INDUSTRIAL DATA PROCESSING APPLICATIONS REPORT

Applications	Integrated Information System
Type of Industry	Aircraft Manufacturer
Name of User	Lockheed-Georgia Co. Division of Lockheed Aircraft Corp. Marietta, Ga.

Equipment Used	Two Univac 490 Real-Time Computers Univac 1004 Combination Card Reader, Card Punch and Printer 54 RCA - EDGE Terminals 29 Teletype KSR-35 Keyboard Send/Receive Units One Teletype TO-35 Tape Distributor Four Teletype RO-28 "Receive Only" Printers 12 IBM 1001 Stub Card Readers 8 IBM 1050 All-Purpose Terminals

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Synopsis

The InterLoc system — an integrated information system — at Lockheed-Georgia is in the first of five phases. When the fifth phase or "plateau" is completed in 1969, Lockheed-Georgia expects that all levels of management will be assisted by a comprehensive reporting system that will supply current information on all plant operations.

At the center of the system are two Univac real-time computers that are connected to a communications network of RCA, Teletype and IBM terminals. Communications terminals are located throughout the Lockheed-Georgia facilities and provide instant access to the central computer and master files.

The functions performed in phase one of the InterLoc system are: Work Order Audit, Shop Order Location, Material Status Control, and Systems Engineering Document Control.

"If you could simultaneously communicate with 32 people, each discussing a different subject and each speaking one of five foreign languages, while you concurrently and efficiently performed your selected occupation, you would be simulating the task, though not the speed, of the real-time software developed at Lockheed-Georgia for Plateau I of InterLoc."

These words, used by Lee N. Fuchcar, management systems research specialist, describe the capability of the InterLoc real-time management information system being implemented by Lockheed-Georgia Co. at its Marietta, Ga., plant.

Two Univac 490 computers direct all information traffic in a complex production flow as reports on job progress come from throughout the giant factory via a data communication network of Teletype, RCA and IBM terminals. The computers record the reports in memory and recalculate the over-all shop picture. Since data is always current, both top management and plant supervisors can receive up-to-the-minute shop status reports. The integrated information system at Lockheed-Georgia is at the beginning of a five-phase program. In 1969, when the fifth phase is scheduled for completion, this system will provide all management levels with timely and systematic methods of analysis and decision.

Founded in 1951 as a division of Lockheed Aircraft Corp., Lockheed-Georgia manufactures a wide variety of major durable equipment ranging from aircraft to nuclear reactors. The Georgia company employs over 22,000 people and contains the largest aircraft factory under one roof in the world — 76 acres of manufacturing floor space. Thirty-seven of its departments are involved in the production of the C-141 StarLifter, a global fan-jet transport for the U.S. Air Force, the multi-purpose C-130 Hercules prop-jet, and the JetStar corporate jet. In addition, Lockheed-Georgia is developing the giant C-5A air transport, to be the world's largest jet transport.

EDP AT LOCKHEED-GEORGIA

Use of computers at Lockheed-Georgia dates back to May 1956 when an IBM 705 I computer was installed. In January 1958, as data processing was expanded at Lockheed, an IBM 705 II was put into operation. This was followed by an IBM 705 III and an IBM 7080 in December 1961.

Lockheed also installed an IBM RAMAC computer that was eventually replaced by an IBM 1410 in 1962.

By 1961, Lockheed-Georgia had successfully mechanized its major systems, obtained experience with data collection, mass storage and inquiry capabilities, and files of essential data were in storage.

With the experience gained, Lockheed recognized that paper output was excessive. Printers were producing reports at the rate of 12,000 words per minute. They could be read at only 600 words per minute.

With its systems and data files not fully integrated, occasional duplication of information in reports and files occurred.

Still, information concerning plant conditions and production status was needed instantaneously from remote locations. In addition, there was a need for mass storage capabilities. Recognizing the limitations of its data processing system, Lockheed-Georgia, in 1960, initiated a study aimed at the installation of a totally integrated management information system.

This study drew persons from Engineering, Finance and Manufacturing. Together with representatives from IBM they contacted all levels of management to help in determining the requirements of an integrated information system.

Real-time capabilities were considered from the beginning of the InterLoc study, but did not evolve into a concrete concept of InterLoc until further along in the study.

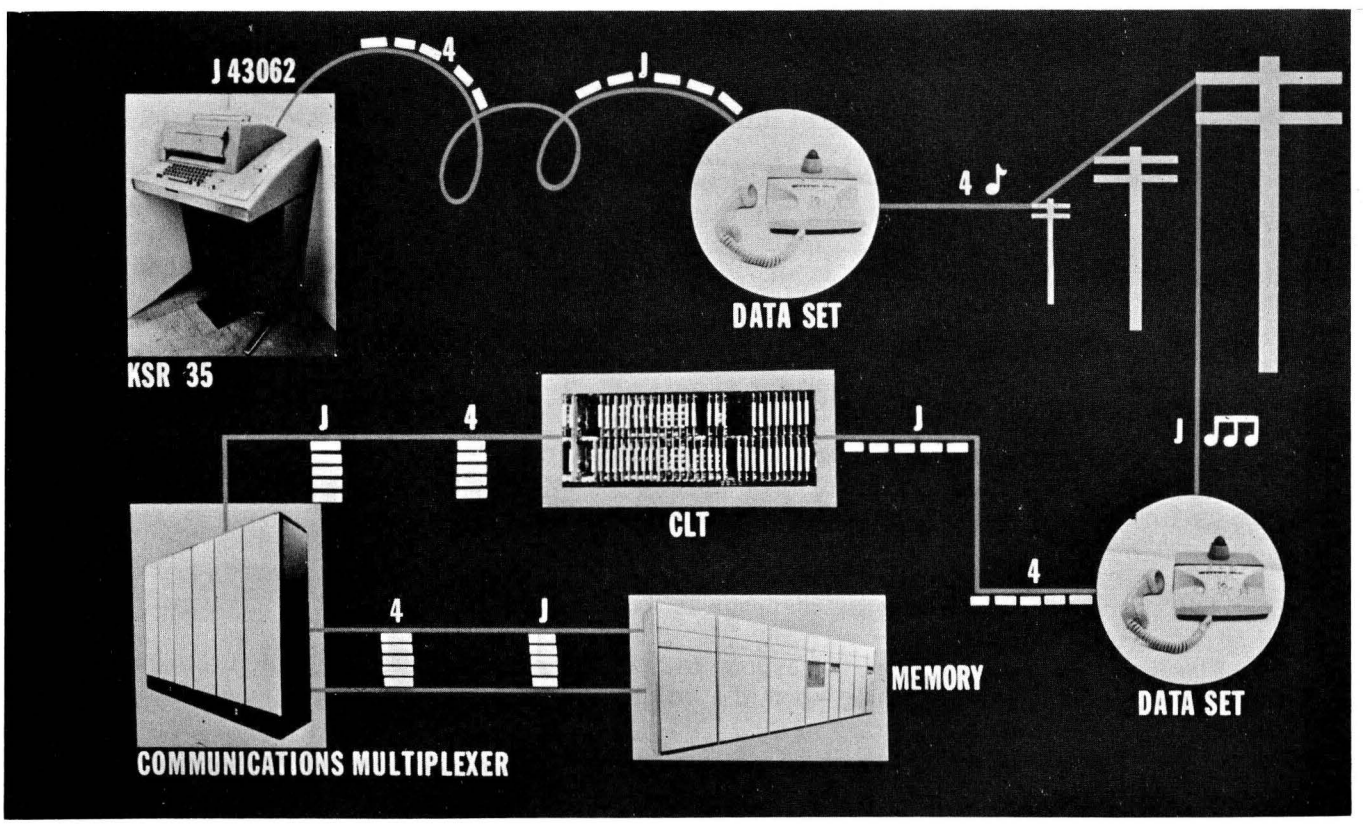
The major functions of manufacturing that were to be integrated into the InterLoc system were: parts requirements, material, manufacturing plan, tools, fabricated parts and assembly.

The master plan for the integrated information system was segmented into five phases or "plateaus" as they are known at Lockheed-Georgia. Phases one, two and three include information systems required to physically build an aircraft. Phases four and five will include comprehensive quality and financial control systems.

This report deals with phase one of the InterLoc system. Included within this phase are: Work Order Audit, Shop Order Location, Material Status Control and Systems Engineering Management Document Control.

THE INTERLOC SYSTEM AT LOCKHEED-GEORGIA

Effective management control requires two types of information: historical and current. Historical information is generally attainable in a large corporation but current information is not readily available except when a real-time computer system is used.



COMMUNICATIONS INTERFACE OF INTERLOC SYSTEM.

At the center of the InterLoc system are two Univac 490 computers. With 327,680 characters of memory, rapid access to any of a large number of documents is available. In addition, data may be typed out at any one of many locations. Records are stored on fast access drums which can stored 516 million characters of data. Ultimately, 2.25 billion characters of storage will be required. This ability to store records shows conditions as they exist throughout the factory. As events change any of the conditions, files are updated instantly. Over 345,000 events can be recorded each day.

These events are recorded by the use of 54 on-line remote devices placed in seven buildings which send data to, and receive data from, the computer, and an ultimate 200 RCA-EDGE terminals currently operating off-line. Replies to queries are received within less than one second.

In this communications network, five different types of remote terminals are used and all terminals can either transmit or receive messages simultaneously with each type of terminal transmitting in a different code.

In order to explain how this equipment is used, an example of a single transaction will be given here. Assume that a production control expediter requires information as to the location and current status of shop orders for a particular part number. He would transmit an inquiry — in this case by utilizing a KSR-35 terminal — which consists of a three digit record type code (to define the type of information desired) and the part number. As each key is depressed, the terminal transmits serially 11 bits or pulses (a start bit, eight data bits and two stop bits) to data set number one. This data set converts the bits into audible tones of varying frequency and sends them via voice grade telephone lines to data set number two which converts the audible tones back into bits. From data set number two, the bits are sent serially to a communication line terminal (CLT). This terminal gathers the bits and sends them as a character (parallel-by-bit) through the communication multiplexer to the computer. It is the function of the communication multiplexer to monitor the line to the computer to insure, first, that the computer is ready to accept the character and, second, to service all CLTs as required.

Each line has two CLTs associated with it, one for input, the other for output, and four core buffers, two input and two output. As a character is presented to the computer, an addendum is attached by the input CLT and specifies the core location and input buffer into which the character shall be placed. Cycle time for processing of this input to the computer is 15.6 microseconds.

The length of each input buffer is defined and controlled by software to contain a maximum of 10 characters. When the buffer is full, a processing interrupt is generated by the hardware. Software recognizes which buffer is full, instructs the associated CLT to place the next character into the alternate input buffer, audits the input, translates it into the code of the computer and moves the 10 characters into a software work buffer where the message will be accumulated.

When the complete message has been accumulated, software places the message on an input queue which is stored on a Flying Head 880 drum.

The input message is placed into a predetermined core location on a first-in-first-out basis as processing time becomes available. The operating program is then identified and read into another core location and control is shifted to this program.

The operating program then processes the query by locating master records and extracting the desired information. A response message is then built up and is moved to an output queue.

The length of time required to respond to an inquiry of this type will vary between 300 milliseconds and four seconds, depending upon the volume of activity, length of queues and the nature of the inquiry.

EQUIPMENT

The major components of the InterLoc system are two Univac 490 computers with 327,680 characters of memory.

Master files are maintained on four FASTRAND II drum units which store up to 516 million characters of data. In addition, three Flying Head 880 drums, which can be accessed much faster than the FASTRAND drums, store nearly 12 million characters of data and are used to control and queue messages from remote terminals.

Fourteen magnetic tape units record data for recovery purposes, for normal input and output and for retention of historical data.

A Univac 1004 combination card reader, card punch and printer is connected to the computer for the purpose of error message testing and operational control.

Input/Output to the communications network consists of RCA-EDGE, Teletype KSR-35, TO-35, RO-28, and IBM 1050 terminals.

Systems Objectives

One of the major objectives of phase I of InterLoc is to control Systems Engineering Management documents and to supply information retrieval and editing capabilities as required.

Another objective is to effect control of material and shop orders — from initial material requisition preparation to receipt of material in stores, and from initial shop order preparation through closure of the parts to stock.

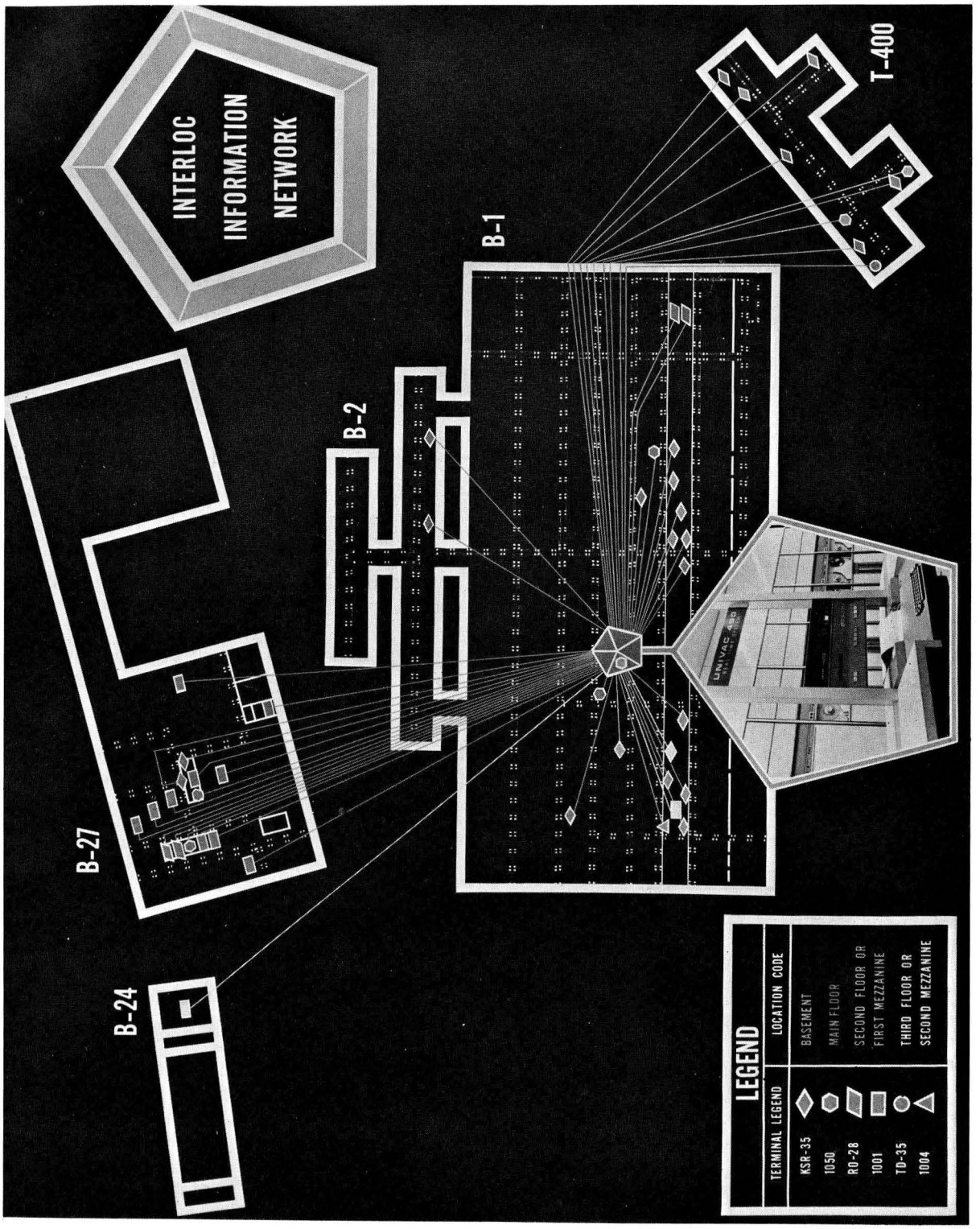
A third objective is to initiate and maintain a master work order audit under the centralized control of cost accounting, and lastly, to develop and perfect "building block" and file organization techniques.

Systems Engineering Management Control

To document Lockheed-Georgia's proposal for the C-5A aircraft, it was necessary to create functional flow block diagrams. From generalized functions they expanded into several detailed levels.

Documents accompanying each block were controlled by the InterLoc system which insured systematic and complete planning, forming a sound basis for program evaluation.

By remote inquiry, engineers can ascertain current specific interrelationships between functions and documents. Under previous systems, up to a week was needed from the time a parts requirement was generated until the time information reached production control, material control and manufacturing engineering. The present integrated information system accomplishes this process in a matter of minutes. In addition, the InterLoc system provides a daily edit of document relationships resulting in the pinpointing of missing or duplicate documentation, or flaws in engineering design definition.



THE INTERLOC SYSTEM.

System Engineering Management Master Files

Two System Engineering Management (SEM) master files are used in the InterLoc system, one a function number index master and the other a document status master.

The function number index master contains each function number and the related document number or numbers. This allows a cross-reference from each function number to related documents.

The document status master contains the document number, document title, number of pages, the engineering job number, related function numbers and status information such as latest revision data, security classification, etc.

The information contained in these files is immediately available to engineering personnel via remote terminals.

MATERIAL CONTROL

Up-to-date status information concerning all raw materials, purchased parts and usage materials is available at all times to appropriate manufacturing personnel. Remote terminals are used for inquiries and for output of computer initiated action. The material code master file contains seven categories of status information.

The first is committed disbursements, or the amount of material required by open requisitions for which disbursements have not been made.

The second is purchase order references, and the third, stores location. The fourth category identifies the buyer and the fifth indicates shortage conditions. The average cost of the material code item, or unit price and material on hand make up the last two categories.

LOCKHEED PERSONNEL CHECKING QUERIES FROM REMOTE STATIONS.

Material Shortage

One area that is handled by the material control system is material shortages. Under the previous system, utilizing an IBM 7080 computer, purchased parts requisitions were prepared and delivered to material stores the following day for billing. A shortage condition was not detected until the storekeeper actually went to the storage bin to fill the order and then manually prepared a shortage notification. This would be forwarded to the shortage control group.

With the InterLoc system, before the requisition is written on the computer, the material code master is checked to determine if material is on hand to fill the requisition. If a shortage exists, notification is made to the shortage control group and a potential shortage condition is noted in the computer. The shortage control group then investigates the potential shortage condition and expedites any material within the receiving-to-stores process.

Under the previous system, reports had to be manually analyzed to locate material. This would be done working with reports that were 24 hours old. With the present system, by a remote inquiry, material can be pinpointed as to its location, as of the moment.

The present integrated information system at Lockheed-Georgia also gives the buyer immediate access to current status information on any related purchase orders and/or receiving memos eliminating manual research previously required.

One of several inquiries the buyer may make is a "shortage inquiry." In this case the buyer specifies the information desired and the computer responds by indicating all shortages for the material, all receiving memos "in process," all purchase orders in chronological sequence and all purchase requests. This information enables the buyer to make a decision as to the best way to alleviate the shortage condition.

The action of the buyer results in expediting delivery of the material to receiving and then to material stores for disbursement. Under the previous system the shortage control group constantly screened a list of receipt of shortage material.

LOCKHEED PERSONNEL CHECKING OUTPUT OF TELETYPE TERMINAL.

With the present system, upon receipt of material on dock, a mechanical check against the shortage portion of the material code master is made at the time the receiving memo is remotely prepared by the computer. If there is a shortage on the material received, a remote transmission is sent to the shortage control group advising that the material has been received.

When this material reaches material stores, another remote transmission is sent to the shortage control group advising that the material is now in stores. At this point, upon receipt of the short material into stores, a purchased parts requisition is produced providing the authority for disbursement. In addition, stores is alerted that this requisition is for short material.

PRODUCTION CONTROL

The largest file in the InterLoc system is the fabrication shop order data file. For each shop order, the file contains the scheduled start date of the order, the last operation and date completed, the quantity of parts being built by the order, the date that the present cost center and future cost centers are scheduled to complete their work and the operations required for production and hours required. In addition, flagged data reflecting the expediting priority code and expedited quantity and any "held for" conditions due to lack of tools, materials, etc., are included. Lastly, the file contains the location of the work in progress and the scheduled completion date.

All this information is available by the use of 10 inquiry stations located in the Production Control and factory areas.

Production Control Inquiries

Of the available Production Control inquiries, 11 are related to determining the location of different classes of shop orders. Four of these inquiries determine the location of all unreleased shop orders, the location of the shop order nearest completion, the location of all open orders — which would include all orders except those closed to stock — and the location of all orders including those closed to stock, those unreleased to the opening cost center and those in work.

WORK ORDER AUDIT

Financial controls are included in the fifth phase of the InterLoc system but a basis for these controls is incorporated within each phase. Within the first phase the work order audit master includes a work order description, a work order type, a work order number, a work order status and allowable charges. Work orders are established and maintained in this file by the Cost Accounting Department. This department is the sole source for all charges — material, labor or other. All shop orders, purchase orders and material disbursements have access to the work order audit master and must pass a validity check against this master before action is taken. For example, the validity of a charge is established before a material disbursement requisition or fabrication shop order is released.

In addition, this file permits Lockheed-Georgia personnel to determine the effect of contract charges or cancellations for factors such as fabrication load or material commitments. It also forms the foundation for the integration of real-time PERT-Cost within the work order structure.

SOFTWARE CONSIDERATIONS

To utilize the hardware of the InterLoc system it was necessary to design a combination of generalized controls to isolate operating programs from the complexities of their environment. These generalized controls are called software. In the InterLoc system this software is designed to perform

real-time control, executive control, batch processing control, test capabilities and procedures for recovery.

Executive Control

The real-time executive controls, sequences, establishes priorities and provides for the most efficient allocation use of facilities for operating programs which operate within the total system. It controls one or more real-time operating programs which may be processing concurrently with one or more batch programs. In this way, the need for operating programs to provide for concurrent operations is eliminated, for the executive maintains and restores the operational environment of each program. Each operating program may be written as if it were the only one being run in the system. A number of basic sub-routines are also provided by the executive which assist in input/output control, console control, etc.

Batch Processing Control

Batch processing control in the InterLoc system is basically identical with traditional batch processing. The basic difference lies in that an InterLoc batch program operates concurrently with other batch and real-time programs.

Test Capability

In a real-time system, test capability has to include rigid and complex testing standards. Traditional testing methods which assume a controlled sequence of events are considered to be inadequate for the InterLoc system. When an untested program is being tested, software must protect inadvertent destruction of operating information.

Three distinct levels of testing have been developed at Lockheed-Georgia. Level one provides the capability of testing a single operating program, real-time or batch, in a concurrent batch mode. It also provides for protection of core, drum and other peripheral devices. It allows either a test or compilation environment, maintains a queue of successive programs ready for test, and automatically "dumps" core, drums and/or tape units at the completion of a run.

Level two places operating programs in their normal mode of operation. The real-time environment is simulated to allow a random sequence of tests to be repeated. This level may be used with or without an independent program monitor which will terminate programs and print output upon detection of illegal operations.

The third level is used for testing and monitoring operating programs which are functioning in their true productive, real-time environment; that is, the environment is not simulated. This enables testing of one or more operating programs while the balance of the system is productive.

Recovery Capability

Perhaps one of the most important considerations of a large scale real-time data processing system is that of recovery capability. Included in the InterLoc system is provision for rebuilding master record files in the event they are inadvertently lost due to a hardware malfunction. Recovery capabilities are also provided for protection against loss of operating programs, control queues and location table.

MASTER DATA FILES

In the InterLoc system, with regard to mass storage of information, there are 21 master data files, some of which have been mentioned earlier. The nine major files are: a part number index file, work order audit, SEM functional block diagram cross-reference, receiving memo, fabrication shop order, purchase order, material code, SEM document control, and burden center-cost center-load center.

Data files, each of which occupies a separate area of the FASTRAND drum, are completely independent of each other in that each file may be accessed by its unique control word.

On the other hand, distinct connections between most of these data files are maintained, permitting communication between interrelated functions of Engineering and Manufacturing.

File Indexing

Each master record contains, and is controlled by, its own unique identifier or control word such as material code or part number or shop order number. In the InterLoc system a cross-reference capability has been developed by including one or more related control words in each master record. For example, a part number index master record contains the control word (shop order number) for each shop order master record related to that part number.

Each part number index master also contains the related material code number which is the control word for the material code master record, therefore making the material code master available to an inquiry on part number.

The material code master record contains the part number and all related purchase order numbers. Therefore, an inquiry on part number can retrieve purchase order information by going through the material code master. This logic is extended to other master records.

Burden Center - Cost Center - Load Center Master

The burden center-cost center-load center file carries an up-to-date condition at all times. This includes standard hours forecast data and standard hours sold data. This file is the basic data file into which all organizational type data is stored. It contains information on budgets, personnel counts, machine capacities, shortage and schedule conditions, etc. This has permitted centralization of common data at a point commensurate with authority and responsibility.

RESULTS AND FUTURE PLANS

The InterLoc system at Lockheed-Georgia is not considered a conclusion. At Lockheed-Georgia, it is considered to be a scratch on the surface of real-time systems. According to Lockheed-Georgia, InterLoc enables the company to manage its business, not just account for it, by helping it to know what is happening, rather than what has happened.

Costly and unnecessary duplication of records has been eliminated since information that must be available instantaneously in several different operating departments is maintained in a single master record. Also, exceptional and emergency situations are recognized when they occur and appropriate corrective action can be taken before a problem develops into a major crisis.

The flexibility of the system has allowed Lockheed-Georgia to accommodate a requirement that was not included in the original planning. InterLoc was expanded to include Systems Engineering Management Document Control which has been discussed above.

Automatic Data Acquisition System

In early 1966, Lockheed-Georgia will place on-line its automatic data acquisition system through an interface computer. This system will be tied in through an interface computer to the duplexed Univac 490s. Shop order move and standard hours sold data will then be updated using RCA-EDGE terminals in real-time, eliminating the current paper tape punching and processing.

Purchase Order Preparation

Future plans include automatic and remote preparation of purchase orders. When the computer detects an impending order requirement, the purchase orders will be remotely prepared, requiring the addition of only the buyer's approval and possibly vendor price confirmation.

Requirements and Inventory Maintenance

Many material requirements, which presently require considerable manual effort to prepare, will be generated automatically as a product of maintaining files in mass storage. Engineering requirements, tooling requirements and manufacturing requirements will be analyzed and modified to include spares requirements. These combined requirements will then be fitted to the master manufacturing schedule to insure the timely arrival of materials with maintenance of minimum inventory balances.

Manufacturing Time Standards

In the expanded InterLoc system all manufacturing operation sheet data will be maintained in the mass storage files. The time standards master file will also be maintained to allow the computation and application of time standards to certain new manufacturing operations. Operation sheets subsequently produced will include the applicable standard times.

Other Applications

Other real-time applications that Lockheed-Georgia is developing revolve primarily around the data requirements of the C-5A aircraft. These include mechanization of engineering process specifications, computer aided planning, engineering maintenance data and spares provisioning.

Presently, Lockheed-Georgia is processing over one million messages a month of which 80 percent are updating information and the other 20 percent are inquiries. Lockheed-Georgia expects that these figures will double and triple in the near future.

Finally, InterLoc is expected to provide all management levels with timely and systematic methods of analysis and decision making.