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MPAD MCC WORKSTATION SYSTEM: ADDAM AND EEVE

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ABSTRACT

The flight control consoles in mission control at NASA's Johnson Space Center (JSC) have evolved in sophistication to the level where "expert sytems" are now being incorporated into them as "flight controller assistants."

This paper describes the evolution of a gateway node, designed to obtain and redistribute numerous kinds of data provided by Mission Control computers over a laser-optical network to enable rapid-prototyping development of the above application expert systems.

This automated data distribution and management system serves as an effective buffering system for assuring the necessarily separate requirements of the operational and developmental environments. This is accomplished through the evolutionary enhancement of the gateway's ancillary monitoring and control expert system that was originally designed to "watch and react" to system anomalies in the operational state, but whose role has been substantially expanded.

BACKGROUND

The Mission Control Center (MCC), at NASA/JSC has traditionally provided flight data via digital tape to applications subscribers outside of the center. Although called near-realtime data, the time delays required to prepare the tapes limited their use for playback and post-flight analysis modes. A growing demand for timely data during the flights necessitated the development of a local area network (LAN) to ship to sites remote from the MCC the kinds of data that had only been available to the MCC realtime support laboratories adjacent to the MCC.

A prototype laser-optical LAN was installed to test the feasibility of providing high-quality realtime and near-realtime data to remote subscribers. Known as the MITS LAN, its two-year test program has proven successful, enabling the system to be brought up to operational status. This means that remote nodes will be able to serve as both developmental and operational extensions of the MCC. A rigorous system of configuration management has been designed and is in the process of being installed to ensure that only properly verified and validated applications programs are maintained within the operational MCC environment.

Not surprisingly, the new concept of the MCC distributed LAN provided a resource that piqued the imaginations of Mission Planning and Analysis Division (MPAD) personnel working in the environment of developing expert systems for use as "assistants to" flight controllers. They came to view their node of the MITS LAN as a means to both develop their prototype programs and to eventually run them in actual operational states. At the same time the level of sophistication of the anticipated programs accelerated.

Other groups within MPAD were given the responsibility to ensure that data emanating from the MCC-distributed LAN node to MPAD were timely and of sufficient reliability to ensure meaningful development of expert systems and other application programs. A prototype data distribution and management workstation concept was devised in conjunction with the prototype of the MITS LAN. This paper describes the three phases of data workstation development for the automated data distribution and management (ADDAM) system and the design of an associated monitoring and control expert system, the Effective Evaluation Expert (EEVE), that is responsible for ensuring data integrity.

THE FIRST PROTOTYPE

Figure 1 depicts the initial ADDAM workstation concept devised in conjunction with the proof-of-concept MITS LAN. Workstation software to accommodate one "walk-up" user at a time was provided on a HP9000 minicomputer. Through a series of displays, menus and entryforms, the user selected types of data desired and a storage medium for that data (either disk files or digital data tapes). Gateway software was provided on the HP9000 that serves as one of the MITS LAN nodes. The gateway's function was to ensure that only appropriate data requests were transmitted to the MCC and within the correct design frequency load limits.

The idea for the addition of an expert system to this configuration resulted from certain anomalies within this earliest version of the MITS LAN. Frequent abrupt data terminations and dropouts necessitated development of a monitoring and control system to assess system integrity and provide remedial actions as required. Written in the programming language LISP, the Effective Evaluation Expert (EEVE) was run concurrently on a Symbolics 3640 tied to the gateway HP9000 via a direct cable/-RS232 interface. In this simplest of expert system configurations, EEVE provided what could be termed "operator emulation." Figure 2 shows "the face of EEVE" as manifested within the graphics environment available on the Symbolics computer. Status update windows and mouse activation fields were provided to enable observation of the performance of the expert system during operation.

Although both the MITS LAN and workstation system prototypes proved effective, both necessarily were limited by the proof-of-concept design constraints. The prototype workstation system could only serve one user at a time and data could only be stored before usage.

THE CURRENT PROTOTYPE

The increasing sophistication of the user/application community during the test phase of the MITS LAN prototype necessitated an expansion of the working concept of the MCC workstation system to accommodate their needs. Figure 3 shows the enhanced version of the workstation system prototype currently under assembly. Notable in this design are increased responsibilities and capabilities for all previous processors as well as the addition of new processors, specialized workstations, and improved techniques for moving data and information over the local MPAD LAN.

On the workstation side of the MPAD LAN, multiple MCC Application workstations are separate from the MCC Data Management workstation; the latter comprising a Britton Lee database machine hosted by a HP9000. The data management workstation is utilized to store data types and sequences for playback during specialized analyses or during flight simulations.

Each application workstation can provide data directly to automated applications, particularly realtime expert systems, on a datastream basis, through the new Enhanced Development Environment Networked Node (EDENN) processors in conjunction with the expanded capabilities of the ADDAM gateway.

On the gateway side of the local MPAD LAN, the ADDAM processors have been upgraded to service multiple workstations with an expanded list of data types and variations. Within the automated maintenance monitoring and control milieu, the EEVE systems design role now calls for hypothesis construction and testing beyond mere operator emulation. In addition, the EEVE system will be rehosted from the Symbolics 3470 (in LISP), to the same HP9000 containing the ADDAM processors (in the inferencing engine/language CLIPS), that also serves as the node terminal to the MITS LAN.

THE ADVANCED PROTOTYPE

Even as the current prototype is under construction, demands for increased performance have been requested from both the data provider side of the chain (the system herein described), and the data utilizer side (the application expert systems). Consequently the plan for an even more advanced operational structure is now also in preparation. Figure 4 illustrates the increased complexity over the current prototype.

It is important to note the addition of a generalized communications interface technology among the gateway and the workstations. Called the Remote Information Interchange Buffer (RIIB) processors, they intermediate among the data-oriented executives (ADDAM and EEVE) and the networks utilized to transfer data and advisories. As such, the RIIB's serve as "session managers" on behalf of the executives within a User Datagram Protocol/Internetwork Protocol (UDP/IP) networking environment. Also planned for the RIIB's are generalized display terminal support functions that allow for the dynamic reconfiguration of terminals within the Transmission Control Program/Internetwork Protocol (TCP/IP) network environment. Figure 5 illustrates that using the accepted International Standards Organization Open Systems Interconnection Protocols (ISO OSI) network communications scheme, both ADDAM and EDENN comprise Application Level 7, whereas the RIIB occupies the Session and Presentation Levels, 5 and 6.

This new uniformity in communications enables EEVE to take on the added task of network failure response. In this mode, EEVE can restart applications by rerouting the users' terminals via the network to the new hosting node. To accomplish this, EEVE accesses the Data Management workstation database for a local configuration management library.

Both the ADDAM and EEVE systems have full backup versions, as shown in Figure 4, that are fully ready to step in should the "master" gateway/monitor fail. When the backup EEVE senses that the current master has failed, it promotes the backup ADDAM to master status, reboots, and arranges for the switchover of data and advisories to any and all workstations waiting in abeyance. New backup versions of ADDAM and EEVE are then created and placed in readiness.

Specialized versions of EEVE, called EEVE II, have been added to the workstations to provide the levels of interpretation of the flight-specific environment for the online application expert systems. This focuses EEVE's duties on the gateway to levels of interpretation regarding flight control host activities and network and performance configuration.

Importantly, this design embodies two parallel and interdependent means of communication as symbolized by the solid and dotted lines. The solid lines, connecting the realtime data and advisory processors, including ADDAM and EDENN, symbolize the autonomic neuralnet system (ANS) side of the entire configuration. Conversely, the dotted lines represent a "virtual LAN" that connects EEVE, EEVE II and even the online application expert systems and, as such, symbolize the central neuralnet system (CNS) side of the configuration. This design allows the CNS to perform symbolic processing without hindering the realtime response of communications interfaces. It also enables the various expert systems to converse, negotiate, and even "argue" about network priorities and flight environment realities.

AN EXPERT CONVERSATION

The following scenario is presented to illustrate the levels of interpretation that will exist in the symbolic discourse between application expert systems and EEVE/EEVE II:

The application E/S innocently asks about the status of its flight (fearing the worst since data is missing) to the local EEVE II system. EEVE II discovers that there are holes in its fact database and makes further inquiries to EEVE at the gateway.

The application system would begin with a message to the EEVE II on the local workstation:

FROM: **Application E/S: USER43**
TO: **EEVE II @ MCC**
Workstation: FM8

(QUERY FLIGHT-STATUS)

(REQUESTOR SESSION USER43)

EDENN automatically adds the session identifier, USER43, as the inquiry is forwarded to EEVE II.

EEVE II consults its database,

(DATA-REQUIREMENT USER43 NRT)

(DATA-REQUIREMENT USER43 TRJ
(CYCLIC-STREAMS
(HIGH-SPEED-MISC))
(DEMAND-STREAMS
(ATTITUDE-TIMELINE
VECTOR-ADMIN-TABLE)))

(DATA-REQUIREMENT USER43 CAS)

(FLIGHT-LOGON USER43 FLIGHT 71-B)

and concludes that it needs to consult EEVE at the gateway about the status of the Near Realtime Telemetry (NRT), trajectory (TRJ), and Calibrated Ancillary Telemetry System (CAS) data streams for flight 71-B.

Thus EEVE II sends the following message to EEVE:

FROM: **EEVE II @ MCC**
Workstation: FM8
TO: **EEVE @ MCC Gateway**

(QUERY DATA-STREAM-STATUS FLIGHT 71-B NRT)

(QUERY DATA-STREAM-STATUS FLIGHT 71-B TRJ)

(QUERY DATA-STREAM-STATUS FLIGHT 71-B CAS)

(REQUESTOR WORKSTATION FM8)

The last fact is added by ADDAM as the message is forwarded to EEVE.

Correspondingly, EEVE consults its database at the gateway,

(DATA-STREAM NRT FLIGHT 71-B STATUS ACTIVE AT 17:08)
(DATA-STREAM TRJ FLIGHT 71-B STATUS UNKNOWN AT 17:05)
(DATA-STREAM CAS FLIGHT 71-B STATUS PENDING AT 17:07)

(CONTINGENCY FLIGHT 71-B TRJ NO-RESPONSE AT 17:05)
(CONTINGENCY FLIGHT 71-B TRJ CHECKPOINT-WARNING AT 16:58)
(CONTINGENCY FLIGHT 71-B CAS RESTART-REQUESTED AT 17:07)

and would have to shrug its allegorical shoulders if it were not for the sudden entry of a new fact and the expiration of a timer (all sensed by ADDAM) --

(CONTINGENCY FLIGHT 71-B CAS RESTART-ACKNOWLEDGED AT 17:10).

After a few simple rules fire EEVE then has the following facts with which to resolve the question:

(RESOLUTION FLIGHT 71-B CAS RESTART-CONFIRMED AT 17:10)
(RESOLUTION FLIGHT 71-B TRJ CHECKPOINT-ASSUMED AT 17:10)

(DATA-STREAM CAS FLIGHT 71-B STATUS IN-RESTART AT 17:10)
(DATA-STREAM TRJ FLIGHT 71-B STATUS (CHECKPOINTED .95) AT 17:10).

The rule operating for the pending status on the CAS data stream is clear enough. However, the assumed checkpoint rule is obviously one of interpretation -- guessing -- on the part of EEVE. Thus EEVE asserts that the flight control host system supporting the trajectory data stream must be in the grips of a checkpoint procedure. EEVE further notes that it does not know this with certainty, but rather that it feels reasonably sure (.95) that this must be the case since a checkpoint warning was received some 12 minutes previously.

It is not implied that EEVE is implemented using fuzzy logic. EEVE simply provides a confidence level for its deductions that may or may not be used by an EEVE II or application expert system when making further decisions.

At any rate, EEVE returns what it knows about flight 71-B to the FM8 workstation:

```
FROM:    EEVE     @ MCC Gateway
TO:      EEVE II @ MCC
         Workstation:  FM8
```

(RESPONSE-TO WORKSTATION FM8 AT 17:10)
(DATA-STREAM-STATUS FLIGHT 71-B NRT ACTIVE AT 17:08)
(DATA-STREAM-STATUS FLIGHT 71-B CAS IN-RESTART AT 17:10)
(DATA-STREAM-STATUS FLIGHT 71-B TRJ (CHECKPOINTED .95) AT 17:10)

The EEVE II at FM8 now has enough information to respond to USER43:

```
FROM:    EEVE II @ MCC
         Workstation:  FM8
TO:      USER43  @ MCC
         Workstation:  FM8
```

(RESPONSE-TO SESSION USER43 AT 17:10)
(FLIGHT-STATUS FLIGHT 71-B ACTIVE AT 17:10)

While the application system received an answer to its question, it turns out that USER43 is sophisticated enough to ask even more detailed questions:

```
FROM:    USER43  @ MCC
         Workstation:  FM8
```

TO: **EEVE II @ MCC**
Workstation: FM8

(QUERY DATA-STREAM-STATUS TRJ)
(QUERY DATA-TYPE-STATUS
(HIGH-SPEED-MISC
VECTOR-ADMIN-TABLE NRT))
(REQUESTOR SESSION USER43).

To which EEVE II can directly respond:

FROM: **EEVE II @ MCC**
Workstation: FM8
TO: **USER43 @ MCC**
Workstation: FM8

(RESPONSE-TO SESSION USER43)
(DATA-STREAM-STATUS FLIGHT 71-B TRJ
(CHECKPOINTED .95) AT 17:10)
(DATA-TYPE-STATUS FLIGHT 71-B
((HIGH-SPEED-MISC CYCLIC
HALTED AT 17:10)
(VECTOR-ADMIN-TABLE ON-DEMAND
HALTED AT 17:10)
(NRT ON-DEMAND ACTIVE AT
17:08)))!!

IN CONCLUSION

It is evident from the foregoing dialogues that much work has yet to be done to reach the level of sophistication implied by the symbolic information transfer that is taking place among the expert systems. It will be no small challenge to build the domains of interpretation required of the expanded EEVE and the new EEVE II's. Much proof-of-concept testing has yet to be inspired and embraced. Even before the bases for interaction are established among EEVE and the EEVE II's over the "virtual LAN," the servicing interfaces must be worked out between an EEVE II and the application expert systems that reside on its workstation. This, in itself, is a substantial undertaking because of the amount of time required to meet with the application expert system designers in order to understand their special needs and requirements. One such project, currently under way, has resulted in the requirement for a time synchronization processor to be added to an EDENN system.

Optimistically, once the central neuralnet is in place in even rudimentary form, thus linking all of the service and application expert systems together, the symbolic-oriented design will enable a continuous and evolutionary growth in capability as time and resources permit.

ABBREVIATIONS, ACRONYMS AND TERMS USED IN THIS PAPER

ADDAM	-	Automated Data Distribution and Management system
ANS	-	Autonomic Neuralnet System
ATT	-	Attitude Table data
CAS	-	Calibrated Ancillary System
CM	-	Configuration Management
CNS	-	Central Neuralnet System
COTS	-	Commercial Off-The-Shelf
DB	-	Database
DM	-	Data Manager
EDENN	-	Enhanced Development Environment Networked Node
EEVE	-	Effective Evaluation Expert
E/S, ES	-	Expert System
HP9000	-	Hewlett Packard minicomputer
IP	-	Internetwork Protocol
IPS	-	Instrument Pointing System
ISO	-	International Standards Organization
JSC	-	Johnson Space Center
LAN	-	Local Area Network
LLA	-	Link Level Access
MCC	-	Mission Control Center
MITS	-	MOD-IPS-TACAN System (LAN)
MNV	-	Maneuver table data
MOC	-	Mission Operations Center
MOD	-	Mission Operations Directorate
MPAD	-	Mission Planning and Analysis Division
MSD	-	Mission Support Directorate
NASA	-	National Aeronautics and Space Administration
NRT	-	Near Realtime Telemetry data
OSI	-	Open Systems Interconnection Protocols
RIIB	-	Remote Information Interchange Buffer
TACAN	-	Tactical Air Control and Navigation system
TCP/IP	-	Transmission Control Program / Internetwork Protocol
TRJ	-	Trajectory data
UDP	-	User Datagram Protocol
VAT	-	Vector Administration Table data
XNS	-	Xerox Network System

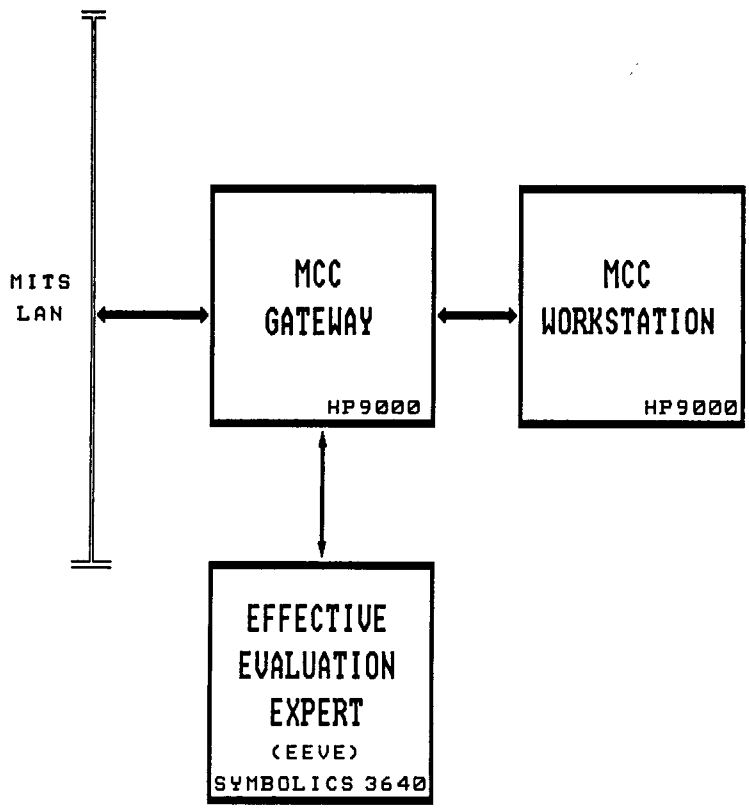

Figure 1 - The First Prototype

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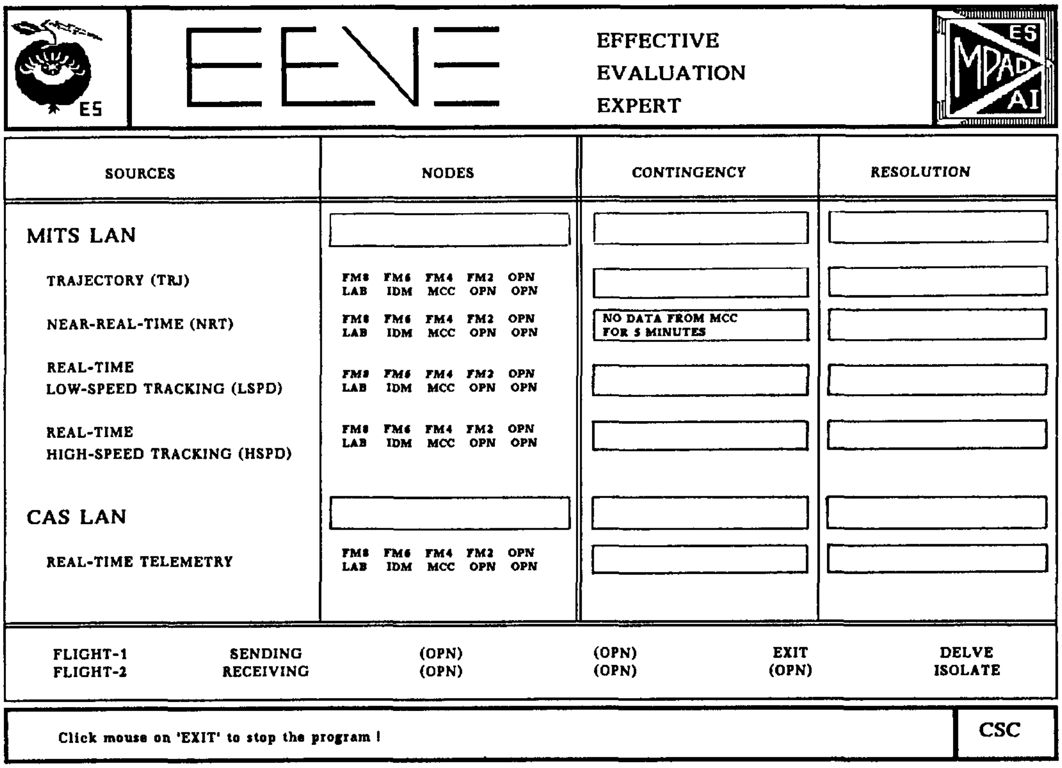

Figure 2 - The Face of EEVE

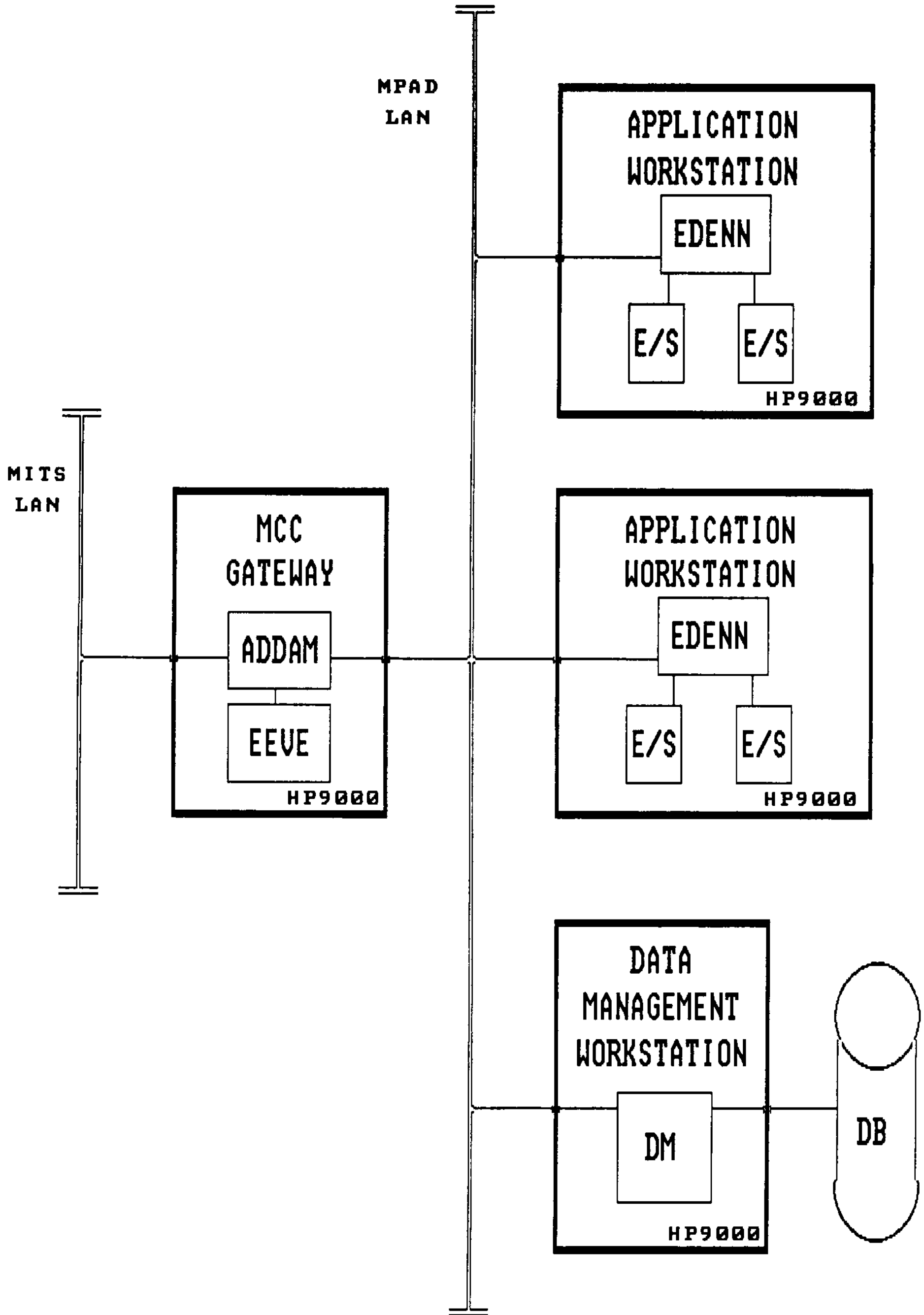

Figure 3 - The Current Prototype

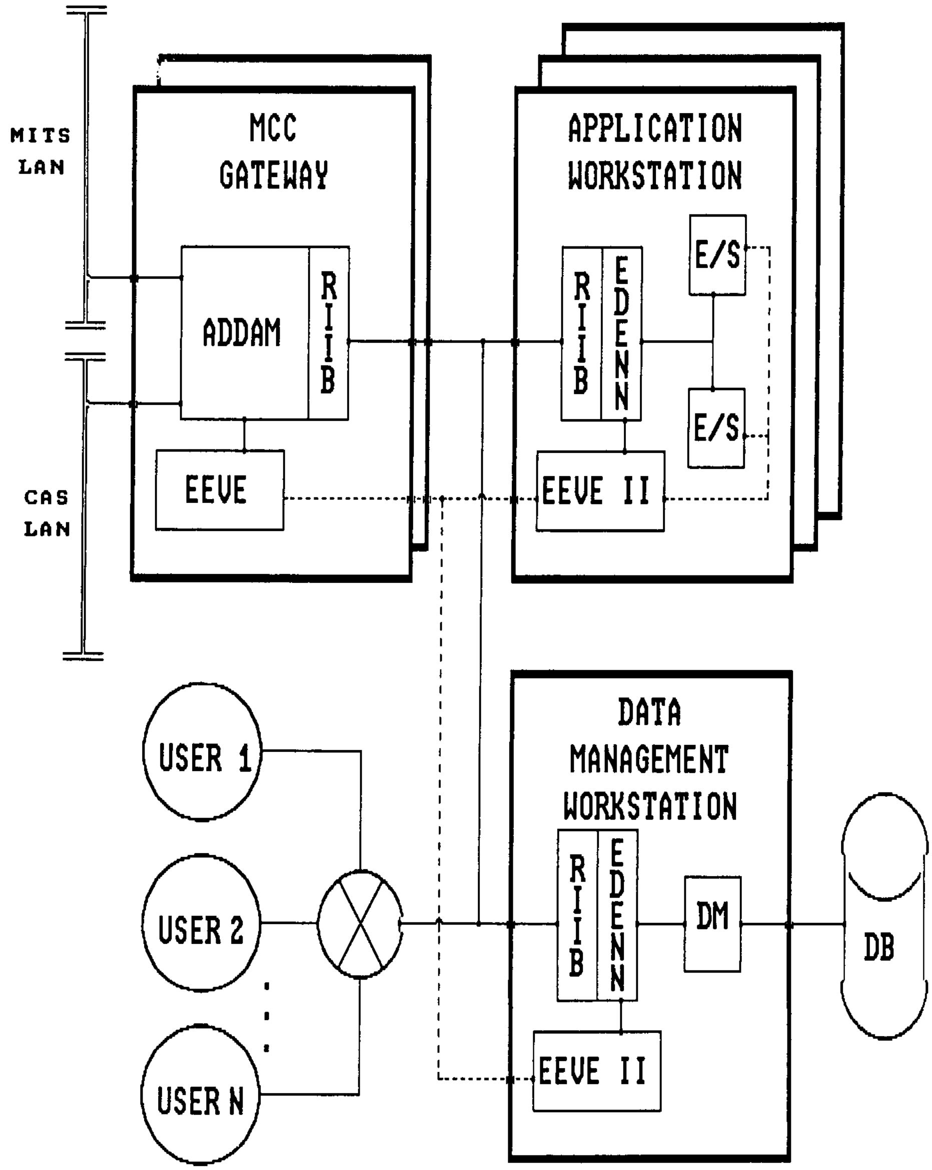

Figure 4 - The Advanced Prototype

INTERNATIONAL STANDARDS ORGANIZATION
OPEN SYSTEMS INTERCONNECTION PROTOCOLS

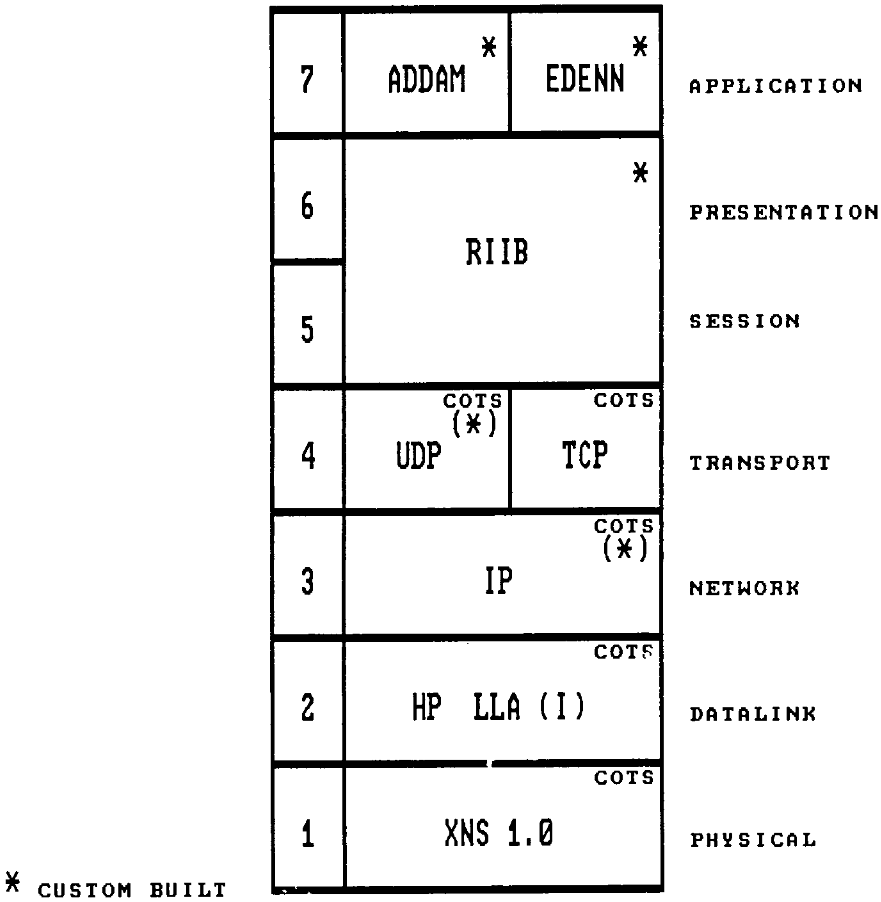

Figure 5 - The ISO OSI Network Communications Model