# CDO Execution and Wind Updates

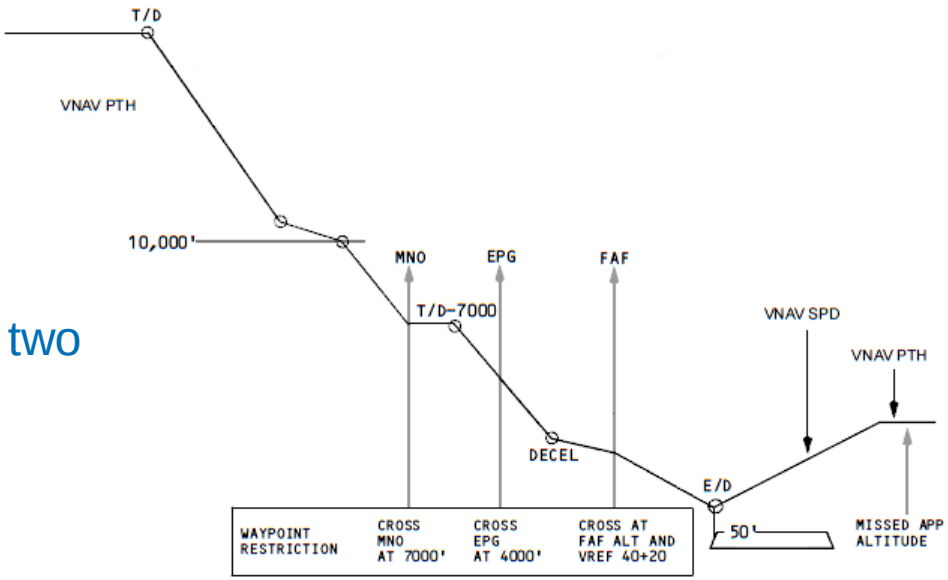
Louis Bailey
The Boeing Company, BR&T

## How will it fly the CDO descent?

Copyright © 2013 Boeing. All rights reserved.

# Descent

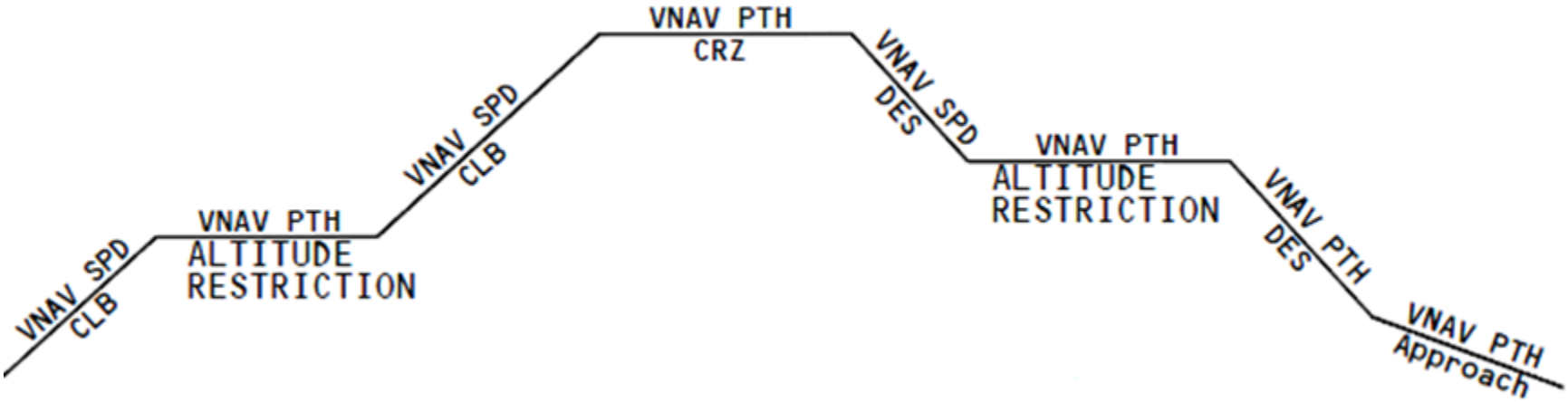
- Top of Descent is the point where the cruise phase changes to the descent phase
  - May not be where it leaves the cruise altitude
  - Consider descent speed deceleration & acceleration
- The FMS can perform the descent in two modes:
  - VNAV Path
  - VNAV SPD




- During VNAV Path the FMC uses idle thrust and pitch control to maintain <u>the vertical path</u>.
- During VNAV SPD the FMC uses idle thrust and pitch control to maintain <u>the descent speed</u>.

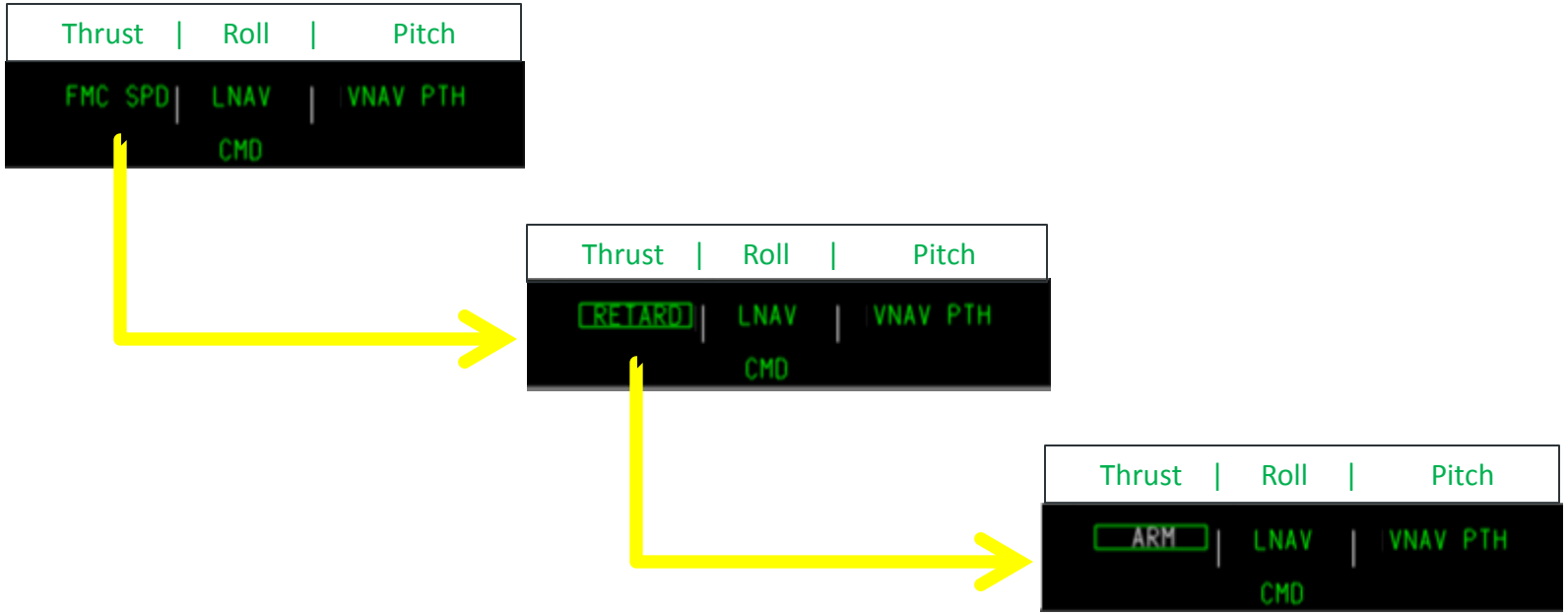
Copyright © 2013 Boeing. All rights reserved.

# Vertical Navigation Modes




Copyright © 2013 Boeing. All rights reserved.

# Idle Descent




Copyright © 2013 Boeing. All rights reserved.

# Descent Path Construction

- The Descent Path is constructed assuming an idle or near-idle descent is desired.
- The path is built from the approach to intercept with cruise altitude.
- Early entry of descent considerations is best to ensure computations are complete prior to descent.
- Speed and altitude constraints are computed for idle thrust. Aircraft will control pitch to meet the constraints.
- Considerations (to name a few):
  - Noise
  - Deceleration Distances
  - Cost Index
  - Descent Forecast Winds
  - Enroute Forecast Winds
  - Temperatures
  - Speed and Altitude Constraints
  - Speed Restrictions
  - Speed Transitions
  - Current Weather Conditions
  - The approach
  - Anti-ice

Copyright © 2013 Boeing. All rights reserved.

# CDO and FMC VNAV

- VNAV Path descent is most economical for route and weather.
- VNAV SPD descent generally flown for:
  - VNAV overspeed
  - Late descents
- VNAV SPD results in use of speedbrake and/or thrust.
- Returning to path or reducing airspeed will return to VNAV Path.
- For both VNAV Path and SPD descents, the FMC will still comply with waypoint and airport speed restrictions.

Copyright © 2013 Boeing. All rights reserved.

# CDO & FMC VNAV Descent

- Using VNAV (vertical navigation)
  - VNAV Path, the FMC commands pitch to keep the vertical path.
  - VNAV SPD, the FMC commands pitch to keep the target speed.

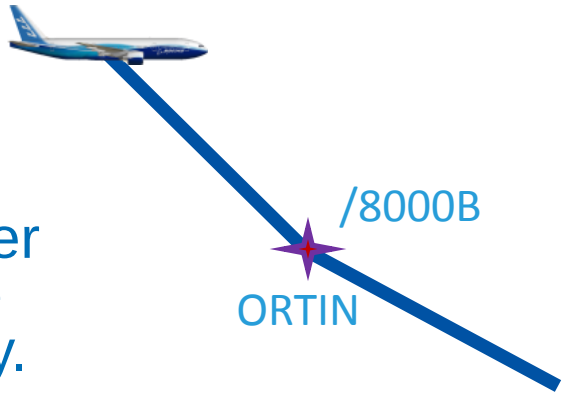
- FMC controls pitch to stay on descent path.
- Pilot monitors and adjusts the speed.

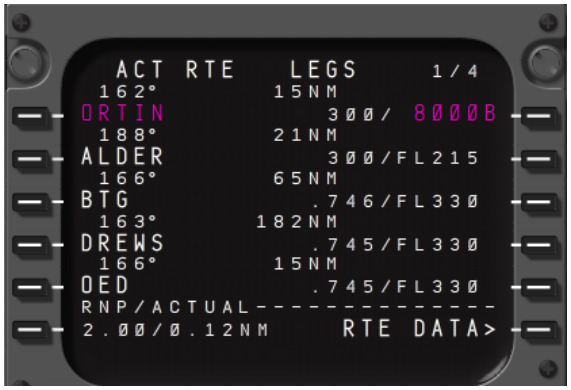
- FMC controls pitch to keep an airspeed.
- Pilot monitors and adjusts the rate of descent to stay on descent path.

Copyright © 2013 Boeing. All rights reserved.

# Altitude Constraints

- Types of altitude constraints:
  - At
  - At or Below (AB)
  - At or Above (AA)
  - Window Constraints (ex: 240B210A)
- Use of AB, AA and Windows allow greater degree of continued idle descent – more economic while maintaining predictability.
- Path is built to meet the altitude constraints
- Scratchpad message is given if altitude constraint cannot be met.



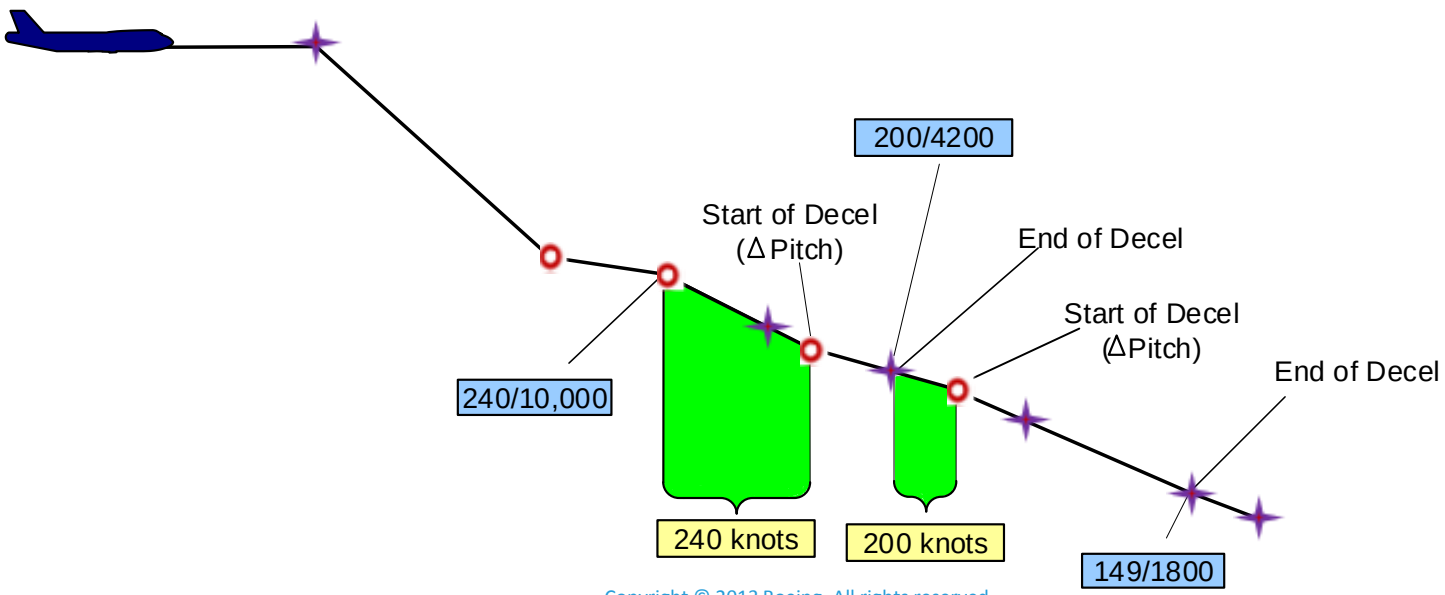




Copyright © 2013 Boeing. All rights reserved.

# Speed Constraints

## What is it doing now?

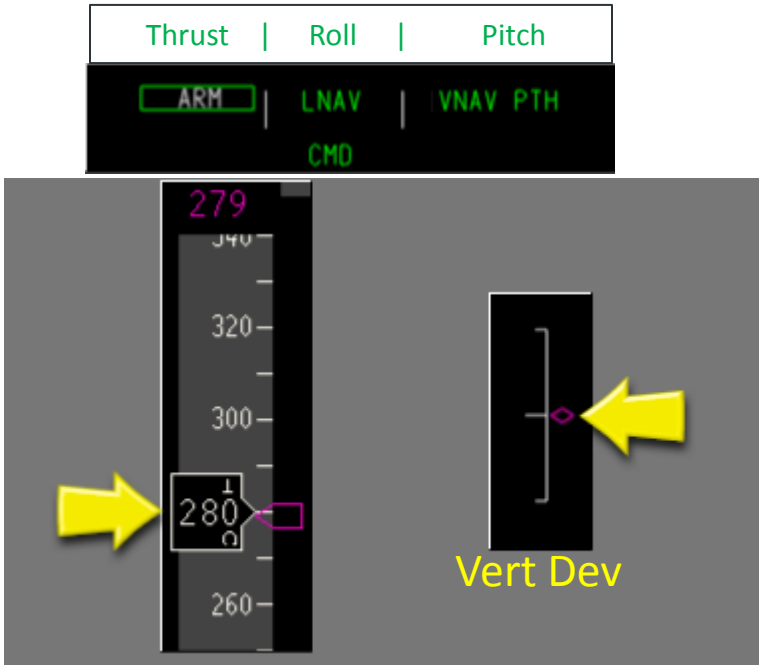
- Speed constraints are considered At or Below.
- Entry of a speed constraint in descent requires an altitude constraint.

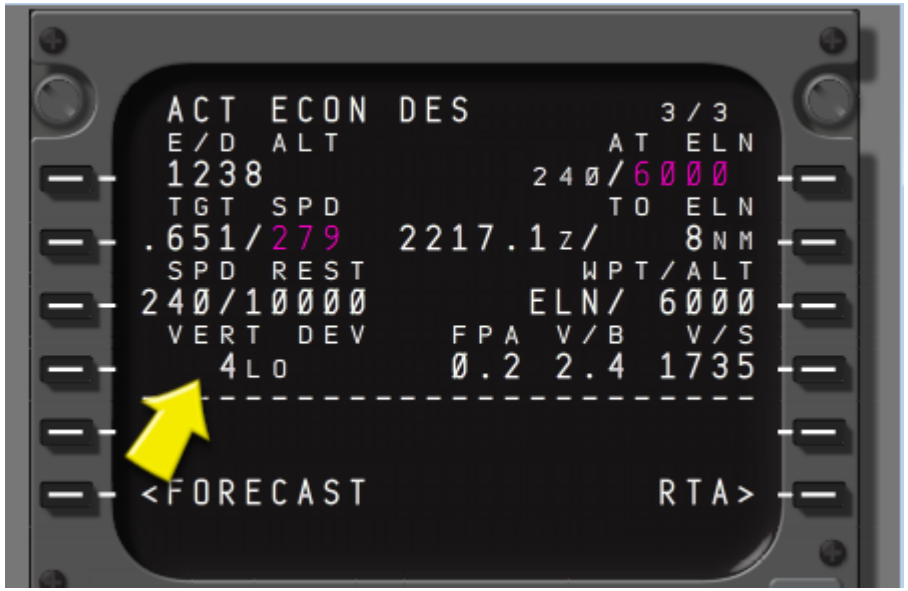



Copyright © 2013 Boeing. All rights reserved.

# Flying the CDO
## (On Path and On Speed)

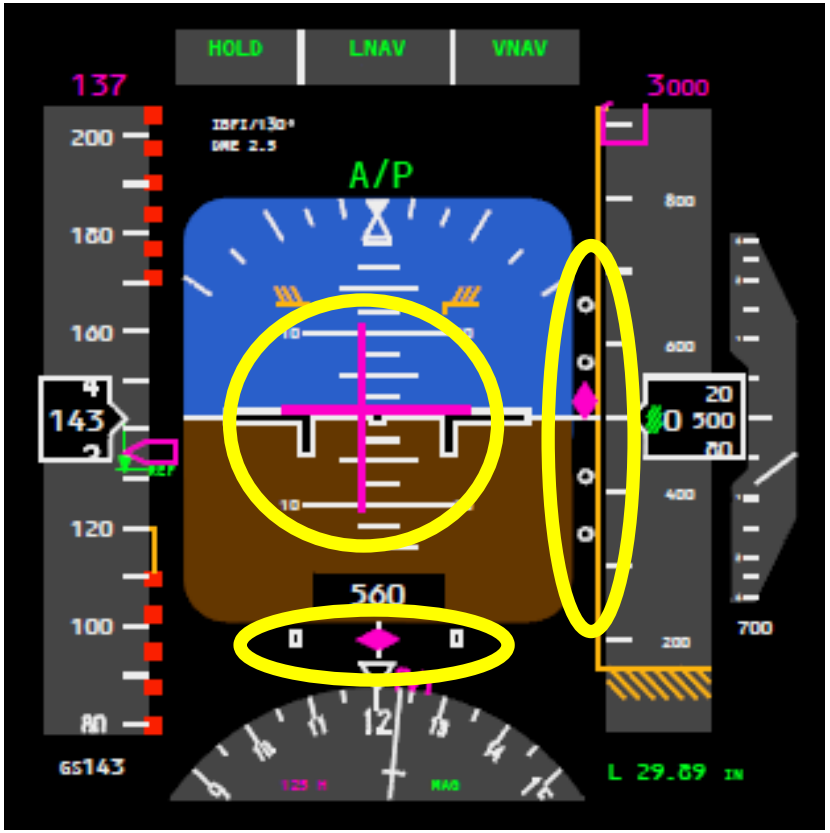
- Thrust is idle
- Pitch to keep path




Copyright © 2013 Boeing. All rights reserved.

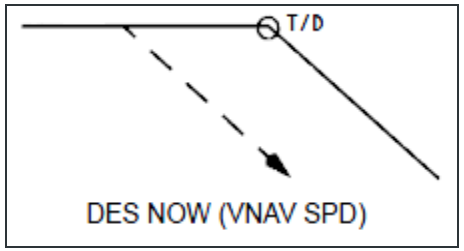
# Path Conformance

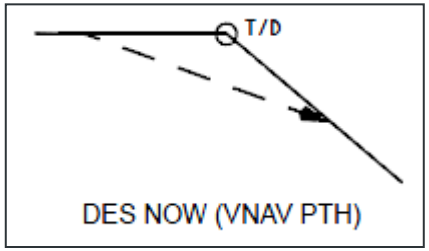


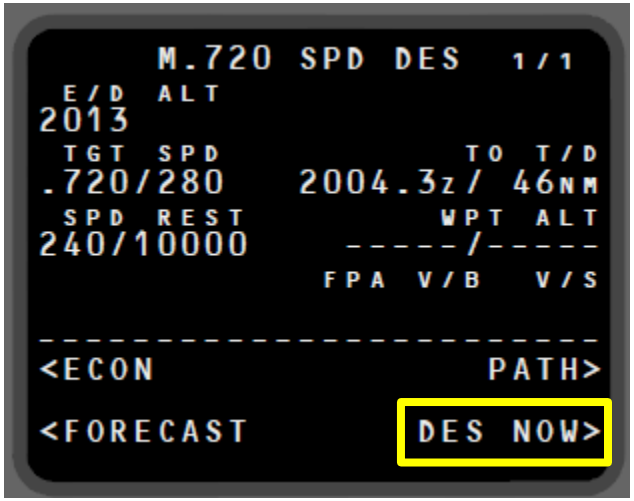

Copyright © 2013 Boeing. All rights reserved.

# Early Descents and VNAV

- "DES NOW" or MCP can be used to start descent early and capture the idle path.
- Using MCP too early can result in "Cruise Descent"
- Early descents could result in
  - VNAV SPD or
  - VNAV Path



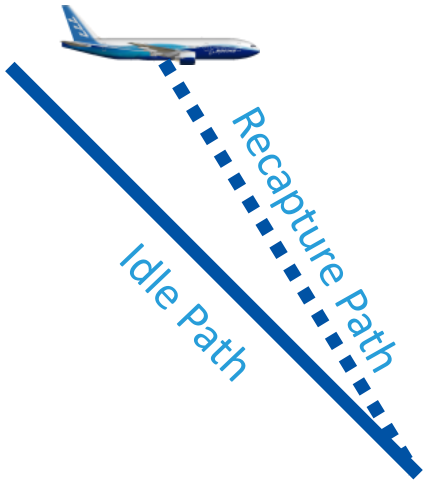



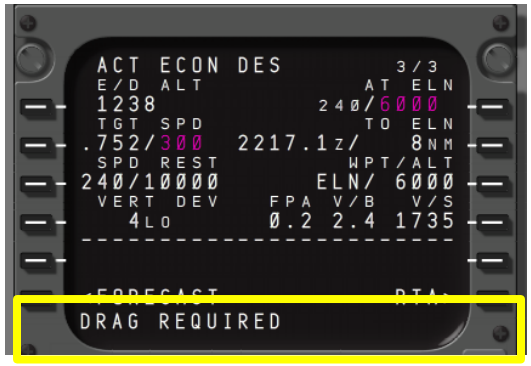




Copyright © 2013 Boeing. All rights reserved.

# Late Descents and VNAV

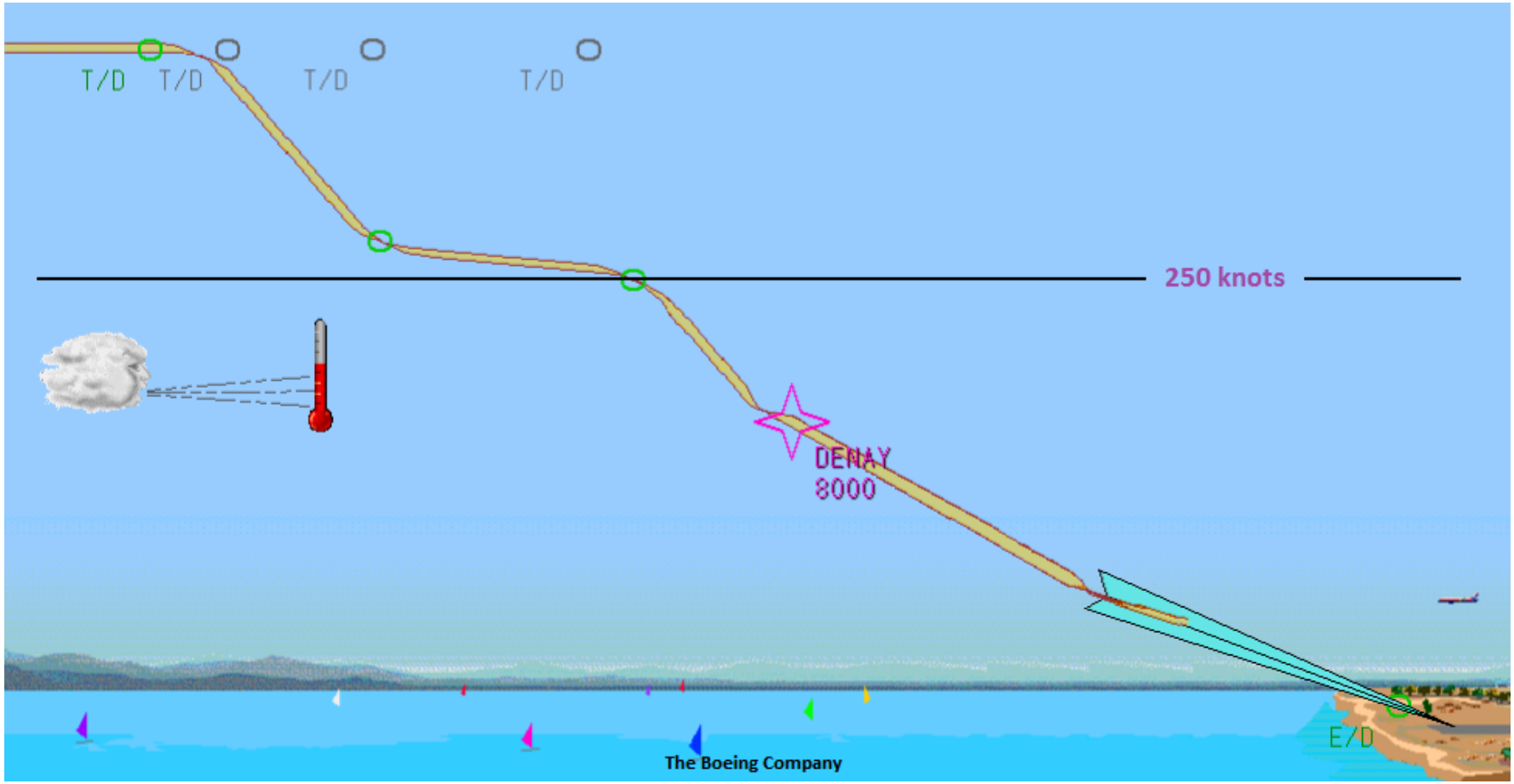
- Late descents or above path conditions may be a result of:
  - ATC
  - Geometry of the descent
  - Tailwinds
  - Late entry of altitude constraints
- Loss of efficiency




Copyright © 2013 Boeing. All rights reserved.

# The weather effect

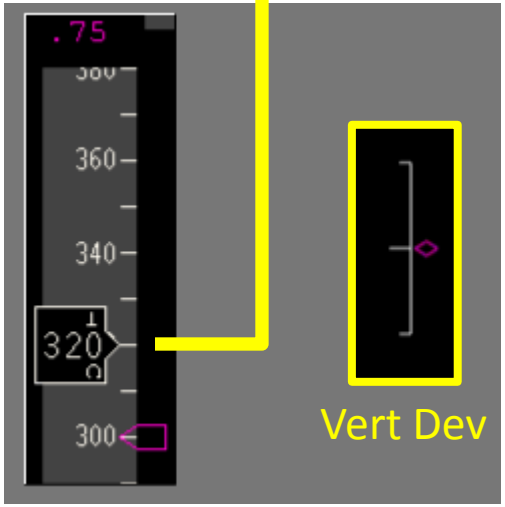


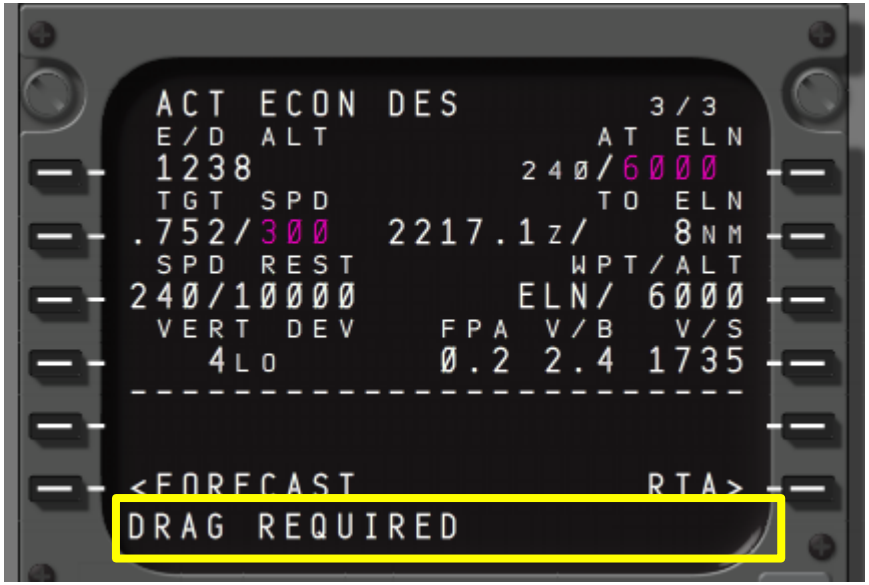

Copyright © 2013 Boeing. All rights reserved.

# Greater Tailwind

## (VNAV Path)

- Loss of efficiency
- Maintaining path increases airspeed



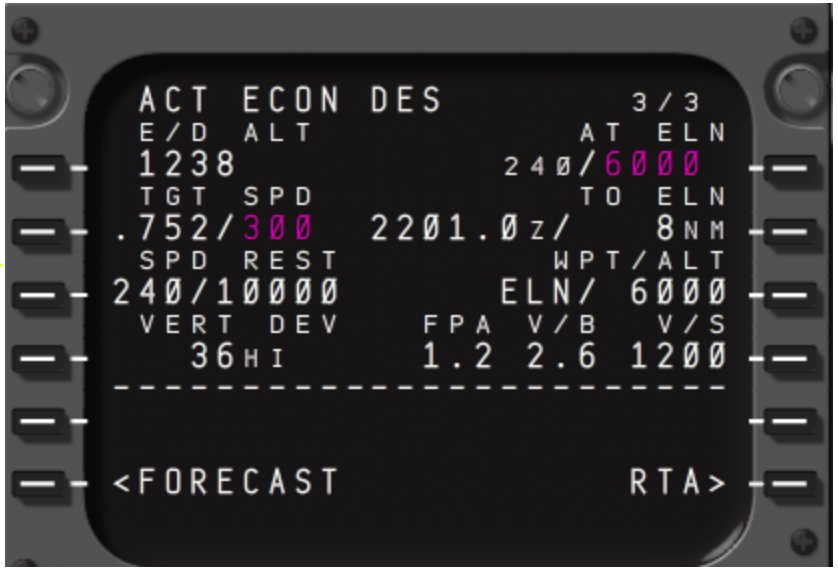

- Apply speedbrake to decrease airspeed
- Potentially revert to VNAV SPD

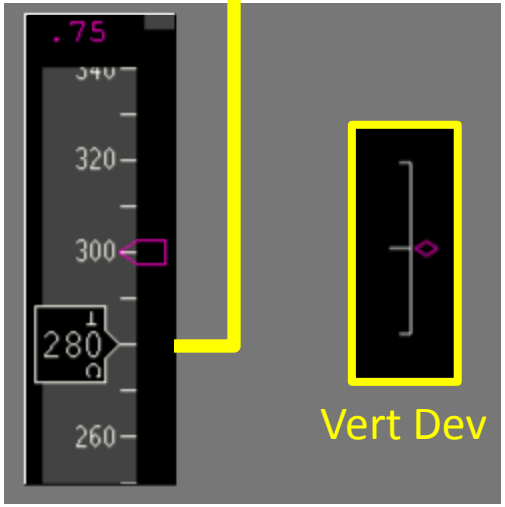
Copyright © 2013 Boeing. All rights reserved.

# Greater Headwind

## (VNAV Path)

- Loss of efficiency
- Maintains path
- Airspeed is lost



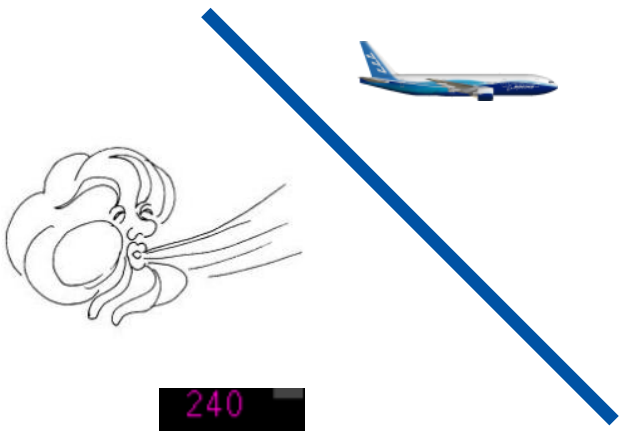



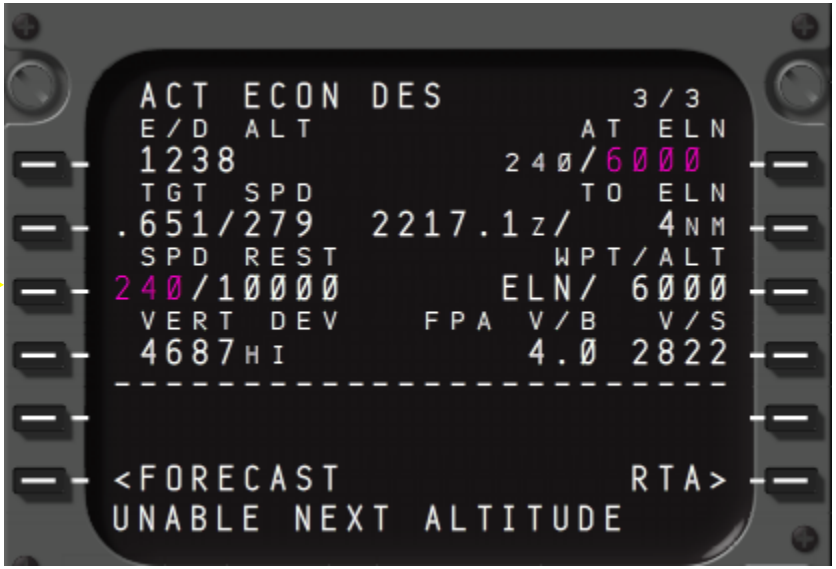

- Add thrust to regain/maintain airspeed.
- If thrust is not added, the result is FMC Spd Mode. Stays in VNAV Path.

Copyright © 2013 Boeing. All rights reserved.

# Unaccounted Tailwind

## (Above path and poor forecast entry)



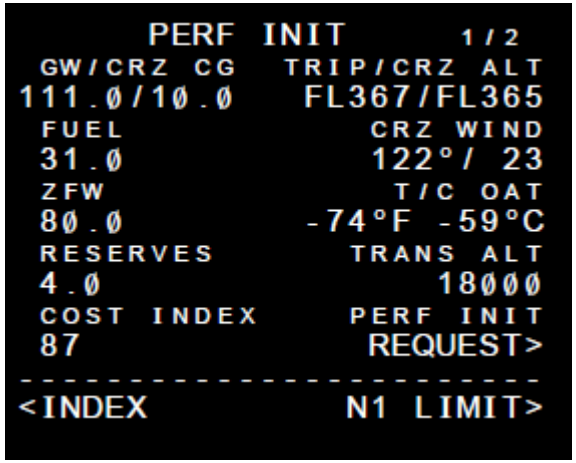



- Tailwind would continue to increase the altitude above the path, but no change in airspeed.
- Result could potentially be unable to meet the altitude constraint.

Copyright © 2013 Boeing. All rights reserved.

# Weather Forecast Entry

- A real need to enter accurate weather (winds and temperatures) forecasts into the Flight Management Computer (FMC).
- When weather data is uplinked is just as important as what you uplink.
- Inaccurate weather forecast can cause the pitch mode to revert from VNAV Path to VNAV SPD.
- Wind forecasts are used in a variety of FMC computations and may adversely affect the airplane flight efficiency.
- Wind forecasts are used in calculations waypoints such as:
  - Top-of-Climb
  - Top-of-Descent
  - Position of step climbs
  - Positions of acceleration or deceleration
  - Optimum Altitude
  - RTA
  - Path Construction

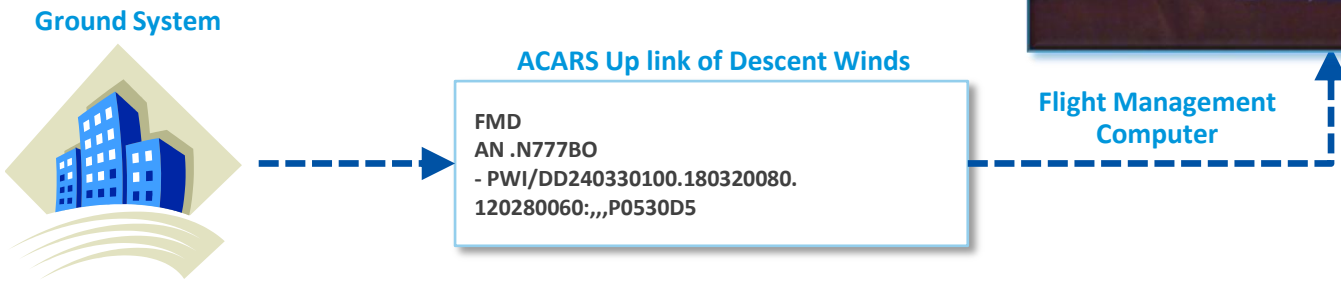



Average Trip Wind

Copyright © 2013 Boeing. All rights reserved.

# Automate Wind Uplink

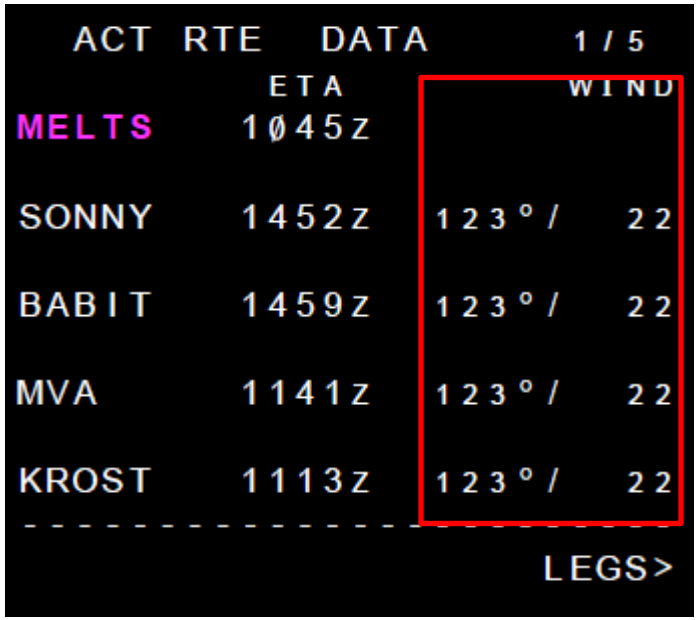
- Timely delivery to allow adequate time for computations.
- Improves predictability
- Enables additional economic savings (i.e. TOD placement)
- Dependent on aircraft type and operation
- Reduces workload and entry error



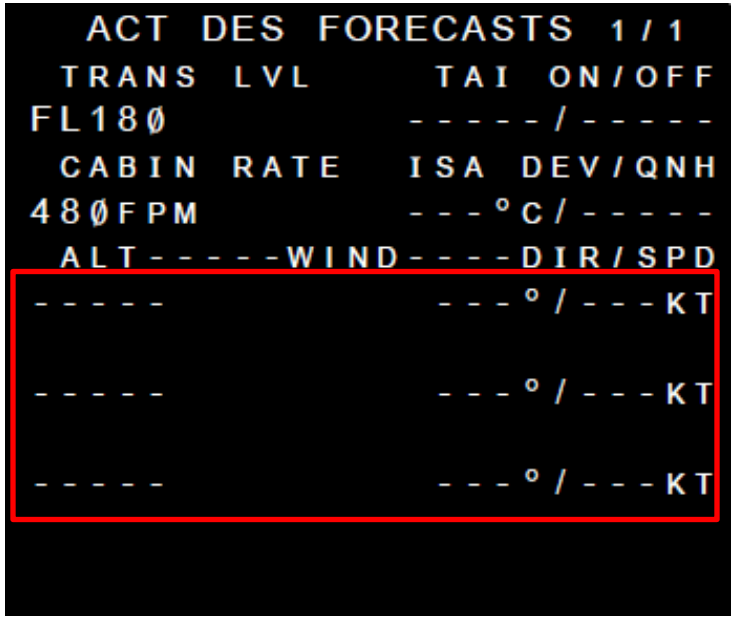

Copyright © 2013 Boeing. All rights reserved.

# Forecast Wind Entry

- Forecast wind entry can entered for the descent, on each enroute waypoint and as an average for the flight.
- Many entry variations across the many FMC vendors but all perform the same basic function – improving predictability and economy.




Wind entry on enroute waypoints




Descent Wind Forecast Entry

Copyright © 2013 Boeing. All rights reserved.

# Thank You