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# NAVAL POSTGRADUATE SCHOOL
## Monterey, California

REAL-TIME GRAPHICS IN SUPPORT OF
THE UNIFIED NETWORKING TECHNOLOGY PROJECT:
A PROGRESS REPORT

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The Naval Postgraduate School's Graphics and Video Laboratory is halfway through the first year of a project in support of the Naval Ocean Systems Center's Unified Networking Technology (UNT) project. NPS's goal is to develop real-time computer graphics displays of network status for that project. In this report, we propose (1) an appropriate set of displays (2) a user interface to select and modify these displays (3) an architectural design for this display (which we have entitled UNETGRAF) and (4) a progress report on UNETGRAF development to date.

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# Real-Time Graphics in Support of the Unified Networking Technology Project -- A Progress Report ‡

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*ABSTRACT*

The Naval Postgraduate School's Graphics and Video Laboratory is halfway through the first year of a project in support of the Naval Ocean Systems Center's Unified Networking Technology (UNT) project. NPS's goal is to develop real-time computer graphics displays of network status for that project. In this report, we propose (1) an appropriate set of displays (2) a user interface to select and modify these displays (3) an architectural design for this display system (which we have entitled UNETGRAF) and (4) a progress report on UNETGRAF development to date.

‡ This work was supported by a grant from the Naval Ocean Systems Center, San Diego.

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## 1. INTRODUCTION

The Naval Ocean Systems Center (NOSC) Unified Networking Technology (UNT) project is a large scale feasibility study whose goal is to demonstrate, during FY1990, a highly robust and survivable naval battle group communications networking system which supports data and voice in broadcast and point-to-point services using HF and UHF media. In support of the UNT project, the Naval Postgraduate School's Graphics and Video Laboratory has begun developing a real-time computer graphics display subsystem for UNT. The following are the objectives established for this subsystem, which we have entitled UNETGRAF [ZYD87]:

(1) Determine computer graphics displays that best convey in as rapid a manner as possible the information flow and message routing activities within the UNT network.

(2) Propose a user interface for this system that will facilitate the use of these displays.

(3) Develop a portable prototype UNETGRAF system on the NPS Graphics and Video Laboratory's IRIS graphics workstations.

Discussions with NOSC personnel [GRI87] have provided sufficient information on the tasks and environment of prospective UNETGRAF users for us to formulate our answers to objectives (1) and (2). In this memorandum, we (1) present these results and (2) describe the architectural design of our prototype.

## 2. METHOD OF STUDY

Neither UNT nor UNETGRAF are existing systems. Thus the starting point for our systems analysis was an examination of UNT requirements specifications as set forth in [CAS86]. This reference identifies three functional modules within UNT: Link Controller (LC), Multinetwork Controller (MC) and Network Administrator (NA). Discussions with NOSC personnel [GRI87] confirmed some significant inferences:

(1) MC functions correspond closely to those of the Network layer of the International Standards Organization (ISO) Open Systems Interconnection model.

(2) LC functions correspond closely to those of the Link layer of the ISO model.

(3) The NA is a storage module that manages the data used by the LC and MC and despite its name, does not perform any network management functions.

(4) UNT network architecture closely resembles that of a distributed packet radio network.

Thus the ISO Open System Interconnection model and packet radio networking have provided the framework for fitting these UNT modules into a more familiar context. Within this framework, many references are available. [STA85] contains a good description of packet radio networking issues including distributed routing protocols and the special problems associated with mobile network nodes. [HER82] provides a highly readable introduction to packet radio networking as well as an algorithm for solving the distributed routing problem. [TAN81] remains a standard reference for detailed descriptions of each layer of the ISO model.

As for drawing a *picture* of an operating network which is of any cognitive value--here we encountered a major and unexpected hurdle in our study. Available literature on graphics-based network monitors proved to be minimal and the one such system we were able to examine, Digital Equipment's DECNet Monitor, provides some high level views of connectivity but quickly gets into text-based displays as one descends in detail. More on this issue of "meaningful" pictures in the Analysis section below.

Finally, user interface issues seem to invite emotional debate or, at best, subjectivity. We unapologetically base our prototype's user interface on Macintosh-like principles. These are, quite simply, the de-facto standard for interactive graphics applications. Our rationale is more fully discussed below.

## 3. ANALYSIS

### 3.1. OBJECTIVES

To review, UNETGRAF's objectives are :

(1) Determine computer graphics displays that best convey in as rapid a manner as possible the information flow and message routing activites within the UNT network.

(2) Propose a user interface for this system that will facilitate the use of these displays.

(3) Develop a portable prototype system.

We discuss our reasoning and results for the first two objectives below.

## 3.2. NETWORK DISPLAYS

The ISO model defines the levels of detail in any network. Specifically, the network layer is concerned primarily with routing decisions that are based on the connectivity, utilization and error statistics collected on the activities of the link layer. Within UNETGRAF, we are concerned with depicting the activities of the network and link layers of a packet radio network.

Networks have traditionally been represented by directed graphs. But directed graphs alone are an abstraction--a mental step is required to convert vertices and edges into the real thing. The UNT network consists of physical radio equipment aboard real ships and aircraft at actual locations. If possible, it should be so depicted.

Displaying network nodes in a proper geographical context also permits the effects of range, terrain, weather and enemy action (e.g., jamming) to be more easily seen. Though the network itself cannot be expected to provide location information, the ship's combat reporting system (i.e. NTDS) provides a ready made source of positioning data. The NTDS display with its familiar symbology provides an excellent initial picture upon which the network picture can be overlaid. Selectable network routing and connectivity overlays provide a highly usable picture to anyone who must engage the enemy in electronic battle.

Correlating a UNT network node with its matching NTDS contact is a necessary and non-trivial step in this scheme. Also some cost will be involved in providing real-time NTDS data to UNETGRAF; however, the realism and usability of the resulting display offset these factors.

Node level activities (e.g., packet counts) represent a step down in detail. Their depiction should be available on demand, but is most appropriately displayed in a window that can be called up when it becomes necessary to more fully analyze routing or connectivity problems.

## 3.3. USER INTERFACE

UNETGRAF is a network monitor system, not a control system. Thus user interaction can be limited to moving about on the network display and going up or down in detail. In particular, no requirement for text input is anticipated, so the only user input required is "picking" done by either a mouse or trackball.

Menus are to be minimized. Though they are recommended for the system novice, menus are longwinded and frustrating for most other users. Balancing this requirement with the high degree of functionality required of the UNETGRAF system does present a usability challenge for the designer of the user interface. The answer lies in establishing several "modes" of user interaction.

Ideally, UNETGRAF should be completely modeless. That is, a specific user input should not have different results depending upon the systems "mode" or state. If it is necessary to change modes, a positive, continuous and easily recognized indication of the mode change should be made. A familiar example of this concept is the Macintosh MacPaint application which provides the user with a "palette" of what are essentially mode changes. For instance a paint bucket fills polygons, a pencil draws lines, etc. A selection from this "palette" highlights the selection and changes the user's cursor, providing all the visual cues necessary to convince the user that the system is responding consistently to his input. Such techniques are now accepted standards in interactive graphic applications and are incorporated within UNETGRAF's user interface. (See Appendix B for annotated sample displays.)

## 4. UNETGRAF ARCHITECTURAL DESIGN

### 4.1. OVERVIEW

Since UNETGRAF is presently a protype system, we have concentrated our design effort on inter-module communication rather than detailed module development. The issues of portability, evolution and repair have been given major emphasis. Specifically, we have:

(1) defined "public" record types for *individual* NTDS contacts and *individual* network nodes. A list of NTDS contacts is maintained by the NTDS Storage module. A list of network nodes is maintained by the UNT Storage module. See Appendix D for formats of these records.

(2) provided each module with the minimum set of "public" functions to permit inter-module communication but hide (in the software engineering sense) "private" data structures.

The subject of inter-module communication brings up an alternative to the single-process implementation of our prototype. It is likely that a "production" UNETGRAF system might instead consist of several cooperating processes which individually run the UNT Storage, NTDS Storage, UNT/NTDS Correlation, and User Interface/Display modules. This alternative is mentioned because it bears on the subject of minimum host system requirements which we discuss briefly below.

## 4.2. MODULE DESCRIPTIONS

*Inter-module Communication.* See Appendix C for a high-level view of module interaction.

*UNT Storage Module.* The purpose of this module is to (1) maintain statistics on link-level protocol performance and (2) maintain current information on network connectivity and message routing. Our prototype generates and updates link-level statistics and connectivity values by pseudo-random number-based functions. Based on these connectivity values, we compute and store shortest paths between all pairs of nodes in the network using a variation on Djikstra's shortest-path algorithm [HOR83].

*NTDS Storage Module.* The purpose of this module is to maintain current information on NTDS tracks. Our prototype initially reads a list of contacts from a text file. The update process involves randomly selecting an existing contact for a random course and/or velocity change. Duration between updates is declared as a constant.

*UNT/NTDS Correlation Module.* The purpose of this module is to determine the proper display symbol and position for a network node. We do this setting up tables that permit UNT and and NTDS records to be cross-referenced. In the present implemention, we make the tractable assumption that the NTDS record maintained by the NTDS Storage module (See Appendix B) will contain the UNT network address,if any, of the NTDS contact.

*User Interface Module.* This module allows the user to select network overlays to the default

NTDS display, alter the default NTDS display, and move between the network and link level displays of the UNT network. The main() function is included in this module.

*Display Modules.* See Appendix B for the graphics screens generated by these modules. The Node Detail Display module is not yet implemented.

## 5. UNETGRAF SYSTEM REQUIREMENTS

UNETGRAF does not require three-dimensional graphics, shading or other advanced computer graphics features. However, a considerable volume of information is required to display the real-time workings of a communications network, particularly a distributed packet radio network in which rapid reconfigurations are a normal occurrence. When this network picture is provided as an overlay to a tactical display, peak graphics loads are even higher.

We recognize that physical constraints should be imposed as late as possible during system development. However, our work with the UNETGRAF prototype has convinced us of some minimum host system requirements:

(1) Font building and editing facilities are needed for the specialized characters used in tactical and network displays.

(2) High performance graphics hardware is needed to handle the graphics loads described above.

(3) Assuming that UNETGRAF is eventually implemented not as a single process but as several cooperating processes (as described above), a multi-tasking operating system with adequate inter-process communication facilities is needed.

## 6. PROGRESS REPORT

UNETGRAF development is on schedule. With the exception of the Node Detail Display module, all modules have been implemented and tested. The user manual and detailed prototype system documentation will be completed by 15 June 1987.

## 7. CONCLUSIONS

We have described the network displays that are appropriate for depiction of UNT status and operation. The nature of these displays as overlays to the NTDS display has been emphasized. A Macintosh-like user interface has been proposed. An architectural design for UNETGRAF has been described and some features of the current individual modules discussed. Some minimum requirements for any host system on which UNETGRAF is to be implemented have been stated.

## APPENDIX A (REFERENCES)

[CAS86] Casey, Roger, "Advanced Technology Demonstration (ATD) Phase I Program Plan for Intra-Battle Group Networking (UNT/DCS)", Naval Ocean Systems Command, 4 December 1986.

[GRI87] Griggs, L. W., "Memorandum for record: Discussions between Mr. Roger Casey (NOSC UNT Project Manager) and L. W. Griggs (NPS thesis student) on 27-28 Jan 87", dtd 2 Feb 87.

[HER82] Heritsch, Robert R., "A Distributed Routing Protocol for a Packet Radio Network", Master's Thesis, Naval Postgraduate School, Monterey, California, March 1982.

[HOR83] Horowitz, Ellis and Sartaj Sahni, *Fundamentals of Data Structures,* Computer Science Press Rockville, MD:1983.

[MON84] Monk, Andrew, *Fundamentals of Human-Computer Interaction* , Academic Press, London: 1984.

[STA85] Stallings, William, *Data and Computer Communications* , Macmillan, New York: 1985.

[TAN81] Tanenbaum, Andrew, *Computer Networks* , Prentice Hall, Englewood Cliffs, NJ: 1981.

[ZYD87] Zyda, Michael, "Research Proposal: High Performance Interactive Graphics for a Multinetwork Controller Monitoring Station (NPS Reference NC4(52ZK)/mjz)", dtd 6 Jan 87.

## APPENDIX B (SAMPLE DISPLAY SCREENS)

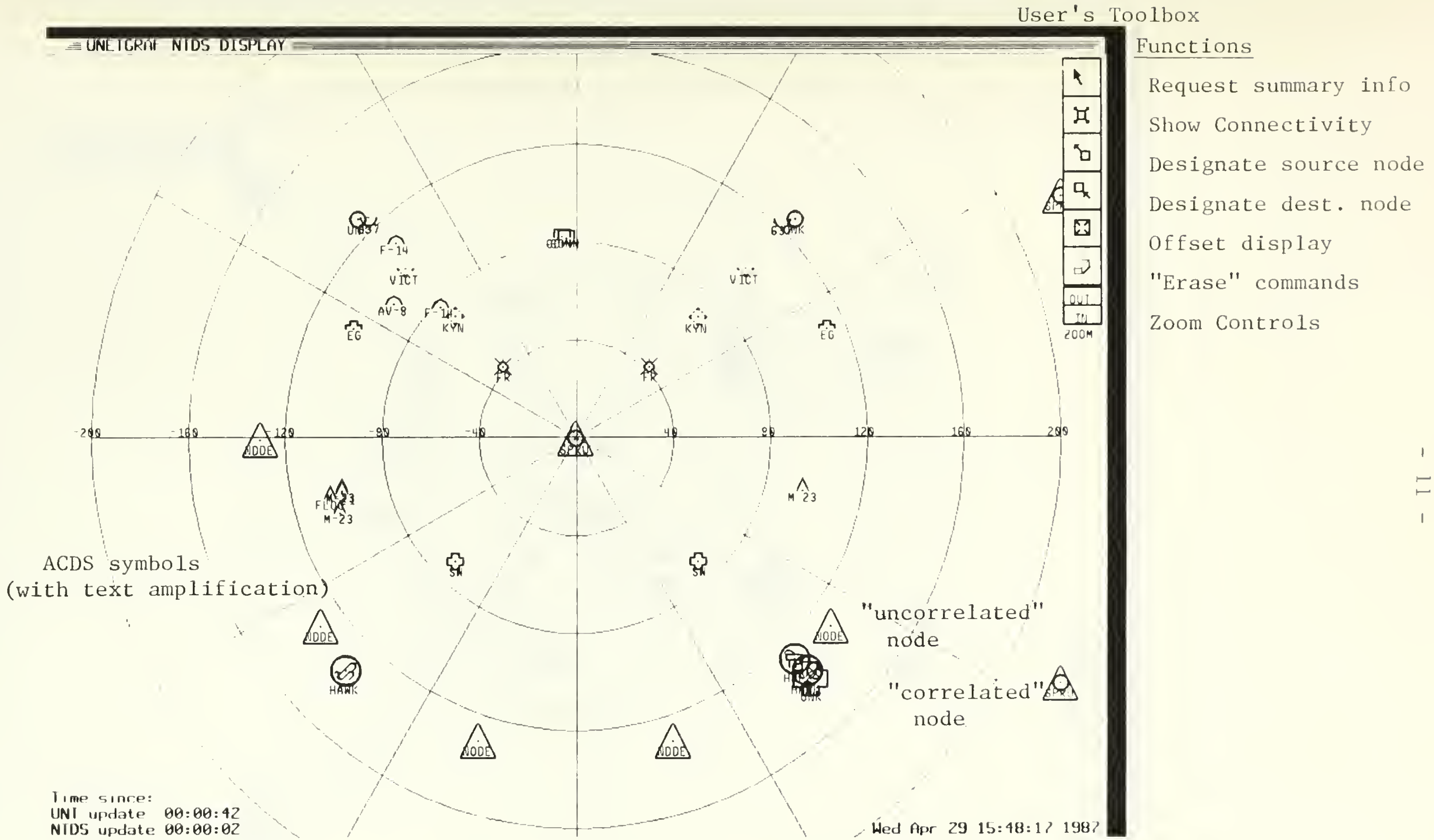


Figure 1: NTDS Display Screen

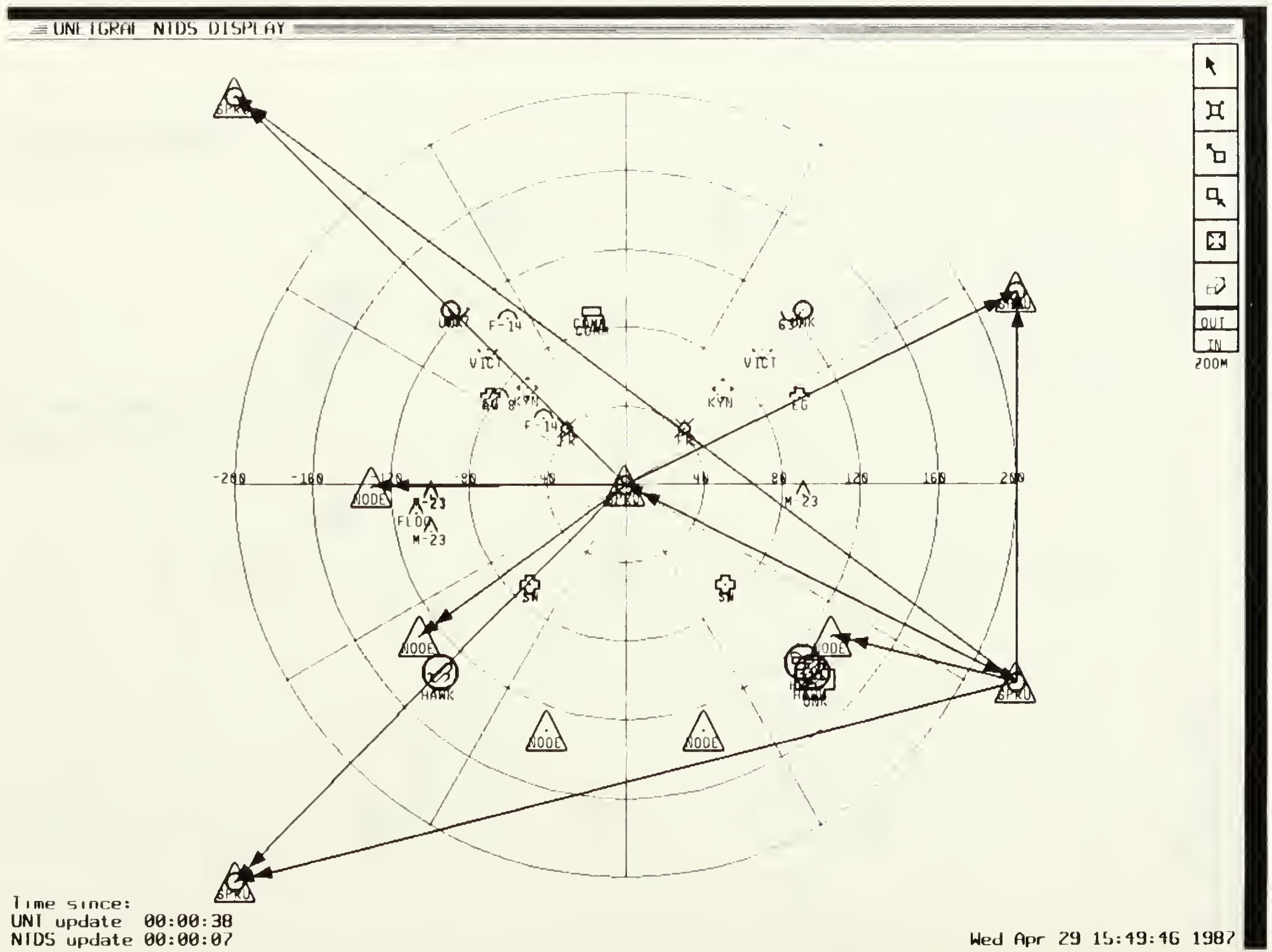


Figure 2: Connectivity "Overlay" Screen

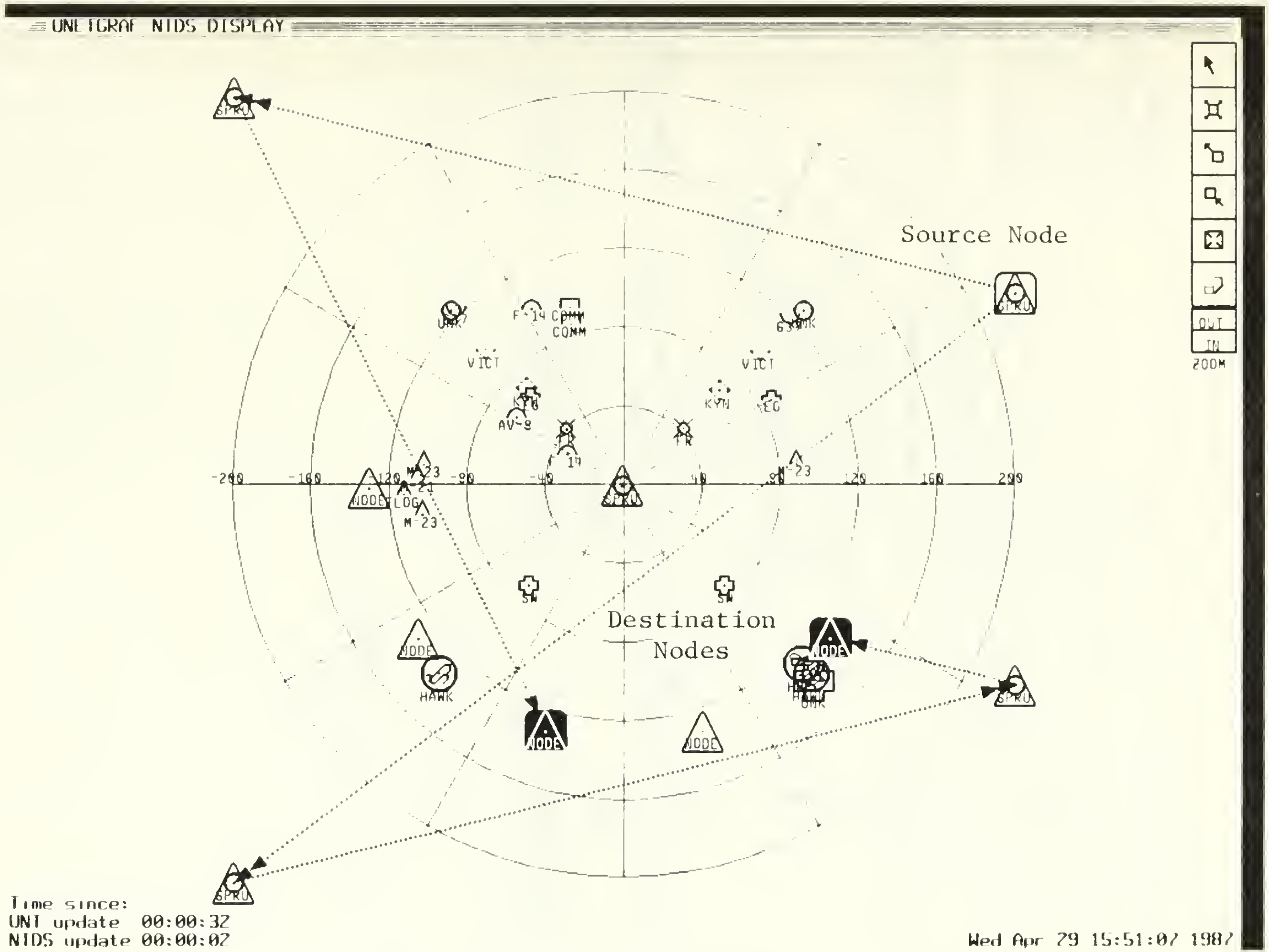


Figure 3: Routing "Overlay" Screen

## APPENDIX C (UNETGRAF HIGH LEVEL DESIGN)

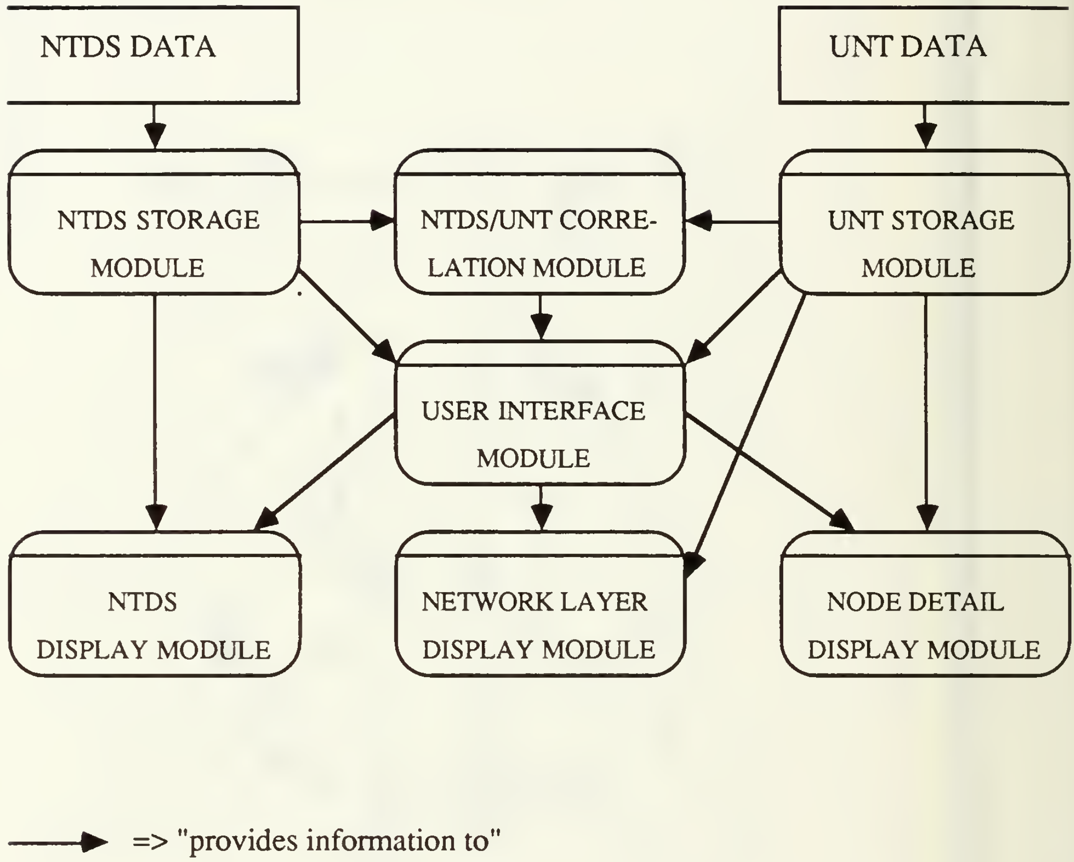


Figure 4: UNETGRAF High Level Design

## APPENDIX D (RECORD FORMATS)

```
/* structure to hold information about an NTDS contact */
typedef struct {
	int	index;		/* position in the contact list */
	int	net_id;		/* network address */
	char	track_no[6];		/* NTDS track number */
	char	contact_desc[20];/* text describing contact, eg "enemy air"*/
	char	corr_char[2];/* character(s) in specialized ACDS font */
	char	 mod[4];	/* text describing contact, eg "SPRU" */
	float	course;		/* true heading of contact */
	float	speed;		/* velocity in knots */
	float	grid_x;		/* position on NTDS grid */
	float	grid_y;		/* position on NTDS grid */
	float	DRx;	/* current x position based on DR */
	float	DRy; /* current y position based on DR */
	float	 track_hist[120][2]; /* stores last 120 track positions with
				an x and a y coordinate */
	int	min_no; /* length of history for this contact */
	int	track_flag; /* determines if track history
			is displayed or not */
	int	circle_flag; /* determine whether or not to display the
			contact's uncertainty circle */
	int	uptime; /* elapsed time between update n and update n+1 */
	int	updated; /* TRUE if this report is newly updated */
} contact_report;

/* structure to hold information about a UNT network node */
typedef struct
{
	int	net_id;		/* network address */
	short	index;		/* position in the nodelist */
	short	unt;	/* boolean indicating whether node is UNT-capable (store-and-forward capable) */

/* rest of structure to be implemented with Node Detail Display module */
} node_report;
```

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