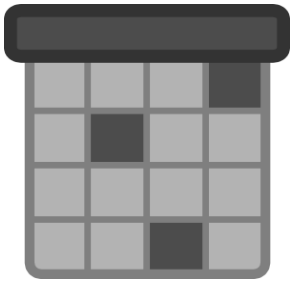
Continuously Pushing the Limits of Innovation, Technology & Conventional Thinking

RCM Theory and Concepts Workshop

Module 2- RCM Process Overview

Agenda

- **RCM Process Introduction**
- **Planning & Preparation**
- **RCM Analysis**
  - Equipment Kick-off Meeting
  - Initial Data gathering
  - Hardware Partitioning
  - FMECA
  - Failure Consequences
  - Task Evaluation
  - Task Selection
- **Review and Summary**

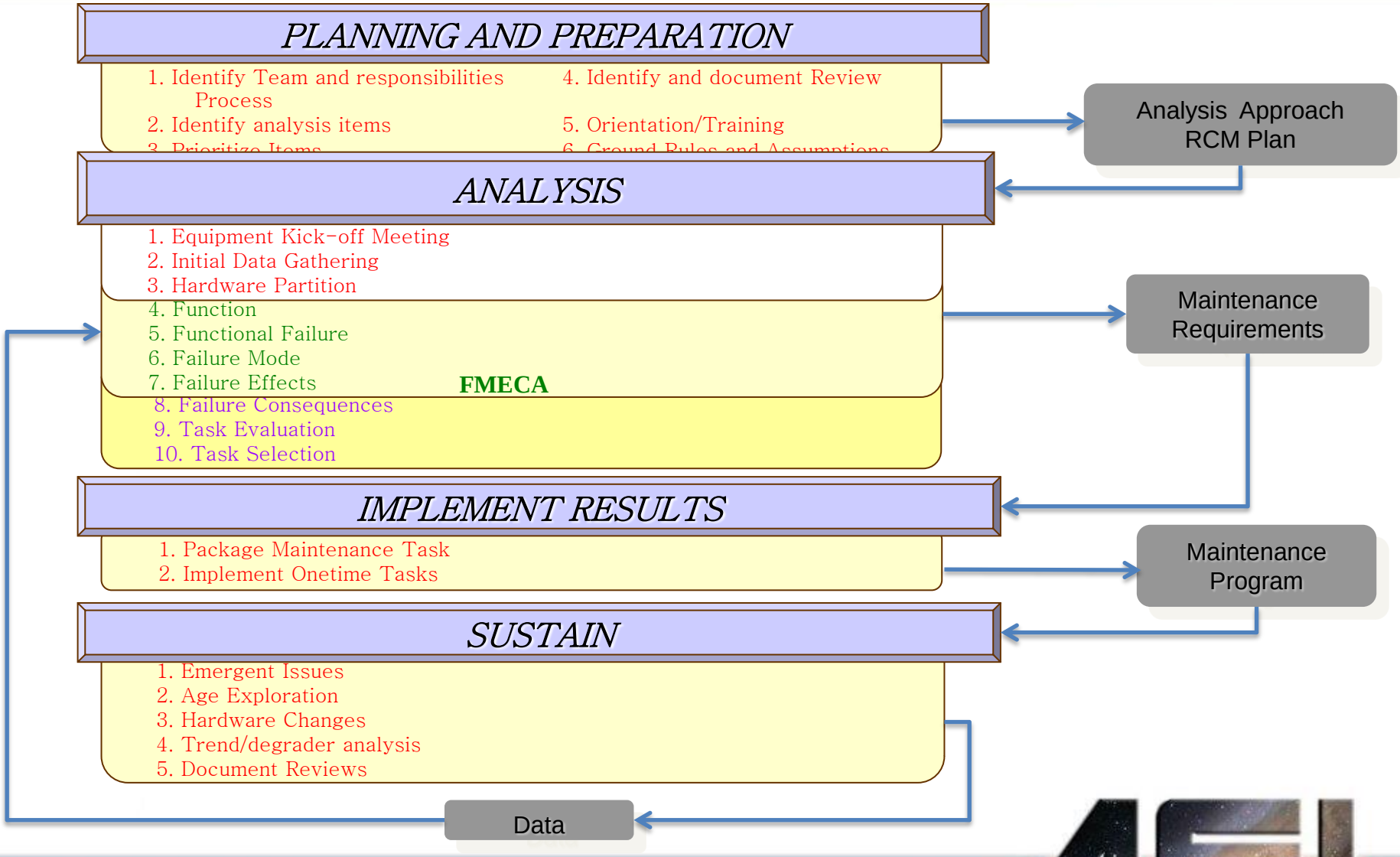


RCM Process Elements

There are 4 basic elements of an RCM Program:

1. Planning and Preparation
2. Initial RCM Analysis
3. Implementation of Results
4. Sustaining the Analysis

RCM Process Overview



RCM Process

Planning and Preparation

- Identifies and resolves issues that must be addressed prior to beginning an analysis.

- Answers the following:
  - Who
  - What
  - In what order
  - How
  - With what resources
  - When

RCM Process

Planning and Preparation

- Team and Responsibilities
- Analysis scope (what and what order)
- Review and approval process
- Training Requirements
- Ground Rules and Assumptions
- RCM Sustaining procedures
- Hazard Risk Assessment Matrix
- Funding requirements
- Plan of action and milestones (schedule)
- Contractor/consulting support requirements
- Deliverables

RCM Process

Develop Organization & Review process

- RCM Analysis Core Team
  - Analysts
  - Maintainers/Operators
  - Cognizant engineer
- Review Process
  - Initial review: Analyst and SME
  - Final review/approval
  - Implementation

RCM Process

Prioritize Equipment

Factors used in the equipment selection process:

- Equipment utilization
- Equipment uniqueness
- Critical program
- Workload queue
- Safety
- Environmental

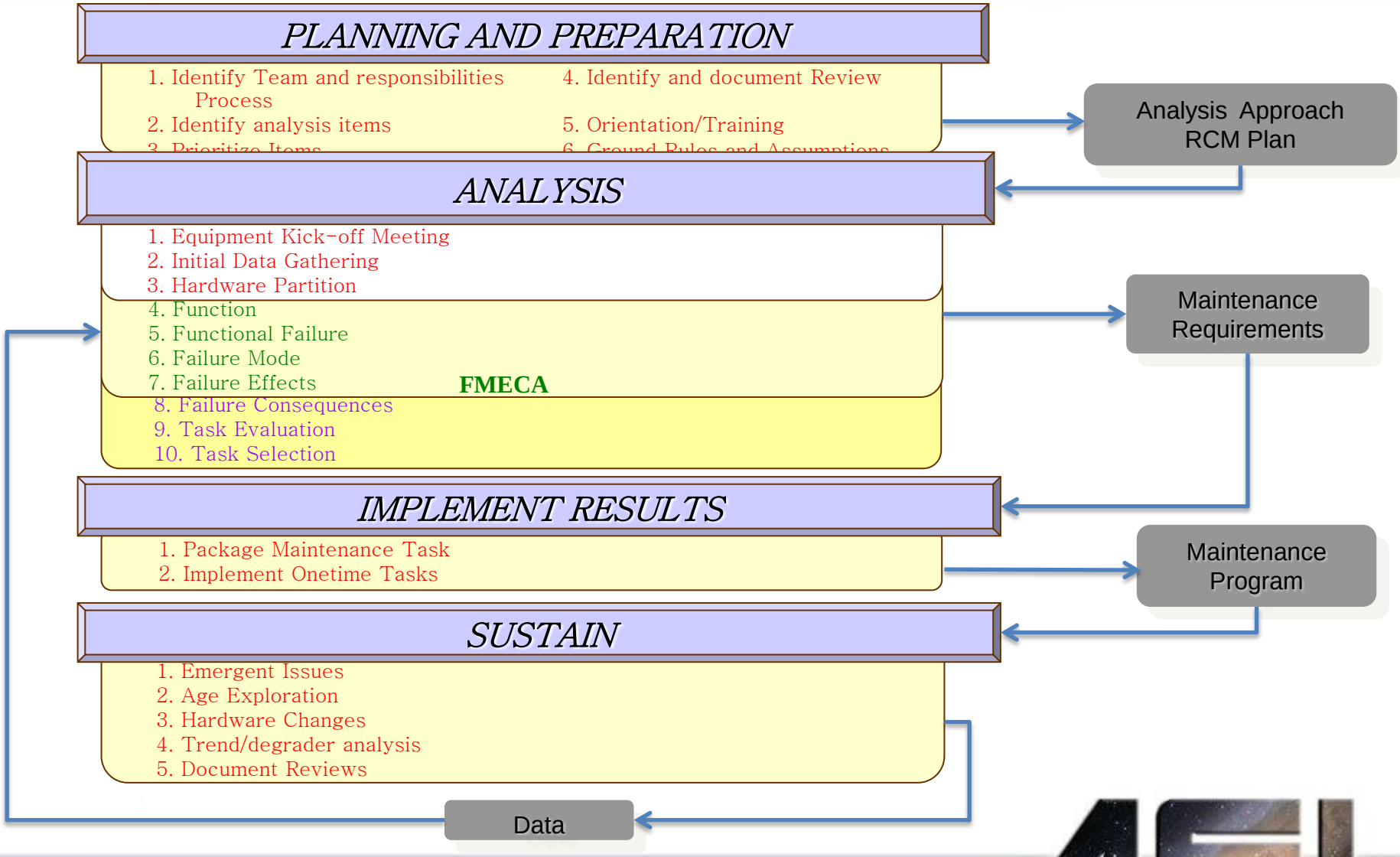
RCM Process

Ground Rules & Assumptions

- **A document with a compilation of information needed by the RCM team to perform the analysis**

- **Elements include:**
  - Guidelines for conducting the analysis
  - Standard operating procedures
  - Data sources
  - Failure Mode sources
  - Analytical methods
  - Cost-benefit analysis methods
  - Default Values

RCM Process Overview



RCM Analysis

Once an asset has been selected for analysis and the proper groundwork has been accomplished, the analysis phase begins.

Analysis Steps:

- Equipment Kick-off Meeting
- Initial Data gathering
- Hardware Partitioning
- FMECA
- Failure Consequences
- Task Evaluation
- Task Selection

RCM Process

Two “preliminary” steps in the Analysis Process:

- Equipment Kick-off meeting
  - Critical for “buy-in”
  - Should include key persons associated with item being analyzed
  - Necessary to facilitate transfer of information from SME’s
  - Can be formal or informal
  - Provides a detailed overview of the process: what is expected of participants and how it will benefit them (if not done in the initial “Orientation/Training” session)
- Data Gathering
  - Acquiring data such as pubs, logs, access to failure databases, etc. prior to beginning analytical work makes the analysis proceed faster and more efficiently
  - ASAP after orientation to keep up “momentum”

RCM Process

Data Gathering

Possible Data sources:

- Operator/Maintainer Knowledge
- Current PM task lists/documentation
- Operator/Maintenance Manuals
- Equipment Logs
- Maintenance History Records (CMMS such as OOMA or ULLS etc.)
- Work orders
- Vendor information
- Spares purchase data
- Available PdM equipment
- Maintenance/Operating SOPs

RCM Process

Hardware Partitioning

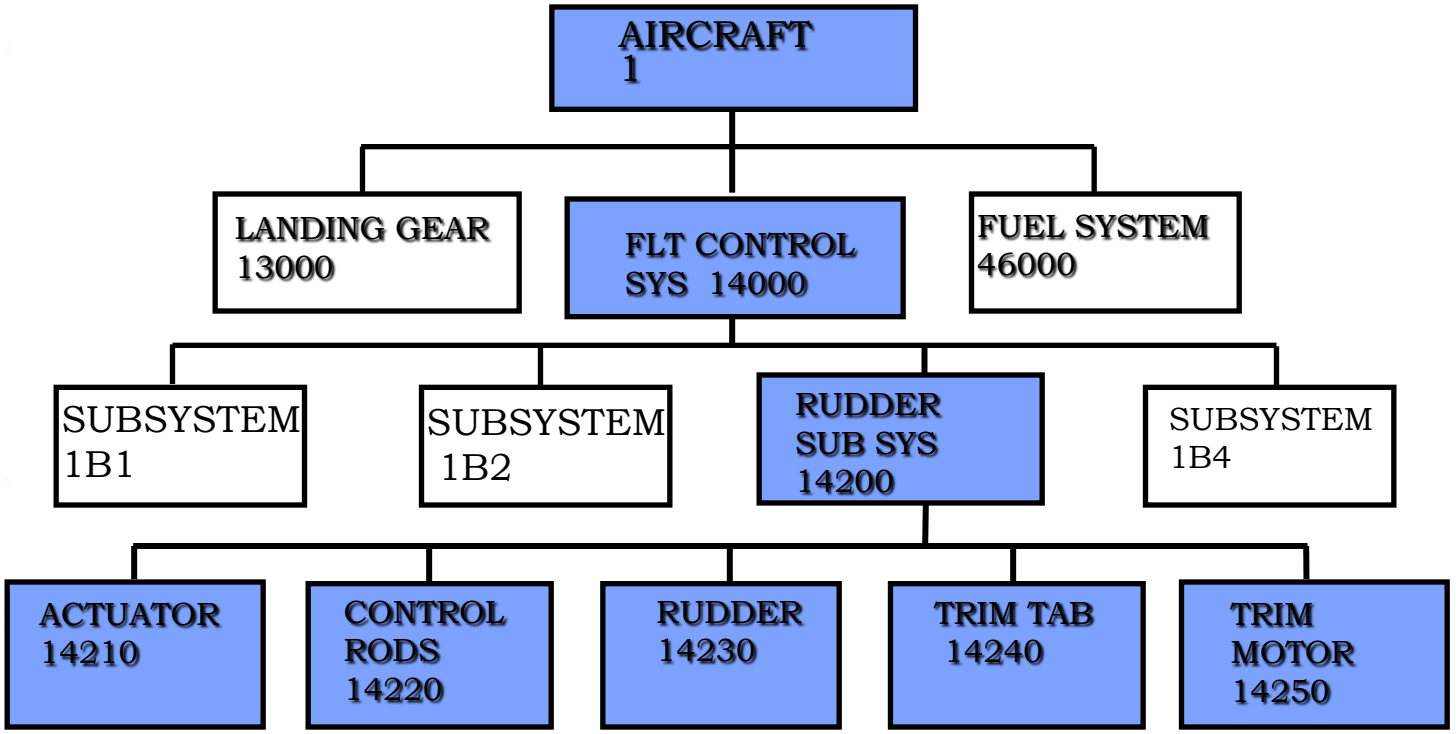
Setup the Hardware Partition

- Hardware Partition is a logical, hierarchical division of an asset into progressively lower levels to show relationships among systems, subsystems, components, etc.

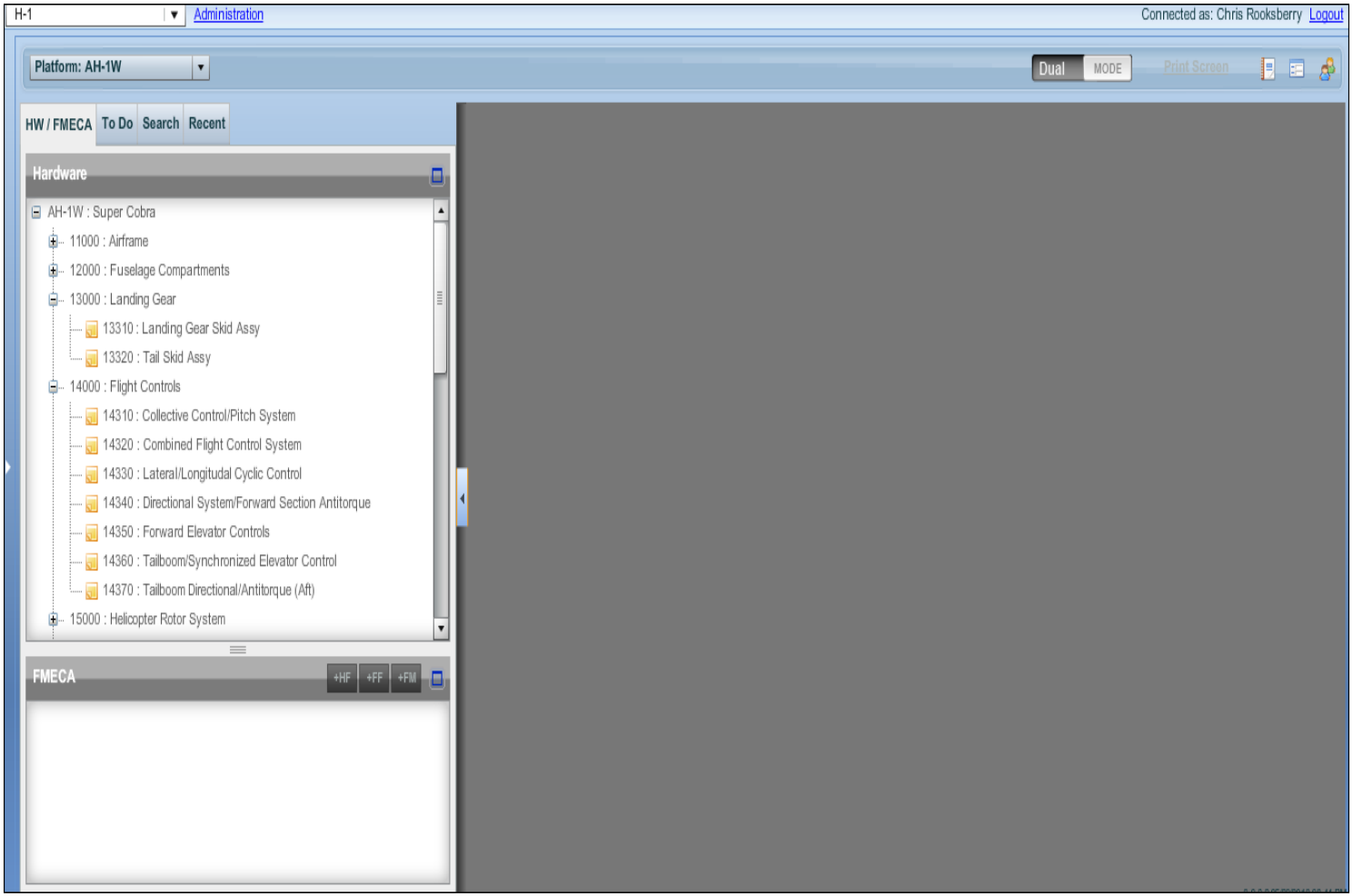
Also called EQUIPMENT HIERARCHY or HARDWARE BREAKDOWN

RCM Process

Initial RCM Analysis - Hardware partitioning



Hardware Partition Example



RCM Process

FMECA: Failure Mode, Effects, and Criticality Analysis

- Develop FMECA

  Process used to identify, document, and rank the importance of potential failure modes for a system or piece of equipment:

- Steps involve identifying…
  - Functions – what it does for you
  - Functional Failures – how it fails to do it
  - Failure Modes – why it fails to do it
  - Failure Effects – what happens
  - Severity of Failure – How bad it is
  - Failure Frequency – How often it happens

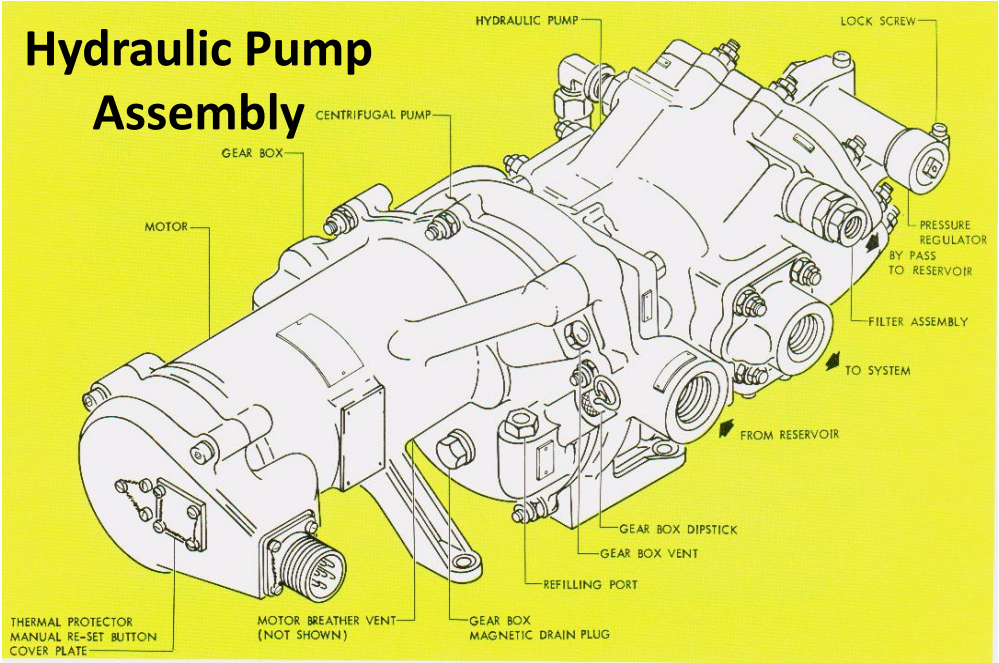
RCM Process

Functions/Functional Failures

- A function is what the user wants the item to do within a desired standard of performance.

- A functional failure is defined as the inability of an item to perform a specific function within the desired performance limits.

Functions



Provides hydraulic fluid at a pressure of 3000 psi +/- 200 psi

FUNCTION

What the user expects the asset or system to do within a required standard of performance.

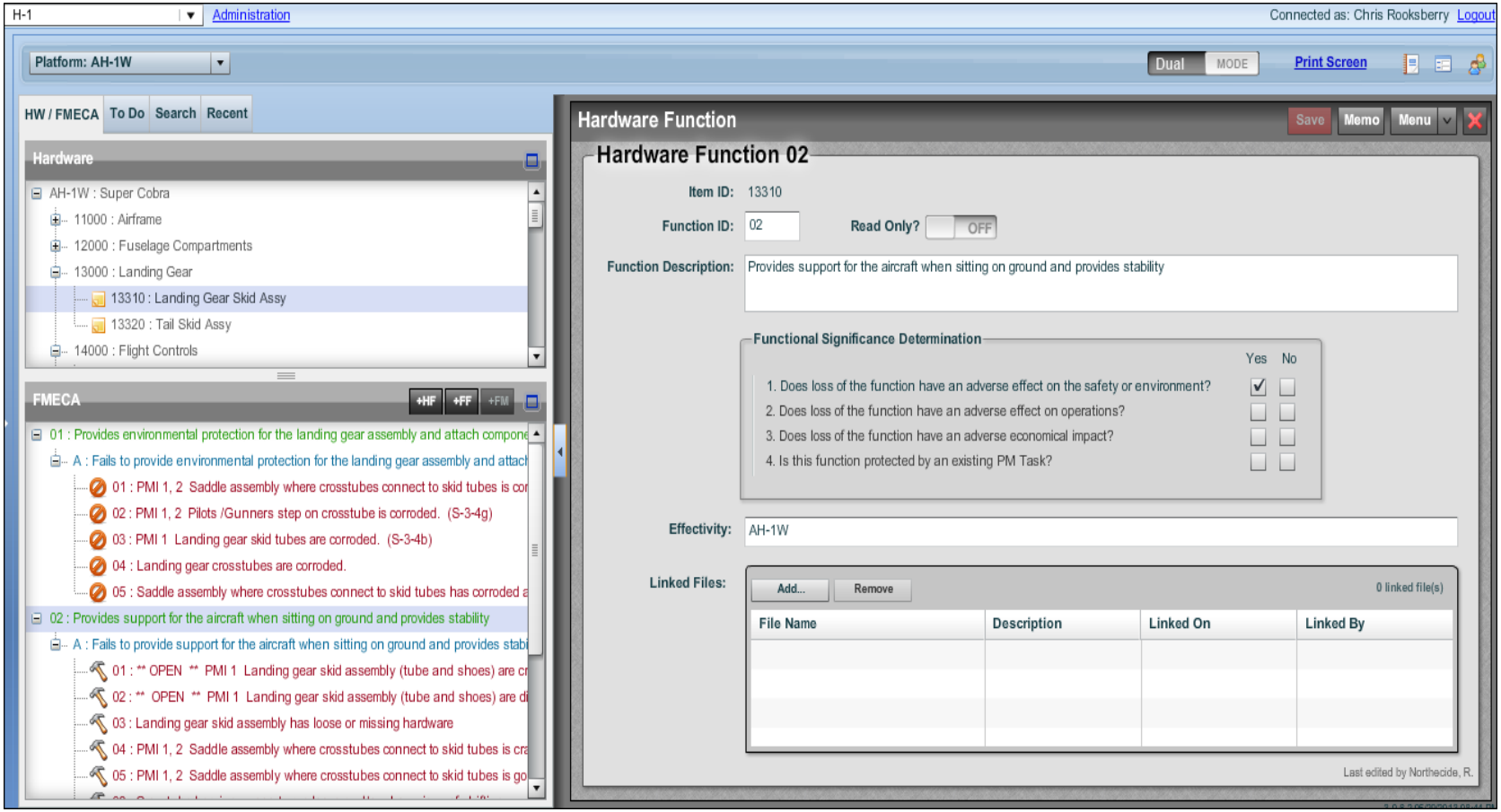
Functions

All equipment has primary and secondary functions

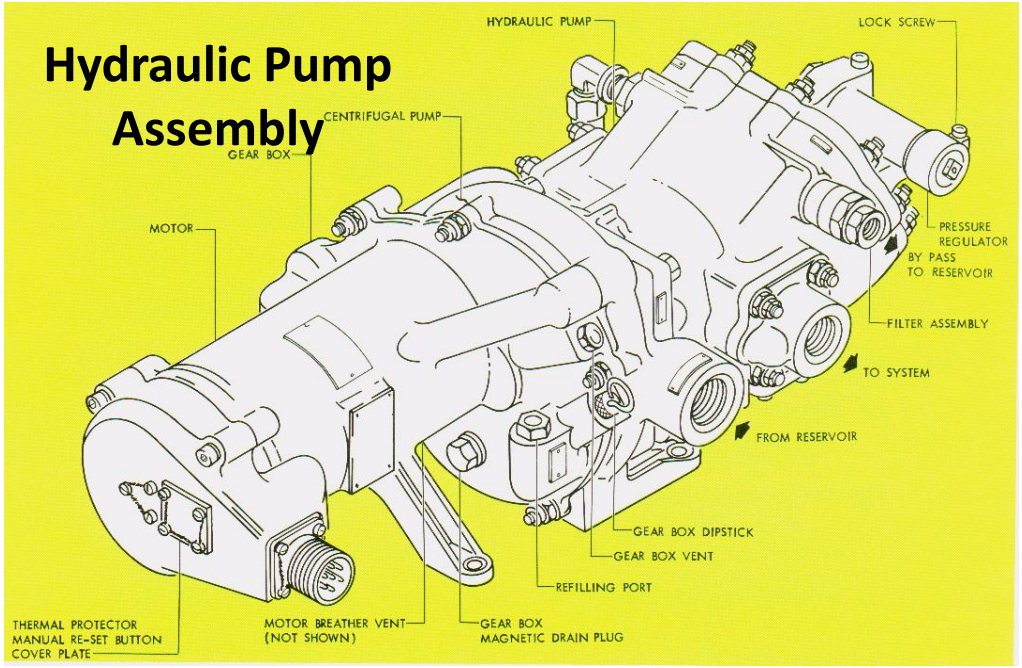
FMECA for RCM analysis should identify ALL primary AND secondary functions. Typical Secondary Functions:

- Control
- Warning or status indication
- Environmental protection
- Physical support or attachment
- Safety or protective functions
- Comfort and Aesthetics
- Fluid Containment

Function Example



Functional Failures



Fails to provide hydraulic fluid at a pressure of 3000 psi +/- 200 psi

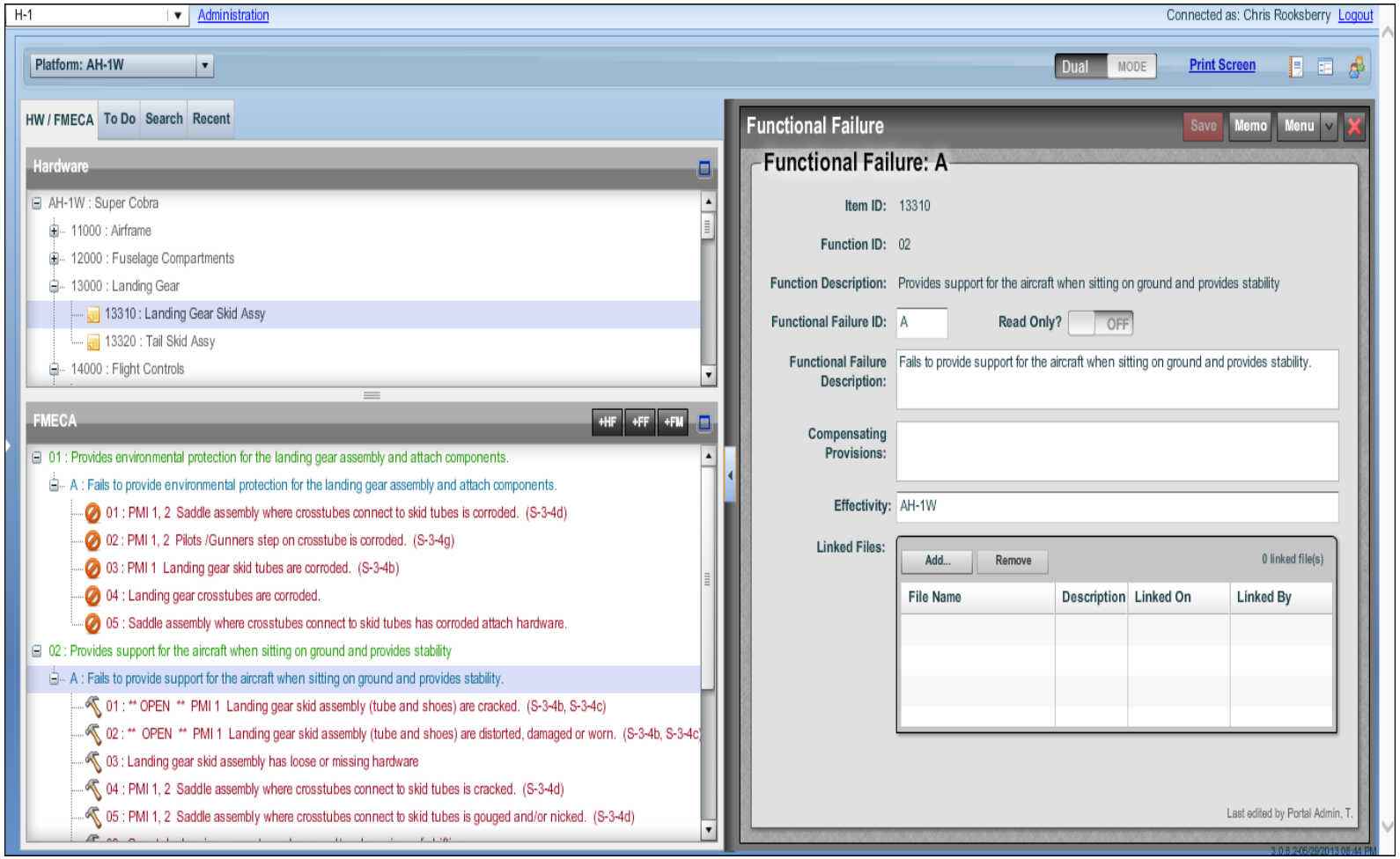
FUNCTIONAL FAILURE

The inability of an item to perform a specific function within specified limits.

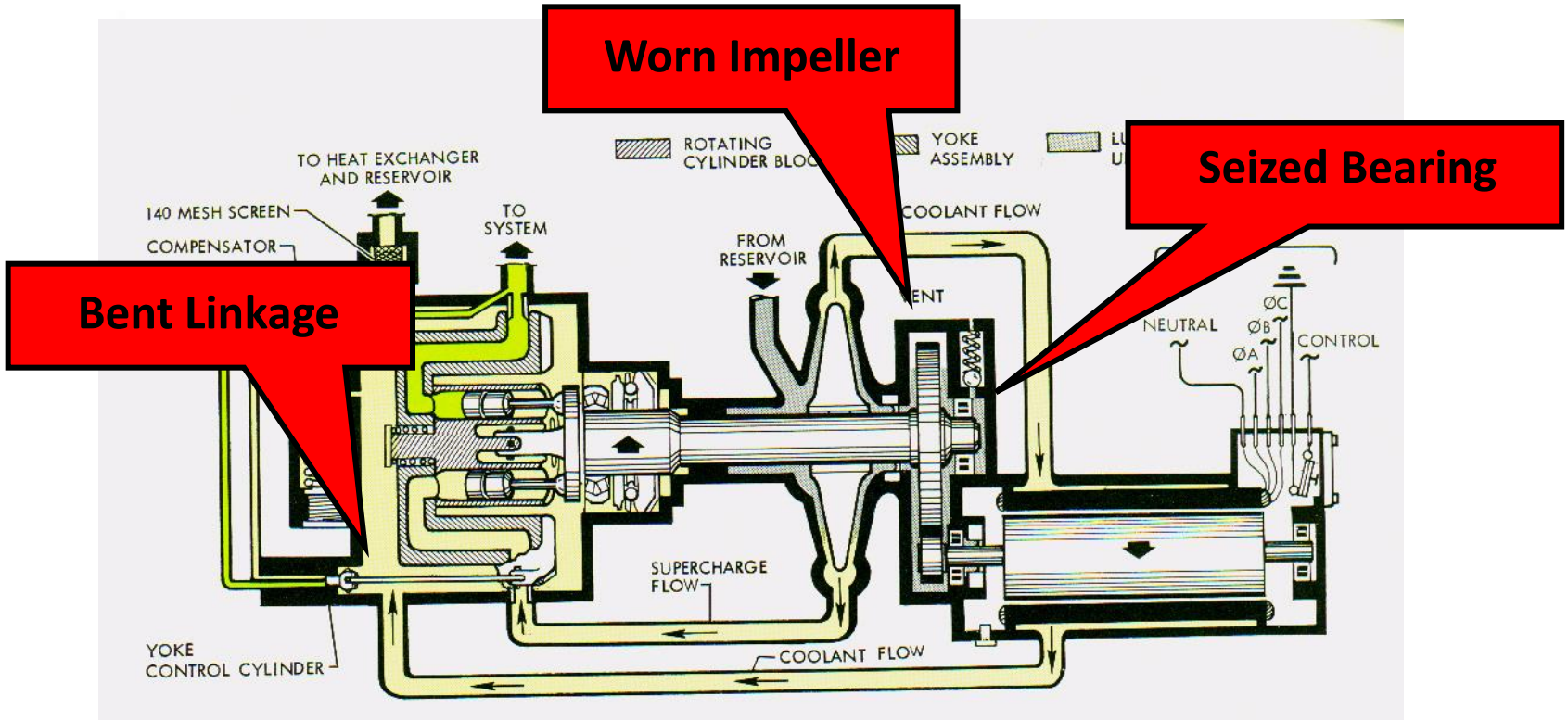
Functional Failures

- Note that functional failure may not be a complete loss of the function
- Separate functional failures should be listed where the effects of less than total loss of the function are different from total loss
- Ensure functional failure addresses the function as defined
- Common Errors:
  - Confusion with failure modes of hardware
  - Confusion with potential failures

Function Failure Example



Failure Modes



FAILURE MODE

A specific physical condition that causes a particular functional failure.

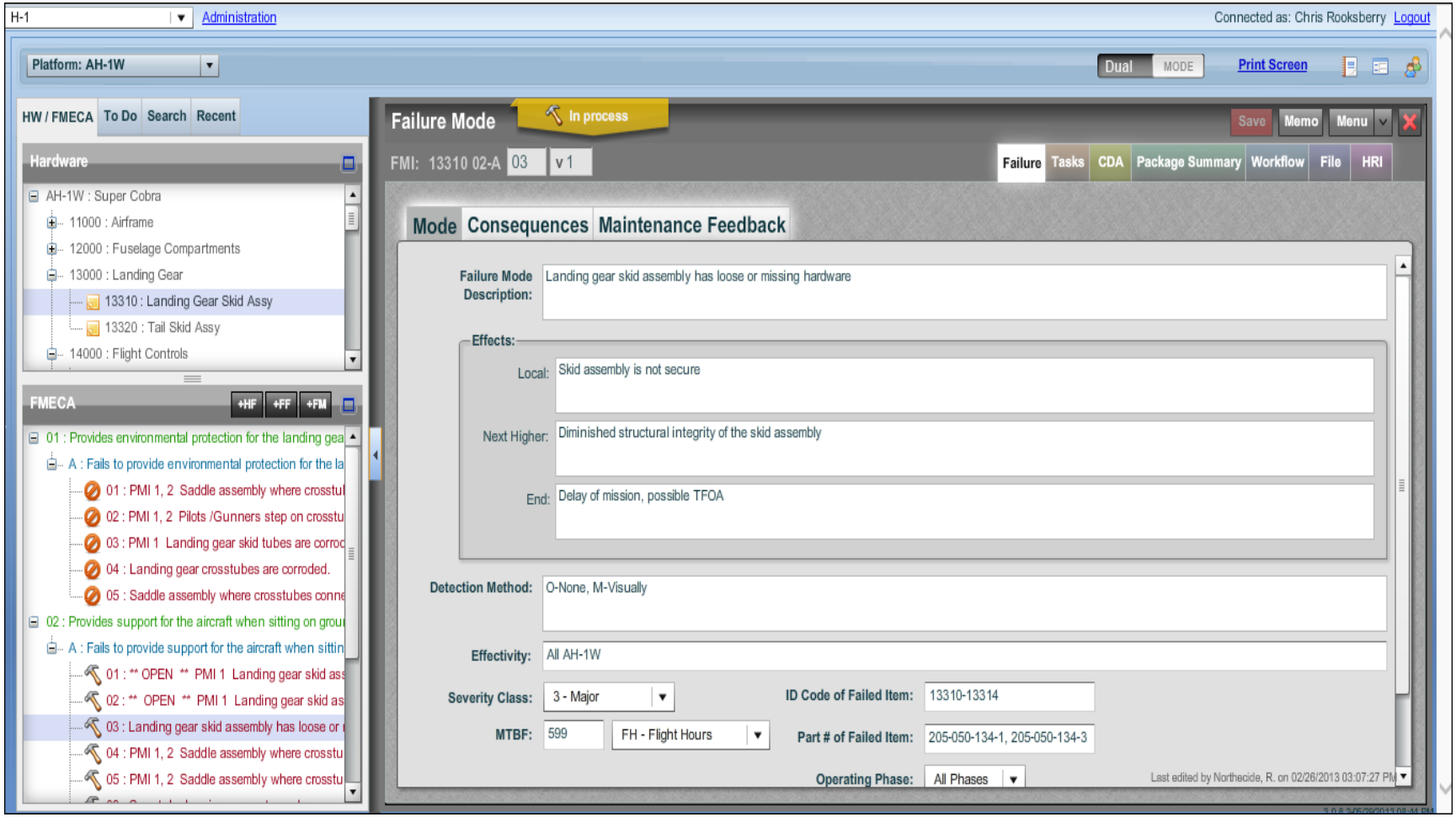
Failure Modes

- When possible list failure cause or mechanism, ex. “cracked spar due to fatigue”
- List all failure modes that are “reasonable”.
- Be as descriptive as possible
- Do not combine failure modes where failure effects, rates, or possible failure management solutions may be different
- Methods to identify “significant” failures vary by project.

RCM Process

- Possible Failure Mode sources:
  - Current PM tasks
  - Operator/Maintainer Knowledge
  - Logbooks
  - Work orders
  - Maintenance History Records
  - Spares purchase data

Failure Mode Example



Failure Effects/Detection

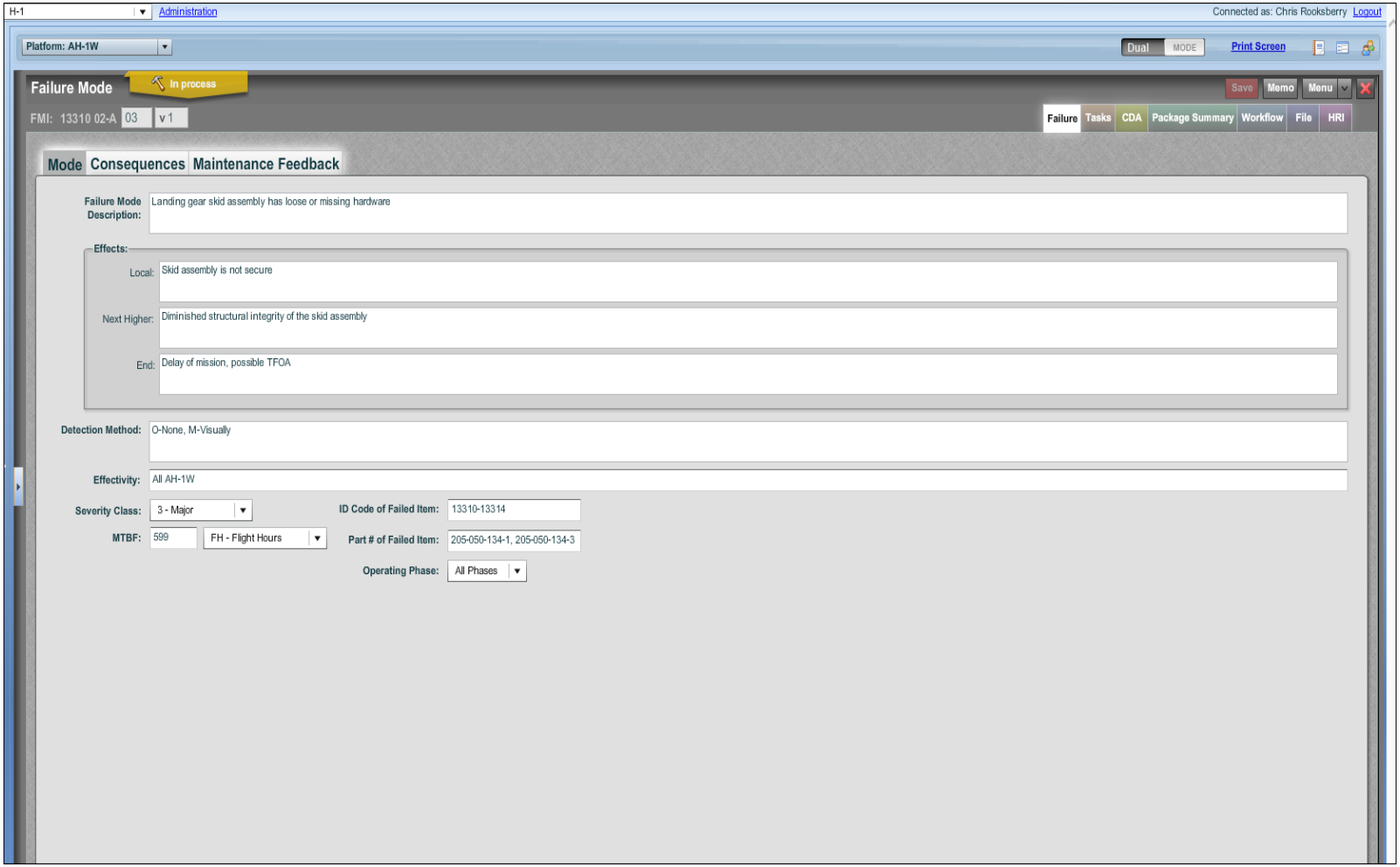
Determine the Failure Effects

- A failure effect is the result of a functional failure on surrounding items, the functional capability of the end item, and hazards to personnel and environment.

Determine the detection method

- A description of the method or methods by which functional failures are detected and how their failure modes are identified. Both operator and maintainer methods should be addressed

Failure Mode Example



RCM Process

Failure Frequency

Determine MTBF – How often does it fail?

- MTBF is a basic measure of reliability
- Possible sources for MTBF
  - Use part failure data if possible
  - Operator/Maintainer interviews
  - Work Orders
  - Engineering judgment/default numbers

RCM Process

Severity Classifications

- Severity Classifications are qualitative measures used to categorize potential effects of each failure mode on the end item

- Severity Class, along with failure frequency, may be used to determine whether or not action has to be taken to address a failure mode

Hazard Risk Matrix Example:

FREQUENCY / SEVERITY	FREQUENT ≥ 1 per 1,000 Hours	PROBABLE ≥ 1 per 10,000 Hours	OCCASIONAL ≥ 1 per 100,000 Hours	REMOTE ≥ 1 per 1,000,000 Hours	IMPROBABLE < 1 per 1,000,000 Hours
CATASTROPHIC (I) • Death or Severe Injury • Significant Environmental Impact • Damage > $1M • Loss of availability > 1 week	1 HIGH	2 HIGH	4 HIGH	8 MED	12 ACCEPT
CRITICAL (II) • Minor Injury • Damage >$100K and < $1M • Loss of availability > 24 hrs and < 7 days	3 HIGH	5 HIGH	6 MED	10 LOW	15 ACCEPT
MARGINAL (III) • Damage >$10K and < $100K • Loss of availability > 4 hrs and < 24 hrs	7 MED	9 MED	11 LOW	14 ACCEPT	17 ACCEPT
MINOR (IV) • Damage <$10K • Loss of availability < 4 hrs	13 ACCEPT	16 ACCEPT	18 ACCEPT	19 ACCEPT	20 ACCEPT

Failure Consequences

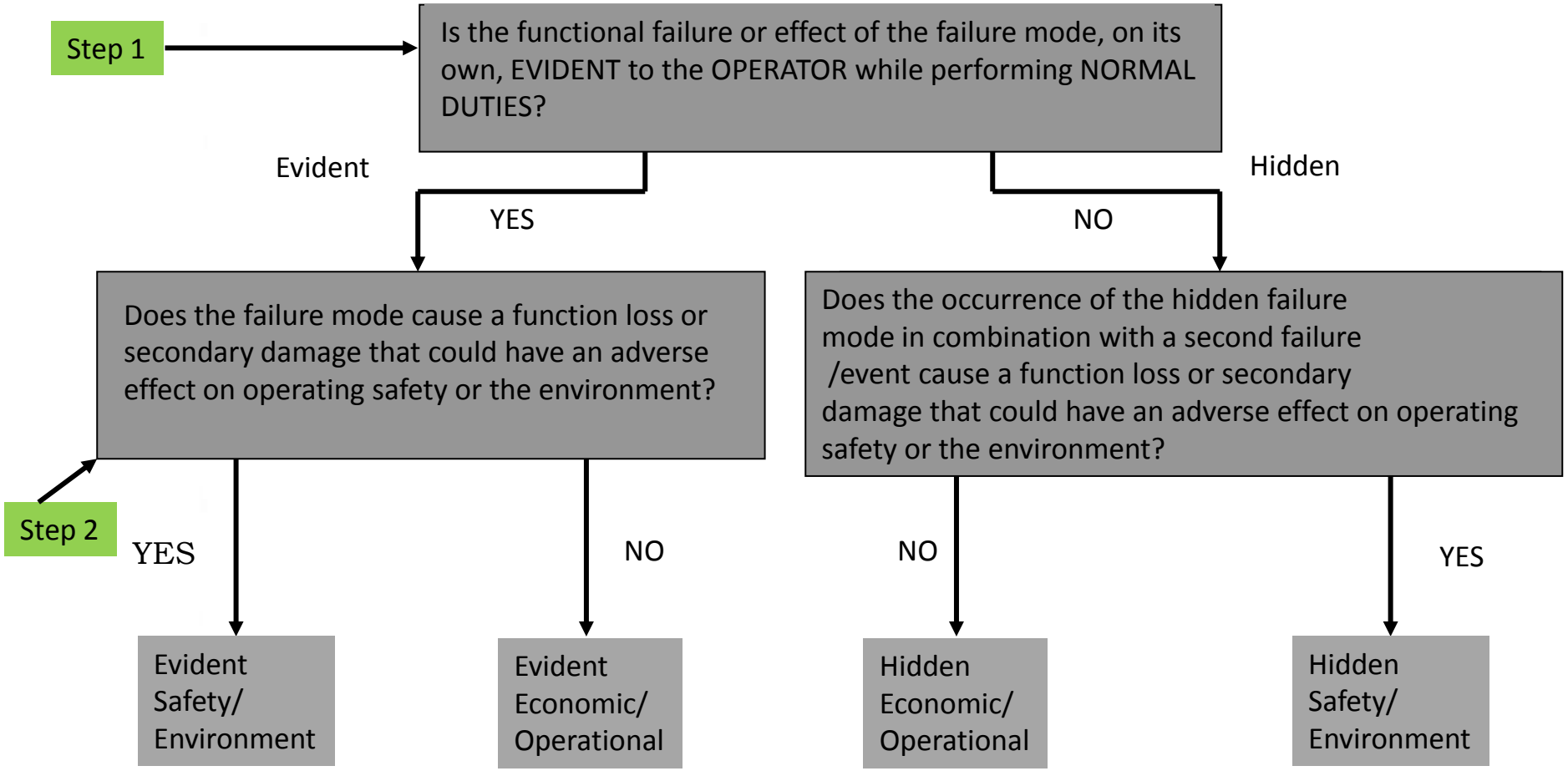
Determine the consequences

- Failure consequences describe the impact that a failure has on the equipment, the operators of the equipment and the environment around the equipment.
- Failure consequences are identified in terms of safety, the environment, operations, economics, and whether or not the failure is evident to the operator of the equipment.

Failure consequences are categorized in two steps:

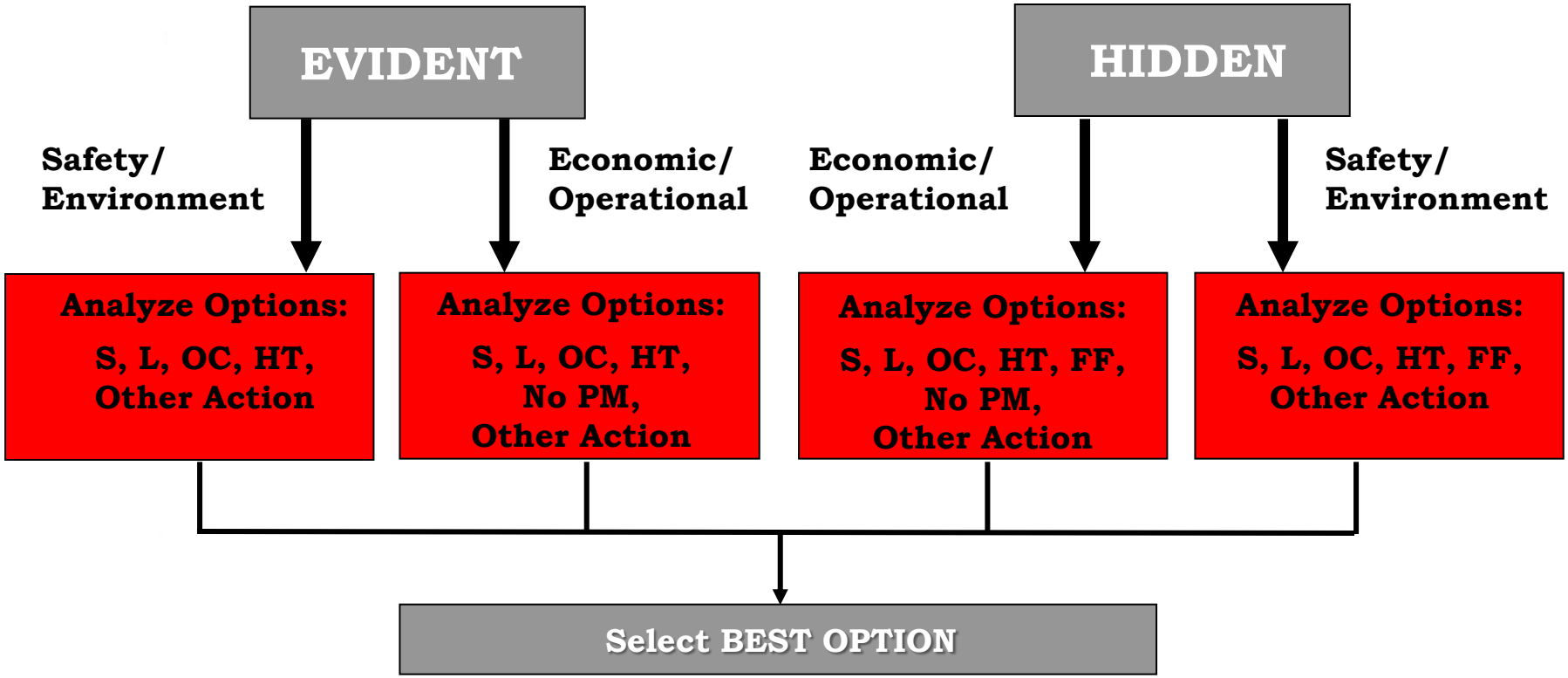
- Hidden or Evident
- Safety/Environment or Operational/Economic

RCM Process


Step 1
Is the functional failure or effect of the failure mode, on its own, EVIDENT to the OPERATOR while performing NORMAL DUTIES?
Evident
Hidden
YES
NO
Does the failure mode cause a function loss or secondary damage that could have an adverse effect on operating safety or the environment?
Does the occurrence of the hidden failure mode in combination with a second failure /event cause a function loss or secondary damage that could have an adverse effect on operating safety or the environment?
Step 2
YES
NO
NO
YES
Evident Safety/ Environment
Evident Economic/ Operational
Hidden Economic/ Operational
Hidden Safety/ Environment

RCM Process

Task Evaluation and Selection



RCM Process

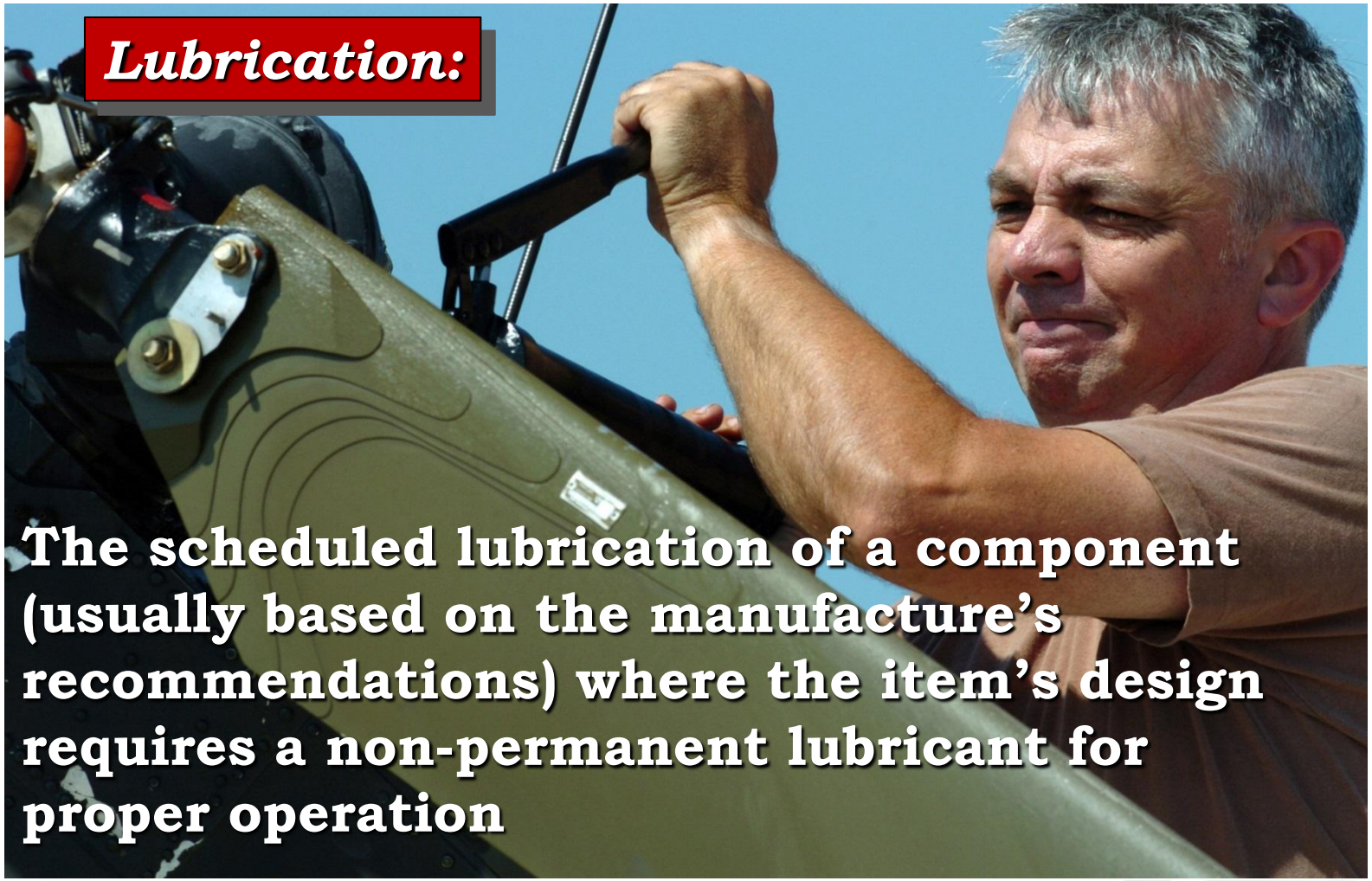
Task Evaluation

- Servicing/Lubrication requirement
- On-Condition requirement (e.g. inspection-potential failure)
- Hard-Time requirement (e.g. overhaul, life-limit)
- Failure Finding (e.g. op check)
- Age Exploration (If more information needed)

PM Task Types

Servicing:

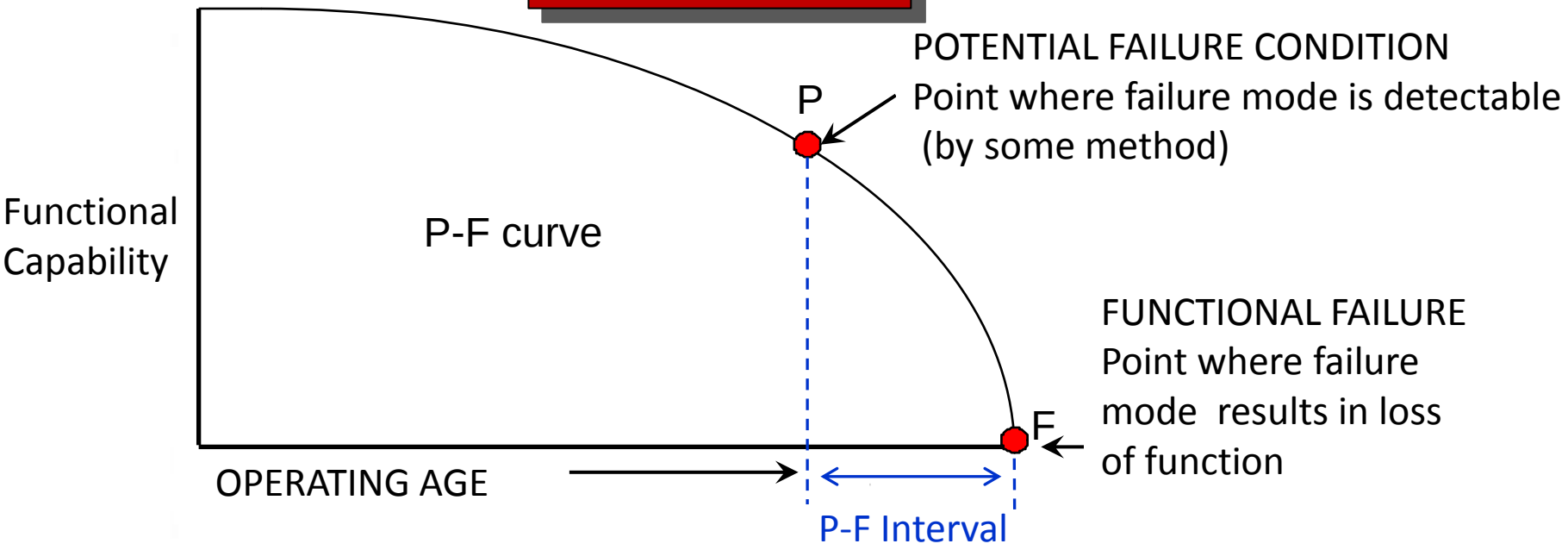
PM Task Types



PM Task Types

PM Task Types

On-Condition:



- If the inspection reveals a potential failure condition, corrective action is taken before functional failure. If potential failure condition is not detected, nothing is done, item continues in service
- Maximizes the useful life of each piece of equipment by allowing operation until potential failure is detected

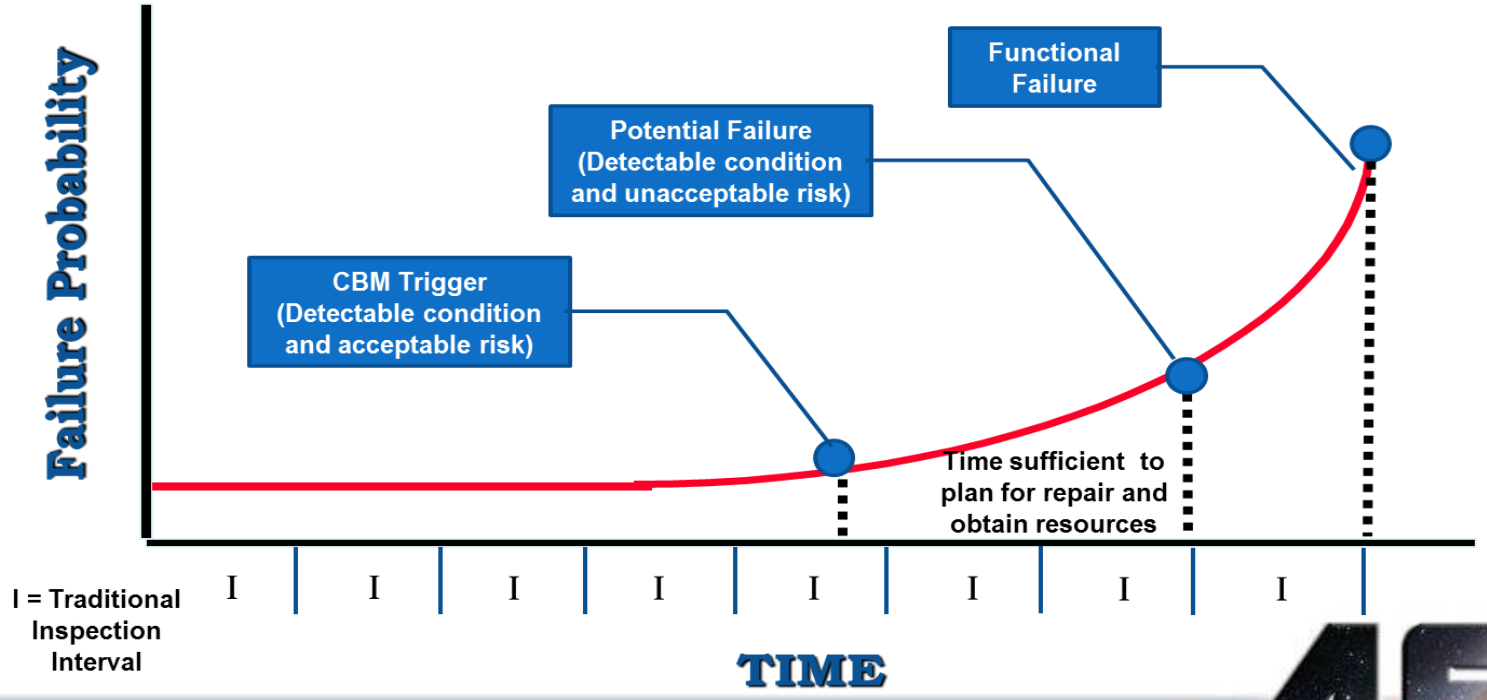
PM Task Types

Condition Based Maintenance (CBM):

- A CBM course of action is a preventative or restorative action performed only upon evidence of need identified through direct or indirect monitoring.
- CBM requires specific knowledge of an asset's condition over time during its operating life. This knowledge allows a mitigating action to be planned with sufficient lead time to minimize the impact (safety, cost, and operational) of the occurrence of the failure mode.

PM Task Types

- CBM differs from “on-condition” maintenance in that under CBM, knowledge of asset condition at any given time provides an understanding he of how much time is available to perform the required maintenance.



PM Task Types

Hard Time:

Scheduled removal of an item or a restorative action at some specified age limit to prevent its functional failure

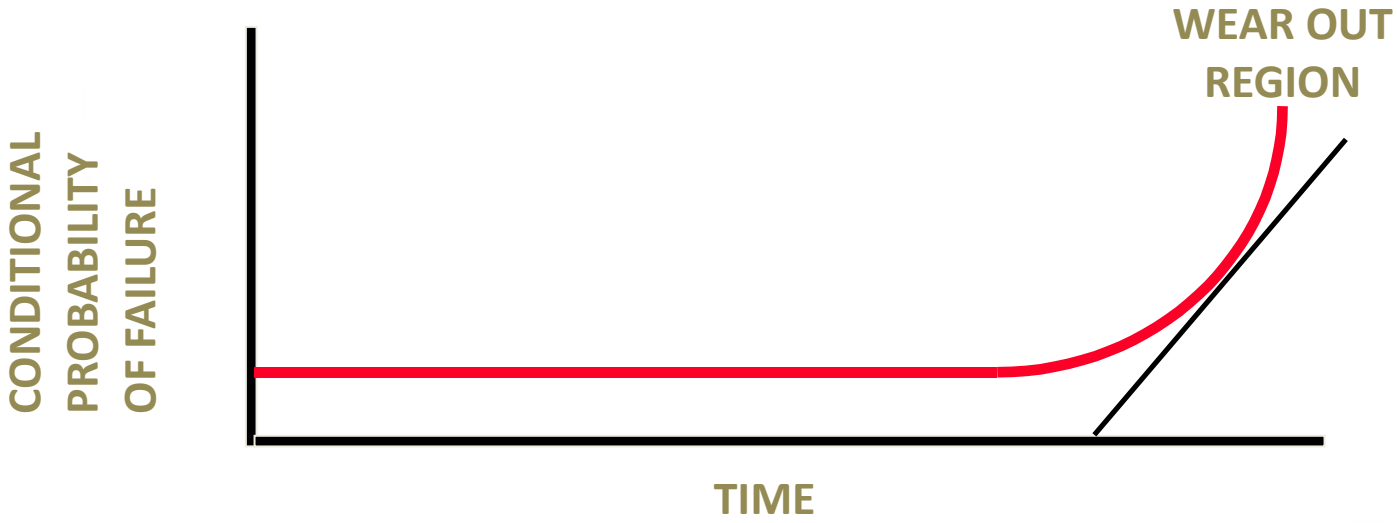
For example commonly referred to as:

- Scheduled Removal
- Rework
- Overhaul

PM Task Types

Hard Time:

- Some items show well defined wear out age where rapid increase in probability of failure occurs
- Described as increase in conditional probability of failure with age



Slope Of Curve Determines Wear Out

PM Task Types

Failure Finding:

A task performed at a specified interval to determine whether a hidden functional failure has occurred.

Prevalent in Back-up or Instrumentation Systems

Failure Management Strategy

Other Actions:

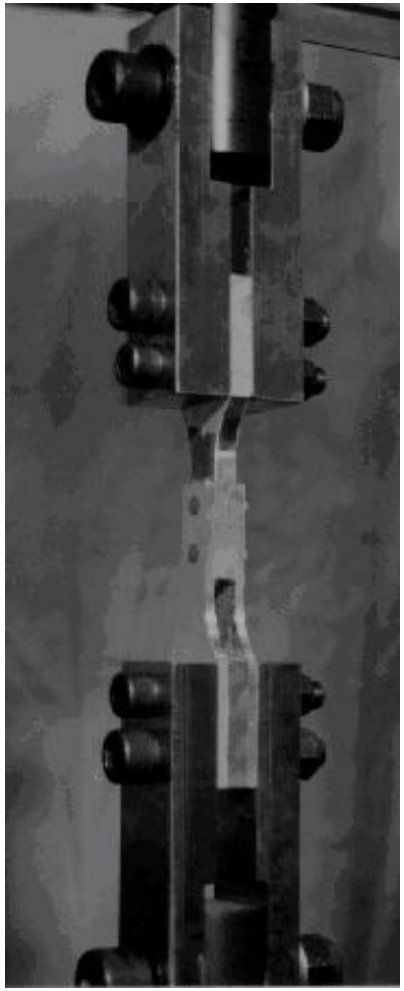
Usually a one time action, other than PM, that effectively reduces consequences of failure or resolves problems identified during the conduct of the analysis

Examples:

- *Design changes*
- *Operational or maintenance procedure changes*
- *Operating restrictions*
- *Training updates*
- *Publications*
- *Technology insertion*

Age Exploration

- Specific tasks to collect data to:
  - Refine RCM analysis assumptions and data
  - Optimize PM tasks
- Age Exploration tasks are targeted to specific failure modes and data shortfalls
- Age Exploration tasks may be:
  - In-service inspections or tests
  - Laboratory tests and studies
  - Data analysis
- For safety consequence failure modes, Age Exploration must not expose operators to unacceptable risk of failure



RCM Process

Task Evaluation

Determine task interval (in preferred order)

- Use hard data (previous studies) if available
- Use other analytical techniques when required
- Use engineering/analysts judgment
  - ✓ **Input from operators/maintainers**
  - ✓ **Engineering staff**
- Consider existing PM task
  - ✓ **Effectiveness**

Task Evaluation

Determine cost of each task option

- Cost to perform task
- Cost to repair failures
- Costs include:
  - Man hours
  - Material
- Costs obtained from experience, supply, and work order data

RCM Process

Task Evaluation

Once a failure mode has been subjected to the Decision Logic, one of the following outcomes is possible:

- PM Required- SL, OC, HT, FF
- No PM- Run to failure
- Other Action

RCM Process

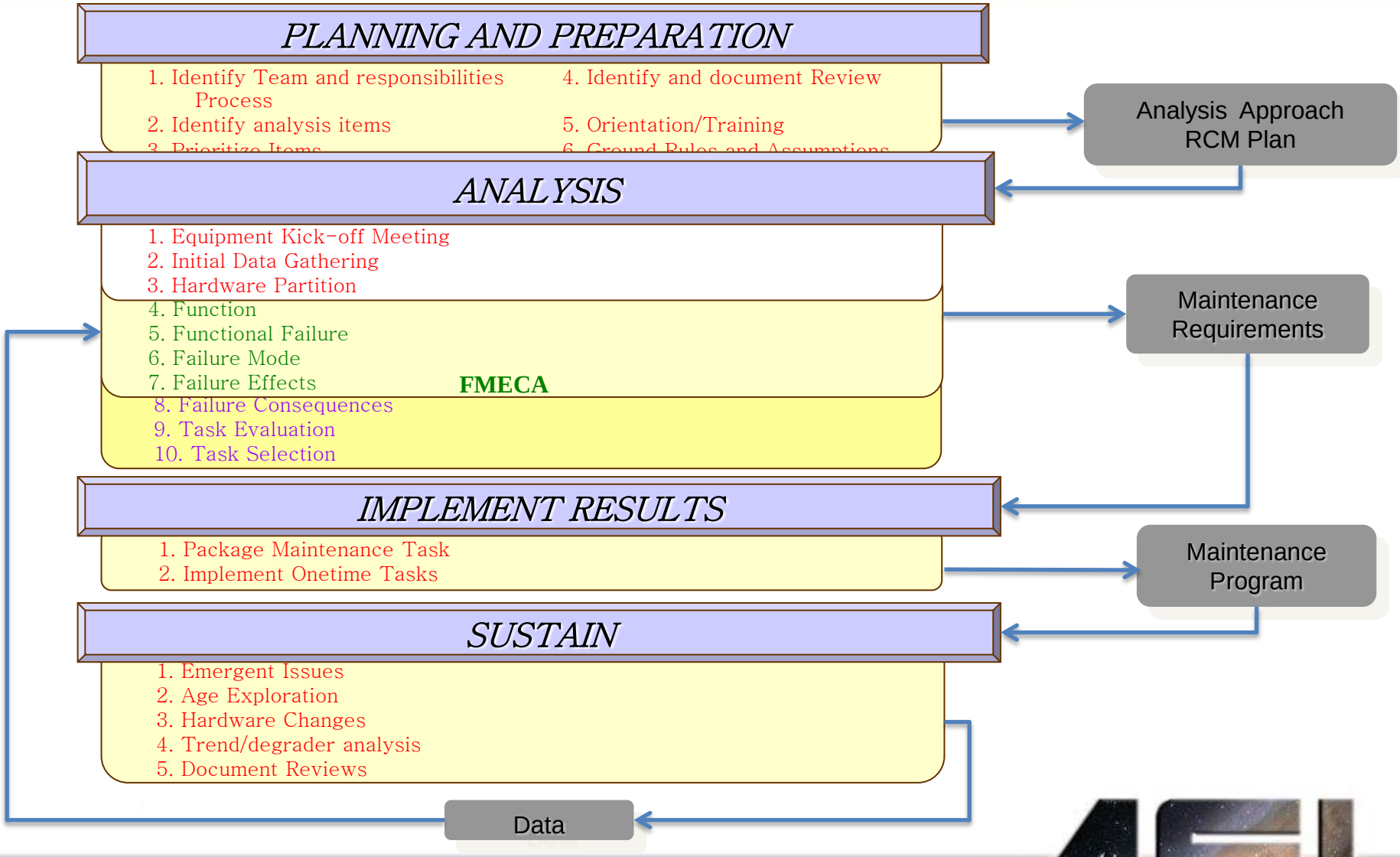
Task Selection

One or more PM tasks may prevent or reduce the probability of failure to an acceptable level. These tasks along with...

- a decision to allow the failure mode to occur (No PM)
- some “other action”...

… from a pool of options from which solutions can be generated.

RCM Process Overview



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Questions ?