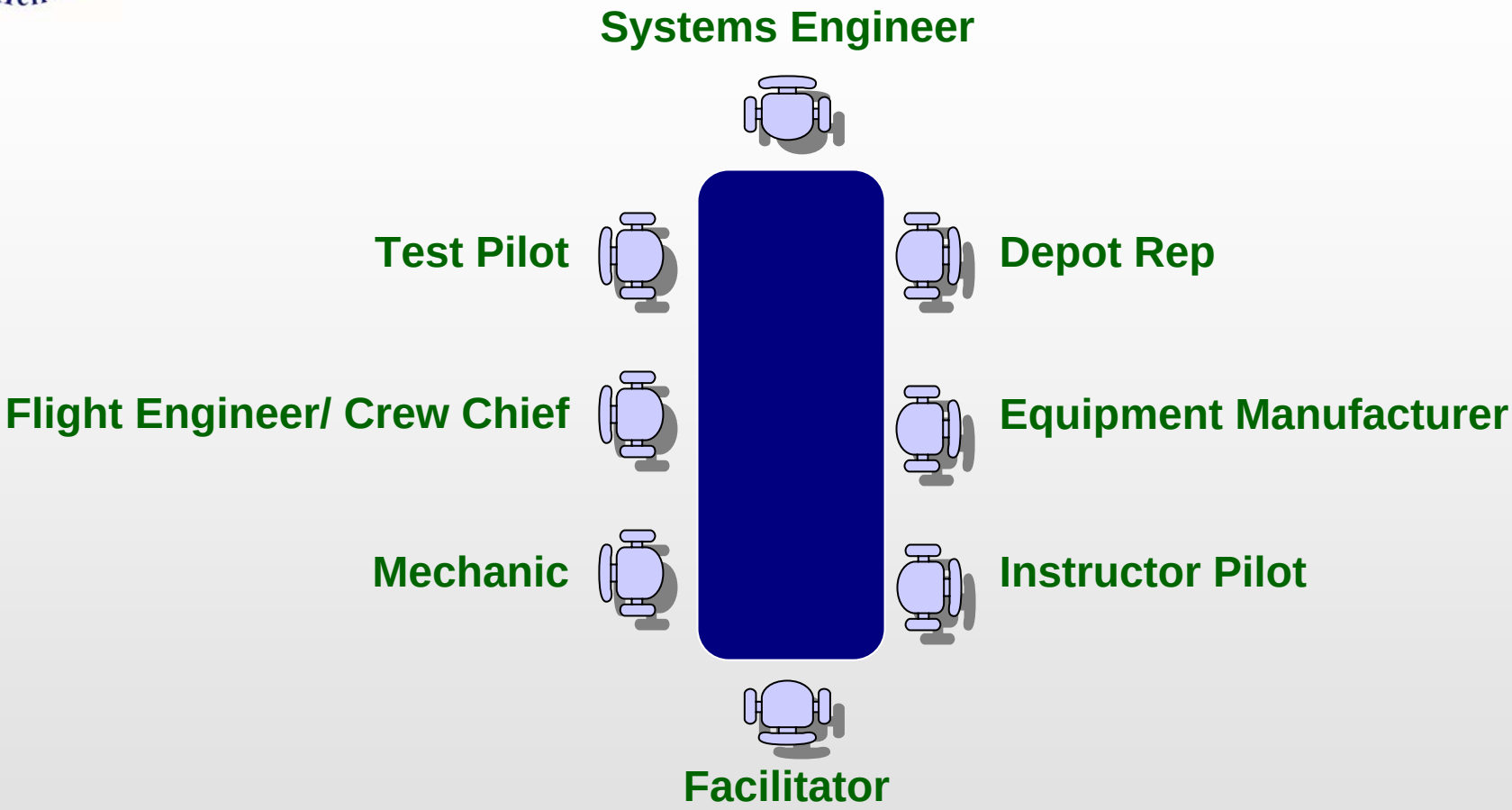
1. Functions
2. Functional Failures
3. Failure Modes
4. Failure Effects
5. Failure Consequences
6. Proactive Maintenance and Intervals
7. Default Strategies

Application of Reliability Centered Maintenance to the CH-47D

Application of RCM to the CH-47

- **To reverse the trend of increasing Operation and Support costs**
- **Chief focus of maintenance had been on the prevention of failures**
  - Common assumption that, in most cases, equipment “wears out” and inevitably becomes less reliable with age
- **With RCM analysis, focus began to shift from preventing failures to managing the consequences of failures as they affect the aircraft as a whole.**

RCM Working Group



In the absence of specific data on failure rates and characteristics, intervals are largely determined based on service experience.

Often the most truthful source of data

Maintenance Transformation

BEFORE RCM	AFTER RCM
200 Hour Phase maintenance	400 Hour Cycle Service Plan 200 Hour Servicing/Inspection

- Number of Phase Maintenance tasks reduced by **73%**
- Phase Maintenance requires **50% fewer** man hours to complete
  - 200 Phase: ~67 days downtime
  - 400 hour Cycle Service: ~19 days downtime
  - 200 hour Cycle Service: ~10 days downtime
- Produced an *increase in readiness*!

Application of RCM to the CH-47

Maintenance
Pre-Flight
Daily
Corrosion Inspection
Special Inspections

- Eliminated unnecessary tasks
  - Eliminated Duplication of Effort
    - 200 Hour Phase Maintenance Program: Independent Activities
    - 400 Hour Cycle Service: Supportive Activities
  - Technical Justification
    - Pitot Static System Check
  - In response to single events
    - Retorque droop stop bolts (due to bad lot of hydrogen embrittlement)
  - Extended intervals
    - Wheel bearing repacking (Extended from 200 to 400 hours)
  - Move to On-Condition Maintenance
    - Brake pad replacement

200 Flight Hour Phase Maintenance to 400 Flight Hour Cycle Service Plan

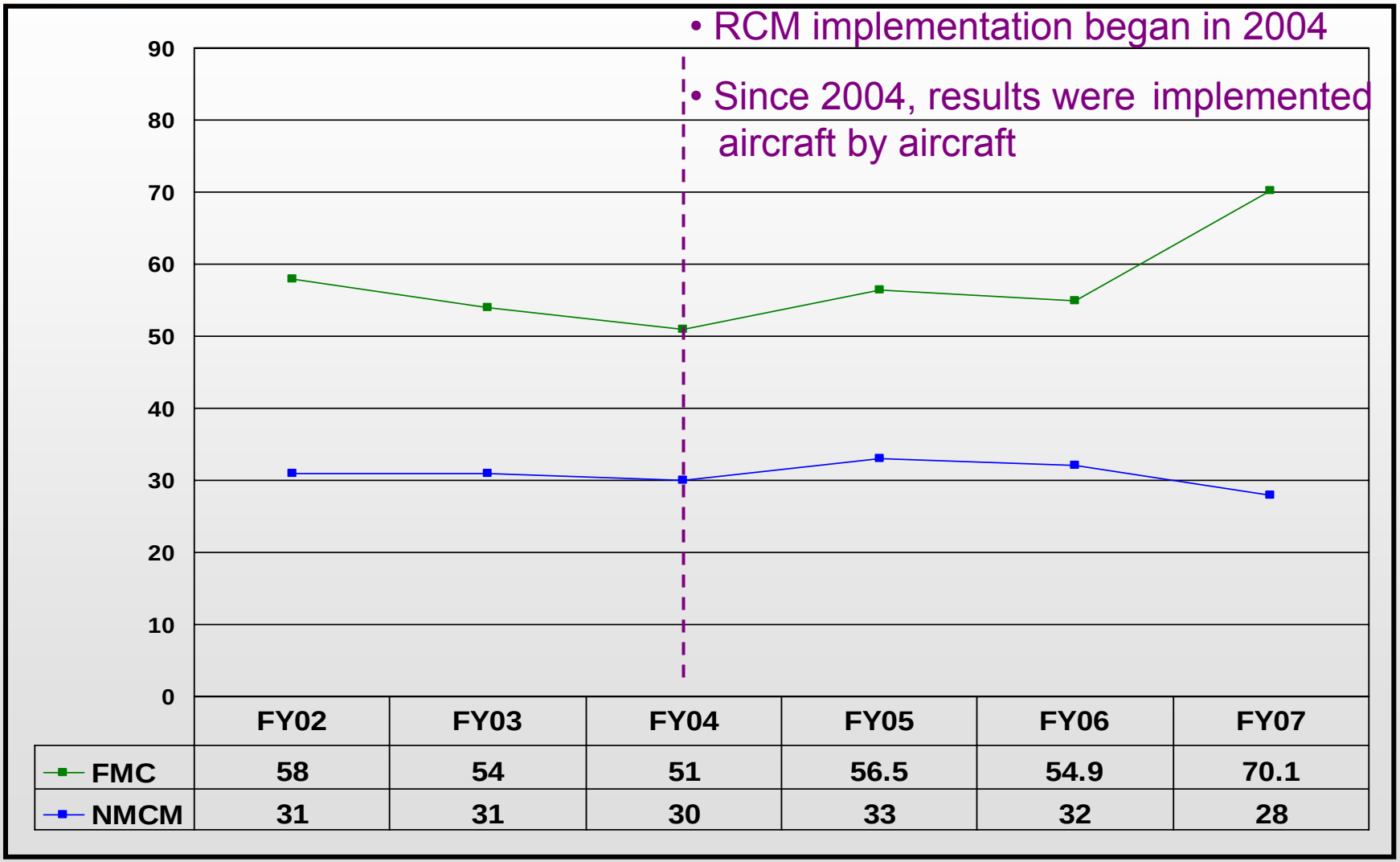
	# of Tasks ***Before*** RCM
200 Flight Hour Phase	428

	# of Tasks ***After*** RCM
200 Flight Hour Servicing and Inspection	68
400 Flight Hour Cycle Service Plan	48
Total	**116**

Application of RCM to the CH-47

- RCM implementation began in 2004.
  - In August 2007, the CH-47 achieved its readiness goal of 75% Fully Mission Capable (FMC) for the first time!

CHINOOK (CH47D) TOTAL ARMY



	FY02	FY03	FY04	FY05	FY06	FY07
FMC	58	54	51	56.5	54.9	70.1
NMCM	31	31	30	33	32	28

DA GOAL 75% FMC

FY02 – FY07

SOURCE OF DATA: RIDB

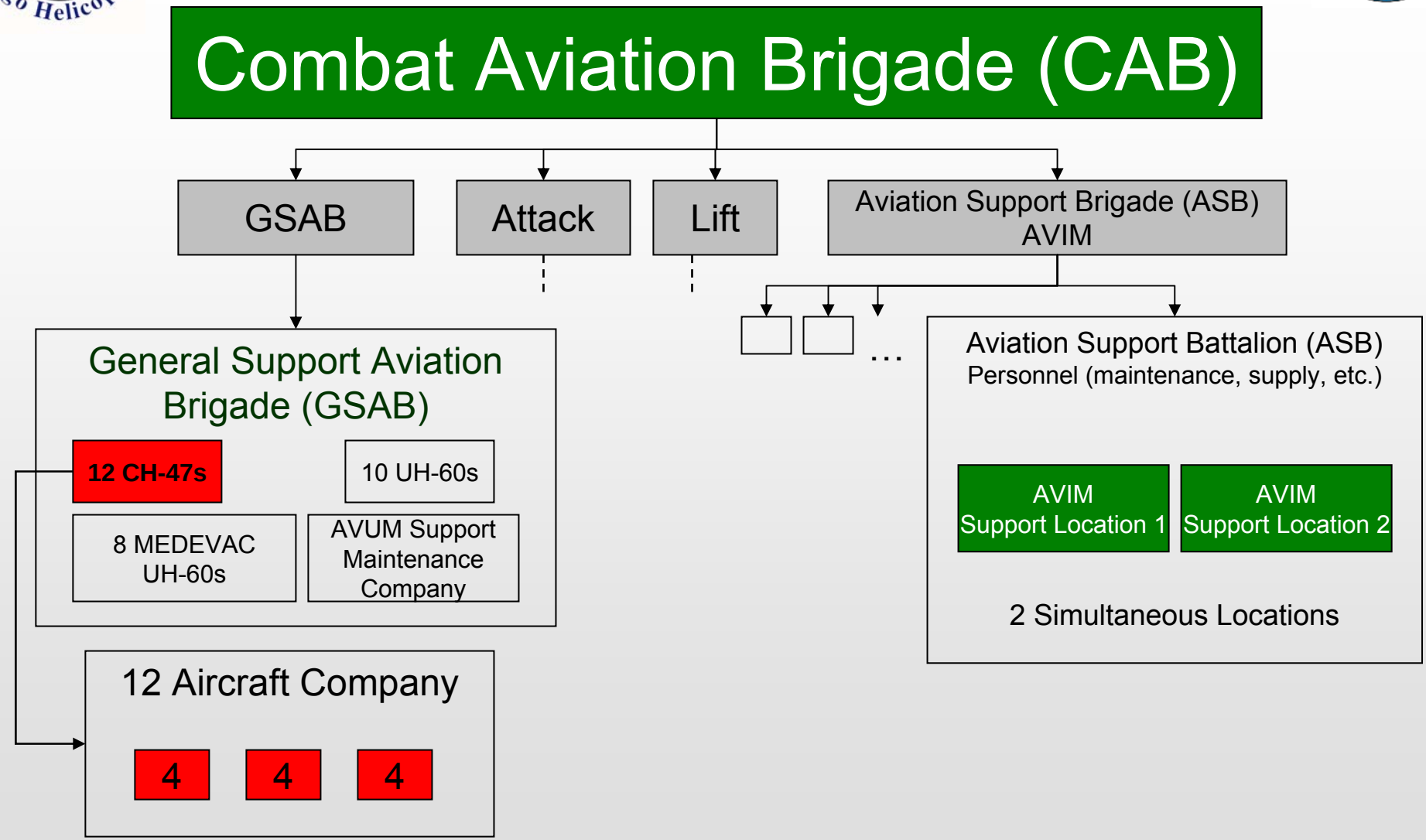
Power and Value of RCM go far beyond equipment maintenance

RCM Principles Applied to Special Tools and Test Equipment (STTE)

STTE

- Analysis initiated to determine suitable Basis of Issue (BOI) to support Army Transformation
- BOI for STTE that was being was used estimated by Boeing ~1960s
  - Assumption that units stayed together
  - 1 of every applicable Tool was allotted *per 25 Helicopters*
- Needed to determine suitable BOI so the Field could operate under the new doctrine of Split Based Ops

Army Transformation Affect on STTE



STTE

- How do RCM Principles apply to STTE (tools)?
  - Allows a clear understanding of the Operating Context
  - Reviewed all maintenance tasks and analyzed tools
    - What tools were currently recommended versus what was needed
  - Functions, Functional Failures, Failure Modes and Failure Effects, and Failure Consequences
- Determined new BOI to support Army Transformation

RCM Principles Applied to STTE

"The Big List" *Before*	CH-47 STTE *After*
• 422 STTE line items	• 224 STTE line items

- Purged obsolete tools
  - All -712 engine tools purged (~120)
- Many items that were identified as STTE but were common tools
  - Dial Indicator
- Purged unnecessary tools
  - STVA (Self Tuning Vibration Absorber) Trailer Adapter

RCM Principles Applied to STTE

- Increased BOI in most cases
  - *Example: Actuator Safety Blocks and Rotor Head Lockout Pins from 1 set per 25 aircraft to 1 set per aircraft*
  - Field will be supplied with what they need
- Established Accountability
  - In process of putting all STTE on the MTOE (Modified Table of Organization and Equipment)
    - Means it must be inventoried and accounted for
    - Most STTE before this process were not required to be inventoried.

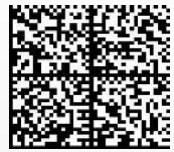
RCM Principles Applied to STTE

- Acquisition of additional STTE began 2 years ago
- First two units equipped in May and June 2007
- Analysis *results justified* an increase in STTE funding
  - As a results, the PM awarded $6M additional funding *per year* for the next 10 years
    - Funds 2 Combat Aviation Brigades
- The real success is that the guy in the Field has the tools he needs!!

Unique Identification

DoD UID Mandate: Parts Marking

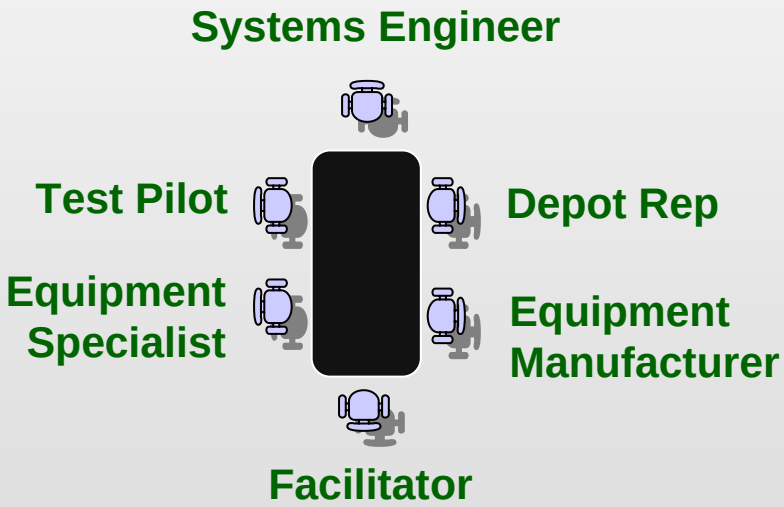
- July 2003, Office of the Under Secretary of Defense set forth policy to uniquely identify all legacy and new asset parts with a 2-D barcode if a part meets 1 or more of 5 criteria



- Raises important concerns: *how to mark, where to mark, and how to safely mark*
- CH-47: Approximately 1,000 components required to be marked
- Independent study performed on 300 components

DoD UID Mandate: Parts Marking

- Realized that Parts Marking Decisions in such a critical environment require analysis
- Parts marking solutions identified using RCM Principles
  - Systematic review of all Failure Modes, Failure Effects, and Consequences of each marking opportunity



- Facilitated Group Approach
  - Ensures the right people who are sensitive to the hazards of the equipment in its operating environment are the decision makers

- Incorporates safety and operating context into the core of the parts marking decision making.

DoD UID Mandate: Parts Marking

Results:

- ~280 items approved for label marking
- 100 items under review for marking approval
- 167 Direct Part Marking Candidates
- Over 13,000 items marked in the DoD UID registry

CBM+

CBM and RCM

- CBM: Powerful Failure Management Strategy that allows
  - Impending failure to be identified *before the failure occurs* so that proactive action can be taken in enough time to *manage the consequences of failure.*
    - Ex. Measuring brake pads, eddy current, continuous monitoring, etc.
- In other words, failure is handled on the equipment custodian's terms – *not the equipment's terms*
- CBM and RCM are often mistaken as two different processes. *They are not!*

DoDI 4151.22

- 2 December 2007, Mr. John Young, the Under Secretary of Defense for Acquisition, Technology, and Logistics signed DoDI 4151.22, *Condition Based Maintenance Plus (CBM+) for Materiel Maintenance*
  - Establishes policy for the application of Reliability Centered Maintenance (RCM) and Condition Based Maintenance Plus (CBM+)
  - CBM+ is intended …"to expand the application of sensors on weapons systems enhancing maintenance efficiency and effectiveness…"
  - CBM must be performed correctly in order to achieve the DoD's goals.

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Consideration of Condition Based Maintenance

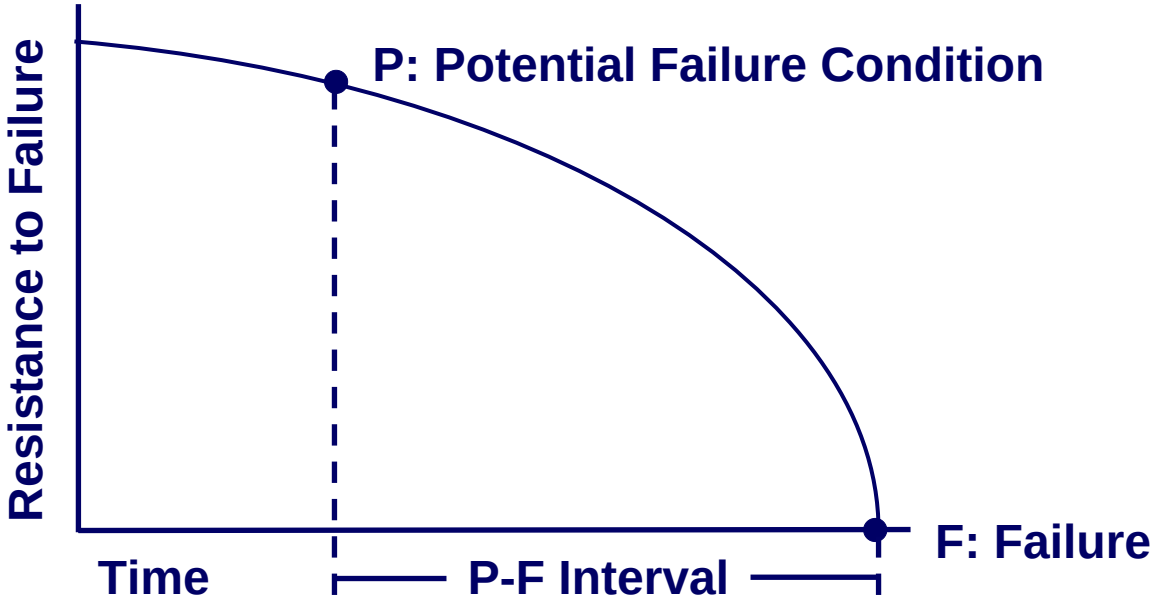
Start by Identifying Failure Modes to be managed

- Physical assets are managed *at the Failure Mode level*
  - Failure Mode: What specifically causes a Functional Failure
- CH-47 example
  - Failure Mode: *Drive shaft hanger bearing wears due to normal use*

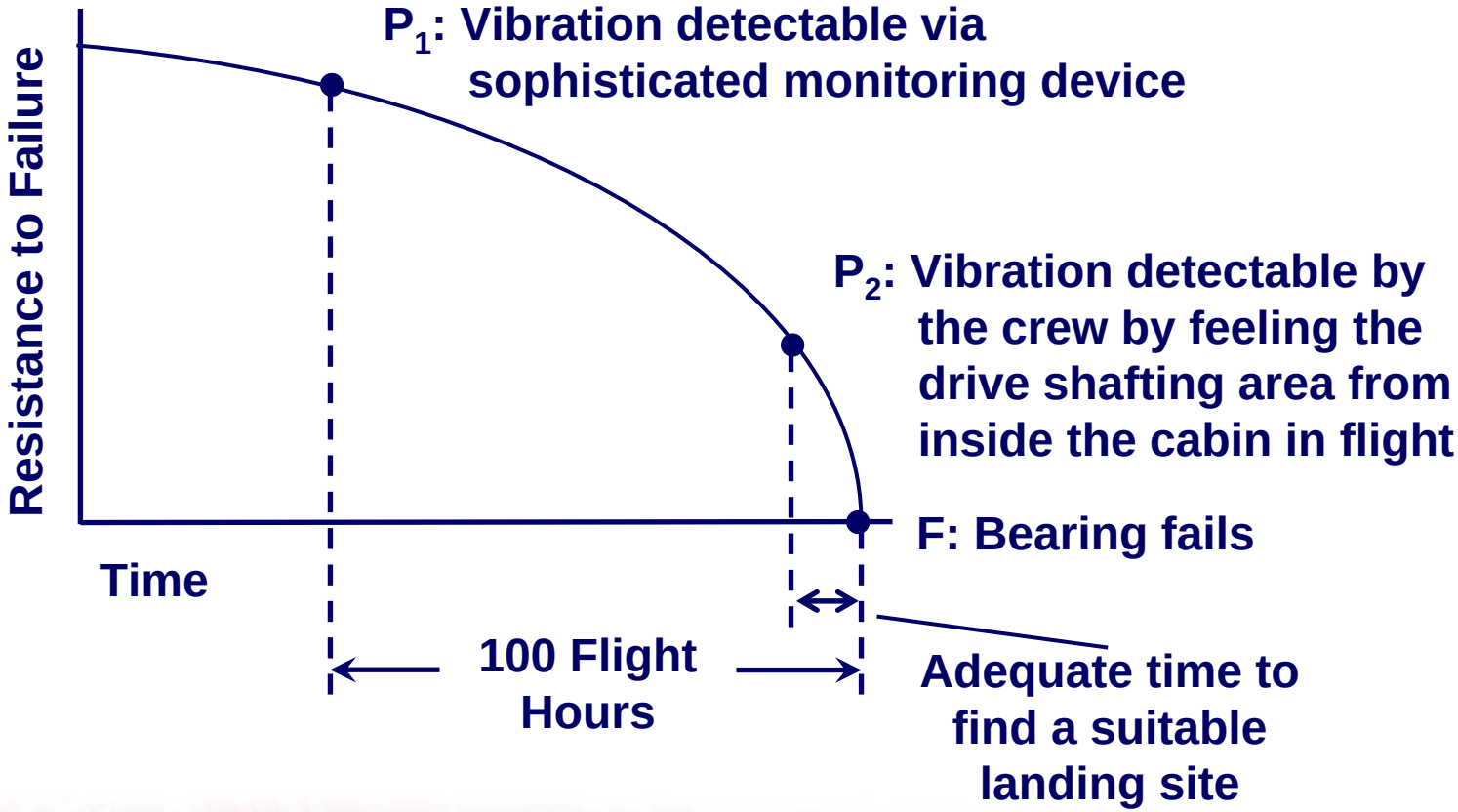
Detect Evidence of Impending Failure

- Nearly all Functional Failures give some sort of evidence that failure is imminent.
  - Referred to as a *Potential Failure Condition or "P"*
- Failure Mode: *Drive shaft hanger bearing wears due to normal use*
  - P_1: Vibration that is detectable via a continuous monitoring device applied directly to the equipment.
  - P_2: Vibration that is detectable by the crew by feeling the drive shafting area from inside the cabin in flight.

P-F Curve

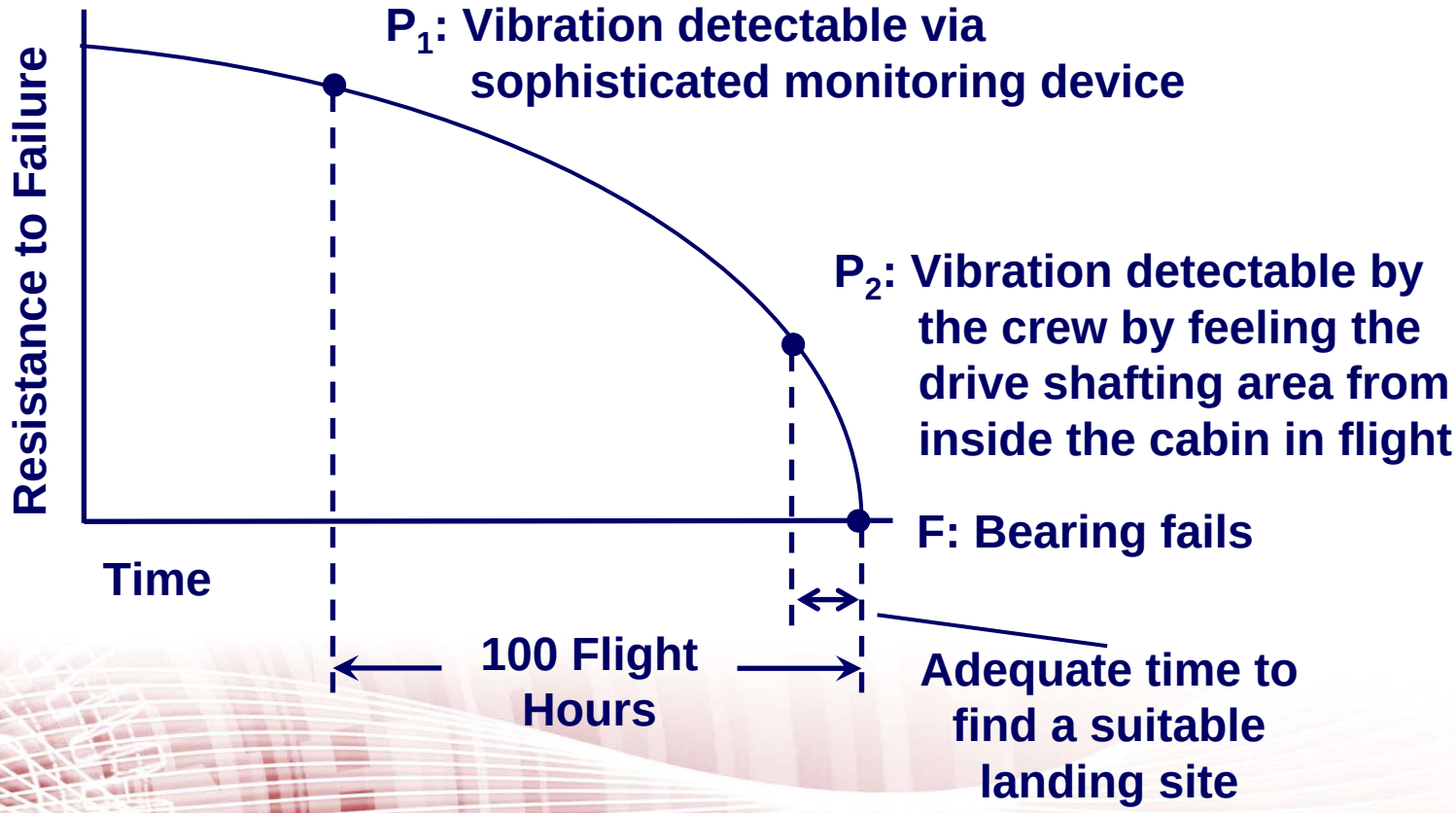

Resistance to Failure
P: Potential Failure Condition
F: Failure
Time
P-F Interval

Failure Mode: *Drive Shaft Hanger Bearing wears due to normal use*



Failure Mode: *Drive Shaft Hanger Bearing wears due to normal use*

- It would likely be practical to check the data at intervals less than 100 flight hours
- It would be equally practical to feel for vibration in flight every 30 minutes



CH-47 CBM+

- 49 specific CH-47 components selected for CBM+ analysis.
- Acknowledge that a FMEA is required to properly implement CBM+ strategy
- Components evaluated to identify Failure Modes that could be monitored.
  - Forward Transmission: 13 Failure Modes such as
    - Stationary ring gear wears due to normal use.
    - FWD transmission 1st stage planetary carrier splines wear due to normal use.
    - FWD transmission spiral bevel pinion gear wears due to normal use.
- Each Failure Mode prioritized for CBM+ Implementation based upon
  - Failure consequences
  - Frequency of failure
  - Effort required for implementation (ex. cost of equipment, training, etc.)
- 161 Failure Modes were identified as candidates for Condition Based Maintenance

RCM Implementation

What RCM Achieved

- *"RCM makes you take a real hard look at what you're doing."*
- RCM offers results to better support the Warfighter
  - Reduced Downtime and improved Readiness
  - Reduction of workload to the soldier
    - Relieves unnecessary burdens
  - Improved Health of Aircraft
  - RCM has the ability to change the maintenance philosophy

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