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Aerobatics Manual

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1 INTRODUCTION AND ACKNOWLEDGEMENTS

The Gliding Australia (GAus) aerobatic manual has been written to provide information and guidance on safety issues related to aerobatic flights. It clarifies the rules relating to aerobatic flight, provides information on the regulatory requirements for the issue of aerobatic qualifications and low-level aerobatic permissions, and deals with risk management and Threat and Error Management (TEM) principles that may be applied to aerobatics.

This manual is not meant to be an extensive reference for the whole subject of aerobatics. There are several reference books and training guides available. The strictness and finesse of competition aerobatics is not addressed.

The Training Units associated with this manual will provide tuition in how to fly aerobatic manoeuvres and pilots should undertake training with an appropriately qualified flight instructor for this purpose.

Once printed, this is an uncontrolled version of the manual which will not be updated by GAus; it should not be relied upon for any regulatory purpose. The current manual can be viewed at any time via the GAus website at http://www.glidingaustralia.org.

We wish to thank the many colleagues whose support was essential for the production of this manual.

This manual was made possible through the dedication, skill, and generous contribution of time by the volunteer members of GAus. Their collective knowledge and many years of experience in aerobatics, flight training, and safe gliding operations have been invaluable in shaping this document.

We gratefully acknowledge all those who contributed ideas, shared technical insights, reviewed drafts, and helped ensure the accuracy and quality of this manual. Their commitment to advancing safe and enjoyable glider aerobatics is deeply appreciated.

2 Purpose

Aerobatic training transcends the thrill of performing complex manoeuvres in the sky; it fundamentally enhances a pilot's flying proficiency. By mastering aerobatics, pilots gain a deeper understanding of their aircraft's capabilities and limitations within an extended flight envelope, allowing them to handle a wider range of flight attitudes confidently. More importantly, aerobatic skills are crucial for averting and managing in-flight emergencies, such as stall-spin scenarios, cable break/premature release, and inadvertent flight into cloud, which can be lifesaving. Thus, the true value of aerobatics lies in the significant safety benefits and heightened situational awareness it imparts to pilots.

The aim of Aerobatics is fourfold:

1 Improvement in handling and coordination skills.

2 Development in recovery from unusual attitudes.

3 Enjoyment of aerobatics in a safe manner.

4 More opportunities to fly during the stable winter period.

3 Definitions and Terminology

Current regulations refer to 'acrobatic flight', however 'aerobatics' is a more specific term which is in widespread use. Aerobatic flight is currently defined in CASR 91.185 as: Manoeuvres that involve:

1 bank angles that are greater than 60°; or

2 pitch angles that are greater than 45°, or are otherwise abnormal to the aircraft type; or

3 abrupt changes of speed, direction, angle of bank or angle of pitch.

3.1 Acrobatic Category

Acrobatic category means an aeroplane is certified for aerobatic manoeuvres in accordance with relevant design rules. Limitations for aerobatic flight are shown in the aircraft's flight manual.

3.2 Utility Category

Utility category means an aeroplane is certified for limited aerobatic manoeuvres in accordance with relevant design rules. Permitted manoeuvres and limitations are shown in the aircraft's flight manual.

3.3 Aresti Diagrams

An international method to draw diagrams representing manoeuvres and the flow of an aerobatic sequence which can be used to brief, an aide memoir during and debrief or score a sequence.

3.4 Zero Lift Axis (ZLA)

The Zero Lift Axis (ZLA) is an imaginary line, going through the leading edge and trailing edge of the wing. It's the line of the aircraft with no angle of attack set. It is often used as a reference line in aerobatics and glider flight to assess aircraft attitude in manoeuvres where angle of attack may vary widely.

3.5 General Definitions

- MOSP 2: Manual of Standard Procedures 2 OPS0001- GAus Operations Manual
- GPC: GAus Glider Pilot Certificate
- EMO: GAus Executive Manager Operations
- RMO: GAus Regional Manager Operations

4 Aerobatic endorsements and permissions

4.1 Conditions

A current Flight Review confirms a GAus pilot's authority to carry out spin practice. Any other aerobatic manoeuvres requires either a Basic or Advanced Aerobatic Endorsement.

Spin training does not form part of the aerobatics syllabus. It is already a fundamental component of the Glider Pilot Certificate (GPC) training syllabus. All GAus instructors are qualified to teach spins, and all pilots awarded a GPC have demonstrated both theoretical understanding and practical competence in spin recognition, entry, recovery, and avoidance. A separate spin endorsement is not required. For aerobatics training purposes, spins may still be reviewed or refined as part of manoeuvre sequencing or competition techniques, but the core training itself is addressed through the GPC syllabus.

GAus Manual of Standard Procedures 2 (MOSP 2) specify the issue of aerobatics endorsements. The syllabus for training is available in the GAus Training Manual OPS002.

Basic Aerobatics: GAus Level 1 instructors (or higher) who are properly trained and have the required logbook endorsement can teach pilots Basic Aerobatics, but only for the manoeuvres they are endorsed to instruct. Club Chief Flying Instructors (CFI) are required to review their instructors' logbooks and aerobatic experience, as well as aerobatic recency. The CFI will issue a logbook sticker.

Advanced Aerobatics: Pilots and instructors wishing to apply to perform and/or train advanced aerobatics are required to submit evidence of competency and support by the club CFI to the Executive Manager Operations (EMO) by email: emo@glidingaustralia.org The EMO will review the application and issue a logbook sticker.

GAus recognises that recognition of prior learning (RPL) is important. Instructors approved to issue ratings will take RPL into consideration when endorsing the training syllabus. Having said this, competency and currency is paramount. Endorsements are not to be given without confirming competency and currency.

Flight Reviews are conducted per OAN 01/20. An updated Flight Review Form contains a section on aerobatics.

4.2 The Basic Aerobatic Endorsement

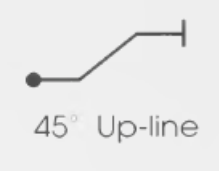
GAus offers a Basic Aerobatics Endorsement to pilots who demonstrate competency in performing fundamental aerobatic manoeuvres safely.

The manoeuvres included in the Basic Aerobatic Endorsement are:

45 Degrees Down-Line

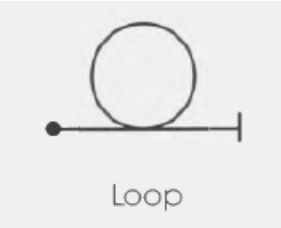
A short horizontal line should be followed by a pitch transition to a 45 degrees Down-Line held steady for a moment before pitching back to another straight horizontal line. The radii of both the pitching segments should be the same. The 45-degree line is based on fuselage angle and should not be wind corrected.

45 Degrees Up-Line



This should look like a mirror image of the 45 degrees Down-Line. It is not wind-corrected. Target entry speed should be anything from 90-110 knots if possible, but in practice it will be whatever the previous figure allows.

Loop

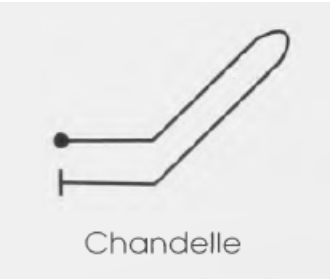


This is one of the most basic manoeuvres, but not easy to fly well. To make the loop perfectly round, start with a pullup of about 3 - 4 g. Once past the vertical, the back pressure on the elevator is slowly relaxed to float over to top of the loop to keep it round. Past the top, the back pressure is slowly increased again throughout the back part till horizontal flight. The plane must stay in one plane with the wings orthogonal to the flight path. Rudder is used to maintain the plane of the figure and ailerons are used to maintain the orientation of the wings and correct for effects of wind drift.

Canopy-down Humpty Bump

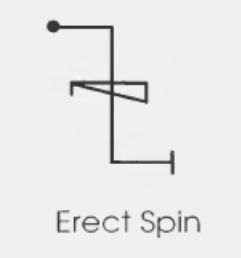
The figure starts with a quarter loop to a vertical climb. A half loop then results in a vertical downline. The figure completes with another quarter loop to horizontal flight. The looping part on the top of the figure does not have to be the same radius as the two other looping portions (the quarter loops going into and coming out of the humpty).

Chandelle



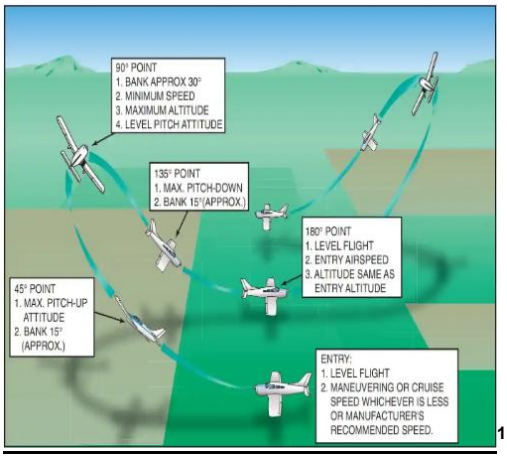
During this manoeuvre the plane will constantly be increasing altitude, decreasing airspeed, and the nose track should describe a straight line through 180° of turn. Fly a constant bank angle of 60° until the roll-out is initiated

Spins exiting onto a heading.



From level flight the spin entry should give the impression that the glider drops directly into a steady spin with no discernible pitch up of the nose or hesitation or other interruption to the flight path. The spinning should be symmetrical and uniform with a crisp stop in a vertical nose down attitude at recovery. A short vertical downline is then held, followed by a high-speed horizontal line on the defined heading.

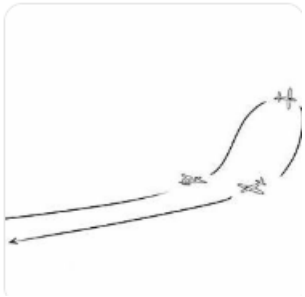
Lazy Eight



[1]

A Lazy Eight is a gentle, coordinated maneuver used in general aviation and pilot training – it is not an Aresti figure. This is a slow, lazy manoeuvre with constantly changing pitch and roll. The sailplane will be describing a Figure 8 by making two 180° turns in the opposite direction. Throughout the manoeuvre the yaw string should be centered.

Wingover



A wingover, like the Lazy Eight, is also not officially included in the Aresti Catalogue. It is considered a smooth, non-precision maneuver mostly for training or display, not judged aerobatics. Pull up and at the same time as banking the plane. When the bank increases past 45 degrees, the nose will start to drop while the bank keeps increasing and the plane keeps turning. Halfway through the manoeuvre, the plane has turned 90 degrees, the fuselage is level with the horizon and the bank is 90 degrees. The plane is above the original flight path. The nose then keeps dropping below the horizon and the plane keeps turning, while the bank is shallowed. When the bank drops below 45 degrees, the nose is pulled up towards the horizon and the plane reaches horizontal flight with wings level after 180 degrees of turn. At the completion of the maneuver, the plane is at the same altitude as on entry and

[1] Source cfinotebook.net

flying in the opposite direction.

4.3 Instructing Basic Aerobatics

GAus Level 1 instructors (or higher) who are properly trained and have the required logbook endorsement may instruct pilots in Basic Aerobatics, but only for the specific manoeuvres they are endorsed to teach.

Club CFIs are responsible for reviewing an instructor's logbook, aerobatic experience, and recency. If satisfied with the instructor's qualifications and current competency, the CFI will issue a logbook sticker authorising instruction in the approved manoeuvres.

All GAus flying instructors are already certified as competent to instruct in stalls and spins.

However, instruction in any other aerobatic manoeuvres requires a specific endorsement in the instructor's logbook. This endorsement must be issued by a Regional Manager Operations (RMO), or by a CFI or Level 3 Instructor who is approved by the RMO and holds an aerobatic training endorsement themselves. The endorsement must clearly state the manoeuvres the instructor is approved to teach.

The assessment of competence for the issue of an aerobatic training endorsement should be based on the instructor's demonstrated ability to:

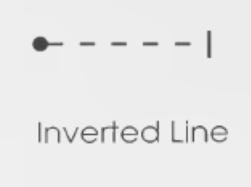
- Deliver ground instruction in the relevant aerobatic topics,
- Provide effective in-flight training, and
- Assess student competence for each of the units and elements defined in the GAus Aerobatics Syllabus (refer to the GAus Training Manual).

4.4 The Advanced Aerobatic Endorsement

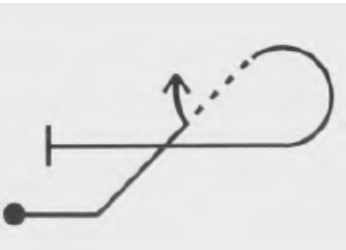
The Advanced Aerobatic Endorsement is a GAus recognition for pilots who have demonstrated competence in higher-level aerobatic manoeuvres beyond the Basic syllabus.

It confirms a pilot's skills to safely fly more complex figures and combinations within the structural and flight envelope limits of their glider. In addition to the basic manoeuvres, the advanced manoeuvres are considered to be critical in aircraft type and execution (e.g. due to rolling G risk) and as such are endorsed individually. A non-exhaustive list of advanced manoeuvres are:

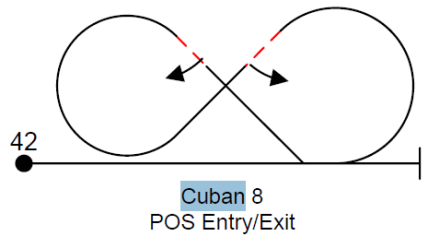
Inverted Flight



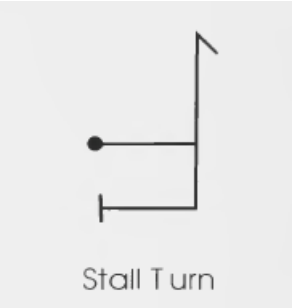
Half Cuban Eight



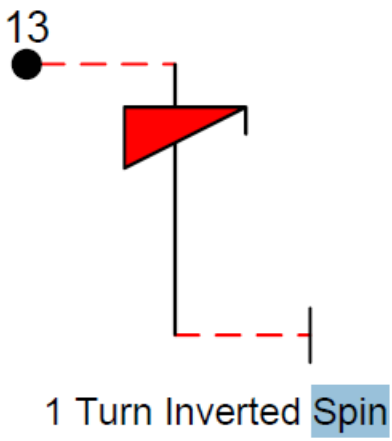
Full Cuban



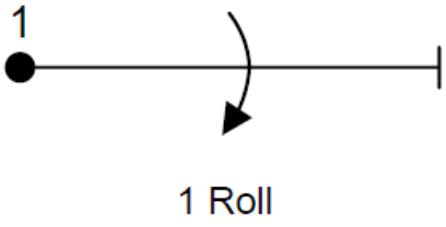
Stall Turn



Inverted Spin



Slow Roll



- Flick roll;

- Humpty-Bump.

Flick manoeuvres are rapid rolling motions induced by a stalled condition of flight and tend to be abrupt manoeuvres which place additional stress on the aircraft and pilot. Some aerobatic aircraft may have limitations prohibiting flick manoeuvres. However, aircraft design standards allow for this. A lower maximum entry speed for a corresponding reduced maximum G load in accordance with the flight manual must be adhered to. Some aerobatic aircraft may have limitations restricting the type allowed or may prohibit flick manoeuvres all together.

4.5 Instructing Advanced Aerobatics

Instruction of advanced aerobatics is not a blanket instructor endorsement. It is limited to individual manoeuvres. The instructor is approved for instruction in each manoeuvre. The instructor must be approved by the GAus EMO who will consult with the RMO, the CFI and a L3 who also holds the instruction of aerobatic endorsement for the manoeuvre approved. The endorsement will state the individual advanced manoeuvres that the instructor is approved to teach.

4.6 Low Level Aerobatic Training

Instructors conducting low-level aerobatic training must hold a current low-level aerobatic permission issued under the authority delegated by CASA to GAus in accordance with Part 149 and the GAus Exposition.

Permission must be issued by the Executive Manager Operations (EMO) or a delegated official only where GAus is authorised by CASA to do so. This permission specifies the minimum permissible height for training flights and may be time-limited or event-specific.

All low-level aerobatic operations must comply with CASA regulations and any additional operational limitations defined by GAus. Where CASA authorisation is required and not delegated, applications must be made directly to CASA.

4.7 Aerobatic Height Limitations

Low-level aerobatics involve significantly increased risk due to the reduced safety margins available for error detection and recovery. Approval for low-level aerobatic flight should therefore be based not only on a pilot's demonstrated aerobatic skill, but also on their ability to effectively assess and manage the operational risks—particularly those affecting third parties on the ground and other airspace users.

As part of the approval process, competency assessment should consider the pilot's ability to apply Threat and Error Management (TEM) principles, situational awareness, and sound decision-making under time and altitude pressure.

This manual does not prescribe detailed requirements for maintaining recent experience in low-level aerobatics. Instead, pilots granted this permission are expected to take personal responsibility for assessing their recency, competency, and currency before conducting any flight at a reduced height.

Note: Approval for low-level aerobatics does not constitute permission to:

- Perform aerobatics over public gatherings or at airshows, this requires separate approval.
- Conduct low flying operations unrelated to aerobatics, minimum heights for flight remain governed by CAO 95.4 and MOSP 2 and must be complied with at all times.

4.8 Airshows

Aerobatic displays at public events such as air shows involve additional operational and regulatory requirements beyond standard aerobatic or low-level permissions. These activities must be carefully managed to ensure the safety of spectators and compliance with aviation safety standards.

4.8.1 Approval to Conduct Aerobatics at Airshows

To conduct aerobatics at an airshow or other public gathering, pilots must obtain specific authorisation from GAus Executive Manager Operations (EMO). This is required regardless of whether the pilot holds a low-level aerobatics permission.

The following conditions apply:

- A formal application must be submitted to the EMO in advance, typically at least 30 days prior to the planned event.
- The pilot must demonstrate:
    - Current aerobatic competency in the manoeuvres to be performed.
    - Suitability of the aircraft, including compliance with its flight manual and structural limits.
    - That the display will take place in a designated aerobatic area with appropriate crowd separation and safety zones.
    - That a risk assessment and display briefing has been completed.
- Additional coordination with CASA may be required depending on the nature and location of the event.

Note: A general aerobatic or low-level permission does not automatically authorise participation in public displays.

4.8.2 Conducting Low-Level Aerobatics at Airshows

Where a pilot intends to conduct low-level aerobatics during an airshow or public display, the following additional requirements apply:

- The pilot must already hold a valid low-level aerobatics permission issued in accordance with GAus policy.
- The lowest altitude to be flown during the display must be clearly specified and approved in advance by the EMO.
- The manoeuvres must be:
    - Appropriate for the aircraft type and its limitations, and
    - Well within the demonstrated competency and recency of the pilot.
- The display must be flown strictly in accordance with the approved sequence, within the pre-briefed box or airspace, and with all relevant display flying safety protocols in place.

Failure to meet any of these conditions may result in the display approval being withheld or withdrawn.

Important: Safety margins at airshows are critical. Pilots must prioritise precise planning, self-discipline, and conservative decision-making when operating in public display environments.

4.9 Aerobatic Currency

Aerobatic skills degrade quickly and need to be maintained by constant practice. Pilots therefore need to develop their own strategies for maintaining or regaining proficiency and ensuring they are sufficiently in practice to perform the planned aerobatic manoeuvres safely.

Strategies for regaining proficiency after lack of recent practice may include:

- Obtain dual instruction.
- Limit practice to basic manoeuvres initially.
- Operate at a higher altitude to provide a greater safety margin.
- Practice emergency recovery procedures; and
- Allow sufficient practice time to re-acclimate to high G forces.

4.10 Club Designated Aerobatic Area

Many club sites feature undulating terrain, which can pose additional hazards during aerobatic flight, especially if a manoeuvre is mishandled or the pilot becomes disoriented. To manage these risks, clubs are encouraged to conduct a formal risk assessment when establishing or reviewing their designated aerobatic areas, and to seek professional advice where appropriate.

The aerobatic area should ideally be positioned over lower ground, and close to, but clear of, the active circuit area to support orientation and allow for an abbreviated circuit recovery if required. It should also be clear of active airspace and normal approach or departure routes, particularly when operating near controlled or uncontrolled aerodromes.

A well-defined aerobatic area also improves position reporting, supports targeted lookout procedures, and enhances overall safety for both aerobatic and non-aerobatic traffic in the vicinity.

4.11 Aerobatic Competency Standards

GAus recognises multiple pathways for establishing and assessing competency in aerobatic manoeuvres. Competency must be demonstrated and recorded for each individual manoeuvre.

4.11.1 Competency gained via GAus Aerobatic Training

Pilots are deemed competent to perform individual aerobatic manoeuvres if they have:

- Completed GAus-approved training in basic or advanced aerobatics; and
- Done so at club level or via a state-based course; and
- Had their training syllabus fully completed and signed off by a suitably endorsed instructor.

Similarly, instructors who have completed GAus-approved instructor training in basic or advanced aerobatics, and have a signed-off syllabus, are considered qualified to instruct only those specific manoeuvres for which they have demonstrated competence.

4.11.2 Competency gained through overseas experience

Pilots who hold aerobatic qualifications issued by an overseas authority must:

- Submit their credentials to the GAus Executive Manager Operations (EMO).
- Undergo a competency assessment with a suitably qualified GAus instructor, arranged in consultation with the Regional Manager Operations (RMO).
- Upon successful assessment, receive a logbook endorsement specifying the manoeuvres approved.

- Ensure the endorsement is recorded in the GAus membership system.

4.11.3 Flight Reviews and Aerobatics

Aerobatic competency is reviewed as part of the pilot's Flight Review. The reviewing instructor must be:

- Qualified and endorsed to assess aerobatic manoeuvres; and
- Aware of the pilot's planned flying activity in the period following the review.

The Flight Review form must indicate which aerobatic manoeuvres the pilot is currently competent to perform. If any endorsed manoeuvres require further training, the pilot should complete this within one month. A revised logbook endorsement must then be issued and the update recorded in the GAus membership system.

5 Aerobatic Theory

5.1 Human factors and body limitations

5.1.1 Physiological Effects of G Forces

Aerobatic manoeuvres involve rapid changes in speed and direction which impose significant accelerative forces on the aircraft and pilot. The physiological effects of these G forces can range from minor discomfort to loss of consciousness.

Basic aerobatic manoeuvres produce effects that are at the lower end of the scale. With experience, most pilots do not experience adverse effects during basic aerobatics.

Pilots beginning aerobatics may be adversely affected by airsickness, disorientation and discomfort but continued practice, and the use of appropriate methods of mitigating the physiological effects, will allow most pilots to adapt quickly to standard aerobatic manoeuvres.

Generally, basic aerobatics involve up to +4G forces and advanced aerobatics may require higher G loadings, and rapid changes in G over extended periods, which can result in hazardous physiological effects such as loss of consciousness. Even experienced aerobatic pilots must keep in practice and be aware of their physical limitations in respect of G to safely perform advanced aerobatics.

5.1.2 Positive G (+G)

Pull-up manoeuvres (Figure 1) produce a +G loading, causing the body and limbs to feel heavier and more difficult to move. Blood is forced towards the lower part of the body and the extremities, resulting in reduced blood pressure and therefore oxygen to the brain and eyes. When the blood circulation to the brain and eyes decreases because of +G forces, a pilot may experience grey-out, tunnel vision, black-out, and finally loss of consciousness (GLOC). If +G is increased steadily, the eyes are generally affected by a reduction of blood pressure before the brain, providing some visual warning that incapacitation is imminent.

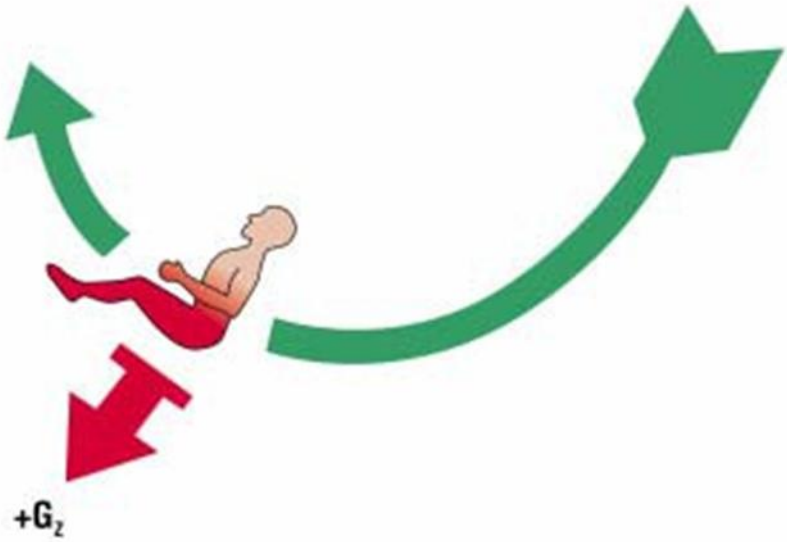


Figure 1: G's acting on a pilot in a pullup from a dive

5.1.3 Grey-out

The first visual indication of high +G may be a loss of colour perception and clarity known as 'grey-out', probably accompanied by a loss of peripheral vision. The grey-out phase is a warning to reduce +G

forces.

5.1.4 Tunnel Vision

Grey-out may be followed by a concentric narrowing of the field of vision that is termed 'tunnel vision'. If the pilot experiences tunnel vision, relax the back stick/g force because tunnel vision is a precursor to black-out and loss of consciousness.

5.1.5 Black-out

If +G is maintained or increased, the field of vision narrows completely so that that vision is lost and 'black-out' occurs. The pilot is still conscious but cannot see. Loss of consciousness is likely to follow quickly if +G is not reduced.

5.1.6 Rapid Onset +G

If high G forces are applied rapidly enough, for a period of around five seconds or more, then loss of consciousness can occur without any of the visual warning signs of low-level tunnel vision or black-out.

5.1.7 G Induced Loss of Consciousness (GLOC)

Loss of consciousness will occur if the blood flow to the brain, and therefore the supply of oxygen, is sufficiently reduced by the +G forces being experienced. High -G for a significant period may also have a similar effect.

High +G for short periods may not be sufficient to cause GLOC, because without blood flow, the brain and eyes can continue to function on oxygen reserve for about four to seven seconds. However, longer than this period at +5 G or more is generally sufficient to bring on GLOC as illustrated by the graph below.

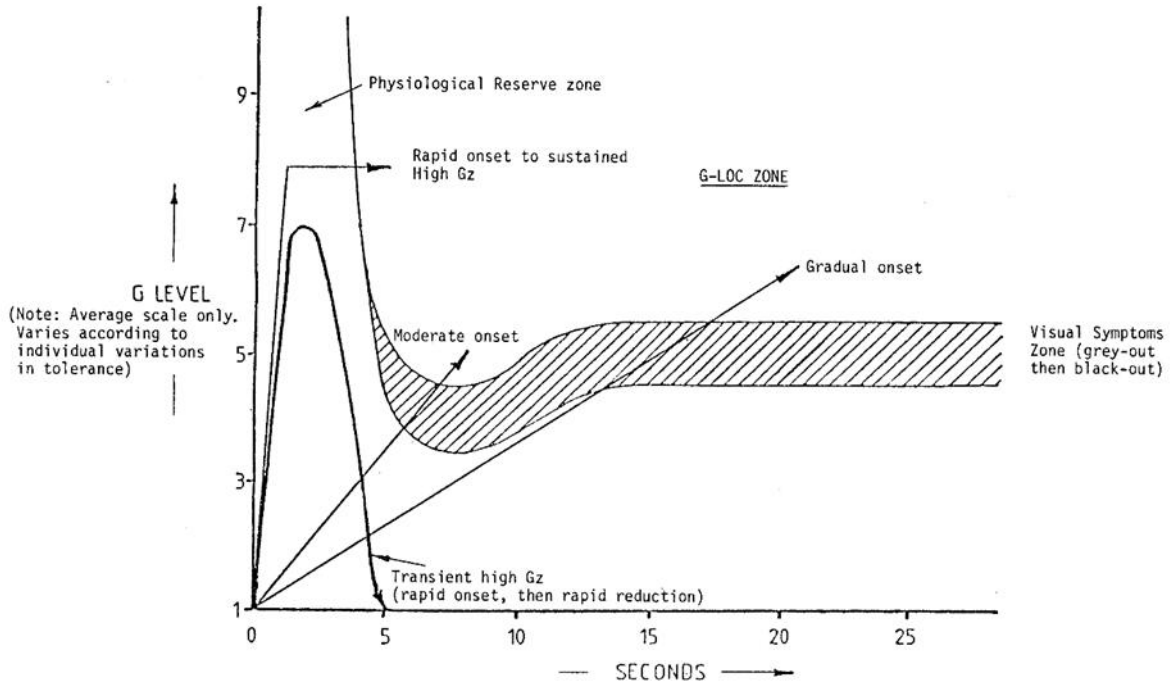


Figure 2: Gz onset rate and Gz tolerance

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5.1.8 G Incapacitation

In a GLOC event, there will be a short period of total incapacitation where the pilot is completely unconscious, followed by a recovery period of relative incapacitation where the pilot has regained consciousness but is in a confused state and unable to control the aircraft. However, after recovering sufficiently to regain control, there is likely to be a longer period before full normal functioning and situational awareness returns.

GLOC in flight normally results in the pilot relaxing the control forces and therefore reducing the G force, so that the actual duration of loss of consciousness may only last, on average, for about 15 seconds. The following period of relative incapacitation may last another 15 seconds but could be up to 50 seconds.

Full recovery may take several minutes, during which time the pilot will be functioning below normal ability and may be more susceptible to another GLOC episode.

A particularly insidious aspect of GLOC is that it can often occur without the pilot subsequently being aware of it. Centrifuge studies have shown that 50% of pilots do not recall a GLOC event. Warning signs that this may have happened could be an unexplained loss of altitude or an unusual aircraft attitude, either of which may be good reason for discontinuing aerobatic manoeuvres on that flight.

Obviously, the period during which control of the aircraft is lost following GLOC is extremely hazardous, particularly if aerobatics are being conducted at low-level.

Visual symptoms, such as grey-out and black-out, are a warning that oxygen reserves are seriously depleted, that GLOC is imminent, and that G forces should be immediately reduced. However, they should not be relied on to provide a warning, because GLOC can often occur without prior visual symptoms.

5.1.9 Negative G (-G)

Push-over manoeuvres (Figure 3) produce -G loading and force blood and body organs towards the head. The pilot initially feels weightless and is pushed out of the seat against the safety harness. Under mild conditions of -G forces, the pilot will experience the sort of face and head congestion felt when standing or hanging inverted, but at higher levels of -G discomfort can be acute and possibly be accompanied by haemorrhaging of small blood vessels in the eyes, nosebleed or headache. Due to the discomfort, it may take longer to adapt to -G.

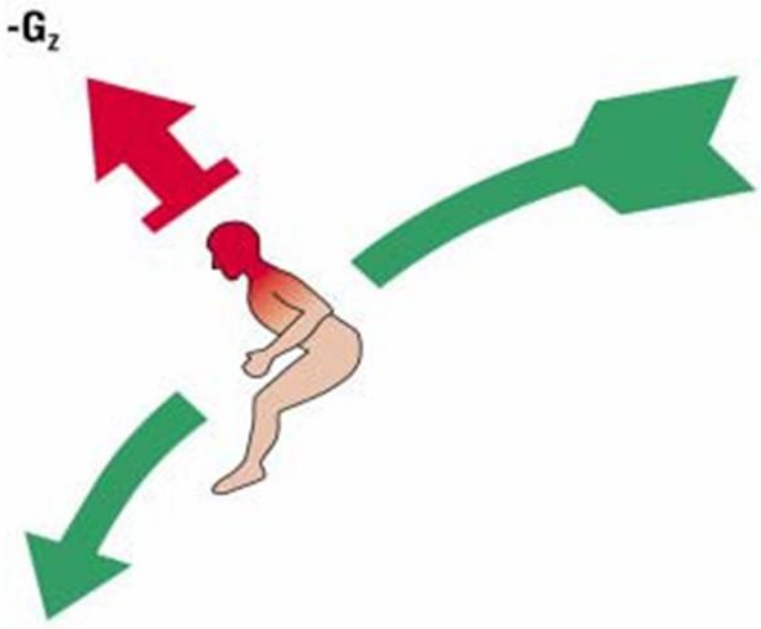


Figure 3: G's acting on a pilot in a pushover

5.1.10 Red-out

It was once thought that the lower eyelids rise to cover the pilot's pupils during high -G, causing the pilot to see only a red field, the opposite of a black-out. This condition was called 'red-out' but has not been well documented and several pilots question its existence.

5.1.11 Change from -G to +G

A rapid change from -G to +G also presents a potential hazard. When a pilot is subjected to -G, blood pressure receptors in the neck and chest respond to the increased blood pressure in the upper body by slowing the heart rate. If the -G is followed by a rapid change to +G, there is a rapid reduction in blood pressure in the upper body and the heart rate cannot respond rapidly enough to maintain adequate blood pressure to the brain. Maintaining -G for three to four seconds is enough to significantly reduce a pilot's normal tolerance to +G and may lead to loss of consciousness well before the pilot would normally expect it, (as low as +3G). Figure 5 shows an aerobatic sequence, a vertical 8 with an outside loop on top (-G) and an inside loop on the bottom (+G) as an example of a manoeuvre which could easily constitute a GLOC risk.

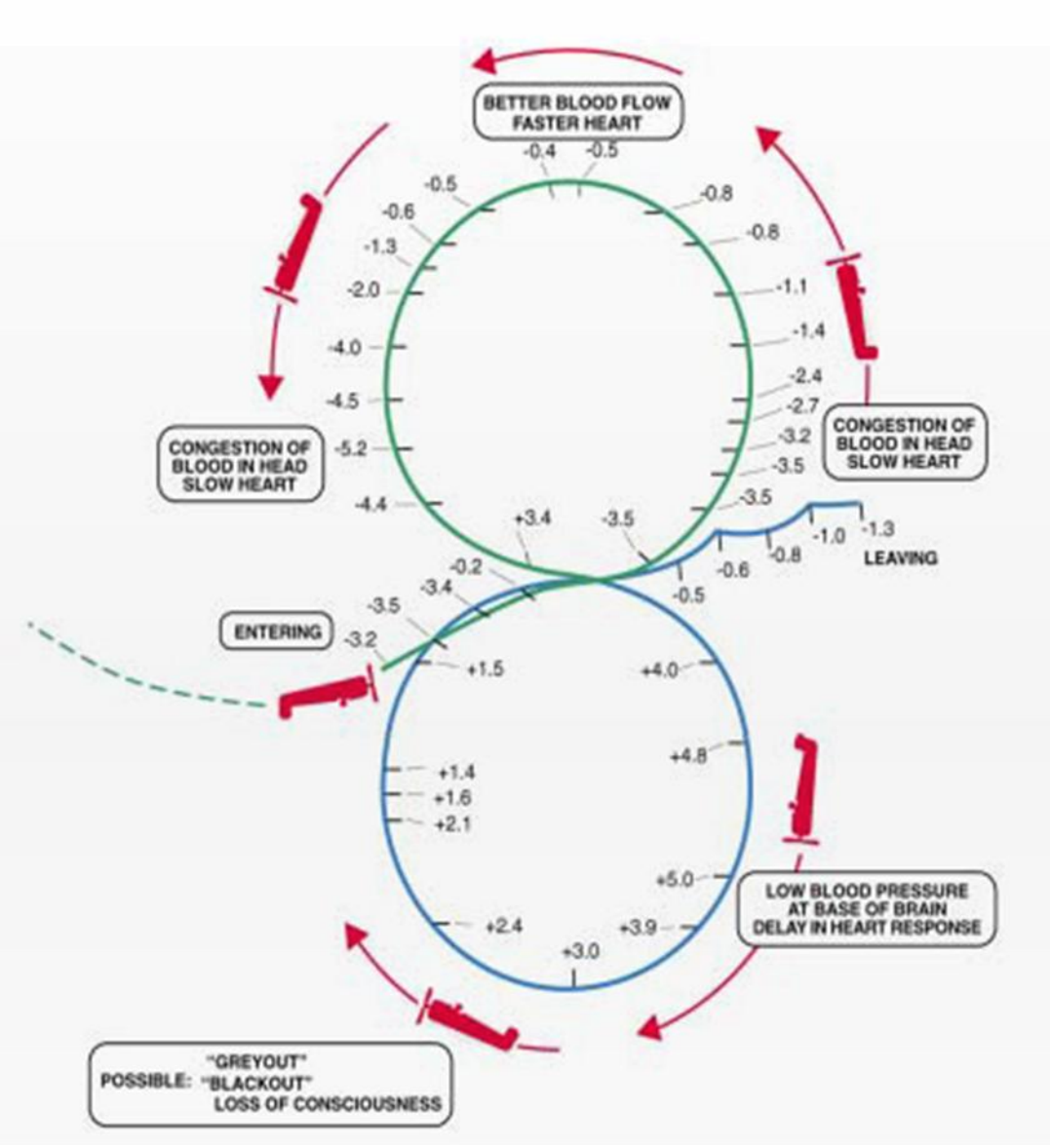


Figure 4. Negative and positive G'z recorded second-by-second during the outside (upper loop)-inside

(lower loop) vertical 8 manoeuvre. The major physiological consequences are indicated at their respective positions in the manoeuvre. The rapid change from negative to positive is particularly stressful.

5.1.12 Other G Forces

G forces in aerobatics are usually positive or negative and forces acting sideways or fore and aft are generally minor by comparison, other than in some advanced aerobatic manoeuvres where the pilot may be flung about if not properly restrained.

5.1.13 G Tolerance

The average pilot can probably tolerate +3G to +5G for extended periods without losing consciousness, but this figure can vary significantly for different individuals, and an individual's tolerance can also vary from day to day.

The following table gives some idea of normal levels of G tolerance.

Table 1. Thresholds in Relation to +G Tolerance

Symptom	Average Threshold	Deviation	Standard Range
'Grey-out'	4.1 G	± 0.7 G	2.2 to 7.1 G
'Black-out'	4.7 G	± 0.8 G	2.7 to 7.8 G
Unconsciousness	5.4 G	± 0.9 G	3.0 to 8.4 G

5.1.14 Establishing Individual G Tolerance G Tolerance

Some pilots can tolerate more G than others, but all have a limit which can vary considerably from day to day for the same individual. Not all pilots may be capable of competing in advanced aerobatic competitions because of the extreme G forces associated with the required manoeuvres.

Aerobatic pilots need to realise the potential hazards of high G and establish personal limits based on their own experience and considering their current state of health, fitness, and recent aerobatic experience.

A warmup manoeuvre of three to five G for ten seconds will confirm adequate G tolerance on the day and raise the G tolerance level slightly by increasing blood pressure.

5.1.15 G Resistance Straining

G resistance straining can significantly increase +G tolerance but needs to be initiated prior to the application of G forces to be fully effective. Effective straining is intended to prevent pooling of blood in the extremities, particularly the legs and lower body, thus maintaining sufficient blood pressure to the brain. Properly done, the straining manoeuvre can increase normal +G tolerance by three G or more.

Straining consists of tensing the lower body muscle groups, abdominals, buttocks and upper leg muscles. Straining should be commenced as +G is applied and maintained until +G is released. Relaxing the straining while still pulling +G could result in immediate GLOC.

Frequent aerobatic practice and physical conditioning can increase the effectiveness of the straining manoeuvre. Conditioning exercises should aim at increasing the strength of the abdominal and upper leg muscles. Aerobic exercise and fitness are beneficial in increasing endurance and assisting recovery from high G but will not of itself raise the G tolerance level.

5.1.16 The Anti-G Straining Manoeuvre

There are two components to the recommended Anti-G Straining Manoeuvre (AGSM):

1. A continuous and maximum contraction, if necessary, of all skeletal muscles including the arms, legs, chest, and abdominal muscles and any other muscles if possible. Tensing of the skeletal muscles reduces blood in the G dependent areas of the body and assists in retaining or returning the blood to the thoracic (chest) area, the heart and brain.

2. The respiratory component of the AGSM is repeated at 2.5 - 3.0 second intervals. The purpose of the respiratory component is to counter the downward G force by increasing chest pressure by expanding the lungs. This increased pressure forces blood to flow from the heart to the brain.

The respiratory tract is an open breathing system which starts at the nose and mouth and ends deep in the lungs. The respiratory tract can be completely closed off at several different points.

The most effective point is to close the system off at the glottis.

Closing the glottis, which is located behind the "Adam's Apple", yields the highest increase of chest pressure. You can find it and close it off by saying the word "Hick." This should be said following a deep inspiration and forcefully closing the glottis as you say "Hick." Bear down for 2.5 to 3.0 seconds, and then rapidly exhale by finishing the word "Hick." This is immediately followed by the next deep inhalation repeating the cycle. The exhalation and inhalation phase should last no more than 0.5 to 1.0 second.

Quick Tip

1. Do not hold your respiratory straining too long (more than five seconds) since this will prevent the proper returning of blood to the heart and may result in loss of consciousness.

2. Anticipate a rapid-onset, high G exposure whenever possible. The skeletal muscles should be tensed prior to the onset of G and coupled with the "Hick" cycle as the increasing of G begins.

Initiating the AGSM too early can inhibit the body's natural cardiovascular reflex responses. Starting the AGSM too late is a difficult situation to make up without reducing the G-stress.

5.1.17 Head Elevation

Reducing the distance of the head above the heart, or elevating the legs, will reduce the pressure required to maintain blood circulation to the brain during +G. The semi-reclining position in most sailplanes will assist.

5.1.18 Resistance Strategies for -G

There is no known method to counter the effects of -G, other than to continue to breathe normally and relax the abdominal and leg muscles, although it has been suggested that practising hanging or standing inverted may possibly assist adaptation.

5.1.19 Physiological Factors Adversely Affecting G Tolerance

Pilots can build up their tolerance to G with practice but need to be aware that tolerance levels that have been established can be significantly reduced by various factors affecting their physical condition. For example, studies have shown that dehydration can reduce G tolerance by up to 50%. Factors that can reduce G tolerance include:

- Dehydration.

- Low blood sugar level.
- Eating a large meal before flying.
- Fatigue.
- Prolonged standing or sitting.
- Hypoxia.
- Illness.
- Smoking.
- Alcohol.
- Drugs.
- Medications.
- Low blood pressure.
- Cardiovascular fitness level.
- Recent weight gain or loss.

Pilots with any medical condition listed would be advised to consult a DAME before undertaking aerobatics.

Lack of recent aerobatic practice will also reduce a pilot's G tolerance and pilots returning to aerobatics after some time away will need to check and then gradually re-establish their tolerance level.

5.1.20 Disorientation

The human balance mechanism was not designed for the forces experienced during normal flight, let alone aerobatics. Balance therefore cannot be relied on for orientation, and maintaining visual reference to the horizon and prominent ground features is the best method of minimising feelings of disorientation.

Rapid head movements or turning the head while performing high G manoeuvres is known to cause severe disorientation and should be avoided. There is also the risk of neck injury by moving the head about under high G.

The best practice is to hold the head still during high G manoeuvres, which requires the pilot to anticipate the direction in which he or she needs to be looking during the manoeuvre so that only minimal head movements are necessary.

Sustained rapid rotation, such as in flick manoeuvres or spins, can also lead to disorientation because visual reference is made difficult due to the rapid rotation and there is no visual correction to the confused signals from the balance mechanism.

Recent ear, nose, throat infections may cause injury or pain, as well as disorientation, during aerobatics.

5.1.21 G Induced Vestibular Dysfunction

Sometimes known as 'the wobblies' or Coriolis, this is a condition that is not well understood, but which has affected several advanced aerobatic pilots, both in Australia and overseas. It seems to

occur when pilots are subjected to high G loadings, particularly –G, and turn their head from one side to the other.

Symptoms consist of loss of balance and nausea experienced after the aerobatic performance and can sometimes be long lasting for days or even months. Several pilots have been forced to abandon aerobatic flying because of this condition.

> **Quick Tip**
>
> Pilots experiencing symptoms should seek medical advice, preferably from a Designated Medical examiner (DAME), and refrain from aerobatics while symptoms persist. They may also need to consider whether they continue to meet the aviation medical standard for other types of flying.

5.1.22 Airsickness

Airsickness is probably due to the disruption to the balance mechanism brought about by the unusual and changing forces acting on the body, and particularly on the abdominal organs, during flight. Some degree of airsickness can be expected when commencing aerobatics but should settle or reduce with practice and when the trainee begins flying the manoeuvres. Leaving spinning manoeuvres until the end of an aerobatics session is good practice for beginning pilots.

Aerobatics sessions may need to be cut short if airsickness is experienced, although fresh air and a short break from manoeuvring may help. Tensing the abdominal muscles and holding the internal organs firmly in place during manoeuvres and maintaining visual reference will help. Several aerobatic pilots have overcome initial severe airsickness problems by perseverance.

Readily accessible airsick bags should be a pre-flight checklist item for aerobatic training flights.

5.1.23 Medical Fitness

> **Quick Tip**
>
> If you experience incapacitation or have any lingering symptoms because of aerobatics, you should consult a DAME before resuming flying.

5.2 Technical subjects

5.2.1 Effect of Gusts

A very sudden gust will not instantly stall the wing. Briefly the wing can produce 25% more lift. Load factors can increase by 25% as a result. According to JAR-22.333 at VB a sailplane must be capable of withstanding positive up and negative down gusts of 15 m/s. This is defined as a strong gust and is about 30 kts. Rough air is all air in lee-wave rotors, thunderclouds, or over mountain crests. VA cannot be more than VB. In practice they are very close. Strong gusts are not an issue up to VB (Max Rough Air). Weak gusts are +7.5 m/s.

In the example below, the sailplane is at 110 kts and meets a weak gust. If the glider pulls 3g in a loop at the same moment, the aircraft will be outside the placarded limits.

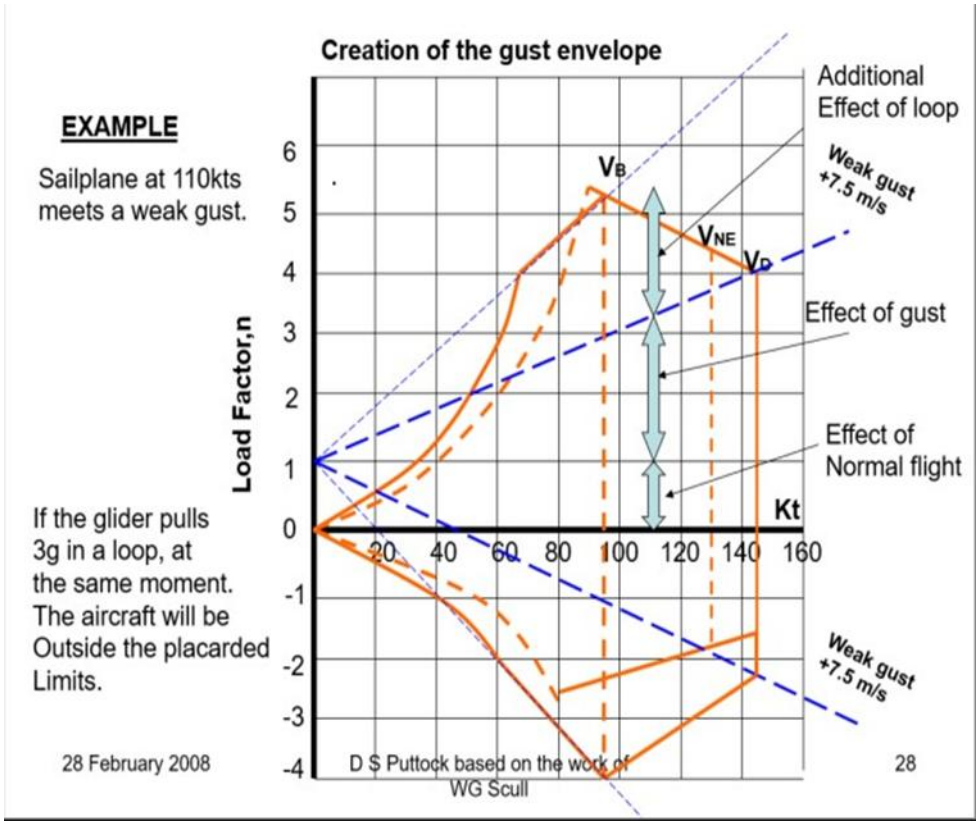


Figure 5: The effect of gusts (https://dartmoorgliding.co.uk/pilots/training-material/in-flight/flight-principles-6-the-gust-envelope/)

5.2.2 Aresti Diagrams

Introduced in 1964, the Aresti aerobatic shorthand and scoring system, was the contribution of a Spanish aerobatic aristocrat, Count Jose Louis Aresti.

The figure starts at the small solid circle and ends at the vertical bar. All aerobatic figures start and end from horizontal lines in either upright or inverted flight. Solid lines describe upright flight; dashed lines describe inverted flight. A combination of figures is combined in the diagram to create the sequence.

See Bibliography and References for further information on Aresti diagrams.

5.2.3 Aerobatic Figures

Aerobatics are described in diagrams, figures and the symbols used to represent them. The elements used in these figures are horizontal, vertical and 45° lines. These describe straight flight in these directions. Parts of loops connect these line segments. The looping portions in almost all figures must have the same radius in all parts of a figure

Rolls on vertical lines and on 45° lines must be centred on this line to score well. Any deviation from the centre results in a downgrading during a competition.

The K-values included with the competition figures give an indication of the difficulty of each of these manoeuvres. Higher K-values mean more difficult manoeuvres.

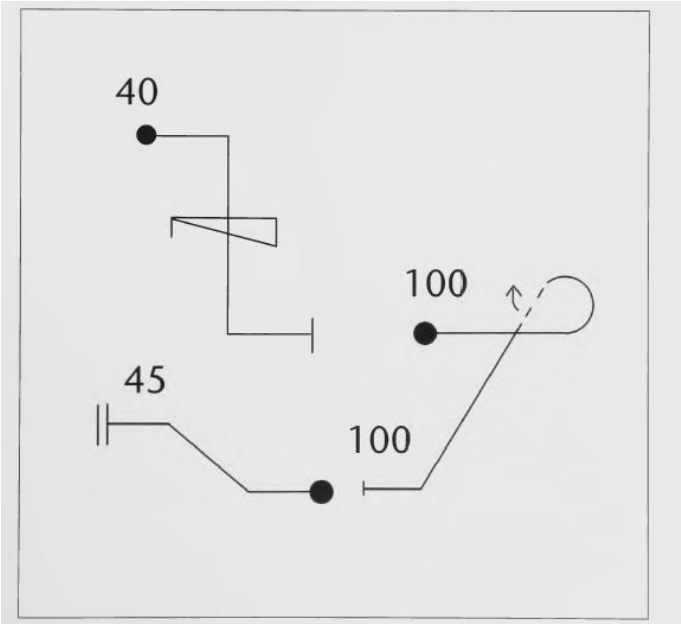
See Bibliography and References for further information on aerobatic figures.

5.2.4 Aerobatic Sequences

Aerobatic sequences join the various manoeuvres together in a compatible way. Using the energy and position of the previous manoeuvre to aid with the current one. It is beyond this manual's scope to delve into designing sequences. Consult the Bibliography and References for further information.

The following, from "The Handbook of Glider Aerobatics" explains a simple sequence.

"For example, a Half Cuban Eight needs to follow a speed-gaining figure such as a spin, with perhaps a 45° up-line to finish as shown below."



Simple Aerobatic Sequence of Compatible Figures.

5.2.5 Rolling Loads (G)

Recognising and managing rolling G-loads in glider aerobatics is crucial for maintaining structural integrity and ensuring pilot safety. Rolling G occurs when a glider experiences roll (aileron-induced) inputs and pitch (elevator-induced) inputs simultaneously. This can lead to asymmetric loading on the airframe.

CS 22.349 says: "The sailplane must be designed for the rolling loads resulting from the aileron deflections and speeds specified in CS 22.455 in combination with a load factor of at least two-thirds of the positive manoeuvring load factors prescribed in CS 22.337."

The following diagram from the Handbook of Glider Aerobatics (see References) shows the inverted rolling G limit.

Consult references for further reading on rolling loads.

Finally, the BGA says: "It would be the height of stupidity, not to mention extremely risky, to try and teach rolling manoeuvres, say, if your only experience of them was via the hit and miss of self-teaching; or these days, in a computer flight simulator."

[2] The Handbook of Glider Aerobatics: Mallinson & Woollard; Airlife Publishing Ltd., England 1999

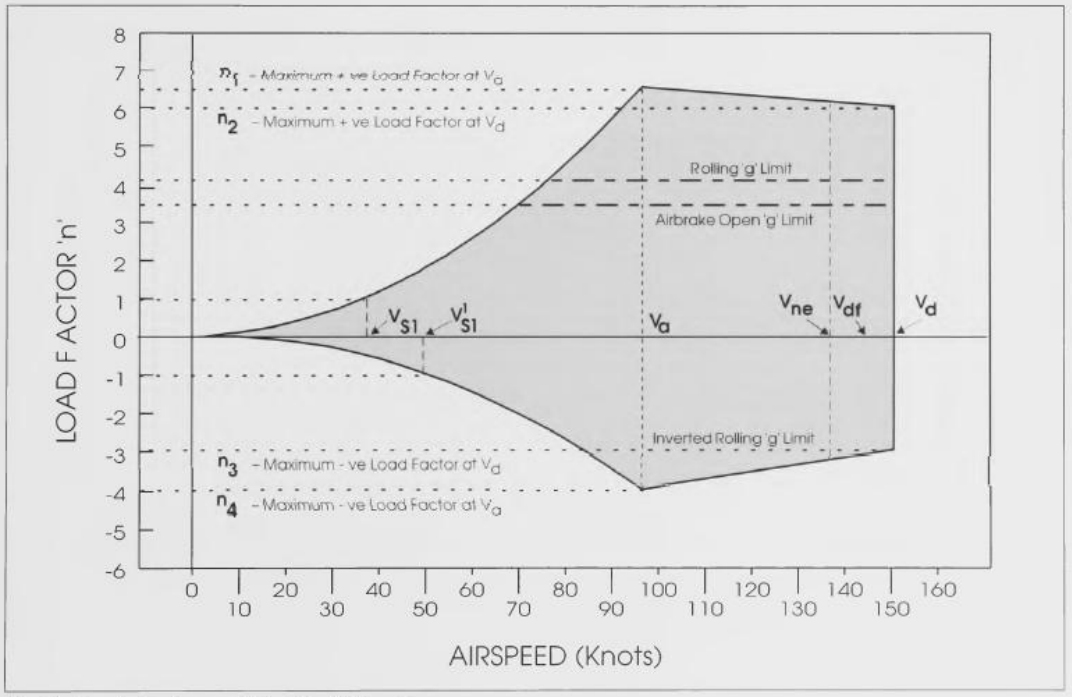


Fig 1: Basic Features of the Flight Envelope [3]

5.3 Aircraft limitations

5.3.1 Aircraft Airworthiness for Aerobatics

In utility category sailplanes, the manoeuvres that can be performed safely are listed in the approved aircraft flight manual and/or on placards located in the cockpit.

Acrobatic category sailplanes are normally suitable for most standard aerobatic manoeuvres, but some types may have certain restrictions. The aircraft flight manual or cockpit placards are the reference and will normally specify any manoeuvres that are not permitted or any other restrictions on aerobatic flight.

5.3.2 Aircraft Airspeed limitations

The aircraft flight manual will specify airspeed limitations for the sailplane. Limitations that are particularly relevant in aerobatics are:

- VNE – never exceed speed.
- VNO – normal operating limit speed.
- VA – maximum manoeuvring indicated air speed (IAS).
- Entry speeds for manoeuvres.
- Maximum flick manoeuvre IAS.

5.3.3 Manoeuvring Speed

Manoeuvring speed (VA) is the speed above which full deflection of the elevator control will exceed

[3] The Handbook of Glider Aerobatics: Mallinson & Woollard; Airlife Publishing Ltd., England 1999

aircraft structural limitations. Below VA the aircraft will stall before structural limits can be exceeded. Va will be specified in the aircraft's flight manual and placarded in the cockpit. Full control deflection of any flight control must be avoided above this speed.

It is important to note that VA is established at the aircraft's maximum all-up weight or maximum aerobatic weight, and that at lighter weights it is possible to exceed G limitations at speeds less than the specified VA.

It could be argued that exceeding G limitations at a lighter weight may not necessarily overstress the wing structure because the lift forces imposed at the lighter weight for the same G are proportionately less, and therefore the wing structure should be strong enough to withstand the load. However, other airframe components such as engine mountings, battery mountings, attachments and other equipment still experience the full G loading, and these structural components could fail even though the wing does not.

Thus, to stay within a safe operating envelope, the pilot should manoeuvre near VA with caution, monitor the accelerometer rather than rely solely on airspeed limitations, respect rolling G and flick roll limits, and be cautious in the use of abrupt control inputs.

5.3.4 Airframe Fatigue and High G Loadings

While G limitations are established to ensure the aircraft structure can withstand the maximum specified loading, the cumulative effect of deliberately imposing maximum or greater loads on numerous occasions can have an adverse effect on the fatigue life of an aircraft by weakening the aircraft structure.

Some aircraft manufacturers note that providing the aircraft is always manoeuvred within the flight manual limitations, there is no change to the life of fiberglass gliders.

Frequent rapid application of maximum G loadings should be avoided unless the aircraft has been specifically designed for this purpose. Particular attention should be paid to the structural integrity of aircraft known to have been subjected to such regimes.

5.3.5 Older Aircraft

Many sailplanes still flying were designed to older, less demanding standards. In the absence of flight manuals or placards, pilots will need to seek information regarding the aerobatic capabilities of these aircraft from reliable sources.

Owners and pilots must also be aware of possible effects on structural strength generally related to aircraft age, such as corrosion, material quality, delamination of glued structures, metal fatigue, and other factors which may degrade an aircraft's structural integrity.

There are various regulatory and other systems for advising pilots and operators about how to deal with the airworthiness issues related to aging aircraft. Owners and pilots of old aircraft should consult airworthiness engineers and authorities and respect their advice.

Material stress is cumulative – a manoeuvre that could be safely performed in a particular aircraft some years ago could be fatal in the same aircraft today.

5.3.6 Occupant Restraint

Proper aerobatic harnesses in good condition are essential to securely restrain the occupants under the higher stresses imposed by aerobatics.

Many aerobatic aircraft incorporate an additional lap-strap to separate attachment points (five-point harness), with separate buckles latching in the opposite direction to minimise the risk of accidental release.

Harnesses and attachments should not be worn if damaged, and latching mechanisms should fasten securely and not be susceptible to inadvertent release. Harnesses should always be secured as tightly as possible so the body cannot be thrown around during manoeuvres.

5.3.7 Engine Systems

Refer to the aircraft flight manual for engine-on aerobatic manoeuvres in powered sailplanes.

Batteries need to be sealed or otherwise designed to prevent the escape of corrosive substances.

Lithium batteries must be thoroughly secured to prevent impacts which would render the battery unserviceable and/or a fire risk.

5.4 Aerobatic manoeuvres and recovery

5.4.1 Stick Position and the Stall

An important aspect of both normal and aerobatic flight is the relationship of the stick position to the angle of attack of a wing for a specific flap setting or centre of gravity, at the stall. The fore and aft position of the control column determines the angle of the aircraft's wings to the airflow. For example, the stick positions for cruise, glide and the stall move progressively aft. Once the stick position for the stall has been determined (and remembered), it can be used as a measure of whether an aircraft's wing is stalled or not. If the stick is forward of the 'stalled stick position', the aircraft will always be in unstalled flight, regardless of aircraft attitude or airspeed.

Appreciation of this concept, and the ability to recognise and apply stick position to achieve CLMAX (that is the point just before a wing stalls) can increase awareness and enhance a pilot's confidence and aircraft handling at this critical phase of flight.

5.4.2 Recognition and Recovery from Mis-handled Manoeuvres

Early recognition requires less control input. Remember rolling G is limited to 2/3 symmetrical G. This is an established practical aerobatic rule. Rolling causes asymmetric loading where one wing sees more lift than the other. To prevent overstress, pilots are taught to limit rolling pull-ups to approximately 2/3 of the max positive limit.[4]

Air brake significantly lowers the manoeuvring tolerance. Extended airbrakes can affect maximum allowable speed and change structural margins. Some glider flight manuals warn about not exceeding certain airspeeds or G with airbrakes extended.[5]

It is very easy to be consumed by the overall flow of an aerobatic sequence.

> **Quick Tip**
>
> A pilot must always be prepared to terminate a mishandled manoeuvre with the required nose high or nose low recovery action and not persist with the needs of the next manoeuvre entry.

For example, a half Cuban Eight is a turnback manoeuvre where the upline needs to be 45 degrees or the exit speed can easily result in exceeding either the limiting airspeed or the limiting positive manoeuvring load factor for the sailplane.

[4] CS 22.337 Limit manoeuvring load factor and CS 22.349 Rolling manoeuvres
[5] CS 22.441 Manoeuvring loads CS 22.455, Air brakes and drag devices, CS 22.685 Air brake systems

Quick Tip

In aerobatic flight, there is always the possibility of unintentional entry into a spin or disorienting unusual attitude, and the application of an incorrect recovery procedure is likely to exacerbate the problem.

It is beyond the scope of this manual to provide detailed procedures for recovery from all situations in all types of aircraft, but pilots need to research the aircraft flight manual or Pilot Notes and be able to recognise and take appropriate recovery action applicable to the aircraft type for each of the following:

- Extreme unusual attitudes, upright or inverted, nose high or low.
- Upright spin.
- Inverted spin; and
- Spiral dive.

5.4.3 Unusual Attitude Recovery

Unusual attitudes may occur during mis-handled manoeuvres, disorientation, loss of situational awareness, or because of aerodynamic upset. The pilot's priority in all cases is to promptly recognise the aircraft's attitude and safely recover to level flight while remaining within the aircraft's structural and operational limits.

This procedure focuses on nose-high and nose-low recovery scenarios. It does not require the pilot to identify the specific manoeuvre that led to the unusual attitude, only to recognise the relationship between the nose and the horizon and apply the correct recovery technique.

High Nose Attitude Recovery

A high nose attitude can lead to a tail slide, loss of control effectiveness, or entry into a spin. Prompt action is required.

Tail Slide Caution

If rearward movement is detected (i.e., the glider begins to slide backwards), do not attempt to centralise the controls. The aerodynamic loads will overpower the control forces and may cause surface flutter or damage. Instead:

- Brace the elevator fully against the stop (forward or aft).
- Hold rudder and ailerons firmly against their stops to prevent surface oscillation or damage.

As soon as the nose drops below the horizon, apply the following steps:

1. Prevent yaw with coordinated rudder input.
2. Roll the aircraft upright, aligning the wings level with the horizon.
3. Return to level flight with smooth pitch control, observing airspeed and G limitations.

Low Nose Attitude Recovery

A nose-low unusual attitude may result in rapidly increasing airspeed and G loading. Immediate corrective action is essential.

1. Unload the aircraft by easing control pressure to reduce G forces.
2. Roll the wings level using coordinated aileron and rudder input.
3. Pull up smoothly to level flight, adjusting G depending on available height and airspeed.

Quick Tip

Refer to the aircraft flight manual regarding the use of airbrakes during recovery. In some aircraft, deploying airbrakes while under high load factors can exceed structural limits (see CS 22.345). Avoid use unless explicitly approved for such conditions.

5.4.4 Spin Recovery

Modern aerobatic capable aircraft designs normally have predictable spin characteristics and respond to the standard spin recovery technique. However, some aircraft may have special characteristics which require recovery procedures. Therefore, pilots need to be familiar with, and practised in, the spin recovery procedure specified for the aircraft type.

Standard spin recovery procedures and actions are detailed in Unit 18 of the GPC Trainer Guide and Pilot Guide..

5.5 Emergency Procedures

5.5.1 Recovery from unusual attitudes

For procedures and guidance, refer to Section 5.4.3 Unusual Attitude Recognition and Recovery.

5.5.2 Drills for the use of parachutes and aircraft abandonment

Whilst hopefully not needed, it is wise to practice procedures for exiting the aircraft in flight and deployment of a parachute.

6 Risk Management and TEM

Risk management and Threat and Error Management (TEM) are broad topics. The GAus Safety Management and Operations document areas contain resources that should be referenced.

This section addresses Risk management and TEM in a specific manner for aerobatic flights.

6.1 Risk Management

Risk management is a process that can be applied before deciding to undertake a proposed flight, to determine whether it should be conducted or modified, based on the assessment of the risk involved.

> Quick Tip
>
> The basic question that risk management addresses is whether the level of risk for a proposed flight is acceptable or, if not, can it be managed to make it acceptable?

6.2 Identify the hazards or 'Threat' risks

Before deciding to conduct an activity, try to identify the main risks applicable to the type of operation as well as those that might affect the flight. For example, does the flight involve:

- Lower than normal operating levels?
- Particularly difficult manoeuvres?
- Unsuitable environmental conditions?
- Aircraft airworthiness issues?
- Issues of pilot fitness, level of training and recent experience? OR
- Extraneous pressures?

6.3 Categorise the Likelihood and Consequence of Adverse Events Stemming from the Hazard or Threat (Risk)

How likely is it that the hazard (risk) identified may have an adverse consequence?

Who will be affected and what is the likely severity of the consequence? It is highly probable that the consequence of an error or failure during low-level aerobatics will be fatal to the participants.

Categorising the risk suggests the level of effort that needs to be applied to manage or mitigate the risk.

We must include assessment of risks to third parties (other airspace users and people and property on the ground).

6.4 Plan to Manage/Mitigate Risk

What strategies can be applied to mitigate risk (reduce the likelihood or severity of consequences, or both)?

For example, cancel flight, operate at a higher level, leave out a manoeuvre? Be sure of the entry parameters required for successful completion of all manoeuvres and emergency recovery procedures. And warm up at a higher level.

6.5 Implement Risk Management Plan

Stick to the plan and the risk mitigation strategy. Modify the plan if necessary, but do not include unplanned spontaneous manoeuvres. Know and do not exceed aircraft and personal limitations.

6.6 Review performance

- Did the flight go as planned?
- Was the plan adequate?
- Were there any unexpected occurrences?
- How can the risk management plan or strategies be improved for future flights?

6.7 Threat and Error Management

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 proactive approach for pilots to use in identifying and managing threats and errors (hazards) that may affect the safety of the flight.

> Quick Tip
>
> A definition worth remembering is that threats come at you, while errors come from you.

TEM uses many tools, including training, Standard Operating Procedures (SOPs), 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 Organization (ICAO) as an integral part of pilot training at all licence levels from student to airline transport pilot. It is also a useful concept for aerobatic pilots to apply to their operations.

There is some overlap between risk management and TEM, particularly at the stage of developing and implementing plans to mitigate risks and in reviewing the conduct of a flight, but 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.

The following sections provide a brief introduction to TEM to assist aerobatic pilots who may wish to apply the principles to their own operations.

6.8 Threats

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. They may be anticipated, or they may be unexpected, or they may be latent in the operational system. 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 aerobatic operations might be:

- Strong winds and/or turbulence.
- High density altitude.
- Other traffic.
- High terrain or obstacles.

- Pre-existing structural damage.
- Third parties on the ground.

6.9 Errors

The TEM model accepts that it is unavoidable that pilots, as human beings, will make errors. Errors may be intended or unintended actions or inactions on the part of the pilot(s) and 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).

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 aerobatics flight might be:

- Setting altimeter subscale incorrectly.
- Aircraft handling errors.
- Failure to use or achieve manoeuvre entry parameters.
- Impulsive deviation from intended routine; or
- Not observing G or other limitations.

6.10 Undesired Aircraft State

Threats and errors that are not detected and managed correctly can lead to an undesired aircraft state, which is 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. Aerobatic flight requires recognition and recovery from undesired aircraft state in a very short timeframe before an outcome, such as unintended spin, descent below minimum height or GLOC occurs. Examples of an undesired aircraft states in aerobatics might be:

- Pre-stall (buffet) during manoeuvre.
- Manoeuvre commenced with insufficient energy state (height and/or speed).
- Approaching G or other airframe limitation.
- Incorrect attitude recognised during manoeuvre; or
- Grey-out and/or tunnel vision.

Good TEM requires the pilot to plan and use appropriate countermeasures to prevent threats and errors from 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; and
- Review countermeasures–including evaluating and modifying plans as the flight proceeds, and inquiry and assertiveness to identify and address issues in a timely way.

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

6.11 TEM Application

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 programme is that around 50% of crew errors go undetected.

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.

Error management requires an acceptance that errors are unavoidable and the use of standard operating procedures, checklists, monitoring and cross-checking procedures to both minimise the risk of errors and to detect and manage those that occur. Good situational awareness at all times is essential to TEM.

The following summary is intended to assist pilots to apply TEM to aerobatic 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 aerobatic sequence.
- Include anticipated threats and countermeasures in briefings.
- Continuously monitor and cross check visual and instrument indications and energy state to maintain situational awareness.
- Prioritise tasks and manage workload so as not to be overloaded and to maintain situational awareness.
- Identify and manage threats and errors.
- Identify the threat/error.
- Maintain control of the aircraft and flight path.
- Manage the threat or error, and
- Monitor the progress of the sequence and abort if necessary.
- Identify and manage undesired aircraft state.
- Identify undesired aircraft state.
- Aircraft control and flightpath and abort if necessary are the first priority.
- Do not fixate on error management.
- Manage the undesired aircraft state.
- Recover to planned flight and normal safety margins as the priority.

6.12 Situation Awareness

Situation awareness is the awareness of all the elements in the environment, how they affect your flight, and how they could affect it in the future. Situation awareness requires good anticipation and asking, 'what if'? Considering all possibilities and planning operations to proactively identify and manage the potential threats and errors for each flight will aid in enhancing situational awareness.

Typical issues to consider for aerobatics activities are:

- Pilot fitness.
- Pilot G awareness and readiness.
- Aircraft airworthiness.
- Aircraft G loading and manoeuvre limitations.
- Aircraft airspeed and engine limitations.
- Manoeuvre entry parameters.
- Unusual attitude/spin recognition and recovery.
- Density altitude effect on performance.
- Area/ terrain/ground features.
- Height limitations.
- Cloud base and visibility.
- Airspace requirements and other traffic.
- Use of clearing manoeuvres.
- Extraneous pressures.
- Possible effects on persons, animals and property on the ground.

6.13 Decision Making

The ability to assess a situation, identify the need to decide and then to implement the decision in the time available is an essential element of aircraft operation and successful TEM.

Emotions often play a significant role in decision-making with the decision being an emotional reaction to a situation rather than the result of a logical and structured process. The use of a logical and structured decision-making process will reduce the likelihood of emotions clouding or confusing the result. Decisions can be proactive (anticipating a problem), or reactive (dealing with an unexpected problem) but the decision-making process always involves:

- Identifying a problem.
- Collecting relevant information.
- Generating and analysing options.
- Deciding on the most appropriate option.
- Implementing the decision.
- Monitoring progress against intended outcomes and modifying actions as required.

Good decision making relies on good situation awareness and the ability to identify problems and available options promptly to decide on the best course of action without being influenced by extraneous pressures. However, studies show that pilots mostly base decisions on previous experience and learned rules and procedures, particularly in situations where time is limited, such as in aerobatics.

Aerobatic decision making therefore needs to concentrate on a proactive approach, because there is unlikely to be much time to fully consider all aspects of a problem when something goes wrong. Proactive decision-making uses TEM to identify potential threats and errors, and to plan countermeasures such as establishing parameters for commencing and aborting manoeuvres or sequences, so that the pilot has already decided as to the action required in a particular situation.

Avoid 'spur of the moment' decisions to conduct manoeuvres which have not been planned and the implications not thought through and particularly avoid making such decisions based on extraneous pressures.

6.14 Fatigue Management

Aerobatics is very strenuous and fatiguing. Inadequate rest or hard physical exertion before a flight can affect performance and G tolerance, particularly the ability to do effective G resistance straining. Plan aerobatics sessions to be well rested beforehand and accept there is a limit to the length of a session and the number of sessions that the body can handle in each period. Good physical conditioning will increase endurance and assist recovery from aerobatics.

6.15 Keeping Current

Aerobatic skills degrade quickly and need to be maintained by constant practice, but regulations do not specify any requirements for recent experience for aerobatic pilots. Pilots therefore need to develop their own strategies for maintaining or regaining proficiency and ensuring they are sufficiently in practice to perform the planned aerobatic manoeuvres safely.

Strategies for regaining proficiency after lack of recent practice may include:

- Obtain dual instruction.
- Limit practice to basic manoeuvres initially.
- Operate at a higher altitude to provide a greater safety margin.
- Practice emergency recovery procedures; and
- Allow sufficient practice time to re-acclimatise to high G forces.

6.16 Recent Experience

Following endorsement to carry out aerobatics, a pilot will have guidelines from the endorsing Instructor and will generally be the best person to know if further “oversight” is required. For advanced aerobatics, it would be normal for a time limit to apply to Type 2 manoeuvres.

For pilots planning to conduct aerobatics below 1000' AGL, special approval will need to be sought through the EMO. In this case, strict recency limits are imposed as guidance for maintaining a suitable level of aerobatic currency. However, it is the pilot’s own responsibility to assess the suitability of this advice for his or her needs, and to decide whether the experience specified here is adequate to ensure that he or she is in sufficient current practice to safely conduct the manoeuvres planned.

The following recent aerobatic experience is suggested as the minimum that would provide an adequate level of current practice to safely conduct aerobatics below the levels specified in the following paragraphs:

1. Below 1000' AGL – the pilot has performed an aerobatic sequence at least three times in the preceding 12 months.
2. Below 500’ AGL – the pilot has performed an aerobatic sequence in the preceding 30 days down to a height of 500' AGL or below.
3. Below 300' AGL – the pilot has performed an aerobatic sequence in the preceding 30 days down to a height of 500' AGL or below; and preferably performed a sequence down to 300' preparatory to performing below 300'.

6.17 Peer Review

While recent experience is important in maintaining proficiency, independent opinion on performance is an equally valuable tool for enhancing safety. Because of the high level of skill and the fine safety margins involved in low-level aerobatics, it is strongly suggested that low-level permission holders should undertake a peer review of their performance on a regular basis. An appropriate frequency would ensure that a peer review had been completed within the 30 days before conducting any advanced or low-level aerobatics.

The peer review process is intended to provide an independent assessment by a similarly qualified person or persons on the way the pilot conducts the activity and to identify any incorrect techniques or practices that the pilot may have developed over time. It is not intended to be a flight test for the renewal of the permission, but an opportunity for constructive discussion with other practitioners with a view to enhancing the safety of a pilot's performance.

The following is the recommended procedure for the peer review process:

- The pilot should have had sufficient recent practice and/or training to be able to conduct a sequence of advanced or low-level aerobatics safely.
- The pilot should brief the observer(s) on the sequence to be flown.
- The pilot should fly the sequence under observation, either from the ground or the aircraft down to the level of the permission, or the level to which the pilot intends to exercise the permission, if higher.
- After the flight, the pilot and the observer(s) should de-brief the sequence to identify ways in which performance and safety could be improved; and
- The review is entered in the pilot's logbook and signed by the pilot and by the observers as a record to indicate that the observation and discussion has taken place. It could include a disclaimer that the observer is not certifying the pilot's competence.

The observers would need to have proficiency in low-level aerobatics and preferably also in assessing low-level aerobatic performance. Suitable observers would be any one of the following:

- CFI with advanced aerobatic endorsement and low-level permissions; or
- At least two other low-level permission holders with similar endorsements or permissions; or
- RMO or Delegate Level 3 Instructor with advanced aerobatic endorsement and low-level permissions.

During the debriefing process it is important to be objective in identifying items that were done well and those that could have been done better. Emphasis should be on providing input and advice on ways to improve safety and performance rather than on questioning an individual's ability.

Signing off as an observer for peer review should not be construed as certifying the competency of the pilot, but that the review has taken place and that any issues of concern have been brought to the pilot's attention.

The object is not to assess the pilot as suitable or otherwise to continue to hold the permission, but in cases where continued operation by the pilot would constitute a serious risk to air safety there would be some moral responsibility for the participants to counsel the pilot and, if necessary, bring this to the attention of Club CFI/RMO/EMO.

7 Aerobatic Flying Training

7.1 Pre-Flight

7.1.1 Pre-flight Planning

- Pilot is qualified and current for aerobatics.
- Pilot physical and mental fitness for aerobatics.
- Aircraft is suitable for planned aerobatics.
- AFM limitations checked and known.
- Day visual flight rules (VFR) with meteorological conditions suitable for aerobatics.
- Suitable area selected.
- Airspace and height limitations checked.
- Manoeuvre sequence planned; (Aresti sequence to be followed posted to instrument panel)
- Manoeuvre safe entry parameters known.
- Threat and error management reviewed; and
- For low-level aerobatics, check aircraft all up weight and the expected density altitude for the effect on performance.

7.1.2 Pre-flight Inspection

The normal GAus pre-flight inspection is designed to cover the items below.

These issues have caused SOAR reports before, so it's worth pointing out the ones that are vital for aerobatic safety.

Structure–check for visual evidence of damage or failure including struts and strut connections, elevator and rudder stops, wrinkles in the metal or fabric covering and looseness in any structural part. Also check control surfaces, cable trim tabs and actuating rods etc.

Seatbelts and shoulder harness - make sure the harness is suitable for aerobatics, is in good condition, and check that the latching mechanisms lock securely. Check that unoccupied seats have their seat cushions and harnesses secured so that controls cannot be fouled.

Doors and canopies–Check doors, windows and canopies for secure locking.

Controls–With all occupants seated and strapped in, ensure that the controls can be operated freely through the full range of movement and work in the correct sense.

Loose objects–Don't carry items that are not essential for the flight, and make sure any loose objects are secured or stowed. Check for foreign objects in the cockpit and in the fuselage to ensure that there are no loose objects which could jam the controls during manoeuvres. For all occupants, empty pockets or ensure that they are securely closed and that there are no loose items in clothing. Make sure the cockpit floor is clean, and any side pockets are empty and closed. Ensure that batteries are adequately secured.

Cameras-Mounting these via canopy suction cups is fraught with danger, especially in aerobatic situations.

7.1.3 Passengers

If passengers are carried on aerobatic flights they should be fully briefed on aerobatic considerations:

- Safety harness is tightly fitted and always secured.
- Seats securely locked in position.
- Briefed not to interfere with controls.
- Are they fit for aerobatics? (No illness or medical condition);
- The manoeuvres and sensations to be expected.
- To alert pilot of feelings of nausea or problems with harness or seat.
- Location of ventilation controls and sick bags.

It is advisable not to subject passengers who are not used to aerobatics to Negative G loadings.

7.2 In Flight Checks

7.2.1 Airspace

Select an area that is not in congested airspace and is away from aerodromes and built-up areas. Check that the area around and below is clear before performing spins or aerobatic manoeuvres and maintain a lookout and listening watch for other traffic while performing.

7.2.2 Pre-aerobatic Checks

Prior to commencing aerobatic manoeuvres carry out appropriate checks. Use the normally trained acronym HASLL.

- Height–sufficient to recover by 1000' AGL (or the lower limit of the pilot's permission) (2,000ft AGL if within a 2 NM radius of a certified aerodrome).
- Airframe– Flaps, airbrakes, undercarriage set as required. Trim as required. Hatches and vents closed and locked as appropriate.
- Security–harness secure, loose objects stowed.
- Location– Clear of built-up areas, cloud, controlled airspace. In an appropriate area, forced landing options reviewed, major features identified.
- Look-out–180 degree plus 90 turn turns checking carefully around, above and underneath.

> **Quick Tip**
>
> Review HASSLL between manoeuvres. Broadcast intentions.

7.2.3 Advanced Aerobatics and Low-level Checks

The following additional checks can be performed at a safe height prior to conducting advanced or low-level aerobatics:

- Inverted check for loose articles and for aircraft systems functionality.
- a slow loop to check aircraft handling characteristics.
- a manoeuvre that takes a known height, to check aircraft performance and altimeter indications.
- a G awareness manoeuvre, such as a high G turn. This should be three to four G for 10 seconds to allow the pilot to practice the G straining manoeuvre and to ready the cardiovascular system for high G. It is not to check maximum G tolerance.

7.2.4 In-flight Exceedances

Monitor airspeed, engine and accelerometer indications during all manoeuvres.

If at any time during a flight the aircraft limitations are exceeded, the aircraft should be immediately returned to the aerodrome for an inspection by a GAus authorised airworthiness inspector. If something doesn't feel right during the flight, for instance abnormal control pressures or responses, unusual vibrations etc., the same advice applies.

7.3 Post-Flight Inspection

7.3.1 Overstressing

If any aircraft limits were exceeded on any manoeuvre, immediately terminate the manoeuvring and return to land. Have the aircraft inspected by a GAus authorised airworthiness inspector for damage that may have occurred or become evident following the flight.

7.3.2 Maintenance Release

Enter damage, defects or exceedances in the maintenance release or flight technical log.

> **Quick Tip**
>
> Some clubs may require aerobatic flights to be noted in the maintenance release or other flight logging systems. Check your club's local procedures.

7.3.3 Responsibility to Other Pilots and Operators

To ensure that significant safety issues are not overlooked, the pilot has a responsibility to subsequent pilots, not only to enter defects or exceedances in the maintenance release, but to bring to the attention of the owner, operator or subsequent pilot, any matter about which there could be a concern in relation to airworthiness. Several in-flight airframe failures have been attributed to stresses experienced by the aircraft on a previous flight or accumulated over several previous flights.

Do not reset the accelerometer, leave it as evidence to the next pilot of the G loadings experienced. Note: accelerometer can be slewed due to rough landing and take-off surface. Depending on the surface, this has limited value.

7.4 Confidence Manoeuvres and recoveries

The GAus Training manual (11.3.2) specifies the following manoeuvres for building confidence:

- slow flights and stalls, (GPC Unit 12)
- steep turns, (GPC Unit 29)

- side slips, (GPC Unit 28)
- spins and recovery, (GPC Unit 18)
- recovery from spiral dives, and (GPC Unit 18)
- recovery from unusual attitudes.

The procedures for performing these manoeuvres are documented in the GAus GPC training manual.

7.5 Basic Aerobatic Manoeuvres

After completing confidence manoeuvres and recovery exercises, the student pilot should progress to training in basic aerobatic manoeuvres. These foundational figures help build coordination, situational awareness, and energy management skills essential for safe aerobatic flight.

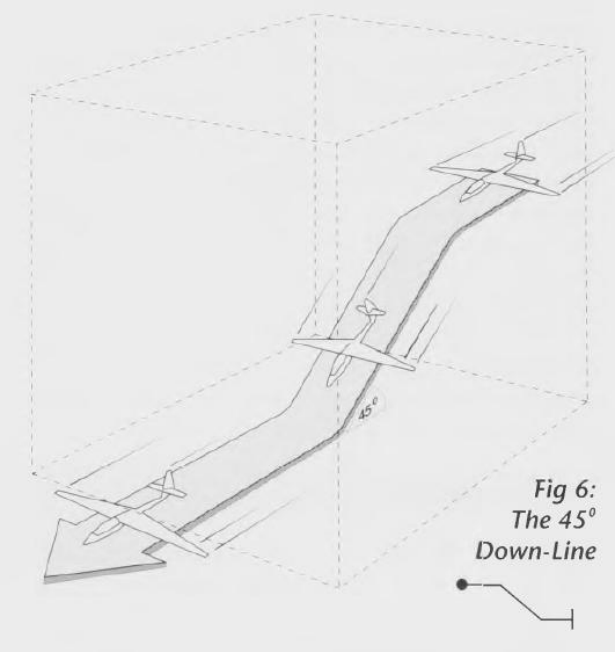
Once a student demonstrates competence in a given manoeuvre—through both ground understanding and in-flight performance—they may be signed off by an appropriately endorsed instructor to practice that manoeuvre solo.

The following figures are considered part of the Basic Aerobatics syllabus:

- 45-degree climbing and diving lines (performed as aerobatic manoeuvres),
- Inside loops,
- Wingover or chandelle,
- Lazy eight,
- Spins (with accurate recovery to a heading).

This manual provides practical guidance for each of these manoeuvres. However, students and instructors are encouraged to consult additional reference books and training guides, as this manual is not intended to be the sole source of instruction.

7.5.1 45 degree down-line



[6]

- Commence from stalled level flight with the level wings and no yaw:
- use the wing tip reference to check the 45° down line
- use the forward aiming point to maintain constant attitude control
- pull out to horizontal flight at the correct (preselected) airspeed.

COMMON FAULTS

- Dive too shallow. Ideally use a wing tip triangle and not the wing tip to judge.
- Dive shallows-out as speed builds. Incorrect pitch control as stick forces vary.
- Exit speed incorrect. Use a transition speed of, typically, 10kt less than the target speed - use pull out speed of 10kt less than target.

[6] The Handbook of Glider Aerobatics: Mallinson & Woollard; Airlife Publishing Ltd., England 1999

7.5.2 45 degree up-line

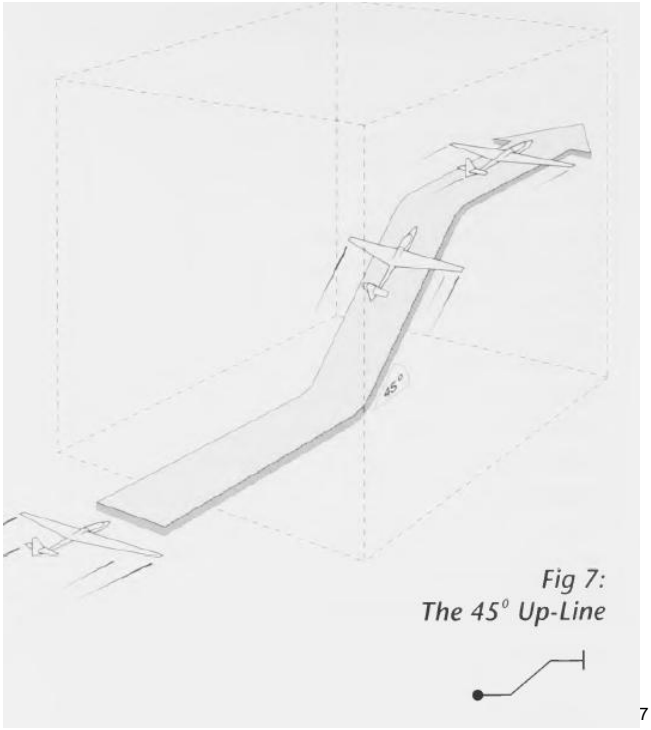


Fig 7: The 45° Up-Line

[7]

- begin from level flight with the wings level and no yaw present
- use the wing tip reference to judge the 45° up line
- push over to achieve horizontal flight a little above stalling speed.

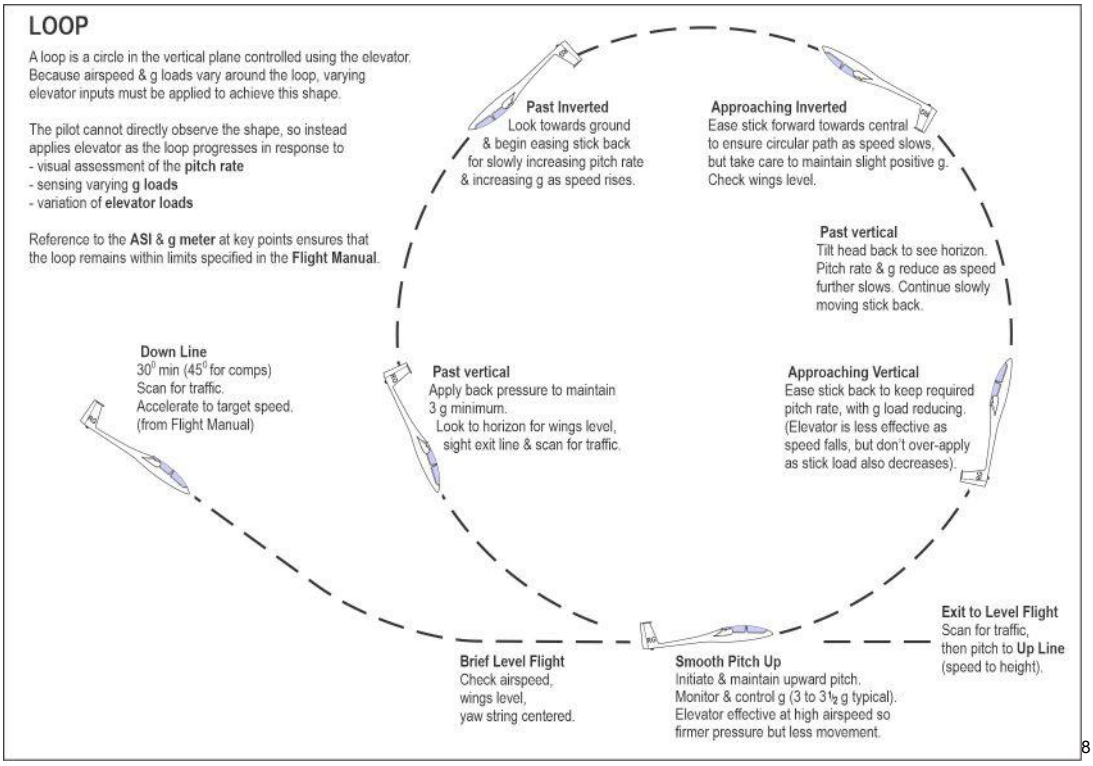
WARNING! Most gliders are very susceptible to spinning in this condition.

COMMON FAULTS

- Climb angle too shallow/too steep/not constant - use attitude reference eg., clouds.
- Incorrect exit speed - use the ASI to judge correct push over speed.
- Pitch up to 45° not sharp enough - use the 3G load factor.
- Exit speed too slow - push over at VS + 20kt indicated airspeed.

[7] The Handbook of Glider Aerobatics: Mallinson & Woollard; Airlife Publishing Ltd., England 1999

7.5.3 Inside loops



[8]

- begin from horizontal flight at the correct entry speed 2.5 x VS
- at entry, the wings must be level, and the glider must be free from yaw
- pull-up should be progressive, typically with 3G load applied in first quarter
- at the top of the loop
    - the wings should be level and no yaw present
    - the load factor should remain positive (0.25G)
    - the stick should be on rear stop
- at the vertical up/ down position, the wing tips should be equidistant above the horizon during the second half of the loop the elevator control must prevent initial over-tightening of the circle, whilst ensuring a horizontal exit at the same speed as the entry - or the selected target speed for the next figure.

COMMON FAULTS

- Harsh pulling and/or pushing of the stick.
- Tightening of the circle during the second half of the figure.
- Entering the loop from a dive rather than from level flight.
- Incorrect lines and glider orientations throughout manoeuvre.

[8] Diagram supplied by Richard Geytenbeek

- Shape not circular. Segmented (angular sided).
- Failure to finish in level flight by pulling up into a climb to reduce speed.

7.5.4 Wingover or Chandelle and Lazy Eight

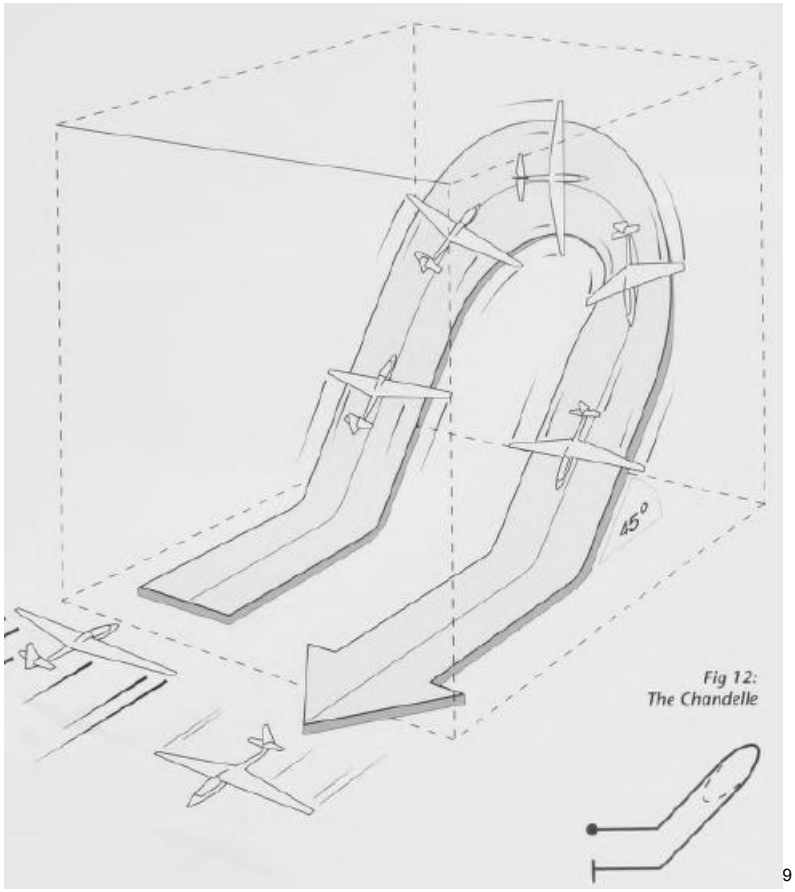


Fig 12: The Chandelle

[9]

- entry should be from horizontal flight at the chosen entry speed
- with level wings and no yaw present, the glider should be pulled up into a held 45° line
- a 180° direction change is effected via a 45° banked turn. Combined with the 45° up line this results in wings vertical after 90° change in heading
- a 45° held down line of equal length to the up line should precede a return to horizontal flight at the same speed as at entry to the figure.
- A Lazy Eight is simply doing a wingover or chandelle in the opposite direction once the first is completed.

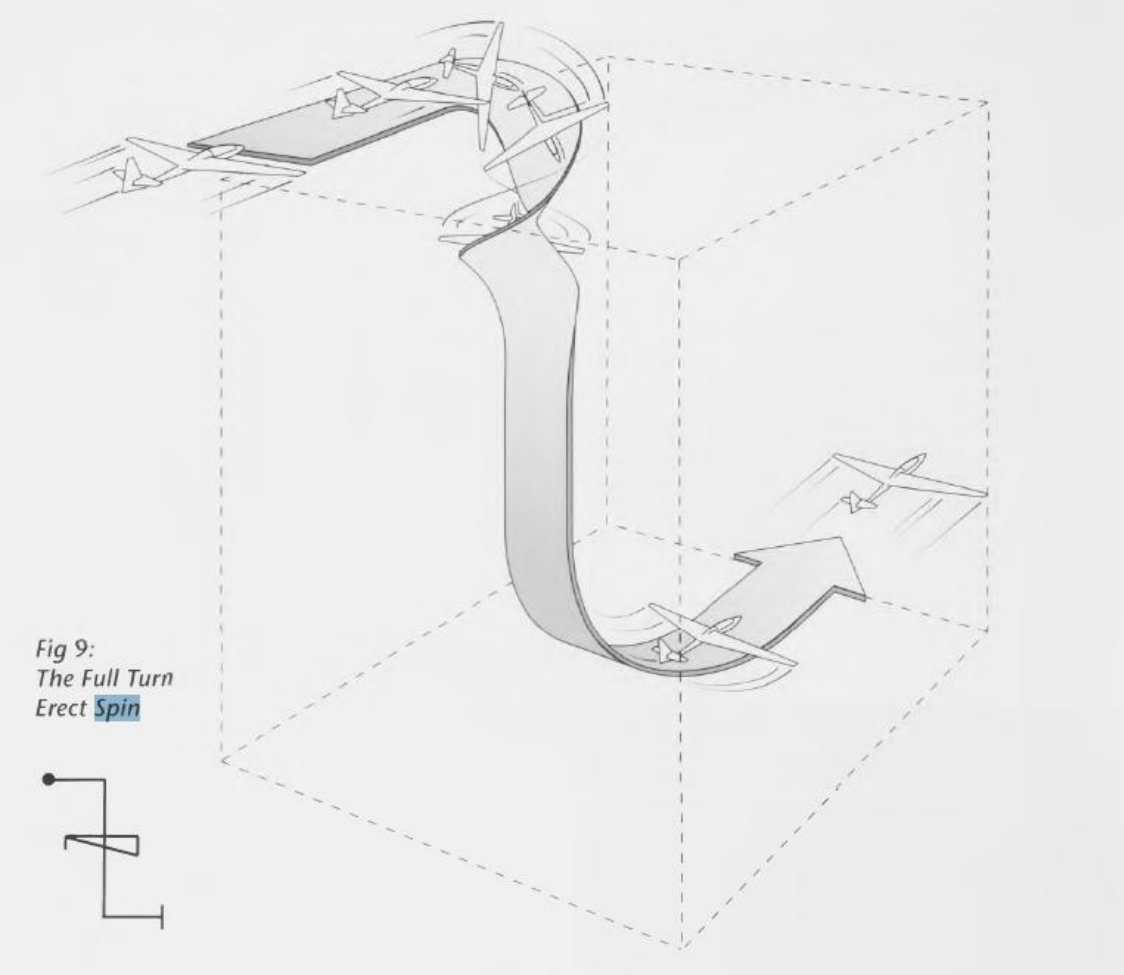
COMMON FAULTS

- 45° lines too steep or too shallow with no check at the 45° line before commencing the turn.
- Wings not horizontal/ vertical when required.
- Axis orientation compromised.

[9] The Handbook of Glider Aerobatics: Mallinson & Woollard; Airlife Publishing Ltd., England 1999

- Glider stalls rather than flies around the turn due to insufficient energy, ie. the manoeuvre becomes a shallow stall turn.
- 45° up and down lines of unequal length.

7.5.5 Spin exiting on to a heading



[10]

- Entry from horizontal flight at VS plus 2kt with no discernible pitch-up:
- exit should be exactly on desired heading e.g., one turn, one half turn etc
- exit dive should be momentarily vertical followed by transition to horizontal flight
- the recovery 'lead' angle must be clearly defined with regard to useable ground reference features e.g., roads, railway lines, runways etc.

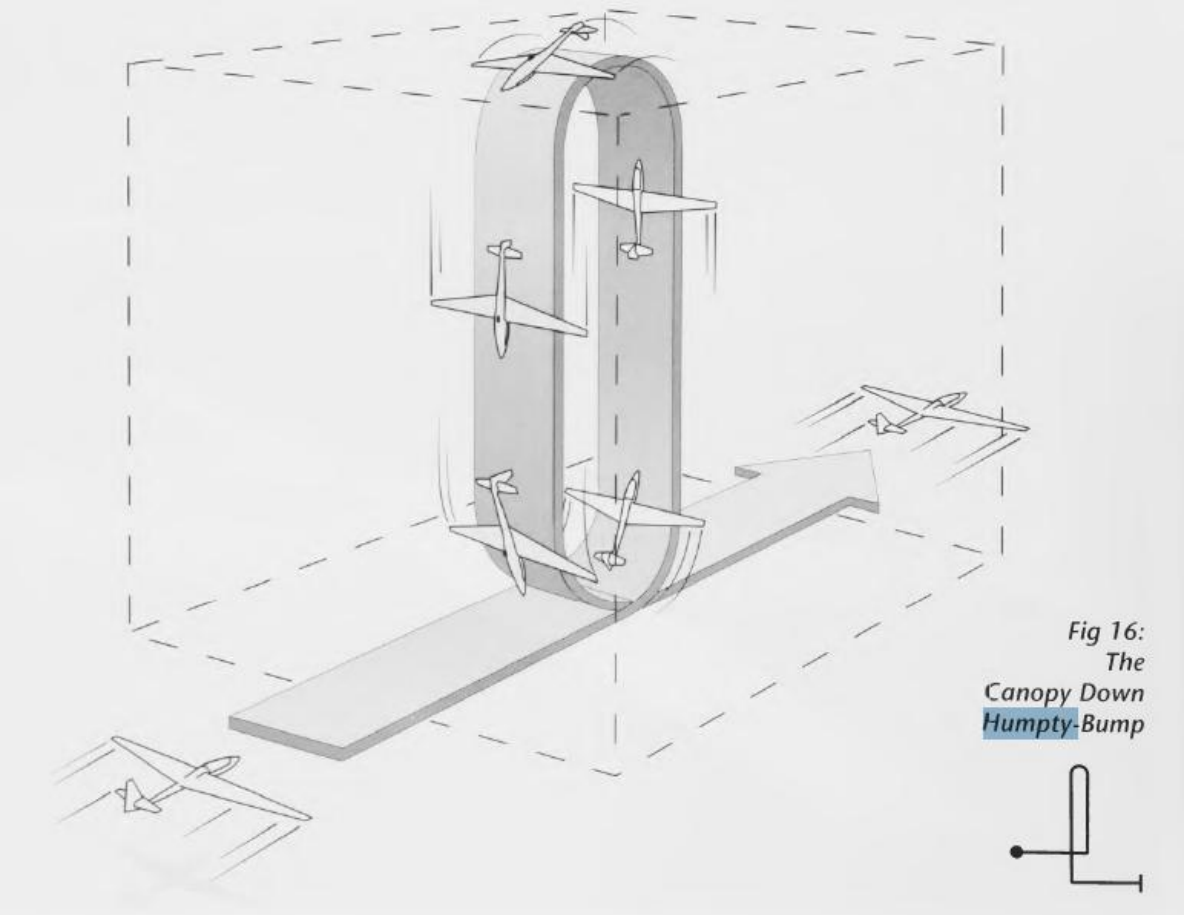
COMMON FAULTS

- Entry not clean. Any amount of initial pitch up should be avoided.
- Spin not maintained. Spiral dive develops.
- Exit dive not on heading, and/ or not vertical and/or yawed.

[10] The Handbook of Glider Aerobatics: Mallinson & Woollard; Airlife Publishing Ltd., England 1999

- Transition from vertical to horizontal flight too gentle.

7.5.6 Humpty Bump – Canopy Down



[11]

This is an excellent figure for introducing trainees to vertical flight. Entry speed from horizontal is generally high, typically 2.5 x VS plus 15kt. As this is well above VA, care must be taken to limit the G during the pull-up.

- vertical lines must be vertical; ideally use a wing tip reference triangle
- the glider must not yaw or roll during the figure
- a 3G pull-up to the vertical line is required
- the pull over at the top should be effected whilst the glider still has sufficient (but not much) airspeed. The glider must fly, not fall over the top
- the vertical down line should be held briefly before a 3G pull out to horizontal flight at the target exit speed.

COMMON FAULTS

- Vertical lines not vertical or of even length.
- Entry and exit speeds substantially different.

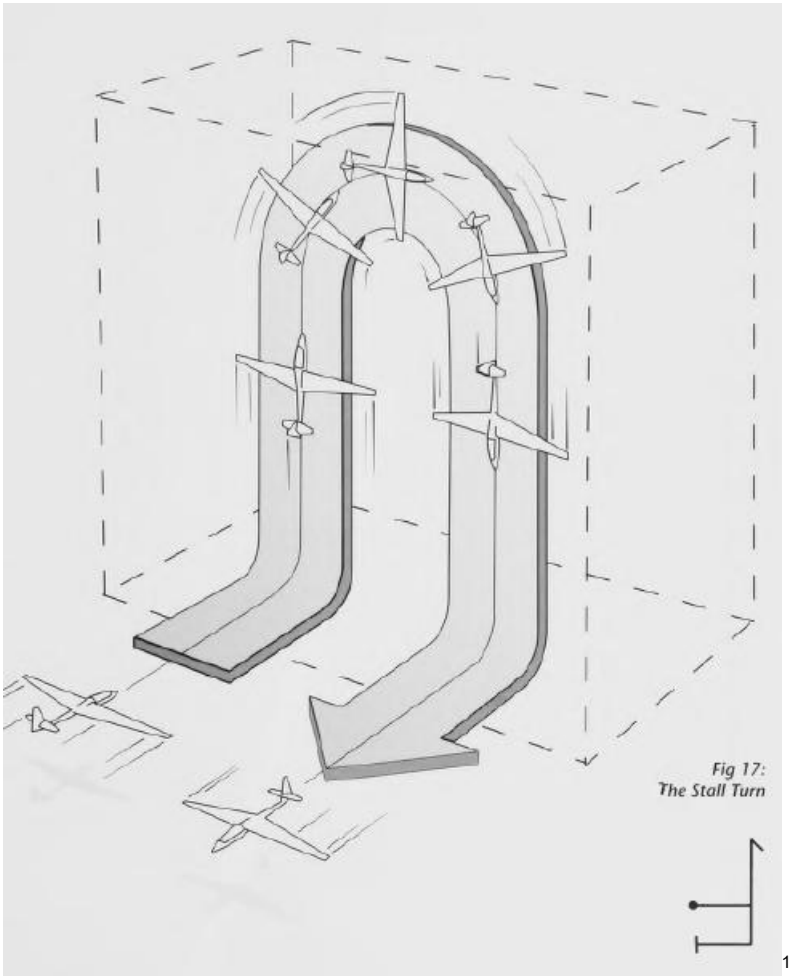
[11] The Handbook of Glider Aerobatics: Mallinson & Woollard; Airlife Publishing Ltd., England 1999

- Glider yawed in vertical line - check distance of each wing tip above horizon in both horizontal and vertical lines.
- Glider falls off the top of figure as a result of pulling over when too slow.
- Glider flies over top of figure at too high an airspeed so that vertical lines are not distinct, causing the figure to resemble an elliptical loop.

7.6 Advanced Aerobatic Flying Training

Advanced aerobatics requires specialised training. It is not flying to be taken lightly. It requires currency and rigorous planning. The glider flight manual must be consulted. In a club operation permission should be gained via the club committee and club instructor and operations panel.

7.6.1 Stall Turn



[12]

The entry conditions are similar to those used for the Humpty Bump although lower airspeed can be used with good effect on a 60° up line.

- to avoid the inherent dangers of a tail slide, this manoeuvre should only be taught at 'club' level from a 60° rather than a vertical up line
- the glider should yaw cleanly about the chosen wing tip, with no more than a single wingspan of lateral displacement.

[12] The Handbook of Glider Aerobatics: Mallinson & Woollard; Airlife Publishing Ltd., England 1999

COMMON FAULTS

- Wings yawed and rolled once up line established
- 60° up line not held constant
- Rudder kicked too early resulting in yawed upward flight and excessive lateral displacement
- Rudder kicked too late, resulting in tail slide or ‘fallen’ figure
- Up/ down lines of unequal length
- Exit and entry speeds substantially different
- Glider does not stop cleanly after yawing around to the down line (People grossly underestimate the difficulty of this figure in gliders!)

7.6.2 Inverted Flight

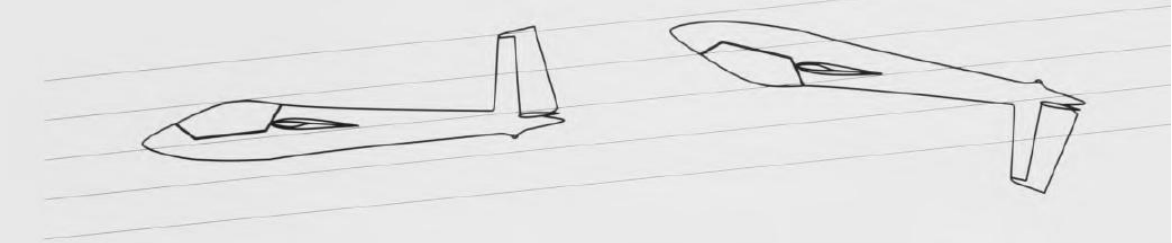


Fig 23: Flight Attitude in Erect and Inverted Flight

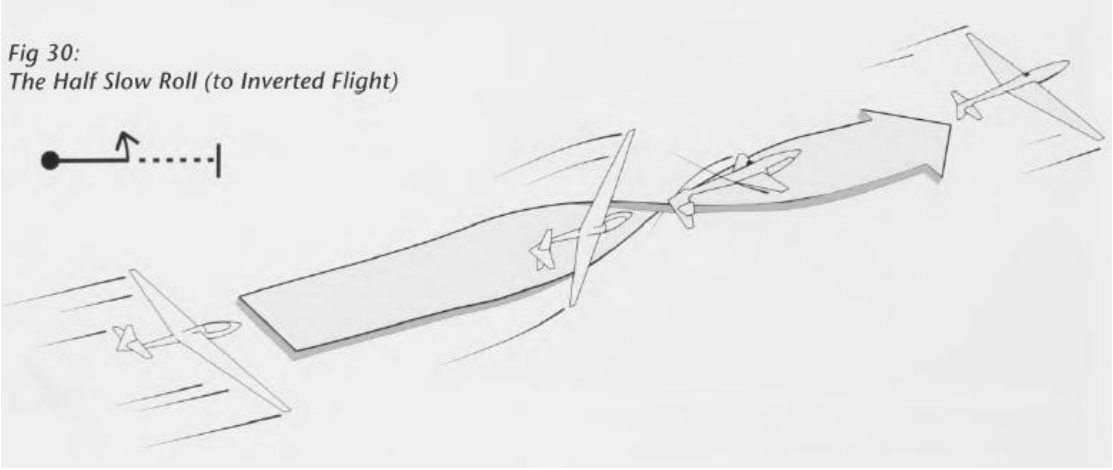
[13]

For an explanation of inverted flight, we have paraphrased “The Handbook of Glider Aerobatics”:

- Inverted flight is physically uncomfortable and demanding.
- Blood pressure reduces significantly, and heart rate drops by half.
- Body weight hanging on straps can cause discomfort.
- It takes several flights to gain comfort. Better value can be gained doing this in an aerobatic powered aircraft first, like a Pitts as there is a limited time a glider can remain inverted.
- Key is maintaining the correct steady attitude. Attitude is very nose high due to the incident of the wings. In erect flight the fuselage points slightly nose down when the wing root is horizontal.

[13] The Handbook of Glider Aerobatics: Mallinson & Woollard; Airlife Publishing Ltd., England 1999

7.6.3 Half Slow Roll



[14]

- Roll at a constant rate
- Keep pitching of the nose to a minimum
- Stop roll after 180 degrees

COMMON FAULTS

- Not maintaining the nose to horizon attitude at each stage of the roll
- Wings not level on exit
- Incorrect inverted attitude

[14] The Handbook of Glider Aerobatics: Mallinson & Woollard; Airlife Publishing Ltd., England 1999

7.6.4 Half Cuban Eight

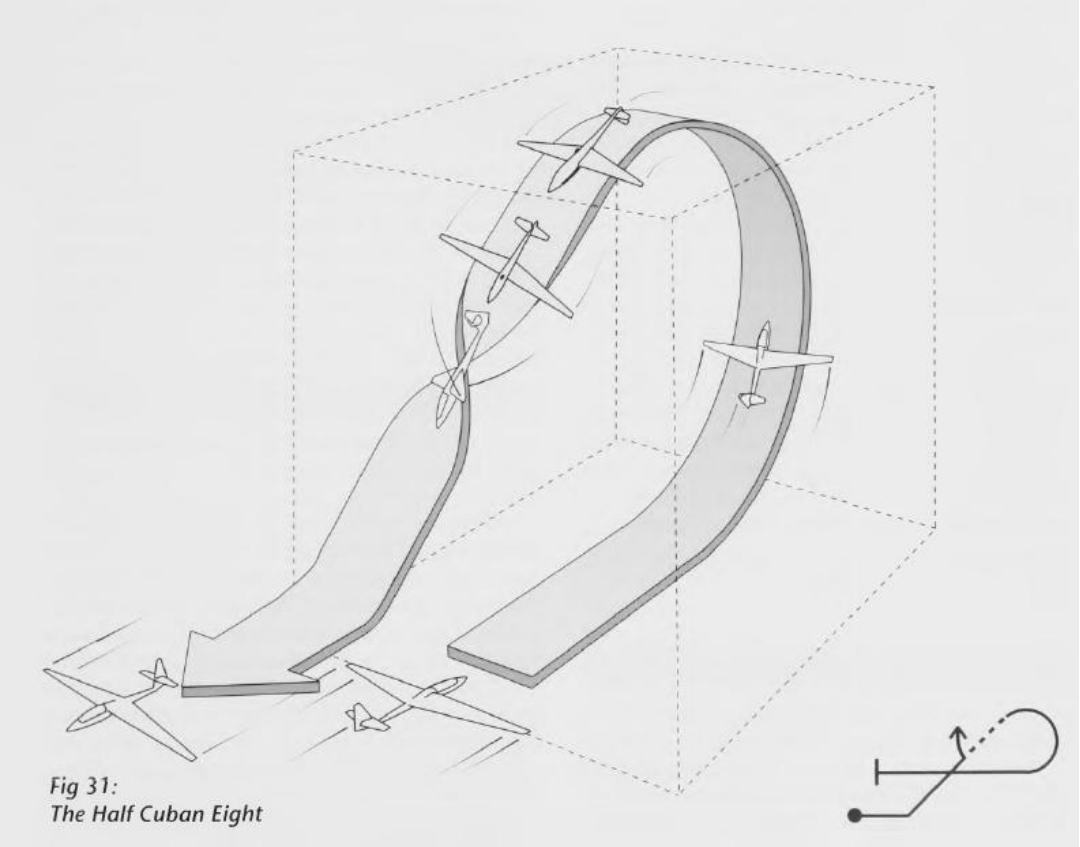


Fig 31:
The Half Cuban Eight

[15]

- When flown twice gives full Cuban Eight
- First part is the same as a loop
- After the inverted point he nose is allowed to come down to a 45 degree down-line, wings held level
- Then a half roll to erect flight on 45 degree down-line
- Rotate back to horizontal flight on reciprocal heading
- Be aware of Va and Vne and if going to be exceeded use a 30 degree down-line
- Plan and review the aircraft flight manual

COMMON FAULTS

- Not maintaining an accurate down-line throughout the roll. Warning: this can build speed quickly
- Misuse of rudder during roll

[15] The Handbook of Glider Aerobatics: Mallinson & Woollard; Airlife Publishing Ltd., England 1999

8 Aerobatics Safety Summary

- Aircraft is airworthy and prepared.
- Pilot physically and mentally ready for spins and aerobatics.
- Know the limitations of both you and the aircraft.
- In case of disorientation, plan to roll upright, level to the nearest horizon rather than pull through, and take time out to recover equilibrium.
- Review the emergency spin recovery procedure for upright and inverted.
- Review procedure for unusual attitude recovery.
- Assess the possibility of GLOC in the manoeuvre sequence.
- Do the full 'HASLL' check before commencing manoeuvres.
- Use a clearing procedure before all manoeuvres.
- Review the entry parameters for ensuring safe manoeuvring.
- Start with sufficient height to give plenty of margin for recovery.
- Maintain a good lookout during any sequence of manoeuvres.
- Do not exceed maximum engine RPM or manifold pressure.
- Monitor and react appropriately to engine temperatures and pressures, particularly during prolonged inverted flight.
- Never exceed the G or VNE limits of the aircraft.
- Do not make full-range or aggressive control movements near or above manoeuvring speed (VA).
- Do not roll the aircraft above its rolling G limit.
- Do not do flick manoeuvres above the speed stipulated in the flight manual.
- Do not pull significant G above Va in turbulent conditions (a gust could overstress the aircraft).
- Constantly monitor your height for recovery margins.
- Constantly monitor G forces in relation to physiological and structural limitations.

9 Bibliography and References

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