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AEROSPACE RECOMMENDED PRACTICE

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FLIGHT MANAGEMENT SYSTEM (FMS)

1. SCOPE:

1.1 This document recommends criteria and requirements for a Flight Management System (FMS) for transport aircraft.

1.2 The FMS provides the functions of Lateral Navigation, Vertical Navigation, Performance Management and may include Time Control.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this specification to the extent specified herein. The latest issue of all SAE Technical Reports shall apply.

This Annex should be used in conjunction with ARP4102 Core Document.

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

ARP4102/4 Flight Deck Alerting System (FAS)
ARP4102/6 Communication and Navigation Equipment
ARP4102/7 Electronic Displays
ARP4105 Nomenclature and Abbreviations
ARP4103 Instrument and Flight Deck Lighting

2.1.2 FAA Publications: Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591.

FAA Advisory Circular, AC 90-45A

SAE ARP4102/9

2.1.3   Other Publications:

CAA Airworthiness Leaflet, AD/IL/0118/1-19 Flight Management Systems

ARINC 424 Specification Navigation Systems Base

ARINC 702-3 Specification Air Data Systems

RTCA DO-187 MOPS for Airborne Area Navigation Systems using multi-sensor inputs

2.2   Definitions and Abbreviations:

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).

CLEAR (CLR): A MCDU term usually associated with "clearing" or voiding a previous manual entry.

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 AND DISPLAY UNIT (CDU): A device which provides the pilot interface with the FMS for inserting data, controlling and selecting parameters and modes and includes alpha numeric display that permits pilot verification of data.

COST INDEX (CI)/FLIGHT INDEX: The operator's cost factor for that specific flight that takes into account such variables as refueling fuel cost, time of day, gate scheduling, etc.

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.

- 2 -

2.2 (Continued):

DEFAULT: A MCDU term associated with applying a pre-stored "default" input to a selection or computation if no other value is pilot selected.

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

DESCENT INTERCEPT POINT: The geographical position at which a designated descent altitude is attained.

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

DESIRED TRACK ANGLE (DTK) (DSRTK): The clockwise angle from true north to an imaginary line or path on the earth's surface connecting successive waypoints over which flight is desired. This line describes the great circle path between successive waypoints and is also defined by the intersection of a plane and the earth's surface when the plane passes through (2) successive waypoints and the center of the earth. Consequently, DTK is most meaningful when the aircraft position is close to the great circle path defined by the FROM-TO waypoints.

DISTANCE (DIST) (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 accumulative distance between the present position and a designated downstream waypoint or waypoints.

DRIFT ANGLE (DA): The angle between the aircraft's centerline 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 (I): 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 (E/D)/BOTTOM OF DESCENT (BOD (B/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 or BOD will be the downstream end of that segment. The EOD or BOD includes a geographical position, altitude and speed. It may also include a required or estimated time of arrival.

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

2.2 (Continued):

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 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).

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

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) (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.

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

LATERAL NAVIGATION (LNAV) (HNAV): 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. Currently used interchangeably with R-NAV.

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.

MULTI-FUNCTION CONTROL AND DISPLAY UNIT (MCDU): A CDU which, in addition to interfacing with the FMS, exercises control and display over other systems and sensor devices.

NAVAID: A general term for navigation aids including VOR, VOR/DME, VORTAC, DME and Low Frequency beacons.

NAVIGATION DATA BASE: The non-volatile memory which provides the FMS with general airspace and company specific navigation data. This data base needs regular update in conjunction with Aeronautical Information Revision Amendment Cycle (AIRAC).

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

- 4 -

2.2   (Continued):

PERFORMANCE (AND ENERGY) MANAGEMENT (PM): The performance functions including thrust which provides 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 signals may be directed to the flight guidance system pitch channel and auto throttles as well as 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 (PROF)/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 below) may be varying or constant, resulting in a curved or straight vertical profile.

R-NAV - AREA NAVIGATION (Originally Random Navigation): A term currently used interchangeably with LNAV (Lateral Navigation).

REQUIRED TIME OF ARRIVAL (RTA): A term associated with 4D control representing the required ETA or the ETA programmed at a designated downstream waypoint or waypoints.

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 setting may be fixed or variable and may be used independently. These modes may be used independent from Lateral Navigation.

SPEED MANAGEMENT - TIME CONTROL (4D): 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 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. 4D means four-dimensional, i.e., latitude, longitude, altitude and time. An assigned speed at the final (or designated) waypoints is also implied.

TIME ERROR: The difference between the current ETA and the Required Time of Arrival (RTA) at any designated downstream waypoint or waypoints.

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.

2.2 (Continued):

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.

VERTICAL BEARING (VBRG) (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) (VN): The function which provides guidance signals to control the aircraft during climb or descent for flying performance management 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 throttles 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 baro altitude rate, but may also be radar altitude rate or inertial vertical velocity.

VERTICAL TRACK DISTANCE/ERROR/DEVIATION (VDEV) (VTK) (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) (WD): The clockwise angle from true north to the wind velocity vector.

WIND PROPAGATION: The use of current present position instantaneous winds for all downstream leg ETE's and ETA's. The ETE's and ETA's are continuously revised as the present position winds change. The accuracy is increased if the wind is resolved into directional components corresponding to the downstream leg direction of flight rather than using present position ground speed for all downstream legs.

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

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

3. OPERATIONAL REQUIREMENTS:

3.1 General Requirements:

- 6 -

3.1.1 System Performance: The FMS shall perform the navigation and guidance (lateral and vertical), performance energy management and speed-time control functions necessary to complete a defined flight plan in the most energy efficient and/or cost effective manner while complying with Air Traffic Management constraints. Data may be provided to the FMS from:

3.1.1.1 Pilot inputs through the MCDU.

3.1.1.2 Pilot inputs through the flight guidance-autothrottle mode panel(s), including direct intervention to vertical and lateral navigation and speed management modes.

3.1.1.3 Sensors or other systems located in the aircraft.

3.1.1.4 Data base storage from internal memory or from an external flight data storage unit. Using this data, the FMS shall compute and deliver to using systems the data necessary to control the aircraft in four dimensions.

3.1.1.5 A data link system.

3.1.2 System Operation:

3.1.2.1 The FMS shall not add to flight deck workload at critical phases of flight (generally departures and arrivals) compared to non-FMS equipped aircraft. Further, during any flight phase, the workload shall not be so significant as to cause crew distraction or interference with other normal duties.

3.1.2.2 Inadvertent entries shall not result in immediate flight path changes.

3.1.2.3 The MCDU page format, data requirements and any page sequence shall be very evident.

3.1.2.4 It shall be possible to operate in manual flight or basic autopilot modes at any time, and return to full FMS controlled flight without introducing uncomfortable or out of limit speed error, altitude error, course error, thrust transients or significant workload.

3.1.2.5 Independent operation of lateral and vertical modes shall be accomplished by pilot selection. The respective lateral and vertical modes shall be clearly annunciated.

3.1.2.6 Automatic flight system response to FMS inputs shall occur only with appropriate vertical, lateral or thrust modes engaged.

3.1.2.7 Selection of new flight guidance modes shall be accomplished smoothly and with no discontinuities or transients.

3.1.2.8 The FMS shall compute and display all appropriate commands or advisories whether the aircraft is operated in manual, semi-automatic or fully automatic flight.

3.1.2.9 Electrical transients or loss of power shall not permanently erase or change the flight plan, displays, operating modes or inserted programs. Logic shall be provided for automatic erasure of the flight plan after completion of the flight.

SAE ARP4102/9

3.1.2.10　After short duration transients (approximately 0 to 7 seconds), operation should resume without significant pilot attention or action.

3.1.2.11　After longer duration interruptions (greater than approximately 7 seconds), pilot corrective procedures shall require only correction of the time based functions such as UTC, nav position, gross weight/fuel, etc. Appropriate warnings and procedural steps should be spelled out on the MCDU or the updating and position fixing should be automated.

3.1.3　Flight Plan Activation:　The pilot shall be able to select or enter the required flight plan through the MCDU. Alternative data entry methods or devices may also be utilized.

3.1.3.1　The pilot shall be able to review and modify all nav information, in any flight plan sequence such as Standard Instrument Departures, enroute waypoints, altitudes, Standard Terminal Arrival Routes, holding patterns, instrument approaches and Missed Approach procedures, without altering the navigation data base.

3.1.3.2　The FMS shall be able to store all data necessary to execute the active flight plan.

3.1.4　The Navigation Data Base:　The data base required to support the operational requirements of the FMS may be stored internally within the computer or externally in an additional data base storage unit.

3.1.4.1　The size of the navigation data base shall be sufficient to store all the navigation data required to support the route structure of the airline. The data should be capable of being updated on the aircraft. The capability of updating small strategic items through the MCDU (if provided) shall include proper safeguards. Means shall be provided to display to the pilot the currency of the data base being used. Navigation data base update may also be provided through data link or from another valid FMS by cross load as a controlled ground maintenance function.

3.1.4.2　Performance data should be stored separately from the navigation data base and be suitably protected to prevent changes when the navigation data base is being updated. Performance data shall not require frequent updating, however, the capability to update shall be provided.

3.1.4.3　Data stored in the data base shall not be alterable through the MCDU unless specific precautions are taken to prevent inadvertent alteration by the pilot when making routine use of the MCDU. An option to provide pilot input capability of a limited number of navaids, runway thresholds and waypoints to a dedicated volatile memory section of the data bank may be provided.

3.1.4.4　A section of volatile memory shall be provided to allow uplink by data link of temporary waypoints associated with variable airway structures. The temporary waypoints shall be capable of being designated by a flight plan identifier or company route number also contained in the data link signal.

SAE ARP4102/9

3.1.4.5   FMS interface with data link is desirable. The pilot should have the capability of assessing the ground transmitted data before commanding the insertion into the FMS. It is essential that sufficient checks are conducted of the data as transmitted and received to ensure that the integrity of the data is maintained. Transmission of the following data are desirable:

    a.   Flight plans, forecast winds and temperatures
    b.   Takeoff and landing performance and loadsheet data

3.1.4.6   Data link of cost index and performance factors shall be inhibited in flight.

3.1.5   Flight Planning Capability: The FMS shall be capable of displaying the optimum or required flight plan over a specified route depending on operating gross weight, current and forecast meteorological conditions, ATC restrictions and other available flight planning data. As a minimum it should include the following lateral flight plan capability.

3.1.5.1   An assembly or modification of a flight plan both before and in flight.

3.1.5.2   Selection of a flight plan identifier or company route number.

3.1.5.3   Selection of city pairs ("From"/"To").

3.1.5.4   Selection of appropriate waypoints from the data base storage.

3.1.5.5   Selection of non-stored waypoints defined by lat/long, or by bearing/distance from a stored waypoint. In addition, waypoints may be defined by place/bearing/place/bearing or waypoint/distance for along track waypoints.

3.1.5.6   Join routes, route segments, SIDs, STARs or approaches.

3.1.6   Performance Management: Operators standard recommended selections should be preset and implemented with one initialization. All entered data shall be capable of last minute updating. Data entry steps are outlined below.

3.1.6.1   General Data:

    a.   UTC
    b.   Fuel
    c.   Center of gravity
    d.   Forecast winds
    e.   Temperatures
    f.   Cost (or flight) index

- 9 -

SAE ARP4102/9

3.1.6.2 Select Climb Speed Schedule:

    a. Min cost
    b. Min fuel
    c. Min trip time
    d. Max angle or gradient
    e. Max rate
    f. Select IAS and/or Mach and/or flight path angle
    g. Acceleration altitude restrictions (when required)

3.1.6.3 Select Climb Thrust:

    a. Max climb
    b. Fixed or variable de-rate
    c. Performance based de-rate

3.1.6.4 Select Cruise Altitude:

3.1.6.5 Select Cruise Schedule:

    a. Min cost
    b. Min fuel (max range or Long Range Cruise (LRC))
    c. Min trip time
    d. Max endurance
    e. Select Mach or IAS

3.1.6.6 Select Descent Schedule:

    a. Min cost
    b. Min fuel
    c. Min trip time
    d. Select Mach and/or IAS and/or flight path
    e. Angle deceleration altitude restrictions (when required)

3.1.7 Vertical Navigation: Data entry steps are outlined below.

3.1.7.1 Designate climb altitude/waypoint or altitude distance crossings.

3.1.7.2 Select climb flight path angle if appropriate (angle may already be defined).

3.1.7.3 Designate Top of Descent and/or Bottom of Descent geographically or Distance To Go.

3.1.7.4 Designate descent altitude/speed/waypoint or altitude distance crossings.

3.1.7.5 Select descent flight path angle if appropriate (angle may already be defined).

3.1.8 Speed Management - Time Control (4D): Data entry steps are outlined below.

3.1.8.1   Select required time of arrival (RTA).

    a.   Waypoint
    b.   Metering fix
    c.   Runway

3.1.9   Data Verification: The pilot shall be able to review upon the MCDU (or other suitable display) all flight data from the flight plan for verification both before using and during the time the data is being used by the FMS. Pilot verification of data shall not affect the navigation or performance data outputs from the system.

3.1.9.1   The pilot shall also be able to assemble and verify an alternate or diversionary flight plan without affecting the active flight plan.

3.1.9.2   Parameters relevant to operational needs of any stored airport, waypoint or navaids shall be capable of being called up by the pilot for review.

3.1.10   Navigation Data Base Storage Update: The navigation data base will require periodic updating to remain current with the operational environment. The pilot shall be able to verify the currency of the nav data base to ensure operation with valid data.

3.1.10.1   The integrity of the data base shall be preserved and will not be alterable by the pilot except as provided by 3.1.4.3.

3.1.10.2   Before flight an alert shall be provided to the pilot when the nav data base is invalid.

3.2   Functional Requirements:

3.2.1   Flight Planning: The capability shall be provided to assemble a flight plan and establish fuel requirements before flight and to monitor, modify and generate alternative flight plans in flight.

3.2.2   Lateral Navigation and Guidance:

3.2.2.1   Lateral navigation and guidance shall be independent of performance management or vertical navigation and guidance.

3.2.2.2   Position shall be computed from the best available navigation sensors, i.e., Multiple DME, VOR/DME within specified limitations, inertial latitude/longitude, GPS or any other suitable navigation sensor.

SAE ARP4102/9

3.2.2.3   FMS lateral navigation shall be capable of operating in basic modes, for example:

a.   Inertial/Omega/Radio Update Mode: The inertial track and position are updated from DME/DME, VOR/DME, Omega or other radio data.

b.   Inertial Mode: The aircraft track and position derived from inertial data.

c.   Radio Mode: The aircraft track and position derived from radio data.

d.   Dead Reckoning Mode (long range over water): The DR mode shall use magnetic heading and true airspeed, and existing or pilot inserted winds.

3.2.2.4   Operating status shall be clearly annunciated on the Nav Display or primary MCDU page. Sequences required for pilot selection of modes and/or abnormal operation must be clearly spelled out in MCDU responses.

3.2.2.5   The pilot shall have a means of assessing the quality of navaids automatically tuned and used for current navigation, or the system logic for automatic tuning shall preclude the use of poor quality radio information. On approach, the assessment capability shall be highly visible whether included on the Primary Flight Display, Nav Display, MCDU or Alerting Display.

3.2.2.6   The capability of manually tuning and/or selecting navaids (normally automatically tuned) shall also be provided. Specific navaids may be required on approach for accuracy requirements. This can be achieved by a control panel or MCDU.

3.2.2.7   Lateral track navigation shall be computed in terms of great circle courses between waypoints in the flight plan, or as legs defined in ARINC 424.

3.2.2.8   Automatic leg changes should normally anticipate the turns:

a.   For leg changes of 90° or less, by making a tangential turn inside the intersecting course legs.

b.   For leg changes of more than 90°, by turning so that any overshoot does not go beyond the perpendicular to the inbound track through the turn waypoint.

Specific procedures requiring exception to the above desired tangential turns (that is overflying the waypoint) should be designated in the navigation data base.

3.2.2.9   When flying off course, automatic leg changes should generally occur approximately abeam the position at which the leg change would have taken place on course. Additional logic to ensure reasonable automatic leg changes is recommended. Such logic may be required for closely spaced waypoints and "change of flight plan" or "joining new route" in flight. Automatic leg changes may be inhibited by cross track distance.

3.2.2.10   If an electronic map display is not provided, an alert advisory shall be displayed before the turn is commenced. Inhibition of the alert or cancellation capability in terminal areas is optional.

- 12 -

3.2.2.11 Logic to ensure comfortable turns, and to observe maneuver limit and buffet boundary margins shall be provided. Bank angles may also be pilot selectable with appropriate roll rates.

3.2.2.12 ETAs should be based on great circle distances. Speeds used should be a blend of existing and programmed/predicted speeds. Actual wind, blended with inserted/programmed wind should be used. ETA readouts should be in hours, minutes (and seconds for 4D).

3.2.2.13 The desired track or course capture shall be accomplished using a pilot selected (or aircraft positioned) intercept angle. When the automatic navigation mode is engaged, the aircraft shall remain on the previously selected heading until reaching the capture boundary. Logic should be included to ensure capture prior to the next waypoint.

3.2.2.14 It shall be possible to initiate a direct leg from present position to any waypoint. The "Direct To" leg should be computed from the tangent to the turn in front of the aircraft (not the existing position) such that the capturing turn - commenced immediately - will roll out on track. It should also be possible to display and return to any upstream point in the original flight plan.

3.2.2.15 Waypoints, manually entered in the flight plan by latitude/longitude or other definition (and not permanently stored in the navigation data base) shall remain in the FMS and be available for recall by identification for the duration of that specific flight. Manually entered waypoints shall be deleted on flight completion.

3.2.2.16 Parallel offset track operation shall be provided by means of a pilot selected offset distance, right or left of the computed track. The FMS should command a maximum of 45° intercept heading (dependent on offset distance) to the offset track and capture it with minimum overshoot. This function shall also be available on "DIR TO" legs. A parallel offset track shall not be propagated into an arrival or approach procedure, unless initiated by the pilot.

3.2.2.17 The original waypoint(s) shall remain in the system while in parallel offset track operation and be available for display to the pilot. The cross-track deviation shall be zero when the aircraft is on the desired offset track. Parallel offset track operation shall be clearly annunciated. Return from parallel offset track shall be accomplished in a similar manner to the capture maneuver when initiated by the pilot or when designated by flight plan.

3.2.2.18 Published holding patterns should be stored in the navigation data base. The pilot shall be able to select a published holding pattern or modify or establish a holding pattern at any point, including present position. The FMS shall compute standard holding pattern entry procedures using optimum holding or maximum regulatory speeds, whichever is less. The pilot shall be able to modify pattern and/or speed.

3.2.2.19 The FMS display shall include all pertinent holding parameters. It shall be possible to designate a time for departing the holding fix and/or making good a downstream ETA whereupon the FMS shall shorten the final holding pattern legs as appropriate. It shall be possible to exit a holding pattern at any time.

- 13 -

3.2.2.20 Lateral guidance signals related to aircraft position, flight plan, and all leg types defined in ARINC 424 shall be developed for display to the pilot and for use by the Flight Guidance System.

3.2.2.21 Displayed information shall be consistent with ARP4102/7.

3.2.3 Performance Management (PM): The FMS shall provide and automatically display data as required for the current flight phase and to complete the defined flight plan. Performance management should consider lateral and vertical navigation inputs.

3.2.3.1 Aircraft basic performance data shall not be adjustable by the pilot. The capability to compute and display (or use) a limited performance factor on basic specific range may be provided. Appropriate safeguards shall be included.

3.2.3.2 Performance information to aid the crew in flight planning, normal aircraft operation, optimum flight profile control, abnormal and emergency conditions shall be available for display. These parameters may include, but are not limited to the following where 1 is recommended, 2 is desired and 3 is optional:

   a. Static and/or total air temperature: 1
   b. Takeoff computation - thrust/speeds/altitudes: 2
   c. Takeoff windshear - detection/information: 3
   d. Climb - speed/thrust (with and without ATC speed restriction): 1
   e. Cruise - optimum altitude/speed/thrust: 1
   f. Cruise climb - optimum altitude/speed/thrust: 2
   g. Step climb (up or down) - altitude/speed/thrust/time/fuel or cost comparison: 1
   h. Maximum altitude or service ceiling capability: 1
   i. Buffet boundary: 1
   j. Turbulent air penetration - speed: 3
   k. Fuel over destination, or destination and alternate: 1
   l. Range capability: 3
   m. Thrust/driftdown or climb speed/level-off altitude/step climb/cruise speed/range capability with engine(s) inoperative: 1
   n. Loss of pressurization - speed/range capability: 3
   o. Descent - speed/thrust (with and without ATC speed restriction): 1
   p. Holding - speed/thrust/endurance: 1
   q. Approach and go-around windshear - detection information: 3
   r. Landing and go-around - thrust/speeds/capability/attitudes: 3
   s. Global Navigation Satellite System (GNSS)

3.2.3.3 Climb, cruise and descent parameters may be optimized on the basis of one or more of the following criteria where 1 is recommended, 2 is desired, and 3 is optional:

   a. Minimum trip cost: 1
   b. Minimum trip fuel: 1
   c. Minimum trip time: 2
   d. Minimum rate of climb or descent: 2
   e. Maximum angle of climb or descent: 2

- 14 -

3.2.3.4   Pertinent data for the particular installation (engine type, aircraft configuration, etc., shall be stored in the FMS).

3.2.3.5   Signals for controlling engine thrust automatically or manually, shall be provided.

3.2.3.6   Performance selection and thrust ratings used in a completed flight should be automatically re-initialized, after landing, to the operator's standard recommended selections.

3.2.4   Vertical Navigation and Profile Guidance:

3.2.4.1   The air data input signals shall be corrected baro altitude, corrected airspeed and Mach, vertical speed and outside air temperature. Inertially derived signals shall be ground speed, vertical velocity, vertical acceleration, and flight path angle. Flight path angle may also be derived from combined air and inertial data.

3.2.4.2   Vertical guidance signals with respect to the selected vertical profile shall be computed for display to the pilot and for use by the Flight Guidance System. Guidance signals may include, but are not limited to, the following where 1 is recommended, 2 is desired, and 3 is optional:

    a.   Vertical track deviation (distance): 1
    b.   Flight path angle (earth reference): 2
    c.   Flight path angle deviation: 2
    d.   Vertical bearing: 3
    e.   Predicted altitude at any waypoint: 1
    f.   Altitude intercept - distance/time: 1/2
    g.   Vertical steering (Mach/IAS, vertical speed, flight path angle, etc.): 1
    h.   Path intercept - distance/time: 1/2

3.2.4.3   The transition from climb or descent to level flight including interim level off, shall be accomplished smoothly (pitch control, speed and thrust). Required speed and thrust changes should be anticipated and programmed in a manner compatible with passenger comfort.

3.2.4.4   All altitude changes shall be pilot initiated and may be preprogrammed. Any preprogrammed changes of altitude shall be annunciated or displayed.

3.2.4.5   Normally, the End of Descent E/D or programmed B/D or Bottom of Descent (B/D) shall be defined by one or more lower altitude/airspeed levels corresponding or related to specific waypoints or distance to go. This data may be a part of the original flight plan, or can be inserted later by the pilot through the MCDU.

3.2.4.6   The Top of Descent (T/D) shall be computed using the Performance Management criteria, E/D, B/D or runway data, and required time and arrival if appropriate, and the winds at altitude modified by wind modeling during descent. Insertion of actual descent winds via data link or by pilot entry through the MCDU are encouraged. The latter shall include pilot review safeguards.

3.2.4.7   Descent management shall include guidance information which enables thrust or drag (as well as pitch) corrections to be applied after the descent has been initiated so as to arrive at the required altitude, airspeed and arrival time. Modification of the descent program or initiation of a descent shall be possible at any time with reasonable pilot input activity.

3.2.4.8   If the FMS predicts that the acquisition of required altitude/airspeed is not within the practical capability of the aircraft, an advisory alert shall be displayed promptly.

3.2.4.9   It shall be possible to interrupt the programmed climb/descent with interim altitude holds at any time (holding existing speed) and then resume, if practical, a revised climb/descent direct to the next designated waypoint (altitude/speed crossing).

3.2.4.10   It shall be possible to initiate a climb or descent at any time in an expeditious manner.

3.2.4.11   It shall be possible to initiate a diversion at any time during the descent or arrival in an expeditious manner.

3.2.5   Speed Management - Time Control 4D: The system shall be capable of controlling speed to make good a required time of arrival (RTA) at one or more downstream waypoints. The system shall continually assess progress and advise or apply necessary corrections in an optimum manner. This function combines with the previously described functions to provide 4D. Control should begin from enroute cruise (earlier not excluded) and continue through descent to a designated control waypoint or waypoints (usually a Metering Fix and/or E/D or runway).

3.2.5.1   A "Flexibility" time window should be displayed for the designated control waypoint (or waypoints) showing the current ETA, RTA max, RTA min (or equivalents) in UTC hours, minutes, and seconds. The pilot should then be able to select an RTA within the time window and assess the required command Mach or IAS before activating 4D control. Alternate means of pilot control by assigning TAS or Ground Speed may be provided.

3.2.5.2   The 4D control mode may include logic to limit maximum and minimum speeds to practical values considering such factors as economics, performance and buffet boundaries.

3.2.5.3   The 4D wind modeling control law should combine existing and predicted winds in a manner that minimizes short term command airspeed changes. This includes the effects of either existing wind changes or transients from existing/predicted wind differences as at waypoint passage. The pilot should have the capability of updating predicted winds at any time. Improved or automated methods (such as data link) of achieving greater accuracy of predicted winds is encouraged, with appropriate pilot review safeguards.

3.2.5.4   When the real time 4D control solution conflicts with the optimized performance management profile a display of cost and fuel penalty under 4D control should be provided.