National Institute of Standards and Technology
Technology Administration
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Chapter 20

ASSESSING AND MITIGATING THE RISKS TO A HYPOTHETICAL COMPUTER SYSTEM

This chapter illustrates how a hypothetical government agency (HGA) deals with computer security issues in its operating environment.[140] It follows the evolution of HGA's initiation of an assessment of the threats to its computer security system all the way through to HGA's recommendations for mitigating those risks. In the real world, many solutions exist for computer security problems. No single solution can solve similar security problems in all environments. Likewise, the solutions presented in this example may not be appropriate for all environments.

This example can be used to help understand how security issues are examined, how some potential solutions are analyzed, how their cost and benefits are weighed, and ultimately how management accepts responsibility for risks.

This case study is provided for illustrative purposes only, and should not be construed as guidance or specific recommendations to solving specific security issues. Because a comprehensive example attempting to illustrate all handbook topics would be inordinately long, this example necessarily simplifies the issues presented and omits many details. For instance, to highlight the similarities and differences among controls in the different processing environments, it addresses some of the major types of processing platforms linked together in a distributed system: personal computers, local-area networks, wide-area networks, and mainframes; it does not show how to secure these platforms.

This section also highlights the importance of management's acceptance of a particular level of risk—this will, of course, vary from organization to organization. It is management's prerogative to decide what level of risk is appropriate, given operating and budget environments and other applicable factors.

20.1 Initiating the Risk Assessment

HGA has information systems that comprise and are intertwined with several different kinds of assets valuable enough to merit protection. HGA's systems play a key role in transferring U.S. Government funds to individuals in the form of paychecks; hence, financial resources are among the assets associated with HGA's systems. The system components owned and operated by HGA

[140] While this chapter draws upon many actual systems, details and characteristics were changed and merged. Although the chapter is arranged around an agency, the case study could also apply to a large division or office within an agency.

are also assets, as are personnel information, contracting and procurement documents, draft regulations, internal correspondence, and a variety of other day-to-day business documents, memos, and reports. HGA's assets include intangible elements as well, such as reputation of the agency and the confidence of its employees that personal information will be handled properly and that the wages will be paid on time.

A recent change in the directorship of HGA has brought in a new management team. Among the new Chief Information Officer's first actions was appointing a Computer Security Program Manager who immediately initiated a comprehensive risk analysis to assess the soundness of HGA's computer security program in protecting the agency's assets and its compliance with federal directives. This analysis drew upon prior risk assessments, threat studies, and applicable internal control reports. The Computer Security Program Manager also established a timetable for periodic reassessments.

Since the wide-area network and mainframe used by HGA are owned and operated by other organizations, they were not treated in the risk assessment as HGA's assets. And although HGA's personnel, buildings, and facilities are essential assets, the Computer Security Program Manager considered them to be outside the scope of the risk analysis.

After examining HGA's computer system, the risk assessment team identified specific threats to HGA's assets, reviewed HGA's and national safeguards against those threats, identified the vulnerabilities of those policies, and recommended specific actions for mitigating the remaining risks to HGA's computer security. The following sections provide highlights from the risk assessment. The assessment addressed many other issues at the programmatic and system levels. However, this chapter focuses on security issues related to the time and attendance application. (Other issues are discussed in Chapter 6.)

20.2 HGA's Computer System

HGA relies on the distributed computer systems and networks shown in Figure 20.1. They consist of a collection of components, some of which are systems in their own right. Some belong to HGA, but others are owned and operated by other organizations. This section describes these components, their role in the overall distributed system architecture, and how they are used by HGA.

20.2.1 System Architecture

Most of HGA's staff (a mix of clerical, technical, and managerial staff) are provided with personal computers (PCs) located in their offices. Each PC includes hard-disk and floppy-disk drives.

The PCs are connected to a local area network (LAN) so that users can exchange and share

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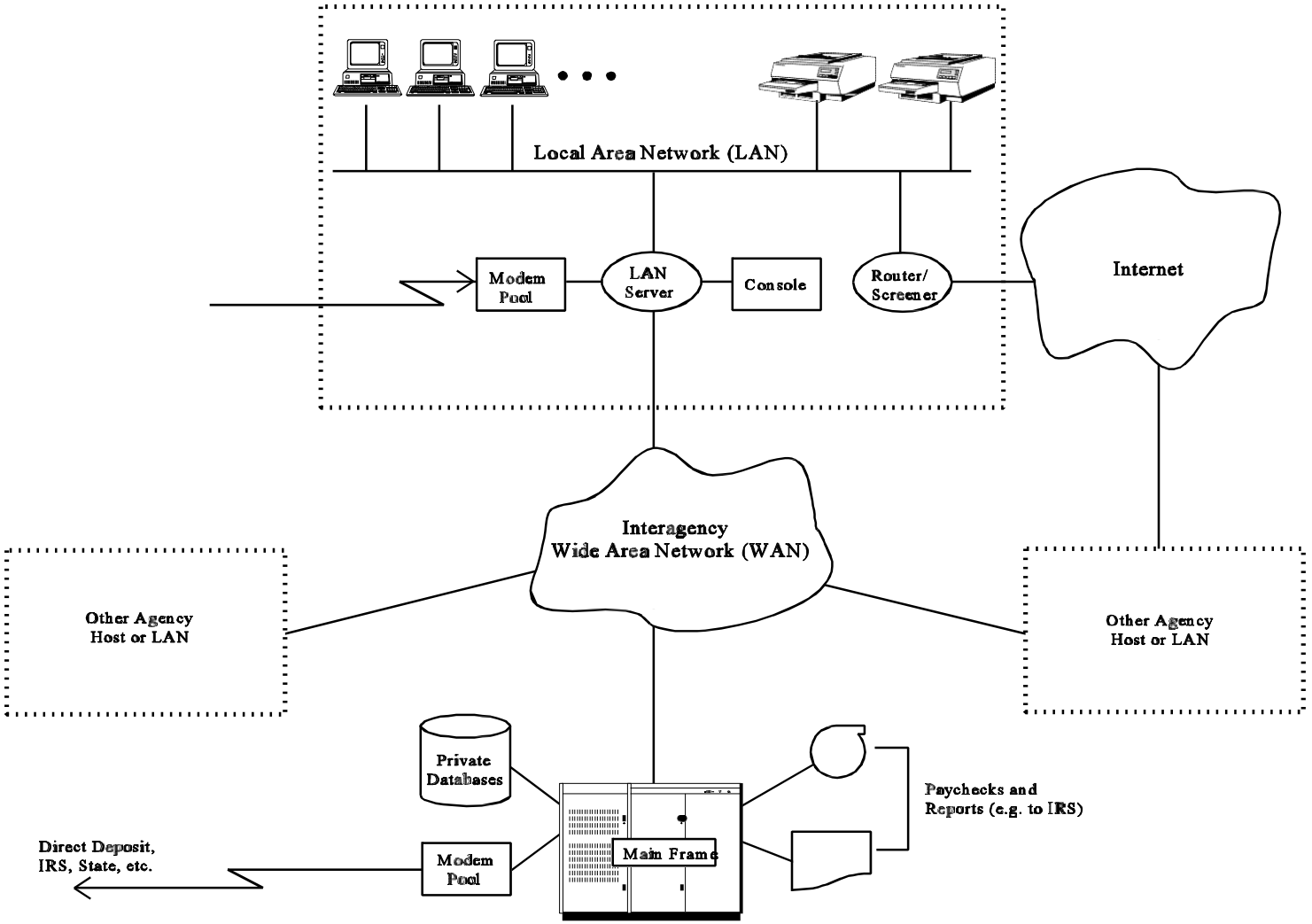

information. The central component of the LAN is a *LAN server*, a more powerful computer that acts as an intermediary between PCs on the network and provides a large volume of disk storage for shared information, including shared application programs. The server provides logical access controls on potentially sharable information via elementary access control lists. These access controls can be used to limit user access to various files and programs stored on the server. Some programs stored on the server can be retrieved via the LAN and executed on a PC; others can only be executed on the server.

To initiate a session on the network or execute programs on the server, users at a PC must log into the server and provide a user identifier and password known to the server. Then they may use files to which they have access.

One of the applications supported by the server is *electronic mail* (e-mail), which can be used by all PC users. Other programs that run on the server can only be executed by a limited set of PC users.

Several printers, distributed throughout HGA's building complex, are connected to the LAN. Users at PCs may direct printouts to whichever printer is most convenient for their use.

Since HGA must frequently communicate with industry, the LAN also provides a connection to the Internet via a *router*. The router is a network interface device that translates between the protocols and addresses associated with the LAN and the Internet. The router also performs *network packet filtering*, a form of network access control, and has recently been configured to disallow non–e-mail (e.g., file transfer, remote log-in) between LAN and Internet computers.

The LAN server also has connections to several other devices.

- A *modem pool* is provided so that HGA's employees on travel can "dial up" via the public switched (telephone) network and read or send e-mail. To initiate a dial-up session, a user must successfully log in. During dial-up sessions, the LAN server provides access only to e-mail facilities; no other functions can be invoked.

- A *special console* is provided for the server administrators who configure the server, establish and delete user accounts, and have other special privileges needed for administrative and maintenance functions. These functions can only be invoked from the *administrator console*; that is, they cannot be invoked from a PC on the network or from a dial-up session.

- A *connection to a government agency X.25-based wide-area network* (WAN) is provided so that information can be transferred to or from other agency systems. One of the other hosts on the WAN is a large multiagency mainframe system. This mainframe is used to collect and process information from a large number of

agencies while providing a range of access controls.

20.2.2 System Operational Authority/Ownership

The system components contained within the large dashed rectangle shown in Figure 20.1 are managed and operated by an organization within HGA known as the Computer Operations Group (COG). This group includes the PCs, LAN, server, console, printers, modem pool, and router. The WAN is owned and operated by a large commercial telecommunications company that provides WAN services under a government contract. The mainframe is owned and operated by a federal agency that acts as a service provider for HGA and other agencies connected to the WAN.

20.2.3 System Applications

PCs on HGA's LAN are used for word processing, data manipulation, and other common applications, including spreadsheet and project management tools. Many of these tasks are concerned with data that are sensitive with respect to confidentiality or integrity. Some of these documents and data also need to be available in a timely manner.

The mainframe also provides storage and retrieval services for other databases belonging to individual agencies. For example, several agencies, including HGA, store their personnel databases on the mainframe; these databases contain dates of service, leave balances, salary and W-2 information, and so forth.

In addition to their time and attendance application, HGA's PCs and the LAN server are used to manipulate other kinds of information that may be sensitive with respect to confidentiality or integrity, including personnel-related correspondence and draft contracting documents.

20.3 Threats to HGA's Assets

Different assets of HGA are subject to different kinds of threats. Some threats are considered less likely than others, and the potential impact of different threats may vary greatly. The likelihood of threats is generally difficult to estimate accurately. Both HGA and the risk assessment's authors have attempted to the extent possible to base these estimates on historical data, but have also tried to anticipate new trends stimulated by emerging technologies (e.g., external networks).

20.3.1 Payroll Fraud

As for most large organizations that control financial assets, attempts at fraud and embezzlement are likely to occur. Historically, attempts at payroll fraud have almost always come from within HGA or the other agencies that operate systems on which HGA depends. Although HGA has thwarted many of these attempts, and some have involved relatively small sums of money, it

considers preventing financial fraud to be a *critical* computer security priority, particularly in light of the potential financial losses and the risks of damage to its reputation with Congress, the public, and other federal agencies.

Attempts to defraud HGA have included the following:

- Submitting fraudulent time sheets for hours or days not worked, or for pay periods following termination or transfer of employment. The former may take the form of overreporting compensatory or overtime hours worked, or underreporting vacation or sick leave taken. Alternatively, attempts have been made to modify time sheet data after being entered and approved for submission to payroll.

- Falsifying or modifying dates or data on which one's "years of service" computations are based, thereby becoming eligible for retirement earlier than allowed, or increasing one's pension amount.

- Creating employee records and time sheets for fictitious personnel, and attempting to obtain their paychecks, particularly after arranging for direct deposit.

20.3.2 Payroll Errors

Of greater likelihood, but of perhaps lesser potential impact on HGA, are errors in the entry of time and attendance data; failure to enter information describing new employees, terminations, and transfers in a timely manner; accidental corruption or loss of time and attendance data; or errors in interagency coordination and processing of personnel transfers.

Errors of these kinds can cause financial difficulties for employees and accounting problems for HGA. If an employee's vacation or sick leave balance became negative erroneously during the last pay period of the year, the employee's last paycheck would be automatically reduced. An individual who transfers between HGA and another agency may risk receiving duplicate paychecks or no paychecks for the pay periods immediately following the transfer. Errors of this sort that occur near the end of the year can lead to errors in W-2 forms and subsequent difficulties with the tax collection agencies.

20.3.3 Interruption of Operations

HGA's building facilities and physical plant are several decades old and are frequently under repair or renovation. As a result, power, air conditioning, and LAN or WAN connectivity for the server are typically interrupted several times a year for periods of up to one work day. For example, on several occasions, construction workers have inadvertently severed power or network cables. Fires, floods, storms, and other natural disasters can also interrupt computer operations, as can equipment malfunctions.

Another threat of small likelihood, but significant potential impact, is that of a malicious or disgruntled employee or outsider seeking to disrupt time-critical processing (e.g., payroll) by deleting necessary inputs or system accounts, misconfiguring access controls, planting computer viruses, or stealing or sabotaging computers or related equipment. Such interruptions, depending upon when they occur, can prevent time and attendance data from getting processed and transferred to the mainframe before the payroll processing deadline.

20.3.4 Disclosure or Brokerage of Information

Other kinds of threats may be stimulated by the growing market for information about an organization's employees or internal activities. Individuals who have legitimate work-related reasons for access to the master employee database may attempt to disclose such information to other employees or contractors or to sell it to private investigators, employment recruiters, the press, or other organizations. HGA considers such threats to be moderately likely and of low to high potential impact, depending on the type of information involved.

20.3.5 Network-Related Threats

Most of the human threats of concern to HGA originate from insiders. Nevertheless, HGA also recognizes the need to protect its assets from outsiders. Such attacks may serve many different purposes and pose a broad spectrum of risks, including unauthorized disclosure or modification of information, unauthorized use of services and assets, or unauthorized denial of services.

As shown in Figure 20.1, HGA's systems are connected to the three external networks: (1) the Internet, (2) the Interagency WAN, and (3) the public-switched (telephone) network. Although these networks are a source of security risks, connectivity with them is essential to HGA's mission and to the productivity of its employees; connectivity cannot be terminated simply because of security risks.

In each of the past few years before establishing its current set of network safeguards, HGA had detected several attempts by outsiders to penetrate its systems. Most, but not all of these, have come from the Internet, and those that succeeded did so by learning or guessing user account passwords. In two cases, the attacker deleted or corrupted significant amounts of data, most of which were later restored from backup files. In most cases, HGA could detect no ill effects of the attack, but concluded that the attacker may have browsed through some files. HGA also conceded that its systems did not have audit logging capabilities sufficient to track an attacker's activities. Hence, for most of these attacks, HGA could not accurately gauge the extent of penetration.

In one case, an attacker made use of a bug in an e-mail utility and succeeded in acquiring System Administrator privileges on the server—a significant breach. HGA found no evidence that the attacker attempted to exploit these privileges before being discovered two days later. When the

attack was detected, COG immediately contacted the HGA's Incident Handling Team, and was told that a bug fix had been distributed by the server vendor several months earlier. To its embarrassment, COG discovered that it had already received the fix, which it then promptly installed. It now believes that no subsequent attacks of the same nature have succeeded.

Although HGA has no evidence that it has been significantly harmed to date by attacks via external networks, it believes that these attacks have great potential to inflict damage. HGA's management considers itself lucky that such attacks have not harmed HGA's reputation and the confidence of the citizens its serves. It also believes the likelihood of such attacks via external networks will increase in the future.

20.3.6 Other Threats

HGA's systems also are exposed to several other threats that, for reasons of space, cannot be fully enumerated here. Examples of threats and HGA's assessment of their probabilities and impacts include those listed in Table 20.1.

20.4 Current Security Measures

HGA has numerous policies and procedures for protecting its assets against the above threats. These are articulated in HGA's *Computer Security Manual*, which implements and synthesizes the requirements of many federal directives, such as Appendix III to OMB Circular A-130, the Computer Security Act of 1987, and the Privacy Act. The manual also includes policies for automated financial systems, such as those based on OMB Circulars A-123 and A-127, as well as the Federal Managers' Financial Integrity Act.

Several examples of those policies follow, as they apply generally to the use and administration of HGA's computer system and specifically to security issues related to time and attendance, payroll, and continuity of operations.

20.4.1 General Use and Administration of HGA's Computer System

HGA's Computer Operations Group (COG) is responsible for controlling, administering, and maintaining the computer resources owned and operated by HGA. These functions are depicted in Figure 20.1 enclosed in the large, dashed rectangle. Only individuals holding the job title System Administrator are authorized to establish log-in IDs and passwords on multiuser HGA systems (e.g., the LAN server). Only HGA's employees and contract personnel may use the system, and only after receiving written authorization from the department supervisor (or, in the case of contractors, the contracting officer) to whom these individuals report.

COG issues copies of all relevant security policies and procedures to new users. Before activating

a system account for a new users, COG requires that they (1) attend a security awareness and training course or complete an interactive computer-aided-instruction training session and (2) sign an acknowledgment form indicating that they understand their security responsibilities.

Authorized users are assigned a secret log-in ID and password, which they must not share with anyone else. They are expected to comply with all of HGA's password selection and security procedures (e.g., periodically changing passwords). Users who fail to do so are subject to a range of penalties.

Examples of Threats to HGA Systems

Potential Threat	Probability	Impact
Accidental Loss/Release of Disclosure-Sensitive Information	Medium	Low/Medium
Accidental Destruction of Information	High	Medium
Loss of Information due to Virus Contamination	Medium	Medium
Misuse of System Resources	Low	Low
Theft	High	Medium
Unauthorized Access to Telecommunications Resources[*]	Medium	Medium
Natural Disaster	Low	High

[*] HGA operates a PBX system, which may be vulnerable to (1) hacker disruptions of PBX availability and, consequently, agency operations, (2) unauthorized access to outgoing phone lines for long-distance services, (3) unauthorized access to stored voice-mail messages, and (4) surreptitious access to otherwise private conversations/data transmissions.

Table 20.1

Users creating data that are sensitive with respect to disclosure or modification are expected to make effective use of the automated access control mechanisms available on HGA computers to reduce the risk of exposure to unauthorized individuals. (Appropriate training and education are in place to help users do this.) In general, access to disclosure-sensitive information is to be granted only to individuals whose jobs require it.

V. Example

20.4.2 Protection Against Payroll Fraud and Errors: Time and Attendance Application

The time and attendance application plays a major role in protecting against payroll fraud and errors. Since the time and attendance application is a component of a larger automated payroll process, many of its functional and security requirements have been derived from both governmentwide and HGA-specific policies related to payroll and leave. For example, HGA must protect personal information in accordance with the Privacy Act. Depending on the specific type of information, it should normally be viewable only by the individual concerned, the individual's supervisors, and personnel and payroll department employees. Such information should also be timely and accurate.

Each week, employees must sign and submit a time sheet that identifies the number of hours they have worked and the amount of leave they have taken. The Time and Attendance Clerk enters the data for a given group of employees and runs an application on the LAN server to verify the data's validity and to ensure that only authorized users with access to the Time and Attendance Clerk's functions can enter time and attendance data. The application performs these security checks by using the LAN server's access control and identification and authentication (I&A) mechanisms. The application compares the data with a limited database of employee information to detect incorrect employee identifiers, implausible numbers of hours worked, and so forth. After correcting any detected errors, the clerk runs another application that formats the time and attendance data into a report, flagging exception/out-of-bound conditions (e.g., negative leave balances).

Department supervisors are responsible for reviewing the correctness of the time sheets of the employees under their supervision and indicating their approval by initialing the time sheets. If they detect significant irregularities and indications of fraud in such data, they must report their findings to the Payroll Office before submitting the time sheets for processing. In keeping with the principle of separation of duty, all data on time sheets and corrections on the sheets that may affect pay, leave, retirement, or other benefits of an individual must be reviewed for validity by at least two authorized individuals (other than the affected individual).

Protection Against Unauthorized Execution

Only users with access to Time and Attendance Supervisor functions may approve and submit time and attendance data — or subsequent corrections thereof — to the mainframe. Supervisors may not approve their own time and attendance data.

Only the System Administrator has been granted access to assign a special access control privilege to server programs. As a result, the server's operating system is designed to prevent a bogus time and attendance application created by any other user from communicating with the WAN and, hence, with the mainframe.

The time and attendance application is supposed to be configured so that the clerk and supervisor functions can only be carried out from specific PCs attached to the LAN and only during normal working hours. Administrators are not authorized to exercise functions of the time and attendance application apart from those concerned with configuring the accounts, passwords, and access permissions for clerks and supervisors. Administrators are expressly prohibited by policy from entering, modifying, or submitting time and attendance data via the time and attendance application or other mechanisms.[141]

Protection against unauthorized execution of the time and attendance application depends on I&A and access controls. While the time and attendance application is accessible from any PC, unlike most programs run by PC users, it does not execute directly on the PC's processor. Instead, it executes on the server, while the PC behaves as a terminal, relaying the user's keystrokes to the server and displaying text and graphics sent from the server. The reason for this approach is that common PC systems do not provide I&A and access controls and, therefore, cannot protect against unauthorized time and attendance program execution. *Any* individual who has access to the PC could run any program stored there.

Another possible approach is for the time and attendance program to perform I&A and access control on its own by requesting and validating a password before beginning each time and attendance session. This approach, however, can be defeated easily by a moderately skilled programming attack, and was judged inadequate by HGA during the application's early design phase.

Recall that the server is a more powerful computer equipped with a multiuser operating system that includes password-based I&A and access controls. Designing the time and attendance application program so that it executes on the server under the control of the server's operating system provides a more effective safeguard against unauthorized execution than executing it on the user's PC.

Protection Against Payroll Errors

The frequency of data entry errors is reduced by having Time and Attendance clerks enter each time sheet into the time and attendance application twice. If the two copies are identical, both are considered error free, and the record is accepted for subsequent review and approval by a supervisor. If the copies are not identical, the discrepancies are displayed, and for each discrepancy, the clerk determines which copy is correct. The clerk then incorporates the corrections into one of the copies, which is then accepted for further processing. If the clerk

[141] Technically, Systems Administrators may still have the ability to do so. This highlights the importance of adequate managerial reviews, auditing, and personnel background checks.

makes the same data-entry error twice, then the two copies will match, and one will be accepted as correct, even though it is erroneous. To reduce this risk, the time and attendance application could be configured to require that the two copies be entered by different clerks.

In addition, each department has one or more Time and Attendance Supervisors who are authorized to review these reports for accuracy and to approve them by running another server program that is part of the time and attendance application. The data are then subjected to a collection of "sanity checks" to detect entries whose values are outside expected ranges. Potential anomalies are displayed to the supervisor prior to allowing approval; if errors are identified, the data are returned to a clerk for additional examination and corrections.

When a supervisor approves the time and attendance data, this application logs into the interagency mainframe via the WAN and transfers the data to a payroll database on the mainframe. The mainframe later prints paychecks or, using a pool of modems that can send data over phone lines, it may transfer the funds electronically into employee-designated bank accounts. Withheld taxes and contributions are also transferred electronically in this manner.

The Director of Personnel is responsible for ensuring that forms describing significant payroll-related personnel actions are provided to the Payroll Office at least one week before the payroll processing date for the first affected pay period. These actions include hiring, terminations, transfers, leaves of absences and returns from such, and pay raises.

The Manager of the Payroll Office is responsible for establishing and maintaining controls adequate to ensure that the amounts of pay, leave, and other benefits reported on pay stubs and recorded in permanent records and those distributed electronically are accurate and consistent with time and attendance data and with other information provided by the Personnel Department. In particular, paychecks must never be provided to anyone who is not a bona fide, active-status employee of HGA. Moreover, the pay of any employee who terminates employment, who transfers, or who goes on leave without pay must be suspended as of the effective date of such action; that is, extra paychecks or excess pay must not be dispersed.

Protection Against Accidental Corruption or Loss of Payroll Data

The same mechanisms used to protect against fraudulent modification are used to protect against accidental corruption of time and attendance data — namely, the access-control features of the server and mainframe operating systems.

COG's nightly backups of the server's disks protect against loss of time and attendance data. To a limited extent, HGA also relies on mainframe administrative personnel to back up time and attendance data stored on the mainframe, even though HGA has no direct control over these individuals. As additional protection against loss of data at the mainframe, HGA retains copies of all time and attendance data on line on the server for at least one year, at which time the data are

archived and kept for three years. The server's access controls for the on-line files are automatically set to read-only access by the time and attendance application at the time of submission to the mainframe. The integrity of time and attendance data will be protected by digital signatures as they are implemented.

The WAN's communications protocols also protect against loss of data during transmission from the server to the mainframe (e.g., error checking). In addition, the mainframe payroll application includes a program that is automatically run 24 hours before paychecks and pay stubs are printed. This program produces a report identifying agencies from whom time and attendance data for the current pay period were expected but not received. Payroll department staff are responsible for reviewing the reports and immediately notifying agencies that need to submit or resubmit time and attendance data. If time and attendance input or other related information is not available on a timely basis, pay, leave, and other benefits are temporarily calculated based on information estimated from prior pay periods.

20.4.3 Protection Against Interruption of Operations

HGA's policies regarding continuity of operations are derived from requirements stated in OMB Circular A-130. HGA requires various organizations within it to develop contingency plans, test them annually, and establish appropriate administrative and operational procedures for supporting them. The plans must identify the facilities, equipment, supplies, procedures, and personnel needed to ensure reasonable continuity of operations under a broad range of adverse circumstances.

COG Contingency Planning

COG is responsible for developing and maintaining a contingency plan that sets forth the procedures and facilities to be used when physical plant failures, natural disasters, or major equipment malfunctions occur sufficient to disrupt the normal use of HGA's PCs, LAN, server, router, printers, and other associated equipment.

The plan prioritizes applications that rely on these resources, indicating those that should be suspended if available automated functions or capacities are temporarily degraded. COG personnel have identified system software and hardware components that are compatible with those used by two nearby agencies. HGA has signed an agreement with those agencies, whereby they have committed to reserving spare computational and storage capacities sufficient to support HGA's system-based operations for a few days during an emergency.

No communication devices or network interfaces may be connected to HGA's systems without written approval of the COG Manager. The COG staff is responsible for installing all known security-related software patches in a timely manner and for maintaining spare or redundant PCs, servers, storage devices, and LAN interfaces to ensure that at least 100 people can simultaneously

perform word processing tasks at all times.

To protect against accidental corruption or loss of data, COG personnel back up the LAN server's disks onto magnetic tape every night and transport the tapes weekly to a sister agency for storage. HGA's policies also stipulate that all PC users are responsible for backing up weekly any significant data stored on their PC's local hard disks. For the past several years, COG has issued a yearly memorandum reminding PC users of this responsibility. COG also strongly encourages them to store significant data on the LAN server instead of on their PC's hard disk so that such data will be backed up automatically during COG's LAN server backups.

To prevent more limited computer equipment malfunctions from interrupting routine business operations, COG maintains an inventory of approximately ten fully equipped spare PC's, a spare LAN server, and several spare disk drives for the server. COG also keeps thousands of feet of LAN cable on hand. If a segment of the LAN cable that runs through the ceilings and walls of HGA's buildings fails or is accidentally severed, COG technicians will run temporary LAN cabling along the floors of hallways and offices, typically restoring service within a few hours for as long as needed until the cable failure is located and repaired.

To protect against PC virus contamination, HGA authorizes only System Administrators approved by the COG Manager to install licensed, copyrighted PC software packages that appear on the COG-approved list. PC software applications are generally installed only on the server. (These stipulations are part of an HGA assurance strategy that relies on the quality of the engineering practices of vendors to provide software that is adequately robust and trustworthy.) Only the COG Manager is authorized to add packages to the approved list. COG procedures also stipulate that every month System Administrators should run virus-detection and other security-configuration validation utilities on the server and, on a spot-check basis, on a number of PCs. If they find a virus, they must immediately notify the agency team that handles computer security incidents.

COG is also responsible for reviewing audit logs generated by the server, identifying audit records indicative of security violations, and reporting such indications to the Incident-Handling Team. The COG Manager assigns these duties to specific members of the staff and ensures that they are implemented as intended.

The COG Manager is responsible for assessing adverse circumstances and for providing recommendations to HGA's Director. Based on these and other sources of input, the Director will determine whether the circumstances are dire enough to merit activating various sets of procedures called for in the contingency plan.

Division Contingency Planning

HGA's divisions also must develop and maintain their own contingency plans. The plans must

identify critical business functions, the system resources and applications on which they depend, and the maximum acceptable periods of interruption that these functions can tolerate without significant reduction in HGA's ability to fulfill its mission. The head of each division is responsible for ensuring that the division's contingency plan and associated support activities are adequate.

For each major application used by multiple divisions, a chief of a single division must be designated as the *application owner*. The designated official (supported by his or her staff) is responsible for addressing that application in the contingency plan and for coordinating with other divisions that use the application.

If a division relies exclusively on computer resources maintained by COG (e.g., the LAN), it need not duplicate COG's contingency plan, but is responsible for reviewing the adequacy of that plan. If COG's plan does not adequately address the division's needs, the division must communicate its concerns to the COG Director. In either situation, the division must make known the criticality of its applications to the COG. If the division relies on computer resources or services that are *not* provided by COG, the division is responsible for (1) developing its own contingency plan or (2) ensuring that the contingency plans of other organizations (e.g., the WAN service provider) provide adequate protection against service disruptions.

20.4.4 Protection Against Disclosure or Brokerage of Information

HGA's protection against information disclosure is based on a need-to-know policy and on personnel hiring and screening practices. The need-to-know policy states that time and attendance information should be made accessible only to HGA employees and contractors whose assigned professional responsibilities require it. Such information must be protected against access from all other individuals, including other HGA employees. Appropriate hiring and screening practices can lessen the risk that an untrustworthy individual will be assigned such responsibilities.

The need-to-know policy is supported by a collection of physical, procedural, and automated safeguards, including the following:

- Time and attendance paper documents are must be stored securely when not in use, particularly during evenings and on weekends. Approved storage containers include locked file cabinets and desk drawers—to which only the owner has the keys. While storage in a container is preferable, it is also permissible to leave time and attendance documents on top of a desk or other exposed surface in a locked office (with the realization that the guard force has keys to the office). (This is a judgment left to local discretion.) Similar rules apply to disclosure-sensitive information stored on floppy disks and other removable magnetic media.

- Every HGA PC is equipped with a key lock that, when locked, disables the PC.

When information is stored on a PC's local hard disk, the user to whom that PC was assigned is expected to (1) lock the PC at the conclusion of each work day and (2) lock the office in which the PC is located.

- The LAN server operating system's access controls provide extensive features for controlling access to files. These include group-oriented controls that allow teams of users to be assigned to named groups by the System Administrator. Group members are then allowed access to sensitive files not accessible to nonmembers. Each user can be assigned to several groups according to need to know. (The reliable functioning of these controls is assumed, perhaps incorrectly, by HGA.)

- All PC users undergo security awareness training when first provided accounts on the LAN server. Among other things, the training stresses the necessity of protecting passwords. It also instructs users to log off the server before going home at night or before leaving the PC unattended for periods exceeding an hour.

20.4.5 Protection Against Network-Related Threats

HGA's current set of external network safeguards has only been in place for a few months. The basic approach is to tightly restrict the kinds of external network interactions that can occur by funneling all traffic to and from external networks through two interfaces that filter out unauthorized kinds of interactions. As indicated in Figure 20.1, the two interfaces are the network router and the LAN server. The only kinds of interactions that these interfaces allow are (1) e-mail and (2) data transfers from the server to the mainframe controlled by a few special applications (e.g., the time and attendance application).

Figure 20.1 shows that the network router is the only direct interface between the LAN and the Internet. The router is a dedicated special-purpose computer that translates between the protocols and addresses associated with the LAN and the Internet. Internet protocols, unlike those used on the WAN, specify that packets of information coming from or going to the Internet must carry an indicator of the kind of service that is being requested or used to process the information. This makes it possible for the router to distinguish e-mail packets from other kinds of packets—for example, those associated with a remote log-in request.[142] The router has been configured by COG to discard all packets coming from or going to the Internet, except those associated with e-mail. COG personnel believe that the router effectively eliminates Internet-based attacks on HGA user accounts because it disallows all remote log-in sessions, even those accompanied by a legitimate password.

[142] Although not discussed in this example, recognize that technical "spoofing" can occur.

The LAN server enforces a similar type of restriction for dial-in access via the public-switched network. The access controls provided by the server's operating system have been configured so that during dial-in sessions, only the e-mail utility can be executed. (HGA policy, enforced by periodic checks, prohibits installation of modems on PCs, so that access must be through the LAN server.) In addition, the server's access controls have been configured so that its WAN interface device is accessible only to programs that possess a special access-control privilege. Only the System Administrator can assign this privilege to server programs, and only a handful of special-purpose applications, like the time and attendance application, have been assigned this privilege.

20.4.6 Protection Against Risks from Non–HGA Computer Systems

HGA relies on systems and components that it cannot control directly because they are owned by other organizations. HGA has developed a policy to avoid undue risk in such situations. The policy states that system components controlled and operated by organizations other than HGA may not be used to process, store, or transmit HGA information without obtaining explicit permission from the application owner and the COG Manager. Permission to use such system components may not be granted without written commitment from the controlling organization that HGA's information will be safeguarded commensurate with its value, as designated by HGA. This policy is somewhat mitigated by the fact that HGA has developed an issue-specific policy on the use of the Internet, which allows for its use for e-mail with outside organizations and access to other resources (but not for transmission of HGA's proprietary data).

20.5 Vulnerabilities Reported by the Risk Assessment Team

The risk assessment team found that many of the risks to which HGA is exposed stem from (1) the failure of individuals to comply with established policies and procedures or (2) the use of automated mechanisms whose assurance is questionable because of the ways they have been developed, tested, implemented, used, or maintained. The team also identified specific vulnerabilities in HGA's policies and procedures for protecting against payroll fraud and errors, interruption of operations, disclosure and brokering of confidential information, and unauthorized access to data by outsiders.

20.5.1 Vulnerabilities Related to Payroll Fraud

Falsified Time Sheets

The primary safeguards against falsified time sheets are review and approval by supervisory personnel, who are not permitted to approve their own time and attendance data. The risk assessment has concluded that, while imperfect, these safeguards are adequate. The related requirement that a clerk and a supervisor must cooperate closely in creating time and attendance

data and submitting the data to the mainframe also safeguards against other kinds of illicit manipulation of time and attendance data by clerks or supervisors acting independently.

Unauthorized Access

When a PC user enters a password to the server during I&A, the password is sent to the server by broadcasting it over the LAN "in the clear." This allows the password to be intercepted easily by any other PC connected to the LAN. In fact, so-called "password sniffer" programs that capture passwords in this way are widely available. Similarly, a malicious program planted on a PC could also intercept passwords before transmitting them to the server. An unauthorized individual who obtained the captured passwords could then run the time and attendance application in place of a clerk or supervisor. Users might also store passwords in a log-on script file.

Bogus Time and Attendance Applications

The server's access controls are probably adequate for protection against bogus time and attendance applications that run on the server. However, the server's operating system and access controls have only been in widespread use for a few years and contain a number of security-related bugs. And the server's access controls are ineffective if not properly configured, and the administration of the server's security features in the past has been notably lax.

Unauthorized Modification of Time and Attendance Data

Protection against unauthorized modification of time and attendance data requires a variety of safeguards because each system component on which the data are stored or transmitted is a potential source of vulnerabilities.

First, the time and attendance data are entered on the server by a clerk. On occasion, the clerk may begin data entry late in the afternoon, and complete it the following morning, storing it in a temporary file between the two sessions. One way to avoid unauthorized modification is to store the data on a diskette and lock it up overnight. After being entered, the data will be stored in another temporary file until reviewed and approved by a supervisor. These files, now stored on the system, must be protected against tampering. As before, the server's access controls, if reliable and properly configured, can provide such protection (as can digital signatures, as discussed later) in conjunction with proper auditing.

Second, when the Supervisor approves a batch of time and attendance data, the time and attendance application sends the data over the WAN to the mainframe. The WAN is a collection of communications equipment and special-purpose computers called "switches" that act as relays, routing information through the network from source to destination. Each switch is a potential site at which the time and attendance data may be fraudulently modified. For example, an HGA PC user might be able to intercept time and attendance data and modify the data enroute to the

payroll application on the mainframe. Opportunities include tampering with incomplete time and attendance input files while stored on the server, interception and tampering during WAN transit, or tampering on arrival to the mainframe prior to processing by the payroll application.

Third, on arrival at the mainframe, the time and attendance data are held in a temporary file on the mainframe until the payroll application is run. Consequently, the mainframe's I&A and access controls must provide a critical element of protection against unauthorized modification of the data.

According to the risk assessment, the server's access controls, with prior caveats, probably provide acceptable protection against unauthorized modification of data stored on the server. The assessment concluded that a WAN-based attack involving collusion between an employee of HGA and an employee of the WAN service provider, although unlikely, should not be dismissed entirely, especially since HGA has only cursory information about the service provider's personnel security practices and no contractual authority over how it operates the WAN.

The greatest source of vulnerabilities, however, is the mainframe. Although its operating system's access controls are mature and powerful, it uses password-based I&A. This is of particular concern, because it serves a large number of federal agencies via WAN connections. A number of these agencies are known to have poor security programs. As a result, one such agency's systems could be penetrated (e.g., from the Internet) and then used in attacks on the mainframe via the WAN. In fact, time and attendance data awaiting processing on the mainframe would probably not be as attractive a target to an attacker as other kinds of data or, indeed, disabling the system, rendering it unavailable. For example, an attacker might be able to modify the employee data base so that it disbursed paychecks or pensions checks to fictitious employees. Disclosure-sensitive law enforcement databases might also be attractive targets.

The access control on the mainframe is strong and provides good protection against intruders breaking into a second application after they have broken into a first. However, previous audits have shown that the difficulties of system administration may present some opportunities for intruders to defeat access controls.

20.5.2 Vulnerabilities Related to Payroll Errors

HGA's management has established procedures for ensuring the timely submission and interagency coordination of paperwork associated with personnel status changes. However, an unacceptably large number of troublesome payroll errors during the past several years has been traced to the late submission of personnel paperwork. The risk assessment documented the adequacy of HGA's safeguards, but criticized the managers for not providing sufficient incentives for compliance.

20.5.3 Vulnerabilities Related to Continuity of Operations

COG Contingency Planning

The risk assessment commended HGA for many aspects of COG's contingency plan, but pointed out that many COG personnel were completely unaware of the responsibilities the plan assigned to them. The assessment also noted that although HGA's policies require annual testing of contingency plans, the capability to resume HGA's computer-processing activities at another cooperating agency has never been verified and may turn out to be illusory.

Division Contingency Planning

The risk assessment reviewed a number of the application-oriented contingency plans developed by HGA's divisions (including plans related to time and attendance). Most of the plans were cursory and attempted to delegate nearly all contingency planning responsibility to COG. The assessment criticized several of these plans for failing to address potential disruptions caused by lack of access to (1) computer resources not managed by COG and (2) nonsystem resources, such as buildings, phones, and other facilities. In particular, the contingency plan encompassing the time and attendance application was criticized for not addressing disruptions caused by WAN and mainframe outages.

Virus Prevention

The risk assessment found HGA's virus-prevention policy and procedures to be sound, but noted that there was little evidence that they were being followed. In particular, no COG personnel interviewed had ever run a virus scanner on a PC on a routine basis, though several had run them during publicized virus scares. The assessment cited this as a significant risk item.

Accidental Corruption and Loss of Data

The risk assessment concluded that HGA's safeguards against accidental corruption and loss of time and attendance data were adequate, but that safeguards for some other kinds of data were not. The assessment included an informal audit of a dozen randomly chosen PCs and PC users in the agency. It concluded that many PC users store significant data on their PC's hard disks, but do not back them up. Based on anecdotes, the assessment's authors stated that there appear to have been many past incidents of loss of information stored on PC hard disks and predicted that such losses would continue.

20.5.4 Vulnerabilities Related to Information Disclosure/Brokerage

HGA takes a conservative approach toward protecting information about its employees. Since information brokerage is more likely to be a threat to large collections of data, HGA risk

assessment focused primarily, but not exclusively, on protecting the mainframe.

The risk assessment concluded that significant, avoidable information brokering vulnerabilities were present—particularly due to HGA's lack of compliance with its own policies and procedures. Time and attendance documents were typically not stored securely after hours, and few PCs containing time and attendance information were routinely locked. Worse yet, few were routinely powered down, and many were left logged into the LAN server overnight. These practices make it easy for an HGA employee wandering the halls after hours to browse or copy time and attendance information on another employee's desk, PC hard disk, or LAN server directories.

The risk assessment pointed out that information sent to or retrieved from the server is subject to eavesdropping by other PCs on the LAN. The LAN hardware transmits information by broadcasting it to all connection points on the LAN cable. Moreover, information sent to or retrieved from the server is transmitted in the clear—that is, without encryption. Given the widespread availability of LAN "sniffer" programs, LAN eavesdropping is trivial for a prospective information broker and, hence, is likely to occur.

Last, the assessment noted that HGA's employee master database is stored on the mainframe, where it might be a target for information brokering by employees of the agency that owns the mainframe. It might also be a target for information brokering, fraudulent modification, or other illicit acts by any outsider who penetrates the mainframe via another host on the WAN.

20.5.5 Network-Related Vulnerabilities

The risk assessment concurred with the general approach taken by HGA, but identified several vulnerabilities. It reiterated previous concerns about the lack of assurance associated with the server's access controls and pointed out that these play a critical role in HGA's approach. The assessment noted that the e-mail utility allows a user to include a copy of *any* otherwise accessible file in an outgoing mail message. If an attacker dialed in to the server and succeeded in logging in as an HGA employee, the attacker could use the mail utility to export copies of all the files accessible to that employee. In fact, copies could be mailed to any host on the Internet.

The assessment also noted that the WAN service provider may rely on microwave stations or satellites as relay points, thereby exposing HGA's information to eavesdropping. Similarly, any information, including passwords and mail messages, transmitted during a dial-in session is subject to eavesdropping.

20.6 Recommendations for Mitigating the Identified Vulnerabilities

The discussions in the following subsections were chosen to illustrate a *broad sampling*[143] of handbook topics. Risk management and security program management themes are integral throughout, with particular emphasis given to the selection of risk-driven safeguards.

20.6.1 Mitigating Payroll Fraud Vulnerabilities

To remove the vulnerabilities related to payroll fraud, the risk assessment team recommended[144] the use of stronger authentication mechanisms based on smart tokens to generate one-time passwords that cannot be used by an interloper for subsequent sessions. Such mechanisms would make it very difficult for outsiders (e.g., from the Internet) who penetrate systems on the WAN to use them to attack the mainframe. The authors noted, however, that the mainframe serves many different agencies, and HGA has no authority over the way the mainframe is configured and operated. Thus, the costs and procedural difficulties of implementing such controls would be substantial. The assessment team also recommended improving the server's administrative procedures and the speed with which security-related bug fixes distributed by the vendor are installed on the server.

After input from COG security specialists and application owners, HGA's managers accepted most of the risk assessment team's recommendations. They decided that since the residual risks from the falsification of time sheets were acceptably low, no changes in procedures were necessary. However, they judged the risks of payroll fraud due to the interceptability of LAN server passwords to be unacceptably high, and thus directed COG to investigate the costs and procedures associated with using one-time passwords for Time and Attendance Clerks and supervisor sessions on the server. Other users performing less sensitive tasks on the LAN would continue to use password-based authentication.

While the immaturity of the LAN server's access controls was judged a significant source of risk, COG was only able to identify one other PC LAN product that would be significantly better in this respect. Unfortunately, this product was considerably less friendly to users and application developers, and incompatible with other applications used by HGA. The negative impact of changing PC LAN products was judged too high for the potential incremental gain in security benefits. Consequently, HGA decided to accept the risks accompanying use of the current product, but directed COG to improve its monitoring of the server's access control configuration

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[143] Some of the controls, such as auditing and access controls, play an important role in many areas. The limited nature of this example, however, prevents a broader discussion.

[144] Note that, for the sake of brevity, the process of evaluating the cost-effectiveness of various security controls is not specifically discussed.

and its responsiveness to vendor security reports and bug fixes.

HGA concurred that risks of fraud due to unauthorized modification of time and attendance data at or in transit to the mainframe should not be accepted unless no practical solutions could be identified. After discussions with the mainframe's owning agency, HGA concluded that the owning agency was unlikely to adopt the advanced authentication techniques advocated in the risk assessment. COG, however, proposed an alternative approach that did not require a major resource commitment on the part of the mainframe owner.

The alternative approach would employ digital signatures based on public key cryptographic techniques to detect unauthorized modification of time and attendance data. The data would be *digitally signed* by the supervisor using a private key prior to transmission to the mainframe. When the payroll application program was run on the mainframe, it would use the corresponding public key to validate the correspondence between the time and attendance data and the signature. Any modification of the data during transmission over the WAN or while in temporary storage at the mainframe would result in a mismatch between the signature and the data. If the payroll application detected a mismatch, it would reject the data; HGA personnel would then be notified and asked to review, sign, and send the data again. If the data and signature matched, the payroll application would process the time and attendance data normally.

HGA's decision to use advanced authentication for time and attendance Clerks and Supervisors can be combined with digital signatures by using smart tokens. Smart tokens are programmable devices, so they can be loaded with private keys and instructions for computing digital signatures without burdening the user. When supervisors approve a batch of time and attendance data, the time and attendance application on the server would instruct the supervisor to insert their token in the token reader/writer device attached to the supervisors' PC. The application would then send a special "hash" (summary) of the time and attendance data to the token via the PC. The token would generate a digital signature using its embedded secret key, and then transfer the signature back to the server, again via the PC. The time and attendance application running on the server would append the signature to the data before sending the data to the mainframe and, ultimately, the payroll application.

Although this approach did not address the broader problems posed by the mainframe's I&A vulnerabilities, it does provide a reliable means of detecting time and attendance data tampering. In addition, it protects against bogus time and attendance submissions from systems connected to the WAN because individuals who lack a time and attendance supervisor's smart token will be unable to generate valid signatures. (Note, however, that the use of digital signatures does require increased administration, particularly in the area of key management.) In summary, digital signatures mitigate risks from a number of different kinds of threats.

HGA's management concluded that digitally signing time and attendance data was a practical, cost-effective way of mitigating risks, and directed COG to pursue its implementation. (They also

noted that it would be useful as the agency moved to use of digital signatures in other applications.) This is an example of developing and providing a solution in an environment over which no single entity has overall authority.

20.6.2 Mitigating Payroll Error Vulnerabilities

After reviewing the risk assessment, HGA's management concluded that the agency's current safeguards against payroll errors and against accidental corruption and loss of time and attendance data were adequate. However, the managers also concurred with the risk assessment's conclusions about the necessity for establishing incentives for complying (and penalties for not complying) with these safeguards. They thus tasked the Director of Personnel to ensure greater compliance with paperwork-handling procedures and to provide quarterly compliance audit reports. They noted that the digital signature mechanism HGA plans to use for fraud protection can also provide protection against payroll errors due to accidental corruption.

20.6.3 Mitigating Vulnerabilities Related to the Continuity of Operations

The assessment recommended that COG institute a program of periodic internal training and awareness sessions for COG personnel having contingency plan responsibilities.The assessment urged that COG undertake a rehearsal during the next three months in which selected parts of the plan would be exercised. The rehearsal should include attempting to initiate some aspect of processing activities at one of the designated alternative sites. HGA's management agreed that additional contingency plan training was needed for COG personnel and committed itself to its first plan rehearsal within three months.

After a short investigation, HGA divisions owning applications that depend on the WAN concluded that WAN outages, although inconvenient, would not have a major impact on HGA. This is because the few time-sensitive applications that required WAN-based communication with the mainframe were originally designed to work with magnetic tape instead of the WAN, and could still operate in that mode; hence courier-delivered magnetic tapes could be used as an alternative input medium in case of a WAN outage. The divisions responsible for contingency planning for these applications agreed to incorporate into their contingency plans both descriptions of these procedures and other improvements.

With respect to mainframe outages, HGA determined that it could not easily make arrangements for a suitable alternative site. HGA also obtained and examined a copy of the mainframe facility's own contingency plan. After detailed study, including review by an outside consultant, HGA concluded that the plan had major deficiencies and posed significant risks because of HGA's reliance on it for payroll and other services. This was brought to the attention of the Director of HGA, who, in a formal memorandum to the head of the mainframe's owning agency, called for (1) a high-level interagency review of the plan by all agencies that rely on the mainframe, and (2) corrective action to remedy any deficiencies found.

HGA's management agreed to improve adherence to its virus-prevention procedures. It agreed (from the point of view of the entire agency) that information stored on PC hard disks is frequently lost. It estimated, however, that the labor hours lost as a result would amount to less than a person year—which HGA management does *not* consider to be unacceptable. After reviewing options for reducing this risk, HGA concluded that it would be cheaper to accept the associated loss than to commit significant resources in an attempt to avoid it. COG volunteered, however, to set up an automated program on the LAN server that e-mails backup reminders to all PC users once each quarter. In addition, COG agreed to provide regular backup services for about 5 percent of HGA's PCs; these will be chosen by HGA's management based on the information stored on their hard disks.

20.6.4 Mitigating Threats of Information Disclosure/Brokering

HGA concurred with the risk assessment's conclusions about its exposure to information-brokering risks, and adopted most of the associated recommendations.

The assessment recommended that HGA improve its security awareness training (e.g., via mandatory refresher courses) and that it institute some form of compliance audits. The training should be sure to stress the penalties for noncompliance. It also suggested installing "screen lock" software on PCs that automatically lock a PC after a specified period of idle time in which no keystrokes have been entered; unlocking the screen requires that the user enter a password or reboot the system.

The assessment recommended that HGA modify its information-handling policies so that employees would be required to store some kinds of disclosure-sensitive information only on PC local hard disks (or floppies), but not on the server. This would eliminate or reduce risks of LAN eavesdropping. It was also recommended that an activity log be installed on the server (and regularly reviewed). Moreover, it would avoid unnecessary reliance on the server's access-control features, which are of uncertain assurance. The assessment noted, however, that this strategy conflicts with the desire to store most information on the server's disks so that it is backed up routinely by COG personnel. (This could be offset by assigning responsibility for someone other than the PC owner to make backup copies.) Since the security habits of HGA's PC users have generally been poor, the assessment also recommended use of hard-disk encryption utilities to protect disclosure-sensitive information on unattended PCs from browsing by unauthorized individuals. Also, ways to encrypt information on the server's disks would be studied.

The assessment recommended that HGA conduct a thorough review of the mainframe's safeguards in these respects, and that it regularly review the mainframe audit log, using a query package, with particular attention to records that describe user accesses to HGA's employee master database.

20.6.5 Mitigating Network-Related Threats

The assessment recommended that HGA:

- require stronger I&A for dial-in access or, alternatively, that a restricted version of the mail utility be provided for dial-in, which would prevent a user from including files in outgoing mail messages;

- replace its current modem pool with encrypting modems, and provide each dial-in user with such a modem; and

- work with the mainframe agency to install a similar encryption capability for server-to-mainframe communications over the WAN.

As with previous risk assessment recommendations, HGA's management tasked COG to analyze the costs, benefits, and impacts of addressing the vulnerabilities identified in the risk assessment. HGA eventually adopted some of the risk assessment's recommendations, while declining others. In addition, HGA decided that its policy on handling time and attendance information needed to be clarified, strengthened, and elaborated, with the belief that implementing such a policy would help reduce risks of Internet and dial-in eavesdropping. Thus, HGA developed and issued a revised policy, stating that users are individually responsible for ensuring that they do not transmit disclosure-sensitive information outside of HGA's facilities via e-mail or other means. It also prohibited them from examining or transmitting e-mail containing such information during dial-in sessions and developed and promulgated penalties for noncompliance.

20.7 Summary

This chapter has illustrated how many of the concepts described in previous chapters might be applied in a federal agency. An integrated example concerning a Hypothetical Government Agency (HGA) has been discussed and used as the basis for examining a number of these concepts. HGA's distributed system architecture and its uses were described. The time and attendance application was considered in some detail.

For context, some national and agency-level policies were referenced. Detailed operational policies and procedures for computer systems were discussed and related to these high-level policies. HGA assets and threats were identified, and a detailed survey of selected safeguards, vulnerabilities, and risk mitigation actions were presented. The safeguards included a wide variety of procedural and automated techniques, and were used to illustrate issues of assurance, compliance, security program oversight, and inter-agency coordination.

As illustrated, effective computer security requires clear direction from upper management.

Upper management must assign security responsibilities to organizational elements and individuals and must formulate or elaborate the security policies that become the foundation for the organization's security program. These policies must be based on an understanding of the organization's mission priorities and the assets and business operations necessary to fulfill them. They must also be based on a pragmatic assessment of the threats against these assets and operations. A critical element is assessment of threat likelihoods. These are most accurate when derived from historical data, but must also anticipate trends stimulated by emerging technologies.

A good security program relies on an integrated, cost-effective collection of physical, procedural, and automated controls. Cost-effectiveness requires targeting these controls at the threats that pose the highest risks while accepting other residual risks. The difficulty of applying controls properly and in a consistent manner over time has been the downfall of many security programs. This chapter has provided numerous examples in which major security vulnerabilities arose from a lack of assurance or compliance. Hence, periodic compliance audits, examinations of the effectiveness of controls, and reassessments of threats are essential to the success of any organization's security program