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PROTOTYPING AIR SURVEILLANCE DISPLAYS (THREE PROTOTYPING DISPLAY ACTIVITIES)

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ABSTRACT

There are a number of display prototyping tools and techniques that have recently surfaced. These tools and techniques rely on the new Reduced Instruction Set Computer (RISC) based workstations and many of them use standards such as X-Windows and Graphic Kernel Set (GKS). E-Systems has been investigating a number of these tools and techniques for various air surveillance applications. This paper will describe three prototyping activities. The first prototyping activity was an air surveillance application using Over-The-Horizon (OTH) sensors, the second activity was a missile warning application, and the third activity was an air surveillance application using long-range primary and secondary radar. The missile warning application has a display that looks and feels significantly different from the two air surveillance applications. However, with the use of a prototyping tool, not only has the man-machine interface (MMI) matured very quickly for all three applications, but the underlying tools were also capable of effectively supporting the runtime environments. This paper will also identify a number of these tools and where E-Systems currently believes these tools can be most appropriately applied.

BACKGROUND

In 1989 E-Systems began examining the requirements of a program to integrate new sensors into the existing Joint Surveillance System (JSS). A new program would use an existing prototype as a foundation to support the integration of new sensors such as OTH into JSS. The existing prototype managed track data in tabular format. E-Systems concluded this was a severe limitation and began developing a concept for using an air situation display and tabular information to manage the track data. The dilemma was to find a cost effective solution for providing an air situation display not unlike what is found in the current FAA's Enroute Sector Suite Radar position.

The search for an air situation display solution began with traditional views of the technical issues and a traditional technical approach. It was assumed that custom hardware and software would be required to support the subsecond response time requirements of functions such as range scale and offset. Vendors in the turnkey display business were examined and in some cases contacted. Further, formal product evaluations with vendor visits and presentations were initiated. The solutions that surfaced were unacceptable from a cost and requirements point of view. If all the requirements were satisfied the costs were prohibitive. If the costs were considered reasonable only a small subset of requirements were supported.

The search for an effective air situation display solution soon became diverse and included developing a custom solution using internal engineering resources to an examination of prototyping software and RISC commercial workstations. E-Systems established a lab in 1989 to verify the feasibility of using prototyping software and RISC commercial workstations (ref. 1). What emerged from that experience is a new way of thinking about air situation displays and a series of activities which resulted in the development of three separate MMI's using a rapid development/rapid prototyping tool.

Man-Machine Interface 1 – OTH Prototype

The first MMI that was prototyped supported the new "OTH JSS" integration program (figure 1). Since there were no detailed requirements for the situation display on this program, E-Systems had a free hand in conceiving the look and feel of the interface. The primary system requirements were to receive, filter, and forward air/surface/subsurface track data to the collocated JSS or other command centers. The prototype was a stand-alone device using an internal track simulator as part of the rapid prototyping tool package.

Early in the activity it was decided that all actions would be based on variable function keys, fixed function keys, tables/lists, keyboard entry and trackball/mouse actions. The function keys would be displayed on the CRT, preferably in a manner that would not obstruct the view of the track data on the situation display. The track symbology was based on a combination of air traffic control (ATC) track symbology and air defense track symbology. Limited and full data blocks were displayed near the track symbol and a plethora of display filters were provided to declutter the display. The filters included static overlay filters such as maps, cities, airbases, airports, nav aids, landmarks, sectors, ADIZ, etc. The filters also included track filters

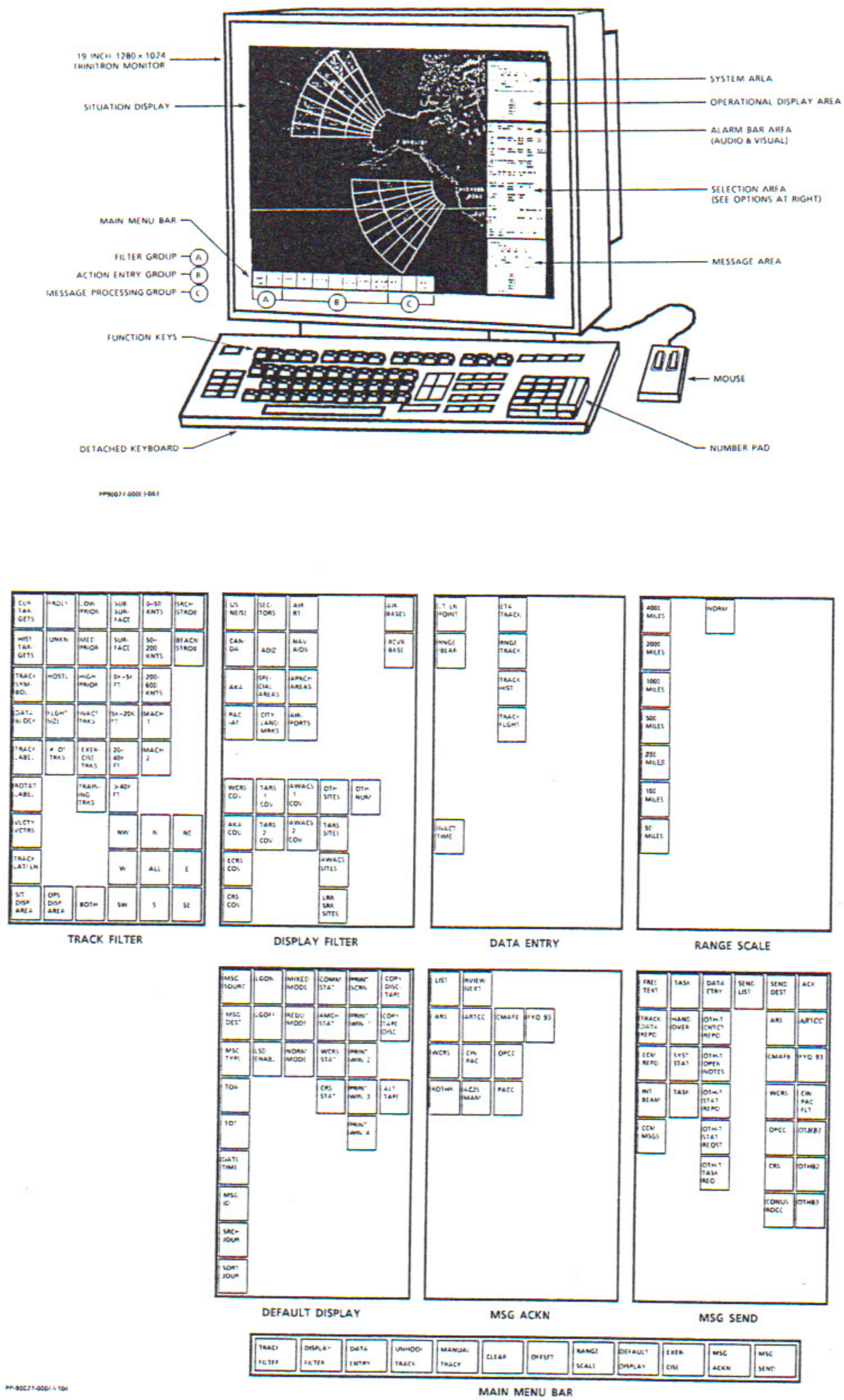

Figure 1. Man-Machine Interface 1 (OTH Prototype)

MAN-MACHINE INTERFACE TRADE-OFF

EVALUATION CRITERIA	ALTERNATIVES					
	1	2	3	4	5	6
Track Presentation	3	2	3	3	1	1
Message Presentation	3	2	3	1	2	1
Display Performance	1	3	3	2	1	2
Growth and Expansion	1	2	3	1	1	2
Hardware Portability	1	1	3	1	1	3
Software Complexity	1	2	3	1	1	2
Maintenance	1	2	3	1	1	2
Schedule Risk	1	2	3	2	1	1
Cost Risk	1	3	2	1	1	3
Technical Risk	1	2	3	2	1	1
Total	14	21	29	15	11	18
Grade	1.0	1.6	2.2	1.1	0.8	1.3

3 = Excellent 2 = Fair 1 = Poor

Selection Rationale:

- Low Risk from COTS
- Responsive Performance
- Ease of Modification
- Eliminates 200,000 LOC Display Development
- Truly Platform Independent

Alternatives:

- Build New
- Virtual Prototypes
- Intermapics
- Hughes Trackview 100
- TRW Tromni/vista
- E-Systems ESY View

EVALUATION CRITERIA	ALTERNATIVES						
						TURNKEY DISPLAYS	
	1	2	3	4	5	6	7
Performance	3	3	3	2	3	2	1
Hardware Reliability	3	2	3	3	3	2	1
Software Reliability (UNIX, etc.)	1	3	3	3	2	2	1
Growth and Expansion	3	3	3	2	3	1	1
Flexibility	3	3	3	3	2	1	1
Open System Commitment	1	3	1	2	2	1	1
Software Development	2	3	2	2	2	1	1
Logistics Support	3	3	1	1	1	2	1
Maintainability	3	3	2	3	3	1	1
E-Systems Lab Experience	1	3	2	2	None	None	None
Schedule Risk	2	3	2	2	2	1	1
Cost Risk	1	2	1	3	1	1	1
Technical Risk	1	3	3	2	2	1	1
Total	27	37	29	30	26	16	12
Grade	2.0	2.8	2.2	2.3	2.0	1.2	0.9

3 = Excellent 2 = Fair 1 = Poor

Alternatives:

- IBM
- DEC
- Silicon Graphics
- SUN
- HP
- Hughes
- Aydin

Figure 4. Prototyping Tools and Hardware Platforms

such as type, priority, speed, altitude, heading, history, etc. There were also functions such as track calculations, range scale, offset, and message control.

The main menu bar supported 12 buttons that were approximately .75" square. A single main menu bar button supported three rows of five characters each to define its function. The submenus contained 6 columns × 9 rows of buttons for a total of 54 buttons. The submenus measured 2.75" × 4.75". The intent was to use 56 pixels in the horizontal direction of the 1280 × 1024 resolution display to provide a situation area of approximately 1024 × 1024 pixels. The buttons themselves were 2-state or 6-state (two for current tracks, two for hooked tracks, and two for new tracks) with a simple "box like" look. There was a gray background panel, the buttons were a lighter shade of gray-blue in the off state and light green in the on state. There was a small border around each button, again another shade of gray.

Color was also used in the situation display that included hostile tracks (red), unknown tracks (yellow), identified tracks (green), map (green), sectors (white), and shades of green for cities, landmarks, airports, and airbases.

The MMI was designed primarily by two individuals at E-Systems in approximately two days. The two designers captured their view of the MMI design using a storyboard technique. Each storyboard defined a single screen. There were approximately 60 storyboards developed for the prototype MMI design. These storyboards were then used to implement the MMI design. The implementation took approximately 30 days and was performed by the rapid prototyping tool developer. Once the "configured" product was delivered to E-Systems, it took approximately one week to finalize the MMI design and implementation. This was performed by one of the E-Systems MMI designers who changed roles and worked with the tool using "phone" assistance from the tool developer when required.

The whole point of this exercise was to prove that this was a valid low risk approach to providing a situation display for the "OTH JSS" integration program. This approach was based on commercial workstations, a rapid development/prototyping tool, and a strawman MMI design.

Man-Machine Interface 2 – Missile Warning Test Display

The second MMI supported an internal demonstration of a missile warning application. E-Systems provides a number of subsystems for the BSTS program and it was determined that an end-user display could be used to illustrate the features of these subsystems. The approach was based on the OTH prototype experience of using RISC commercial workstations and rapid development/rapid prototyping software. In this case, the display was interfaced to these subsystems using an RS-232 interface and a simple track create, update, and delete ASCII protocol.

The first job was to determine what the users, in this case the E-Systems developers of the BSTS subsystems, wanted to see on the display. This was not a trivial activity and required several iterations of the MMI design. The first iteration included the display of missile trajectories projected on the surface of the earth and certain satellites with their area of coverage. The second iteration involved the display of only launch points and projected impacts that "fanned" out from the launch points, and a message window. The final iteration (figure 2) displayed launch points, projected impact points using circles and lines that connected the launch point to the impact point, the missile trajectory, and a message window.

The missile warning MMI was based on the OTH prototype MMI. However, by the time all the changes occurred, the look and feel of the display was significantly different. The changes included modifying the track filter, display filter, and range scale submenus. Two views of a world map were installed and made selectable from the display filter submenu. At one point a satellite view of the earth was considered but eventually discarded. New track types and their associated symbology were created to represent the launch points, impact points, and trajectories.

Only three of the menus were used from the prototype and they were modified to reflect new functions and new terminology. The changes in the track filter submenu included removing the altitude and speed filters and adding launch, impact, trajectory filters, and changing terminology to threat, non-threat, and unknown. The display filter submenu was modified to provide map projection selection and satellite coverage filters. Since a world map was installed, the range scale was modified to include selection of up to 30,000 miles.

This MMI was also implemented using a rapid development/rapid prototyping tool. The tool vendor provided the first implementation of this second MMI in approximately three weeks and E-Systems significantly modified that implementation over the next 30 days. These modifications were driven by user requirements and comments.

Although initial work was on an XD8810 workstation from Tektronics, E-Systems hosted this second MMI on a DEC 5000, DEC 3100, and a Sun SPARC 2 with no change in the MMI design. The bottom line is that open systems do exist at some level and they have gone beyond being open just at the local area network.

Man-Machine Interface 3 – Air Surveillance Display

In this case, E-Systems prototyped a system which uses this third MMI as part of the total system solution. This program is currently in source selection. The E-Systems solution was demonstrated in late June of 1991.

The third MMI (figure 3) abandoned the screen layout of the first two MMI's in terms of information layout and button structure. The main menu was physically reduced and placed under the submenus or selection area. All of the buttons were reduced in vertical size. The buttons themselves were modified to simulate the mechanical structure of a real button with the use of careful shading. Further, the customer has a number of these types of systems operational, such as JSS, and there was significant direction in the area of track symbology and associated track data. Effectively, there is a significant base of functionality and preconceived notions about how the system should operate. This was not the case in the first two MMI prototyping activities.

In this case the MMI was developed using a customer specification that contained some detail about how it could be structured. E-Systems chose to follow this structure and many buttons in the track and display filter submenus of the first two MMI's were interchanged and mixed on two new submenu's: category select and feature select. The track calculations, speed filters, altitude filters, and track type filters were added by E-Systems and are not part of the current customer specification.

The most significant change in the MMI was driven by the amount of track data. In the first two MMI's the hooked track data appeared as part of an expanded data block. In this case a separate hooked track window was provided while the feature select panel was used to control the amount of data displayed in the "limited data block." It contains filter buttons for each field of the data block on the situation display. Several new submenus were added and a summary of all the submenu functions is provided below:

Category Select – Filters static areas on the display and filters broad categories of track data.

Feature Select – Filters data block fields shown on the display and filters tracks based on speed and altitude.

Range Scale – Provides traditional range scales and non-traditional features which permit the selection of predefined centers and range scales based on console defaults and air base locations.

Track Control – Provides the ability to initiate tracks, assign tracks, drop tracks, and create manual tracks.

Pilot Control – Used in simulation and provides the simulation pilot operator to control up to ten airplanes.

Console Control – Permits the operator to create special areas, print tabular or situation data, and set the local time of day.

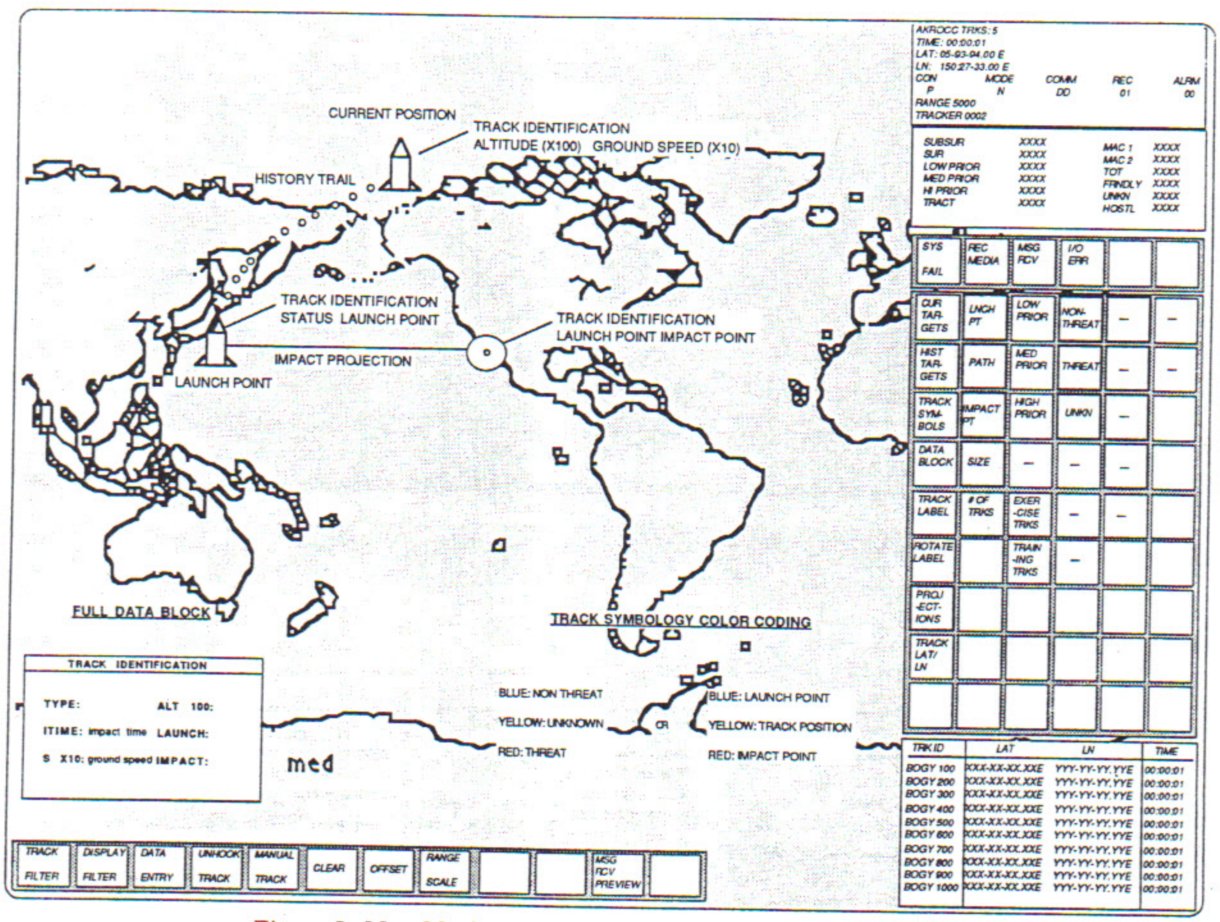

Figure 2. Man-Machine Interface 2 (Missile Warning Test Display)

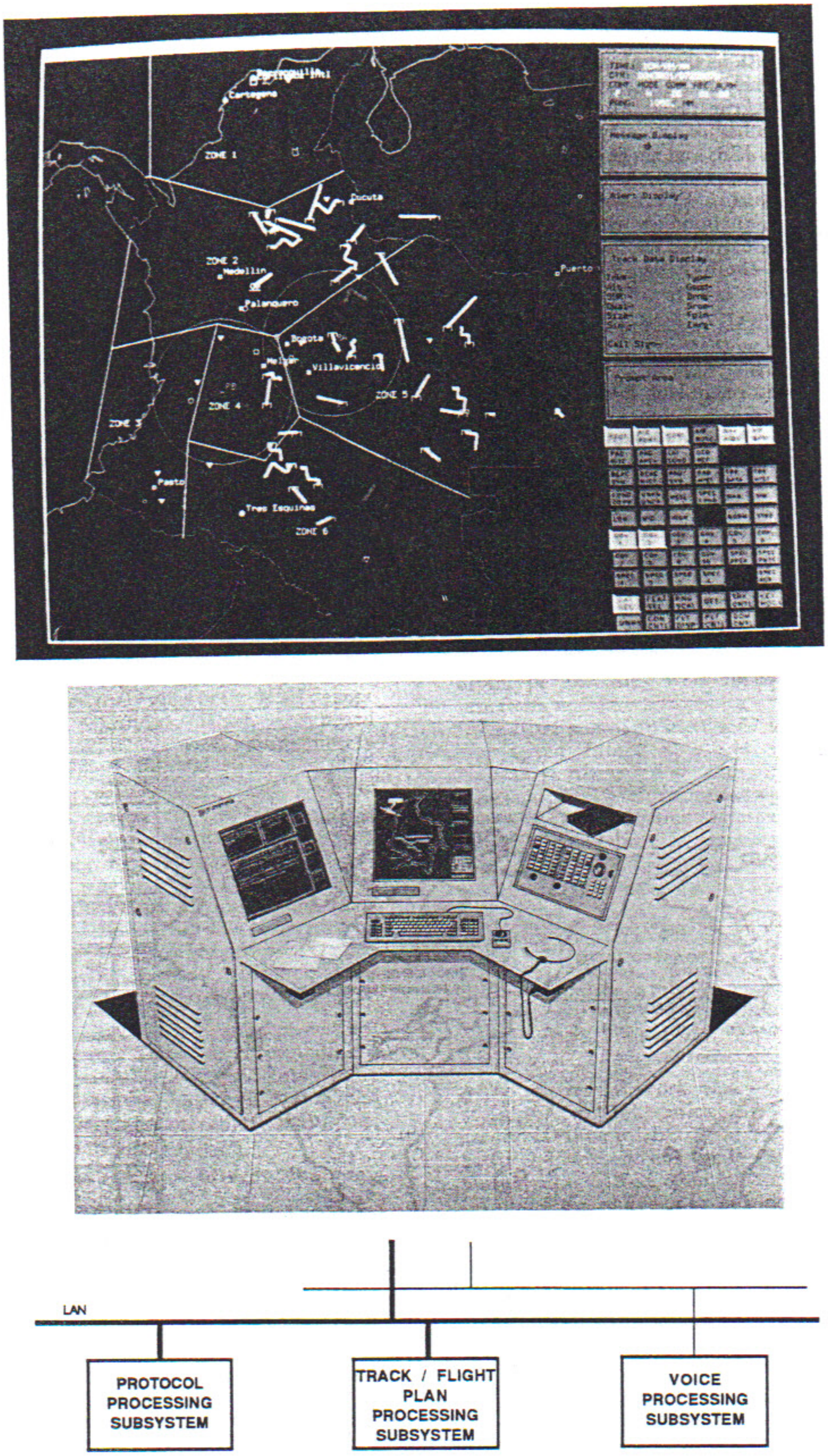

Figure 3. Man-Machine Interface 3 (Air Surveillance Prototype)

DQM Control - Permits various radar data to be filtered from DQM display, and provides various system management functions such as setting the system time.

This MMI was the most elaborate of the three MMI's developed. The MMI was designed and implemented in approximately two months.

TOOLS SUMMARY

As part of these efforts, E-Systems has conducted comparative trade studies of traditional versus new prototyping display approaches as shown in figure 4. These studies show that there has been a technology shift in display hardware and display software. It is now possible to purchase a commercial workstation with reasonable resolution (1280 × 1024) and support a responsive air situation display. Further, the underlying software no longer needs to be coded in a language, such as "C," and "interface" directly with the graphics generator. Instead, "binding" with various graphics generators can occur using standards such as GKS and/or X-Windows. Further, implementing the MMI can be accomplished using techniques other than a traditional language, such as "C". For example, one rapid development/rapid prototyping tool implements the MMI using a Data/Dialogue Definition Language (DDL). E-Systems has implemented the MMI's described in this paper with less that 16,000 lines of DDL. E-Systems estimates that 200,000 lines of "C" code may have been averted with the use of this tool.

There has been some internal discussion about rapid prototyping and rapid development. In the case of rapid prototyping, tools are available that permit static displays to be implemented in a few days. In the case of rapid development, tools are available that permit turnkey operational displays to be implemented in two weeks. What is the difference? In either case operators can sit down side-by-side with the tool expert and finally see his or her view of the MMI on the screen in real time. Further, operators can be trained in a reasonable amount of time to use these tools to implement MMI's using only their imagination and a commercial workstation.

There are analogs to this approach in other industries. For example, there are a number of tools in the process control industry from companies such as Nematron, Xycom, Wonderware, Azonicx, Arora, etc.

CONCLUSIONS

Two years ago there were legitimate doubts regarding whether a process of the type described in this paper and the new technologies would work. Traditional air surveillance displays utilize very different technology. E-Systems tried using this new technology to see if it really could provide a viable solution.

There are enormous implications to this change. There is a big difference in viewing an MMI design using graphics such as in this paper or operational sequence diagrams and transaction flows such as in a formal program and just sitting down and watching the real thing in operation in real time with no editing. The implications go beyond the contractor's ability to offer a unique solution to a program and include the characteristics of the entire program. For example, unless a 20" × 20" display is required, the entire solution can be based on commercial hardware using standards (X-Windows, UNIX*, etc.) which permit the architecture to become truly open. The MMI can be implemented to some level prior to contract award as part of the proposal and matured during the execution of the contract with weekly releases. In the past, more time and resources were required to implement the MMI in a language such as "C" than to conceive the MMI. This is no longer the case. Currently it may take more time and resources to conceive the MMI and develop a useful consensus on that MMI than to implement it using a rapid development/rapid prototyping tool.

There is an important issue that does need to be addressed and that is the issue of programs which are new with minimal preconceived notions of the MMI design and programs which replace existing infrastructure. The third MMI design in this paper may fall into the latter category. Before the "new" MMI is matured, all the existing nuances of the previous MMI must be captured to ensure that the "replacement" system is as good as the "old" system. This is not a trivial task and duplicating an existing infrastructure that took decades to develop using old techniques will never provide a solution above and beyond the original "old" system capabilities.

*UNIX is a product of AT&T Corporation.

REFERENCES

1. Walter Sobkiw, "The Potential Use of Over-The-Horizon Sensors for Oceanic Air Traffic Control", 1990 ATCA Proceedings.
2. Ralph E. Whitney and Thomas B. Allen, "Selecting a Graphical Interface for Air Traffic Control Radar Simulation", 1990 ITSC Proceedings, pp. 150-156.
3. Cynthia Hubbell, "The Benefits of Desk Top Rapid Prototyping", 1990 ITSC Proceedings, pp. 313-319.
4. K. E. Ufelman, "Flying 800 Planes Simultaneously via Simulation", Photonics Spectra, April 1991, pp. 108-110.
5. I & CS, "Special Report On: Operator Interfaces", May 1991, pp. 53-85.