

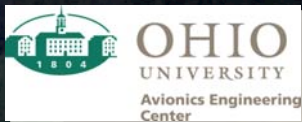
An Energy Management Display for General Aviation Safety Enhancements

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Outline

- Introduction
 - Problem Statement
 - Research Objective
- Technical Background
 - definitions & symbology
- Path and Energy Based Approach Guidance
 - intercept tunnel
 - energy cues
- Implementation & Test Status
 - part-task simulator
 - flight testing



Problem Statement

- Loss-of-Control (LOC) is the leading cause of fatal accidents
- Especially high for GA – 50% of all accidents
- Loss of energy-state awareness is a primary cause
 - CFIS continues to be an all-too-common result
- Number of vehicles in the NAS expected to triple by 2025
- Increased traffic densities in NextGen will be achieved by reducing nominal separation.

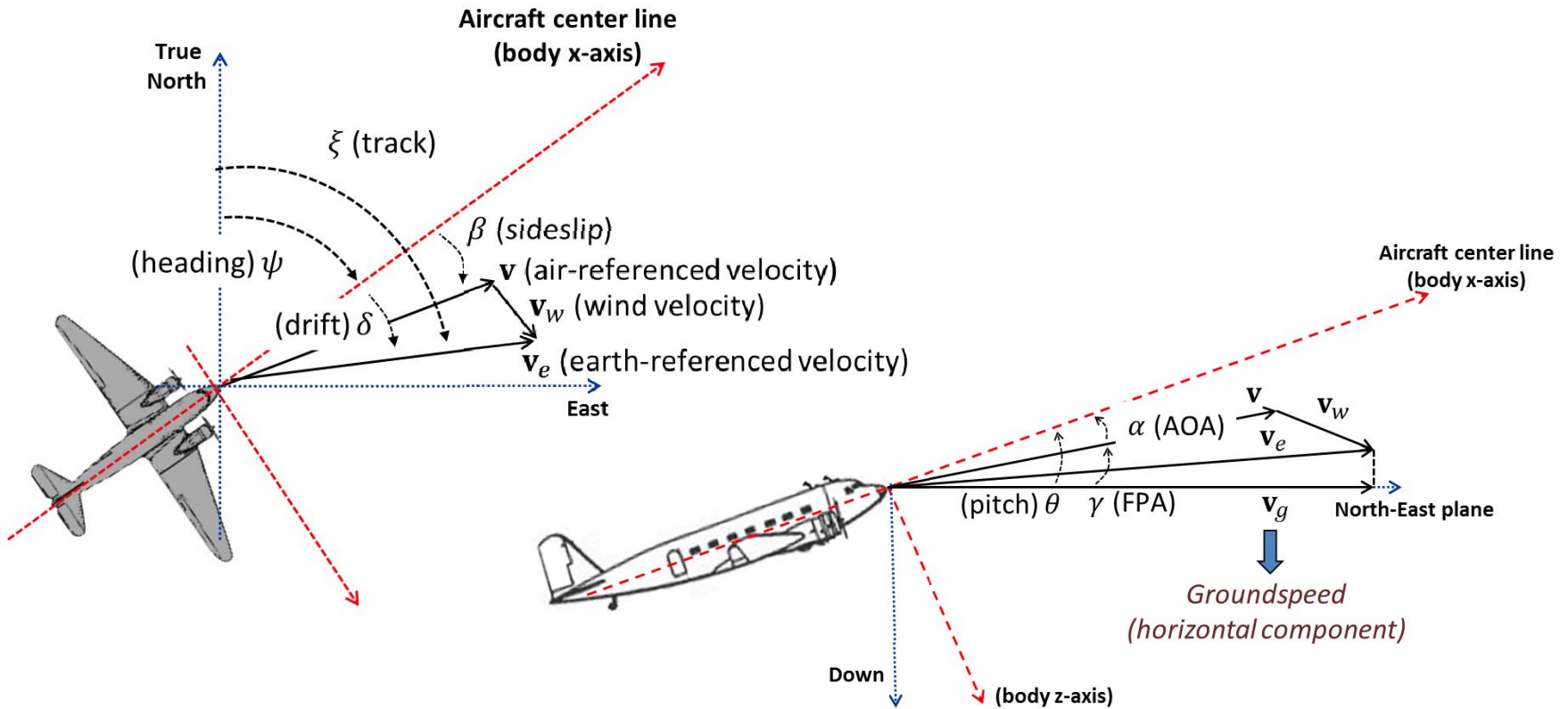


Research Objective – Focus on GA

- To develop, implement, and test a GA display that includes a **dynamically generated** path-way in the sky to provide GA pilots with flight path guidance during the arrival and approach phases of flight.
- The pilot can **follow this desired path** by lining up the flight path marker (FPM) with the center of the path.
- Simultaneously, the pilot can **monitor the aircraft energy state and make efficient use of flight controls** using energy cues added to the primary flight display (PFD).



Definitions: Flight Parameters

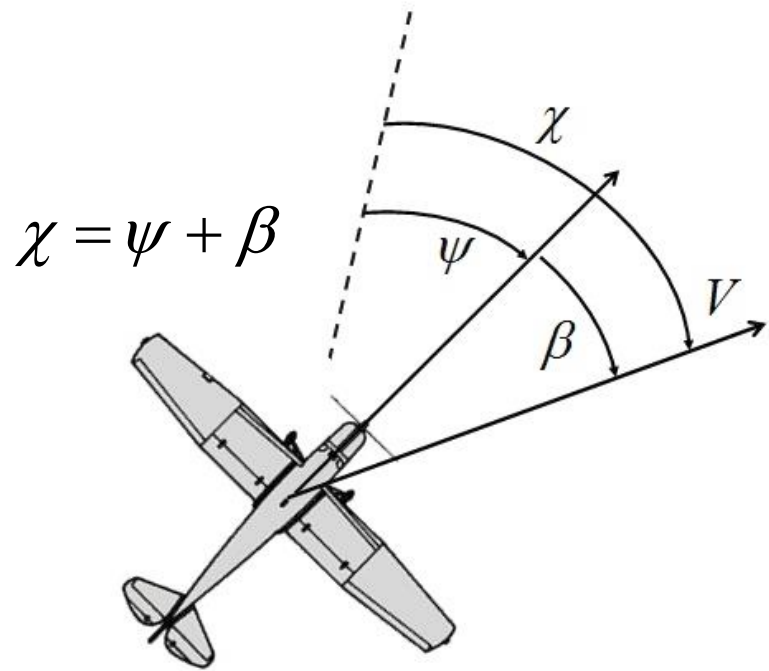


Airspeed: $V = \|\mathbf{v}\|$

Groundspeed: $V_g = \|\mathbf{v}_g\|$



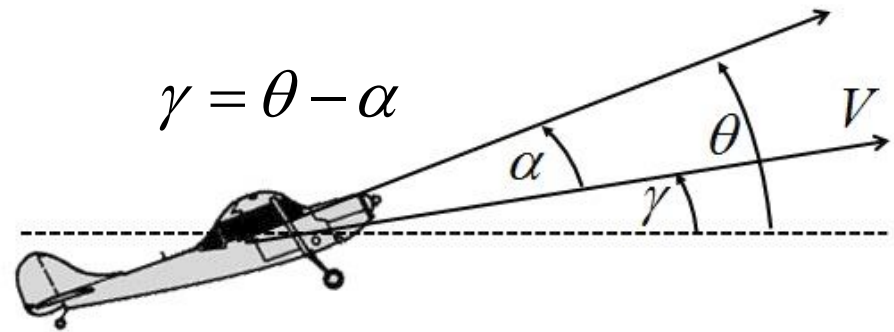
Definitions: Flight Parameters



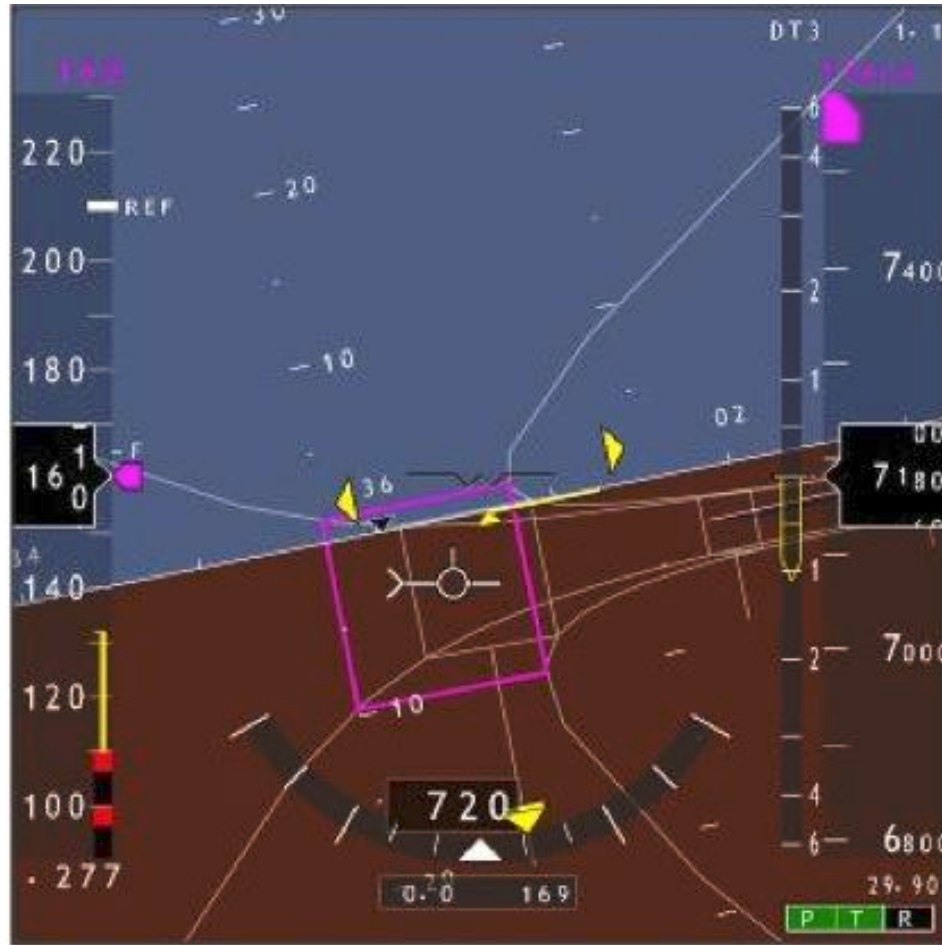
Flight Path Vector:

$$FPV = f(V, \gamma, \chi)$$

The direction of the Flight Path Vector is indicated by the Flight Path Marker (FPM)



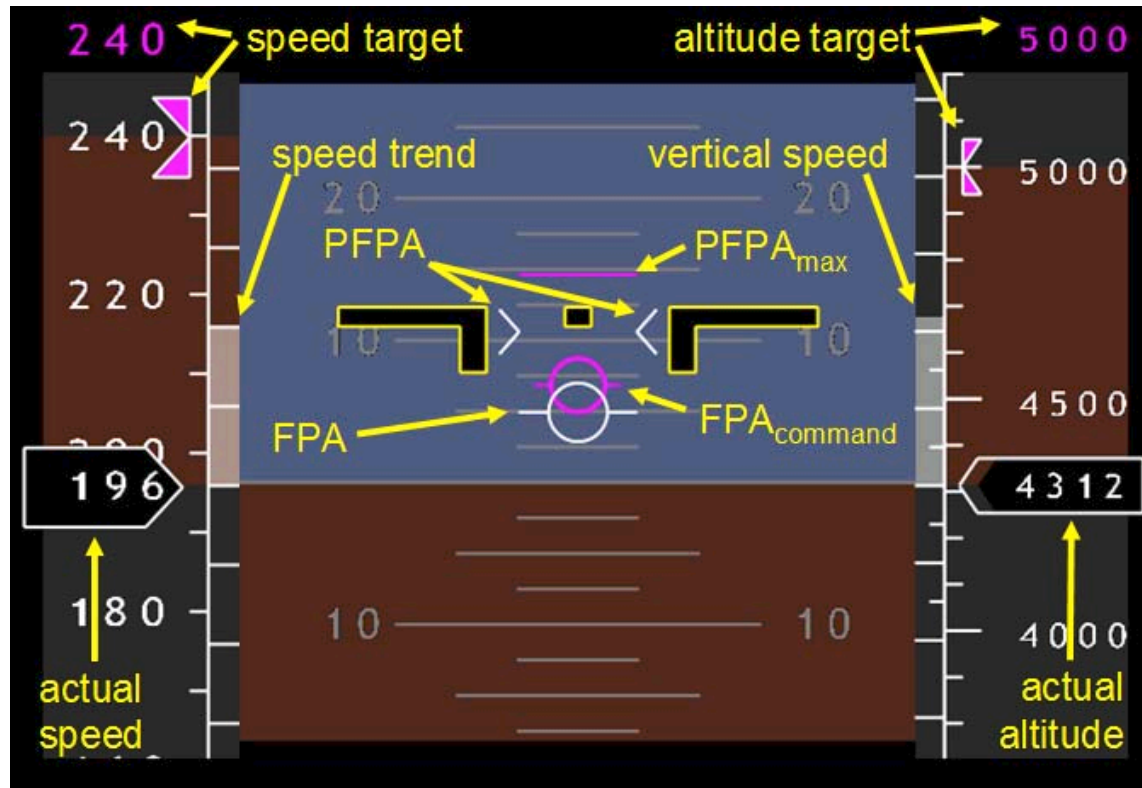
Display – SVS PFD with Pathway



Theunissen et al.: "Guidance, Situation Awareness and Integrity Monitoring with an SVS+EVS", AIAA GNC Conference Proceedings, August 2005



Display - Energy Management PFD



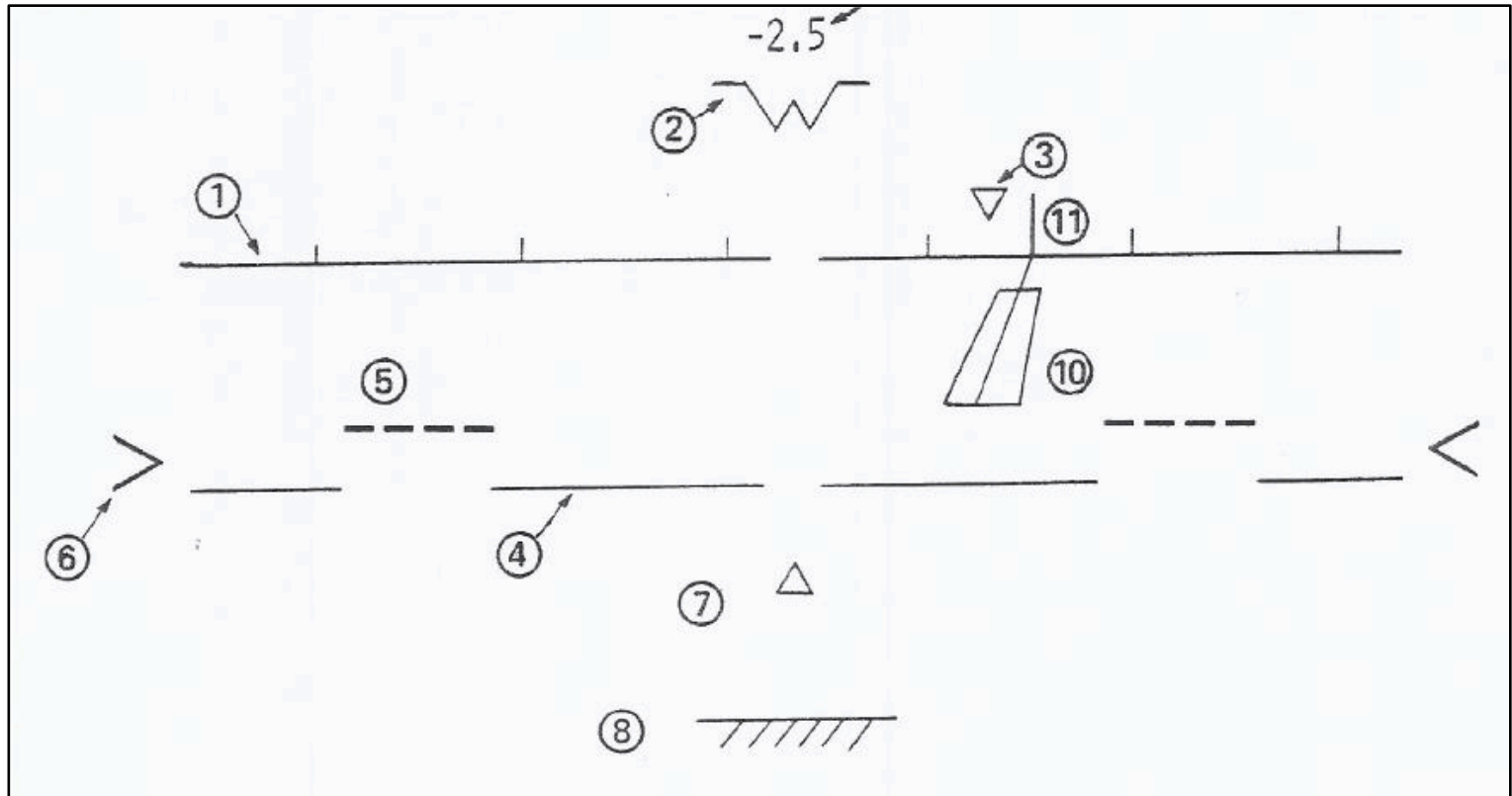
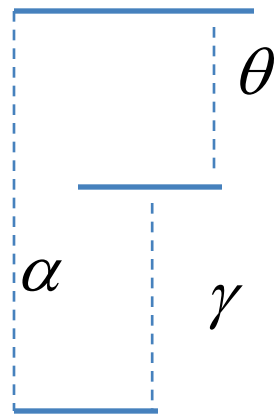
Lambrechts, T., R. Rademaker, E. Theunissen, "A New Ecological Primary Flight Display Concept," Proceedings of the IEEE/AIAA 27th DASC, St. Paul, MN.



Symbology: Primary Flight Display (PFD)



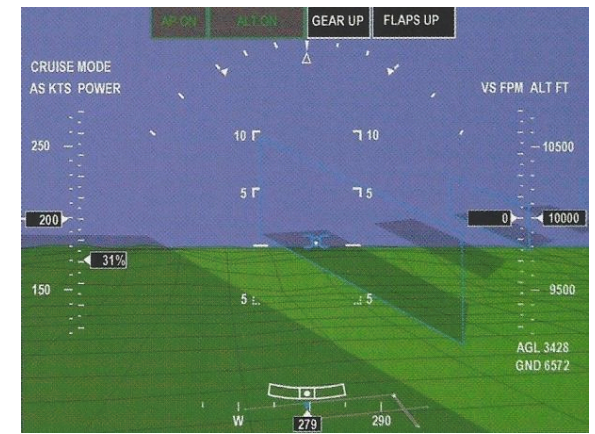
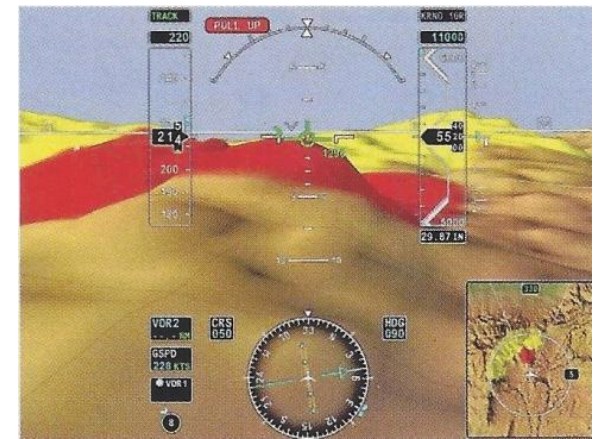
Klopfstein Head-up Display (HUD)



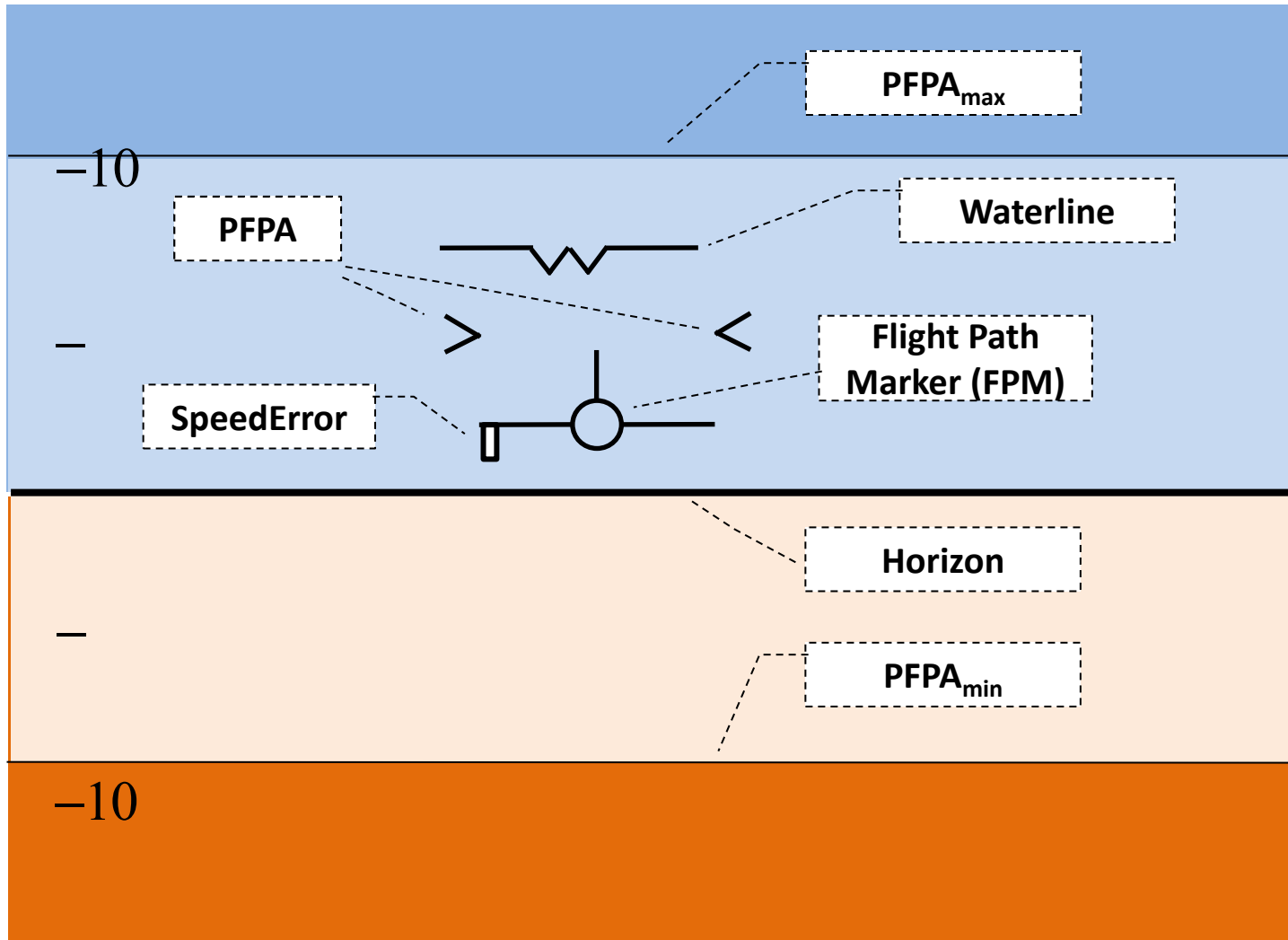
Monagan, S.J. and R.E. Smith (1981). *Head-Up-Display Flight Tests. Proceedings of the Fifth Advanced Aircrew Display Symposium, pp. 104-116, September 15-16, Naval Air Test Center, Patuxent River, Maryland.*



Synthetic Vision Examples

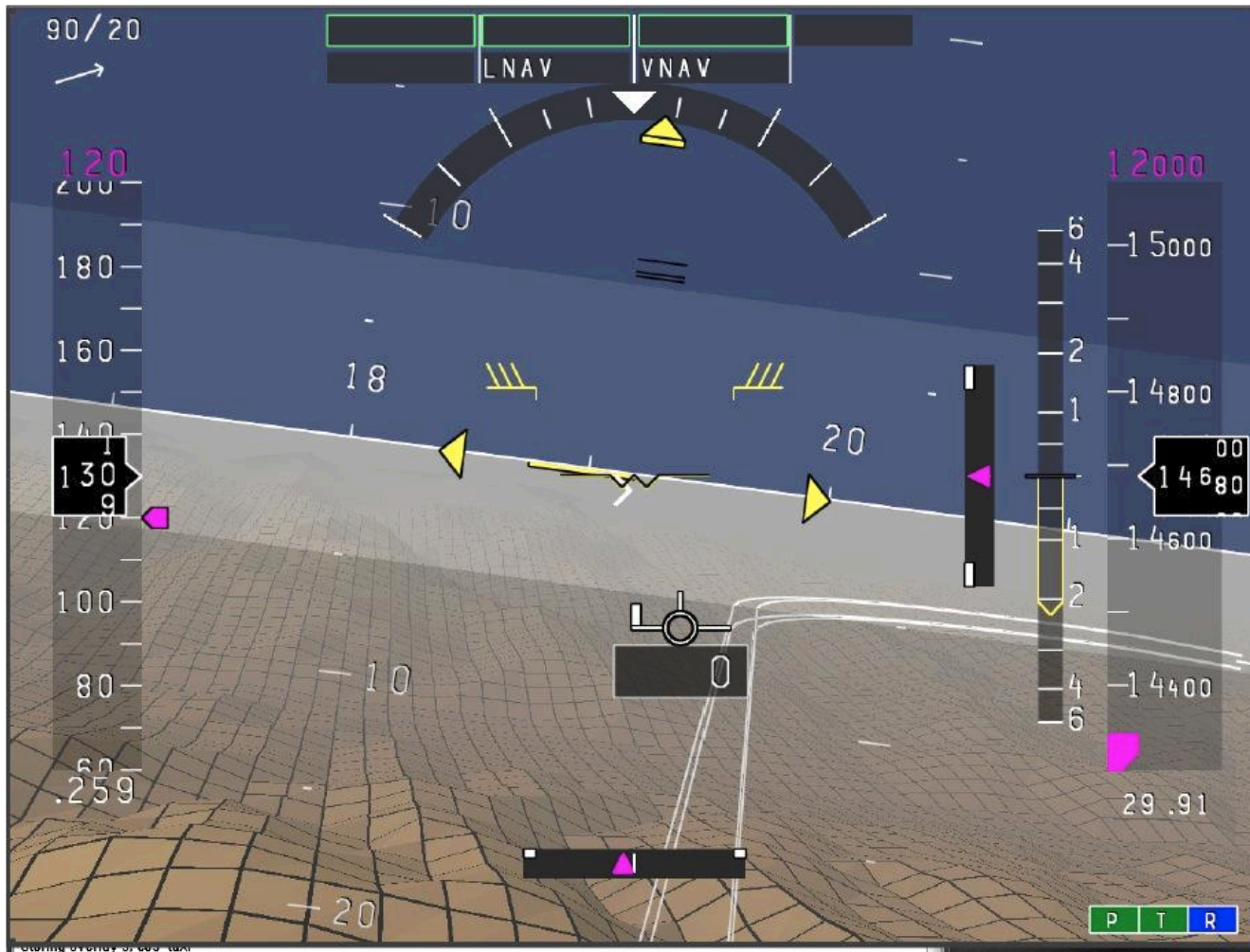


Display: Energy-related Cues



Flight Path Angle: $\gamma(FPA)$, Potential FPA $\gamma_p(PFPA)$

Display: Preliminary Design



FPM and PFPA

- FPM:

- Vertical component γ (quickened to minimize PIO)

$$\gamma_{\text{display}} = \gamma + 0.25q$$

- Horizontal component: χ (not quickened currently)

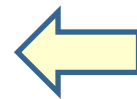
- PFPA:

- attainable FPA at the current speed at the current throttle setting (or, the FPA the airplane attains when the rate of change of the velocity is reduced to zero by applying elevator/pitch control only).

$$\gamma_P = \gamma + \frac{\dot{v}}{g},$$

- PFPA_{max}:

$$\gamma_{P_{\text{max}}} = \gamma + \frac{\dot{v}_{\text{max}}}{g}$$

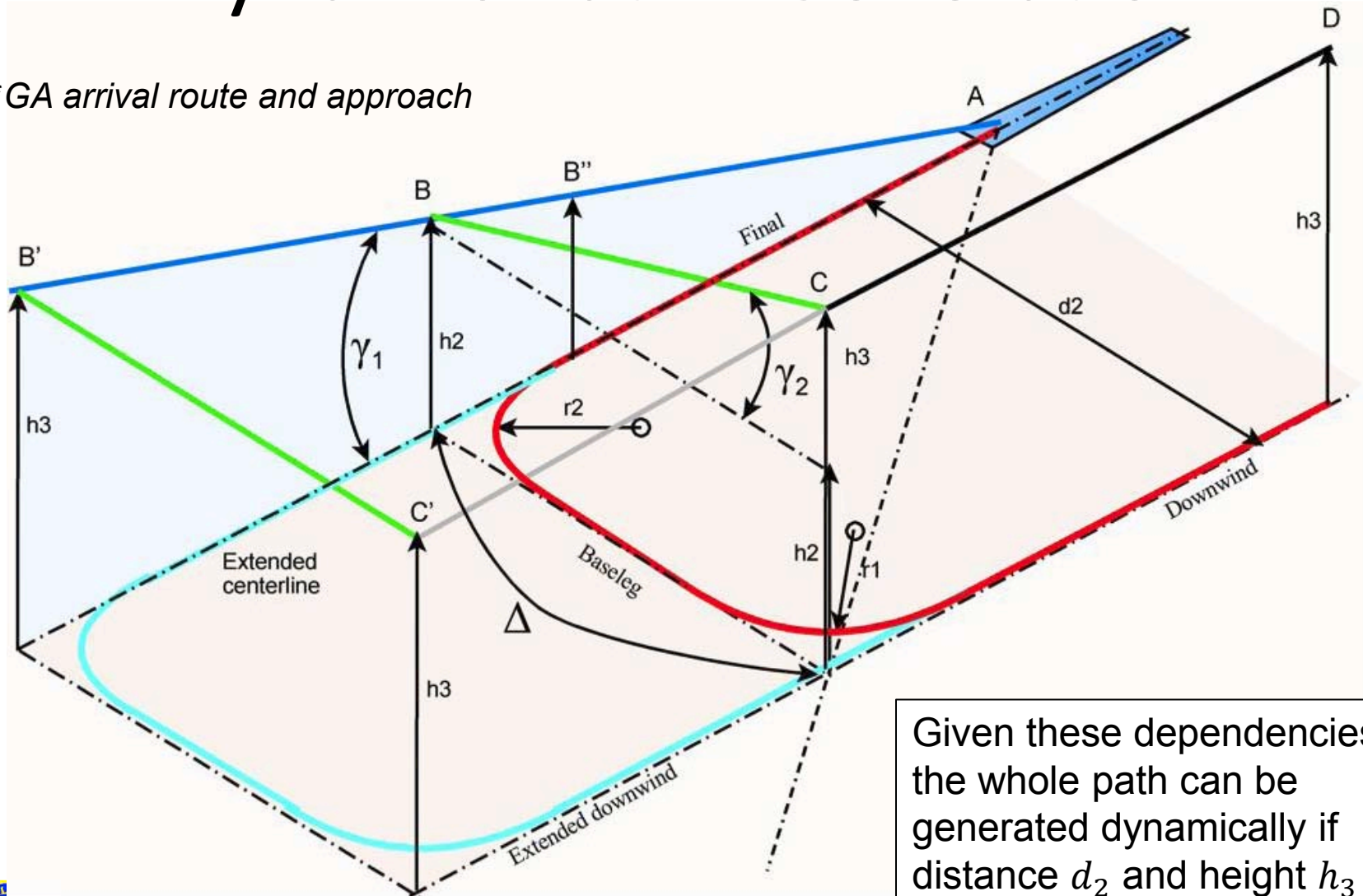


Maximum throttle



Dynamic Path* Generation

*GA arrival route and approach



Given these dependencies, the whole path can be generated dynamically if distance d_2 and height h_3 are defined.



Dynamic Path Generation: Rules

- **Example rules for distance d_3 choice:**
 - Spatially defined limit;
 - Turn-radius defined limit based on *current* velocity and maximum bank angle;
 - Turn-radius defined limit based on *specified* velocity and maximum bank angle.
- **Example rules for height h_2 choice:**
 - Current ownship altitude;
 - Specified height above ground for downwind leg.
- **Additional constraints imposed on the base leg such as:**
 - Maximum glideslope angle γ_2 , or
 - Maximum vertical speed,



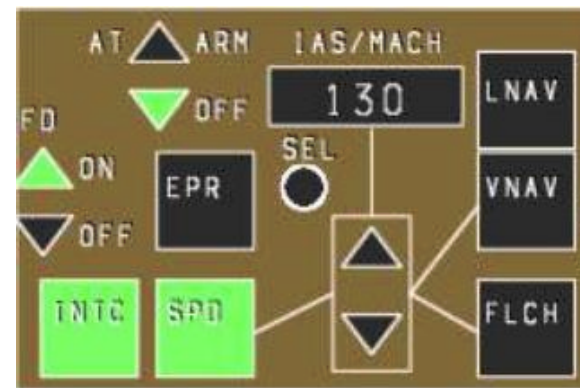
Flying the Dynamic Path

- When close to the downwind the algorithm computes a dynamic path to a selected runway and, when it becomes available, provides the pilot with an option to initialize/select it:

Path Available

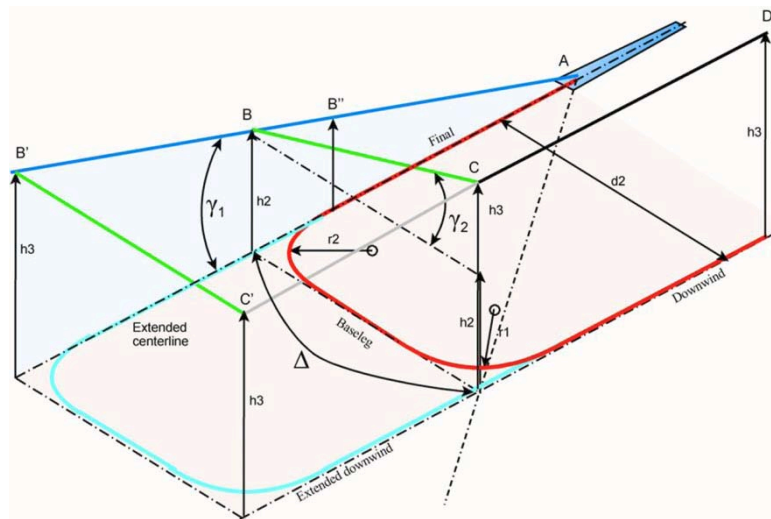


Path Selected



Flying the Dynamic Path

- FPM to fly the dynamically generated path;
- Additional velocity constraints drive the energy cues that must be monitored by the pilot;
 - E.g. V at point B should be between V_{ref} and $V_{ref}+3kts$, V at point A should be between V_{ref} and $V_{ref}+1kts$; aka energy funnel.



Implementation Example

- Dynamic paths into Johnson County Executive Airport (KOJC)



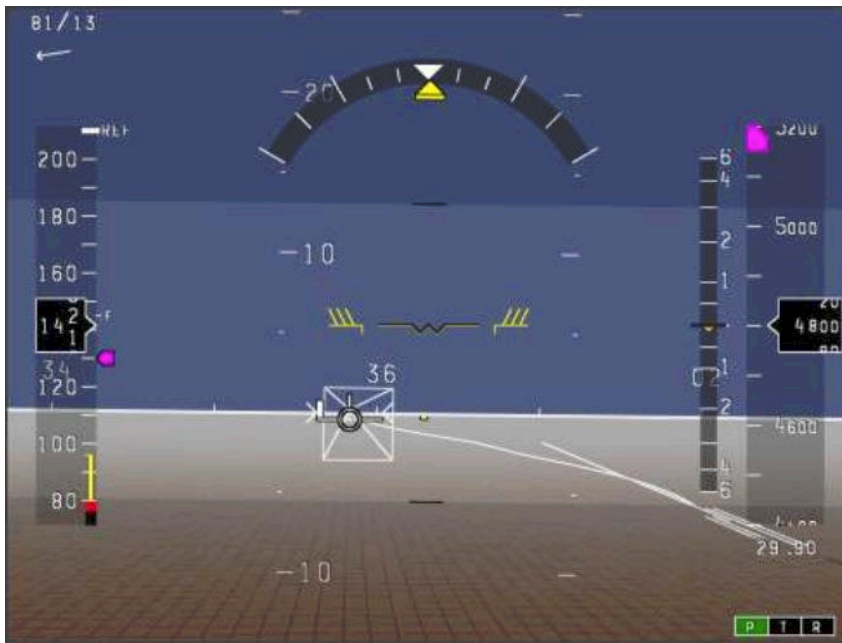
Entry Point to Approach Path (PFD)



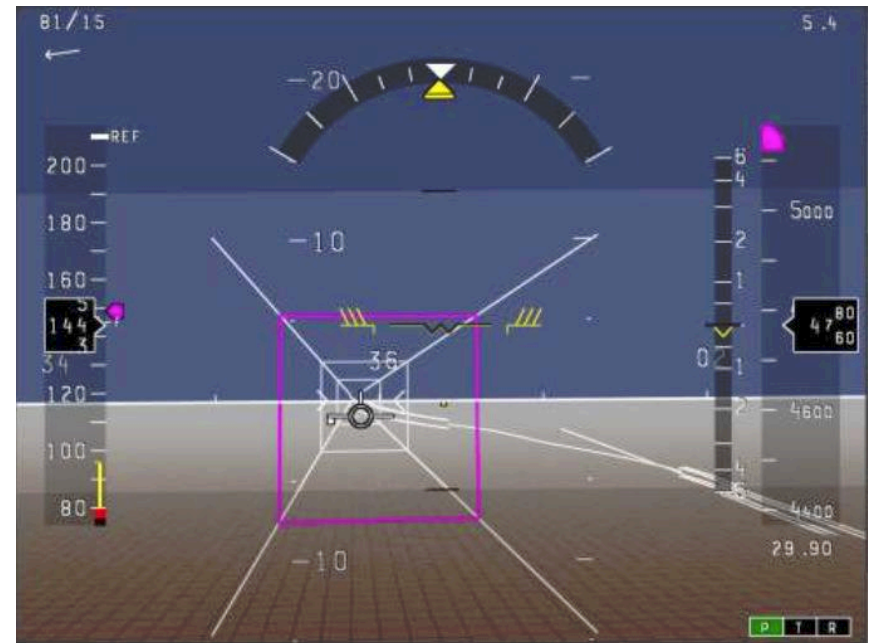
Approach Path on ND



Implementation Example



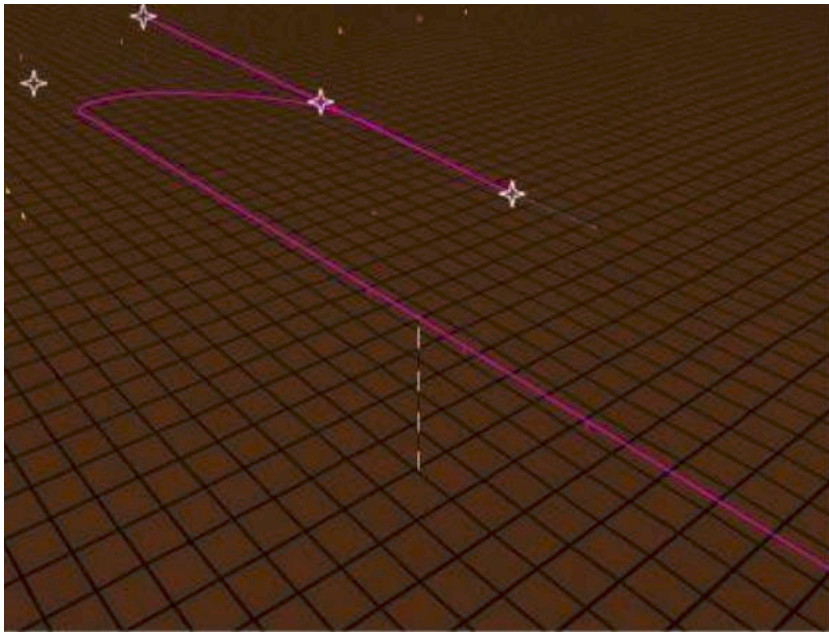
Nearing Approach Path (PFD)



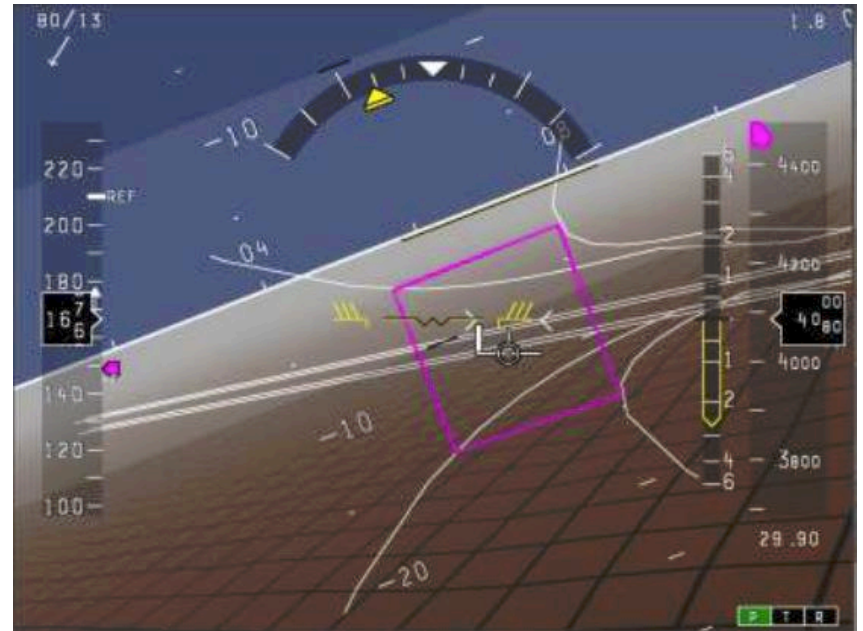
Flying through tunnel



Implementation Example



Exocentric view of approach path



Turning onto base leg



Planned Tests: simulator

- Small study in Ohio University part-task simulator:



Planned Tests: flight test

- Flight test at Ohio University and FAA with GA aircraft;
- Portable flight equipment: AHRS, GPS, Computer, Tablet, ADS-B, etc.



Summary

- A synthetic vision display has been developed and implemented that provides dynamic generation of an arrival and approach path for a general aviation aircraft given a set of predefined constraint choices;
- Furthermore, energy state cues are included so the pilot can monitor its energy state along the flight path.
- Tests are currently being prepared in a fixed-base part-task simulator and GA aircraft (e.g. Cessna 172)



Thank You

Questions?

