Chapter 2
Job Aiding: Performance Enhancement System

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2.0 Introduction

One of the tasks in the Human Factors in Aviation Maintenance and Inspection Research Program involves investigating advanced technologies and how these technologies might be applied to aviation maintenance tasks. We have been investigating pen computing technology and have developed a prototype application, called the Performance Enhancement System (PENS), for the FAA Flight Standards Service. We have also been working on a transition of our experiences from this project to industry. The bulk of this chapter describes the Flight Standards work, while Chapter 2 - Appendix addresses the work we have done with an industry partner.

We had several milestones with PENS in the last year. The first field study was completed in April 1994, and the results of that study were published last fall. Fall 1994 also saw the initiation of FAA training of Aviation Safety Inspectors on PENS concepts. Version 2 of the system software was completed in preparation for a second field study in Winter 1994/1995. Finally, a number of computers have been evaluated in-house, and several units have been selected for in the study to evaluate.

2.1 Background

The Performance Enhancement System represents a series of investigation and implementation phases supporting the goal of matching the needs and responsibilities of Flight Standards Service (AFS) Aviation Safety Inspectors (ASIs) with automation capabilities. This project is a direct result of the AFS Training and Automation Committee's Information Systems Strategy, which recommended that all future automation systems be developed in conjunction with the work force so that systems are designed to meet workers' needs and desires. The Training and Automation Committee has been instrumental in supporting PENS and in providing project oversight.

Field data collection is one characteristic of ASI activities. The data are collected on paper forms, and data entry clerks transcribe these forms into computer databases. These data are then recorded in a national database and are used to monitor the aviation industry's safety. Another characteristic of field inspectors' activities is that they must authoritatively answer questions as they arise. This requires ASIs to carry voluminous, cumbersome field copies of regulations and guidance.

Four primary concerns provided the impetus for development of PENS. First, data entry clerks are a significant annual expense for AFS. If it were easy for inspectors to enter data into the computer databases themselves, AFS would save the money it now spends on data entry. Second, there is a significant time delay of up to two weeks in form transcription. By decreasing that time delay, AFS could be more effective at monitoring and ensuring compliance in the aviation industry. Third, many data transcription errors occur in the current process, so many that the Government Accounting Office has repeatedly criticized the FAA for the poor quality of its data. Fourth, paper regulations and guidance materials are not used effectively because they are bulky and difficult to maintain. The combination of all these factors points toward automation as a potential solution. Field automation, at a minimum, would allow ASIs: 1) to store data directly in the proper database format; 2) to verify the validity of data at the time of an inspection; 3) to eliminate the time delay associated with transcription; and 4) to use on-line guidance materials quickly, easily, and with minimal maintenance of the documents. Other benefits would accrue as more tools were added to field computers.

The project began as an investigation, sponsored by the Office of Aviation Medicine (AAM), into the utility of pen computers for aviation industry inspectors and maintenance technicians. This phase of the project continued from approximately January until August 1992. During this time, FAA Administrator Thomas Richards learned about pen computers and thought that they might be a good tool for Aviation Safety Inspectors. To this end, he requested briefings from the Flight Standards Service. The Flight Standards Service learned of the AAM research and requested information in August 1992. After a series of briefings to FAA personnel, including Clyde Jones, AFS Director Thomas Accardi, and Associate Administrator for Regulation and Certification Anthony Broderick, we briefed Administrator Richards in November 1992, and Acting Administrator Joseph Del Balzo in January 1993.

Between January and August 1993, PENS received a lot of publicity within Flight Standards Services, both in AFS Headquarters and in the field. The project continued with a low level of funding from the Office of Aviation Medicine. From August 1992 through August 1993, a series of task analyses and prototypes were carried out to determine the basic content of a field computer tool. The Fort Lauderdale Flight Standards District Office (FSDO) was fundamental to the success of these initial analyses and prototypes.

Funding for a national field human factors study of PENS concepts was provided in August and October of 1993. Because of all of the publicity the project had received over the previous year, AFS Headquarters felt considerable pressure to start the field study quickly once funding was available. After some very rapid prototyping and testing with Atlanta FSDO inspectors, the national field study began on November 15, 1993, continuing until March 1, 1994.

2.2 Summary of Field Study Results

The following is a summary of Performance Enhancement System concepts that were evaluated, the nature of the field study, the important results, and considerations for full implementation. The full results and discussion can be found in *The Performance Enhancement System Field Evaluation Report*.

2.2.1 Inspector Characteristics

Four airworthiness (maintenance) aviation safety inspectors at each of nine sites, a total of 36 inspectors, participated in the study. The inspectors averaged 49 years in age, had been inspectors for five and a half years (most airworthiness inspectors are former aircraft mechanics), and had five and a half years of computer experience. Sixty-five percent of the inspectors use the current data entry system, and sixty percent own computers.

Note that inspectors' computer experience correlates with their experience as ASIs. The current computer systems installed at the field evaluation sites run a very limited set of DOS applications, not Microsoft Windows applications. PENS runs in Microsoft Windows for Pen Computing.

Training was given according to time, rather than to criterion. Inspectors were trained for two days. The first day consisted of an explanation of file storage conventions, DOS, Windows, and handwriting recognition, including training the computer to recognize the inspectors' handwriting. The second day consisted of training on PENS software.

We spent much more time covering basics in Windows than we thought would be necessary. Even though each office had Windows installed on its workstations, inspectors were generally inexperienced Windows users. The most likely explanation for their inexperience was that few inspectors had any need to run Windows software. The extra Windows training did not significantly affect the amount of training devoted to PENS; there was time left at the end of the second training day.

2.2.2 Materials

Three different models of pen computers and one standard notebook computer were fielded at each office. Thus, 36 computers were put into the field. Computers were selected based on their particular combination of features and their differentiating characteristics. That is, the computers were selected because they had certain features in common, but each also had a particular feature that made it unique. These computers allowed inspectors to evaluate the tradeoffs between weight, versatility, and speed. The computers' features are summarized in Table 2.1. The features listed in Table 2.2 are common to all four computers.

2.2.3 Results--Computer Platforms

The inspectors were asked to rate a number of usability characteristics of each computer. The characteristics included weight, ease of use, screen characteristics, environments in which the computer was used, and the like. With regard to particular characteristics of pen computers, the only significant result was that the GRiD Convertible was judged more comfortable than the NEC VersaPad. This result is consistent with inspectors' comments that its case made the VersaPad difficult and cumbersome; the Convertible was much more compact and easy to use.

Table 2.1 Characteristics of the Four Computers Used in Field Study

GRiD Convertible	NEC VersaPad	TelePad SL	Toshiba Satellite T1900
486/25 MHz CPU	486/25 MHz CPU	386/25 MHz CPU	486/25 MHz CPU
200 Mb Hard Drive	80 Mb Hard Drive	200 Mb Hard Drive	120 Mb Hard Drive
Built-in Keyboard	Separate Keyboard	Separate Keyboard	Built-in Keyboard
Pen Stylus	Pen Stylus	Pen Stylus	Trackball

When ratings for pen computers are compared with the notebook computer (Toshiba Satellite T1900), both the GRiD Convertible and the TelePad SL were judged to be faster. Inspectors generally disliked the VersaPad, and that may have biased the inspectors' evaluations. We originally thought that the VersaPad was a good computer to use to examine tradeoffs between computer characteristics because it had a smaller hard disk and was also much lighter.

Finally, inspectors addressed the tradeoff between weight and capability. Many inspectors complained that the VersaPad did not have enough hard disk capacity because it was too small to contain on-line versions of both the FARs and the Airworthiness Inspectors' Handbook.

Table 2.2 Common Features of the Four Computers

8 Mb RAM
Backlit LCD Monochrome display
PCMCIA Data Storage Card
DOS 6.0
Windows
Microsoft Word 2.0 (except the NEC VersaPad)
PENS Prototype Software

Perhaps the most telling data on the computers were collected in response to the question, "Would you use this computer in the field as part of your job?" Inspectors generally preferred the GRiD Convertible and the TelePad SL over the NEC VersaPad and the Toshiba Satellite. However, none of these computers are currently in production: the GRiD Convertible and the NEC VersaPad have been removed from the market; the TelePad SL is due to be replaced this Fall with the TelePad 3; and the Toshiba Satellite T1900 has been replaced with another model.

Because the notebook computer was comparatively heavy and cumbersome, it was extremely difficult for inspectors to use it while they performed an inspection. While they could easily operate a pen computer with two hands, the notebook computer really needed to lie on a flat surface. Inspectors indicated that they definitely would not be able to use a standard notebook computer as part of their daily routine, although a pen computer was feasible.

Inspectors were unanimous in requesting smaller, lighter computers. They were particularly interested in devices that would fit in their coat pockets such as personal digital assistants, e.g., Apple Newton, Tandy/Casio Zoomer, etc. However, such devices currently do not have either the storage or the processing resources to run applications necessary for ASIs. Inspectors were also intrigued by the possibility of using speech recognition for data collection, as this would keep their hands free.

2.2.4 Additional Issues

Interviews with inspectors revealed that, although immediate recording of field data may not always be required, immediate access to previous data or regulatory materials is required. For inspectors, a computer is more useful as an information management and retrieval tool than as a data collection vehicle for inspection activities.

Inspectors raised a number of additional concerns during the study. Many inspectors were concerned about liability for the equipment should it be stolen, dropped, or left on an airplane. Some inspectors were concerned with perceptions of people they were inspecting, i.e., they were worried that they appeared inept or incompetent when using a computer. Other inspectors were concerned that a computer lent an air of permanence to notes they made, and, as a result, operators would be less cooperative, even though notes on paper have the same degree of permanence. While there are practical solutions to all these issues, the issues themselves go well beyond the questions of which computer is better or if a field computer can be used for one-time data capture.

With regard to environmental considerations, inspectors noted that the computers stopped working when the temperature approached freezing. Cold temperatures also make it more difficult to use a computer because of the inspector's need to wear gloves, bulky coats, etc. Finally, as one might expect, inspectors were reluctant to use computers in snow or rain for fear of damaging the machines.

2.3 Training

The Regulatory Standards and Compliance Division, AMA-200, has begun training new ASIs on the concepts embodied in the Performance Enhancement System. Although the system is not ready for full implementation, inspectors should be initiated into future system capabilities as they receive their first training. In this way, inspectors will see the system as a tool in their compliance arsenal and as an integral part of their jobs.

Version 2 of the software was only recently completed, so the training group has provided only a brief system introduction during the training courses. However, the training group has indicated that they will gladly incorporate more training as soon as the system is ready for full implementation.

2.4 Version 2 of the Performance Enhancement System Software

Version 2 of the Performance Enhancement System software has been completed and is ready for the next field study. This software incorporates changes and improvements over the last version in four major areas:

1. the code was converted from C/C++ to Microsoft Visual Basic to allow significant improvements in the software's design and maintainability
2. the software has greatly expanded its functionality to address all three ASI specialties: Operations, Airworthiness, and Avionics
3. the Program Tracking and Reporting Subsystem (PTRS) data collected have been subjected to the same validation procedures used on data entered through the Flight Standards Automation System (FSAS)
4. the three leading FAA digital regulatory guidance document systems will be compared in the field study.

The following sections address each of these areas.

2.4.1 Software Conversion to Visual Basic

One of the biggest changes in Version 2 is that it has been converted from C/C++ to Visual Basic, which is rapidly becoming the standard development environment for Microsoft Windows software. This switch has improved the "look and feel" of the software, has made development easier, has increased maintainability, has improved our ability to add functionality, and has improved database capabilities.

The enhancements in Version 2 improve usability and user acceptance. As shown in Figures 2.1 and 2.2, the scroll bar has been removed from the PTRS form and has been replaced with tabs. This change makes navigation between sections of the form easier and more direct. Forms generally have more visual depth, appearing three dimensional. This new appearance facilitates functional grouping and makes buttons distinct from fields. Version 2 gives users the impression that it is a professional product, rather than a research and development tool.

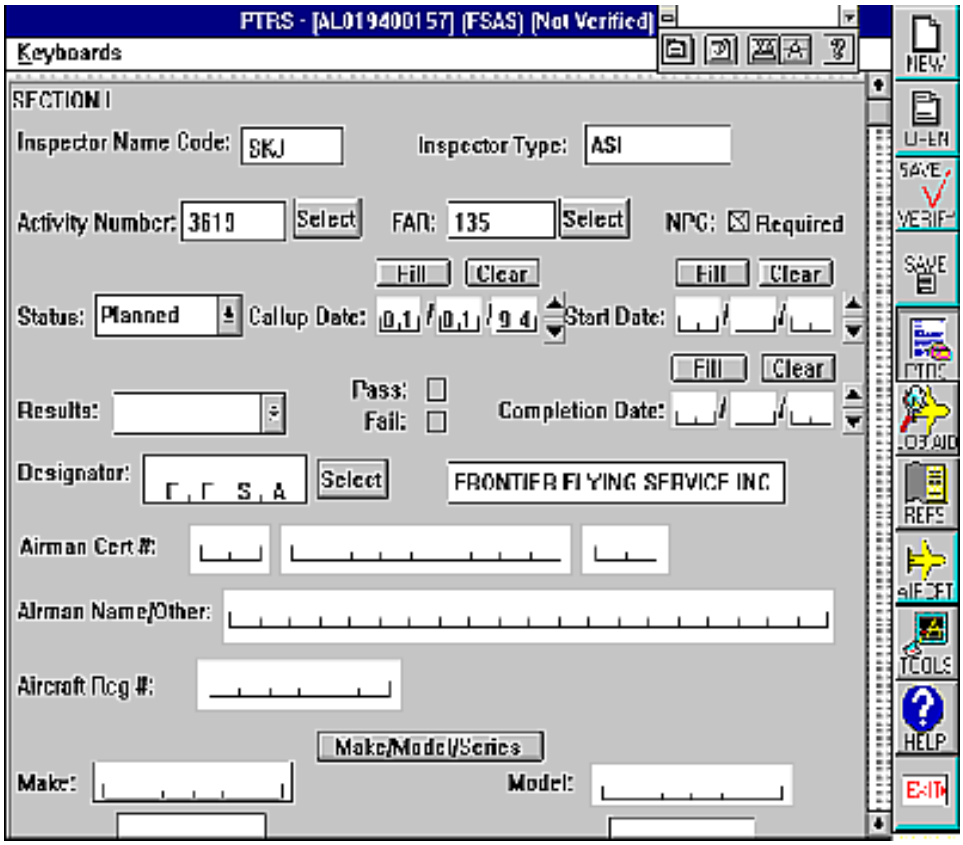

Figure 2.1 Performance Enhancement System ***Version 1***

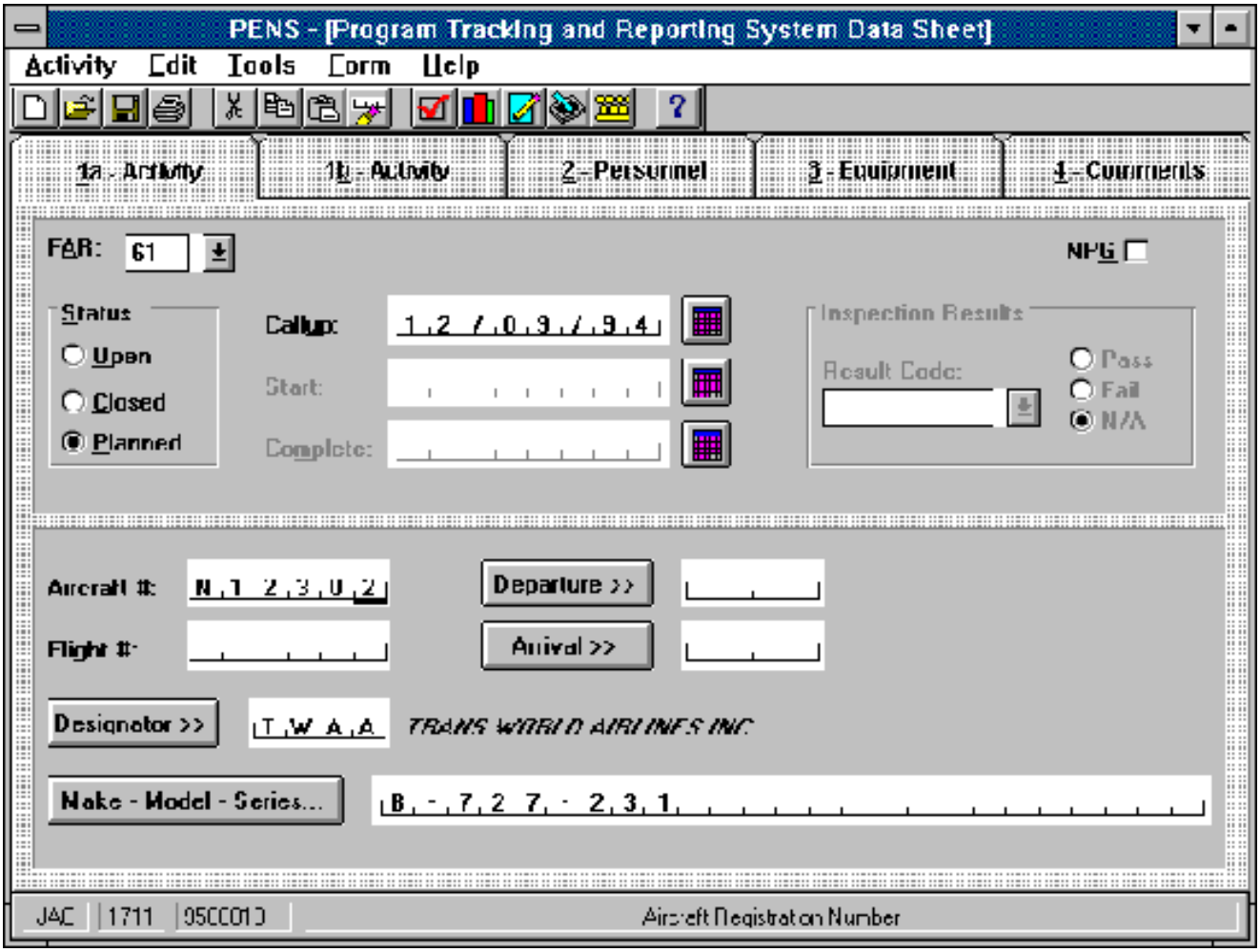

Figure 2.2 Performance Enhancement System *Version 2*

Because many development tasks are handled by Visual Basic, rather than by a programmer, software development has become much easier. Since the programmer does not have to worry about low level Windows routines necessary to make buttons work, he or she can focus on greater design issues of layout, error prevention, database support, and the like. Furthermore, Visual Basic improves Version 2's maintainability because it is now much easier to follow the software's flow of control and structure. Since Visual Basic uses the Basic programming language (which is frequently the first computer language one learns) the odds that the FAA will be able to maintain the software are greatly improved-especially when Visual Basic is compared with an esoteric language like C or C++.

Visual Basic supports myriad control features allowing one to add features supporting specific requirements of an application. These controls are called VBXs, and many are supplied by Microsoft with Visual Basic. Thousands more are available from third parties. Had the project been continued in C/C++, these types of controls would have been developed in-house, requiring significant time and effort. In Version 1 of PENS, virtually any desired control outside the very limited set supported by the C/C++ compiler would have to have been developed from scratch.

Finally, Visual Basic includes database support for a variety of databases, including Microsoft Access and Paradox 3.5. This support allows us easily to migrate the software to support future databases as AFS systems evolve. The current AFS standard database format is Paradox 3.5, but it appears that in the near future Microsoft Access and SQL formats will be used. Visual Basic has built-in support for each of these formats.

2.4.2 Expanded Software Capabilities

Version 1 of PENS consisted of three primary modules: the data collection and on-line policy module; the data transfer module; and the supervisory review module. Each module and its improved version is discussed in turn.

The data collection and on-line policy module consisted of the PTRS form for data collection, the Federal Aviation Regulations (FARs), and the Airworthiness Inspector's Handbook (FAA Order 8300.10). Version 2 of this module has been split into its constituent parts. The data collection portion has been expanded to include the ten forms most commonly used *in the field* (not in the office), including the PTRS form. These ten forms address the operations and avionics specialties, in addition to airworthiness.

New data management capabilities have been designed into Version 2. Work has been divided into three general categories: work yet to be begun resides in the "In Box"; work started, but incomplete, resides in "Work in Progress"; the "Out Box" contains completed activities before they are transferred to the office databases. A fourth data repository, the "Archive," maintains a backup set of all data that have ever resided on the portable computer. With this structure, inspectors quickly determine what activities are currently open, what activities are completed, and what activities remain to be accomplished. This capability is illustrated in Figure 2.3.

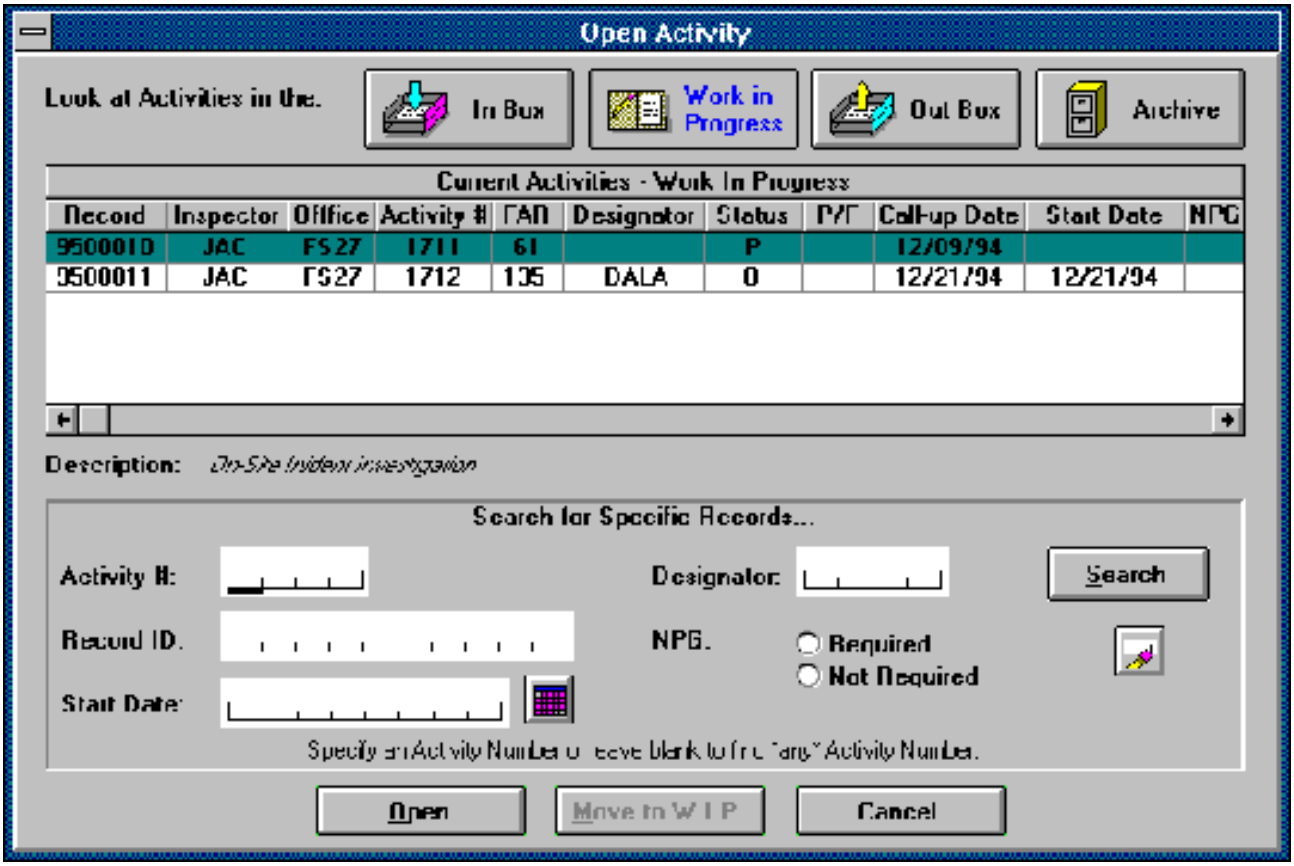

Figure 2.3 Work Program Management

Extensive error prevention mechanisms have been built into these forms. The philosophy of the PENS design process is to guide users so that they enter correct data, not to correct errors after-the-fact. Wherever possible, databases have been incorporated to allow the user to select from a set of possible entries, rather than to generate his or her own entries. Data that can be inferred from previous entries are automatically entered into the forms. For example, values for the Callup, Start, and Completion Dates are constrained by the inspection's status. As shown in Figure 2.3, the "Start Date" field is grayed because the Status is "P" for planned. Once the Status is "O" for open, the "Start Date" field is immediately available. Finally, data that are redundant across forms are automatically shared so that an inspector need record those data only once.

The on-line help system has been expanded to include Version 2's new functional capabilities. Help now addresses how to use the software, rather than how to complete a given activity. However, steps to complete an activity will be included in Version 3 of the software because Job Task Analyses are to be incorporated. Two additional help features have also been incorporated in Version 2: Bubble Help and Micro Help. Bubble Help is familiar to most Microsoft software product users; it is the text description appearing when the pointer rests on an icon. Bubble Help ensures that toolbar functionality is clear. Bubble Help is illustrated in Figure 2.4. Micro Help is a text description of the function currently in use appearing at the bottom of the screen. For example, when a user clicks on the "Make-Model-Series" field in the PTRS form, Micro Help indicates that the code may be selected from a list. Micro Help is shown in Figure 2.5.

The on-line FARs and Handbooks in Version 1 were very difficult to maintain and keep current. Because some commercial vendors specialize in such documents, it was deemed appropriate that inspectors compare the most promising of commercial alternatives. The in-house versions of these documents are not incorporated in Version 2. This topic is discussed in more detail below.

The data transfer module has been divided into two separate utilities in Version 2. One of these utilities transfers FSAS data to the field computer; the other transfers data from the field computer to FSAS. The former utility will be used rarely, for example when a field computer is initially loaded with the inspector's work program. The inspector will use the latter utility whenever he or she returns from the field and is ready to transfer field data to the office file server.

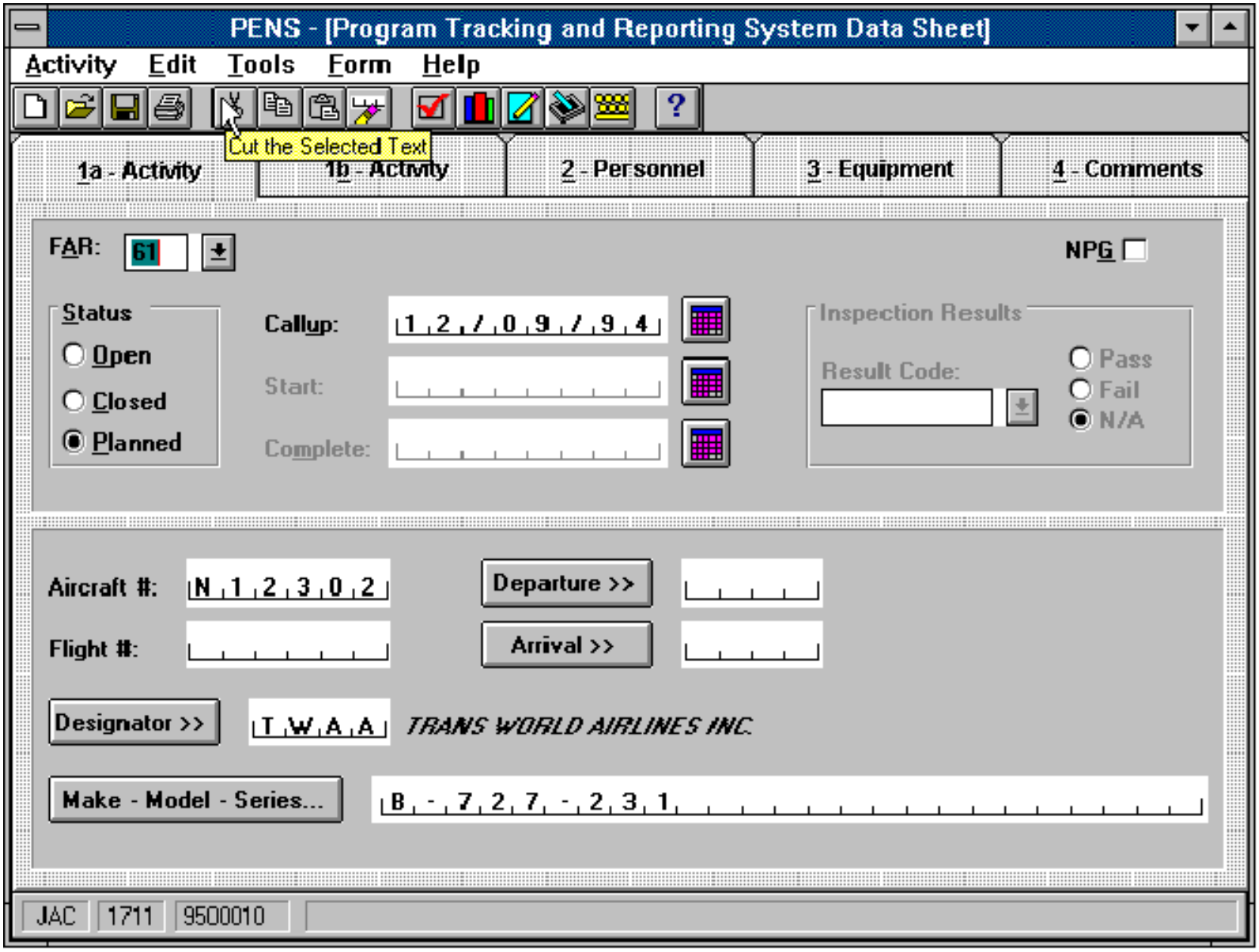

Figure 2.4 Bubble Help Example

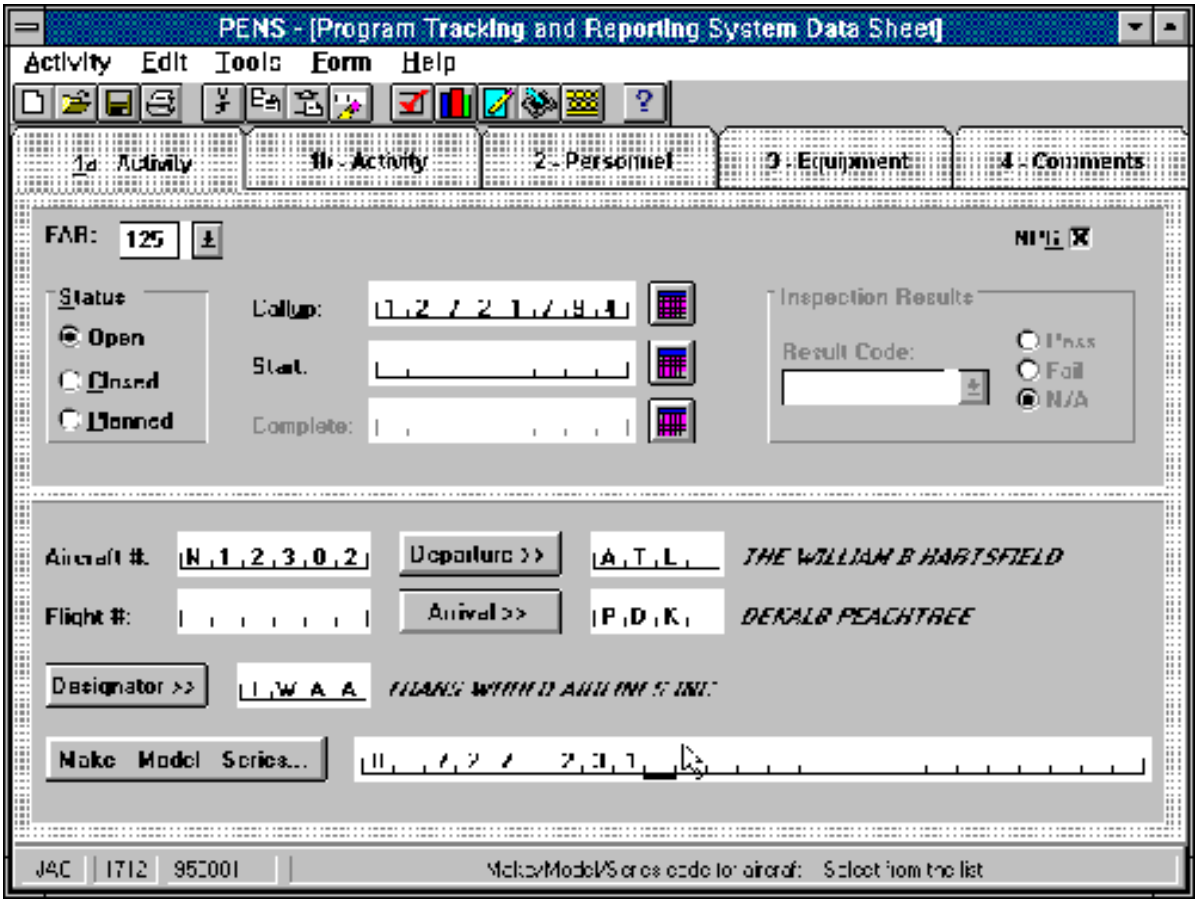

Figure 2.5 Micro Help Example

The supervisory review module has been dropped from Version 2 because inspectors rarely used it in the first field evaluation.

2.4.3 PTRS

Data Validation, the Regulatory Support Division, AFS-600, and the Operational Systems Branch, AFS-620, in particular, have been instrumental in allowing us to test the PTRS data collection software. The Operational Systems Branch initiated a procedure that allows us to send PTRS data collected with our software through the same upload procedure utilized in FSDOs, including data validation. This allows us to ensure that all data are consistent with the current FSAS data entry system. With Version 1, we had difficulties with some hidden database fields our software did not fill and we were unaware of these difficulties until we started field-testing the software. Version 2's data validation capability allows us to work out such kinks *before* we get the software into the field.

2.4.4 Digital Regulatory Guidance Documents

As noted above, one of the critical needs inspectors cited in the first field study is an ability to research policy and regulatory guidance while they are in the field. Version 1 of the software supported a prototype of this capability. At the time, it was necessary for us to develop this prototype in-house because the products were not available commercially. However, three commercial providers now have released extensive Windows-based systems: Aviation Compliance Services (ACS) released the FAR Library; Aircraft Technical Publishers (ATP) released the United States National Aviation Regulatory Library; and Summit Aviation released the Computerized Aviation Publications Library. Each system contains the Federal Aviation Regulations, some Advisory Circulars, some FAA Orders, and additional publications. Each package is unique, and each publisher releases updates on its own schedule.

The ACS and Summit systems have a simple document viewer with simple searching techniques. The ATP system is a powerful research tool, containing significant cross referencing of documents and aircraft information. There are significant cost differences among the products. Our current plan is to compare all three products in a small field study and then to let inspectors determine which product best meets their needs. ACS and ATP have agreed to supply their product at cost; negotiations with Summit are underway.

2.5 On-going Computer Evaluations

We are continuing to evaluate portable computers to stay abreast of the latest developments in portable computing technology. Portable computers are becoming smaller and lighter, with more processing power, and a longer battery life. New developments in pen computer technology have allowed manufacturers to reduce their size and weight while simultaneously increasing their capabilities and battery life. These units have improved so much recently that they deserve a fresh look from inspectors, particularly from airworthiness inspectors.

Subnotebook computers offer a compromise between the capabilities of full notebook computers and their weight. Subnotebooks typically have somewhat smaller hard disk drives of around 120 MB (although this is increasing) and use external floppy drives; they are much smaller than notebook computers and weigh approximately half as much. A subnotebook computer will fit in a large overcoat pocket, which approaches inspectors' requests for a unit that would fit in a pocket.

While subnotebook computers may fit a majority of inspectors' needs, inspectors may also wish to do research on policy guidance in the field. In the last year several notebook computers with internal CD ROM drives have been introduced. These CD ROM notebooks have full multimedia capabilities, as well. These machines come in two configurations. One design has a CD ROM drive underneath its keyboard; the other uses a separate CD ROM docking station attached beneath a standard notebook computer. The first design has CD ROM available always; its drawback is that the user must always carry additional weight. The second design has the merit of allowing an inspector to leave the CD ROM drive (and its weight) behind when it is not needed; its drawback is that an inspector has to keep track of a second piece of equipment.

We envision providing samples of these computers to inspectors at the Atlanta FSDO prior to the actual field study. These inspectors will give us a first pass evaluation of the options; in turn, we can determine which computers offer the most promise for the field study.

Chapter 2 - Appendix
Job Aiding: Transition of Performance Enhancement System Concepts to Industry

Introduction

The Performance Enhancement System's success has brought the aviation industry's attention to the possibilities of supporting mobile maintenance technicians and auditors with portable computing technology. This is somewhat ironic, given that we started the research with these applications in mind but were unable to interest industry. During the last year, we have been working with a partner airline to transition PENS job aiding concepts to industry personnel. The following is a brief description of that work.

Airline Partner's Needs

Our partner airline has two groups of maintenance auditors within the Technical Standards office: Compliance Auditors and Vendor Surveillance Analysts. Both groups use a variety of forms to document the results of their audits. Both groups also have standards which they apply to the organizations that they audit, including Federal regulations (Federal Aviation Regulations, Airworthiness Directives, etc.) and internal standards. Our partner airline wanted to support both groups of auditors.

The Vendor Surveillance group is responsible for auditing companies supplying materials and services to the airline to ensure that those companies are in compliance with Federal guidelines and with industry standards. Our partner airline is a member of the Coordinating Agency for Supplier Evaluations (CASE). The CASE organization is a consortium of airlines that pool their resources and auditing results. If a CASE member, e.g., our partner airline, evaluates a supplier and certifies that the supplier is in compliance with Federal regulations and CASE standards, then other CASE members know that they can use the supplier without having to perform their own audit. CASE provides both auditing forms and standards to its members. There are currently six CASE forms, although this number changes as new forms are added and old forms are retired.

The Compliance Auditor group is responsible for ensuring that our partner airline's maintenance operations are in compliance with Federal guidelines and with its own standards. The Compliance Auditors use approximately 32 forms.

Software Prototype

We have developed prototype software to support both Compliance Auditors and Vendor Surveillance Analysts. Both prototypes were developed for use on pen computers because the auditors wanted capability similar to the clipboards they currently use. The collected data are stored in databases and can be printed out in standard report formats or exported to Microsoft Word. This is a vast improvement over the current method of manual transcription of handwritten paper forms.

We developed an application that contains four of the forms Vendor Surveillance Analysts use most frequently. Each form is saved separately because a vendor normally provides only one supply or service. An example is shown in Figure 2a.1. The application allows an inspector to identify whether a vendor is in compliance and to make a comment for each item on the form, as shown in Figure 2a.2.

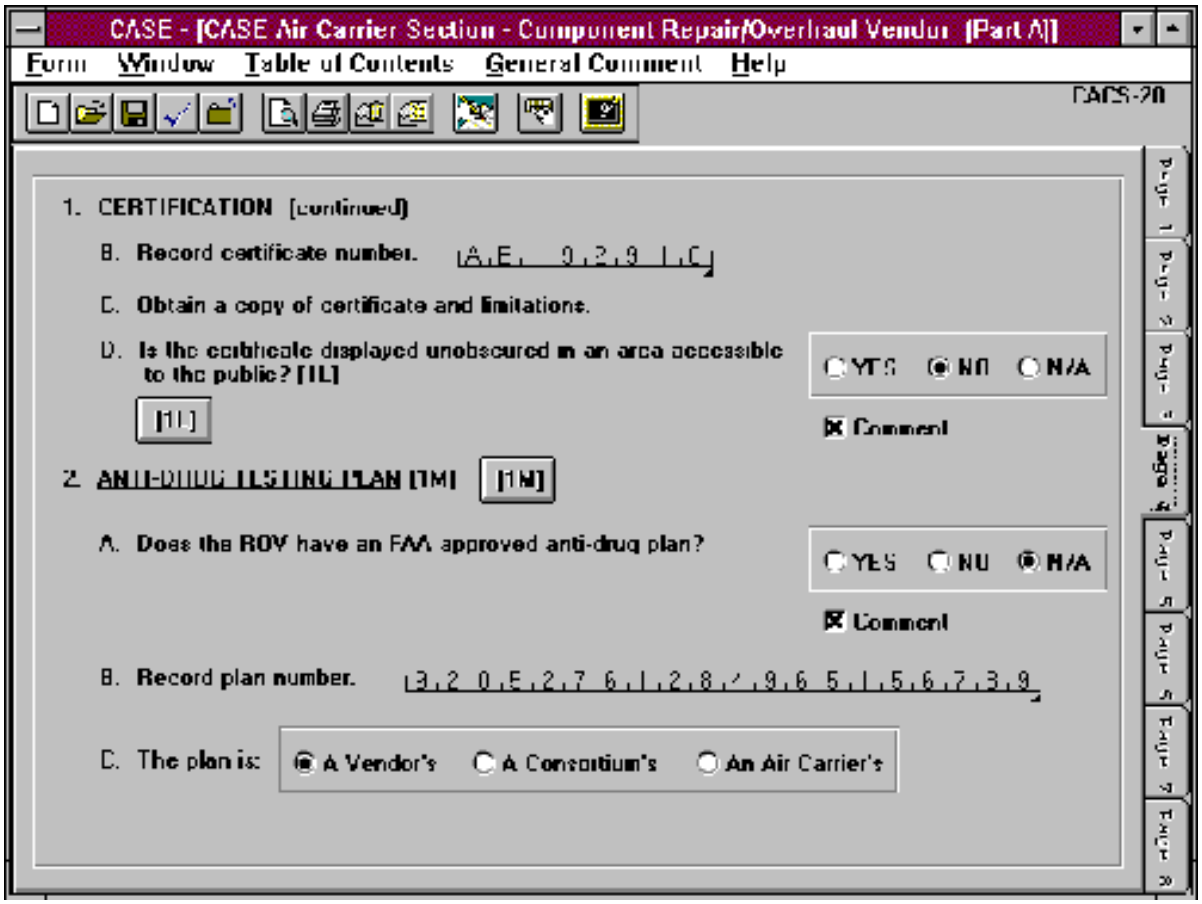

Figure 2a.1 Example CASE Form

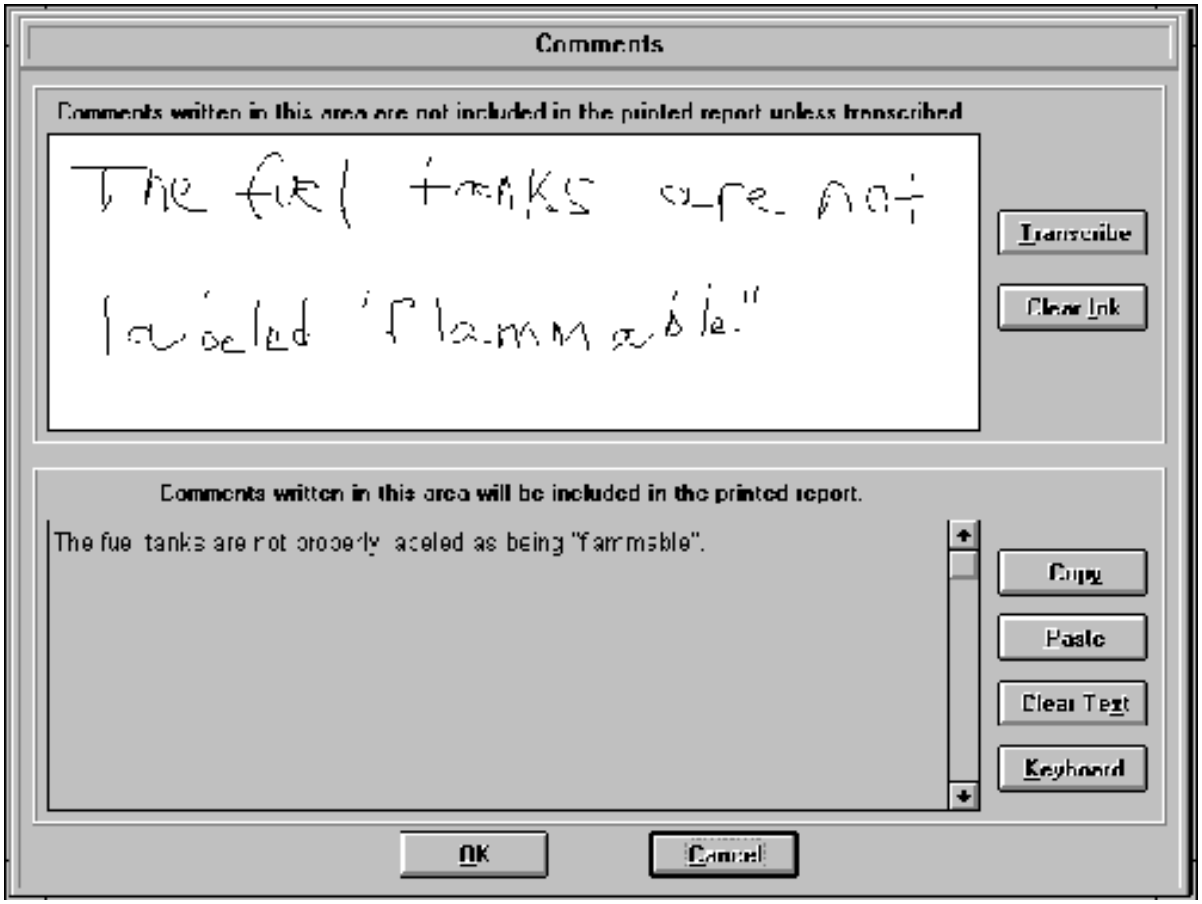

Figure 2a.2 Example Comment

The application also contains links to the CASE standards appropriate to the questions on the auditing forms. This allows an auditor quickly to access the standards for reference while performing an audit. As shown in Figure 2a.3, there is a button next to a surveillance item ("Does ROV hold an FAA repair station certificate?") that identifies the standard. When an auditor pushes the button, the standard appears in Windows Help, as shown in the figure. Auditors like this capability because they can read the standard and because they can copy and paste it into their reports. Whereas their reports previously contained the auditor's recollection of the standard, they now contain the standard's exact wording.

We developed a similar application for the Compliance Auditors. Unlike the Vendor Surveillance application, forms are saved in "sessions"; all forms used in a given audit are saved together. This difference in design results from the fact that a given maintenance facility of our partner airline normally performs several different types of maintenance and requires multiple forms. Because the content of the forms is proprietary to our partner airline, we cannot publish examples. However, the format and content are very similar to the Vendor Surveillance forms. Because our partner airline has proprietary standards for evaluating their practices, its managers have been unwilling to share them with us so we could put them on-line.

Evaluation

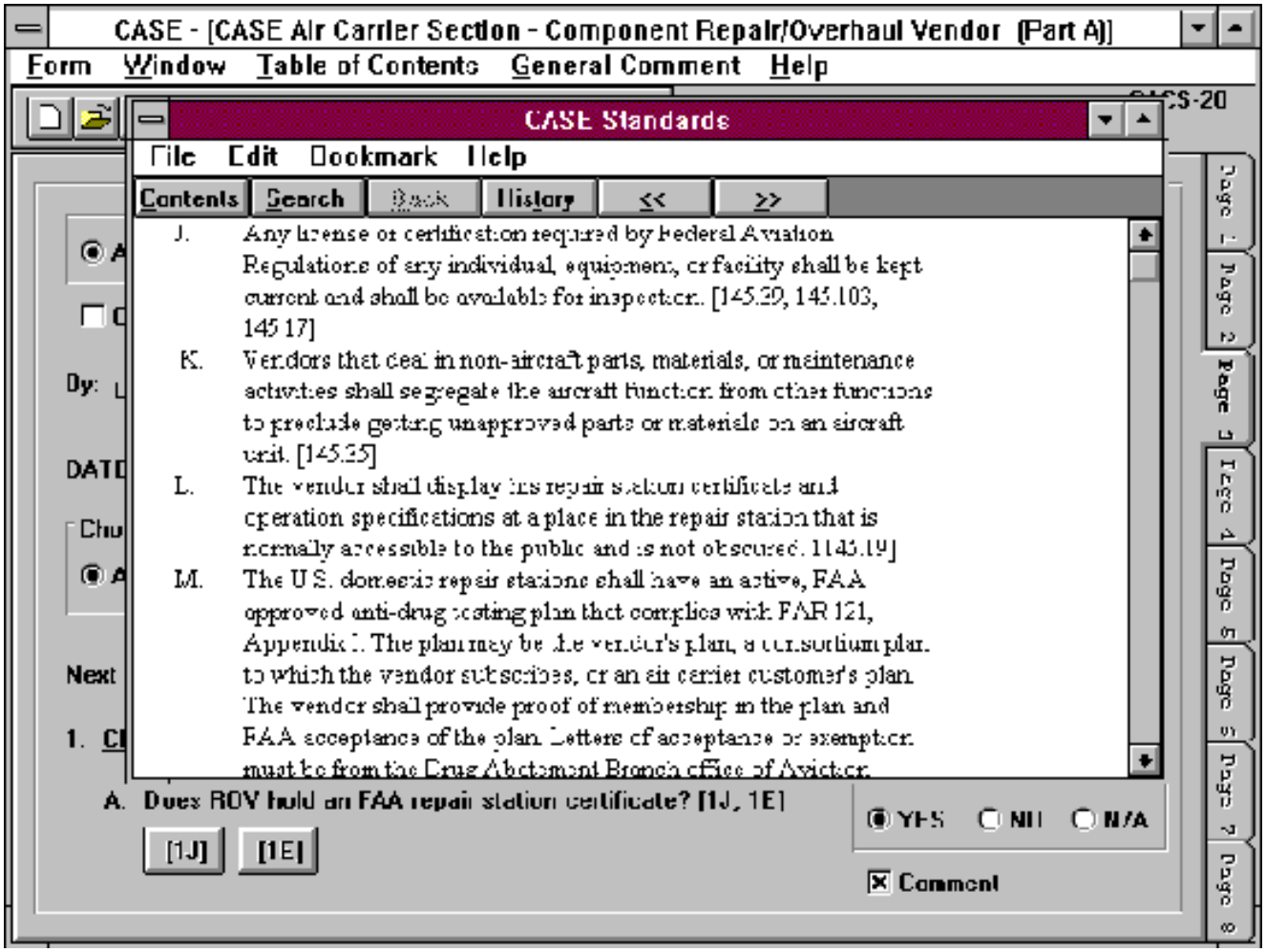

Figure 2a.3 Example of On-Line Standard

Both prototypes are currently under evaluation at the airline. We provided both groups of auditors with a number of pen computers and copies of the prototype software. Auditors are also using the software on their desktop computers. We expect the evaluation to run sixty to ninety days. Upon successful completion of the evaluation, we plan to work with the airline and the CASE organization to determine how these concepts can be applied within the broader aviation community.