GEC-Marconi Electronic Systems

ESD2020

Engine Monitoring System (EMS)

- *Increases flight safety*
- *Reduces life cycle costs*
- *Extends engine life*
- *Chosen by UK MOD and US DOD for GR Mk5/AV-8B HARRIER*
- *Modular design supports multiple applications of D. ENG T2712*

The GEC-Marconi Radar & Defence Systems-Electronic Systems Division (GMRDS-ESD). ESD2020 Engine Monitoring System (EMS) is designed to meet all the requirements of hardware and software operating in severe environments experienced by aircraft such as the Harrier GR5/AV-8B.

The aim of military aircraft gas turbine engine monitoring is, in simple terms, to reduce maintenance costs and increase flight safety. Current maintenance policy for engines is removal for inspection at fixed time intervals. These intervals are presently defined by engine running hours and take little account of the number and type of missions flown. Obviously the amount of damage which an engine experiences varies according to the mission flight profile, weather conditions, pilot skill etc. Because these features are unknown, large tolerance factors are inherent in the present system of lifing engines based on hours run.

Engine monitoring is a technique for gathering data during each sortie and computing the amount of damage suffered by engine components in real time. This damage is quantified as engine life counts and since the significant features of each sortie are known, it becomes unnecessary to apply large tolerance factors to engine lifing.

A reduction in tolerance factors leads to an extension of engine life (in most cases) which in turn means that the time between overhauls is increased and leads to significant cost savings. A further advantage of quantifying engine damage is the added confidence in engine serviceability which leads to improvements in flight safety.

For the AV-8B and GR5 where great emphasis has been placed on size and weight constraints, the engine monitoring system hardware is comprised of the following airborne and ground units:

- Airborne
  Engine Monitoring Unit (EMU)
  Quick Access Recorder (QAR) (optional)
- Ground
  Data Retrieval Unit (DRU)

The airborne units are mounted in the wheel well and are used respectively to computer engine life and store raw data. The DRU ground data handling equipment is a back-pack or hand carried unit capable of extracting data from the EMU. This unit can also be used to diagnose transducer/signal input failures and/or produce first-line engine diagnostics for service use.

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Unit descriptions

ESDS2021 engine monitoring unit

This is a single box, data acquisition and processing unit for use in severe environments

The EMU provides the following functions in a small, lightweight, low power unit.

- Engine life counts
  Low cycle fatigue calculations on 6 engine components
  Creep and thermal fatigue calculations
- Continuous monitoring
  vibration analysis
- Warnings
  Incident/exceedance monitoring and recording
  Continuous recording of raw data.

The information required to perform these functions is available from five different types of data source:

Analogue transducers
Mulitplex Data Bus (1553)
Digital engine control system data bus
Engine display panel UART link
Vibration Transducer

Results are stored in non-volatile memory and are available for output to the ground based support equipment (DRU), the cockpit Digital Display Indicator (DDI) and to an onboard data storage set via the MIL-STD-1553 databus. Discrete outputs are provided in the form of a cockpit amber caution lamp and a refuelling panel incident/exceedance warning indicator. Raw data obtained from continous recording is availalbe in tape cassette or tape cartridge form.

Incident/exceedance detection

In order that transient events may be analysed in detail, the EMS software is configured to recognise key parameters and trigger a recording of data surrounding each event. These events are of particular interest at first line so the maximum value, duration of exceedance, elapsed time into mission and engine run number are all stored with the identification of the incident/exceedance type. The information is available during flight through the cockpit display (DDI) and immediately after flight through the ground support equipment DRU, the DDI and the optional remote Display Unit (DU). The following incidents are detected by the EMS:

NF overspeed
NH overspeed
CCOC overpressure
JPT over temperature
Hot start
Surge
In flight relight
Pilot event
AC power failure

In all cases historic data preceding (as well as data following) a particular event is stored to assist analysis. Data for a succession of events up to a total cf one minute is stored within the EMU.

Vibration

The vibration algorithm is designed to detect gradual degradation of engine components as well as gross failures. The vibration signal from the engine mounted sensor is split into fifteen frequency bands. The vibration level in each of the bands is continuously analysed and referenced to the LP and HP spool speeds. Following the installation of a new engine, a vibration signature is constructed for that engine/airframe configuration.

Vibration maintenance warnings

Maintenance warnings will be generated if the vibration pattern of a running engine differs significantly from its stored signature.

Vibration alarms

If a vibration level in any of the fifteen bands exceeds a pre-defined alarm level, a vibration alarm is signalled to the pilot allowing him to take appropriate action. Both vibration alarms and maintenance warnings cause engine and aircraft data to be stored for subsequent analysis leading to corrective maintenance actions or an updated overhaul timescale.

Engine lifting major activities

Calculation

- Low cycle fatigue
- Turbine blade creep
- Thermal fatigue
- Vibration spectrum

Monitoring

- Temperatures
- Pressures
- Shaft speeds
- Vibration signature

Warning (Incidents)

- Over pressure
- Over speed
- Over temperature
- Vibration alarm
- Surge
- In flight relight
- Hot start

Recording

- Life counts
  (cumulative and per flight)
- Snapshot incident data
- Summary of incidents
- Run number
- Aircraft ident

Vibration monitor logging

A further facility is provided allowing routine monitoring of vibration levels by storing a record of the levels in each vibration band at take-off and every fifteen minutes during the flight.

Built-in Test Equipment (B.I.T.E.)

Comprehensive BITE facilities allow fault isolation to module level. This includes a detailed test ot the

random access memories at power on. Other tests of the processing sub-system and interface modules are carried out as a continuous background task.

ESD2026 Data Retrieval Unit (DRU)

A rugged portable unit

The data retieval unit extracts all engine lifing results from the EMU together with exceedance summaries and raw data. Inspection of incidents and lifing results is achieved using a simple MENU driven display. A privileged mode of operation allows the EMU documentary data and accumulated life counts to be set up. This allows the data base within the EMU to be initialised in the event of an engine change or major overhaul. A particularly useful feature of the DRU is the test set capability. This mode allows ground/maintenance personnel to examine each input signal to the EMU in real time and fault find rapidly. A special long cable option allows direct engine transducer monitoring during tied down ground runs. The DRU may be powered by an integral battery when aircraft supplies are not available and can therefore be used to dump data directly from a 'dead' aircraft. After connecting the special cable, data dumping is accomplished in three seconds after which the DRU may be unplugged and used on the next aircraft and so on. The non-volatile memory in the DRU holds data from up to 25 aircraft (dependent on incidents stored). This allows one operator to gather data from a full squadron of aircraft on the flight line before returning to the maintenance area to analyse each dump. An integral RS232 interface port allows hard copy print out on a standard line printer.

For maintenance management purposes the same port can be used to transfer data to a desk top computer or central processing system.

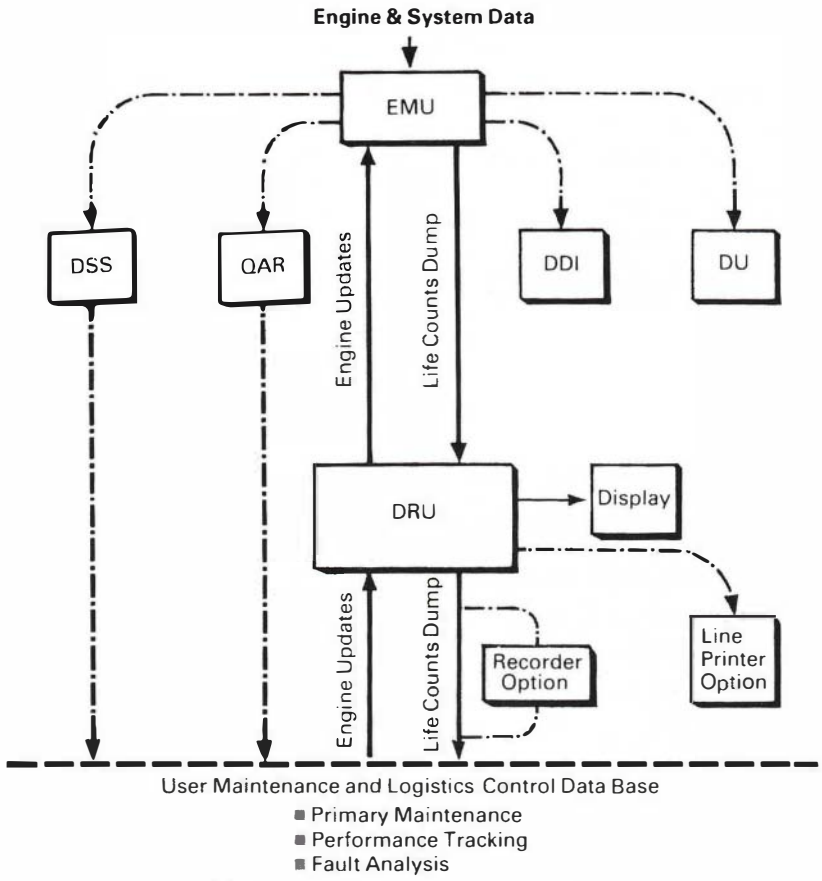
A carrying frame is available to enable the operator to wear the DRU as a backpack in an operational environment, leaving his/her hands free for other tasks.

Futher expansion of the DRU is planned such that the unit may examine recovered data and perform simple diagnostics to assist maintenance crew when away from base.

ESD2023 Display Unit (DU)

In some applications it maybe required to take a 'quick look' at the engine life counts or status information stored in the EMU non-volatile memory. If there is no multiplex data bus system available to transfer such data to a general purpose display on the vehicle the ESD2023 may be used.

This unit is contained in a small rugged box which may be mounted adjacent to the EMU or remotely in an operator accessible position.



Engine Monitoring System Data Flow

The display itself is formed from 16 light emitting arrays that are used to generate alphanumeric characters. The data is presented as a mnemonic with associated value under push-button control.

Raw data recording

The Davall 1267-002 is a compact, light-weight, cassette-loaded digital Quick Access Recorder (QAR). Data is recorded in a blocked format with a total storage capability of about 20Mbit using a severe environment computer grade version of the C60 cassette.

Data bus option

For the AV-8B the QAR is replaced by a Hamilton standard solid state recorder (data storage set). Incident data, continous data, and engine life counts are transferred via the MUX BUS port to the solid state recorder under control of the mission computer.

The recorder forms part of the AV-8B standard fit and has spare capacity which is utilised to store EMS data, thus minimising overall system weight.

Ground replay

GMRDS-ESD also supplies a comprehensive range of ground replay equipments.

ESD3010 replay interface chassis

For recovering and resynchronising data which has been recorded on cassette in the EMS, the unit provides a 14 bit parallel data output which is simple to interface with the user's replay computer system.

ESD1823B Portable Ground Replay Unit (PGRU)

The PGRU is a robust, compact, portable unit designed to replay cassettes obtained from an EMS. It is also compatible with other GMRDS-ESD structural and engine usage monitors in the ESD1820 series. The PGRU has a built-in 16 character display, a printer and 6 analogue outputs for rapid data analysis.

-Key data summary

EMU analogue inputs

DC input ranges
-2.5 to +2.5v
OV to +5V
-5V to +5V
Accuracy (input to digital)
+0.1% typ -20°C to +70°C
+0.2% typ -40°C to +85°C
+0.4% typ -55°C to +90°C
Special purpose conditioner options
Vibration analysis: Alarm and maintenance warnings*
Oil debris detector: Major event alarm, minor event counting*
Tachometer, thermocouple etc.
*Alarms may be supplied as outputs for crew alert if required

EMU digital inputs/outputs

Data bus interfaces

In addition to special purpose data links to DRU, QAR and display, currently available modules may be selected for interface with data buses to the following standards:

- DEF STAN 00-18 part 2/1
- DEF STAN 00-18 part 3/1
- MIL- STD -1553A
- MIL- STD -1553B
- STANAG 3838
- MDC A5232
- BAe 81-1057

Others are in preparation
Discrete interfaces
DEF STAN 00-18 part 4/1 section D15 and D14 (semiconductor), differential, or special purposes.
QAR data output
Each parameter is contained in 10 bits of a 12 bit word, the 11th bit being a compression flag; the 12th reserved for parity, to be inserted by the QAR electronics. Data, clock and frame synchronisation signals are driven out in differential form.
DRU inputs/outputs

- Port 1 RS422 Manchester encoded HDLC link to EMU
- Port 2 RS422
- Port 3 RS423
- Port 4 RS423-RS232C compatible

Computers

EMU

CPUs:

1. Very large scale hybrid integrated circuit high speed 32 bit microprocessor communicating via 16 bit buses with external memories
2. High performance 8 bit microprocessor with 16 bit internal registers

Program ROM:
128kbytes of CPU1 (expandable to 256kbytes) 8Kbytes for CPU2
RAM:
4kbytes internal to CPU1 for executive use (expandable to 16K)
8kbytes internal to CPU1 for applications (expanable to 32K)
8kbytes for CPU2
4kbytes shared
Non-volatile memory:
1kbytes expandable to 2kbytes for CPU1
8kbytes expandable to CPU2

B.I.T.E.:
Comprehensive automatic self testing and fault diagnosis down to module level.

DRU

CPUs:

1. High performance 8 bit microprocessor with 16 bit internal registers
2. VLSI 8 bit microcomputer with on-chip RAM, timer and I/o port

Program ROM:
40kbytes of CPU 1
8kbytes for CPU2

RAM:
8kbytes (expanable) for CPU1
112bytes internal to CPU1
32bytes for display buffer
Non-volatile memory:
128kbytes expandable to 512kbytes for CPU1
(512kbytes expandable to 4Mbytes)

B.I.T.E:
Comprehensive automatic self testing and fault diagnosis down to module level.

Power requirements

EMU

+28V(+14%,-43%) to MIL-STD-704C and BS3G100 part 3.
The EMU incorporates a transient suppression circuit so that data processing is not corrupted by power dropouts
Power consumption is typically 30W at 28V

DRU

The DRU may be fitted with 24V batteries, 2Ah and 4Ah types are available. Alternatively the DRU may be powered via the EMU from vehicle supplies. Power consumption is typically 15W.
Display unit,
+28V(+14%,-43%) to MIL-STD-704C and BS3G100 part 3 (normally via the EMU).
Power consumption typically 10W.

Dimensions, weights and temperature ranges

EMU

L x 192 x 123mm. The lenght L, depends on the number of plug-in modules used, but is typically 180mm. The unit may be hard-mounted to the vehicle structure using the flanges provided; it had been designed to meet the requirements of MIL-STD-810C, BS3G100, MDC3780 and DEFSTAN 07-55. Typical weight (GR5/AV-8B) = 4kg. Operational temp range - 55°C to 90°C.

DRU

289 x 260 x 80mm, not including carrying frame and battery pack. The hand-held keyboard and display sub-unit occupies an envelope of 173 x 95 x 35mm and is attached to the main part of the unit via a 1.25m umbilical (other lengths are available). Weight (GR5/AV-8B) =5kg with optional battery 7kg. Operational temp range - 20°C to +40°C
Display unit
The display unit may be provided in a number of enclosures depending on mounting and environment required. Typically the envelope dimensions do not exceed 150 x 60 x 65mm Typical weight = 500gm. Operational temp range - 55°C to +90°C.

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