ENGINE CONTROLS & INDICATING

THROTTLE CONTROL SYSTEM

THROTTLE CONTROL LEVER

The Throttle control handle comprises:

- a throttle control lever which incorporates stop devices, autothrust instinctive disconnect pushbutton switch
- a graduated fixed sector
- a reverse latching lever

The throttle control lever is linked to a mechanical rod.

This rod drives the input lever of the throttle control artificial feel unit.

The throttle control lever moves over a range from -20 deg. TLA (Reverser to the Full Throttle stop) at +45 deg. TLA:

- -20 degrees TLA corresponds to Reverser Full Throttle stop
- +45 degrees TLA corresponds to Forward Full Throttle stop

An intermediate mechanical stop is set to 0 deg. TLA.

This stop is overridden when the reverse latching lever is pulled up for selection of the reverse power.

This stop is reset as soon as the throttle control lever is selected back to forward thrust area.

In the forward thrust area, there are two detent points, the MAX CLIMB detent point set to 25 deg. TLA and the MAX CONTINUOUS/FLEX TAKE-OFF detent point set to 35 deg. TLA.

In the reverse thrust throttle range, there is one detent point at – 6 deg. TLA.

This position agrees with the selection of the thrust reverser command and the Reverse Idle setting.

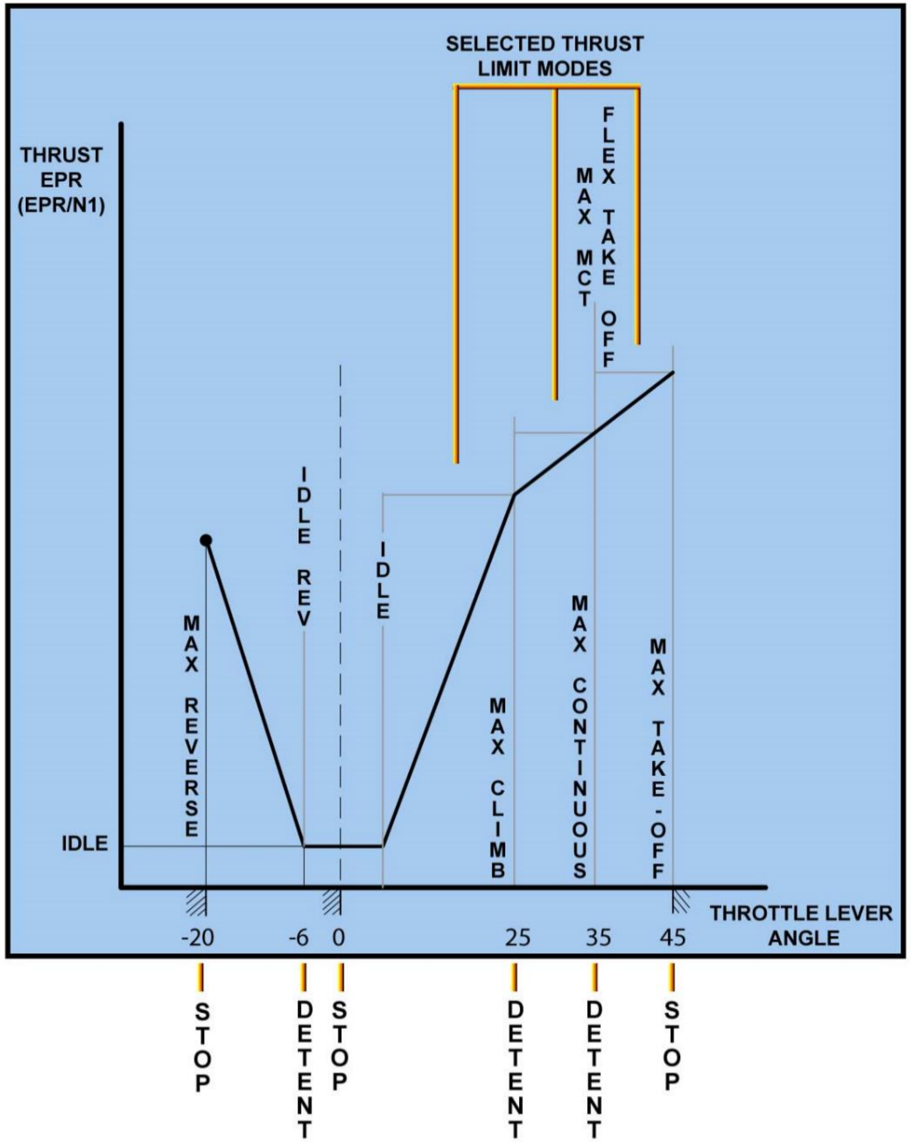
In the middle throttle range (0 deg. To 35 deg. TLA), the autothrust function can be active if engaged.

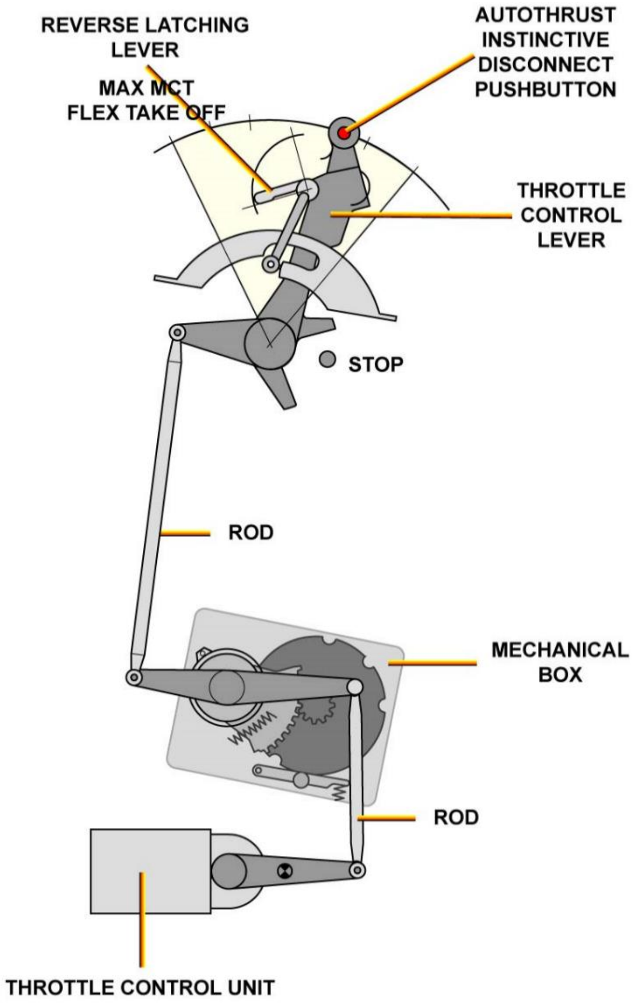
This range agrees with the selection of MAX CLIMB or MAX CONTINUOUS thrust limit mode (in single engine operation).

If the autothrust is not engaged, the engine control is manual.

In the forward range (35 deg. To 45 deg. TLA), the autothrust function cannot be activated (except in alpha floor condition).

This range agrees with the selection of FLEX TAKE-OFF/MAX TAKE-OFF Mode.


SELECTED THRUST LIMIT MODES
THRUST EPR (EPR/N1)
MAX MCT
FLEX TAKE OFF
IDLE REV
IDLE
MAX REVERSE
MAX CLIMB
MAX CONTINUOUS
MAX TAKE-OFF
IDLE
THROTTLE LEVER ANGLE
-20
-6
0
25
35
45
STOP
DETENT
STOP
DETENT
DETENT
STOP


REVERSE LATCHING LEVER
MAX MCT FLEX TAKE OFF
AUTOTHRUST INSTINCTIVE DISCONNECT PUSHBUTTON
THROTTLE CONTROL LEVER
STOP
ROD
MECHANICAL BOX
ROD
THROTTLE CONTROL UNIT

THROTTLE CONTROL UNIT

A mechanical rod transmits the throttle control lever movement.

It connects the throttle artificial feel unit to the input lever of the throttle control unit. The throttle control unit comprises:

- An input lever
- Mechanical stops, which limit the angular range
- 2 resolvers (one resolver per FADEC (ECU/EEC)
- 6 potentiometers installed three by three
- A device, which drives the resolver and the potentiometer
- A pin device for rigging the resolver and potentiometers
- 1 switch whose signal is dedicated to the EIU
- 2 output electrical connectors

The input lever drives two gear sectors assembled face to face.

Each sector drives itself a set of one resolver and three potentiometers.

The relationship between the throttle lever angle and throttle resolver angle (TRA) IS LINEAR AND 1 DEG.TLA = 1.9 TRA.

The accuracy of the throttle control unit (error between the input lever position and the resolver angle) is 0.5 deg. TRA.

The maximum discrepancy between the signals generated by two resolvers is 0.25 deg. TRA.

The TLA resolver operates in two quadrants.

The first quadrant is used for positive angles and the second quadrant for negative angles.

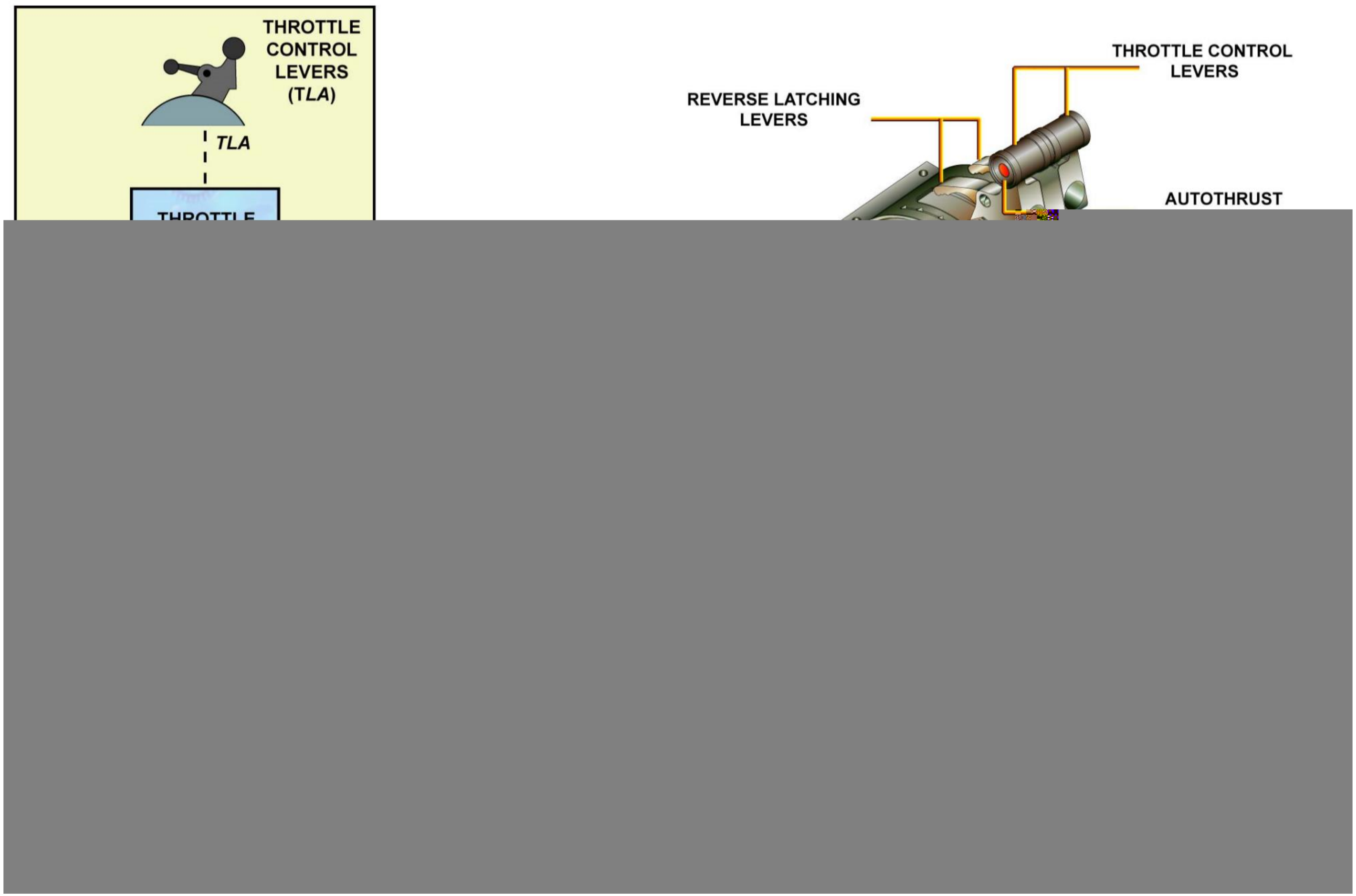
Each resolver is dedicated to one FADEC channel (ECU / EEC) and receives its electrical excitation current (6 VAC) from the related FADEC channel (ECU / EEC)

The ECU considers a throttle resolver angle value:

less than -47.5 deg. TRA or greater than 98.8 deg. TRA as a resolver position signal failure.

The ECU includes a resolver fault accommodation logic.

This logic allows engine operation after a failure or a complete loss of the throttle resolver position signal.


THROTTLE
CONTROL
LEVERS
(TLA)
TLA
THROTTLE CONTROL
LEVERS
REVERSE LATCHING
LEVERS
AUTOTHRUST

BUMP FUNCTION (PW1100G and IAE ENGINES ONLY)

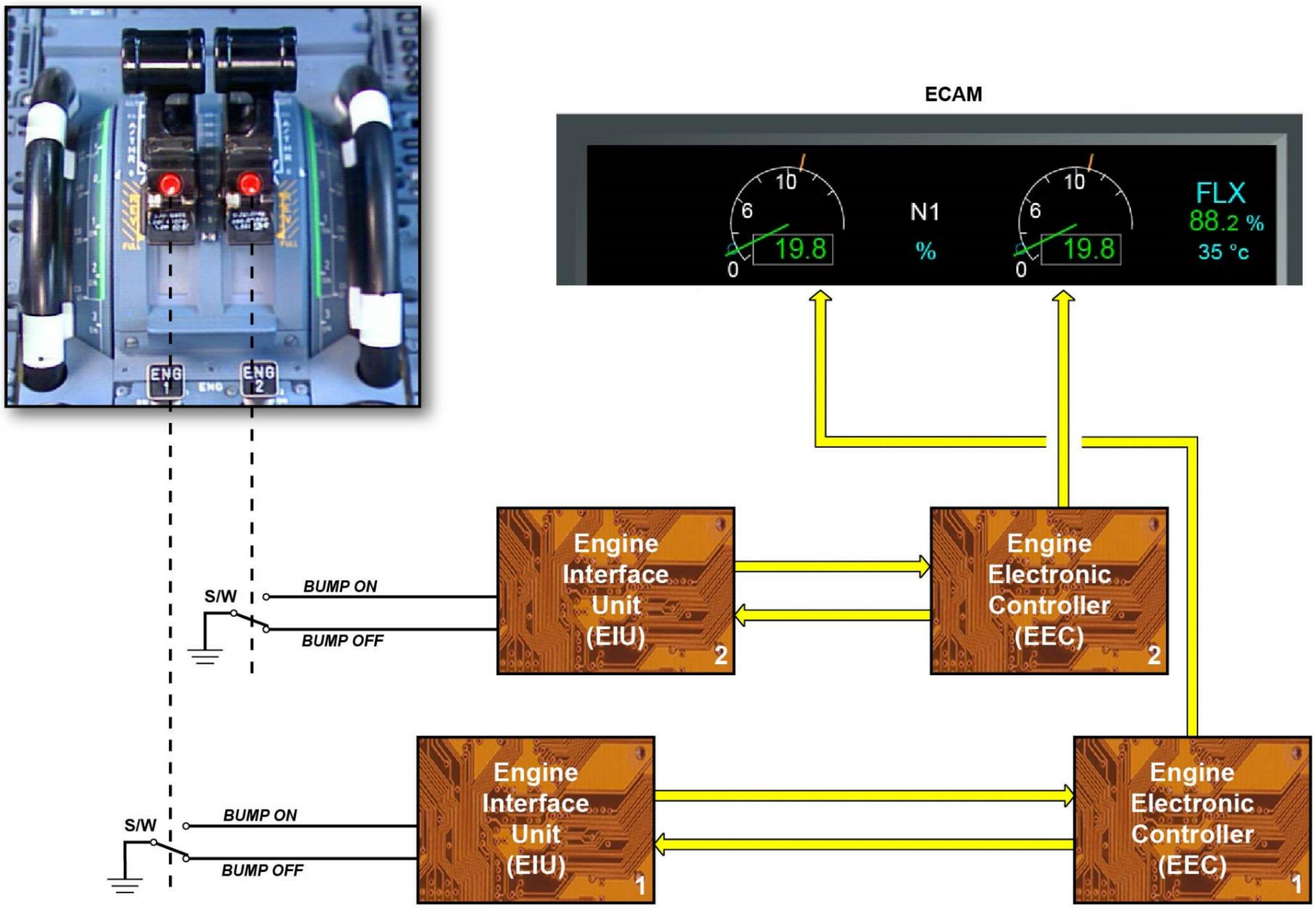
If an airline requests the bump function, this function is selected in the aircraft by guarded pushbutton switch with TLA at TOGA position (one on each throttle control lever).

With this switch, a signal can be sent to the two FADEC units at the same time through the Engine Interface Unit (EIU).

Thrust bump can be used to obtain additional thrust capability during take-off.

It can be used either with two engines or in single engine operation.

With the throttle levers at TOGA and the Bump P/B pushed, 'B' appears on the right side of the EPR/N1 dial on the EWD.


ENG 1
ENG 2
ECAM
10
6
0
19.8
N1
%
10
6
0
19.8
FLX
88.2 %
35 °c
S/W
BUMP ON
BUMP OFF
Engine Interface Unit (EIU) 2
Engine Electronic Controller (EEC) 2
S/W
BUMP ON
BUMP OFF
Engine Interface Unit (EIU) 1
Engine Electronic Controller (EEC) 1

ENGINE THRUST MANAGEMENT

GENERAL

The engine thrust is controlled under the management of the Electronic Engine Controller (EEC).

The engine thrust can be set:

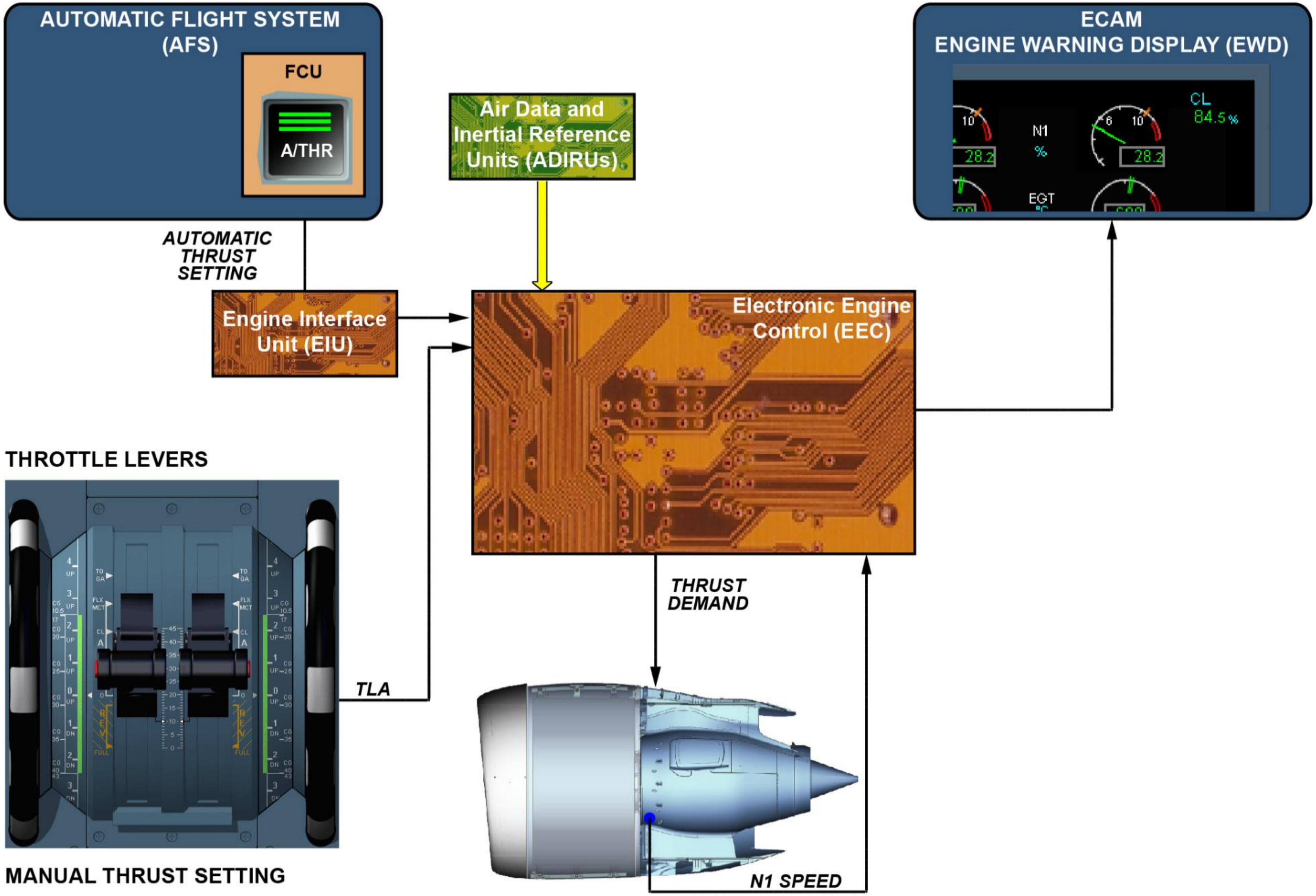
manually from the throttle control lever or,

automatically from the Auto Flight System (AFS).

The engine thrust parameters are displayed on the ECAM.

The main thrust monitoring parameter is the N1 speed (LP shaft).

The main thrust demand parameter is the engine Fuel Flow (FF).


AUTOMATIC FLIGHT SYSTEM (AFS)
FCU
A/THR
AUTOMATIC THRUST SETTING
Air Data and Inertial Reference Units (ADIRUs)
ECAM
ENGINE WARNING DISPLAY (EWD)
Engine Interface Unit (EIU)
Electronic Engine Control (EEC)
THROTTLE LEVERS
TLA
THRUST DEMAND
N1 SPEED
MANUAL THRUST SETTING

THRUST LIMIT MODE

The throttle levers are used as thrust limit mode selectors.

Depending on the throttle lever position, a thrust limit mode is selected and appears on the upper ECAM display.

If the throttle levers are set between two detent points, the upper detent will determine the thrust limit mode.

An additional Soft Go-Around (SGA) mode is available.

It is automatically selected if during approach, the TOGA detent is set and the thrust levers are then moved back to the FLX/MCT detent.

NOTE:

On the ground with the engines running, the displayed N1 rate limit corresponds to the TO/GA thrust limit whatever the thrust lever position is.

On the ground with the engines running and if FLEX mode is selected, FLEX N1 is displayed whenever the thrust lever position is between IDLE and FLX/MCT.

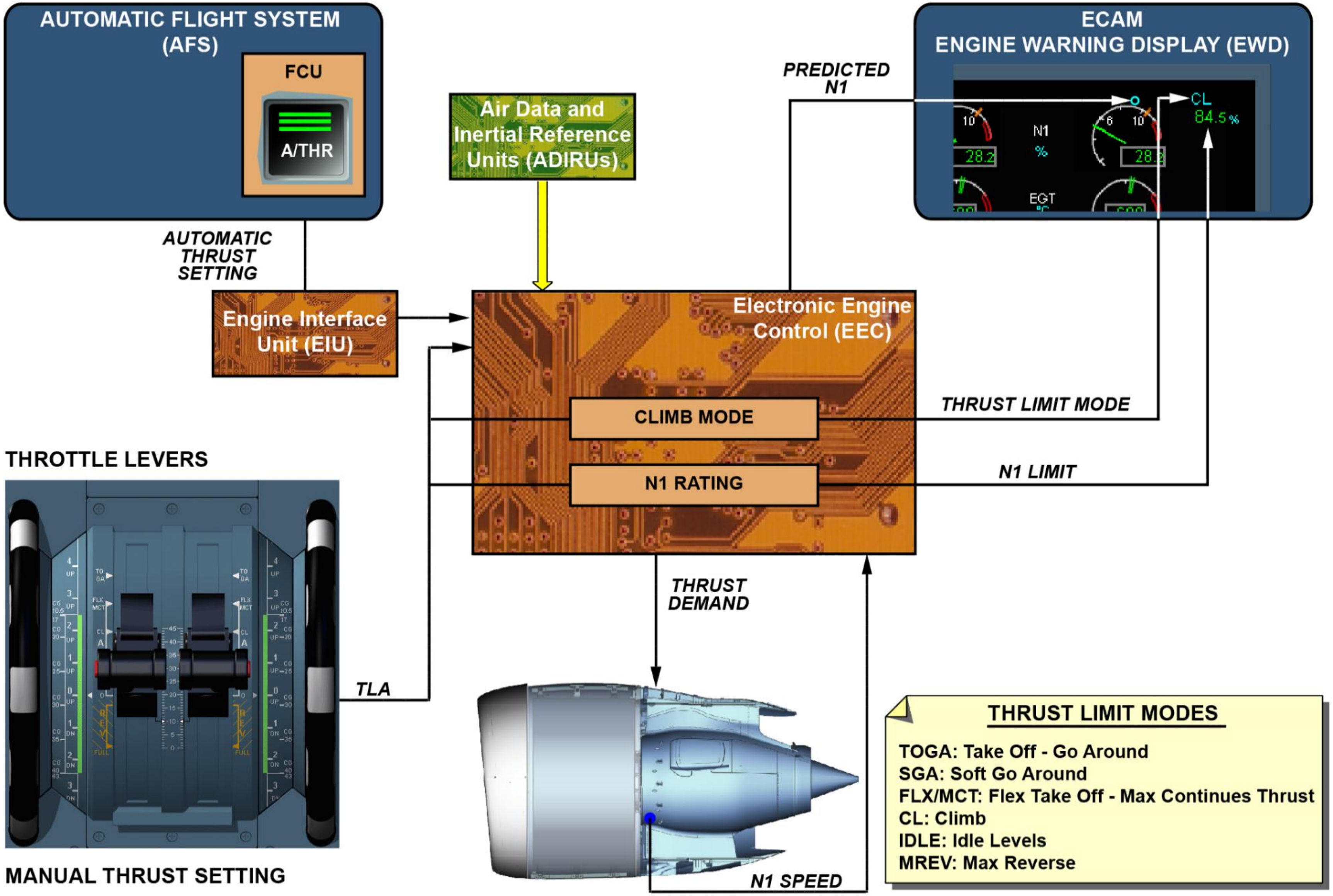
N1 LIMIT

For each thrust limit mode selection, an N1 rating limit is computed by the EEC according to Thrust Lever Angle (TLA) and the air data parameters from the Air Data Inertial and Reference Units (ADIRUs).

This indication is displayed in green on the upper ECAM display near the thrust limit mode indication.

PREDICTED N1

The predicted N1 is indicated by a blue circle on the N1 indicator and corresponds to the value determined by the TLA.



AUTOMATIC FLIGHT SYSTEM (AFS)
FCU
A/THR
Air Data and Inertial Reference Units (ADIRUs)
PREDICTED N1
ECAM
ENGINE WARNING DISPLAY (EWD)
CL
84.5 %
N1
%
EGT
AUTOMATIC THRUST SETTING
Engine Interface Unit (EIU)
Electronic Engine Control (EEC)
CLIMB MODE
N1 RATING
THRUST LIMIT MODE
N1 LIMIT
THROTTLE LEVERS
TLA
THRUST DEMAND
N1 SPEED
MANUAL THRUST SETTING
THRUST LIMIT MODES
TOGA: Take Off - Go Around
SGA: Soft Go Around
FLX/MCT: Flex Take Off - Max Continues Thrust
CL: Climb
IDLE: Idle Levels
MREV: Max Reverse

ACTUAL N1

The actual N1 is the actual value given by the N1 speed sensor and is used as a reference for the engine thrust control loop.

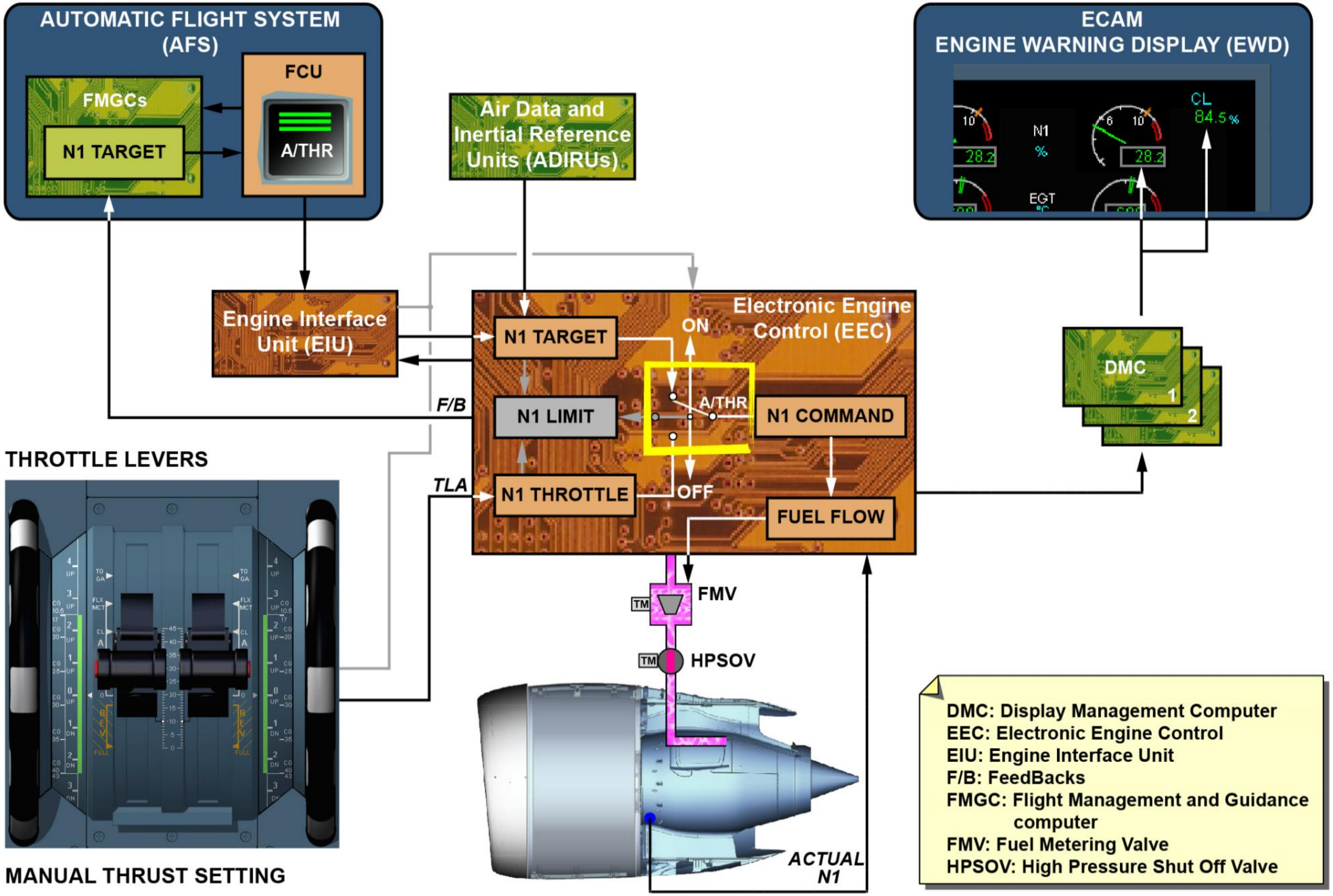
This actual N1 is displayed in green on the N1 indicator.

N1 COMMAND

The N1 command, is used to regulate the fuel flow

N1 TARGET

In A/THR mode, the FMGCs compute an N1 target according to the AFS command, the air data and the engine parameters and send this demand to the EECs.


AUTOMATIC FLIGHT SYSTEM (AFS)
FCU
FMGCs
N1 TARGET
A/THR
Air Data and Inertial Reference Units (ADIRUs)
ECAM
ENGINE WARNING DISPLAY (EWD)
Engine Interface Unit (EIU)
Electronic Engine Control (EEC)
ON
N1 TARGET
A/THR
N1 LIMIT
N1 COMMAND
F/B
TLA
N1 THROTTLE
OFF
FUEL FLOW
DMC
1
2
THROTTLE LEVERS
FMV
HPSOV
TM
ACTUAL N1
MANUAL THRUST SETTING
DMC: Display Management Computer
EEC: Electronic Engine Control
EIU: Engine Interface Unit
F/B: FeedBacks
FMGC: Flight Management and Guidance computer
FMV: Fuel Metering Valve
HPSOV: High Pressure Shut Off Valve

AUTOTHRUST CONTROL MODE

The A/THR function is engaged manually when the A/THR P/B is selected or automatically at take-off power application.

AUTOTHRUST ACTIVE

When engaged, the A/THR function becomes active when the throttle levers are set to CLimb detent after take-off.

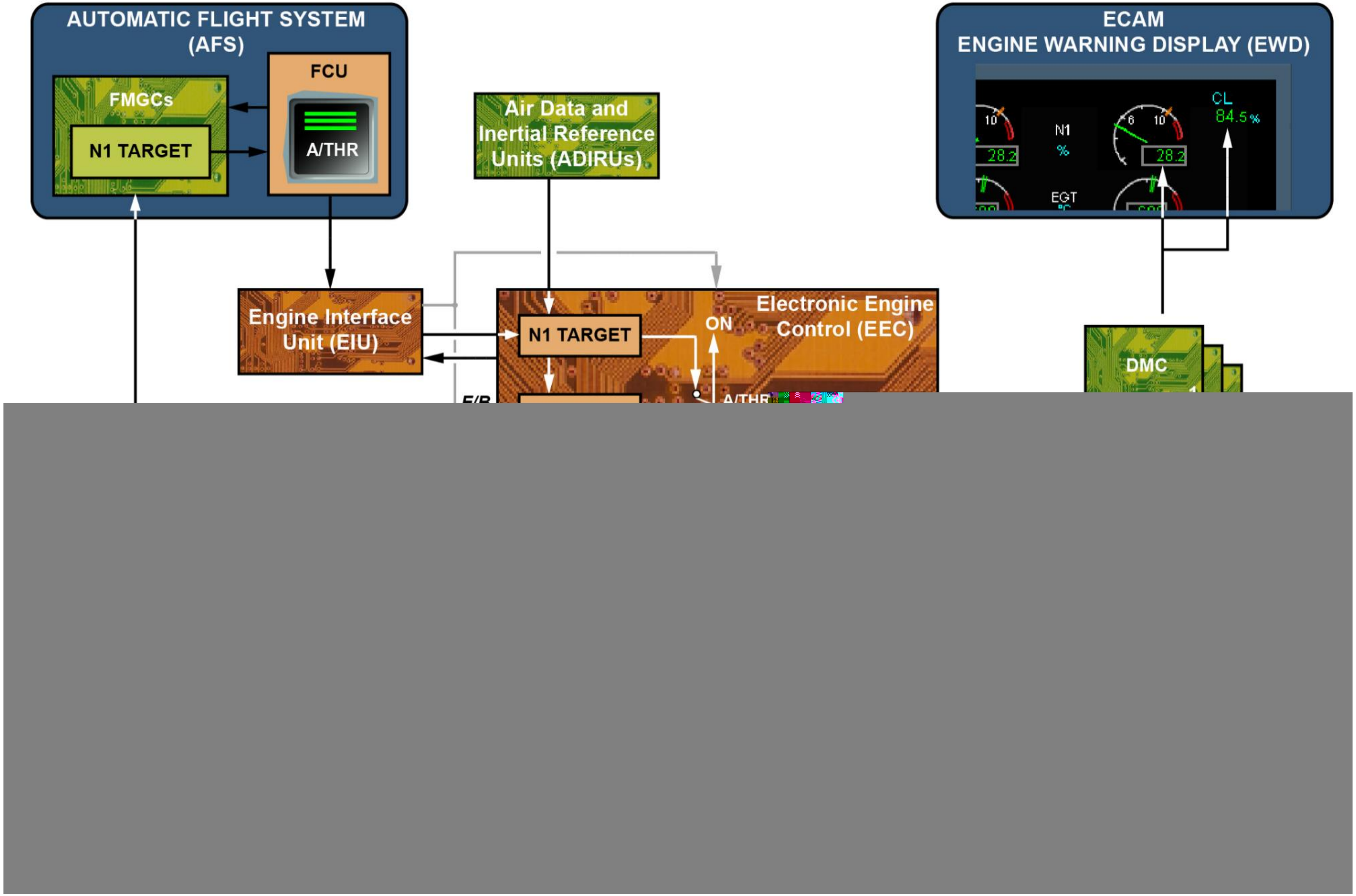
The N1 command is the FMGC N1 target.

The A/THR function is normally active when the throttle levers are set between IDLE and CLimb (including CLimb).

The A/THR active range is extended to MCT in the case of single engine operation.

When the throttle levers are set between two detent points, the N1 command is limited by the throttle lever position.

NOTE: Note: In case of Alpha Floor detection, the A/THR function becomes active automatically and the N1 target is to TOGA.


AUTOMATIC FLIGHT SYSTEM (AFS)
FCU
FMGCs
N1 TARGET
A/THR
Air Data and Inertial Reference Units (ADIRUs)
ECAM
ENGINE WARNING DISPLAY (EWD)
CL
84.5 %
N1
%
EGT
28.2
Engine Interface Unit (EIU)
N1 TARGET
ON
Electronic Engine Control (EEC)
DMC

AUTOTHRUST NOT ACTIVE

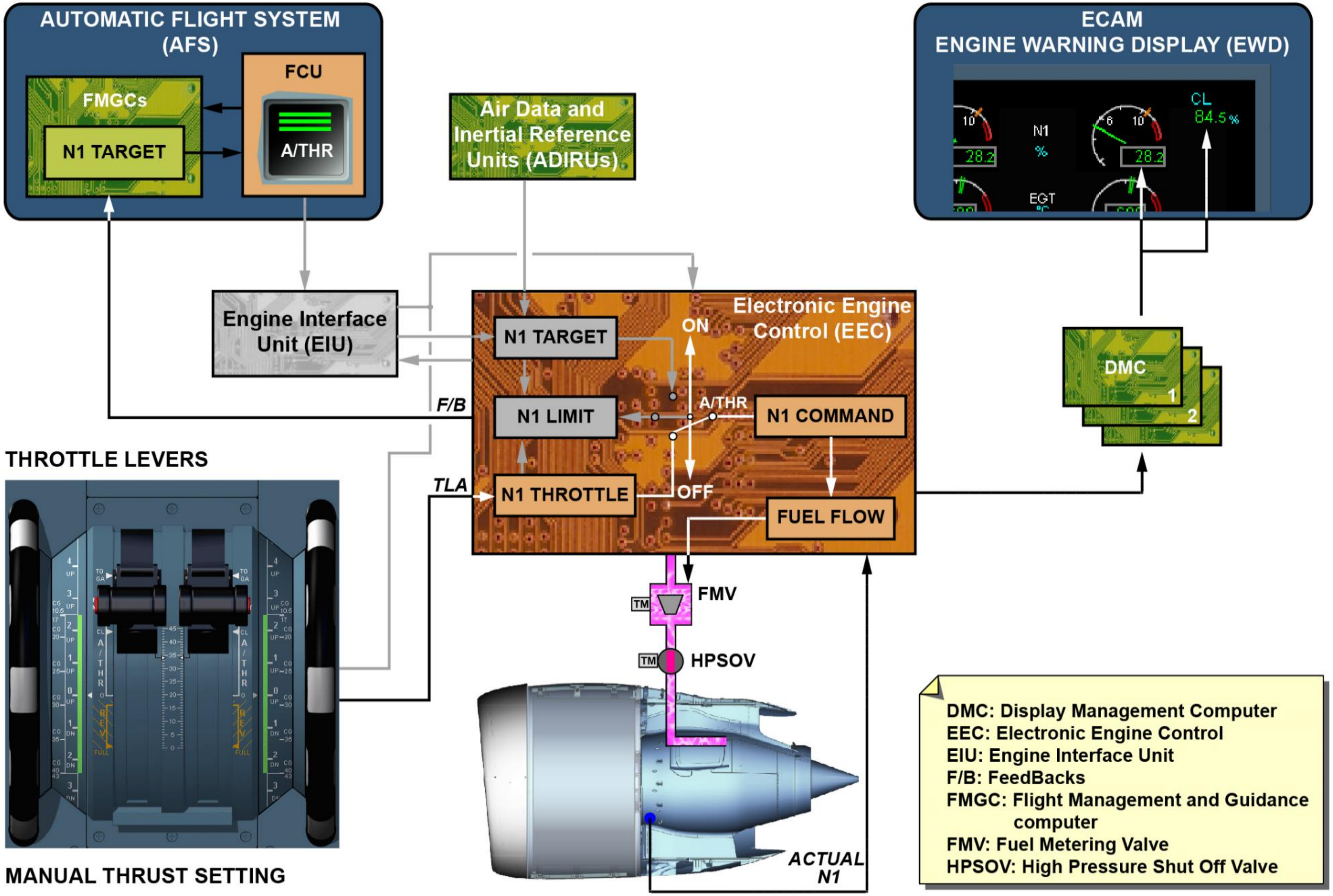
When engaged, the A/THR function becomes inactive when the throttle levers are set above CLimb with both engines running.

In this case, the N1 command corresponds to the N1 throttle (TLA).

NOTE:

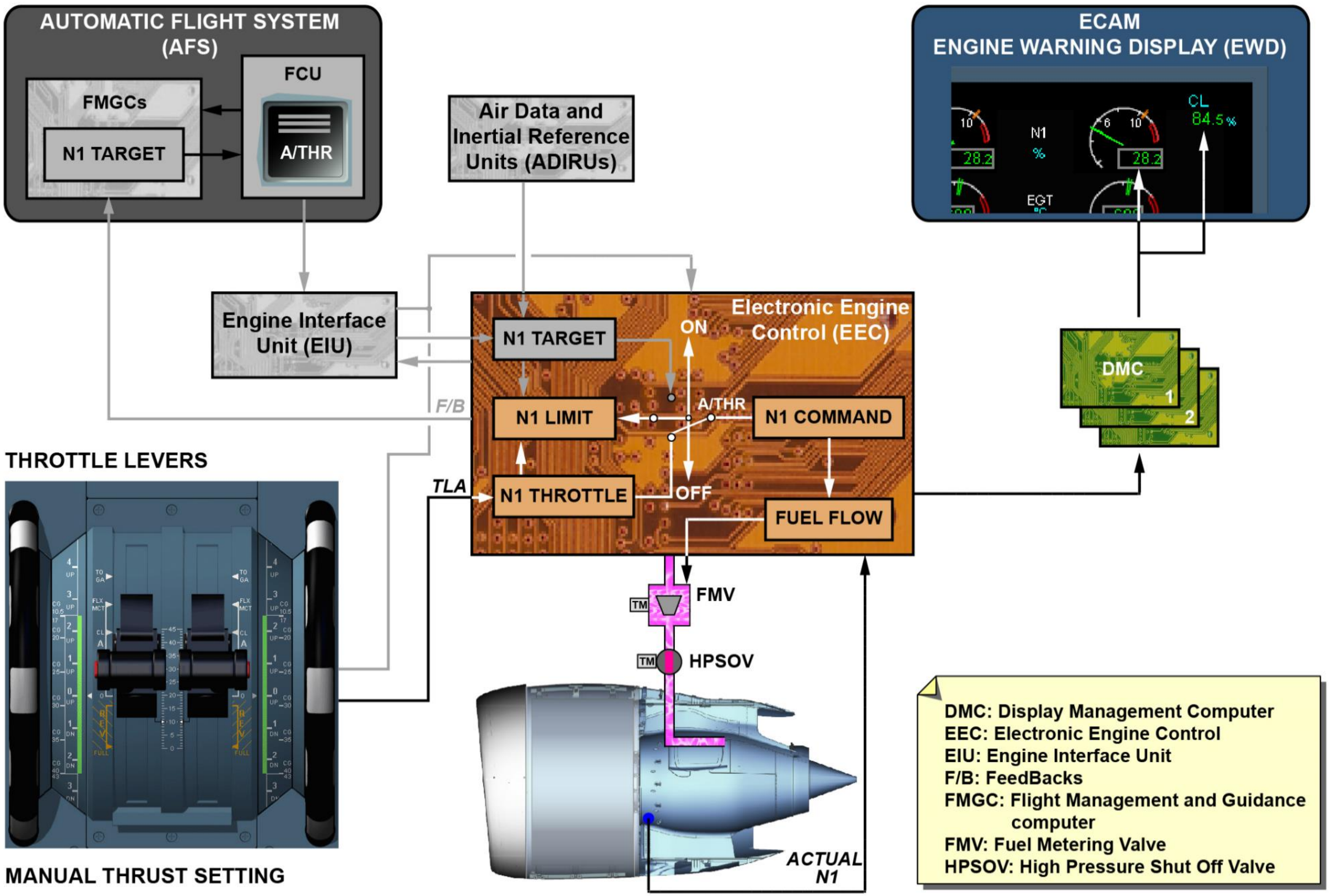
The A/THR function is inactive above MCT in case of single engine operation.

The A/THR function is disengaged when the throttle levers are set at IDLE stop.


AUTOMATIC FLIGHT SYSTEM (AFS)
FMGCs
N1 TARGET
FCU
A/THR
Air Data and Inertial Reference Units (ADIRUs)
ECAM
ENGINE WARNING DISPLAY (EWD)
N1
%
EGT
CL
84.5%
28.2
28.2
Engine Interface Unit (EIU)
Electronic Engine Control (EEC)
N1 TARGET
ON
N1 LIMIT
A/THR
N1 COMMAND
N1 THROTTLE
OFF
FUEL FLOW
F/B
TLA
DMC
1
2
THROTTLE LEVERS
MANUAL THRUST SETTING
FMV
TM
HPSOV
TM
ACTUAL N1
DMC: Display Management Computer
EEC: Electronic Engine Control
EIU: Engine Interface Unit
F/B: FeedBacks
FMGC: Flight Management and Guidance computer
FMV: Fuel Metering Valve
HPSOV: High Pressure Shut Off Valve

MANUAL CONTROL MODE

The engines are in manual control mode when the A/THR function is not engaged, or engaged and not active (throttle levers not in the A/THR operating range and no Alpha Floor detected).

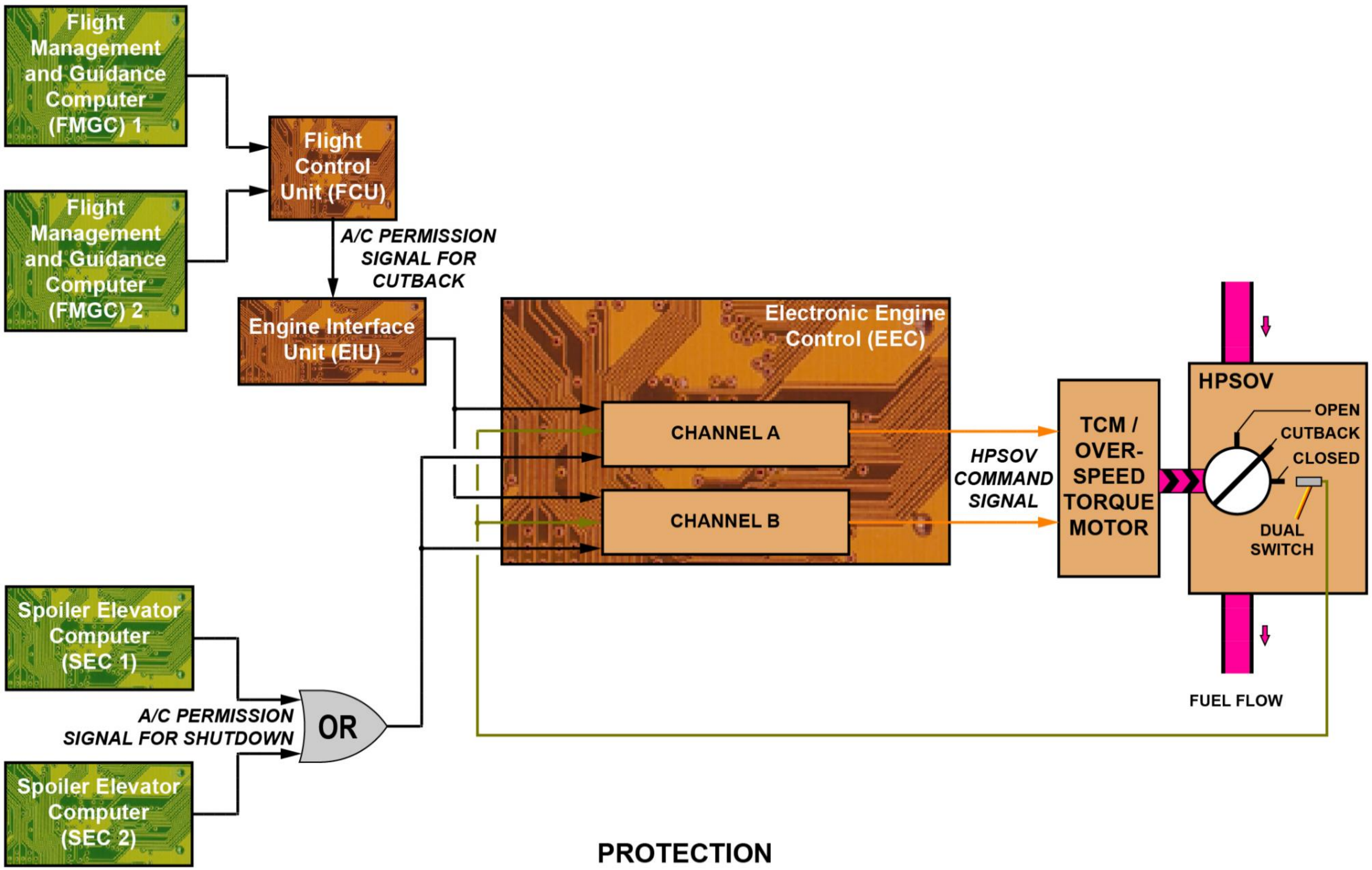

AUTOMATIC FLIGHT SYSTEM (AFS)
FMGCs
N1 TARGET
FCU
A/THR
Air Data and Inertial Reference Units (ADIRUs)
ECAM
ENGINE WARNING DISPLAY (EWD)
N1
%
EGT
CL
84.5 %
28.2
28.2
Engine Interface Unit (EIU)
Electronic Engine Control (EEC)
N1 TARGET
ON
N1 LIMIT
A/THR
N1 COMMAND
F/B
N1 THROTTLE
OFF
TLA
FUEL FLOW
DMC
1
2
THROTTLE LEVERS
FMV
TM
HPSOV
TM
ACTUAL N1
MANUAL THRUST SETTING
DMC: Display Management Computer
EEC: Electronic Engine Control
EIU: Engine Interface Unit
F/B: FeedBacks
FMGC: Flight Management and Guidance computer
FMV: Fuel Metering Valve
HPSOV: High Pressure Shut Off Valve

THRUST CONTROL MALFUNCTION

The Thrust Control Malfunction (TCM) is a FADEC protection function against un-commanded and uncontrollable excessive power excursion in which the normal thrust control becomes inoperative.

NOTE: The FADEC logic uses TCM permission data from FMGCs to FCU to automatically reduce engine thrust during flare.

NOTE: When the Thrust Control Malfunction is active Continuous Ignition is also applied to reduce the risk of a flame out



Flight Management and Guidance Computer (FMGC) 1
Flight Management and Guidance Computer (FMGC) 2
Flight Control Unit (FCU)
A/C PERMISSION SIGNAL FOR CUTBACK
Engine Interface Unit (EIU)
Electronic Engine Control (EEC)
CHANNEL A
CHANNEL B
HPSOV COMMAND SIGNAL
TCM / OVER-SPEED TORQUE MOTOR
HPSOV
OPEN
CUTBACK
CLOSED
DUAL SWITCH
FUEL FLOW
Spoiler Elevator Computer (SEC 1)
Spoiler Elevator Computer (SEC 2)
A/C PERMISSION SIGNAL FOR SHUTDOWN
OR

PROTECTION

ENGINE MONITORING

INDICATING

The engine indicating system has sensors that measure some engine parameters.

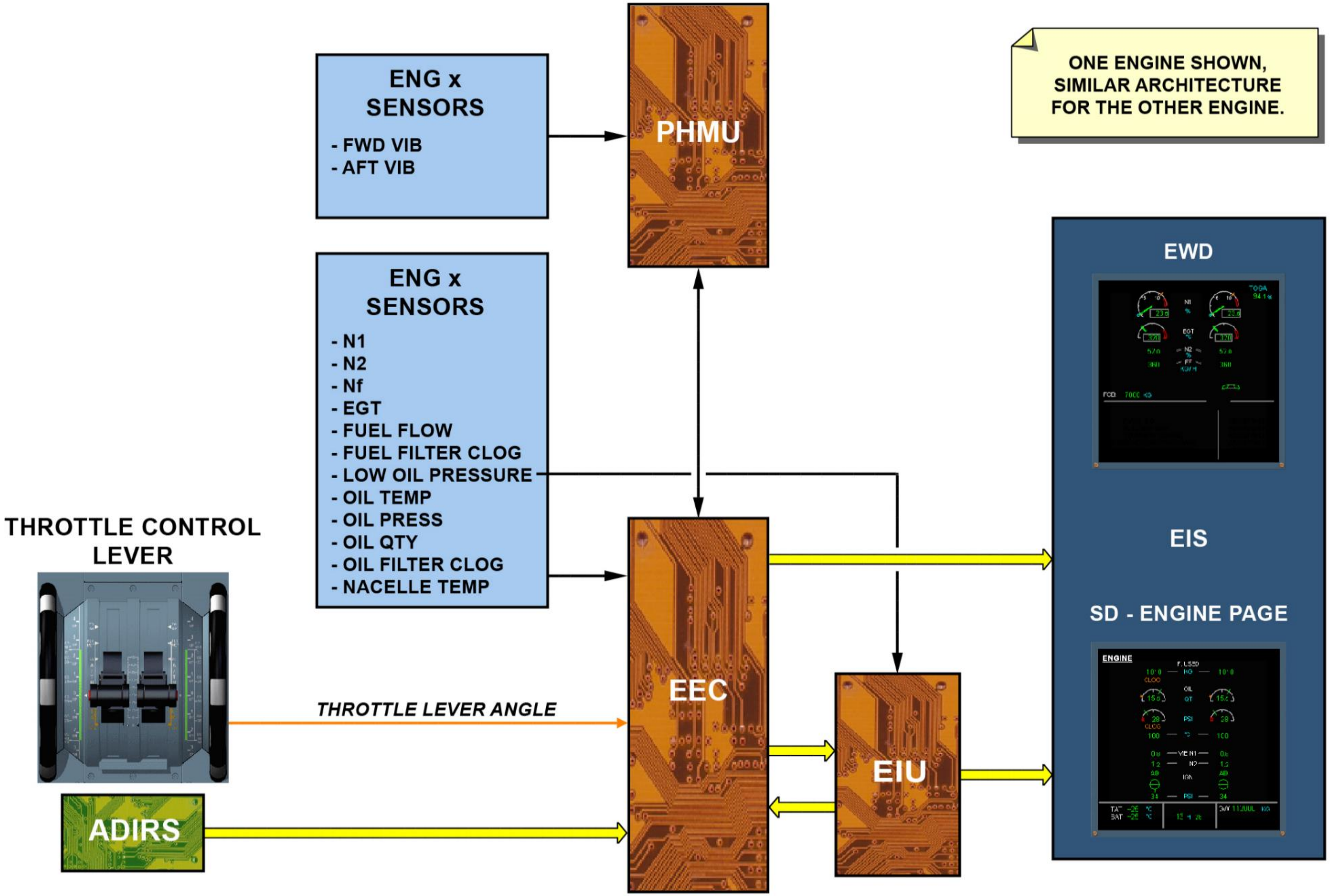
These parameters are supplied to the Electronic Engine Control (EEC) and / or to the Prognostic and Health Monitoring Unit (PHMU) for computation and transmission.

They are sent to the Electronic Instrument System (EIS) for display on the EWD and on the SD-ENGINE Page.

Engine Primary Parameters direct from the EEC to the DMCs

Engine Secondary Parameters from the EEC to the EIU then to the SDACs

In conjunction with inputs from the ADIRS, they are also used to control and monitor the engine with the Throttle Lever Angle (TLA) position in manual thrust control mode or with the Engine Interface Unit (EIU) inputs in auto thrust control mode.


ENG x SENSORS
- FWD VIB
- AFT VIB
PHMU
ONE ENGINE SHOWN, SIMILAR ARCHITECTURE FOR THE OTHER ENGINE.
ENG x SENSORS
- N1
- N2
- Nf
- EGT
- FUEL FLOW
- FUEL FILTER CLOG
- LOW OIL PRESSURE
- OIL TEMP
- OIL PRESS
- OIL QTY
- OIL FILTER CLOG
- NACELLE TEMP
EWD
EIS
SD - ENGINE PAGE
THROTTLE CONTROL LEVER
THROTTLE LEVER ANGLE
EEC
EIU
ADIRS

PRIMARY PARAMETERS

ROTATIONAL SPEED PARAMETERS DESCRIPTION

The N1 speed sensor is mounted on the rear of the Compressor Intermediate Case (CIC) at approximately 4 o'clock position.

The N1 speed sensor detects the rotational speed of LP rotor assembly.

The indication is shown in the ECAM EWD by a needle and a N1 digital indication display.

The N2 speed sensor is installed on the right-hand side of the Angle Gear Box (AGB).

The N2 speed sensor detects the rotational speed of the HP rotor assembly.

The N2 rotational speed is indicated in the ECAM EWD by digits.

The digital display is shown on a grey background during engine start.

Both the N1 and N2 speed sensors are dual channel magnetic speed sensors and transmit the corresponding signals to the EEC for processing and monitoring and to the PHMU via the EEC for vibrations computation.

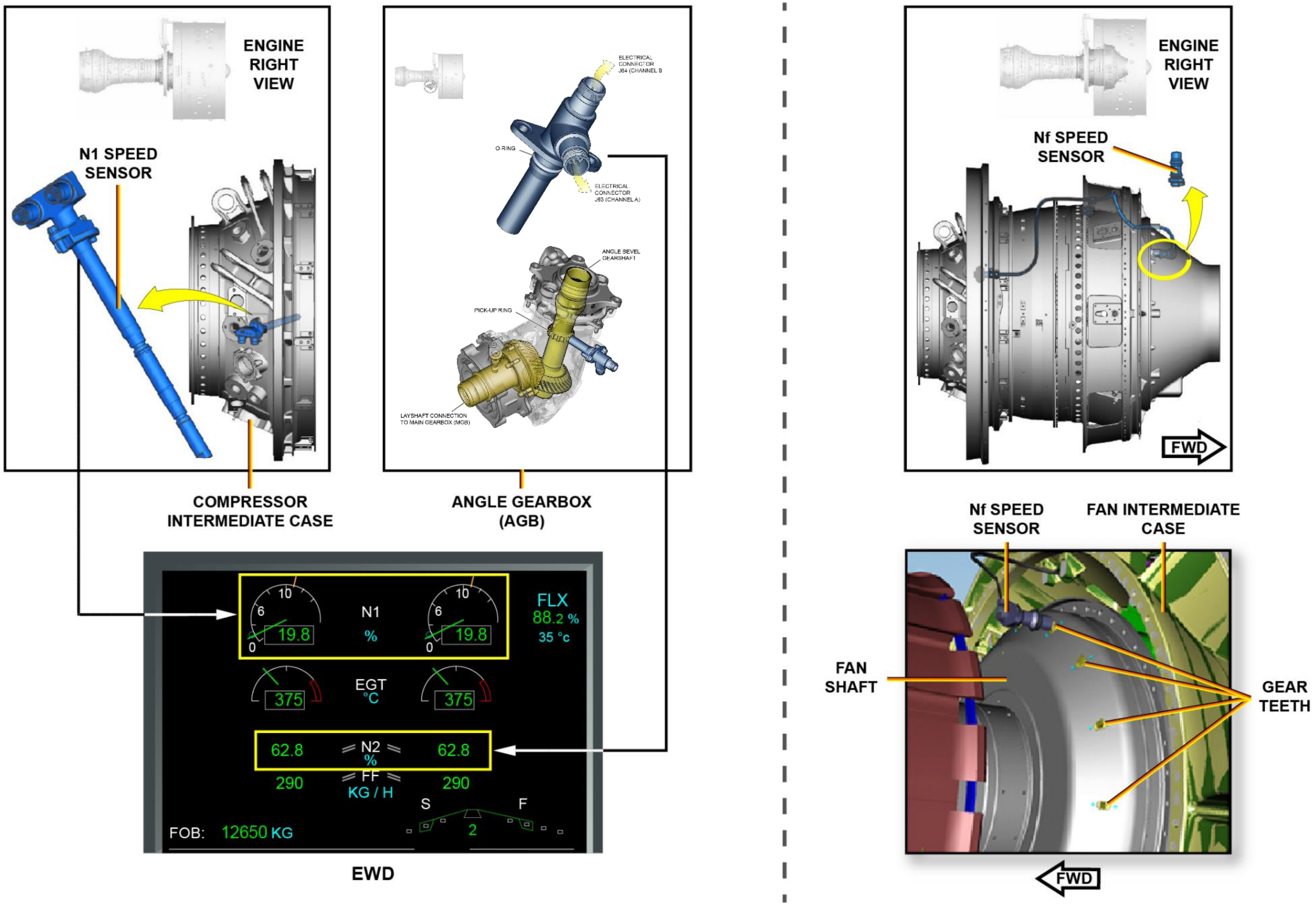
The N1 and N2 sensors are line replaceable units.

The Fan Speed (Nf) sensor senses the fan rotor speed and sends it to the EEC. There is no indication of Nf on the ECAM.

The EEC uses the Fan Speed sensor to detect de-coupling of the Fan Shaft from the LP shaft (sheared shaft) by comparing the Nf to the N1.

The PHMU uses the Fan Speed from the EEC in conjunction with Fan Rotor vibrations to monitor Fan Rotor vibration and calculate trim balance solution for maintenance purposes.

The Nf sensor is a Line Replaceable Unit (LRU).


ENGINE
RIGHT
VIEW
N1 SPEED
SENSOR
COMPRESSOR
INTERMEDIATE CASE
ANGLE GEARBOX
(AGB)
N1
%
19.8
19.8
FLX
88.2 %
35 °c
EGT
°C
375
375
62.8
N2
%
62.8
290
FF
KG / H
290
S
F
FOB: 12650 KG
2
EWD
ENGINE
RIGHT
VIEW
Nf SPEED
SENSOR
FWD
Nf SPEED
SENSOR
FAN INTERMEDIATE
CASE
FAN
SHAFT
GEAR
TEETH
FWD

EGT PARAMETERS

The engine EGT is sensed and averaged by four thermocouple probes (T5 probes) located around the circumference of the Turbine Exhaust Case (TEC).

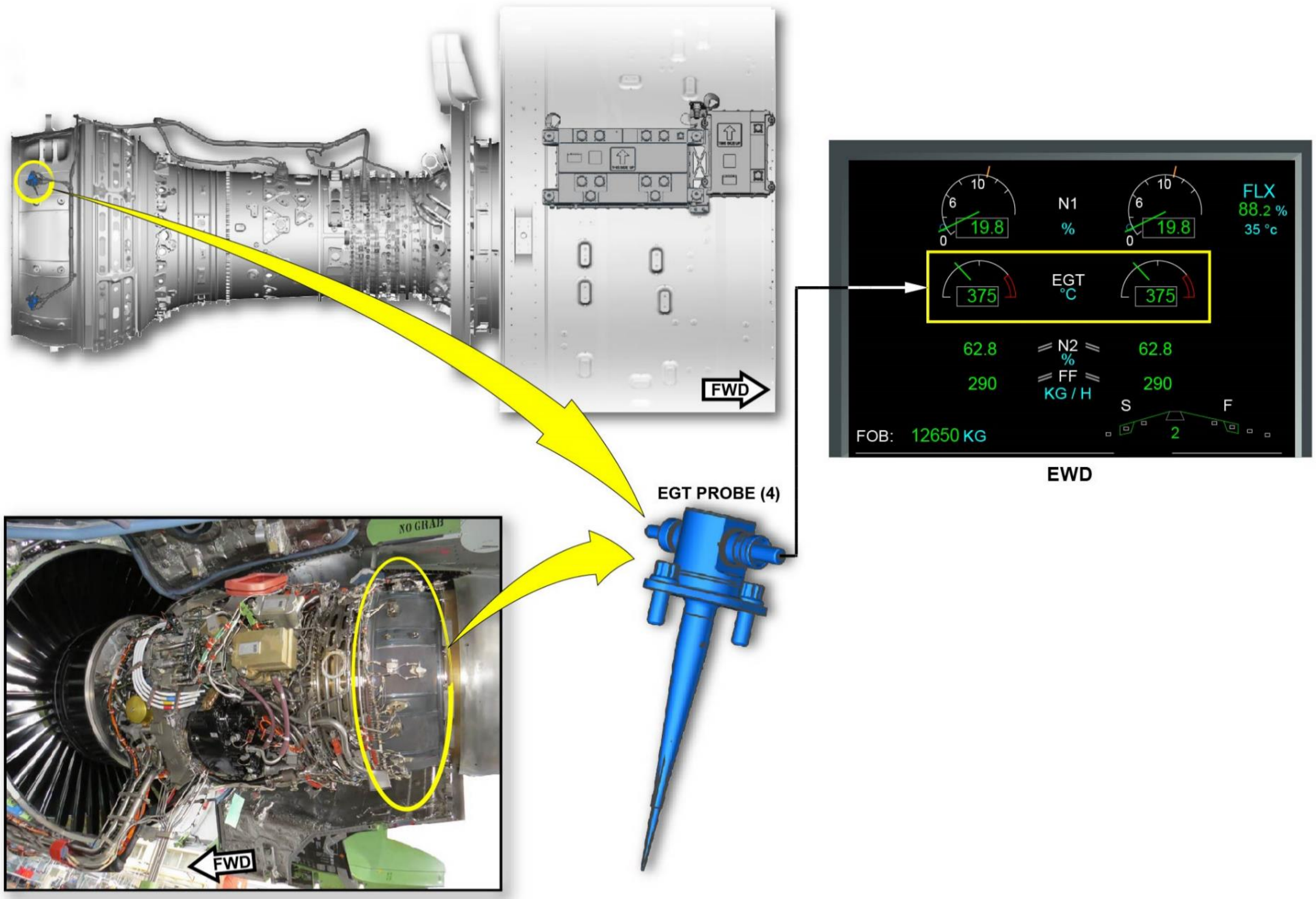
The actual engine EGT is displayed in the ECAM EWD by a needle and an EGT digital indication.

Each probe is a single channel Chromel / Alumel thermocouple.

The signals from the two T5 probes on the left side of the engine are electrically averaged and sent to Channel A of the EEC.

The signal from the two T5 probes on the right side of the engine are electrically averaged and sent to channel B of the EEC.

The EGT thermocouples are LRUs.


FWD
EGT PROBE (4)
NO GRAB
FWD
10
6
0
19.8
N1
%
19.8
FLX
88.2 %
35 °C
375
EGT
°C
375
62.8
N2
%
62.8
290
FF
KG / H
290
S
F
2
FOB: 12650 KG
EWD

FUEL PARAMETERS DESCRIPTION

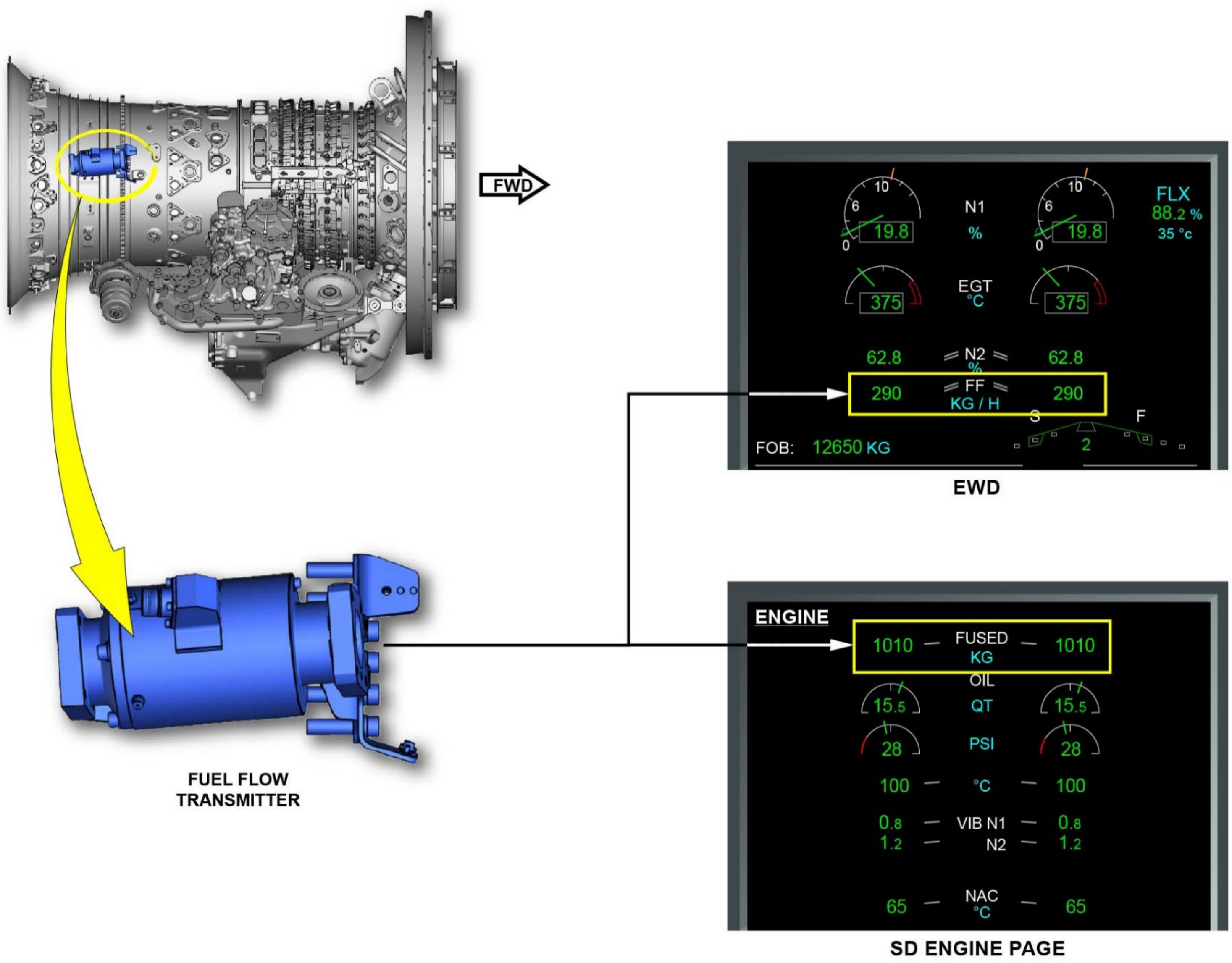
The Fuel Flow Meter (FFM) is installed on the intermediate case right-hand side of the engine core at approximately the 3 o'clock position.

The fuel flow and the fuel used are displayed on the ECAM EWD by digital indications. The FFM is a magnetic drum and impeller type.

The fuel used value is computed by the EIS from the fuel flow value sent by the EEC.

The fuel used for each engine is computed from the engine start to the engine shutdown. It is reset to 0 at the next engine start.

The FFM is an LRU.

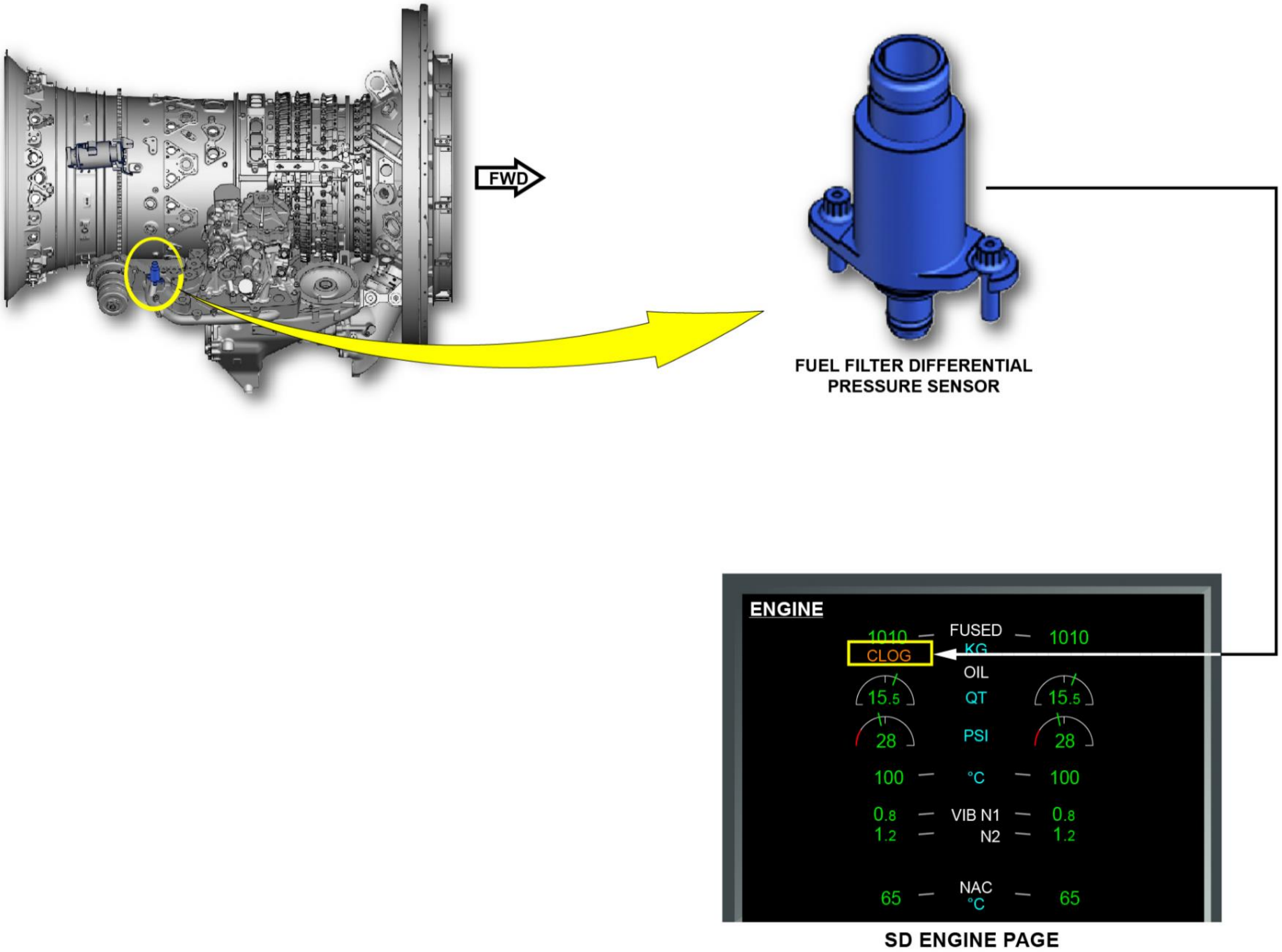

FWD
FUEL FLOW
TRANSMITTER
N1
%
FLX
88.2 %
35 °c
19.8
19.8
EGT
°C
375
375
62.8
N2
%
62.8
290
FF
KG / H
290
S
F
FOB: 12650 KG
2
EWD
ENGINE
1010
FUSED
KG
1010
OIL
15.5
QT
15.5
28
PSI
28
100
°C
100
0.8
VIB N1
0.8
1.2
N2
1.2
65
NAC
°C
65
SD ENGINE PAGE

FUEL PARAMETERS DESCRIPTION

The fuel filter differential pressure sensor is bolted to the fuel manifold which is attached to the Main Gearbox (MGB) at the 3 o'clock position.

The sensor signal is transmitted by the EEC to the ECAM system to generate clogging alerts when the fuel differential pressure across this filter exceeds the thresholds.

Two indications are available: DEGRAD or CLOG.



FWD
FUEL FILTER DIFFERENTIAL PRESSURE SENSOR
ENGINE
1010
FUSED
KG
1010
CLOG
OIL
15.5
QT
15.5
28
PSI
28
100
°C
100
0.8
VIB N1
0.8
1.2
N2
1.2
65
NAC
°C
65
SD ENGINE PAGE

SECONDARY PARAMETERS

OIL PARAMETERS DESCRIPTION

The Oil Level (OL) sensor is located in the oil tank.

It sends the oil quantity analogue signal to the EEC. The EEC sends the signal for display on ECAM SD ENGINE page.

The Main Oil Pressure (MOP) sensor is located on the left-hand side of the engine on the Oil Control Module (OCM), rear lower side.

It is a dual channel sensor which sends the signal to the EEC for monitoring.

EEC sends the signal for display on ECAM SD ENGINE page.

The Main Oil Temperature (MOT) sensor is a dual channel sensor and is used to measure the temperature of the scavenge oil returning to the tank.

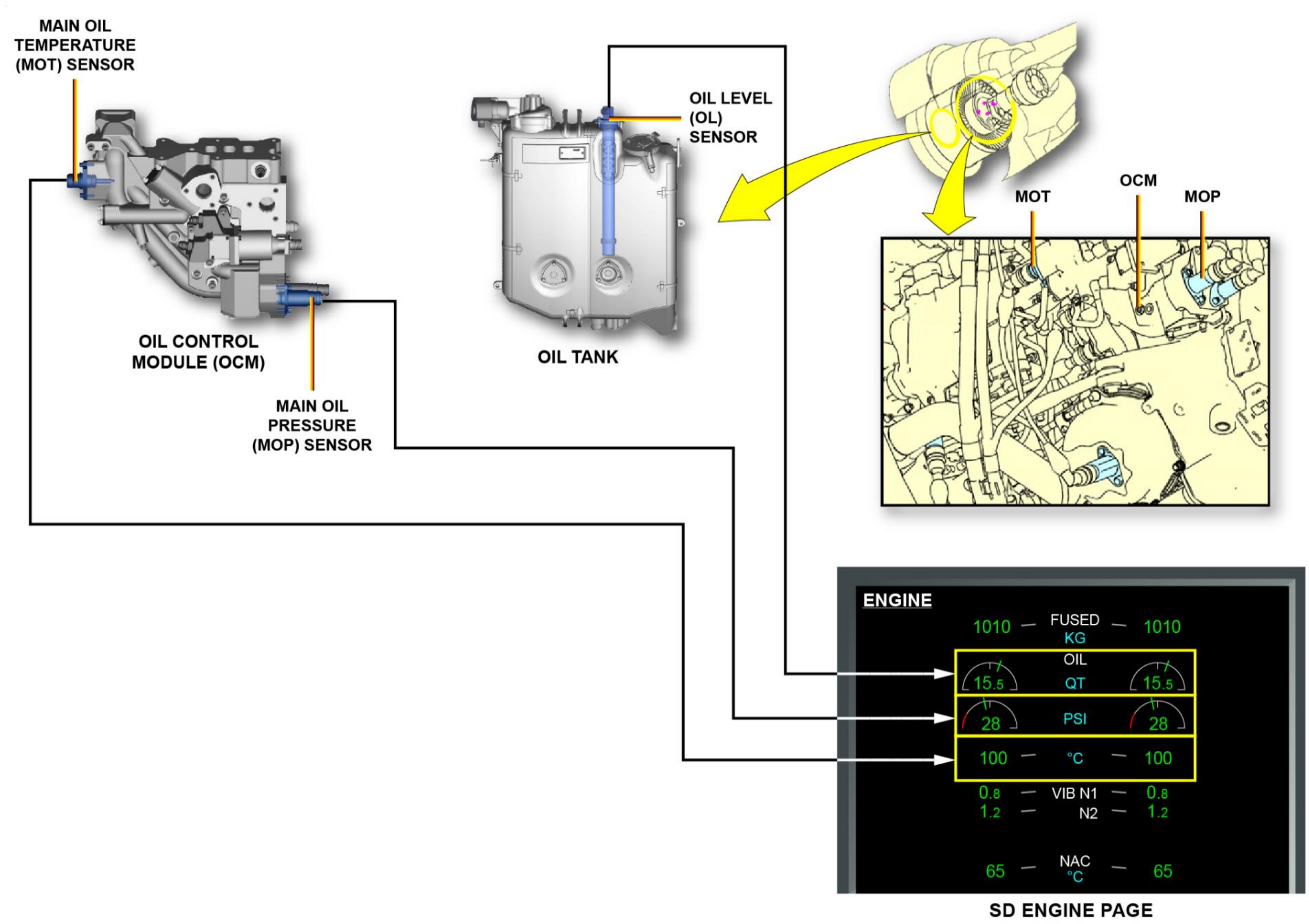
This data is monitored by the EEC and is displayed on the ECAM SD ENGINE page.

The sensor is located on the front face of the OCM.
In case of abnormal condition, sensors send signals to trigger messages on ECAM and / or CFDS.

An Oil Filter Differential Pressure (OFDP) sensor is installed adjacent to the oil pressure filter unit on the Lubrication and Scavenge Oil Pump (LSOP) unit.

The pressure sensor signal is transmitted by the EEC to the ECAM system to generate the main oil filter clogging alerts when the oil differential pressure across this filter exceeds the thresholds.

Two indications are available: DEGRAD or CLOG.


MAIN OIL TEMPERATURE (MOT) SENSOR
OIL CONTROL MODULE (OCM)
MAIN OIL PRESSURE (MOP) SENSOR
OIL LEVEL (OL) SENSOR
OIL TANK
MOT
OCM
MOP
ENGINE
1010
FUSED
KG
1010
OIL
15.5
QT
15.5
28
PSI
28
100
°C
100
0.8
VIB N1
0.8
1.2
N2
1.2
NAC
°C
65
65
SD ENGINE PAGE

An Auxiliary Oil Pressure (AOP) sensor is located on the left side of the engine, below the Variable Oil Reduction Valve /Journal Oil Shuttle Valve (VORV/JOSV).

It measures the pressure of oil delivered to the journal bearings in the Fan Drive Gear System (FDGS).

It sends a signal to the EEC, where it is used in conjunction with other oil parameters to detect a Fan Drive Gearbox (FDG) auxiliary oil supply malfunction.

The Low Oil Pressure (LOP) switch signals the EIU when the oil pressure drops below a threshold. It is located on the left-hand side of the engine on the Oil Control Module (OCM).

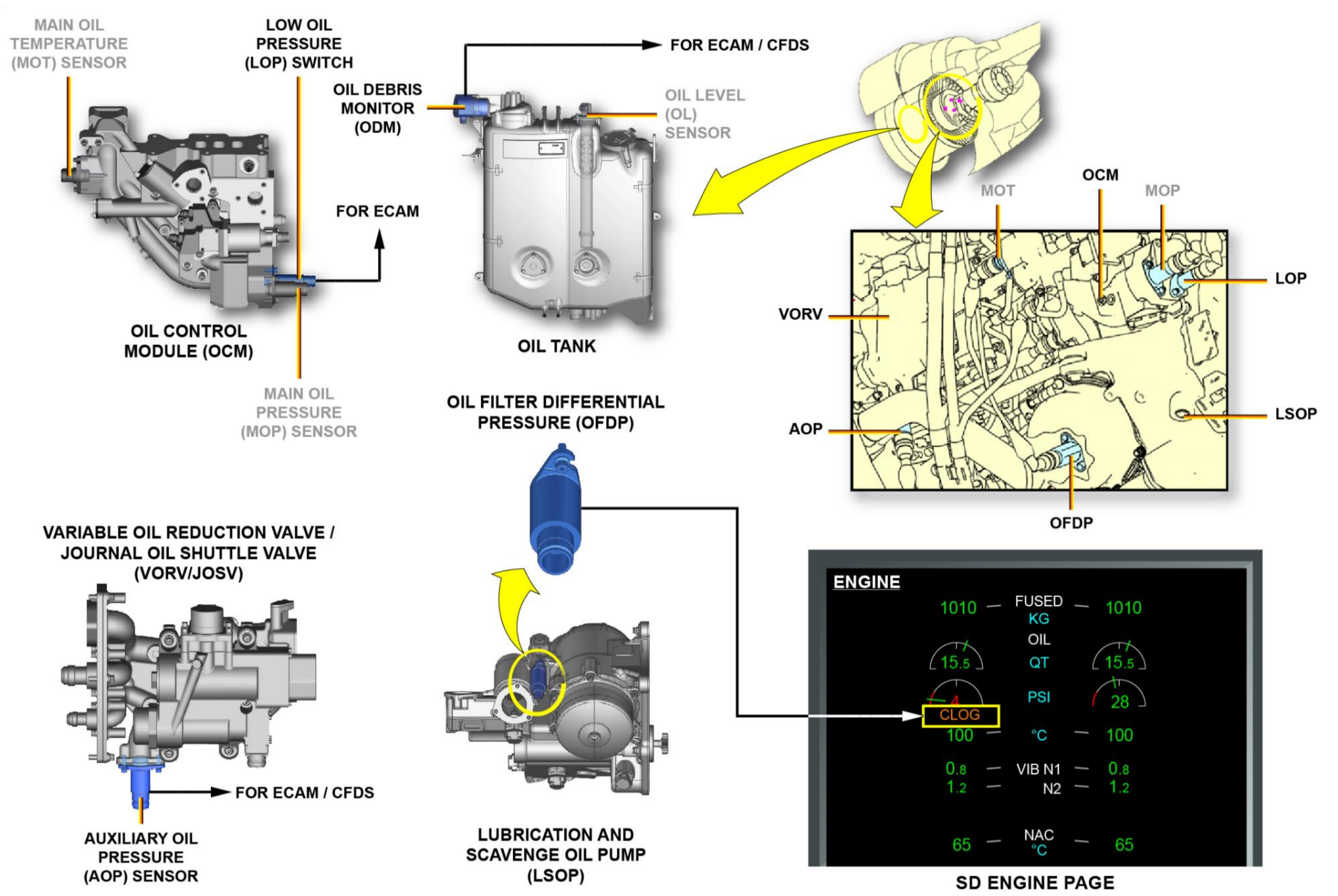
The Oil Debris Monitoring (ODM) sensor is located on the top front side of the oil tank.

It sends signals proportional to size and type of the pollution particles to the PHMU.

The PHMU monitors the debris for quantity and identifies whether it is ferrous or non-ferrous debris.

The data is transmitted to the EEC for analysis and to generate an ECAM message and trend monitoring accordingly.

The data is also stored in the Data Storage Unit (DSU).


MAIN OIL TEMPERATURE (MOT) SENSOR
LOW OIL PRESSURE (LOP) SWITCH
OIL DEBRIS MONITOR (ODM)
FOR ECAM / CFDS
OIL LEVEL (OL) SENSOR
FOR ECAM
OIL CONTROL MODULE (OCM)
OIL TANK
MAIN OIL PRESSURE (MOP) SENSOR
OIL FILTER DIFFERENTIAL PRESSURE (OFDP)
MOT
OCM
MOP
LOP
VORV
AOP
LSOP
OFDP
VARIABLE OIL REDUCTION VALVE / JOURNAL OIL SHUTTLE VALVE (VORV/JOSV)
FOR ECAM / CFDS
AUXILIARY OIL PRESSURE (AOP) SENSOR
LUBRICATION AND SCAVENGE OIL PUMP (LSOP)
ENGINE
1010
FUSED
KG
1010
OIL
15.5
QT
15.5
PSI
28
CLOG
100
°C
100
0.8
VIB N1
0.8
1.2
N2
1.2
65
NAC
°C
65
SD ENGINE PAGE

VIBRATION PARAMETERS DESCRIPTION

The vibration monitoring function within the PHMU uses the two vibration sensors to measure the Fan related vibrations (VIB N1) and the Core related vibrations (VIB N2), stores this information and sends it to the EEC.

It is used for ECAM display in the ENGINE SD page.

It's also used for the fan trim balance procedure.

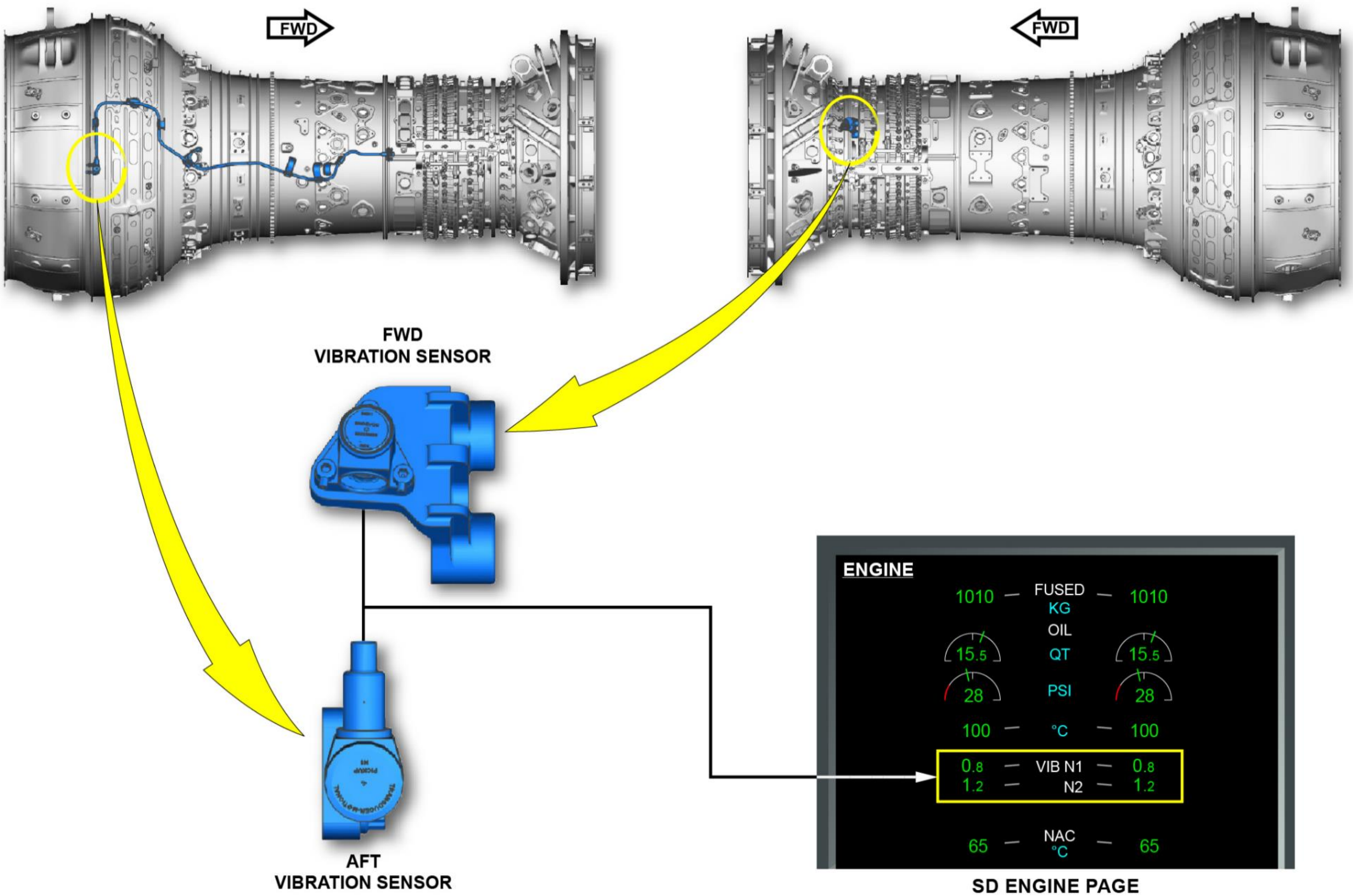
The PHMU receives Nf, N1 and N2 data from EEC to capture and compute the appropriate vibration data.

The Forward Vibration Sensor is a single channel piezoelectric accelerometer, installed at 10 o'clock on the HP Compressor casing.

The Aft Vibration Sensor is a single channel piezoelectric accelerometer, installed at 3 o'clock on the LP Turbine casing.

If the signal from one vibration sensor (either forward or aft vibration sensor) is lost during engine operation, the vibration monitoring function is still able to provide both vibration signals (N1 and N2) for cockpit display.

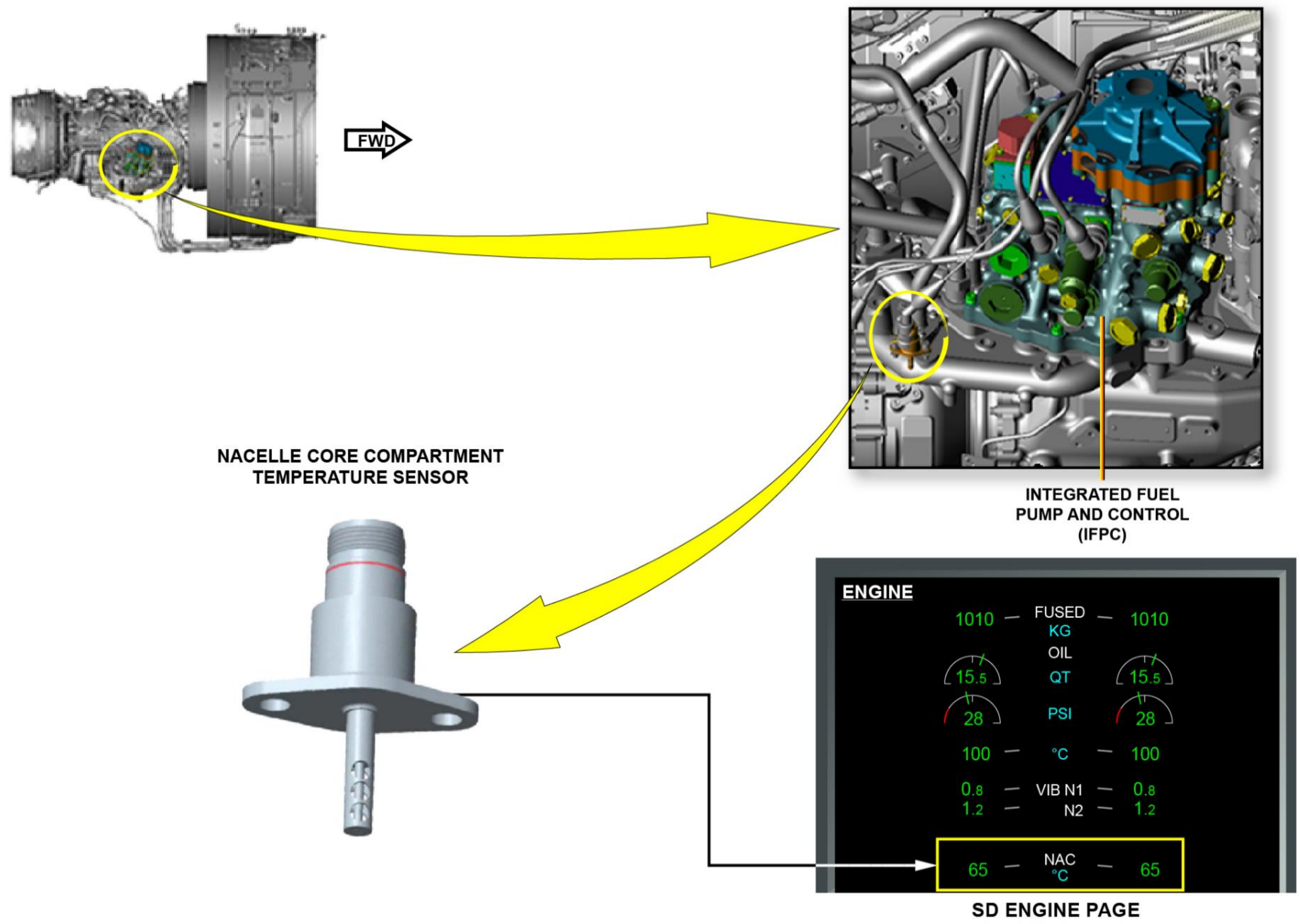
However, the display for the affected sensor will be presented in degraded mode.


FWD
FWD
FWD
VIBRATION SENSOR
AFT
VIBRATION SENSOR
ENGINE
1010
FUSED
KG
1010
OIL
15.5
QT
15.5
28
PSI
28
100
°C
100
0.8
VIB N1
0.8
1.2
N2
1.2
65
NAC
°C
65
SD ENGINE PAGE

NACELLLE TEMPERATURE INDICATION

The nacelle temperature is monitored by a temperature probe installed in the ventilated core compartment.

The nacelle temperature is displayed on the ECAM ENGINE SD, except during starting or cranking sequences where it is replaced by starting parameters.


FWD
NACELLE CORE COMPARTMENT
TEMPERATURE SENSOR
INTEGRATED FUEL
PUMP AND CONTROL
(IFPC)
ENGINE
1010
FUSED
KG
1010
OIL
15.5
QT
15.5
28
PSI
28
100
°C
100
0.8
VIB N1
0.8
1.2
N2
1.2
65
NAC
°C
65
SD ENGINE PAGE

OTHER SENSORS FOR ENGINE CONTROL AND MONITORING

Various sensors are used by the EEC for the engine control and monitoring.

The T2 sensor measures the air inlet temperature for engine rating, Mach number calculation and bleed scheduling.

It is in the air inlet cowl at 1 o'clock position. (Aft looking Fwd)

The P 2.5/T 2.5 sensor measures the air pressure and temperature downstream of the booster at the High-Pressure Compressor (HPC) inlet.

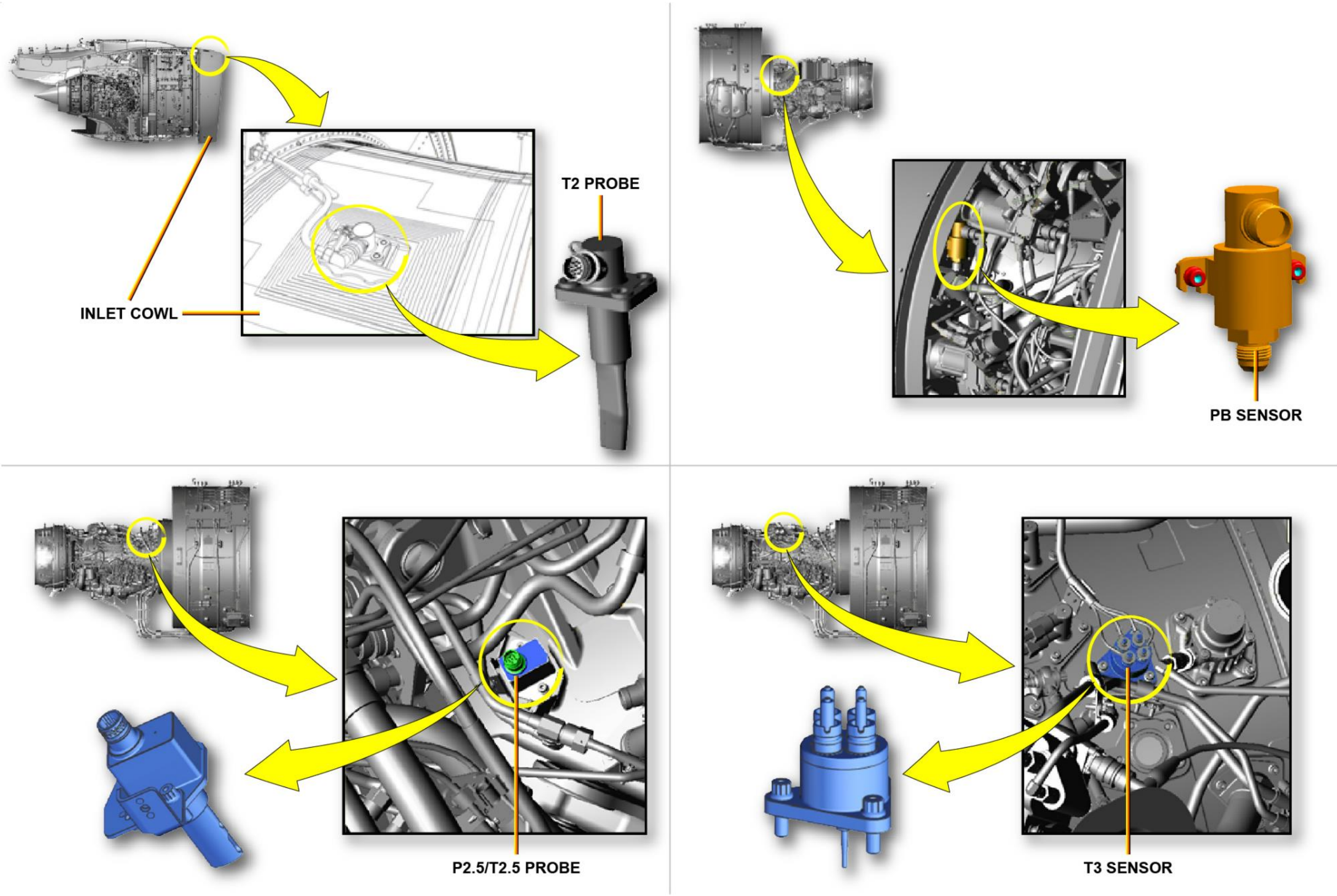
It is located on the Compressor Intermediate Case at 1 o'clock position.

The Burner Pressure (PB) sensor measures the pressure related to the combustion for fuel scheduling, surge recovery, stall detection, idle modulation and continuous ignition logic.

It is in the LH side Compressor Intermediate case firewall at 11 o'clock position.

The T3 sensor measures the compressor discharge temperature for total temperature calculation.

It is located on the diffuser case, forward of the fuel nozzles at 1 o'clock position.


T2 PROBE
INLET COWL
PB SENSOR
P2.5/T2.5 PROBE
T3 SENSOR

INDICATING SYSTEM COMPONENT DESCRIPTION

The Indicating System senses, transmits and provides cockpit display of engine operating parameters and information such as engine speeds, temperatures, vibration and Electronic Centralized Aircraft Monitor (ECAM) messages.

The system is composed of three subsystems, described in the table.

System	Indication
Power Indicating	Rotor speeds
Temperature Indicating	Exhaust Gas Temperature (EGT)
Analyzers	Engine vibration and health management, using data from engine sensors and components

Safety Conditions

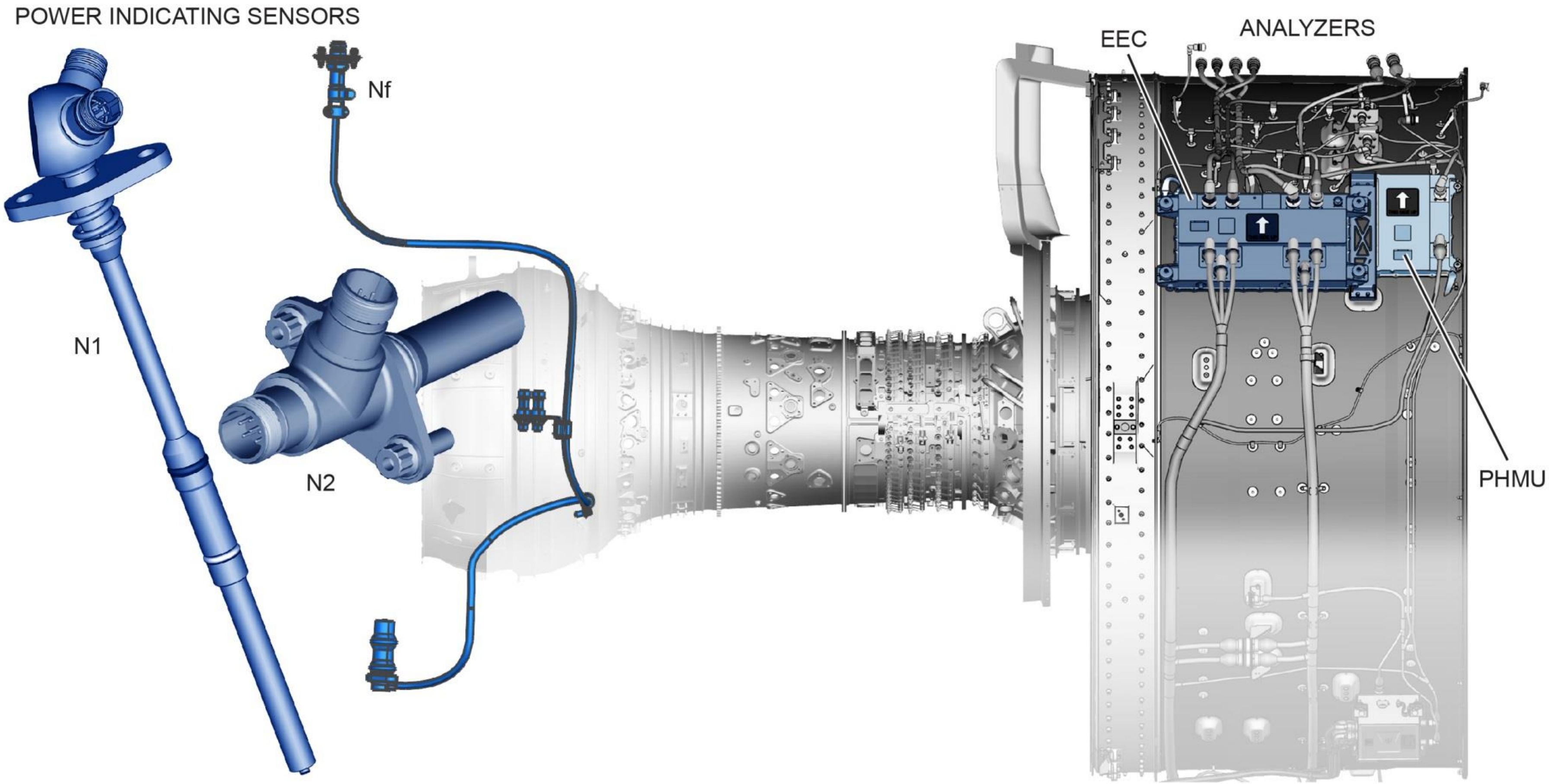
WARNING

BE CAREFUL WHEN YOU WORK ON THE ENGINE AFTER SHUTDOWN.

THE ENGINE AND ENGINE OIL CAN STAY HOT FOR A LONG TIME. IF YOU DO NOT OBEY THIS WARNING, INJURY CAN OCCUR.

REFER TO THE MSDS FOR ALL MATERIAL USED AND THE MANUFACTURER'S SAFETY INSTRUCTIONS FOR ALL EQUIPMENT USED.

IF YOU DO NOT OBEY THIS WARNING, INJURY CAN OCCUR.



POWER INDICATING SENSORS
Nf
N1
N2
EEC
ANALYZERS
PHMU

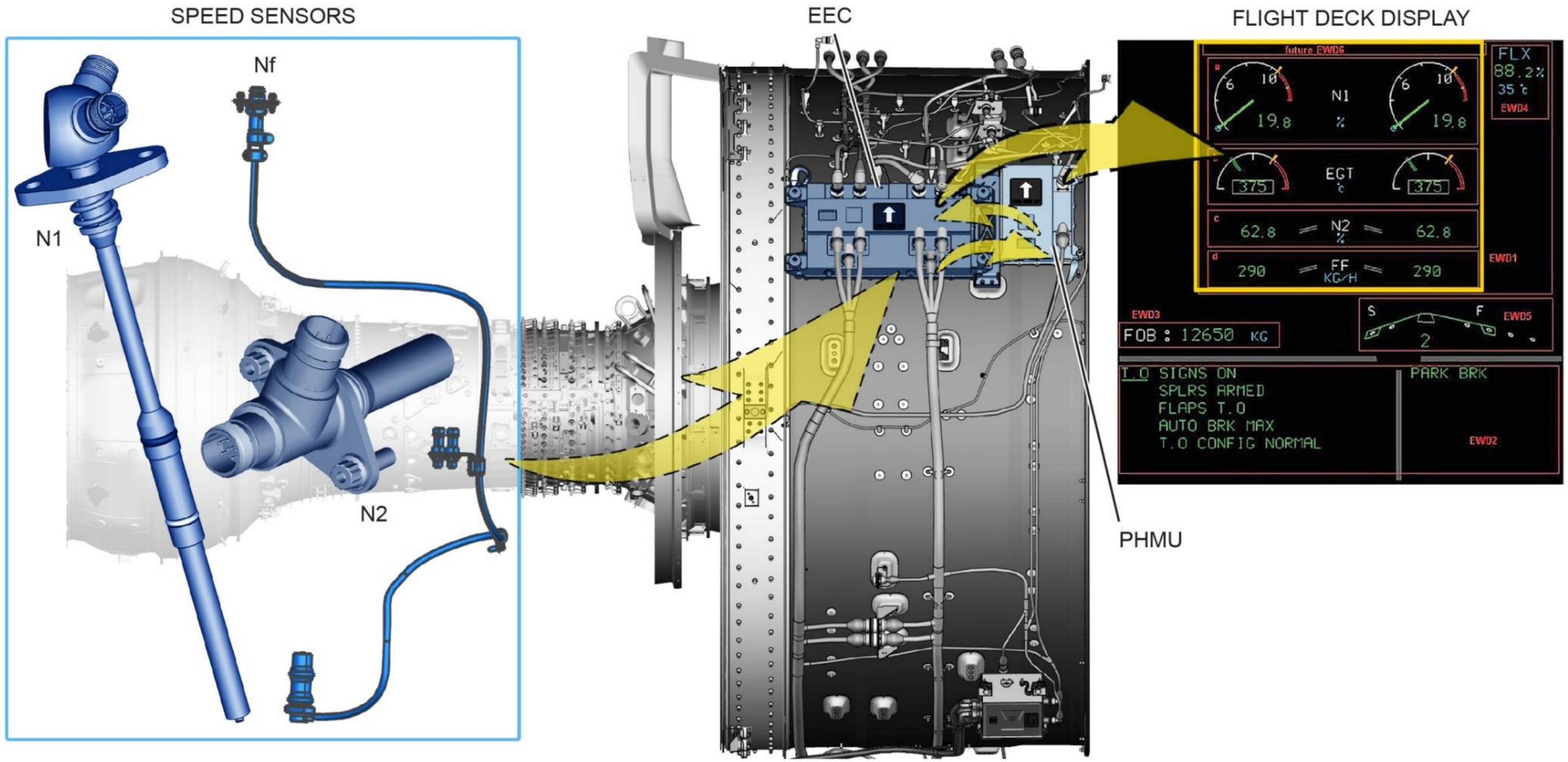
POWER INDICATING SYSTEM

The Power Indicating System senses and transmits speeds for the low rotor (N1), fan rotor (Nf), and high rotor (N2).

Both the EEC and the Prognostics and Health Management Unit (PHMU) use these indications to control and monitor engine operations.

System components include the N1, N2 and Nf speed sensors, detailed in the table.

Indicator	Function	Used By
N1	• Primary thrust control parameter	EEC
N2	• Starting fuel and igniters • Overspeed monitoring	
Nf	• Trim balancing	PHMU
	• Sheared input shaft detection	EEC


SPEED SENSORS
Nf
N1
N2
EEC
FLIGHT DECK DISPLAY
FLX
88.2%
35°C
N1
%
19.8
19.8
EGT
°C
375
375
62.8
N2
%
62.8
290
FF
KG/H
290
FOB : 12650 KG
S
F
2
T.O SIGNS ON
SPLRS ARMED
FLAPS T.O
AUTO BRK MAX
T.O CONFIG NORMAL
PARK BRK
PHMU

N1 Speed Sensor

Purpose:

The N1 speed sensor transmits low rotor speed to the Electronic Engine Control, where the indication is used as the primary thrust control parameter for ECAM display.

Location:

The N1 speed sensor is mounted on the rear of the Compressor Intermediate Case at approximately 4:00. The sensor is installed through the no. 4 strut of the CIC.

Description:

The probe is a dual-channel sensor having a common magnet stack with two independent, isolated coils and electrical connectors.

A two-bolt mounting flange with jackscrew holes allows for probe removal.

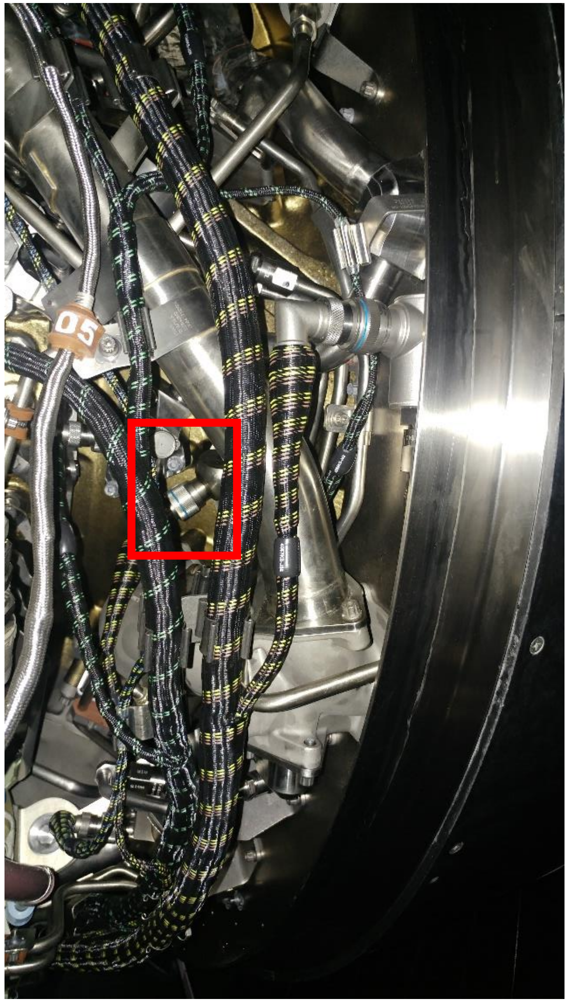
The tip gap between the tip of the N1 speed sensor and the teeth of the N1 pick-up ring is set by the sensor's lower flange, which seats against a mating flange on the CIC.

Tolerance stack-up is taken up by the spring located between the lower flange and the mount flange.

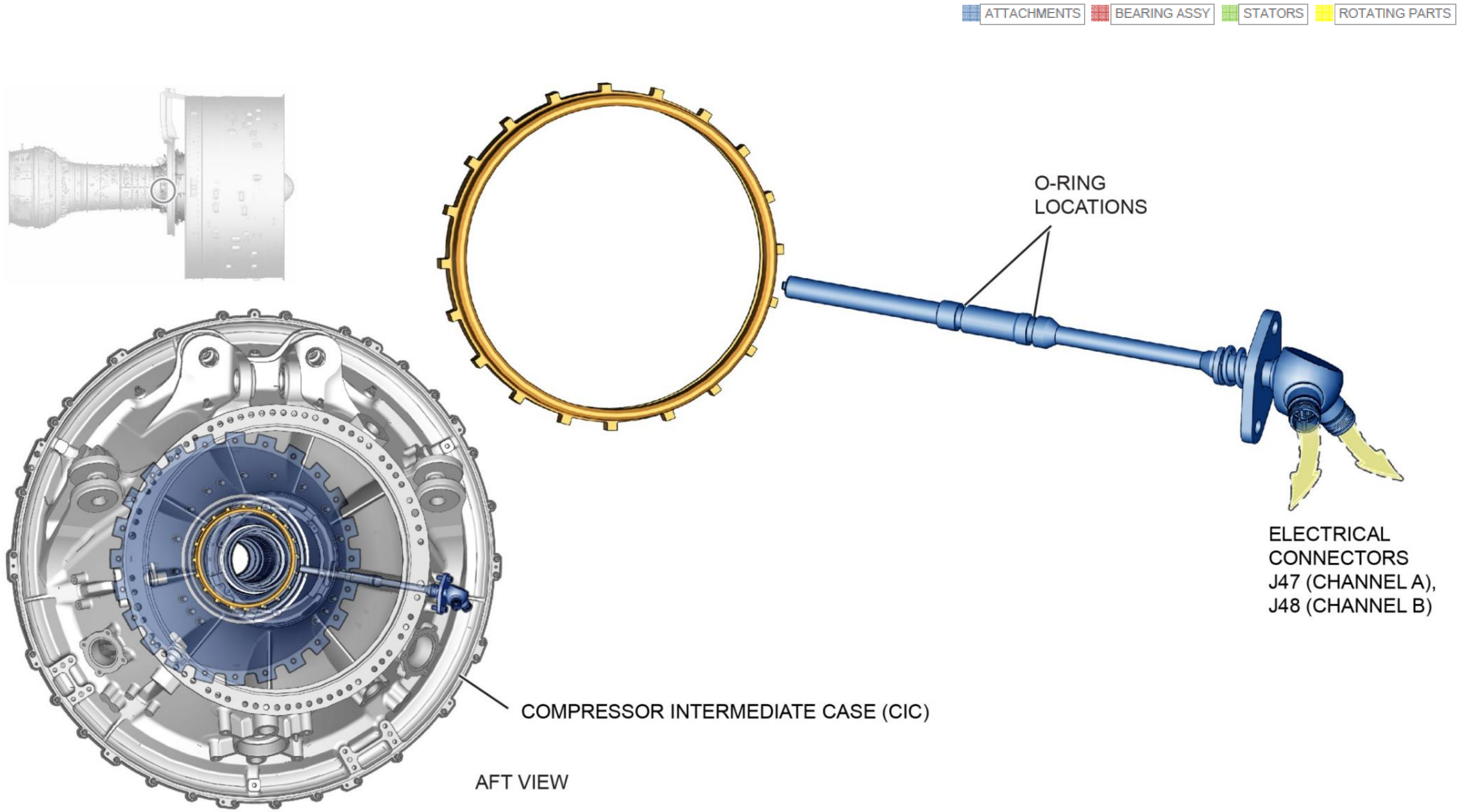
Because of this design, no shimming is required when the sensor is installed new or replaced on-wing.

Two O-rings on the sensor body prevent oil from leaking out of the No. 3 Bearing compartment.

If the N1 speed sensor is removed on wing or during a shop visit, the O-rings should be replaced.



FWD


ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
O-RING
LOCATIONS
ELECTRICAL
CONNECTORS
J47 (CHANNEL A),
J48 (CHANNEL B)
COMPRESSOR INTERMEDIATE CASE (CIC)
AFT VIEW

Operation:

The N1 speed pickup ring has 20 teeth. One tooth on the pickup ring is shorter than the others and is identified by a dimple on the end.

Each time one of the teeth passes the N1 speed sensor, a change occurs in the magnetic field.

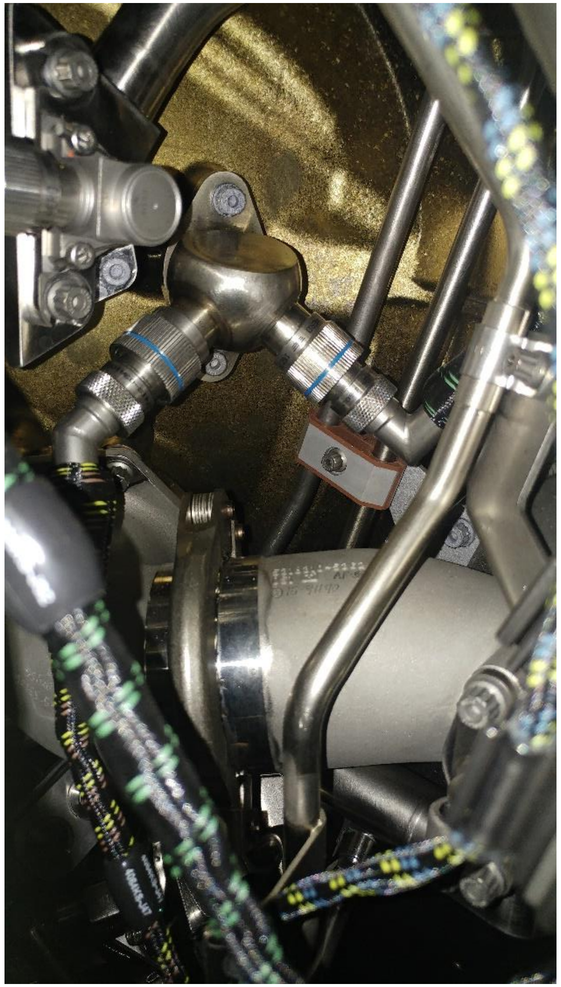
The change produces a signal frequency that the EEC will use to calculate an N1 speed proportional to the coupling's rotational speed.

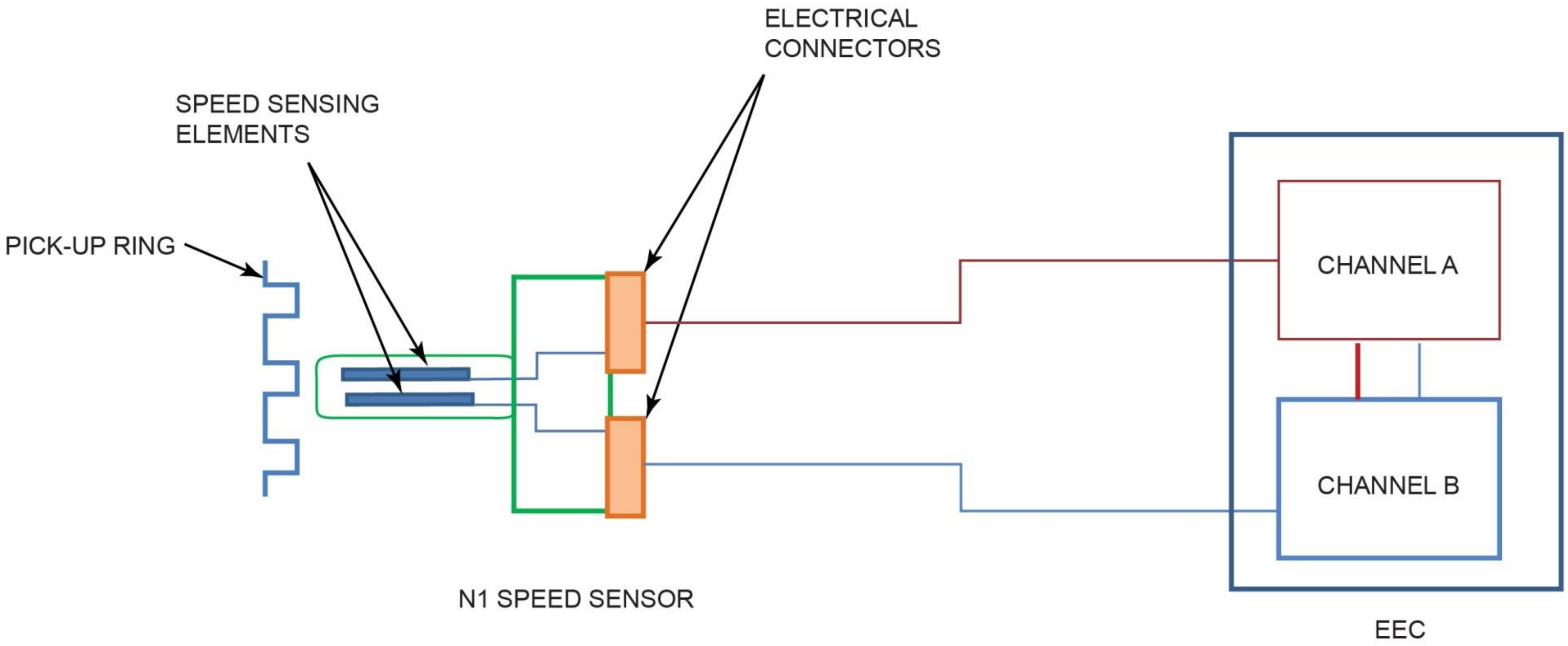
The short tooth will cause a different frequency which is used to locate zero degree for N1 trim balance purposes.

The upper limit, known as the *overspeed warning*, is set to N1 = 100%.

When the indicator shows N1 = 100%, the display changes to red, the master caution light illuminates, and a single chime sounds.

At 105% N1, the overspeed solenoid in the IFPC will de-energize and fuel flow will decrease to idle.





ELECTRICAL CONNECTORS
SPEED SENSING ELEMENTS
PICK-UP RING
CHANNEL A
CHANNEL B
N1 SPEED SENSOR
EEC

N2 Speed Sensor

Purpose:

The N2 speed coil senses and transmits N2 speed to both channels of the EEC, which uses the signal for control of fuel and ignition during starting, and also for monitoring overspeed condition of the high rotor.

Location:

The sensor is located on the right side of the Angle Gearbox housing.

Description:

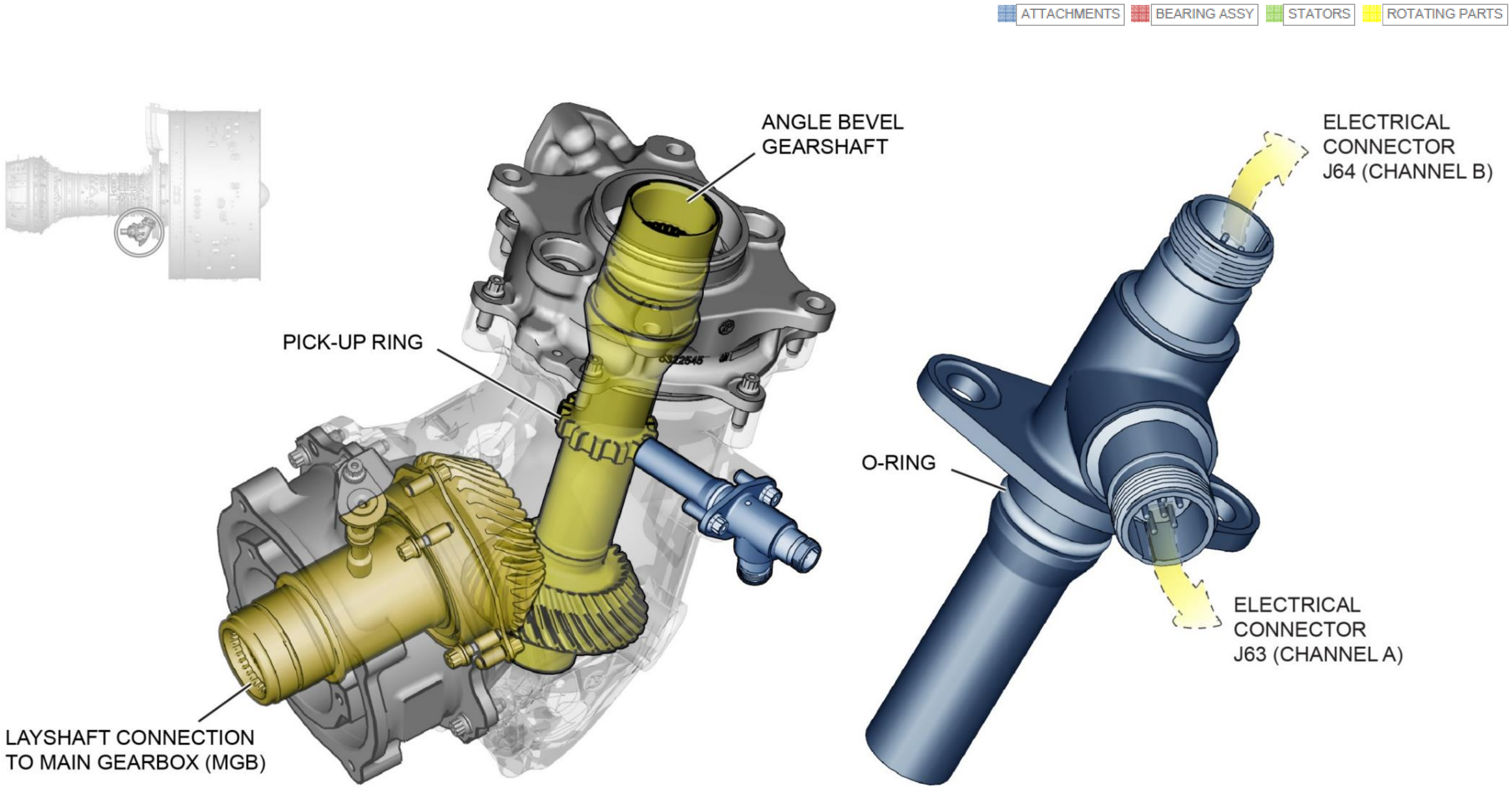
The N2 speed sensor is a one-piece sealed unit consisting of a dual channel magnetic speed sensor, using a single permanent magnet, two separate coils and two electrical connectors.

The sensor is mounted with a two-bolt mounting flange.

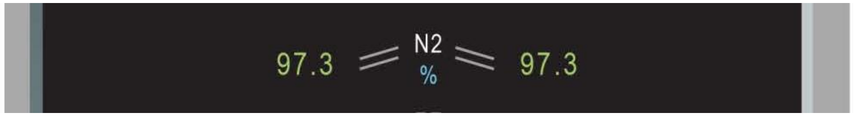
The tip gap between the tip of the probe and the pick-up ring in the Angle Gearbox is set by the mount flange on the N2 speed sensor, which seats against a mating flange on the AGB housing.

This design means that no shimming is required when the sensor is installed new or replaced on-wing.

An O-ring on the sensor body prevents oil from leaking out of the AGB. If the N2 speed sensor is removed on-wing or during a shop visit, the O-ring should be replaced.


ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
ANGLE BEVEL GEARSHAFT
PICK-UP RING
LAYSHAFT CONNECTION TO MAIN GEARBOX (MGB)
ELECTRICAL CONNECTOR J64 (CHANNEL B)
O-RING
ELECTRICAL CONNECTOR J63 (CHANNEL A)

Operation:



The tip of the probe is positioned adjacent to a 14-tooth pick-up ring on the radial bevel gear shaft in the Angle Gearbox.

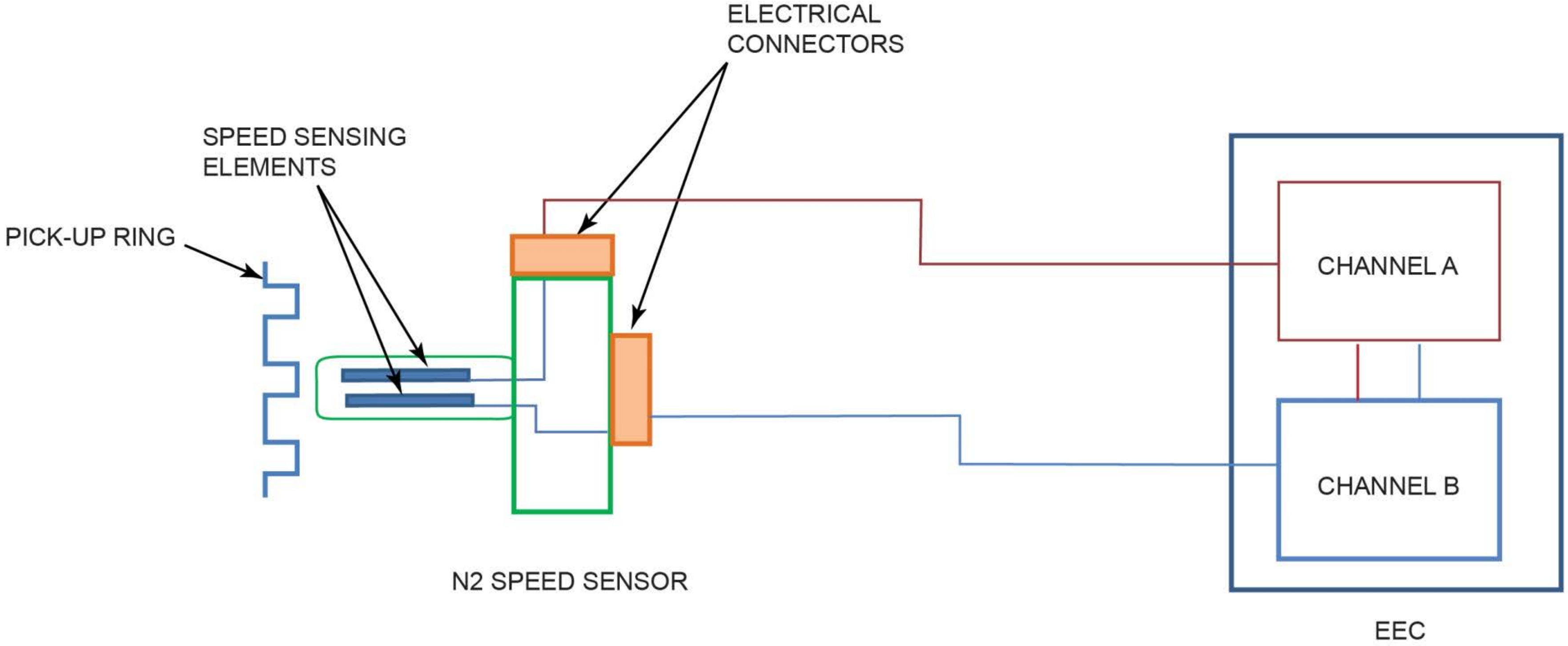
The N2 speed sensor detects high rotor shaft speed by sensing each tooth as it passes the tip of the magnetic probe.

As the teeth of the radial bevel gear shaft pass by the face of the magnet, a change occurs in the magnetic field, creating a time varying electrical pulse signal.

The signal is transmitted to both the EEC and PHMU and converted to a rotational speed.

The rotational speed is then sent to the EIU for display in the cockpit.

If the N2 speed signal from both channels is lost during engine operation, an ECAM warning displays in the cockpit to indicate that the N2 speed sensor has failed.


ELECTRICAL
CONNECTORS
SPEED SENSING
ELEMENTS
PICK-UP RING
CHANNEL A
CHANNEL B
N2 SPEED SENSOR
EEC

Nf Speed Sensor

Purpose:

The Nf speed sensor senses and transmits fan rotor (Nf) speed to the EEC.

Location:

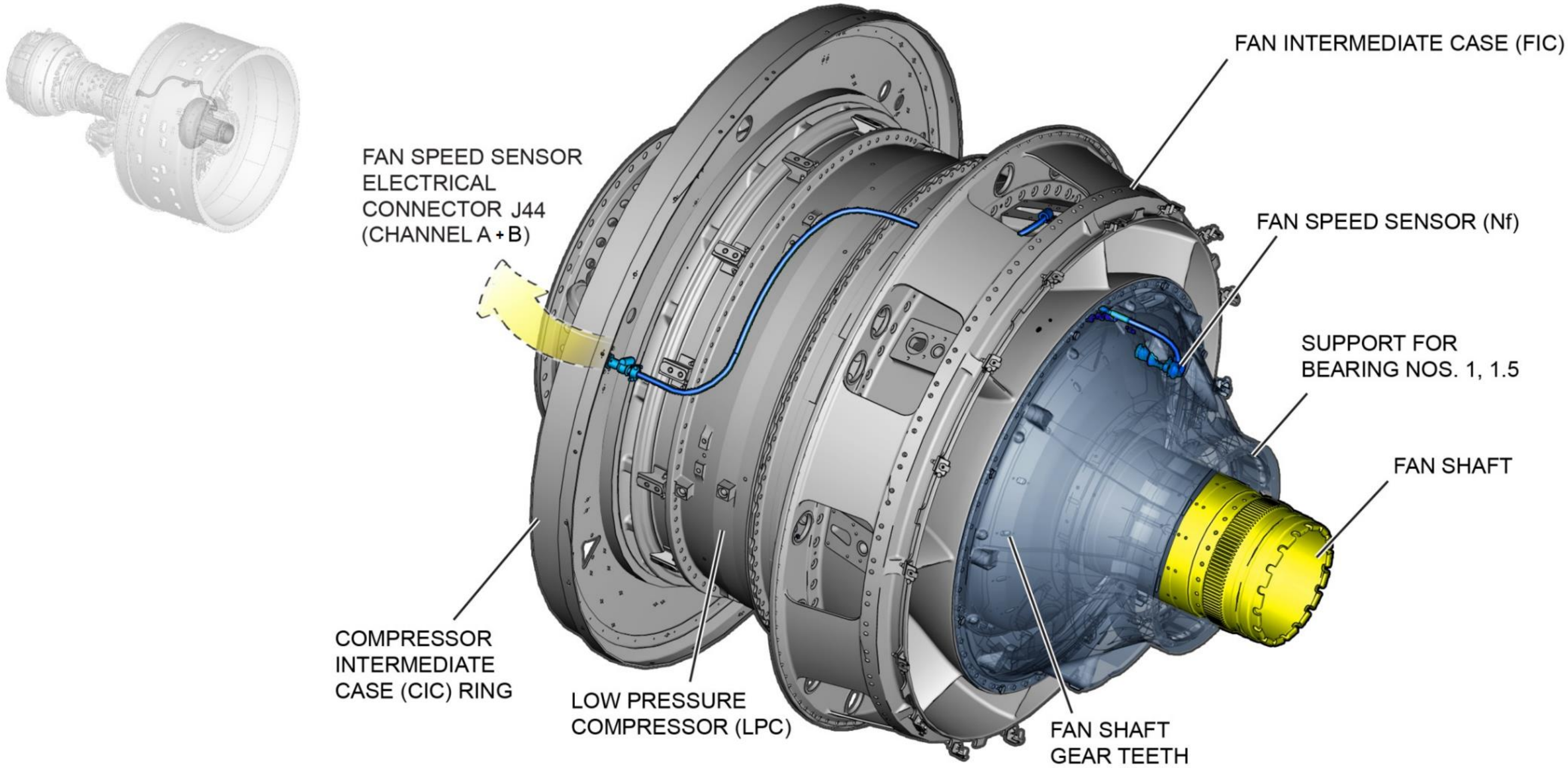
The sensor is mounted at 12:00 to the support for bearing nos. 1 and 1.5, and is internal to the engine.

Description:

The probe is a single-channel sensor having a single magnet coil and electrical connector.

A two-bolt mounting flange with jackscrew holes allows for probe removal.

Nf Speed sensor can be viewed directly using the AIDS system via the MCDU


FAN INTERMEDIATE CASE (FIC)
FAN SPEED SENSOR ELECTRICAL CONNECTOR J44 (CHANNEL A + B)
FAN SPEED SENSOR (Nf)
SUPPORT FOR BEARING NOS. 1, 1.5
FAN SHAFT
COMPRESSOR INTERMEDIATE CASE (CIC) RING
LOW PRESSURE COMPRESSOR (LPC)
FAN SHAFT GEAR TEETH

Operation:

The tip of the Nf speed sensor is positioned adjacent to 16 teeth attached to the fan shaft.

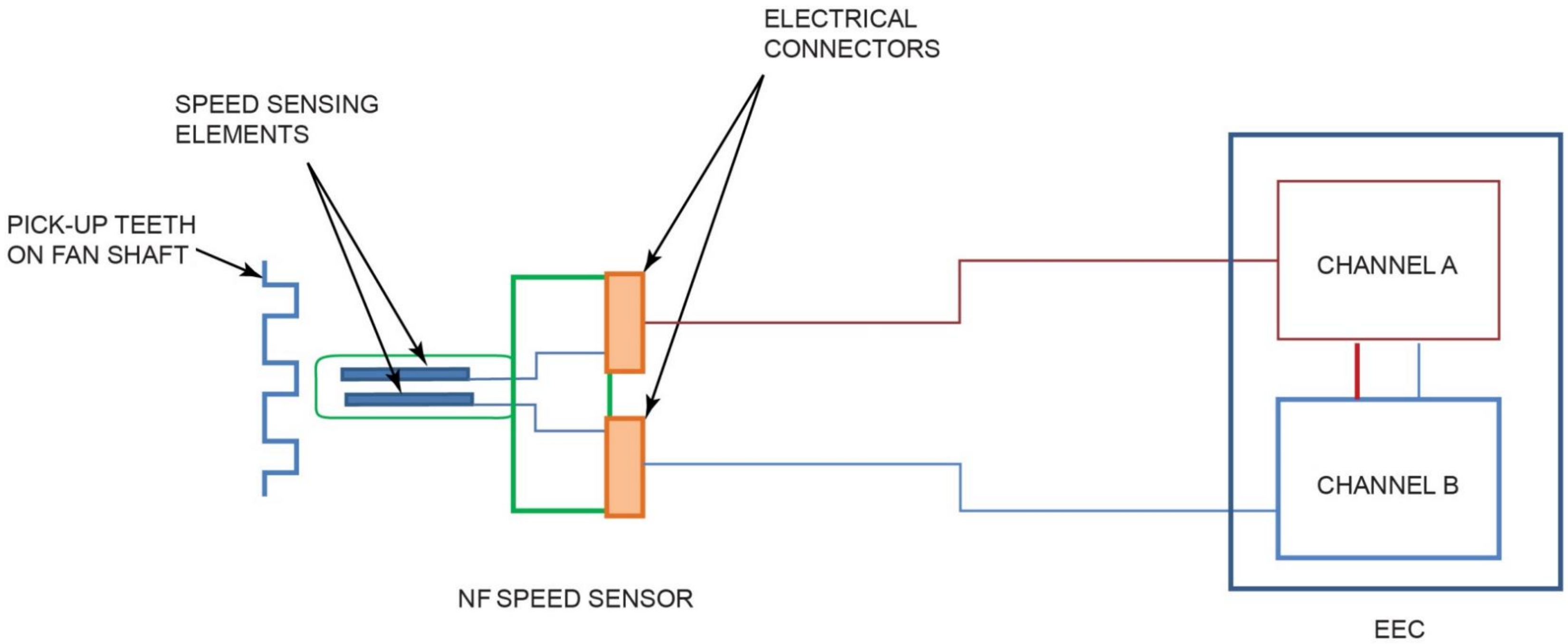
The sensor gauges fan rotor shaft speed by detecting each tooth as it passes the tip of the magnetic probe.

As the teeth attached to the fan shaft pass by the face of the magnet, a change occurs in the magnetic field, creating a time varying electrical pulse signal.

The signal is then transmitted to the EEC and PHMU and converted to a rotational speed.

The EEC compares the fan speed indication to the LP shaft's N1 speed to detect decoupling of the fan shaft.

The PHMU uses fan speed in conjunction with fan rotor vibration to


ELECTRICAL
CONNECTORS
SPEED SENSING
ELEMENTS
PICK-UP TEETH
ON FAN SHAFT
CHANNEL A
CHANNEL B
NF SPEED SENSOR
EEC

TEMPERATURE INDICATING SYSTEM

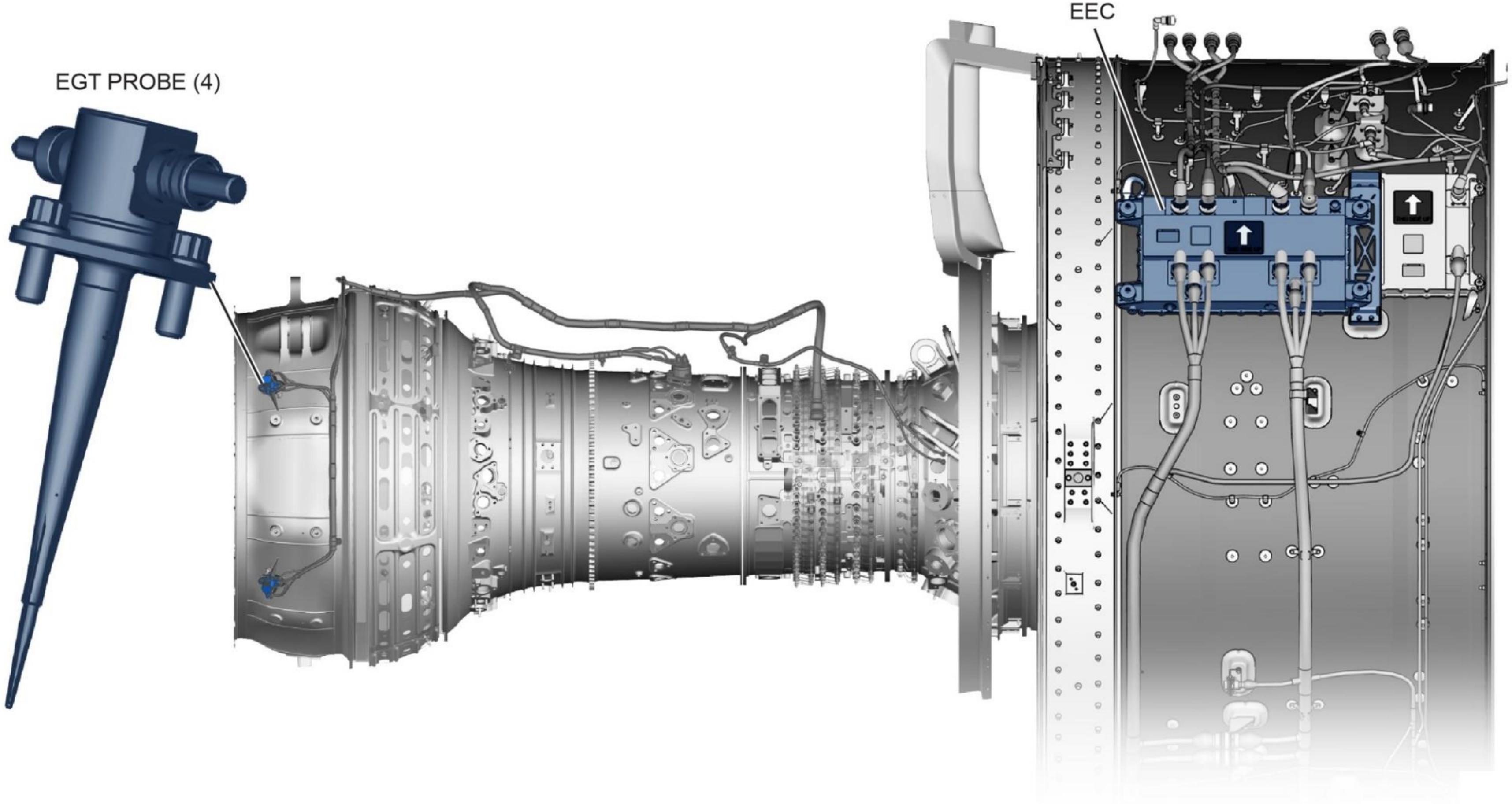
The Temperature Indicating System uses four EGT sensors to detect gas path temperatures and to transmit the EGT temperature signal to the Electronic Engine Control.

The EEC processes and sends the signal to the Engine Indicating Unit (EIU) display.

Indicating sensors for the respective stations are known as T5 and T3 sensors.

The four thermocouple EGT sensors are positioned at semi-regular intervals around the circumference of the Turbine Exhaust Case (TEC). Each array is called an EGT probe and cable assembly.

The two arrays are connected to an EGT (T5/T3) wiring harness.


EGT PROBE (4)
EEC

EGT (T5) Sensor And Cable Assembly – Right and Left Sides

Purpose:

Four EGT (T5) sensors detect gas path temperatures and transmit the EGT temperature signal to Electronic Engine Control.

Location:

T5 sensors are positioned around the circumference of the Turbine Exhaust Case (TEC) at semi-regular intervals at 2:00, 4:00, 8:00 and 10:00.

Description:

Each sensor is a single-channel, Chromel/Alumel thermocouple probe that detects gas path temperature at the exit of the Low-Pressure Turbine.

The sensor consists of a Type K thermocouple element that is covered by an insulated metal sheath.

The sheath is covered by the element support, except for a short length near the tip where engine gas temperature is to be measured.

The element support is welded to the mount flange/terminal assembly, holding the metal sheath and limiting its exposure to the engine gas path airflow.

Thermocouple wires are potted with aluminium-silica material within the terminal assembly.

The studs are insulated from the body by ceramic spacers which eliminate the possibility of a secondary junction.

Safety Conditions

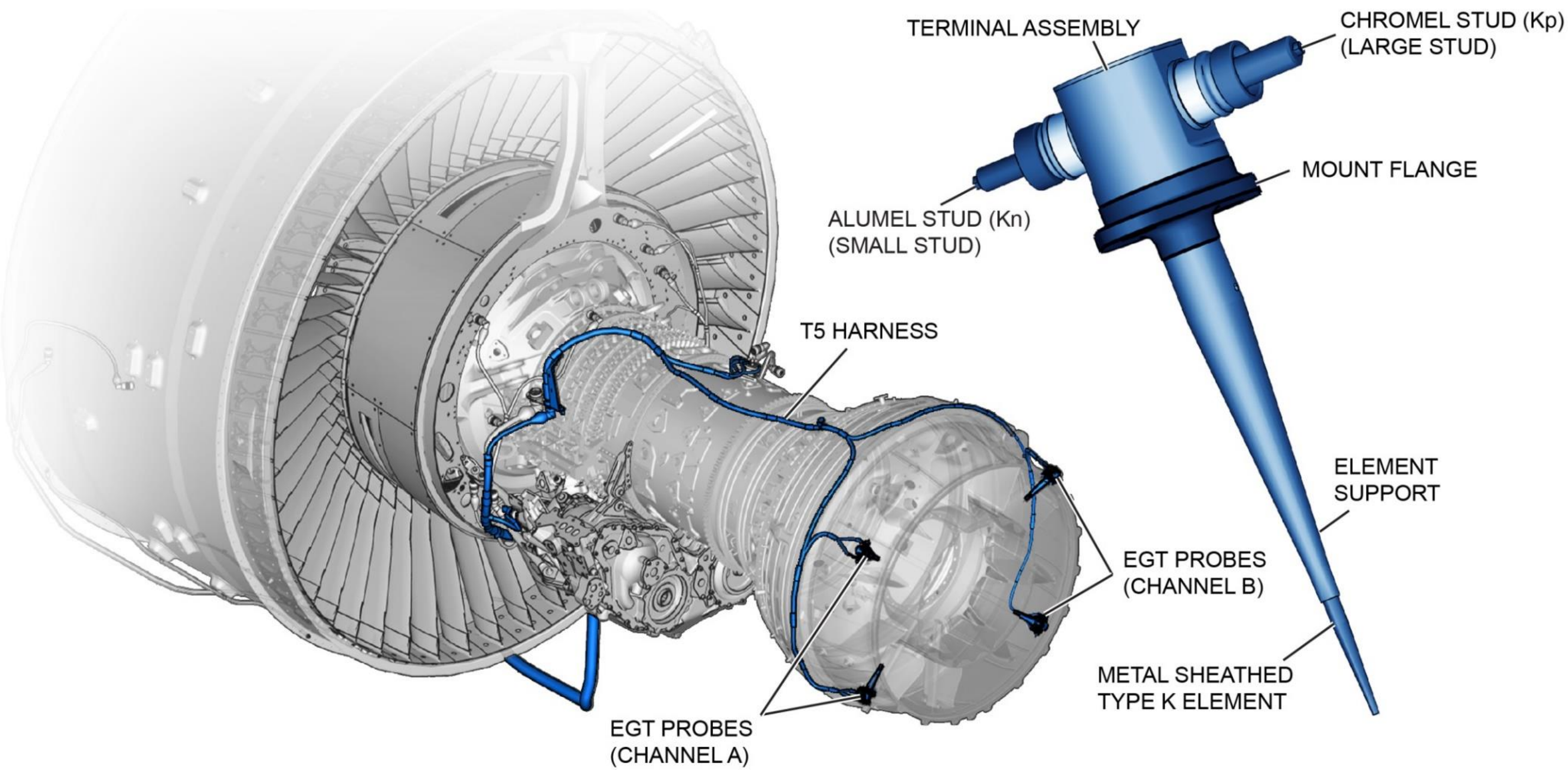
WARNING

WAIT 5 MINUTES MINIMUM TO MAKE SURE THAT THE OIL SYSTEM IS NOT PRESSURIZED BEFORE DOING THIS PROCEDURE. IF YOU DO NOT OBEY THIS WARNING, INJURY CAN OCCUR.

CAUTION

DO NOT TORQUE THE STUD NUTS MORE THAN THE SPECIFIED TORQUE.

IF YOU DO, YOU CAN DAMAGE OR BREAK THE STUDS.


TERMINAL ASSEMBLY
CHROMEL STUD (Kp)
(LARGE STUD)
MOUNT FLANGE
ALUMEL STUD (Kn)
(SMALL STUD)
T5 HARNESS
ELEMENT
SUPPORT
EGT PROBES
(CHANNEL B)
METAL SHEATHED
TYPE K ELEMENT
EGT PROBES
(CHANNEL A)

Operation:

1. The four signals from the probes are electrically averaged into one signal that is sent to the EEC through the EGT/T3 harness.

The two signals from the left side are averaged into the Channel A signal and the two signals from the right side are averaged into the Channel B signal.

2. The Cold Junction Compensation (CJC) used by the EEC to compute Exhaust Gas Temperature is located at the Main Oil Temperature sensor.

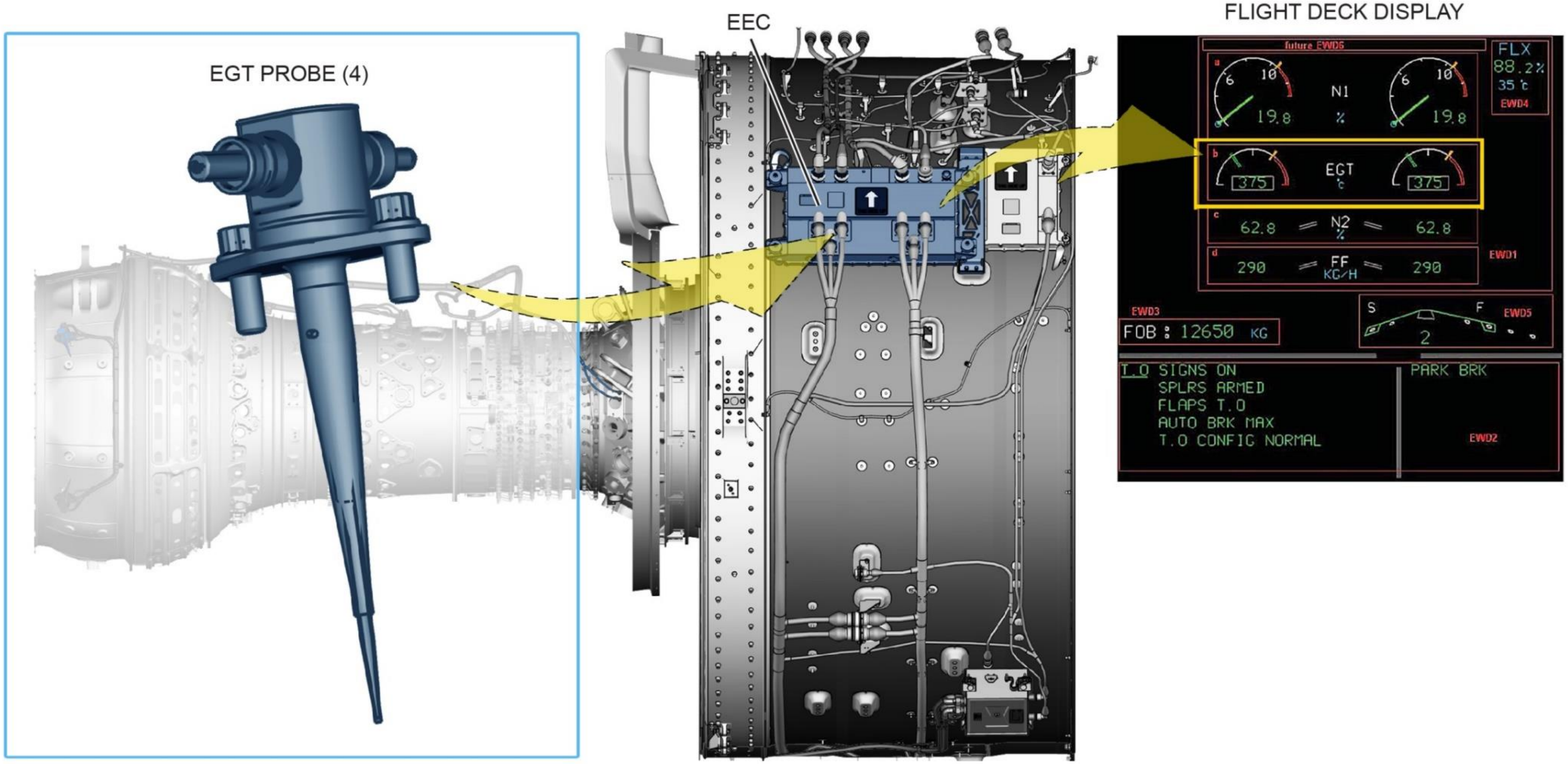
The EGT harness assembly transmits the analogue signals from the EGT probes to the EEC, which then computes the EGT in degrees C or F for channels A and B.

The EEC converts the analogue signal to a digital signal and then transmits the signal to the EIU.

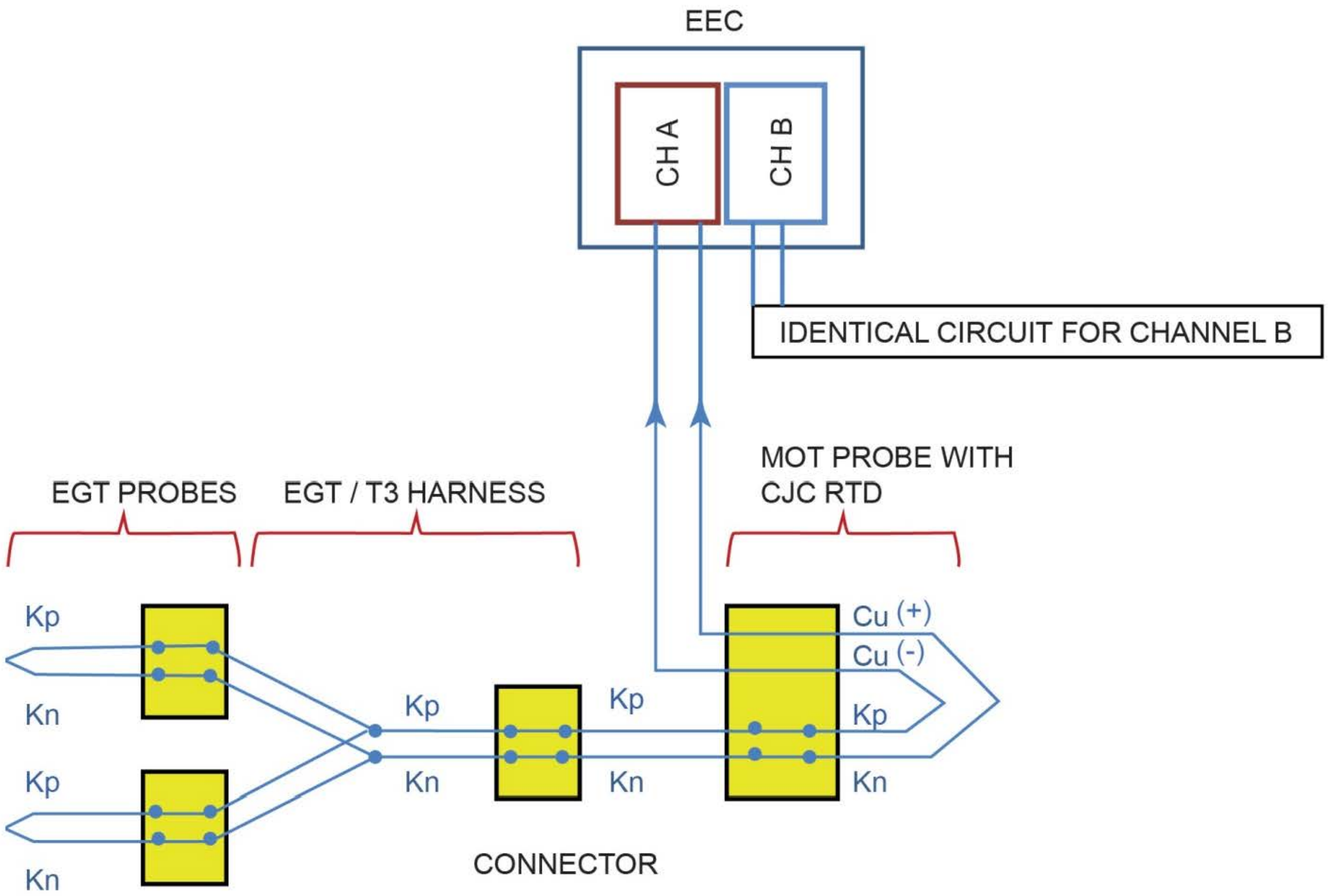
3. EGT indication on the upper ECAM displays in analogue form by means of a mark from 0–1200° C. EGT also displays in digital form with 4 digits from -99 to 2048, in 1° increments.

Both analogue and digital displays are green in colour during normal engine operation.

The display changes from green to amber if the EGT value exceeds a second, higher predetermined value. If the computed EGT temperature is determined to be out of range for both channels A and B, the EGT digital display is replaced by amber crosses.


EGT PROBE (4)
EEC
FLIGHT DECK DISPLAY
N1
EGT
N2
FF
KG/H
FLX
88.2%
35 °C
19.8
375
62.8
290
FOB : 12650 KG
S
F
2
T.O SIGNS ON
SPLRS ARMED
FLAPS T.O
AUTO BRK MAX
T.O CONFIG NORMAL
PARK BRK

INTENTIONALLY BLANK


EEC
CH A
CH B
IDENTICAL CIRCUIT FOR CHANNEL B
MOT PROBE WITH
CJC RTD
EGT PROBES
EGT / T3 HARNESS
Kp
Kn
Kp
Kn
Kp
Kn
Kp
Kn
Cu (+)
Cu (-)
Kp
Kn
CONNECTOR

ANALYZER SYSTEM

Overview

The Analyzer System provides critical information about oil debris monitoring, vibration monitoring, and auxiliary oil pressure to the EEC and the flight deck.

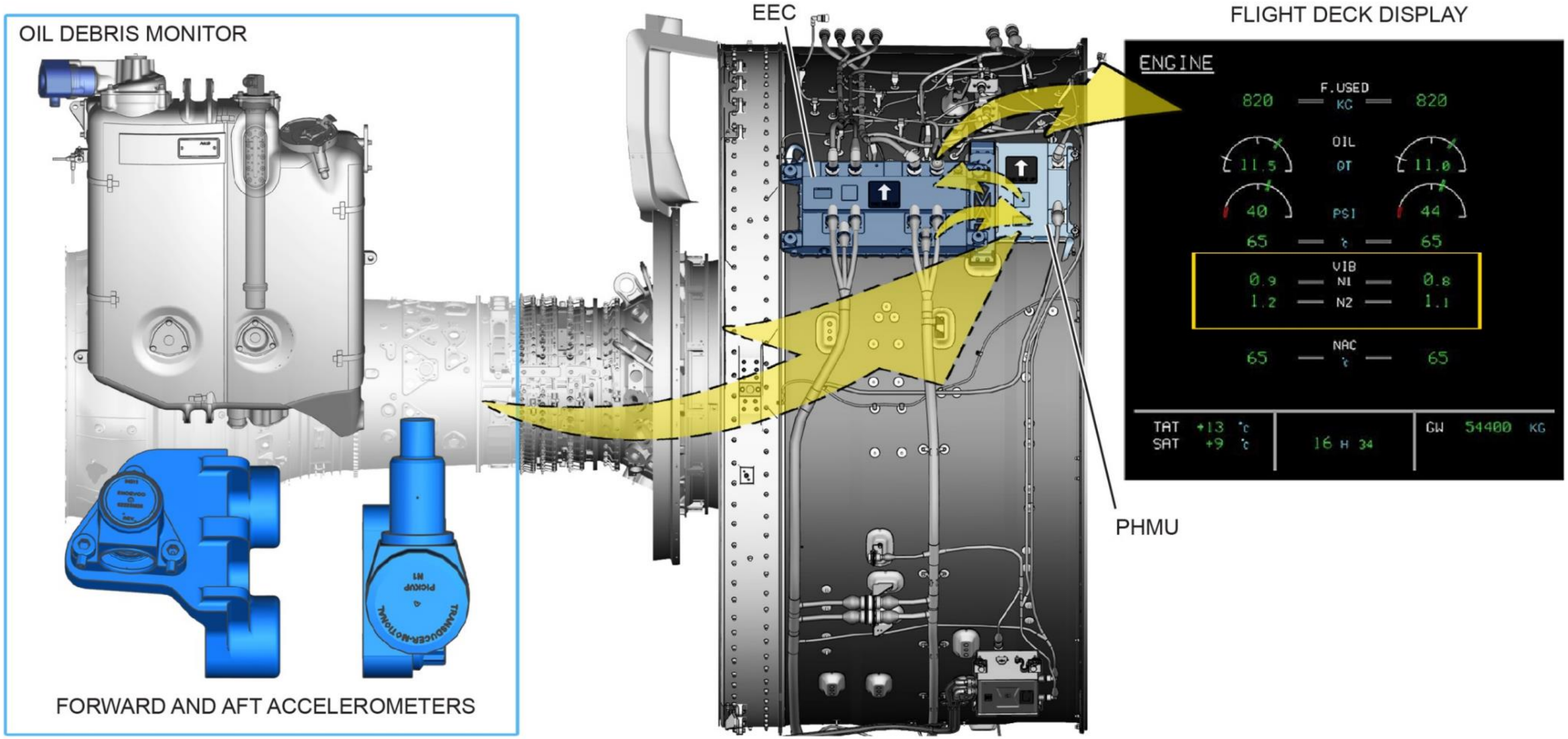
A primary component of this system is the Prognostics and Health Management Unit (PHMU).

The chart shows the roles of the Analyzer System and how the PHMU functions to fulfil each one.

The PHMU continuously computes engine trim balance solutions using Nf, N1, and N2 speed signals received from the EEC, and from the vibration signals received from the aft and forward accelerometers.

This information is stored by the PHMU in the Data Storage Unit (DSU). A trim balance procedure in the cockpit interprets the stored data using the interactive mode, and provides instructions to trim balance the fan.

Analyzer Roles	PHMU Functions
Oil debris monitoring	• Provides early indication of ferrous and non-ferrous particles in engine oil, based on data from the Oil Debris Monitor • Detects exceedances based on the rate of particle generation over a period of time
Vibration monitoring	• Detects vibration exceedances based on data from engine vibration sensors, plus N1, N2, and Nf inputs from the EEC • Calculates optimum fan trim balance solutions using flight or ground data
Auxiliary oil pressure monitoring	• Indicates low oil pressure in Auxiliary Oil System


OIL DEBRIS MONITOR
FORWARD AND AFT ACCELEROMETERS
EEC
PHMU
FLIGHT DECK DISPLAY
ENGINE
F.USED
KG
820
820
OIL
QT
11.5
11.0
PSI
40
44
65
65
VIB
N1
N2
0.9
0.8
1.2
1.1
NAC
65
65
TAT +13 °C
SAT +9 °C
16 H 34
GW 54400 KG

Prognostics and Health Management Unit (PHMU)

Purpose:

The Prognostics and Health Management Unit monitors and processes levels for engine oil debris and rotor vibration. It also calculates fan trim balance solutions.

Location:

The PHMU is mounted on the fan case at 2:00 forward of the EEC.

Description:

The PHMU is a vibration-isolated, convection air-cooled unit weighing 6.3 lbs and powered by aircraft 28 Vdc.

Its single-channel unit contains a processor and has two connectors, J9 and J10.

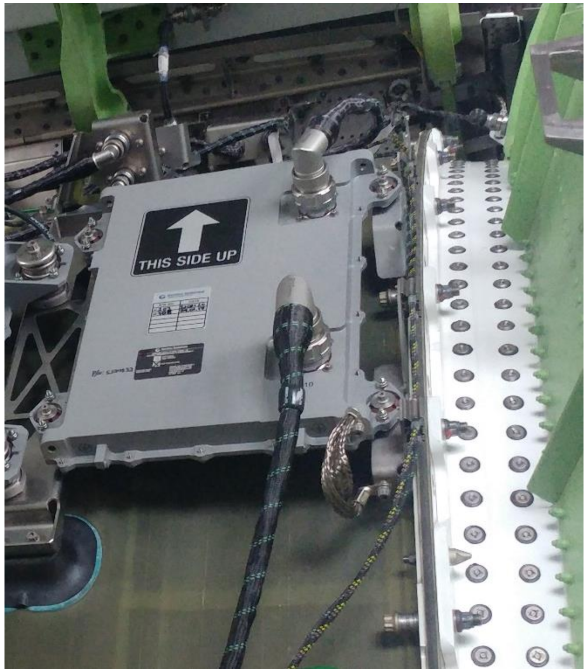
The PHMU monitors itself for internal faults and overall health, and checks components and functions shown in the following list.

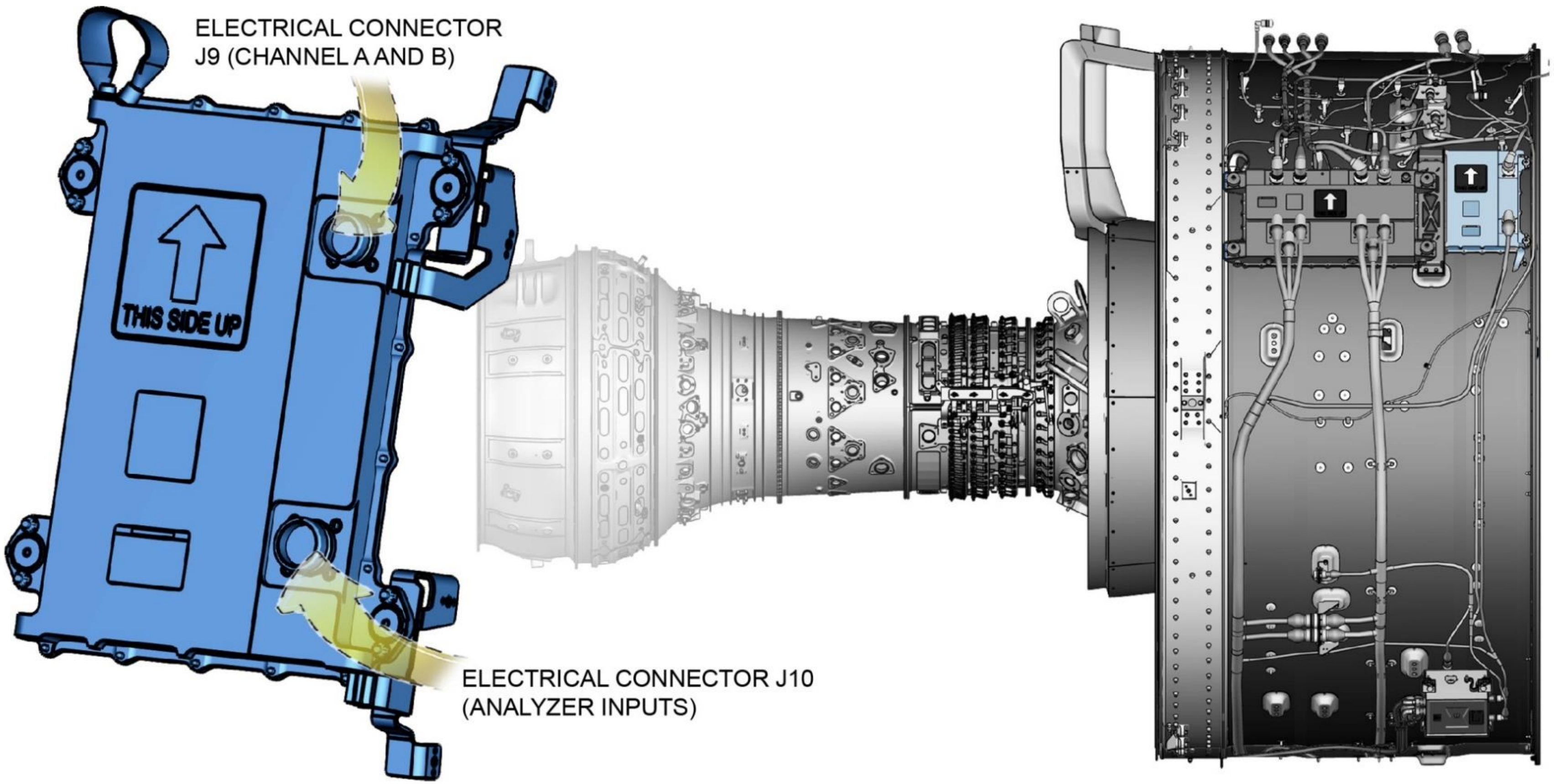
Auxiliary Oil Pressure Sensor AOPS
Vibration monitoring
Oil Debris Monitor ODM
Wiring between EEC and PHMU

Operation:

The PHMU receives signals from the Oil Debris Monitor (ODM), forward and aft engine accelerometers, and the Auxiliary Oil Pressure Sensor, and sends the processed output signals to the EEC.

The PHMU communicates with the EEC via a Control Area Network (CAN) data bus. The PHMU is re-programmable on-wing either from the flight deck or via use of a portable software loader.

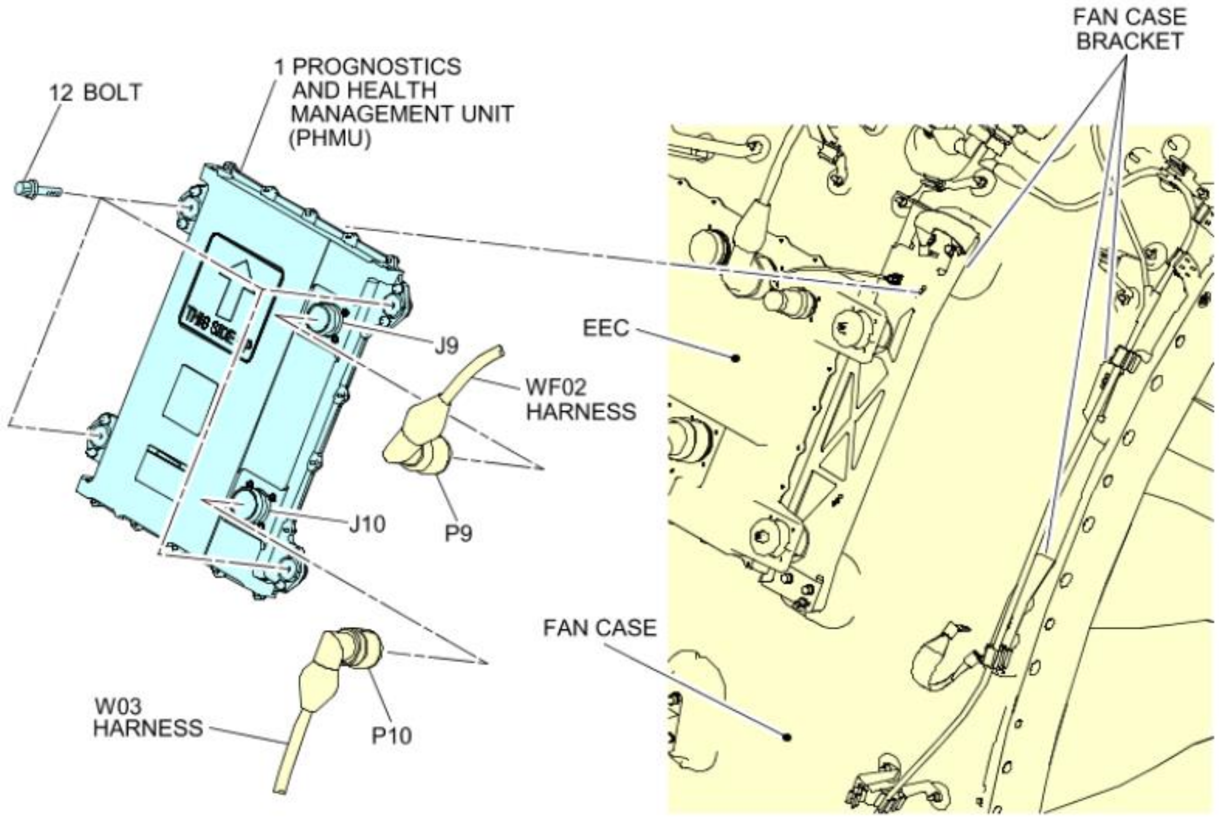


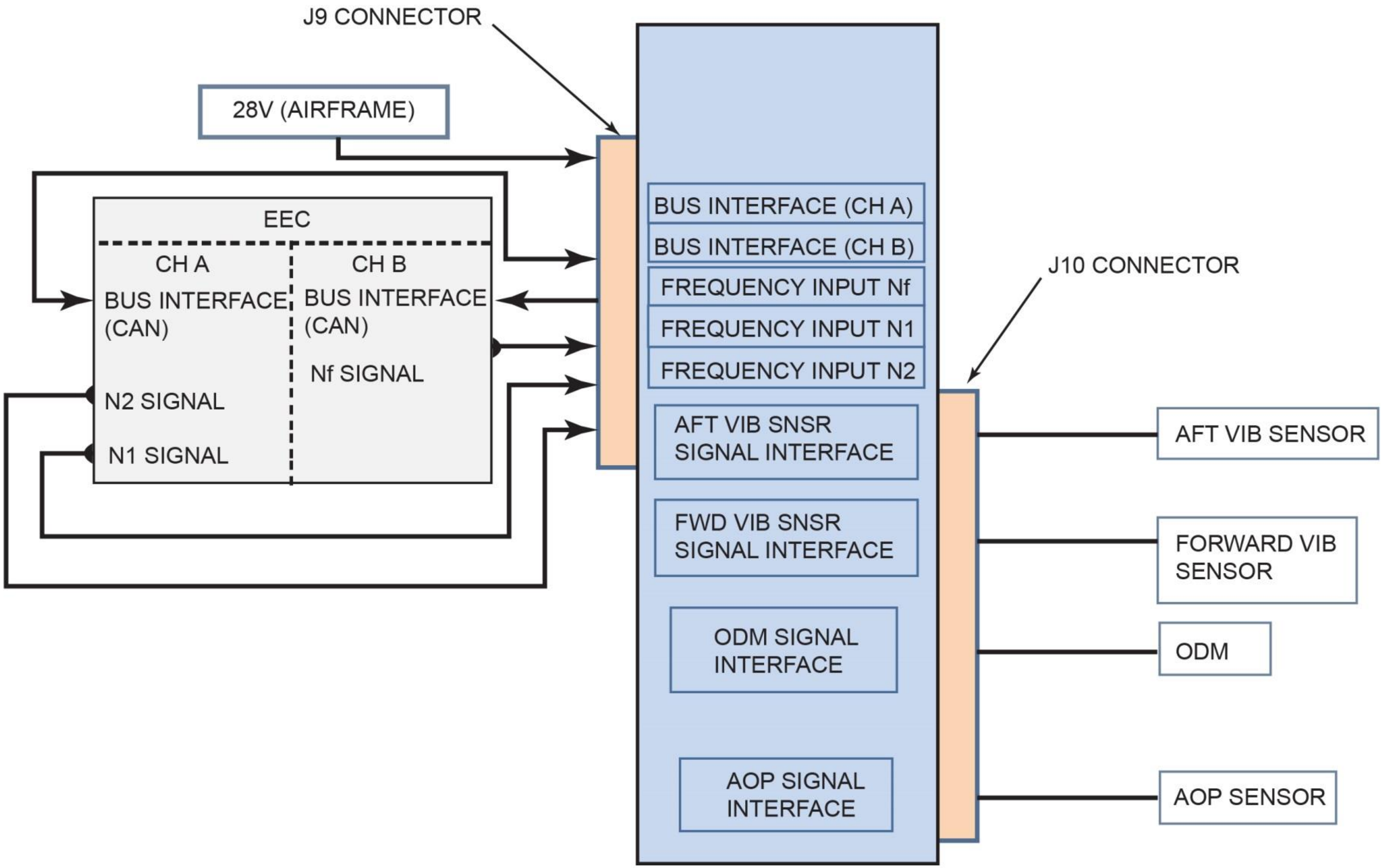

ELECTRICAL CONNECTOR
J9 (CHANNEL A AND B)
THIS SIDE UP
ELECTRICAL CONNECTOR J10
(ANALYZER INPUTS)

Operation (Cont.):

The J9 connector provides the EEC with 28Vdc input power, receives speed signals ((N1, N2, Nf) from the EEC, and provides an interface for the Controller Area Network (CAN) bus.

The J10 connector receives inputs from the forward and aft vibration sensors and the Oil Debris Monitor (ODM).




J9 CONNECTOR
28V (AIRFRAME)
EEC
CH A
CH B
BUS INTERFACE (CAN)
BUS INTERFACE (CAN)
Nf SIGNAL
N2 SIGNAL
N1 SIGNAL
BUS INTERFACE (CH A)
BUS INTERFACE (CH B)
FREQUENCY INPUT Nf
FREQUENCY INPUT N1
FREQUENCY INPUT N2
J10 CONNECTOR
AFT VIB SNSR SIGNAL INTERFACE
FWD VIB SNSR SIGNAL INTERFACE
ODM SIGNAL INTERFACE
AOP SIGNAL INTERFACE
AFT VIB SENSOR
FORWARD VIB SENSOR
ODM
AOP SENSOR

Forward Vibration Sensor

Purpose:

The forward vibration sensor measures fan- and core-related vibrations and communicates this information to the EEC.

Location:

The sensor is externally mounted to E flange on the Compressor Intermediate Case (CIC) at 9:00.

Description:

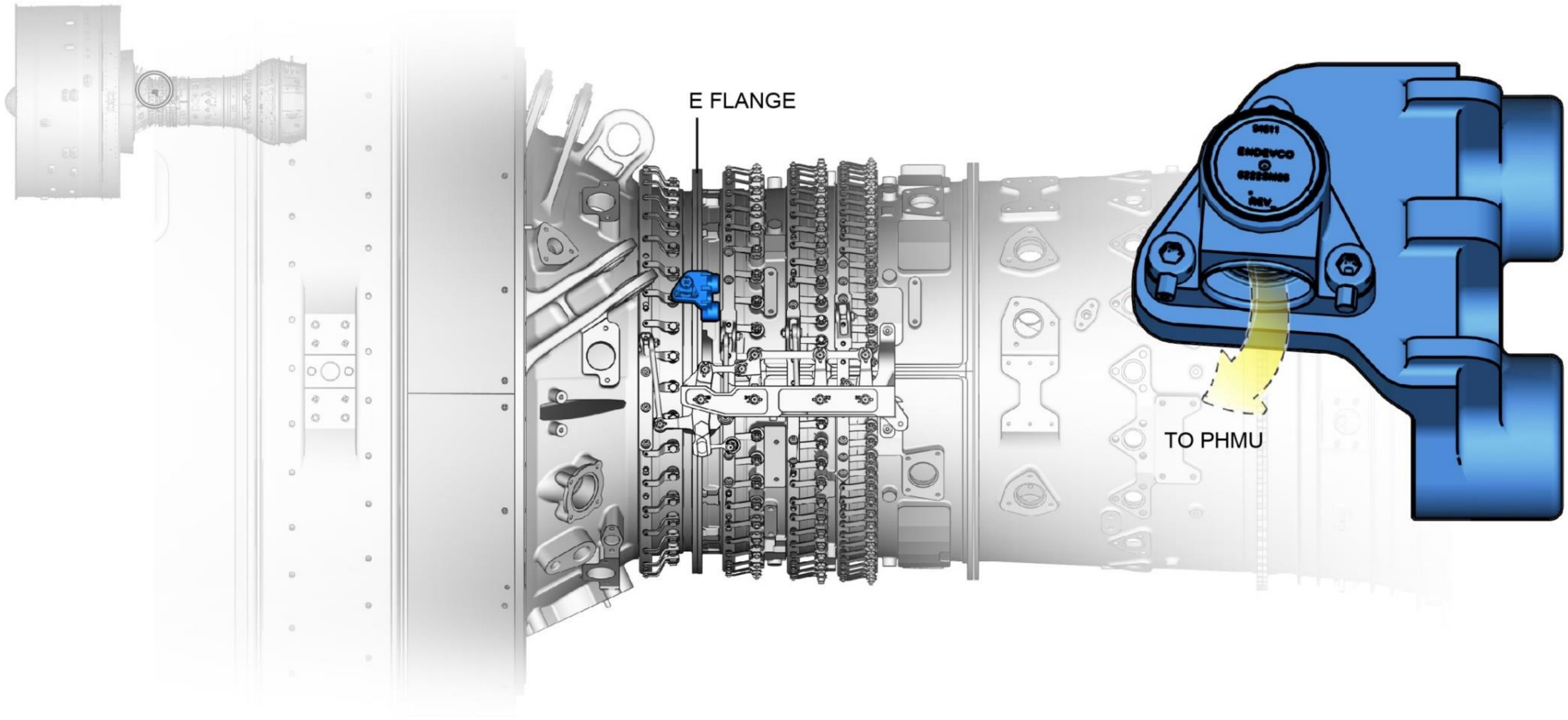
The forward vibration sensor is a single-channel, piezoelectric accelerometer contained in a sealed body.

The sensor is mounted to the CIC with two bolts and has an integral electrical connector.

Operation:

The sensor provides an electric output signal proportional to the acceleration it is subjected to.

If the sensor fails, its cockpit display is replaced with amber crosses.


E FLANGE
TO PHMU

Aft Vibration Sensor

Purpose:

The aft vibration sensor measures fan- and core-related vibrations and communicates this information to the EEC.

Location:

The sensor is mounted to P flange on the LPT housing at 3:00.

Description:

The aft vibration sensor is a single channel, piezoelectric accelerometer contained in a sealed body.

The sensor is mounted to the LPT housing with two bolts and has an integral hard line cable and electrical connector.

Operation:

The sensor provides an electric output signal proportional to the acceleration it is subjected to.

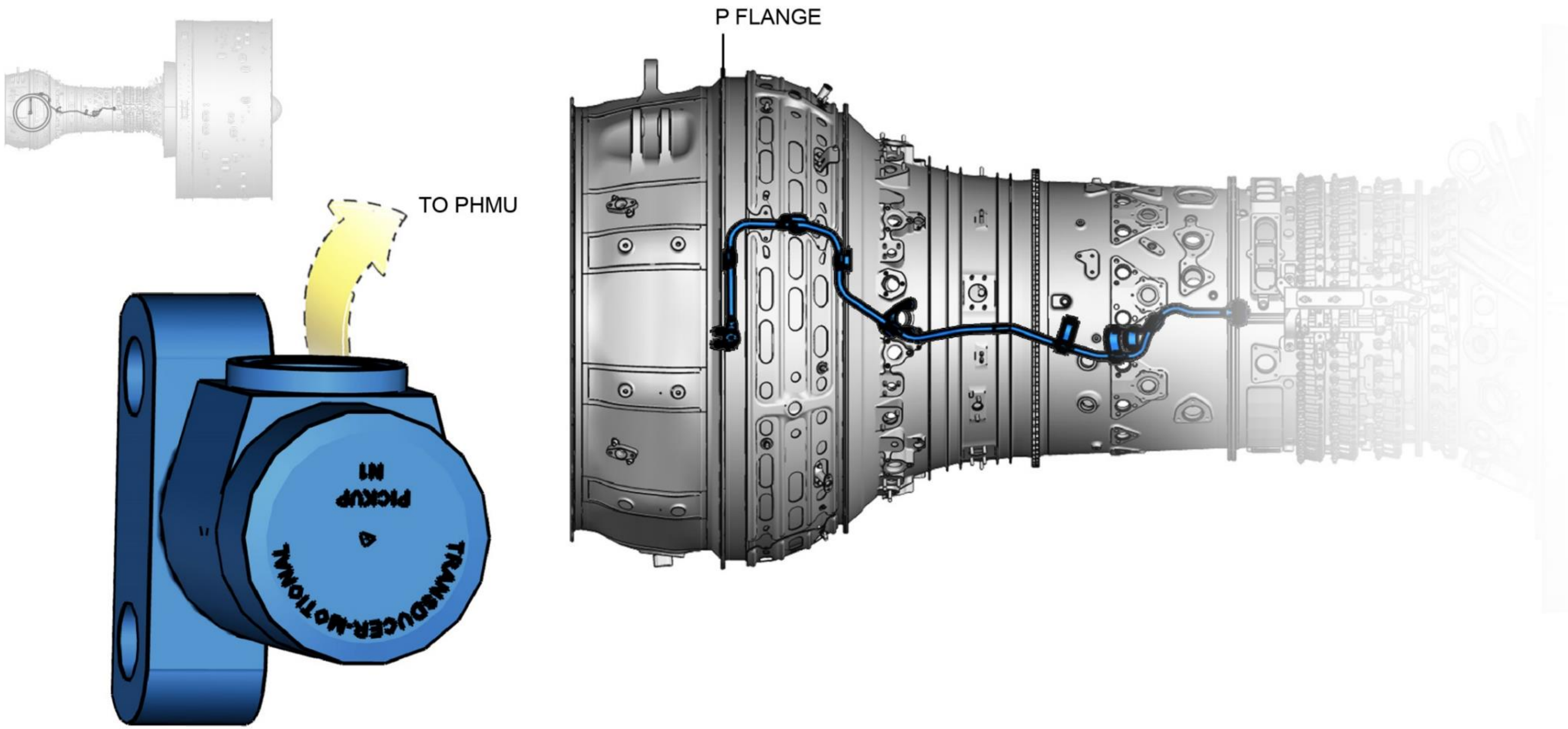
If the sensor fails, its cockpit display is replaced with amber crosses.

Safety Conditions

CAUTION

MAKE SURE THAT THE AFT VIBRATION SENSOR CABLE DOES NOT TOUCH SHARP-EDGE SURFACES, FUEL LINES, OIL LINES, HIGH PRESSUMRE PNEUMATIC DUCTS, PNEUMATIC SENSOR LINES, OR FABRIC BELLOWS.

MAKE SURE THAT THE AFT VIBRATION SENSOR CABLE DOES NOT HAVE ANY KINKS. IF YOU DO NOT FOLLOW THIS INSTRUCTION YOU COULD DAMAGE THE CABLE.


P FLANGE
TO PHMU
N1
PICKUP
TRANSDUCER-MOTIONAL

Vibration Monitoring

The forward and aft vibration sensors detect engine vibration levels and send vibration signals to the PHMU.

The PHMU processes the signals from the vibration sensors in four steps.

1. Within the PHMU, both the speed and vibration signals are filtered and converted from analogue to digital format by the vibration interface circuitry.

2. The vibration signals are directed to the Field Programmable Gate Array (FPGA) concurrently with the Nf, N1, and N2 speed sensor signals.

The FPGA calculates the Nf, N1, and N2 speeds coincident with the vibration data for synchronous analysis and sends the signal to the Digital Signal Processor (DSP).

3. Data is transformed to a frequency domain and sent to the higher level Central Processing Unit (HCPU).

4. The HCPU performs the following functions:

calculates frequency domain vibration information

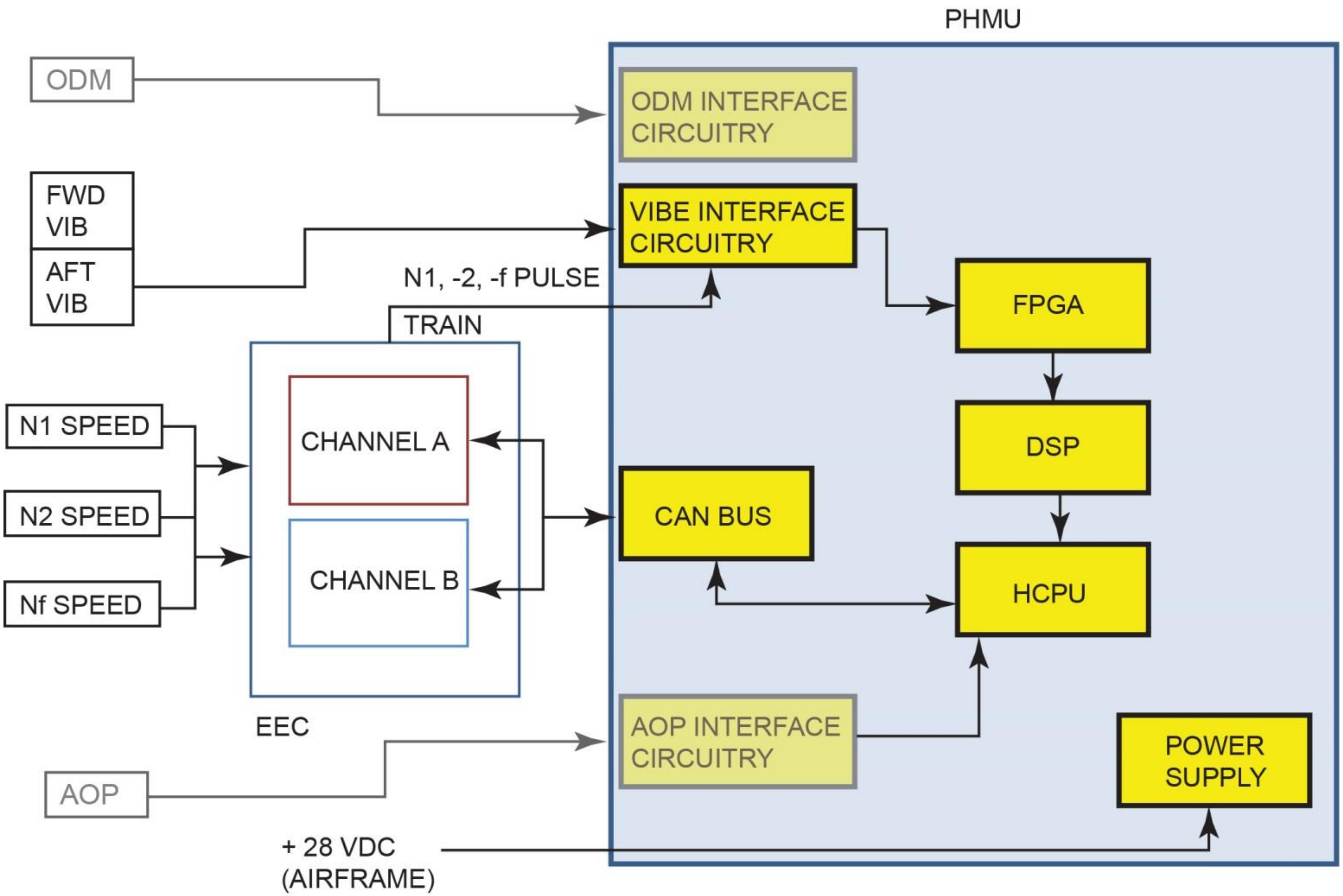
detects exceedance conditions

scales the signals from engineering units to cockpit display units

performs trim balance functions

detects vibration system faults and fault enunciation

supports engine heath monitoring functions based on vibration data.


PHMU
ODM
ODM INTERFACE CIRCUITRY
FWD VIB
AFT VIB
VIBE INTERFACE CIRCUITRY
N1, -2, -f PULSE
TRAIN
FPGA
N1 SPEED
N2 SPEED
Nf SPEED
CHANNEL A
CHANNEL B
DSP
CAN BUS
HCPU
EEC
AOP INTERFACE CIRCUITRY
AOP
POWER SUPPLY
+ 28 VDC
(AIRFRAME)

Vibration Monitoring

The HCPU also separates the processed vibration signals into three categories: fan vibration, high rotor vibration and low rotor vibration.

The processed fan vibration signal is sent to the EEC as the N1 vibration signal.

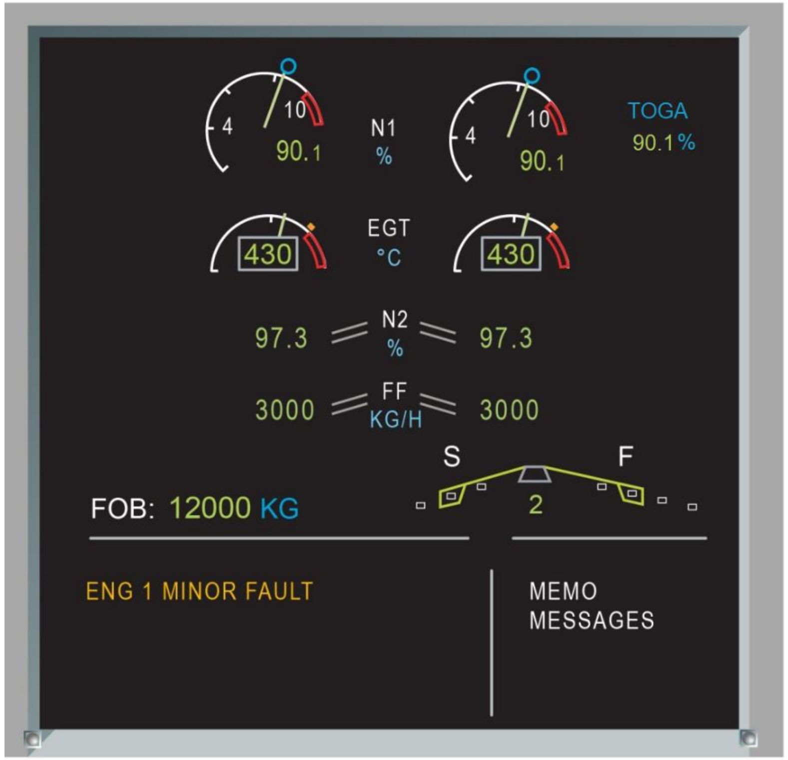
The largest processed high or low rotor vibration signal, referred to as the *core* vibration, is sent to the EEC as the N2 vibration signal.

The EEC sends the N1 and N2 signals to the EIU, which forwards the information to the cockpit for display on the engine page.

Indications are displayed in digital form, using 3 digits from 0.0 to 10.0, with a step of 0.1 unit. An associated ECAM warning also appears.

Indications for N1 and N2 display as described in the table.

FLIGHT CREW INITIAL WARNING



ENGINE/WARNING DISPLAY

INTERACTIVE MODE FOR MAINTENANCE ACTION

MULTIPURPOSE CENTRALIZED DISPLAY UNIT (MCDU)

SAMPLE ECAM MESSAGE FOR ATA 77

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