# Integration of Flight Inspection Guidance in Standard IFIS Instrumentation

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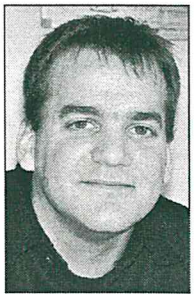


## ABSTRACT

Costs for flight inspection can directly be reduced by saving flight time.

Flight time can be saved if unnecessary positioning delays are avoided during flight inspection missions. Such delays may be caused by difficulties in intercepting the desired procedure start point and subsequently following the flight inspection procedure. Reasons for these difficulties include the fact that standard cockpit instrumentation does not provide flight guidance for all flight inspection procedures.

Further delays can be caused by misunderstandings between flight inspector and pilots about the desired procedure profile.

Detailed flight inspection guidance in the cockpit can improve quality and repeatability of Flight Inspection results.

This paper describes different techniques to bring flight inspection guidance to the pilots: Starting from analogue cross pointer instrumentation and ending up with sophisticated, Flight-Management-System-like flight guidance, including autopilot coupling and automatic flight plan generation/visualization.

## PURPOSE

This paper describes the implementation of cockpit flight guidance for flight inspection aircrafts. A Flight Inspection System (FIS) generates synthetic flight guidance data for indication in the cockpit. The capabilities of different indicators are described together with their limitations.

## BACKGROUND

Flight inspection of ground based navigation aids like VOR, TACAN, NDB, DME, MKR and ILS require to fly special inspection procedures. Some of these procedures are difficult to intercept and fly using standard cockpit instrumentation because the navaid itself does not provide the information to follow the procedure.

High accuracy and repeatability of flight inspection data can only be obtained if the procedures are flown precisely.

Modern flight inspection systems are based on highly accurate 3D-Reference Position Systems and use an internal Facility Database containing precisely surveyed navaid locations for evaluation of navaid errors.

The highly accurate Reference Position System and the Facility Database allow to calculate FMS-like flight guidance data for visualization in the cockpit and even for using the autopilot for automatic track keeping along any flight inspection procedure independent from ground based navaids. Beside improved accuracy of the flight inspection measurement it allows to minimize costly flight time by avoiding detours to the procedure's start point and reducing the risk for repeating a procedure caused by unacceptable deviations from the nominal procedure track.

## SUBJECT

Typical Flight Inspection procedures for inspection of En-route Navaids and Landing Aids are: Orbit, Partial Orbit (Arc), Radial, Level Run, Approach and Offset Approach. The task of flying an inspection procedure can be separated in two parts:

1) Intercepting the procedure's start point
2) Keeping track on the procedure

FIS guidance during both parts of the flight inspection task reduces flight time and improves repeatability of the measurements.

### Solutions for Guidance Indicator

For visualization of FIS guidance a suitable indicator is required in the cockpit. The requirements for such an indicator are:

1) Certified for cockpit installation
2) Minimum space consuming
3) Capabilities for guidance along all types of flight inspection procedures and their intercept
4) Easy to interpret (typical cockpit instrument)
5) Readable under sunlight conditions

The use of TSO'd equipment is preferred to avoid high certification costs.

## FIS-Guidance on cross pointer

Most of the flight inspection system in use today provide only very simple flight guidance using an additional installed dedicated FIS-cross-pointer indicator:

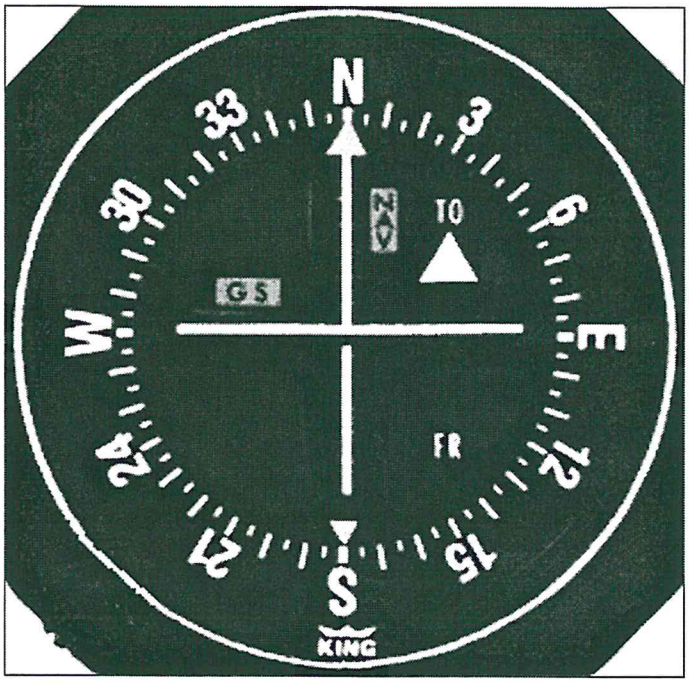



**Figure 1: Analog Cross Pointer**

The cross pointer can indicate only two parameters:

1) Lateral Deviation
   (with flag/status)
2) Vertical Deviation
   (with flag/status)

The deviation data indicated on the cross pointer is direct analog VOR/ILS-receiver output. Some flight inspection systems can apply +/- 75 µA offsets to the deviations to allow to fly offset approaches with needles centered. For orbit procedure guidance some systems can indicate "Deviation from DME-Range" for Orbit/Partial Orbit procedures.

Advantages:

- Very simple
- Allows to fly offset approaches with needles centered

Disadvantages:

- Additional space in cockpit required for indicator
- If offsets are applied to one of the primary VOR/ILS receiver: no receiver redundancy is available during offset approaches in the cockpit.
- No sufficient guidance for orbit/partial orbit procedures
- No guidance to intercept the desired start point of the procedure
- No information about the Desired Track/Course
- No distance information (start point, stop point, threshold, station)
- No bearing information (station under inspection)
- No graphical representation of the desired procedure
- High workload for pilots and FIS-operator: Missing information must be exchanged by voice between FIS-operator and pilots.

The number of disadvantages raise the demand for improvement:

## FMS-like FIS-Guidance on EFIS

Modern Flight Inspection Systems are based on highly accurate multi sensor 3D-Reference Position Systems. Together with the internal Facility Database the FIS can calculate complex synthetic FMS-like flight guidance for intercepting and track keeping of the desired flight inspection procedure. Some big advantages compared to receiver based guidance come along with this:

- The guidance can follow any procedure independent from ground based navaids
- The guidance allows to follow exactly the nominal procedure even if the ground navaid is misaligned or can not be received (out of coverage).
- Bearing and distance information is available for any station (bearing to DME, distance to NDB etc.)

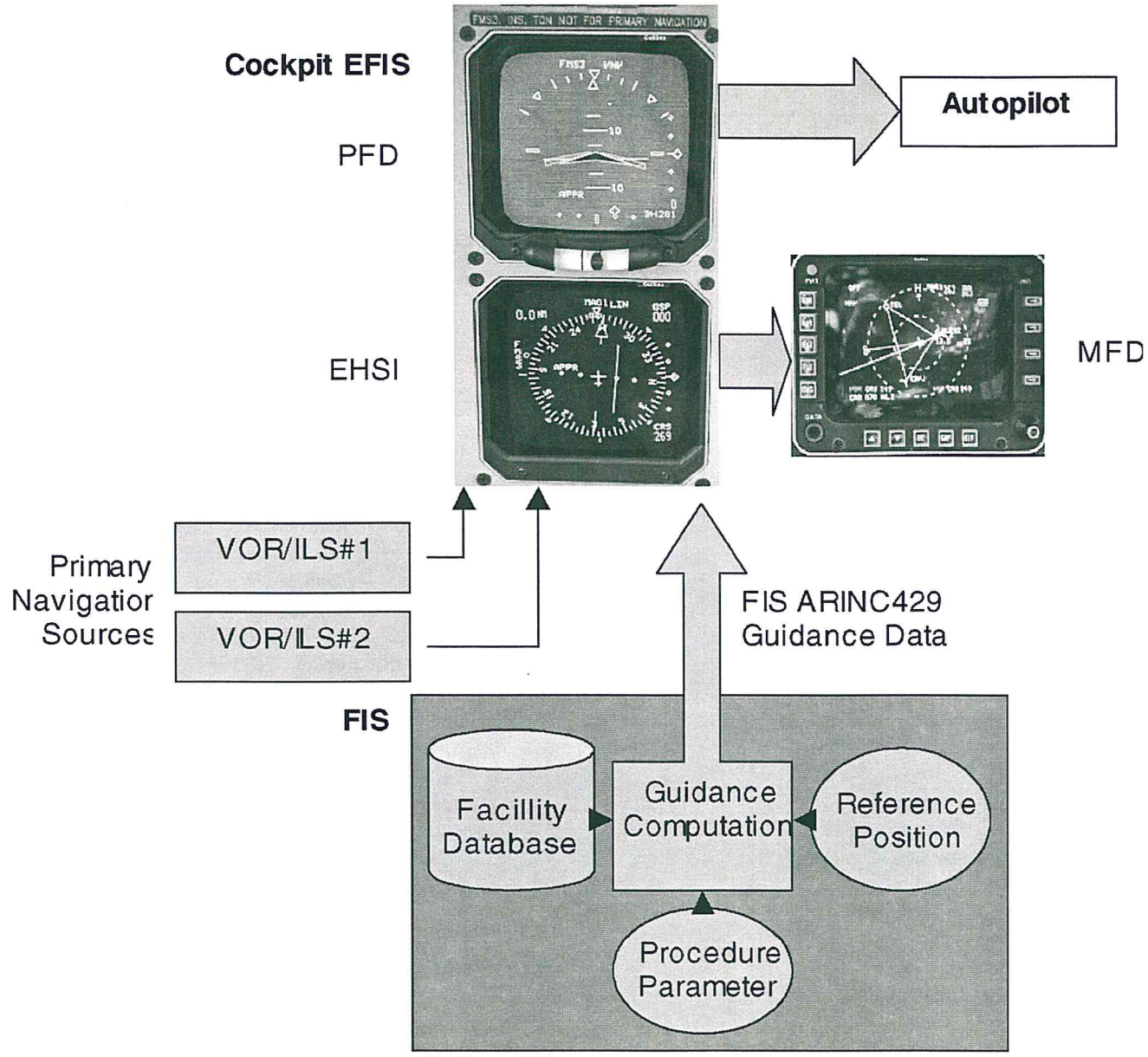
An Electronic Flight Instrument System (EFIS) is standard cockpit avionic of new aircrafts today. Typical displays of a EFIS are: Primary Flight Display (PFD), Electronic Horizontal Situation Indicator (EHSI) and Multi Function Display (MFD). Instead of using an additional FIS-indicator, this primary Electronic Flight Instrument System can be used for indication of the FIS-guidance. The FIS is connected to the EFIS as an additional navigation source and can be selected for navigation by the pilot (e.g.: "FMS3").

The autopilot is connected to the EFIS and can be coupled to the selected navigation source.

This allows automatic autopilot controlled intercept and track keeping of flight inspection procedures.

If no primary EFIS is installed a small dedicated FIS-EFIS instrument (e.g. Honeywell KI 825), with the dimensions of a cross pointer is installed. In this case the autopilot is directly steered by the FIS.

The EFIS receives all guidance data from the FIS via a digital ARINC429 bus which requires only one twisted pair wiring between FIS and EFIS.




**Note:**
**FIS Guidance is not for IFR navigation. Mission safety must be maintained by other means of navigation at all times.**

**Figure 2: Blockdiagram**

## EFIS Capabilities

An EFIS provides capabilities for complex flight guidance during intercept and the procedure itself:

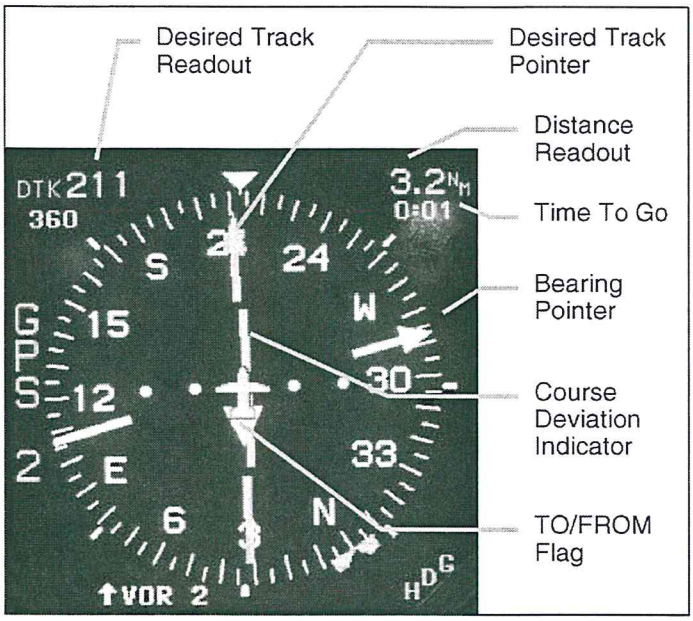



**Figure 3: EHSI in HSI mode**

Typically an EFIS provides the following indicators together with flag/status information:

- Compass Rose (Heading)
- Desired Track / Course pointer
- Desired Track readout
- Course Deviation indicator
- Vertical Deviation Indicator
- Bearing Pointer
- Distance Readout
- Time To Go readout

All indicators can be used by the FIS for guidance during intercept and along the procedure.

Depending on the EFIS and its mode of operation different indicators are displayed on the PFD, EHSI and MFD. An EFIS further allows to display flight plans in map- or arc mode:


**Figure 4: EHSI in Map-Mode with flight plan**

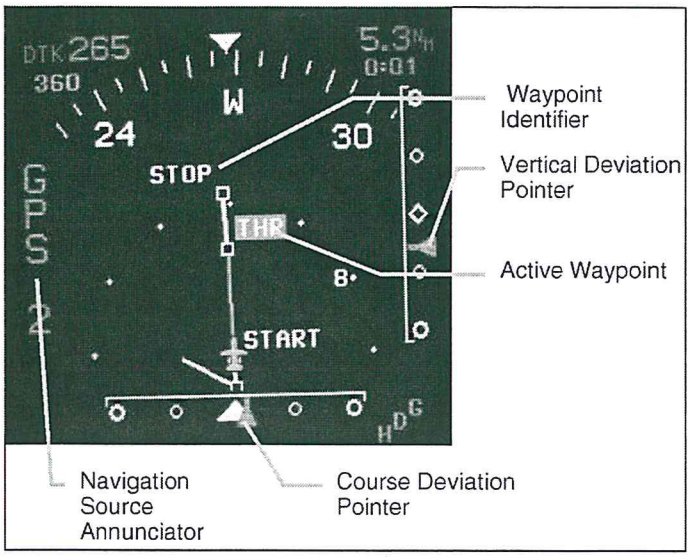



**Figure 5: EHSI in Arc-Mode with flight plan**

For graphic representation of the desired flight inspection procedure the FIS generates a synthetic flight plan based on the following waypoints:

1) Aircraft position in the moment when procedure is activated; not labeled
2) Initial Fix: for easy intercept of the procedure. Labeled:
   a. IOF: Initial Orbit Fix
   b. IRF: Initial Radial Fix
   c. IAF: Initial Approach Fix
3) Start point: Corresponding to procedure set up by FIS operator; labeled: START
4) Intermediate waypoints; not labeled.
5) Stop point: Corresponding to procedure set up by FIS operator; labeled: STOP

## Procedure set up on the FIS

In preparation of a flight inspection procedure, the operator of the FIS defines the inspection procedure by selecting the navaid to be inspected and the type of measurement. A graphical user interface (GUI) allows to modify suggested procedures parameters. For ILS approaches the suggested settings reflect the requirements for the ILS category (CAT I, CAT II and CAT III).

Several procedures can be set up in advance. Each prepared procedure appears in a flight list on the GUI of the FIS. The FIS operator can freely rearrange the order of procedures or can repeat procedures without filling out the procedure definition dialog again.

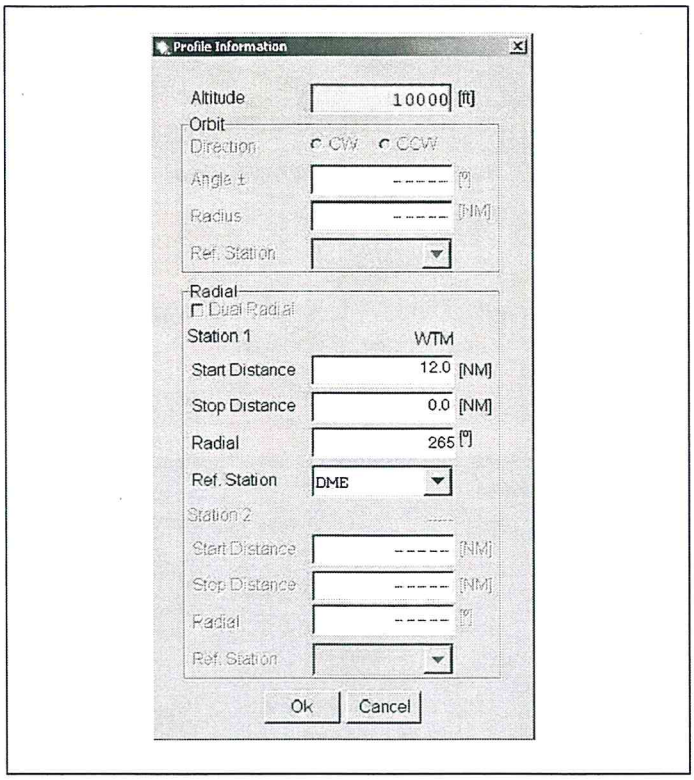



**Figure 6: Procedure Definition with FIS**

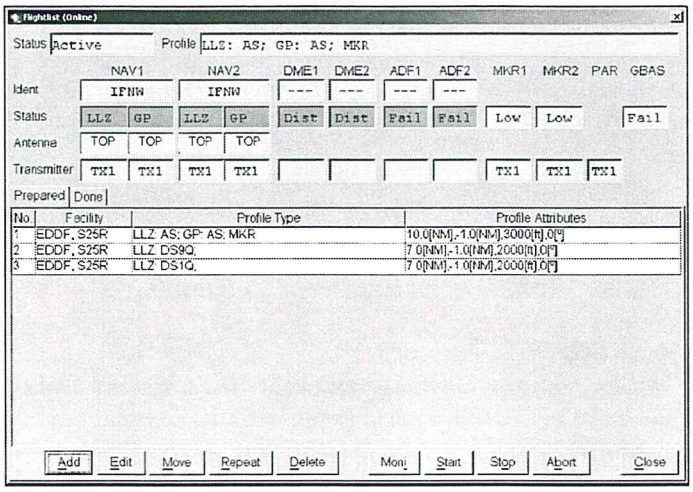



**Figure 7: Flight List with procedures**

## Calculated Guidance Data

The following describes the guidance data that is calculated automatically by the FIS depending on the selected inspection procedure.

### Intercept

The intercept is used to guide the aircraft from its present position to the start point of the measurement procedure. To make sure that the aircraft is established on the procedure when over-flying the desired start point an additional initial fix waypoint is calculated by the FIS. During intercept the guidance leads to this initial fix. The following data is available during this phase:

- Desired Track to initial fix
- Cross Track Distance
- To/From indication
- Bearing to initial fix
- Distance to initial fix
- Time to initial fix
- Graphical representation of procedure as flight plan

After passing the initial fix, guidance along the procedure begins:

Orbit / Partial-Orbit
During Orbit/Partial Orbit the flight guidance consist of:

- Desired Track
  (tangent to orbit; continuously changed)
- Cross Track Distance to Orbit
- To/From indication
- Bearing to Station
- Distance to End of procedure
- Time to End of procedure
- Orbit flight plan

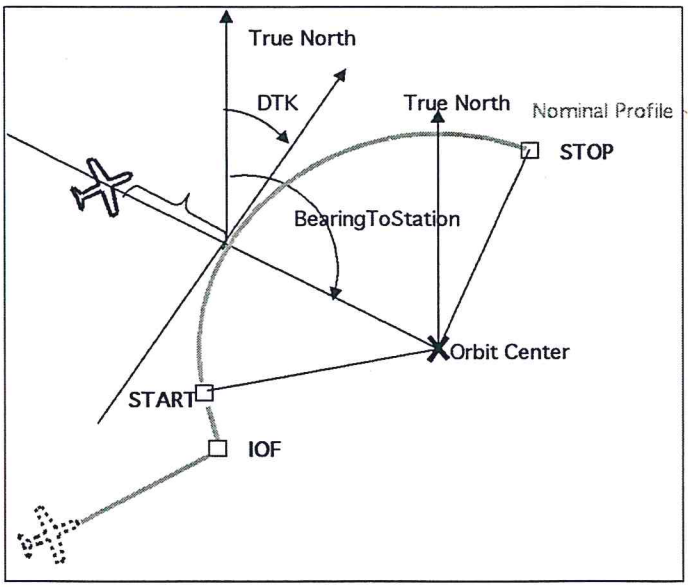



**Figure 8: Guidance for Orbits/Partial Orbits**

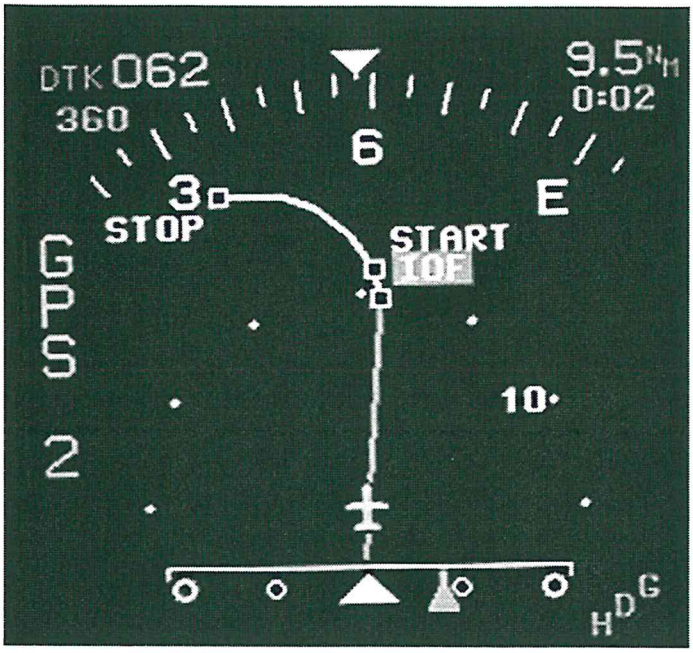



Figure 9: Example: Intercept to Partial Orbit


Figure 10: Example: Orbit Procedure

## Radial/Level Run

During Radial/Level Run procedures the flight guidance consists of:

- Desired Track (Radial/Level Run Course)
- Cross Track Distance
- To/From indication
- Bearing to Station
- Distance to Station/End of procedure
- Time to Station/End of procedure
- Radial/Level Run flight plan

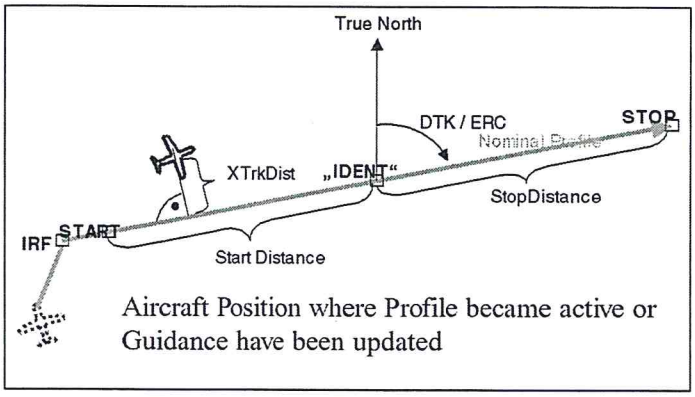



Figure 11: Guidance for Radials/Level Runs

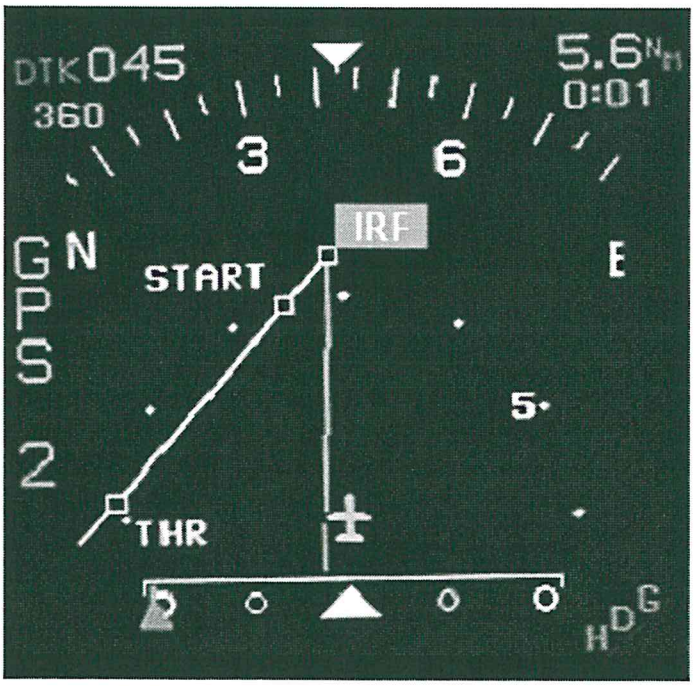



Figure 12: Example: Intercept to Radial

Approach/Offset-Approach

During Approaches/Offset Approaches the following flight guidance is calculated corresponding to the internal facility database:

- Approach Course (Runway orientation)
- Calculated Localizer Deviation to nominal approach (including offset in case of offset approach)
- Calculated Glideslope Deviation to nominal approach (including offset in case of offset approach)
- Bearing to Threshold
- Distance to Threshold/end of procedure
- Time to Threshold/end of procedure
- Approach flight plan

The nominal approach includes offsets in case of offset approaches. Needles are centered when the aircraft is on approach/offset approach.

To highlight the different modes of the Course deviation indicator (linear Cross Track Distance and angular Localizer

Deviation) the indication appears in different colors depending on the current mode.

When the aircraft descents below a minimum height for safety reasons the vertical guidance is set invalid. The lateral guidance remains valid and guides the aircraft to the stop point corresponding to procedure set up by FIS operator.

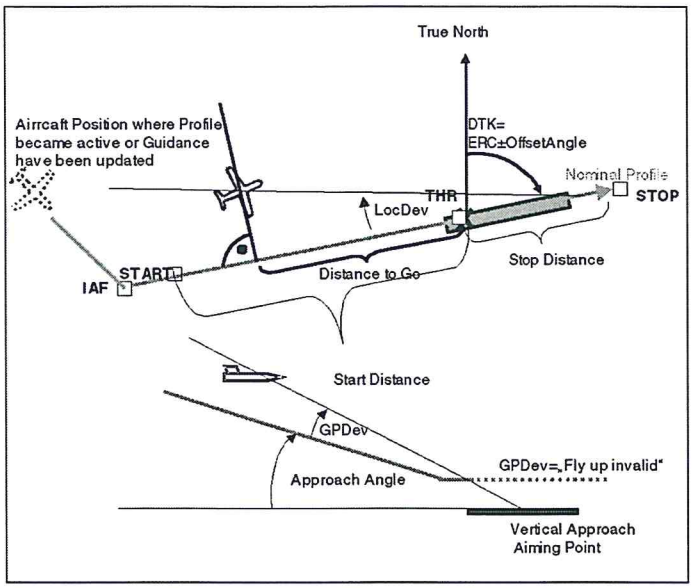



**Figure 13: Guidance for Approaches**

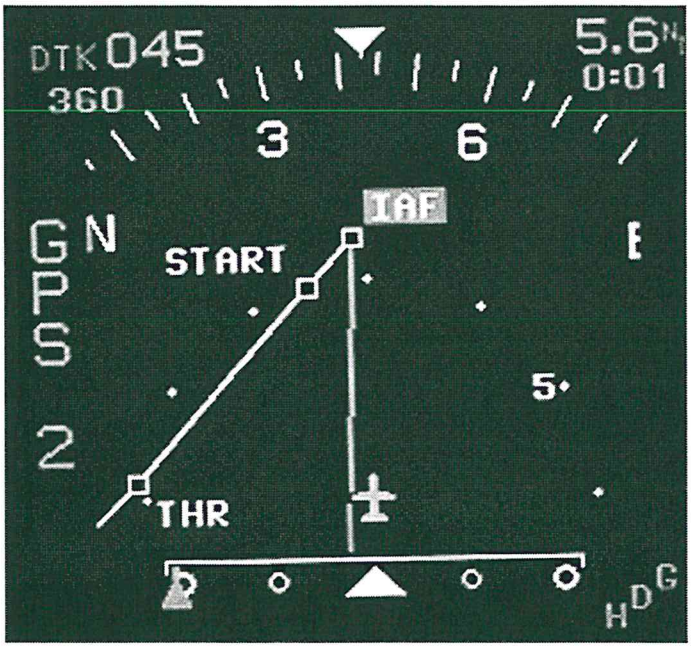



**Figure 14: Example: Intercept to Approach**

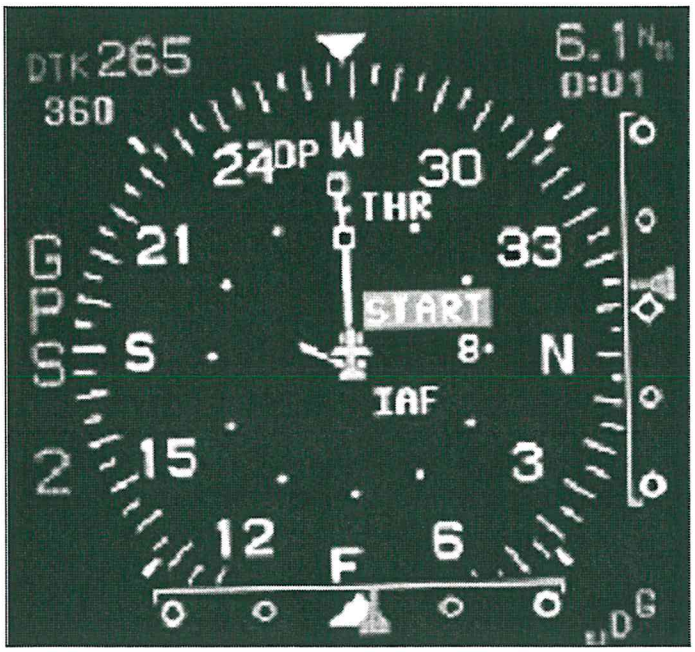



**Figure 15: Example: Approach**

## CONCLUSIONS

Flight guidance for intercept directly saves flight time by avoiding detours. Guidance along flight inspection procedures is required for accuracy and repeatability of measurements and results.

An analog cross pointer does not provide guidance for intercepting the procedure and does not provide sufficient guidance for flight inspection procedures.

The primary EFIS or an alternatively additionally installed FIS-EFIS offer a large set of functionality that can be used for detailed guidance information in the cockpit.

The guidance shall not replace a detailed pre-flight briefing but allows pilots and FIS operator to crosscheck the current procedure. The FIS guidance is not for IFR navigation. Mission safety must be maintained by other means of navigation at all time.

Complex Flight guidance and autopilot coupling for flight inspection procedures visualized by EFIS helps to save costly flight time. It reduces the workload for pilots and FIS operators.

## REFERENCES

[1] Honeywell, Pilot's Guide, KI825, 2002

[2] ICAO Annex 10

[3] ICAO Doc 8071

[4] ARINC 429 Mark 33 Digital Information Transfer System (DITS)