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AN INTEGRATED PERFORMANCE AND AIR DATA SYSTEM FOR HELICOPTERS

by

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ABSTRACT

Paper No.40 describes the XM-143 Helicopter Air Data Subsystem supplied for the Bell AH-1S Enhanced Cobra Attack Helicopter and an independent development of that technology by Marconi Avionics. This air data subsystem is especially suited to meet the tactical requirements of Army aviation and close support operations.

By using a unique swivelling pitot-static pressure probe located in the rotor induced flow field together with an integral air temperature sensor, the system can determine essential air data parameters to a high degree of accuracy under all flight conditions, including low speed operation.

The integrated Lift Margin System combines air data parameters with engine, rotor, and transmission sensor inputs to compute and display mission-critical performance information to the flight crew.

The system accepts inputs from the air data subsystem, together with inputs from existing sensors in the helicopter power train and a weight and balance subsystem and computes a comprehensive range of performance parameters which are presented to the pilot as visual displays or warnings.

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1.0 INTRODUCTION

This paper describes the XM-143 Helicopter Air Data Subsystem supplied for the Bell AH-IS Enhanced Cobra Attack Helicopter and a development of that system, which provides comprehensive helicopter performance data.

The Lift Margin System combines air data parameters with engine and transmission sensor inputs to compute and display mission-critical performance information to the flight crew.

The system accepts inputs from the air data subsystem, together with inputs from existing sensors in the helicopter power train and a weight and balance subsystem. From these inputs the system computes:

Longitudinal TAS	Maximum Rotor Torque
Longitudinal CAS	Longitudinal CAS Limits
Lateral TAS	Gross Weight and CG
Lateral CAS	Lateral CAS Limits
Vertical TAS	Hover Ceiling
Altitude Rate	Maximum Altitude Rate
Downwash CAS	Best Climb CAS
Pressure Altitude	Static Air Pressure
Density Altitude	Air Density
Static Air Temperature	Maximum Gross Weight
Engine Performance Index	Rotor Performance Index
Power Margin	Obstacle Clearance Performance
Weight Margin	Remote Site Performance

2.0 XM-143 AIR DATA SYSTEM

The XM-143 is a helicopter air data system especially suited to meet the tactical requirements of Army aviation and close support operations.

By using a unique swivelling pitot-static pressure probe located in the rotor induced flow field together with an integral air temperature sensor, the system can determine essential air data parameters to a high degree of accuracy under all flight conditions, including low speed operation.

The facilities provided by the XM-143, its equipment engineering, method of operation, data display and maintainability features have been designed to satisfy the following objectives:

(a) Provide accurate instantaneous data to user subsystems (eg fire control, performance, and navigation systems) to increase aircraft mission effectiveness. Minimize installed weight of system.

(b) An instantaneous display of airspeed and direction to reduce pilot workload and improve safety in the low speed flight region.

(c) Provide a system with high reliability and minimal maintenance actions to maximize availability and mission success rates.

2.1 General Description

The XM-143 Air Data System (Figure 1) consists of three principal units; the Airflow and Direction Sensor, the Electronic Processor Unit and the Low Airspeed indicator.

The Airflow and Direction Sensor is a swivelling pitot-static pressure probe which is mounted external to the fuselage (Figure 2). The Sensor has an integral Air Temperature sensor and is equipped with anti-icing heaters. The probe is aligned with the local airstream under the rotor by stabilizing vanes and angle resolvers are used to measure the local flow direction.

The Electronic Processor Unit accepts input data from the Sensor consisting of airflow direction, air temperature, total pressure and static pressure. The Processor uses two pressure transducers to generate electrical data from the pneumatic inputs and a digital microprocessor converts the input data into the required outputs. The microprocessor computation applies corrections to the data to remove errors generated by fuselage and rotor

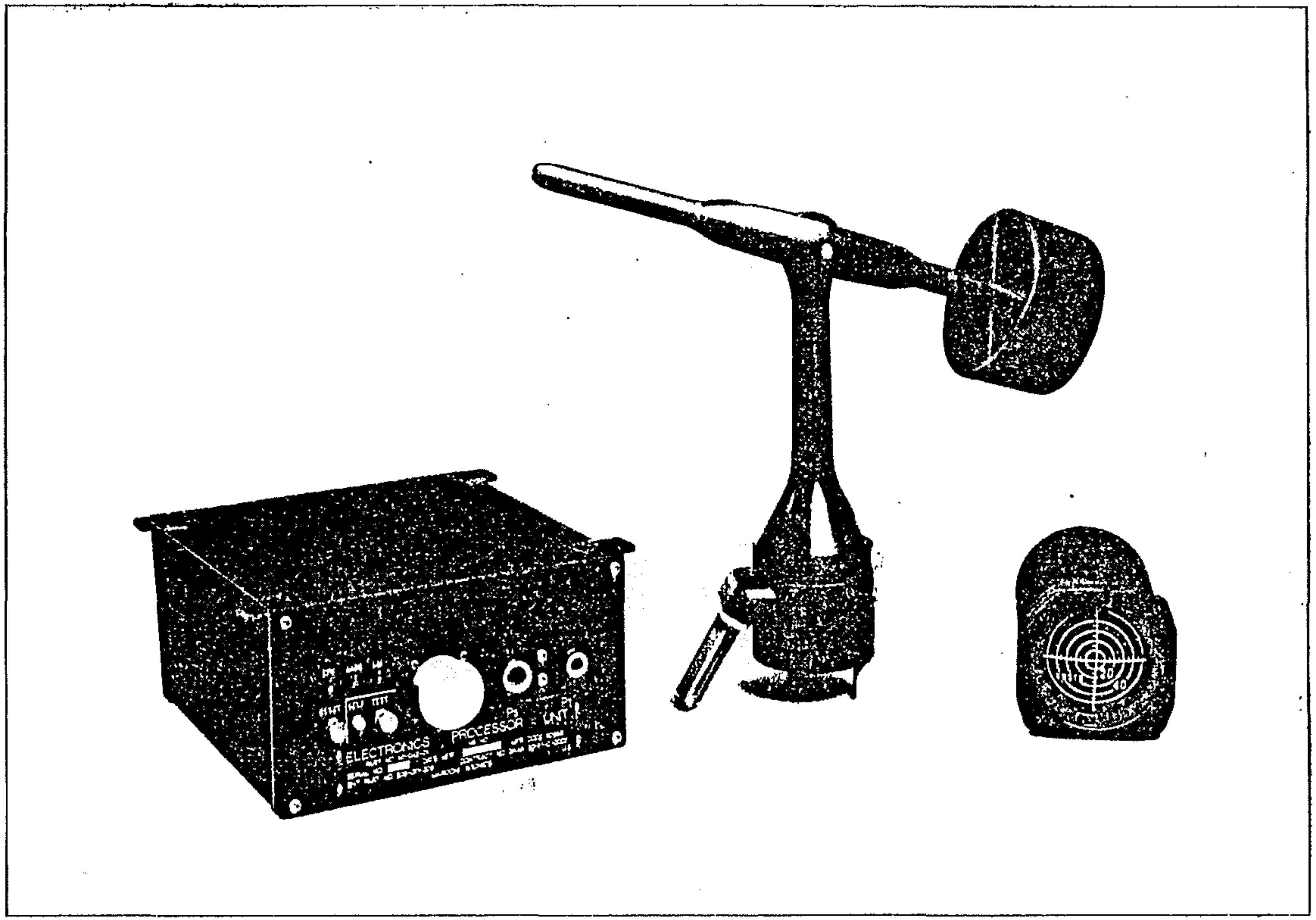


Figure 1 XM-143 Air Data Subsystem

Figure 2 AH-IS Cobra in Flight showing Probe Installation

induced flow effects. The processor also performs continuous system integrity monitoring and organizes the manually operated Built-In Test Sequence.

The Low Airspeed indicator accepts data from the Processor to provide the pilot with a cross-pointer display of longitudinal and lateral airspeed in the low airspeed region (below 50 Kn IAS). The indicator also provides a warning malfunction flag symbol in the event of system failure.

2.2 System Characteristics

Power Consumption	+28V dc 30W
Velocity Range	50 Kn Aft to 200 Kn Forward
	50 Kn Left to 50 Kn Right
	4000 Ft/Min Climb/Descent
Altitude Range	-2000 Ft to 15000 Ft
Velocity Accuracy	±3 Kn
Output parameters	Longitudinal TAS and IAS, Lateral TAS and IAS, Vertical TAS, Static Air Pressure, Static Air Temperature, Downwash airspeed TAS, System Fail Discrete
Output Transmission	Serial Digital and DC Voltage Analog

Dimensions and Weights

	Height	Width	Depth	Weight
Airflow and Direction Sensor	3.8in	12.5in	9.67in	2lb 6oz
Electronic Processor Unit	4.2in	8.2in	7.5in	7lb 6oz
Low Airspeed Indicator	3.25in	6.0in	3.25in	1lb 6oz

Reliability

System Mean Time Between Failures of 1000 hours

3.0 HELICOPTER ENGINE AND ROTOR MANAGEMENT SYSTEM (HERMES)

The problems identified in Vietnam relating to effective helicopter operation formed the basis for development of the HERMES system shown in Figure 3. The aims of the system were primarily to reduce the 'rule-of thumb' approach to helicopter flight by providing pilots with a continuous update of power drawn from the engine. This was expressed as a percentage of maximum N1 and T4 power available, accounting for measured changes in atmospheric conditions and also for engine degradation by pilot entry of topping check calibration data. The lift capabilities of the helicopter were also computed using the calculated maximum power available, rotor equations, and pilot estimated gross weight.

The analog prototype system was completed in 1973, and was subjected to flight-test evaluation on a S-61 Sea King helicopter at the Royal Aircraft Establishment, Farnborough, England, during 1974. At that time, research into accurate helicopter gross weight measurement was incomplete, the system did not incorporate a weight and balance subsystem. To overcome this difficulty, a pilot input of estimated gross weight was entered for the momentum theory based lift margin calculation. Remote site performance capabilities were determined by a 'Predict' mode of operation, using pilot-entered remote site atmospheric data.

Due to Helicopter availability problems, the flight evaluation was not fully completed, but results obtained showed a significant improvement in the Engine Torque display over conventional instrumentation. System development continued, this development now forms the basis for the digital Lift Margin System (see Paragraph 4).

3.1 Design Specification and Performance

The system was designed to meet the requirements of RAE Specification No.9, March 1972. This called for three LRUs, a Computer, Maximum Torque Indicator

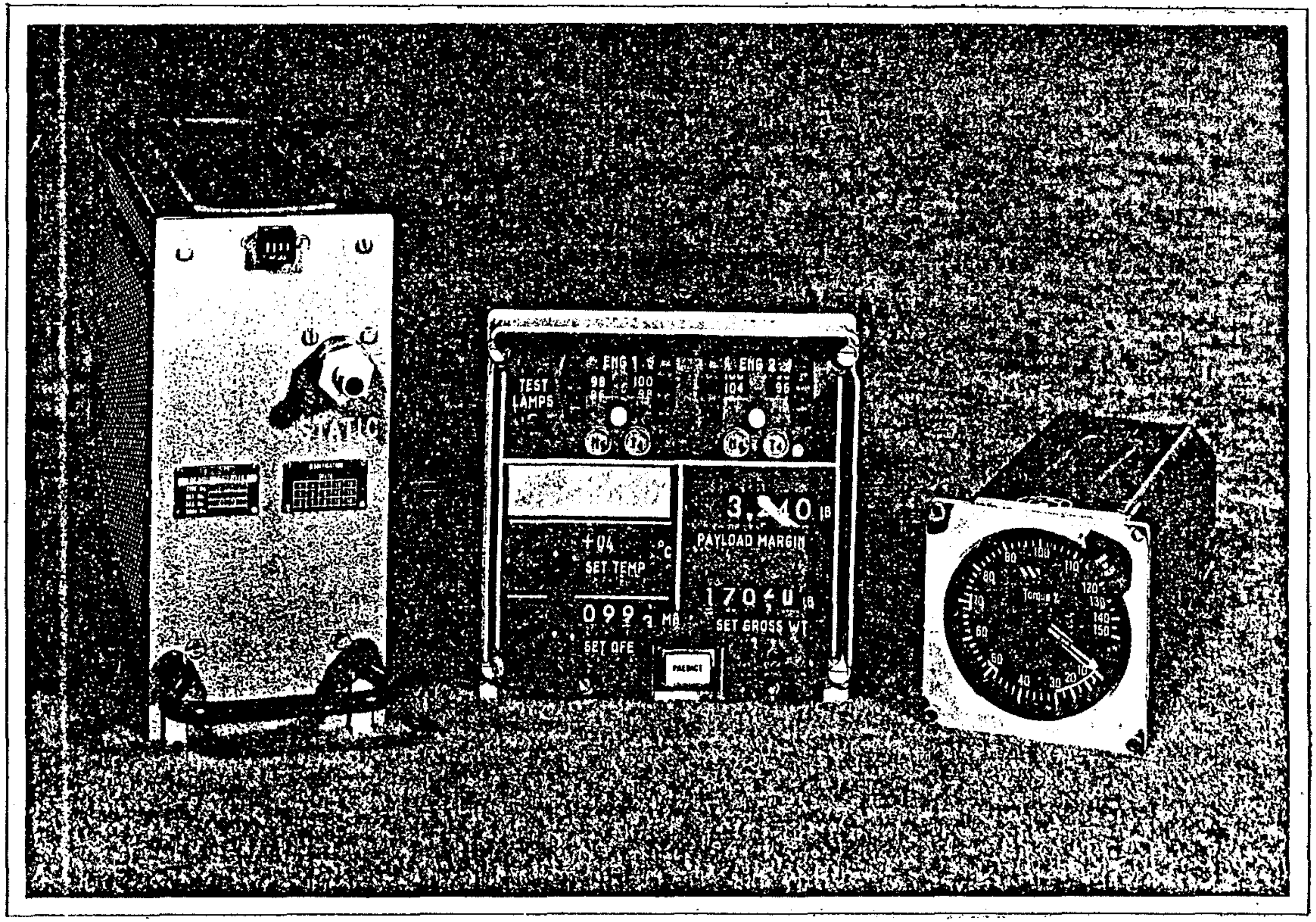


Figure 3 Helicopter Energy and Rotor Management System (HERMES)

and Payload Margin Indicator. Prime requirements for the system were to calculate and display the following parameters:

Parameter	Range	Accuracy	Remarks
Torque Ratio	30% to 150%	$\pm3\%$	(Against Predicted MPA)
Payload Margin	-400lb to 7500lb	200lb	Current and Predicted
Torque Output	30% to 150%	$\pm3\%$	(Against Brochure Date)

3.2 Operation

3.2.1 Normal Operation

In normal operation the maximum torque indicator (MTI) indicates the torque output of each engine as a percentage of the maximum torque available at either the T4 limit, the N_G limit or the transmission limit whichever is the lower.

The Payload Margin Indicator (PMI) indicates the margin between the maximum gross weight that can be lifted vertically in still air out of ground effect and the value of gross weight which the pilot has set on the 'set gross weight' counter. The PMI also indicates which of the limits dictate the 100% value on the MTI by means of the engine limit lamps. If the helicopter is transmission limited no lamps will be illuminated, if however the helicopter is engine power limited the lamps indicate the limit which is applicable to each engine (ie N_G or T4).

3.2.2 Standby Mode

This mode is in effect a reversion to a standard torque display, and can be selected manually by using the knob on the instrument bezel. The mode may also engage automatically if a failure is detected in the computer, or the computer is removed, or if the PREDICT mode is selected. The mode is identified by a flag on the indicator face which will show STBY in white characters.

4.0 CURRENT LIFT MARGIN SYSTEM

4.1 Introduction

The current Lift Margin System employs microprocessor technology similar to that used in the XM-143 Air Data Subsystem. The system is being developed for flight trials evaluation, with the object of determining the optimum production system architecture. The Lift Margin System (LMS), supplies the aircrew with helicopter performance data including:

- gross weight, centre of gravity and cargo hook loading
- weight and hover margin information
- engine performance and engine condition information
- helicopter flight performance capability
- prediction of remote site capabilities

These parameters are displayed on a Control and Display Unit, which has an alphanumeric display integral with a data entry control keyboard. In addition a Maximum Torque Indicator gives a continuous indication of engine performance. The system Performance Processor Unit has sufficient flexibility to interface with sensors incorporated in any single or multi-engined helicopter, an Air Data Subsystem and a Weight and Balance Subsystem. Digital outputs of all calculated parameters are available via an Arinc 429 compatible output channel.

Prior to system implementation in flying hardware, extensive investigation was carried out to evaluate fully the required operation of the system and its capabilities.

The direct result of this study has been the extension of the system capabilities to include an interface with a ground weighing system, extended sensor input capability and expansion of the output data available from the system.

The flight test system was designed with special consideration towards flexibility and ease of modification. This enables compatibility with all types of helicopter and provides adaptability to different mission profiles and changing crew information needs.

4.2 System Hardware

4.2.1 Introduction

The Lift Margin System 03-022-01 consists of three LRUs:

(a) Performance Processor Unit (PPU) Type No.31-019-01

(b) Control and Display Unit (CDU) Type No.25-034-01

(c) Maximum Torque Indicator (MTI) Type No.75-005-01

The Lift Margin System takes inputs from an Air Data Subsystem, Weight and Balance Subsystem and aircraft sensors.

The system configuration is shown in Figure 4, Pilot interface is via the CDU and MTI. The PPU carries out all interface control functions and calculation required for the operation of the Lift Margin System.

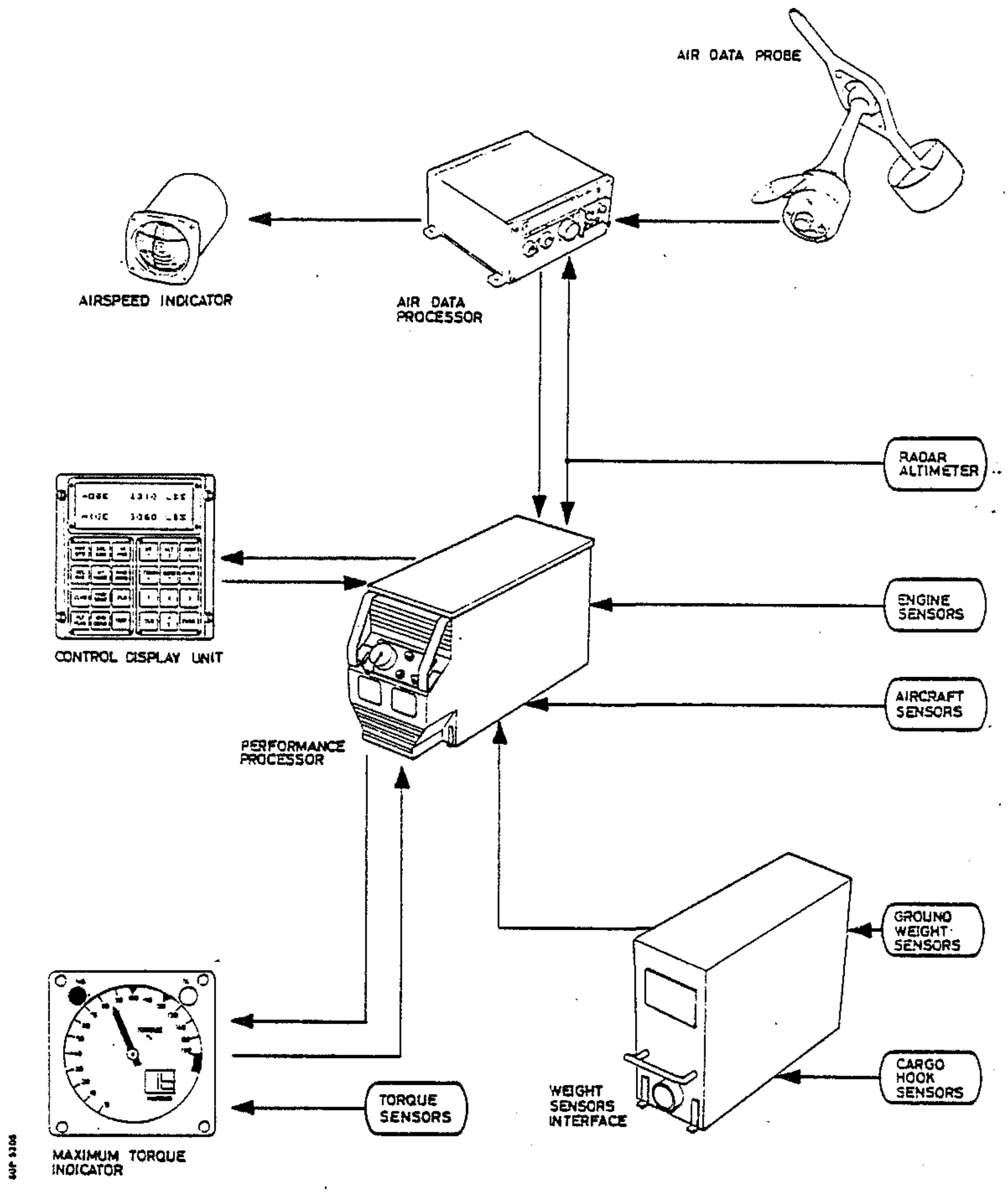


Figure 4 Lift Margin System Type No.03-022-01

4.2.2 LRU Description

4.2.2.1 Performance Processor Unit (PPU)

The PPU is packaged in a 1/2 ATR short case of dip-brazed construction, and has space for 14, 6 inch x 4 inch circuit cards, and a power supply unit. The case is fitted with a front mounted test connector and a rear mounted DPX connector. The PPU weight is less than 12lb.

The digital circuits are implemented in Transistor-to-Transistor Logic (TTL) and the central processor is configured around a Texas Instrument SBP9900 microprocessor.

The PPU is arranged in five functional blocks:

- Central Processor Unit
- Power Supply Unit
- Analog Interface Unit
- Digital Inputs Interface Unit
- Outputs Interface Unit

These units require eight circuit cards. The remaining six card spaces allow for extensive potential system growth, such as additional interface capability.

4.2.2.2 Control and Display Unit (CDU)

The CDU is housed in an enclosure conforming to MS 25212. The design is based on the concept of providing a general purpose interface between operator and the Lift Margin System, and the display format and keyboard functions can be adapted to meet specific system requirements.

The control panel is divided into two areas; on the right of the unit are the controls for data entry into the LM System for remote site performance prediction, and on the left are the controls which select the modes of system operation. The control details are given in Table 1 and a view of the Front Panel shown in Figure 5.

TABLE 1 Control Functions

Button	Display Parameters
WT MARG	In and out of ground effect hover weight margin.
PWR MARG	In and out of ground effect hover power margin.
CLMB	Vertical rate of climb and maximum rate of climb with the airspeed at which it is achieved.
VNE/OBST	Distance to clear a fixed height obstacle and the V_{NE} airspeed.
PLD	Gross weight, center of gravity and cargo hook load.
FLT PLAN	Maximum range and maximum endurance and the airspeeds to achieve them.
RMT SITE } SGL ENG } INT POWER}	Modifiers for the above parameters for remote site conditions single engine operation and intermediate power limits.
RCL RMT	Recalls the remote site parameters of altitude, temperature, gross weight and baroset.
ENG COND	Engine condition and maintenance information.
TEST	Initiates LMS self test.
WT } ALT } TEMP} BARO}	For modifying remote site parameters of gross weight, geophysical altitude, temperature and barometric pressure setting.
GDWT) HVWT)	Stores either the ground weight or the hover weight.
Numeric Keyboard	For entering data

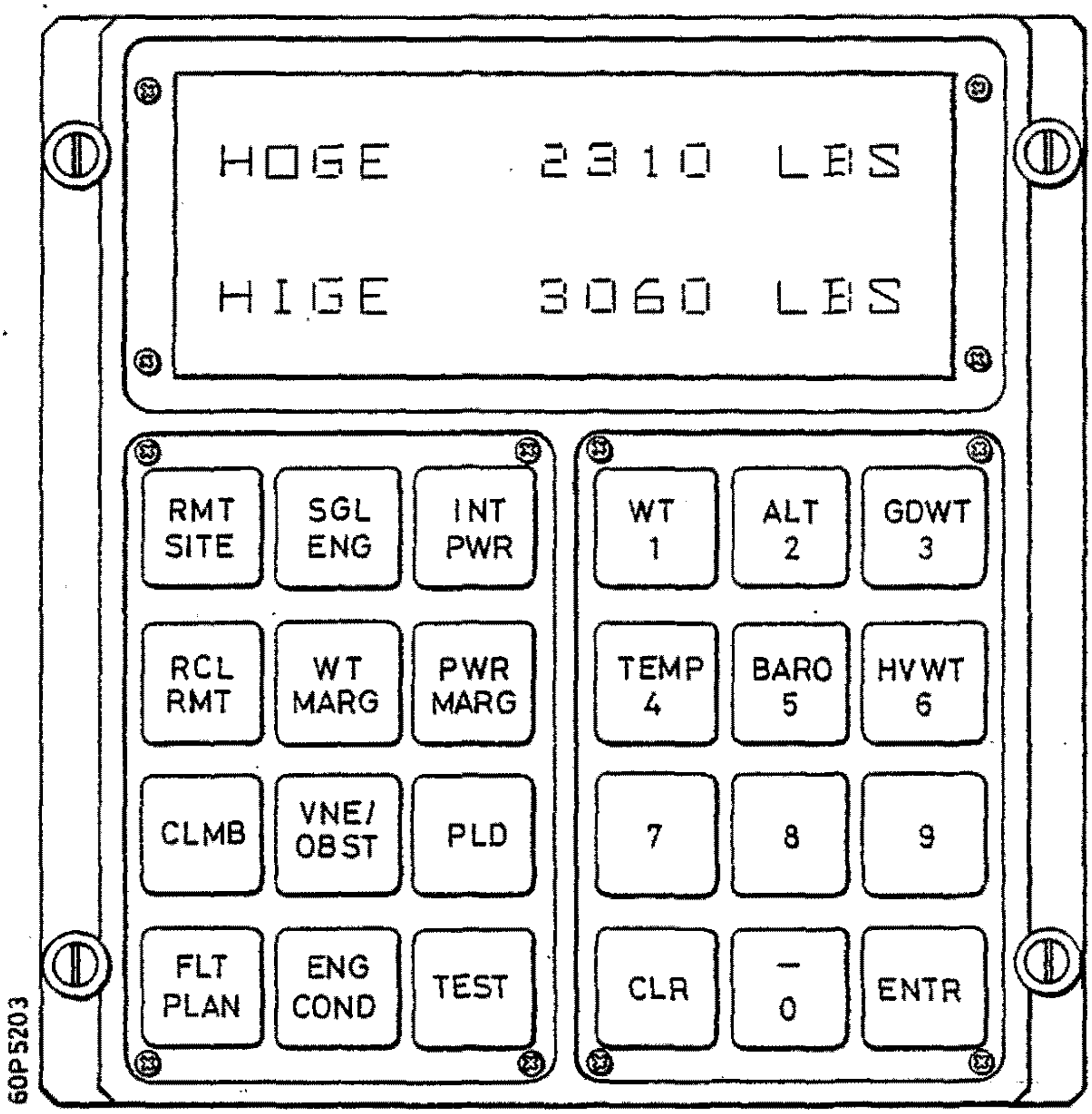


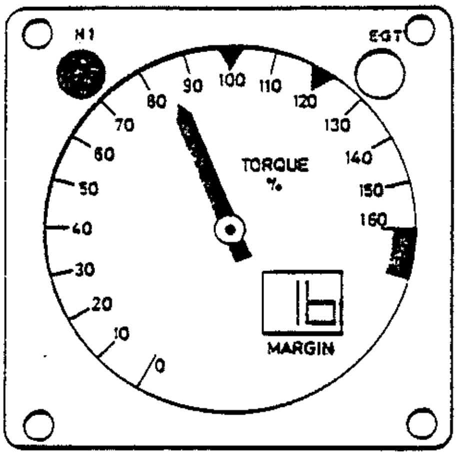
Figure 5 Lift Margin System - Control Display Unit Front Panel

4.2.2.3 Maximum Torque Indicator (MTI)

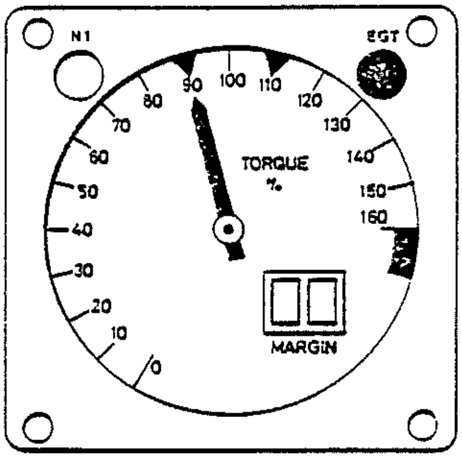
The Maximum Torque Indicator provides the pilot with a display of the instantaneous torque being generated by the engine, expressed as a percentage of the maximum torque available from a defined baseline engine model. Also displayed are the actual engine torque limits applicable at any given time, continuously updated to account for changes in atmospheric conditions as well as the effects of overall engine performance changes. The limits are calculated by the Performance Processor Unit (PPU), and displayed for both Gas Generator Spool Speed (N1) and Turbine Gas Temperature (TGT).

The indicator takes in data directly from engine torque sensors and can therefore continue to operate in a reversionary mode as a conventional torque indicator in the event of a failure in the remainder of the system.

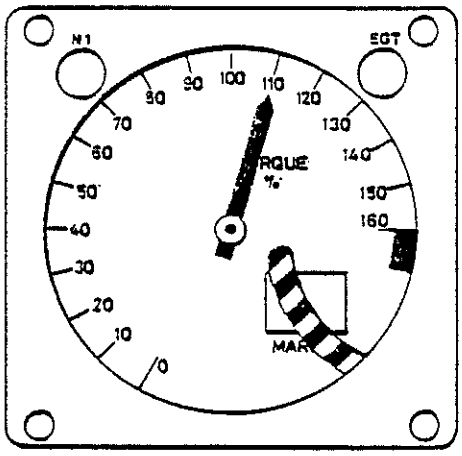
The indicator (shown in Figure 6) is housed in a case conforming to MS 33556, and the weight of the unit is less than 3lb.



TORQUE LIMITS DUE TO N1
ENGINE PRODUCING 84% TORQUE.
MARGIN OF 16% TO MAX. CONTINUOUS LIMIT.



TORQUE LIMITS DUE TO EGT
ENGINE PRODUCING 90% TORQUE
ENGINE OPERATING ON MAX. CONTINUOUS LIMIT.



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LMS FAILURE.
LIMIT MARKERS OBSCURED.
MARGIN DISPLAY OBSCURED.
ENGINE PRODUCING 110% TORQUE.

Figure 6 LMS Maximum Torque Indicator Type 75-005-01

4.3 Summary

By integrating air data, power train data, weight and balance data and pilot entered information, the Lift Margin System can calculate and display the following range of helicopter performance parameters to enhance mission efficiency and flight safety.

- In and out of ground effect weight margin
- In and out of ground effect power margin
- Vertical and maximum rates of climb with the airspeed at which they are achieved.
- Distance to clear a fixed height obstacle and the V_{NE} airspeed.
- Gross weight, centre of gravity and cargo hook load.
- Maximum range and endurance and the airspeeds to achieve them.
- The above parameters modified for remote site conditions, single engine operation and intermediate power situations.
- Engine condition and maintenance information.
- Airspeed and sideslip data.
- Air Data.