Mac OS X

A Brief Technical Introduction

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LISA Hit the Ground Running, December 2005

`http://www.occam.com/osx/`

Contents

Opening Remarks

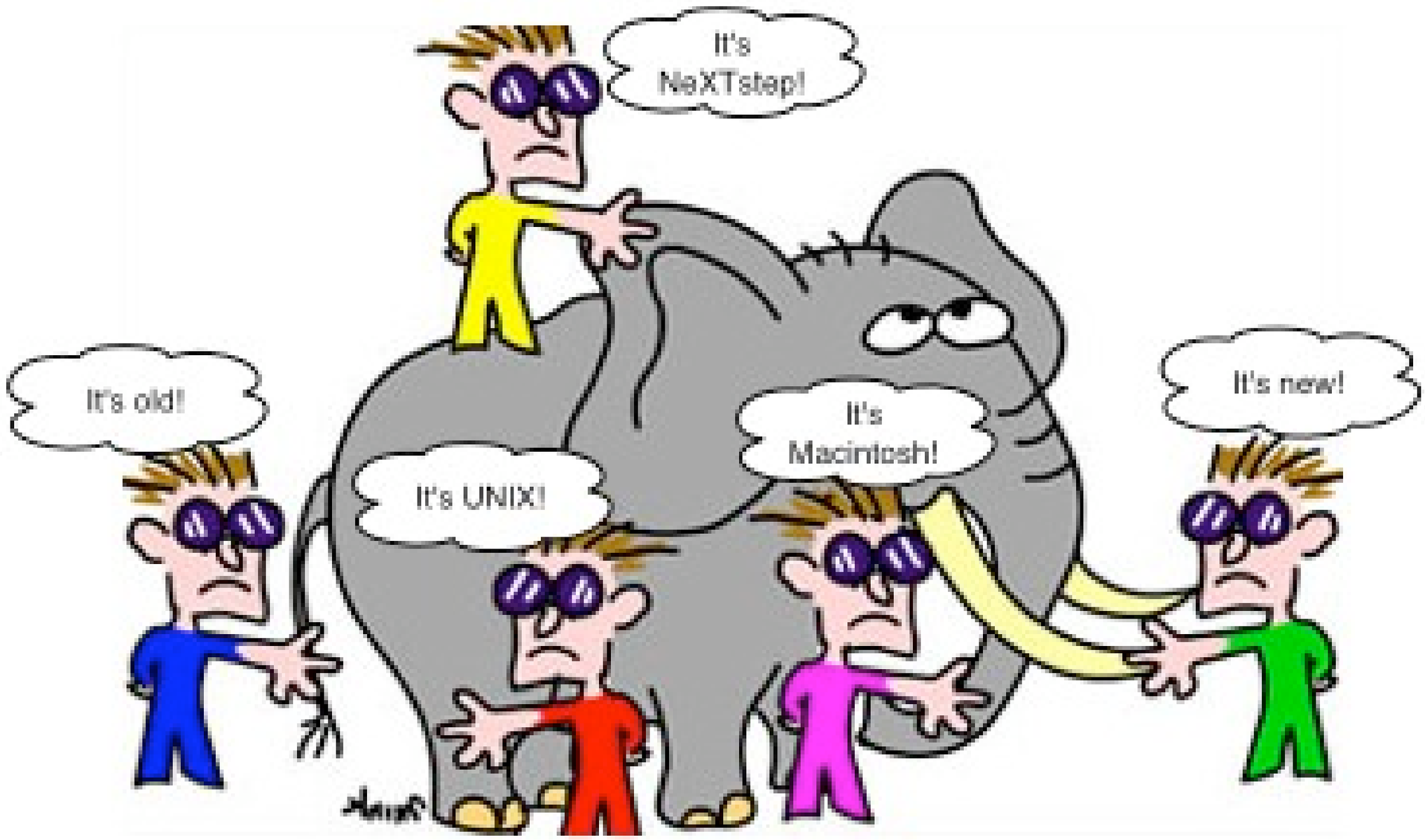
- This is a technical introduction to Mac OS X, mainly targeted to experienced UNIX users for whom OS X is at least relatively new
- This presentation covers primarily Mac OS X 10.4.3 (Darwin 8.3), aka Tiger

Legal Notices

What Is It?

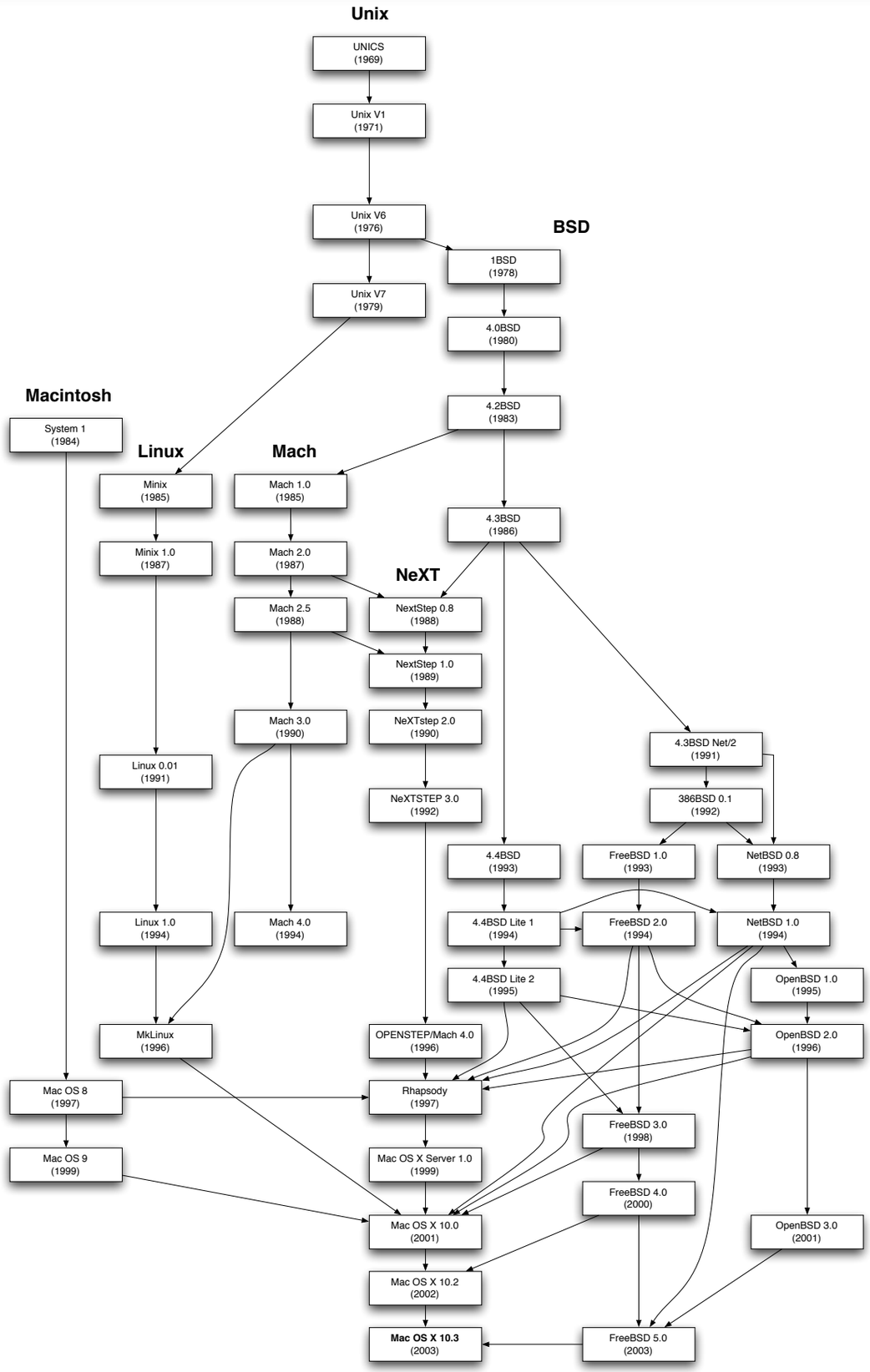
- Answers
- Ancestry
- Operating System Products
- The Structure of Mac OS X

- It's an elephant



- I mean, it's like the elephant in the Chinese/Indian parable of the blind men, perceived as different things depending on the approach

- Inheritor of the Mac OS legacy
  - Evolved GUI, Carbon (from Mac Toolbox), AppleScript, QuickTime, etc.
- The latest version of NeXTstep
  - Mach, Quartz (from Display PostScript), Cocoa (from OpenStep), NetInfo, apps (Mail, Terminal, TextEdit, Preview, Interface Builder, Project Builder, etc.), bundles, faxing from Print panel, NetBoot, etc.
- A new flavor of UNIX
  - More specifically, a BSD UNIX variant
  - Full set of command-line utilities, libraries, server software, etc.
- All of the above

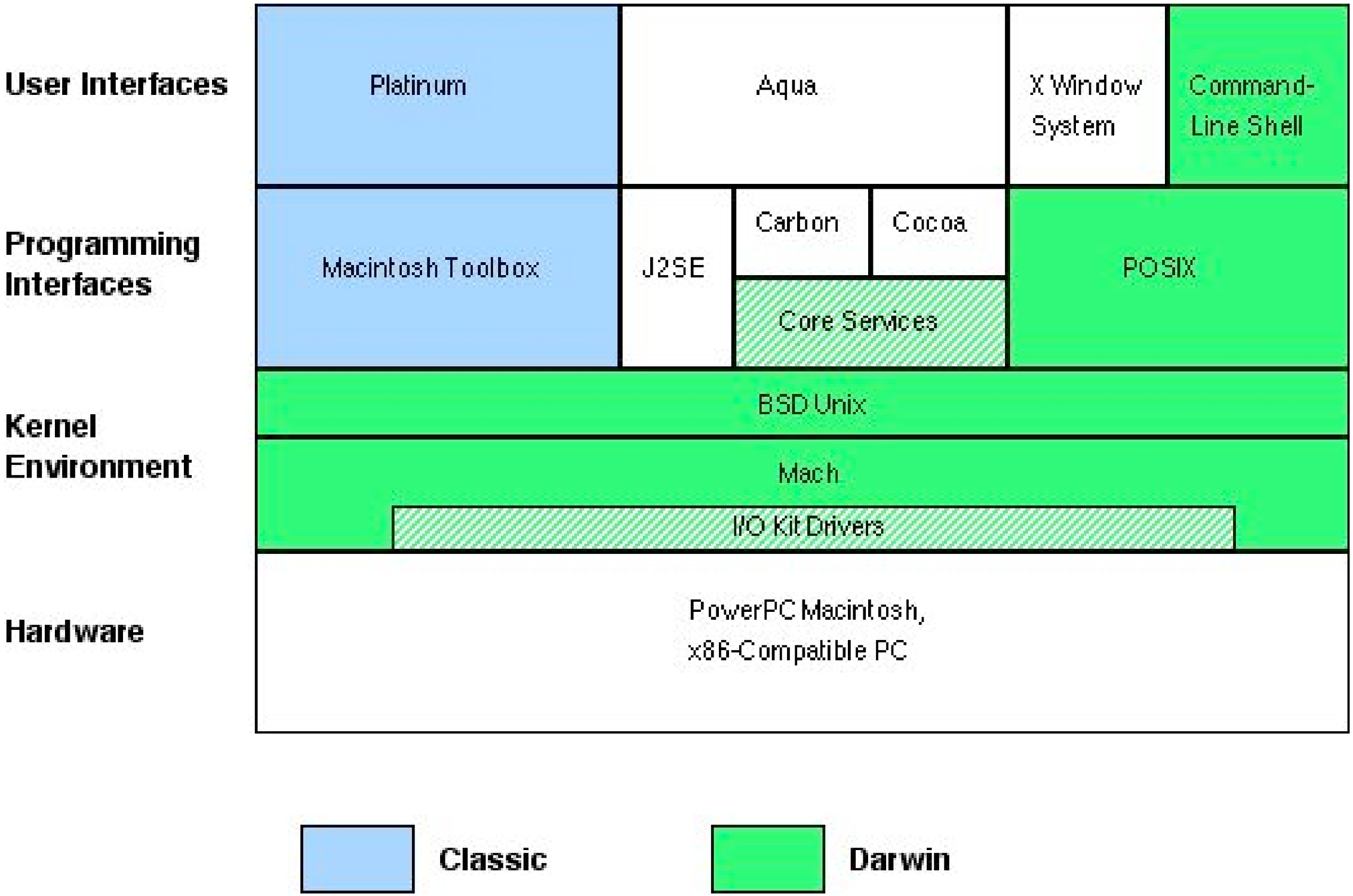


Operating System Ancestry of Mac OS X

- UNIX components primarily based on FreeBSD
  - Also NetBSD and OpenBSD, as well as NeXTstep's version of BSD
- Kernel based on Mach 3.0, MkLinux, and NeXT Mach

- Mac OS X
  - Apple's flagship operating system
- Classic
  - An instance of Mac OS 9 running in a self-contained execution environment within Mac OS X
- Darwin
  - The open-source foundation of Mac OS X
- Mac OS X Server
  - Mac OS X with additional server and administrative software

Hexley, the unoffical Darwin mascot



The Structure of Mac OS X

- Open Standards
- Open Source

- Mac OS X is UNIX
  - On the whole, the similarities far outweigh the differences
- Open Standards
  - Protocols and formats: TCP/IP, LDAP, IPsec, Zeroconf, SMB, NFS, PDF, ...
  - Hardware: SDRAM, USB, ATA, PCI/AGP, FireWire, HyperTransport, Wi-Fi, Bluetooth, ...

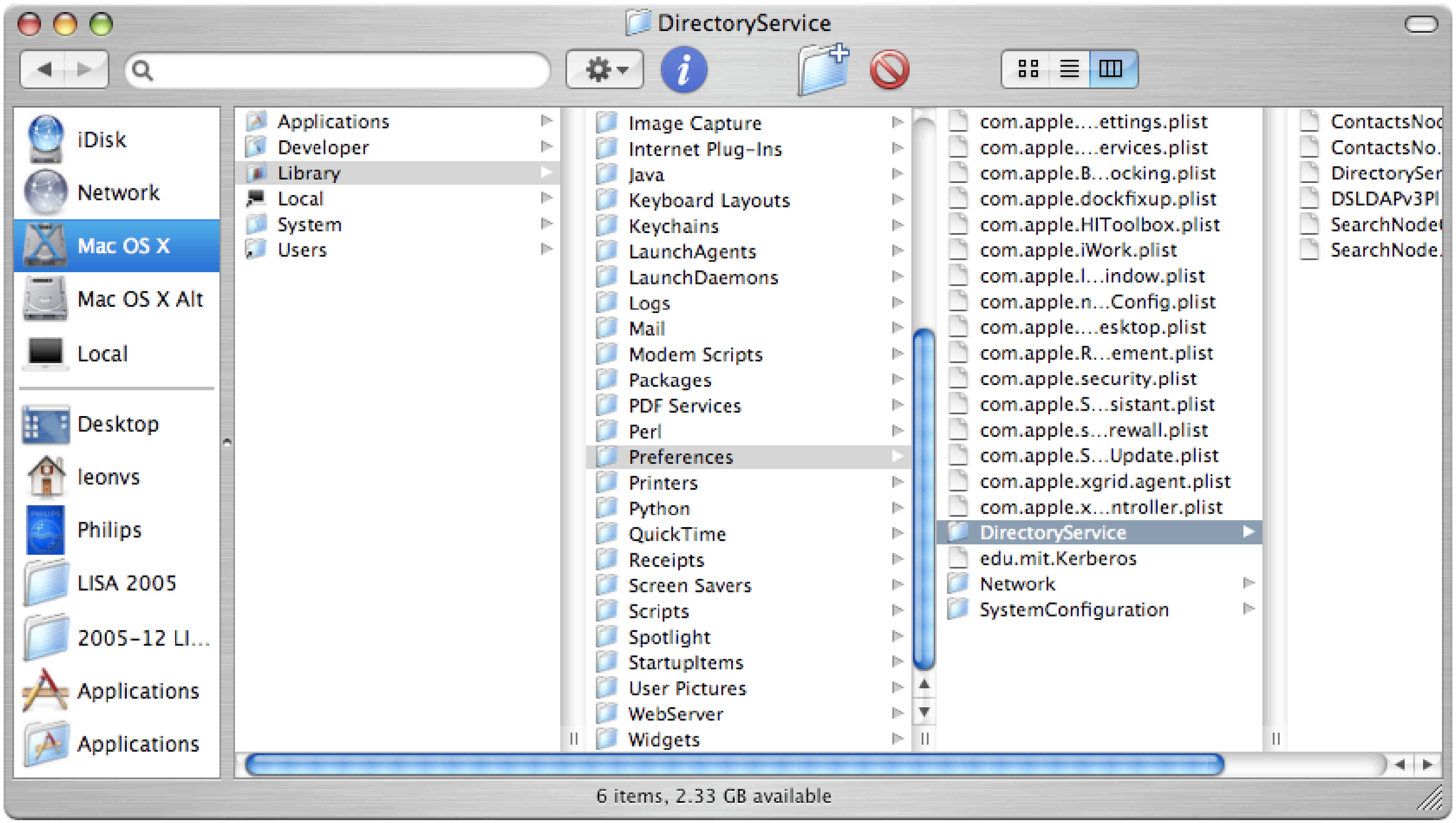
- Much of OS X is based on open-source software
- Darwin, FreeBSD, NetBSD, OpenBSD, Mach
- Apache, CUPS, OpenLDAP, Postfix, Cyrus, OpenSSH, MySQL, Samba, BIND
- Bonjour, KAME, OpenSSL, XFree86
- Perl, Python, Tcl, Ruby
- And much more

A Different UNIX

- A Focus on Differences
- The Directory Hierarchy
- HFS+
- Mach
- `launchd`
- Directory Services
- Administrative Users
- Why Is It So Different?

- While much of Mac OS X is familiar from other operating systems, there are many important differences that make it unlike any other UNIX system you've used
- Due to the approach of this presentation, and to human nature, we'll be focusing on these differences

- Parts of the OS X directory hierarchy look pretty familiar when viewed from the command line: `/bin`, `/sbin`, `/dev`, `/usr`, ...
  - `/etc`, `/var`, and `/tmp` are symlinks to subdirectories of `/private`
    - NeXTism related to NetBoot
  - `/Applications`, `/Library`, `/System`, `/Users`, `/Network`, `/Developer`
  - By default, non-root filesystems are mounted on subdirectories of `/Volumes` by `diskarbitrationd`
    - `fstab` configuration is possible, but unnecessary
- From the Finder (the graphical file manager), things look different
  - Some directories, called bundles, look like single files in the Finder
    - Applications, frameworks, plug-ins, mailboxes, ...



The View from the Finder

- The default local filesystem format is HFS+
- Coming from a UNIX background, HFS+ exhibits behaviors that take some getting used to
- Multiple forks per file
  - Data and auxiliary resources can be stored in separate filesystem objects
    - Resource fork used for things like file-specific icons, application multimedia, whatever
- For the most part, the extra forks are invisible
  - Resource forks are visible with `ls -l` *`filename`*`/..namedfork/rsrc`

- File attributes
  - HFS+ supports extensive file metadata
  - Typical UNIX metadata: owner, group, permissions, mod date, etc.
  - BSD flags: immutable, append-only, etc. (`man chflags`)
  - Macintosh file attributes: type, creation date, locked, invisible, etc.
    - Stored in attribute fork (or in `._`*`filename`* on UFS)
    - In `/Developer/Tools/`, `SetFile` lists available flags, `GetFileInfo` *`filename`* displays type, creator, and flags
- NTFS-compatible ACLs (added in Tiger)

- Case-preserving, but case-insensitive
  - `ReadMe` is stored with mixed case retained for display, but it can also be accessed as `README`, `Readme`, or `readme`
  - `ReadMe` and `README` cannnot exist in the same directory
  - Panther introduced fully case-sensitive HFS+ variant
  - Tip: `tcsh` command completion is still case-sensitive unless you set `complete = enhance` in `~/.tcshrc`
- The path separator is a colon (`:`), not a slash (`/`)
  - Pathnames are converted on-the-fly by the kernel, so that colons look like slashes
  - Carbon apps convert slashes back to colons

- Application libraries access filesystem objects by numerical file IDs, not pathnames
  - File IDs are unique per disk volume
  - Lookups are faster than by pathname
  - Kind of like inode numbers; in fact, `ls -i` displays file IDs on HFS+
  - File IDs don't change when files are moved around on a disk volume
- If you know a file's ID, and the the ID of the volume it's on, you can always access it as `/.vol/`*`vol_ID`*`/`*`file_ID`*
  - If you know the ID of the directory containing a file, you can access it as `/.vol/`*`vol_ID`*`/`*`dir_ID`*`/`*`filename`*

- Aliases
  - An alias is a lightweight reference to a file or directory
    - Like a symbolic link, but uses both pathname (preferably) and file ID (as backup)
  - An alias can continue to refer to a file even if it's moved (on the same volume) or renamed
  - Both aliases and symlinks are useful in different circumstances
    - If the actual pathname is all-important, or you need to use it from the CLI, use a symlink
  - No way to create symlinks from GUI, or aliases from CLI

- Hard links
  - On UFS, a hard link is simply another reference to a file's inode
    - With no inodes, HFS+ lacks support for hard links
  - OS X supports hard links for backwards compatibility, but they're implemented in the kernel as symbolic links, faked out to look and act like hard links
- Number of links shown for a directory in `ls -l` output counts all items within the directory, including files
- HFS+ lacks support for sparse files; void extents are zero-filled
- HFS+ supports journaling, for faster recovery after crash
- See Wil Sanchez USENIX paper for more on filesystem design decisions

- Developed at CMU as experiment in microkernel design
- Early versions integrated BSD, which NeXT used
- Mac OS X kernel primarily derived from Mach 3.0 used in MkLinux, with NeXT enhancements
- Still a monolithic kernel, for performance
- Manages memory, processes, and hardware access
- Theoretically capable of highly scalable multiprocessing, but Apple has so far released only dual- (and now quad-) processor machines
  - Better kernel resource locking in Tiger for improved multiprocessing

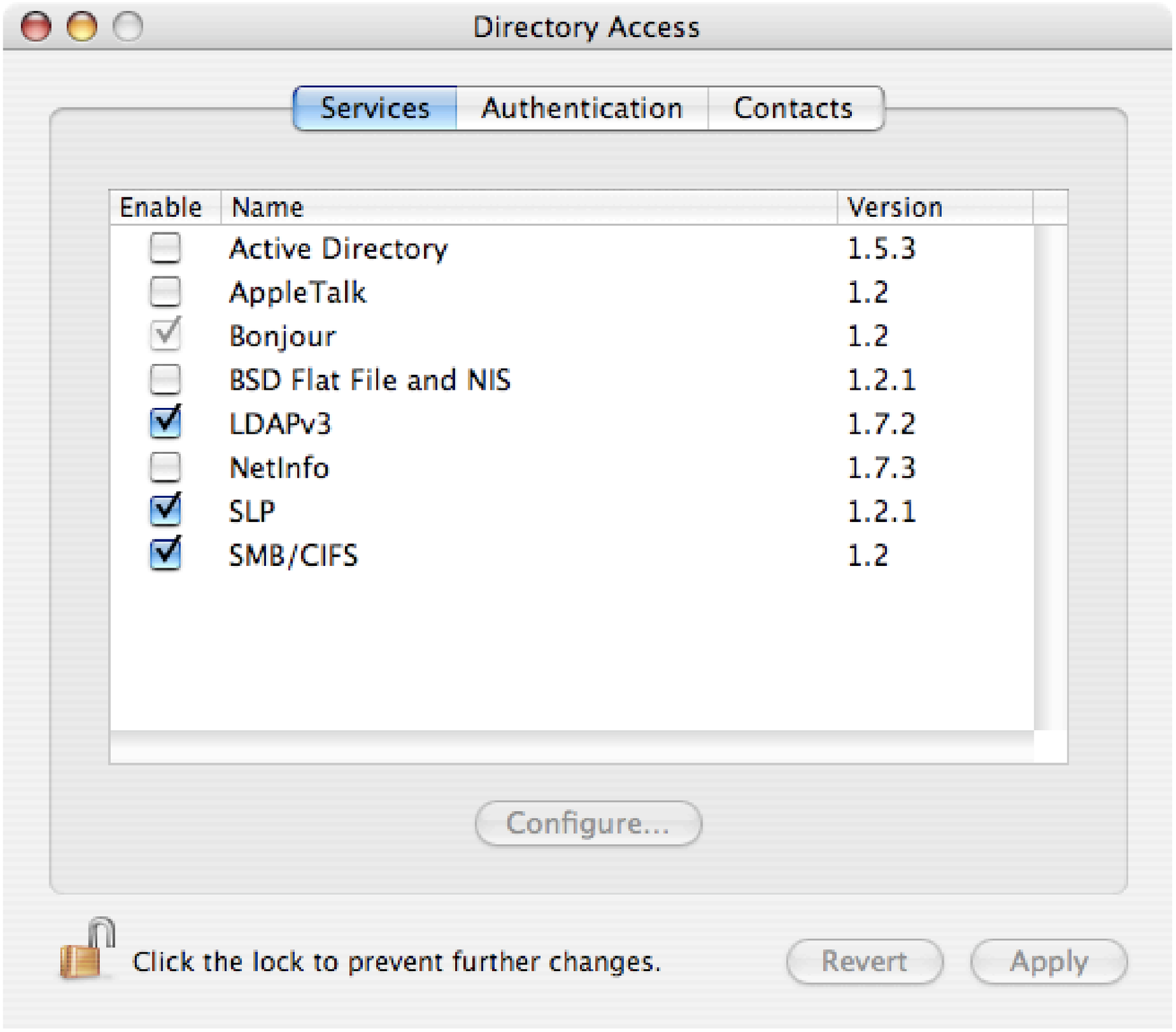
- Mach features an efficient virtual memory implementation
  - Backing store is file-based
    - It doesn't use a specially formatted disk partition (e.g., Solaris)
      - Definitive performance comparisons haven't been made, but it's sufficiently fast to not be a problem
        - Of course, you're much better off with enough RAM to avoid paging in the first place
    - Allocated as individual files in `/var/vm/`, acc. to the parameters of the `dynamic_pager` command in `/etc/rc`
    - VM disk usage grows and shrinks dynamically
  - Use `vm_stat` (note the underscore) to keep an eye on memory usage

- launchd is a replacement for init, rc scripts, SystemStarter, Mach bootstrap daemons, cron, inetd, login hooks...
  - Not quite there yet; other methods are deprecated, but still functional in Tiger
  - Very similar design goals to Solaris 10 SMF
- launchd is now PID 1
- System daemons or per-user agents are configured by XML property lists
  - See launchd.plist man page for syntax
  - Daemon config files are in either /System/Library/LaunchDaemons/ or /Library/LaunchDaemons/
  - Agent config files are in /System/Library/LaunchAgents/, /Library/LaunchAgents/, or ~/Library/LaunchAgents/

- `launchctl` is the `launchd` user interface
  - Start and stop services, load/unload/list configured services, etc.
- Example config file, for `syslogd` (translated from XML to NeXT property list format for clarity):

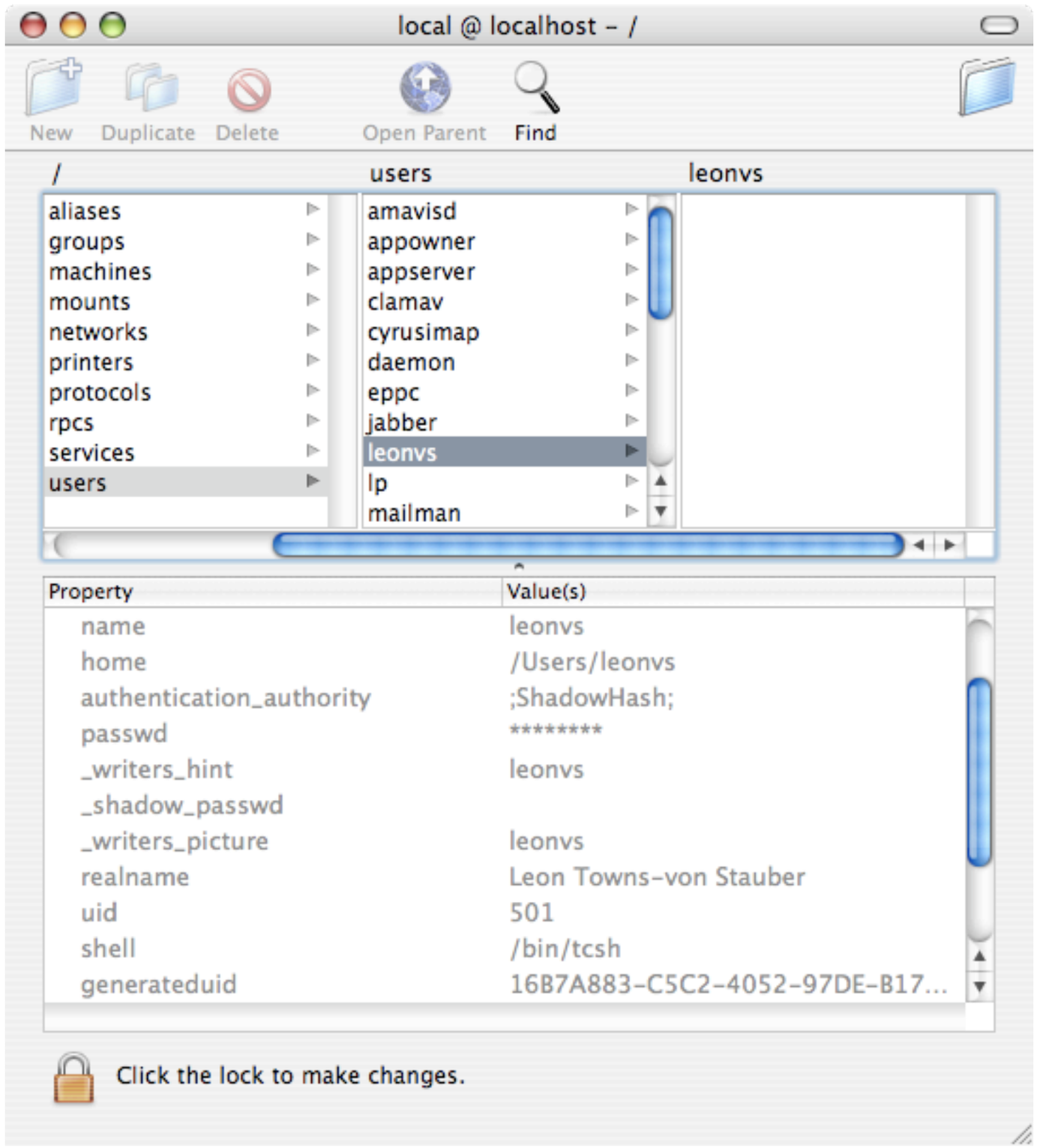
```
{
        Label = "com.apple.syslogd";
        OnDemand = 0;
        ProgramArguments = ("/usr/sbin/syslogd");
        ServiceDescription = "Apple System Log Daemon";
        ServiceIPC = 0;
}
```

- Mac OS X has a deep history with directory services, owing to its NeXT lineage, and is probably the most flexible client and provider of directory services there is
- In OS X, lookups for many kinds of configuration data are made through the Directory Services API
  - For legacy UNIX programs, the `getXbyY` system calls are rewritten to proxy lookups through `lookupd`, a daemon that makes use of DS
  - The data sources consulted by DS are configured in the Directory Access application
- OS X includes its own directory service, named Open Directory, based on OpenLDAP



Directory Access

- Host-local information still in NetInfo
  - NeXT-legacy access protocol and database format
  - Within a NetInfo-formatted database, information is organized in a directory hierarchy, analogous to a filesystem directory hierarchy
    - Root is `/`, subdirectories include `/machines`, `/users/leonvs`, etc.
    - Nodes have properties, each one key to a set of values
      - Properties include `name`, `uid`, `ip_address`, `passwd`, etc.
- The Big Surprise
  - Most traditional UNIX flat files in `/etc` (`passwd`, `group`, etc.) aren't used by default (except in single-user mode)
- CLI tools: `dscl`, `nicl`, `nidump`, `niload`, `nireport`, `nifind`, `nigrep`



NetInfo Manager

- By default, `root` logins are disabled on OS X (by an invalid password)
  - To enable, use NetInfo Manager->Security->Enable Root User, `dsenableroot`, or simply `sudo passwd root`
  - On Mac OS X Server, `root` password same as initial admin user
    - Consider changing one or the other, so they're not the same
- Administrative work is designed to be accomplished by members of the `admin` group, who possess special privileges
  - Some privileges are configurable, and may be removed or reassigned, while others are hard-coded to the `admin` group
  - NB: The user account created during installation is in the `admin` group

- File permissions
  - Directories and files in `/Applications/`, `/Library/`, and `/Developer/` are owned and writable by group `admin`, permitting software installation
- sudo
  - Admin users have superuser access to CLI commands, configured in `/etc/sudoers`
- su
  - Can only `su` to `root` if in group `admin` or `wheel`
  - Configurable in `/etc/pam.d/su`

- Authorization Services
  - Part of the Security framework
  - Gives admin users superuser privileges for certain GUI activities: running software installers, configuring directory access, changing certain things in System Preferences, etc.
  - Configured in `/etc/authorization`
- NetInfo
  - Admin users have full write access to NetInfo domain contents
  - Hard-coded

- Apple Filing Protocol (AFP) server
  - Administrators can connect as any user, authenticating with their own password, and they gain special access privileges
  - Hard-coded to `admin` group, but can be configured with properties in Open Directory, under `/config/AppleFileServer` in `local` domain
    - `attempt_admin_auth`: Determines whether authentication is attempted against administrator passwords
    - `special_admin_privs`: Grants admins read access to all folders
    - `permissions_model`: Gives admins the ability to change ownership of all files if set to `unix_with_classic_admin_permissions`
    - `admin_gets_sp` (Boolean, default `0`): Lets admins mount share points instead of volumes

- Some important differences: Quartz vs. X11, HFS+ vs. UFS, Objective-C vs. C++, NetInfo vs. LDAP, AFP vs. NFS, file-based VM, etc.
- Many design decisions were made in the middle to late 1980s, during the development of NeXTstep
  - Many of today's ubiquitous technologies (X11, C++, YP/NIS, LDAP) were not yet well-established
  - NeXT was among the first to implement a UNIX GUI, a standard OO dev environment, directory services, etc., and happened to choose differently than the rest of the industry later did
- Some changes were made to support Apple's existing user base
  - HFS+, AFP, secure default config

- But why does Apple stick with technologies that require special training?
  - Because some are just better than the alternatives
    - Objective-C is a cleaner, more flexible language than C++
    - HFS+ is arguably more capable than UFS under certain circumstances
      - Most other UNIX platforms also intend to replace UFS, or have already done so
        - UFS2 (FreeBSD), XFS (IRIX), ZFS (Solaris), etc.
    - Quartz performs well and is self-consistent
  - Because Apple controls these technologies, and can drive their improvement
- They are willing to accomodate alternatives (UFS, NFS, X11, C++) or even replace proprietary technologies (NetInfo -> LDAP)

Resources

- Web Sites
- Mailing Lists
- Books

- Apple's Mac OS X Site
  - http://www.apple.com/macosx/
- Mac OS X Hints
  - http://www.macosxhints.com/
- O'Reilly Mac DevCenter
  - http://www.macdevcenter.com/
- The Challenges of Integrating the Unix and Mac OS Environments
  - http://www.mit.edu/people/wsanchez/papers/USENIX_2000/

- macos-x-server (Apple)
  - http://www.lists.apple.com/mailman/listinfo/macos-x-server/
- macosx-admin (Omni Group)
  - http://www.omnigroup.com/developer/mailinglists/macosx-admin/
- macosx-talk (Omni Group)
  - http://www.omnigroup.com/developer/mailinglists/macosx-talk/
- security-announce (Apple)
  - http://www.lists.apple.com/mailman/listinfo/security-announce/

- Mac OS X Tiger for Unix Geeks
  - Brian Jepson, Ernest E. Rothman
- Mac OS X Tiger in a Nutshell
  - Andy Lester, Chris Stone, Chuck Toporek, Jason McIntosh
- Running Mac OS X Tiger
  - Jason Deraleau, James Duncan Davidson
- Essential Mac OS X Panther Server Administration
  - Michael Bartosh, Ryan Faas