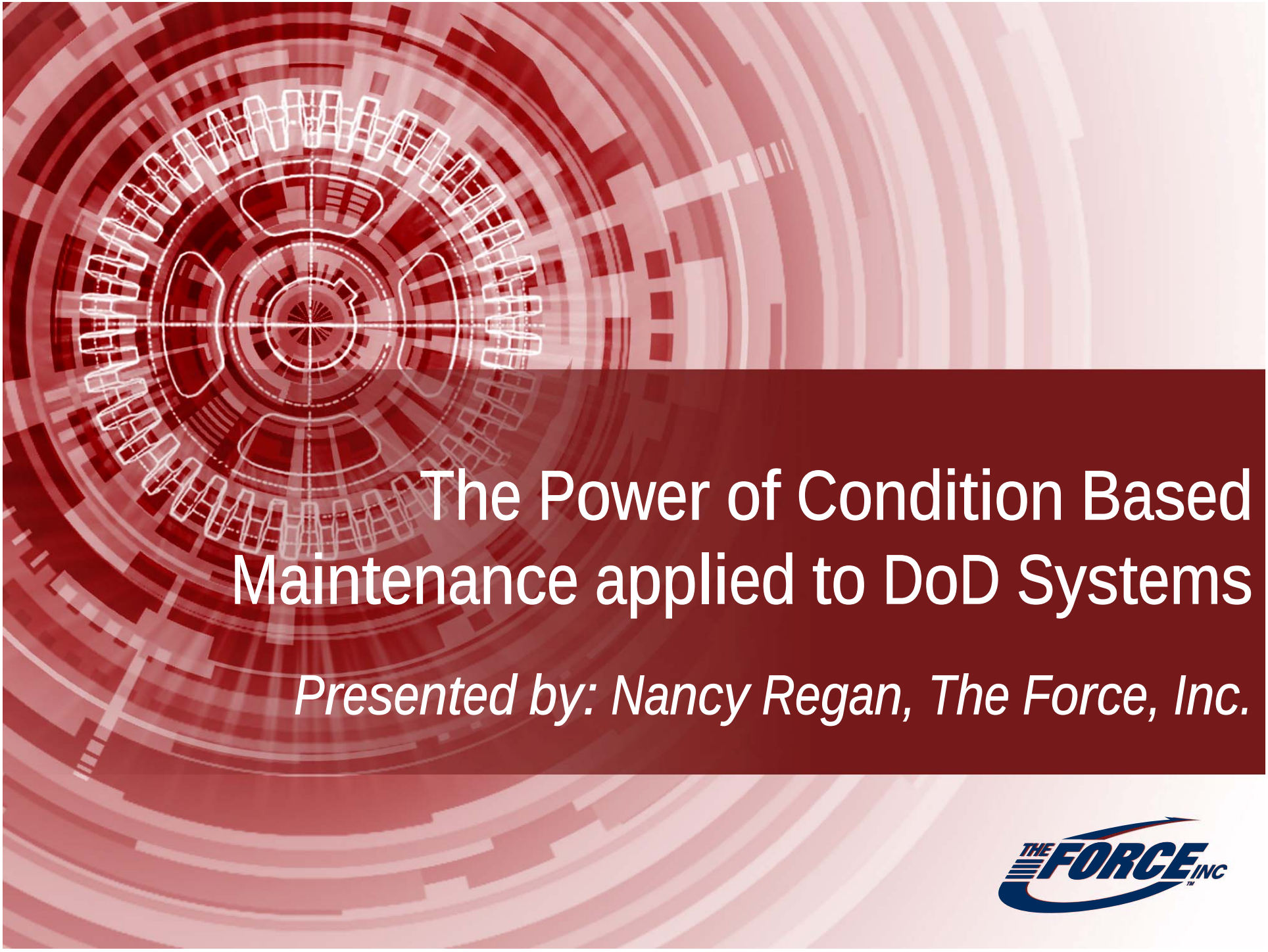

The Power of Condition Based Maintenance applied to DoD Systems

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Presentation Agenda

- What is Condition Based Maintenance (CBM)?
- Relationship Between RCM and CBM
- DoDI 4151.22, *Condition Based Maintenance Plus (CBM+) for Materiel Maintenance*
- CBM Implementation
- CH-47 CBM Effort
- Summary

What is Condition Based Maintenance (CBM)?

Condition Based Maintenance Task

- A proactive inspection performed at a defined interval *to detect a Potential Failure Condition*
  - Potential Failure Condition: an identifiable condition that indicates a failure is imminent
    - *Ex. vibration, fatigue cracks, heat, gauge readings, illumination of warning lights, etc.*
- Maintenance is performed *only on the evidence of need*.

What Techniques can be used to conduct CBM?

- Using relatively simple techniques such as monitoring gauges, measuring brake linings, or feeling for vibration (Human Senses)
- Employing more technically involved techniques such as thermography, frequency analysis, or eddy current
- Continuous monitoring with devices installed directly on the aircraft (ex. HUMS)

Condition Based Maintenance (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*
    - Heed a hydraulic system warning light that allows enough time to land safely
    - Detect a specific vibration level in enough time to order the bearing and schedule the maintenance so that operations are not adversely affected
    - Detect low oil level and replenish oil before the engine is damaged
- In other words, failure is handled on the equipment custodian's terms – *not the equipment's terms*

Relationship Between RCM and CBM

RCM

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

RCM

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Consideration of Condition Based Maintenance

CBM Implementation

CBM Implementation

- Often, CBM is mistaken as the alternative type of maintenance.
  - Actually, on average, only 40% of Failure Modes can be managed using CBM.
- Physical assets are managed at the Failure Mode level
  - To properly implement a CBM program, first start by identifying the Failure Modes to manage.
  - Oftentimes, the latter step in the process is accomplished first – *starting with the technology*

    → Results in data being captured that equipment custodians don't quite know what to do with

Steps in Implementing a CBM Program

How CBM analysis should be executed

1. Identify the Failure Modes to be managed.
2. Determine if a CBM task is technically the right thing to do and if it is the most effective task for that Failure Mode.
3. Procure monitoring equipment, if required.
4. Implement the CBM task.

Step 1:

Identify the Failure Modes to be managed.

Step 1: Identify the Failure Modes to be managed

- Failure Mode: What specifically causes a Functional Failure
  - Ex. wear, corrosion, fatigue, etc.

- Example associated with the drive train of a heavy lift helicopter
  - Failure Mode: *Drive shaft hanger bearing wears due to normal use*

Step 2:

Determine if a CBM task is technically the right thing to do
and
if it is the most effective task for that Failure Mode.

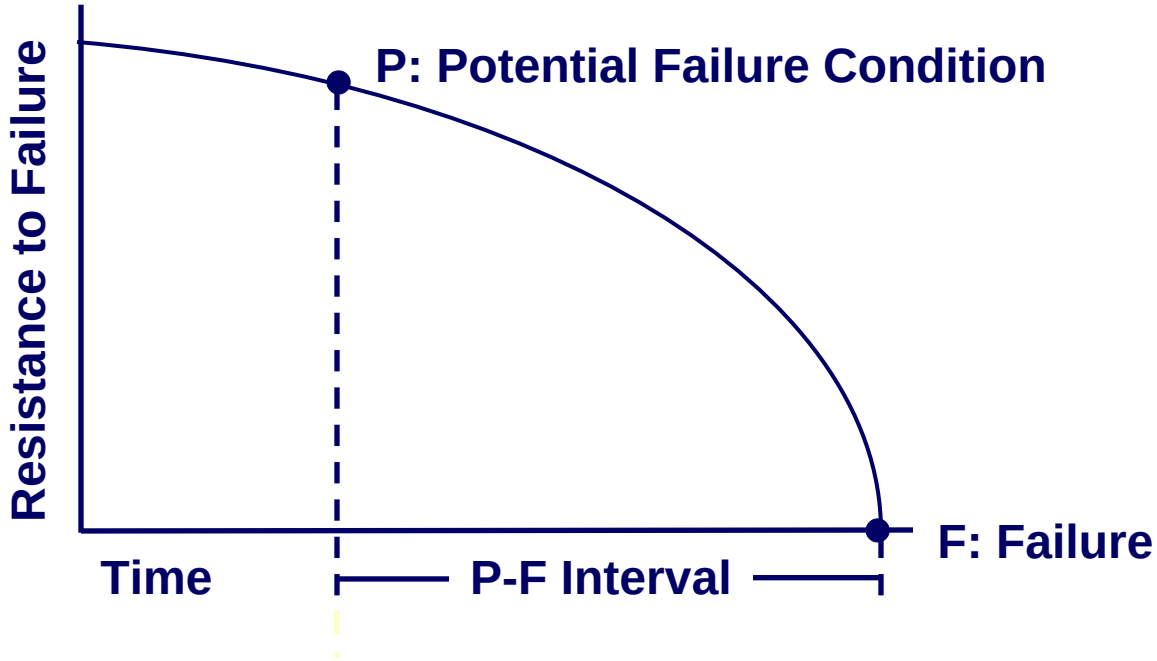
Determining CBM Tasks

- 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.

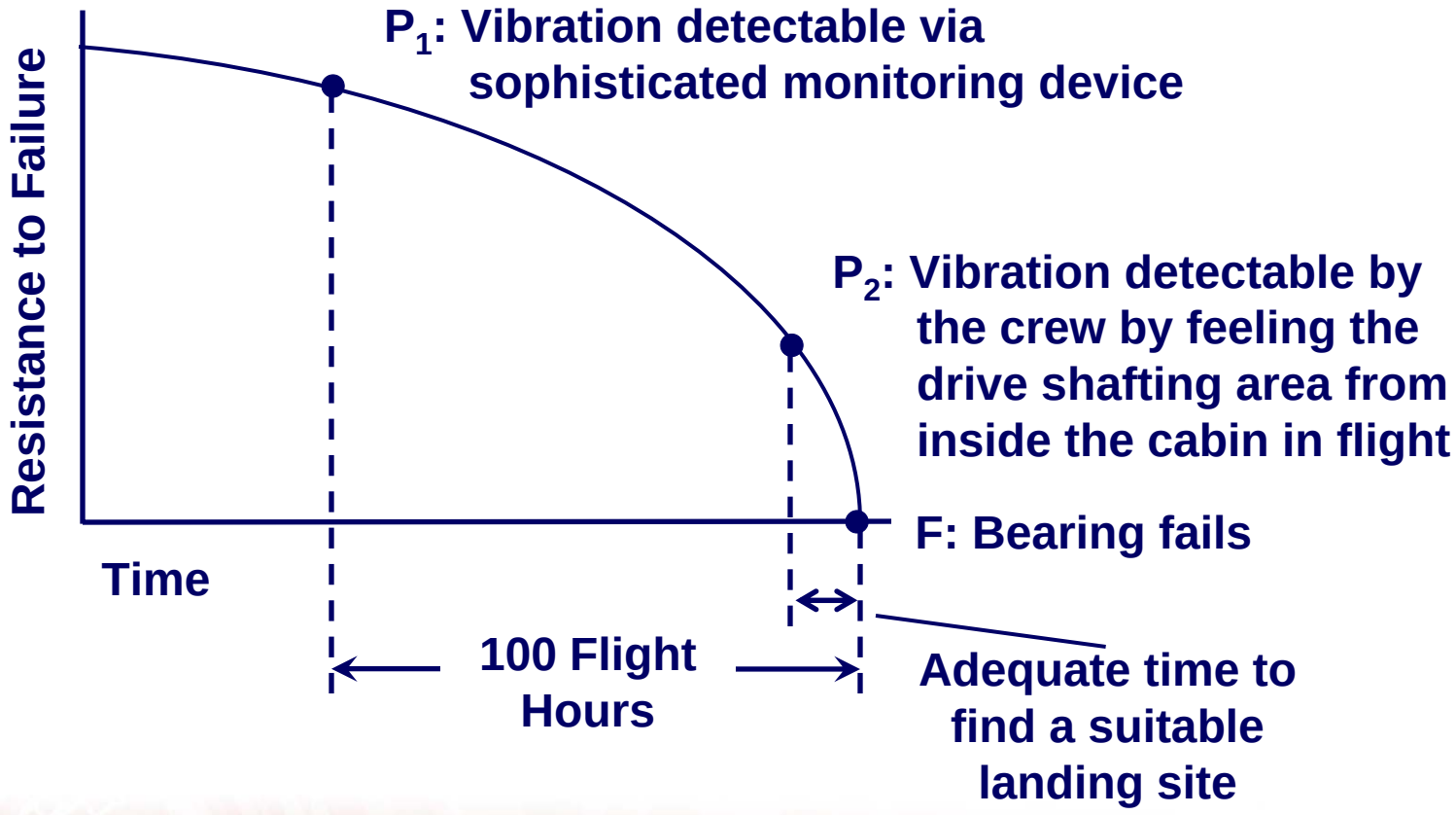
Determining CBM Task Intervals

- Biggest misconception of CBM is determining how often a CBM task should be performed
  - Often *incorrectly* believed that inspection intervals are based solely on the Mean Time Between Failure (MTBF) or the *criticality* of the Failure Mode
- How often a CBM task is performed is based on the P-F Interval

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*



Determining CBM Tasks

- Using sophisticated or continuous monitoring devices typically requires considerable investment
  - If the benefits are not realized, then why do it?
- Quantifying Potential Failure Conditions and P-F Intervals often requires extensive research and costs a lot to determine
  - Must determine if it is worth the investment
- There may be occasions where sophisticated monitoring devices *could* be used but it may be more cost effective to perform a visual inspection (or tactile inspection).

Step 3:

Procure monitoring equipment, if required.

Step 4:

Implement the CBM task.

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
  - Consequences of Failure
  - Frequency of failure
  - Effort required for implementation (ex. cost of equipment, training, etc.)
- 161 Failure Modes were identified as candidates for Condition Based Maintenance

Summary

- CBM can be an incredibly powerful failure management strategy for many Failure Modes.
  - Maintenance is performed only upon evidence of need
- Can be as simple as a visual inspection or monitoring a cockpit gauge or as sophisticated as a reviewing data generated by a continuous monitoring device
  - In either case, CBM allows a component to stay in service as long as possible thus realizing its maximum useful life.
- Many organizations purchase and install sophisticated monitoring devices as a first step in CBM implementation.
  - In order to achieve the maximum results from a CBM program, implementation should be performed systematically by identifying Failure Modes first.

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