

# Control System Certification

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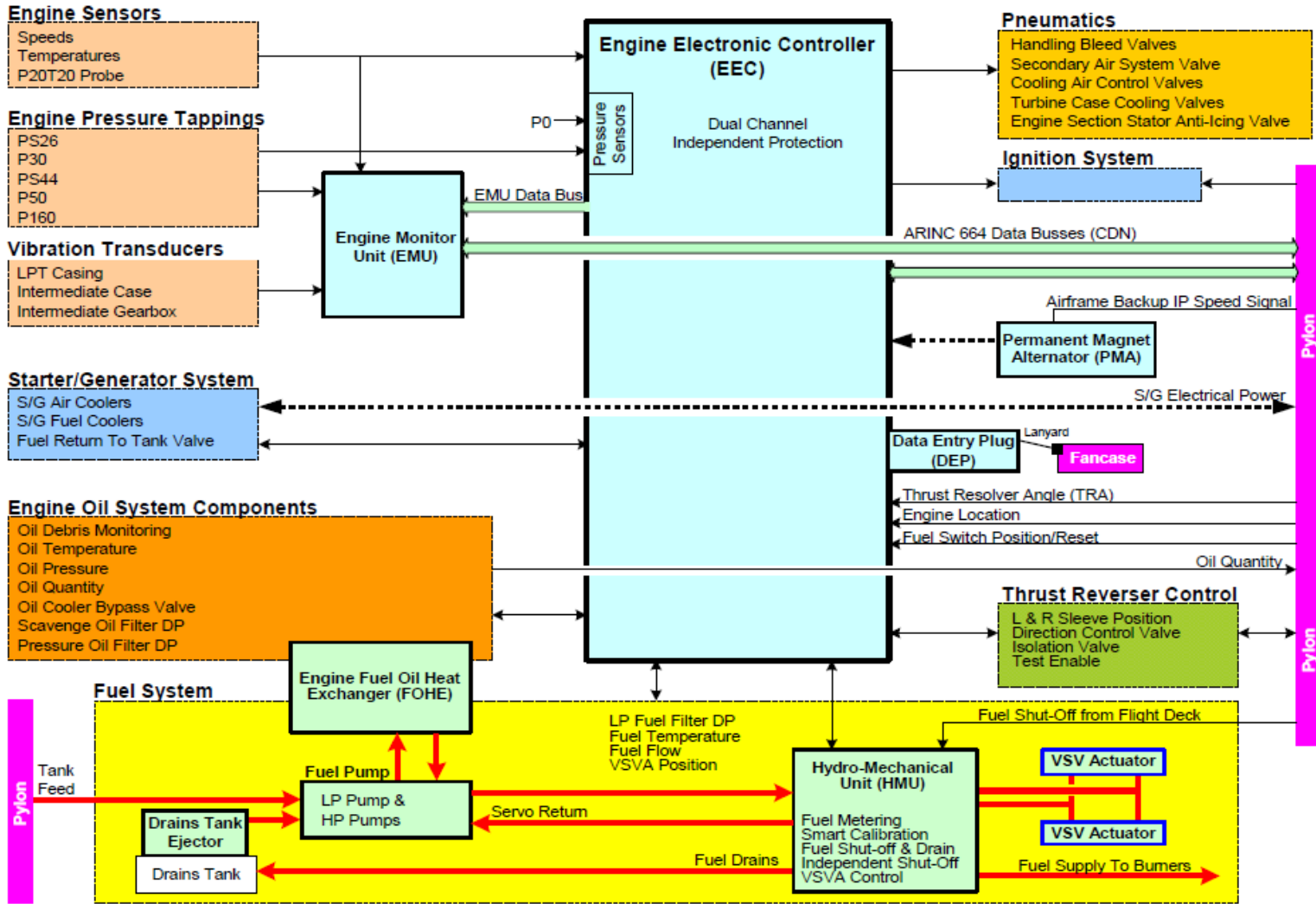
# The Engine Control System

- The control system in its simplest form delivers thrust as commanded by the pilot
- It is both complex and highly integrated, linking together many units, sensors, valves, switches, etc. across the whole engine
- It interfaces with other engine systems, such as: fuel system, oil system, thrust reverser system, cooling/sealing air system, etc.
- The communication links allow the flow of data, such as: commands, feedback, key parameters, health status, etc.
- It interfaces with the cockpit for commands and displays
- Inevitably it is a key driver in delivering engine safety
- At its heart is the EEC – the Electronic Engine Controller



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# Engine Control System



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# Control System Architecture & Functions

- ARP4754 guidelines used to define Control System architecture and requirements decomposition
- Dual channel FADEC, further separated into control & protection
  - Engine start/relight and shutdown.
  - Thrust control and automatic limiter functions
  - Handling bleed valves and variable vanes
  - Surge recovery & flameout protection
  - Heat management system
  - Engine protection systems
  - Input fault detection & accommodation
  - Tip clearance control
  - Aircraft communications management
  - Engine indication and warnings
  - Reverse thrust
  - Data Entry Plug for engine data selection
  - Maintenance/troubleshooting management/dispatch limitations
  - Engine health monitoring
  - etc.



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# Relevant Specifications

The main regulatory requirements relevant to Engine Control System certification are:

<b>CS-E 50</b>	<b>Engine Control System</b>
<b>CS-E 60</b>	<b>Provision for Instruments</b>
<b>CS-E 80</b>	<b>Equipment</b>
<b>CS-E 130</b>	<b>Fire Prevention</b>
<b>CS-E 170</b>	<b>Engine Systems &amp; Component Verification</b>
<b>CS-E 500</b>	<b>Functioning</b>
<b>CS-E 510</b>	<b>Safety Analysis</b>
<b>CS-E 560</b>	<b>Fuel System</b>
<b>CS-E 745</b>	<b>Engine Acceleration</b>
<b>CS-E 1030</b>	<b>Time Limited Dispatch</b>
<b>AMC 20-3A</b>	<b>Certification of Engines Equipped with Electronic Engine Control Systems</b>



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# Typical Compliance Strategies

CS-E 50 Engine Control System	Typical Compliance
(a) Engine Control System Operation (b) Control Transitions (d) System Safety Assessment (e) Protection Systems (g) Aircraft Supplied Data (i) Air Pressure Signal (k) Rapid Engine Shutdown Provision	Design & architecture Definition of engine operating instructions System verification testing Control System Safety Assessment
(c) Engine Control System Failures	Design & architecture Control System Fire & Overheat testing EMC testing System verification testing Control System Safety Assessment
(f) Software and Programmable Logic Devices	Software development to DO-178B Complex hardware development to DO-254
(h) Aircraft Supplied Electrical Power	Electrical power testing

# Control System Verification

- **CS-E 50 & CS-E 170 compliance**
- **Extensive use of hardware-in-the-loop integration bench testing**
- **Simulated engine, sensors, actuators**
- **Fuel system component integration**
- **All system-level requirements verified**
  - Normal operation throughout flight envelope
  - Starting/relighting (windmill/starter assist)
  - Control stability, accel/decel
  - Surge detect/recovery
  - Operation of automatic protection (e.g. overspeed)
  - Fault detection & accommodation
  - Operation of limiters
  - Cockpit display operation including abnormal conditions
  - Maintenance functions including interactive tests
  - Health monitoring functions
  - etc.

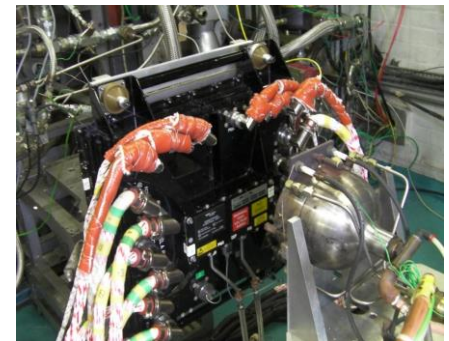


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# Environmental Qualification

## CS-E 80 Equipment - environmental effects

- **Qualification via test & analysis to ED-14/DO-160**
- **24 environmental effects to be complied with**
  - Compliance via, test, analysis, similarity, read-across – or any combination of these
- **EMC: full system bench test of all hardware components to ED-14 and Airframer defined HIRF/lightning/emissions threats**





# Engine Tests

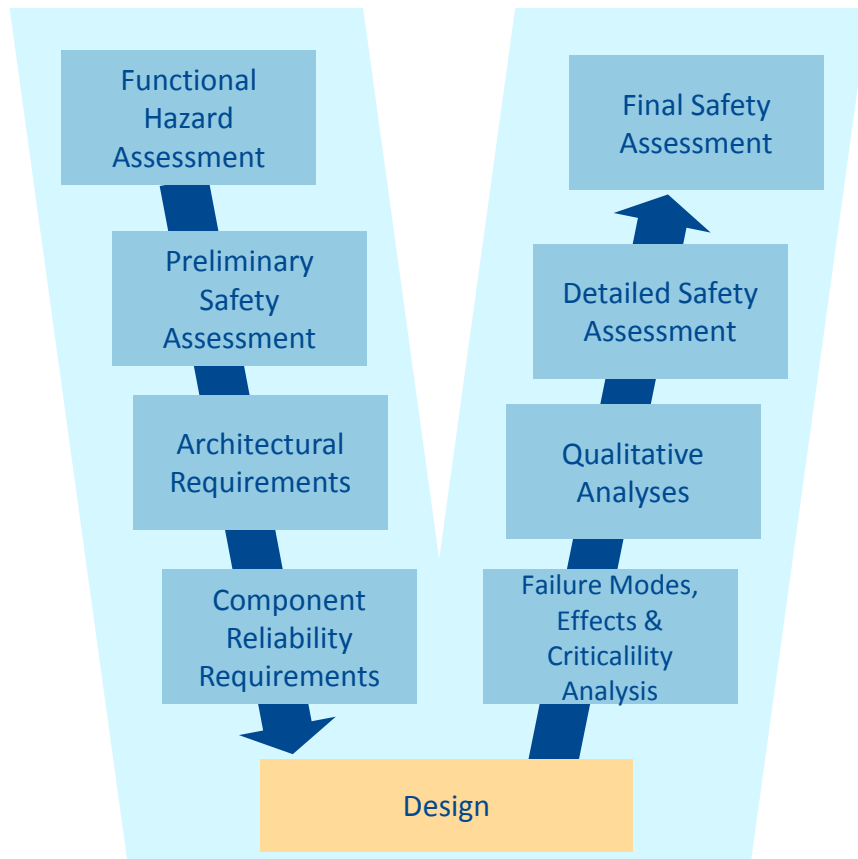
Control System also exercised and validated during following tests:

- **CS-E 500**            **Functioning**
- **CS-E 560**            **Fuel System**
- **CS-E 670**            **Contaminated Fuel**
- **CS-E 740**            **Endurance Test**
- **CS-E 745**            **Engine Acceleration**
- **CS-E 750/770**      **Starting**
- **CS-E 780**            **Tests in Ice Forming Conditions**
- **CS-E 790**            **Ingestion of Rain & Hail**
- **CS-E 890**            **Thrust Reverser Tests**
- **CS-E 910**            **Relighting**
- **CS-E 1040**         **ETOPS**



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# Control System Safety Analysis



- **Compliance to CS-E 50, CS-E 510, CS-E 1030**
- **ARP 4761 process used - Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment**
- **Identifies hazards applicable to the system, including common-mode threats**
- **Defines requirements on system and components**
- **Verifies design complies with applicable safety requirements**
- **Dispatch analysis**



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