AIRCRAFT SYSTEM MAINTENANCE

Mr. M. Tozan
KFUPM
Objectives

- Become familiar with aircraft ground handling procedures
- Understand operation principles, components & maintenance practices of aircraft systems
- Provide you with basic knowledge of non-destructive inspection methods
- Improve your understanding for analyzing, developing and managing aircraft maintenance programs
Course Outline

- Aircraft Ground Handling
- Aircraft Systems/avionics/engine
- Corrosion and Aircraft Inspection Methods
- Aircraft Maintenance Planning & Management
Aircraft Ground Handling
Sources of Hazard in Ground Operations

- Fuel
- Electricity
- Compressed gases
- Spilled oil and grease
- Foreign Objects
- Running aircraft
Be careful around running aircraft
It is also better to be careful in front of the running engine
Ground Support Services & Operations

- Electric & Hydraulic service
- Air conditioning & Heating
- Refueling
- Towing & taxiing
- Baggage loading
- Passenger boarding
- Catering
- Others
Ground Support Equipments (GSE)

GPU (Ground Power Unit-Electricity)

Air conditioning unit

Air Starter
Refueling
Aircraft towing

TOWBAR

WING WALKER
Aircraft should only be towed by appropriate vehicle
Example: B-777 Ground servicing

- Fuel
- Elect.
- a/c
- Tow
- air
- water
- Food
- Cargo
- Lav
- Clean

5.1.1 AIRPLANE SERVICING ARRANGEMENT - TYPICAL TURNAROUND
MODEL 777-200LR
A typical ground handling of an aircraft
Most significant risk factors for ground damages

1. Towing
2. Ramp movements
3. Ground service equipment (GSE)
4. Hangar movements
IATA (International Air Transport Association) estimates that ground damages cost $5 billion/yr
AIRCRAFT SYSTEMS
AIRCRAFT HYDRAULIC SYSTEM
Hydraulic powered systems

- Flight Control Systems
- Utility Systems
  - Landing gear
  - Brakes
  - Steering
  - Cargo doors
Hydraulic fluids

MINERAL BASED HYDRAULIC

SYNTHETIC (SKYDROL) HYDRAULIC
Basic hydraulic system components

- Reservoirs
- Pumps
- Valves
- Accumulators
- Filters
- Actuators
- Back-up systems
Hydraulic system components
Hydraulic Backup Systems

"A" Hydraulic System
(system pressure 3000 psi)

- Reservoir: 2.0 gal
- Left engine-driven pump
- Ram air turbine
- Hydraulically driven hydraulic power transfer unit
- "A" system electric pump
- To "A" hydraulic system components

"B" Hydraulic System
(system pressure 3000 psi)

- Reservoir: 2.0 gal
- Right engine-driven pump
- Air turbine motor
- "B" system electric pump
- To "B" hydraulic system components

Legend:
- Pressurized system fluid
- Low-pressure fluid
- Check valve
- Electric selector/operating valve
- Mechanical hydraulic pump
- Electric hydraulic pump

Manual landing gear extension standpipe
Manual gear extension pump
To gear extension actuator

High-pressure bleed air from pneumatic system
Ram Air Turbine (RAT)
Hydraulic system failures

There are two main causes of hydraulic system failures:

- Hydraulic fluid contamination
- Hydraulic leakage
Hydraulic contamination

Hydraulic Contamination

Solid Contamination
- Organic
- Metallic
- Inorganic

Fluid Contamination
- Air
- Water
- Solvents
- Foreign fluids
Hydraulic leakage may come from wrong pipe installation or crack on components.
AIRCRAFT PNEUMATIC SYSTEM

A Pre Cooler
B Cold Air Unit
C Heat Exchanger
D MSOG
Functions of pneumatic system

**High-pressure system provides power for:**
- Engine and wing anti icing
- Operating engine thrust reversers
- Cabin pressurization, heating and cooling
- Powering engine starters

**Low pressure system provides power for:**
- Driving gyros in the flight instruments
- Deicing boots
- Inflation of door seals to sustain pressurization
Pneumatic system

- Pneumatic starter
- Pressure regulator: 18 psi
- Bleed air for engine inlet anti-ice
- High-pressure bleed air is drawn from engine compressor section.
- High-pressure bleed
  - Low-pressure air (18 psi)
  - Cooled high-pressure air
  - Empty pneumatic line
  - Vacuum
- Engine start valve
- INSTRUMENT / GYRO AIR
- VACUUM TO CONTROL PRESSURIZATION OUTFLOW VALVES
- Isolation valve
- Boot timer/ controller
- Thermal wing anti-ice valve
- Pressurization air to environmental "pack"
- APU BLEED AIR
- Ground source high-pressure air
- Inflatable door seals
Auxiliary Power Unit (APU)
APU functions

- Start engine
- Power generators to provide auxiliary electrical power
- Power environmental systems such as air conditioning
- Provide power for crew functions such as preflight and galley operations
Auxiliary Power Unit (APU)
AIRCRAFT FLIGHT CONTROL SYSTEM
Flight Control Systems

FLIGHT CONTROL SYSTEMS

PRIMARY FLIGHT CONTROLS
• AILERONS
• ELEVATORS
• RUDDERS

SECONDARY FLIGHT CONTROLS
• FLAPS
• LEADING EDGE DEVICES
• SPOILERS
• SPEED BRAKES
• TRIM & CONTROL TABS
Primary Flight Control surfaces

- Ailerons
- Elevator
- Rudder
- Flight spoilers
- Stabilizer
- Balance tabs
- Yaw
- Longitudinal axis
- Lateral axis
- Roll
- Vertical axis
- Center of gravity
- Pitch
Secondary Flight Control surfaces

- Leading Edge Flaps
- Leading Edge Slats
- Trailing Edge Flaps
- Ailerons
- Rudder
- Flight Spoilers
- Winglets
Secondary Flight control surfaces

- SPEED BRAKE
- Spoiler
- SLATS
- FLAPS
Aircraft flight control surfaces
Types of control linkage systems

- Mechanical command & mechanical actuation
- Mechanical command & hydraulic actuation
- Electric signal command & hydraulic actuation (Fly by wire)
Mechanical command-mechanical actuation

The National Transportation Safety Board
Office of Research and Engineering

The Beechcraft 1900D
Pitch Control Cable System

DCA03MA022
Air Midwest Flight 5481
Beechcraft 1900D Loss of Pitch Control During Takeoff

Charlotte, North Carolina
January 8, 2003
Mechanical command-Hydraulic actuation

Reduces pilot effort when control hinge moments are large, e.g. large control displacements at high speed.
Mechanical command-Hydraulic actuation
Electrical command- hydraulic actuation

- Pilot provides input
- Computer controls input
- Electric wire transmits input
- Hydraulic system provides power
- Surface moves

- Pilot provides input, computer controls the input, electrical wire transmits the input, hydraulic system provides power.
Electrical command hydraulic actuation
Main reasons for flight control malfunctions

- Maneuvers that have exceeded operational design limits of the control system.
- Corrosion and/or distorted or disconnected linkage.
- Inadequate lubrication and external contamination.
In-flight failures of flight control system

Most significant causes of failures are flaps and vibration.

![Pie chart showing the percentage distribution of in-flight failures.]

- Flap: 37%
- Spoller: 8%
- Yaw Damper: 5%
- Vibration: 12%
- Alleron: 7%
- Other: 22%
- Elac: 9%

(ATA 27 distribution (129 events Jan. 01 - Sept. 04))
AIRCRAFT LANDING GEAR SYSTEM
Functions of landing gear system

- Support the weight of the aircraft while it is on the ground
- Take off and land the aircraft safely
- Absorb landing and taxiing shocks
- Steer the aircraft
- Stop the aircraft
Operation of Shock Strut

- Nose Gear, Assembly
- Normal Load
- Sudden Increase
- Readjustment to Normal Load

Oleo Strut
Main landing gear servicing

737 NG Main Landing Gear
Nose landing gear

- Approach
- Indexer
- Shimmy
- Damper
- Steering Cylinders
- Oleo Struts
Forgetting to remove the safety pin is a contributing factor in LG failure
Aircraft Fuel System

Provides continuous flow of fuel to engine in all flight conditions. Main components are:

- Fuel tanks
- Fuel Pumps and valves
- Fuel Filters
- Fuel heaters
- Fuel instruments
Fuel tanks

- Centre wing box tank
- Inboard and outboard wing box tanks
- Tail plane torsion box tanks

Diagram showing fuel tanks in an aircraft with labels such as Right Engine Feed, Left Engine Feed, Right Wing Tank, etc.
Aircraft Fuel System Components

- Fuel control unit (FCU) delivers fuel to engine
- Engine-driven fuel pump
- Fuel filter bypass line
- Firewall fuel shutoff valve
- Single-point refueling station
- Crossfeed valve
- Aux pump (boost pump)
- To other engines and fuel tanks
- To APU
Fuel Quantity Indicator
Magnetic Fuel Quantity Stick

To manually check fuel quantity, stick is unlocked and lowered from bottom of wing. Fuel quantity is determined from calibration marks exposed under wing.
Fuel system troubles

- Contamination
  - Water
  - Mixing with other types of fuel
  - Foreign particles
  - Microbial growth
  - Sediment

- Leakage
Fuel leakage classification

- Stain: 3/4" MAX.
- Seep: 3/4" to 1-1/2"
- Heavy Seep: 1-1/2" to 4"
- Running Leak:
  - Fuel will usually flow in this area along skin contour after it is wiped dry.
  - Fuel usually drips at this point.

Size will vary with location and intensity.
AIRCRAFT CABIN ATMOSPHERE (ENVIRONMENTAL CONTROL) SYSTEM
Functions of cabin pressurization system

- Automatically maintain a maximum cabin altitude of about 8,000' at the aircraft's maximum designed cruising altitude
- Prevent rapid changes of cabin altitude regardless of rate of climb or descent
- Reasonably fast fresh air exchange to eliminate odors and remove stale air
Cabin pressurization

Cabin altitude: 8,000 ft

Aircraft altitude: 24,000 ft.

Environmental system cools and conditions air

High-pressure bleed air from engine compressor section

Outflow

Cabin altitude: 8,000 ft
Cabin altitude vs. aircraft altitude
System components

Neg. Pres. Safety valve
Pressurization valves on aircraft

Outflow valve

Neg. Pres. Safety valve

Pos. Pres. Safety valves
Cabin pressure indicators
Air conditioning system

- Maintain a comfortable cabin temperature throughout all conditions of flight
- Control cabin humidity to assure passenger comfort
- Prevent window fogging
- Provide cooling for avionics
Types of air conditioning systems

There are two types of air conditioning system used in aircraft.

- Air cycle machine (ACM) system
- Vapor cycle system
Operation of air cycle machine

FVC: Flow Control Valve
PHX: Primary Heat Exchanger
MHX: Main Heat Exchanger
RHX: Reheater
CD: Condenser
WE: Water extractor
Animation of operation of ACM system
Air conditioning packs/ram air inlets

RAM AIR INLETS

AC PACK#1

AC PACK#2

Ram air outlets
Distribution of conditioned air

Temperature Sensor
Environmental system failures

Between 2001 and 2004, 14% of in-flight interruptions have been attributed to environmental control system. They can be further divided as shown in the figure.
Water separator is the major problematic component with the highest failures.
AIRCRAFT ENGINES

F117-PW-100 Turbofan Engine
Dependable Power for the C-17
Operation of a turbine engine

1. Outside air is scooped into engine.
2. Air is compressed.
3. Fuel is added and combustion occurs.
4. Expansion and acceleration of hot gases turn turbines and produce thrust.

Spinner guides air into compressor section. Compressors progressively "squeeze" air in preparation for combustion.
Combustion chamber.
Combustion is continuous and self-sustaining.
Igniters are used for starting and to prevent flameouts in precipitation.
Nozzle accelerates gases.
Turbines are turned by escaping gases. They, in turn, drive the compressors through shafts.
Turbine engine components
Air inlet

Compressor  Burner  Turbine  Nozzle

Subsonic

Axisymmetric Supersonic

Rectangular Supersonic
Centrifugal Compressor
Axial flow compressor

Axial-Flow Compressor

An Axial-Flow Compressor
Combustion chamber (burner)
Exhaust section (Nozzle)
Types of turbine engines
Types of turbine engines

- **Turbojet**: Illustration showing the flow of air through the engine, with a shrouded fan indicated.
- **Turbofan**: Diagram highlighting the bypass of cool air around the core, with hot gases escaping.

Images of actual turbine engines complement the diagrams.
Thrust reversers

- Shorten the routine landing distance
- Reduce the load on the brakes
- Improve braking control on wet, snow-covered or icy runways
Types of thrust reversers

Clamshell reverser

Cascade reverser
Engine Malfunctions

- **Compressor Surge:**
  A compressor surge (sometimes called a compressor stall) is the result of instability of the air flow through compressor. It is recognized by a loud bang similar to an explosion.

- **Flame out:**
  A flameout is a condition where the combustion process within the burner has stopped.

- **Hot Start:**
  During engine start, due to fuel scheduling, strong tail wind, etc. turbine temperature rises to relatively high temperatures. This is known as a hot start.
Engine Malfunctions

- **Foreign Object Damage:**
  Foreign Object Damage (FOD) is ingestion of objects such as tire fragments, runway debris or animals into the engine.

- **Engine Seizure:**
  Engine seizure describes a situation where the engine rotors stop turning in flight, perhaps very suddenly. The static and rotating parts lock up against each other, bringing the rotor to a halt.
Engine failure causes

Major failure causes of aircraft engine during the last four years:
- Vibration
- Low pressure compressor (N1) problem
- Compressor vane
Engine Maintenance

- **Cold Section**
  - Compressor
  - Foreign Object Damage

- **Hot Section**
  - Combustion chamber, turbine, exhaust
  - Cracks due to thermal shocks
  - Dictates TBO (time before overhaul)
Foreign object damage (FOD)
Aircraft corrosion
Most Common Types of Aircraft Corrosion

- Pitting corrosion
- Crevice corrosion
- Intergranular corrosion
- Exfoliation corrosion
- Bimetallic corrosion
- Stress cracking corrosion
- Fretting corrosion
Pitting corrosion is a localized form of corrosion by which cavities or "holes" are produced in the material.
Crevice corrosion

- Crevice corrosion is a localized form of corrosion usually associated with a stagnant solution in crevices (shielded areas) such as those formed under gaskets, washers, insulation material, fastener heads.
Intergranular corrosion is localized attack along the grain boundaries.

Microscopic picture of Inter-granular corrosion of an aircraft component made of 7075-T6 aluminum.
Exfoliation corrosion

- It is the severe form of intergranular corrosion.
Bimetalic (dissimilar metal) corrosion

It occurs when two (or more) dissimilar materials are brought into electrical contact under water.

A stainless steel screw in contact with a cadmium plated steel washer.
Stress corrosion cracking

- It occurs as the result of the combined effect of sustained tensile stresses and a corrosive environment.

Stress corrosion crack on horizontal stabilizer due to severe metal forming.
Fretting corrosion

- It occurs when two mating surfaces, normally at rest with respect to each other, are subject to slight relative motion.

Fretting corrosion of tin-plated electrical connector pins mated with gold-plated sockets in F-16 aircraft main fuel shutoff valve.
Corrosion prone areas

- Battery compartment
- Exhaust areas
- Engine inlet
- Wheel well
- Flap enclosure
Avionic systems corrosion

Avionics are more prone to corrosion than aircraft because;

- Dissimilar metals are often in electrical contact
- Small amount of corrosion can make equipment inoperative
Effect of Atmospheric Conditions

- Weather conditions
- Atmospheric pollutants
Atmospheric conditions at an air force base in Turkey

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>ANNUAL MEAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute humidity (g/m³)</td>
<td>10.32</td>
</tr>
<tr>
<td>Relative humidity (%)</td>
<td>76.00</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>14.30</td>
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<tr>
<td>Rainfall (cm)</td>
<td>69.44</td>
</tr>
<tr>
<td>Particulates (μg/m³)</td>
<td>70.00</td>
</tr>
<tr>
<td>Sulfur dioxide (g/m³)</td>
<td>170.00</td>
</tr>
<tr>
<td>Distance to sea (km)</td>
<td>1.50</td>
</tr>
</tbody>
</table>
Protective maintenance against aircraft corrosion

- Washing
- Sealing / Application of inhibitors
- Protective coating (metallic, organic)
- Maintaining water drain valves and drain holes for proper operation
- Training and equipment
Corrosion
AIRCRAFT INSPECTION METHODS
Non-destructive inspection (NDI) methods

- Penetrant inspection
- Magnetic particle inspection
- Eddy current inspection
- Radiography inspection
- Ultrasonic inspection
- Borescope inspection
Penetrant inspection

- Detects only surface cracks
- Easiest method

1 - Cleaning
2 - Drying
3 - Dye application
4 - Inspection
Penetrant inspection

crack
Magnetic particle inspection

Detects surface or near-surface cracks only in ferrous parts.

1 - Cleaning
2 - Magnetization
3 - Powder application
4 - Inspection
Magnetic particle inspection

Lateral magnetization

Longitudinal magnetization
Magnetic particle inspection
Magnetic particle inspection

[Image of two close-up views of a metal component, with one showing a crack indicated by an arrow.]
**Eddy current testing**

Detect surface or near-surface cracks in conductive parts.
Eddy current testing

- Crack parallel to eddy currents - not detected
Eddy current inspection probes
Ultrasonic inspection

It can detect cracks inside the metallic & nonmetallic part.
Ultrasonic inspection
Ultrasonic inspection techniques (angular application)
Immersed ultrasonic inspection
Radiography Inspection

It can be used to detect crack inside the ferrous and non-ferrous materials
Borescope inspection

It is used to inspect the areas which are hardly accessible such as engine compressor & turbine.
Borescope inspection
Borescope kits
# Quick reference for choosing appropriate NDI method

<table>
<thead>
<tr>
<th>Discontinuity Type</th>
<th>Material</th>
<th>NDI method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface cracks</td>
<td>Nonferrous</td>
<td>PT/ET/RT</td>
</tr>
<tr>
<td></td>
<td>Ferrous</td>
<td>MT/PT/RT</td>
</tr>
<tr>
<td>Sub-surface cracks</td>
<td>Nonferrous</td>
<td>RT/ET</td>
</tr>
<tr>
<td></td>
<td>Nonferrous/ferrous</td>
<td>RT/UT</td>
</tr>
<tr>
<td>Corrosion</td>
<td>Nonferrous</td>
<td>UT/RT/ET</td>
</tr>
<tr>
<td>Laminations</td>
<td>Metal/composites</td>
<td>UT</td>
</tr>
</tbody>
</table>

RT = Radiographic testing  
UT = Ultrasonic testing    
ET = Eddy current testing  
PT = Penetrant testing     

MT = Magnetic part testing
AIRCRAFT MAINTENANCE
MANAGEMENT & PLANNING
Maintenance

Maintenance is any one or combination of activities such as;

- Inspection
- Modification
- Repair
- Replacement
- Overhaul

...to restore an aircraft or aircraft component or to keep it in working condition.
Authorities involved in maintenance program development

- FAA (Federal Aviation administration)
- EASA (European Aviation Safety Admin.)
- ICAO (International Civil Aviation Organization)
Maintenance Regulations & Documents

- Maintenance Manuals
- Service Bulletins
- Federal Aviation Regulations (FAR)
- Joint Aviation Requirements (JAR)
- Airworthiness Directives
- Advisory Circulars
- Minimum Equipment List (MEL)
- Technical orders
Maintenance Processes

- **Preventive maintenance**
  Predictive maintenance is performed in order to prevent failure of an item or to discover a hidden failure.

- **Corrective maintenance**
  Corrective maintenance is performed after the failure to correct the fault.
Maintenance Processes in aviation

- Hard time
- On condition
- Condition Monitoring

Flight operations  Maintenance Operations
Hard-time Maintenance

- It is the oldest, primary preventive maintenance process.

- It requires that an appliance or part be periodically overhauled at certain intervals in accordance with the carrier’s maintenance program, or it should be removed from the service.

- As soon as the part age reaches predetermined time (flight hour, cycle, or calendar time), it is overhauled or replaced with a new component.
On-condition Maintenance

- This is a primary preventive maintenance process.
- It requires that an appliance or part be periodically inspected or checked against some appropriate physical standards to determine whether it can continue in service.
- The purpose is to use the part as long as possible before it fails during normal operation (in service operation).
Condition Monitoring

- This is a maintenance process for items that have neither “hard time” or “on-condition” maintenance as their primary maintenance process.
- Condition monitoring is the maintenance process for locating and resolving problem areas through analytical study of malfunctions or failures, not affecting safety of aircraft.
Aircraft operator maintenance program

An air carrier's maintenance program should contain at least the following information:

1) What (Item to be maintained)
2) When (time limit)
3) How (task)
1) Items to be maintained (What ?)

The item (part, component, or system) to be maintained should be indicated clearly and accurately. This is done usually by ATA (air Transport Association) Chapter numbers, part serial numbers, etc.
2) Time Limit (When ?)

- The time limit is the maintenance interval when you perform the maintenance task.
- There are three (3) units of measure used to establish these limits. An item may have no limits, one limit, or any combination of these limits.
Time Limit

- CALENDER TIME
- FLIGHT HOURS
- CYCLES (no. of landings)
3) Maintenance Tasks (How ?)

These include the maintenance services to be done. The maintenance program consists of three types of tasks:

- Scheduled maintenance tasks
- Unscheduled maintenance tasks
- Specific maintenance requirements for major components of aircraft (engine, propeller, etc.)
Types of Scheduled Maintenance Tasks (services)

- Preflight / post-flight
- Transit Service
- Overnight Heavy Service
- Heavy Maintenance Service
- Overhaul Service
Maintenance tasks and letter checks

- In maintenance program, the maintenance tasks which are carried out at the same time are grouped into maintenance packages.
- These maintenance packages are indicated by "A", "B", "C" and "D" checks. For this reason they are called "letter checks".
## Transfer of task types in maintenance program

<table>
<thead>
<tr>
<th>SERVICE TYPE</th>
<th>CHECK</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVERNIGHT HEAVY SERVICE</td>
<td>A</td>
</tr>
<tr>
<td>HEAVY MAINTENANCE SERVICE</td>
<td>C</td>
</tr>
<tr>
<td>OVERHAUL SERVICE</td>
<td>D</td>
</tr>
</tbody>
</table>
## Military aircraft maintenance

<table>
<thead>
<tr>
<th>Maintenance types</th>
<th>Ordinary (O)</th>
<th>Intermediate (I)</th>
<th>Depot (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-flight inspections, scheduled maintenance, minor failure repair</td>
<td>Term maintenance, failure repair</td>
<td>Term maintenance, damage repair</td>
</tr>
<tr>
<td>Location</td>
<td>Squadron</td>
<td>Airbase</td>
<td>Factory-level facility</td>
</tr>
<tr>
<td>Duration</td>
<td>Minutes - hours</td>
<td>Hours - weeks</td>
<td>Weeks - months</td>
</tr>
<tr>
<td>Example tasks</td>
<td>Refueling, minor repairs, e.g. light bulb change</td>
<td>Component change/repair, e.g. hydraulic pump change</td>
<td>Elaborate component or structure changes/repairs, e.g. bird crash repair</td>
</tr>
</tbody>
</table>
How to package the maintenance tasks?

There are two questions that need to be answered about the TIME LIMIT correctly:

1) What is the best time measurement unit (Calendar day, flight hour or cycle)?
2) What is the optimum time limit for part replacements or inspections?
1) What is the best time measurement unit for me (Calendar day, flight hour or cycle)?

Aircraft: Boeing 747-400
Usage by design: High daily flight hour utilization
“C” check interval: 15 months or 3500 flight hours

Operator A:
- Average usage: 7000 fh/year
- “C” checks: 3500 flight hour

Operator B:
- Average usage: 7000 fh/year
- “C” checks: 15 months

Result: Operator A will perform more “C” checks than Operator B which results in increase in maintenance cost with no increased level of safety and reliability.
2) What is the optimum time limit for part scheduled replacements or inspections?

- Scheduled tasks are to be performed at regular intervals.
- Maintenance Planning Document (MPD) prepared by the manufacturer is the main document that provides the user with time intervals for various tasks.
- However, these are recommended intervals by the manufacturer. Each operator should customize these recommended time intervals based upon its own operating and environmental conditions, maintenance capabilities.
- To determine the optimal interval is a very difficult task that has to be based on information about the failure rate function.
Operating life and failures of a component

Operating life of a component may include three periods from the failures point of view:

- Early life period
- Useful life period
- Wear-out life period
Failure Characteristics of aircraft components

- **Decreasing failure rate**
  - Early life

- **Constant failure rate**
  - Useful life

- **Increasing failure rate**
  - Wear Out

- **Candidates for periodic replacement**

- Time (flight hours): 0, 500, 1000
Early life period

- *Early failures* occur early in the operating life of a component and are characterized by a decreasing failure rate with increasing age.

- Main causes of early failures are:
  - Poor manufacturing techniques
  - Poor quality control
  - Improper storage of the component
  - Improper installation
  - Contamination
Useful life period

- **Useful life period** is characterized by constant (or random) failure rate. During useful life components fail by change unexpectedly.
- Main causes of change failures are:
  - Misapplication
  - Abuse
  - Storms, lightning, etc.
  - Foreign object damage (FOD)
Wear-out period

- **Wear-out failures** occur late in operating life and characterized by an increasing failure rate with increasing age.
- Main causes of wear-out failures are:
  - Aging
  - Wear
  - Fatigue
  - Corrosion and erosion
  - Poor service, maintenance, and repair.
Manufacturer's maintenance document recommends replacement of a spring in aircraft APU fuel pump at an interval of 60 flight hours. Although you are applying the manufacturer recommendation, fuel pump often fails unexpectedly and produce many unscheduled maintenance tasks. You are assigned to analyze and recommend solution to this problem.
# STEP#1: Collection and Arrangement of Failure Data

<table>
<thead>
<tr>
<th>Failure No</th>
<th>Time to failure (aircraft flight hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>38</td>
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<td>65</td>
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<tr>
<td>7</td>
<td>75</td>
</tr>
<tr>
<td>8</td>
<td>88</td>
</tr>
</tbody>
</table>
## STEP#2: Calculation of failure rate

### Failure Rate Table

<table>
<thead>
<tr>
<th>Failure Number (i)</th>
<th>Time to failure (flight hour)</th>
<th>Time between failures Δt</th>
<th>Failure rate FR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>15-10=5</td>
<td>1 / [(5)(8+1-1)]=0.025</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>25-15=10</td>
<td>0.014</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
<td>13</td>
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</tr>
<tr>
<td>8</td>
<td>88</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

n= 8 (total number of failures)
STEP#3: Analysis

Plot column # 4 vs. Column # 2

This is the optimum replacement time.
A continuous airworthiness maintenance program (CAMP) is the set of processes certificate holders (operators) must use to keep their aircraft in an airworthy condition.

The FAA requires operators to establish and maintain two separate, but equal, functions within their CAMP:
- required maintenance actions
- required maintenance inspection
Electrical System

- Electrical Power sources
- Electrical Components
  - Control devices
  - Conversion devices
  - Protection devices.
- Power distribution systems and loads
Electric Power Sources

Aircraft equipments operate at two electrical power levels
- 115 VAC @ 400 Hz
- 28 VDC

There are two power sources on the aircraft to generate these electric powers:
- Batteries
- Generators
Electrical power requirements during a typical flight

- Exterior lighting
- Flight compartment lighting
- Passenger cabin lighting
- Galley
- Toilets
- Entertainments
- Windschild heating
- Avionics
- Air conditioning
- Fuel
- Hydraulics
- Flight controls
Always start at the power source, and follow the flow of electricity through the system.

- Electric generator driven by APU.
- Electric generator driven by aircraft engine.
- Generator control unit ("GCU") controls generator connection to system.
- Transformer rectifier unit ("TRU") converts AC power to DC power (one direction only).
- Bus ties are relays that disconnect buses or reroute power in the event of faults. Some are manual, some are automatic, and some are both.
- Diode acts as one-way "check valve" in electrical system, allows electrical flow only in direction of arrow.
- Electrical buses are independently powered electrical "manifolds." Electrical devices are powered by different buses, in order to provide circuit protection and alternate power sources for backup systems.
- Inverter converts DC power to AC power (one direction only).
- Circuit breaker ("CB") disconnects bus from circuit in the event of a short or other fault drawing high current.
- Transformer changes electrical voltage (one direction only).
Electrical components

- RELAY
- Transformer rectifier unit (TRU)
- CIRCUIT BREAKERS
Open circuit: Circuit that is not complete or continuous. When an open occurs the affected component stop to operate, but the other components still remain in operative condition.

Short Circuit: It occurs when electricity is allowed to take a shortcut through or around a component or system. It has two effects:

- Affected components have no power and fail to operate
- The other component will be subjected to higher level of current causing them to burnout.
Right generator bus fault

Right generator bus has been isolated due to fault. Pilots would be notified by caution or warning light, plus loss of various electrical components. Right GCU has taken right generator offline. Left generator is now powering all buses except for the "right gen bus." Any components on that bus are unpowered, and plans must be made to complete the flight without them. Course of action begins with pilot call for "Generator Bus Failure Checklist."
CONTINUOUS AIRWORTHINESS MAINTENANCE PROGRAM (CAMP)

- SCHEDULED MAINTENANCE
- AIRCRAFT INSPECTION
- UNSCHEDULED MAINTENANCE
- RELIABILITY CONTROL