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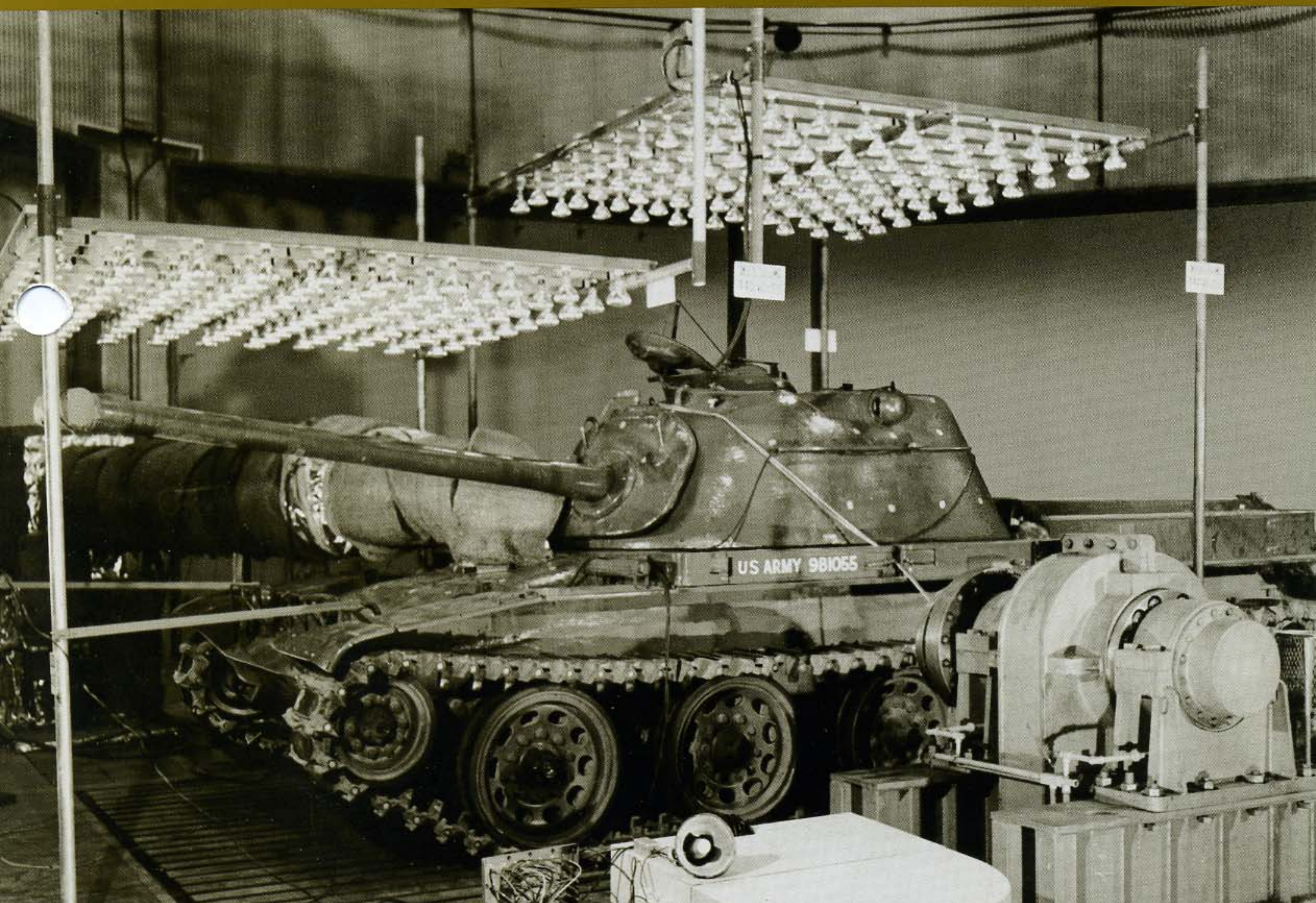
APPLICATIONS OF COMPUTERIZED DIGITAL DATA ACQUISITION SYSTEMS

Minicomputer systems aid military vehicle testing

A Solution to a Measurement Problem for: U.S. ARMY TANK-AUTOMOTIVE COMMAND
Warren, Michigan



Typical of the broad scope of specialized testing capabilities at the U.S. Army Tank-Automotive Command in Warren, Michigan is this environmental test chamber. Here, cooling system tests are being conducted under simulated field conditions.
(U.S. Army photograph)

Minicomputer systems aid military vehicle testing

Ranking high among the factors which greatly influence techniques and tactics of warfare are the mobility and mobile firepower available at all levels of command. Large-scale use of land vehicles by the military is taken for granted, that is, vehicles are "expected" to be on hand when needed and "expected" to perform as required. But where do these vehicles come from, and who is responsible for producing vehicles to successfully meet the wide variety of stringent military requirements?

The answers can be found at the U.S. Army Tank-Automotive Command (TACOM) in Warren, Michigan. TACOM is entrusted with the immense task of providing management control and major support responsibilities for the tracked and wheeled vehicle fleet assigned to all branches of the U.S. Armed Forces. Its mission includes design, development, procurement, maintenance and operational doctrine development, and repair parts supply; similar services are provided for our foreign allies. TACOM (a separate agency, reporting directly to the U.S. Army Materiel Command) carries out its mission on a 340-acre site, officially designated as the Detroit Arsenal, where it has earned international recognition as the military tank-automotive capital of the world. The team of civilian and military personnel makes up what is perhaps the largest staff of military automotive development and production experts in the free world.

Essential elements contributing to TACOM's well-deserved reputation are the results of efforts devoted to research and development, with emphasis placed on utilizing the latest advances in science and technology to solve problems and fulfill the needs. Engineering R&D efforts are the responsibility of the Mobility Systems Laboratory of TACOM, made up of three major "hardware" laboratories. They are: (1) Vehicular Components and Materials Laboratory which is concerned with materials used in vehicles, with emphasis on rigid testing to assure compliance with exacting military specifications, (2) Propulsion Systems Laboratory which is responsible for exploratory research, development, and production of engines, transmissions, and cooling and exhaust systems as well as development and evaluation of diagnostic equipment, and (3) Surface Mobility Laboratory which deals with frame, suspension, track, and terrain locomotion problems.

While all divisions are engaged in R&D activities, the very nature of the work also requires varying degrees of measurement and testing to properly evaluate specific progress. In this respect, the Propulsion Systems Division is unique in both capacity and depth of specialized testing equipment available, particularly in the area of automated digital data acquisition systems. The lab has been conducting automotive tests for many years, using increasingly more sophisticated measuring instrumentation as it became available and as demanded by advances in automotive design.

COMPREHENSIVE TESTING CAPABILITIES

Present facilities of the Propulsion Systems Division include ten large well-equipped and instrumented test cells, each with its own control room. Six of the cells are mainly used for testing engines, two are for testing transmissions or engine/transmission packages, and one is for emission studies. Another cell, the Climatic Test Chamber, subjects complete vehicles to wind conditions varying in both direction and velocity, along with temperatures ranging to 160°F. The facilities are used for research and development (not production) testing, inspection testing, and tests for Government contractors who do not have the specialized equipment required to test to military specifications. Every type of military vehicle is tested, ranging from the small "mule" to five-ton trucks to tanks.

Traditionally, automotive tests have been conducted by manually reading analog meters and manually recording the readings for subsequent use by design engineers. While this was the best available method for acquiring data, it was slow, tedious, and subject to errors from human interpretation of actual meter readings.

The advent of digital automated systems eliminated the source of errors associated with numeric interpretation. These systems accept analog inputs from the various test sensors and print out the results in numerical form, *greatly enhancing the speed of data acquisition and improving the overall accuracy*. Other refinements, such as typewritten readout directly in engineering units, further added to the speed and accuracy of the data acquisition process. Presently, six Hewlett-Packard systems of this type are in use throughout the Propulsion Systems Division. Test results are printed out in typewritten form in engineering units (utilizing a data linearizer for the conversion). These are stand-alone systems, normally used without a computer, but can be interfaced to HP computers with standard plug-in cards. For example, in the area of the lab where testing is being done under computer simulated terrain conditions, a system acquires data, and inputs in real-time to a computer which, in turn, controls simulation test parameters (as described later).

A few years ago general purpose, stored-program digital computers became economically feasible for data acquisition. They provide all the capabilities of non-computer systems while at the same time offer a number of improvements. In the Propulsion Systems Division, an HP computer system operates in real-time mode acquiring data from tests in progress, manipulating the data as required, and printing out the results in engineering units. The block diagram, Figure 1, shows the hardware configuration for this system.

REAL-TIME DATA ACQUISITION AND CONTROL EXECUTIVE SYSTEM

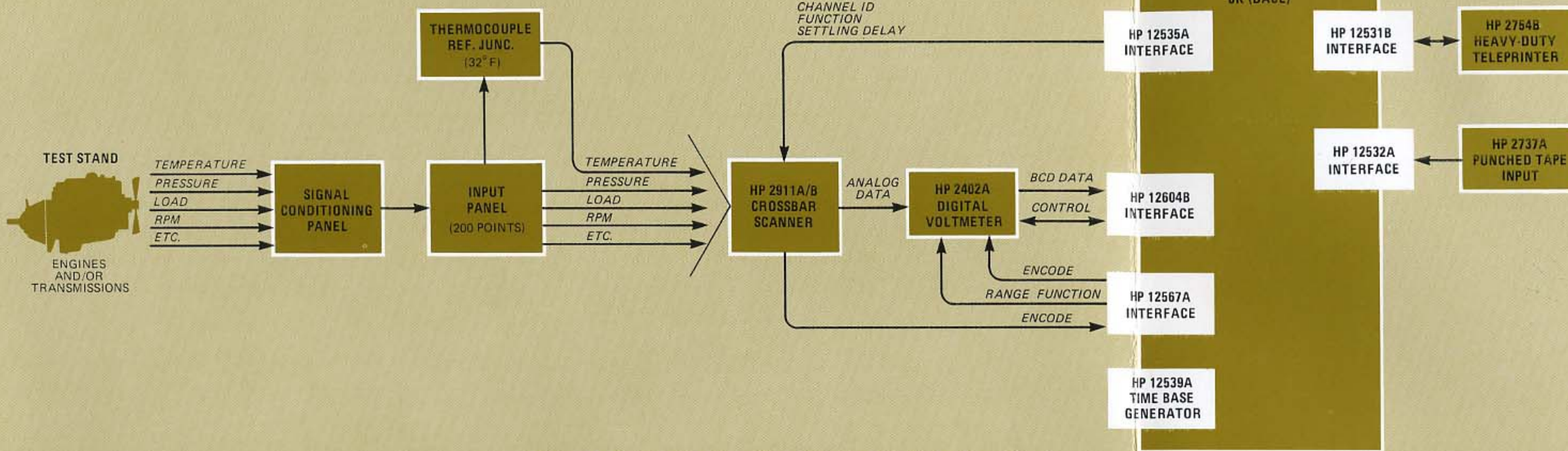


Figure 1. Computer system for real-time acquisition of test data.

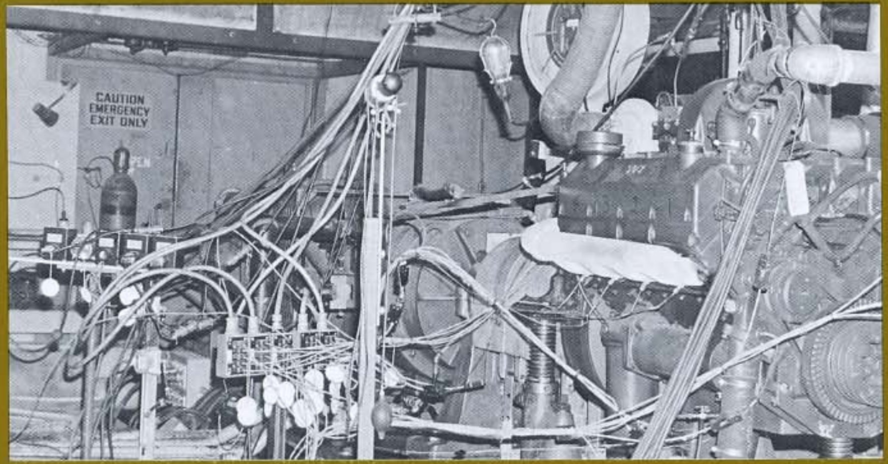


Figure 2. An engine ready for testing. A dynamometer (rear) supplies the load while the multitude of sensor lines carries data to the computer system.

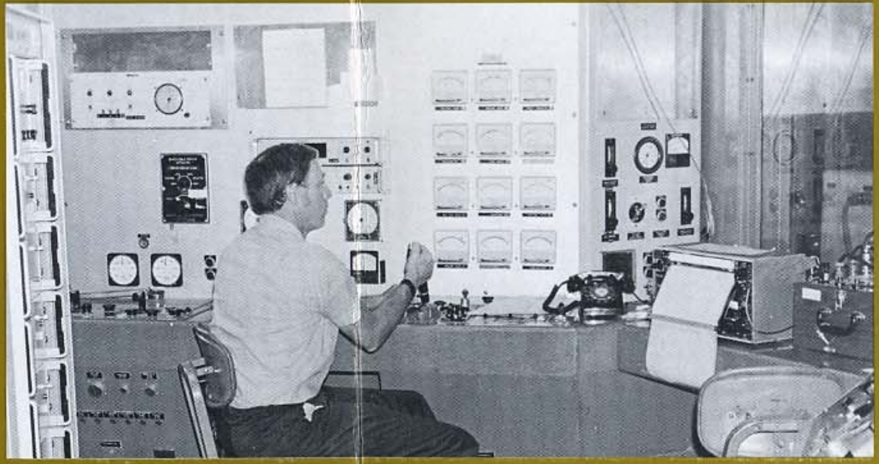


Figure 3. Inside the control room a test technician closely watches an engine under test while adjusting the RPM control. Note the computer system at the left.

MULTIPROGRAMMING REAL-TIME EXECUTIVE SYSTEM

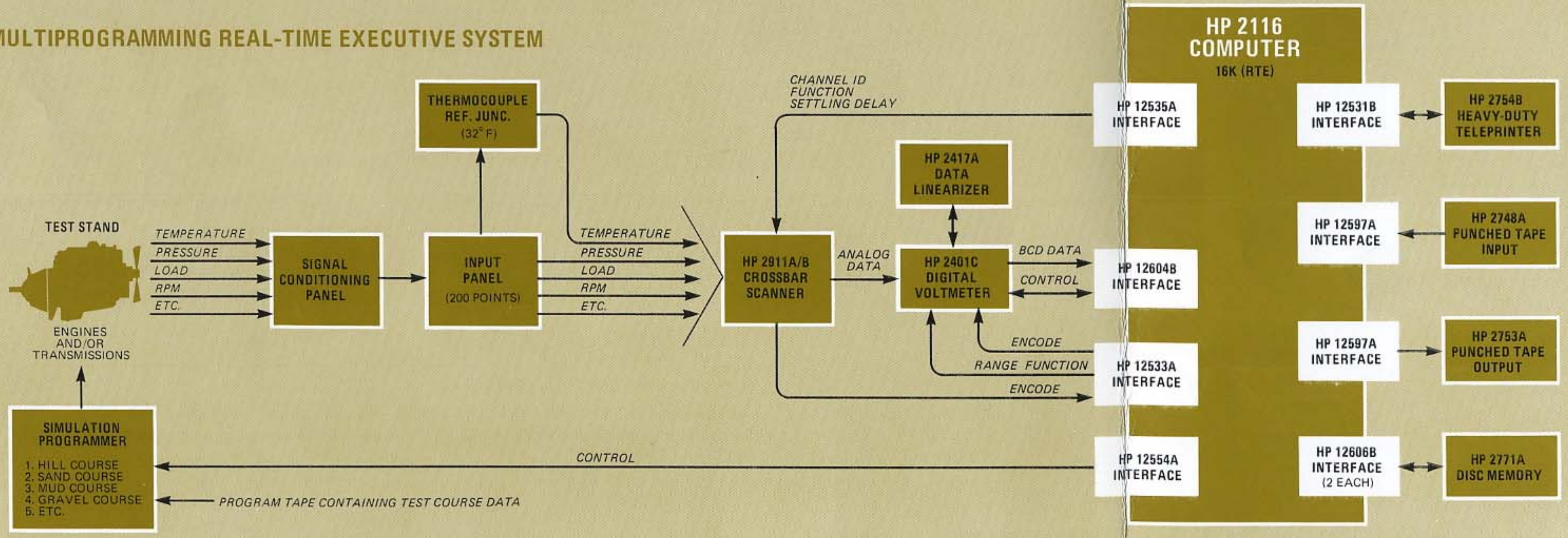


Figure 4. Computer-controlled simulation test system is saving time and money by running "field" tests without leaving the lab.

At the heart of the system is a general-purpose, stored-program digital computer with 8K (16-bit words) memory. The computer is equipped to interface with a wide variety of data logging and display peripherals and data input devices, in addition to those specifically used for propulsion system testing. Analog inputs to the system are through the 200-channel crossbar scanner, and then through the voltmeter where they are digitized for input to the computer. A software clock, referenced to the hardware time base generator, schedules the execution of "tasks" (measurements, calculations, etc.). The teleprinter provides communications between the operator and the computer; it is also the system output terminal, providing a punched tape or typewritten copy of the measurement results. The punched tape input handles program inputs to the computer.

A comprehensive software package, supplied with the system, includes drivers for all the computer interfaces, diagnostic and verification software, an analog scan routine which simplifies data acquisition operations under interrupt control and allows random or sequential scanning of the analog inputs, plus a data acquisition and control executive (DACE) which schedules and coordinates all data acquisition activities in real-time.

RUNNING THE TESTS

Since the Propulsion Systems Division is engaged in research testing, the types of tests conducted differ from engine to engine (transmission to transmission, etc.) and, because of this, no two tests are sufficiently alike to indicate types of "typical" tests conducted. There is, however, a standard 500-hour endurance test which most engines are put through. Another standard test is the 400-hour NATO (North Atlantic Treaty Organization) cycle, which is a planned test procedure agreed upon by NATO forces for comparing engines from friendly countries.

Testing procedures at TACOM begin with the individual test specifications which are formulated by the development engineer. They are then forwarded to the Instrument Maintenance and Support Group whose responsibility it is to provide electronic test instrumentation needed to perform the specified test. In addition, test technicians set up the equipment and verify proper operation, and are available as needed during the running of tests.

Figure 2 is a closeup view of an engine installed in a test cell ready for testing. Its drive shaft is connected directly to an eddy-current dynamometer which places the engine under various loads, as might be encountered in actual use. Note the large number of sensor lines needed to collect measurement data from many points on the engine. Inside the test cell control room, Figure 3, the test technician visually monitors the engine under test while manipulating the engine RPM control. After all sensors are in place on the unit under test, and the measuring instruments checked out for proper operation, the entire data acquisition process then operates under program control in real-time, as scheduled through the DACE software system. Under DACE, the computer automatically executes the measurement tasks in real-time and at specified intervals in the order of priority set up by the test technician, in accordance with the test specifications.

RUNNING THE TESTS (continued):

Since the measurement needs differ from unit to unit, not all tests require the full 200-channel measuring capacity of the computerized system, nor do all require the same type of measurement parameters. There are, however, certain critical parameters which must be measured on every engine, namely, (1) actual RPM of the engine at selected times during the test, (2) the load, in pounds, which is being applied on the engine by the dynamometer, and (3) the amount of fuel consumed, in lb/hr, during the course of the test.

Engine RPM, in the range of 0-7000 RPM, is detected by electromagnetic transducers and input through the signal conditioning panel and the input panel to the crossbar scanner, as a frequency proportional to the engine RPM. The load, in the range of 0-5000 ft-lb, under which the engine is operating, is monitored by load cell and load scale transducers, conditioned as needed and input through the input panel to the crossbar scanner, as a voltage proportional to the actual load. A fuel consumption weigh system measures fuel flow in weight-time (lb/hr) and inputs through the signal conditioner to the measurement system. Temperatures, in the range of -15 to 2500°F, are measured by thermocouples through the signal conditioning panel and input panel and an ice-point reference junction to the crossbar scanner, as a voltage proportional to the temperature. Various parameters are detected by pressure transducers, with pressures ranging to 400 psig and accuracies to ±0.1%.

Individual readings, as measured by the digital voltmeter, are converted to engineering units (°F, RPM, etc.) by a computer program (subroutine) which compares readings against limits to determine which portion of a linearized curve to use for the conversion factor.

Real-time availability of data has proved to be very useful to the engineers, who often need data while tests are in progress, in order to perform some preliminary evaluations. If system parameter constants must be changed, the new information is simply typed in on the teleprinter without the need to modify or recompile the original test program.

SIMULATION TESTING

After satisfactorily completing all lab tests, the component (engine, transmission, etc.) is then installed in a test vehicle for actual field testing. In the field, the vehicle is driven over a series of test courses (hills, sand, mud, gravel, etc.) as a final test of its ability to meet stringent military requirements.

This is an essential part of the comprehensive testing procedures and supplies valuable data which cannot be obtained from present-day instrumentation in the test labs. Field testing, though, is costly. Particularly costly is the outfitting of a test vehicle with test instrumentation and transporting the entire vehicle to the test ground (which may be several thousand miles distant). Other costs are incurred from travel time, expense money, replacement parts, and even bad weather, which can defer a test, during which costs accrue while personnel and equipment remain idle.

To alleviate some of the expenses and at the same time realize a number of technical advantages, TACOM is pioneering in techniques to allow testing to be performed inside the lab under conditions simulating terrain patterns, gear shifting, speed variations, etc. encountered by a fully-instrumented vehicle during actual field tests. *Thus, engines or engine/transmission combinations are run over the same terrain as the original test vehicle without leaving the lab.* The savings in man-hours and lead time (that is, from initial design to final delivery to the military) are proving to be very significant factors. For example, improvements are made in the lab much faster and at less cost than in the field. Also, the number of parameters that can be tested in the field is limited by the instrumentation available. No longer must the test engineer wait for results because they are now available immediately after a test has been run; he requests rerun of tests, or portions of tests, as desired. *This kind of repeatability is very difficult, if not impossible, to obtain under actual field conditions.*

The simulation test system is controlled by a second HP computer in the Propulsion Systems Lab. A block diagram of the computerized system is shown in Figure 4.

The computer is an HP 2116 with 16K (16-bit words) memory. The crossbar scanner, digital voltmeter, and data linearizer from the non-computer system are compatible with computer operation and are performing the same functions in the computer-controlled system. The heavy-duty teleprinter provides communications between the operator and computer and also provides hard-copy printout. The punched tape input provides high-speed program/data inputs to the system. Measurement results are available, as desired, in punched tape format. The disc memory provides data storage and makes the data available for subsequent hard-copy printout on the teleprinter. The simulation programmer reads the tapes that contain the test course data which, in turn, causes changes such as engine speed, dynamometer controls, etc. to be made while the test is in progress.

Simulation testing is under control of the HP real-time executive (RTE) software operating system which allows TACOM to conduct tests in a real-time, priority-oriented, multiprogramming environment. With the RTE, the computer maintains control over simulation testing in the real-time mode and at the same time allows low-priority activities such as program compilation and debugging to take place. Real-time collection of test data is handled in a section of computer memory designated as foreground, while low-priority activities are handled in the background area of core.

Figure 5. Technique for producing program tape containing simulated test course. Data obtained from an actual test course run are converted to digital punched tape representing all the parameters measured in the test run.

PREPARING SIMULATED PROGRAMS

Preparing a program to simulate a test course run is as shown in Figure 5. Note that the same computer is used for both program preparation and test system control. Data obtained from the actual field test course runs are recorded on multichannel magnetic tape recorders in the vehicle. The magnetic tape is input to the computer (through an analog-to-digital converter interface) which, in turn, produces a digital printout corresponding to the analog information on the tape. The digitized information is then input to the tape punch. (The tape punch is a companion unit to the simulation programmer and is used only for program preparation purposes.) The punched tape output now digitally represents all the parameters encountered on the test course. *Typically, simulation techniques yield test cell parameters that are accurate to within 5% of actual field conditions.*

RUNNING SIMULATION TESTS

After the program tape is loaded into the simulation programmer and the engine/transmission test specimen is set up in the test cell, the computerized system is ready for operation. The test specimen begins its "run" over the simulated test course on command from the simulation programmer. The programmer reads the punched tape (containing mud course, hill course, sand course, etc.) and, through relay closures, operates air valves on a simulator control stand in the test cell. The valves, in turn, are connected to linkages which control engine speed, dynamometer controls, etc. The simulation programmer very effectively manipulates test cell parameters in much the same manner as the test technician shown in Figure 3.

The simulation programmer moves from step to step in the program as directed by the computer. For example, one step may call for a test at 600 RPM with no load. The valves are then positioned for this condition. The computer initiates a scan and reads the transducer inputs and then issues a command to the programmer to go to the next step. The programmer positions the valves for, say, 1000 RPM and 10 ft-lb load on the right rear wheel. The computer again reads out the transducers and issues a step command. Thus, only after the computer takes a reading and determines that all data points are within predetermined limits can the program proceed to the next step. This built-in checking system is particularly important at the high RPM and high load levels where the possibility of malfunction is greatest.

The vast amounts of data collected are stored on the disc memory and subsequently printed out on the teleprinter. Thus, the test engineer has a complete account of every measurement taken, enabling him to observe exactly how the test specimen responded to changing parameters. Especially valuable is the profile of measurement levels showing activity leading up to a malfunction or out-of-limits condition.

FOR THE FUTURE

After proving that a measured test course can be successfully simulated in the laboratory, TACOM has expanded its capabilities to include a second test cell for simulation testing; a third cell will be ready in the near future. The HP computer and its RTE software operating system are fully capable of handling the projected multi-cell testing needs on a real-time simultaneous basis.

Future plans also call for expanded use of the RTE system by conducting a good portion of the engine/transmission testing in the closed-loop mode. The first item of priority in this phase is expected to be automatic shutdown of the test cell in the event of impending catastrophic failure.

BENEFITS OF COMPUTERIZED TESTING

Computerized data acquisition has sharply increased the testing capabilities in the Propulsion Systems Division. Real-time availability of data in engineering units enables engineers to perform evaluations while tests are in progress and to early recognize any unusual operating conditions. TACOM's pioneering efforts in simulation testing utilizing the HP RTE system are yielding excellent results. Particularly noticeable is the cost savings, largely due to reduced time and manpower requirements, as compared with conventional field testing. Further, the consistently accurate repeatability in test after test gives TACOM engineers a degree of assurance not attainable under actual field conditions.

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