Unit 25: Aircraft Take-off and Landing Performance

Unit code: T/504/3883

QCF Level 3: BTEC Nationals

Credit value: 4

Guided learning hours: 24

Aim and purpose

The aim of this unit is to give learners an understanding of how aircraft performance during the critical phases of take-off and landing is measured and can be altered.

Unit introduction

It is widely understood that the most safety critical phases of flight are during the take-off and landing processes. What is less well understood is that, to a large extent, it is the actions and diligence of airport ground crews that helps to ensure commercial aviation remains safe throughout the entire flight. In the context of this unit, aircraft performance relates to the way in which an aircraft is able to take-off, climb, descend and land. Not all aircraft can operate from all airports – learners will find out why.

Before exploring the role of the ground crews learners must first examine why the take-off and landing processes are considered to represent a higher risk than other phases of flight. To do this, learners will look at how lift is generated and how it is possible for a 500-tonne piece of machinery to fly.

Learners will then be introduced to some of the criteria that are used when calculating aircraft performance. This will include elements of aircraft performance (for example speed, weight and rate of climb) and also airfield factors (for example runway length, runway slope and elevation of airfield).

The way in which aircraft performance is measured during take-off and landing is examined. This will help to explain how a pilot can be sure that the take-off, climb out, approach and landing phases will all be conducted safely.

On completion of this unit, learners will appreciate how they can help contribute to flight safety, whether employed by an airline, a ground handling agency or an airport authority.

Learning outcomes

On completion of this unit a learner should:

1 Understand how aircraft performance is measured

2 Understand factors that affect aircraft performance at take-off and landing.

Unit content

1 Understand how aircraft performance is measured

Lift generation:

- wing shape, e.g. camber, area
- airflow, e.g. laminar, turbulent
- angle of attack, e.g. increase lift, stall
- air temperature/density, e.g. lift reduction

Aircraft performance criteria:

- groundspeed
- airspeed (V1, Vr, V2)
- aircraft required distances, e.g. take-off distance required (TODR), landing distance required (LDR)
- rate of climb (feet per minute)
- rate of descent

Airport performance criteria:

- runway declared distances, e.g. take-off run available (TORA), take-off distance available (TODA), emergency distance available (EMDA), landing distance available (LDA)
- runway slope, e.g. up, down
- runway surface, e.g. hard/dry, grass
- obstacles, e.g. clearway, climb-out

2 Understand factors that affect aircraft performance at take-off and landing

Effects of increased mass on take-off performance:

- aircraft limits, e.g. maximum take-off mass (MTOM), regulated take-off mass (RTOM), maximum landing mass (MLM)
- causes, e.g. passenger load, cargo, fuel, ice build up
- degraded take-off performance, e.g. inertia, longer take-off run, reduced climb-out performance, reduced obstacle avoidance capability
- climb-out performance, e.g. climb rate at given altitudes

Effects of increased mass on landing performance:

- degraded landing performance, e.g. momentum, longer landing run

Effects of moving centre of mass (balance):

- incorrect balance, e.g. nose heavy (rotation and flare), tail heavy (tail strike, tipping)

Environmental factors that must be considered:

- airfield location, e.g. airfield elevation, air density
- weather related, e.g. air temperature, wind (direction, strength)
- runway contamination, e.g. water, snow, ice
- wing contamination, e.g. ice, snow

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 Describe key elements of aircraft lift	**M1** Explain how an aircraft operator uses published runway data to assess safe aircraft performance	**D1** Assess the methods employed by airport authorities and aircraft operators to ensure safe aircraft take-off and landing performance is maintained
P2 Explain how take-off and landing performance is measured		
P3 Describe airport runway measurement criteria [IE]		
P4 Explain how changes in aircraft mass and balance affect take-off and landing performance	**M2** Analyse how runway declared distances and environmental factors can combine to restrict take-off mass	
P5 Explain how environmental factors can affect take-off and landing performance		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

It is anticipated that this unit will be delivered primarily through class-based theoretical input, possibly enhanced by visits to airports or the inclusion of guest speakers. For learners already employed at an airport, it would be advantageous for them to explore runways, examine clearways and runway end safety areas (RESAs) and speak to loaders, dispatchers and flight crew.

To provide a context, delivery should start with an explanation of what is meant by aircraft performance and why the take-off and landing elements deserve special attention.

As aircraft performance is directly related to an aircraft's ability to generate lift, learners should then be introduced to the theory of lift production. This can be limited to wing shape, airflow, angle of attack, air temperature and density. There are numerous short video clips available online, together with pilot training manuals, to support this input.

Learners should be introduced to the difference between groundspeed and airspeed, which leads directly to critical speeds (V1, Vr, V2) and the runway distances required.

Once lift and speed is understood, learners should explore the fundamentals that allow aircraft performance at specific airports to be calculated. Using the criteria in the unit content, actual data from UK airports (National Air Traffic Service (NATS) AIS website) and aircraft (manufacturer's websites) can be collated to assess theoretical compatibility. Particular attention should be paid to individual aircraft performance data and how this must be modified to allow for aircraft mass, runway slope, altitude, temperature and other influencing factors. Once again, there are a number of quite dramatic video clips, often taken by members of the public, that illustrate when performance calculations were perhaps not as thorough as they might have been (search for "scary landing/take-off" – emphasise to learners that these are exceptional – not the norm!).

The unit continues by examining how changes to loading will affect aircraft take-off and landing performance. Initially, it would be useful to look at a selection of typical commercial aircraft, from regional (for example Dash 8, ATR42) to long-haul (for example B777, A380) to discover how great the capacity (passenger and cargo) and weight range are. This can be followed up by examining performance data from the manufacturers (e.g., http://www.boeing.com/commercial/airports/plan_manuals.html and http://www.airbus.com/fileadmin/media_gallery/files/tech_data/AC/Airbus-AC-A380-20111101.pdf).

Performance tables can be quite complex, so it is important to select only one or two representative tables to illustrate the differences in take-off or landing run and maximum take-off or landing mass.

When learners have seen examples of changes to aircraft performance, they should be encouraged to suggest why these changes occur (for example increased take-off mass increasing inertia, resulting in a longer take-off run to achieve the required take-off speed, or increased elevation of the airfield resulting in reduced air density meaning the creation of lift is restricted).

The consequential difference between maximum take-off mass (MOTM) and regulated take-off mass (RTOM) should be explained to learners and the implications on day-to-day operations at weight critical or short runway airports.

The significance of correct and incorrect positioning of load on an aircraft must be emphasised to learners. An aircraft may be within its mass restrictions but be loaded in such a way that it is unbalanced and therefore dangerous especially during take-off or landing. To illustrate the balance calculation process it would be useful to include completion of a simple aircraft balance chart as a project. It may be possible to obtain a blank manual mass and balance chart from an airline or handling agent for this purpose. Learners should be encouraged to predict the potential outcome of grossly unbalanced aircraft (for example nose heavy, tail heavy).

To conclude the unit, the influence of external factors must be examined. Including the topics in the unit content, learners should by now be able to anticipate how such factors may degrade (or improve) aircraft take-off and landing performance. Their hypothesis can be verified by reference to the performance charts they have already discussed.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way of planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Introduction to the unit including overview of why take-off and landing are the most critical phases of flight.
Tutor input and class discussion – how lift is generated, including descriptions of wing types, wind shapes, airflow, angle of attack and the significance of air density.
Tutor input and research – discuss the difference between groundspeed and airspeed. Explain significance of V1, Vr, V2 and their relationship with take-off distance required (TODR). Extend the discussion to include landing distance required (LDR) and climb/descent rates.
Tutor input and research airport data – how runway characteristics are measured: runway declared distances, slope, surface and obstacles (use actual data as examples).
Combine the learning from P1, P2 and P3, using published airport and aircraft data, to predict whether a specific aircraft could safely take-off or land at a particular airport under 'standard day' conditions.
Preparation for assignment **Assignment 1: Aircraft Performance** (P1, P2, P3, M1) **Feedback on assignment**
Class discussion – how increasing aircraft mass or loading an aircraft in an unbalanced way can affect take-off or landing performance. Demonstrate calculations by creating a simple mass/balance chart.
Tutor input and class discussion – how environmental factors can affect aircraft performance including: elevation, temperature, wind, runway contamination, wing contamination.
Combine existing knowledge of runway-declared distances with environmental factors to discover how allowable mass may be reduced (or increased) on a day-to-day basis. Use published performance tables to demonstrate how these modifications are calculated.
Class discussion – how airport authorities and aircraft operators ensure safe take-off and landing performance is maintained. This should include elements discussed above together with: accurate measurement of obstacles, frequent weather reports (wind, temperature), reporting and clearance of runway contaminants (snow, ice, flooding), restricting aircraft loads.
Preparation for assignment **Assignment 2: Factors Affecting Performance** (P4, P5, M2, D1) **Feedback on assignment**

Assessment

This unit could be assessed in a number of ways, for example through a brief portfolio, a training booklet for new ramp staff or conventional assignments including a presentation. The format is designed so merit and distinction criteria extend naturally from the pass criteria.

P1 – P2 – P3 – M1

To achieve P1, learners will need to describe key elements of aircraft lift, with particular reference to the take-off and landing phases of flight. Whilst not requiring aerodynamic formulae, learners must be able to describe the principles.

To achieve P2, learners will need to explain different ways in which aircraft take-off and landing performance is measured. This should include aircraft speeds, runway required distances and climb rates.

To achieve P3, learners must describe runway measurement criteria including: available runway lengths, runway slope, runway surface, obstacles. Published data from UK airports should be used to illustrate the examples.

To achieve M1, learners must explain how an aircraft operator uses published runway data to assess safe aircraft performance. Examples taken from both aircraft performance tables and airport runway data should be compared to demonstrate that, under given conditions, safe take-off or landing is theoretically possible.

P4 – P5 – M2 – D1

To achieve P4, learners will need to explain how changes to aircraft mass and balance affect take-off and landing performance. Explanations should include all items of the unit content, for example increase take-off run, increase landing run, reduce climb rate.

To achieve P5, learners will need to explain how environmental influences may further affect aircraft performance at take-off and landing. All items of the unit content should be included, for example airfield elevation, wind velocity, runway contamination.

To achieve M2, learners must analyse how runway declared distances and environmental factors can combine to restrict take-off mass. It is expected that a simple take-off or landing performance calculation would be included, demonstrating that 'standard day' data may have to be modified to accommodate deviations.

To achieve D1, learners must assess, using actual examples, methods aircraft operators and airport authorities use to ensure safe take-off and landing performance is maintained. This should combine data used in M1 and M2 and be extended to include measuring and interpreting factors such as air temperature, wind velocity, runway contamination, obstacles and runway surface contamination.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, M1	Assignment 1: Aircraft Performance	Working for a ground handling agency, create an induction session for new ramp employees.	Presentation Information pack
P4, P5, M2, D1	Assignment 2: Factors Affecting Aircraft Performance	Working for a ground handling agency, create an induction pack for new ramp employees.	Report and sample calculations Case study Presentation

Links to other BTEC units

This unit forms part of the BTEC aviation sector suite. This unit has particular links with the following unit titles in the aviation suite.

Level 2	Level 3	Level 4
n/a	Unit 24: The Principles of Flight	n/a

Essential resources

Learners should have access to library and research facilities. Internet access is particularly important as much of the required material is accessible from web-based sources.

Printed copies of selected performance data would be useful to avoid learners being overwhelmed by the vast numbers found on manufacturer's web pages.

Copies of mass and balance charts are needed.

Employer engagement and vocational contexts

Visits to airports (airside if possible) and guest speakers would enhance the classroom input.

Indicative reading for learners

Publication

CAP 642 Airside Safety Management (Civil Aviation Authority, 2006) ISBN 978-0860396109

Journals

Airports International – *Key Publishing Ltd*

Flight International – *Reed Business Publishing*

Websites

www.boeing.com/commercial/airports/plan_manuals.html	Boeing – information on airplane characteristics
www.nats-uk.ead-it.com/public/index.php.html	NATS – aeronautical information site
www.takeofftube.com	Take Off Tube – online aviation video clips

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	investigating runway measurement criteria and published runway data making comparisons with aircraft performance tables.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Independent enquirers	exploring the factors that affect aircraft performance
Team workers	working in groups to discuss the factors that affect aircraft performance
Self-managers	managing the workload of the unit.

Functional Skills — Level 2

Skill	When learners are ...
ICT — Use ICT systems	
Select, interact with and use ICT systems independently for a complex task to meet a variety of needs	using a variety of systems to explain how aircraft performance is measured
Use ICT to effectively plan work and evaluate the effectiveness of the ICT system they have used	planning and carrying out research using appropriate search criteria
Manage information storage to enable efficient retrieval	organising work into folders to enable retrieval and development
Follow and understand the need for safety and security practices	logging in to a variety of systems securely and visiting trusted websites
Troubleshoot	as required.
ICT — Find and select information	
Select and use a variety of sources of information independently for a complex task	investigating runway measurement criteria and exploring aircraft performance tables
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	using appropriate search criteria in order to select suitable published runway data.
ICT — Develop, present and communicate information	
Enter, develop and format information independently to suit its meaning and purpose including: • text and tables • images • numbers • records	entering and developing images, diagrams and text to communicate how aircraft performance is measured
Bring together information to suit content and purpose	collating notes and research findings to explain how factors can affect aircraft performance
Present information in ways that are fit for purpose and audience	explaining how aircraft performance is measured coherently and accurately
Evaluate the selection and use of ICT tools and facilities used to present information	selecting the most appropriate ICT tools to produce presentations and reports throughout the unit
Select and use ICT to communicate and exchange information safely, responsibly and effectively including storage of messages and contact lists	receiving and sharing published documents with and from tutor and colleagues, paying attention to confidentiality issues.
Mathematics	
Understand routine and non-rotine problems in a wide range of familiear and unfamiliear contexts and situations	exploring the factors that affect aircraft performance at take-off and landing
Identify the situation or problem and the mathematical methods needed to tackle it	

Skill	When learners are ...
Mathematics	
Select and apply a range of skills to find solutions	carrying out sample calculations
Use appropriate checking procedures and evaluate their effectiveness at each stage	
Interpret and communicate solutions to practical problems in familiar and unfamiliar routine contexts and situations	exploring the factors that affect aircraft performance at take-off and landing.
Draw conclusions and provide mathematical justifications	
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	working in groups to interpret and discuss complex aircraft performance data
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	reading published runway data from UK airports
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	writing a report on factors affecting aircraft performance.