Solaris 10 Security
Technical Deep Dive

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Solaris Security Goals

- **Defending**
  - Provide strong assurance of system integrity.
  - Defend system from unauthorized access.
- **Enabling**
  - Secure authentication of all active subjects.
  - Protect communications between endpoints.
- **Deploying**
  - Emphasize an integratable stack architecture.
  - Interoperate with other security architectures.
  - Ease management and use of security features.
  - Receive independent assessment of security.

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Solaris 9 Security Review

- Access Control Lists
- Role-based Access Control
- IPsec / IKE
- Solaris Auditing
- TCP Wrappers (inetd, rpcbind)
- Flexible Crypt
- Signed Patches
- Granular Packaging
- SSL-enabled LDAP
- WAN Boot
- IKE Hardware Accel.
- Solaris Fingerprint DB
- Solaris Secure Shell
- Kerberos
- /dev/[u]random
- Enhanced PAM Framework
- Smartcard Framework
- Java Security
- SunScreen 3.2
- Solaris Security Toolkit
- sadmind DES Auth
- LDAP Password Management

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Solaris 10 Technical Security Deep Dive

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Reduced Networking Metacluster

Metacluster	Size (MB)	# Pkgs	# Set-UID	# Set-GID
Reduced Networking SUNWCrnet	250	119	27	11
Core SUNWCreq	290	176	34	14
End User SUNWCuser	3000	731	66	22
Developer SUNWCprog	3700	978	67	22
Entire SUNWCall	3800	1035	81	23
Entire + OEM SUNWCXall	3800	1114	87	23

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Reduced and Minimal Configurations

- Some environments remove or simply do not install software packages that are not needed (business or technical reasons)
  - Less software to install, upgrade, patch, and maintain.
  - Less software equates to reduced exposure to security vulnerabilities.
- Refer to Sun's Rules of Engagement for the Support of Reduced or Minimal Configurations
  - http://www.opensolaris.org/os/community/security/files/minimization-support-rules-ext.pdf
- Solaris Package Companion can be used to understand software package relationships and dependencies
  - http://www.opensolaris.org/os/project/svr4_packaging/package_companion/

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Solaris Package Companion Examples

EXAMPLE 1: What packages depend on StarOffice?

```
$ spc-v0.7.ksh -r ./nv72.rep -l -F -f /opt/staroffice8/program/soffice
SUNWCstaroffice

$ spc-v0.7.ksh -r ./nv72.rep -F -Z -v SUNWCstaroffice
SUNWCstaroffice                [C] StarOffice
```

EXAMPLE 2: On what does SSH depend?

```
$ spc-v0.7.ksh -r ./nv72.rep -D -F -v SUNWCssh
SUNWCcs                        [C] Core Solaris
SUNWCfwcmp                     [C] Freeware Compression Utilities
SUNWCopenssl                   [C] OpenSSL
SUNWCssh                       [C] Secure Shell
SUNWcakr                       [P] Core Solaris Kernel Architecture (Root)
SUNWcar                        [P] Core Architecture, (Root)
SUNWgss                        [P] GSSAPI V2
SUNWgssc                       [P] GSSAPI CONFIG V2
SUNWkvm                        [P] Core Architecture, (Kvm)
SUNWloc                        [P] System Localization
```

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Cryptographically Signed ELF Objects

- ELF Objects Cryptographically Signed
  - > binaries, libraries, kernel modules, crypto modules, etc.

```
# file /usr/lib/ssh/sshd
/usr/lib/ssh/sshd:      ELF 32-bit MSB executable
SPARC Version 1, dynamically linked, stripped

# elfsign verify -e /usr/lib/ssh/sshd
elfsign: verification of /usr/lib/ssh/sshd passed.

# elfsign list -f signer -e /usr/bin/ls
CN=SunOS 5.10, OU=Solaris Signed Execution,
O=Sun Microsystems Inc
```

- Cryptographic modules must be signed by Sun.
  - > Signature must be validated before module can be loaded.
  - > Crypto. modules will not load if not signed or have invalid signature.

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Non-Executable Stack Example

```
#include <stdio.h>
#include <string.h>

typedef void (*fptr)(void);


#ifdef __sparc
char shellcode[] =
"\x2d\x0b\xd8\x9a\xac\x15\xa1\x6e\x2f\x0b\xdc\xda\x90\x0b\x80\x0e"
"\x92\x03\xa0\x08\x94\x1a\x80\x0a\x9c\x03\xa0\x10\xec\x3b\xbf\xf0"
"\xdc\x23\xbf\xf8\xc0\x23\xbf\xfc\x82\x10\x20\x3b\x91\xd0\x20\x08";
#endif

int
main(int argc, char **argv)
{
        fptr f;
        char code[100];

        memcpy(code, shellcode, sizeof(shellcode));
        printf("Attempting to start a shell...\n");
        f = (fptr)code;
        f();
        return (0);
}
```

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Non-Executable Stack Example

```
$ cc -o shell-exstk shell.c
$ cc -o shell-noexstk -M /usr/lib/ld/map.noexst shell.c
```

```
$ ./shell-exstk
Attempting to start a shell...
$ exit

$ ./shell-noexstk
Attempting to start a shell...
Segmentation Fault(coredump)

Sep 16 15:06:06 kilroy genunix: [ID 533030 kern.notice]
NOTICE: shell-noexstk[23132] attempt to execute code on
stack by uid 101
```

Stacks can be globally configured to be non-executable using the noexec_user_stack tunable in /etc/system.

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Service Management Facility

- Provide a uniform mechanism to disable/manage services.
  - e.g., `svcadm [disable|enable] telnet`
- Support alternative service profiles
  - e.g., “Secure by Default” profile (in Solaris 10 11/06)
- Leverage authorizations to manage/configure services.
- Define context to permit services to be started as a specific user and group and with specific privileges.
- Support automatic service dependency resolution.
  - e.g., `svcadm enable -r nfs/client`
- Facilitate delegated service restarts.

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SMF Example #1

```
$ profiles
Service Operator
Basic Solaris User
All

$ svcs network/inetd
STATE          STIME    FMRI
online          1:28:15 svc:/network/inetd:default

$ svcadm disable network/inetd

$ svcs -x -v network/inetd
svc:/network/inetd:default (inetd)
 State: disabled since Thu Jul 13 17:05:36 2006
Reason: Disabled by an administrator.
   See: http://sun.com/msg/SMF-8000-05
   See: man -M /usr/share/man -s 1M inetd
   See: /var/svc/log/network-inetd:default.log
Impact: 5 dependent services are not running:
```

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SMF Example #2

```
# svcprop -v -p defaults inetd
defaults/bind_addr astring ""
defaults/bind_fail_interval integer -1
defaults/bind_fail_max integer -1
defaults/con_rate_offline integer -1
[...]
defaults/stability astring Evolving
defaults/tcp_trace boolean false
defaults/tcp_wrappers boolean false

# svcprop -p config/local_only rpc/bind
false

# svcs -x sendmail
svc:/network/smtp:sendmail (sendmail SMTP mail transfer agent)
 State: maintenance since Wed Dec 01 01:31:35 2004
Reason: Start method failed repeatedly, last exited with
status 208.
   See: http://sun.com/msg/SMF-8000-KS
   See: sendmail(1M)
Impact: 0 services are not running.
```

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SMF Access Control

- Integrated with Solaris Roles (Rights Profiles)
  - *Service Administrator*
  - *Service Operator*
- Integrated with Solaris Authorizations
  - *Global:* *solaris.smf.modify*
  - Global: *solaris.smf.manage*
  - Per Service: *action_authorization*
- Services may have property-group specific authorizations
  - *value_authorization* – change existing property values
  - *modify_authorization* – add, modify, or delete properties

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SMF Example #3

```
# svcprop -p httpd -p general apache2
general/enabled boolean false
general/action_authorization astring
sunw.apache.oper
general/entity_stability astring Evolving
httpd/ssl boolean false
httpd/stability astring Evolving
httpd/value_authorization astring sunw.apache.admin
```

Example taken from the Sun BluePrint: Restricting Service Administration in the Solaris 10 Operating System, http://www.sun.com/blueprints/0605/819-2887.pdf

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SMF Execution Context

- `exec` methods can be forced to run as a given user:
  - `{start, stop, etc.}/user`
- `exec` methods can be forced to run as a given group:
  - `{start, stop, etc.}/group`
- `exec` methods can be forced to use specific privileges:
  - `{start, stop, etc.}/privileges`
  - `{start, stop, etc.}/limit_privileges`
- Other `exec` context can also be defined:
  - default project and resource pool, supplemental groups, etc.

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SMF Example #4

```
# svcprop -v -p start apache2
start/exec astring /lib/svc/method/http-apache2\ start
start/timeout_seconds count 60
start/type astring method
start/user astring webservd
start/group astring webservd
start/privileges astring
basic,!proc_session,!proc_info,!file_link_any,
net_privaddr
start/limit_privileges astring :default
start/use_profile boolean false
start/supp_groups astring :default
start/working_directory astring :default
start/project astring :default
start/resource_pool astring :default
```

Example taken from the Sun BluePrint: Limiting Service Privileges in the Solaris 10 Operating System, http://www.sun.com/blueprints/0505/819-2680.pdf

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Solaris Secure By Default

- Only Secure Shell is reachable by default.
  - `root` use of Secure Shell is not permitted by default.
- Existing services are configured in SMF to either be:
  - Disabled by default
  - Listening for local (e.g., loopback) connections only
- Configuration can be selected using CLI or JumpStart:
  - `netservices`: `open` (traditional) or `limited` (SBD)
  - `service_profile`: `open` or `limited_net`
- Default installation method in Nevada/OpenSolaris:
  - Solaris upgrades are not changed or impacted.
  - Solaris 10 initial (fresh) installations can select SBD mode.

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Solaris Secure By Default Example #1

```
# netservices
netservices: usage: netservices [ open | limited ]

# netservices limited
restarting syslogd
restarting sendmail
dtlogin needs to be restarted. Restart now? [Y] y
restarting dtlogin

# netstat -af inet -P tcp | grep LISTEN
[...]
*.sunrpc             *.*    0    0 49152      0 LISTEN
*.ssh                *.*    0    0 49152      0 LISTEN
localhost.smtp       *.*    0    0 49152      0 LISTEN
localhost.submission *.*    0    0 49152      0 LISTEN
```

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Solaris Secure By Default Example #2

Service	FMRI	Property	Values
rpcbind	svc:/network/rpc/bind	config/local_only	**true**, false
syslog	svc:/system/system-log	config/log_from_remote	true, **false**
sendmail	svc:/network/smtp:sendmail	config/local_only	**true**, false
smcwebserver	svc:/system/webconsole:console	options/tcp_listen	true, **false**
wbem	svc:/application/management/wbem	options/tcp_listen	true, **false**
X11	svc:/application/x11/x11-server	options/tcp_listen	true, **false**
CDE	svc:/application/graphical-login/cde-login	dtlogin/args	[null], **-udpPort 0**
ToolTalk	svc:/network/rpc/cde-ttdbserver:tcp	proto	tcp, **ticotsord**
calendar	svc:/network/rpc/cde-calendar-manager	proto	tcp, **ticlts**
BSD printing	svc:/application/print/rfc1179:default	bind_addr	[null], **localhost**

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User/Password Management

- Enforced for All Naming Services
  - Password Complexity Checks
    - Login Name != Password
    - White Space Permitted
    - Minimum Characters by Class
      - Alphabetic, Non-Alphabetic, Uppercase, Lowercase, Digits, Special
    - Maximum Consecutive Repeating Characters
  - Local Banned Password List (Dictionary)
- Enforced for “files” Naming Service Only
  - Local Password History
  - Local Account Lockout (3 Strikes)
- New “Account Locked” Semantics

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Password Management Example

```
$ passwd gbrunett
Enter existing login password:
New Password:
passwd: The password must contain at least 1 numeric or special
character(s).

Please try again
New Password:
passwd: The password must contain at least 1 uppercase alpha character(s).

Please try again
New Password:
passwd: Too many consecutively repeating characters. Maximum allowed is 3.
Permission denied

$ passwd gbrunett
Enter existing login password:
New Password:
passwd: Password in history list.
```

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Kerberos

- MIT Kerberos Code-base Refresh
- Kerberos Ticket / Credentials Auto-Renewal
- KDC Incremental Propagation
- kclient Auto-configuration Tool
- pam_krb5_migrate KDC Auto-population Tool
- TCP and IPv6 Support
- AES-128, AES-256, 3DES, RC4-HMAC Support
- SPNego – GSS-API Dynamic Security Negotiation
- Bundled Remote Applications (Clients & Servers)
  - telnet, ftp, rlogin, rsh, rcp, rdist, Secure Shell, Mozilla and Apache
- Public Kerberos Developer APIs

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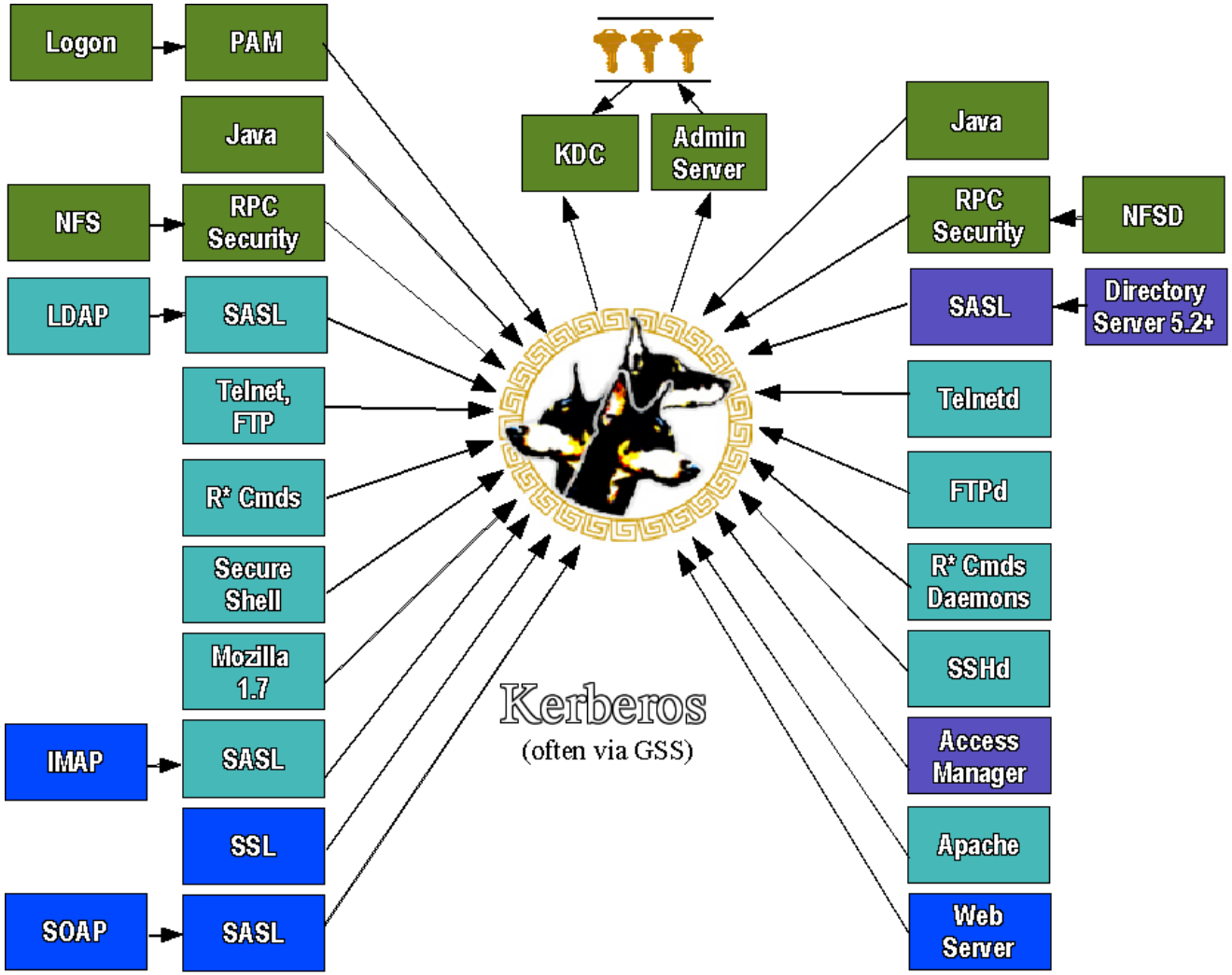
Kerberos Ecosystem Progress



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Secure Shell

- OpenSSH 3.6p2++ Refresh
- GSS-API Support
- Enhanced Password Aging Support
- Keyboard “Break” Sequence Support
- X11 Forwarding “on” by default
- RC4, AES CTR mode Encryption Support
- /etc/default/login Synchronization
- SSH2 Rekeying
- Server Side Keepalives

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User Rights Management (Roles)

Solaris Users versus Roles

- Roles can only be accessed by users already logged in.
- Users cannot assume a role unless authorized.

```
$ id -a
uid=80(webservd) gid=80(webservd)

$ roles
No roles

$ su - root
Password:
Roles can only be assumed by authorized users
su: Sorry
```

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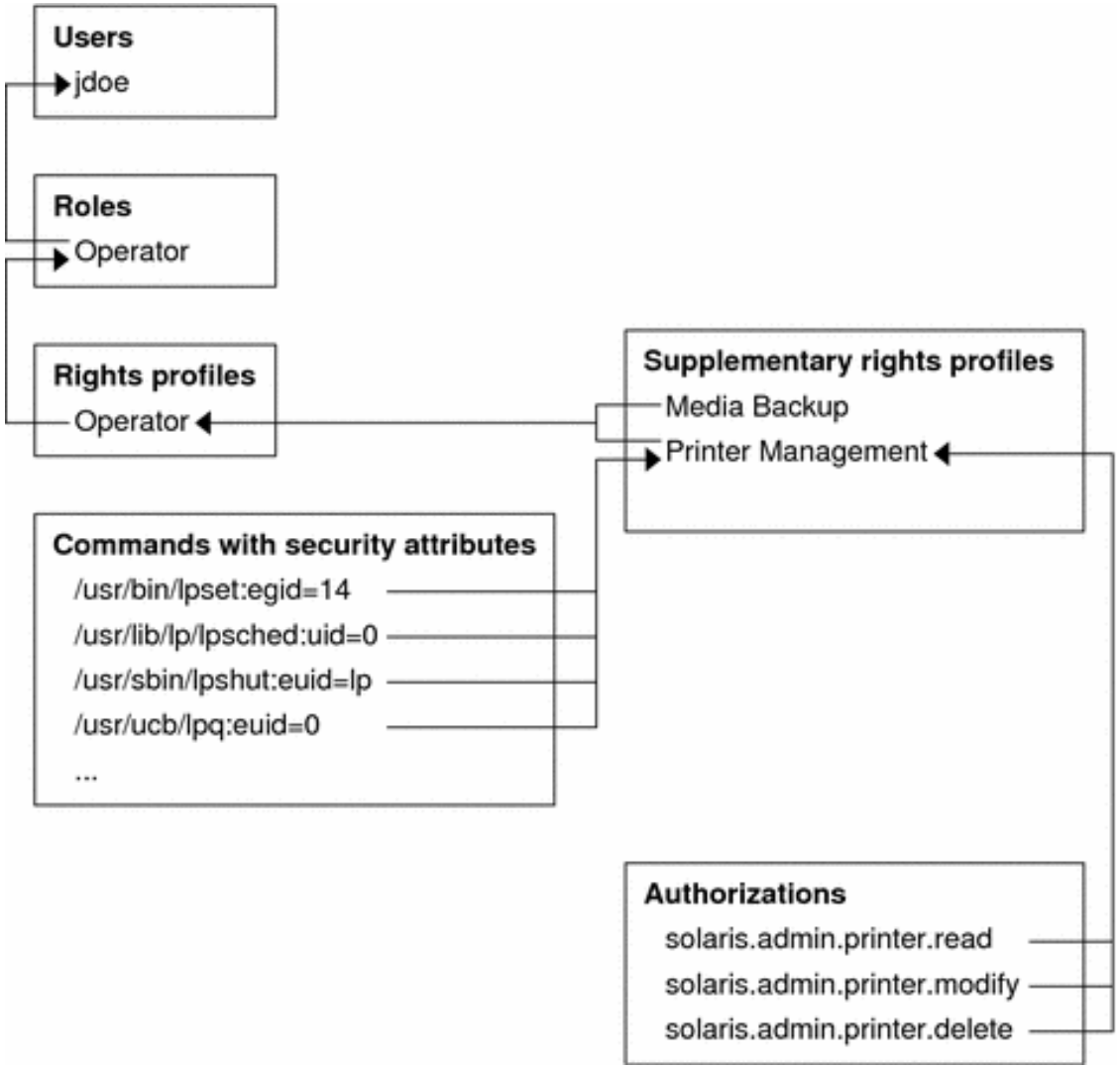
User Rights Management (Rights)



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User Rights Management Example #1

```
$ profiles -l

      Object Access Management:

          /usr/bin/chgrp    privs=file_chown
          /usr/bin/chmod    privs=file_owner
          [...]

      [...]

$ ls -ld mnt
drwxr-xr-x   2 gbrunett gbrunett     512 Nov  7 12:54 mnt

$ chown bin:bin mnt
chown: mnt: Not owner

$ pfexec chown bin:bin mnt

$ ls -ld mnt
drwxr-xr-x   2 bin      bin          512 Nov  7 12:54 mnt
```

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User Rights Management Example #2

```
# svcprop -p httpd -p general apache2
general/enabled boolean false
general/action_authorization astring sunw.apache.oper
general/entity_stability astring Evolving
httpd/ssl boolean false
httpd/stability astring Evolving

# auths weboper
sunw.apache.oper

# profiles -l weboper

      Apache Operator:
          /usr/sbin/svcadm
          /usr/bin/svcs
```

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User Rights Management Example #2

```
$ svcs -o state,ctid,fmri apache2
STATE          CTID   FMRI
online        91050   svc:/network/http:apache2

$ svcadm restart apache2

$ svcs -o state,ctid,fmri apache2
STATE          CTID   FMRI
online        91064   svc:/network/http:apache2

$ ls
ls: not found

$ echo *
local.cshrc local.login local.profile
```

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Process Privileges

- Solaris kernel checks for privileges and not just `UID == 0`!
  - Division of `root` authority into over 60 discrete privileges.
  - Privileges can be granted to processes based on need.
  - Privileges can be disabled or dropped when not needed.
  - Child processes can have different (fewer) privileges than the parent.
- Completely backward compatible and extensible.
  - No changes required to use existing code.
- Privilege bracketing helps to mitigate effects of future flaws.
  - e.g., `proc_fork` and `proc_exec`
  - e.g., `proc_info`

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Process Privileges Listing

contract_event	contract_observer	cpc_cpu	dtrace_kernel
dtrace_proc	dtrace_user	file_chown	file_chown_self
file_dac_execute	file_dac_read	file_dac_search	file_dac_write
file_downgrade_sl	**file_link_any**	file_owner	file_setid
file_upgrade_sl	graphics_access	graphics_map	ipc_dac_read
ipc_dac_write	ipc_owner	net_bindmlp	net_icmpaccess
net_mac_aware	net_privaddr	net_rawaccess	proc_audit
proc_chroot	proc_clock_highres	**proc_exec**	**proc_fork**
proc_info	proc_lock_memory	proc_owner	proc_priocntl
proc_session	proc_setid	proc_taskid	proc_zone
sys_acct	sys_admin	sys_audit	sys_config
sys_devices	sys_ip_config	sys_ipc_config	sys_linkdir
sys_mount	sys_net_config	sys_nfs	sys_res_config
sys_resource	sys_suser_compat	sys_time	sys_trans_label
win_colormap	win_config	win_dac_read	win_dac_write
win_devices	win_dga	win_downgrade_sl	win_fontpath
win_mac_read	win_mac_write	win_selection	win_upgrade_sl

Legend

a = Basic

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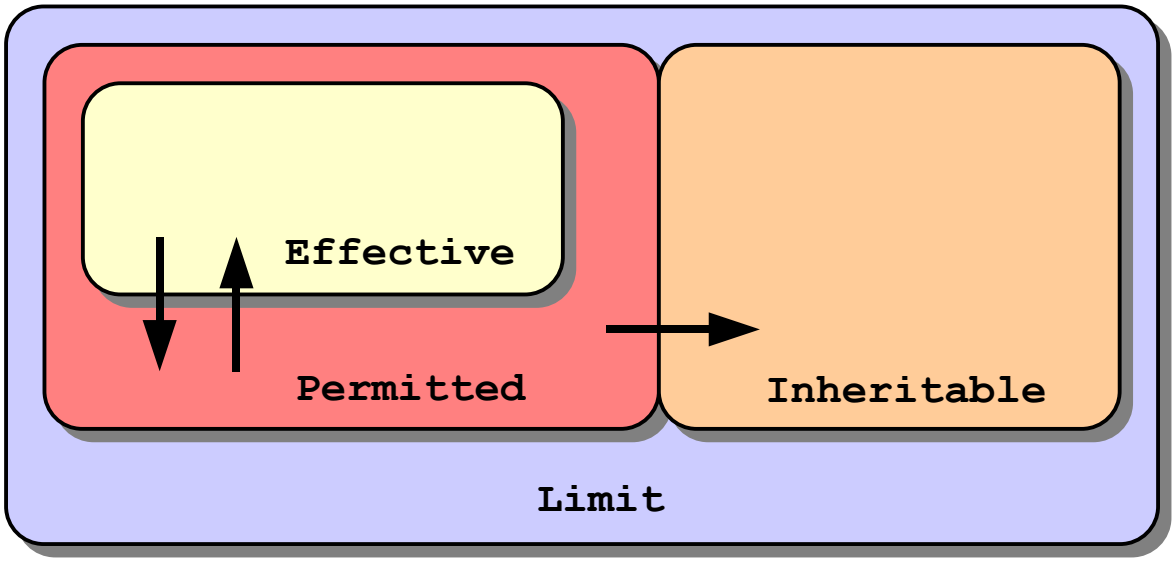
Process Privilege Sets

- E - Effective
  - Privileges in effect
- P - Permitted set
  - Upper bound of E
- I - Inheritable set
  - Privileges of executed programs
- L - Limit set
  - Upper bound for the process and all its descendants



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Process Privilege Inheritance

- Limit (L) is unchanged
- L is used to bound privileges in Inheritable (I)
  - $I' = I \cap L$
- Child's Permitted (P') & Effective (E') are:
  - $P' = E' = I'$
- Typical process
  - P = E = I = {basic}
  - L = {all privileges}
  - Since P = E = I, children run with same privileges

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Root Account Still Special

- *root* owns all configuration/system files
  - `UID 0` is therefore still very powerful
- Privilege escalation prevention
  - Require ALL privileges to modify objects owned by *root* when euid ≠ 0
  - Fine tuning in certain policy routines
    - Not all privileges, only *nosuid* mounts
- Prefer services be non-`UID 0` + privileges
  - Additive approach is safer than `UID 0` – privileges

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Using Process Privileges

- ppriv(1)

```
# ppriv -e -D -s -proc_fork,-proc_exec /bin/sh -c finger
sh[387]: missing privilege "proc_fork" (euid = 0, syscall = 143)
needed at cfork+0x18
/bin/sh: permission denied
```

- User Rights Management (RBAC)

```
# grep "Network Management" /etc/security/exec_attr
Network Management:solaris:cmd:::/sbin/ifconfig:privs=sys_net_config
Network Management:solaris:cmd:::/sbin/route:privs=sys_net_config
```

- Service Management Framework (SMF)

```
# svcprop -p start rpc/bind | grep privileges
start/privileges astring
basic,file_chown,file_chown_self,file_owner,net_privaddr,
proc_setid,sys_nfs,net_bindmlp
stop/limit_privileges astring :default
```

- Privilege Aware Commands / Services

e.g., *ping*, *rmformat*, *quota*, *rpcbind*, *nfsd*, *mountd*

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Process Privileges Example #1

```
$ ppriv $$
28983:  bash
flags = <none>
        E: basic
        I: basic
        P: basic
        L: all
```

```
$ ppriv -l basic
file_link_any
proc_exec
proc_fork
proc_info
proc_session
```

```
$ ppriv -De cat /etc/shadow
cat[3988]: missing privilege "file_dac_read" (euid =
101, syscall = 225) needed at ufs_iaccess+0xc9
cat: cannot open /etc/shadow
```

```
$ ppriv -s -proc_fork,-proc_exec -De /bin/vi
[attempt to run a command/escape to a shell]
vi[4180]: missing privilege "proc_fork" (euid = 101,
syscall = 143) needed at cfork+0x3b
```

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Process Privileges Example #2

```
# ppriv -S `pgrep rpcbind`
933:    /usr/sbin/rpcbind
flags = PRIV_AWARE
        E: net_bindmlp,net_privaddr,proc_fork,sys_nfs
        I: none
        P: net_bindmlp,net_privaddr,proc_fork,sys_nfs
        L: none

# ppriv -S `pgrep statd`
5139:   /usr/lib/nfs/statd
flags = PRIV_AWARE
        E: net_bindmlp,proc_fork
        I: none
        P: net_bindmlp,proc_fork
        L: none
```

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Process Privileges Example #3

usr/src/lib/print/libpapi-lpd/common/lpd-port.c

```
#ifdef  PRIV_ALLSETS
    if ((priv_set(PRIV_ON, PRIV_EFFECTIVE,
            PRIV_FILE_DAC_READ, PRIV_FILE_DAC_WRITE, NULL)) < 0) {
        syslog(LOG_ERR, "lpd_port:next_job_id:priv_set fails: : %m");
        return (-1);
    }
#else
    seteuid(0);
#endif

    /* open the sequence file */
    if (((fd = open(JOB_ID_FILE, O_RDWR)) < 0) && (errno == ENOENT))
        fd = open(JOB_ID_FILE, O_CREAT|O_EXCL|O_RDWR, 0644);

    syslog(LOG_DEBUG, "sequence file fd: %d", fd);

#ifdef  PRIV_ALLSETS
    /* drop file access privilege */
    priv_set(PRIV_OFF, PRIV_PERMITTED,
            PRIV_FILE_DAC_READ, PRIV_FILE_DAC_WRITE, NULL);
#else
    seteuid(getuid());
#endif
```

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Process Privileges Example #3

usr/src/lib/print/libpapi-lpd/common/lpd-port.c

```
#ifdef  PRIV_ALLSETS
    if ((priv_set(PRIV_ON, PRIV_EFFECTIVE,
            PRIV_FILE_DAC_READ, PRIV_FILE_DAC_WRITE, NULL)) < 0) {
        syslog(LOG_ERR, "Turn on effective privilege set fails: : %m");
        return (-1);
    }
#else
    seteuid(0);
#endif

    /* open the sequence file */
    if (((fd = open(JOB_ID_FILE, O_RDWR)) < 0) && (errno == ENOENT))
        fd = open(JOB_ID_FILE, O_CREAT|O_EXCL|O_RDWR, 0644);

    syslog(LOG_DEBUG, "sequence file fd: %d", fd);

#ifdef  PRIV_ALLSETS
    /* drop file access privilege */
    priv_set(PRIV_OFF, PRIV_PERMITTED,
            PRIV_FILE_DAC_READ, PRIV_FILE_DAC_WRITE, NULL);
#else
    seteuid(getuid());
#endif
```

Turn Required Privileges On

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Process Privileges Example #3

usr/src/lib/print/libpapi-lpd/common/lpd-port.c

```
#ifdef  PRIV_ALLSETS
    if ((priv_set(PRIV_ON, PRIV_EFFECTIVE,
            PRIV_FILE_DAC_READ, PRIV_FILE_DAC_WRITE, NULL)) < 0) {
        syslog(LOG_ERR, "Turn on effective privilege set fails: : %m");
        return (-1);
    }
#else
    seteuid(0);
#endif

    /* open the sequence file */
    if (((fd = open(JOB_ID_FILE, O_RDWR)) < 0) && (errno == ENOENT))
        fd = open(JOB_ID_FILE, O_RDWR|O_CREAT, 0644);

    syslog(LOG_DEBUG, "sequence file fd: %d", fd);

#ifdef  PRIV_ALLSETS
    /* drop file access privilege */
    priv_set(PRIV_OFF, PRIV_PERMITTED,
            PRIV_FILE_DAC_READ, PRIV_FILE_DAC_WRITE, NULL);
#else
    seteuid(getuid());
#endif
```

Turn Required Privileges On

Perform the Privileged Operation(s)

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Process Privileges Example #3

usr/src/lib/print/libpapi-lpd/common/lpd-port.c

```
#ifdef  PRIV_ALLSETS
    if ((priv_set(PRIV_ON, PRIV_EFFECTIVE,
            PRIV_FILE_DAC_READ, PRIV_FILE_DAC_WRITE, NULL)) < 0) {
        syslog(LOG_ERR, "Turn on effective privilege set fails: : %m");
        return (-1);
    }
#else
    seteuid(0);
#endif

    /* open the sequence file */
    if (((fd = open(JOB_ID_FILE, O_RDWR)) < 0) && (errno == ENOENT))
        fd = open(JOB_ID_FILE, O_RDWR|O_CREAT, 0644);

    syslog(LOG_DEBUG, "sequence file fd: %d", fd);

#ifdef  PRIV_ALLSETS
    /* drop file access privilege */
    priv_set(PRIV_OFF, PRIV_PERMITTED,
            PRIV_FILE_DAC_READ, PRIV_FILE_DAC_WRITE, NULL);
#else
    seteuid(getuid());
#endif
```

Turn Required Privileges On

Perform the Privileged Operation(s)

Turn Required Privileges Off

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Process Privilege Debugging

```
web_svc zone:   # svcadm disable apache2

global zone:    # privdebug -v -f -n httpd

web_svc zone:   # svcadm enable apache2

global zone:    [output of privdebug command]
```

STAT	TIMESTAMP	PPID	PID	PRIV	CMD
USED	273414882013890	4642	4647	net_privaddr	httpd
USED	273415726182812	4642	4647	proc_fork	httpd
USED	273416683669622	1	4648	proc_fork	httpd
USED	273416689205882	1	4648	proc_fork	httpd
USED	273416694002223	1	4648	proc_fork	httpd
USED	273416698814788	1	4648	proc_fork	httpd
USED	273416703377226	1	4648	proc_fork	httpd

privdebug is available from the OpenSolaris Security Community:
http://opensolaris.org/os/community/security/projects/privdebug/

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Zones

- Zones are virtualized application environments.
  - No direct access to hardware.
- Zones have security boundaries around them.
- Zones have their own:
  - root directory, naming service configuration, process containment, resource controls, devices, etc.
- Zones communicate via network only (default).
- Zones operate with fewer privileges (default).

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Why run services in Zones?

- Restricted Operations for Enhanced Security
  - Individual Solaris OS hardening and RBAC configurations.
  - Prohibited from directly accessing the kernel or raw memory.
  - Prohibited from manipulating network interfaces and kernel modules.
- Enforcement with Integrity
  - Configurable privileges, sparse root zones, IP Instances, IP Filter, etc.
- Resource Control and Management
  - CPU, Memory, Disk, Networking, Devices, etc.
- Observability with Integrity
  - BART, Solaris Auditing, etc.

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Zones Security – System Calls

- Permitted System Calls:
  - *chmod(2)*, *chroot(2)*, *chown(2)*, and *setuid(2)*
- Prohibited System Calls:
  - *memcntl(2)*, *mknod(2)*, *stime(2)*, and *pset_create(2)*
- Limited System Calls:
  - *kill(2)*

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Zones Security – Devices

- */dev* Permitted System Calls:
  - *chmod(2)*, *chown(2)*, and *chgrp(1)*
- */dev* Prohibited System Calls:
  - *rename(2)*, *unlink(2)*, *symlink(2)*, *link(2)*, *creat(2)*, and *mknod(2)*
- Forced *nodevices* mount option
  - Prevents import of malicious device files from NFS and other foreign sources.
- Security audit performed on all drivers included in default zone configuration.

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Zones Security – Privileges

contract_event	contract_observer	cpc_cpu	dtrace_kernel
dtrace_proc	dtrace_user	file_chown	file_chown_self
file_dac_execute	file_dac_read	file_dac_search	file_dac_write
file_downgrade_sl	file_link_any	file_owner	file_setid
file_upgrade_sl	graphics_access	graphics_map	ipc_dac_read
ipc_dac_write	ipc_owner	net_bindmlp	net_icmpaccess
net_mac_aware	net_privaddr	net_rawaccess	proc_audit
proc_chroot	proc_clock_highres	proc_exec	proc_fork
proc_info	proc_lock_memory	proc_owner	proc_priocntl
proc_session	proc_setid	proc_taskid	proc_zone
sys_acct	sys_admin	sys_audit	sys_config
sys_devices	sys_ip_config	sys_ipc_config	sys_linkdir
sys_mount	sys_net_config	sys_nfs	sys_res_config
sys_resource	sys_suser_compat	sys_time	sys_trans_label
win_colormap	win_config	win_dac_read	win_dac_write
win_devices	win_dga	win_downgrade_sl	win_fontpath
win_mac_read	win_mac_write	win_selection	win_upgrade_sl

Legend

a = Mandatory

a = Optional

a = Prohibited

a = Default

a = TX

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Zones Example #1

```
# modload autofs
Insufficient privileges to load a module

# modunload -i 101
Insufficient privileges to unload a module

# snoop
snoop: No network interface devices found

# mdb -k
mdb: failed to open /dev/ksyms: No such file or
directory

# dtrace -l
   ID   PROVIDER            MODULE                    FUNCTION
NAME

# ppriv -D -e route add net default 10.1.2.3
route[4676]: missing privilege "sys_net_config"
(euid = 0, syscall = 4) needed at ip_rts_request+0x138
add net default: gateway 10.1.2.3: insufficient
privileges
```

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Zones Example #2

```
# mount -p
/          -  /          zfs       - no

rw,devices,setuid,exec,atime
/dev       -  /dev       lofs   - no zonedevfs
/lib       -  /lib       lofs   - no ro,nodevices,nosub
/platform    -  /platform    lofs   - no ro,nodevices,nosub
/sbin      -  /sbin      lofs   - no ro,nodevices,nosub
/usr       -  /usr       lofs   - no ro,nodevices,nosub
[...]

# mv /usr/bin/login /usr/bin/login.foo
mv: cannot rename /usr/bin/login to /usr/bin/login.foo:
Read-only file system
```

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Zones Example #3

```
# zonecfg -z myzone info limitpriv
limitpriv: default,sys_time

# zlogin myzone ppriv -l zone | grep sys_time
sys_time

# zlogin myzone svcs -v ntp
STATE          NSTATE         STIME    CTID   FMRI
online         -              10:17:58    214
svc:/network/ntp:default

# zlogin myzone ntpq -c peers
  remote      refid         st t when poll reach  [...]
=================================================[...]
*blackhole 129.146.228.54  3 u   48   64   77   [...]

# ssh blackhole date ; date ; zlogin myzone date
Thu Jun 15 10:25:25 EDT 2006
Thu Jun 15 10:25:25 EDT 2006
Thu Jun 15 10:25:25 EDT 2006
```

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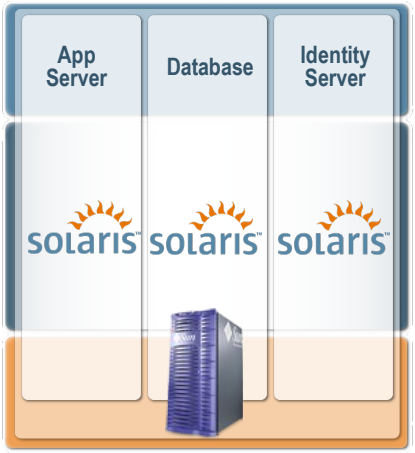
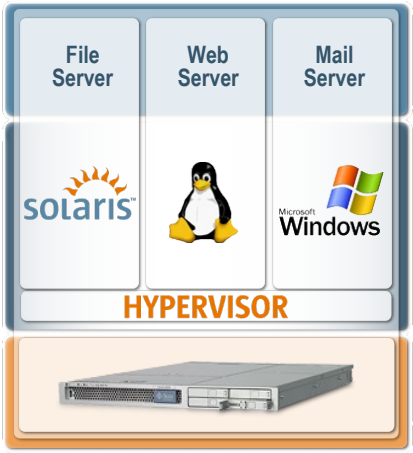
Virtualization / Compartmentalization

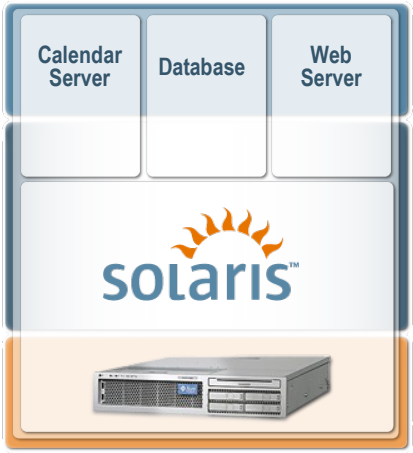
Hard Partitions



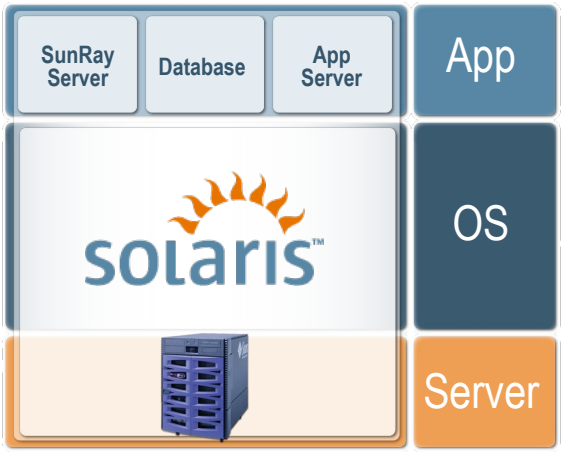
Virtual Machines



OS Virtualization



Resource Management



Multiple OSs ← → **Single OS**

Trend to flexibility → ← **Trend to isolation**

Dynamic System Domains	Logical Domains Xen VMware Microsoft Virtual Server	Solaris Containers (Zones + SRM) Solaris Trusted Extensions Solaris Containers for Linux Applications	Solaris Resource Manager (SRM)

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What is Solaris ZFS?

A new way to manage data

End-to End Data Integrity

With check-summing and copy-on-write transactions

Easier Administration

A pooled storage model – no volume manager

Immense Data Capacity

The world's first 128-bit file system

Huge Performance Gains

Especially architected for speed

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ZFS Data Integrity

- Everything is “copy on write”
  - Never overwrites live data
  - On disk state is always valid
  - No need to fsck(1M)
- Everything is transactional
  - Related changes succeed or fail as a whole
  - No need for journaling
- Everything is validated with a 256-bit checksum
  - No silent data corruption
  - No panics due to corrupted meta-data
  - “Bad data” can be healed using mirrored copies

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ZFS Data Security

- NFSv4 / NTFS-style Access Control Lists
  - Granular access can be allowed/denied (w/inheritance)
- Authentication with Cryptographic Checksums
  - Selectable 256-bit checksum algorithms, including SHA-256
  - Uber-checksum provides check for the entire ZFS pool
- File system Snapshots
  - Read-only version of a file system at a specific point in time.
- File system Quotas and Reservations
  - Set maximum (quota) or minimum (reservation) usage limits.

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ZFS Example #1

```
$ touch testfile

$ chmod 600 testfile
$ chmod A+user:gmb:read_data:allow testfile

$ ls -l testfile
-rw-------+  1 gbrunett gbrunett       0 Nov  7 14:22 testfile

$ ls -v testfile
-rw-------+  1 gbrunett gbrunett       0 Nov  7 14:22 testfile
 0:user:gmb:read_data:allow
 1:owner@:execute:deny
 2:owner@:read_data/write_data/append_data/write_xattr/
   write_attributes/write_acl/write_owner:allow
 3:group@:read_data/write_data/append_data/execute:deny
 4:group@::allow
 5:everyone@:read_data/write_data/append_data/write_xattr/
   execute/write_attributes/write_acl/write_owner:deny
 6:everyone@:read_xattr/read_attributes/read_acl/
   synchronize:allow
```

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ZFS Example #2

```
$ touch test-xattr

$ runat test-xattr cp /etc/motd .

$ runat test-xattr ls
motd

$ touch test-no-xattr

$ chmod A+user:gbrunett:write_xattr:deny test-no-xattr

$ runat test-no-xattr cp /etc/motd .
runat: cannot open attribute directory for test-no-xattr:
Permission denied
```

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ZFS Example #3

```
$ profiles
[...]
ZFS File System Management
[...]
Basic Solaris User
All

$ pfexec zfs set quota=4g laptop/ws

$ pfexec zfs list -o name,mountpoint,quota
NAME                    MOUNTPOINT              QUOTA
laptop                  /laptop                  none
laptop/briefcase        /laptop/briefcase        none
laptop/ws               /laptop/ws                 4G
```

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TCP Wrappers

- Supports both tcpd and libwrap and integrated with:
  - ssh and sendmail (automatically)
  - rpcbind (optionally)

```
$ svcprop -p config rpc/bind | grep wrappers
config/enable_tcpwrappers boolean false
```

  - inetd-services (optionally, globally or per-service)

```
$ svcprop -p defaults inetd | grep wrappers
defaults/tcp_wrappers boolean false
```

```
$ inetadm -l telnet | grep wrappers
default  tcp_wrappers=FALSE
```

- Configured using /etc/hosts.{allow, deny} and logs to syslog:

```
Nov 10 15:18:03 blackhole sshd[17568]:
[ID 947420 auth.warning] refused connect from 192.168.1.136
```

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IP Filter

- Stateful and stateless packet inspection – IPv4, IPv6
- Kernel-based packet filtering
- Protocol proxies (TCP, UDP, FTP, rcmds, etc.)
- Transparent proxy support
- Text-based configuration
- Support for both NAT and PAT
- SYSLOG Logging
- Lightweight, small footprint, high performance

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IP Filter Example

```
pass out quick all keep state keep frags

# Drop all NETBIOS traffic but don't log it.
block in quick from any to any port = 137 #netbios-ns
block in quick from any to any port = 138 #netbios-dgm
block in quick from any to any port = 139 #netbios-ssn

# Allow incoming IKE/IPsec
pass in quick proto udp from any to any port = ike
pass in quick proto udp from any to any port = 4500
pass in proto esp from any to any

# Allow ping
pass in quick proto icmp from any to any icmp-type echo

# Allow routing info
pass in quick proto udp from any to port = route
pass in quick proto icmp from any to any icmp-type 9 #
routeradvert
pass in quick proto igmp from any to any

# Block and log everything else that comes in
block in log all
block in from any to 255.255.255.255
block in from any to 127.0.0.1/32
```

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Cryptographic Framework

- Standards-based, pluggable framework
  - Kernel support as well as user-land (PKCS#11)
  - Supports administrative policies (e.g., FIPS 140 algorithms only)
- By default, supports major algorithms.
  - Encryption : AES, Blowfish, RC4, DES, 3DES, RSA
  - Digest : MD5, SHA-1, SHA-256, SHA-384, SHA-512
  - MAC : DES MAC, MD5 HMAC, SHA-1 HMAC, SHA-256 HMAC, SHA-384 HMAC, SHA-512 HMAC
  - Optimized for both SPARC, Intel and AMD
- Framework supports pluggable hardware/software providers:
  - e.g., UltraSPARC T1 and the Sun CryptoAccelerator 6000

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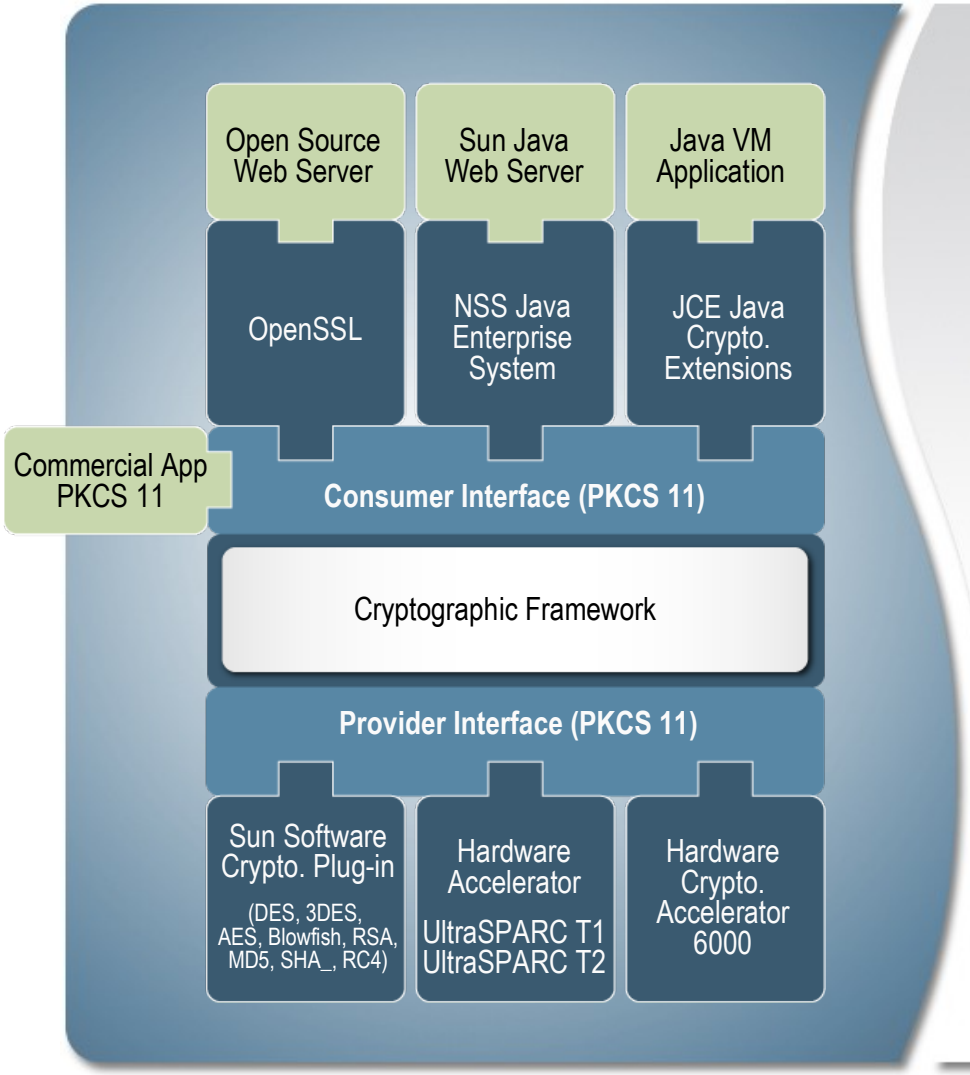
Cryptographic Framework



Now the framework for cryptography is standardized and extensible.

Your current cryptographic choices and any future technology can easily plug in and just work.

- Standards-based framework
- Same API, software or hardware
- Extensible for future technologies

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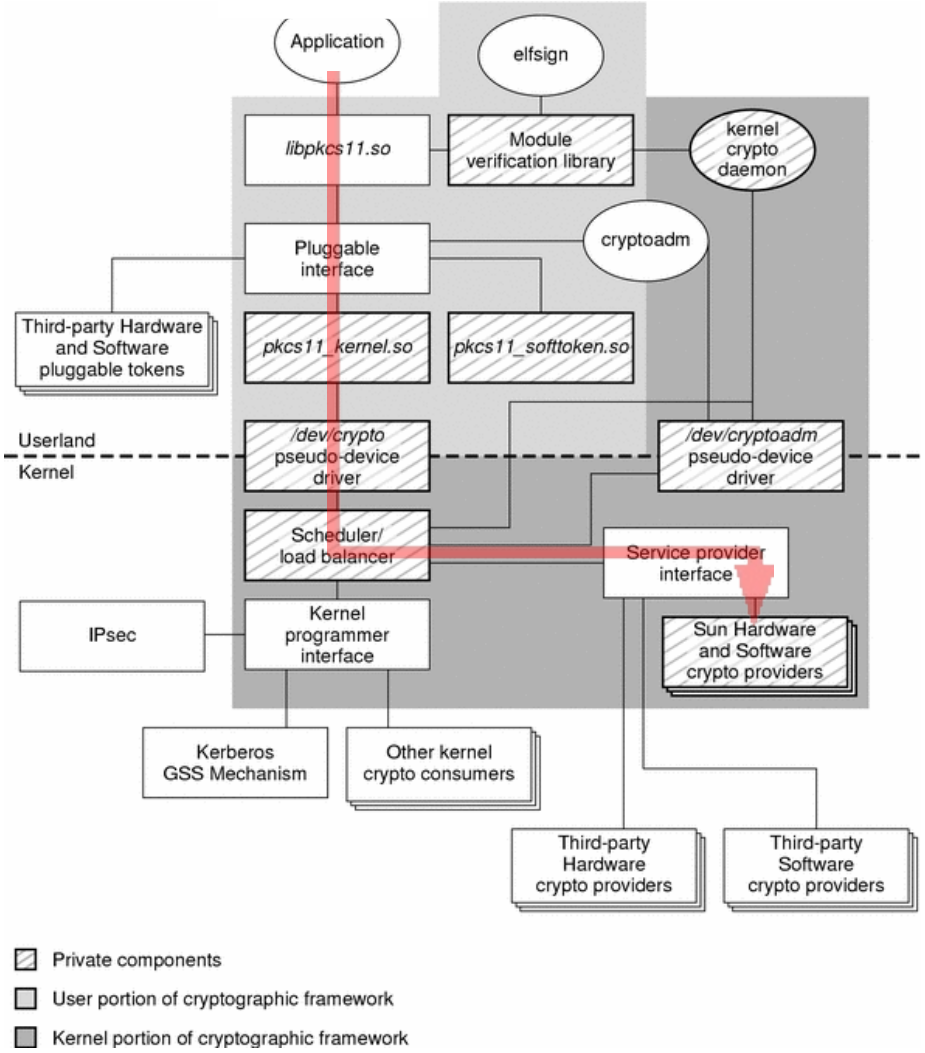
T2/Solaris Cryptographic Architecture

- Access to T2 accelerators is controlled by Solaris CF
- Userland access is via PKCS#11
  - Simple to modify applications to use PKCS#11 (if not used already)
  - Can interface via OpenSSL
  - Offload from Java (JCE)
- Kernel modules communicate directly with the kernel crypto framework
  - e.g. KSSL, IPsec



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UltraSPARC T2 Processor Performance

Competitive Cryptographic Performance

- Outperforms competing processors by up to 10X
  - With significant core idle time that can be used for other processing

Cipher	2.2GHz dual-core Opteron	2.7GHz quad-core Clovertown	1.4GHz UltraSPARC T2
RSA1024	2.3K Ops/sec	4.8 K Ops/sec	37.0K Ops/sec
AES-128	1.6 Gb/sec	4.2 Gb/s	44.0 Gb/sec

- Outperforms accelerator cards by a wide margin

Cipher	Sun SCA6000	Cavium Nitrox PX	1.4GHz UltraSPARC T2
RSA1024	13K Ops/sec	12K Ops/sec	37K Ops/sec
AES-128	1.0Gb/sec	2.5Gb/sec	44Gb/sec

- On-chip accelerators are more versatile than off-chip solutions
  - Cost effective to off-load even small packets with UltraSPARC T2 processor

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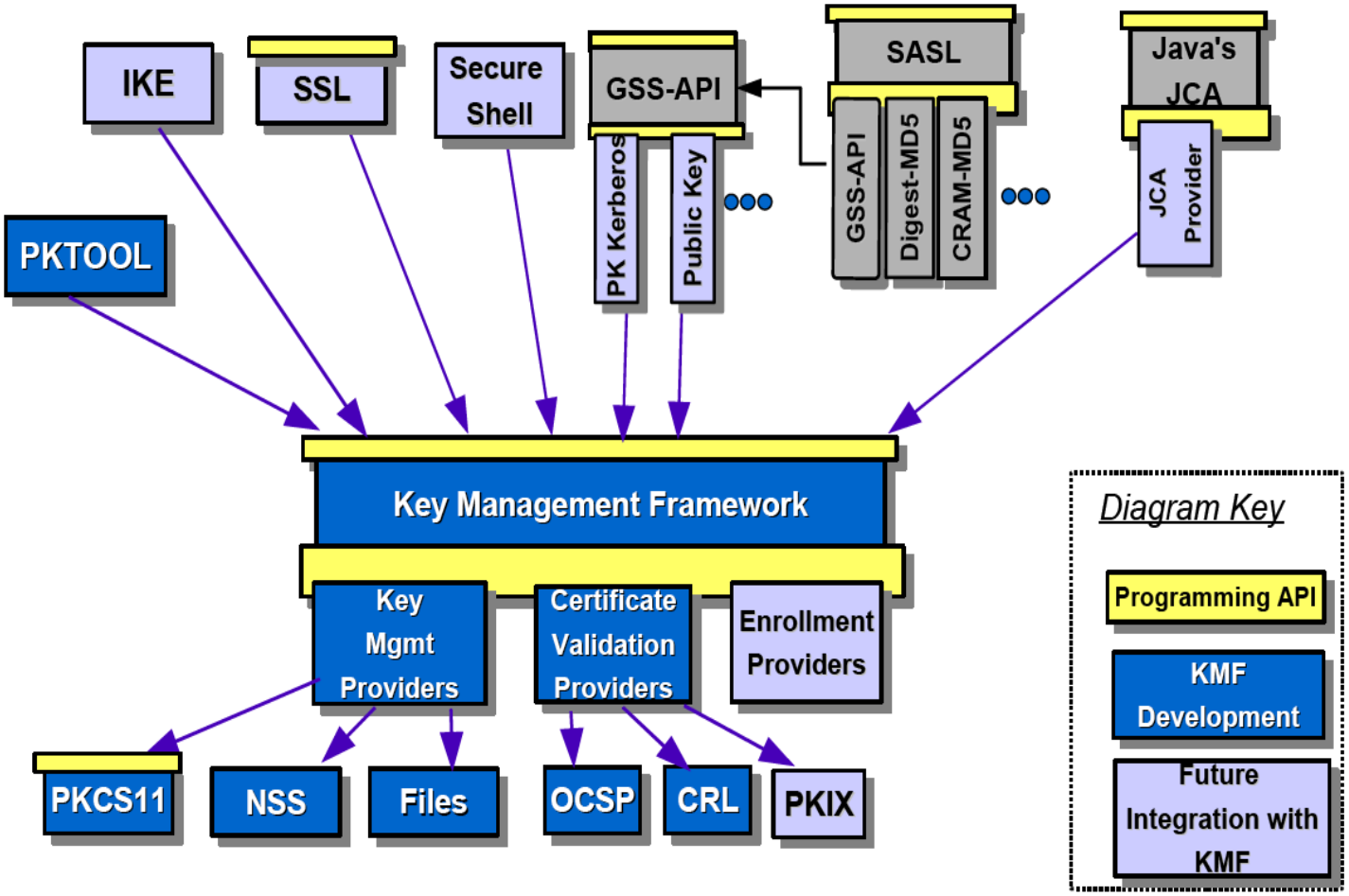
Key Management Framework



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Basic Audit and Reporting Tool

File-level integrity validation tool:

- Evalutes: uid, gid, permissions/acls, contents, mtime, size, type, etc.
- Enables point-in-time comparison against a previous snapshot.

```
# cat ./rules
/etc
CHECK all

# find /etc | bart create -I > newManifest

# bart compare -r ./rules ./oldManifest ./newManifest
/etc/user_attr:
size control:28268  test:23520
acl  control:user::rw-,group::rw-,mask:r-x,other:r--
        test:user::rw-,group::rw-,mask:r-x,other:rw-
  contents  control:28dd3a3af2fcc103f422993de5b162f3
                test:28893a3af2fcc103f422993de5b162f3
```

Sun BluePrint: Automating File Integrity Checks, http://www.sun.com/blueprints/0305/819-2259.pdf

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Solaris Fingerprint Database

Searchable database of MD5 fingerprints for files included in Solaris, Trusted Solaris, and bundled software.

```
# digest -v -a md5 /usr/lib/ssh/sshd
md5 (/usr/lib/ssh/sshd) =
b94b091a2d33dd4d6481dffa784ba632
```

[Process fingerprint using the Solaris Fingerprint DB]

```
 b94b091a2d33dd4d6481dffa784ba632 -
(/usr/lib/ssh/sshd)
 - 1 match(es)
     * canonical-path: /usr/lib/ssh/sshd
     * package: SUNWsshdu
     * version: 11.10.0,REV=2005.01.21.15.53
     * architecture: sparc
     * source: Solaris 10/SPARC
```

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Solaris Audit

- Kernel auditing of system calls and administrative actions.
  - Can record events happening in any zone (from the global zone).
    - Can also delegate audit configuration to local zone administrators.
  - Can capture complete command line and environment.
  - Records original (audit) ID as well as current credentials.
  - Audit trail can be formatted as text, XML, and/or delivered via syslog.
- Example:

```
header,77,2,su,,tundra,2006-11-06 21:55:31.386 -08:00
subject,joe,joe,other,joe,other,2444,1898931306,
12114 22 marduk
text,root
return,failure,Authentication failed
```

Example adapted from the Sun BluePrint: Enforcing the Two-Person Rule Via Role-based Access Control in the Solaris 10 OS, http://www.sun.com/blueprints/0805/819-3164.pdf

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Trusted Solaris History

Product	Year	Evaluation
SunOS MLS 1.0	1990	TCSEC Conformance (1985 Orange Book)
SunOS CMW 1.0	1992	ITSEC Certified for E3 / F-B1
Trusted Solaris 1.2	1995	ITSEC Certified for E3 / F-B1
Trusted Solaris 2.5.1	1996	ITSEC Certified for E3 / F-B1
Trusted Solaris 8	2000	Common Criteria Evaluated: CAPP, RBACPP, LSPP at EAL4+

Mandatory Access Control, Labeled Desktop, Labeled Printing, Labeled Networking, Labeled Filesystems, Device Allocation, etc.

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Solaris Trusted Extensions

- A redesign of the Trusted Solaris product using a layered architecture.
- An extension of the Solaris 10 security foundation providing access control policies based on the sensitivity/label of objects.
- A set of additional software packages added to a standard Solaris 10 system.
- A set of label-aware services which implement multilevel security.

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Extending Solaris 10 Security Features

- Process Rights Management
  - Fine-grained privileges for X windows
  - Rights management applied to desktop actions
- User Rights Management
  - Labels and clearances
  - Additional desktop policies
- Solaris Containers (Zones)
  - Unique Sensitivity Labels
  - Trusted (label-based) Networking

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Trusted Extensions in a Nutshell

- Every object has a label associated with it.
  - Files, windows, printers, devices, network packets, network interfaces, processes, etc.
- Accessing or sharing data is controlled by the relationships between the labels of different objects.
  - 'Secret' objects can not see 'Top Secret' objects.
- Administrators utilize Solaris Roles for duty separation.
  - Installation, System Admin., Security Admin., etc.

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What are Label-Aware Services?

- Services that are trusted to protect multi-level information according to predefined policy.
- Trusted Extensions label-aware service include:
  - Labeled Desktops
  - Labeled Printing
  - Labeled Networking
  - Labeled Filesystems
  - Label Configuration and Translation
  - System Management Tools
  - Device Allocation

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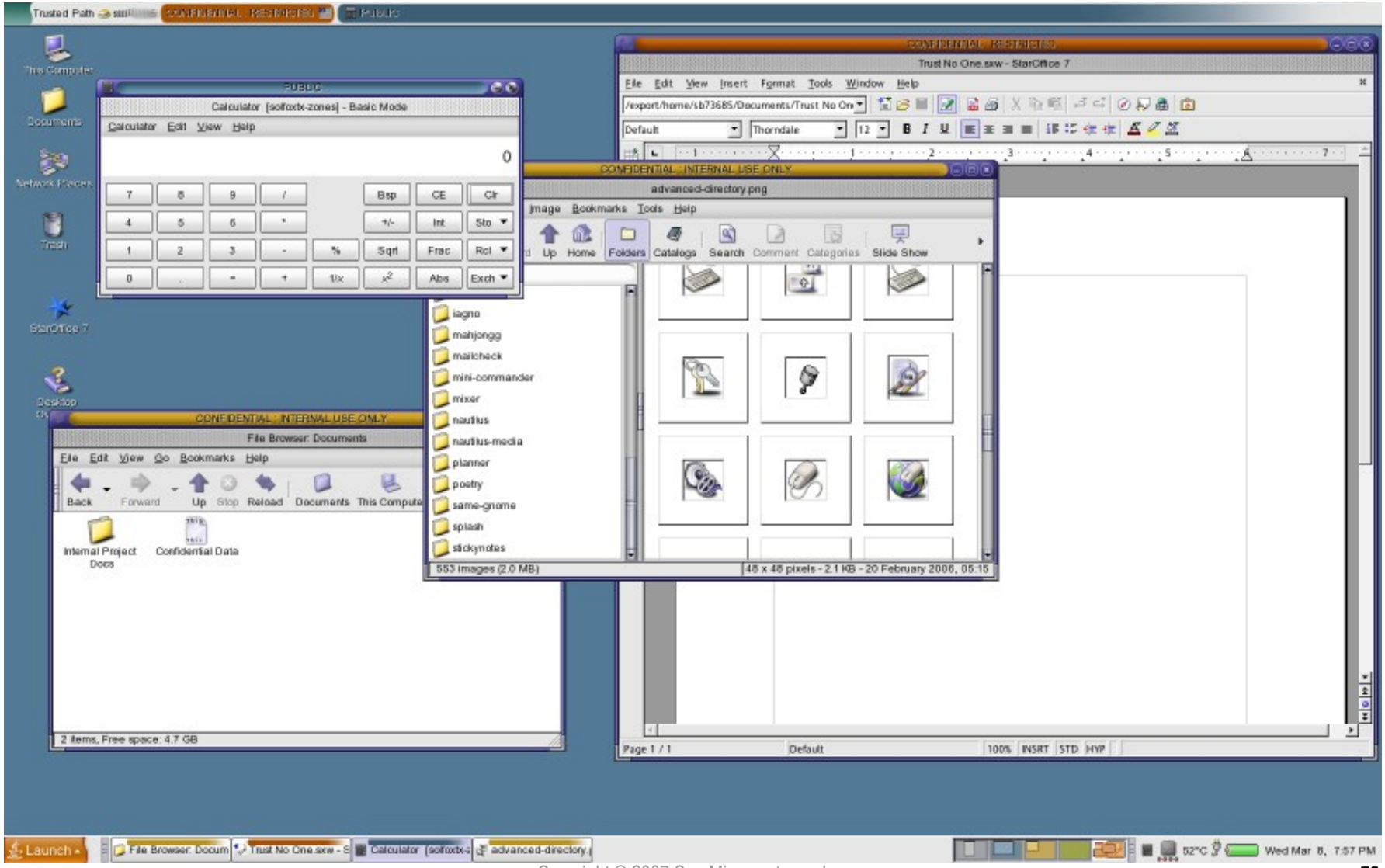
Labeled Desktop



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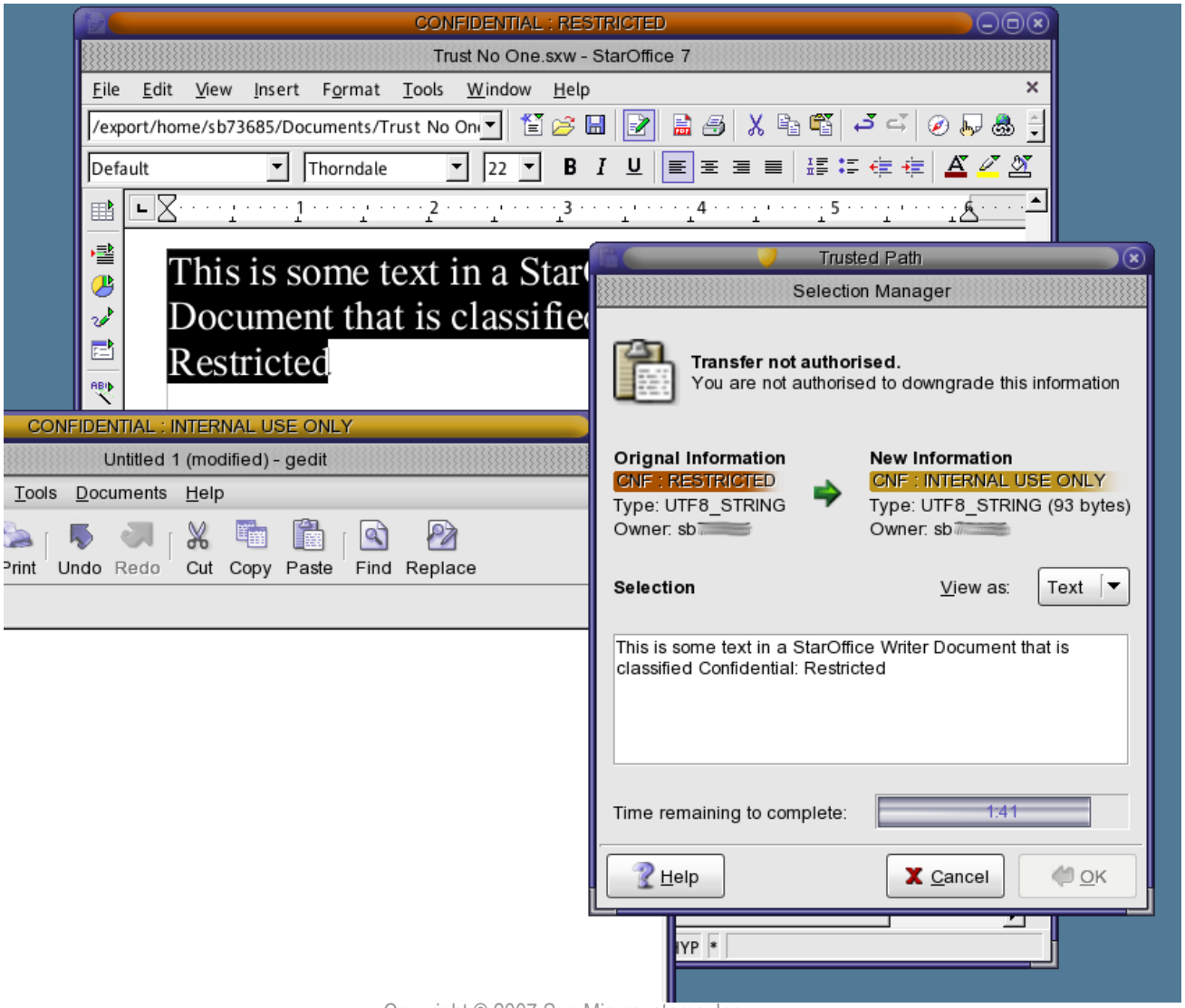
Mandatory Access Control



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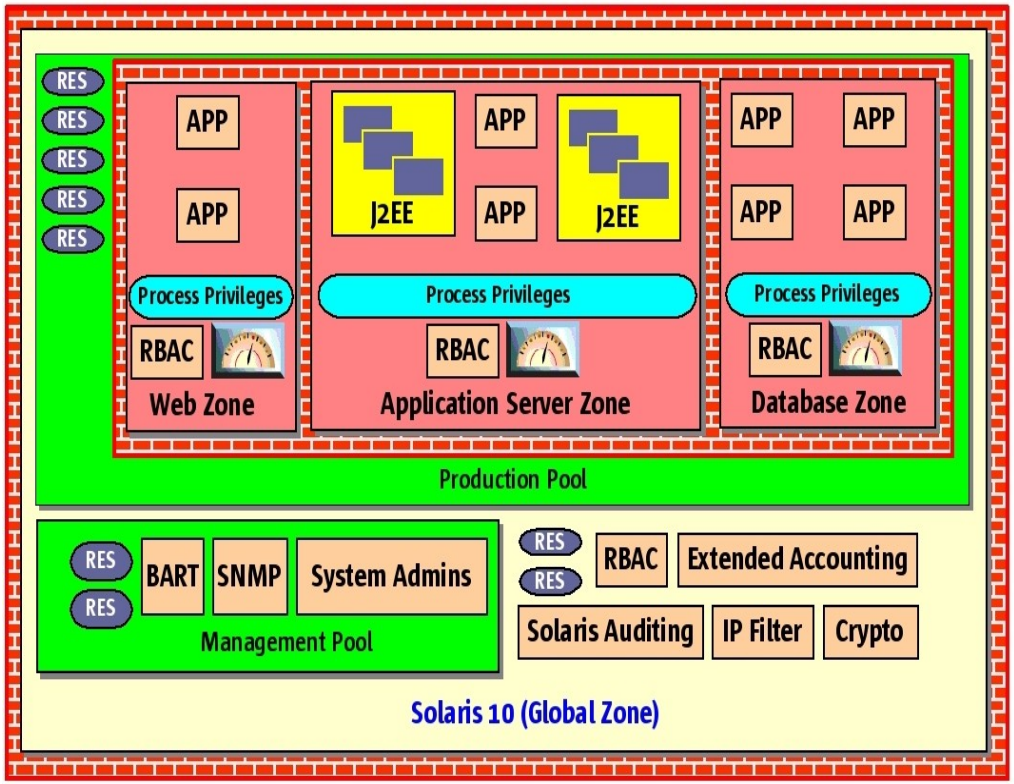
Putting It All Together

Solaris 10 Security – A Secure Foundation for Success:

- Reduced Networking Meta Cluster
- Signed Binary Execution
- Solaris Security Toolkit
- Secure Service Management
- User Rights Management
- Process Rights Management
- Resource Management
- Kerberos, SSH, IPsec
- Cryptographic Framework
- Containers / Zones
- IP Filter, TCP Wrappers
- Auditing, BART
- Trusted Extensions



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But wait! There's more!

- Network Security Improvements
  - Kernel SSL Proxy
  - IPsec/IKE NAT Traversal
  - RIPv2 Protocol Support
  - Packet Filtering Hooks
  - Randomized TCP/UDP Ephemeral Port Selection
- Auditing Improvements
  - Audit Trail Noise Reduction
  - Audit Event Reclassification
- New Mount Options
  - noexec, nodevices

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and more...

- vacation(1) Mail Filtering
- “root” GID is now “0” (root) not “1” (other)
- ip_respond_to_timestamp now “0”.
- find(1) Support for ACLs
- “death by rm” safety
- OpenSSL libraries with a PKCS#11 engine
- Hardware RNG using Crypto Framework
- open(2) [O_NOFOLLOW], getpeerucred(3c), and many other developer enhancements...
- “Off the Record” plugin for pidgin (nee gaim)
- Sendmail support for TLS

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and more...

- NFSv4
  - Support for GSS_API, ACLs, etc.
- Sendmail 8.13.8
  - Support for rate limiting and milters, TLS, etc.
- BIND 9.3.4
  - DNSSEC, Views, IPv6 Support
- Java 5 Security (1.5.0_12)
  - Security tokens, better support for more security standards (SASL, OCSP, TSP), various crypto and GSS security enhancements, etc.

... and the list keep right on going...

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Actions...

1. Evaluate, pilot and use Solaris 10 Today!
2. Join the OpenSolaris Community!
3. Share your requirements, experiences, etc!

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For More Information

- Sun Security Home
  - http://www.sun.com/security
- OpenSolaris Security Community
  - http://www.opensolaris.org/os/community/security
- Sun Security Coordination Center
  - http://blogs.sun.com/security & security-alert@sun.com
- Sun Security BluePrints
  - http://www.sun.com/blueprints
- Sun Security Bloggers
  - http://blogs.sun.com

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Solaris 10 Security
Technical Deep Dive

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OpenSolaris Project: LOFI Encryption

- Loopback File Driver (lofi)
  - Allows individual files to be treated as a block devices
  - Originally developed for mounting CD ISO images
- Extend the Loopback File Driver
  - Specify cryptographic algorithm (currently only AES_CBC) and provide a key (that can be stored on removable media)
- Enables encrypted block devices
  - Including support for encrypted “disks” and swap
  - User's encrypted “disks” can be mounted at login

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OpenSolaris Project: LOFI Encryption

Current Status

- Source code is publicly available via opensolaris.org.
  - Code review announced August 11, 2007.
- Architecture review case is in progress.
  - Completion is necessary for actual code “putback”.
- More details are available at:
  - http://www.opensolaris.org/os/project/loficc/

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OpenSolaris: ZFS Crypto

Operational goals are to support:

- software-only and hardware-accelerated environments as well as those requiring hardware key storage.
- “secure delete” via “key destruction”
- delegation of key management to individual zones
- restrict data sets to/from specific zones
- keep native ZFS copy on write semantics
- local hardware security module (HSM), trusted platform module (TPM), smart card or password or remote key manager

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OpenSolaris: ZFS Crypto

- Current design decisions:
  - Encryption policy will be set at the ZFS data set level.
    - Allows zones to have different keys/algorithms
    - Defined/set at data set creation time
  - Support for encrypted zvols
    - Encrypted raw storage (for databases, etc.)
- Other design considerations:
  - Support for encrypted root filesystems
  - Support for encrypted ZFS send/receive

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OpenSolaris: ZFS Crypto

- Integrity protection of both data and meta-data
  - Fletcher and SHA-256
- Confidentiality of both data and filesystem meta-data
  - AES-128, AES-192, AES-256
  - Modes: CBC (Prototype), CCM/GCM (Production)
- No direct use of asymmetric cryptography

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OpenSolaris: ZFS Crypto

What is Encrypted?

- YES:
  - All “application” and zvol data
  - POSIX layer data (e.g., permissions, owner, etc.)
  - Directory structure
  - ZFS clones and snapshots
- NO:
  - ZFS pool meta-data (e.g., disks, mount times, raid, etc.)
  - Data set names and properties

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OpenSolaris: ZFS Crypto

Current Status

- Phase 1 of 4 in progress
  - Per data set policy for enabling encryption, including algorithm and key length.
  - Per data set keys wrapped by single per pool key
  - Pool key from passphrase using PKCS#5 PBE
  - Pool key stored in PKCS#11 token
- Design review completed
  - Scheduled for 11/2007 code integration into OpenSolaris
- More details at:
  - http://www.opensolaris.org/os/project/zfs-crypto/

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