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DEVELOPMENT TESTING OF INTEGRATED AVIONICS SYSTEMS USING DYNAMIC ENVIRONMENT SIMULATION

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ABSTRACT

The evolution of sophisticated integrated avionics packages and their incorporation into Civil and Military helicopters has caused and will continue to cause significant perturbations to avionics and airframe manufacturers' integration plans.

A coherent testing philosophy is discussed which co-ordinates avionic system design with its supporting development and validation tools. Highlighted is the use of inherent system performance data to maintain, system integrity during validation of the developed system core whilst permitting full test automation.

The facilities developed by Westland Helicopters for dynamic simulation and performance assessment and presentation are described.

These techniques are shown to reduce costs, improve effectiveness and provide a high demonstrable level of confidence in the resultant integrated system.

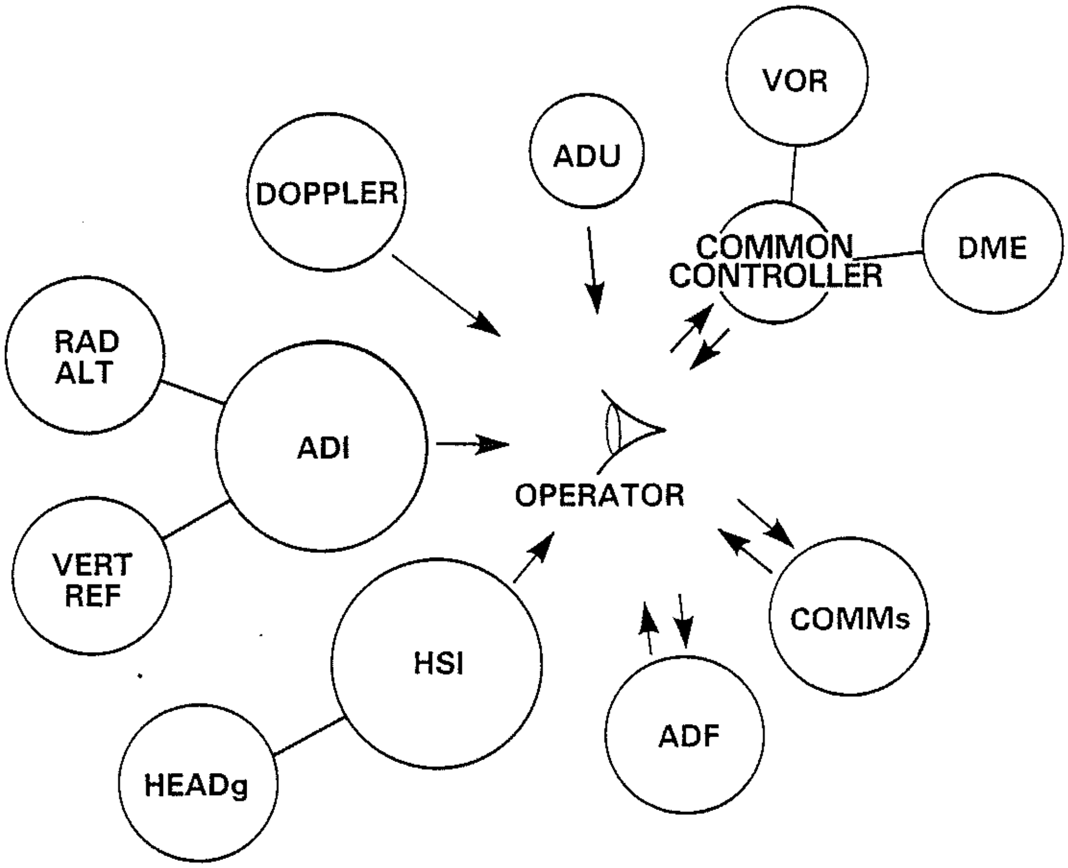


FIG 1 PARTITIONED AVIONIC SYSTEM

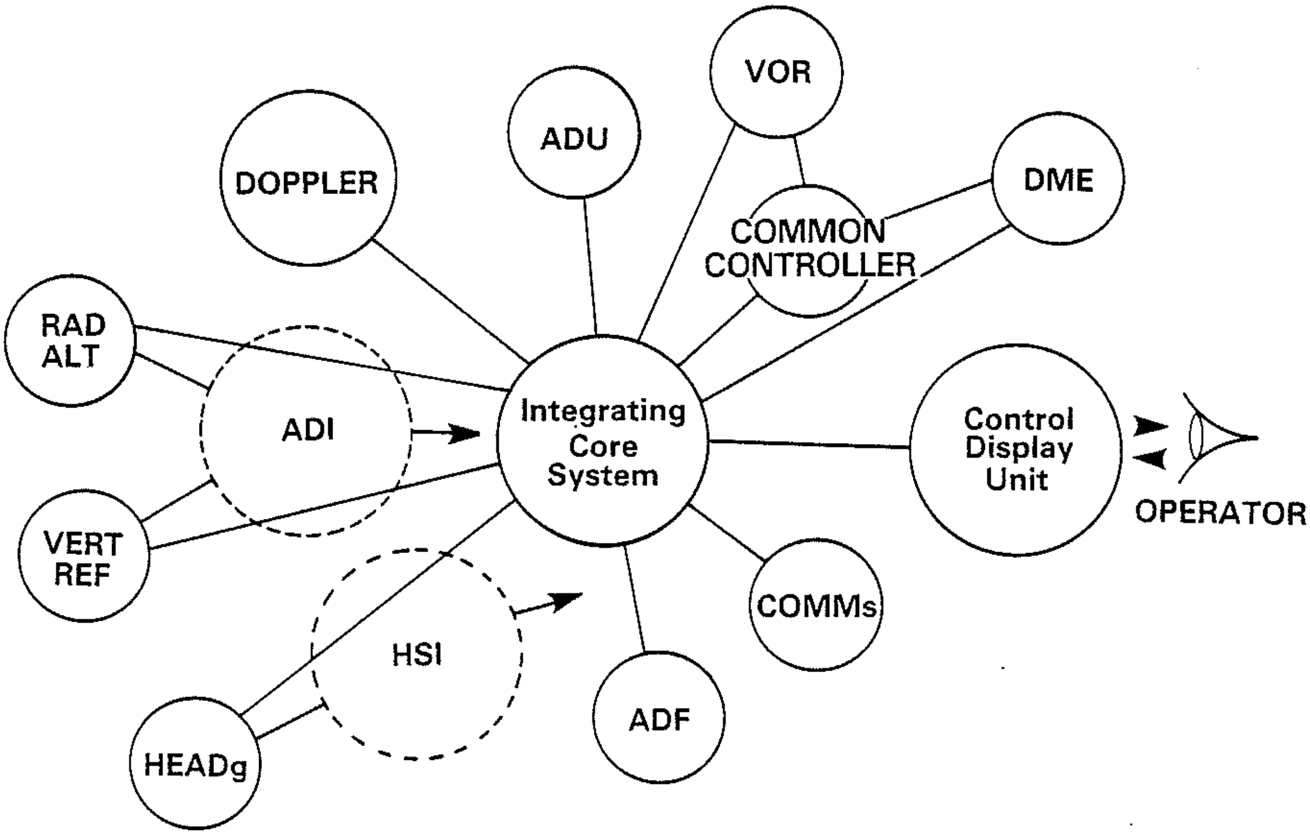


FIG 2 INTEGRATED AVIONIC SYSTEM

1.0 INTRODUCTION

In the past avionic systems have consisted of sensors and functions all relatively well partitioned, both physically and functionally, permitting a high degree of confidence when using modular approaches to testing on the ground and in the air.

Many of these sensor systems directly support and are controlled by an embedded computer system with its own associated architecture and operational constraints. In addition the inherent flexibility of the system implies the possibility of many configurations of sensors and computational functions as the product evolves.

The major impact on testing comes from the integrated architecture of the systems and experience indicates that failure to recognise and validate this in a fully controlled manner leads to severe difficulties and even failure to achieve satisfactory system validation when relying entirely on flight testing as the prime integration and validation tool.

The development approach adopted at Westland has been to develop a rigorous test method using largely ground based emulation and simulation. This allows greater control and visibility of the development testing. Flying time may then be devoted to tasks better solved by that method, releasing the aircraft from the long, tedious, costly and often dangerous, flying programs which would otherwise be necessary.

2.0 REQUIREMENTS

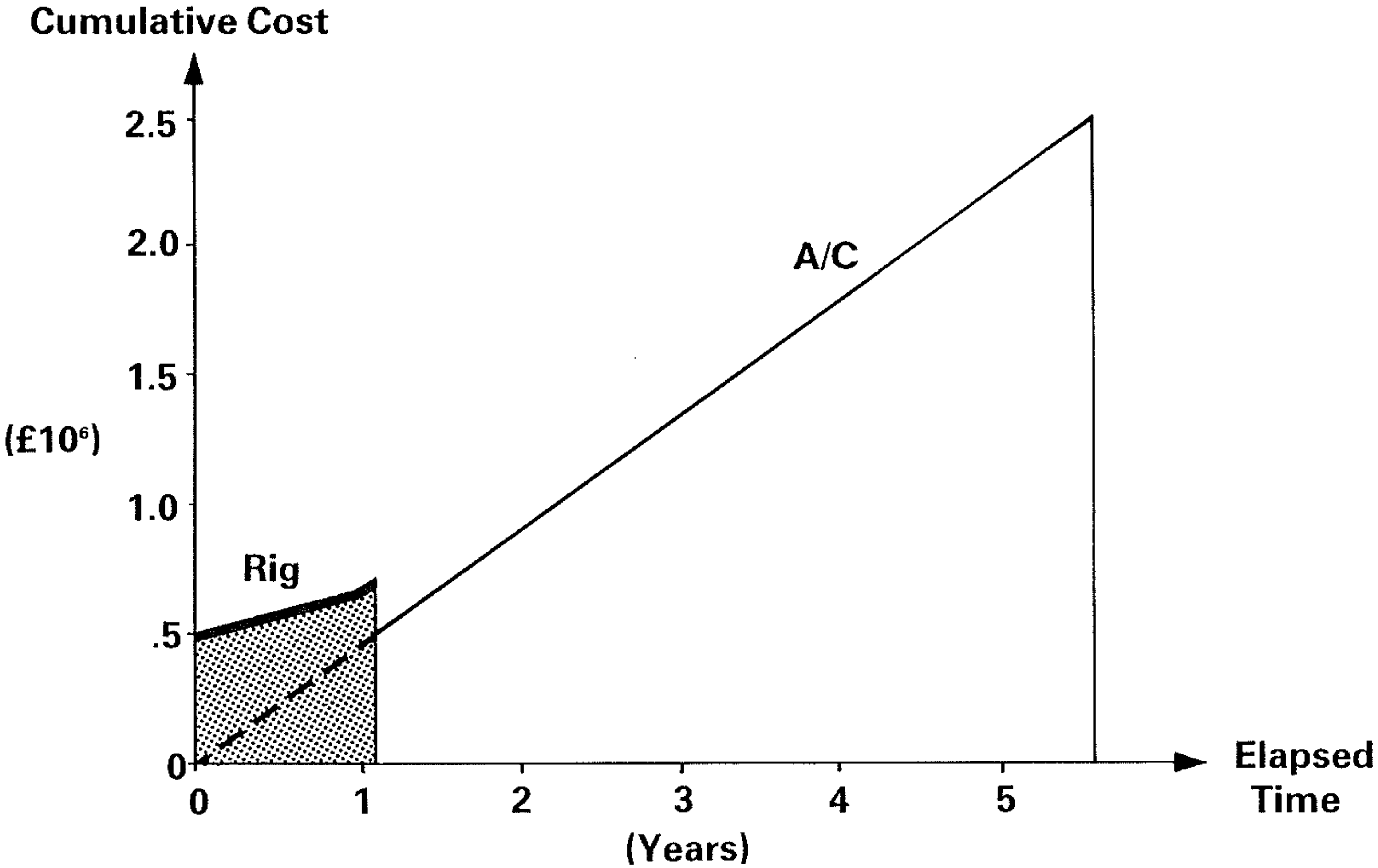
2.1 The fundamental tennet of the development process is the achievement of a safe, effective and viable system. In pursuit of this aim a number of detail considerations particularly relevent to integrated system stimulation must be addressed.

a) Validation of avionic system interfaces
b) Integration of system interfaces
c) Functional effectiveness
d) Computational accuracy
e) Functional integration
f) Software 'in target' validation
g) Failure and reversion modes
h) Systems bus operations
i) EMC assessment
j) Human factors development

2.2 Three factors have a dominant influence on the process of achieving a convergent solution to product development.

i) The development process must be cost and time effective. Specialised hardware and software aquisition can prove to be time and resource expensive requiring careful control from the outset to control these costs.

FIG 3 RIG - A/C COMPARATIVE DEVELOPMENT TRAILS COSTS



ii) Testing of flight standard equipment must be non-invasive to preserve confidence that the system under test truly reflects the system in flight (That is, it should not alter the structure or operation of the system under test). Validation of software, for example, is not acceptably achieved by host based testing or the use of monitors and in circuit emulators in target. This data monitoring must be via designed in access modes which are present functionally throughout the product life cycle.

iii) Test facilities used on integrated systems must anticipate multi-role and evolutionary stages of product development and must therefore be designed for flexibility with careful consideration of its configuration control aspects.

3.0 STRATEGY

It is clear that in order to prove and certificate a real time embedded computer system, that system must reside within the representative environment for which it is destined to operate. Further- more that environment must be representative in both state and rate, that is dynamic and co-ordinated. It must also be colatable with the response of the system under test.

Multiple co-ordinated data sources encountered in avionic systems exacerbate this problem.

3.1 External 'Real' Environment Generation

Stimulus of a total system may be achieved by generating environmental information at sub-system sensor level (RF, Analogue, physical parameters - attitude, motion, temperature and so forth).

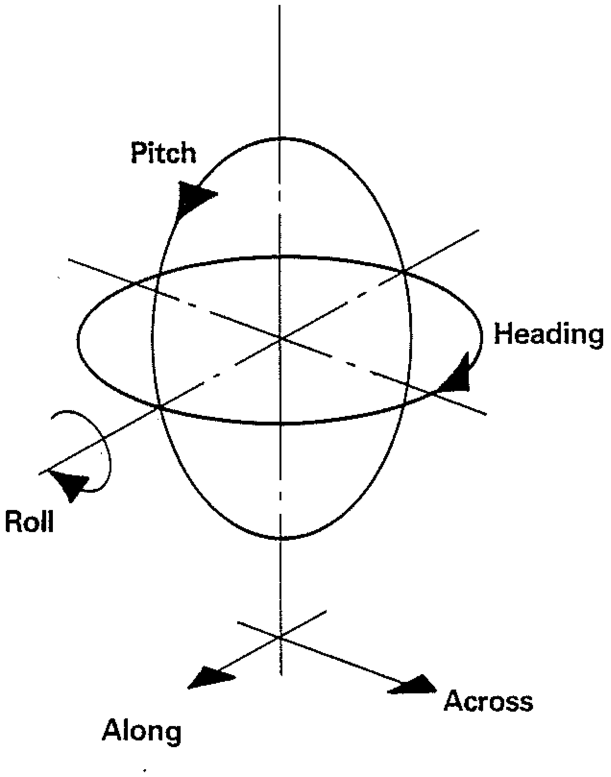
3.1.1 This direct approach is most realistically and readily accomplished by flight testing an installed system. However, there are a number of disadvantages:

- Flight programs are inherently expensive, exhibit poor ratios of trial/elapsed time and are dependent on many other factors irrelevant to the avionics task

- Iterative development is not easily supported

- The need to operate the system in a flying environment demands full sub-system functionality before demonstration of the embedded core, thus increasing development technical risks during later phases.

- Full exploration of system performance, particularly during failure and reversion may entail risk to airframe and crew.



5 Parameters
3 States

[I] Assuming Partitioning into
2 Groups (2 + 3)
= $3^2 + 3^3 = 36$ Discreet Conditions
@ 1 min/Condition → 36 min Program

[II] Assuming No Partitioning
$3^5 = 243$ Discreet Conditions
@ 1 min/Condition → 4 Hour Program

FIG 4 COMBINATIONAL TESTING PROGRAMME TIME EFFECTS

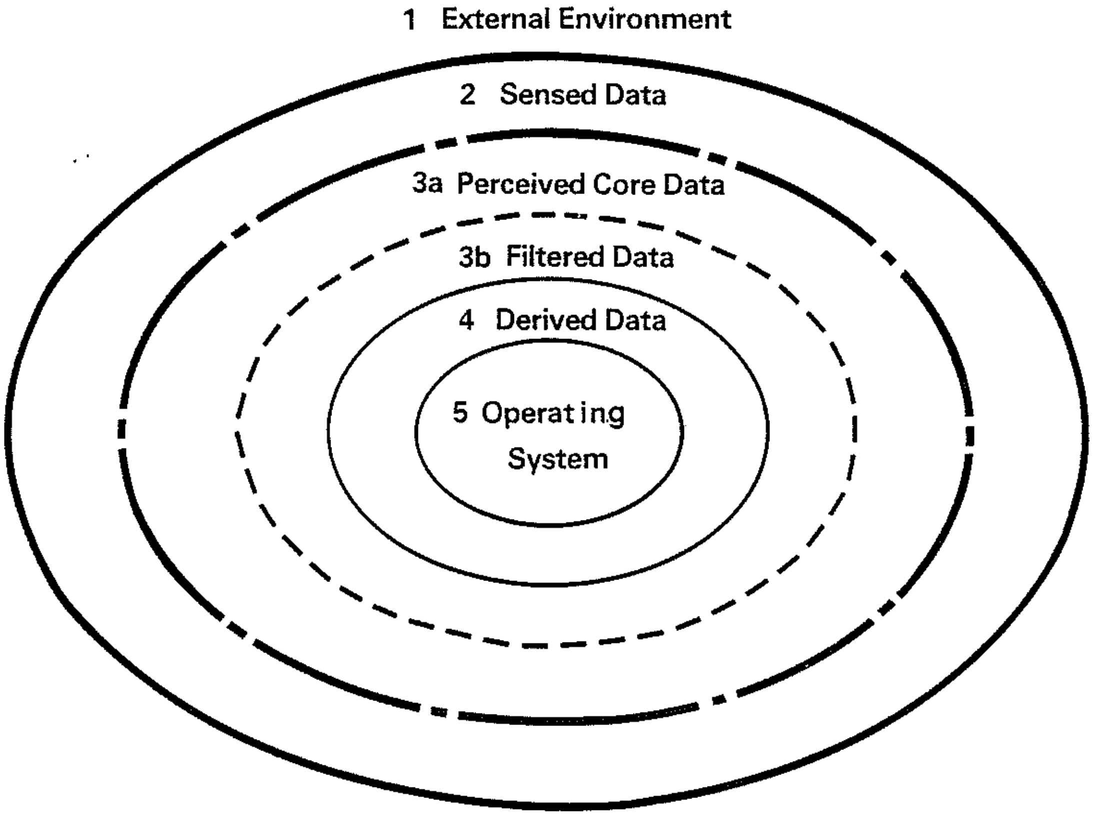


FIG 5 LAMINAR DATA MODEL

- Visibility of system performance particularly in real time is not easily accomplished.

3.1.2 The very nature of integrated systems implies a high level of interconnected systems and the effects of partitioning induce long program times when demonstrating partitional functions.

A simple example is shown which quantifies the effects of combinational handling of attitude information with velocities.

3.1.3 Techniques currently being considered for software assurance and system reliability require the aquisition of data over many operating hours and several program phases to generate useful maturity profiles and validate predictive modelling techniques. This data must be identified against specific events, time and configuration.

In response to these difficulties a cheaper more effective method of excersising the system is being adopted which also reduces the technical achievement risk loading from the later product devolopment phases.

3.2 The Radio Technical Commission for Aeronautics document (ref 1) considers software related certification guidance and proposes basic techniques for verification and validation of digital systems which are finding wide acceptance.

Westland Helicopters have adopted the general principles embodied in this document. However, a fuller consideration of the implications of the simulation testing approach on system performance and activity monitoring with flight standard equipment is required.

3.2.1 A review of the system structure in terms of the data residing in it shows the levels of data extraction and simulation which are available within the system itself.

An integrated avionics system may be represented by a simple laminar model consisting of six concentric levels of system operating data. Data from these levels are used for system characterisation and performance assessment.

1. <u>External Environment</u> - System interactions with the real world environment external to the aircraft (radio beacons, attitudes, velocity, air data, etcetera).

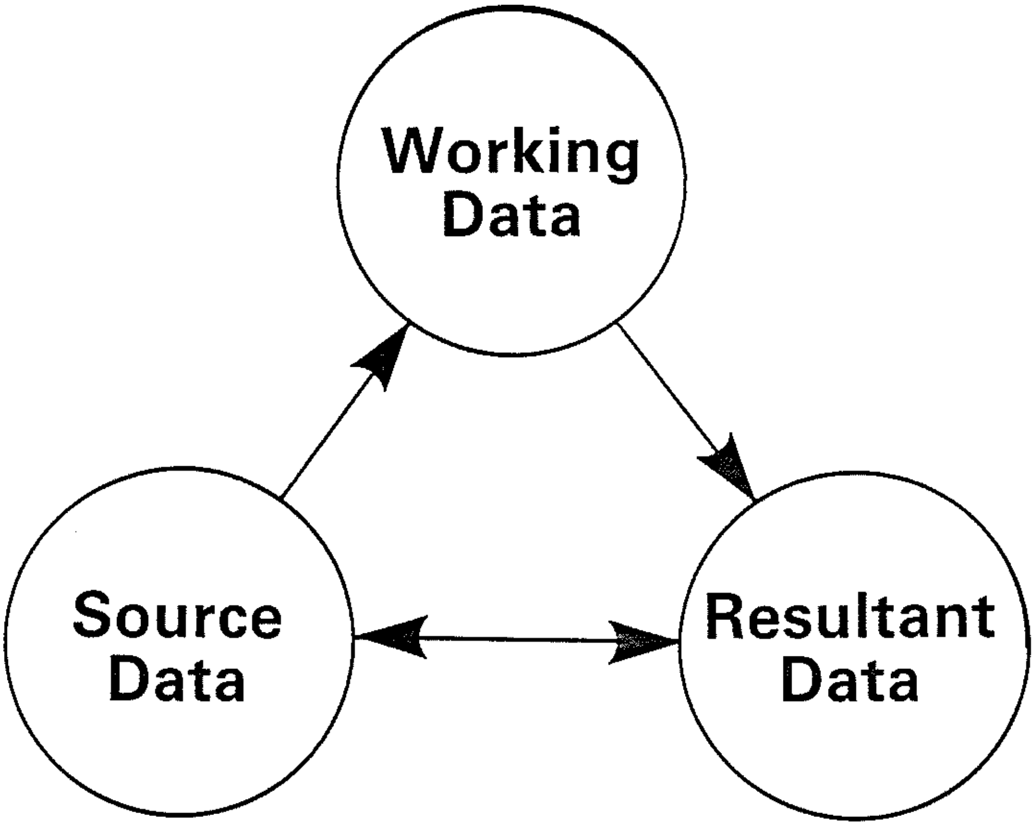


FIG 6 PRINCIPAL TEST SYSTEM DATA CATEGORIES

2. <u>Sensed Data</u> - Information, sensed/conditioned by individual sub-systems and interfaced for exchange with the core systems.

3a) <u>Perceived Data</u> - Information present at the core system H/W - S/W interface boundaries. This information is relationally equivalent to the sensed data, but may be modified by format transformation, skew, jitter, sample rates, aliasing etcetera.

3b) <u>Filtered data</u> - Digitally filtered "derived" or "perceived" data which may be interpreted as a refinement applied as a pre or post processing phase.

4. <u>Derived Data</u> - Functional computation and handling of process information derived from sub-systems, operator inputs or pre-programmed knowledge. A Major part of its data is usually presented as information to the operator, sub- systems and stores control.

5. <u>Operating System</u> - Whilst not generally operating on sensor or user derived information, the core system and its effective operational topology is controlled by an operating system enabling system bus control, reversion modes, BIT and housekeeping.

3.3 Westland Helicopters present generation avionic system architecture sustains physical partitioning of the major sensor groups down to the system data interface at level 2/3.

This aspect of the architecture permits individual sub-system development programmes on a parallel rather than serial program logic with reduced cost and technology risk.

Independence from sub-systems and sensors allows a quasi - environment generation with excitation of the minimum core system with its co-ordinated data set as the essential stimulation requirement of the integration core of the avionic system.

3.4 Data Monitoring Categories

3.4.1 In order to rationalise the process data has been divided into three principle categories giving reference, results and visability.

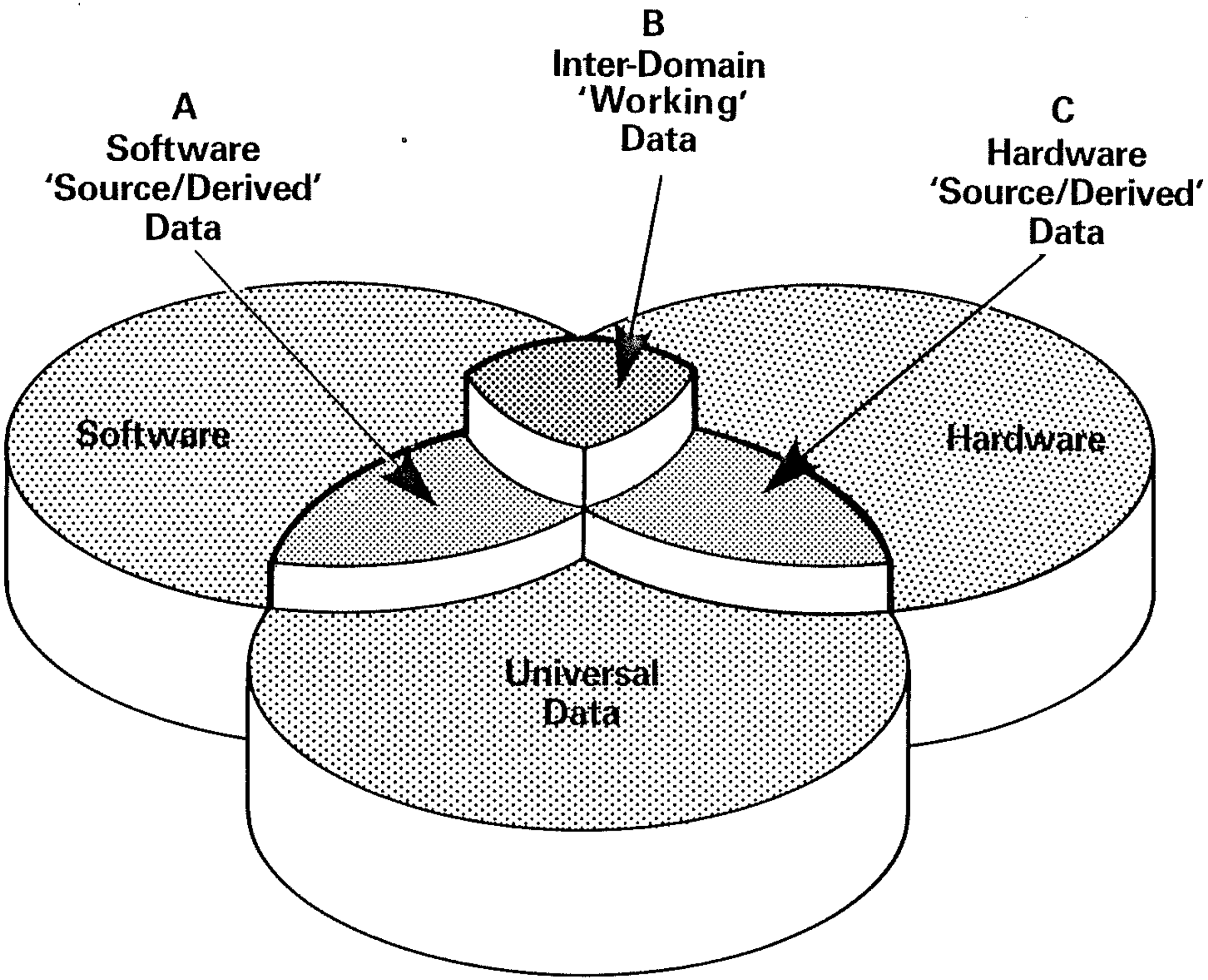


FIG 7 DATA LOCATION DOMAINS

- Data "resultant" upon system computations and responses comprising of numeric data as displayed to operators and sub-system response data originating from level 5.

- Recognition of the intrinsic modifying characteristics of the system transfer mediums, interfaces and filtering computations requires that a third "working" data set be gathered generally from levels 3 and 4 of the model. This permits clearer analysis of systems operation by isolating the effective working data set from the embedded processors.

3.4.2 Further consideration of the avionics system as three simple domains shown in figure 7 serves to identify the three data category locations.

- Area A containing the software source/resultant data
- Area C containing the hardware source/resultant data
- Area B containing the intermediate "working" data

Data residing in domains A B and C should be directly related by the hardware and software functions designed into the avionic system and thus their interdependance entirely predictable by design assurance tools.

Configuration of the system bus transactions to present selected data from these areas permits good system operational visibility and automated information transfer without significant system architecture penalty or intrusive test processes.

The validation and verification of the design and the assurance tools used is an important aspect of simulation testing which is not as yet well supported by data. The detailed data from these testing processes will provide this support.

4.0 TEST FACILITY OPERATION

The test facility has two principle modes of operation;

1) As an Automated Test Set
2) As a dynamic simulated flight avionic data environment scenario operator

The simulation system structure permits excitation of the system under test by open or closed loop control, closing the loop by use of system generated flight director information directly linked or via operator interpretation. Open loop operation is by stored flight profile control.

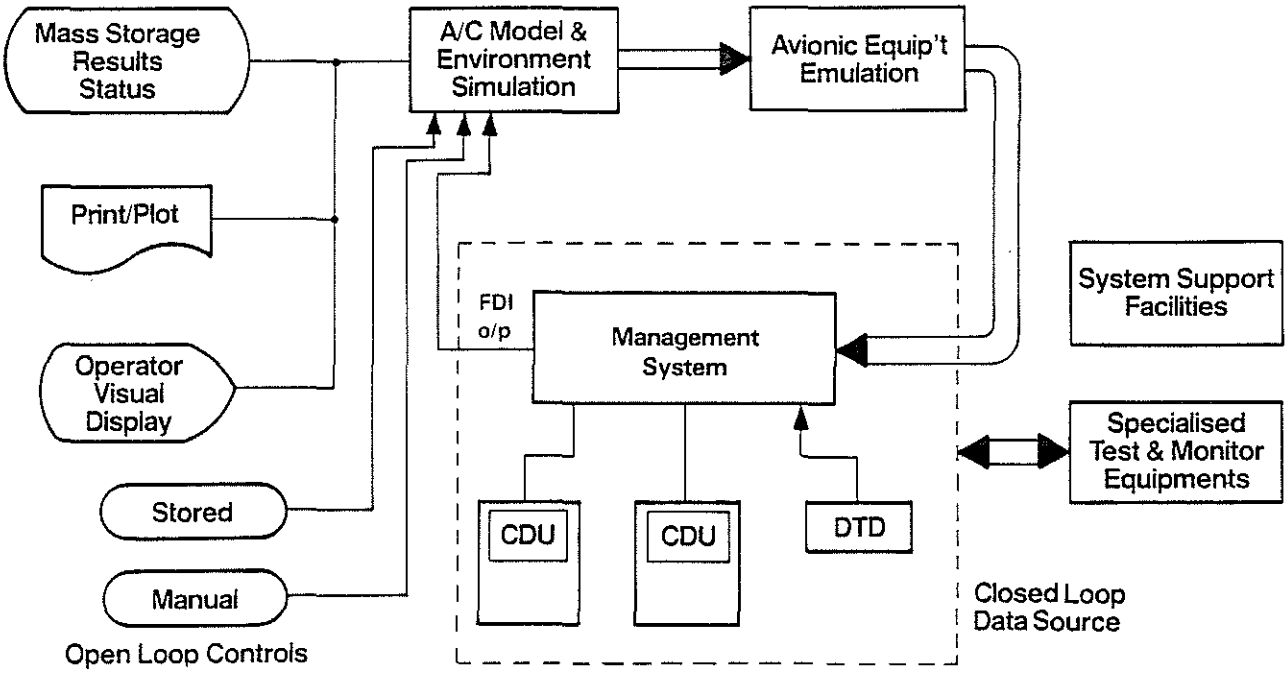


FIG 8 STIMULATION CONTROL

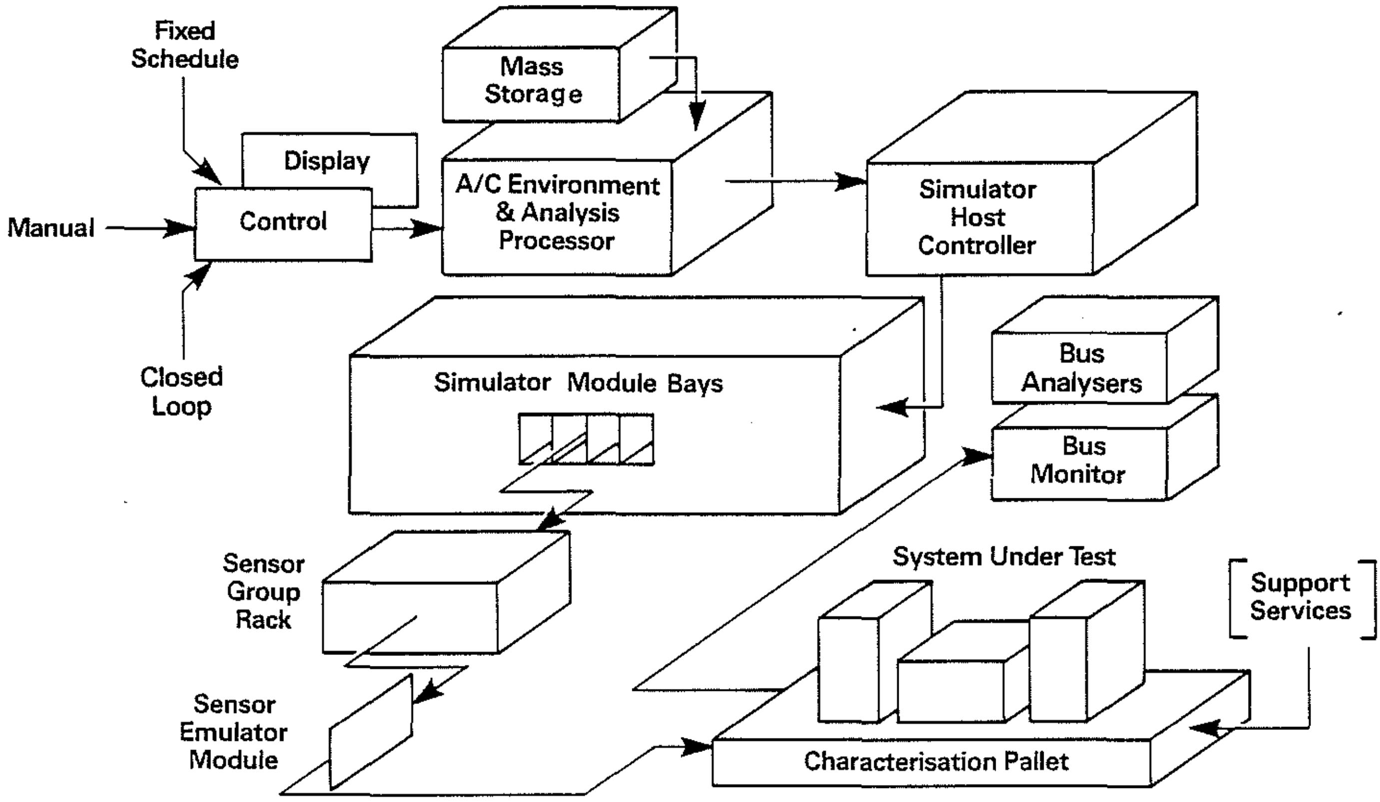


FIG 9 TEST SYSTEM ARCHITECTURE

Essential operation is as follows:-

An aircraft model may be flown within a limited environment both contained in software models. The models are simplistic representations of generalised helicopter and sensor related environment parameters including beacons, ground height, air temperature and pressure (profiled against height) wind direction and speed.

The scenarios thus generated are integrated and used to control a number of avionic sensor equipment emulators representing the avionics fit as seen by the particular system under test. These emulators are used to drive the hardware interfaces of the core system in real time mode.

Control of the scenario is by three methods, each of them permitting independent entering of the environment parameters.

1) Direct manual control of the aircraft model via a joystick control with trim options. This may be from the flight directors where available or independently controlled.

2) Prestored flight plans may be used to drive the aircraft model which take no account of the effect on the scenario or the avionic system outputs and are open loop tests.

3) Automatic closed loop controlled by feedback of flight director bar information into the aircraft model.

During the course of all test runs data logging, real time analysis and error exceedance will be carried out continuously and automatically with operator options to display, on VDU, selected pages of information including test progress diagrams and status tables.

The test rig may be configured without scenario generation in a controlled static emulation mode, which more closely approximates to the conventional Automated Test Equipment (ATE) role, allowing individual or grouped sensor interface testing and excitation. Control of the tests in this role is achieved by use of a proprietary high level test language.

5.0 ARCHITECTURE

The system under test is directly stimulated and where possible maintained by modular emulators at the sensor interfaces. Dynamic parameters are calculated at fixed intervals "Stimulation Update Steps" (SUS) by the scenario generators and transfered via the test system bus to the host processor controlling the emulators. This parameter information is scaled, processed and distributed to the emulators via the bus at the same update rate.

A data interpolation between these SUS is carried out within these emulators and ten steps are inserted between each SUS permitting smooth excitation. Also incorporated are smoothing algorithams, predetermined waveform superimposition and calibration functions. The SUS rates are programmable.

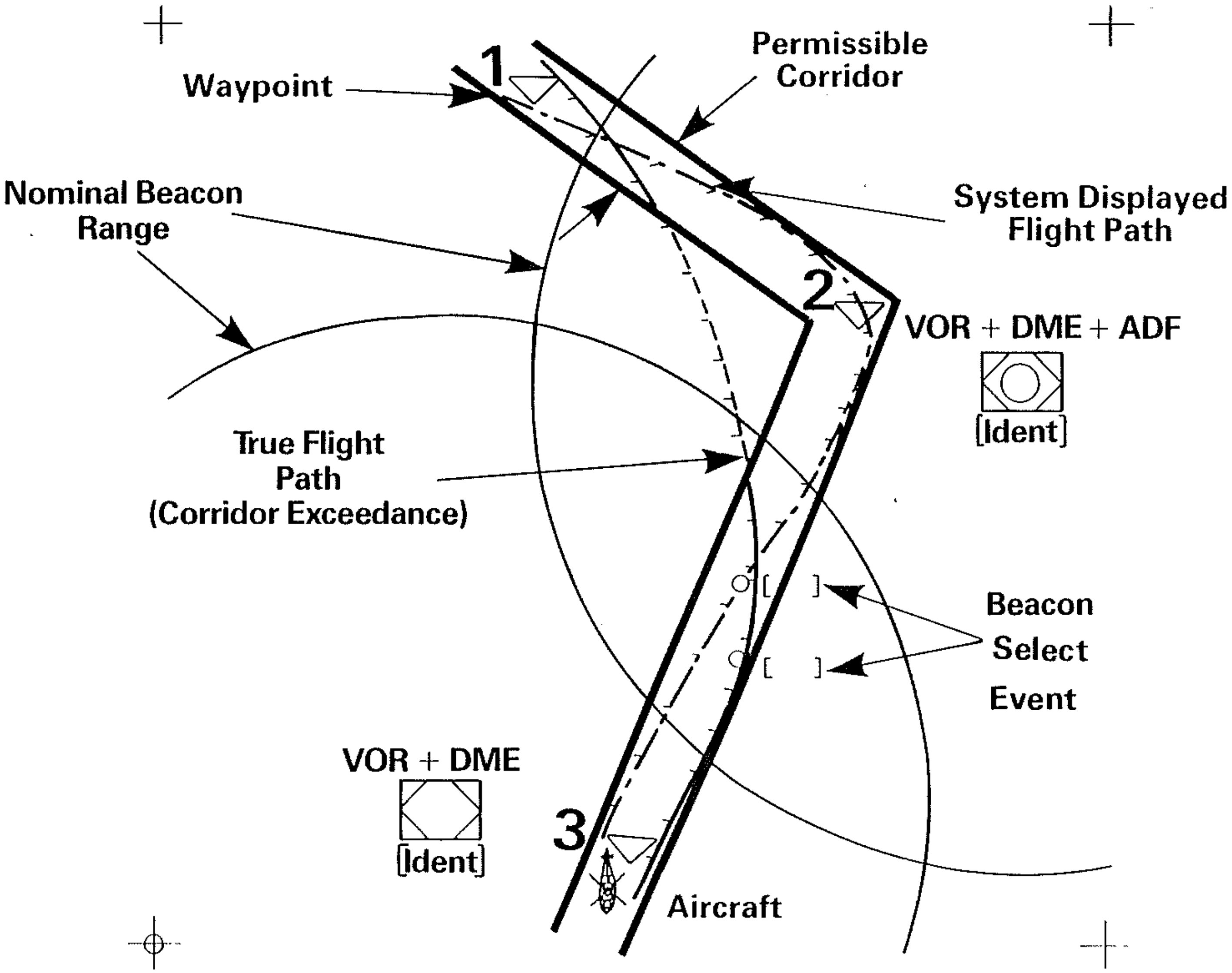


FIG 10 FLIGHT SCENARIO PLOT

The system under test is housed in a support pallet characterising the facility to the avionics system and providing power, access and special controls.

Embedded system data is transmitted in blocks via a monitor part on the avionics system bus (MIL STD 1553B/DEF STD 0018) regardless of system modes and display pages selected. Monitored data is taken via a special purpose interface designed to give Direct Memory Access (DMA) to the analysis/logging processor.

Avionics system bus operation monitoring is carried out on a specialist intelligent serial bus analyser backed up by waveform monitoring on an intelligent waveform analyser both of which have local storage, and can be accessed by the test system bus.

Data logging takes place on a fixed 16M Bytes Winchester disc with 2 hour continuous capability supported by tape cartridge back up.

6.0 DATA PRESENTATION

The achievement of readily assimilated test data presentation is regarded as a prime necessity as is its support by the philosophy of raw source data storage. Operator attention is always drawn to exceedances or unexpected information.

A number of display media are used to provide real time in run information and post run hard copy. All real time displays use the system VDU which presents a series of pages of graphical and textual information.

In run presentation rests principly on the model state page containing the scenario and aircraft position on a map style display. Overlays may be included detailing the three position plots of planned, perceived and true flight paths, where there is variance. Error status display pages are selectable providing linear strip indicators of stimulus - response divergence complemented by absolute value monitors.

Additionally a continuously available statistical presentation of the MIL STD 1533B system bus operation is available containing information on error rates, terminal activity modes and other specialised programmable functions.

A post run analysis is intended to enable the generator to investigate more fully the operation of a previously generated test run. It effectively provides a 'zoom' and replay function on the end of run synopsis data for any selected run.

This function uses the same data set and no special logging is required.

The operator can define a time period in the test run and command a full page plot of the flight profile with selectable parameter and scenario data for that period.

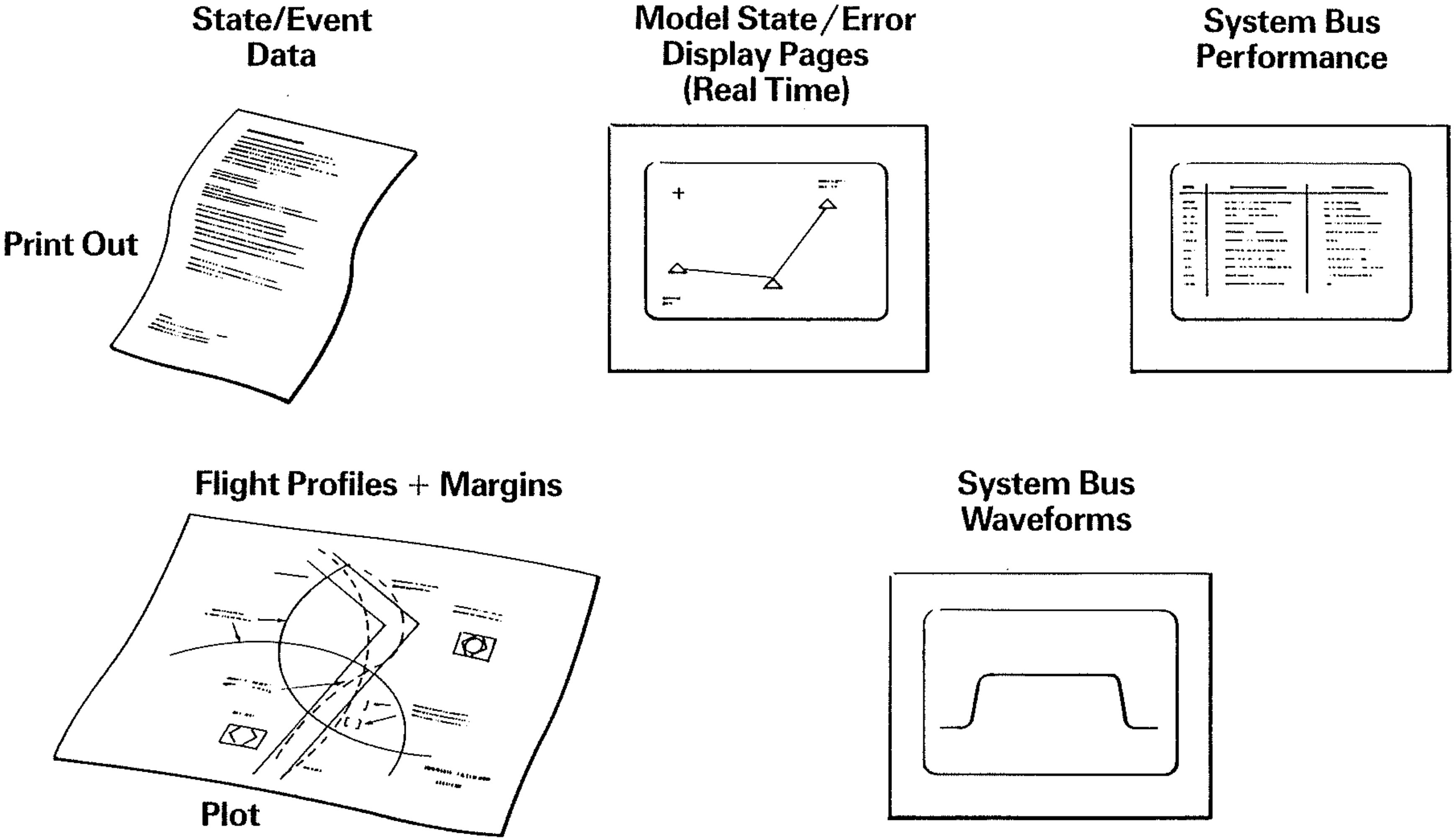


FIG 11 DATA PRESENTATION MODELS

Post run presentation includes the system VDU, with a full colour graphical plotter and printer for hard copy documentation. To preserve control and clarity a display decluttering system is available under operator direction.

7.0 PERFORMANCE ASSESSMENT CRITERIA

The criteria against which performance is to be assessed depends upon the nature of the parameters involved.

Certain parameters particularly linearly related may be represented in absolute value, by the test facility in one of three ways:

a) Desired value (flight plan)
b) Measured (perceived by system)
c) True (actual value)

Linearly related data typically consists of navigation information, such as true position, heading, wind vector and velocities. These may well be supplemented by the other data in VOR/DME and ADF information which is generally asynchronous sequential event data.

Predetermined data values, such as expected position, have error margins assigned to them and actual data generated by the avionic system is continually compared with these error margin. In the event of exceedance the operator is alerted and options provided to examine and overide the alert. Safety measures are built in to prevent unwitting suppression of alerts.

A scenario overlay for navigational testing is provided for corridor limit assessment and a moving error boundary may be generated for absolute position monitoring. Corridor limits may be generated based on the FAA advisory circulars 40-45A and 95-1, defining position fixing accuracy and corridor widths for airways navigation.

The three parameter measurements are displayed with limits on a model state page.

Event related parameters are continually monitored for change and upon identification of state change the time tagged event is stored. Two tables are thus generated one containing operator determined action and the other containing identified state changes from the system under test. Illegal or incorrect data is then readiliy deduced by table comparison.

All operator actions are logged by event and time and fully correlate across the parameter log.

8.0 CONCLUSIONS

The use of recent advances in electronics and computational power density has enabled the provision of a compact system which allows the system integrator to 'fly' the avionics system on the ground on a cost effective basis. The power of this approach is comparable to the use of cockpit simulators for pilot training.

It is essential that manufacturers recognise and reflect in design the need for access to the working and display data sets within the system for effective validation, monitoring and excitation.

Good automated techiques are essential for quantified assessment of function and performance particularly for software within flight standard equipment.

As yet there are no generally agreed detailed standards, specifications and guidlines for system design, development and performance validation specific to the generation of avionic systems. It is vital that the techniques being proposed continue to be supported and augmented in the establishment of quantitative validation procedures.

Future developments will tend to increase complexity and expand the boundaries of airframe integration making the use of combined cockpit airframe and avionics simulators a neccessity. Therefore these techniques must be universally adopted by airframe and avionics manufactures and avionics integrators if they are to remain in a competitive position whilst providing high integrity, viable avionics installations.

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