Brief Introduction to Flight Management Systems

Flight Management Systems (FMS) are able to compute all relevant aspects of an entire flight using navigation and performance databases stored in the unit as well as pilot entered data. Pilots interact with the system by using one to three identical Multipurpose Control and Display Units (MCDU).

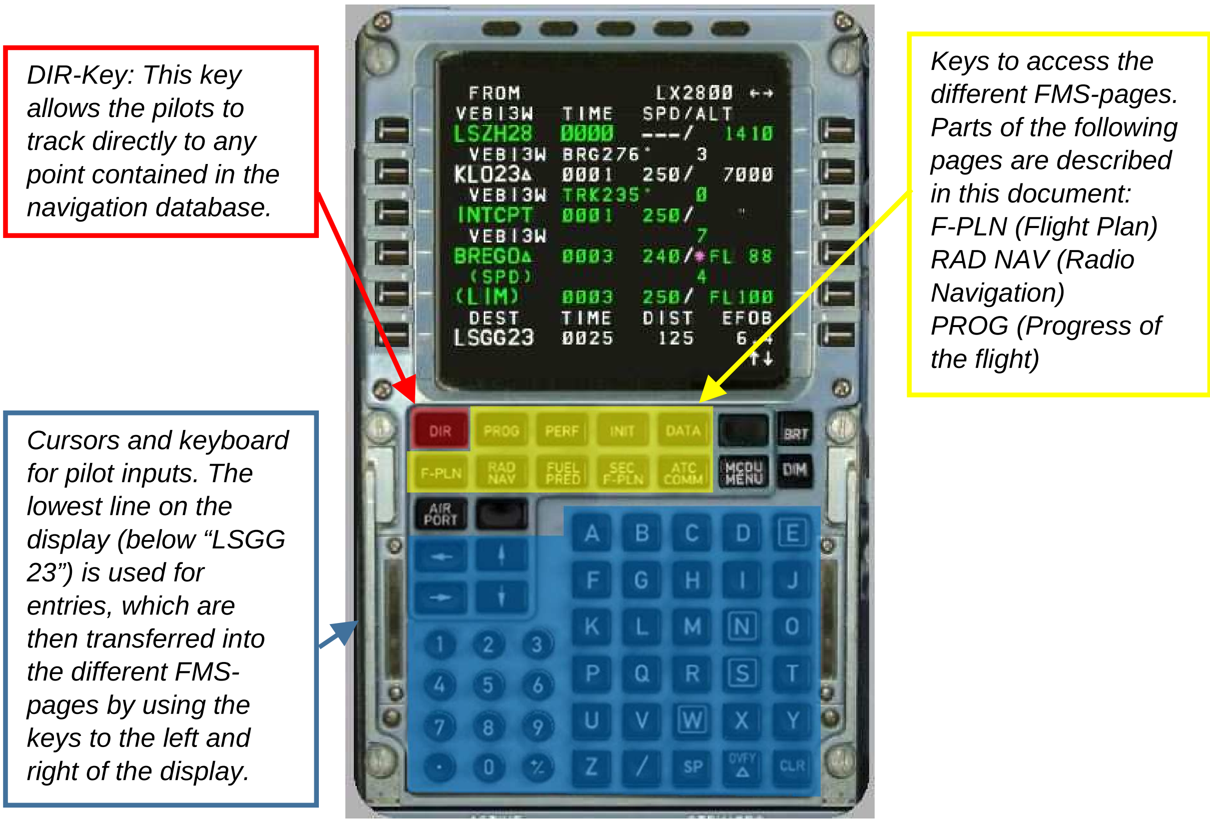


Fig. 1: Overview of the Multipurpose Control and Display Unit (MCDU) used in the Airbus A320.

F-PLN page: This page contains the entire flightplan from the departure to the landing runway, in this example Zurich's runway 28 (LSZH28) to Geneva's runway 23 (LSGG23). At each waypoint, an estimated time of overflight, the expected speed, the estimated altitude and the estimated remaining fuel on board is calculated, considering navigational as well as performance and weather data. Pilots can adapt the flightplan by entering e.g. a new waypoint in the bottom display line and then entering it into the existing flightplan by using the keys to the left of the display.

INIT page 1: Used for initialization of the system before the flight, this page contains basic data like departure and destination airport, flight number, cost index to be used, planned cruising flight level, wind and weather data.

INIT page 2: Zero fuel weight and the corresponding center of gravity position as well as fuel figures (block fuel, taxi fuel, reserve fuel) are inserted here.

Fig. 2: FMS flightplan and initialization pages.

Navigation functions of the FMS

Modern aircraft are still able to navigate using the techniques developed in the early days of instrument flying. By tuning ground based navigation aids (VORs and NDBs) according to airways depicted on maps, radials to or from a station are indicated on the pilot's navigation display and can be followed using autopilot basic modes – heading-mode in lateral and vertical speed in vertical direction. Today, this kind of flying is used in case of technical failures only. As constant re-tuning of navigation aids as well as manual corrections for wind influence are required, a high workload for the pilots results.

Ground based navigation aids (VORs and NDBs) are tuned on the RAD NAV page by inserting their three-letter codes. Frequencies are contained in the database and are automatically tuned by the FMS. A radial (CRS) can be inserted if required.

The pilot's navigation displays can be set up in order to show a classic HSI-layout.

Fig. 3: Use of ground based navigational aids.

Pilot's tasks are significantly reduced by the FMS: Its database contains all airports, navigation aids and waypoints (points set at arbitrary coordinates) and is able to calculate an entire route from a departure airport via waypoints to the destination. Details like intercept procedures when overflying a waypoint, wind corrections or entering and flying a holding pattern considering the actual aircraft speed and even automatic tuning of frequencies for approach navigation aids (VOR, ILS) are performed automatically by the FMS.

Due to intense traffic in terminal areas of important airports, precise lateral navigation alone is not enough to separate the aircraft in an efficient manner. Departure and arrival procedures often contain altitude and speed constraints at certain points, which are either programmed in the FMS database or can be entered manually by the pilots. Considering all constraints, the FMS then computes a three dimensional flightpath and automatically adjusts the target speed if required. These signals are sent to the flight director and to the speed indication/autothrottle system and are followed by the autopilot.

Altitude (below the line ALT CSTR) and speed constraints (below the line SPD CSTR, empty in this example) can be programmed at any waypoint in the flightplan. They are displayed in magenta on both the MCDU-display as well as the navigation display (e.g. flight level 150 at waypoint "TIGER" and 250 knots at waypoint "BIG12"). The FMS calculates its three dimensional flight path in order to respect all constraints as long as aerodynamically possible.

Fig. 4: Altitude and speed constraints

Furthermore, flight management systems are able to perform four dimensional navigation. Pilots can enter a target time at a specific waypoint (e.g. the point where they start their final descent and approach), leaving the task of adjusting the speed to the FMS (within the aerodynamic capabilities of the aircraft). This method could help to reduce delays and holding times, however, it is seldom used in the current air traffic control environment.

Performance functions of the FMS

Due to economic and ecologic reasons, fuel saving is of utmost importance in today's airline business. Optimum speeds during all phases of a flight depend on aircraft mass and wind conditions as well as on the relationship between fixed costs (e.g. crew or maintenance costs, depreciation of the aircraft) and fuel costs, which is modelled using a so called Cost Index in modern aircraft. Final approach speeds depend on mass and actual winds and need to be calculated for each approach. All of these computations could be performed manually, using the performance tables provided by the manufacturer. However, to relieve the pilots from such time consuming routine tasks, the FMS contains the aircraft's performance data, enabling it to optimize the flight profile. Speeds are computed as well as the optimum altitude (again depending on aircraft mass and wind) and the top of descent (point at which to start the descent to allow for an economic approach) and subsequent descent profile.

The PROG page (progress of the flight) shows the actual (CRZ), the most economic (OPT) and the maximum (REC MAX) cruising altitude. These values are continuously updated.

In order to allow an efficient descent and approach, the FMS computes a top of descent (white flash at waypoint "VEBIT") and from there on an altitude profile to the landing runway.

Fig. 5: Examples of FMS optimization functions.

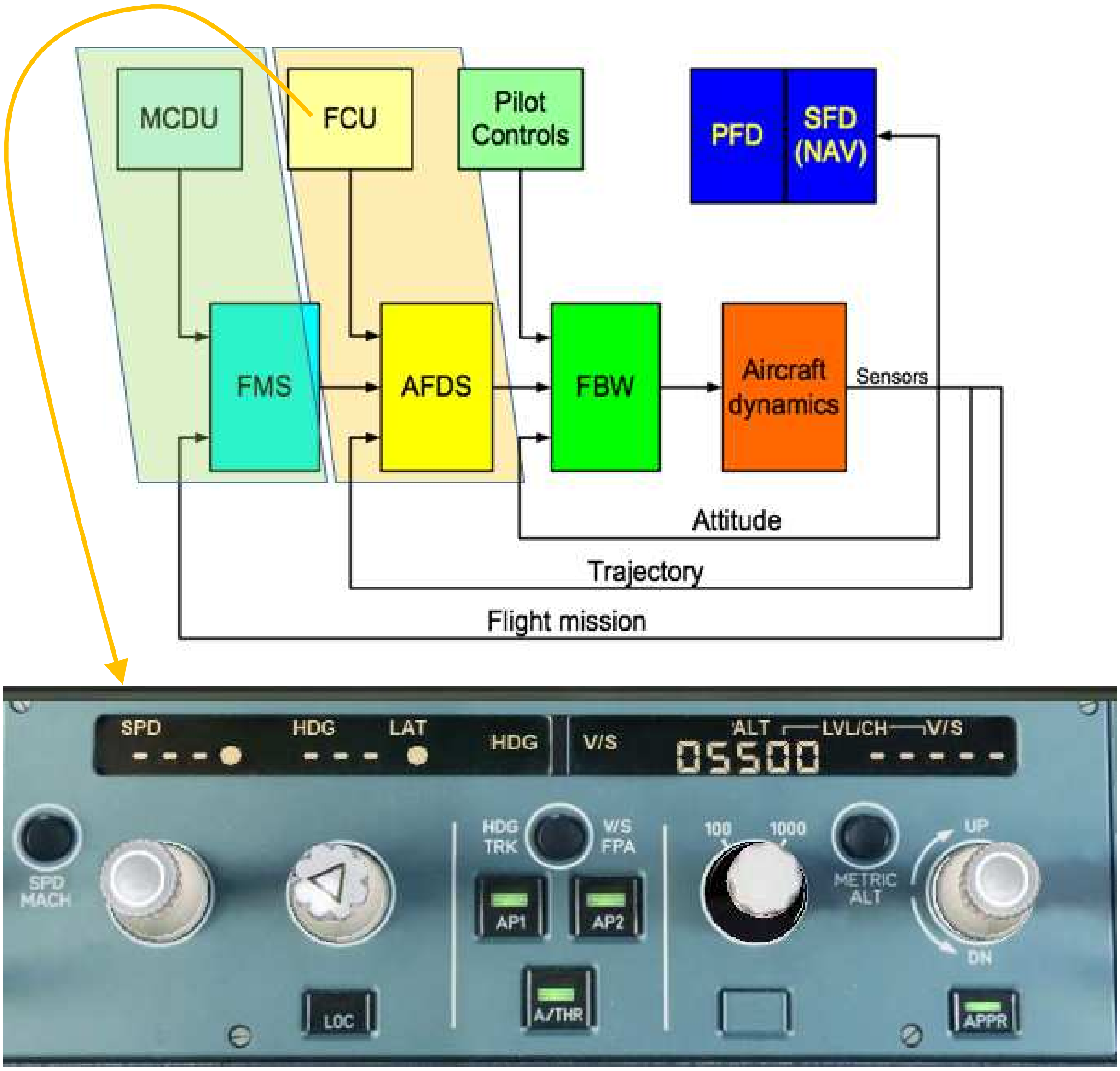
General considerations

Contrary to the paragraphs above, the distinction between navigation and performance functions of the FMS is not entirely precise and visible to the pilots, they handle the system as one unit. If traffic permits, air traffic control often allows pilots to fly shortcuts, dropping a few waypoints from the flightplan. Even though such "direct to" commands are obviously navigational tasks, there might be an impact on the performance as well (e.g. different wind component due to heading change leading to an adjusted cruise speed). Vice versa, a change in cruising altitude will affect speed and therefore flight time to all subsequent waypoints.
One of the most important tasks performed by the FMS is the continuous calculation of the fuel remaining on board at every waypoint and at the destination airport. Both performance values and the programmed flight route contribute to these figures.

Despite all advantages of modern flight management systems, there are a few drawbacks:

- Programming of the system takes some time, most of it needs to be completed before departure.
- Data inserted need to be precise. Wrong input e.g. of winds on the route lead to inaccurate predictions of time and fuel consumption.
- Inputs to the FMS are made using the MCDU. This unit is positioned on the central pedestal of the flight deck and requires the pilot to look down and to his side, loosing continuous watch on the primary flight displays and/or outside reference. Each input on the MCDU consists of several key strokes, making it error prone when under time

pressure.
The FMS is well suited for strategic and long term inputs and calculations. However, it is hard or even impossible to perform (unexpected) short term actions or air traffic control orders like heading changes or speed reductions with immediate effect using the FMS. To handle this type of instructions, pilots use the Flight Control Unit (FCU) which directly influences the Autopilot and Flight Director System (AFDS), disabling the FMS from its navigational duties.
It is important to highlight that in any aircraft at any time the FMS may be overruled using FCU and AFDS or by flying the aircraft manually using the pilot controls.



The FMS is well suited for long term planning and inputs. In case of sudden changes or technical malfunction it can always be overruled by taking over command through the Flight Control Unit (FCU) or by disengaging the autopilot. Using the FCU, inputs to speed, heading, altitude and vertical speed can be done with immediate effect.

Fig. 6: Flight Control Unit (FCU) vs. FMS