Compartmented Mode Workstations

James A. Rome
Oak Ridge National Laboratory
jar@ornl.gov
http://www.epm.ornl.gov/~jar/cmwdoe.pdf

Presented to
DOE Computer Security Meeting
Seattle, WA
April 23, 1995

We all know security is important . . .

Recent events:

- A Russian broke into Citicorp's computers and illegally transferred $8 million.
- The Netscape SSL 40-bit code that was supposed to be used for secure VISA and MasterCard transactions was broken by a French student in a week. California students broke the seed for the random key in a minute.
- Over $40 trillion is transferred electronically each year. This will grow rapidly when credit card transactions on the Internet become a reality.
- Our electric grid, air space, financial markets, phone system, . . . are all controlled by large computer networks.
- We are embarking on large distributed collaborative research efforts.

Are we secure enough?

Security can be applied to three main areas

- The network
  - Cryptography and inter-realm authentication
  - ESNet is using DCE + Kerberos 5
- The network/LAN interface
  - Firewalls
  - Proper router programming

Most computer attacks come from within rather than without . . .

- The computer nodes
  - Hidden password files
  - Discretionary access control (DAC)
    File access by owner, group, world
  - Audit trails
  - Security patches

These are all "band-aids" to patch up a system with many security vulnerabilities.

Compartmented Mode Workstations (CMW) provide a significantly higher level of security.

Ideal venues for a CMW-based system

The DOE-OSS Fileroom Project

- Millions of pages of documents need to be searched and retrieved electronically.
- Some of the data are classified.
  - Reclassification is required.
- Eventually, the non-sensitive data may be available to the public.

Tech Center 2020

- Lockheed-Martin "incubator" company for high-tech startup companies.
- One high-end workstation used by different companies.
- Proprietary information protection must be guaranteed.

"Big science" database

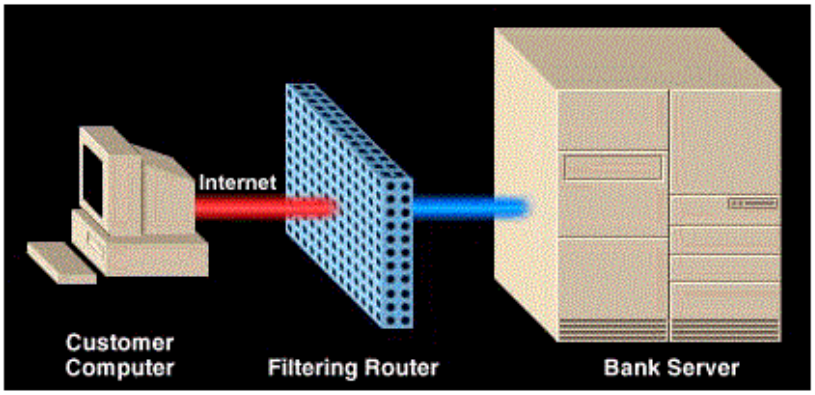
- New data are stored in the same table as old data and are held confidential until papers are published.
- Data can be retracted.

Internet bank (www.sfnb.com)

Internet Security at SFNB

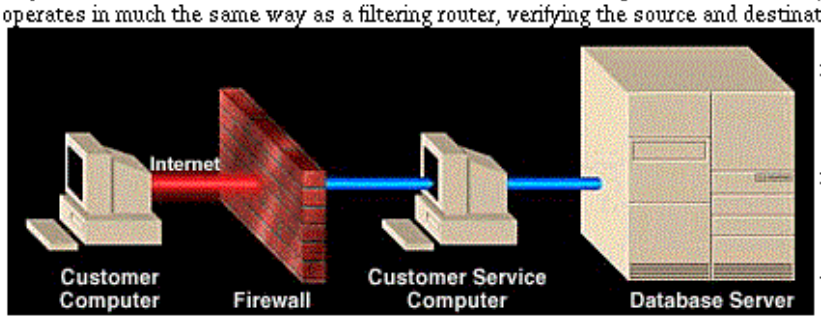
Filtering Routers and Firewalls

Security First has gone to great lengths to ensure that your money and personal data are protected against any type of intruder or attack.



The bank is protected by a system of filtering routers and firewalls, which form a barrier between the outside Internet and the internal bank network. The filtering router verifies the source and destination of each network packet, and determines whether or not to let the packet through. Access is denied if the packet is not directed at a specific, available service.

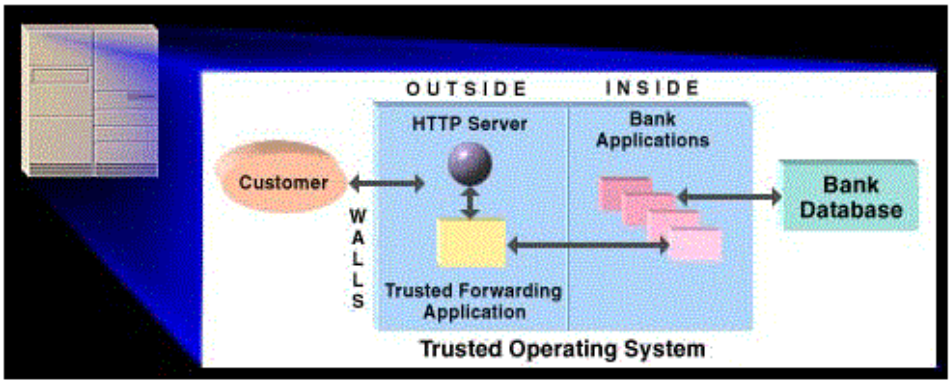
The firewall is used to shield the bank's customer service network from the Internet. All incoming IP traffic is actually addressed to the firewall, which is designed to allow only e-mail into the customer service environment. Traffic through the firewall is subjected to a special proxy process which operates in much the same way as a filtering router, verifying the source and destination of each information packet. The proxy then changes the IP address of the packet to deliver it to the appropriate site within the customer service network. In this way, all inside addresses are protected from outside access, and the structure of the bank's internal networks is invisible to outside observers.



Trusted Operating System

While there are important security issues associated with transit across the Internet, the greatest risk to your financial information occurs within the bank itself. Security First addresses this issue using SecureWare's SecureWeb platform. An important part of this architecture is the Trusted Operating System, the dominant security platform in government computing. Security First's use of this trusted operating system, called CMW+, represents the first commercial implementation of this highly successful platform, used for years by the Department of Defense and other high-security government agencies.

The trusted operating system acts as a "virtual vault," protecting customer information and funds inside the bank. It uses multilevel technology and contains privilege and authorization mechanisms to control access to functions and commands. It also contains an audit mechanism which records logins and logouts, use of privilege, access violations and unsuccessful network connections. This allows quick identification of any suspicious activity.



CMW system

Summary of "Orange Book" security features

Criterion	C1	C2	B1	CMW	B2	B3	A1
Identification and Authentication (IAA)							
Discretionary Access Control (DAC)							
System Architecture (Least Privilege)							
Security Testing							
Auditing							
Object Reuse							
Labeling							
Label Integrity and Label Export							
Multilevel Export							
Single-Level Export							
Printout Labeling							
Mandatory Access Control (MAC)							
Sensitivity Labels							
Device Labeling							
Trusted Path							
Covert Channel Analysis							
Trusted Facility Management							
Configuration Management							
Trusted Recovery							
Trusted Distribution							
Information Labels							
Authorizations							

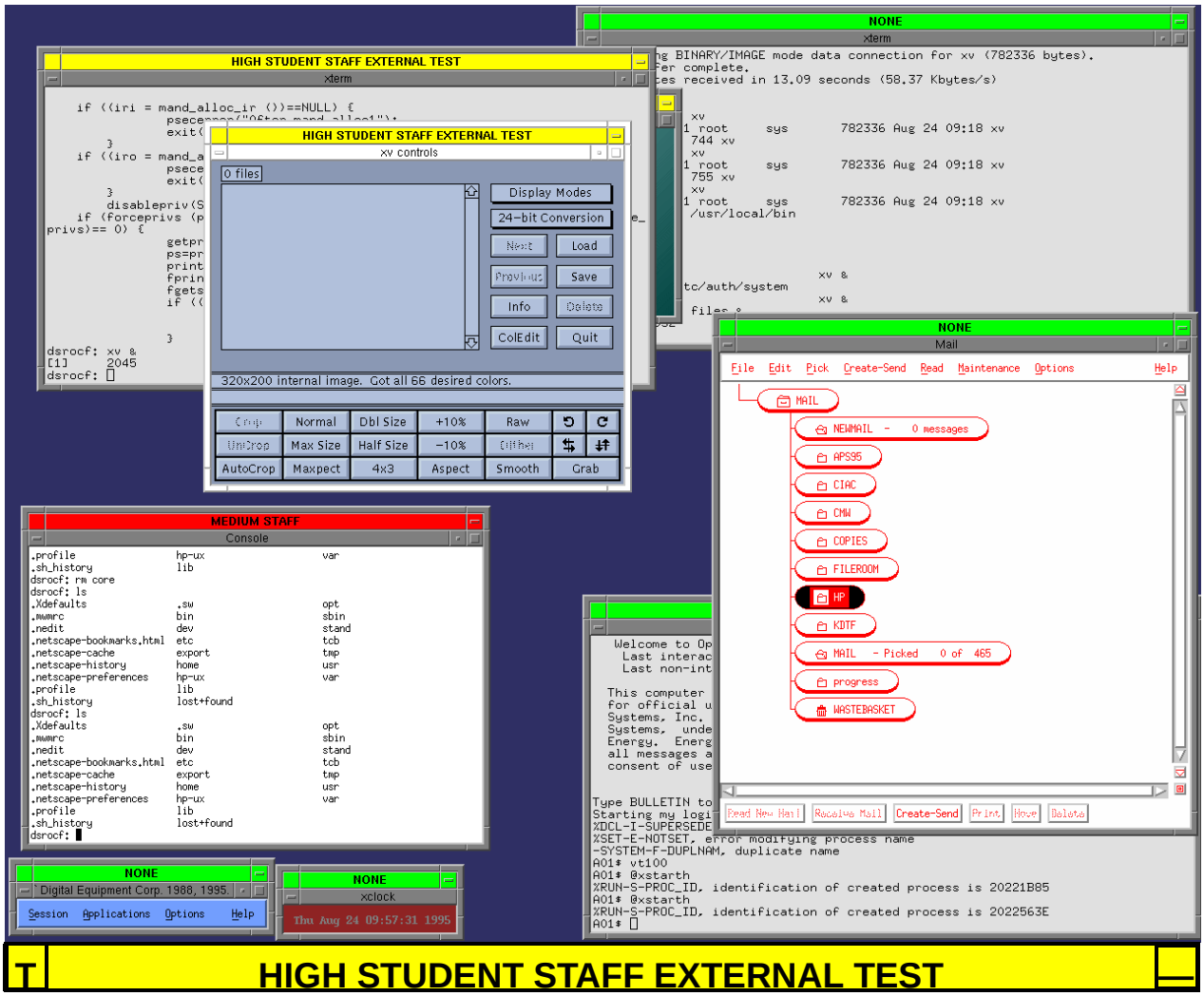
Why not start with a more secure system?

Compartmented mode workstation (CMW) Unix systems are now ready for deployment.

- Developed by DoD and NSA for multilevel classified work.
- Rated *B1* in the NSA Orange Book with many features of the higher *B2* and *A* levels. This is significantly higher than the *C1* or *C2* rating of most conventional systems.
- There are CMW versions for Sun, IBM, HP, DEC, SCO (Intel) platforms.
  They are different.
- The major database (Oracle, Informix, Sybase, Ingress) vendors have multilevel-secure versions of their products.

These systems have now emerged from being "bleeding edge" technology to being useful technology.

What does a CMW system look like?



Hewlett Packard HP-UX 10.09 screen

- Every window is labeled
- Trusted stripe (on bottom) can't be occluded
- Read-down/write-up policy enforced by window manager

Aside: The previous screen shot was secure

The program *xv* worked perfectly and captured a shot of the screen. But,

- All windows were black holes.

The CMW Motif Window Manager is much more protective than on a usual Unix system where the screen can be read relatively easily by determined hackers.

To capture the screen, assuming the role of information system security officer (ISSO) I had to

- Modify a file that gives programs privileges. I gave *xv* the *WindowManager* privilege.
- I rebuilt the database that checks program privileges using the above file.
- I set *xv* to have a *System High* security label.

Thus, I could only run it from a *System High* session. Otherwise, the screen shot would declassify information. The resulting TIFF file was automatically labeled *System High*.

What makes a CMW system more secure?

In addition to the usual Unix features, CMW systems add

- **Mandatory access control:**
  All files (subjects) on the system are labeled with a classification and one or more compartments or "need to know" categories.
  - The file system is different. The inodes contain the labels.
  - Access to any system resource is automatically controlled according to the subject's clearance, and the program's privileges.
- **Root privileges are split up:**
  On conventional Unix system programs run with a *uid* of 0 (root) which gives them all privileges. On a CMW system, the operating system routines have been rewritten.
  - Programs do not run at *uid* 0.
  - They only assume privileges when needed and drop them when no longer needed. This is called the *principle of least privilege*.

CMW security features (continued)

- **System administration is split up into roles:** Administrator, Information System Security Officer (ISSO), Operator, and Network Security Officer (NSO).
- **Two man rule:**
  It takes two people to set up a user account, the Administrator and the ISSO.
- **Enhanced audit trail:**
  Every action of individual users, groups, or combinations thereof can be audited.
  - File access and modification
  - Success or failure of system operations
  - Usage of system resources
- **Sysadmin tools:**
  Security-sensitive system administration tools can only be run from the console.
- **Communicates with selected hosts only:**
  Connections are refused unless the other host is listed in the *M6RHDB* database.
- **External non-CMW hosts enter at one label.**

Can it implement DOE's security policy?

The CMW security model can be looked upon as being a table:

	Compartments		
Clearance	NRD	NSI	FRD
Top Secret			
Secret			
Confidential			

A user is generally given a single clearance, and any number of compartments. The user has access to all of these compartments up to the (single) clearance level.

In the above example, the user has access at Secret and below in the compartments NSI and FRD.

DOE requires that a single user has a different clearance in each comprtment. In addition, there are handling caveats.
Hierarchical compartments solve this problem.

Hierarchical compartments

In the computer, everything is a collection of bits, 0's and 1's.

- Compartment specifications are just bit fields:
  - One compartment dominates another compartment if it contains at least all of the bits in the other compartment.
- Hierarchical compartments might be specified as follows:

Compartment Name	Bits
TS_NRD	1,2,3
S_NRD	1,2
C_NRD	1
TS_NSI	5,6,7
S_NSI	5,6
C_NSI	5

  - A user in S_NRD can see C_NRD but not TS_NRD, or any NSI compartments.
  - If he also is in TS_NSI, he can see all NSI compartments, but not TS_NRD.

Handling caveats (markings)

DOE must also implement handling caveats, also known as markings (e.g., **NOFORN, WNINTEL**,...).

Handling caveats can be accomplished by treating each caveat as an extra compartment:

Caveat	Bits
NOFORN	120
WNINTEL	121
EYES_ONLY	122

So, the bit field for a document that was classified SECRET_NSI NOFORN would have the bit field 5,6,120.

The caveats are not hierarchical, so they can be added to any document classified at any level to restrict access to only those with this caveat in their clearance.

Is it really secure?

- Certified by the National Computer Security Center.
- Unaffected by a Satan attack.

But, the administrator must carefully evaluate new software and hardware to maintain this level of security. Some issues to be considered are:

- What was the "certified configuration?"
- Does commercial off-the-shelf software (COTS) run without special privileges? At any security level? By any user?
  - Used to be a problem. Now COTS usually works "out of the box."
- How do you interface with other CMW and non-CMW computers?
- What privileges do you give to the average user?

Example of a trusted program

```
/* This trusted program changes the */
/* level of a user coming from a      */
/* unlabeled host (if authorized)     */

/* gcc flevel.c -o flevel -lsecurity      */

#include <prot.h>
#include <stdio.h>
#include <sys/types.h>
#include <sys/secdefines.h>
#include <sys/security.h>
#include <mandatory.h>
#include <unistd.h>

main (int argc, char **argv)
{
     mand_ir_t *iri, *iro;
     char string1[200];
     char *ps;
     privvec_t  eprivs;
/* Initialize security parameters and allocate
security arrays */
     set_auth_parameters (argc, argv);
     initprivs();

     if ((iri = mand_alloc_ir ())==NULL) {
          exit(1);
     }
     if ((iro = mand_alloc_ir ())==NULL) {
          exit(1);
     }
/* Make sure auditing is on !! */
     disablepriv(SEC_SUSPEND_AUDIT);
/* Turn on only privileges needed to allow
user to change levels */
     if (forceprivs (privvec(SEC_CHSUBJSL,
          SEC_CVTLABEL,-1), save_privs)== 0) {
/* Get user's desired level */
          fprintf (stderr,
               "Enter desired sensitivity label: ");
          fgets (string1, 199, stdin);
/* Convert from named level to internal
representation */
          if ((iri = mand_er_to_ir (string1)) == NULL) {
               exit(1);
          }
/* Set user's desired level. Will fail if not
dominated by user's clearance */
          if (setslabel (iri)) {
               fprintf (stderr, "Not authorized\n");
               psecerror("Error");
          }
          else {
/* Check and be sure it worked */
               getslabel (iro);
               fprintf (stderr,
                 "New sensitivity level for process:  %s\n"
               mand_ir_to_er (iro));
          }
/* Restore privileges user had on entrance */
          (void)seteffprivs(save_privs, NULL);
/* Free memory */
          mand_free_ir (iri);
          mand_free_ir (iro);
/* Exec a shell for user with new level */
          execl ("/bin/ksh", "-", NULL);
     }
/* or tell user why it failed... */
     else {
          psecerror("Forceprivs failed");
     }
}
```

Advantages of CMW systems

In addition to the resistance to attack CMW systems offer other advantages.

- Compartments automatically protect proprietary information with no additional programming, and can't be subverted.
  - *Problem*: The employee evaluation program requires that the fitness reports for every employee are in one directory, but they should only be accessible to each employee's supervisory chain.
    Solution: Label each employee's report with the supervisor's compartment. The supervisor's boss is a member of all his sub-supervisors compartments.
  - *Problem*: Protect proprietary data from an industrial partner in a CRADA, but be able to look at the data from several partners at once.
    Solution: Put each partner's data in a separate compartment
  - *Example*: Tech 2020 (startup incubator) uses CMW on the shared computer.

Advantages of CMW systems (cont.)

- Enhanced auditing allows more fine-grained actions.
  - Be able to tell who has accessed a table on a row-by-row basis to allow for data retraction. (Trusted database)
  - Create "citation" index to evaluate worth of data. (Trusted database)
  - Track activities of public to be able to prove that they did or did not find something on the computer.
- More flexible database administration.
  - Labels apply to rows, not just to tables.
    - Two people making the same query of the same table get different answers according to their clearances.
  - Compartments eliminate need for separate query tools for each group to segregate data.
  - Classification levels allow users to select the reliability level of data. All data will be seen at a high classification. Only old data at a low level.

Networking issues

CMW systems were designed to operate in secure network environments.

- *rlogin* may or may not require a password. If so, it is sent in clear text.
- Multilevel hosts exchange labeled packets.
  - Many protocols: CIPSO, RIPSO, MAX6, TSIX,...
  - Applied at both network and application level.
  - Issue: how to translate levels from site to site. Manufacturer's group (TSIG) made up standards, but still "Tower of Babel." http://ftp.sterling.com/tsig/tsig.html
- NFS extended to labeled file systems. Another CMW host will automatically apply all MAC and DAC access restrictions to an imported volume.
- Sun uses Yellow Pages (NIS) to administer a network of CMW machines as a single entity. (It is even accredited as a distributed system.)

Networking issues (continued)

CMW platforms do not yet support

- AFS
- DCE
- Kerberos
- Smart Cards

It would violate the system security to replace the usual daemons with the Kerberized versions.

As these systems become more widely used in the commercial world, enhanced network security features will surely be added.
(Sun has a CMW http daemon.)

Conclusions

- Today's CMW systems are usable
  - COTS programs usually work without privileges.
  - Enhanced tools make the task of system administration reasonable. (But, it is still harder to administer these systems than conventional Unix . . .)
- These systems are much more secure than conventional systems. This level of security is needed.
- It is time to start using these systems for security-critical tasks.
  - Kerberos server
  - Time card server
  - Medical data
- CMW workstations make the most secure form of server for databases.
- Enhanced networking features that work on CMW platforms are still required.