



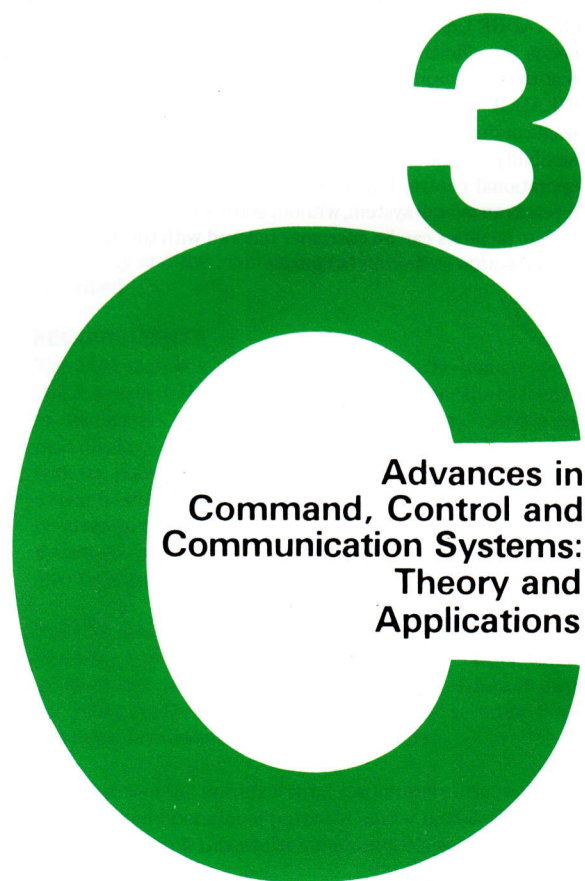
The IUKADGE Work Station

a flexible Man-Machine Interface for C³I Systems

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Marconi
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Advances in
Command, Control and
Communication Systems:
Theory and
Applications



Synopsis

Marconi Radar Systems Limited has designed and is supplying the workstations for the NATO-funded Improved United Kingdom Air Defence Ground Environment Programme (IUKADGE), drawing on its long experience of air defence user needs for efficient man-machine interfaces in this demanding real-time environment. The paper describes the principal IUKADGE workstation, which can be configured readily for single or dual operator manning. A noteworthy feature is its role-flexibility – it not only meets the varied needs of a particular operational centre, but also those of the several hierarchical levels in an overall system, without software or hardware change and its facilities can be customer tailored with the aid of a high-level Position Definition Language.

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INTRODUCTION

In 1981, the Ministry of Defence placed a contract for the supply of a large system to improve the air defence capability of the United Kingdom (IUKADGE – Improved Air Defence Ground Environment) and the work station to be described is a component of it. A special feature of this work station is that it can be adapted readily to provide a wide variety of role-dependent facilities. Defence systems are usually organised in a hierarchical structure of operational cells, with cells at different levels having different functions. For example, reporting posts and control-and-reporting posts link upwards to sector operations centres, which in turn link upwards to air defence operations centres, in the command hierarchy. With any one of these cell types there is further variety: for example, work stations will be configured to provide facilities for intercept controllers, tracking operators, etc. Historically, work stations were specific-to-role which resulted in higher costs, not only because of the variety which had to be produced, but also because extra work stations were needed to provide an acceptable system availability. The introduction of software controlled work stations and particularly table-driven software made it possible to produce a universal work station. However, user adaptation was still more of a promise than a reality. The IUKADGE work station includes a feature which has established

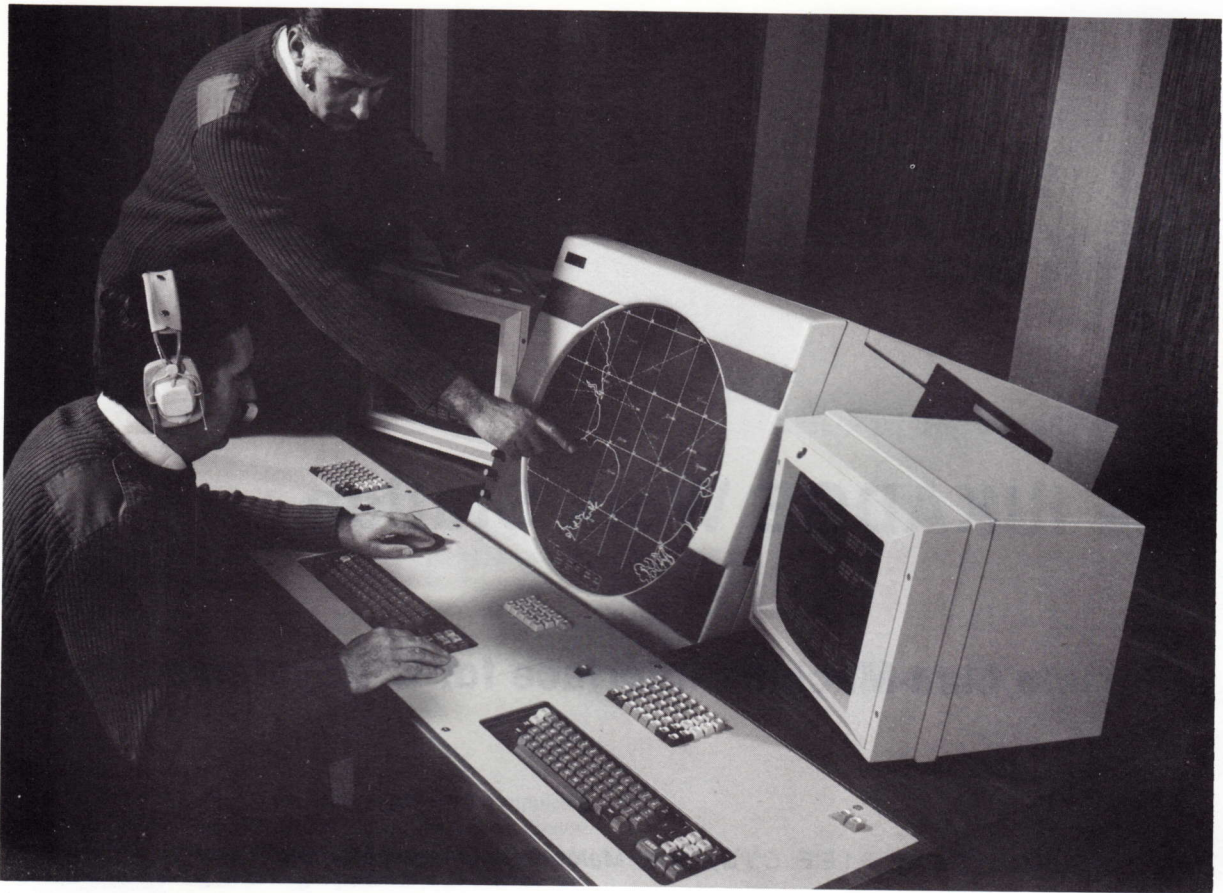
this reality and the manner in which this has been achieved is described.

REQUIREMENTS

The work station is the interface between the human operator and the main data handling system, and the means to feed back to this system requests and responses. It must provide easily read displays, easily usable input devices, a processing structure with the power to give quick responses to operator actions, and a clear flexible voice communications system. Recognition must be given to the inevitability of failure, however infrequent, and measures provided to maintain system availability whilst effecting speedy repair.

The IUKADGE universal work station additionally required the flexibility to allow either one or two operator control, variation in the formatting and detailed characteristics of data on display, the ability to change the function of input and selection devices, and the minimisation of its physical volume.

Derivatives of the universal work station were also required, for more limited operational purposes, and a modular system was needed to permit this whilst minimising consequential logistics impact.



OVERVIEW

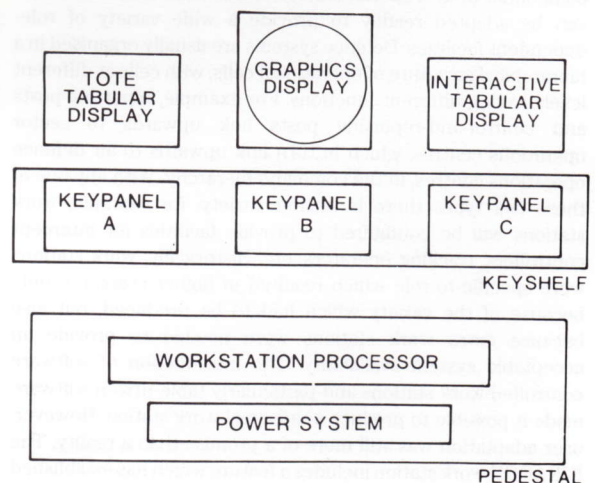
Before describing the work station itself, its position in the overall system will be explained. Each cell in the air-defence structure receives data from a variety of sources, such as radar sensors, aircraft, other cells, and outside agencies such as the air traffic control network. Similarly, data which it generates by operator and processor action may need to be communicated elsewhere. Consequently, cells are provided with data and voice communications network controllers and switches. Each cell also contains a data handling system (DHS) which provides centralised facilities for processing this data and distributing it amongst the work stations, according to their roles. Each work station is linked to the DHS by a shared simplex high-speed serial channel and a private duplex low-speed serial channel, the former providing the principal path for data transfer to it, and the latter serving largely as a return path for operator commands and responses. The voice communications service is provided by a high-speed duplex serial channel, time multiplexed, with up to three other work stations and linked directly with the network access switch.

Three displays are provided: a 560mm diameter, four colour, high definition, cursively scanned graphics unit; and two 380mm diagonal, monochrome, high definition, raster scanned tabulated-data units (with graphics options). The keyshelf is furnished with three different types of key-panel, and includes circuitry to support pulse-code modulated (PCM) voice communications.

The processor and the power unit supplying the work stations

needs, fit in the pedestal beneath the displays. This processor contains extensive firmware distributed amongst its dedicated and general-function processing modules, and it also receives software from the DHS. Fifteen microprocessors are used, the total power available exceeding 4 million instructions per second (Mips).

WORK-STATION SCHEMATIC



COMPONENT DETAILS

Displays

The graphics display is used for presenting geographically disposed plots, labels etc., on a background of maps, grids, etc., to provide a picture of the real-time air-situation. A small presentation area is also provided for tabulated alpha-numeric data, which can be positioned by its operator at any convenient place on the screen. An input sequence area is reserved at the bottom of the screen to display an input echo-line, a system reply-line, associative-key labels and prompts. The screen refresh rate reduces progressively and automatically under heavy loads, with provision for load shedding when a software defined minimum has been reached.

One of the raster displays serves as a tote-tabular, and the other as an interactive tabular. As installed, they can both display up to 40 lines of 80 characters at a time, but provision has been made in the associated processor for optional graphics enhancement. Areas at the top and bottom of the screens are reserved for indicating operational conditions, alerts, echoes, replies, and associative-key labelling.

Both the single and the dual-operator roles are accommodated by mounting the three displays on horizontal surfaces, with the smaller raster units elevated to an ergonomically satisfactory viewing height by simple 'boxes'. The relative position of the displays can be altered to suit the required role by uncoupling the few cables linking them to the pedestal and re-arranging these 'boxes'.

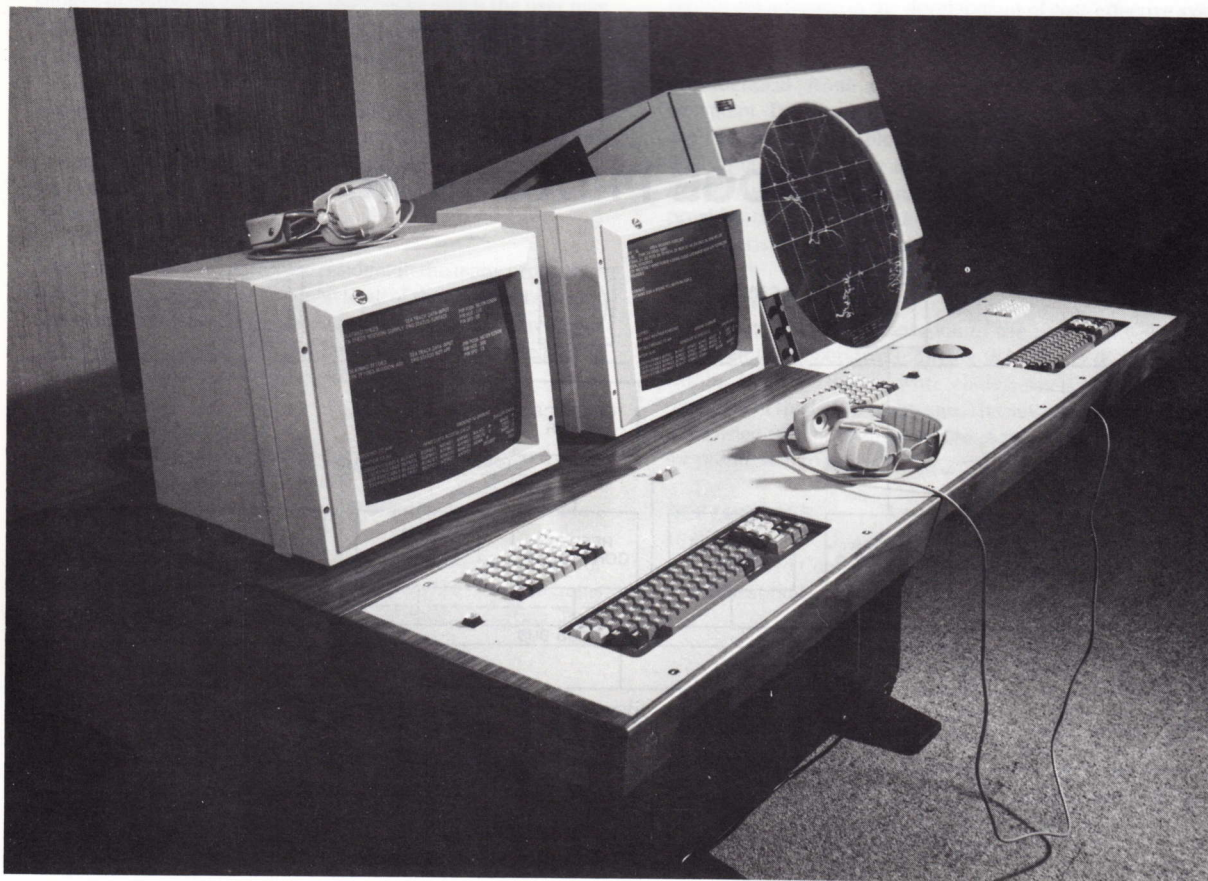
Keyshelf and Panels

The three different keypanels can be positioned either for single or dual role working, repositioning being facilitated by the minimisation of connections resulting from data serialisation. Fixed-function keys serve common-user functions, whilst programmed-function keys accommodate those which are role-specific, their labels being presented on the adjacent display above. A QWERTY key-set, with edit keys, is fitted to two of the panels, one of which also includes a rate-sensitive rolling ball. Key illumination provides state indication, under program control, an example being communications call-states, where the steps in the interconnection sequence between caller and called, are indicated by steady and flashing illumination.

The keyshelf also accommodates the coding, decoding and multiplexing circuits for the PCM speech channels, with provision for individual adjustment of received signal level, and noise injection for operator training purposes. In the dual-operator role, both operators have available for independent selection the full range of ground-ground and ground-air channels, within the overall constraint set by the channeling capacity. A conference facility is also selectable.

Processor

Powerful local processing is provided in the work station to minimise the communication load with the DHS and improve the response time to operator inputs. A LOCUS system performs distributed multi-processing, intelligent processors being linked by a standard parallel high-speed bus to each other, and to global



RAM. Further ROM and RAM is available to them on-card. Dual-ported RAM storage is also provided. The LOCUS concept, described by Watkins (1), has been developed continuously, in-step with advances in integrated-circuit technology, and has been applied successfully to a variety of air and naval defence and air traffic control systems.

The particular LOCUS configuration used in the work station is shown in Figure 4. Three Arithmetic Logic Processors (ALP) are fitted of two types. One of these, (ALP6), uses bit-sliced LSI technology to provide a general-purpose machine, with two-level program operation and special instructions to facilitate program switching, whilst the other type, (ALP4), employs a commercial microprocessor, driven by instructions held in a 64 kbyte on-card ROM, with 16 kbytes on-card RAM.

Global RAM may be provided by inserting a selection of 64 kbyte and/or 512 kbyte single-port, single card modules. A store management module on the bus extends the address range to 1 Mbyte, each ALP having access at a given time to sixteen 4 kbyte blocks forming a regime. Regimes are allocated on a per-processor basis under software control, allowing both exclusive and shared use of 4 kbyte blocks as required. A 128 kbyte dual-ported RAM module provides refresh storage for the graphics display's data.

Two types of intelligent communications processor serve the high-speed and low-speed communications links to the DHS. Two microprocessors on the high-speed module manage the protocol-handling, filtering and direct memory access functions, and provide automatic memory addressing by data type. The communications processors both include local RAM storage for

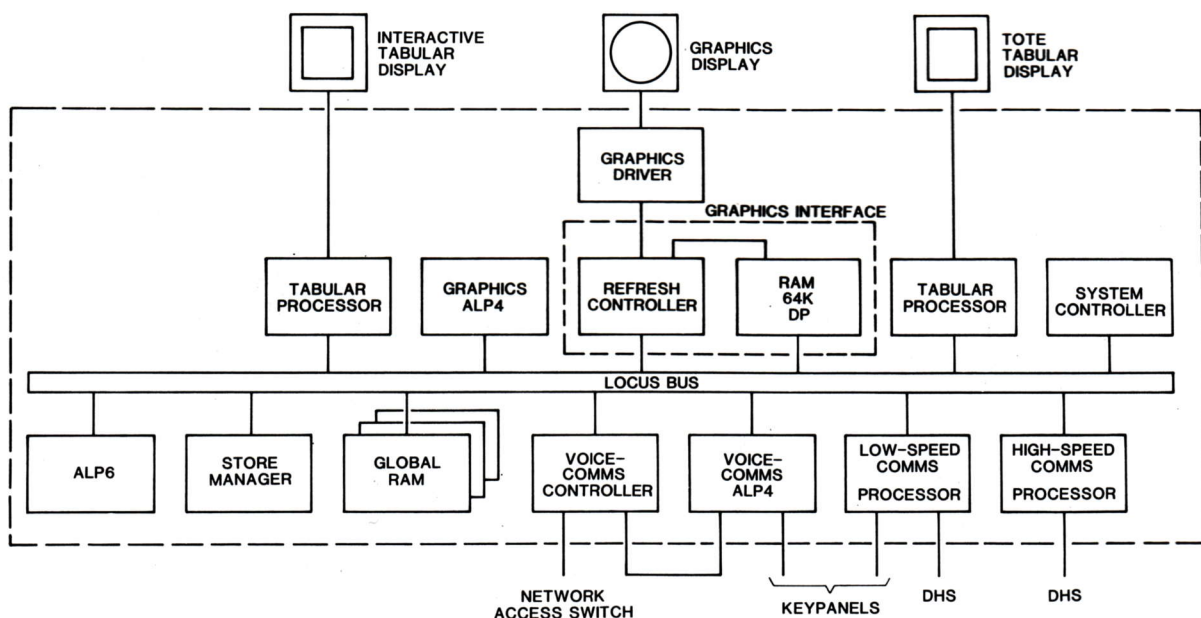
message buffering and obey instructions held in local ROM. In addition to its main role, the low-speed processor services the rolling ball, and keys, excepting the voice communications keys.

Each of the three displays is served by its own controller, interfaced to the LOCUS bus. The identical raster display controllers are fitted with microprocessors, ROM and RAM to allow considerable autonomy of operation. The on-board refresh store is directly accessed to provide scrolling and windowing. A ten thousand character capacity logical picture can be freely windowed by up to 128 logical display frames for presentation on the physical display, which can present up to 40 lines of 80 characters. With the addition of a second board, the controller provides a full graphics capacity.

The dual-port store used for main graphics refresh is managed by an ALP4, and is partitioned according to displayed data-colour, to minimise display EHT switching, reducing dissipation and dead-time.

Comprehensive voice communications handling is provided by two powerful dedicated modules resident in the processor unit, an ALP4, and a microprocessor supported controller. This ALP links with the communications controlling keys, and via the LOCUS bus, with the central DHS. In addition to accepting key-action inputs, it also controls key illumination, and the switching and mixing of channels according to parameter tables received from the DHS. The communications controller executes these switching and mixing functions and interfaces the coded speech channels to the network access switch, multiplexing them with the channels of up to three other work stations.

IUKADGE PROCESSOR



Processor Software

One of the principal benefits expected from the initial introduction of software-controlled data processors into air-defence systems was flexibility – promising user-freedom to recover from errors in the specification of operational requirements, and to adapt to changing needs.

Unfortunately, primitive software design techniques, and gross under-estimations of program sizing, frequently resulted in software which was virtually untouchable after delivery. Progressively things improved, and developments such as table-driven software made role-changing at a work station feasible. They also made it practicable for the user to avoid releasing sensitive weapon-performance and map data to the supplier. However, a further development was needed before the user could readily adapt a particular role to an evolving need, namely, a means of easily creating or modifying the tables. A special high-order language, known as the Position Description Language (PDL) has been produced for this purpose in IUKADGE. Through it, the user can change the detailed behaviour of the work station in the performance of a particular role completely, transforming the way in which data is displayed, and the response to key actions and system inputs. To execute a change, the user accesses a bureau computer via a terminal, which offers the normal keying facilities of a visual display unit (VDU). Using PDL and a query-assisted input dialogue, the specific requirements for the work-station are entered and checked against a dictionary which defines the bounds of the on-line system. From them the computer generates a new set of position definition tables, which can be directly loaded into the appropriate DHSs over the data network and the work stations can receive them at the next log-on of operators for that role, subject of course to any procedural checks which the user may wish to introduce. The DHS receives information about the role required at log-on via the low speed link.

The operational software is loaded into the work station by a two-stage process and is initiated from an engineer's control position at the operational site. A bootstrap is first sent to it via the low-speed link from the DHS, followed by the main load over the high-speed link.

This software and the firmware resident in the many processors within a work station are common to all of the universal stations and unaffected by changes in the tables. Programs have been developed for on-line and off-line diagnostics, as well as in support of a software development bureau.

OTHER FEATURES

The work station is powered by a battery-backed unit incorporating switched-mode power modules and microprocessor supported monitoring and fault diagnostics.

Extensive built-in test (BITE) facilities are incorporated; for example, every processor module runs on-line test programs interleaved with the applications programs, reporting fault

occurrences and recording diagnostic data automatically. Extensive data checking takes place, with some automatic error correction.

Provision has been made for connecting powerful diagnostics equipment directly to the LOCUS bus, as well as to each module individually, for both on-line and off-line testing.

Great care has been taken in the design to protect data against interference from outside the work station, and to avoid the leakage of secure data. For example, all of the enclosures are constructed of folded and welded sheet metal with necessary apertures well protected to strongly attenuate electromagnetic penetration. Interconnections have been made using triple-screened cable, optical fibres, etc., as appropriate.

In addition to the principal work station, single-operator positions are required for alpha-numeric data handling only, and large screen displays have to be driven. The modular nature of the LOCUS system has made it possible to achieve extensive commonality of hardware with the main work stations. Similarly, economics in software development have been achieved.

Other types of man-machine interfacing device are easily implemented, for example, touch-masks are available for menu selection and accurate position-entry, and a fully chromatic raster-graphics display can be introduced for those applications in which colour-filled boundaries or very detailed mapping are required.

CONCLUSION

The powerful IUKADGE universal work station marks a significant advance in the development of cost-effective system components to meet C³I needs. It has made it possible to implement a large multi-level system with work stations which are identical from a hardware and operational software viewpoint. The detailed functions provided for any particular role are determined by tables which can be generated readily off-line, using a high-order language, and are stored in the data-handling system for loading into the work station at log-on. This provides the user with the capability of changing the detailed characteristics of the system to meet evolving requirements.

ACKNOWLEDGEMENTS

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