Unit 53: Airframe Mechanical Systems

Delivery guidance

This unit is designed to introduce learners to the function, operation and maintenance of key systems typically found on modern aircraft. You should assume that from prior learning, or from current learning in other units associated with the course being delivered, that your learners understand the overall function of an aircraft. If, from other units, the learners have developed an understanding of how, aerodynamically, the elevator controls pitch manoeuvres, then this unit will instruct them on **how** those elevator motions are executed.

Ideally, you should coordinate your delivery closely with the tutors of the other units for consistency/relevance. To return to the control surface analogy, when the learners are covering those portions concerning control surfaces in *Unit 48: Aircraft Flight Principles and Practice*, you should deliver the portions of this unit that discuss the operation of the devices.

Given the need to examine and understand the function and operation of the devices and systems concerned, it would be advisable to acquire as many example devices for display or demonstration as you possibly can. Schematics and cutaway drawings have limited impact as learning aids. The opportunity to handle, dismantle and operate real devices will ensure superior retention through active and experiential learning. Moreover, if this unit is being delivered as part of a training programme concerning aircraft maintenance, the manipulation of these devices will constitute development of direct employment skills and experience.

You can involve local employers in the delivery of this unit if there are opportunities to do so.

Approaching the unit

You should begin by developing the learners' broad understanding of the range and complexity of aircraft systems. You might begin with a categorised view of aircraft systems, including manoeuvre control, landing systems, environmental control, fuel systems etc. This approach is supported by the layout of the unit specification. You may, however, wish to adopt a different strategy. Begin by developing knowledge of the operation of mechanisms according to type, for example hydraulics, mechanical linkages, pneumatics etc. Then proceed to the systems and devices that utilise these methods.

All of the systems and their devices detailed in the specification are not simply designed for functionality. They are also subject to the restrictions and demands of certification requirements. While the specification does not call for any learning regarding this topic, the impact on the design and operation of aircraft systems as a function of certification is of primary importance. This is also true in the maintenance of airworthiness. You should link the requirements to the devices wherever possible. Safe and continuous operation is a key parameter.

Ideally, you will have access to an aircraft which features all the specified devices and can be stripped, inspected and re-assembled over the course of the unit. Each learning aim might begin with a broad treatment of the system in question, the types of devices commonly in use, the manner of their operation, and the mode of inspection. This could then be followed by direct treatment of the example aircraft, stressing that device type differs for other aircraft even if the function remains the same. When manipulating the device on the aircraft you should refer the learners to the maintenance manual for that aircraft and the Federal Aviation Administration (FAA) (or European Union Aviation Safety Agency [EASA] or international equivalents) requirements. In addition to contextualising the activities, this exercise will habitualise the learners to common industrial practice and standards. With regards to the familiarisation with normal working practices and standards in the aircraft industry, you should make efforts to secure a visit from a professional in the context of aircraft inspection and maintenance. Note that if you are using a real aircraft in a hanger environment, you will require an appropriate power source to charge the systems on board the airframe. Suitable support trestles to leave the undercarriage free for test will also be required, though not strictly necessary.

If access to a live airframe is not possible, then a full suite of example devices must suffice. If possible, have these devices mounted on representative rigs that simulate the operation. For example, a hydraulic actuator might be fitted within a representative wing section with aileron. The treatment of the devices will be the same as with the complete airframe.

Development of the fundamental theories that support each system would best be approached through demonstration rigs. Educational pneumatic, hydraulic and electronics rigs are readily available. Such learning aims may well be common to other units and you should liaise with the other tutors to establish where concurrent teaching or common assessment might take place.

Delivering the learning aims

As suggested earlier, you should begin with a broad overview of an aircraft system's technology, purpose and typical execution. Draw attention to the variety of devices that might be encountered and how the choice in device will be dictated by aircraft size, operating altitude, manoeuvrability, operating environment, weight concerns etc. You should link the other aspects of aircraft science at this stage. Assess the learners' knowledge of flight mechanics, airframe design and construction, thermodynamics, aerodynamics and solid mechanics. Clearly you are not responsible for delivering the tutoring/learning for these subjects, nor do the learners require an in-depth understanding of them, but the basics are essential. The learner must first comprehend the purpose of the systems if they are to appreciate the function.

The learning aims open with a treatment of the fundamentals of hydraulics. The focus is predominantly on the components and their control. Hydraulic design and operation can certainly be demonstrated from a purely parametric standpoint (black box), but learner comprehension of these parameters will be improved if they simultaneously understand the theoretical principles (what is in the black box). Both theory and operation can be developed brilliantly with an appropriate demonstration rig. Ensure that the rig chosen for this purpose includes all the major components. Hose lines, differing control valves, indicators, a variety of actuator types etc. With such a rig at your disposal, you could develop a number of discrete exercises designed to develop learner competence with hydraulic equipment. Each exercise would start with an outline of theory and application of parameters, followed by a tutor led demonstration, followed by a set task in which the learner is directed to achieve some given outcome with the apparatus available to them. Connect each outcome to application of the real devices as found on the aircraft. Importantly, you should invite the learners to consider the ramifications of loss of function in any part of the system they have been investigating. This would also be a suitable point to start introducing fault-finding techniques. Note that this is not strictly included in the specification so should not be laboured.

The second part of learning aim A deals with landing gear. The hydraulic actuation of typical landing gear can be explicitly linked to the learning developed on the demonstration rig. Introduce the specific devices and invite the learners to examine the operation and parameters from the perspective of what they learned previously. If you have access to an aircraft or at least a landing gear assembly, introduce the maintenance manual for that specific system.
Ensure the learners understand how to reference the document to extract the specific data, especially the directives concerning the inspection and test of the undercarriage. Lessons might take the form of access-inspect-repair processes that reflect the real-world processes. This will allow the simultaneous development of knowledge with industrial protocols. You may also wish to introduce a standard recording format as typically used in order to familiarise learners and develop directly pertinent industrial experience. Given the range of devices stipulated in the learning aims, it seems unlikely that you will have examples of all of them. At the very least, you should have one device type per application and support the missing device types through images and drawings with supporting explanation.

The final part of learning aim A is concerned with flight control systems. It would be sensible to commence this portion by defining why a mechanical system might be adopted in preference to a hydraulic one, or vice versa, depending on the aircraft in question. Invite the learners to explore this question in the light of supported learning. For example, for an aircraft of such a size and such a typical operation, what are the advantages and disadvantages to each system? If we combine these systems, are there any potential advantages? If you have access to an aircraft it is likely that it will not be overly large and will likely be somewhat aged. Therefore, it is likely that it will have examples of both systems on the airframe. Direct the learners to witness the effects of cockpit controls on surface movements, track how these control inputs are transmitted to the surfaces and record their findings. This can be performed for all surfaces. Ensure that the learners appreciate the purpose of these surfaces and the ramifications of loss of function. Support this learning by indicating alternative solutions that might be present on different aircraft. Without access to an aircraft, you will need to rely heavily on images and drawings to support teaching. However, you should at least have a rig that can simulate control input to surface movement, even if only a model. This rig should have all the likely mechanical system components. Simulation of hydraulic actuation could be achieved via the hydraulic rig mentioned previously, providing you have access to supplementary controls such as a control column and some means of translating electrical signals to hydraulic component activation. This would also allow the demonstration of electro-hydraulic signal transmission as a mechanism.

Learning aim B is concerned primarily with environmental control systems. If the aircraft you have access to was designed and hence equipped for high altitude flight then you will have access to all the devices and systems noted in the specification. If not, then a large quantity of the devices will require a purely theoretical approach. Ensure, this being the case, that you have an adequate pre-prepared supply of supporting images and drawings to utilise in support of this learning. If this approach is adopted, you should make efforts to secure a visit, if possible, to a maintenance centre where some aircraft is presently undergoing a C or preferably, D check. This would allow the learners to view the devices in an exposed state and, importantly, witness the procedures for the
inspection and testing of these systems. Note that such a visit could also be used to witness the MRO (maintenance, repair and operation) of all other systems of interest in this unit. The final part of this learning aim concerns protection systems and their operation. Note that this segment is focused on how these devices are used by the crew and passengers. You could arrange a visit to any active civilian airport where cabin crew could be asked to indicate the devices

onboard, their location, their operation and the conditions under which they might be used.

Learning aim C opens with an exploration of fuel systems and the composition of the fuel itself. If the learners have, or are, pursuing learning in thermodynamics, you should link that learning to the treatment of combustible substances. This will make a good scaffold for dealing specifically with aviation gasoline (AVGAS) and its treatment. Proceed to additives and their purpose. Fuel systems can be demonstrated directly on an example aircraft or schematically supported by examples of the various devices such as pumps and valves.

Treatment of the anti-icing and de-icing systems should begin with the causes and dangers of icing on aircraft. You should link to *Unit 48: Aircraft Flight Principles and Practice* at this point to support the foundation theories. For example, how and why is ice formed? Why is it a problem? Clearly draw the distinctions between pre-emptive and reactive systems. Why is one approach selected over the other? You can then proceed to the specific systems themselves and their operation.

The final part of the learning aim is concerned with the detection, suppression and extinguishing of fire. You should commence with an exploration of the potential sources of ignition and of the relative flammability and toxicity of the materials and substances that comprise the airframe. Detection systems can be explored through the example aircraft as simulation of ignition sources is easily achieved. Create structured exercises where specific alarms are activated and have the learners identify the location and source. The operation of the specific devices might be pursued through an examination of example devices subjected to the differing environmental conditions which activate them, e.g. thermal, chemical, infrared etc. Fire suppression systems can then be examined. You should distinguish clearly between those systems that require operator intervention and those which are automatic.

Learning aim	Key content areas	Recommended assessment approach
A Investigate how the operation of hydraulic-power, landing-gear and flying-control systems contribute to safe flight	**A1** Hydraulic-power systems and components **A2** Landing-gear systems and components **A3** Mechanically and hydraulically powered flight control systems	A report based on inspections of systems and research, covering the function and operation of aircraft-hydraulic power, landing-gear and flight- control systems as well as components and their contribution to safe flight.
B Examine how the operation of cabin environmental control and protection systems contribute to the protection of passengers and crew	**B1** Cabin environmental control systems and components **B2** Cabin protection systems	A report covering the operation of cabin environmental control and protection systems as well as components and their contribution to the protection of passengers and crew.
C Examine how the operation of airframe fuel-, ice- and fire-protection systems contribute to safe flight	**C1** Airframe fuel systems and components **C2** Anti-icing and de-icing systems **C3** Fire detection and extinguishing systems and components	A report covering the operation of airframe fuel-, ice- and fire- protection systems as well as components and their contribution to safe flight.

Assessment guidance

The assessment criteria for learning aim A calls explicitly for the inspection, recording of findings, analysis and reporting of three systems. Namely, at least one of each of the following:

- hydraulic power system
- landing gear system
- flight control system.

Note that this will require access to an aircraft. If an aircraft is not available, as per the suggested activities detailed throughout this document, you will be obliged to arrange a visit to a location where some particular aircraft is available on which you can carry out the necessary inspections. The unit specification recommends as an example, 'Inspection of a hydraulic supply system will be used to determine the identity, layout and function of the system and its power source(s), oil-storage components, fluid plumbing, control valves and feeds to the hydraulic services'. Note that neither the assessment criteria nor the example guidance require that the learner identify faults or for that matter quantify the status of the system. The objective is to identify the system components and then to explain their operation. The landing system and the flight control system chosen are subject to the same requirements. You should direct the learners to document all details during their inspection. You may wish to direct them to photograph the systems for the purposes of insertion into any report. Video recording or learner observation records/witness statements of the activities can constitute an aspect of the evidence for completion of assessment criteria A.P1. However, A.P2, A.M1, and A.D1 require the generation and submission of findings. This might be done through a presentation, but it is recommended for the sake of robust assessment, as well as evidence, that you direct learners to generate a written report.

The assessment criteria for learning aim B do not explicitly require any access to an aircraft. The learners might simply be directed to report on the function and operation of the stipulated systems. However, if you have access to an aircraft, either on or off site, you may wish to make the assessment specific to that aircraft. The learners might generate a report where they identify the systems on the aircraft, document their type and operation and explain how they maintain the comfort and protection of the crew and passengers. You might create an assessment opportunity for 'analysis' by providing a scenario in which there is a system or sub-system failure and inviting the learner to explore and report on the ramifications. For 'evaluation' you might extend the task to include an exploration of alternative solutions to the system in hand and why these might be superior or inferior.

The assessment criteria for learning aim C follow precisely the same format as for learning aim B. The only difference being in the systems under investigation. With this similarity in mind, the suggestions proposed for learning aim B are equally valid for learning aim C.

Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 53: Airframe Mechanical Systems

Introduction

The most likely objective for any learner pursuing this unit is either in manufacture/assembly or maintenance of aircraft. With this in mind, familiarisation with the devices and systems involved within a realistic environment cannot be underestimated. Most of the systems could be investigated in isolation from the aircraft, but experiencing these in the ultimate context will give the best possible learning environment. Direct experience of working on a real aircraft will not only facilitate effective learning, but will also constitute invaluable and relevant industrial experience. In short, directly applicable skills and experience in the aerospace sector.

Where possible, have ready a wide range of example devices that can be handled, dismantled, inspected and explored. Let the learners develop knowledge through direct experience of handling these components. The operation and theory of these devices can then be readily developed.

Learning aim A – Investigate how the operation of hydraulic-power, landing-gear and flying-control systems contribute to safe flight

Hydraulic power systems and components

- Hydraulic transmission
  - Begin by establishing any previous or concurrent learning regarding hydraulics with the learner cohort. Where this learning is not present you will need to start by developing the fundamental principles of force and pressure in fluids.
  - Fluid types, properties and requirements can be covered theoretically, but take care to establish the typical types as used in airframe hydraulic systems, in particular any system the learners will use, be it on a real aircraft or the demonstration rig.
- Hydraulic power-supply systems and components
  - Power source function and layout. From the theoretical framework developed previously, you can now begin to introduce the practical applications, starting with pumps. Focus on the pump type(s) you have to hand but ensure the learners are aware of the different types that might be encountered and how these operate.
  - Identification, function and layout of fluid storage, control, conditioning and actuation components. This requirement will definitely profit from the use of a demonstration rig outfitted with a broad range of differing components. This will allow the operation of such devices to be explored in a comfortable and simplified environment prior to examining real devices in the context of an actual aircraft. In a real environment the devices may not immediately betray their function by appearance and may be heavily embedded within the airframe, making inspection difficult.
  - Operation of hydraulic power supply systems. This portion of the learning aim would definitely benefit from access to a live aircraft as the alternative will involve static images and verbal explanations, which will provide a poor substitute.

Landing gear systems and components

- Identification, function and layout of landing gear and retardation components
  - This could be explored through images and explanations, but since the assessment will ultimately require access to an aircraft, it would be sensible to ensure the learners have access, at the very least, to an isolated undercarriage assembly. The function and operation of the components could be explored through separate exercises. For example, the hydraulic actuators via the hydraulics rig.
  - Ensure that regardless of what undercarriage type you have acquired, the learners are made aware of the full range of devices that might be employed.
- Function and operation of extension/retraction system
  - This portion would ideally be delivered through the operation and examination of a real system in use. If you have access to an aircraft, this will of course require that the airframe can be supported to free the undercarriage. Note that there is a requirement to understand and interpret the indicators present in the cockpit.

Mechanically and hydraulically powered flight control systems

- Function and operation of mechanical flight control systems and identification, function and layout of system components
  - Begin by ensuring that the learners understand the purpose of flight controls and how these affect flight.
  - As suggested in the delivery guidance, you might want to utilise the systems present on an example aircraft. The learners could be invited to witness the effect of cockpit control input on flight control surfaces, and then investigate how these motions were transmitted.
  - Appropriate models of mechanical systems could be used to simulate such systems either as substitutions for the above or as supplementary support to the above.
- Function and operation of hydraulically powered flying control systems and identification, function and layout of system components
  - The requirements here are the same as for the previous section but involving specifically hydraulic devices.
  - Following previous suggestions, you should note that since the learners will be assessed on their ability to identify and explain these system components, it is essential that they have an opportunity to familiarise themselves with such items prior to assessment. This implies that they will require access to an aircraft, or at the very least, isolated segments of an aircraft that contain representative components.

Learning aim B – Examine how the operation of cabin environmental control and protection systems contribute to the protection of passengers and crew

Cabin environmental control systems and components

- Pneumatic-supply systems
  - Pneumatics can again be explored through the use of a suitable demonstration rig. However, the focus here is on the application within the airframe systems. From this perspective, the systems can again be explored from a purely hypothetical standpoint, but access to real systems would be preferable in order to contextualise their operation.

- Identification, function and layout of supply system components. Reference to example items might be made here, but again, examining the systems and their components in place on an aircraft would be preferable.

- Cabin air-conditioning and pressurisation systems and components
  - As suggested in the delivery guidance and in the assessment guidance, this segment might be conducted by visiting an MRO facility where some commercial aircraft is under a C or D check. With the system and its components exposed, the learners can be guided through the system and its operation.
  - The above activity should be supported by directed learning on return to your institution.

Cabin protection systems

- Function and operation of aircraft oxygen systems
- Identification, function and layout of cabin and crew equipment
  - Both of the above segments could be pursued with a visit to an active commercial aircraft. A member of cabin crew could be approached to guide the learners around the aircraft, directing their attention to the devices, how they are operated, and under what conditions they are operated.

Learning aim C – Examine how the operation of airframe fuel-, ice- and fire-protection systems contribute to safe flight

Airframe fuel systems and components

- Fuel types and properties
  - Assess the learners for previous or current learning regarding thermodynamics and the behaviour and properties of combustible substances. Link this learning to the present segment.
  - Indicate the importance of the parameters involved and guide the learners to explore the significance of these in light of the aircraft operation, in particular with regards to safety.
- Type and function of fuel additives, including ice and corrosion inhibitors, antioxidants, anti-static agents
  - This segment could only, realistically, be conducted theoretically. The emphasis is on developing learner comprehension on why these additives are necessary.
- Fuel system component identification and function
  - Direct viewing of such devices on an aircraft will be hampered by access restriction. You should acquire as many of the representative devices as possible for examination off aircraft. Ensure that these devices and their functions are placed in context regarding the overall system.
- Fuel-tank layout, e.g. wing inboard and outboard tanks, fuselage tanks, ventral tanks, longitudinal balance fuel system and trim tanks
  - This can be achieved by direct examination of an aircraft, but should be supported by adequate schematic representations to fully develop an understanding of the complexity of such systems. Link to the concepts of trim and balance as encountered in *Unit 48: Aircraft Flight Principles and Practice*.
- Fuel system operation
  - This follows logically from the previous section and again, direct inspection should be supported by schematic interpretation. Put each of the processes into context. Why might it be necessary to jettison fuel?

Aircraft anti-icing and de-icing systems

- Ice formation, rim ice, glaze ice and Hoare frost, effects of ice and snow
  - Again, link to *Unit 48: Aircraft Flight Principles and Practice*. What are the ramifications of ice accretion?
- Ice detection, eg probes, vanes, electronically activated, mass activated
  - If not present on an accessible aircraft, these will have to be explored purely theoretically.
- Function and operation of pre-emptive anti-icing systems
  - You should begin by stressing why an anti-icing system would need to be pre-emptive as opposed to reactive. Link directly to the relative importance or criticality of the systems in which anti-icing is applied.
  - Proceed to the demonstration or explanation of how these operate.
- Function and operation of reactive de-icing systems
  - As before, demonstrate or explain how these operate. Fire detection and extinguishing systems and components
- Fire detection
  - Fire-detection zones, including engines, APU, jet pipes, cargo compartment, toilets. Commence this segment by inviting the learners to consider why each of these zones requires fire detection, and then proceed by examining the potential dangers posed by ignition in any of these zones. Examine the likely sources of ignition.
  - Function and operation of fire/overheat detector systems. These systems will realistically be examined theoretically; however, if you have access to example devices, these can be energised and subjected to simulated conditions which will activate them for the purposes of examining operation.
  - Function and operation of smoke-, carbon monoxide- and flame-detection systems. This segment can be pursued in exactly the same manner as the previous one.
  - Nature of flight-deck and cabin-fire warnings, including location indicators, red lights, claxons and overheat indicators. Without access to an aircraft, this can be examined through a simulated cockpit display schematically or otherwise.
- Fire extinguishing
  - Commence with an examination of the differing classes of fire and the relevant suppressing techniques.
  - Proceed by examining the fire suppression systems, both user applied and automatic. Link the devices to the retarding chemical they contain and therefore the previous segment.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

Pearson BTEC International Level 3 Qualifications in Engineering:

- *Unit 50: Aircraft Gas Turbine Engines*
- *Unit 51: Aircraft Propulsion Systems*
- *Unit 54: Aircraft Electrical and Instrument Systems*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC International Level 3 Qualifications in Engineering. Check the Pearson website (http://qualifications.pearson.com/en/support/published-resources.html) for more information as titles achieve endorsement.

Textbooks

- Moir I & Seabridge A – *Aircraft Systems – Mechanical, electrical, and avionics subsystems integration, 3rd edition* (Wiley-Blackwell, 2008)
  ISBN 9780470059968.
  This textbook covers all of the systems detailed in this unit in great depth and detail. This makes a great resource for teaching but should be considered with care before being recommended as a resource for learners at Level 3. The complexity that many of the chapters reach is, fundamentally, beyond what the learners require or are expected to manage.
- Langton R et al – *Aircraft Fuel Systems, 1st Edition* (John Wiley and Sons Ltd, 2009) ISBN 9780470057087.
  Given the relative complexity of fuel systems, it is worth having a reference text to explain the manifold issues and devices involved. This text is exhaustive on the topic and should be treated with the same caution as the above text if you are considering making it available to the learners.