# Chapter Five
# Hardware /Software Studies for Database Storage and Retrieval for Future Systems

## 5.1 Summary

The objective of this subtask was to investigate advanced technology platforms and software for data display and information management. Based on several years of working with Aviation Safety Inspectors (ASI), a general list of automation assets has been identified and their relative merit to the needs of different ASIs has been compiled. Numerous notebook computer systems were researched and compared to the various needs of the ASIs. Several operating systems were also researched for their potential to support ASI activities. The ultimate objective of these investigations is to allow the Flight Standards Service (AFS) to optimize the performance of their ASI staff versus investment tradeoff for the life of the next investment period (approximately five years).

## 5.2 Advanced Technology Platforms

### 5.2.1 Aviation Safety Inspector Requirements

The Performance Enhancement System analysis conducted in the Fall of 1993 provided a better understanding of the computer hardware requirements of ASIs. The analysis of these results, and numerous follow-on discussions and on-site visits, resulted in the identification of three general classifications of ASI users, each with differing computational needs.

The first type of ASI is an intense user of automation tools and wants, (1) the ability to record new data on forms in the field or office and (2) to access all AFS information anywhere, anytime. Many of these ASIs travel to outlying areas within their district several times each month. The purpose of these extended trips is to perform inspections and investigations on remote operators and airline support companies. To support them on these trips they wanted the computational resources of their desktop computer with them. But they did not want to maintain two different primary storage devices (e.g., a hard disk drive [HDD] on a portable computer and a separate HDD on the office desktop computer). Weight of the laptop computer was not a primary concern when compared to the volume of material that is carried today with the current use of paper references.

The second type of inspector was a moderate user of automation tools and wanted to access only the data that was routinely used during an inspection. They also identified an occasional need to record new data on forms while in the field. A majority of these ASIs return to their offices and desktop computers to perform the research and paperwork to complete an inspection or investigation. There was a mix of inspectors in this category; some who travelled frequently from the office and some that typically remained close to the office. Weight of the computer was an important concern. The issue of maintaining two separate HDDs was also a concern.

The third type of inspector was a minimal user of automation and expressed little desire for computational tools in the field but did feel that some occasional access to data and some ability to record brief notes and comments was desirable. These inspectors typically only travelled to local inspections sites. All of these ASIs conduct their work on a desktop computer at the office. Weight and size of the computer and the number of peripheral components were primary issues.

### 5.2.2 Computer Hardware Summary

To support these three different needs a review of available computer equipment was performed. One factor that could not be held constant during this evaluation of computer hardware was the introduction of new technology. New hardware and improved equipment are being released continuously. Significant changes in the computer industry are being made roughly every 12 months (e.g., more sophisticated processors, larger/faster storage devices, intelligent peripherals, etc.) and have a profound effect on the application of computer hardware to a specific set of requirements. Therefore, it must be noted that the results of this review are as of December, 1994.

Based upon these analyses of ASI needs and available technologies, a general computer solution was developed for each ASI type. The distinction between these types of computer systems is not exact but it gives the reader an idea of the capabilities the hardware provides to the ASIs. Table 5.1 presents a matrix showing the relative value of computational requirements to the different types of ASIs.

**Table 5.1 Computational Requirements Matrix**

| | Relative Value | | |
|---|---|---|---|
| **Computational Requirements** | **Intense User** | **Moderate User** | **Minimal User** |
| Data Collection | High | Medium | Low |
| Reference Materials | High | High | Medium |
| Number of Applications | High | Low | Low |
| Resources Requirements | High | Medium | Low |
| Environmental | High | High | High |
| Data Security | High | High | High |
| Cost | Low | Low | Low |

The ASI who is an intense user of automation tools may best be suited with a full-featured notebook computer that has the same functionality as a desktop computer. This would give an ASI the ability to take his/her office applications and files anywhere. These types of notebook computers are designed primarily to be carried from place to place, plugged in, and used. Though these units have batteries, the battery life is limited (roughly 2-3 hours of steady use) thus only allowing for occasional unplugged use. These computers weigh approximately seven pounds and are tightly packed with supporting devices. They have large color displays (10 inch diagonal), fast processors, full-size alpha-numeric keyboard (and reduced-size function keys), large hard disk drives, 8 MB or more Random Access Memory (RAM), two Type II (or one Type III) Personal Computer Memory Card International Association (PCMCIA) card slots, a floppy drive, integrated pointing device, and occasionally a Compact Disc - Read Only Memory (CD-ROM) drive. Appendix A contains detailed computer specifications of the computers under consideration. To supplement these notebook computers at the office, a docking station option is typically available. A docking station converts a notebook computer to a desktop computer. The docking station does not have its own processor nor RAM but relies on the notebook computer to supply these. The docking station gives the user the option to use a full size color monitor, full size keyboard, additional internal peripheral bays (for a CD-ROM drive, tape drive, HDD, etc.), and expansion slots (for a Local Area Network [LAN] card, SCSI controller card, etc.). The most attractive feature of the docking station concept is that it allows the user to maintain only one HDD. One of the problems with a notebook computer and a docking station is the incompatibility of peripheral components for the system. Several peripheral components evaluated were incongruous with the docking stations due to allocation of computer resources and/or interface configuration differences. Docking station systems are also more difficult to integrate

into a complex networking and software development environment. Finally, the depth of these docking station units is also a minor issue. Most of these units exceed the depth of standard computer tables and use up the entire depth of a standard office desk. Figure 5.1 illustrates a docking station concept.

**Figure 5.1 Notebook Computer/Docking Station**

We believe that the moderate user of automation tools would be best suited by a sub-notebook computer. These computers are lighter in weight (less than 4 pounds) and have a longer battery life. The trade-off for these two features is that these units have a slower processor and decreased storage capability when compared to the full-size notebook computers. These units typically have a smaller color display, moderately fast processors, moderate HDD storage, a single PCMCIA Type II card slot, smaller keyboard, integrated cursor-control device, and an external floppy drive. These systems typically have an option of a port replicator. The port replicator provides some of the capabilities of a docking station (e.g., connection to a full size monitor and keyboard) but are an awkward solution for a desktop system due to the many cables and external peripheral devices that surround the computer and port replicator. Therefore, a full-featured desktop computer may be required at the office as the primary computer. This brings up the issue of maintaining two HDDs. There are currently available several hardware products to move data (wirelessly or with a cable connection) between the sub-notebook computer and their separate desktop computer. These systems are fairly easy to use but require planning to keep both HDDs up to date. It must be noted that the distinctions between the sub-notebook computers and the full-size notebooks are rapidly diminishing as technology advances.

The ASI who desires minimal use of automation tools could best be served with a compact pen tablet computer or a Personal Digital Assistant (PDA). The current pen tablet computers are a little smaller than the size of a 8.5 inch by 11 inch piece of paper, are less than 1.5 inches thick, and weigh roughly three to four pounds. The pen computers typically use less powerful processors to maximize battery life (though again this may change with the recent introduction of faster processors with low power consumption). These units typically have a surprising amount of RAM for there size (up to 20 MB), two Type II PCMCIA slots, up to 105 MB of storage (PCMCIA storage or HDD storage), and a six to eight inch diagonal monochrome LCD display (some are currently introducing color LCD displays). The pen computers typically operate with the Microsoft Windows operating environment. During the first Performance Enhancement Systems field study several "convertible" pen computers were used. Very few of these types of computers are in production today because these designs tried to be all things to all users. Instead, too many compromises were made with these computers and they did not perform well in any task.

The PDAs are roughly seven inches by five inches, less than an inch thick, and weigh about one pound. They utilize a low power processor, up to 4 MB RAM, one Type II PCMCIA slot and a three inch by four inch monochrome LCD display. The PDAs use either a pen-based DOS or a proprietary pen-based operating system. Handwriting recognition is only one element of a pen-based operating system. The specific user interface metaphors are different but overall, they all utilize the pointing ability of the pen for navigating through the operating system or interacting with an application. They also capture graphic images by storing "electronic ink." To date, PDAs do not have the processing or storage capabilities to be the primary computer for the ASIs but they could perform well in a limited role.

As stated previously, the distinctions between these systems and the differences between the computational requirements of the ASIs are not exact. Ideally, a single system that could meet all of the specified needs would be desirable. Realistically, the solution will be either one computer system that is the best compromise to meet a majority of the ASI requirements or several different computers that better satisfies nearly all the requirements. Continued work with the ASIs in the field will help drive the final decision. Emerging technologies such as continued miniaturization, faster processors, and new peripherals will also continue to impact the final selection. The notebook and sub-notebook computers listed in Appendix A are units that we have evaluated. Some of the pen computers and the PDAs have been evaluated in-house while others were reviewed from published reports.

## 5.3 Review of Client/Server Technology

Client/server is a very efficient computing model because it handles processing where it makes the most sense. Processing is split between powerful servers and desktop machines. The client/server front-end located on the desktop computers is traditionally either a pre-packaged or customized application that is able to present and manipulate data in a graphical, easy-to-use, understandable fashion. The desktop is networked to a back-end server application that is responsible for storing, retrieving and protecting data.

Client/server computing provides the framework needed to support key business application, including exploiting the full computing power of both desktop and server machines, and integrates heterogeneous systems and applications. These features produce a range of user benefits:

1. Users gain immediate access to up-to-date corporate data when they need it, without compromising security. They also can use familiar tools, such as spreadsheets and database systems, to access it.
2. A consistent, easy-to-use graphical user interface (GUI) reduces training, learning time, and costs.
3. By integrating client/server applications with personal productivity applications, users can quickly build customized solutions to meet changing needs.
4. Client/server systems are less expensive and quicker to deploy than traditional mainframes and minicomputers. These systems are easily scalable (e.g., can add new processors, servers, and clients as needs increase) and very flexible.
5. A rich set of tools and application programming interfaces (APIs) are available thus allowing client/server systems to be easily developed.

The client/server model can provide AFS with many benefits. These benefits include increased productivity, lower operating costs, the enabling of new applications, efficient management, and enhanced network performance. Client/server computing will allow AFS to achieve better price/performance ratios by using smaller, less-expensive, networked personal computers to take over tasks traditionally performed by larger, more costly minicomputers and mainframes.

## 5.4 Operating Systems and Environments

### 5.4.1 Microsoft Windows

The Microsoft Windows operating environment provides a GUI that makes using an IBM compatible personal computer easier. This non-preemptive multi-tasking system provides a common and consistent user interface, applications base, and programming model. Having a consistent product family means:

1. MIS managers and support personnel benefit in reduced training and administration costs.
2. End-users can use an application on one platform (e.g., their desktop), and know it will operate the same way on another (e.g., a pen-based notebook). Training is reduced because all applications work according to a consistent set of principles.
3. Hardware and software developers protect their existing investments in product development and gain access to vast market of windows based products.

Microsoft Windows 3.1 is presently being used as a standard in AFS offices but not all applications operate within the Windows environment. Current use of non-Windows applications (e.g., FSAS) requires the user perform the tedious task of unloading Windows to start a DOS application or vice versa. As more AFS applications move to the Windows environment, AFS users can enjoy the benefit of working in one integrated environment. Users have the capability to easily move from one application to another without memory concerns.

If an application running in the Windows environment fails, it can potentially cause the Windows environment to crash. The possibility of the system crashing becomes greater as more applications are run simultaneously. In addition, a minimal amount of RAM for certain tasks, such as printing and intense computational tasks, will severely slow the Windows system until these tasks are completed.

### 5.4.2 Microsoft Windows for Workgroups

The Microsoft Windows for Workgroups operating environment is very similar in terms of functionally to the Windows operating environment. However, it is very different when it comes to networking capabilities. It comes equipped with a 32-bit network software that enhances performance and conserves memory so that more is available for MS-DOS based applications. Windows for Workgroups provides enhanced networking features which allows users to communicate and share information with other users.

The Windows for Workgroups File Manager and Print Manager allow users to share resources, such as directories and printers. Users can also monitor how shared resources are being used. File Manager includes the ability to share directories on computers so that other users can access those files. Through Print Manager, a user can designate a printer to be shared so that other users can connect and print to it.

The system provides Electronic Mail functionality, built-in fax software, and a Scheduler. Electronic Mail allows users to exchange files and electronic messages with other users on the network. The built-in fax software allows users to send and receive faxes. The Scheduler allows users to keep track of appointments and tasks and record notes to themselves.

Windows for Workgroups offers advanced resource sharing capabilities. It allows multiple users to access word processing and spreadsheet documents simultaneously. The Windows for Workgroups package offers AFS personnel one tightly integrated package to perform tasks that is presently being done with multiple software packages.

### 5.4.3 Microsoft Windows NT and Windows NT Advanced Server

At the high end of the Microsoft Windows family of solutions is the Microsoft Windows NT operating system which was designed to be a powerful operating system platform for client/server computing. This 32 bit, preemptive, multi-tasking operating system is an excellent front-end system for client/server computing, as well as for a powerful high-end stand-alone personal computer.

Windows NT Advanced Server, the server version of Windows NT, provides a platform for full implementation of client/server solutions, as well as the network services necessary to build LANs that scale from small, single-server sites to the largest multi-server, multi-site systems.

Windows NT allows virtually unlimited memory and storage capacity. The system can access up to 2 GB of virtual memory per application (4 GB RAM) and more than 408 million terabits storage. Windows NT can take full advantage of the most hardware because it is platform-independent. It allows users to add additional processors (up to 32) as the system and applications demand it.

Windows NT includes built-in features to provide high reliability for client/server computing. The system is robust and is quick to recover in case of failure. Several key features were implemented to ensure the system is always available, even if an isolated application fails, including protected application subsystems, protected virtual memory, and hardware isolation. This is a major advantage over Windows and Windows for Workgroups.

The Windows NT operating system is ideal for the client/server environment. It is a reliable and a powerful operating system. The Windows NT advanced server functions well as a database server and Windows NT functions well as a true multitasking operating system on the desktop. The Windows NT system is easily installed and maintained. This system can easily be maintained by AFS network administrators will minor training. The price that must be paid for this type of system are the large computer resources. As a network server, Windows NT requires a minimum of 16 MB of RAM, with 32 MB being adequate, and 64 MB preferred. The minimum RAM for the Windows NT Workstation is 8 MB

### 5.4.4 Unix Operating System

The Unix operating system is a powerful 32-bit preemptive multitasking, multi-user operating system. The system consists of two major components, the kernel and the shell. The kernel is the core of the operating system. It is the part of the system software that is responsible for managing the computer's hardware and software resources and for processing commands. The work that the kernel performs is hidden from most users by the shell. The shell is the part of the system that the user interacts with.

The Unix system is a powerful operating system that provides database servers with the processing power they need. Use of the Unix operating system provides users with a tremendous choice of utilities, powerful scripting facilities, and a stable, robust operating environment. However, the system is more difficult and costly to maintain, and it requires top-of-the-line hardware to run efficiently. Additional training is required in order to efficiently maintain this system. The user interface is a command line format that is more complex and requires the user to understand many details of the underlying operations of the kernel. The use of X-Windows, a graphical user interface for Unix, enhances the users proficiency with the system but is still more complex that the Microsoft Windows interface.

### 5.4.5 IBM OS/2

The IBM OS/2 Version 3.0 operating environment is a another GUI system that provides the desktop user a intuitive, graphical Workplace Shell. The workplace shell uses drag-and-drop capabilities with 3-D and animated icons. It also provides an easy- to-learn approach for the management of printers, drives, files, and programs. The OS/2 system is true 32-bit preemptive, multi-tasking operating environment. It allows the users to run OS/2, Microsoft Window 3.1, and traditional DOS applications within the OS/2 environment . It is expected to require a minimal amount of time to re-train AFS personnel currently familiar with the Windows operating environment to efficiently use the OS/2 environment.

The basic hardware requirement for OS/2 is the same as Microsoft Window Version 3.1. Therefore, no additional hardware needs to be purchased to use this operating environment. Because of the preemptive multi-tasking capacity, OS/2 system can process multiple DOS, Windows, and OS/2 applications concurrently.

The latest release of OS/2 system includes a group of the OS/2 utilities called BonusPak. BonusPak offers numerous functions, such as a fax utility, information services, and an Internet connection utility. The OS/2 system also offers support for multimedia functions such as sound and video capture and playback.

### 5.4.6 Operating Systems and Environments Summary

As was discussed in the review of hardware systems in section 5.2.2, one factor that could not be held constant during this evaluation was the introduction of new operating systems. New and/or improved operating systems are being released continuously. These changes will most likely have a profound effect on the application of computer operating environments to a specific set of requirements. Therefore, it must be noted that the results of this review are as of December, 1994.

Current AFS System Architecture

AFS presently uses Microsoft Windows 3.1 and cc:Mail for Windows by Lotus Development Corporation on a Novell Netware network.

| Network Server System | Desktop Operating Environment | Mail System | Mobile Operating Environment |
|---|---|---|---|
| Novell 3.x | Windows 3.1 | cc:Mail | None |

Based upon information collected during this project, it was confirmed that AFS is planning to migrate to a client/server environment To transition a FSDO office to a client/server-based system will require a change in software and a possible change in hardware depending on the approach used. There are three basic options that have been identified, each with several additional options that need to be considered prior to making a final decision.

Option 1: Extend the Current System Architecture

This option begins by upgrading the current Novell Network file server software from 3.x to 4.10. This upgrade will add improved network security features, allow for a more integrated networking environment, provide faster network services, and make the network manager's task easier due to a Windows-driven interface. This upgrade alone will keep the network users interface, from the ASI's perspective, exactly as it is today while providing a noticeable increase in speed for network functions (e.g., file and print services).

| Network Server System | Desktop Operating Environment | Mail System | Mobile Operating Environment |
|---|---|---|---|
| | Windows 3.1 | cc:Mail | Windows 3.1 |
| | Windows for Workgroups 3.11 | cc:Mail | Windows for Workgroups 3.11 |
| Novell 4.x | Windows NT Workstation or Windows 3.1 | cc:Mail | Windows NT Workstation |

| | | | |
|---|---|---|---|
| | | | OS/2 |
| | | cc:Mail | |
| | | | OS/2 |
| | | for OS/2 | |

To improve performance on the desktop and mobile computers, the Windows for Workgroups operating environment should be considered. The enhanced 32-bit functionality will speed access to the network (100% faster that Windows 3.1) and to the hard disk drive (up to 50% faster on disk-intensive tasks). Other improvements over Windows 3.1 are a new File and Print Manager toolbars and Microsoft At Work fax capabilities. In some instances these features may not be enough to justify the cost of upgrading existing computers currently using Microsoft 3.1, but this operating environment should definitely be considered when purchasing new computers.

To better operate in the client/server environment, a more capable version of this option continues with upgrading the desktop and/or mobile operating system to the Windows NT Workstation software. This upgrade coupled with the Novell upgrade provides the user with a powerful front-end operating system that is more operationally robust than the existing FSDO systems and better able to function in a client/server environment. To gain this performance advantage though requires the desktop and/or mobile computer to have a minimum of 12 MB of RAM, a CD ROM, and 90 MB of HDD space available.

A final version of this option is to use IBM's OS/2 Version 3 operating environment. This desktop operating environment can run on a 386 or better computer with a minimum of 4 MB RAM within the Novell network. It will also run all Windows, DOS, and OS/2 applications although Windows applications will run considerably slower compared to a Windows operating system. The 32-bit operating system would be capable of running several applications effectively, like the Windows NT Workstation system, but is not optimized to run in a client/server setting. A cc:Mail program tailored to operate in the OS/2 environment would need to be purchased for this option. Some additional training for all non-OS/2 trained personnel would be required.

Option 2: Windows NT System Architecture

This option begins with upgrading the FSDO servers to the Microsoft Windows NT Advanced Server 3.5 and upgrading the desktop and mobile computers to Windows for Workgroups 3.11. This networking system was designed to support a client/server environment as well as providing a fast, robust network server that is easily scalable from a small number to a large number of users. The main advantages of this system over a Novell system is that it is optimized to operate in a client/server environment and is designed to support remote access for mobile users. The disadvantages are that it runs a little slower and has more demanding hardware requirements. As discussed in the previous section, in order for a server to effectively utilize this system, 64 MB of RAM should be installed for best performance.

| **Network Server System** | **Desktop Operating Environment** | **Mail System** | **Mobile Operating Environment** |
|---|---|---|---|
| | Windows for Workgroups 3.11 | cc:Mail 3.11 | Windows for Workgroups |
| WindowsNT Advanced Server | Windows NT Workstation or Windows for Workgroups 3.11 | cc:Mail | Windows NT Workstation |
| | | | OS/2 |
| | | cc:Mail | |
| | | | OS/2 |
| | | for OS/2 | |

To compliment the Window NT server it is recommended that Windows for Workgroups be installed on the client systems. Windows for Workgroups is designed to support the use of 32-bit protect mode networking components to communicate with the Windows NT server. Windows for Workgroups also supports the use of client-side cache as part of the 32-bit File Access feature. This greatly increases processing speed for many activities.

The remaining variations of this second option are identical to that of Option #1

Option 3: UNIX System Architecture

The third option is a major departure from the existing hardware and software resident at each FSDO. This begins with the requirement for a UNIX based computer and the UNIX operating system. UNIX is a powerful 32-bit, multi-tasking operating system that would meet many of the AFS requirements such as supporting multiple users, shells to support other application types (e.g., DOS, Windows, OS/2), file sharing, system security, and operational robustness. On the negative side, this option requires the greatest expenditures of capital for upgrading both the hardware and software for the server. It also has the greatest requirement for retraining for both the users and the system operators. The use of the GUI-based operating environment for UNIX, called X-Windows, would be an improvement over the command line interface of plain UNIX but is still more difficult to use than Windows or OS/2 interfaces.

Considering that AFS has standardized on the Windows operating system and that AFS users are already familiar with DOS and Windows environments on a Novell network, a switch to a UNIX operating system would be a costly and time consuming operation.

The three main system upgrade options that have been reviewed are all capable of supporting the current and future needs of the ASIs at each FSDO. Each option has distinct advantages and disadvantages that need to be considered by AFS prior to making a decision as to which upgrade path is preferred. The research team will continue to support this decision-making process and is available for further consultation at your convenience.

| **Network Server System** | **Desktop Operating Environment** | **Mail System** | **Mobile Operating Environment** |
|---|---|---|---|
| | Windows for Workgroups 3.11 | cc:Mail | for UNIX<br>Windows for Workgroups 3.11 |
| UNIX | Windows NT Workstation | cc:Mail | for UNIX<br>Windows NT Workstation<br>or<br>Windows for Workgroups 3.11 |
| | OS/2 | cc:Mail for UNIX | OS/2 |

## APPENDIX - CHAPTER THREE

### Acronyms and Abbreviations

| **Abbreviations** | **Explanations** |
|---|---|

CPI Characters Per Inch

OMNItools A hand writing recognition software

OMR Optical Mark Recognition

PTRS Form Program Tracking and Reporting System data sheet

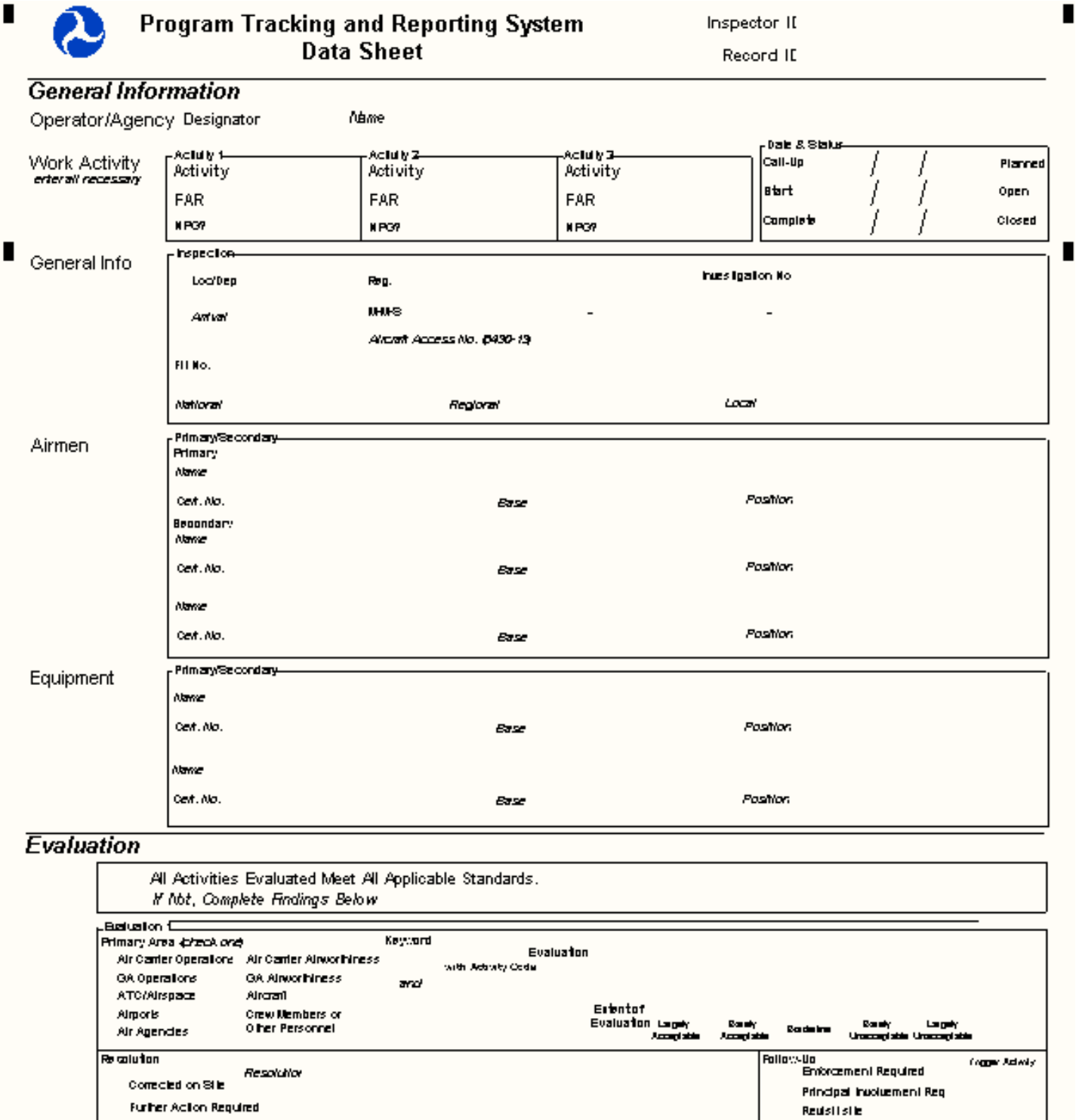
VISIO Software which is used to create the PTRS form

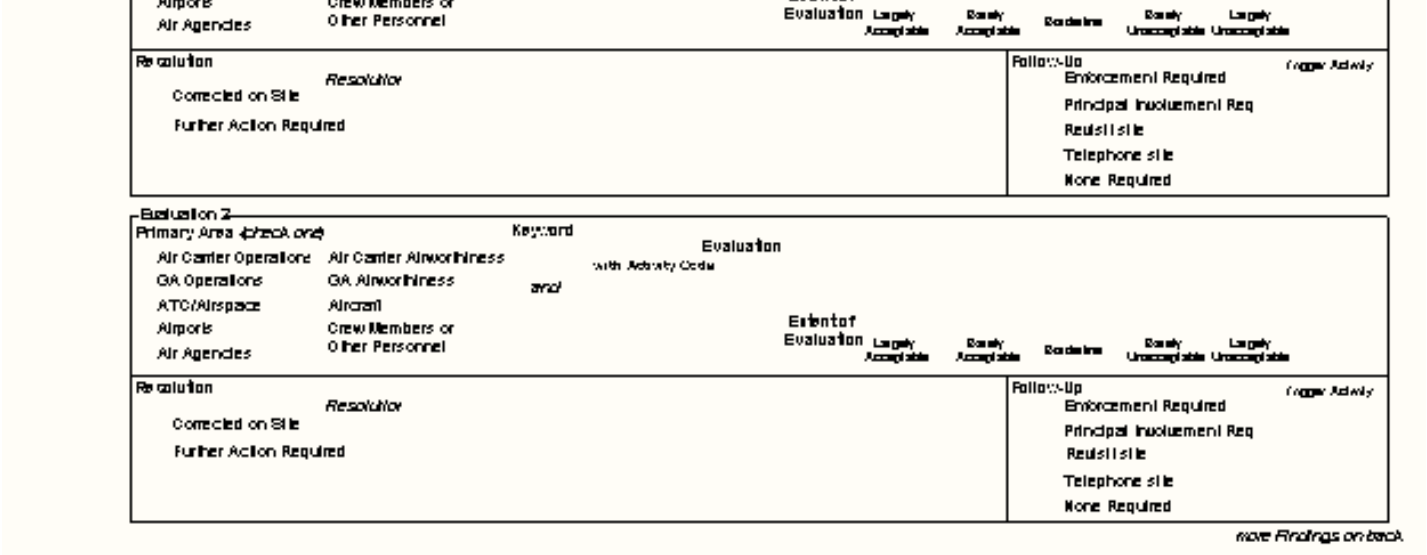
ZDF Zone Definition Form

ZRF Zone Recognition File

## Modified PTRS form

The modified PTRS form is shown below.






Information for each figure

**Figure 3.1 data**

| Configuration | Brightness | Form Removal | CPI | Constraint | De-skew | Long line removal | Average |
|---|---|---|---|---|---|---|---|
| **1** | 150 | N | 0 | restricted | N | N | 82.01% |
| **2** | 150 | N | 6 | restricted | N | N | 83.84% |
| **3** | 150 | N | 0 | restricted | Y | N | 82.32% |
| **4** | 150 | N | 6 | restricted | Y | N | 82.59% |
| **5** | 150 | N | 0 | restricted | N | Y | 81.47% |
| **6** | 150 | N | 6 | restricted | N | Y | 84.33% |
| **7** | 150 | N | 0 | restricted | Y | Y | 81.70% |
| **8** | 150 | N | 6 | restricted | Y | Y | 84.51% |
| **9** | 150 | N | 0 | relax | N | N | 75.31% |
| **10** | 150 | N | 6 | relax | N | N | 76.96% |
| **11** | 150 | N | 0 | relax | Y | N | 75.45% |
| **12** | 150 | N | 6 | relax | Y | N | 75.58% |
| **13** | 150 | N | 0 | relax | N | Y | 74.46% |
| **14** | 150 | N | 6 | relax | N | Y | 77.14% |
| **15** | 150 | N | 0 | relax | Y | Y | 74.42% |
| **16** | 150 | N | 6 | relax | Y | Y | 77.14% |
| **17** | 150 | Y | 0 | restricted | N | N | 76.07% |
| **18** | 150 | Y | 6 | restricted | N | N | 78.48% |
| **19** | 150 | Y | 0 | restricted | N | Y | 76.07% |
| **20** | 150 | Y | 6 | restricted | N | Y | 78.48% |
| **21** | 150 | Y | 0 | relax | N | N | 68.44% |
| **22** | 150 | Y | 6 | relax | N | N | 70.49% |
| **23** | 150 | Y | 0 | relax | N | Y | 68.44% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **24** | 150 | Y | 6 | relax | N | Y | 70.49% |
| **25** | 80 | N | 0 | restricted | N | N | 76.74% |
| **26** | 80 | N | 6 | restricted | N | N | 77.90% |
| **27** | 80 | N | 0 | restricted | Y | N | 76.61% |
| **28** | 80 | N | 6 | restricted | Y | N | 77.72% |
| **29** | 80 | N | 0 | restricted | N | Y | 76.83% |
| **30** | 80 | N | 6 | restricted | N | Y | 78.04% |
| **31** | 80 | N | 0 | restricted | Y | Y | 76.74% |
| **32** | 80 | N | 6 | restricted | Y | Y | 77.90% |
| **33** | 80 | N | 0 | relax | N | N | 69.11% |
| **34** | 80 | N | 6 | relax | N | N | 70.22% |
| **35** | 80 | N | 0 | relax | Y | N | 68.71% |
| **36** | 80 | N | 6 | relax | Y | N | 69.82% |
| **37** | 80 | N | 0 | relax | N | Y | 69.06% |
| **38** | 80 | N | 6 | relax | N | Y | 70.45% |
| **39** | 80 | N | 0 | relax | Y | Y | 68.71% |
| **40** | 80 | N | 6 | relax | Y | Y | 70.09% |
| **41** | 80 | Y | 0 | restricted | N | N | 70.36% |
| **42** | 80 | Y | 6 | restricted | N | N | 71.70% |
| **43** | 80 | Y | 0 | restricted | N | Y | 70.36% |
| **44** | 80 | Y | 6 | restricted | N | Y | 71.70% |
| **45** | 80 | Y | 0 | relax | N | N | 61.88% |
| **46** | 80 | Y | 6 | relax | N | N | 63.53% |
| **47** | 80 | Y | 0 | relax | N | Y | 61.88% |
| **48** | 80 | Y | 6 | relax | N | Y | 63.53% |

**Figure 3.2 data**

| Configuration | CPI | Constraint | De-skew | Long line removal | Average |
|---|---|---|---|---|---|
| **1** | 0 | restricted | N | N | 82.01% |
| **2** | 6 | restricted | N | N | 83.84% |
| **3** | 0 | restricted | Y | N | 82.32% |
| **4** | 6 | restricted | Y | N | 82.59% |
| **5** | 0 | restricted | N | Y | 81.47% |
| **6** | 6 | restricted | N | Y | 84.33% |
| **7** | 0 | restricted | Y | Y | 81.70% |
| **8** | 6 | restricted | Y | Y | 84.51% |
| **9** | 0 | relax | N | N | 75.27% |
| **10** | 6 | relax | N | N | 76.96% |

| | | | | | |
|---|---|---|---|---|---|
| **11** | 0 | relax | Y | N | 75.40% |
| **12** | 6 | relax | Y | N | 75.58% |
| **13** | 0 | relax | N | Y | 74.42% |
| **14** | 6 | relax | N | Y | 77.14% |
| **15** | 0 | relax | Y | Y | 74.38% |
| **16** | 6 | relax | Y | Y | 77.14% |

**Figure 3.3 data**

| Configuration | Brightness | CPI | De-skew | Long line removal | Average |
|---|---|---|---|---|---|
| **1** | 150 | 0 | N | N | 82.01% |
| **2** | 150 | 6 | N | N | 83.84% |
| **3** | 150 | 0 | Y | N | 82.32% |
| **4** | 150 | 6 | Y | N | 82.59% |
| **5** | 150 | 0 | N | Y | 81.47% |
| **6** | 150 | 6 | N | Y | 84.33% |
| **7** | 150 | 0 | Y | Y | 81.70% |
| **8** | 150 | 6 | Y | Y | 84.51% |
| **9** | 80 | 0 | N | N | 76.74% |
| **10** | 80 | 6 | N | N | 77.95% |
| **11** | 80 | 0 | Y | N | 76.61% |
| **12** | 80 | 6 | Y | N | 77.77% |
| **13** | 80 | 0 | N | Y | 76.79% |
| **14** | 80 | 6 | N | Y | 78.04% |
| **15** | 80 | 0 | Y | Y | 76.70% |
| **16** | 80 | 6 | Y | Y | 77.90% |

**Figure 3.4 data**

| Configuration | CPI | Form Removal | De-skew | Long line removal | Brightness =150 | Brightness = 80 |
|---|---|---|---|---|---|---|
| **1** | 0 | N | N | N | 82.01% | 76.74% |
| **2** | 6 | N | N | N | 83.84% | 77.95% |
| **3** | 0 | N | N | Y | 81.47% | 76.79% |
| **4** | 6 | N | N | Y | 84.33% | 78.04% |
| **5** | 0 | Y | N | N | 76.07% | 70.40% |
| **6** | 6 | Y | N | N | 78.48% | 71.74% |
| **7** | 0 | Y | N | Y | 76.07% | 70.40% |
| **8** | 6 | Y | N | Y | 78.48% | 71.74% |

**Figure 3.5 data**

| Configuration | CPI | Constraint | De-skew | Long line removal | Average |
|---|---|---|---|---|---|
| **1** | 0 | restricted | N | N | 90.20% |
| **2** | 6 | restricted | N | N | 93.00% |
| **3** | 0 | restricted | Y | N | 90.20% |
| **4** | 6 | restricted | Y | N | 93.00% |
| **5** | 0 | restricted | N | Y | 91.00% |
| **6** | 6 | restricted | N | Y | 94.40% |
| **7** | 0 | restricted | Y | Y | 91.00% |
| **8** | 6 | restricted | Y | Y | 94.40% |
| **9** | 0 | relax | N | N | 70.20% |
| **10** | 6 | relax | N | N | 72.00% |
| **11** | 0 | relax | Y | N | 70.20% |
| **12** | 6 | relax | Y | N | 72.20% |
| **13** | 0 | relax | N | Y | 70.00% |
| **14** | 6 | relax | N | Y | 72.40% |
| **15** | 0 | relax | Y | Y | 70.00% |
| **16** | 6 | relax | Y | Y | 72.60% |

**Figure 3.6 data**

| Configuration | Brightness | CPI | Constraint | Long line removal | Average |
|---|---|---|---|---|---|
| **1** | 150 | 0 | relax | N | 75.00% |
| **2** | 150 | 6 | relax | N | 78.89% |
| **3** | 150 | 0 | relax | Y | 75.00% |
| **4** | 150 | 6 | relax | Y | 78.89% |
| **5** | 80 | 0 | relax | N | 50.00% |
| **6** | 80 | 6 | relax | N | 54.44% |
| **7** | 80 | 0 | relax | Y | 49.44% |
| **8** | 80 | 6 | relax | Y | 53.89% |

**Figure 3.7 data**

| Configuration | Brightness | Form Removal | De-skew Removal | Long Line Correctness | Original Correctness | Modified |
|---|---|---|---|---|---|---|
| **1** | 150 | N | N | N | 31% | 97% |
| **2** | 150 | N | N | Y | 31% | 97% |
| **3** | 150 | N | Y | N | 31% | 98% |
| **4** | 150 | N | Y | Y | 31% | 98% |

| | | | | | | |
|---|---|---|---|---|---|---|
| **5** | 150 | Y | N | N | 31% | 97% |
| **6** | 150 | Y | N | Y | 31% | 97% |
| **7** | 150 | Y | Y | N | 32% | 97% |
| **8** | 150 | Y | Y | Y | 32% | 97% |
| **9** | 80 | N | N | N | 32% | 78% |
| **10** | 80 | N | N | Y | 32% | 78% |
| **11** | 80 | N | Y | N | 33% | 74% |
| **12** | 80 | N | Y | Y | 33% | 75% |
| **13** | 80 | Y | N | N | 32% | 78% |
| **14** | 80 | Y | N | Y | 32% | 78% |
| **15** | 80 | Y | Y | N | 32% | 79% |
| **16** | 80 | Y | Y | Y | 32% | 79% |

**Figure 3.8 data**

| | Configuration Removal | Brightness | Form removal | CPI | Constraint Lower | De-skew | Long line | Upper | Lower | Overall excluding |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 150 | N | 0 | restricted | N | N | 89.49% | 70.90% | 87.95% | |
| **2** | 150 | N | 6 | restricted | N | N | 89.87% | 73.08% | 89.59% | |
| **3** | 150 | N | 0 | restricted | Y | N | 89.74% | 71.54% | 88.08% | |
| **4** | 150 | N | 6 | restricted | Y | N | 85.77% | 73.59% | 87.40% | |
| **5** | 150 | N | 0 | restricted | N | Y | 88.59% | 69.74% | 87.74% | |
| **6** | 150 | N | 6 | restricted | N | Y | 90.26% | 73.21% | 90.27% | |
| **7** | 150 | N | 0 | restricted | Y | Y | 88.59% | 70.26% | 87.81% | |
| **8** | 150 | N | 6 | restricted | Y | Y | 90.26% | 73.59% | 90.34% | |
| **9** | 150 | N | 0 | relax | N | N | 87.95% | 65.90% | 80.27% | |
| **10** | 150 | N | 6 | relax | N | N | 88.33% | 68.33% | 81.58% | |
| **11** | 150 | N | 0 | relax | Y | N | 88.21% | 66.03% | 80.41% | |
| **12** | 150 | N | 6 | relax | Y | N | 84.23% | 68.33% | 79.45% | |
| **13** | 150 | N | 0 | relax | N | Y | 86.92% | 64.62% | 79.66% | |
| **14** | 150 | N | 6 | relax | N | Y | 88.59% | 68.33% | 81.85% | |
| **15** | 150 | N | 0 | relax | Y | Y | 86.54% | 64.74% | 79.52% | |
| **16** | 150 | N | 6 | relax | Y | Y | 88.33% | 68.33% | 81.85% | |
| **17** | 150 | Y | 0 | restricted | N | N | 84.23% | 59.36% | 85.00% | |
| **18** | 150 | Y | 6 | restricted | N | N | 84.36% | 64.36% | 86.03% | |
| **19** | 150 | Y | 0 | restricted | N | Y | 84.23% | 59.36% | 85.00% | |
| **20** | 150 | Y | 6 | restricted | N | Y | 84.36% | 64.36% | 86.03% | |
| **21** | 150 | Y | 0 | relax | N | N | 82.44% | 54.62% | 75.82% | |
| **22** | 150 | Y | 6 | relax | N | N | 82.82% | 58.59% | 76.85% | |
| **23** | 150 | Y | 0 | relax | N | Y | 82.44% | 54.62% | 75.82% | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **24** | 150 | Y | 6 | relax | N | Y | 82.82% | 58.59% | 76.85% |
| **25** | 80 | N | 0 | restricted | N | N | 83.72% | 66.03% | 82.47% |
| **26** | 80 | N | 6 | restricted | N | N | 84.74% | 67.44% | 83.56% |
| **27** | 80 | N | 0 | restricted | Y | N | 83.46% | 65.90% | 82.33% |
| **28** | 80 | N | 6 | restricted | Y | N | 84.62% | 67.31% | 83.36% |
| **29** | 80 | N | 0 | restricted | N | Y | 83.59% | 66.28% | 82.40% |
| **30** | 80 | N | 6 | restricted | N | Y | 84.62% | 67.44% | 83.70% |
| **31** | 80 | N | 0 | restricted | Y | Y | 83.33% | 66.15% | 82.33% |
| **32** | 80 | N | 6 | restricted | Y | Y | 84.49% | 67.31% | 83.56% |
| **33** | 80 | N | 0 | relax | N | N | 80.64% | 61.15% | 73.36% |
| **34** | 80 | N | 6 | relax | N | N | 81.54% | 61.92% | 74.66% |
| **35** | 80 | N | 0 | relax | Y | N | 79.74% | 60.77% | 72.95% |
| **36** | 80 | N | 6 | relax | Y | N | 80.77% | 61.54% | 74.25% |
| **37** | 80 | N | 0 | relax | N | Y | 80.64% | 60.90% | 73.29% |
| **38** | 80 | N | 6 | relax | N | Y | 81.54% | 61.79% | 75.00% |
| **39** | 80 | N | 0 | relax | Y | Y | 79.36% | 60.64% | 72.88% |
| **40** | 80 | N | 6 | relax | Y | Y | 80.90% | 61.41% | 74.66% |
| **41** | 80 | Y | 0 | restricted | N | N | 78.46% | 51.79% | 80.34% |
| **42** | 80 | Y | 6 | restricted | N | N | 78.59% | 55.38% | 80.48% |
| **43** | 80 | Y | 0 | restricted | N | Y | 78.46% | 51.79% | 80.34% |
| **44** | 80 | Y | 6 | restricted | N | Y | 78.59% | 55.38% | 80.48% |
| **45** | 80 | Y | 0 | relax | N | N | 76.67% | 46.79% | 69.93% |
| **46** | 80 | Y | 6 | relax | N | N | 77.18% | 50.38% | 70.55% |
| **47** | 80 | Y | 0 | relax | N | Y | 76.67% | 46.79% | 69.93% |
| **48** | 80 | Y | 6 | relax | N | Y | 77.18% | 50.38% | 70.55% |

# APPENDIX - CHAPTER FIVE

## Notebook Computers

| **Feature** | Notebook #1 | Notebook #2 | Notebook #3 | Notebook #4 | Notebook #5 |
|---|---|---|---|---|---|
| **Processor** | 486 DX4/ 75 MHz | 486 DX4/ 75 MHz | 486 DX4/ 75 MHz | 486 DX4/ 75 MHz | 486 DX2/ 50 MHz |
| **HDD Capacity** | 540 MB | 340 MB | 510 MB | 340 MB | 540 MB |
| **RAM** | 4/36 MB | 4/20 MB | 4/24 MB | 8/24 MB | 4/20 MB |

| | | | | | |
|---|---|---|---|---|---|
| **PCMCIA Slots** | One Type III or Two Type II | One Type III or Two Type II | One Type III or Two Type II | One Type III or Two Type II | One Type III or Two Type II |
| **Floppy Drive** | 3.5" 1.44 Internal | 3.5" 1.44 Internal | 3.5" 1.44 Internal | 3.5" 1.44 Internal | 3.5" 1.44 Internal |
| **Display** | 10.4" active matrix TFT | 8.4" active matrix TFT | 10.4 " active matrix TFT | 9.5" active matrix TFT | 9.5" active matrix TFT |
| **Battery** | NiMH rechargeable | NiMH rechargeable | NiMH rechargeable | NiMH rechargeable | NiMH rechargeable |
| **Operating Environment** | DOS/Windows | DOS/Windows | DOS/Windows | DOS/Windows | DOS/ Windows |
| **Size, Weight** | 2.0"x 11.7"x8.3" 6.4lbs | 1.9"x11.0"x8.5" 6.4lbs. | 1.8"x11.5"x8.5" 6.6 lbs. | 2.0"x11.8"x8.9"3 6.9lbs. | 2.0"x11.7"x9.6" 6.9 lbs. |
| **Options** | Docking station, PCMCIA fax/modem. | Docking station, PCMCIA fax/modem. | Docking station, PCMCIA fax/modem. | Docking station, PCMCIA fax/modem. | Docking station, PCMCIA fax/modem. |

## Sub-notebook Computers

| **Feature** | Sub-Notebook #1 | Sub-Notebook #2 | Sub-Notebook #3 | Sub-Notebook #4 | Sub-Notebook #5 |
|---|---|---|---|---|---|
| **Processor** | 486BL2/ 50 MHz | 486 DX2/ 50 MHz | 486 DX4/ 75 MHz | 486SL/ 33 MHz | 486 DX4/ 75 MHz |
| **HDD Storage** | 200 MB | 250 MB | 260 MB PCMCIA | 250 MB | 350 MB |
| **RAM** | 4/20 MB | 8/24 MB | 8/16 MB | 4/8 MB | 8/24 MB |
| **PCMCIA Slots** | One Type II | One Type II Two Type II | One Type III or Two Type II | One Type II or | One Type III |
| **Floppy Drive** | External | External | External | External | External |
| **Display** | 7.7" diag,passive-matrix color LCD | 8.4" active matrix TFT | 8.5" DSTN color passive-matrix color LCD | 8.0" diag, matrix TFT | 9.5" active matrix TFT |
| **Battery** | NiMH Rechargeable | LiIon Rechargeable | NiMH Rechargeable | NiMH Rechargeable | LiIon Rechargeable |
| **Operating Environmt** | DOS/Windows | DOS/Windows | DOS/Windows | DOS/Windows | DOS/ Windows |

| | | | | | |
|---|---|---|---|---|---|
| **Size, Weight** | 1.8"x10.5"x 7.75" 4.0lbs. | 1.8"x9.9"x7.9" 4.4. lbs | 1.57"x11.28"x 7.28" 3.8 lbs. | 1.7"x10.25"x7.5 4.2 lbs. | 1.2"x11.0"x8.5" 4.0 lbs. |
| **Options** | Port replicator, PCMCIA fax/modem. | Port replicator, PCMCIA fax/modem. | Port replicator, PCMCIA fax/modem. | Port replicator, PCMCIA fax/modem. | Port replicator, PCMCIA fax/modem. |

## Pen Computers

| **Feature** | Pen Computer #1 | Pen Computer #2 | Pen Computer #3 | Pen Computer #4 | Pen Computer #5 |
|---|---|---|---|---|---|
| **Processor** | 486DX2/ 50 MHz | 386SXLV/ 25 MHz | 486SX/ 33 MHz | 482DX2/40 MHz (3.3volt) | 386SL/ 25 MHz |
| **HDD Storage** | 105 MB(Type III PCMCIA) | 85 MB | 105 MB (Type III PCMCIA) | 80 MB | 80/170 MB |
| **RAM** | 4/20 MB | 8/16 MB | 4/20 MB | 4/20 MB | 4/8 MB |
| **Floppy Drive** | External | External | External | External | External |
| **Display** | 9.4" diag 640 x 480 pixels | 6" x 4.5" 640 x 480 pixels | 9.5" Diag 640 x 480 pixels | 9.5" Diag 640 x 480 pixels | 10" Diag 640 x 480 pixels |
| **Battery** | Li-Ion, (camcorder-type) Rechargeable | NiCad, Rechargeable | NiCad, (Dual battery) Rechargeable | Li-Ion, Rechargeable | NiCad, Rechargeable |
| **Operating Environmt** | WinPen, PenRight! PenDos | WinPen PenRight!, PenDos | WinPen, OS/2, PenDos | WinPen, PenRight! | WinPen, PenRight!, PenPoint |
| **Size, Weight** | 7.2"x10.7"x1.5" 2.6 lbs. | 9.7"x 6.4"x 1.8" 3.5 lbs | 10.6"x8.3"x1.4" 3.5 lbs | 10.6"x8.2"x 1.6" 4.4lbs | 11.0"x11.0"x1.3" 4.5 lbs |
| **Options** | floppy drive, keyboard, memory/fax/data cards. | K100 docking station, keyboard. | floppy drive, keyboard, LAN cards. | floppy drive, keyboard, memory/fax/data/ keyboard. | GPS, camera, CD-ROM, memory cards barcode, cellular phone, |

## Personal Digital Assistants

| **Feature** | PDA #1 | PDA #2 | PDA #3 | PDA #4 | PDA #5 |
|---|---|---|---|---|---|
| **Processor** | Casio Custom (x86 compatible) | ARM 610/20 MHz 68349/16 MHz | Motorola Dragon 68349/16 Mhz | Motorola Dragon MHz | NEC VG230/16 |
| **HDD Storage** | PCMCIA memory **card** | PCMCIA memory card | PCMCIA memory card | PCMCIA memory card | PCMCIA memory card |

| | | | | | |
|---|---|---|---|---|---|
| **RAM** | 1MB (4 MB ROM) | 1MB (4 MB ROM) | 1MB (4 MB ROM) | 512 KB (4 MB ROM) | 3 MB 6 MB Mask |
| **Desktop Connect** | PC (option) Connectivity (opt) | Mac & Windows | PC (option) Connectivity pack | Mac & Windows | Serial LapLink |
| **Display** | 3.1" x 4" 320 x 256 pixels | 3" x 4" 336 x 240 pixels | 3.0" x 4.5" 480 x 320 pixels | 3.0" x 4.5" 480 x 320 pixels | 7.4" diag 640x400 pix |
| **Battery** | Three AA bat., AC/DC | NiCad, Four AA bat. | NiCad, AC/DC | Six AAA bat., AC/DC | Six AA bat., AC/DC |
| **Operating Environmt** | GEOS, PenRight! | Newton | Magic Cap | Magic Cap | GEOS Intelligence |
| **Size, Weight** | 6.8"x4.2"x1.0" 0.95 lbs. | 8.0"x4.0"x1.25" 1.28 lbs | 7.5"x5.75"x1.2" 1.7 lbs | 7.5"x5.2"x1.0" 1.2 lbs | 9.2"x6.4"x1.4" 2.4 lbs |
| **Options** | Message card, fax modem, printer connection, flash storage. | Message card, fax modem, printer connection, flash storage. | Message card, printer connection, flash storage. | Pager card, keyboard, head set, memory card. | LapLink, Li-Ion Bat. |

## Docking Stations

| **Feature** | Docking Station #1 | Docking Station #2 | Docking Station #3 | Docking Station #4 | Docking Station #5 |
|---|---|---|---|---|---|
| **Connect** | Manual | Motorized | Manual | Manual | Manual |
| **Expansion Slots** | One | Two | Two | Two | Two |
| **External Bays** | One | Two | Two | Two | One |
| **Interfaces** | Parallel, Serial, VGA,PS/2 mouse and keyboard, headphone | Parallel, Serial VGA,PS/2 mouse and keyboard, microphone, headphone | Parallel, Serial, VGA,PS/2 mouse and keyboard, | Parallel, Serial, VGA,PS/2 mouse and keyboard, | Parallel, VGA, PS/2 mouse and keyboard |
| **Dimension** | 16"W x 10"D x 5"H | 14"W x 17"D x 5.4"H | 13.6W x 15.9"Dx 4.4"H | | |
| **Integral Display Stand** | Display Stand optional | Yes | Yes optional | Yes | Display Stand |

| | |
|---|---|
| **Additional Features** | Integral speakers, Network ready One internal bay Security lock SCSI,multi-media Ethernet. SCSI video and audio interfaces, spare connections, battery charging security lock. station. |