Electronic Propulsion Control System/Aircraft Interface Control Documents

RATIONALE

In response to a committee initiative, the revision of this document is intended to elaborate on the structure and content of an Interface Control Document for the Electronic Propulsion Control System, to be used by the airframe/engine manufacturers. This document is based on the previously released ARP4874. It has been revised to reflect input collected as part of the '5-Year Review' process.

FOREWORD

Electronic Propulsion Control systems have become established for a number of applications in the commercial field.

Frequently, a given aircraft can have engines from different engine manufacturers, and also a given engine type may be used in different aircraft. Without an accepted standard this multiplicity can lead to large resource expenditure in documenting the interfaces between the engine and the aircraft.

As electronic propulsion control systems become more complex, with increased data and functional integration, this problem will be aggravated in the future and significant benefit will result from an accepted standard which can apply to all applications.

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1. SCOPE

This SAE Aerospace Information Report (AIR) provides guidelines to document the functional and physical interface requirements for the electrical systems (including an EPCS and its components) between a given propulsion system and the aircraft on which the system is installed and the functionality pertinent to each interface.

The scope includes civilian aircraft powered by turbofan, turboprop, and turboshaft engines equipped with electronic engine controls.

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 the 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.

2.1.1 EASA Publications

Available from European Aviation Safety Agency, Postfach 10 12 53, D-50452 Koeln, Germany, Tel: +49-221-8999-000, www.easa.eu.int.

AMC 20-1 Certification of Aircraft Propulsion Systems Equipped with Electronic Controls

2.2 Acronyms/Abbreviations

DFDR	Digital Flight Data Recorder
EEC	Electronic Engine Control
EECS	Electronic Engine Control System
EPCS	Electronic Propulsion Control System
EVMS	Engine Vibration Monitoring System
FADEC	Full Authority Digital Engine Control
ICD	Interface Control Document
LRU	Line Replaceable Unit

3. INTERFACE DEFINITION OVERVIEW

3.1 Purpose

The purpose of defining interfaces between powerplant controls and other airplane and powerplant systems is to ensure the powerplant controls, and the airplane as a whole, perform safely, effectively, predictably and reliably.

The definition of the interfaces between a powerplant control system and the related aircraft systems is the physical and functional relationship of one system to the other (i.e., how they fit and function together). In addition, identification of these interfaces is a necessary part of certifying an aircraft propulsion system equipped with electronic controls

3.2 Interface Definition Requirements

Considerations to be addressed when determining and documenting interfaces include:

a. Physical Interface Characteristics: These include electrical, mechanical, optical and environmental characteristics.

b. Functional Interface Characteristics: The objectives of the functions performed and the data exchanged between the aircraft and the electronic propulsion control systems involved that allow the engine and aircraft to operate as an integrated system.

4. INTERFACE CONTROL DOCUMENT (ICD)

4.1 Purpose

The purpose of the ICD is to define the physical and functional interface for the electrical systems, including the EEC, between a given propulsion system and a given aircraft.

The ICD can be initially developed a source of high level system requirements, however it is a living document that captures the actual characteristics of the system, as it is implemented.

The definition of physical and functional interface characteristics should embrace both normal and abnormal operating conditions together with appropriate fault detection, accommodation, and annunciation requirements.

NOTE: This is not intended to make the ICD a failure modes and effects analysis report, but instead to describe and define the system functional requirements which are related to failures of aircraft and control system components/interfaces/data, which can be used as aircraft system design requirements.

The functional definition will cover all operating modes including reversionary and get-you-home modes (if implemented).

The intended audience of the ICD will include the responsible design engineering organizations at both the engine manufacturer and at the aircraft manufacturer. The completed ICD is a useful resource document for certification substantiation, certification test procedure development, for engine and aircraft manufacturer's maintenance training organizations, for airline maintenance engineering organizations, and for manufacturers of flight and maintenance crew training simulators.

Distribution of the ICD is sometimes constrained by proprietary data concerns or by government export license restrictions. These factors and the intended audience should be discussed before preparation of the document to ensure it fulfills its intended purpose.

4.2 ICD Preparation

The ICD is one of several sources of engineering data which define the installation of the engine control system in the aircraft. The complete definition of the installation generally includes, but may not be limited to:

- Engine installation drawing
- Engine Installation Manual

Typically, the aircraft manufacturer and engine manufacturer will jointly define and agree on the development and configuration management plan for the ICD, as a part of the engine specification and engine integration plan negotiation process, and complete it during the subsequent design phases for the propulsion system and engine.

The means for controlling the configuration of the document needs to be agreed upon at the beginning of the program, because this may affect the structure of the document (see Paragraph 4.3).

The plan for development of the ICD should be designed to recognize the existence of all sources of engineering data, including the previous drawings and manual, and avoid duplication of information.

During the developmental and mature program phases, a revision to the ICD should be made in accordance with the following criteria: software update to the EEC (or the aircraft electronic systems that interface with the EEC), when functional or interface requirements are impacted. This will ensure accurate documentation of changes to the aircraft/engine interfaces or features which affect the engine control system. A well-maintained/accurate ICD is also an essential tool to avoid interface issues in mature programs undergoing retrofit upgrades, by providing tracking status of interface changes which have occurred to the engine or aircraft.

Where specific chapters of the ICD contain information / requirements concerning other manufacturers / suppliers to the Aircraft (i.e: Avionics, Landing Gear, Throttle Quadrant, etc), their information should be included within the chapters with which they are involved.

4.3 ICD Format and Content

A example of an outline structure for the ICD is shown in Figure 1. The specific section placement order and numbers shown for each topic are intended to be for reference only. However, specific sections, such as paragraphs discussing system description, functionality and functional interface requirements, should be expanded as necessary for a given application.

In some applications, it may be of use to configure each section as a stand-alone item. For projects which require large documents, this approach allows the ICD to be divided into smaller, more manageable sections which may be configured and released separately as the design progresses. In this arrangement, each section would contain a detailed change history, table of contents, signature sheets, etc. A 'Master Summary' document could be created to identify the latest version of each section.

For configuration control purposes, it is suggested that the document defines the application, physical interface configuration and software version.

The document will provide a description of the overall system, providing information and requirements on all aircraft and propulsion system LRU's to which the electronic propulsion control system components interface.

The detailed definition will cover the functional requirements and both the physical and functional characteristics of all data, signals and power associated with the aircraft to propulsion system interface and vice-versa. The use of data tables and 'high level' flow / logic diagrams may be used to describe the functional requirements. Due to Export Control constraints of detailed logic diagrams which are used to create executable software code, it may be suggested not to include these logic diagrams in the ICD.

It is highly suggested that the ICD documents the use of aircraft data in engine control functions and engine data in aircraft control functions. The data supplier should be made aware that their transmitted data is being used in a specific function and that no changes to the data format or characteristics should occur without proper and complete impact analysis by the receiver system.

Appendix "A" presents additional, more specific details for suggested ICD content. Note that the suggested format incorporates all discussion of functional interface requirements in Section 8. Alternatively, individual functional requirements may be included in separate paragraphs, e.g., Section 8.2. Aircraft Provided Data Management, Section 8.5 Thrust/Power Management, etc. Aspects such as fault detection, accommodation, annunciation and dispatch criteria for each function may be included as subsections within the paragraph that discusses that function.

4.4 Electronic Transfer of Documents

In preparing the plan for development of the ICD, consideration should be given to permit transfer of the document electronically between the engine manufacturer and the aircraft manufacturer.

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NOTE: This outline and the section numbering is provided as a guideline.

FIGURE 1 - SUGGESTED INTERFACE CONTROL DOCUMENT OUTLINE

5. NOTES

A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain only editorial changes.

APPENDIX A - SUGGESTED CONTENT FOR INTERFACE CONTROL DOCUMENT

A.1 TABLE OF CONTENTS

The table of contents should include items such as:

a. Text

b. List of figures

c. List of tables

d. Appendices

A.2 REVISION HISTORY

The revision history should allow document changes to be easily identified and be traceable to specific change requests. In addition, the revision history will provide the ability to identify all active pages of the document.

A.3 SCOPE

For each revision of the ICD, the scope section should:

a. Define the airframe-engine application

b. Define hardware configuration and software version for the electronic propulsion control system and interfacing aircraft systems (i.e: Avionics, etc), where it has impact on functionality.

c. Provide the corresponding Power Management Deck reference

d. Include a “CAVEATS” section which lists deviations or discrepancies to requirements existing for a given hardware/software configuration. The Caveats may be separated into categories pertaining to Propulsion System software, Aircraft component (Avionics, etc) software or other interface items.

A.4 REFERENCE DOCUMENTS

The reference section of the ICD should include references, such as:

a. Applicable government regulations

b. Applicable industry standards

c. Aircraft manufacturer specifications

d. Engine and/or component specifications

e. Engine and/or component installation drawings

Where appropriate, a precedence statement may be included for resolution of conflicting requirements. Agreed-upon deviations from reference documents may also be listed.

A.5 SUPPLEMENTAL INFORMATION

Supplemental information may include:

A.5.1 Definitions

This section will explain terms used in the ICD, including ARINC Format and other definitions which will help make the document fully comprehensive.

A.5.2 Acronyms, Abbreviations

This section provides explanation of the acronyms and abbreviations used in the ICD.

A.5.3 Mnemonic Name Cross-Reference

This list will define mnemonics used in the ICD, including identifying where the mnemonic is defined and where it is used in other functions.

A.5.4 Traceability

A traceability section which describes the source of requirements in the ICD may be found useful for documenting the history of design decisions for later use when product improvements or future requirements changes are considered. Examples may include design modifications to enhance engine operability or to conform to aircraft system modifications.

Traceability may be documented in the ICD by including a reference to another report, in cases where a separate document is prepared on this subject.

Where appropriate, in cases where a testable requirement is presented, a 'tag' may be used to facilitate traceability.

A.6 SYSTEM OVERVIEW

A.6.1 Aircraft Systems Description

The aircraft systems description should contain:

A.6.1.1 System Overview

The overview should include a block diagram showing the aircraft subsystems and units comprising the system.

A.6.1.2 Aircraft System Components

A list of aircraft units or subsystems which perform functions related to the electronic propulsion control system.

A.6.1.3 System Functions

A description of aircraft system functions related to the electronic propulsion control system.

A.6.1.4 Allocation of Functions

For each aircraft function related to the engine control system, a description of which aircraft units are involved in implementing the function should be presented.

A.6.1.5 Aircraft System Operating Modes

This section should include:

a. A list and description of interfacing Aircraft system operating modes, e.g., automatic versus manual flight control, normal versus reversionary engine control modes.

b. Definition of configurations (e.g., with faults present in the system) for which aircraft dispatch is to be allowed.

c. Description of any noteworthy differences in operating and performance characteristics for all dispatchable configurations, in comparison to a normal or fully-operational system dispatch.

A.6.2 Electronic Propulsion Control System (EPCS) Description

The system description should contain:

A.6.2.1 System Overview

The overview should include a block diagram of the system showing the subsystems and units comprising the system.

A.6.2.2 System Components

A list of units or subsystems comprising the system.

A.6.2.3 System Functions

A list of EPCS functions including a brief overview of their relation to engine operation, for example:

a. Thrust control

b. Control of fuel flow

c. Overspeed protection and Overthrust protection (TCMA)

d. Control of compressor variable geometry and bleeds

e. Starting functions

f. Heat management, etc.

For each function, a description of the LRUs involved in implementing the function should be provided.

A.6.2.4 EPCS Operating Modes

This section should include:

a. A list and description of EPCS component operating modes, e.g., initialization, ground tests, engine running, etc.

b. State transition diagram or equivalent describing transition between operating modes.

A.6.3 Aircraft/EPCS Interface Description

This section should include a list of the interfaces between the aircraft and the electronic propulsion control system. The listing may be arranged to group the Analog/Discrete signals according to source/destination and include a reference to the specific ICD chapter where details are presented.

A.7 PHYSICAL INTERFACE CHARACTERISTICS

Physical characteristics including electrical, mechanical, optical, and environmental interface characteristics should be defined.

A.7.1 Electrical Interface Characteristics

A.7.1.1 General Requirements

This section would provide harness wiring pinout information and also address issues such as:

a. Channel-to-channel isolation

b. Response to fault conditions (including common mode)

c. Aircraft to propulsion system isolation

d Information to prepare a Voltage Drop Analysis (wire lengths, resistance, capacitance per foot, etc)

A.7.1.2 Analog Signal Interfaces

Items that typically should be defined for each signal path into and out of a system or component include:

a. Shielding requirements

b. Impedance requirements or limits

c. Connector designation and contact number (or the equivalent for other types of disconnects such as terminal strips)

d. Form of the aggregate interconnection (twisted-pair, twisted-triplet, coaxial, etc.)

e. Bonding and grounding requirements

The signal should be defined in sufficient detail so that the interface can be designed to function correctly in all allowable operating conditions. No important characteristic of the signal can be left to chance. Factors such as the maximum operating temperature or worst-case signal characteristics should be defined.

Characteristics of each signal that may be specified, depending on the specific type and application of the interconnection, include:

a. Name, source, and purpose of the signal

b. Electrical voltage, current, impedance, or power ranges for all operating modes and conditions (i.e., with equipment powered and depowered, and for all temperatures expected), at both sides of the interface disconnect

c. Electrical parameter relationship to the sensed quantity (for sensor inputs), including accuracy, linearity, and resolution specifications for the signal

d. Frequency, wave shape, duty cycle, and other pertinent data for alternating current signals

A.7.1.3 Discrete Signal Interface Characteristics

Important characteristics of discrete signal interfaces include:

a. Signal name, source, and purpose

b. Signal type (e.g. contact closure or voltage)

c. Minimum open circuit resistance and threshold detection value

d. Maximum closed circuit resistance and threshold detection value

e. Maximum voltage

f. Minimum, maximum, and typical current levels

A.7.1.4 Digital Data Bus Signals

Characteristics of each data bus crossing the interface need to be specified. These include:

a. The specification used (ARINC 429, RS232, etc.)

b. Bus specification options, such as operating mode (voltage or current, clock speed, etc.)

c. Bus terminal identifier and terminal bus interface characteristics (if appropriate)

Digital data should be defined in detail. Table A1 lists typical parameters that must be included in the definition.

A.7.1.5 Power Supply

Electrical power requirements must be defined including type and quality of electrical power, maximum power or current, maximum in-rush current (if appropriate), etc.

A.7.2 Mechanical Interface Characteristics

Physical details of electrical (or optical) interconnections across system or component boundaries should be specified. These details include:

a. The part number (i.e: series, shell size) of each connector on both sides of the interface

b. The keyway orientation for each interface connector pair

c. The connector contact arrangement and contact signal assignments

d. Additional information for the connector, as applicable (i.e: ‘firewall’, ‘scoop proof’, ‘high temperature’, etc)

If physical limits such as the maximum length, maximum thickness, or maximum permitted bend radius of an interconnection are pertinent, they should also be included in the ICD and observed in the design. In some installations, pneumatic pressure sense line may also cross the interface between the aircraft and the electronic engine control system. This is another type of mechanical interface which should be specified. This interface occurs, for example, when aircraft provided pneumatic lines are connected to the electronic engine control system for measurement of freestream total or static pressure.

A.7.3 Optical Interface Characteristics

Important aspects of optical interfaces may include interconnecting fiber characteristics, optic connector(s), signal format, power budget and wavelength.

A.7.4 Environmental Characteristics

Environmental characteristics which may be considered as part of the interface include specification of thermal, vibration, and electromagnetic characteristics to which components of the system are exposed. Where these subjects are treated outside the scope of the ICD, it is appropriate for the ICD to reference other documents rather than duplicating requirements identified elsewhere.

A.8 FUNCTIONAL INTERFACE CHARACTERISTICS

The Functional Interface Characteristics sections should provide an overview of the aircraft/engine interfaces pertaining to each system described, including the source type (i.e: LVDT, hardwire or ARINC signal), the sense interpreted (i.e: TRUE = Valve-not-Closed) and defaults used by the FADEC if an ARINC signal is not valid or available.

A schematic of the control circuit/component layout may be useful if included to accompany descriptive text.

A.8.1 Propulsion System Inputs and Outputs

This section of the ICD should capture all inputs and outputs of the Propulsion System and list them according to type (i.e: ARINC discrete, ARINC Binary Numeric, electrical discrete, electrical analog) and source/destination (i.e: FADEC to/from Aircraft, FADEC to/from Propulsion System, or FADEC cross-engine).

The listing should also identify the ICD chapters which pertain to each specific input / output, such that it clarifies the extent to which a signal is used on the aircraft (i.e: Engine running discrete) or in specific FADEC control functions (i.e: Weight-On-Wheels).

A.8.2 Aircraft-Provided Data Management

Typical Electronic Propulsion Control systems accept data from multiple sources, such as flight condition information obtained from engine-mounted sensors as well as data received from aircraft avionics computers.

In multi-engine aircraft, electronic propulsion control system design may allow the electronic propulsion controls on each engine to receive data from the same aircraft computer(s). This configuration minimizes operational differences between engines (e.g., throttle stagger) but requires that safeguards are included to prevent failure of a single aircraft system from causing a hazardous thrust loss or otherwise adversely affecting the operation of more than one engine.

The ICD should be used to establish requirements for use of aircraft-supplied information in the electronic propulsion control, and for the use of EPCS-supplied information in aircraft systems. The aircraft computer power-up/initialization times, software criticality levels and the accuracy of the transmitted data should be provided.

A.8.3 Digital Data Bus Interfaces

This section of the ICD should describe the interface between the EEC and the Avionics. Where details of the data is presented, the information should contain items per Table A1 (below). Other details to be included are:

a. Digital Data Bus wiring schematic, showing the transmit and receive ports of the interfacing computers

b. Output data bus characteristics during channel swap and reset occurrences

c. Aircraft computer source selection logic

d. FADEC data label transmission sequence

TABLE A1 - PARAMETERS USED IN DEFINITION OF DIGITAL DATA

ITEM PARAMETER NAME	**TYPICAL ENTRY (COMMENTS)**
Mnemonic (if applicable)	
Data Label	Decimal, Octal or Hexadecimal
Signal Format	Binary, Discrete, or Binary-coded decimal
Units	Dimensionless, Degrees C, RPM, %, etc.
Maximum / Minimum Value	
Encoding scheme	(if applicable, see note 1)
Scale Factor	(power of 2 which includes maximum and minimum values)
Significant bits	(extent of valid data in bits)
Nominal/Maximum Transmit Interval	
Maximum Update Interval	(Maximum interval at which a digital data bus output is updated with new data relative to the last previous data input acquisition or internal computation. The maximum update interval may be greater than the maximum transmit interval.)
Resolution	(see note 2)
Maximum transport delay	
Meaning of "No Computed Data" flag	
Meaning of "Functional Test" flag	
Accuracy	
Description	(Provides details to understand the meaning of the parameter)
SPECIFIC TO DISCRETE DATA	
Data Label and Bit	(Includes the persistence delay when the FADEC confirms the condition is set and when it sets the corresponding ARINC bit)
Delay to Set	(Includes the persistence delay when the FADEC confirms the condition is cleared and when it clears the corresponding ARINC bit)
Delay to Clear	(Designates if the bit is latched and the conditions under which it will be cleared)
Latch	

NOTES:

1. Data may be normalized.
2. The number of bits in the data word and the scale factor determine the resolution of the data word. This number can be calculated as: Resolution = 2 exp(-(L - n)), where 'L' is the word length in bits, and 'n' is the next integer greater than the quantity [log(maxvalue)/log2].

A.8.4 Configuration Selection

This section of the ICD should describe the interface functions required for selection of engine configuration such as:

a. Description/method of implementation

b. Engine configuration data specifics:

- Selection of thrust rating
- Engine serial number
- Variable geometry schedule selection
- Parameter trim/modifier selection data, etc.

c. Aircraft system pin-program or software options

d. Fault detection/accommodation and annunciation

A.8.5 Thrust/Power Management

This section of the ICD should describe the interface functions required for thrust management, such as:

a. Thrust/power rating computations (logic and data) for forward and reverse thrust (Note that the data may be included by reference to another document)

b. Primary and alternative thrust/power control mode logic/characteristics

c. Automatic flight control interface functions

d. Idle schedules

e. Bleed air (ECS, Anti-Ice) configurations and discrete characteristics

f. Synchronization

g. Associated indications

A.8.6 Overspeed / Overthrust Protection Systems

This section of the ICD should describe the functional interface logic requirements for engine overspeed and overthrust (TCMA) protection, such as:

a. System architecture details /schematic

b. Detection / inhibit criteria

c. System test / failure annunciation details