

# THE JACOBSON FLARE ®

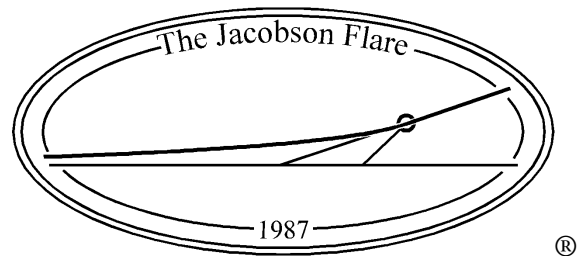
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**OVERVIEW:** In this age of technical precision, the manual landing flare manoeuvre has remained imprecise. Conventional flare techniques have involved an inconsistent, critical estimation of height above the landing surface and are subject to a number of variable factors, summarised as aircraft, pilot, and environmental. There has been no acceptable, quantifiable, universal landing technique in the history of aviation, nor any recognition of the need for one.

We have accepted second-rate, trial-and error “*Goldilocks*” techniques of “too high, too low, and just right!” In doing so, we have been:

- Wasting valuable training time and expensive resources in trying to teach landing judgement.
- Causing unnecessary stress on students, instructors, passengers and aircraft.
- Accepting the lack of consistency and predictability, even for experienced pilots.
- Using guess-work to solve only the immediate problem. What about the next aircraft? And the next?
- Unable to trouble-shoot and critique sensibly and constructively.
- Suffering far too many landing accidents.

This paper discusses the development of a practical and very tolerant technique for establishing a consistent landing flare that does not rely on the pilot's perception of vertical height. It applies simple triangulation to provide a **visual fix** for commencement of the flare. The flare point is derived from a pre-determined **longitudinal** position on the runway centre-line, ultimately superimposed by the cockpit lower visual cut-off angle. No device or modification is required. Therefore no costs are incurred. Major advantages over existing techniques are:

- Landing an aeroplane may now be regarded as a **skill that can be learned**. Pilots are provided with a predictable and consistent visual eye path from final approach through to touch-down. Traditional training methods have assumed the manual landing to be non-quantifiable; this concept enables an original and precise interpretation for a manoeuvre historically regarded as an 'art'.
- Most of the variables affecting perception and judgement may be discounted.
- It simplifies elementary and advanced pilot training for student and instructor, reducing time and cost.
- This technique is "pilot portable" and may be adapted to successive aircraft conversions.
- Experienced pilots can better maintain consistency of standard by utilising this "visual fix" to complement their highly developed levels of judgement, co-ordination and skill.
- It minimises runway occupancy times.
- It greatly enhances safety.

**REFERENCE: JACOBSON D. M. WHERE TO FLARE ? © 1987**

## 1. INTRODUCTION

Of all manoeuvres flown in fixed-wing aircraft, the landing flare is an enigma. It is critical to the safe and satisfactory conclusion of flight and yet, historically, has attracted little serious attention. Students and experienced pilots alike regard it as alternately satisfying and frustrating, simple and complex, safe and hazardous.

In this age of technical precision, the manual landing flare manoeuvre has remained imprecise. Conventional flare techniques have involved an inconsistent, critical estimation of height above the landing surface, and are subject to many variable factors, summarised as aircraft, pilot, and environmental.

This paper discusses the development of a practical and very tolerant technique for establishing a consistent landing flare that does not rely on the pilot's peripheral perception of vertical height. It applies simple triangulation principles, as used in navigation and aerobridge visual docking guidance systems, and some simple mathematics to provide a **visual fix** for commencement of the flare. The flare point is derived from a pre-determined position on the runway centre-line, between the threshold and the aim point, ultimately superimposed by the cockpit lower visual cut-off angle. No device or modification is required, therefore no costs are incurred. Safety is enhanced and the technique is "pilot-portable" across the many aircraft types.

**NOTE:** The author has assumed use of the masculine gender to include the feminine gender.

## 2. GLOSSARY

### 2.1 Definitions

**Aim point:** Intercept of pilot-eye path and landing surface; the visual centre of expansion on final; also the pre-determined intended point of main-wheel contact with the landing surface.

**Cockpit lower cut-off angle:** The lower limiting angle of pilot vision through the windshield, from horizontal, at the Design Eye Point (**DEP**).

**Eye path:** The locus of the pilot's eye.

**Flare Point:** Position where the eye path to the aim point is varied and the flare commenced.

**Flare cut-off point:** The intercept on the landing surface of the cockpit lower cut-off angle projected from the flare point.

**Flight path:** The locus of the aircraft mass, assumed as co-incident with the main-wheel path.

**Impact point:** The intercept of the main-wheel path and landing surface, assuming no flare.

**Landing surface:** A plane surface suitable for a landing. (a runway or strip.)

**Mainwheel path:** Locus of the main wheels.

### 2.2 Abbreviations

**$\Delta a$  (aim):** Distance on the landing surface forward from the aim point on to the touch point.

**$\Delta f$  (flare):** Distance on the landing surface from the aim point back to the flare cut-off point.

**$\Delta x$ :** Distance on the landing surface from aim point back to impact point (similar to  $\Delta f$  but unrelated, mathematically).

**$\gamma^\circ$  (gamma):** Flight path inclination angle.

**$\kappa^\circ$  (kappa):** Cockpit lower cut-off angle.

**MEHT:** Minimum eye height - threshold.

**PAPI:** Precision approach path indicator.

**TCH:** ILS threshold crossing height.

**T-VASIS:** Visual approach slope indicator.

**X1, X2:** Component lengths of  $\Delta x$ .

**Xe, Ye:** Eye co-ordinates of flare point.

**Xw, Yw:** Main-wheel co-ordinates at flare point.

**Yh / Yp:** Pilot-eye height above: **main wheels / main wheel path**, respectively, on a stable approach in the landing configuration and attitude.

### 3. THE LANDING FLARE

#### 3.1 Current Convention

The landing flare is one of the last critical phases of flight to which the term "seat of the pants" may still be applied. D.P. Davies ("Handling the Big Jets," 1973) stated, "**The only manoeuvre left worth doing, the only manoeuvre calling for any real native flying skill, is the landing.**"

Conventional flare techniques involve a critical estimation of height above the landing surface (**Ye**), and are inherently inconsistent due to many variable factors including, but not limited to:

- aircraft type
- aircraft size
- aircraft configuration (normal/ non-normal)
- approach path technique
- glide path angle
- landing surface dimensions (including slope)
- landing by day or night
- pilot total experience
- pilot recent experience
- pilot experience on aircraft type
- pilot seating position
- pilot performance
- visibility and other meteorological factors.

Historically, instruction in determining a suitable and consistent flare point **for each aircraft type** has been inadequate, to say the least. We are attempting consistently to recognise and extract the flare point by familiarity and practice. The best that we instructors have been able to manage, collectively, is to demonstrate a suitable flare point for a particular aircraft as being "**about here!**". The student is expected to remember it.

The student pilot has no proper model except in his memory, and that in itself is unreliable. Trial and error are the arbiters in determining the soundness of his developing judgement. Unfortunately, even after the basic skills are mastered, the problem still exists, because every aircraft type requires a different flare height, and as a pilot converts to successive aircraft types, he faces the same problem over and over. He has no proper model at the very time he needs one most.

Just as the student pilot consolidates his flare-height

judgement, so does the experienced pilot after conversion to another aircraft type. After a time, he becomes comfortable with his aircraft, if he consolidates and flies regularly, and can land it as well as any flown previously. There is perhaps a subconscious recognition of something, visible to the pilot through his windshield, that is providing the vital cue for commencement of the flare. We have attempted to teach judgement, perception, and proficiency through repetition and practice. Unfortunately these come only with experience, in their own time. For some it does not come easily.

#### 3.2 The Jacobson Flare

This technique acknowledges these well-known facts, developing an original and very practical explanation for the landing manoeuvre. We have always known **what** to do. Now, the **Where? When? and How?** of landing can be sensibly described and understood, removing the mystery.

**Appendix A** details the mathematical derivations of the relevant formulae, with the associated geometry illustrated in **Appendix B**.

### 4. WHERE TO AIM?

#### 4.1 Without glide-slope assistance

Many GA-trained pilots have traditionally been taught that on final approach, airspeed must be controlled by attitude and rate of descent controlled by thrust. Control of airspeed through the secondary effect of the elevators **is** certainly applicable when thrust is fixed, such as when climbing, and when gliding or practising forced landings. These are lately termed **speed descents**.

Thrust however, does not **directly** control rate of descent. The application of additional thrust increases airspeed; the pilot pitches up slightly to hold the required airspeed, the flight path angle reduces and the rate of descent reduces as a consequence of this flight path angle reduction.

The **speed descent** evolved from glide approaches in the earliest days of aviation, but is not good enough when conducting accurate powered approaches into a defined runway or strip length.

It must be understood that a constant angle final approach to a nominated aim point requires a stable **path descent** where the aircraft glide-path angle is primarily controlled by the elevators and airspeed is primarily controlled by thrust. This technique is **universally suitable** for light aircraft and larger or high performance aircraft. **Speed descent** techniques are **not essential for light aircraft**, despite commonly held views to the contrary, and they are **not suitable for larger or high performance aircraft**. Interestingly, the advocates of the **speed descent** dogma become quite inconsistent in recommending a **path** descent technique to maintain an ILS glide-slope!

On final approach, rate of descent assumes its correct prominence as a function of glide-path angle and ground-speed. It is a result, not a contributor, evolving from a correct and stable approach path at the nominated approach speed.

Once configured on final, the aircraft occupies space vertically (in practical terms in this context) between the pilot's eye and the main wheels. Two parallel paths may be traced down the approach path: the upper pilot-eye path intersects the landing surface at the **aim point** and, assuming for now that no flare is initiated, the lower main-wheel path would intersect the landing surface at a point defined here as the **impact point**.

For a given aircraft type, knowing the distance between the aim and impact points ( $\Delta x$ ) assures adequate runway threshold clearance by the main gear. This provides undershoot protection, by clearly defining the position of a suitable aim point on the runway.

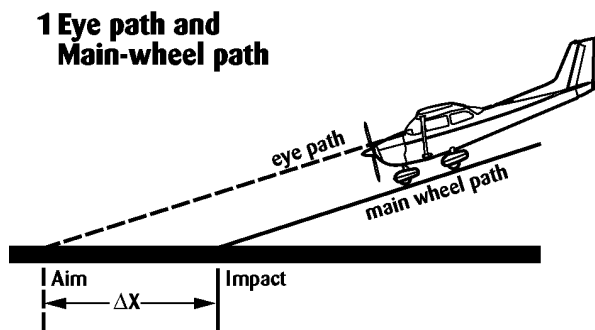


Figure 1

In this way the aircraft can be aimed more accurately, positioning the aim point correctly in the windscreen with elevator pitch control. This is similar to sighting a rifle. The desired position of the aiming point in the windscreen, (commonly but misleadingly referred to as "about one third of the way up the windscreen,") is a simple function of the pilot's seated eye-level position in relation to the top of the glare-shield. This relationship is modified by the aircraft attitude as a consequence of flap configuration and airspeed, when on a constant approach angle to the nominated aim point.

It may help a student understand this concept by visualising the main-wheel path as a constant-angle **fresh-concrete ramp** down base and final to the runway. By selecting and aiming at a suitable aim point, the main wheels can be imagined to be tip-toeing down the soft wet surface, leaving a continuous tyre tread impression. This overcomes the instability inherent when flying speed descents.

For a given aircraft type, the distance between the aim and impact points ( $\Delta x$ ) may be expressed as:

$$\Delta x = Y_h \cot \gamma + X_2 \quad (1)$$

### 1a The Calculation

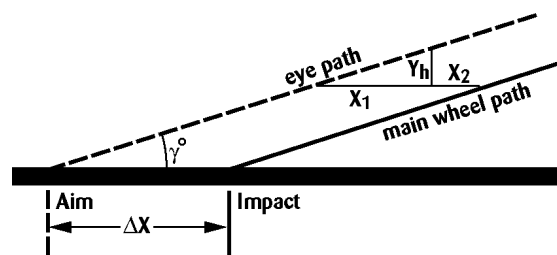


Figure 1a

Or, as a practical rule-of-thumb, (from 1:60 rule), expressed most simply as:

$$\Delta x \approx Y_h \times 60/\gamma + X_2 \quad (1a)$$

For example, for a standard ILS glide path of  $3^\circ$

$$\begin{aligned} \Delta x &\approx Y_h \times 60/3 + X_2 \\ &\approx Y_h \times 20 + X_2 \end{aligned}$$

**GA airmen** may prefer to use an assumed  $\gamma = 4^\circ$   
See **Appendix E** for specific application examples.

For aircraft with **main wheels forward** of the pilot as in many tail-wheel aircraft:

$$\Delta x = Y_h \cot \gamma - X_2 \quad (1b)$$

See Inset in Diagram 4 in APPENDIX B

Dimensions  $X_2$  and  $Y_h$  are noted in aircraft operations manuals, or may be simply ascertained mathematically, or by measurement or estimation.

## 4.2 With glide-slope assistance

### 4.2.1 T-VASIS and PAPI

The **T-VASIS** and **PAPI** are most helpful, but their limitations should be understood. The standard T-VASIS has a MEHT of approximately 49ft/15m, (actual height 48.208 ft). At the nominal approach slope of  $3^\circ$ , the wing-bar is located at 920ft/280m from the approach threshold ( $48.208 \times \cotan 3^\circ (19.081) = 920$ ). See the schematic diagram of indicator light positions and approach angles, **Diagram 5, in Appendix C.**

The **T-VASIS** provides set of **virtually parallel  $3^\circ$  paths to seven different aim points.**

If the MEHT is less (or more) than 15m/49ft, then all the lights are correspondingly closer to (or further from) the threshold. To calculate the location of the wing-bars of a non-standard T-VASIS, multiply the quoted MEHT  $\times \cotan 3^\circ$ , (19.081), and add 90m/150ft. A reasonable approximation is obtained from (MEHT  $\times 20$ ).

Armed with this knowledge, the lights themselves can become useful in fixing the flare point. A series of T-VASIS aiming points can be defined as the mid-point of the horizontal axis between any pair of indicator lights, i.e. at the intercept of any of the T-VASIS paths and the runway surface.

Once these parameters are fully understood, the T-VASIS becomes a most useful aid. Increased eye height over the threshold (e.g., for long/wide bodied aircraft), can be achieved by flying the approach with the wing-bar and one or more of the "fly-down" lights visible as required.

Conversely, if corrected (reduced) eye height is required to compensate for a T-VASIS installed

more deeply along the runway, for example, in a B737 for MEL Rwy 27, the approach may be flown with the wing-bar and one of the "fly up" lights visible, in this example of MEL 27, to align with the required 300m / 1000 ft aiming point.

Some further refinement is available within the vertical tolerance of each light indication (approximately 5m/16ft). The corrected indication may then become the datum for 'standard call' tolerances. In this way, it becomes practical to tailor the T-VASIS to the required visual aiming point, instead of the other way around.

In comparison, the PAPI is a virtual **point source, providing a  $3^\circ \pm 10/15''$  eye path to just one aim point**, located at MEHT  $\times \cotan 2.8^\circ$  (20.45).

### 4.2.2 ILS

ILS charts show threshold crossing height (**TCH**). Multiply this figure by 20 (actually 19.08), as above to estimate the glide-slope intercept (aim) point, and compare with desired visual aim point.

### 4.2.3 Approach Path Disturbance

There are several factors that may disturb a stable approach path to the aim point:

- Pilot anticipation )
- Ground effect ) Overshoot Aim Point
- Wind gradient )
- Wind-shear ) Overshoot or Undershoot

Pilot anticipation refers to starting a premature flare, usually to provide some extra "cushioning" to compensate for any flare misjudgement, while ground effect can influence very large aeroplanes prior to the flare. Wind gradient is the third of these factors that **all** tend to **cause the pilot to overshoot** the aim point. Under most conditions, the head-wind component on final tends to reduce as the aircraft descends. At a constant airspeed, the ground-speed will increase. This will usually require a downward pitch correction to hold the required eye-path (or glide-slope) and, unless thrust is reduced as well, the consequent increase in airspeed will cause an overshoot of the aim point. It may be necessary to make small but steady reductions of thrust to hold both path and speed, down final approach.

Wind-shear is often recognised far too late, because it can be "masked." In the case of undershoot shear, a pilot flying a speed descent will tend to pitch down to chase the reduction in airspeed. In larger and heavier aircraft, an excessive sink rate will be well established before it is recognised and corrective action taken.

When the aim point is maintained accurately, any shear, whether undershoot or overshoot will become very apparent by a sudden change in indicated airspeed. A prompt thrust correction will usually allow the approach path to remain relatively undisturbed. Obviously, a missed approach will be a sensible option in extreme cases.

Once these concepts are clearly understood, pilots have little difficulty in selecting and flying a reasonably consistent visual eye path (the *hypotenuse* of a right-angled triangle), to a nominated aim point on the runway, with or without glide-slope guidance, in any aircraft.

**5. WHEN TO FLARE ?**  
or  
**Triangles have three sides**

Accepting that the glide angle ( $\gamma^\circ$ ) may be reasonably fixed within acceptable tolerances, it follows that any point located longitudinally on the approach path (the *adjacent* side), short of the aim point, will correspond with a particular vertical height (the *opposite* side). Therefore, a flare-height fix of greater consistency than is possible using perception and judgement could be provided by a suitably chosen point along the approach path and overtaken by the aircraft.

**2 Longitudinal Fix V/S Vertical Perception**

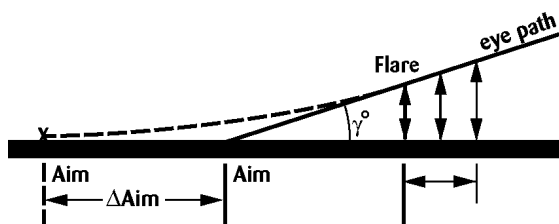


Figure 2.

The aim point has long been regarded as the centre of expansion of a flow pattern, providing the pilot with a visual illusion as points surrounding the motionless aim point appear to accelerate radially outwards as the aircraft approaches the ground. Points beyond the aim point will appear to move upward from the aim point while **points short of the aim point will appear to move downward.** It is a point in this "six o'clock" sector of the pilots' view that has proven useful in quantifying the flare point.

**3 Expansion Pattern**

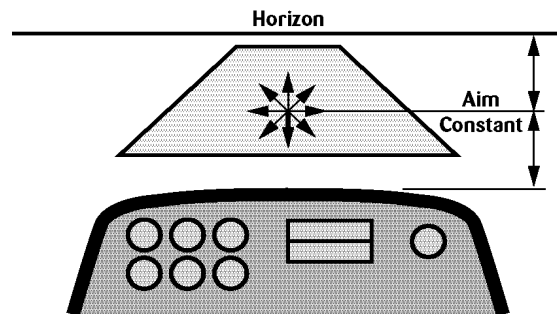


Figure 3.

If such a point is selected and identified, a consistent longitudinal fix for the flare point for a given aircraft can be obtained as this pre-selected point appears to move down the windshield (due to increasing depression angle) to the point where it reaches the lower cut-off angle (limit depression angle,  $\kappa^\circ$ ) of the cockpit. This angle is dictated by the geometry of the pilot's eye-level (seating) position in relation to the aircraft structure (where some design consistencies exist between aircraft types), modified by the aircraft attitude as a consequence of configuration and airspeed.

**3a Cut-off angle as a fix**

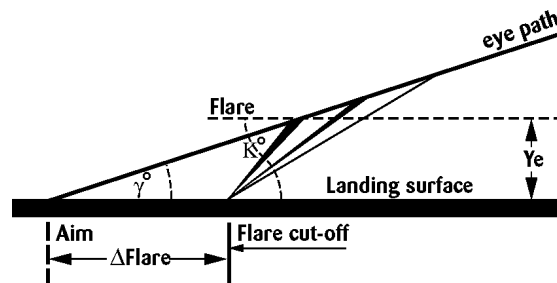


Figure 3a.

The flare is initiated when, on a stable approach, the pre-determined cut-off point is overtaken by the aircraft cockpit lower cut-off angle ( $\kappa^\circ$ ). In practice, it is the simplest of tasks to notice the forward edge of the aircraft glare-shield, at the base of the windscreen, superimpose the cut-off point while flying an approach using standard **path** techniques. It does not detract from the pilot's attention, because the point in question is at "six o'clock" to the aim point on the approach centre-line, continuously in the pilot's normal peripheral field of view. (It has always been there!) It is a visual fix from two position lines, not a calculated guess. Obviously, to achieve predictability and consistency, some quantification is necessary.

Calculation of this distance from the aim point back to the flare cut-off point ( $\Delta f$ ), involves energy and geometry considerations developed in practice by experience, but complicated to derive by analysis, unless the flare eye height ( $Ye$ ) is known and radio altimeter cues are utilised.

### 5.1 Where Flare Height ( $Ye$ ) is Known:

Where the required flare eye height ( $Ye$ ) is nominated, (including most of the wide-body jet transports) an accurate flare cut-off point ( $\Delta f$ ) may be calculated using:

$$\Delta f = Ye (\cot \gamma - \cot \kappa) \quad (2)$$

See **Appendix D** for specific application examples

### 5.2 Where Flare Height ( $Ye$ ) is Not Known:

For the majority of types, ranging from very light aircraft to medium jet transports, the desired flare eye height is neither nominated nor identifiable. It has always been a subjective estimation, a guess.

However, a suitable approximation for the flare cut-off point ( $\Delta f$ ), based on aircraft and approach geometry and thorough practical testing, has provided a simple and effective alternative base technique with near-universal application.

For a given aircraft type, the distance between the aim and impact points ( $\Delta x$ ), already discussed in 4.1 above to determine a suitable aim point, has also proven to be suitable for quantification of the

flare-point. This distance accommodates the critical variations in glide angle ( $\gamma^\circ$ ), pilot-eye height above main wheels ( $Yh$ ) and horizontal distance of main wheels from pilot-eye ( $X2$ ). It does not accommodate the cockpit lower cut-off angle ( $\kappa^\circ$ ) and is therefore a different distance from  $\Delta f$ , except by coincidence. Some correction may be required to optimise  $\Delta x$  for this and factors such as seat height.

### 3b Cut-off angle as a fix

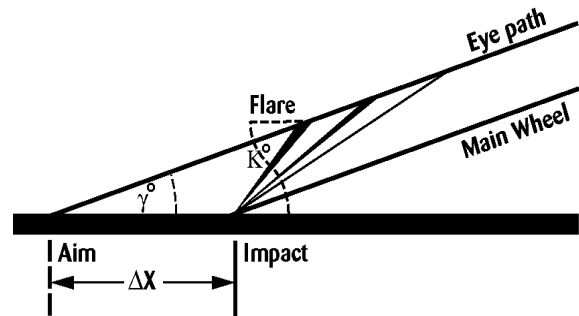


Figure 3b

Where the near-universal main-wheel path approximation is utilised,  $\Delta x$  may be expressed as shown above:

$$\Delta x \approx (Yh \times 60/\gamma) + X2 \quad (1a)$$

Pilot-eye height at the flare point ( $Ye$ ) may be expressed by substituting  $\Delta x$  for  $\Delta f$  and transposing (2) above:

$$Ye = \frac{\Delta x \text{ (for } \Delta f)}{(\cot \gamma - \cot \kappa)} \quad (2a)$$

### 5.3 Locating the Cut-off Point

The next important step is to locate the calculated cut-off (impact) point on the landing surface, short of the aim point. Runway surface markings often include centre-line marks of 30m/100ft in length. Distance guides of 30m/100ft commence at 150m/500ft, and 45m/150ft with one of 45m/150ft at 300m/1000ft from the threshold.

Simple interpolation of these markings by the pilot satisfies the practical requirements for a visual fix along the approach axis, day and night. Where distance markers do not exist on a landing surface, the pilot can estimate the position of the cut-off ( or impact) point using variations in surface colour or texture for identification. For night operations

from these surfaces, calculations based on the longitudinal distance between runway-edge lights can provide the pilot with a similar usable cue.

This flare-point concept is extremely **tolerant** when compared with traditional height-perception techniques. For a standard 3° glide path any error of flare height judgement will be reflected on the runway by approximately 20 times, longitudinally.

In marked contrast, any longitudinal inaccuracy will be reflected as only 1/20th of that figure, vertically. The twenty times expanded scale of the runway axis together with a visual fix provides a model that is visible and which provides unparalleled accuracy and consistency of recognition for student and experienced pilot alike.

#### 5.4 Non-standard Approaches

The cut-off point calculated for a normal approach also serves for non-standard landing configurations, with their likely variations in aircraft attitude. An aircraft on approach at a higher attitude (body angle) than normal would require a higher flare point to accommodate the lower main wheel clearance. The higher attitude **self compensates**: the lower cut-off angle is reached further back up the approach path, providing an earlier cue to flare, as would be required. The converse also applies.

In the case of a full glide approach (e.g. forced landing), the normal approach cut-off point displacement ( $\Delta x$ ), subtended from a **steeper** glide path by the **increased** lower cut-off angle, will trigger a higher flare point which would be required for the increased rate of descent.

#### 5.5 Up- / Down-sloping Runways

Up- or down-sloping runways will cause the apparent distance between the aim point and the flare cut-off point to appear greater (or lesser), respectively. This illusion will **self-compensate**, scheduling the earlier (or later) flare which would be required to accommodate the greater (or lesser) flare amount demanded by the runway slope.

#### 5.6 Light/heavy-weight landings

At light landing weights, the flare could be made

slightly later than usual, but the author's preferred technique is to flare at the usual point, recognising that a slower flare-rate may better accommodate the lighter weight, lower ground speed and lower rate of descent.

Conversely, at maximum landing weights, it may be preferable to commence the flare slightly earlier, recognising that flaring at the usual point may require an unacceptable flare-rate to accommodate the greater inertia, higher ground-speed and the consequently higher rate of descent.

#### 5.7 Strong head-winds/tail winds

These effects are virtually the same respectively, as the light/heavy-weight landings, above. A strong head-wind will require a later or preferably a slower flare-rate and a tailwind will require a faster flare rate or, preferably, an earlier flare. This is due to the variations in groundspeed and vertical speed.

### 6. HOW TO FLARE ?

#### 6.1 Current Practice

Conventional techniques generally provide (subject to certain variations) for simultaneous reductions of rate of descent towards zero and of thrust to idle, positioning the aircraft just above the landing surface and converging slightly with it.

The actual rate and the amount of flare required depends on a number of variables including, but not limited to:

- aircraft inertia
- rate of descent
- control effectiveness
- density altitude
- wind-shear effects
- pilot factors.

#### 6.2 The Gentle Touch

Having commenced the flare at the point pre-determined in the above discussion, a further visual cue is available. David Robson's technique ("**The Gentle Touch**" 1987), guides the pilot through the flare and on to the touchdown point. The pilot raises his line of sight, selecting a new aim point, towards or even **at** the centre of the far end of the

landing surface. By endeavouring to "fly" his eyes progressively towards this aim point, over 3-4 seconds, he will be guided to the amount and the rate of aircraft rotation required prior to touch-down, while accommodating the changing aircraft attitude. Thrust reduction to idle is made progressively, ahead of, during, or after the flare, depending on the aircraft speed and inertia at the time, as usual.

For a runway of uniform slope (not necessarily level), the centre of the far (upwind) end of the runway is perfect as the new aim point for the following reasons:

- It provides a new constant aim point toward which the eyes may be 'flown'.
- There is no need to guess height or flight path from rapidly moving peripheral cues.
- The eye path is related to the runway slope, converging with it and causing the main gear to gently converge. In practice, the touchdown will occur on or just beyond the original aim point.
- The aircraft should not 'float' down the runway, nor should it bounce or over-flare.
- This point can be 'tailored' (shortened) to increase the angle of convergence and thus the impact with the runway when it is wet, to minimise aquaplaning.
- On shorter runways, this 'tailoring' occurs naturally (e.g. SYD RWY 07 compared with 16R) resulting in a proportionally shorter touch-down on the shorter runway - a useful feature.
- It can be 'tailored' to suit uphill, downhill or varying runway slopes (e.g. XMX, DRW, LST), so that the main wheel path converges with the runway touchdown zone. The full-length upwind-end aim point may be unsuitable as it could cause the main wheel path to diverge from the touchdown zone.
- It is the best reference for pitch, roll, yaw, drift and distance information, reducing control inputs and providing a safe, gentle touch-down.
- This technique is independent of aircraft type

(i.e., size): The flare position has accommodated the aircraft main wheel geometry.

- 'Feel' is not necessarily required, solving a major training problem. The visual eye path (in pitch, roll and yaw) is ahead and clearly visible. The pilot concentrates on the distant and stable reference point and continues to fly the aircraft to a consistent, smooth touch-down. The required control inputs suggest themselves as on an ILS.

## 7. FINALLY, A FLARE FOR LANDING

It is now possible to describe in **three simple steps 'how'** to land an aircraft.

**1. Hold an accurate eye path to the nominated aim point**, utilising ILS, VASIS, or PAPI if available, **in the 'slot'**, within nominated limits.

**2. When the aircraft glare-shield superimposes the pre-determined flare cut-off point, start the flare**, reducing thrust as discussed above.

**NOTE: Do not try to watch the cut-off point pass under the nose. Maintain most attention towards the aim point** and note the visual flare fix occur in the lower peripheral field. This greatly reduces the possibility of a premature touch down before the flare is completed.

**3. Fly the eyes progressively up the runway over 3-4 seconds until the new aim point is moving neither up nor down** in the visual field, check that thrust has been reduced to a minimum and continue to **'fly the eyes' towards this point** until touch-down.

## 8. CONCLUSIONS

This comprehensive technique is simple, practical, and extremely effective. It has been developed since 1985 and tested in many aircraft types, ranging from gliders and single-engine light aircraft to large jet transports, by civil and military pilots of various ages, abilities and experience. Since 1990, it has been the mainstay of landing training technique at some of Australia's foremost Aviation Colleges and flying training organisations. The feed-back is comprehensively positive.

The concept of universal application is not an oversimplification of obvious differences between aircraft. Rather, it addresses those differences while consolidating the obvious argument for a basic system of flying which may be adapted as necessary to meet specific requirements. It is long overdue.

While adding to a pilot's satisfaction, this flare technique offers the following major advantages:

- Landing an aeroplane may now be regarded as a **skill that can be learned**. Pilots are provided with a predictable and consistent visual eye path from final approach through to touch-down. Traditional training methods have assumed the manual landing to be non-quantifiable; this concept enables an original and precise interpretation for a manoeuvre historically regarded as an 'art'.
- Most of the variables affecting perception and judgement may be discounted. It is tolerant.
- Elementary and advanced pilot training is simplified for student and instructor, reducing time and costs.
- This technique is 'pilot portable' across aircraft types and may be developed and applied to successive aircraft conversions.
- Experienced pilots can better maintain consistency of standard by utilising this 'visual fix' to complement their highly developed levels of judgement, co-ordination and skill.
- Runway occupancy times are minimised.
- Safety is greatly enhanced.

Support from all sections of the industry continues to be most encouraging, demonstrating far-reaching consequence for fixed wing aviation.

## 9. ACKNOWLEDGEMENTS

The author wishes to thank many people for their assistance in the research and development of this technique. Since 1985, the number has grown too large to record here, but the clear objectivity, honesty, and genuine encouragement of

these professionals will always be appreciated.

As a matter of interest, the original inspiration (in 1965) for this technique was the "*Dam Busters*" operation by **617 Squadron RAF**, in May, 1943.

## 10. DEDICATION

Special mention must be made of the caring support and encouragement, and the professional objectivity of my wife, Paddi Roberts-Jacobson - Psychologist, who, without prejudice, could see what I could see, and still shares my enthusiasm.

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## APPENDIX A

See Figures 1a, 3a, 3b, and Diagram 4 in Appendix B.

### 1. SOLVING FOR $\Delta x$

From figure 4,

$$\Delta x = X1 + X2 \quad (i)$$

Solving for X1:

$$X1/Yh = \cot \gamma^\circ$$

Therefore:

$$X1 = Yh \cot \gamma^\circ$$

Substituting  $Yh \cot \gamma^\circ$  for X1 in (i) above,

$$\Delta x = (Yh \cot \gamma^\circ) + X2 \quad (1)$$

A simple rule may be developed from (1):

$$\text{Since for small angles, } \cot \gamma^\circ \approx 60/\gamma^\circ \quad (1:60 \text{ rule})$$

$$\text{Then, by substitution I (1), } \Delta x \approx (Yh \times 60/\gamma^\circ) + X2 \quad (1a)$$

With main wheels are forward of pilot eye position, as in tail wheel aircraft, from inset diagram 4

$$\text{Then } \Delta x \approx (Yh \times 60/\gamma^\circ) - X2 \quad (1b)$$

### 2.SOLVING FOR $\Delta f$

From figure 4, substituting  $\Delta f$  for  $\Delta x$  (considered interchangeable for this purpose),

$$\text{Since } \cot \gamma^\circ = \frac{\Delta f + (Xe - \Delta f)}{Ye}$$

$$\text{therefore: } Ye \cot \gamma^\circ - \Delta f = (Xe - \Delta f) \quad (i)$$

$$\text{And } \cot \kappa^\circ = \frac{(Xe - \Delta f)}{Ye}$$

$$\text{therefore: } Ye \cot \kappa^\circ = (Xe - \Delta f) \quad (ii)$$

$$\text{From (i) and (ii) } Ye \cot \gamma^\circ - \Delta f = Ye \cot \kappa^\circ$$

$$\text{therefore: } Ye \cot \gamma^\circ - Ye \cot \kappa^\circ = \Delta f$$

$$\text{therefore: } \Delta f = Ye (\cot \gamma^\circ - \cot \kappa^\circ) \quad (2)$$

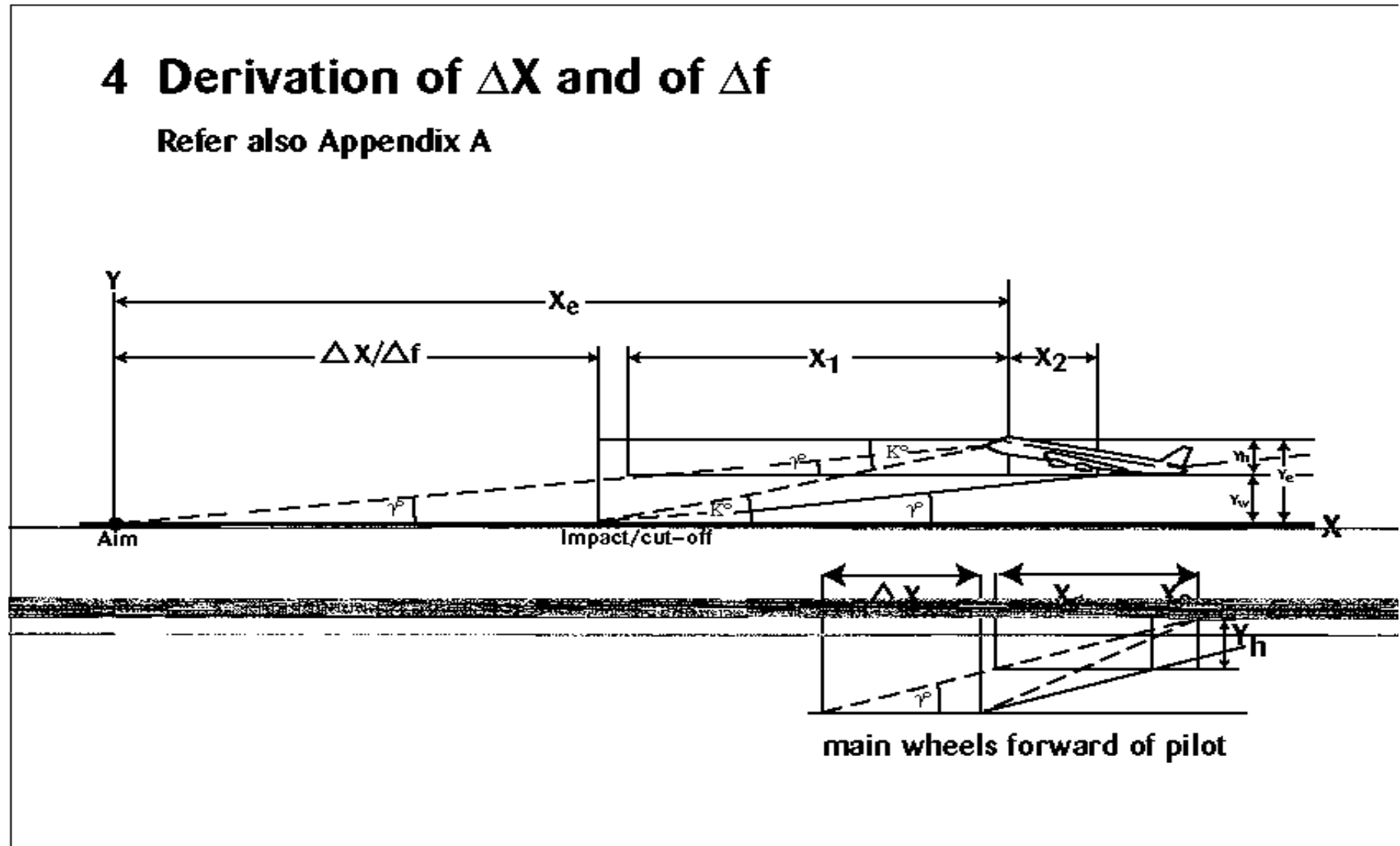
Pilot-eye height at the flare point ( $Ye$ ) may be calculated by transposing expression (2) above, and interchanging  $\Delta f$  and  $\Delta x$ , as required:

$$\text{therefore: } Ye = \frac{\Delta f \text{ (or } \Delta x)}{(\cot \gamma^\circ - \cot \kappa^\circ)} \quad (2a)$$

APPENDIX B

# 4 Derivation of $\Delta X$ and of $\Delta f$

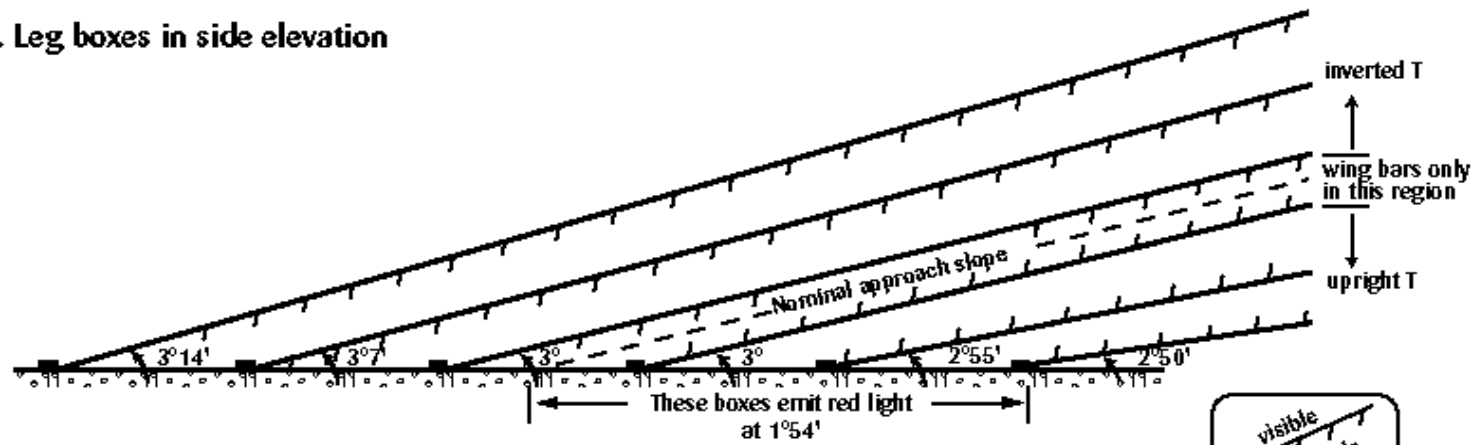
Refer also Appendix A



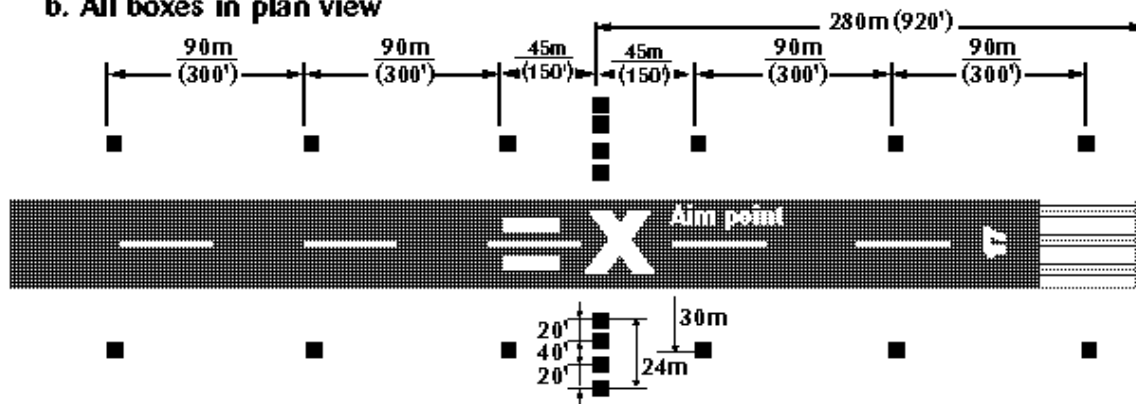
APPENDIX C

# 5 T-VASIS Schematic

a. Leg boxes in side elevation



b. All boxes in plan view



**APPENDIX D**

**Where the following parameters are KNOWN:  
(See Notes on Appendix D, Page 17)**

<b>Aircraft Type</b> <b>Some examples</b>	<b>Cockpit lower cut-off angle (<math>\kappa^\circ</math>)</b>	<b>Nominal gear level at flare point <math>Y_w</math> (ft)</b>	<b>Eye level to main-wheel <math>Y_h</math> (ft)</b>	<b>Eye level at flare point, <math>Y_e = Y_w + Y_h</math> (ft)</b>	<b>Cotangent cockpit lower cut-off angle <math>\cotan \kappa^\circ</math> (ft)</b>	<b>Distance <math>\Delta f = Y_e (\cot \gamma - \cot \kappa)</math> Glide angle (<math>\gamma = 3^\circ</math>) <math>\cotan 3^\circ = 19.08</math></b>	<b>Normal aim point from threshold <math>\Delta Aim</math> (ft)</b>	<b>Cut-off point located from threshold <math>\Delta Aim - \Delta f</math> (Rounded, ft)</b>
<b>J31</b>	13.0	10	8.5	<b>18.5</b>	<b>4.33</b>	<b>272.88</b>	1000	<b>727</b>
<b>DHC-8</b>	16.0	12	8.0	<b>20.0</b>	<b>3.49</b>	<b>311.80</b>	1000	<b>688</b>
<b>F27 F50 BAE-146</b>	18.0	12	11.0	<b>23.0</b>	<b>3.08</b>	<b>368.00</b>	1000	<b>632</b>
<b>DC-9-30</b>	13.0	15	13.3	<b>28.3</b>	<b>4.33</b>	<b>417.43</b>	1000	<b>583</b>
<b>F100 B737-1/200</b>	13.0	15	17.0	<b>32.0</b>	<b>4.33</b>	<b>472.00</b>	1000	<b>528</b>
<b>B737-300/500</b>	13.0	15	18.0	<b>33.0</b>	<b>4.33</b>	<b>486.75</b>	1000	<b>513</b>
<b>B737-400</b>	13.0	15	19.0	<b>34.0</b>	<b>4.33</b>	<b>501.50</b>	1000	<b>499</b>
<b>B737-800</b>	13.0	15	20.0	<b>35.0</b>	<b>4.33</b>	<b>516.25</b>	1000	<b>484</b>
<b>B707-120/138/320</b>	13.0	20	19.0	<b>39.0</b>	<b>4.33</b>	<b>575.25</b>	1000	<b>425</b>
<b>B707-320B</b>	13.0	20	19.0	<b>39.0</b>	<b>4.33</b>	<b>575.25</b>	1000	<b>425</b>
<b>B727-100</b>	13.0	20	19.0	<b>39.0</b>	<b>4.33</b>	<b>575.25</b>	1000	<b>425</b>
<b>B727-200</b>	13.0	20	20.0	<b>40.0</b>	<b>4.33</b>	<b>590.00</b>	1000	<b>410</b>
<b>A320 MD-87</b>	16.0	20	21.0	<b>41.0</b>	<b>3.49</b>	<b>639.19</b>	1000	<b>361</b>
<b>MD-80 / B717</b>	16.0	20	23.0	<b>43.0</b>	<b>3.49</b>	<b>670.37</b>	1000	<b>330</b>
<b>B757-200</b>	17.5	25	25.0	<b>50.0</b>	<b>3.17</b>	<b>795.50</b>	<b>1150</b>	<b>355</b>
<b>B767-200</b>	17.5	25	27.0	<b>52.0</b>	<b>3.17</b>	<b>827.32</b>	<b>1150</b>	<b>323</b>
<b>B767-300</b>	17.5	25	28.0	<b>53.0</b>	<b>3.17</b>	<b>843.23</b>	<b>1150</b>	<b>307</b>
<b>A300-B2/B4</b>	13.0	25	28.0	<b>53.0</b>	<b>4.33</b>	<b>781.75</b>	<b>1150</b>	<b>368</b>
<b>A300-600</b>	18.0	25	29.0	<b>54.0</b>	<b>3.08</b>	<b>864.00</b>	<b>1150</b>	<b>286</b>
<b>A340</b>	18.0	25	27.0	<b>52.0</b>	<b>3.08</b>	<b>832.00</b>	<b>1150</b>	<b>318</b>
<b>A330-200</b>	15.0	30	35.0	<b>65.0</b>	<b>3.73</b>	<b>997.75</b>	<b>1150</b>	<b>152</b>
<b>A330-300</b>	17.9	30	34.0	<b>64.0</b>	<b>3.10</b>	<b>1,022.72</b>	<b>1150</b>	<b>127</b>
<b>B747SP</b>	16.0	30	39.0	<b>69.0</b>	<b>3.49</b>	<b>1,075.71</b>	1500	<b>424</b>
<b>B747-1/200</b>	16.0	30	40.0	<b>70.0</b>	<b>3.49</b>	<b>1,091.30</b>	1500	<b>409</b>
<b>B747-300</b>	16.0	30	41.0	<b>71.0</b>	<b>3.49</b>	<b>1,106.89</b>	1500	<b>393</b>
<b>B747-400</b>	15.0	30	41.0	<b>71.0</b>	<b>3.73</b>	<b>1,089.85</b>	1500	<b>410</b>



**APPENDIX F**

**Where the following parameters are KNOWN:  
(See Notes on Appendix F, Page 17)**

Aircraft Type	INTRODUCING Eye level to main- wheel path Yp (ft) Aircraft Manual	INTRODUCING Eye level to main- wheel path Yp (ft) ICAO ADM	60 \ glide angle $\gamma$ ° (approx cotan $\gamma$ °)	Distance $\Delta x =$ (Yp x 60/ $\gamma$ °) (ft)	Normal aim point from threshold $\Delta$ Aim (ft)	Cut-off point located from threshold $\Delta$ Aim - $\Delta x$ (Rounded, ft)
J31	9.1		20	182.0	1000	818
DHC-8	9.9	9.0	20	198.0	1000	802
F27 F50 BAE146		12.0	20	240.0	1000	760
DC-9-30	15.8		20	316.0	1000	684
F100 B737-1/200		19.0	20	380.0	1000	620
B737-300/500	18.3	20.0	20	366.0	1000	634
B737-400	19.3	21.0	20	386.0	1000	614
B707-120/138/320		21.0	20	420.0	1000	580
B707-320B		22.0	20	440.0	1000	560
B727-100		22.0	20	440.0	1000	560
B727-200	21.5	23.0	20	430.0	1000	570
A320 MD-87	22.0	24.0	20	440.0	1000	560
DC-8-63		25.0	20	500.0	1000	500
MD-80		26.0	20	520.0	1000	480
B757-200		29.0	20	580.0	1150	570
A310-300 B767-200	29.0	30.0	20	580.0	1150	570
B767-300	30.0	31.0	20	600.0	1150	550
A300-B2/B4	36.3	32.0	20	726.0	1150	424
A300-600		33.0	20	660.0	1150	490
B747SP	37.0	42.0	20	740.0	1500	760
B747-200	39.0	45.0	20	780.0	1500	720
B747-3/400	43.0	45.0	20	860.0	1500	640
Your aircraft:						

### NOTES ON APPENDIX D

1. The assumed values shown in **APPENDIX D** are derived from Company Flight Crew Training manuals and ICAO Aerodrome Design Manual Doc 9157-AN/901 Part 4 App 6 Table A6-1, and are intended to provide for a wide range of aircraft operational considerations. The formula used is:

$$\Delta f = Y_e (\cot \gamma^\circ - \cot \kappa^\circ)$$

2. The results shown should be regarded as ‘**ball-park**’ figures initially and refined later as experience is gained. Accurate figures for all specific models may require further detailed consultation. Alternatively, the ‘ball-park’ figures calculated here may be varied slightly to suit individual flare-rate preferences, and seat-height variations from DEP (design eye point) by increasing or decreasing the distance, ( $\Delta f$ ), visually, and then noting it for future reference. Seat height variations from DEP will, of course, affect the cut-off angle, ( $\kappa^\circ$ ) and therefore the accuracy of the particular flare cut-off point being used.

3. The dimensions derived from ICAO Aerodrome Design Manual Doc 9157-AN/901 Part 4 App 6 Table A6-1, namely, eye above wheel height, (**Yh**), are slightly conservative. The reason is due to the fact that, while a 3° glidepath is assumed, the flap setting for each aircraft is **less** than the normal landing flap setting, to exaggerate the aircraft attitude slightly more nose-up, to provide a greater margin of main-gear clearance. The dimension (**Yh**), therefore, is probably greater than the corresponding figure derived from aircraft or airline manuals. Allowing for the greater conservatism (ie, slightly earlier/higher flare point), the ICAO table A6.1 provides some consistency for comparative measurement for the range of aircraft examples listed here.

### NOTES ON APPENDIX E

1. The assumed values shown in **APPENDIX E** are derived from aircraft manuals and physical measurement and are intended to provide for a wide range of aircraft operational considerations. The formula used is:  $\Delta x \approx (Y_h \times 60/\gamma^\circ) + X_2$

\* See note below

2. These results should be regarded as ‘**ball-park**’ figures initially and refined later as experience is gained. Accurate figures for all specific models may require further detailed consultation. Alternatively, the ‘figures calculated here may be varied slightly to suit individual flare-rate preferences, and seat-height variations from DEP (design eye point) by increasing or decreasing the distance, ( $\Delta x$ ), visually, and noting it for future reference. Seat height variations from DEP will affect the cut-off angle, ( $\kappa^\circ$ ) and the accuracy of the particular flare cut-off point being used.

3. The assumed figures of 3° and 4° are generally well accepted as typical, even though confirmation of glidepath angle by electronic or visual means may not be available at all aerodromes.

### NOTES ON APPENDIX F

1. Appendix F introduces a new expression to the discussion: **eye level to main wheel path (Yp)**. This vertical dimension between these two paths is the one nominated by some manufacturers.  $\Delta x$  may be calculated from this dimension by:

$$\Delta x = Y_p \times \cot \gamma^\circ \quad \text{or} \quad \Delta x \approx Y_p \times 60/\gamma^\circ *$$

\* See note below

2. Where aircraft manual data was accessible to the author, this has been used. Where it was not, **Yp** data was obtained from the **ICAO ADM** described for **Appendix D**, above. The same conservatism applies, however. In the **Appendix F** table, the **Yp** used in the example calculation is shown in **bold** type in the applicable ‘**Yp**’ column.

### SUMMARY

1. Appendices **D**, **E**, and **F** demonstrate three methods of calculating a starting figure for  $\Delta f/\Delta x$ , depending on the basic aircraft data available. A comparison of **differing results** for  $\Delta f/\Delta x$  between the tables, **for the same type of aircraft**, serves to illustrate the effects of using different base data. The pilot can make any necessary corrections.

2. \* Remember that the expressions for  $\Delta x$  do **not** accommodate the cockpit lower cut-off angle ( $\kappa^\circ$ ).