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Australian Government
Civil Aviation Safety Authority

Civil Aviation Advisory Publication

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Multi-engine aeroplane operations and training

This Civil Aviation Advisory Publication (CAAP) provides guidance, interpretation and explanation on complying with the *Civil Aviation Regulations 1988* (CAR) or a Civil Aviation Order (CAO).

This CAAP provides advisory information to the aviation industry in support of a particular CAR or CAO. Ordinarily, the CAAP will provide additional 'how to' information not found in the source CAR, or elsewhere.

Note: *Read this advisory publication in conjunction with the appropriate regulations/orders.*

This CAAP will be of interest to:

- multi-engine aeroplane pilots
- flight instructors
- approved testing officers (ATO)
- flying training providers.

Why this publication was written

Following a number of multi-engine aeroplane accidents caused by aircraft systems mismanagement and loss of control by pilots, flight instructors and persons approved to conduct multi-engine training, this CAAP was written to address threats and errors associated with multi-engine operations and provide advice on multi-engine training. This CAAP also includes competency standards for multi-engine operations, suggested multi-engine and flight instructor training syllabi and a questionnaire to assist pilots to learn and assess their aircraft systems knowledge.

Status of this CAAP

This is the third CAAP to be written on this subject. This CAAP will be superseded with a Part 61 Advisory Circular (AC) in the future.

For further information

Telephone Flight Standards Branch on 131 757.

Contents

1. The relevant regulations and other references

- CAOs:
  - 20.7.0: Aeroplane weight limitations – General
  - 20.7.4: Aeroplane weight & performance limitations – Aeroplanes not above 5,700 kg – Private aerial work
  - 20.7.1B: Aeroplane weight & performance limitations – Aeroplanes above 5,700 kg – All operations (turbine & piston-engine)
- Part 61 Manual of Standards (MOS)
- Parts 23 and 25, 61, 141 and 142 of *the Civil Aviation Safety Regulations 1998 (CASR)*
- Flight Training-Multi-Engine Rating–R. D. Campbell
- Flying High Performance Singles and Twins – John Eckalbar
- Multi-Engine Flight Manual for Professional Pilots – John Chesterfield
- Multi-Engine Piston-Aviation Theory Centre – David Robson
- Understanding Light Twin Engine Aeroplanes – Russ Evans
- 'Even worse than the real thing' Flight Safety Australia, March-April 2002
- Civil Aviation Authority Publication (CAP of the United Kingdom) 601 – Multi-Engine Piston Aeroplane Class Rating Training Syllabus
- Federal Aviation Administration (FAA) AC 61-9B – Pilot Transition Courses for Complex Single-engine and Light Twin-Engine Airplanes
- FAA Flight Instructor Training Module Volume 2 System Safety – Course Development Guide
- Transport Canada-Instructor Guide – Multi-Engine Class Rating
- ICAO Doc 10011 Manual on Aeroplane upset prevention and recovery Training

2. Acronyms

AC	Advisory Circular
AC	Alternating Current
AGL	Above Ground Level
amsl	Above Mean Sea Level
AOC	Air Operator's Certificate
ASI	Air Speed Indicator
ATC	Air Traffic Control
ATO	Approved Testing Officer
ATPL	Airline Transport Pilot Licence
ATSB	Australian Transport Safety Bureau
AUW	All Up Weight
CAAP	Civil Aviation Advisory Publication

CAO	Civil Aviation Order
CAR	Civil Aviation Regulations
CASA	Civil Aviation Safety Authority
CFI	Chief Flying Instructor
CG	Centre of Gravity
CPL	Commercial Pilot Licence
CRM	Crew Resource Management
CSU	Constant Speed Unit
DA	Decision Altitude
DC	Direct Current
EFATO	Engine Failure After Take-off
ELT	Emergency Locator Transmitter
ENR	En-route
ETP	Equi Time Point
FAA	Federal Aviation Administration (of the USA)
FAR	Federal Aviation Regulation (of the USA)
fpm	feet per minute
FTO	Flying Training Organisation
IAS	Indicated Air Speed
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
ISA	International Standard Atmosphere
ITT	Interstage Turbine Temperature
MAP	Manifold Air Pressure
MAUW	Maximum All Up Weight
MDA	Minimum Descent Altitude
MOS	Manual of Standards
N1	Gas Generator Speed
N2	Second Stage Turbine Speed
Ng	Gas Generator Speed
Np	Propeller Speed
NTS	Negative Torque Sensing System

OAT	Outside Air Temperature
OEI	One Engine Inoperative
PIC	Pilot-in-Command
POB	Persons on Board
POH	Pilot Operating Handbook
RPM	Revolutions per minute
SOP	Standard Operating Procedures
TAS	True Air Speed
TEM	Threat and Error Management
VFR	Visual Flight Rules
VP	Variable Pitch Propellers
V	Velocity
V_A	Maximum Manoeuvring Speed
V_{FE}	Flap Extension Speed
V_{LE}	Maximum Speed with Landing Gear Extended
V_{LO}	Landing Gear Operating
V_{LO2}	Landing Gear Operation Down
V_{MC}	Minimum Control Speed
V_{MCA}	Minimum Control Airspeed Airborne (Red line speed)
V_{NE}	Never Exceed Speed
V_{NO}	Normal Operating Speed
V_{S0}	Stall Speed with Undercarriage and Flap Selected
V_{S1}	Clean Stall Speed
V_{SSE}	Safe Single-engine Speed
V_{TOSS}	Take-off Safety Speed
V_X	Best Angle of Climb Speed
V_{XSE}	Best Single-engine Angle of Climb Speed
V_Y	Best Rate of Climb Speed
V_{YSE}	Best Single-engine Rate of Climb Speed (Blue line speed)
V_1	Take-off Decision Speed

3. Definitions

AEROPLANE/AIRCRAFT IS BALANCED: The skid ball in the balance indicator is less than a quarter of the ball diameter from the centre. In a multi-engine, asymmetric aeroplane with bank toward the functioning engine, the aircraft is balanced when the ball is positioned vertically below the fore-aft axis.

AIRCRAFT IS TRIMMED: The aircraft is trimmed within 10 seconds of achieving stabilised and balanced flight, after an attitude, power or configuration change, so that no control input is required from the pilot to maintain this state. During asymmetric operations aircraft trimmed within 10 seconds of Phase 1 actions.

BETA: Manually controlled mode for constant speed propellers on turboprop aircraft.

GO-AROUND: A pilot initiated abandonment of a visual approach for a landing.

SAFE (LY): Means that a manoeuvre or flight is completed without injury to persons, damage to aircraft or breach of aviation safety regulations, while meeting the standards specified by the Civil Aviation Safety Authority (CASA).

VISUAL COMMITTAL HEIGHT: A nominated height at or above which a safe asymmetric go-around can be initiated, and below which the aircraft is committed to land.

4. Background

4.1 An Australian Transport Safety Bureau (ATSB) Aviation Research Report analysed accidents and incidents over a ten-year period caused by power loss in twin-engine aircraft weighing less than 5,700 kg. Of the 57 accidents investigated, one third were double engine failures, the majority caused by fuel exhaustion due to mismanagement. Eleven of the accidents were fatal and 10 of the fatalities were caused by loss of control of the aircraft. Forty-six percent of the engine failures happened during take-off, rather than any other phase of flight. Additionally, 16% of reported multi-engine accidents were associated with planned power losses during training.

4.2 These statistics indicate that fuel mismanagement leading to double engine failures caused a significant number of accidents. Asymmetric engine failures led to 10 fatal accidents that were due to loss of control of the aeroplane. It is not unrealistic to assume that inadequate aircraft systems knowledge or practice, lack of familiarity with asymmetric aircraft handling, and inadequate management of asymmetric training are noteworthy reasons that multi-engine aircraft accidents occur.

4.3 The ATSB Aviation Research Report B2005/0085 provides additional interesting information and is available at www.atsb.gov.au.

4.4 Personnel responsible for competent operation of an aircraft

4.4.1 Regulation 61.385 of CASR clearly states that it is the pilot's responsibility to ensure that they are competent to operate all the aircraft systems, and to perform normal and emergency flight manoeuvres, as well as calculate aircraft performance and weight and balance, and complete all required flight planning.

4.4.2 The difficulty with this requirement is that some pilots may be relatively inexperienced and unable to competently assess their ability to comply with the order. Normally, pilots assume that if they complete the required training then they meet the above requirement. This may not always be the case, and the information that follows in this CAAP will help pilots to determine if they meet the requirements of regulation 61.385 of CASR.

4.5 Engine shutdowns while in flight

4.5.1 Any pilot qualified to operate a multi-engine aircraft may shutdown an engine in flight. However, CASA strongly recommends that this only be done with a qualified flight instructor present, as there is likelihood for errors and engine mismanagement. Flight instructors regularly practice this procedure and are less likely to cause problems.

4.5.2 In addition, engines must not be shut down in flight when carrying passengers (except in an actual emergency), as emergency training is not permitted when transporting them. CASA also recommends that passengers not be carried on training flights as they can be a distraction and limit the type of training that may be conducted.

4.6 Multi-engine endorsement requirements

4.6.1 Subpart 61.L of CASR includes the legislative requirements for aircraft ratings and endorsement as applicable to the aircraft type the pilot intends to operate.

4.7 Certification of multi-engine aeroplanes

4.7.1 An understanding of the weight and performance limitations of multi-engine aeroplanes requires an understanding of the performance of single-engine aeroplanes.

4.7.2 The Pilots Operating Handbook (POH) or Flight Manual for most single-engine aeroplanes provides for two requirements for climb capability:

- **Take-off** - the aeroplane in the take-off configuration at maximum weight with maximum power must have an adequate climb capability in standard atmospheric conditions. For most light aeroplane types, adequate climb capability is defined as either 300 feet per minute (fpm) or a gradient of 1:12 (8.3%) at sea level.
  - This definition is given in Part 23 of the US FAA Federal Aviation Regulations (FAR) regulations (see FAR 23.65). Paragraph 7.1 of CAO 20.7.4 specifies a minimum take-off gradient of 6%. CAO 20.7.4 is expected to be repealed when Parts 91 and 135 of CASR commence.
- **Baulked Landing** - the aeroplane in the landing configuration at maximum weight with maximum power must have an adequate climb capability in standard atmospheric conditions. For most light aeroplane types, adequate climb capability is defined as either 200 fpm or a gradient of 1:30 (3.3%) at sea level.
  - This definition is given in Part 23 of the US (see FAR 23.77). Paragraph 9.1 of CAO 20.7.4 specifies a landing climb gradient of 3.1%. CAO 20.7.4 is expected to be repealed when Parts 91 and 135 of CASR commence.

4.7.3 Light multi-engine aeroplanes with all engines operating must possess the climb capabilities described above for single-engine aeroplanes. In addition, light multi-engine aeroplanes with one engine inoperative (OEI) must have an adequate climb capability at 5,000 ft density altitude. For most light aeroplane types, adequate climb capability with OEI is a positive rate of climb at 5,000 feet density altitude. This definition is given in Part 23 of the FAR (see FAR 23.67). Subsection 8 of CAO 20.7.4 specifies en-route climb gradients of 0% and 1%. CAO 20.7.4 is expected to be repealed when Parts 91 and 135 of CASR commence.

4.7.4 At practical operating weights, light multi-engine aeroplanes do not have climb capability with OEI after take-off. It is usually not until the propeller has been feathered, the aeroplane's undercarriage and wing flaps have been retracted and its airspeed reaches the optimum speed (V_{YSE}) that light multi-engine aeroplanes have the capability to climb with OEI.

4.7.5 This is most significant for pilots of light multi-engine aeroplanes. It means that if the aeroplane suffers an engine failure shortly after take-off it is unlikely to be able to climb. It is more likely that the aeroplane will descend and the pilot will have no alternative other than a forced landing.

4.7.6 Multi-engine aeroplanes with maximum take-off weight greater than 5,700 kg have performance requirements that are significantly different to those of light multi-engine aeroplanes. Large multi-engine aeroplanes must have the capability to climb with OEI after take-off regardless of the configuration of the propeller, wing flaps and undercarriage. It is important that pilots of light multi-engine aeroplanes understand that their aeroplanes do not possess the same climb capability as large aeroplanes.

4.8 Recent experience

4.8.1 Subpart 61.E of CASR includes the legislative requirements for recent experience as applicable to the aircraft class or type the operator is intending to operate.

4.9 The aim of recency

4.9.1 The pilot should be familiar and competent to plan the flight and operate and control the aeroplane. Before getting airborne, pilots must ensure that all possible pre-flight contingency planning is completed and normal and emergency procedures can be confidently and competently managed.

Things the pilot should take into consideration include would they be able to:

- load the aircraft to ensure adequate post take-off asymmetric performance on the day of the flight?
- calculate single-engine climb performance?
- manage a take-off or landing with a maximum permissible crosswind?
- manage an engine failure after take-off?
- confidently cross-feed and balance fuel during asymmetric flight?
- manage fuel pump failures?
- manage electrical/electronic malfunctions?
- manage propeller malfunctions?
- manually lower the undercarriage?
- manage an unexpected malfunction/failure during the en-route flight phase and divert to an unfamiliar aerodrome?

4.9.2 If the answer to any of the items listed above is 'No', then a review of the POH, Operations Manual or some flight training is required. Recency may not be an issue for a pilot who is operating a multi-engine aeroplane on a regular basis and receives ongoing training, but could be a significant problem for a pilot who flies infrequently, or has not practiced asymmetric operations in recent times.

5. Multi-engine training

5.1 The importance of receiving good multi-engine training

5.1.1 Good training for any aircraft type is extremely important. However, training is normally more involved in a multi-engine aircraft because of additional and complex systems and flight characteristics that require increased management and skills. The first multi-engine endorsement that a pilot receives is probably the most crucial.

5.1.2 During this training it is critical that aircraft systems and normal and asymmetric flight characteristics are well understood and practiced, and the pilot can comfortably maintain control of the aircraft under all circumstances. This can be achieved if the training is comprehensive and pilots apply themselves to attain these goals.

5.1.3 Professional organisations such as airlines, charter operators and defence forces acknowledge the importance of good flight training and dedicate considerable expenditure to this task. As there are financial costs to obtain safety training, each pilot should carefully consider what training they require to operate a multi-engine aircraft safely. The standards included in this CAAP detail what the pilot must be able to achieve at the end of their training. It also provides advice for them to determine if they are competent to safely operate a multi-engine aeroplane weighing less than 5,700 kg. However, also included in this CAAP is guidance on training techniques and practices that should lead to the development of a good level of competency and confidence.

Note: For information on training syllabus requirements refer to the Part 61 MOS and the flying training organisation operations manual.

5.2 Qualified multi engine flight training organisation

5.2.1 A flying training organisation (FTO) that has the multi-engine aircraft included in the Air Operator Certificate (AOC), and a multi-engine syllabus of training contained in the Company Operations Manual, is permitted to conduct multi-engine training.

Additionally, a flight instructor must hold a multi-engine or type rating training endorsement.

5.3 Choosing a flying training organisation

5.3.1 Many FTOs offer multi-engine training. This CAAP emphasises the importance of receiving good training, particularly for a pilot’s first multi-engine endorsement, and the selection of a flight-training operator will their decision. It is important for the pilot to be well informed when making such a decision.

5.3.2 A personal recommendation from another pilot is always helpful. However, the pilot should not consider a recommendation based solely on cost. It would be worthwhile for the pilot to research a number of operators across the market to see what they have to offer.

5.3.3 The first item to examine is the syllabus of training that all FTOs must have in their operations manual. It should detail in a logical sequence all the theory and flight training exercises involved in the course. For guidance, refer to the Part 61 MOS and map the requirements against this document. The pilot should ask how many flying hours will be involved. Experience has shown that it is unlikely that all the flight sequences for multi-engine aeroplane class rating or a type rating can be adequately covered in less than 5-7 hours of flight time.

5.3.4 The same time frame applies to the aeronautical knowledge training. A structured, well-run course should be the pilot's goal. In selecting a training provider to conduct their training, trainees should ensure that the organisation has an appropriate written syllabus and training plan.

5.3.5 CASA requires training providers to supply adequate and appropriate training facilities before an AOC is issued. However, the pilot should examine the facilities and look for:

- briefing facilities (lecture rooms and training aids)
- flight manuals and checklists
- training notes
- reference libraries
- comprehensive training records
- sufficient experienced instructors (available at the time of enquiry)
- flight testing capability close to the end of training.

5.3.6 The pilot should then inspect the aircraft. It should be well presented and clean. The interiors should be neat with no unnecessary equipment or publications left inside. Windows should be clean and unscratched, and the condition of the paintwork is often an indicator of the care taken of the aircraft.

5.3.7 To ensure training is not delayed due to aircraft unserviceabilities, the pilot should also:

- examine maintenance documents to ensure there are no long-standing unserviceabilities
- review the maintenance release to ensure that unserviceabilities are entered (as sometimes this is not done).

5.3.8 The next component to review is the flight instructor. The value of a flight instructor who helps the pilot gain knowledge and skills and develop a positive and robust safety culture cannot be over emphasised. The pilot should ensure they are satisfied with the instructor's performance and professional behaviour. It is important for the pilot to:

- discuss their aims and any concerns they may have about the flight training
- establish good communication
- determine that the instructor is available when they are. Some training providers will substitute flight instructors and this can cause time wasting while the new instructor re-assesses the trainee to establish what training is required.

5.3.9 The pilot should not just accept an instructor that they feel uncomfortable with or have doubts about.

5.4 Knowledge training

5.4.1 Logical and comprehensive briefings by flight or specialist technical instructors are an essential component of pilot training. Ideally, the aeronautical knowledge briefings should be coordinated with their flight training to ensure that maximum benefit can be gained.

5.4.2 CASA recommends use of the publications listed in Section 1 that provide excellent guidance material for multi-engine pilots and any others that are equivalent. The pilot should study such documents well before starting their multi-engine training. It is also important to ensure that a flight manual or POH is readily available. The pilot should become very familiar with this document to ensure that they are comfortable using all the performance charts and tables. They should also familiarise themselves with the layout and table of contents of flight manuals, and know how to quickly look for any information that is needed.

5.4.3 A good knowledge of the aircraft systems, performance planning and fuel management can reduce, if not eliminate, the chance of multi-engine accidents occurring. An important aspect of safe operations is the ability to apply knowledge in a practical sense. Being able to apply knowledge to analyse faults and make appropriate decisions can enhance safe operations. Too often pilots have only superficial knowledge that enables them to manage normal operations, but may limit their performance during abnormal situations. Therefore, pilots must apply themselves to understand and manage aircraft performance and systems confidently and competently.

5.5 Flight training

The purpose of flight training is to teach a pilot to control the aircraft, and to operate and manage all the aircraft systems in normal and abnormal flight. During training, pilots should be shown all the flight characteristics of the aircraft, and be given adequate time and practice to consolidate their skills.

5.6 Understanding and operating the aircraft systems

5.6.1 Good training and conscientious application by a pilot can ensure confidence and competence when operating all the aircraft systems. It is important to refine knowledge obtained through study of the reference publications and the approved flight manual and apply it to the aircraft. Pilots should not forget that competence and recency are as important as each other. If the pilot does not fly regularly, they should review the flight manual to refresh their systems knowledge before flying.

5.6.2 The following paragraphs offer advice about issues, characteristics and some potential ‘traps’ of individual aircraft systems.

5.7 Fuel system

5.7.1 Mismanagement of the fuel system has been the cause of many multi-engine accidents. These accidents included:

- poor fuel planning leading to fuel exhaustion
- inappropriate use of engine controls
- cross-feed and fuel pump mismanagement
- incorrect tank selection
- failure to visually inspect fuel contents.

5.7.2 Fuel system configuration and operation vary with aircraft type and range from simple to complex. The simplest system may have one fuel tank in each wing with a cross-feed system to transfer fuel from one side to the engine on the opposite wing. More complex systems may have three fuel tanks on each side with multiple tank selections and cross-feed combinations, using auxiliary fuel pumps. Fuel systems may even be different in similar models.

5.7.3 It is vitally important that the pilot understands the configuration and operation of the fuel system in the aircraft they are flying.

5.7.4 There is a lot of benefit in just sitting in an aircraft on the ground and using the fuel system (or any other systems) controls to accommodate various scenarios. This type of practice, while not under pressure of actually flying the aircraft, can be an effective learning experience.

5.7.5 Visual inspection of fuel contents applies to all aircraft types, but some larger multi-engine aircraft may have fuel tanks that are difficult to inspect. For example, wing tip tanks are often hard to reach. It is particularly important to check the contents on the first flight of the day after the aircraft has been standing overnight. There have been numerous incidents of fuel being drained from the tanks of unguarded aircraft, in some cases with tragic results.

5.7.6 Fuel gauges in some aircraft can be inaccurate and must be used with a calibration card. Tanks should be dipped and the amounts compared to the fuel log and actual gauge indications.

5.7.7 Pilots should know exactly how much fuel is in the aircraft on start, be familiar with the expected fuel flow rate of the aircraft and monitor these rates in flight to confirm normal engine performance.

5.8 Engines

5.8.1 Modern multi-engine aeroplanes can be fitted with a variety of engines including normally aspirated and turbo/supercharged piston engines and turboprops. Most pilots would be familiar with normally aspirated engines and should operate them within prescribed limitations. However, supercharged or turbocharged engines require extra attention. Older supercharged engines are susceptible to over and under boosting, which can cause significant damage to an engine. Pilots must carefully monitor engine performance at all times, but particularly when applying full power or descending rapidly so that manifold pressure limitations are not exceeded.

5.8.2 Modern turbocharged engines are generally fitted with an automatic waste gate and are simple to operate. It is important to use all the engine controls smoothly and not too rapidly, and in the correct sequence. If the pilot is going to fly an aircraft with fixed or manual waste gates a little more attention needs to be paid to engine management and the manifold pressure gauge may require more monitoring. As turbochargers are driven by exhaust gas, they are subject to high temperatures.

5.8.3 Prior to shutdown, it is important to ensure that the temperature of the turbocharger has stabilised (comply with POH time limits), and if the cylinder head temperature is in the normal range this is also an indication that the turbocharger is within shutdown temperature limits.

5.8.4 Turbine propeller or turboprop engines are generally less difficult to manage than a piston engine. They are reliable and quite rugged. However, there have been cases of the compressor stalling in these types of engines when intakes are affected by ice build-up. Care should be taken when operating in these conditions.

5.8.5 Pilots should also pay attention when starting turboprop engines. If excessive fuel gets to the combustion chambers, or the engine is slow to accelerate (possibly caused by low battery voltage), a ‘hot start’ can occur. This is likely to cause expensive damage and ground the aircraft. However, if the engine is operated within the prescribed limitations, it will provide reliable service.

5.8.6 On aeroplanes fitted with propellers, one engine has a greater yawing moment because of the effects of lift being produced by the down going propeller blade when the wing has an increased angle of attack. American built engines rotate clockwise when viewed from behind. Additionally, torque and slipstream effect add to the control difficulty. Therefore, the thrust of the down going blade of the right engine has a greater moment arm than the left engine, and consequently a greater yawing force. Therefore, the loss of the left engine presents the pilot with a greater control problem than the loss of the right engine, so the left engine is called the critical engine. In some cases this problem is overcome by fitting counter-rotating propellers.

5.8.7 Pilots must always manage aircraft engines within the engine operating limitations, ensure that the specifications for fuel and oil are met and comply with maintenance requirements and they should enjoy trouble free operation of aero engines.

5.9 Propeller systems

5.9.1 Following an engine failure in multi-engine aeroplanes, a pilot needs to be able to feather the propeller to reduce drag. The feathering function complicates the design of a basic constant speed unit (CSU) as fitted to a single-engine aircraft. A good understanding of how such a system works will help the pilot appreciate any limitations that the design can impose.

5.9.2 In most CSUs, pressure is transmitted to the propeller through the engine oil and forces the propeller to move to the fine pitch stops.

5.9.3 Conversely, as the oil pressure is reduced, the propeller increases its blade angle to a coarser pitch by the action of spring and gas pressure contained in the propeller dome at the front of the propeller hub. The downside of this design is that, as the oil pressure reduces to zero when an engine is stopped on the ground, the propeller would feather. To overcome this, a centrifugal latch engages when the propeller speed decreases to between 700 to 1,000 revolutions per minute (rpm), and this prevents the propeller from moving past the coarse pitch angle. Therefore, pilots should be aware that if an engine failure occurs in flight, the propeller must be feathered before the centrifugal latch engages if the rpm drops below 1,000. Normally a windmilling propeller rotates at a speed well above this figure, but if a catastrophic failure occurs the engine may slow down rapidly and then it will not be possible to feather the propeller.

5.9.4 Restarting an engine that has been shut down usually involves using the starter motor to turn the engine and feathered propeller until the increasing oil pressure moves the propeller towards fine pitch. However, before doing this the propeller pitch control lever must be moved to the fine pitch stops to allow the oil pressure to be directed to the propeller. As the blade angle decreases, aerodynamic forces help turn the propeller and with the addition of fuel and ‘spark’ (ignition) the engine starts. Alternatively, if an unfeathering accumulator is fitted, the action is initiated by moving the propeller pitch control lever forward to allow oil to flow under pressure from the accumulator to the propeller. This type of start is usually smoother and less stressful on the engine than a starter motor unfeathering procedure.

5.9.5 Pilots must analyse the situation they are faced with before restarting an engine that has been shut down in flight. This action could lead to greater damage to an engine or cause an engine to windmill without starting, leading to a dangerous degradation of flight performance.

5.10 Electrical system

5.10.1 Multi-engine aircraft introduce pilots to electrical systems with multiple power sources and bus bars. Modern aircraft usually have two alternators (older aircraft may have generators) that provide electrical power to all the aircraft electrical equipment. Alternators have on-off switches, voltage regulators, over voltage protection, field switches and voltmeters. Pilots must understand the functions and application of these devices. The on-off switches isolate the alternators from the electrical system and should be turned off in the event of an alternator failure.

5.10.2 Voltage regulators maintain the voltage within the normal operating range, but if an over voltage occurs, relays will trip and take the alternator off-line. If an alternator is turned on and will not produce electrical power, it may require activation of the field switch to excite the alternator to produce electricity. The voltmeter shows the battery charge or discharge rate, the amount of current being delivered into or drawn from the electrical system (amperes) and the bus voltage, depending upon the mode selection, when fitted.

5.10.3 Pilots must be able to interpret the voltmeter reading to determine what is happening to the electrical system. Normally a switch connects the battery or individual alternators to the ammeter or voltmeter so that the pilot can monitor power or voltage of the electrical power delivery systems (alternator or battery). High amperage or low voltage can be an indicator of problems and remedial action may be required as detailed in the approved flight manual.

5.10.4 Bus bars are simply a metal bar connected to a power source (battery or alternator) to which all the aircraft electrical services are connected. Pilots should be familiar with what power sources the bus bars are connected to, and what services run off the bus bar. Some bus bars may be isolated to lighten the load on the electrical system during abnormal operations. For example, the battery bus would include all the services that are required to start an aircraft including the starter motors, radios, fuel pumps, avionics and lighting. These electrical services would also be required during flight if a double alternator failure occurred. After the engine is started and the alternator comes on-line more services may be added through other bus bars.

5.10.5 Flight instructors should ensure that trainees are able to interpret voltmeter readings, know the location and function of the circuit breakers, be able to identify and isolate services that demand high amperage (power) and demonstrate competency managing all electrical abnormal and emergency procedures.

5.11 Pressurisation system

5.11.1 Some multi-engine aircraft will introduce pilots to pressurisation. Because of the extra performance available, some multi-engine aircraft are able to operate at high altitude. Simply explained, engine driven pumps pressurise a sealed cabin. In the case of turbo-prop or turbine engines, bleed air is used. An automatic outflow valve regulates the pressure in the cabin. The pressurisation is normally turned on after engine start and is controlled automatically.

5.11.2 The pilot’s primary role is to monitor the system and ensure that it works correctly. They must be familiar with all the pressurisation-warning devices, monitor the cabin altitude and differential and understand the implications of high altitude operations. They should also be confident of manually operating the system (if required) and be able to identify and manage outflow valve problems if they arise. In addition, they should always recognise the symptoms of hypoxia and the action that should be taken to remedy this situation. It is important to be familiar with all the actions involved in an emergency descent following a pressurisation failure, including amended fuel usage, which should be addressed during pre-flight planning.

5.11.3 Pilots should never fly above a cabin altitude of 10,000 ft without oxygen. There have been cases of fatal accidents caused by pressurisation failures that have gone undetected. Therefore, this system should not be treated lightly. Instructors must ensure that a new multi-engine pilot is competent to operate the system during normal and emergency operations, conducts regular checks of the system and is familiar with the physical hazards of high altitude flight.

5.12 Undercarriage system

5.12.1 The normal function of an aircraft undercarriage is ‘gear goes up, gear goes down’ and malfunctions are rare. However, when they do occur pilots must be familiar with all the actions that must be taken. On some aircraft, emergency lowering of the undercarriage is a simple process.

5.12.2 However, in other cases, it may well be a long and involved procedure. It may require multiple actions with selectors, switches, valves and circuit breakers, as well as manual pumping or winding. Pumping or winding an undercarriage may entail a lot of physical effort and time. A pilot must also continue to stay in control of the aircraft, and maintain situational awareness; this could be a real problem in instrument conditions, at night or bad weather.

5.12.3 Therefore, a pilot must be familiar with limiting speeds and minimum speeds to reduce air loads, the normal and emergency undercarriage system, warning and undercarriage down indicators and the time frame required to complete the emergency lowering procedure. The best way of achieving these goals is to actually experience a practice emergency undercarriage lowering. It should be a standard part of endorsement training and never overlooked.

5.12.4 In some cases, manual undercarriage lowering requires significant maintenance action to return the aircraft to operation condition. In these circumstances, it may be preferable to simulate the manual undercarriage extension procedure while an aircraft is on jacks (during maintenance).

5.12.5 It is also important to discuss action in the event of a main wheel or nose gear failing to lower. Include in the discussions fuel burn-off to reduce the fuel load on landing, when to turn the fuel off during the landing roll, type of runway and advantageous use of crosswind. Finally, consider the evacuation and where to exit the aircraft.

5.12.6 Flight instructors must give guidance to trainees on the considerations that should be included in the planning. Night, minimum control speed (V_{MC}) or instrument meteorological conditions (IMC), traffic, air traffic control (ATC) requirements, turbulence, timeframe, emergency services, passenger briefings and evacuation and flying techniques are just some of the issues that should be taken into account. For example, there may be a need to yaw the aircraft to lock the undercarriage down. This exercise is often overlooked by flight instructors, possibly because it can be time consuming and can require ground servicing to allow the undercarriage to be retracted, but the demonstration should be done at least once during endorsement training.

5.13 Flight instruments

5.13.1 Because of the redundancy built into multi-engine aircraft systems it is unlikely that a vacuum pump failure would affect an attitude indicator, because each engine has a vacuum pump fitted. However, because of the complexity of the system it is remotely possible that a component failure could lead to an attitude failure. For example if a vacuum pump or an engine failed and the shuttle valve that diverts the suction to the other pump failed (stuck), then there may be a need to control the aircraft using -limited instrument panel techniques in IMC. The procedure for checking the system on start-up and/or shutdown should be well understood.

5.13.2 If the pilot is likely to operate in instrument conditions, the instructor should take the time to address this possibility.

5.14 Autopilot and electric trimming systems

5.14.1 The autopilot and trimming systems are a great aid to flight management and aircraft control during both normal and abnormal flight. It is vital that pilots use the systems to relieve workload and assist accuracy.

5.14.2 These systems have been linked together because both have influence on the pitch or roll control of the aircraft. Malfunctions of either system can lead to loss of control of the aeroplane.

5.14.3 Pilots must be familiar with the normal operation of the autopilot and trim systems, but it is critical to understand the abnormal actions contained in the flight manual that apply. Experience has shown that reaction time can be a vital factor in regaining or maintaining control of an aeroplane following an autopilot or pitch trim malfunction. Therefore, pilots must be sure of their actions to manage these malfunctions.

5.14.4 If a fault exists in an autopilot it will often manifest itself when the autopilot is first engaged. Therefore, pilots should monitor the aircraft attitude when engaging the autopilot and be prepared to disengage it immediately if any abnormal attitude changes occur. During normal operations, the autopilot should automatically disengage if excessive roll or pitch deviations occur. Overpowering the autopilot will also normally disengage it. This instinctive reaction is probably the first action a pilot will take and the problem should disappear. If not, the autopilot disengage switch should be activated. As a last resort, the autopilot circuit breaker or the avionics master switch could be used. The primary concern is to regain control of the aircraft and the pilot must monitor the autopilot and be confident about disengaging it.

5.14.5 Runaway electric trim can be a serious problem in an aircraft, and it is not an uncommon problem. Depending upon the aircraft’s airspeed, it is possible that full travel of the trim may cause control column loads that a pilot will not be strong enough to manage. An electrical fault or a sticking trim switch could cause this condition. Normally the electronic trim is disengaged when the autopilot is engaged, so the most likely occasion for trim problems is when the pilot is hand flying the aircraft.

5.14.6 In the first instance, the aircraft should be controlled using the control column and the trim disengage switch should be activated. There have been cases where this has not worked and pilots have repositioned the manual trim to override the system, or pulled the electric trim circuit breaker. Using the manual trim wheel to override the electric trim should pop the trim circuit breaker, but there have been examples where this has not happened, and when the trim wheel has been released, the loads have re-occurred. In addition the pilot should consider reducing airspeed to lower the aerodynamic loads on the flight controls.

5.14.7 Flight instructors should pay attention to the autopilot and trim systems during multi-engine training. Control malfunctions are serious problems and pilots should be competent and quick to remedy them. Ensure that they understand the different methods of disengaging these aids, and are able locate the appropriate circuit breakers without having to look too hard.

5.15 Very light jets

5.15.1 Very light jet aircraft introduce new performance, technology and physiological aspects into multi-engine operations and training. Flight at transonic speeds and high altitude with unique weather and physiological conditions, new systems and avionics/glass cockpit will change the knowledge and skills required by flight instructors and pilots seeking endorsements on these aircraft.

5.15.2 Flight instructors who conduct training on these aircraft will be required to be familiar with technology and operational conditions that they may never have previously experienced. This will require good training and the development of teaching techniques to accommodate the technology and associated human factors.

5.16 Assessing the risks

5.16.1 Before undertaking a flight it is important to assess any associated risks and then implement procedures and practices that mitigate the identified risks. Flight training is no exception. This process is called risk management, and should be done before any flight to determine whether the flight should be undertaken and what modifications need to be made to reduce identified risks. The question that risk management addresses is whether the level of risk is acceptable or, if not, can it be managed to make it acceptable?

5.17 Risks associated with multi-engine training

5.17.1 There are many identifiable risks associated with multi-engine training. Some of the risks are common to all types of flying while others are unique to multi-engine operations. Examples of risks associated with flight training in general are:

- weather
- environmental conditions
- traffic
- task saturation
- fatigue.

5.17.2 These risks can be countered by:

- planning for and avoiding adverse weather
- being familiar with the operating environment and avoiding associated hazards
- maintaining a lookout and traffic listening watch
- prioritising tasks and following fatigue risk management procedures.

5.17.3 Identifying the risks specific to multi-engine training is important because this form of training is potentially dangerous if not well managed.

5.17.4 Risks associated with multi-engine training are:

- inappropriate management of complex aircraft systems
- conducting flight operations at low level (engine failures after take-off)
- conducting operations at or near V_{MCA} or V_{SO} with an engine inoperative
- errors
- asymmetric operations including:
  - inadequate pre-take-off planning and briefing
  - decision making
  - aircraft control
  - performance awareness and management
  - operations with feathered propellers
  - missed approaches and go-arounds
  - final approach and landing
  - stalling.

5.17.5 To mitigate these risks, robust defences must be put into place. Because multi-engine aircraft systems are often complex, it is important for pilots to be familiar with the systems operations. It is also important to be current on the aircraft, though this may not always be possible for private operators who may not have easy access to the full range of training.

5.17.6 Any flight operation at low altitude has potential dangers. Trainers have debated over the decades on the value of practicing engine failures after an actual take-off, near the ground. The general consensus is that despite the risks, pilots must be trained to manage these situations in multi-engine aircraft.

5.17.7 Instructors should consider not simulating engine failures below 400 ft above ground level (AGL) to provide a reasonable safety margin. The use of simulators has reduced the perils of this activity. Other mitigating factors are:

- well trained instructors
- complete knowledge of the theoretical factors involved during asymmetric operations
- proven procedures, provided these are strictly adhered to
- comprehensive pre-flight and pre-take-off planning and briefings
- ongoing training
- situation awareness
- flying competency.

5.17.8 Each take-off is unique and should be carefully planned. Even daily operations from an aerodrome like Sydney airport require each take-off to be planned. Variables that should be included in pre-take-off planning include:

- weight
- weather
- runway length available
- take-off direction
- traffic
- temperature

- departure clearances
- runway conditions.

5.17.9 Terrain and obstructions are very real threats and should also be accommodated in the pilot's planning.

5.17.10 A thorough briefing after planning (either a self or crew brief) will both help with, and minimise, the in-flight analysis required; especially if a critical decision has to be made following an engine failure after take-off. This action will also reduce the workload that may distract from the critical task of flying the aircraft.

5.17.11 Statistics show that a multi-engine aircraft that suffers an engine failure after take-off has a higher probability of experiencing a fatality than a single-engine aircraft. This may be due to the fact a multi-engine aircraft suffering an engine failure presents a host of alternative options for the pilot seeking a remedy. This makes the decision-making, as well as identifying the correct solution, far more complex. If the plan is simple and well-understood the correct solution may be identified without doubtful hesitation and in a timely fashion.

5.17.12 The primary action in any emergency must be to maintain control of the aircraft. If a multi-engine aircraft has an engine failure it is immediately 'out of balance'. The ability to maintain control of the aircraft is paramount and is dependent on sound knowledge of the asymmetric characteristics of the aircraft.

5.17.13 The pilot must stay above V_{MCA} and adjust the aircraft attitude to achieve best single-engine angle of climb speed (V_{XSE}) or best single-engine rate of climb speed (V_{YSE}) so that optimum climb performance is attained for the flight situation. Above all the pilot must maintain control of the aircraft.

5.17.14 Engine failures may occur during any stage of flight and could require considerable time flying around with a propeller feathered. Therefore, a pilot must safely manage the aircraft when in this configuration. Propellers should never be feathered in flight during training below 3,000 ft AGL.

5.17.15 The pilot should practice flight with a feathered propeller, including climbs, descents and turns in both 'clean' and 'dirty' (undercarriage and flap extended) configuration. It is important to be reassured that the aircraft will still fly safely when in this situation and configuration.

5.17.16 Flying asymmetric with the undercarriage or flaps down should only be accepted in the early stages of a take-off or overshoot during a missed approach, and the aircraft should be 'cleaned' up as soon as it is safe to do so, to improve aircraft climb performance.

5.17.17 CASA strongly recommends that, when practicing asymmetric flight, an aircraft should never be landed with the propeller of a serviceable engine feathered. The risk far outweighs the minimal benefits, with a list of examples of such unnecessary risks proving fatal. If a landing with a feathered propeller on a serviceable engine is contemplated, a comprehensive risk assessment should be made and a clear plan developed. The plan should include weather, traffic, ATC and any other factors that could adversely affect the safety of the procedure.

5.17.18 Go-arounds are often mismanaged, resulting in many fatalities. The pilot must establish a visual committal height applicable to them and the aircraft type and not attempt to initiate a go-around below this height.

5.17.19 When initiating a go-around prior to or at the committal height from an approach to land, the pilots must ensure that they apply power smoothly and accelerate to and maintain V_{YSE}, while maintaining directional control. Every change of power on the live engine affects the directional balance of the aircraft, so it is important to anticipate the required change of rudder input to maintain continuous directional control. The pilot must not adjust the nose attitude until they are sure that they can achieve V_{YSE} before establishing the climb. When terrain or obstructions pose a hazard, it may be a safer option to initially climb at V_{XSE} until clear. Raise the undercarriage and flaps as soon as it is safe to do so.

5.17.20 It is important for the pilot to understand the need to maintain directional control of the aircraft during a go-around. They must continue to maintain situational awareness during the process. In this procedure the handling of the aircraft is challenged by its low speed and maximum power setting, which has the potential to bring about a directionally critical flight situation. This may be further aggravated by its proximity to the ground.

5.17.21 Pilots must have a plan of action that ensures a safe result when making an asymmetric approach. The approach and landing speeds and configurations should be as for a normal approach unless there are well-documented reasons for not doing so. Operations manuals should detail the procedures and the recommended approach speed, visual committal heights, when to lower the undercarriage and flaps (if different from a normal approach) and speed control. If these procedures are not available in an operations manual, the pilot should seek guidance from a suitably qualified flight instructor and have these actions clear in their mind before flying.

5.17.22 The pilot must never practice stalls when under asymmetric power. This is an extremely dangerous manoeuvre and autorotation and spinning are likely to occur. Experience has shown that the chances of recovery are poor. Pilots should also be aware that as altitude increases, stall speed and minimum control speed could coincide. Not only will the aircraft stall, but it is almost guaranteed the aircraft will lose directional control. Pilots should also be aware that some aircraft have a V_{MCA} that is very close to the stall speed (for example-Partenavia PN-68) and care should be exercised when operating these aircraft near these speeds.

5.17.23 Although the risks associated with asymmetric operations are manifest, they can be mitigated. Robust procedures, adherence to standard operating procedures (SOP), compliance with flight manual warnings, comprehensive and ongoing training and a willingness to learn about, and practice, asymmetric operations can ensure a safe outcome during multi-engine training.

5.18 Threat and error management

5.18.1 Threat and error management (TEM) is an operational concept applied to the conduct of a flight that includes the traditional role of airmanship, but provides for a structured and pro-active approach for pilots to use in identifying and managing threats and errors (hazards) that may affect the safety of the flight.

5.18.2 TEM uses many tools, including training, SOP, checklists, briefings and crew resource management (CRM) principles to assist pilots to manage flight safely. It has been widely accepted in the airline industry as an effective method of improving flight safety, and is now required by the International Civil Aviation Organisation (ICAO) as an integral part of pilot training at all licence levels from trainee to airline transport pilot. It is also a useful concept for multi-engine pilots to apply to their operations.

5.18.3 There is some overlap between risk management, TEM and CRM, particularly at the stage of developing and implementing plans to mitigate risks and in reviewing the conduct of a flight. Generally risk management is the process of deciding whether or not operations can be conducted to an acceptable 'level' of risk (go or no-go) safely, whereas TEM is the concept applied to managing and maintaining the safety of a particular flight.

5.18.4 The following sections provide a brief introduction to TEM to assist multi-engine pilots and trainers who may wish to apply the principles to their own operations.

5.19 Threats

5.19.1 In the TEM model, threats are events or hazards (e.g. meteorological conditions) whose occurrence is outside the control of the pilot(s) and which may threaten the safety of the flight. These treats may be anticipated, unexpected or hidden in the operational systems. Pilots need good situational awareness to anticipate and to recognise threats as they occur. Threats must be managed to maintain normal flight safety margins. Some typical threats/hazards to multi-engine operations might be:

- weight
- density altitude
- runway length
- other traffic
- high terrain or obstacles
- condition of the aircraft.

5.20 Errors

5.20.1 The TEM model accepts that human error is unavoidable. Errors can be classified as handling errors, procedural errors or communications errors. External threats can also lead to errors on the part of the pilot(s).

5.20.2 While errors may be inevitable, safety of flight demands that errors that do occur are identified and managed before flight safety margins are compromised. Some typical errors in multi-engine flight might be:

- incorrect performance calculations
- aircraft handling errors
- incorrect identification of failed engine
- incorrect systems operation or management
- failure to recognise, achieve or manage optimum performance.

5.21 Undesired aircraft state

5.21.1 Threats and errors that are not detected and managed correctly can lead to an undesired aircraft state, which could be a deviation from flight path or aircraft configuration that reduces normal safety margins. An undesired aircraft state can still be recovered to normal flight but, if not managed appropriately, may lead to an outcome such as an accident or an incident. Multi-engine flight requires recognition and recovery from undesired aircraft state in a very short timeframe before an outcome, such as loss of directional control, failure to achieve optimum climb performance or uncontrolled flight into terrain (UFIT) occurs. Examples of an undesired aircraft states in multi-engines might be:

- mismanagement of aircraft systems
- loss of directional control following engine failure (flight below V_{MCA})

- flight below V_{YSE} or V_{XSE}
- incorrect attitude recognised during manoeuvre
- commencing a missed approach below visual committal height.

5.21.2 Good TEM requires the pilot to plan and use appropriate countermeasures to prevent threats and errors leading to an undesired aircraft state. Countermeasures used in TEM include many standard aviation practices and may be categorised as follows:

- planning countermeasures – including flight planning, briefing, and contingency planning
- execution countermeasures – including monitoring, cross-checking, workload and automation management
- review countermeasures – including evaluating and modifying plans as the flight proceeds, and inquiry and assertiveness to identify and address issues in a timely way.

5.21.3 Once an undesired aircraft state is recognised, it is important to manage the undesired state through the correct remedial solution and prioritise aircraft control for return to normal flight, rather than to fixate on the error that may have initiated the event.

5.22 TEM applications

5.22.1 Threats and errors occur during every flight, as demonstrated by the considerable database that has been built up in observing threats and errors in flight operations worldwide. One interesting fact revealed by this program is that around 50% of crew errors go undetected.

5.22.2 TEM should be integral to every flight, including anticipation of potential threats and errors, and planning of countermeasures. Include potential threats, errors and countermeasures in the self-briefing process at each stage of flight, and avoid becoming complacent about threats that are commonly encountered.

5.22.3 Minimum control speed, often referred to as V_{MC} is a speed that is associated with the maintenance of directional control during asymmetric flight. If the pilot flies below this speed the tail fin and rudder are unable to generate enough lift to prevent the aircraft from yawing. If uncorrected, the yaw causes roll, the nose drops, the aircraft rapidly assumes a spiral descent or even dive, and if the aircraft is at low altitude, it will impact steeply into the ground. This type of accident is not uncommon in a multi-engine aircraft during training or actual engine failure. V_{MCA} is a specific speed that is established for aircraft certification requirements.

Note: With regard to a particular aircraft, V_{MCA} is a specific published speed. V_{MC} can be a range of speeds dependant on altitude, power setting, aircraft configuration etc.

5.22.4 The following summary is intended to assist pilots to apply TEM to multi-engine operations:

- Try to anticipate possible threats and errors associated with each flight, and plan countermeasures.
- Brief (self-brief) planned procedures before take-off and prior to commencing each significant multi-engine sequence.
- Include anticipated threats and countermeasures in briefings.
- Continuously monitor and cross-check visual and instrument indications and energy state to maintain situation awareness.
- Prioritise tasks and manage workload so as not to be overloaded, but to maintain situational awareness.
- Identify and manage threats and errors.

- Maintain control of the aircraft and flight path.
- Monitor the progress of the sequence and abort (if necessary).
- Maintain aircraft control and optimum performance.
- Do not fixate on error management.
- Identify and manage undesired aircraft state.
- Recover to planned flight and normal safety margins rather than dealing with other problems.

5.23 Pre-flight planning and briefing

5.23.1 A multi-engine pilot should never take-off without knowing how the aircraft is capable of performing during all phases of flight, and what options are available should an engine fail. The performance data in the flight manual will provide this information.

5.23.2 The accelerate-stop distance will indicate to the pilot how much runway length is required to accelerate to take-off speed, suffer an engine failure and be able to stop. If the available runway is less than this figure, the pilot should reduce the take-off weight to meet the physical constraint of the available runway length. Otherwise, they may possibly run off the runway end should an engine fail during the take-off run.

5.23.3 The pilot must then calculate the single-engine best rate of climb for the prevailing atmospheric conditions. As an example, a 1978 Cessna 404 at all up weight (AUW) with OEI, will climb at 220 ft/min on a standard day or 140 ft/min at a temperature of 36^{o}C from a sea level aerodrome. This information should be included in the pilot's Engine Failure After Take-off (EFATO) plan.

5.23.4 Does the terrain require a steeper angle of climb? If so, the pilot should consider V_{XSE} and look closely at where they should fly to avoid obstacles to return for a landing on the airfield.

5.23.5 The pilot should also consider that age of the aircraft and question whether it will perform according to flight manual figures. Familiarity with the aircraft will help the pilot when they are considering their options.

5.23.6 The pilot will need to calculate the single-engine service ceiling for various weights and terrain at different stages of the flight, and formulate a plan that will keep the aircraft clear of high ground and allow a safe diversion to a suitable aerodrome/s (as available). The diversion aerodromes should be noted in the flight briefing package for ready access in flight (if required). If possible equi time point (ETP) between each diversion aerodrome should be noted.

5.23.7 The pre-take-off briefing should at least explain the pilot's actions and plans in the event of an engine failure after take-off. The plan should also include a decision speed or point, at which the take-off will be abandoned or continued. Consideration should be given to the conditions in the over-run area of the runway. Having a plan reduces the chances of making a bad decision under the pressure of an emergency. Experience has shown that by verbalising the plan, whether with another crewmember or alone, helps to clarify and reinforce the plan for the pilot-in-command (PIC).

5.24 Understanding the important velocity (V) speeds

5.24.1 Power loss in a light multi-engine aircraft is a problem that requires good management. The asymmetric climb performance in such aircraft is not guaranteed as it is in the case of larger multi-engine aeroplanes such as a Boeing-737. At high-density altitudes, a heavily laden aeroplane may not even be able to climb following an engine failure after take-off.

5.24.2 During multi-engine operations there are a number of airspeeds that a pilot will use. Some of these speeds are defined in Section 2. The pilot should understand the reasons for the speeds, the conditions that affect them and how the speeds are applied. When referring to these speeds, they can be categorized as relating to aircraft control or performance.

5.24.3 The first speed to review is V_{SSE} or safe single-engine speed. The speed is determined by the aircraft manufacturer and is greater than V_{S1} and minimum control airspeed airborne (V_{MCA}), factored to provide a safety margin for intentional asymmetric training operations. In other words, practice engine failures should never be simulated below this speed, and if the operator is in an aircraft where this occurs, they should question the PIC about their actions.

5.24.4 The critical speed associated with asymmetric performance is best single-engine rate of climb speed (V_{YSE}). This speed is typically less than the all engine best rate of climb speed (V_Y) and allows a pilot to attain the best rate of climb under asymmetric conditions. This ensures that a safe height is achieved fast so as to avoid all obstacles and be able to manoeuvre the aircraft for a safe landing.

5.24.5 If an engine failure occurs below V_{YSE}, the nose attitude should be adjusted and maintained to allow the aircraft to accelerate to the optimum speed and then readjusted to maintain the best rate of climb. Pilots should also be aware that V_{YSE} varies with aircraft weight and airspeed differences can be significant. If, because of inadequate performance the aircraft does not climb, V_{YSE} should be maintained even during a descent. This speed is colloquially referred to as the ‘blue line speed’ and is marked by a blue line on the lower speed end of an airspeed indicator (ASI).

5.24.6 In summary, to optimise the chances of survival in a multi-engine aircraft weighing less than 5,700 kg, that is used for asymmetric training or suffers an engine failure, the pilot should:

- never simulate a failure below V_{SSE} (may be unavoidable with an actual failure)
- control the aircraft by preventing yaw, pitch and roll
- achieve best performance by adjusting the nose attitude to maintain or attain V_{YSE}.

6. Flight instructor training

6.1 The multi-engine flight instructor

6.1.1 The multi-engine flight instructor employs the same teaching techniques as any other form of flight training, but the pilot is operating in a regime that is potentially more dangerous than most other flight training. TEM should become an integral part of the instructor's flight training technique. Not only must the instructor follow the practices, but just as importantly, must also teach trainees the TEM principles and show them how to apply TEM to all their flying operations.

6.1.2 Because multi-engine aeroplanes generally have higher performance and greater mass than singles, trainees must be taught the handling characteristics of the aircraft until they are familiar with them. As multi-engine aircraft systems are more complex, the instructor requires substantial knowledge of the aircraft systems on which they are training trainees. The same applies to asymmetric operations. This is a critical area of training that needs both detailed briefings on the factors that apply to this type of flying as well as comprehensive airborne training.

6.1.3 The important role that the flight instructor plays in the development and training of pilots in general and multi-engine pilots in particular cannot be over emphasised. Their ability to correctly teach, influence and direct pilots can help prepare them for a safe and effective flying career.

6.2 Instructor training

6.2.1 The key to achieving well trained and competent pilots is to make sure that the flight instructors who deliver the endorsement training are themselves well trained and competent. They must have the knowledge, skills and behaviour to safely operate an aircraft during all phases of flight and be capable of communicating this knowledge and skills to their trainees.

6.2.2 Under a competency-based training (CBT) system, trainees should be trained to meet a clearly defined standard. The standards applicable to multi-engine aeroplanes are contained in the Part 61 MOS.

6.2.3 Flight instructor training should involve all the sequences that the instructor will be required to teach a trainee. These include actually explaining and assessing the use of all systems during both normal and abnormal operations. Instructors should dedicate considerable effort into developing teaching techniques that ensure trainees are confident and competent operating all the aircraft systems by the end of their training. For example, trainees should be shown the emergency undercarriage lowering sequence. In some aircraft this is a straightforward operation, but in others it can be complicated.

6.2.4 A pilot should never be placed in a position where an actual emergency is the first exposure to a manual landing gear extension. Pilots should be aware of the:

- time involved
- difficulties in controlling the aircraft while maintaining situation awareness
- physical effort that may be required to wind an undercarriage down.

6.2.5 For a pilot flying in instrument flight conditions the problem becomes even more complicated. It may be necessary to devise an alternative method to teach this sequence if manual undercarriage lowering requires maintenance action to return the aircraft to a serviceable state.

6.2.6 The increased flying performance of the aircraft, such as speed and inertia, has to be well managed and well taught. Runway performance and safety considerations demand additional attention by the instructor, and asymmetric operations require a high degree of situational awareness and adherence to SOP. It is also important that trainees thoroughly understand the implications of control and performance and apply all the techniques to ensure a positive result.

6.2.7 The cabin of a multi-engine aircraft is often larger than a single-engine aeroplane, and is capable of carrying more passengers. This requires sound passenger management technique and thorough briefings. Flight instructors should highlight these considerations during a pilot’s training.

6.2.8 Flight instructors must guide trainees on how to formulate valid plans and ensure that during their training they follow the plans when practicing engine failures. Most importantly, emphasise the requirement to have a plan for every take-off.

6.2.9 Before commencing after take-off asymmetric training, which should not be started until the trainee is competent with general aircraft handling, the instructor should clarify:

- the trainee is competent at general aircraft handling
- how engine failures will be simulated
- the trainees actions in the event of a simulated engine failure
- the threats and countermeasures applicable during asymmetric training
- actions in the event of an actual engine failure.

6.2.10 To be an effective multi-engine flight instructor it is essential that all sequences are taught in a logical and comprehensive manner. This involves a good training plan, high-quality technical and flight briefings and continuous TEM.

6.3 Behaviour and responsibility

6.3.1 Flight instructor’s behaviour must be impeccable. Not only do they need to have knowledge and skills, but they must also set an example of good planning, compliance with SOP and regulations, professionalism and self-discipline. Deviations from these principles will be observed, and may be copied by trainees. The influence an instructor has on trainees is a great responsibility that should never be compromised or forgotten.

6.3.2 ATSB statistics indicate that 16% of multi-engine aeroplane accidents occur during training or assessment. Unfortunately, a number of these accidents were caused by unsatisfactory behaviour by instructors or ATOs. This behaviour has ranged from disregard of regulations or best advice to failure to comply with SOP or loss of situational awareness. In this CAAP, the term ‘behaviour’ is used rather than ‘attitude’, as behaviour is something that is observable, measurable and assessable.

6.3.3 One of the hallmarks of a good pilot or instructor is their ability to maintain situational awareness. This is particularly important during multi-engine asymmetric training at low altitude. Instructors must be able to think ahead and anticipate hazards. At critical stages of flight, such as engine failures after take-off, the instructor must constantly monitor the trainee’s performance and be ready to take over and rectify any dangerous event. An instructor must not only maintain situational awareness, but should also teach it to the trainee.

6.4 Engine shutdown and restart

6.4.1 During multi-engine training, engine shutdown and restart is an exercise that the trainee will be required to practice throughout their course. However, it is more than just a training exercise, and pilots must be aware of the serious implications of shutting down and re-starting an engine.

6.4.2 Section 6.8 discusses the symptoms of engine failures in further detail. Pilots should consider this guidance when making the decision to shut down an engine. It is likely that a partial engine failure could occur, and it may be beneficial to delay shutting down an engine until more suitable conditions exist, unless of course a greater risk exists in not shutting the engine down immediately (i.e. mechanical damage, oil/fuel leak or fire in the affected engine).

6.4.3 For example, it may be better to use a partially failed engine to help position the aircraft clear of inhospitable terrain before securing the engine. Once a decision has been made, the pilot must ensure the aircraft and serviceable engine are set up to achieve optimum performance. They must also advise ATC of their actions and intentions. They must also ensure that all actions are conducted in accordance with the approved flight manual and navigate to the nearest suitable landing area.

6.4.4 In the unlikely event that an engine is to be restarted after shutdown, the pilot should give considerable thought to their actions. They should ask themselves will a re-start cause more damage to the engine? And is there a likelihood that the propeller may not unfeather?

6.4.5 There could be a chance after the propeller has come out of feather, the engine may fail to start, but the propeller cannot be re-feathered and continues to windmill. This would create significant drag that may seriously impair the aircraft's performance in maintaining altitude. This situation is not unusual and has caused a number of accidents. When re-starting an engine, pilots should refer to a checklist or the flight manual in order to avoid mismanagement (errors).

6.4.6 Flight instructors must give clear guidance on shutting down and re-starting engines. They must discuss the implications, options and hazards associated with these activities. When conducting the procedure as a training exercise, it is a good opportunity to use a scenario that mimics actual situations.

6.4.7 The exercise should be thoroughly briefed, covering both the trainee and instructor's activities, and clearly state what expectations the trainee is to demonstrate when the propeller is feathered. Throughout the exercise, there needs to be emphasis on maintaining control of the aircraft at all times and to strictly follow checklist procedures.

6.5 Simulating engine failures

6.5.1 Before simulating engine failures in multi-engine aircraft, instructors must be aware of the implications and be sure of their actions. Consult the aircraft flight manual or POH for the manufacturer's recommended method of simulating an engine failure. Prior to undertaking the task, the instructor must ensure that the aircraft is not in a dangerous situation to start with, such as the aircraft is flying too slow, too low, is in an unsuitable configuration or hazardous weather (wind, ice or visibility) is present. There is no benefit introducing more risks than the emergency being trained for.

6.5.2 The instructor should avoid loading the trainee up with multiple emergencies. More will be learned by concentrating on one aspect at a time. Do not simulate an engine failure using procedures that may jeopardise the restoration of power. It is not recommended to simulate an engine failure at low level by selecting the mixture to idle cut-off or turning the fuel selector off. These procedures would be more appropriate at higher altitude

6.5.3 Instructors must emphasise that during a practice engine failure, when the throttle is closed and the propeller is windmilling, this replicates the situation of high propeller drag that exists until the propeller is ‘simulated feathered’, when zero thrust is set.

6.5.4 Slowly closing the throttle is one of the methods used to simulate an engine failure. Although selecting idle cut-off may be kinder to an engine, the engine or aircraft manufacturer may not permit it. So slowly closing the throttle to idle or zero thrust is unlikely to harm the engine and allows for immediate restoration of power.

6.5.5 When setting zero thrust (only after the trainee has completed the simulated feathering), throttle movements should not be rapid, and the trainee should have been briefed about the instructor’s actions.

6.5.6 As a rule, unless a catastrophic engine failure occurs, an engine does not just fail without warning. During an actual failure, pilots should also take the time to determine whether a total failure has transpired or if the engine is still delivering some power. If it is delivering power, use the thrust to get to a safe height before shutting the engine down to avoid further damage, unless a greater risk exists in continuing to operate the engine, such as fire, oil/fuel leaks or significant mechanical damage.

6.5.7 Trainees must be shown how to identify and confirm that an engine has failed. For initial identification, a common method is ‘dead leg, dead engine’. When controlling yaw the leg that is not exerting pressure to the rudder pedal is the ‘dead leg’ and is on the same side as the ‘dead’ or failed engine.

6.5.8 This is probably the most used method as it is a direct function of maintaining control of the aircraft, therefore offering a true indication of which engine has failed. Appropriate engine instruments and thrust gauges may be carefully used to confirm the failure.

6.5.9 It should be noted that the rpm and manifold pressure gauges of a piston engine are not reliable means of identifying a failed engine, as the instrument indications may appear normal. After identifying the failed engine through, for example, the ‘dead leg, dead engine’ method, the pilot should confirm that their identification is correct. This is done by closing the throttle of the failed engine - if no yaw develops as the throttle is eased back, and the serviceable engine operates normally it confirms the identification of the faulty engine.

6.5.10 It is not uncommon for pilots to shut down the wrong engine in haste or panic, so the pilot must train themselves to calm down and take the time to accurately confirm the problem. Although time can be critical in some situations, taking the time to properly identify and confirm the failed engine can reduce the chances of an error.

6.5.11 Trainees should be made to verbalise their actions when practicing asymmetric procedures. They should verbally identify controls and switches and touch them at 90 degrees to the direction of operation to avoid inadvertent activation during turbulence. Flight instructors should guard controls, particularly during initial training, in order to prevent incorrect selections.

6.6 Simulating turboprop engine failures

6.6.1 Because turboprop aircraft are fitted with auto-feather, when simulating engine failures after take-off, power only need be reduced to zero thrust. The propeller of a failed turboprop engine does not windmill, but automatically feathers. If a negative torque sensing system (NTS) is fitted, negative torque is sensed in the gear train between the propeller and the aircraft engine when a failure occurs. When the reverse torque exceeds a selected threshold, hydraulic valves are actuated, which remove oil pressure from the pitch control mechanism of the propeller. This loss of oil pressure causes the propeller to set a pitch that ensures minimal drag. Therefore, to properly replicate the conditions that apply to an actual failure, instructors should ensure that zero thrust is set whenever simulating an engine failure on a turboprop. Some typical zero thrust settings for individual aircraft types are detailed in the next section.

6.6.2 To avoid inadvertent feathering of a propeller, before simulating an engine failure, instructors must turn the auto-feather off if this is recommended in the flight manual, as is the case with the DHC-4 (Caribou).

6.6.3 Identification of a failed turboprop is less complicated than a piston engine. Like all multi-engine aircraft with wing-mounted engines, ‘dead leg, dead engine’ still applies but the torque gauge is an accurate indicator of the condition of the engine. This instrument immediately measures loss of power and is an almost foolproof way of confirming a failed engine. If the power loss is caused by a compressor surge or stall there will be an accompanying rapid increase in turbine temperature.

6.6.4 When performing an actual shutdown and restart of a turboprop, instructors must ensure that the checklist procedures are followed religiously. Feathering a propeller is normally straightforward, but if the re-start is mishandled, the propeller can go into flight idle or even the beta range. Should this occur, the aircraft performance might be so adversely affected that a return to the departure point may not be possible if unsuitable terrain exists. Therefore, before shutting down an engine, pilots should make sure that if the engine will not re-start, it would still be possible to return to the airfield of departure.

6.7 Setting zero thrust

6.7.1 Reports from Australia and overseas have repeatedly shown that fatal accidents have occurred following practice engine failures because instructors have failed to set zero thrust on a windmilling engine to simulate a feathered propeller. A windmilling propeller causes the largest component of drag on an aircraft that suffers an engine failure. If the propeller is not feathered following an actual failure, or in the case of a practice failure zero thrust is not set to simulate a feathered propeller, the aircraft’s climb performance cannot be guaranteed. In many cases, it is likely that the aeroplane will only be able to maintain a descent. Therefore, any pilot giving multi-engine asymmetric training must know how to set zero thrust on the propeller aircraft type that they are flying.

6.7.2 The zero thrust setting depends on the engine type and aircraft’s airspeed, altitude and temperature. In a piston engine aircraft zero thrust is normally achieved by setting a manifold pressure that causes a specified rpm; and a turbine propeller engine by a torque and in some cases rpm for a particular airspeed. Unless stated otherwise in the flight manual, CASA recommends that V_{YSE} be used for setting zero thrust. Remember that if zero thrust is set and the airspeed increases above V_{YSE}, there will be a corresponding increase in propeller drag from the windmilling engine.

6.7.3 Before conducting asymmetric flight training it is important for an instructor to determine an accurate zero thrust power setting for the aircraft type being flown. If a zero thrust power setting is not specified in the aircraft’s flight manual, a method of doing this would be to climb to a minimum of 3,000 ft AGL, feather a propeller, shutdown an engine and find what power setting will allow the aircraft to fly, trimmed at V_{YSE}. Restart the engine and adjust the rpm and manifold air pressure

(MAP) combination on the restarted engine to re-establish the airspeed at V_{YSE}, and return the aircraft to the previously trimmed state. This procedure may take some time and could involve manipulation of the engine controls to determine a reliable power setting. The rpm to indicated air speed (IAS) relationship could vary significantly between aircraft and engine types.

6.7.4 Some typical zero thrust power settings for turbine propeller engine aeroplanes are:

- Beech C90 Kingair: 100 ft pounds of torque at 1800 RPM at V_{YSE}
- Beech 1900D Airliner: 200 pounds of torque at or above V_{SSE}
- de Havilland DHC-6: 5 psi
- de Havilland DHC-8: 14% torque
- Embraer EMB-110 Bandierante: 150 ft pounds of torque at 2200 rpm
- Fairchild Metro III: 10% to 12% of indicated torque
- SAAB SF340: 10% to 20% torque below 120 kts.

6.7.5 With respect to setting zero thrust a company or FTO operations manual should at least state for each aircraft type being operated:

- the procedure for setting zero thrust
- the power setting that represents zero thrust
- that engine failures should be simulated by setting zero thrust on aircraft fitted with NTS or auto feather.

6.7.6 Failure by an instructor to set an accurate zero thrust to simulate a feathered propeller will result in unrealistic asymmetric climb performance that may give the trainee an over optimistic or pessimistic impression of what performance the aircraft is capable of achieving on one engine. Therefore, multi-engine flight instructors must know how and when to set zero thrust before commencing any asymmetric flight training.

6.8 About engine failures

6.8.1 Flight instructors often simulate an engine failure by rapidly closing the throttle or moving the mixture control to idle cut-off. The latter method should never be used at low altitude. However, the majority of engine failures are not instantaneous. If an engine failure is caused by fuel starvation or low fuel pressure the engine will usually cough and splutter before stopping; this may take time and gives a pilot some space to react. When an engine suffers damage such as a broken valve rocker arm, valve stem or pushrod, the engine is likely to run roughly, but still deliver power. It may be possible to reduce power and still develop some useful thrust. However, a precautionary shutdown is probably inevitable.

6.8.2 Low oil pressure coupled with increasing oil temperature indicates that a failure is imminent, with a possible engine seizure and rapid decrease in RPM. The engine should be shut down before the centrifugal latches engage and lock the propeller in fine pitch. Electrical malfunctions usually result in rough running, misfiring and a reduction in power. It may be possible to rectify the problem by isolating a faulty magneto.

6.8.3 Probably the worst type of engine failure is a catastrophic failure caused by a fractured crankshaft or connecting rod. Such a failure can be indicated by a loud bang, vibration and a very quick reduction in RPM. In some cases it may not be possible to feather the propeller. This could be a very serious problem if it occurred shortly after take-off, and quick but precise action needs to be taken to feather the propeller.

6.8.4 Part of managing an engine failure is to recognise the type of problem and then decide the appropriate action. It is very unlikely that an engine failure will be instantaneous, and instructors should give trainees advice about what action to take to manage partial engine failures and attempt to restore power when possible. Consideration should also be given to looking after the serviceable engine. In some circumstance there may be no alternative other than to apply full power. However, pilots should be aware of engine limitations and time limits for the application of full power and plan actions accordingly. During training, the pilot should learn how an aircraft performs with less than full power.

6.9 Engine failure after take-off

6.9.1 Management of an engine failure starts with a clear and well thought-out plan. The pilot should have an clear plan of what to do during various phases of take-off, such as:

- engine failure before the decision speed/point prior to lift-off
- engine failure before the decision speed/point after take-off
- engine failure after the decision speed/point.

6.9.2 Pilots may note that the term 'decision point' is used as well as decision speed. This is another concept to aid decision-making. From the list above, the first two situations will require an aborted take-off, using procedures specified in the flight manual. A decision point can be a predetermined point, on the runway or an action. For example, by adjusting the pilot's grip on the throttle, or retracting the undercarriage, these actions could represent the point at which the pilot has made the decision to continue the take-off and keep on flying if an engine failure occurs. A further example would be a take-off from a 13,000 ft runway like Sydney airport, where the decision point may be when the aircraft passes 200 ft and the undercarriage is selected up. Flight instructors should give clear guidance on how to apply the principles of determining and using the decision point or decision speed.

6.9.3 If a pilot experiences an engine failure after the decision speed/point, actions must be prompt and correct. This section addresses engine failures in a general sense, and pilots must understand that the procedures in the approved flight manual must be followed.

6.9.4 The procedures include:

- Controlling the aeroplane. Prevent yaw with the rudder and adjust the nose attitude to a position where the aircraft is able to maintain or accelerate to V_{YSE}. The wing may also be required to be lowered towards the serviceable engine.
- The pilot must ensure that full power is applied to the good engine and the gear and flap are selected up – *'Pitch up, mixture up, throttle(s) up, gear up, flap up'.*
- The pilot must identify the failed engine (dead leg, dead engine method), but maintain control of the aircraft during this process.
- Once the failed engine is confirmed, the pilot must close the throttle of the failed engine and confirm that the engine noise does not change or no yaw occurs towards the live engine. They also need to visually identify the failed engine propeller lever before activation.

6.10 Feather the propeller

6.10.1 Up to this point a lot has been done in a short time and there is no room for error. Now, it is time to ensure that the aircraft is achieving best performance. Ideally the aircraft should be at V_{YSE}, but depending on the terrain, it may be necessary to climb initially at V_{XSE}. It is vital to maintain the appropriate nose attitude while conducting all other procedures. If the nose attitude is too high, speed can decay towards V_{MCA} very rapidly and cause serious control problems. The pilot must ensure that the wing is lowered towards the serviceable engine with the balance ball appropriately positioned to attain optimum performance.

6.10.2 The pilot must then perform clean up actions in accordance with the flight manual and trim appropriately.

6.10.3 As these procedures take place over a short period of time, actions must be precise and the pilot must maintain situational awareness. Maintenance of situational awareness involves a lot of factors, such as, but not limited to:

- control of the aircraft
- engine identification
- feathering
- performance
- terrain
- traffic
- weather
- ATC.

6.10.4 The pilot will obtain successful training by having a good plan enforced, doing the actions and monitoring and modifying the progress of the procedure.

6.10.5 In summary, it is important to have a logical and systematic approach to an engine failure after take-off. The pilot must:

- maintain control of themselves and the aircraft, and keep it airborne
- make sure the maximum power is set, gear is up, flaps are up (or in the position required by performance considerations)
- correctly identify the failed engine
- feather the appropriate propeller to reduce drag
- achieve optimum performance
- monitor the situation and revise plans if required
- communicate the situation.

6.11 Checklist aide

6.11.1 A good recall-checklist for an engine failure in a multi-engine aircraft, especially after take-off, is ‘CONTROL - IDENTIFY – CONFIRM – FEATHER – CLEAN UP’:

- CONTROL includes not only directional but attitudinal control (speed) and maximum power is applied.
- CLEAN UP calls for undercarriage and flaps to be retracted, but only when it is safe to do so, and to trim the aircraft correctly. Once flight has been brought under control, follow up the recall emergency drills by going through the hardcopy checklist to ensure that nothing has been left out, and to manage the remaining systems (e.g. switching off non-essential busbars and electrical services).

6.12 Minimum control speed demonstration

6.12.1 The minimum control speed sequence is one of the more important in asymmetric training. Before commencing flying training, instructors need to ensure that the trainee fully understands the theory and application of minimum control speed. The trainee should receive a good explanation of minimum control speed and what leads to loss of control, and the quickest method of regaining control. The instructor should also point out all the potential dangers of both practice and actual loss of control.

6.12.2 During the first pre-flight briefing question the trainee is to determine their level of understanding of the topic. It is imperative that the trainee understands how V_{MCA} is derived from minimum control speed (V_{MC}) principles and the relevance of each.

6.12.3 Before getting airborne, the control seats should be adjusted so that both the instructor and trainee are able to apply full rudder in both directions. This step is vital and if an engine fails after take-off could mean the difference between a safe flyaway or a fatal crash. Double check that the seats are locked on the adjusting rails and seat belts are tight, as there may be a need to apply up to 150 lbs (60 kg) of pressure to the rudder pedals to maintain control of an aircraft with a failed engine. This is the seating position that should be used for every take-off.

6.12.4 The demonstration should be given at a height that permits the engines to develop full power or as much power as possible, but is safe for the proposed exercise. The pilot should be aware that the engine may not be developing full power at this height because of the reduced density altitude and minimum control speed may be lower than V_{MCA} published in the flight manual. In fact, there is a critical altitude where the minimum control speed will reduce to where it will coincide with the stall speed (which does not reduce). This is a dangerous area as auto-rotation and a spin could occur. Generally, multi-engine aircraft are not certified to recover from spins.

6.12.5 Similarly, some aircraft have a minimum control speed that is close to the stall. In such cases, the instructor can restrict the application of full rudder in order to avoid auto-rotation, but still demonstrate how directional control is lost. V_{MCA} demonstrations should be terminated when yaw is recognised by the trainee.

6.12.6 During the minimum control speed demonstration point out the yaw, wing drop and change to attitude. Show that the recovery technique depends on two factors, increase in airspeed or/and reduction of power on the live engine. The optimum choice, especially in a take-off climb, should only be to increase airspeed firstly to regain control, and finally to achieve V_{YSE}. However, when the aircraft is very close to the ground, this may not be practical where reduction of power on the live engine remains the only option.

6.12.7 In a critical situation, with low speed near the ground, and possibly with an engine windmilling, the pilot may have to maintain directional control by a combination of a slight lowering of attitude (not below the straight and level for the speed) and very small incremental reduction in power changes, until the airspeed may be coaxed up by feathering of the failed engine and cleaning up the aircraft. The power reduction should be dictated by how much control has been lost. Recovery may only require a small reduction in power to stop yaw and roll, and power re-introduced immediately after speed has been gained through feathering and clean up action.

6.12.8 On the other hand, a major loss of control may require large power changes, but any power changes should be deliberate and measured, even if the throttle needs to be closed completely. The instructor should:

- show how power should be re-applied and any yaw prevented
- mention the height loss in the exercise and relate this to the dangers of an engine failure at low altitude
- highlight that when the exercise is done during straight and level flight, the airspeed might drop off slowly. However, in a situation such as an engine failure shortly after take-off, the nose attitude will be higher and speed will reduce towards minimum control speed more rapidly.

6.13 The instructor should also allow the trainee to experience this situation, and observe how important it is to adjust the nose attitude to maintain or regain airspeed after an engine failure.

6.13.1 When trainees are conducting the minimum control speed exercise, the instructor should ask them to indicate when the aircraft starts to yaw and roll. This will allow the instructor to determine if the trainee is recognizing these conditions early enough. They should also ask the trainee to state how much height was lost during the recovery phase of each demonstration.

6.13.2 It is also important to demonstrate the effect of lowering the wing up to 5^o towards the live engine and keep the balance ball half a ball width from the centre towards the lowered wing. Failure to perform this procedure increases the minimum control speed of the aircraft. Flight tests in an instrumented Cessna Conquest showed that with a published V_{MCA} of 91 kts, if the aircraft was flown in asymmetric flight with full power applied and the wings held level with the rudder balancing the aircraft, minimum control speed increased to 115 kts, an increase of 24 kts.

6.13.3 Conversely, lowering the wing towards the failed engine, minimum control speed increases by about 3 kts per degree of bank. The pilot must ensure the wing is lowered 5^o towards the serviceable engine. They should also consider the direction of turn in order to optimise performance.

6.13.4 This manoeuvre is difficult to perform, particularly in the early stages of the training or when using flight instruments. A lot of concentration is required to maintain the low angle of bank towards the serviceable engine, and to keep the ball ½ to ¾ outside the 'cage', towards the lower wing.

6.14 Single-engine go-around

6.14.1 A single-engine go-around in a multi-engine aircraft weighing less than 5,700 kg must be well managed. Recently there have been a number of accidents involving this procedure, particularly during training. Pilots must be aware of the implications of a single-engine go-around and be prepared to lose height in the process. It is important to have a good understanding of what a visual committal height, is and how to apply this concept

6.14.2 Visual committal height is a nominated height at or above which a safe asymmetric go-around can be initiated, or below which the aircraft is committed to land. It is used for visual flight operations and is to accommodate the performance of the aircraft being flown. It should not be confused with minimum descent altitude (MDA) or decision altitude (DA) that applies to Instrument Flight Rules (IFR) operations.

6.14.3 Ideally, an asymmetric approach should be flown in the configuration recommended in the flight manual. In general, landing flap is not selected - at least until the visual committal height is reached and a landing is assured. However, if the aircraft has to go round before this point, positive and precise action must be taken if a successful single-engine go-around is to be completed. Full power should be applied smoothly, the yaw controlled and the aircraft accelerated and reconfigured in accordance with flight manual procedures. If a single engine go-around is commenced after full flap has been selected, pilots must anticipate a tendency for the aircraft to roll soundly and full aileron may be insufficient to maintain wings level.

Note: Some manufactures warn against this manoeuvre once full flap is selected.

6.14.4 Correct anticipation of the rudder trim change with power change is the fundamental key to smooth and effective handling technique, ensuring confident and safe asymmetric operations.

6.14.5 It is unlikely that the aircraft would be less than minimum control speed during an approach so full power should be applied smoothly. If, for some unforeseen reason, the aircraft speed happens to be below minimum control speed, advancing power to maximum even with full rudder applied will cause the aircraft to yaw. Should this happen, the pilot must not increase the power any further until the yaw is controlled before further increasing power.

6.14.6 Where necessary, the go-around may be conducted in a smooth continuous descent, while the aircraft is cleaned up and V_{YSE} achieved. The committal height is precisely for this manoeuvre where height is traded for speed. Once V_{YSE} has been attained, the nose attitude should be readjusted to maintain V_{YSE}, or when appropriate V_{XSE}, during the climb.

6.14.7 The visual committal height should be designed to accommodate a worst-case scenario (as described above) and a height between 200 - 500 ft AGL is commonly used

6.14.8 MDAs and DA pose another problem. As an MDA is usually at a considerable altitude, a single-engine missed approach should not be a big predicament. However, the case of a DA is different. Because a DA is quite low it may be below the pilot’s visual committal height. This means that once below this height the aircraft is committed to land and if the weather is below minima the aircraft is in an emergency situation and must continue. If the weather minima are known to be below committal height, then the approach should not have been commenced except in an emergency. The information on how to consider this type of situation should be included in the company operations manual as an operating policy.

6.14.9 During training, flight instructors must emphasise the potential dangers of mismanaging a single-engine go-around. The instructor should give the trainee ample opportunity to practice this procedure to ensure they are able to maintain both directional and attitudinal (for speed) control with varying power and/or speed changes. As the trainee’s skill level increases in their control of the aircraft, even with significant changes in power and airspeed, their conduct of a safe, smooth and effective go-around would be assured. However, if recency is not maintained, the level of skill may reduce.

6.15 Stall training

6.15.1 It is important for the trainee to be able to recognise and avoid the stall in any aircraft. Instructors must conduct this exercise in multi-engine aircraft and reiterate the characteristics and devices that warn the pilot of the stall. The stall warning is the primary device, however, airspeed indications, nose attitude, buffet, and reduced control response rate are all indicators of an impending stall. The instructor should allow the trainee to experiment with these characteristics and practice them in different configurations and flight situations. They should also show the pilot a stall while simulating a turn from base leg to final approach. The pilot should commence recovery action well before a stall occurs.

6.15.2 To recover from a stall in a multi-engine aircraft, the procedure is no different to any other aircraft. Unstall the wing by adjusting the elevator position to reduce the angle of attack releasing the backpressure on the control column and simultaneously applying full power while keeping the aircraft balanced.

6.15.3 Stall training should never be done with asymmetric power. This is a very dangerous exercise and numerous aircraft both in Australia and overseas have fatally crashed after entering autorotation and spinning.

6.16 Asymmetric training at night

6.16.1 Engine failures after take-off must never be practiced at night. History has repeatedly shown that a disproportionate number of fatal accidents have occurred while conducting this exercise. The main danger is the loss of visual cues that alert the pilot to the fact that the aircraft performance is inadequate to avoid terrain or obstacles. When operating at night or in poor visibility it is likely that a pilot will be slow to interpret instrument readings that show the aircraft is not climbing or has drifted off track. Therefore, asymmetric training should not be practiced in these conditions. When conducting simulated instrument training, the flight instructor should still be able to see the terrain or obstacles and terminate the exercise immediately a dangerous situation is recognised.

6.16.2 Paragraph 81.3 of the Aeronautical Information Publication – En-route (AIP ENR) 1.1 states that simulated asymmetric flight at night must not be conducted below 1,500 ft AGL.

6.17 En-route engine/system failure training

6.17.1 A number of accidents have been attributed to the mismanagement of engine failures in the en-route phase of flight. To reduce the risks of mismanaging an engine failure, applying TEM during the planning and flight phases is a key aspect. In particular pilots need to consider the following:

- maintaining situational awareness
- understanding the aeroplane systems
- applying the correct drills and procedures
- declaring the appropriate level of emergency
- positively manage the subsequent flight profile
- utilising contingency plans determined prior to flight.

6.17.2 It is recommended that flying school operators, flight instructors and trainees make allowance in the training program so that training in this area is adequately addressed.

6.18 Touch and go landing during a asymmetric training

6.18.1 Experience has shown that it is inadvisable to perform touch and go procedures when conducting asymmetric circuits and landings. There would be increased likelihood for confusion and errors with engine controls and possibly offset elevator, aileron and rudder trim settings that may be fairly different from normal take-off trim settings. Coming to a full stop on each landing and taxiing back to the threshold provides the instructor with the opportunity to perform a good debrief, as well as allowing engine temperatures to stabilise.