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AEROSPACE RECOMMENDED PRACTICE

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FLIGHT MANAGEMENT COMPUTER SYSTEM

1. PURPOSE AND SCOPE:

1.1 Purpose: The purpose of this document is to describe the recommendations of SAE Committee S-7 for a Flight Management Computer System (FMCS) capable of providing the functions and displays listed below to permit completion of a desired flight plan in an energy efficient and/or cost effective manner while meeting the requirements of Air Traffic Control.

1.1.1 Lateral Navigation and Guidance

1.1.2 Performance and Energy Management

1.1.3 Vertical Navigation and Guidance

1.1.4 Speed Management - Time Control

1.1.5 Electronic Nav-Display or EHSI (Nav-Map) Support

1.2 The Flight Management Computer System will receive input signals from a variety of sources and will provide outputs of the computed functions to the flight control system through the autopilot, autothrottles and flight deck control/displays.

1.3 Scope: The recommendations of this document apply to transport aircraft and describe the operational objectives of the FMCS and related controls and displays.

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2. DEFINITIONS:

- 2.1 Operational Characteristics - Those characteristics which define the operational capability of a complete Flight Management Computer System (FMCS). These characteristics are described in Paragraph 3. (Partial systems with lesser capability to compute, display or command are not described in this ARP.)
- 2.1.1 A "building block" design approach for partial systems is recommended so that increased capability can be readily added later.
- 2.2 Functions: Those operations which individually or collectively define the operating modes of the Flight Management Computer System. These functions are described in Paragraph 4.
- 2.3 Control Display Unit (CDU): This device provides the pilot interface with the Flight Management Computer System for inserting data such as gross weights, GMT, flight plans, etc., controlling and selecting parameters and modes, and provides readout capability to permit pilot verification of data.
- 2.3.1 The Control Display Unit may also exercise control over some sensor devices.

3. OPERATIONAL CHARACTERISTICS AND HUMAN FACTORS:

- 3.1.1 The Flight Management Computer System performs the navigation and guidance (lateral and vertical), performance energy management and speed-time control functions necessary to permit completing a desired flight plan in the most energy efficient and/or cost effective manner while meeting the requirements of Air Traffic Control. Data are provided to the Flight Management Computer System from:
- 3.1.1.1 Pilot inputs through the CDU.
- 3.1.1.2 Pilot inputs through the autopilot-autothrottle mode select panel.
- 3.1.1.3 Sensors 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 Flight Management Computer System will compute and deliver to using systems the data necessary to control the aircraft in four dimensions.
- 3.1.2 The systems must not add to flight deck workload at critical phases of flight (generally departures and arrivals) compared to non-FMCS equipped aircraft. Further, during any flight phase, the workload should not be so significant as to cause crew distraction or interference with other normal duties.
- 3.1.3 Mismanagement or moderate turbulence should not introduce disturbing or hazardous oscillations, discontinuities or upsets.

- 3.1.4 It must be possible to operate in manual flight or basic autopilot modes at any time, and return to full FMCS controlled flight without introducing uncomfortable or out-of-limit speed error, altitude error, course error, thrust transients or significant workload.
- 3.1.5 The FMCS should compute and display all appropriate commands or advisories whether the aircraft is operated by manual, semi-automatic or fully automatic flight.
- 3.1.6 Electrical transients or loss of power shall not permanently erase or change the flight plan, displays, operating modes or inserted programs.
- 3.1.7 After short duration transients (approximately 0 to 7 sec), operation should resume without significant pilot attention or action.
- 3.1.8 After longer duration interruptions (greater than approximately 7 sec), pilot corrective procedures should require only correction of the time based functions such as GMT, Nav Position, Gross Weight/Fuel, etc. Appropriate warnings and procedural steps should be spelled out on the CDU or the updating and position fixing should be automated.
- 3.2 Flight Plan Activation: The pilot shall be able to select or enter the required flight plan through the CDU. Alternate data entry methods or devices may also be utilized.
 - 3.2.1 The pilot shall be able to review and modify all Nav data 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 basic Nav data base.
 - 3.2.2 The Flight Management Computer System shall be able to store all data necessary to execute the active flight plan.
- 3.3 Flight Planning Capability: The Flight Management Computer System must 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.
 - 3.3.1 It should be possible to assemble or modify a flight plan in flight.
 - 3.3.2 Typical methods of lateral navigation flight plan assembly are:
 - 3.3.2.1 Selection of a flight plan identifier or company route number.
 - 3.3.2.2 "From"/"To" (City Pairs).
 - 3.3.2.3 Selection of appropriate waypoints from the Data Base Storage.
 - 3.3.2.4 Selection of non-stored waypoints defined by Lat/Long, or by Bearing/Distance from a stored waypoint (or VHF).

3.3.2.5 Join routes, route segments, SID's, STAR's or Approaches.

3.3.3 Typical methods of performance management assembly are listed below. Operators' standard recommended selections should be preset and implemented with one initialization. All entered data must be capable of last minute updating.

3.3.3.1 Input (*May be achieved automatically from other aircraft sensors, systems, data link, etc.).

GMT*

Gross Weight*, Fuel* and Center of Gravity*

Forecast Winds and Temperatures*

Cost (or Flight) Index

3.3.3.2 Selection of Climb Speed Schedule

Min Cost

Min Fuel

Min Trip Time

Max Angle or Gradient

Max Rate

Select IAS and/or Mach and/or Flight Path Angle

Climb/Speed Acceleration Altitude Restriction (when required)

3.3.3.3 Selection of Climb Thrust

Max Climb

Fixed or Variable De-Rate

Performance Based De-Rate

3.3.3.4 Selection of Cruise Altitude

3.3.3.5 Selection of Cruise Schedule

Min Cost

Min Fuel (Max Range or LRC)

Min Trip Time

Max Endurance

Select Mach or IAS

3.3.3.6 Selection of Descent Schedule

Min Cost

Min Fuel

Min Trip Time

Select Mach and/or IAS and/or Flight Path Angle

Deceleration Speed/Altitude Restriction (when required)

3.3.4 Typical method of Vertical Navigation assembly is as follows:

3.3.4.1 Designate Climb Altitude/Waypoint or Altitude/Distance Crossings.

- 3.3.4.2 Select Climb Flight Path Angle if appropriate (Angle may already be defined.)
- 3.3.4.3 Designate Top of Descent and/or Bottom of Descent geographically or Distance to Go.
- 3.3.4.4 Designate Descent Altitude/Speed/Waypoint or Altitude/Distance crossings.
- 3.3.4.5 Select Descent Flight Path Angle if appropriate (Angle may already be defined.)
- 3.3.5 Typical method of Speed Management - Time Control Assembly is as follows:
 - 3.3.5.1 Select Required Time of Arrival (RTA) - Waypoint, Metering Fix and/or Runway.
- 3.4 Data Verification: The pilot will be able to call up on the CDU (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 Flight Management Computer. Pilot verification of data must not affect the navigation or performance data outputs from the system.
 - 3.4.1 The pilot shall also be able to assemble and verify an alternate or diversionary flight plan without affecting the active flight plan.
 - 3.4.2 Data Review: Parameters of any stored airport, waypoint or VHF Nav aids shall be capable of being called up by the pilot for review.
- 3.5 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 stored data to insure : operation with valid and current data.
 - 3.5.1 The integrity of the Data Base will be preserved and will not be alterable by the pilot except as provided by Paragraphs 4.3.1 and 6.2.
- 3.6 Self Test: The Flight Management Computer System will be capable of automatically monitoring or performing tests of its own internal operation.
 - 3.6.1 The Flight Management Computer System may also have a pilot initiated self-test capability providing a visual indication that the FMCS is functioning properly, including displays and annunciators, and is capable of operating within reasonable accuracy limits.
 - 3.6.2 The results of these testing activities will be annunciated to the pilot when a failure or out-of-tolerance condition is noted, and unreliable data will be removed from the pilot's view, or indicated as invalid.
 - 3.6.3 Reasonable Manual Data Input Limits: Reasonable Computer limits should be established for selected parameters as listed below to minimize potential gross input errors. The CDU should also display an alert or advisory for such unreasonable inputs.

3.6.3.1 Gross Weight

3.6.3.2 Fuel Load

3.6.3.3 Temperatures

3.6.3.4 Wind Velocity

3.6.3.5 Cruise Altitudes

3.6.3.6 Speeds

3.6.3.7 Flight Path Angle

3.6.3.8 Vertical Speed

3.6.3.9 EPR and N_1

3.6.4 Navigation Continuity and Infringement: The FMCS should also monitor inputs for routing validity and display appropriate advisories for such errors as the following:

3.6.4.1 Track or Path Discontinuities

3.6.4.2 Offsets

3.6.4.3 MSA, MEA and restricted flight space monitoring is encouraged.

3.6.5 Interface Validity: All interface inputs such as INS, IRS, Omega, VOR/DME, CADC, Compasses and Engine parameters should also be monitored for reasonableness. Limits or tolerances should be established and appropriate rejection logic or alerting provided.

4. FUNCTIONS:

4.1 The primary FMCS functions are:

4.2 Lateral Navigation and Guidance

4.3 Performance and Energy Management

4.4 Vertical Navigation and Guidance

4.5 Speed Management - Time Control

4.6 Electronic Nav-Display or EHSI (Nav-Map) Support

4.1.1 Logic interlocks between basic function mode activation should occur only when required.

4.1.2 Lateral navigation and guidance capability should be independent of performance management or vertical navigation and guidance.

- 4.1.3 Performance management capability should be independent of lateral and vertical navigation and guidance wherever possible.
- 4.1.4 Vertical navigation and guidance incompatibilities or conflicts with performance management should be annunciated with appropriate advisories and/or not accepted.
- 4.1.5 Logic interlocks and operational sequence requirements should be annunciated and clearly spelled out in CDU responses.
- 4.1.6 The capability of operating vertical and lateral modes independently in command or CWS is strongly recommended. This should be accomplished by pilot selection or deselection of modes and should not be initiated by applied control force. The respective vertical and lateral axis modes (command or CWS) must be clearly annunciated.
- 4.1.7 Automatic flight system response to FMCS inputs should occur only with appropriate pitch, lateral or thrust modes engaged.
- 4.1.8 Selection of new modes shall be accomplished smoothly and with no discontinuities or transients.
- 4.2.1 Lateral Navigation and Guidance: The Flight Management Computer System lateral navigation should be capable of operating in basic sub-modes; for example:
 - 4.2.1.1 Inertial Mode - the aircraft track and position are derived from inertial data.
 - 4.2.1.2 Inertial/Omega/Radio Update Mode - the inertial track and position are updated from DME/DME, VOR/DME, Omega, or other radio data.
 - 4.2.1.3 Radio Mode - the aircraft track and position are derived from radio data.
 - 4.2.1.4 Dead Reckoning Mode (Long Range Over Water) - this back-up mode shall use magnetic heading and true airspeed, and existing or pilot inserted winds.
- 4.2.2 Sub-mode status should be clearly annunciated on the Nav-Display or primary CDU page. Sequences required for pilot selection of sub-modes and/or abnormal operation must be clearly spelled out in CDU responses.
- 4.2.3 The pilot must have a means of assessing the quality of radio stations automatically tuned and used for current navigation, or the system logic for automatic tuning must preclude the use of poor quality radio information. On approach, the assessment capability must be highly visible whether included on the Primary Flight, Nav, CDU, or Caution and Warning Displays.
- 4.2.4 The capability of manually selecting stations (normally automatically tuned) must also be provided. Specific stations may be required on approach for accuracy requirements. This can be achieved by either:

- 4.2.4.1 FMCS acceptance of manual tuning on the VOR/DME control panel (preferable).
- 4.2.4.2 Pilot selection of navigation aids through the CDU (less desirable).
- 4.2.5 Lateral track navigation will be computed in terms of great circle courses between waypoints in the flight plan.
- 4.2.6 Position will be computed in terms of latitude/longitude and displayed in established identification or latitude/longitude. Position may also be computed and displayed in terms of radial "from" (or bearing "to") and distance to a VOR/DME facility, where available. Position may also be computed in terms of distances from two or more DME facilities.
- 4.2.7 Leg Change: Automatic leg changes should normally anticipate the turns.
 - 4.2.7.1 For leg changes of 90° or less, make a tangential turn inside the intersecting course legs.
 - 4.2.7.2 For leg changes of more than 90°, turn such that any overshoot does not go beyond the perpendicular to the inbound track through the turn waypoint.
 - 4.2.7.3 Specific procedures requiring exception to the above desired tangential turns (that is overflying the waypoint) should be designated in the specific flight plan software.
- 4.2.8 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 logics to ensure reasonable automatic leg changes are recommended. Such logics may be required for closely spaced waypoints and "change of flight plans" or "joining new routes" in flight.
- 4.2.9 An alert advisory shall normally be displayed beginning approximately 30 seconds before the turn is commenced. Deletion of the alert or cancellation capability in terminal areas may be optional.
- 4.2.10 Logic to ensure comfortable turns and buffet boundary margins for automatic modes must be provided. Max bank angle-roll rates of 28° bank-5°/sec and 15° bank-3°/sec are also acceptable practice for low speed (low altitude) and high speed (high altitude) respectively. Bank angles may also be pilot selective with appropriate corresponding roll rates.
- 4.2.11 Estimated Times of Arrival (ETA's): ETA's should be based on great circle distances (modified by the turn control laws for 4D). Speeds used in ETA's should normally be a blend of existing and predicted (or programmed) conditions. Existing winds should be resolved into directional components when used for downstream ETA's. ETA readouts should be in GMT hours:minutes (and seconds for 4D).

- 4.2.12 Track "All Angle" Capture: The desired track or course capture should be accomplished from a pilot selected (or aircraft positioned) intercept angle. When the automatic Nav mode is engaged, the aircraft should remain on the pilot previously commanded heading until reaching the appropriate capture turn. Logic may be included to display appropriate advisories to ensure capture prior to the next waypoint.
- 4.2.13 "Direct To" Function: The pilot may command a direct leg from his present position to any waypoint in the active flight plan or to a waypoint constructed by the pilot. 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. The option of computing "Direct To" legs from existing position may be provided. It shall also be possible to return to any point in the original flight plan by pilot action through the CDU.
- 4.2.14 Waypoint Retention: Waypoints manually entered in the flight plan by latitude/longitude or other (and not permanently stored in the data bank) should remain in the computer and be available for recall by identification for the duration of that specific flight.
- 4.2.15 "Parallel Offset Track Operation" will be provided by means of a pilot selected cross-track offset distance, right or left of the computed track. The aircraft should turn automatically to an appropriate intercept heading to the offset track and capture it with minimum overshoot. Adequate protection should be provided against geometry situations that are impossible.
- 4.2.16 The parameters of the original waypoint(s) should remain in the system while in parallel offset track operation and be available for display by the pilot for verification. The cross-track deviation will be zero when the aircraft is on the desired offset track. Parallel offset track operation will be clearly annunciated. Automatic return from parallel offset track will be accomplished in a similar manner when initiated by the pilot.
- 4.2.17 Holding Patterns: Specific published holding patterns may be stored in the data base available for sequencing when desired. Additionally, the pilot shall be able to establish a holding pattern at any point, including present position. The Flight Management Computer System should compute an optimum entry, fuel burn maneuvering speed, wind adjusted turns/tracking, and leg lengths that are compatible with standard ATC airspace (and/or airspeed) requirements at the existing altitude. The FMCS should annunciate advisories for pilot inputs which are incompatible with airplane performance or ATC airspace (or airspeed). Inputs will normally consist of the following:
- 4.2.17.1 Holding Fix - Defined by waypoint, VOR, waypoint or (VOR)/radial/distance, latitude-longitude, or present position.
- 4.2.17.2 Inbound Track, Course or radial to the Holding Fix.

- 4.2.17.3 Standard (right) or left turns.
- 4.2.17.4 Standard or outbound leg length in nautical miles (DME based); or outbound leg length in still air minutes (non-DME based). Note above conforms to ICAO. U.S. (non-DME based) pattern adjusts outbound leg to make inbound nominal 1 min (or 1-1/2 min above FL 140). U.S. option may be provided at customer request.
- 4.2.17.5 Configuration (flap setting). The FMCS may also compute (recommend) a configuration.
- 4.2.17.6 The option to select Mach or IAS may be provided. Note minor conflict between ICAO and U.S. on speeds. ATC speed coordinator responsibility may be delegated to the pilot.

Turbojet Altitude	Max Speed IAS	
	ICAO	U.S.
Up to 6000 ft	210	200
6000 ft thru 14000 ft	220	210
Above 14000 ft	240	230

- 4.2.18 Display advisories should include but are not limited to the following:

- 4.2.18.1 Holding Mach or IAS
- 4.2.18.2 Flap/Speed/Airspeed Compatibility
- 4.2.18.3 Pattern Envelope - Length/Width
- 4.2.18.4 Fuel Burn Rate
- 4.2.18.5 ETA at the fix

- 4.2.19 It shall be possible to designate a time for departing the holding fix and/or making good a downstream ETA whereupon the FMCS will shorten the final holding pattern legs as appropriate.

- 4.2.20 Lateral Guidance signals related to aircraft position and flight plan will be developed for display to the pilot and for use by the Automatic Flight Control System.

- 4.2.21 Lateral steering will also be provided as a function of:

- 4.2.21.1 Selected Course or Track
- 4.2.21.2 Track Hold
- 4.2.21.3 Selected Heading
- 4.2.21.4 Heading Hold