LOCUS 16

a modular approach to radar data-handling networks

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Synopsis

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Locus 16: a modular approach to radar data-handling networks

The Locus 16 development was initiated in the early 1970s and comprises a modular range of hardware and software elements on which designs of radar data-handling systems for civil and military users are based. Applications are implemented using the 'distributed data-processing' method in which a network of inter-communicating Locus 16 equipments is used to provide economic and flexible arrangements and to ensure continuity of service. The product range continues to evolve, making use of continuing technical advances, and the paper outlines the physical form and multi-processor organization of the system and briefly describes some of its applications and areas of development.

Marconi Radar

LOCUS 16

a modular approach to radar data-handling networks

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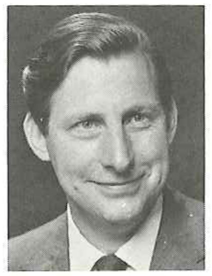


Users of radar equipment, whether for civil air traffic control or for military purposes, require a high level of computer assistance to ensure that complex tasks can be achieved with certainty in the limited time available. Information about aircraft movements typically derives from various sources—from radar heads sited close to a control centre, from other control centres and from pilots' reports—and a variety of other information is used by data-handling systems to support the human operator.

Data are presented mainly on cathode-ray tube displays and selected to meet the individual need, while control is provided by 'rolling-ball' devices, which can move a marker to any desired position on the screen, together with keyboards and developments of them. The human operator also uses an extensive network for speech communication.

1 *A transportable operations cabin equipped with Locus 16 systems*

During the 1960s the Marconi Company had gained a great deal of experience in designing computers and data-handling systems. By the end of the decade the rapid advances in integrated-circuit technology were radically reducing the size and cost of equipment while increasing its capability. Major new developments would certainly be necessary to strengthen the competitive position; however it was by no means clear what form these should take, and at the beginning of 1970 a small group was formed to consider the position and to evolve a technical strategy.

Previous system designs had been based on a central computer complex which provided all the services in a control centre, accepting all data inputs from operators' controls and from communications channels and generating all data outputs to operators' displays and to remote users. As computers were expensive and physically large as few as possible were used, to form the central complex. In some situations one machine was considered sufficient, although it left the total service vulnerable to a single failure; more commonly two were used in a 'main and standby' arrangement, while in a particularly ambitious civil project implemented by the Marconi Company, three had been used to guarantee essentially unbroken service and to provide cross-checking. Some designers had adopted more complex arrangements in which a number of memory units could be shared by a number of data-processors so that failures of individual system components had a more limited effect.

These approaches all had a number of disadvantages: the computer complex had to carry the total load of the system and could well become over-burdened; installation was costly and time-consuming, as multiple high-speed signals had to be distributed to user positions throughout the centre, and security of service often required far-reaching hardware and software developments.

One of the earliest and most fundamental decisions of the group was to move away from these methods and to pioneer a 'distributed processing' approach to system design. Each operator and each major technical service would have its own computer, the control centre being conceived as a network of computers interconnected by simple cables carrying serial messages. The computing load would be decentralized so that overload became less likely, and spare data-generation and operating-position computers could be provided as well as spare communications channels to ensure that single failures could not disable the system. The new method promised other advantages for supplier and user alike: simpler installation and commissioning, a greater uniformity of equipment, improved flexibility in meeting a variety of needs and in adapting to changed requirements.

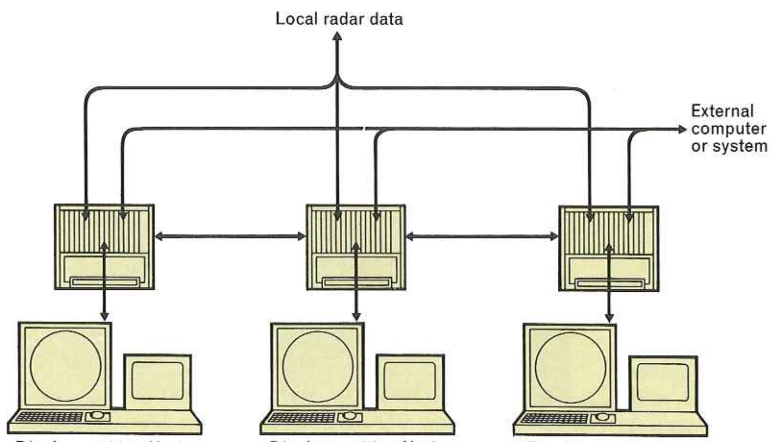
The practical realization of such an approach would clearly need the compact, low-cost, high-performance integrated circuits which were starting to emerge, and it would have to be capable of gaining from continuing advances. It would also demand a highly modular approach to hardware and software realization if the economic advantages were not to be thrown away in specialized design, since each computing equipment in the network would need to be adapted to its intended role by fitting the necessary facilities: displays, communications, operator control interfaces and so on.

In common with leading US minicomputer manufacturers we adopted an approach in which a number of processors and memory modules shared a common data-bus and were all contained in a single compact equipment. Like them we designed processors to provide the necessary functions: computation, communication, display control and so on. Unlike them we employed a structure in which control of the data-bus was provided as a distinct element rather than as a component of the arithmetic processor, so that the number and types of arithmetic processor could be freely chosen. This factor also has implications for such advanced features as memory management, and enables the system to evolve into areas inaccessible to conventional minicomputer data-bus systems.

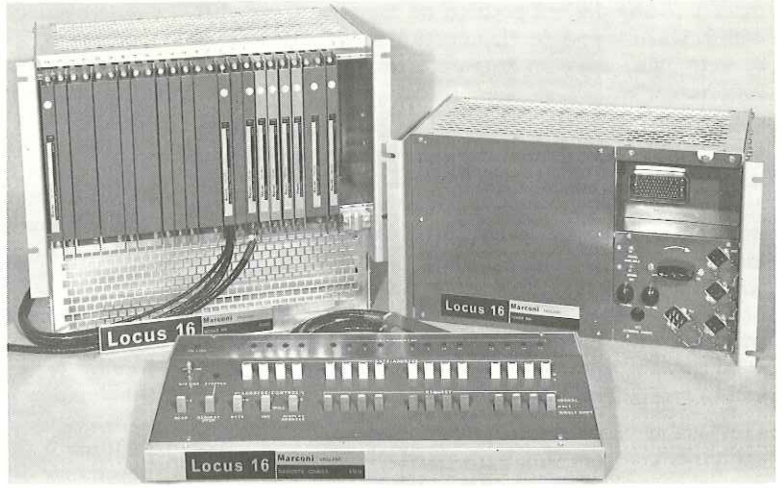
Many customers require a physically strong product capable of being used in military transportable roles and designed with logistic support in mind; these requirements naturally had an impact on the implementation eventually adopted, as did the need for competitive cost levels.

GENERAL DESCRIPTION OF LOCUS 16 EQUIPMENT

The equipment bin looks deceptively simple. It provides 24 edge-connector sockets mounted in a printed-circuit panel. All edge-connectors offer the



2 *General organization of a distributed processing system using Locus 16 configurations*



3 *Locus module bin and power bin shown with the diagnostic console which is attached when processor monitoring is to be undertaken*

same interface, as their corresponding pins are connected in parallel. Equipment modules consist of either one or two printed-circuit boards approximately 200 mm square, and serve varying functions—overall control, memory, computation, communications and display control—in various forms to suit diverse requirements. The boards are held in place in the equipment bin by so-called 'handles' which contain further edge-connectors. These carry the interconnections of two-board modules, the cables to external devices such as modems or display units, and the preset wiring specific to the intended system function. This arrangement eliminates the need for special setting-up before a module is used, as printed-circuit cards take their operating instructions—signalling speed, address, and so on—from wiring in the 'handle'.

The 24 edge-connectors which offer the Locus 16 standard interface are held on a printed-circuit panel, mounted on the rear face of the equipment bin, which connects corresponding pins of edge-connectors together to form a highway or data-bus allowing very fast signalling to take place. One side of the panel constitutes an earth plane and additional pins are dedicated to earthing arrangements to ensure error-free operation. Processors working in this environment are designed to perform autonomously a sequence of operations, appropriate to their function, which will normally require use of the interface to fetch or store data. Either eight-bit or 16-bit data items may be accessed, and the interface provides 16 data and 16 address lines used by processors for that purpose, supplemented by control lines which define the required transaction in more detail.

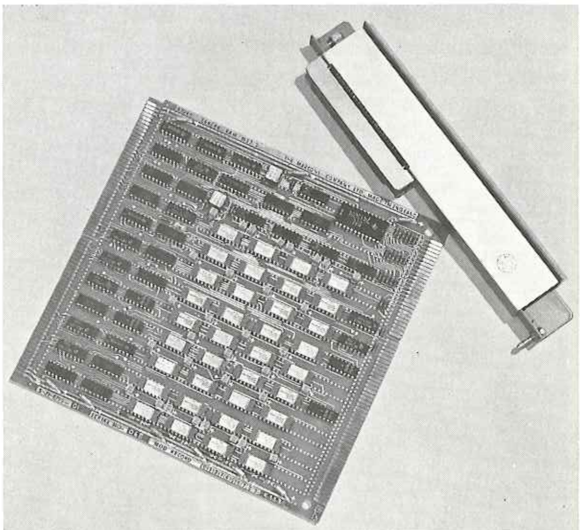
MULTI-PROCESSOR ACTION

As each transaction requires full use of the interface for a period of at least 375 ns, a system is needed to ensure that processors take turns in using it. Locus 16 provides a pair of lines ('request' and 'activate') for each processor, so that where several processors 'request' access at the same time the control system can 'activate' a selected one, simple fixed-priority logic being used to resolve conflicts. A typical configuration might contain a number of processors of this type: an arithmetic processor, processors for generating pictures on displays, processors giving access to disc stores, and so on. The program of the arithmetic processor would provide overall control, writing into the control registers of other processors to initiate or halt their actions. Other processors can also 'interrupt' the program of the arithmetic processor when particular states are reached, and all these interactions take place through the interface, as control registers and the interrupt function have fixed addresses within the system. In this way the various processors are able to run at the same time, queueing where necessary to use the interface and interacting as their programs dictate.

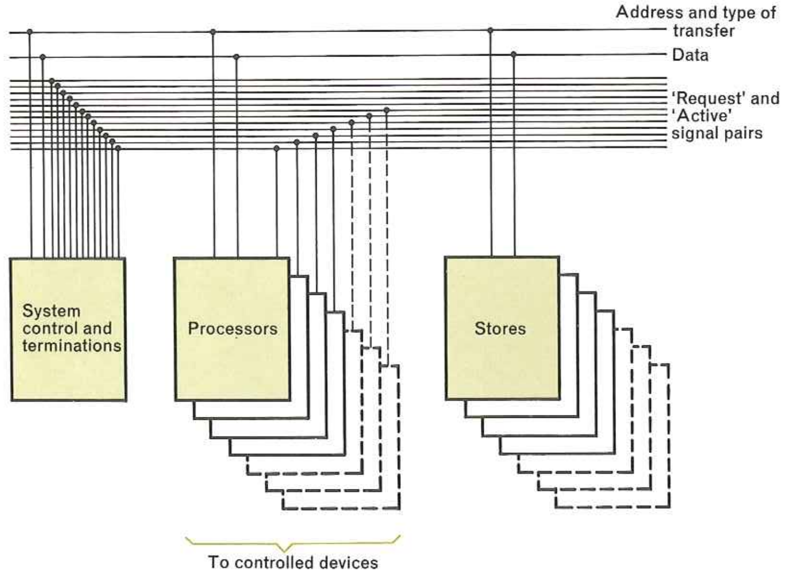
Although applications have so far needed only one arithmetic processor to be fitted in a Locus assembly, the system allows two or more to be used to obtain additional computing capability where necessary. The processor currently used occupies two printed-circuit cards and provides 16-bit fixed-point arithmetic and facilities for handling eight-bit characters. Microprocessors, of course, offer considerable advantages in cost and compactness and can be employed to carry out peripheral functions such as display or communications handling, or can be used as the main arithmetic processor where the role is undemanding.

SYSTEMS DESIGN

When using Locus 16 methods to meet a specific user's requirement, the designer has to devise a network



4 *Typical Locus 16 printed-circuit card and 'handle' (8 k word RAM store, 625 ns)*



5 *Locus 16 data-bus: the main features of the interface*

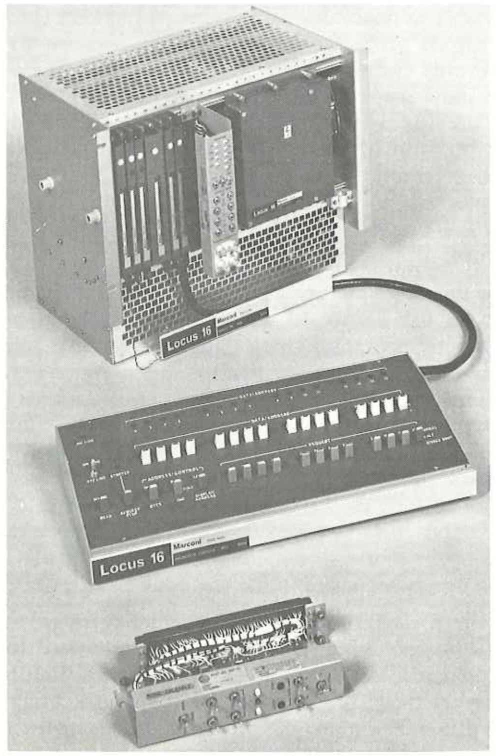
of Locus equipments. Each equipment will contain a selection of modules appropriate to the role it will fulfill, and communications channels are chosen to provide the rates of information flow needed. The network must be designed to provide adequate continuity of service; a failure occurring in an equipment or in a communications channel should lead only to some limited loss of service which can be tolerated by the user. In the more demanding applications this may lead to the provision of spare equipments and alternative communications channels.

Usually the designer is guided mainly by considerations of continuity of service and cost, and these tend to lead him to assign functions to equipments in as simple and direct a way as possible to minimize the rates of information-flow in the network. Of course he has to consider the validity of the assignments he makes: they might imply an excessive number of printed-circuit cards in one equipment, or lead to a computing load so high as to be unrealistic. Account may also be taken of future extensions, and particular users may also have their own preferences.

Appraisal of the computing implications is a particularly time-consuming and uncertain aspect of the task, and in complex applications it is necessary to make allowance for escalation, particularly of program size. It would often be desirable to conduct a major investigation of the computer programming aspects of a project before deciding on a specific approach to hardware, but commercial factors usually preclude such an arrangement. It must therefore be admitted that modern methods do not do a great deal to solve the fundamental problems of large-scale software design; they mainly provide the best possible environment in which to solve them.

We have laid considerable emphasis on a modular approach to software which is supported by the assembly language and by the Coral 66 system, and now have a large amount of proven material which can be deployed in new projects as well as in software support systems.

When a network has been devised, and functions have been assigned to the various Locus 16 (and possibly other) assemblies it contains, the designer proceeds to establish the detailed build-up of each Locus 16 assembly. Altogether he has a large range of items on which to draw, as the modules used in the equipment bin are complemented by, and work in conjunction with, a wide variety of other units: displays, keyboards and other controls, disc memory devices, cabinets of various types and sizes. The intention is to provide designers with a set of building blocks which can be assembled readily and adaptably to meet varying needs and can be produced economically and in quantity. Needs for special interfaces are accommodated by designing special modules to work in the standard environment, but most requirements are met mainly



6 *The in-bin power module used for small configurations, also typical test jigs, used with test software*

7 *Flexible-disc configuration in a commissioning area*

from the basic product range. New modules are also introduced to exploit new technical opportunities.

DISPLAY SUBSYSTEMS

Radar applications are closely associated with display systems, and the Locus 16 product range is of particular interest in this area. Aircraft positions are made available to operators using labelled markers (plaques) shown on precision 16-inch (406 mm) or on 23-inch (584 mm) cathode-ray-tube displays, and these may also show maps of the displayed area. Operators control the display in a variety of ways: to choose the size and position of the displayed area, the categories of aircraft shown, the kind of information given in plaques and in 'mini-tab' tables, the type of the map and the brightness of the various components of the picture.

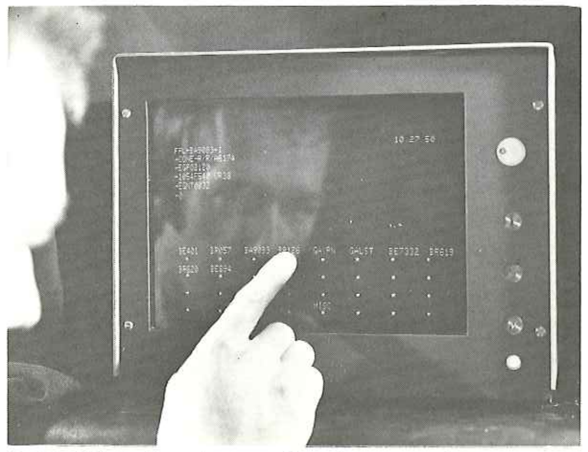
The required picture is described in a 'display file' held in the Locus 16 memory. It is set up by the arithmetic processor using data from various sources: operator controls, pilots' and other reports, radar plots (automatic or manual), data communicated from other centres, and computed instructions, predictions or warnings. This file is read out autonomously by a 'display processor' which uses it to generate pictures on up to four displays, and to 'refresh' them at rates of around 30 to 50 times a second to minimize flicker. This processor is contained on two printed-circuit cards and is contained in the Locus 16 equipment bin.

In some applications a 'radar video picture' (plan-position indicator) is required in addition to the material indicated earlier. In this form of picture the radar video signals are used to modulate the brightness of a displayed line so that as the radar rotates, aircraft echoes appear as bright blotches on the screen. Because these signals enter more or less continuously, it was not possible in earlier systems to display the maps, markers and other material without throwing away some of the video, with consequent loss of performance. In Locus 16, signals are recorded as they enter the system and are played out to the display a few milliseconds later at a rate chosen to enable both video and ancillary material to be written without loss of data. This method also enables the brightness of the displayed picture to be held constant as the 'expansion' is increased (that is, as the viewed area is reduced). In one application of Locus 16 the system will be used to evaluate the performance of automatic radar plot extractors, a use in which these advantages are important.

Where operators require a separate tabular presentation of information a television monitor is used, controlled again by a Locus 16 processor which generates the picture from a stored display file. This device may also be fitted with a touch-sensitive ('Digilux') overlay enabling it to be used as a form of keyboard in which the functions of the individual 'touches', and the labels written below them, can be altered by the computer program to adapt progressively to the operator's needs. At each stage the operator is presented with a range of options, and on his selecting one by an appropriate touch action a new set is presented. The 'Digilux' equipment, in fact, uses optical methods to sense touches, though target markers are provided to help the user.

APPLICATIONS

Distributed processing methods based on Locus 16 are being used on a number of current projects. In a civil application, for the new Scottish Air Traffic Control Centre at Prestwick commissioned by the United Kingdom Civil Aviation Authority, more than 30 Locus 16 configurations will be used to provide air traffic controllers with information from six remote



8 *The 'Digilux' touch-operated overlay, mounted on a television monitor and used as a programmable keyboard*

radar heads. The information, communicated by duplicated narrow-band data-links, is displayed selectively on 29 16-inch displays, each equipped with a keyboard and track-ball, and controlled by its own Locus 16 configuration.

Control is exercised initially by manual methods based on flight progress strips, but provision is made for automated procedures to be introduced later. Radar information may be taken directly from the data-links in fall-back mode, but is normally derived from four Locus 16 pre-processors which perform tracking and other functions before generating new serial messages for the controller's use. Other Locus configurations are devoted to maintenance and software development functions, and provision is made for new software to be developed and assessed prior to real-life use.

The system is notable for the very high levels of continuity-of-service required, and for the small spares holdings and limited cabling requirements. It will cover an area which has a growing flight density, as it accepts North Atlantic traffic and also covers the off-shore oil fields.

For military applications Locus 16 configurations are usually installed in transportable cabins. The 'Furnace' cabin contains three display positions showing synthetic and graphical information with radar video signals and incorporating two Locus 16 configurations. Each display position incorporates a television monitor with 'Digilux' overlay for data entry, as well as a key-shelf and track-ball. The cabin is normally used to accept data from primary and secondary radars, performing tracking calculations and weapons control with a track capacity in the order of 60 tracks. However, the operational role fulfilled by a cabin is largely determined by software. The cabin is 2·26 m high, 3·55 m long and 2·26 m deep, and incorporates voice communication facilities.

Locus configurations have also been installed in cabins 20 feet by 8 feet (6·10 × 2·44 m), an International Standard size for containers. One such cabin incorporates Locus 16 configurations operating four displays, with a supervisory terminal position, and can be used alone or with a computing cabin containing further Locus configurations. This provides 'head-per-track' disc storage, and the combination is used to build-up more complex networks with considerable tolerance of equipment and channel failures. Particular emphasis is given to communications capability, and cabins are linked together when co-located, using the high-speed (1 or 2 Mbit/s) channels mentioned earlier. These cabins also can be deployed to fill varying operational roles.

FUTURE DEVELOPMENTS

In such systems as Locus 16 the permanent features are the data-bus interface and the physical form; in other words, the environment within which modules perform. The product range is always evolving, older modules being replaced and new ones being created to grasp the opportunities offered by integrated-circuit advances. Memory technology is an obvious example, as the original Locus 16 random-access store was based on a 1024-bit semiconductor chip, current production uses a 4096-bit chip, the next development will use a 16 384-bit chip and a 65 536-bit chip is clearly on the way. It has also become possible to provide permanent (read-only) memory so that programs and fixed data can be built into the machine, thus avoiding the need for a 'program-load' phase using paper tape or equivalent. We have implemented an advanced version of this in which programs can be erased using ultra-violet light, and re-written. This feature enables the inevitable early program errors to be corrected without throwing away the memory chips.

Microprocessors, particularly those offering 16-bit arithmetic, have now become sufficiently powerful to warrant a place in this kind of product range, and we see their use initially in looking after device-control functions, particularly those such as communications handling in which significant time-loadings can arise. In particular applications, however, a microprocessor could be used as the sole arithmetic processor in a Locus 16 equipment configuration. More often we are looking towards Locus 16 configurations containing several arithmetic processors, probably including one with floating-point arithmetic, and capable of operating with large amounts of directly-addressable storage. Our experience shows that 'distributed-processing' systems do in fact use large amounts of storage, and need sophisticated memory-management systems so that the many processors can deploy this storage efficiently. Capacities in excess of 500 000 bytes appear readily attainable within the bin.

Clearly, technical advances offer new approaches to many problems in communications, in display facilities, in software preparation and so on, and it is not possible for various reasons to cover them all. However it is gratifying to see that a concept introduced a number of years ago continues to draw strength from current technology.

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