Do you *really* understand how your trim works?

Many do not, and why it matters.

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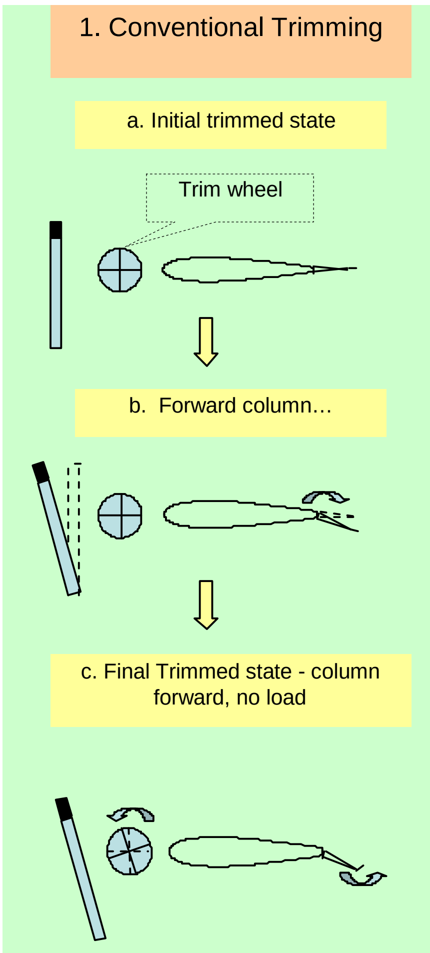
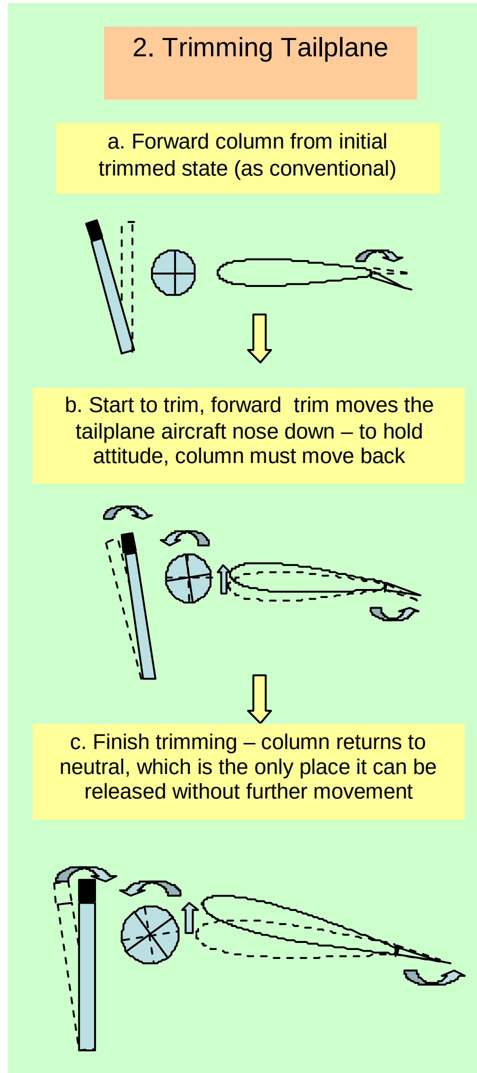
Picture yourself in a conventional airliner, say a 737 of any generation. You have to do a low level go-around, perhaps because your fail passive Cat lll has just failed, er, passively. You apply GA thrust, and the aircraft pitches up. If you are low enough, you may already have some extra helpful nose up trim applied thanks to the 'design feature' that ensures that in the event of AP failure at low level, the aircraft pitches up not down, and so a few units of nose up trim are applied late in the approach. Your speed is low, about V_{app} and the thing is pitching firmly upward. You need ample forward stick/elevator to restrain it. You don't want to carry this load for long so you retrim. Question: if you run the trim forward while maintaining forward pressure on the wheel, what happens? Hands up all those who think the load reduces to zero. I see a lot of hands. My unscientific polling to date suggests that just about everyone is convinced that this is what happens, but it doesn't.



Nearly everyone of my generation trained on a Cessna 150 or a Piper PA28. You fly those aircraft by putting the attitude where you want it, holding it there by holding the stick rigid and retrimming until the load goes to zero. In fact if you didn't do that, but were too quick and started trimming before the aircraft was stable, the instructor would exhibit a severe sense of humour failure. Let's just consider what is going on. Starting from an 'in-trim' state, fig 1(a) (just for illustration I have shown it as everything in the middle, but obviously this isn't essential to the argument); then, fig 1(b), the column is held forward moving the elevator down. Moving the trim wheel, fig 1(c), in this case moves a trim tab which relieves the control load until it goes to zero; the column can again be released, and it stays forward where you left it. So in this scheme, the control column stays forward for high speed and back at low speed. Although I have shown a tab operated system, the same result can be achieved without a tab by means of a spring in the control circuit or by altering the neutral point of the feel system. Aircraft as diverse as the Tiger Moth, the L1011, and Concorde fly this way.

Now there is another class of aircraft that works totally differently. This group includes most conventional transports, and even the non conventional A320 series in direct law. In these, the tailplane is controlled directly by the trim system, while the control wheel controls only the angle of the elevator relative to the tailplane. Now starting again from the out of trim state we started from above (see fig 2), as the nose down trim is applied, the tailplane starts to move leading-edge up. In order to keep the force contributed by *both* the tailplane and elevator constant (i.e. to maintain attitude), the elevator angle has to be reduced as the tailplane incidence increases (fig 2b). To do this, the column/ wheel has to be moved back towards neutral. When the operation is complete, the column/ wheel is back in the neutral position, which is the only place it can be released without further movement (fig 2c); its position does not indicate the trim state of the aircraft. For years Boeing manuals have said flatly that the control wheel cannot be moved opposite to the direction of trimming motion (the trim motors cut out if it is)…. Wrong, it can, and indeed has to, be *moved* in the opposite direction every time the trim is used; the action is achieved by just relaxing the pressure on the column and allowing to drift back to neutral. It is true that if *pressure* is applied to the column opposite to the direction of trim, then the trim cuts out.

This behaviour (column always returns to neutral regardless of speed) is not necessarily limited to aircraft with trimmable tailplanes; for example, if the column operates a servo tab while the trimmer moves a separate trim tab, the effect would be the same (I believe the 146/RJ series works this way). Doubtless there are other combinations too, you really have to study the systems carefully.



When I converted from a ‘conventional’ trimming type (Trident) to a separate trimming tailplane (757), not a word on this subject appeared in the training notes, nor was anything ever said by any training captain. Many years later I did write something for the company Magazine and generic training manual, but apart from one reprint in the Far East it has not been widely circulated. So how do people go through an entire career without realising things have changed from the way they were first taught? I think it is because mostly any column movement is followed immediately by small movements of the trimmer, so large loads are never allowed to develop and the reverse column movements are virtually imperceptible. In ‘normal’ flight operations, movements in pitch are mostly quite small, apart from two: rotate and go around; the latter is relatively rare, while the former is transitory (if the take-off trim is roughly right (!) you can relax the load after lift off with the aircraft roughly at the right attitude).

So why does it matter? The chances are you will fly more smoothly if you understand what is going on, but there are three broad categories of error which are likely if these subtleties are not understood, I will cite examples of each.

1. Failure to understand the trim function (the process described above) itself. This isn’t disastrous. Most pilots are in this category, but they cope well anyway, by simply flying on the trim. This isn’t how they were taught, but, well, it works. It begins to matter when the trim changes are large. I have watched, in the simulator, a 737 go-around from a Cat lll fail passive approach (as described above) with its marked pitch up; HP kept his arms locked forward to contain the attitude whilst simultaneously running the trim forward with the thumb switch. I am sure he was expecting the trim to reduce push needed and he either didn’t know, or had forgotten, that it wouldn’t. We duly pitched straight back quickly into the ground as the tailplane incidence ‘bit’. I can’t cite with certainty any accident that has been caused by doing this, but I strongly suspect this was a factor in the infamous Icelandair upset event at Oslo[1] The aircraft went quickly from +20 deg to -40 deg and was only saved from a CFIT by a 3.5g pull up, bottoming out at 360ft. Sadly, the report does not discuss the control inputs, nor does it contain any FDR traces, so this trim confusion explanation must remain speculation. I would be astonished, however, if there weren’t more examples of this error, particularly in unfamiliar situations.

1 http://www.skybrary.aero/index.php/B752,_vicinity_Gardermoen_Oslo_Norway,_2002_(HF_LOC)

2. Failure to realise that the tailplane, commanded by the trim system, is a totally independent pitch control; it will be available if the primary control is inoperative or ineffective. But if you only think of the trimmer, wrongly, as a column-load reduction device, you may not think of its other use when needed. The following examples illustrate the point; I am certain of the first, the others must remain speculation in the absence of evidence.

3. Some all moving tailplanes are trimmed conventionally – the Trident's was commanded by both the column and the trim wheel; the 'elevator' was a geared tab (reproduced with permission from CAA)

(a) 747-400 Take-off incident[2]. Just after lift off the aircraft suffered an elevator hardover, uncommanded full nose down movement of one elevator; the pitch attitude began to reduce. The crew's reaction not unreasonably was first to pull harder, then a lot harder, which succeeded in preventing an immediate accident, but cannot be said to have truly regained control. The anomaly lasted about 8 secs until a spike in the hydraulic pressure during the gear raising sequence allowed normal control to be resumed. *No one* thought of just blipping the trim button to restore order. Did thinking of the trim as merely a load reducer blind them to the simple solution? The incident report does not mention the alternative control available and does not discuss that part of the pitch control system at all.

(b) THY DC-10 crash at Ermenonville in 1974[3]. This was caused by an improperly secured cargo door which blew off; the floor above it collapsed due to the pressurisation load, disrupting the controls and injecting a nose down elevator input. Rumour, I admit quite unsubstantiated, has it that it could have been flown on the trim as there was still hydraulic power to the tailplane (350 casualties).

4. Trimming tailplanes aren't confined to the jets – this Piper Cub has one, as shown by the slot near the tailplane l.e. which provides access to the actuating link

(c) The BAC 1-11 flight test super-stall[4]. There was insufficient elevator to recover, but the FDR trace shows that no attempt was made to adjust the tailplane which would have been more powerful. It is pure speculation now after 40 years, but it is an intriguing thought that it might have helped. There would certainly have been no similar possibility for the Trident[5] that was lost during a pre delivery test flight a year or so later as the trim and column both operated the tailplane and its geared elevator together (see fig 3).

3. Failure to appreciate that loss of control in pitch might be due to the independent operation of the trim system. Several well known pitch upsets to A300s and A310s (see for instance the TAROM upset at Orly Sep 1994[6], and the A300 at Nagoya, April 1994) have been caused by a tailplane movement which was not fully appreciated by the crew, and was all the more insidious precisely because there was NO change to the load on the column . This is the reverse of the situation in (2) above. None of these occurrences were technically trim runaways, so there were no warnings and no indication to the crew from the feel

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2 http://www.aaib.gov.uk/cms_resources.cfm?file=/1-1995%20G-BNLY.pdf

3 http://www.skybrary.aero/index.php/DC10,_en-route,_Paris_France,_1974_(AW_LOC)

4 The crash during a test flight of -ASHG in October 1963 near Cricklade, Wiltshire as reported in the book 'Test Pilot' by Brian Trubshaw

5 Trident G-ARPY, Felthorpe near Norwich, Norfolk 3 June 1966

6 http://www.skybrary.aero/index.php/A310,_vicinity_Paris_Orly_France,_1994_(HF_LOC)

of the column. The first incident started with the flap overspeed protection system (the designers obviously thought that putting in nose up trim would reduce the speed… well it will if you understand totally what is happening and don't override it); the second, a fatal accident, started with an inadvertent, and probably unnoticed, GA selection.

A system where there are two independent means of control, has obvious safety benefits, but it also has pitfalls if it is not fully understood. The lack of importance given to the trim system in training seems extraordinary. I recall asking for TC guidance during my 757 conversion, to be told that there was no difference to previous types; when I finally convinced His Eminence that there was, he blustered that it didn't matter. I can find no relevant discussion in my edition of the Bible, Handling the Big Jets; I guess the Test Pilots just cope with anything they come across without preconception, and perhaps don't realise how much baggage the rest of us carry from our basic training. Accident investigators would also do well to ask themselves more often just how the unfortunate pilots had been trained, and cover the likely rationale for the control inputs in their reports. The illustrations I have used are obviously very rare events, so it is very unlikely that any one reading this will ever face their like. Engine cuts at V_1 are pretty rare too, but they get a lot more exposure in training than the basic control functions, odd, isn't it.

Safe flying

Postscript

This article was originally published in the Spring 2008 issue of the UKFSC magazine 'Focus'. Since then there has been a spate of accidents and alarming incidents in which 'tailplane ignorance' has played a part. The 737 accident at Amsterdam[7], an as yet unpublicised 737 incident in the Far East, and the Perpignan A320[8] crash all, in different ways, involved a stall and unsuccessful or botched recovery. The shared feature is that in each case the tailplane had wound itself to a fully (aircraft) nose up position, as in (3) above; the combination of pitch up, due to full power, and low speed, meant recovery was probably impossible using elevator alone, to get the nose down meant moving the tailplane back to a more normal position, which means *running the trim forward*. The A320 accident appears to be the result of an improper flight test, but the two 737 cases occurred in normal line flying and illustrate how important it is to understand what the tailplane is doing, and how easy it is for it to finish up somewhere unexpected; in both these cases the trigger was an unnoticed Autothrottle failure on approach, the speed fell and the autopilot duly trimmed progressively further back until it reached full nose up and quit; recently, April 2009, the UK AAIB published a report[9] into yet another 737 near stall and upset and made the following recommendation:

> **Safety Recommendation 2009-045**: It is recommended that Boeing clarify the wording of the approach to stall recovery Quick Reference Handbook Non-normal Manoeuvres to ensure that pilots are aware that trimming forward may be required to enhance pitch control authority.

The report contains the relevant Boeing Ops Manual pages in an appendix, including this:

> To recover from a stall, angle of attack must be reduced below the stalling angle. Nose down pitch control must be applied and maintained until the wings are unstalled. Application of forward control column (as much as full forward may be required) and the use of some nose-down stabilizer trim should provide sufficient elevator control to produce a nose-down pitch rate. It may be difficult to know how much stabilizer trim to use, and care must be taken to avoid using too much trim. Pilots should not fly the airplane using stabilizer trim, and should stop trimming nose down when they feel the g force on the airplane lessen ***or the required elevator force lessen***. (my emphasis)

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7 http://www.skybrary.aero/index.php/B738,_vicinity_Amsterdam_Netherlands,_2009_(HF_LOC)

8 http://www.skybrary.aero/index.php/A320,_vicinity_Perpignan_France,_2008_(LOC_HF_AW)

9 http://www.skybrary.aero/index.php/B733,_vicinity_Bournemouth_UK,_2007_(LOC_HF)

The forces won’t lessen by themselves, so that last remark puzzles me – does the writer think that the column load will go to zero as the trim is run forward? It can certainly be read that way, but if you have understood the rest of this article you should be able to understand the subtle coordination required to bring the tailplane safely into play without creating a worse nose-down problem. But you will also appreciate that the bigger danger at the moment may be that too many pilots don’t think about trimming *at all* in this situation.

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