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Flight Management System (FMS)

RATIONALE

This ARP was significantly revised to incorporate changes to flight management system technology, such as new variants in global satellite navigation systems; references to outdated technologies and terminology have been deleted.

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Documents

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1. SCOPE

This document recommends criteria and requirements for a flight management system (FMS) for transport aircraft.

The FMS shall provide the functions of lateral navigation, vertical navigation, and performance management and may include time of arrival control. The FMS design shall take human factors considerations into account to produce a fault tolerant system.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

ARP4102/9 should be used in conjunction with the ARP4102 core document.

2.1.1 SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

- ARP4102/4 Flight Deck Alerting System (FAS)
- ARP4102/6 Communications and Navigation Equipment
- ARP4102/7 Electronic Displays
- ARP4103 Flight Deck Lighting for Commercial Transport Aircraft
- ARP4105 Abbreviations, Acronyms, and Terms for Use on the Flight Deck

2.1.2 Other Publications

- ARINC 424 Specification Navigation Systems Data Base
- ARINC 702-6 Flight Management Computer System
- RTCA DO-187 MOPS for Airborne Area Navigation Systems Using Multi-Sensor Inputs
- ICAO Annex 4 International Civil Aviation Organization, Annex 4 to the Convention on International Civil Aviation

2.2 Definitions

APPROACH GATE: A point on the final approach track representing the minimum distance from the threshold at which vectored or instructed aircraft should intercept the final course. This normally will be 1 nm outside the final navaid or 5 nm from threshold, whichever is greater.

BASIC NAVIGATION: Course, track, path, profile, and several related terms are defined below. Recent navigation systems have tended to discard the term “course” in favor of “track,” but still show track in angular terms. In the following definitions, great circle course and desired track angle are equivalent. Track has also been applied to the vertical plane when prefixed by “vertical” (i.e., vertical track, etc.). However, the terms “path” and “profile” are preferred as representing an earth referenced three-dimensional path in the sky (altitude, latitude, and longitude).

BOTTOM OF DESCENT (BOD or B/D): The last waypoint in the decent flight phase. See also end of descent (EOD).

CLEAR (CLR): A CDU term usually associated with the “clear key.” Pressing the clear key erases a previous entry in the scratch pad field (typically last line of the display).

CLIMB INTERCEPT POINT: The geographical position at which a designated climb altitude is attained, also referred to as “top of climb” point.

CONSTRAINT (CSTR): A speed or altitude or time restriction or restraint usually related to some downstream waypoint.

CONTROL DISPLAY FUNCTION (CDF): The FMS function that allow the flight crew to interact with the FMS through data entry and display of information. In current systems, this function is provided by the CDU, MCDU, MCP, and various displays and status panels. In future systems, the control and display function may be allocated to different hardware devices. For example, a key pad and pointing device may be used for data entry and to interact with a graphical user interface display (GUI) on the main flight displays.

CONTROL DISPLAY UNIT (CDU): In current systems, this is a hardware device which allows the pilot to interface with the FMS and other systems for the purpose of displaying alpha numeric information, data entry, mode selection, and alerting. See also multifunction control display unit and control display function (CDF).

COST INDEX (CI): The operator's cost factors for a specific flight that takes into account variable costs, such as fuel, and time related costs, such as crew flight time pay to achieve the desired flight profile.

COURSE (CRS): The direction of horizontal travel, expressed as a clockwise angle from a reference direction (usually true or magnetic north).

CROSS TRACK DISTANCE/ERROR/DEVIATION (XTK/XTE): The shortest distance between the aircraft's present position and the desired track. Cross track distance is left when present position is left of the desired track and right when present position is right of the desired track.

DEFAULT: A CDF term associated with applying a pre-stored input to a data field or computation if no other value is entered by the pilot.

DELETE (DEL): A CDF term associated with deleting an item or an entire line.

DESCENT INTERCEPT POINT: The geographical position where the cruise path intersects the descent path. Also referred to as the top of descent point. Signifies the geographic position where the aircraft transitions from the cruise flight phase to the descent flight phase.

DESIRED TRACK: The imaginary line on the earth's surface connecting successive points over which flight is desired.

DESIRED TRACK ANGLE (DTK or DSRTK): The clockwise angle from true or magnetic north to an imaginary line or path on the earth's surface. This line describes the great circle path between two successive waypoints on the earth's surface and is also defined by the intersection of a plane that passes through two successive waypoints on the earth's surface and the center of the earth.

DISTANCE (DIST or DIS): The great circle distance between designated positions, points, or waypoints.

DISTANCE TO GO (DTG): The great circle distance between the present position and the “TO” waypoint or the cumulative distance between the present position and a designated downstream waypoint or waypoints.

DRIFT ANGLE (DA): The angle between the aircraft’s longitudinal axis and ground track or the angular difference between true heading and ground track angle. Drift angle is left when ground track angle is less than true heading and right when ground track angle is greater than true heading.

EARTH REFERENCE OR INERTIAL: Referenced with respect to the earth, as opposed to referenced with respect to the air mass.

ECONOMY (ECON): A FMS designation implying a favorable “economic” mode of operation. The term has been variously applied to min cost climb, cruise, and descent schedules and engine climb de-rate schedules.

END OF DESCENT (EOD or E/D): The metering fix, clearance, or other scheduled end point for the main descent from enroute cruise. If a level flight deceleration segment is programmed at the end flight level, the EOD will be the downstream end of that segment. The EOD includes a geographical position, altitude, and speed. It may also include a required or estimated time of arrival. See also bottom of descent (BOD).

EXECUTE (EXEC): A CDF term usually associated with safeguarding by requiring a second confirmatory action.

FLEXIBILITY (TIME): A term representing the FMS range of control over arrival time at a designated downstream waypoint or waypoints. It may be expressed as an RTA maximum and RTA minimum in respective UTC hours: minutes: seconds.

FLIGHT CONTROL PANEL (FCP): Provides control functions for the flight director, auto pilot, auto throttle (flight guidance system) and the flight management system. Referred to as the mode control panel (MCP) on some aircraft.

FLIGHT MANAGEMENT COMPUTER (FMC): The FMC is the hardware element of the FMS that hosts the flight management function.

FLIGHT MANAGEMENT FUNCTION (FMF): The FMF is a function that computes the aircraft navigation solution, predicts the performance of the aircraft along a defined lateral and vertical flight plan path, and provides guidance information to the flight guidance system to control the aircraft to fly along that path. On many systems the FMF is hosted in a flight management computer and uses a control display unit for data entry and display. On newer, federated systems, the FMF may be only one of many software components that not only provide flight management, but also engine, airframe, environmental, and other management functions.

FLIGHT MANAGEMENT SYSTEM (FMS): The FMS is the combination of hardware and software that is required to perform the Flight Management Function.

FLIGHT PATH ANGLE (FPA): The angle in the vertical plane between the horizon and the aircraft’s flight path or velocity vector. The normal usage implies current angle. The velocity vector may be referenced to either the air mass or the earth in which case the FPA is either air mass or earth referenced (inertial).

FLY-OVER WAYPOINT: Fly-over waypoints are used when the aircraft must fly over the point prior to starting a turn.

FOUR DIMENSIONAL CONTROL (4D): Control of an aircraft in the dimensions of latitude, longitude, altitude, and time.

FUNCTIONS: Those features which individually or collectively define the operating modes of the FMS. These functions are described in 3.2.

GLOBAL POSITIONING SYSTEM (GPS): A space based satellite navigation system that provides accurate 3 dimensional position and time anywhere in the world.

GRAPHICAL USER INTERFACE (GUI): A methodology for control and display of information on a graphical display using a pointing device to select and act on displayed information.

GREAT CIRCLE COURSE (CRS): The direction of the great circle through the point of departure and the destination expressed as a clockwise angle from a reference direction (usually north) to the great circle. The angle varies from point to point along the great circle.

GROUND TRACK/ACTUAL TRACK: The imaginary line or path on the earth's surface connecting successive points over which the aircraft has flown.

GROUND TRACK ANGLE/ACTUAL TRACK ANGLE (TRK or TK): The clockwise angle from true north to an imaginary line on the earth's surface connecting successive points over which the aircraft has flown (ground track). The normal usage implies present track angle, i.e., using the most recent successive points over a relatively short period of time.

GROUND PROXIMITY WARNING SYSTEM (GPWS): A device which provides alerts based on altitude above the ground level (AGL), and may provide alerts incorporating configuration, closure rate, or other factors affecting the flight safety related to flight path and altitude AGL. See also terrain awareness warnings system (TAWS).

INS-DEPENDENT: A FMS that is dependent upon the INS for steering guidance.

LATERAL NAVIGATION (LNAV): A function which provides navigation data in the horizontal plane and provides command signals to the roll channel of the flight guidance system and pilots displays.

METERING FIX (MF): The airport arrival flow control points used by Air Traffic Control to meter spacing for landing. Usually associated with a required flight level, speed, and ETA.

MINIMUM ENROUTE ALTITUDE (MEA): The lowest published altitude between radio fixes which assures acceptable navigational radio coverage and meets the obstacle clearance requirements between those fixes. This minimum altitude applies to the entire width of the airway segment or route between the radio fixes.

MINIMUM SECTOR ALTITUDE (MSA): The minimum altitude that is allowed in defined sectors in the terminal area to clear obstacles.

MINIMUM VECTOR ALTITUDE (MVA): The minimum altitude that is allowed in the terminal area to clear obstacles while the aircraft is being given radar vectors by ATC.

MODE CONTROL PANEL (MCP): Provides control functions for the flight director, auto pilot, auto throttle, flight guidance system, and the flight management system. Referred to as the flight control panel (FCP) on some aircraft.

MULTI-FUNCTION CONTROL AND DISPLAY UNIT (MCDU): A device which allows the pilot to interface with the FMS and other systems for the purpose of displaying alpha numeric information, data entry mode selection, and alerting.

NAVAID: A general term for ground based VHF enroute and terminal navigation aids including VOR, VOR/DME, VORTAC, DME, and low frequency beacons. Landing systems such as ILS and MLS and space based systems such as GPS, GNSS, GLONAS. are usually not included.

NAVIGATION DATABASE (NDB): The flight management system (FMS) database that contains information that will enable the aircraft to navigate along the enroute airways waypoints and airport terminal procedures that are specified in the flight plan. This database can be tailored for the geographic area and airports where the aircraft is expected to operate. The NDB is typically stored in a semi-permanent memory device so that it does not need to be reloaded each time power is applied to the FMS. This data base needs regular 28 day updates in conjunction with ICAO Annex 15 Chapter 6 Aeronautical Information Regulation and Control (AIRAC).

OPTIMUM ALTITUDE: The most economical altitude to fly based on gross weight, cost index, and trip length.

PERFORMANCE MANAGEMENT (PM): Systems which provide guidance signals to control the aircraft in climb, cruise, and descent to achieve optimum or desired performance (minimum cost, minimum fuel, select IAS/Mach, maximum gradient, etc.). These guidance signals may be directed to the flight guidance system pitch channel, auto throttles, and pilot displays.

PERFORMANCE FACTORS: Factors computed or applied to basic performance representing individual aircraft variance with the standard. It may be expressed as a percentage drag factor, fuel factor, or be combined with specific fuel consumption (SFC). Performance factors may also represent an assigned minimum maneuver margin (buffet boundary) or minimum climb and cruise rate of climb.

PRESENT POSITION (PPOS): The latitude and longitude coordinates of the point on the earth's surface directly below the aircraft at any given instant. May also be three-dimensional, including altitude.

PROFILE PATH: An imaginary earth referenced line in space connecting successive three-dimensional points through which flight is desired and/or controlled (altitude, latitude, and longitude). The flight path angle (see above) may be varying or constant, resulting in a curved or straight lateral or vertical profile.

RNAV: Navigation using an area navigation system or flight management system using one or more navigation sensors to control the aircraft along a predefined flight plan path in the lateral and/or vertical planes depending on the capability of the equipment that is being utilized. This term is currently used interchangeably with LNAV (lateral navigation) and VNAV (vertical navigation).

REQUIRED TIME OF ARRIVAL (RTA): A term associated with 4 dimensional aircraft control to arrive at a given waypoint at a prescribed time. Entry of an RTA implies that arrival at a geographic point in space at a given time is a higher priority than operating the aircraft to achieve optimum fixed or variable costs so the cost index is recomputed to achieve the Required Time of Arrival.

SPEED CLIMB (SPD CLB)/SPEED DESCENT (SPD DES): Vertical modes which maintain an assigned speed (or Mach) usually with the elevator or stabilizer. The throttle/thrust setting may be fixed or variable and may be used independently. These modes may be used independently from lateral navigation.

TERRAIN AWARENESS WARNING SYSTEM (TAWS): A predictive device which utilizes a terrain database and aircraft altitude sensors to alert the crew of impending collision with terrain along the flight path. TAWS is a more general term for ground proximity warning system (GPWS) or enhanced ground proximity warning system (EGPWS).

TIME ERROR: The difference between the current ETA and the required time of arrival (RTA) at any designated downstream waypoint or waypoints.

TIME OF ARRIVAL CONTROL - SPEED MANAGEMENT: The functions which provide guidance for adjusting speed and/or flight path so as to conform with air traffic flow control arrival time requirements at a designated downstream waypoint or waypoints. The flight plan should normally include a specified altitude and an arrival speed. The command signals may be directed to the flight guidance system as well as pilot displays.

TIME TO GO (TTG): The time in min (or min:sec) to fly the great circle course from present position to the next waypoint or the cumulative time between present position and a designated downstream waypoint or waypoints.

TOP OF CLIMB (TOC): A calculated point along the flight plan that predicts the point where the aircraft will reach the cruise altitude and transition from the climb flight phase to the cruise flight phase.

TOP OF DESCENT (TOD or T/D): A calculated point along the flight plan that predicts when the aircraft should start to descend. Denotes the point where the flight phase transitions from cruise to descent.

TRACK ANGLE ERROR (TKE): The angle between the aircraft's ground track and the desired ground track or the angular difference between ground track angle and desired track angle. Track angle error is left when the actual track angle is less than the desired track angle and right when the actual track angle is greater than the desired track angle.

TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM (TCAS): An aircraft system that will alert the flight crew of other aircraft in the area that may present a risk of collision.

VERTICAL BEARING (VBRG or V/B): The angle in the vertical plane between the horizon and a line from the present position in space to the next three-dimensional defined waypoint.

VERTICAL NAVIGATION (VNAV or VN): The function which provides guidance signals to control the aircraft during climb or descent to achieve a FPA, path, or profile with the capability of crossing any downstream waypoint at a designated altitude and/or speed. These command signals may be directed to the flight guidance system pitch channel and auto throttle/thrust as well as pilot displays.

VERTICAL PATH/V PATH/PROFILE: Terms used to designate climb and descent modes which control the vertical trajectory to specific earth referenced paths or profiles which include one or more three-dimensional waypoints (latitude, longitude, and altitude). Usually the path (or profile) is controlled by elevator or stabilizer and the speed by throttles or drag. Other techniques may be used. The path (or profile) may be linear or non-linear.

VERTICAL SPEED/ALTITUDE RATE: The rate of change of altitude. The term usually refers to barometric altitude rate, but may also be radar altitude rate or inertial vertical velocity.

VERTICAL TRACK DISTANCE/ERROR/DEVIATION (VDEV or VTK or VTE): The vertical distance or height between existing altitude and the programmed path or profile altitude.

WIND COMPONENT: The wind component acting along the longitudinal axis of the aircraft. A tailwind is positive.

WIND DIRECTION (WDIR or W/D): The clockwise angle from true north to the wind velocity vector.

WIND PROPAGATION: When the winds at each cruise waypoint in the flight plan have not been entered either manually by the pilot or by datalink (e.g., ACARS) forecast winds uplink the present position instantaneous wind direction and speed is typically used for the calculation of all downstream leg ETEs and ETAs. The ETEs and ETAs are continuously revised as the present position winds change.

WIND SPEED (WSPD or WS): The magnitude of the wind with respect to a point on the earth's surface.

WIND VELOCITY (W/V or WV): The direction and magnitude of the wind velocity vector.

2.3 Abbreviations

4D	Four Dimensional (Latitude, Longitude, Altitude, Time)
ACARS	Airplane Communications Addressing and Reporting System
ADS-B	Automation Dependant Surveillance Broadcast
AIM	Aeronautical Information Manual
AIRAC	Aeronautical Information Regulation and Control
AMI	Airline Modifiable Information
ANP	Actual Navigation Performance
AOC	Airplane Operational Control
ATC	Air Traffic Control
ATS	Air Traffic Services
B/D	Bottom of Descent
BOD	Bottom of Descent
CAS	Calibrated Air Speed
CDF	Control Display Function

CDU	Control Display Unit
CI	Cost Index
CLR	Clear
CPDLC	Controller Pilot Data Link Communications
CRS	Course
CSTR	Constraint
DA	Drift Angle
DIS	Distance
DIST	Distance
DME	Distance Measuring Equipment
DSRTK	Desired Track
DTK	Desired Track
E/D	End of Descent
ECON	Economy
EGPWS	Enhanced Ground Proximity Warning System
EOD	End of Descent
EPR	Engine Performance Ratio
EPU	Estimated Position Uncertainty
ETA	Estimated Time of Arrival
ETE	Estimated Time Enroute
EXEC	Execute
FCP	Flight Control Panel
FMC	Flight Management Computer
FMF	Flight Management Function
FMS	Flight Management System
FPA	Flight Path Angle
GBAS	Ground Based Augmentation System
GLONAS	Global Navigation System
GLS	GPS Landing System
GNSS	Global Navigation Satellite System

GPS	Global Positioning System
GPWS	Ground Proximity Warning System
GRAS	Ground Based Regional Augmentation System
GUI	Graphical User Interface
HUD	Head Up Display
IAS	Indicated Air Speed
ILS	Instrument Landing System
LAAS	Local Area Augmentation System
LNAV	Lateral Navigation
LRC	Long Range Cruise
MB	Marker Beacon
MCDU	Multifunction Control Display Unit
MCP	Mode Control Panel
MEA	Minimum Enroute Altitude
MF	Metering Fix
MLS	Microwave Landing System
MSA	Minimum Sector Altitude
MVA	Minimum Vectoring Altitude
NDB	Navigation Database or Non-Directional Beacon
NM	Nautical Miles
OAT	Outside Air Temperature
PFD	Primary Flight Display
PM	Performance Management
PPOS	Present Position
RNAV	Area Navigation
RNP	Required Navigation Performance
RTA	Required Time of Arrival
SBAS	Space Based Augmentation System
SID	Standard Instrument Departure

SPD CLB	Speed Climb
SPD DES	Speed Descent
STAR	Standard Terminal Arrival Route
T/D	Top of Descent
TACAN	Tactical Air Navigation
TAS	True Air Speed
TAWS	Terrain Awareness Warning System
TCAS	Traffic Alert and Collision Avoidance System
TIS	Traffic Information System
TK	Track
TKE	Track Angle Error
TOC	Top of Climb
TOD	Top of Descent
TRK	Track
TTG	Time To Go
UTC	Universal Time Code or Coordinated Universal Time
V/B	Vertical Bearing
VBRG	Vertical Bearing
VDEV	Vertical Deviation
VHF	Very High Frequency
VN	Vertical Navigation
VNAV	Vertical Navigation
VOR	VHF Omni Range
VS	Vertical Speed
VSD	Vertical Situation Display
VTE	Vertical Track Error
VTK	Vertical Track
W/D	Wind Direction
W/S	Wind Speed
W/V	Wind Velocity