PERFECT Landin

Paul Phelan discovers a flying technique that is helping pilots to land better — every time.

"Jeez, fellas, if you'd warned us it was gonna be one of those landings, we'd have worn our sports bras!"

That sassy quip from an unidentified flight attendant, is said to have broken the stunned silence that traditionally pervades on the flight deck at the end of the rollout, after a large jet has made a memorably heavy landing and the flight attendants are busy reassuring the passengers and re-stowing the popped-out oxygen masks.

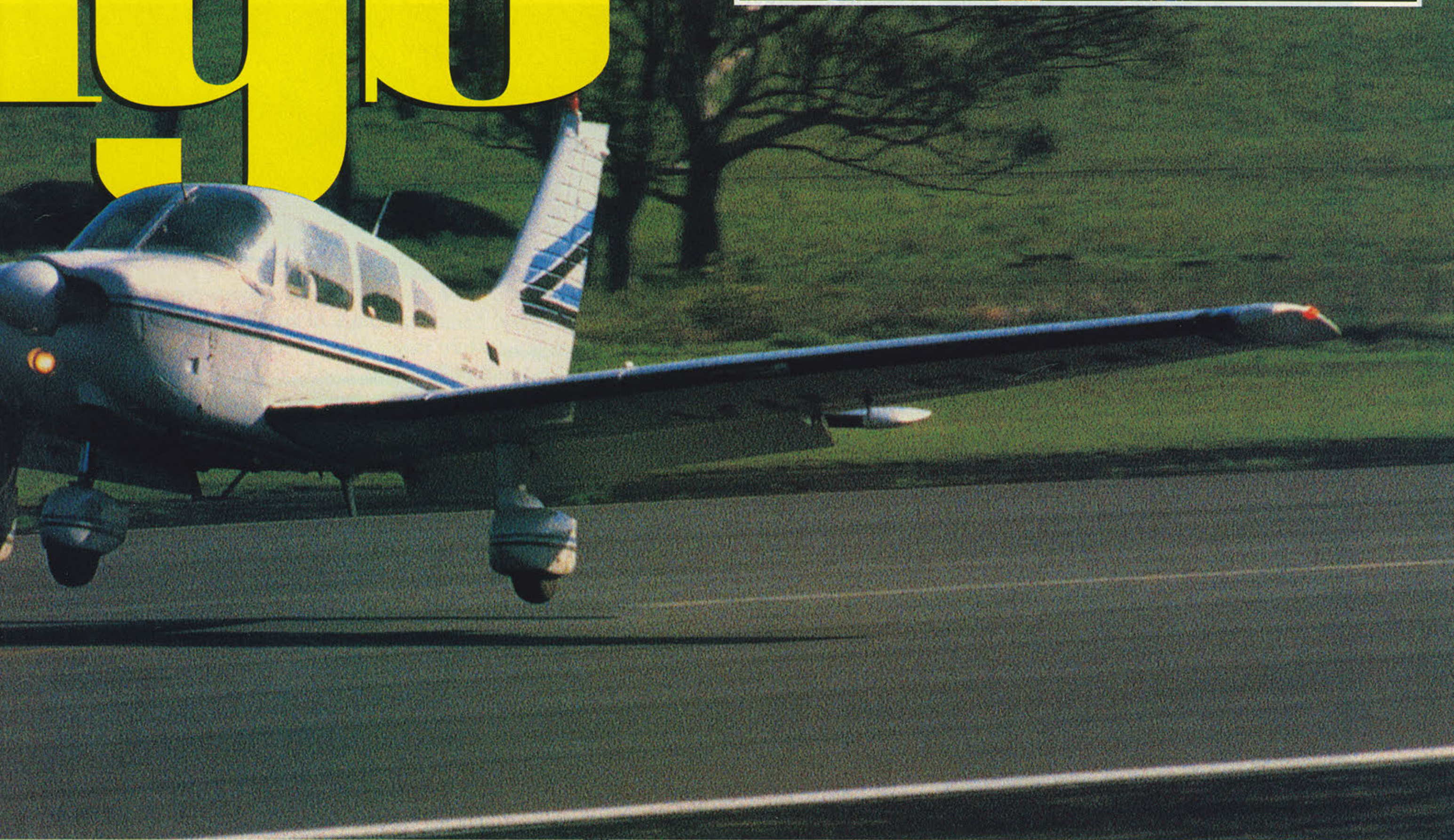
Another (from an overseas captain on the PA): "Sorry about that landing folks, but you'll be glad to hear we now have the hijacker under restraint."

Simply, it's how you do what you do, during the final approach and flare, that determines what will be a good landing and what won't.

Most of us have blown our reputation with at least one megagraunch onto a runway or airstrip somewhere. Qantas captain David Jacobson's moment of truth came on a calm, clear moonlit Hobart night in a Boeing 727, when he admits to having contacted the runway in an un-checked 800 fpm descent. But Jacobson didn't simply write that off to the law of averages as most pilots do. Having researched the final approach and landing sequence since 1985 in search of a solution to such random events, he now attributes them to a glaring and almost universal flaw in the development and understanding of defined landing flare techniques which, he asserts, leaves a similar unfilled gap in pilot training at all levels:

"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. Surprisingly there has been no acceptable, quantifiable technique in the history of aviation; nor any recognition of the need for one."

It's all the more surprising, when you consider the focus on accuracy in every other phase of flight; and the fact that every one foot inaccuracy in estimating flare height, produces a 20 ft longitudinal error. The potential to save fuel, and wear on brakes and thrust reversers; and



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PERFECT LANDINGS

to reduce runway occupancy, alone make it worth investigating closely. (We've used feet as the measurement through this article, as the relationship between feet of altitude and distance is frequently discussed. That doesn't prevent calculations being made in metres.)

"Before offering a solution, the problems inherent in existing traditional techniques must be recognised. They are inadequate, inappropriate, imprecise, complex, hazardous, and frustrating; yet we have stayed with them. Why? We have attempted to teach judgement and perception. Without an adequate framework there is no simple way to teach perception and judgement to those to whom it does not come easily. We have always attempted to teach WHAT we do, but we have failed in our collective attempts to explain HOW. Ask any pilot how he lands; he won't be able to tell you."

Current methods, he insists, rely heavily on skill, memory, perception, familiarity, and practice. Student pilots are generally pretty low on all those resources; and rely on trial and error to develop the judgement necessary to practice them. So do pilots transitioning from one type to another (generally larger) type. In countries where rapid economic growth and determined nationalism in pilot employment policies is propelling relatively inexperienced pilots into very large aeroplanes, it's almost imperative that new initiatives be developed to improve their landing skills to a point where they can achieve a consistent result that won't bend anything.

Jacobson's solution, now known as 'the Jacobson flare' and recently presented at a series of CASA flight safety seminars, is based on simple triangulation, inspired by the technique the 'Dam Busters' used to lob their bombs with precision between a protective boom net and the dam wall. More recently similar triangulation techniques have been adapted to position airline aircraft precisely at aerobridges.

It is already being taught at the Australian Aviation College, which trains cadets for several major international carriers including Qantas. China Southern's WA flying college has now also formally confirmed plans to adopt the Jacobson flare as part of its standard training techniques. Jacobson asserts it will save wasted training time; relieve unnecessary stress on pilots (and passengers); provide standardisation, stability and predictability; offer solutions to immediate problems which will also carry over to larger types; arm trainers with an ability to

troubleshoot and to critique landings sensibly and constructively; and diminish the number of landing accidents — which represent a high proportion of all accidents.

The "Jacobson flare" solution derives a practical and very error-tolerant technique from a series of uncontestable facts, to establish a visual fix for flare initiation — and Jacobson insists they apply equally to a Tiger Moth and a B747:

- In a stable approach, up to the point of flare, the path of the pilot's eye traces a three-dimensionally straight line towards an aiming point on the runway;
- With the aircraft configured, on speed, and 'in the slot' the line of the pilot's view of that point passes through a constant point on the windshield, and the view of all other points appears to move outwards, upwards or downwards across the windshield in relation to it;
- The aircraft's wheels trace a lower line, parallel to the pilot's eyeline, to a point at which they would impact the runway if the aircraft were not flared (Jacobson calls this the "impact point");

For a given aircraft type and approach speed, there is a defined (or definable) wheel height for the initiation of the flare, at the optimum rate of rotation to the flared attitude;

• There is a point on the approach, short of the impact point, at which that wheel height is reached, and at which the optimum flare should be initiated;

That point, although it is directly beneath the aircraft, can be related to a still-visible point further ahead on the runway, which is a geometrically calculable distance short of the aim point. (Jacobson calls this the "flare cut-off point");

• The dimensions of runway markings are universal, and can be used to establish a visual pinpoint of the distance back from the aim point to the flare cut-off point (which Jacobson nominates as the point at which it becomes obscured by the advancing glareshield);

• If at that point the pilot flares at a defined rate of rotation until the end of the runway has become the new aim point, the aircraft will follow an accurate flight path at a reducing rate of descent to a correct flared body angle.

Jacobson emphasises he is not teaching any radical departure from current practice. He has simply defined it, putting those facts together with some simple mathematics, to establish a methodology by which a pilot on approach can accurately locate the flare cutoff point.

Many pilots (including this one) actually went flying to evade evils like geometry, but the calculation is not a daunting one; and in any case, those with a severe pythagoraphobia (being spooked by geometry!) could probably plot the whole thing with a protractor on a large sheet of graph paper.

The Jacobson flare process begins with the recognition that a stable approach path is required: "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, lately termed "speed descents", evolved from glide approaches in the earliest days of aviation, but are not good enough when conducting accurate powered approaches into a defined runway or strip length." Jacobson notes that path descents are the common currency of airline operations, although the concept is less generally accepted in general aviation.

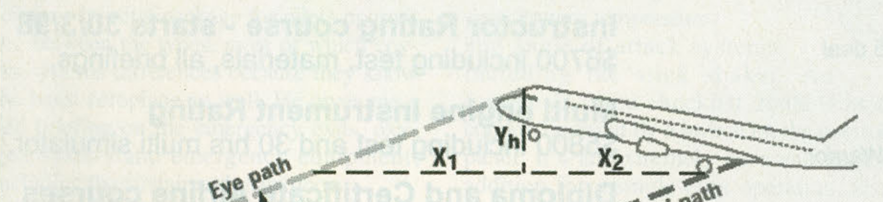
"It must be understood that a constant-angle final approach to a nominated aim point requires a stable path descent where the aircraft glide-path angle is primarily controlled by the elevators and airspeed is primarily controlled by thrust. This technique is universally suitable for light aircraft and 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 are then quite inconsistent in recommending a path descent technique to maintain an ILS glide-slope!"

Where to Aim

For any aeroplane, the aim point is established as a point along the runway which will provide the required wheel clearance and undershoot protection at the runway threshold. The location of the aim point along the runway then depends on the height of the pilot eye path above the main wheel path. The distance between the aim point and the "impact point" (assuming no flare) of the main wheels is easily calculated. The desired position of the aim point in the windscreen is a simple function of the pilot's 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.

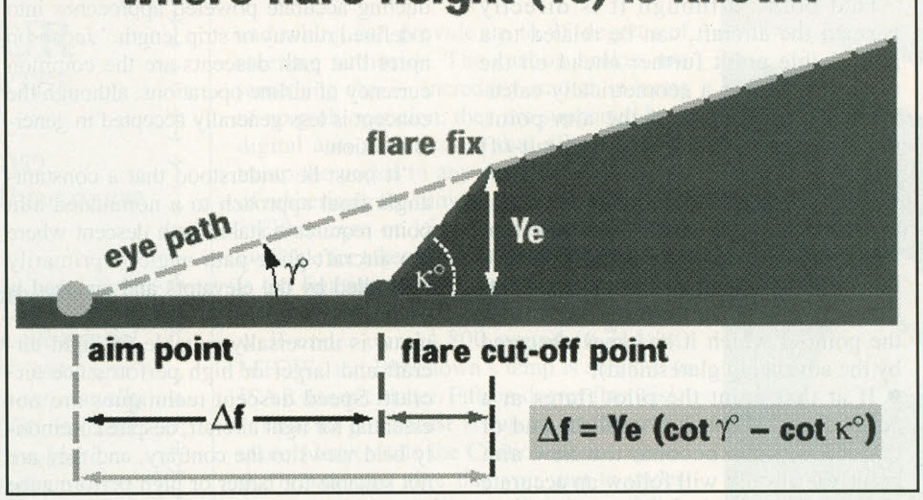
The distance between Aim point and Impact point
(simplified version)

$$\Delta X \approx (Y_h \times 60/\gamma^\circ) + X_2$$



PERFECT LANDINGS

Cut-off angle as a flare fix
where flare height (Ye) is known



When to Flare

The aim point appears motionless in the windscreen, while points around it appear to accelerate radially outwards as the aircraft approaches. The flare is initiated when a predetermined cutoff point along the runway centreline is overtaken by the glareshield.

Once in a stable approach, and having done the calculations for your aircraft type, you have all the necessary tools to locate your "flare cutoff point". Don't be daunted by the maths, which are in fact relatively simple.

From this point, you need to know that there are two slightly different formulae: one for aircraft for which pilot's eye height and flare height are nominated; and another where they are not. The diagrams will help you understand the formulae.

Where the Flare Height (Ye) is Known

Where the required flare height (Ye) is nominated by the manufacturer (and for most widebodies it is), an accurate flare cutoff point (Δf) can be calculated using the formula: Δf = Ye (cot g - cot k°)

The next thing you need is the basis of the various formulae and calculations. In these definitions we've also provided the values for a Boeing 747-200/300/400, for which we'll work an example.

Yh: is the vertical elevation of the pilot's eye above the level of the main wheels in approach configuration (in this case a known value of 43 ft).

Yw: is the main wheel height at flare point (30 ft).

Ye: is the eye height at flare point (Yh + Yw = 73 ft).

g°: flight path inclination angle (3° for a standard ILS).

k°: cockpit lower cutoff angle — the lower limit of pilot vision through the windshield (in the B747 case 16°).

Δf = Ye (cot g - cot k)
 = 73 x (19.08 - 3.49)
 = 1138.07 ft (say 1140 ft)

Available runway markings are then used to locate that point; and all you need is their dimensions. Aim point for a B747 is the 1,500 ft marker, so the point identified on the runway is 1,500' minus 1140', which is 360 ft in from the runway threshold, or 30ft past the end of the beginning of the first runway centreline stripe.

Don't forget you only have to do the sum once for your particular aeroplane, and that point on the runway will quickly become familiar to you. If you're not one of those people who reject other stimulating leisure activities in favour of trigonometry, a cotangent can be a truly terrifying animal. It needn't be. For small angles, the one in sixty rule provides a very closely proximate figure; i.e. 60/3 = 20.

The flare cutoff point is the point at which Δf vanishes under your glareshield. Rotate to the flare attitude at the appropriate rate at that point, and you can get pretty good odds that nobody will fall through the floor at touchdown.

Where the Flare Height (Ye) is Not Known

Now let's do the exercise for the case where the manufacturer has not provided a value for Ye and Yw in respect of the aircraft you're flying — in this case, a B737-300. Jacobson details the method of determining the flare point:

"A suitable approximation for the flare cutoff point (Δx), based on aircraft and approach geometry and through practical testing, has provided a simple and effective alternative technique, with near-universal application."

$\Delta f = (Yh \cot \gamma) + X2$; switching to the 1:60 rule, that's expressed more simply as:

$\Delta f = (16.3 \times 60/3) + 40$

$\Delta f = 16.3 \times 20 + 40 = 366$ ft (rounded to 370).

You then use the runway markings to locate the flare cutoff point 370 ft short of the aim point.

You in the back of the class, do stop twitching over your dearth of mathematical talent; they don't use canes any more, and anyhow it's really very simple. Once you've done it for a particular aeroplane you only need to write the distance where you can find it again, and your ratings with the flight attendants will begin to improve.

"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 (κ°). In practice, it is the simplest of tasks to notice the aircraft glare-shield, at the base of the windscreen, and superimpose the cut-off point while flying an approach using standard path techniques."

Where Ye is not known, the technique works equally well in a B737, a Metro or a Cessna 182 (in which Yh 6 ft). It's notable that it recognises the difference between the Yh for a B737-300 and a -400; and that although Qantas (for example) uses the same flare height for SP and standard-length jumbos, and for B767-200 and -300, in those examples the method provides an opportunity to be more precise than is the current practice.

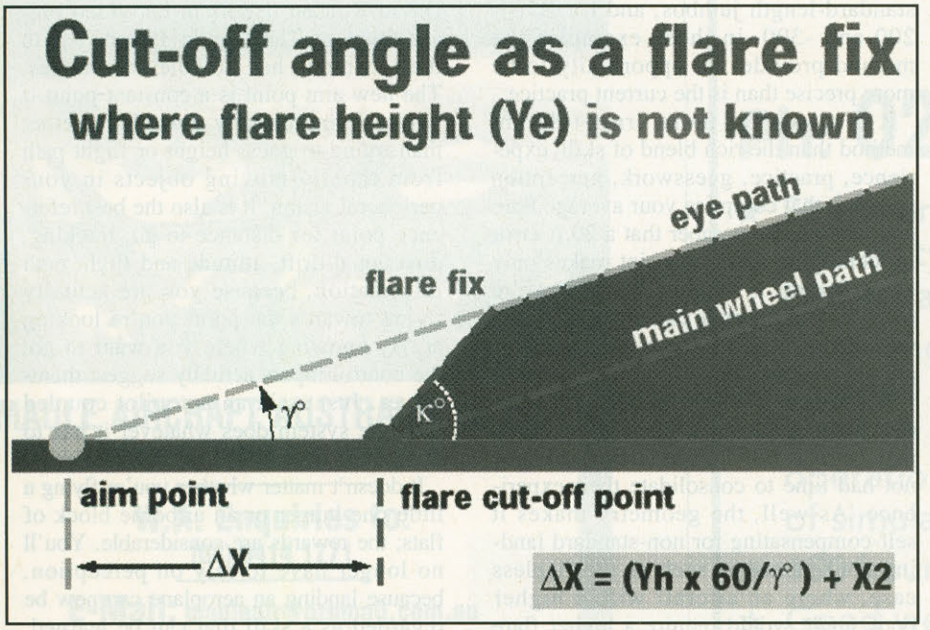
It is also a far more error-tolerant method than the rich blend of skill, experience, practice, guesswork, perception and luck that comprise your average flare and landing. Remember that a 20 ft error in identifying the flare point makes only a one ft error in height. This time we're using a longitudinal cue along the runway. Errors will still occur, but the maths are now on our side.

We suspect it will be particularly valuable to fast-growing airlines whose crews may be relatively inexperienced and have not had time to consolidate their experience. As well, the geometry makes it self-compensating for non-standard landing configurations such as the flapless case, where an aircraft with a higher body angle would require a higher flare point to accommodate the reduced main wheel clearance. The higher attitude self-compensates because the lower cut-off angle is reached earlier in the approach, providing an earlier flare cue; and the reverse applies in any configuration producing a nose-low attitude. The same self-compensation applies for sloping runways. Flare rate is varied with experience to accommodate heavy/light landing weights, and strong headwinds/tailwinds. The technique is also completely portable between aircraft types.

The Last Few Seconds

"How to flare" is also part of the Jacobson recipe. As the thrust comes off during the flare, he urges pilots to 'fly' the eye to a new aim point at the far end of the runway, as well-known instructor David Robson details in his video presentation of The Gentle Touch. Again the technique has notable advantages. The new aim point is a constant point if you're flying directly towards it, rather than trying to guess height or flight path from rapidly-moving objects in your peripheral vision. It is also the best reference point for distance-to-go, tracking, directional drift, attitude and flight path information, because you are actually flying towards the point you're looking at. By knowing where you want to go, the control inputs actually suggest themselves. Just as in an autopilot coupled ILS, the system does whatever it has to do, to hold the localiser and glideslope.

It doesn't matter whether you're flying a little one-lunger or an airborne block of flats; the rewards are considerable. You'll no longer have to rely on perception, because landing an aeroplane can now be regarded as a skill that can be learned, insists Jacobson: "Pilots are provided with a predictable and consistent visual eye path from the final approach through to the touchdown. It's like having a real-world head-up display. Traditional training methods have assumed the manual landing to be non-quantifiable, but this concept enables an original and precise interpretation for a manoeuver historically regarded as "an art". Most of the variables affecting perception and judgement may be discounted; elementary and advanced training is simplified, reducing time and costs; runway



occupancy times are reduced; and safety is greatly enhanced.

Apart from a few enlightened flying schools, a quick roundup of the published comments of some of our training gurus reveals that absolutely no industry-wide consensus, and very little intelligent thought, goes into defining flare and landing techniques.

Interestingly, Ansett uses visual fixes in some types (such as the BAe146) to pinpoint flare cutoff points, although they don't define the geometry they use to do so. In the Boeing 767, they use a 50 ft radio altimeter call as a cue that the aircraft is approaching flare height, and the manufacturer says "between 30 and 20" ft is the ideal flare height. The B767-300 has automated voice calls at 50, 30, 20 and 10 ft; and the B737, if the autothrottle is left engaged, begins throttle retardation at a given height, providing a cue.

Although the airlines have not yet formally evaluated the method, many trainees of Jacobson (who's a training captain) report notably improved landings as a result, and other pilots at all levels now use it effectively in their day-to-day flying. Those who do, affirm that it's in no way a radical departure from current practice — it just defines what they're already doing; makes it more precise; helps take some of the guesswork out of the accepted approach and landing sequence; and gets them a better result.

Triangles have had three sides since a long time before Pythagoras, but for a long time pilots have used two of them in this context. There had to be a better way to explain the landing manoeuvre. Traditional techniques have not materially changed for nearly 100 years. The Jacobson flare enhances these techniques, just as GPS and radio nav enhanced DR navigation.

Just like anything else you do, if you take some time to think about it, you'll probably do it better. ■