INTRODUCTION

As computing system prices go down due to technological advances in hardware, more emphasis is being placed on the overall cost of ownership. To meet this challenge, serviceability features are designed into the HP 300—intertwined throughout the system hardware and software.

THE HP 300

The HP 300 is a broad-capability system for dedicated business data processing applications. It includes general-purpose features found on much larger systems, yet it is designed for direct use in daily business activity.

A typical HP 300 configuration consists of the System Unit (Figure 1), a printer and several application terminals.

The System Unit

The central element in every HP 300 system is the HP 300 Mainframe, or "System Unit." The System Unit combines the HP 300's processing, storage and control functions into a single compact package:

Integrated Display System—A keyboard and display screen form the Integrated Display System, or IDS. The display can be broken into multiple windows, each of which is directly attached to a data file. Eight "softkeys" bordering the right side of the IDS screen provide a push-button choice capability.

Processor—The HP 300 is based on a Silicon-on-Sapphire (CMOS/SOS) LSI processor. The processor has a stack architecture and provides hardware support for virtual memory operation.

Main storage—A standard HP 300 system includes 256 KBytes of semiconductor memory expandable to 1024 KBytes in 128 KByte increments.

Flexible disc drive—The HP 300 System Unit includes a flexible disc drive for offline storage and data exchange with other HP 300 systems.

Online disc storage—A fixed disc provides 12 million bytes of storage for system and user programs and data. It is also used as secondary storage for virtual memory operation. In larger configurations, the fixed disc can be replaced by a stand-alone disc drive.

The 25-slot cabinet in the System Unit contains not only the CPU, memory and I/O boards but also circuit boards for the console (IDS), flexible disc and 12 MByte integrated system disc. Except for the circuitry which must be near either the display tube, the disc mechanisms, or the power supply, every mainframe PC board is in the System Unit card cage—with all configuration switches accessible on the board edges. This simplifies diagnosis by making it very easy to check the mainframe's hardware configuration for human error.

Amigo/300 operating system

The HP 300's operating system, Amigo/300, is an advanced virtual memory operating system, with extensive data management and online processing facilities. In dedicated, terminal-oriented applications, Amigo/300 supports terminal response and interactive processing in addition to concurrent non-interactive jobs.

Some of the key features include:

- Multiprogramming
- Multitasking
- Large addressing space—A potential addressing space of over 260 million bytes for each program.

CLASSES OF SERVICEABILITY FEATURES

Serviceability features exist either to contain faults or to diagnose them.

- Fault containment features correct or detect faults to minimize their effect on the system. The next section covers these features in detail.

The diagnosis features can be split into two sets—Monitoring tools and stimulus-response tools.

- Monitoring tools (fourth Section) allow you to see what
is happening or what has just happened leading up to an error. The tools must disturb the system as little as possible.

- Stimulus-response tools, on the other hand, by their nature perturb the system under test by providing simple, controlled, repeatable stimuli instead of the complex stimuli provided by normal operation. These are covered in the fifth section.

FAULT CONTAINMENT FEATURES

The HP 300 hardware and software have built-in provisions which correct or detect certain faults when they occur. Whether the result of hardware failure or human error, these faults are of the type that cause multiple, obscure (and often delayed) system faults.

Error-correcting memory

The memory subsystem corrects all single-bit memory errors; plus, it detects all double-bit and the vast majority of multi-bit errors. Each memory word consists of 16 data bits plus five Hamming-encoded correction/detection bits and a parity bit.

Privileged mode instructions

Programs may execute in one of two modes—privileged or user. In user mode, a program is confined to its own code and data areas and is prevented from destroying the operating system or directly performing I/O.

Instruction bounds checking

The CMOS/SOS LSI processor performs bounds checking on memory reference instructions, in both user and privileged code, via hardware limit registers. The executing user code segment is kept separate and distinct from the data segments.

Error-detecting disc subsystems

The disc subsystems record cyclic-redundancy error-detecting codes with the data: the controller and driver automatically retry if the data read fails the CRC check.

MONITORING TOOLS

Monitoring tools show what is happening— the current state—or what just happened—a state history. The key to the design of monitoring tools for diagnosis is that they be as non-invasive as possible, i.e., the tool should not affect the circuit under test.

The first group of monitoring tools are intrinsic to the HP 300—they are always present, monitoring the system during normal operation. The last two monitoring tools are extrinsic—they are external instruments connected to the system when a fault is suspected.

Trace-LEDs—HP-manufactured light-emitting diode arrays (with integrated current-limiting resistors) are built into most boards. All of these LEDs are observable by opening the rear door. They provide non-invasive monitoring of normal activity—to check certain key nodes without tools. The Trace-LEDs are, in effect, a low-cost built-in maintenance panel. For example, one LED is connected to the last stage of the CRT timing chain; its once-per-second blink shows that the chain is working. Another LED is connected to the system power-fail-warning line: this circuit is checked by turning the system on and off while watching the LED.

System Error Log—The error logging facility records errors, both user-transparent and fatal, as time-stamped entries in a disc file. The number of I/O requests and errors are tallied for each device, then regularly recorded on the disc. Fault trends may be detected by analyzing this data.

System Trace Table—The operating system keeps a list of the most recent events in a circular table in memory. The data can be dumped via the System Debug facility.

Console Log—A list of the most recent console commands is kept in a disc file so that one can check the sequence of commands which led up to some event.
System Debug—Running under the operating system, System Debug provides to Specialist CEs interactive control, examination and modification of both code and data.

There are two key external tools which Customer Engineers use in monitoring—the Processor Maintenance Panel and state analysis instrumentation.

Processor Maintenance Panel—The Processor Maintenance Panel (PMP) is used by Specialist CEs for detailed tracing of HP 300 microcode and macrocode. The PMP consists of a printed circuit board which plugs into a reserved slot in the system card cage and an HP 9825 Calculator which provides a user interface independent of the system under test. The PMP provides non-invasive breakpoints plus micro-level and macro-level manipulation of the system hardware.

State Analysis Instruments—HP 300 Customer Engineers are trained in the use of the HP 1602A Logic State Analyzer and the HP 1640A Serial Data Analyzer—both standard portable instruments—to trace I/O transactions on the system busses and data communication ports.

STIMULUS-RESPONSE TOOLS

The key to the design of stimulus-response diagnosis tools is that they not only identify that a problem exists but also isolate it to a replaceable module. To do this, tools must:

- Depend as little as possible on portions of the system other than the portion under test.
- Build outward from a small kernel, layer by layer, using already-tested circuit blocks to test additional circuitry.

Figure 2 gives a block diagram of the system hardware. This diagram is then annotated to show the outward progression of the stimulus-response tools. The layer-by-layer sequence of tests starts at the processor, directly attacking the diagnostics-won’t-load problem.

CPU Self-Test

The CPU Self-Test is a ROM-resident microdiagnostic which is invoked on power-on or by depressing a switch on the edge of the CPU Bus Interface board. Its purpose is to check the hardware required to cold-load the system. CPU Self-Test results are displayed on two five-LED arrays next to the CPU TEST switch. The test may be set up to loop continuously, either halting on the first failure or continuing regardless of failure.

The CPU Self-Test first performs a thorough test of the processor, including checksum tests on each of the microcode ROMs. It then tests the Inter-Module Bus handshake lines, checks communication with the Memory Controller
and tests the lowest memory module for stuck bits. The General I/O Channel (GIC) is tested—first proving that the CPU can communicate with the GIC, then looping data completely through the board to the output of the LSI device-bus interface chip and back to the memory via DMA.

The device to test is selected by the Control Panel switch used to select the load/dump device. The CPU Self-Test sends a data pattern through the channel to the device controller’s memory, commands the device to return the data, and then checks for correctness.

When the Control Panel is set up for a cold-load, the CPU Self-Test checks and diagnoses the entire data path from disc to CPU. By changing the Control Panel switches, the loopback process is also used to check out the links to the Interactive Display System, printers and other peripherals. See Figure 3.

**Fixed Disc Self-Test**

The built-in 12 MByte fixed disc has its own independent Self-Test. Actuated by a switch on the disc Controller board, it loops and displays errors in the same manner as the CPU Self-Test.

Key steps include a processor test, ROM checksums, device-bus interface chip loopback, actuator arm motion tests and extensive writing/reading on a reserved track.

**Interactive Display System Self-Test**

An independent self-test is also provided in the Interactive Display System (IDS). It checks for ROM checksums, device-bus interface chip loopback, keyboard scanning and stuck keys, character ROMs in wrong sockets, horizontal oscillator, and correct dot emission to the sweep circuitry. The operator checks the displayed fonts on the display screen.

**Flexible Disc Unit Self-Test**

A similar Self-Test is provided for the flexible disc unit (FDU). If a flexible disc is present, reading will be tested; if an additional switch is depressed at the start of FDU Self-Test, write/read testing is performed.

At this point in the stimulus-response test sequence, the kernel of the system has been tested by microcode (Figure 4). One can now load and run macrocode test programs.

**Diagnostic/Utility System**

A memory-based operating system, the Diagnostic/Utility System (DUS), provides file management of test and utility programs on a flexible disc. DUS provides a simple and deterministic base for software testing of the hardware.

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**Figure 3—CPU Self-Test data paths.**

From the collection of the Computer History Museum (www.computerhistory.org)
DUS is easily used by a CE or trained user to check system hardware. There is a HELP capability which lists the directory and commands; a program is invoked by simply typing its name.

**Processor test program**

This program checks certain software-related CPU functions not tested in the CPU Self-Test.

**I/O map program**

The IOMAP program uses hardware self-identification features to display the type and address of each channel and device in the system. Any number of Identify, Loopback, or Self-Test commands may be sent to any device—for example, a printer’s self-test can be invoked to check out both the I/O path and the device.

**Device diagnostic and test programs**

There is a diagnostic or test program for each device. These are easily used by a CE or trained user—each has step-by-step prompt messages and a default mode which consists of a fast, non-destructive subset of the overall test sequence. If the user suspects a disc problem, for example, the default mode of the disc diagnostic program runs a subset of the test menu which will give a good confidence check of the disc drive without damage to the user’s data base.

Users with more time and knowledge can run these tools at the CE level—this is particularly valuable to OEMs and software houses incorporating the HP 300 into their own products.

**SUMMARY**

The HP 300 has been described in an overview. The product’s serviceability features are broken into three groups—fault containment features, monitoring tools and stimulus-response tools. Each specific feature has been described in detail sufficient to show its role in reaching the overall goal—low cost of ownership for a small commercial system.

**ACKNOWLEDGMENT**

Like quality, serviceability cannot be added to a product by an outside group. The design of serviceability into the HP 300 was intertwined with the system design process—thus, the features described are the result of contributions by every member of the project.