Flight Operations Briefing Notes

Approach Techniques

Aircraft Energy Management during Approach

I Introduction

Inability to assess or manage the aircraft energy level during the approach often is cited as a causal factor in unstabilized approaches.

Either a deficit of energy (being low and/or slow) or an excess of energy (being high and/or fast) may result in approach-and-landing accidents, such as:

- Loss of control;
- Landing short;
- Hard landing;
- Tail strike;
- Runway excursion; and/or,
- Runway overrun.

This Flight Operations Briefing Note provides background information and operational guidelines for a better understanding of:

- Energy management during intermediate approach:
  - How fast can you fly down to the FAF or outer marker?
- Energy management during final approach:
  - Hazards associated with flying on the backside of the power curve (as defined by **Figure 2**).

    Refer also to the Flight Operations Briefing Note **Factors Affecting the Final Approach Speed (V_{APP}).**

II Statistical Data

Approximately 70 % of rushed and unstable approaches involve an incorrect management of the aircraft energy level, resulting in an excess or deficit of energy, as follows:

- Being slow and/or low on approach : 40 % of events;
- Being fast and/or high on approach: 30 % of events.

III Aircraft Energy Level

The level of energy of an aircraft is a function of the following primary flight parameters and of their rate of change (trend):

- Airspeed and speed trend;
- Altitude and vertical speed (or flight path angle);
- Aircraft configuration (i.e., drag caused by speed brakes, slats/flaps and/or landing gear); and,
- Thrust level.

One of the tasks of the pilot is to control and monitor the energy level of the aircraft (using all available cues) in order to:

- Maintain the aircraft at the appropriate energy level throughout the flight phase:
  - Keep flight path, speed, thrust and configuration; or,
- Recover the aircraft from a low energy or high energy situation, i.e., from:
  - Being too slow and/or too low; or,
  - Being too fast and/or too high.

Controlling the aircraft energy level consists in continuously controlling each parameter: airspeed, thrust, configuration and flight path, and in transiently trading one parameter for another.

Autopilot and flight director modes, aircraft instruments, warnings and protections are designed to assist the flight crew in these tasks.

IV Going Down and Slowing Down : How Fast Can you Fly Down to the Marker?

A study by the U.S. NTSB acknowledges that maintaining a high airspeed down to the outer marker (OM) does not favor the capture of the glideslope beam by the autopilot or the aircraft stabilization at the defined stabilization height.

The study concludes that no speed restriction should be imposed when within 3 nm to 4 nm before the OM, mainly in instrument meteorological conditions (IMC).

Nevertheless, ATC requests for maintaining a high airspeed down to the marker (160 kt to 200 kt IAS typically) are frequent at high-density airports, to increase the aircraft landing rate.

The purpose of the following part is to:

- Recall the definition of stabilization heights;
- Illustrate the aircraft deceleration characteristics in level flight and on a 3-degree glide path;
- Provide guidelines for assessment of the maximum speed which, reasonably, can be maintained down to the marker, as a function of:
  - The distance from the OM to the runway threshold; and,
  - The desired stabilization height.

IV.1 Stabilization Height

The definition and criteria for a stabilized approach are provided in the Flight Operations Briefing Note **Flying Stabilized Approaches.**

The minimum stabilization height must be:

- 1000 ft above airfield elevation in IMC;
- 500 ft above airfield elevation in VMC.

IV.2 Aircraft Deceleration Characteristics

Although deceleration characteristics largely depends on the aircraft type and gross-weight, the following typical values can be considered for a quick assessment and management of the aircraft deceleration capability:

- Deceleration in level flight:
  - With approach flaps extended: 10 to 15 kt-per-nm;
  - With landing gear down and flaps full: 20 to 30 kt-per-nm;
- Deceleration on a 3 degree glide path:
  - With landing flaps and gear down: 10 to 20 kt per nm.

Note:

A 3 degree glide path is typically equivalent to a descent-gradient of 300 ft-per-nm or a 700 ft/mn vertical speed, for a final approach ground speed of 140 kt.

Decelerating on a 3 degree glide path in clean configuration usually is not possible.

When established on a typical 3 degree glide slope path with only slats extended (i.e., with no flaps), it takes approximately 3 nm (1000 ft) to decelerate down to the target final approach speed and to establish the landing configuration.

Speedbrakes may be used to achieve a faster deceleration, as allowed by the aircraft type (i.e. speedbrakes inhibition).

Usually the use of speedbrakes is not recommended when below 1000 ft above airfield elevation and/or in the landing flaps configuration.

Typically, slats should be extended not later than 3 nm before the FAF.

Figure 1 illustrates the aircraft deceleration capability and the maximum possible speed at the OM, based on a conservative deceleration rate of 10 kt per nm on a 3 degree glide path.

The following conditions are considered:

- IMC (stabilization height 1000 ft above airfield elevation); and,
- Final approach speed (V_{APP}) = 130 kt.

The maximum deceleration achievable between the OM (typically 6.0 nm from the runway threshold) and the stabilization point (1000 ft above airfield elevation / 3.0 nm) is: 10 kt-per-nm x (6.0 – 3. 0) nm = **30** kt.

In order to be stabilized at 130 kt at 1000 above airfield elevation, the maximum speed that can be accepted and maintained down to the OM is: 130 kt + 30 kt = **160** kt.

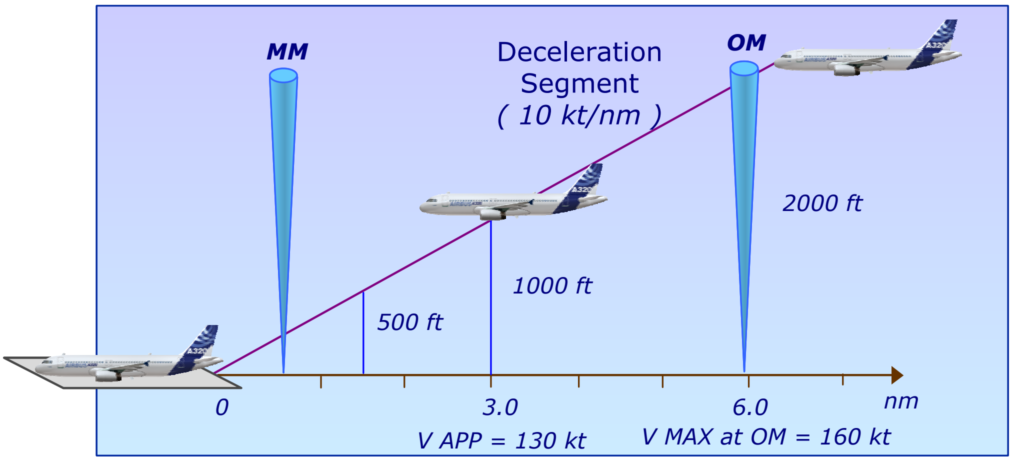

Figure 1

Deceleration along Glide Slope - Typical

Note: *The OM may be located from 4 to 6 NM from the runway threshold.*

Whenever being required to maintain a high speed down to the marker, the above quick computation may be considered for assessing the feasibility of the ATC request.

V Avoiding the Back Side of the Power Curve

During an unstable approach, the airspeed or the thrust setting often is observed to deviate from the target values:

- Airspeed is below the target final approach speed (V_{APP}); and/or,
- Thrust is reduced and maintained at idle.

V.1 Thrust-required-to-fly Curve

Figure 2 illustrates the *"thrust-required-to-fly" curve* (i.e. the *power curve*).

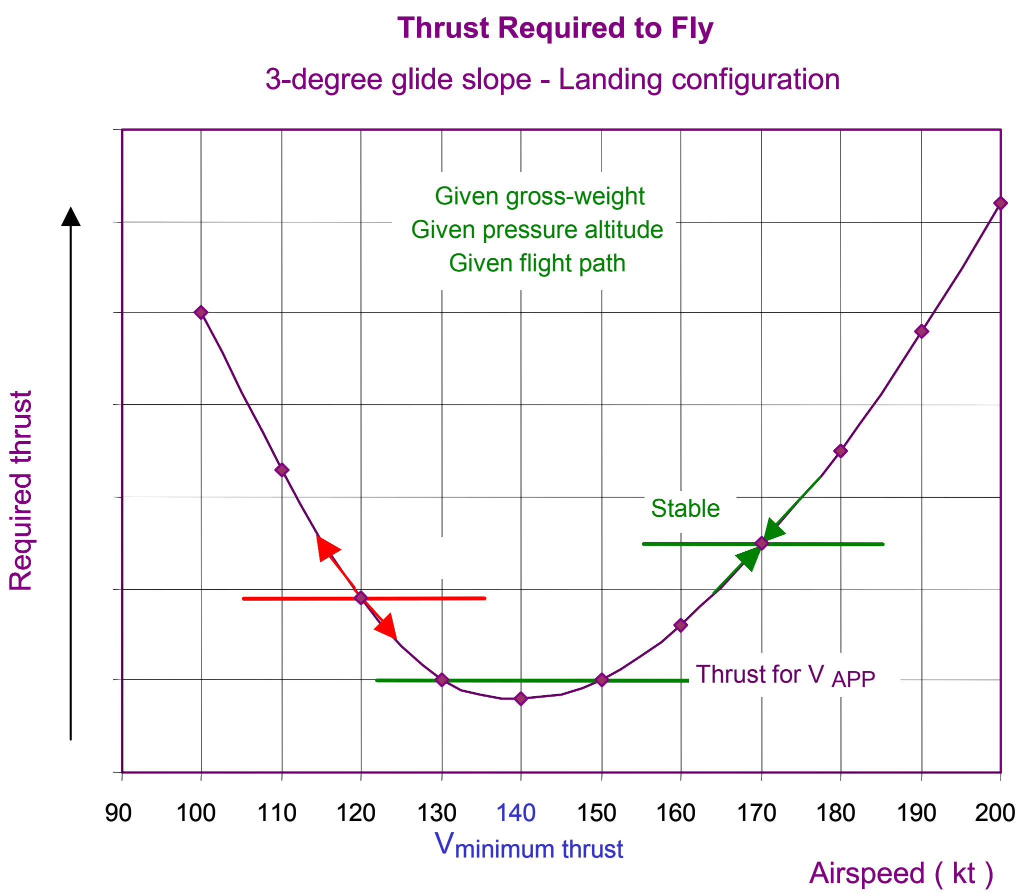

Figure 2

Power Curve – Typical

The power curve is divided in two parts:

- The left side of the power curve, called the *backside of the power curve*;
- The right side of the power curve.

The difference between the available-thrust and the thrust-required-to-fly (i.e., the thrust balance):

- Represents the climb or acceleration capability (if the available-thrust exceeds the required-thrust); or,
- Indicates that speed and/or flight path cannot be maintained (if the required-thrust exceeds the available-thrust).

The *right part of the power curve* is the normal area of operation.

The thrust balance is such that, when the thrust is set to fly V_{APP} on the glideslope, any increase of the aircraft speed due to a perturbation is rapidly washed out, because a higher thrust would be required to fly at this higher speed on the glideslope.

Conversely, when the thrust is set to fly V_{APP} on the glideslope, any speed loss due to a perturbation is rapidly washed out, because a lower thrust would be required to fly at this lower speed on the glideslope.

In other words, in case of perturbation, the aircraft speed tends to come back to the speed stabilized with that thrust level. The right part of the curve is called the *stable* part.

On the *backside of the power curve*, the thrust balance is such that, at given thrust level, any tendency to decelerate increases the thrust-required-to-fly and, hence, amplifies the tendency to decelerate.

Conversely, any tendency to accelerate decreases the thrust-required-to-fly and, hence, amplifies the tendency to accelerate.

The minimum thrust speed (V minimum thrust) usually is equal to 1.35 to 1.4 V stall, in landing configuration.

The minimum final approach speed (i.e. V_{LS}) is slightly in the backside of the power curve.

Note: On Airbus aircraft, this part of the curve is rather flat.

If the airspeed drops below the final approach speed, more thrust is required to maintain the desired flight path and/or to regain the target speed.

If the thrust is set at idle, approximately 5 seconds are necessary to obtain the engine thrust required to recover from a speed loss or to initiate a go-around (as illustrated in **Figure 3**, **Figure 4** and **Figure 5**).

V.2 Engine Acceleration Characteristics

When flying the final approach segment with the thrust set and maintained at idle (approach idle), the pilot should be aware of the acceleration characteristics of jet engines, as illustrated below.

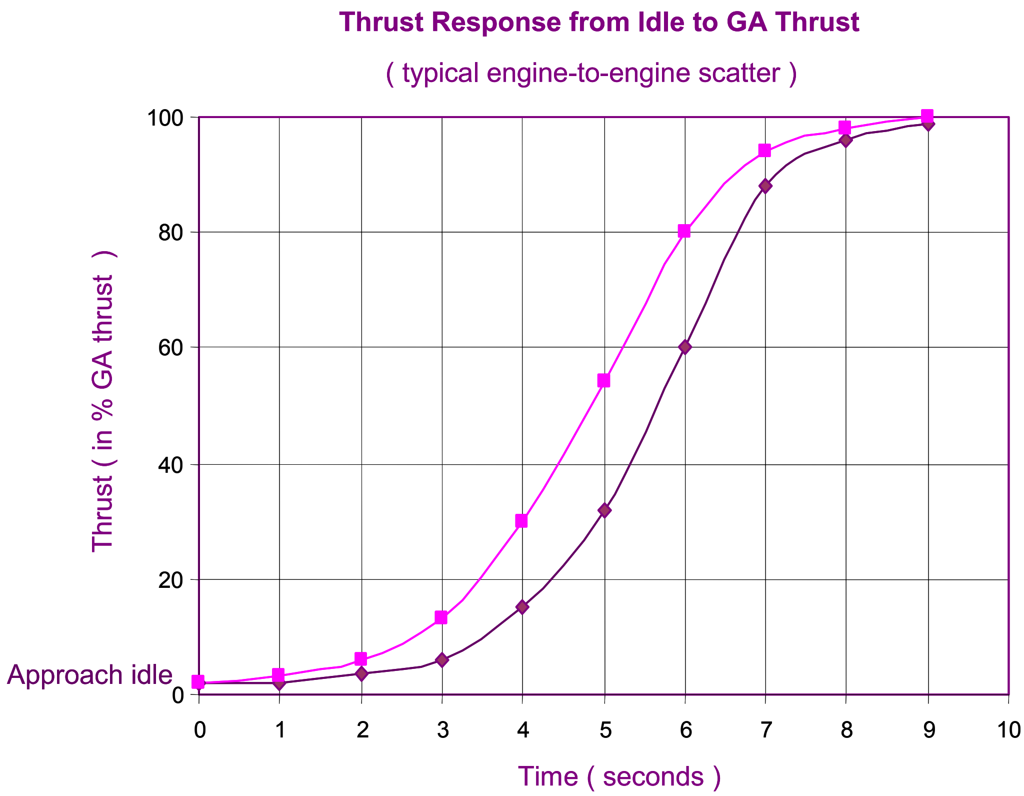

Figure 3

Engine Response Scatter- Typical

The acceleration capability of high by pass ratio jet engine is dictated by its physical characteristics and controlled to:

- Protect the engine against a stall or flameout;
- Comply with the engine and aircraft certification requirements (U.S. FAR – Part 33 and FAR – Part 25, respectively, or the applicable equivalent regulation).

The engine certification (FAR – Part 33) ensures a time of 5 seconds or less to accelerate from 15 % to 95 % of the go-around thrust.

The aircraft certification (FAR – Part 25) ensures that the thrust achieved after 8 seconds from power application (starting from flight/approach idle) allows a minimum climb gradient of 3.2 % for go-around.

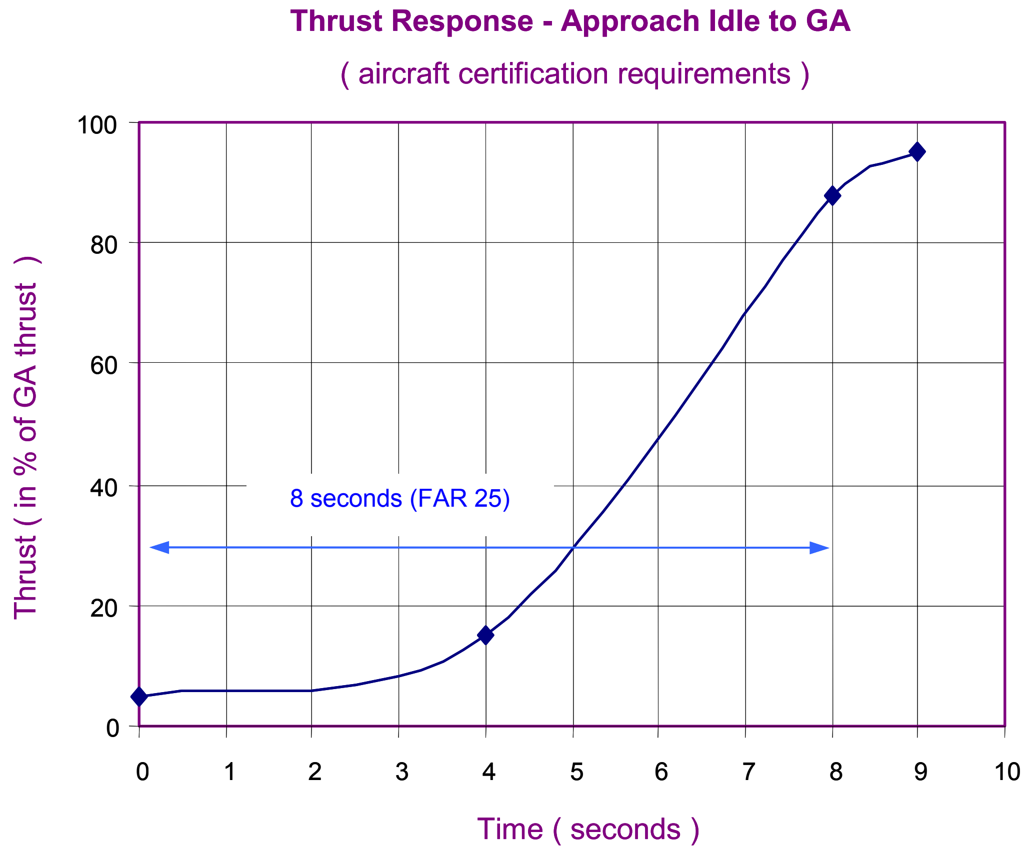

Figure 4

Certified Thrust Response –Typical

V.3 Go-around from Low Speed / Low Thrust

Table 1 indicates the thrust required (in % of the TOGA thrust) in order to achieve the following maneuvers:

Maneuvers	% of TOGA Thrust
Flying a stabilized approach (3-degree glide path / V_{APP})	20 %
Arresting altitude loss and achieving level flight	30 %
Achieving "Positive Climb"	> 30 %

Table 1

Thrust Required during GA Initiation

Figure 5 illustrates the go-around trajectories associated with flying an approach with:

- Speed on the target final approach speed (V_{APP}) with idle thrust;
- Speed below V_{APP} (V_{APP} – 10 kt) with idle thrust.

In case of go-around, the initial altitude loss and the time required for recovering the initial altitude are increased if airspeed is lower than the final approach speed and/or if thrust is set at idle. In particular, the effect of lack of thrust (i.e. thrust at idle) is significant in terms of altitude loss.

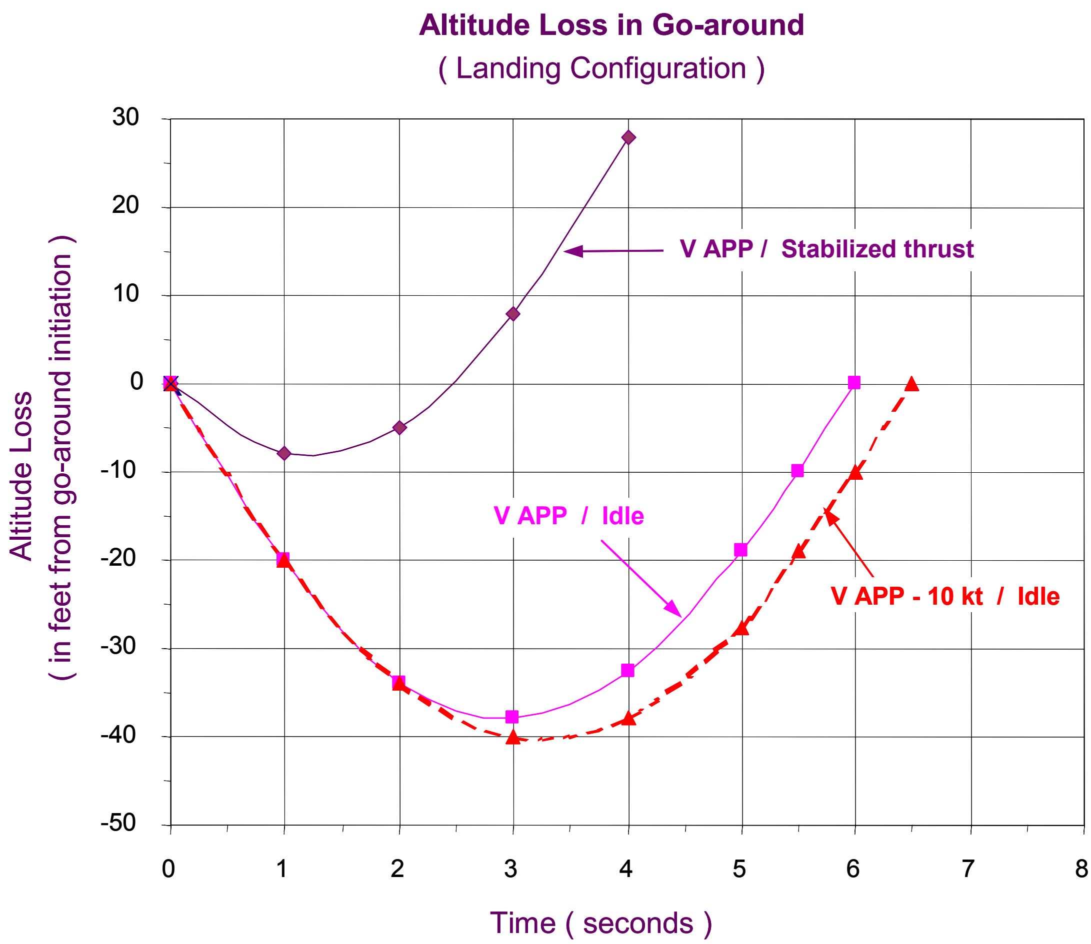

Figure 5

Effect of Initial Speed and Thrust on Altitude Loss during Go-around (Typical)

VI Summary of Key Points

A deceleration below the final approach speed should be accepted only in the following cases:

- GPWS terrain avoidance maneuver;
- Collision avoidance maneuver; and,
- Windshear procedure.

Nevertheless, in all three cases, the throttles/thrust levers must be advanced to the maximum thrust (i.e., TOGA thrust) while initiating the maneuver.

VII Associated Flight Operations Briefing Notes

The following Flight Operations Briefing Notes should be reviewed along with the above information for a complete overview of the approach management:

- **Being Prepared for Go-around**
- **Flying Stabilized Approaches**
- **Flying Constant-angle Non-precision Approaches**
- **Factors affecting the Final Approach Speed (V_{APP})**

VIII Regulatory References

- ICAO – Annex 6 – Operation of Aircraft, Part I – International Commercial Air Transport – Aeroplanes, Appendix 2, 5.18, 5.19.
- ICAO – Procedures for Air navigation Services – Aircraft Operations (PANS-OPS, Doc 8168), Volume I – Flight Procedures.

IX Other References

- U.S. National Transportation Safety Board (NTSB) – Report NTSB-AAS-76-5 – Special Study: Flight Crew Coordination Procedure in Air Carrier Instrument Landing System Approach Accidents.

Airbus Customer Services

Flight Operations Support and Services

1 Rond Point Maurice Bellonte - 31707 BLAGNAC CEDEX France

FOBN Reference : FLT_OPS – APPR – SEQ03 – REV02 – OCT. 2005