Energy Management Strategies During Descent Arrival and Approach.

Disclaimer: *The techniques discussed or suggested in this presentation, is not part of any controlled documentation of the Operations Manual. These techniques are not endorsed procedures. And, just as you are not obligated to use these procedures, they do not, in any way, alleviate you from your obligation to adhere to the procedures dictated by your company.*

The techniques herein are developed, for the purpose of supplying you with some familiarity in operating the aircraft in line operations, normally not trained during type-ratings or operator conversion course.

The objective
The objective when getting a jet down from altitude is:

-To cruise at the most fuel efficient altitude as long as possible and then;

-Descend with the engines at idle power, to the point were the instrument approach begins.

From the point were the instrument approach begins, it is desirable to have the engine come out of idle and to provide some thrust during the final descend, because it takes quite some time for the engines to rise from idle RPM to the RPM were they can provide thrust for go-around. To have the engine at a higher RPM, to overcome the the drag provided by flaps, reduces the time it takes to achieve go-around power.

Figure 1

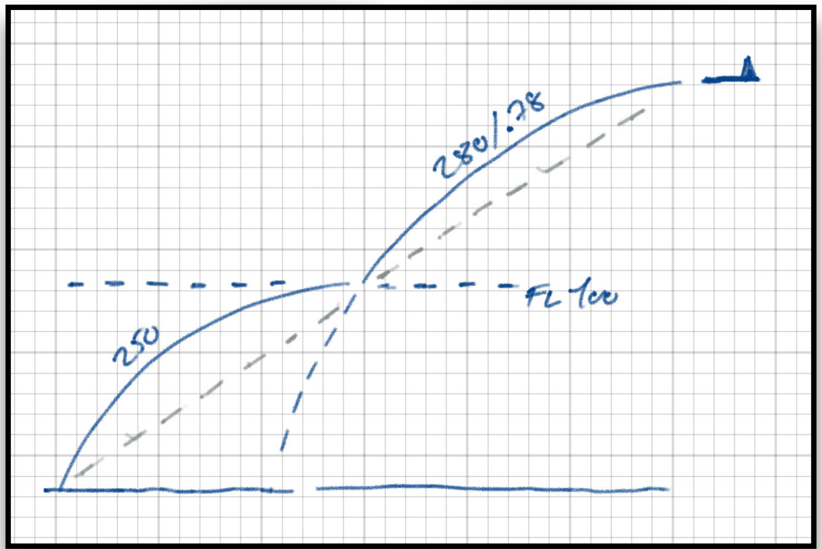


Figure 2

Figure 1, shows the calculated descend path on the lower right corner of the NAV display. The scale indicates +/-500 feet deviations. The figure below the path indicator, shows the vertical distance to the calculated path (12017 feet).

Figure 2 shows how the higher TAS aloft will result in a curved descend path at a constant IAS as the ground speed reduces druring descend. The IAS is normally changed reaching FL100.

The variables
Normally the FMC can calculate the point, were thrust is set to idle and the aircraft begins the glide. If the calculation is correct, the pilot can let the autopilot fly the aircraft with out interfering. But if the FMC is not providing the correct calculations, the flight path suggested from the top of descend, may not provide a situation from which a stabilised approach can be executed.

This calculation will only be correct if:
- The **Track Distance** entered into the FMC is correct
- The **Groundspeed** (wind information) provide to the FMC is correct
- The **Mass** entered into the FMC is correct.

Figure 3,4 and 5.

Figure 3 shows PROG page 1. In the red circle you can read the number of miles remaining, when following the current FMC route. On the right, of that same line, you can read the estimated fuel remaining at the destination.

Figure 4 shows the upper left corner of the NAV display. Here you can read the ground speed calculated by the ADC.

Figure 5 shows the INIT REF page. When airborn, this page shows the total mass of the aircraft entered during pre-flight, subtracted the fuel used during flight.

Normally mass and wind data is entered correctly into the FMC with out problems (and for the rest of this article, wind is not considered). But it is not very often that you are allowed to fly the arrival or approach route, as it is loaded from the route manual database, basically because you are either getting shortcuts or is taken out of the routing for sequencing with other traffic.

A descend from cruise level to the approach, normally takes around 20-30 mins. During this time you will often have to change the planned descend speed, either not to catch preceding traffic, or to prevent trailing traffic from catching up with you.

So your task is to deal with excess altitude, either from restricted descend or changed routing, against the objective of arriving at the final approach at an altitude and a speed that will allow you to continue a stabilised approach. And at the same time, optimise the descend so as to make it as economical as possible by minimising time spend, with engines above idle, at low altitude.

The Tools

The tools you have available, to administer the descend are principally the modes of the AFDS. (We will get to the speed brake, the flaps and the landing gear, later on).

The AFDS have 3 main modes of pitch control:

- **VNAV** - The AFDS will raise or lower the nose to follow the path calculated by the FMC.
- **FLCH** - The AFDS will raise or lower the nose to maintain the IAS selected on the MCP.
- **V/S** - The AFDS will raise or lower the nose to maintain the V/S selected on the MCP

In other words, you have the option to:

- Maintain **PATH** entered in **FMC**, which is why the FMA annunciation is FMC PATH
- Maintain **IAS** selected on **MCP**, which is why the FMA annunciation is MCP SPEED
- Maintain **V/S** selected on **MCP**, which is why the FMA annunciation is V/S

***Note**: You could argue that the thrust levers are also a tool, but since the problem is not to capture the optimum descend path from below - using thrust, but rather to have the thrust levers at idle the whole time, they are not considered as a tool.*

Figure 6,7 and 8.

Figure 6-8 shows the AFDS mode active, as announced on the FMA. All 3 are letting the FMC control the track.
Figure 6 indicates that the FMC control the descend along the calculated path.
Figure 7 indicates that the speed selected on the MCP are defining the descent.
Figure 8 shows that the descent is defined by the rate of descend selected on the MCP.
In all the three examples the auto throttle will activate and maintain the speed selected either in the FMC or on the MCP.

Energy management

It is essential that you recognise, that you are descending with the engines at idle thrust. In this configuration the jet has very good gliding performance and because you descend with engines at idle, you cannot reduce thrust to increase ROD, as you may be used to from propeller aircraft.

Descent
.78/280/250

PRESSURE ALTITUDE (FT)	TIME (MIN)	FUEL (KG)	DISTANCE (NM) LANDING WEIGHT (1000 KG) 40	50	60	70
41000	27	340	102	119	133	142
39000	26	340	97	114	127	136
37000	25	330	92	108	121	130
35000	24	330	88	103	116	125
33000	24	320	84	99	111	120
31000	23	320	80	94	105	113
29000	22	310	75	88	98	106
27000	21	300	70	82	92	99
25000	20	300	66	77	86	92
23000	19	290	61	71	79	85
21000	18	280	57	66	73	78
19000	17	270	52	61	67	72
17000	15	250	48	55	61	65
15000	14	240	44	50	55	58
10000	11	200	30	34	37	39
5000	7	150	18	19	20	21
1500	4	110	9	9	9	9

Figure 9.

Figure 9 shows the table from FCOM Performance Inflight chapter. In the table you can see that at 50T landing weight (-700 and -800 both) it will require approximately 100 NM to descend from FL330.

From the table of figure 9, you can read the it requires 100 NM to descend from 30.000 feet at a low landing weight (see later on mass) and that a high landing mass require 120 NM. We can operationalise this by using the following rule of thumb:

3 NM for each 1000 feet or 3 times altitude (divided by 10).

Note: *The data are valid for .78M/280 knots > FL100 < 250 knots.*
Note: *If you select altitude readout in meters - you can read out the "exact" miles required to descend.*

Dive
You remember the drag versus speed curve? A jet have the speed for minimum drag at the flap manoeuvring speed (flaps up). This means that if you descend at a speed higher than VDmin, you will move up on the right side of the drag curve - increasing total drag by increasing speed and thereby enabling a higher rate of descend.

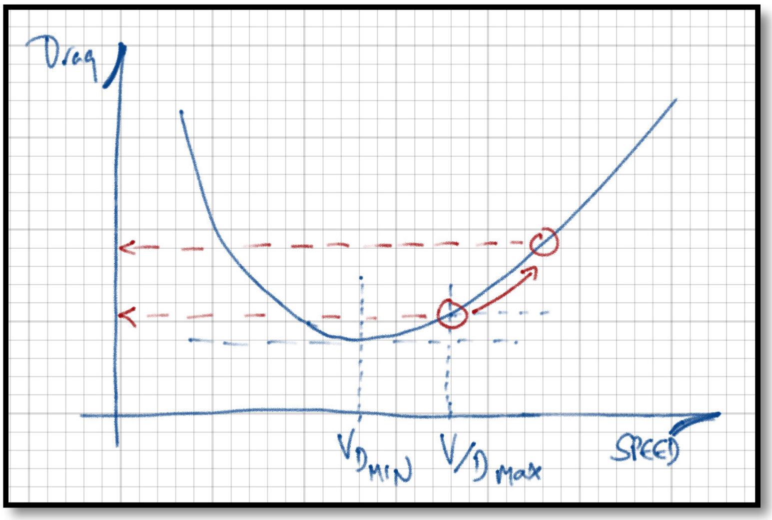


Figure 10.

Figure 10 shows a generalised graph of how total drag develops as speed increases. Most jets are designed to cruise and descend at the speed of best endurance (V/D max).

It may seem counter intuitive, but if you are higher than the planned descend path, you can increase your descend *angle*, by lowering the nose.

Increasing airspeed, can bring you back on the planned descend path. Once you are there, you will now hold a higher speed that needs to be dealt with. You should pay attention to, that the jet is a lot of mass, meaning that, when you convert altitude to speed, the energy does not go away, but must be exchanged, either by reducing descend rate, which will take you away from the path, or by converting it to heat by adding drag to the aircraft.

Using airspeed to control descend path is normally only effective down to flight level 100 since the maximum indicated airspeed is 250 knots. Sometimes you may be released from this restriction by ATC, but you should not exceed 250 knots below 5000 feet, since you will run out of room to bleed of the excess speed. This means that "diving for the path" is only an option in the interval between your cruise altitude and the speed limit altitude.

If the aircraft is heavy, it has more energy and you will require more space to decelerate down to limit speed, maybe even level flight.

The FCTM states the following descend performance:

- 280 KIAS: 2200 FPM
- 250 KIAS: 1700 FPM
- 200 KIAS: 1100 FPM

Extrapolating from these data (*Figure 11*) shows that it would be reasonable to assume, that an additional speed increase of 50 knots would yield 2600 FPM.

Using these data, to compare a descend from FL400 to FL100, at 320 versus 250 knots, we can approximate that:

- 320 KIAS: takes 40000-10000/2600 = 11,5 mins
- 250 KIAS; takes 40000-10000/1700 = 17,5 mins.

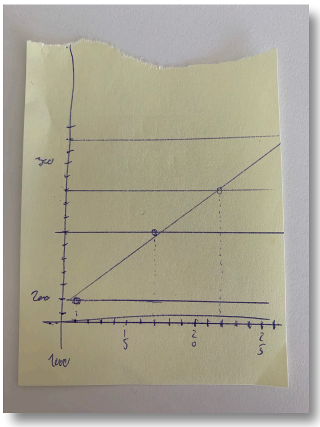


Figure 11.

The difference in time, in theory, means that, in a linear environment, you could postpone a descend for 6 minutes and still be able to catch up with the path by FL100, by increasing speed alone.

According to the graph (*figure 12*) you can recover from as much as 10 000 feet high.

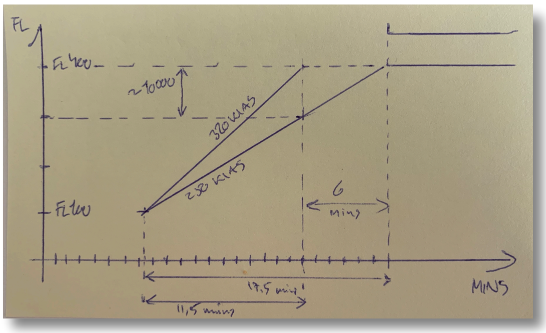


Figure 12.

Consider that the aircraft is cruising normally around level 400. To be recovered by level 100, you have to distribute the height loss over 30 000 feet (or 30 levels). This equates to 10000 feet divide by 30000 = 333 feet high per level available below you. Lets operationalise and say 300 feet above the path for each level above 100, can be recovered by diving. If you are at FL 160, you can only recover from FL160-FL100/10 * 300 feet = 1800 feet above the path - by increasing speed alone.

Note*: The descend data from the FCTM is stated to be valid below FL200, so this calculation may be a little optimistic. But should you ever encounter a situation where you reach this extreme, you can enhance the descend performance with the speed brake.*

Descend Rates and Speed Brake

Looking again at the FCTM Descend chapter, you can see that the jet have the following descend performance, with and with out, the speed brake deployed:

	Clean	SpeedBrake	%-increase
M.78 / 280 KIAS	ROD 2200 FPM	+900	+41%
250 KIAS	ROD 1700 FPM	+600	+35%
Vref 40 + 70 KIAS	ROD 1100 FPM	+300	+27%

Note: *Typical Vref 40 + 70 = 125 + 70 = 195 KIAS operationalized to 200 KIAS. (You find Vref 40 in the QRH: aprox. 120 kts + 1 kts per ton above 50 - valid both -700/-800) (Vref 30 = +2 kts, Vref 15 = +8)*

Notice, that in relation to indicated airspeed, the speed brake have more effect at high speed.

If you instead consider the effect on flight path angle or gradient, you have to consider the rates in relation to ground speed and that gets a little more complicated, since ground speed is a function of true airspeed, which varies greatly with altitude - approximately **IAS + 2% per flight level**.

This means that 250 KIAS at FL400 equates to 250 + (5 knots * 40) = 450 KTAS.

Gradient (MSL) at 250, **clean** = 1700/250 = 6,8%
Gradient (MSL) at 250, **SPBK** = 2300/250 =9,2%

Gradient (FL400) at 250, **clean** = 1700/450 = 3,7%
Gradient (FL400) at 250, **SPBK** = 2300/450 = 5,1%

Increasing speed to 280 KIAS at FL400 equates to 280 + (5,6 knots * 40) = 504 KTAS

Gradient (MSL) at 280, **clean** = 2200/280 = 7,9%
Gradient (MSL) at 280, **SPBK** = 2900/280 =10,4%

Gradient (FL400) at 280, **clean** = 2200/504 = 4,4%
Gradient (FL400) at 280, **SPBK** = 2900/504 = 5,75%

You see that if you are descending from FL400 at 250 KIAS and wish to increase your descend gradient (to catch the calculated path) it is almost as effective to increase the speed (2200 FPM), as it is to deploy the speed brake (2300 FPM).

Finally you see that the **speed brake is most effective at low altitude**, since the greatest gradient increase occur in dense air - for all speeds.

Most pilots prefer to increase speed to reach the path, since it is hardly noticeable and will bring them to the gate a little faster.

You don't need to do the above calculations to fly the jet, but you should be aware of the following:

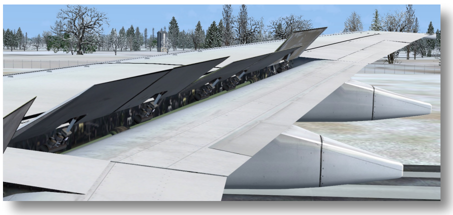


Figure 12.

- Increasing the speed, increases the descend gradient and provide comfort.
- Deploying the speed brake, increases the descend gradient to a similar degree.
- Diving for the path, will result in excess speed, that needs to be bled off.
- Excess speed requires additional distance not included in the calculated descend path.

If you plan to manage your energy without using the speed brake, you will have it available, when you plans fail!

Deceleration

You should assume that the jet **will not decelerate during a descend** on the calculated descend path unless a *decel* segment is provided (the length of track between the small green circles. (*See figure 13*).

Figure 13.

You can assume that the jet will decelerate at **1 knot per second, in level flight.** In the arrival segment, you will most likely fly at 240-250 knots, travelling roughly 4 NM per minute. Considering that some wind exist and that the speed factor changes during deceleration, for all practices and intents you can assume that the jet will **decelerate at 10 knots per NM - in level flight.** Implication of this is then, that if you did a dive for the calculated descend path at fx 280 knots, you will need 8 NM to decelerate in level flight to reach approach speed (200 knots).

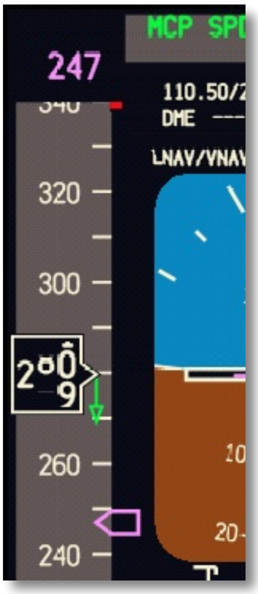


Figure 14.

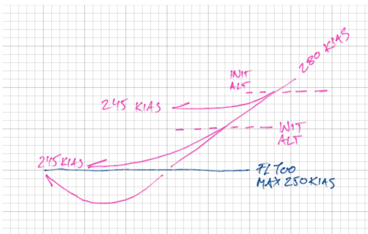
Figure 14 shows the Speed Trend Vector, that shows the speed you will have in 10 seconds. As shown here, 10 knots in 10 seconds equals one 1 per second and is easily identifiable.

In the FCTM descend chapter, you can read that the FMC will try to decelerate by reducing the ROD to approximately 500 FPM.

If you need to decelerate during descend, with out levelling off, you can use this information, for descend planning, when you need to bleed of some speed.

Let's say that you are descending at 280 KIAS and you wish to decelerate to 240 KIAS before passing FL100.

- When should you start the reduction and;
- How much distance do you need to bleed off speed.



Assuming deceleration occurs at 1 knots per second (at ROD 500 FPM), you need 40 seconds to bleed off speed (280-240). You also need some time to reduce the ROD from the 2200 FPM at 280 KIAS, which will require, perhaps 10 additional seconds - 50 seconds in total.

Initial 10 seconds at 2200 FPM going to 500 FPM, averaging 1350 FPM = 225 FT
Following 40 seconds at 500 FPM = 333 FT
Total altitude loss during the 50 seconds = 225 + 333 = 558 FT

To operationalise this method, you could just say, 1000 feet before, per 60 knots deceleration or just assume **150 feet per 10 knots.** Lets try:

-Initial speed 320 (pretty close to Vmo)
-Final speed 240
-10 seconds reduction time at 2900 FPM to 500 FPM, averaging 2200 FPM = 483 FT
-80 seconds bleed time at 500 FPM = 667 FT
-Total altitude loss during the 90 seconds = 483 + 667 = 1150 FT
-Initiation altitude: 11 150 FT
-Approximated initiation altitude: 320-240 = 80 knot at 150 FT per 10 = 1200 FT
-Initiation altitude: 11 200 FT

As you can see it make little difference if you are really correct on the initiation altitude, as long as you are conservative.

When using this method you should be aware that 1 knots per second is not guaranteed at 500 FPM. If your aircraft is heavy (*particularly the -800*) you should monitor the speed trend vector and decrease the ROD to obtain 1 knot per second, rather than aiming for the descend rate. Worst case will be that your descend rate is zero, but you are decelerating and not busting altitudes.

The space you need to decelerate, then comes down to the distance you travel while decelerating. If you were consistent in the deceleration, you can assume that you traveled at the final speed plus half the speed interval, during the time the manoeuvre lasted.

In the 320-240 example you would have traveled at an average speed of 280 for a period of 90 seconds (disregarding wind and air density). This would approximate to speed factor 5 for 1,5 minute = 7 NM. Though you may have complied with the speed restriction, if the FMC did not include this deceleration in the calculated decent path, or you are not following the FMC, you would need an additional 7 NM of track distance.

Deceleration on the calculated descend path

If you are nicely positioned on the calculated descend path and you wish to decelerate, you have the option to decelerate using the speed brake.

When reaching for the speed brake you should always consider if the proper target is set for autopilot. If the autopilot is targeting a path and speed, it is of no consequence if you deploy the speed brake, since the autopilot is still targeting the same parameters, but now have to increase thrust, to maintain.

Some situations do not call for speed brake, but for at AFDS mode change first. So when extending the speed brake, you should have a AFDS mode that is suited for what you wish to obtain:

If you wish to reduce speed and maintain ROD, you must select **V/S**
If you wish to increase ROD and maintain speed, you must select **FLCH**

If you are coming back onto the path and wishes to re-engage VNAV, remember to synchronise your actual speed with the speed set in the FMC DCN page.

If you don't care about the ROD, but wish to reduce speed, you can either use FLCH or change the speed set in the FMC DCN page. In either case, the aircraft will pitch up to reduce speed and for large speed changes - though there is no safety issue - it may appear a bit rough and you may desire to approach your target in V/S and engage other modes, only after you have reach the target (FLCH when actual speed = MCP speed / VNAV when actual speed and ROD = FMC)

For mid to low landing mass, the speed brake will provide some deceleration, but for higher landing mass (particularly on -800), the speed brake may only provide as little deceleration as 10 knots in 40-50 seconds.

The normal picture, Mass
There are 3 aircraft landing configurations you must consider: High, Normal and Low Landing Mass. You do not have to be AT these masses to “qualify”. During you descend preparations, you should check with the INIT page, you actual mass, and deduct the fuel still to be used, to determine if you are above or below the normal.

	-700	-800
Normal full passenger load	12,5T	16 T
Normal associated baggage load	2 T	2,5T
Normal landing fuel status	3T	3T
Average empty mass	40T	41T
Normal landing mass	**57,8**	**62,5**

Consider the aircraft to be “not normal” (either high og low), if deviating more then 5T from these figures and take the following precautions:

> If you are light, you should not have any problem with excess energy, but will bleed it off quicker than usual (mostly relevant in landing).
>
> If you are at normal landing mass, you should not have any problem with excess energy on the -700, but may have on the -800.
>
> If you are heavy according to this approximation, you will have a problem with excess energy if ATC puts constraints on your descend.

Figure 15, 16 and 17.

Figure 15 shows the INIT REF page inflight. In the upper left corner you can read the current mass of the jet. On the PROG page (figure 16), you can read the estimated landing fuel at destination. From your actual fuel status (figure 17), you can see that you will be 2,2T lighter upon arrival - your estimated landing mass is 62,4 - 2 = 60,2 T.

You determine your actual landing mass by reading your current mass on the approach ref page and subtracting the difference between your actual fuel and your estimated fuel at destination. The problem is that you may not be able to decelerate while descending on the calculated descend path - even when using the speed brake. The only option is to reduce the ROD when decelerating, which WILL result in you needing more track miles to complete the descent.

Predicting track to be flown
It is sometimes difficult to know what ATC intents for you - particular when manoeuvring in foreign cultures. This is a problem for you, since 9 out of 10 times, you will not fly the track in accordance with arrival procedures, but will be given changes in the form of short cuts and or radar vectors, to expedite traffic and for separation.

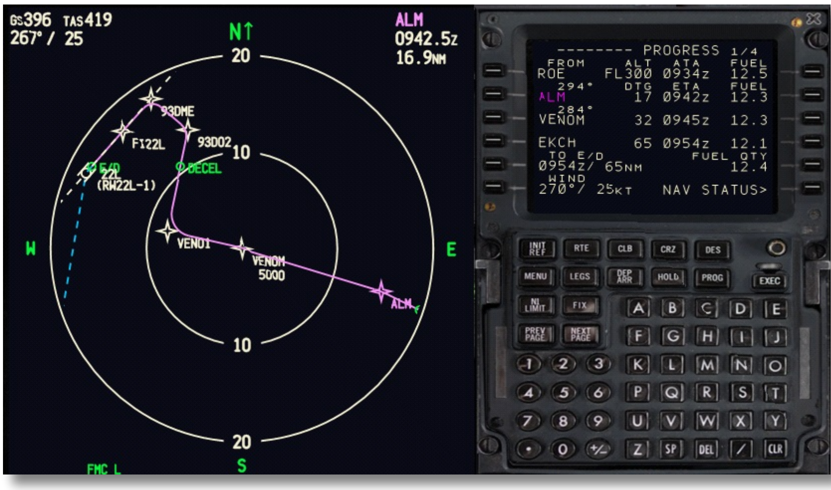


Figure 18.

Figure 18 shows the arrival setup as an IFR pattern with downwind, base and final.

On the FMC PROG page, you see that there are 65 NM from the jets present position to the runway.

Figure 19 shows the same arrival setup but the pilot have foreseen that the downwind leg will not be flown therefore re-routed direct to the beginning of the base leg.

On the FMC PROG page, you see that there are now only 60 NM from the jets position to the runway (the jet is at the same position as in figure 18).

Figure 19.

Figure 20 shows the same arrival as in figure 18 and 19. The pilot have had yet another foresight and believes that the base leg will be the intercept to final while descending to an altitude lower than the intermediate altitude.

Figure 20.

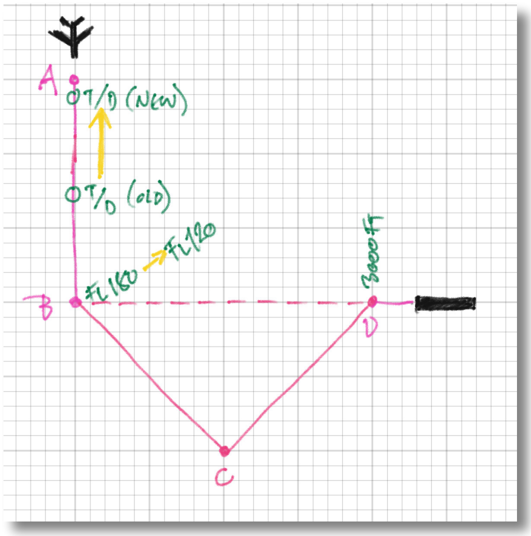
You want this - Particularly because it often cuts out as much as 30 NM from your flight, giving you the option to land ahead of plan and save fuel (and other running costs). But on a 3 degree descend path, 30 miles equates to 10 000 ft - that you probably will not be able to utilise unless you were prepared for such an occasion.

The preparation is to simply compare the track in the flight plan (LEGS page) with a shorter routing. Take a look at the arrival and imaging what ATC might shorten by giving you directs to intermediate points. You can also benefit from trying to guess where the radar vectoring will start and even considering if a glide slope intercept will occur below the intermediate/final approach altitude (EKCH eg sometimes vectors you down to MRA 1600 ft for a glide intercept that normally occurs at 3000 ft.

If your guess is too conservative, worst case is that you will spend fuel at low altitude flying the miles of the arrival you took away. But if you are correct to be conservative, you will benefit from the shortcut you are given and can supply a stress free instrument approach. If you are new to an airport, it would be prudent to select the shortest possible routing. But if you are in familiar territory, try to recall what occurred last you where there and be minded for a more economical approach.

Altitude Anchor

Once you have settled on the shortest scenario, you can modify the existing routing to your best guess. This may be a problem, though, if you were wrong, and suddenly have to reload everything ,if you are not getting the short-cut in the end. To hedge your bets, you can guard against it using the following method:



Lets say that the approach starts at D in 3000 feet and you are cruising at FL400. Your planned routing is A-B-C-D. You determine that a likely short cut would be A-B-D, bypassing C. You enter the new routing - with out executing it - and notice that the FMC predicts to pass B at FL120 in the new routing and that B were to be passed at FL180 in the original routing - you then ERASE the change so that the original routing is in the FMC.

From this you learned that the FMC would start the descend earlier, if the short were introduced, in order to reach B at an altitude lower than planned.

In stead of programming the shortcut right away, you can enter the “shortcut altitude” at B in the original planned track (R-LSK, “/FL120”), thus forcing the FMC to arrange the descend to reach B at that altitude .

In this manner, you do not commit to a different route - or the descend, but the FMC will show a descend path that provides for the shortcut - If you feel that you still need guidance for the original descend, you could read the “original” descend rate of the DECN page and fly use V/S. If you wish to go with your modified plan, you can continue in VNAV .

On figure 21 you can see that the base leg is entered at CH991 at 4318 feet, which will provide a continuous descend for the rest of the approach.

To be at CH991 in that altitude the FMC shows that VALTI is passed at 12163 feet.

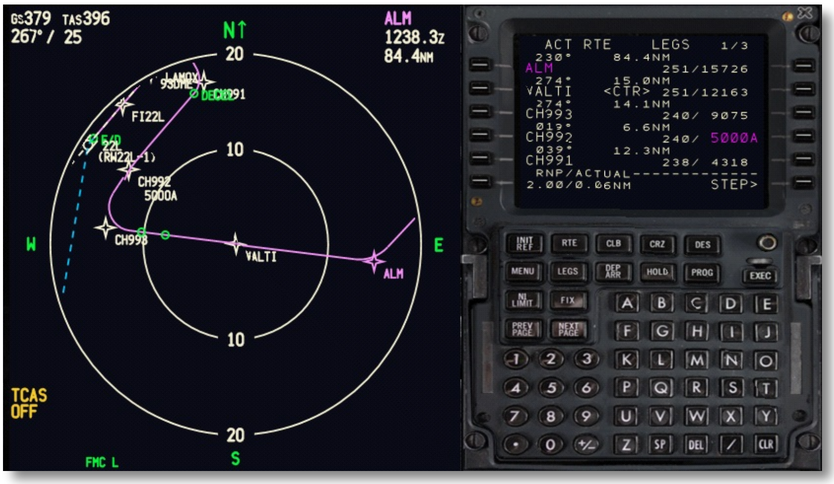


Figure 21.

Figure 22.

Here the pilot are investigating what will happen if the routing is changed from VALTI direct to the base leg.

You see that the FMC have determined, that to pass CH991 at 4318 (that fits the rest of the final approach), VALTI must now be passed at 8684 feet - 3479 feet lower.

Rather than committing to the shortcut, the pilot decides to continue the descent on the original routing, but to force the FMC to pass VALTI at the altitude that is suitable for the short cut.

If the short cut is not coming, the routing is still valid, the jet will probably spend 10 NM in level flight, but the A/T will maintain speed and the work load is not excessive - as it would have been if the FMC were to be reprogrammed that close to the approach.

Figure 23.

Decelerating during arrival

Typically you will succeed in following the calculated descend path in VNAV. Sometimes the FMC asks for the speed brake (Scratch pad reads: “Drag Required”), if the winds are not as predicted and the groundspeed builds up, but in most cases the FMC planned decelerations are correct and will slow you down, so you can configure for approach.

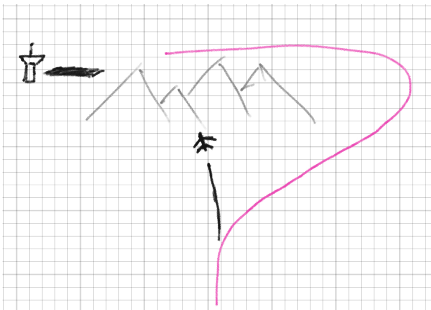
However this is not the case if you are *not* flying the track and/or path that the FMC calculates the descend from.

A typical situation were you are not flying the track in the FMC when entering the last 50-30 NM from the airport (or passing FL100), were ATC starts to give you radar vectors, either cutting of some of the arrival route or directing you to the 5 NM base leg of a 10 NM final.

You have 3 options, once you recognise that you are taken off the FMC route:

- You can MDR the whole thing, by monitoring distance - to a on airport DME or a point entered on the FIX page.
- You can modify the FMC route to reflect the predicted remaining track miles (seen on PROG page) and continue to fly with reference to the VNAV path.
- You can select a point corresponding to the start of a base or final leg and descend with shortest path in mind.

Observe that as soon as you are radar vectored you should disengage from LNAV/VNAV. If you stay in a FMC mode, the descend path is assuming that you are on the track.

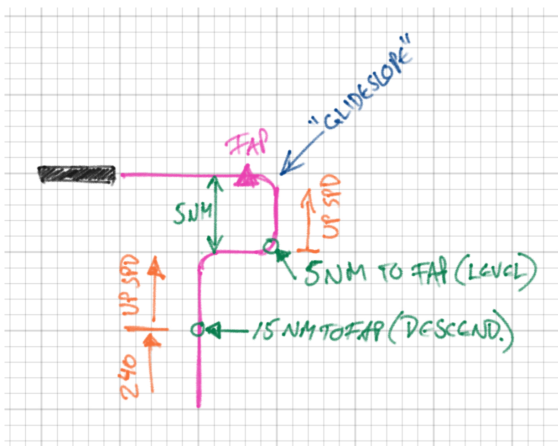


When you are flying radar HDG, you should also disengage the VNAV feature (by selecting FLCH) to prevent undesired descend and not to be misled by the calculated descend path.

That being said, you should most definitely use the VNAV/LNAV information to assesses your situation - just don't let the AFDS do it on its own.

At 240 knots, the jet travels 4 NM a minute. From FL100 you know from earlier that this speed will result in 1700 FPM ROD, giving you 4,5 minutes to reach the average final approach altitude (2500 ft). This means that you need 4,5 mins * 4 NM = **18 NM** to descend before the FAP/FAF and then you also need additional distance to decelerate and configure for final approach.

If you plan to arrive at the FAP or FAF at a speed appropriate for flaps 15, you will be covered for most any situation. You can use the following strategy:



- Fly 240 KIAS as long as reasonable.
- Decelerate to Vref 40 + 70 (clean speed - approx. 200 knots)
- Maintain 200 knots and deploy flaps to 5, this will give you good command of the deceleration, when you need it and enable ATC to expedite traffic (use 210 or 180 as ATC dictates).

- Begin the decelerate from 200 knots to flap 5 speed in level flight, when GS is showing (level flight) or in continuous descend, when 500 feet above final approach altitude. If you reach flap 5 manoeuvring speed, you will be inside flap 15 limit speed.

The FCTM states that medium landing mass the following applies in <u>level</u> flight:

- Deceleration from 250 KIAS to 200 (Vref 40+70): 35 seconds.
- Travelling at 225 knots (average decel speed) for 35 secs: 2,2 NM

Additionally the FCTM suggest that flaps are deployed at the following pace:

- Flap 0 to flap 1: 20 secs (at est. 200 knots): 1,1 NM
- Flap 1 to flap 5: 20 secs, (at est. 200 knots): 1,1 NM
- Flap 5 to flap 15: 10 secs, (at est. 180 knots): 0,5 NM

Note*: Though the flaps will deploy from 0 to 15, in 50 seconds, the jet will not decelerate to flap 15 speed in the same time, but will take a little longer, perhaps 80 seconds.*

Note: *FCTM, state flap manoeuvring speeds FLP1/5/15: Vref 40+70: -20 kt, -20 kt , -10 kt (just as the timing for flap deployment)*

Note: *If you predict to end up flying at 200 KIAS for more than a few miles, you should not extend flap 5 or reduce speed to flap 5 manoeuvring speed, to avoid excessive wear. This also applies if you*

Your deceleration distance from 250 to 180 is then 2,2+1,1+1,1+0,5 =4,9 NM - lets make it **5 NM**. But remember that it only applies if you decelerate in level flight. If you are descending the whole time, i suggest you to **multiply this distance by 3.**

You can program the FMC to be at the final approach altitude, at 250 knots, 5 NM before the FAP and thereby secure that you have the deceleration distance available. But since a constant descend is desirable for both noise abatement and economy, you can also consider both options:

- From FL100 to FAP/FAF with a level segment, you need at least: 18+**5** = 23 NM.
- From FL100 to FAP/FAF with continuous descend you need at least: 18+**15** = 33 NM.

Remember that the PROG page, shows total distance to go, so you should maybe add the final approach leg (8 NM for 2500 ft) to the distances above.

Reality Check
You may not wish to decellerate directly to 200 knots, and you may not wish to maintain 200 knots with flaps 5. Typically ATC restricts you to 230, 210 or 180 knots during the arrival and you must off cause comply with such instructions.

From the assumption that it will take you 5 NM (15NM) to decelerate from 250 to 180 knots, you can operationalize by aproximating 1 NM per 10 knot (times 3 if you are decending). By doing so, you can monitor if the ATC instruction poses a problem for your approach: eg. “Maintain 210 knots” means that you need to start your reduction to final approach speed 3 NM from FAP in level fligth (9 NM before descending). Remember though, the 5/15 rule only applies in the arrival and approach.

Additional deceleration
If you end up being cornered, you have the option of using the speed brake. The FCTM claims that the speed brake will half the 2,2 NM deceleration from 250 to 180 and the initial 18 descend miles may be reduced to 13 NM, but it will not change the time it takes to deploy the flaps.

In short the use of speed brake will result in a reduction in the segment below FL100:

- Initial descend: -5 NM
- Deceleration, level: -2,5 NM
- Deceleration, descending: -7,5 NM
- Flaps deployment: 0 NM

An arrival from FL100 with a level segment will become 23 - 5 -2,5 =**15,5** NM
An arrival from FL100 with a continous descent will become 33 - 5 - 7,5 = **21,5** NM.

If the speed brake is not sufficient to get you out of the corner, you can choose to lower the landing gear and produce additional drag.

From the FCOM, Inflight Performance Chapter, we see tables for descend with the gear extended. At Vref40 + 70 it requires 26 NM to descend from FL100. From this we could approximate that:

2,5 x altitude = distance required with gear down.

To operationalise this information you could say that, below FL100:

- Speed brake cuts of **30**% of required distance
- Landing gear cuts of **20**% of required distance
- Using both speed brake and landing gear cuts of **50**% of required distance

Penalty for reducing ROD
You can approximate the penalty of reducing the rate of descent. The jet descends at 1700 FPM at 250 KIAS. Disregarding the effect of altitude and wind, you can assume, that in the minute it takes to descend 1700 feet, you have travelled 4,166 NM. If you only descend at 850 FPM (1700/2), logically, you will need double the distance to descend to the same altitude - 8,33 NM.

Dividing these additional miles over each 100 FPM decrease, you se that you need 0,49 NM more than the 4,166, for each 100 decrease in 1700 FPM.

To operationalise, lets make it **0,5 NM per 100 FPM** ROD reduction - per minute.

This is conservative, since it is assuming that you are flying at 250 knots through out the deceleration - which you are not.

Bringing it together

You will fly very few approaches that pans out just as you have programmed them, but also very few, where nothing of your planning will support you.

You strategy should be to know how to use above methods to adjust your path/track/speed when needed.

To recognise when need is present, i suggest you to monitor the following at all times:

Crosscheck - when passing FL100 - that you have the distance to FAP/FAF available according to a level decel or a descending decel.

Note: Remember that you are assessing distance to FAP/FAF - not distance to the airport.

Note: *When approaching for a NPA, you should remember that you speed reductions should not be completed at the FAF, but actually 2 NM before (approaching vertical path).*

Compare altitude and track miles to go, according to PROG page or other distance information - include distance to bleed of energy, were needed.

Base leg start 1000 feet above FAP, Downwind Mid-field starts 1000 feet above Base.

Set up arcs on the FIX page, for visual cuing of intermediate trigger points or simply for situational awareness. One standard set up could be, one arc to indicate latest point to have flaps 5 and 200 KIAS, and one arc to indicate latest point for stabilised approach criterion.

Adjustments strategies

If you are high before reaching FL100: Increase speed by 10 kt for each 500 feet above path.

If you are high after reaching FL100:
Read required V/S on DCN page
Deploy speed brake
Set higher V/S than that required on DCN page.
Observe not to break speed limits.

If you are fast before reaching FL100: Select lower speed.
If you are fast before reaching FL100: In LNAV/VNAV, deploy speed brake.

If you are fast after reaching FL100:
Read required V/S on DCN page,
Select V/S,
Set required ROD,
Deploy speed brake
Consider to decrease ROD if deceleration is too slow.