FMECA Case Studies: T-45

INTRODUCTION

> **This workshop is intended to give you practice in applying the RCM theory. Use the IRCMS Program to document your analysis.**

The aircraft in this exercise is the T-45 Goshawk, a US Navy Trainer aircraft. The T-45 is two-seat, single engine jet training aircraft used to train future USN carrier based pilots. The Goshawk has many systems, one of which is the Flight Control System. The Flight Control System is made up of several subsystems including Pitch, Yaw, and Roll Control and Actuation subsystems.

This exercise will concentrate on the Roll Control/Actuation Subsystem

SUBSYSTEM DESCRIPTIONS

Roll Control/Actuation Subsystem (A14B)

The hydraulically operated ailerons are controlled manually by either pilot through lateral movement of the control stick handle, or electrically by a trim actuator. Either action results in the opening of two control valves in each of two power control units (PCU) to supply hydraulic fluid to operate the tandem actuators in the PCU. The aileron controls have a ratio changer mechanism that increases lateral control (increases aileron authority) when the landing gear is down. Aileron position indicators are mounted on each cockpit left console. Aileron position is also provided to the yaw damper controller (YDC).

Power Control Unit - (see Figure W4-1). Each PCU is made up of an input arm, a feedback link, and a body. The body includes a ram with tandem pistons in separate cylinders surmounted by twin selector valves, one for each hydraulic system and cylinder. The body and fitting is bolted to a bracket under the wing lower surface adjacent to rib 13. The input arm, in the form of a stirrup around the body, connects at the upper end to the aileron control system control rod, at the lower end to the feedback link and near the mid-position, pivots with an inner arm that operates the selector valves. The feedback link is connected to and moves with the ram. When the control stick handle is moved, the control rod causes the input arm to pivot on the feedback link and operate the selector valves. (Continued on next page)

Subsystem Descriptions (continued)

(Continued from Roll Control/Actuation Subsystem (A14B))

Aileron Ratio Changer Mechanism - (see Figure W4-2). The aileron ratio changer mechanism consists of an aileron ratio changer and a drive cable interconnected with the landing gear. The ratio changer is connected in the aileron control system by a primary (output) lever and a secondary (input) lever. It is mounted to the right of the aircraft centerline and aft of the inner auxiliary spar. With the landing gear down, the ratio changer reduces the amount of control stick or trim actuator movement required for a given aileron deflection, and increases the aileron range of movement. The ratio changer provides aileron deflection of 12.5 deg. (trim 6 deg.) with gear up and 15.5 deg. (trim 9 deg.) with gear down.

Trim Actuator Spring Feel Unit Assembly – The aileron trim actuator and spring feel unit assembly form two sides of a trapezium, connected at the inboard end to either side of the aileron bellcrank pivot arm, and at the outboard end to either side of a rocking idler arm pivoted to an inverted pillar on the right side of the structure. The trim actuator provides a means of correcting aircraft lateral trim while the spring feel unit provides stick centering at the neutral position and provides feedback feel forces to the pilot.

Aileron Position Airborne Data Recorder (ADR) Potentiometer – The aileron position ADR potentiometer is installed on a bracket secured to the wing structure at the inboard leading edge of the left aileron and actuated by a forked arm secured to the left aileron.
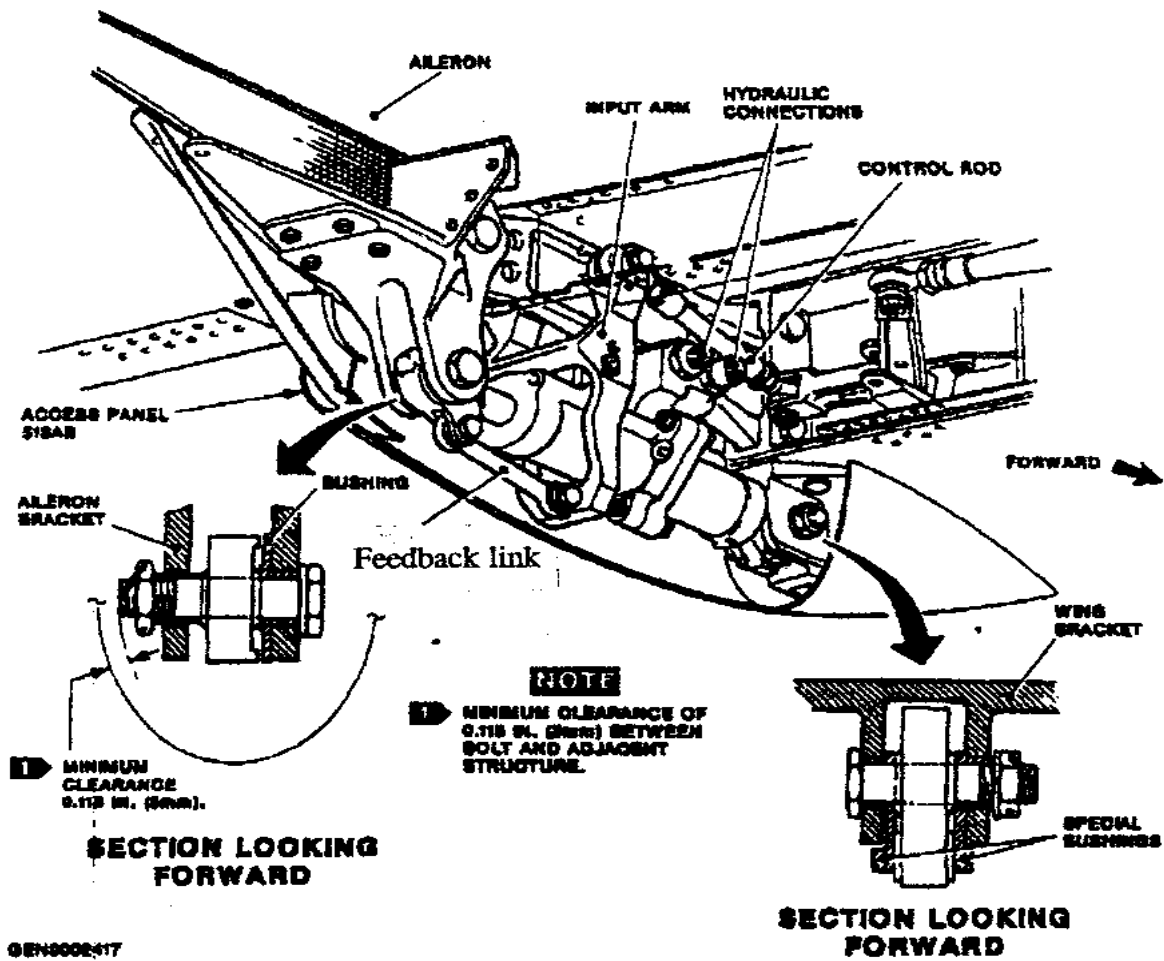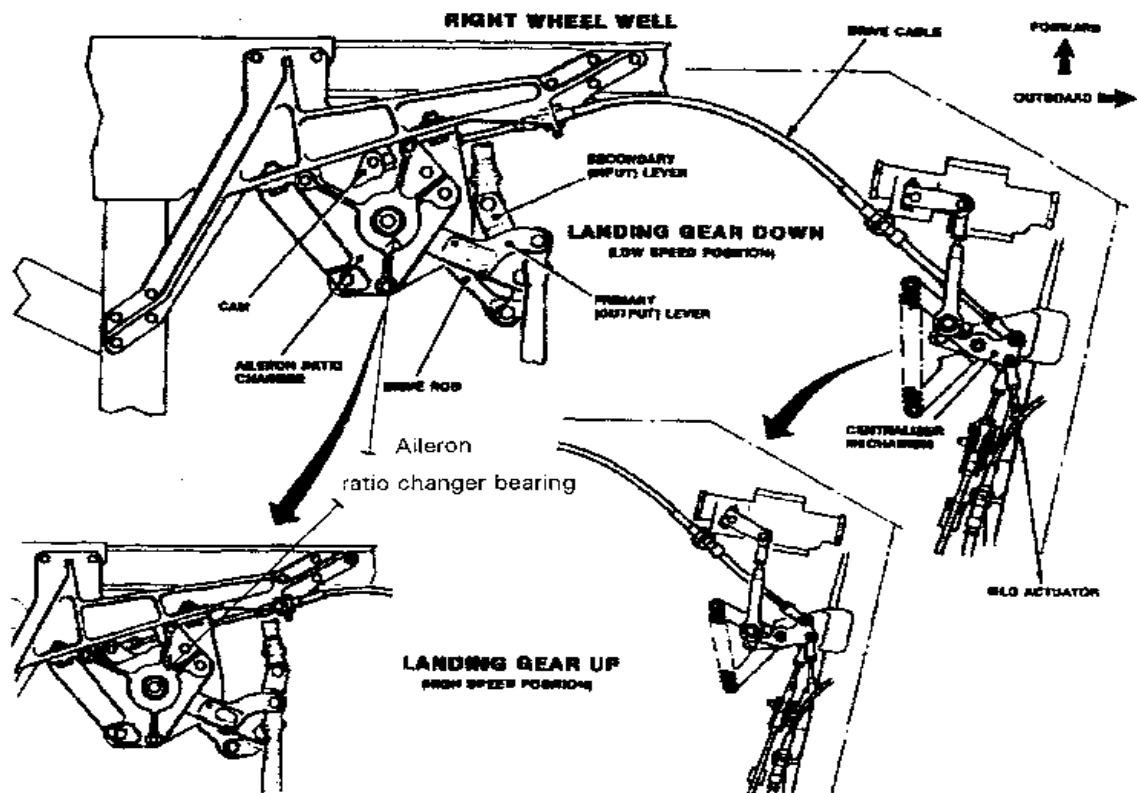
Figure W4-1 Power Control Unit

Figure W4-2 Aileron Ratio Changer Mechanism

WORKSHOP DIRECTIONS

WORKSHOP PART I

> **Note: Use the previous system description and Ground Rules & Assumptions at the end of this exercise as needed to analyze the ROLL CONTROL/ ACTUATION SUBSYSTEM (A14B)** Where no information is given, use your judgment. Fields that do not apply may be left blank. For example "Cost of Lost Operations" is not provided and may be left blank. Also the HRI Matrix as set in IRCMS does not need to be modified.

1. Begin the Workshop.

Login to IRCMS as instructed.

Select the **"T-45 Training"** project in the drop down at the top.

Enter default values into the project setup from the **Ground Rules and Assumptions** (attached).

2. Create the Hardware Breakdown using the Hardware Builder as instructed.

Enter the **Hardware** (end item, systems and subsystems) illustrated in Figure W4-3, before continuing to Functions. Use the LCNs, for example, A14, to identify systems and subsystems.
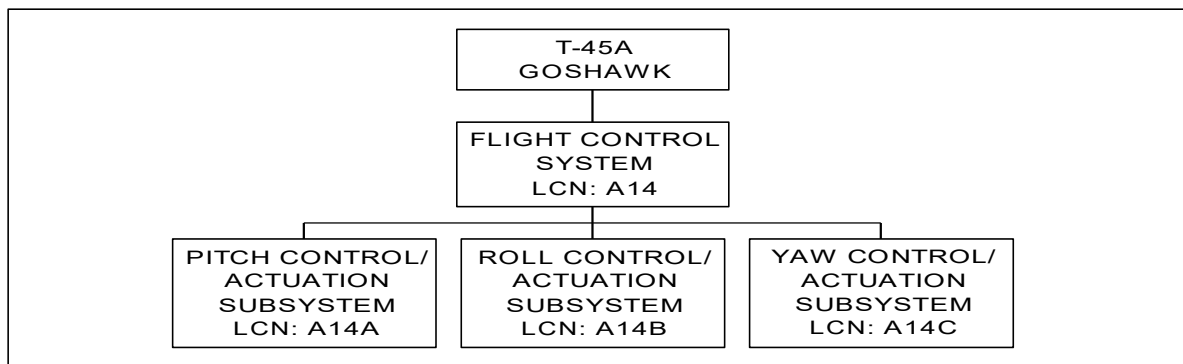
Figure W4-3 Flight Control System Block Diagram

3. Identify Functions.

Identify Functions of the **Roll Control/Actuation Subsystem** and enter them in the FMECA section of IRCMS. (Hint: use the system description)

Example Function 01: *Provides roll control of aircraft.*

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WORKSHOP PART II

4. Under the function "Provides roll control of aircraft" enter the following: (if you don't have this function, enter it). This will be function 01.

> **1) Functional Failure:**
>
>> **Functional Failure A***: Fails to provide roll control of aircraft*
>
> **2) Failure Modes under functional failure A:**
>
>> **Failure Mode 01***: Internal failure of power control unit (PCU)*
>>
>> **Failure Effect and Consequence:** Loss of PCU will cause loss of aileron actuation and may in turn cause loss of aircraft.
>>
>> **Failure Mode 02:** *Cracked/severed PCU feedback link*
>>
>> **Failure Effect and Consequence:** Loss of feedback link will cause loss of aileron actuation and may cause loss of aircraft.
>>
>> **Failure Mode 03**: *Cracked/severed PCU input arm*
>>
>> **Failure Effect and Consequence:** Loss of input arm will cause loss of aileron actuation and may cause loss of aircraft.

5. Under the function "Increases aileron authority with landing gear down (limits aileron deflection to 12.5 deg. (trim 6 deg.) with gear up and 15.5 deg. (trim 9 deg.) with gear down.)" enter the following: (if you don't have this function or something similar, enter it). This will be function 02. Change function numbers as necessary to avoid confusion.

> **1) Functional Failure:**
>
>> **Functional Failure A**: *No reduction in amount of control stick movement for given aileron deflection with landing gear down*
>>
>> **Failure Mode 01**: *Seized aileron ratio changer bearing*
>>
>> **Failure Effect and Consequence:** During operations, seizure of the bearing will not endanger the crew. Seizure causes a noticeable roughness in stick motion. The mission *must* be terminated.
>>
>> **Failure Mode 02**: *Bent secondary (input) lever*
>>
>> **Failure Effect and Consequence:** During operations, a bent secondary lever will not endanger the crew. The bent lever results in no reduction in required stick motion for given aileron deflection with landing gear down. The mission *would* be terminated.

*** STOP HERE ***

T-45 RCM PROGRAM PLAN EXCERPT

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DISCLAIMER
This section was created for use in the T-45 FMECA workshop. Data contained in this section is fictitious and not actual T-45 data.

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1.0   RCM ANALYSIS GROUND RULES, ASSUMPTIONS, AND GUIDELINES

1.1   General

Ground rules and assumptions are provided to ensure that all RCM analyses for the T-45 aircraft are developed using consistent guidelines.   These guidelines are intended to provide guidance where current instructions lack consistency, clarity or applicability, or where alternative processes or procedures have been developed.

The Integrated Reliability-Centered Maintenance System (IRCMS) software, will be used for conducting and documenting all RCM analyses. Documentation of the RCM analyses in the IRCMS software includes inputting values in numerous data fields. Some of the values are unique to the system or component being analyzed, while others are common to all T-45 analyses. This section identifies those values that are common. If the analysis is applicable to only one type/model/series (TMS), use the appropriate values for that TMS.

Integrated Product Team (IPT) leaders will develop a prioritized list of RCM analysis items using data provided by the Readiness Analysis Team. NAVAIR is the final approving authority for all changes to the T-45 XX-XXXXXX-X series Periodic Maintenance Requirement Manuals and Depot Level Maintenance Specifications.

1.2   End Item

The following end item values will be used in all RCM analyses:

Type/Model/Series: **T-45**

Item Name: **Goshawk**

Item Description: **Trainer aircraft**

Number of items in operation: **124**

Item Design Life: **12,500 Flight Hours**

1.3   Acceptable Probability of Failure:

Category I .000001	Category III .0001
Category II .00001	Category IV .001

1.4 Hardware Breakdown

The T-45 RCM Program Manager will perform the aircraft hardware breakdown and determine the levels of analyses that assure maximum benefit. Analyses should be done at the highest level practical – this is typically the system or subsystem level. Logistics Control Numbers (LCN) will be used to uniquely identify hardware in the breakdown.

1.5 Prioritization of Failure Modes

In addition to the Significant Function logic, which selectively limits the functions that are subjected to RCM analysis, the T-45 RCM analysis will further limit analyses to significant failure modes as defined by the criteria shown in Figure W4-4, below. For those failure modes that are already acceptable, record them in IRCMS and make a note in the memo field that these failure modes were considered, but did not meet the criteria for further analysis.

FREQUENCY / CRITICALITY	FREQUENT (A) ≥ 1x10⁻³ ≥ 1 per 1,000 hours	PROBABLE (B) ≥ 1x10⁻⁴ ≥ 1 per 10,000 hours	OCCASIONAL (C) ≥ 1x10⁻⁵ ≥ 1 per 100,000 hours	REMOTE (D) ≥ 1x10⁻⁶ ≥ 1 per 1,000,000 hours	IMPROBABLE (E) < 1x10⁻⁶ < 1 per 1,000,000 hours
CATASTROPHIC (I) DEATH / LOSS OF A/C OR SYSTEM / SYSTEM OR PROPERTY DAMAGE > $1,000,000	1 HIGH	2 HIGH	4 HIGH	8 MED	12 ACCEPT
CRITICAL (II) SEVERE INJURY / PARTIAL DISABILITY / IMMEDIATE PILOT ACTION REQUIRED TO PREVENT CAT I. RESULTING IN SAFETY MISSION ABORT / SYSTEM OR PROPERTY DAMAGE > $200,000	3 HIGH	5 HIGH	6 MED	10 ACCEPT	15 ACCEPT
MARGINAL (III) MINOR INJURY/ 5 OR MORE LOST WORK DAYS / MISSION DEGRADATION / SYSTEM OR PROPERTY DAMAGE > $10,000	7 MED	9 MED	11 ACCEPT	14 ACCEPT	17 ACCEPT
NEGLIGIBLE (IV) LESS THAN MINOR INJURY / CONTINUE MISSION WITH MINIMAL RISK / SYSTEM OR PROPERTY DAMAGE < $10,000	13 ACCEPT	16 ACCEPT	18 ACCEPT	19 ACCEPT	20 ACCEPT

RISK LEVELS:

HIGH — MANDATORY CORRECTION FOR HAZARD ELIMINATION OR CONTROL.

MED — REQUIRES MANAGEMENT REVIEW FOR RISK ACCEPTANCE.

ACCEPT — ACCEPTABLE RISK. REVIEW AS DESIGN MATURES.

Figure W4-4 Hazard Risk Table

1.6   Analytical Methods

1.6.1   On Condition Task Interval (For Failure Modes with Safety Consequences)

The following equations will be used throughout the RCM analysis to determine on condition task intervals for failure modes that affect safety.

Equation (1) $I_{oc} = PF/n$

where:

I_{oc} = task interval
PF   = interval between potential and functional failure
n   = number of inspections during I_{PF}

The PF will be determined as part of the RCM analysis. "n" will be determined using the following equation:

Equation (2) $n = \dfrac{\ln P_{acc}}{\ln (1 - \Theta)}$

where:

Θ = probability of detection during one inspection
n   = number of inspections during I_{PF}
P_{acc} = acceptable probability of failure of the failure mode under analysis

Solve for "n" by estimating a value for Θ. The value of "n" can then be used in Equation (1) to solve for the task interval.

1.7   General Default Values and Conversion Factors

a. Labor rates:

Organizational level	Intermediate level	Depot level
$30/hr	$50/hr	$100/hr

b. Usage rate: 45 FH/Month per a/c

c. Flight length: 1.5 FH/Flight (one flight per day)

d. Life of AC: 12,500 FH

e. Default design crack life: 12,500 FH (based on T-45 design spec and fatigue test)

f. Default component design life: 6000 FH (based on BaE Hawk design life)

h. Program flight hours to date: 345,000

i. Default MTBF for theoretical failures:

Severity Class	Default MTBF
I	1,000,000
II	100,000
III	10,000

************* End of Ground Rule and Assumption Excerpts *************