REQUIREMENTS OF A TRAINING MANAGEMENT SYSTEM FOR AIRCREW TRAINING

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ABSTRACT

This paper reviews the functional requirements of a Training Management System (TMS) for a typical Aircrew Training System (ATS). Requirements include: to maintain all appropriate records for students, instructors, training equipment, and curricula; to manage the progress of individual students as they undertake training, and progressively confirm that students acquire the required skills and knowledge; to identify any deficiencies of individual students, and recommend appropriate corrective action (remediation), to perform optimal scheduling of students, instructors and training equipment, resolve scheduling conflicts, and cope with the inevitable short-term reassignments; to evaluate the overall ATS by analyzing student data, establishing meaningful trends, and to generate reports, so that the overall ATS can be improved. The TMS must be utilized by a variety of user classes, while ensuring appropriate data security. A proposed TMS system architecture is described which includes a UNIX computer system, terminals, optical mark readers, and modems for communicating across the bases, and between sites. Application code is written in a fourth generation database language supplemented by C code where required.

INTRODUCTION

The intent of this paper is to make the reader aware of the requirements of a typical Training Management System (TMS) for use in a large Aircrew Training System (ATS). On *May 15th 1989* Hughes Training Systems was awarded the contract for the C-141 Aircrew Training System, and much of this presentation is drawn from the author's participation in interpreting the TMS requirements for this program.

A large total training program, such as the C-141 Aircrew Training System, provides training for a variety of different job tasks and qualification levels: pilot, navigator, flight engineer, loadmaster, maintenance engine run (MER) technicians, and basic flight engineer (BFE) students. Training is conducted at multiple Air Force (AF) and AF Reserve bases around the country. Training utilizes a variety of different media including classroom instruction, computer-managed instruction (CMI), cockpit procedures trainers (CPT), other specialized training devices such as a loadmaster training device, full-flight simulators (Weapons System Trainers), and the real C-141 aircraft. The ATS consists of a variety of different formal training courses which culminate in a specific qualification level (for example, pilot initial qualification), plus ongoing continuation and recurrent training which occurs throughout each C-141 crewmember's career in the Air Force.

Keeping track of the progress of individual crewmembers in formal training courses and throughout their entire career, scheduling students with training media and instructors, and evaluating the overall performance of the entire ATS are all requirements of the TMS. While these requirements can be met with a manual system, an integrated and automated TMS can enable optimal utilization of available resources while meeting the student training requirements.

An important element in an ATS, such as the C-141 ATS, is the student guarantee. After the training program is implemented at each base (at Site Training Readiness Review), the contractor guarantees the skill and performance level of each of the crewmembers and personnel that passes through the ATS. The TMS is a key element in the record keeping process which enables verification of this promise for individual trainees. In addition, the TMS must perform ongoing analyses of the overall ATS to ensure that the training media and courses provide effective training.

REQUIREMENTS ANALYSIS METHODOLOGY

Structural analysis techniques were used to decompose the requirements for the TMS. An overview of various methodologies and techniques of structural analysis are described in reference [1]. The methodology followed uses data flow diagrams and is described in [2]. Figure 1 is a top-level context diagram which illustrates the overall data flow and the interface between the TMS and the other parts of the ATS. In Figure 1, the rectangles indicate major components of a typical ATS which are **external** to the TMS (the central circle). Rectangles are also sources or sinks of data. The lines and arrows represent named data flows. The major ATS components with which the TMS must interface are as follows:

1. Management controls who is allowed to log on to the TMS through changes to the user roster, provides student enrollment data, site management data, and student management data. In return the TMS provides data and reports on student performance management and evaluation, scheduling and site management, provides an up-to-date master schedule, performs an evaluation of the overall ATS, and provides resultant alerts and recommendations.

2. Students receive from the TMS their individual training schedules, and after completion of training provide their evaluation of the ATS and instructors.

3. Instructors provide evaluation of individual student performance for Instructor-Based Training (IBT) and in Aircrew Training Devices (ATD). This is via completed Optical Mark Recognition (OMR) forms. The TMS will supply blank pre-printed and customized OMR evaluation forms to the instructor for each scheduled training session to facilitate evaluations. Each instructor also gets their own individual work schedule from the TMS.

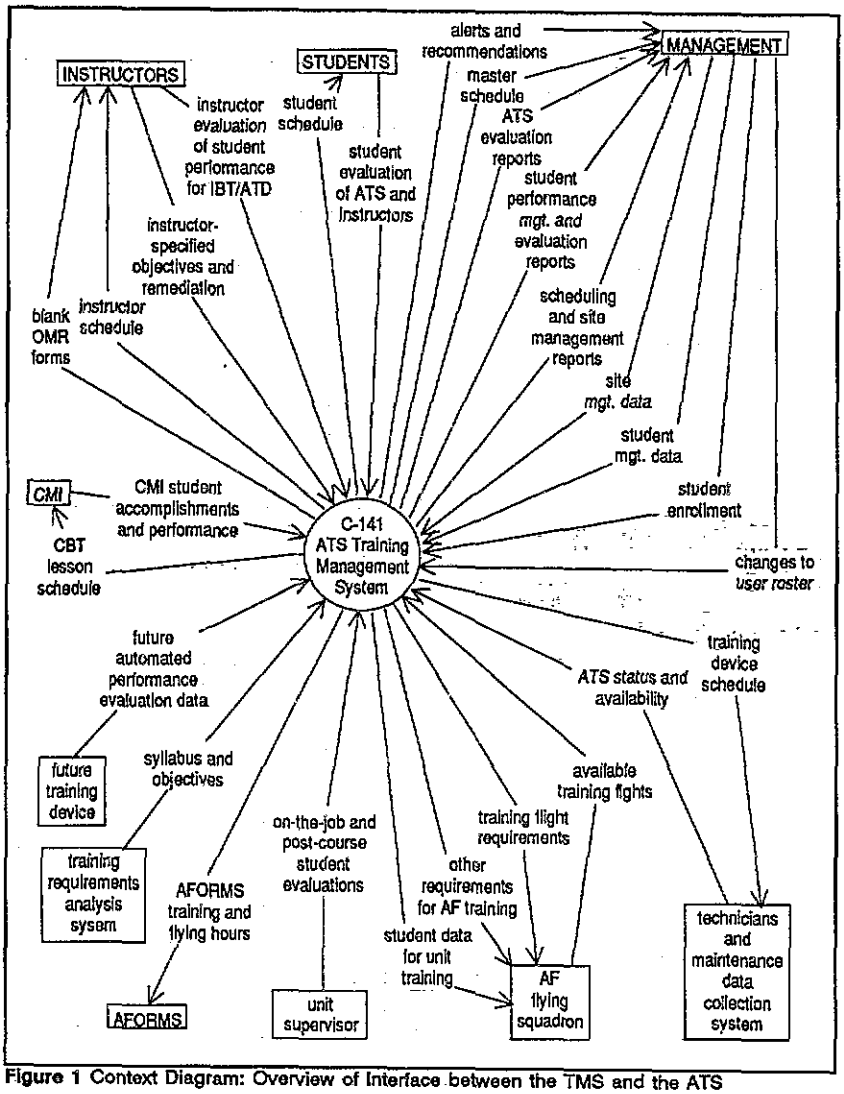

Figure 1 Context Diagram: Overview of Interface between the TMS and the ATS

4. *The* **Computer-Managed Instruction (CMI)** component of the Computer-Based Training (CBT) system automatically collates student accomplishments and performance, which are passed in machine readable format to the TMS. In return, the TMS generates CMI lesson schedules.

5. Training media in the C-141 ATS (other than the CMI system) do not currently have the capability to provide machine-readable automated performance evaluation data. A provision for this data in machine readable format from a **Future Training Device** with automated performance measurement has been shown as a requirement.

6. The objectives and syllabus for the training courses and skills are input to the TMS from a separate **Training Requirement Analysis System (TRAS).**

7. There is a requirement that the TMS interface to the **AFORMS** *system to allow Air Force tracking of crewmember* flying hours and events. This is a one-way transfer from the TMS to AFORMS.

8. After completion of formal training and reassignment to the Air Force unit of assignment, the trainee's **Unit Supervisor** will provide on-the-job and post-course evaluations of the trainee which will be collated by the TMS.

9. The TMS interface to the **AF Flying Squadron** *ensures that data on required* training flights is communicated, and available training flights are returned. Requirements for other specialized types of Air Force-conducted training are also communicated, together with student data for continuation and in-unit training. Student records are passed to the Air Force unit of assignment when the trainee transfers after completion of a formal training course.

10. *The ATS* **Technicians** *use the* Maintenance Data Collection System to provide the TMS with the status of all the training media, and the TMS is also informed of scheduled maintenance periods.

MAJOR TMS FUNCTIONS

A breakdown of the major functional requirements of the TMS are illustrated in Figure 2 and described in the following subsections. *The figure also illustrates the* requirement for a centralized and common database.

1. Access and Security: Allows access to authorized users. Protects unauthorized users from accessing sensitive data (student records, correct test scores etc.).

2. Student Performance Management and Evaluation: Manages students as they *progress through the assigned course* syllabi. Tracks progress of individual students as training progresses.

3. Scheduling and Training Site Management: Schedules students, instructors, and training resources. Manages instructor and training media resources, and allows site personnel to specify the resources available for scheduling.

4. ATS Evaluation: Evaluates performance of the entire ATS *and its components.*

5. Report Generation: Generates required reports.

ACCESS AND SECURITY

An important requirement of the TMS is to allow access to various categories of users such as instructors, schedulers, system administrators, registrars, site managers and (in some cases) students. The various user categories will allow access (or allow data modification) as required, and ensure compliance with the Privacy Act of 1974 so that personal data is not revealed without permission.

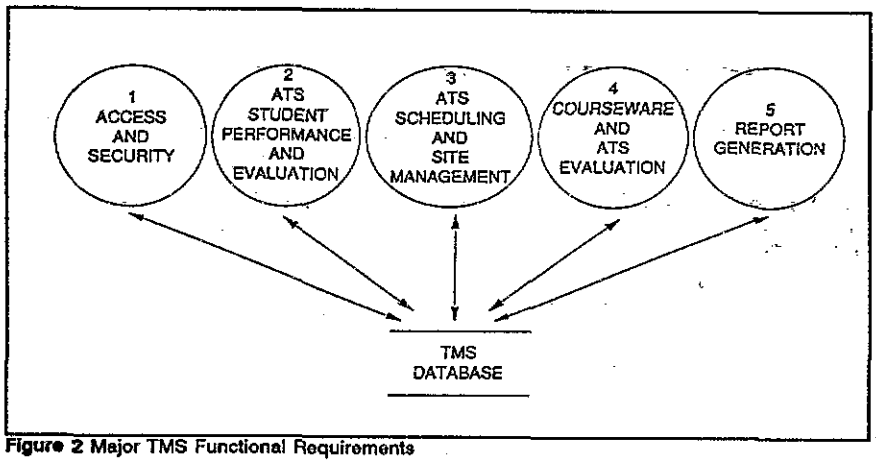

Figure 2 Major TMS Functional Requirements

Each user will be assigned a username, password and access level to control access to the TMS. A number of access levels are proposed which correspond to the user's need to manipulate and change data on the TMS.

STUDENT PERFORMANCE MANAGEMENT

There is a requirement at each training site to maintain course training records for formal training courses, and maintain permanent training records for **continuation training, upgrade courses and in-unit training**. Progress will be tracked to confirm that the students attain the required knowledge, skills and task performance. The cumulative training requirements are collated for ATS Scheduling and Site Management.

A data flow diagram illustrating this requirement is shown in Figure 3. The data which flows into or out of the TMS database represents data stored within that database (e.g. the user roster).

1. Setup Student Training Record. It is necessary to facilitate the creation of an individual Course Training Record during the student's enrollment in a formal school, upgrade, or special qualification course. The student course training record remains active only during student enrollment. In addition, it is necessary to enable the transfer or creation of an individual aircrew member's Permanent Training Record, which contains a summary of the individual's training history (both formal courses and continuation training) as well as the active records for the upgrade courses, continuation and in-unit training.

2. Update Training Record. It is necessary to update the student's Course Training Record for course events (or the student's Permanent Training Record for continuation training events, upgrade courses and in-unit training). Inputs should include: student accomplishments and performance data from the computer-managed instruction (CMI) component of the CBT system, including instructor directed remediation or comments resulting from intervention or remediation in a CBT lesson or test; Instructor evaluations of student performance for Instructor-Based Training, Aircrew Training Device, and flight training events, including instructor directed remediation or comments; On-the-job and post-course student evaluations which originate from the supervisor at the unit of assignment; a provision could be included for the addition of future training devices which can provide automated performance evaluation data. The TMS should be capable of updating student training status in the TMS quickly after of the training event has occurred (within two hours).

3. Analyze and Predict Student Performance. Diagnose deficiencies: student performance should be compared with required objectives and standards. Deficiencies may be flagged if, for example, the student has taken more than the required number of attempts to achieve proficiency of an objective, or has failed to demonstrate continued mastery of an objective during progressive (repeated) testing. Prescribe Remedial Instruction: any objective not met should be flagged to alert the instructor to the need for remediation. Where possible (for selected objectives), the TMS should automatically prescribe a CBT or other "off-line" remediation activity, or provide the instructor with a list of potential remediation activities. Predict Student Performance: it is necessary to also examine an individual's training record in conjunction with the syllabus and objectives and make a prediction of student progress rate and a prediction of possible remediation for future objectives. Specifically, it is necessary to predict when a student will be ready for the next objective or planned training device session in the curriculum by examining the individual's progress rate in earlier academic training and previous records of performance in training devices.

Predictions should be capable of being expanded to provide a proficiency based system, where in addition to the requirement to predict when the student is ready for the next objective, a prediction is also required of the number of training sessions required by the individual for that objective. That is, future objectives for a given individual are flagged if they are likely to require more than the average number of sessions (trials to proficiency) for a given training device (ATD or flight training).

4. Determine Training Requirements. It is necessary to determine which training objectives the student needs to learn next, and indicate required training media/devices and other training sources. A cutoff date by which each objective must (ideally) be accomplished should be appended to each training requirement. This mechanism could be used to identify time deadlines and urgent training requirements to the scheduling function: for example, recurring mandatory flight requirements to stay proficient, crewmembers in-unit who are approaching due dates for continuation training, students in formal school who are behind schedule or are close to their graduation date.

5. Modify Training Requirements. The instructor should have the capability to review, and if necessary supplement, the training requirements generated by the TMS. For example, the instructor can specify additional objectives or training requirements for a given student, or schedule an examination for a student.

6. Generate OMR Evaluation Forms. The TMS should generate (for the instructor's use) customized evaluation

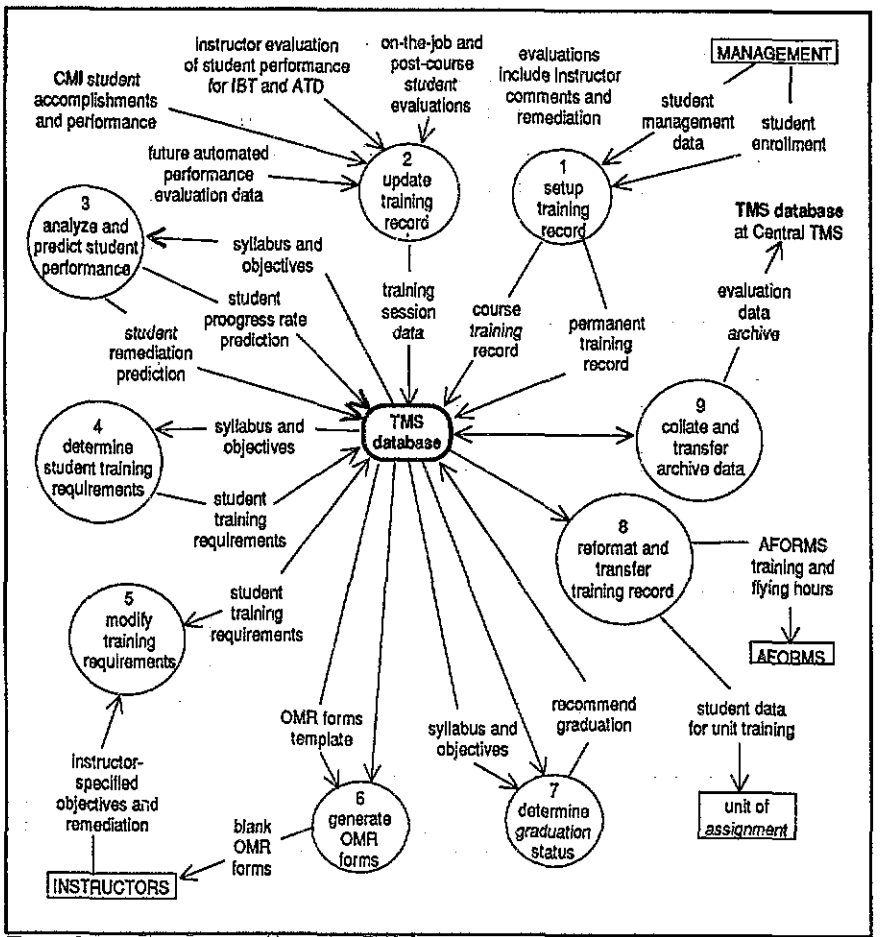

Figure 3 Data Flow Diagram Illustrating TMS Requirements for Student Performance Management and Evaluation

forms for each trainee. These forms could contain evaluation criteria corresponding to the instructional objectives programmed for the upcoming training events. In addition, custom evaluation forms could be produced for use in training events specifically required by certain trainees (due to their unique remedial training needs). These forms will be completed during the appropriate training event, and subsequently read in by the OMR. The OMR forms are also used to input critiques and evaluations, such as student critiques of the ATS and Instructors, and for instructor certification.

7. Determine Graduation Status. By examining individual student performance and progress in conjunction with the syllabus and objectives, the TMS can predict anticipated versus planned graduation for each student. When all qualifications have been achieved, the TMS can recommend graduation for each student. This function is applicable only to formal training. Early graduation (more than two days from scheduled date) or late graduation (anything later than scheduled date) should be flagged to alert the scheduling function and management.

8. Reformat and Transfer Training Record. It is necessary to condense, summarize and reformat the data in the Individual Permanent and Course Training Records. On graduation from a formal school the data in the Course Training Record is condensed and formatted into the Permanent Training Record. The Permanent Training Record is transmitted to the new unit of assignment. For continuation training (in-unit), periodic summarization of the data in the Permanent Training Record will occur to avoid storage problems.

9. Collate and Transfer Archive Data. It is necessary to collate archive data on student performance and management to allow evaluation of the overall ATS. Data are collated and transferred on a periodic basis to the TMS Evaluation component of the TMS (at the central site) for analysis and evaluation.

SCHEDULING AND SITE MANAGEMENT

Scheduling and Site Management allows schedulers and management at each site to specify and interrogate a site-specific master calendar, student availability, instructor availability, training resource availability (including degraded performance of the training equipment), and then to automatically develop a detailed schedule, taking into account appropriate priorities. The Scheduling and Site Management module must also project changes in training throughput, and provide long-term projections. A data flow diagram illustrating these requirement is shown in Figure 4.

1. Master Calendar. It is necessary to allow training personnel at the local site to specify and interrogate a site-specific master calendar for weekly, monthly, and annual periods which define hours of site operation, holidays, and special events which affect the scheduled operation of the training site. These data will be stored in a Master Calendar table.

2. Student Availability. It is necessary to allow formal school personnel and local flying squadron personnel to specify and interrogate the availability for training of individual aircrew members, BFE students, and MER personnel for a six month period to a resolution of half a day (AM and PM time periods). Data for each student will be stored in a Student Availability table.

3. Instructor Availability. It is necessary to allow the specification and interrogation of each instructor's availability for training for a six month period in advance, scheduled work shift, scheduled vacation days for the calendar year, and special qualifications. These data are used to match instructors to training events requiring special qualifications. These data will be stored in a Instructor/Evaluator Availability and Qualification table. The table should also contain the number of remaining (unscheduled) vacation days for each instructor. The inclusion of remaining vacation days allows a computation of any instructor shortage at the end of the year.

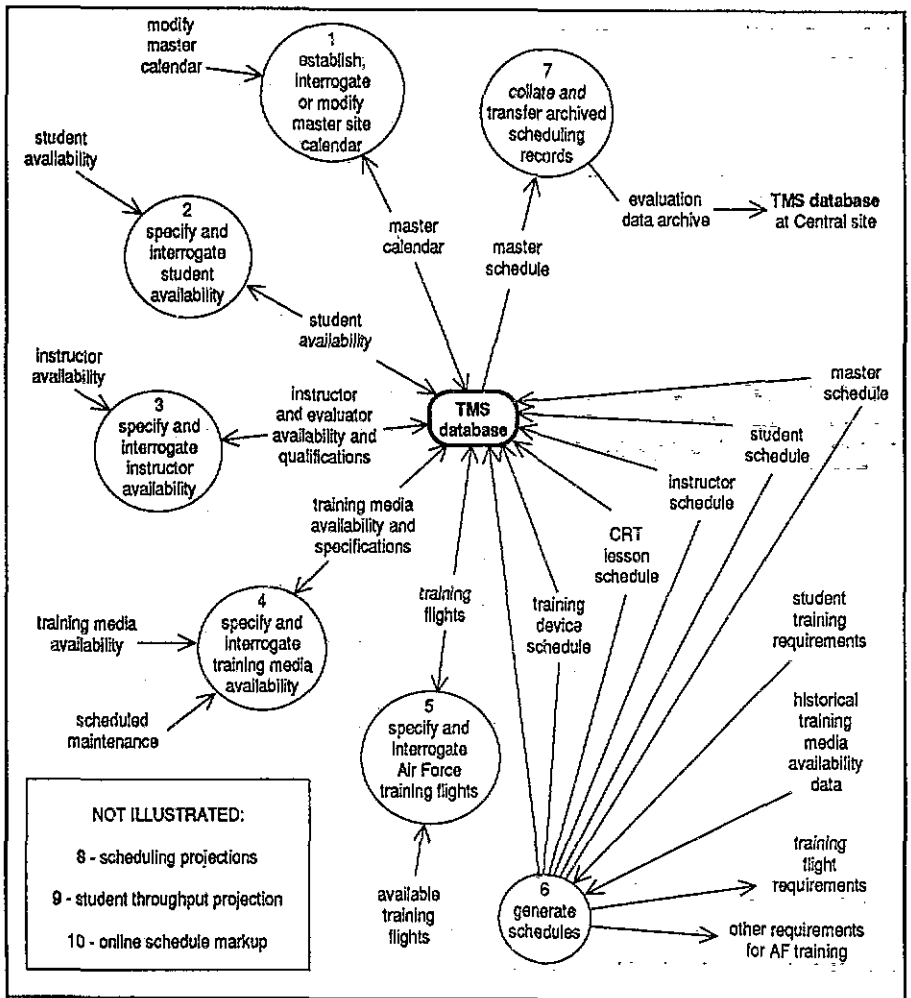

Figure 4 Data Flow Diagram Illustrating TMS Requirements for Scheduling and Training Site Management

4. Training Media Availability and Specifications. It is necessary to establish or modify the availability of training media, devices, and classroom resources for use by contractor and Air Force training personnel. The function will allow users to specify and interrogate the status of training media and devices at the site, together with the specific capabilities and/or constraints of each media or device which affect their selection for a training event. Any degraded or unavailable systems in a given training device could be specified by system title or component code. For example, visual inoperative on WST, fuel system on CPT inoperative. This information is used to alert schedulers to the degraded function in any scheduling assigned to that device, allowing rescheduling to alternate devices. These data will be stored in the Training Media Availability and Specifications table. Data on device availability will be entered into the TMS manually by ATS Technicians. The data will originate from the ATS Maintenance Data Collection System.

5. Identify Available Training Flights. It is necessary to allow local flying squadron personnel to identify available flights which may be used to fulfill formal school, upgrade, and continuation training flight training requirements. Each available flight should be identified by day and time, available crew positions, aircraft configuration, expected flight duration and type of training flight. These data are stored in the Training Flight table.

6. Generate Schedules. Scheduling algorithms facilitate the automatic generation of optimized schedules which match Student Training Requirements with available instructors, training resources, and training flights at each site. Prioritization is an important element within the scheduling algorithms. Other scheduling requirements are to:

a) Permit long range (30 days in advance) predictions of resource requirements as compared to resource availability.

b) Permit online resolution of scheduling conflicts.

c) Schedule training events specified in the course syllabi, those specified by the instructor, and those recommended by the TMS against the site master calendar and available training media and instructors.

d) Schedule training devices for Air Force requested and conducted training events.

e) Request flight training to include mission requirements which fulfill student training needs.

f) Consider student availability for training and priority for training in matching students and training events.

g) Provide online scheduling in each flying squadron with the capability to update the local training flights and schedule at least daily for ATS formal school training and continuation training (both flying and ground training events).

h) Provide the capability to generate and update on a daily basis each student's ground and flying training requirements.

i) Provide the capability for all sites to generate a special update of student training status and availability within two hours of request.

j) Store generated schedules for online retrieval, modification, and printing.

k) Alert the scheduler when a training medium or device is in danger of exceeding its normally scheduled capacity, and when it is in danger of exceeding programmed surge capacity.

l) Allow assignment of start-of-day time for instructor and student on a daily basis, or allow use of a default time (allows scheduling to the hour versus to the day).

7. Collate and Transfer Archive Data. Schedule data, together with data on schedule conflicts, device, media, and resource availability, and scheduled training throughput are

collated and transferred on a periodic basis to the TMS evaluation component of the TMS (at the central site) for subsequent analysis and evaluation.

8. Scheduling Projections. A provision should be included to allow the scheduler and management to play "what-if" games by changing student throughput figures, training media availability, instructor numbers, maintenance schedules, etc. It is necessary to provide predictive information without affecting the daily operational parameters of the TMS. The TMS should also allow management and schedulers to make temporary modifications and see the effects of varying each of the following: instructor availability, training media availability, student availability, other scheduling data and parameters, student throughput data with time, instructor numbers, qualification levels, crew member positions with time, the numbers and capabilities of training media, the number of training devices available, operating hours at the entire training site, the operating hours of the learning center, the operating hours simulator use, the maintenance schedule, and the master calendar.

9. Student Throughput Projection. The TMS should compute a student throughput projection for long-term scheduling. Student throughput projection should be specified in terms of the number of students per year, categorized by qualification, position and course over time. This data is used for comparison to known registered students (i.e., in the short term, the throughput would specify the number of seats which could be filled for an upcoming class. As students enroll, the number of seats decreases, replaced by actual student records.)

10. Online Schedule Markup. The TMS should include a function to facilitate the online markup of the current master schedule. This would allow instructors and managers to review a schedule online, and send a note to the scheduler referencing problems or requested changes to schedule.

ATS EVALUATION

In order to improve the entire ATS, the TMS is required to collate data for student and course evaluation, and validate overall training effectiveness. Collated data is analyzed partly by the TMS and partly by the instructors, flight examiners, and ATS management to establish meaningful trends and develop summary reports for use in revising curricula or performance requirements of training devices/media.

The Courseware and ATS Evaluation function of the TMS should: facilitate automatic comparison of data collected from each training site with trigger values for trend data which might indicate degraded ATS performance; compile performance data into standard periodic reports which are reviewed by test and evaluation personnel to determine the presence or absence of problems, opportunities for improvement, etc; allow the compilation of custom reports and statistical analyses on any available TMS data to prove or disprove evaluation hypotheses specified by test and evaluation personnel.

The TMS should also collate **internal** evaluations of the ATS. Sources of internal evaluation include: instructors (attitude and student performance data); students (attitude data). The TMS should also collate **external** evaluations which identify using external sources if graduates can perform their designed tasks to the level of proficiency specified. External evaluation data should include: supervisor evaluations of students; crew member questionnaires on attitudes towards the TMS; crew member attitudes towards specific courses; crew member attitudes towards a specific crew member; crew member self assessment of learning and performance.

The results facilitated by the ATS Evaluation function of the TMS will be used to modify ATS courseware and curricula to reflect the enhancements.

REPORT GENERATION

Report generation allows the production of a variety of pre-defined and custom reports. The report capability of the TMS should: generate reports relating to the C-141 ATS daily operation; generate reports of student performance which can be used by instructors and managers to facilitate student training and course management; generate student training reports. Develop reports for use in revising curricula or revising the performance requirements of training devices; generate reports on a daily basis of each student's ground training and flying training requirements; generate special update reports of student training status and availability within two hours of request.

1. Student Performance Management Reports. Predefined Student Performance Management Reports could include:

a) Individual student training status
b) Student status grouped by:
- Class
- Course for a specified period
- Training site
- Unit

c) Projected versus original graduation dates
d) Graduation status
e) Student remediations
f) Student training history for a given objective/lesson
g) Student availability for training
h) Student continuation training completion status
i) Student flight training requirements
j) Instructor comments

2. ATS Scheduling and Site Management Reports. Predefined ATS Scheduling and Site Management Reports could include:

a) Daily, weekly, and monthly schedules for:
- Aircrew members, BFE students, and MER personnel
- Instructors
- Flight examiners
- Training resources

b) Training media maintenance schedules
c) Schedule conflicts
d) Training resource availability versus throughput
e) Student availability for training (local site only)
f) Student prioritization for training (local site only)
g) Roster of instructors with availability and qualifications.
h) Roster of available training devices, media, and resources with constraints.
i) Changes to instructor data.
j) Changes to training devices, media, and resources.
k) Paper copy of student's Permanent Training Record.
l) Paper copy of student's Course Training Record.

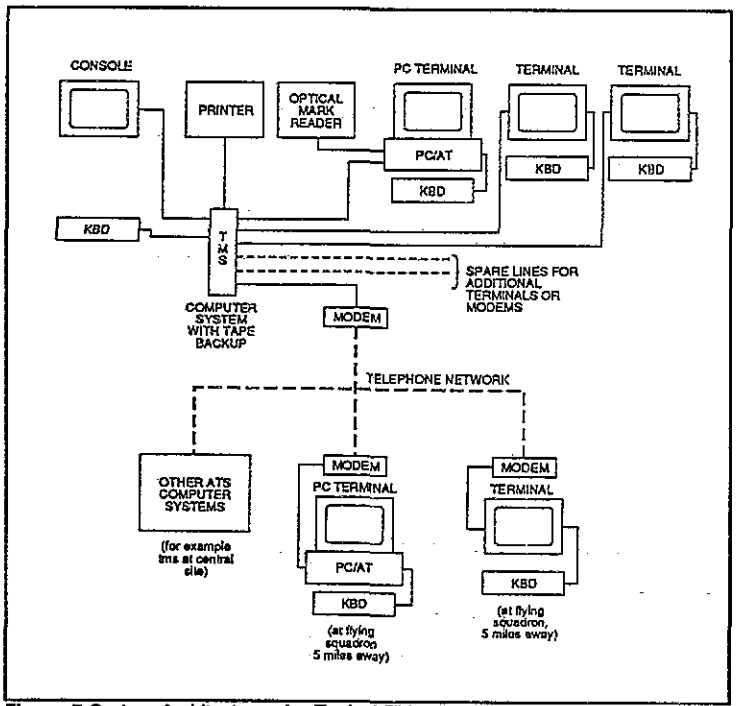

Figure 5 System Architecture of a Typical TMS

m) Course Completion Certificate.

3. ATS Evaluation Reports. Predefined ATS Evaluation Reports could include:

a) Identification of meaningful trends
b) Demographic data for C-141 crew members
c) Average student performance
d) Student performance history/trends

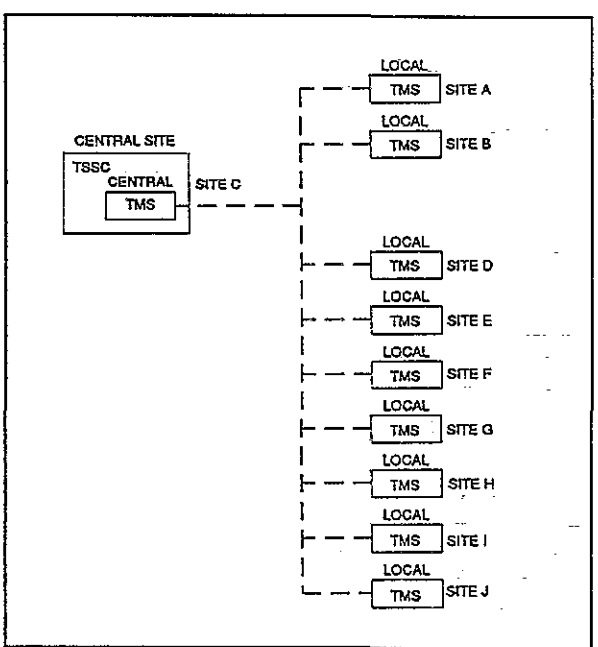

Figure 6 Relationship between Central and Local TMS

e) Remediation statistics
f) Performance of ATS training resources

4. Custom Reports. The TMS should also be capable of generating any customized reports that are required by the instructors, managers, and Air Force personnel. A capability should exist to allow authorized users to compose and store the format of the required custom reports. A user-friendly report format editor should be available to allow the selection of any required fields from the TMS database.

SYSTEM ARCHITECTURE

The system architecture for the TMS was chosen to make maximum use of off-the-shelf software and hardware components. The proposed arrangement at a typical base is illustrated in Figure 5. The computer system is a 80386-based system running UNIX. This arrangement provides a well-supported and cost-effective multi-user multi-tasking environment. The computer will contain a hard drive sufficient to hold the TMS database for that site, and be fitted with a tape backup system. Attached to the system will be an operator's console, keyboard, and printer.

The TMS applications software should have a uniform and user-friendly human interface. User-interface screens will be menu-driven (using Lotus-like ring menus), and allow user-friendly selection and operation of TMS functions. TMS data will be available for review both online and in printed report format.

After a careful trade study, Informix was chosen as the database system. Informix is widely supported, and can be implemented on a wide range of computer systems from DOS-based machines through mainframes. Software development is facilitated using the Informix 4GL (fourth generation) language to rapidly prototype the screens and database applications. The "C" programming language will be used for specialized math-intensive computations associated with scheduling.

At active bases there will be two terminals near the computer system and one terminal per flying squadron. At Air Force Reserve and Air National Guard bases there should be one main terminal and one additional terminal per flying squadron. Where the flying squadron is remote from the TMS computer system, modems should be used to link the remote terminals to the TMS computer.

At selected locations, the standard terminal will be replaced with a 80286-class (PC/AT) Personal Computer. The PC acts as a terminal to the main TMS computer system, and provides a more flexible arrangement than a conventional "dumb" terminal as it facilitates specialized offline data processing without burdening the TMS computer system. The PC can also be used for word processing and other non-TMS functions.

An optical mark reader (OMR) will be attached to selected TMS terminals to permit the entry of optical mark-sense forms for student attitude questionnaires, external supervisor evaluations, and ATD and flight training performance data.

Modems are available at each TMS computer system for communication with other bases and with remote terminals as illustrated in figure 6. Modems are also fitted to the remote terminals and PCs for communication with the TMS computer at the same base.

CONCLUSION

Using the techniques of structured analysis, the requirements of a TMS for a large aircrew training system have been decomposed and documented. Hughes Training Systems is currently engaged in the development of a TMS system which satisfies these requirements, and which will be applied to the C-141 ATS. The theme of this year's IITSC conference is "Training Through TEAMWORK - Meeting the USER'S Needs". In line with this theme, Hughes intends to make maximum use of available TMS designs and software developed for other Air Force Programs. The C-130 TMS is in an advanced state, and may already have been accepted by the Air Force by the time this paper is published. A common approach to the C-130 and C-141 TMS would be very beneficial. The Hughes staff involved in TMS development hopes to benefit from lessons learned on the C-130 program.

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