# Configuration Management

# Topics covered

- Version management
- System building
- Change management
- Release management

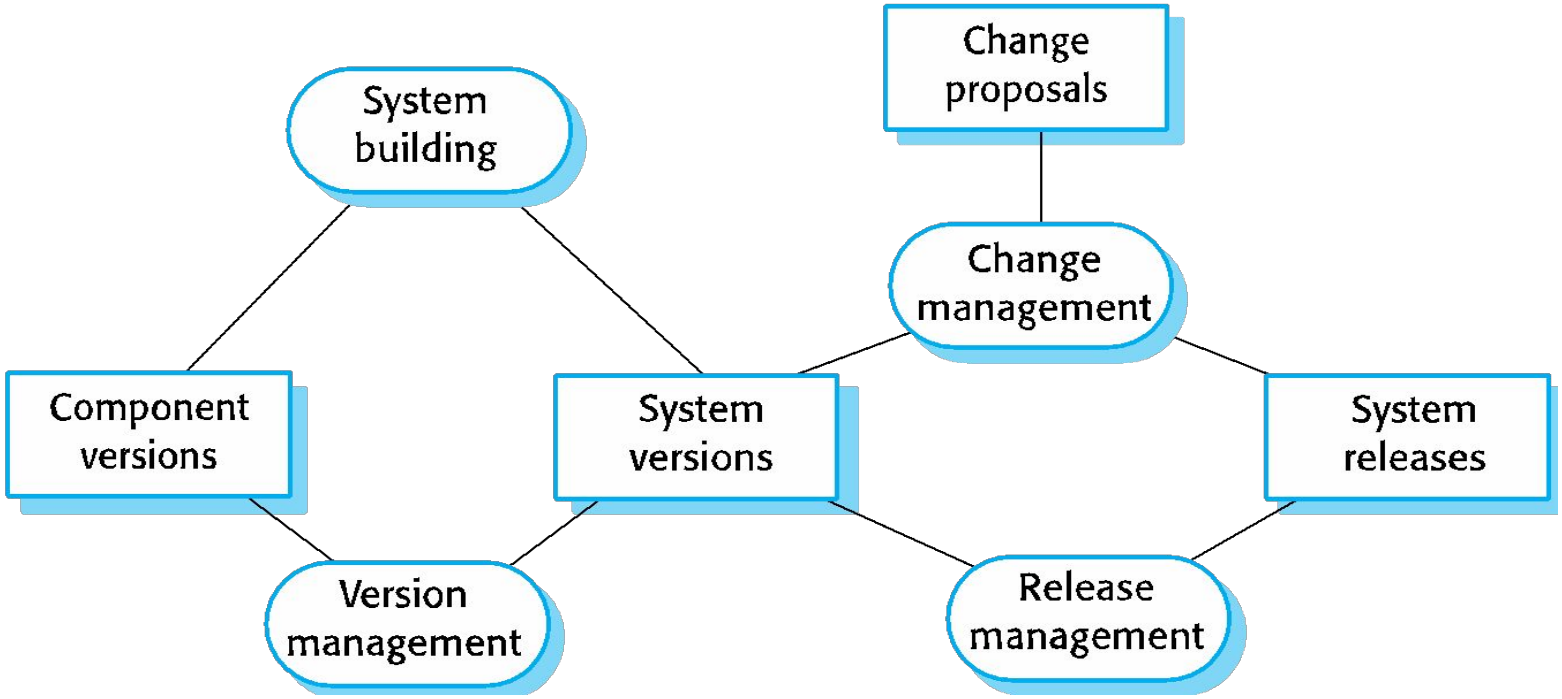
# Configuration management

- Software systems are constantly changing during development and use.
- Configuration management (CM) is concerned with the policies, processes and tools for managing changing software systems.
- You need CM because it is easy to lose track of what changes and component versions have been incorporated into each system version.
- CM is essential for team projects to control changes made by different developers

# CM activities

- Version management
  - Keeping track of the multiple versions of system components and ensuring that changes made to components by different developers do not interfere with each other.
- System building
  - The process of assembling program components, data and libraries, then compiling these to create an executable system.
- Change management
  - Keeping track of requests for changes to the software from customers and developers, working out the costs and impact of changes, and deciding the changes should be implemented.
- Release management
  - Preparing software for external release and keeping track of the system versions that have been released for customer use.

# Configuration management activities



# Agile development and CM

- Agile development, where components and systems are changed several times per day, is impossible without using CM tools.
- The definitive versions of components are held in a shared project repository and developers copy these into their own workspace.
- Developers make changes to the code then use system building tools to create a new system on their own computer for testing.
  - Once they are happy with the changes made, they return the modified components to the project repository.

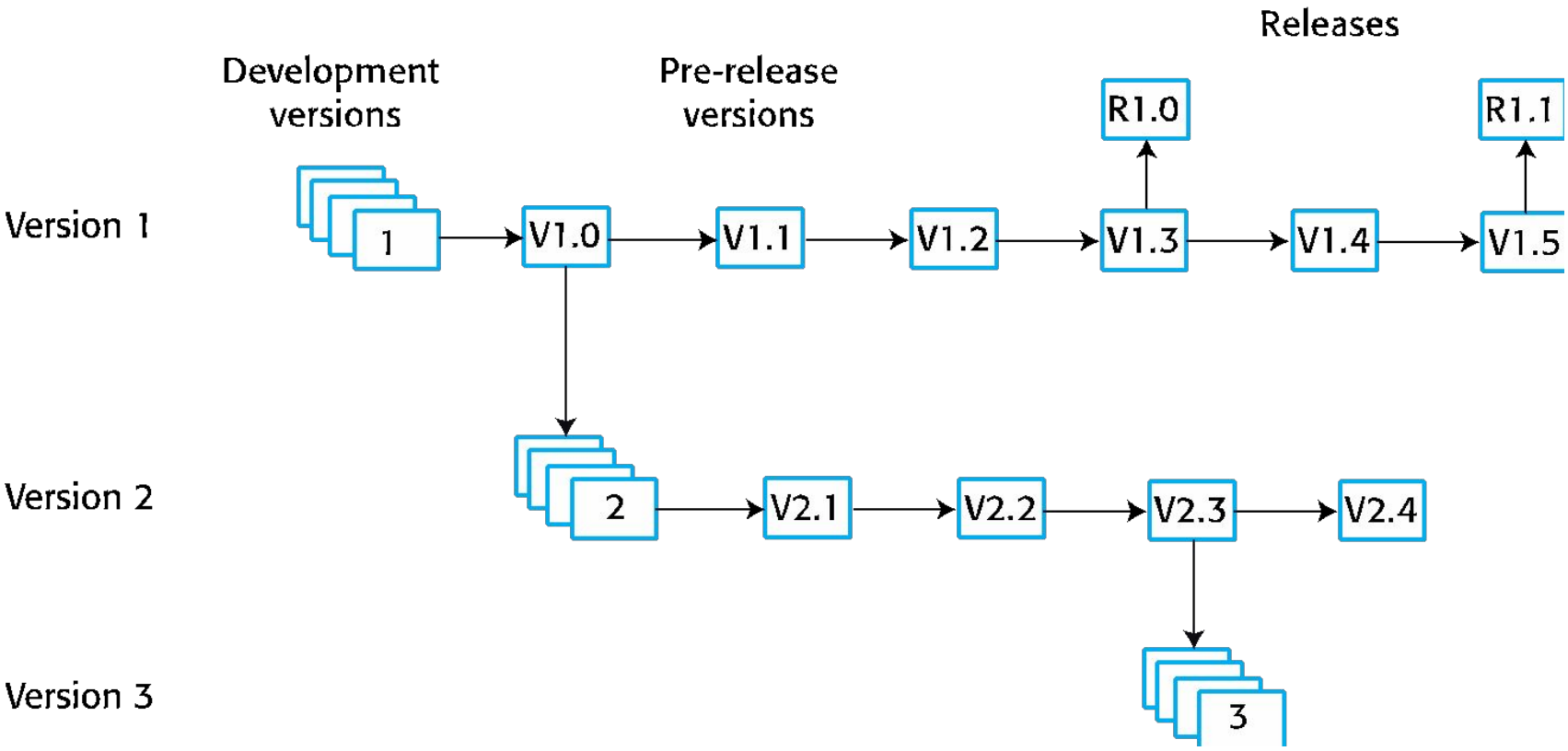
# Development phases

- A development phase where the development team is responsible for managing the software configuration and new functionality is being added to the software.
- A system testing phase where a version of the system is released internally for testing.
  - No new system functionality is added.
  - Changes made are bug fixes, performance improvements and security vulnerability repairs.
- A release phase where the software is released to customers for use.
  - New versions of the released system are developed to repair bugs and vulnerabilities and to include new features.

# Multi-version systems

- For large systems, there is never just one ‘working’ version of a system.
- There are always several versions of the system at different stages of development.
- There may be several teams involved in the development of different system versions.

# Multi-version system development



# CM terminology

| Term | Explanation |
|---|---|
| Baseline | A baseline is a collection of component versions that make up a system. Baselines are controlled, i.e., the versions of the components making up the system cannot be changed. It is always possible to recreate a baseline from its constituent components. |
| Branching | The creation of a new codeline from a version in an existing codeline. The new codeline and the existing codeline may then develop independently. |
| Codeline | A codeline is a set of versions of a software component and other configuration items on which that component depends. |
| Configuration (version) control | The process of ensuring that versions of systems and components are recorded and maintained so that changes are managed and all versions of components are identified and stored for the lifetime of the system. |
| Configuration item or software configuration item (SCI) | Anything associated with a software project (design, code, test data, document, etc.) placed under configuration control, under a unique name. There are often different versions of a configuration item. |
| Mainline | A sequence of baselines representing different versions of a system. |

# CM terminology

| Term | Explanation |
|---|---|
| Merging | The creation of a new version of a software component by merging separate versions in different codelines. These codelines may have been created by a previous branch of one of the codelines involved. |
| Release | A version of a system that has been released to customers (or other users in an organization) for use. |
| Repository | A shared database of versions of software components and meta-information about changes to these components. |
| System building | The creation of an executable system version by compiling and linking the appropriate versions of the system's components and libraries. |
| Version | An instance of a configuration item that differs, in some way, from other instances of that item. Versions always have a unique identifier. |
| Workspace | A private work area where software can be modified without affecting other developers who may be using or modifying that software. |

# Version management

# Version management

- Version management (VM) is the process of keeping track of different versions of software components or configuration items and the systems in which these components are used.
- It also involves ensuring that changes made by different developers to these versions do not interfere with each other.
- Therefore version management can be thought of as the process of managing codelines and baselines.

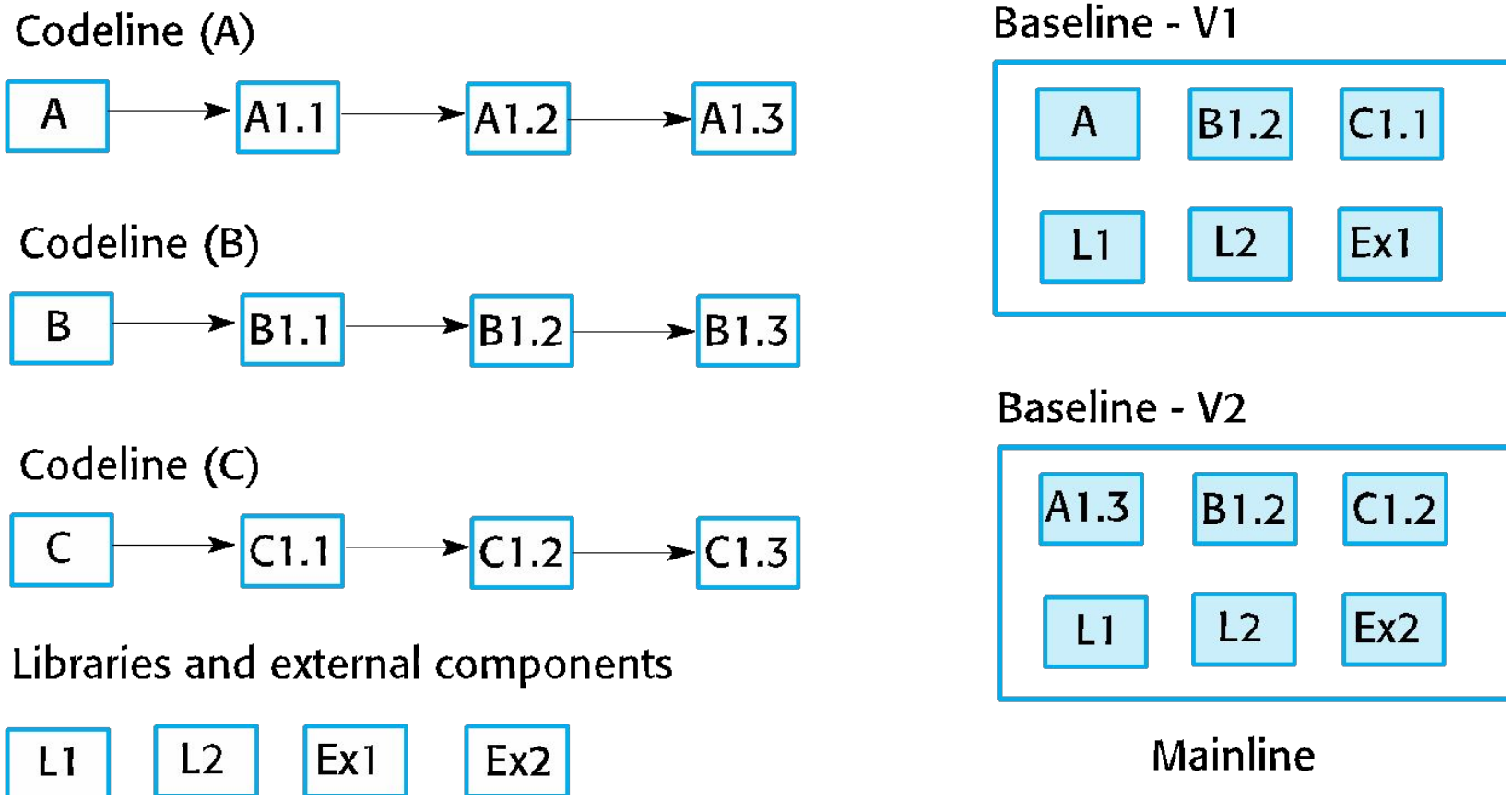
# Codelines and baselines

- A codeline is a sequence of versions of source code with later versions in the sequence derived from earlier versions.
- Codelines normally apply to components of systems so that there are different versions of each component.
- A baseline is a definition of a specific system.
- The baseline therefore specifies the component versions that are included in the system plus a specification of the libraries used, configuration files, etc.

# Baselines

- Baselines may be specified using a configuration language
  - allows you to define what components are included in a version of a particular system.
- Baselines are important because you often have to recreate a specific version of a complete system.
  - For example, a product line may be instantiated so that there are individual system versions for different customers.
  - You may have to recreate the version delivered to a customer if, e.g., that customer reports bugs in their system you must repair.

# Codelines and baselines



# Version control systems

- Version control (VC) systems identify, store and control access to the different versions of components.
- There are two types of modern version control system
  - Centralized systems – a single master repository maintains all versions of the software components that are being developed.
    - E.g., Subversion
  - Distributed systems – multiple versions of the component repository exist at the same time
    - E.g., Git

# Key features of version control systems

- Version and release identification
- Change history recording
- Support for independent development
- Project support
- Storage management

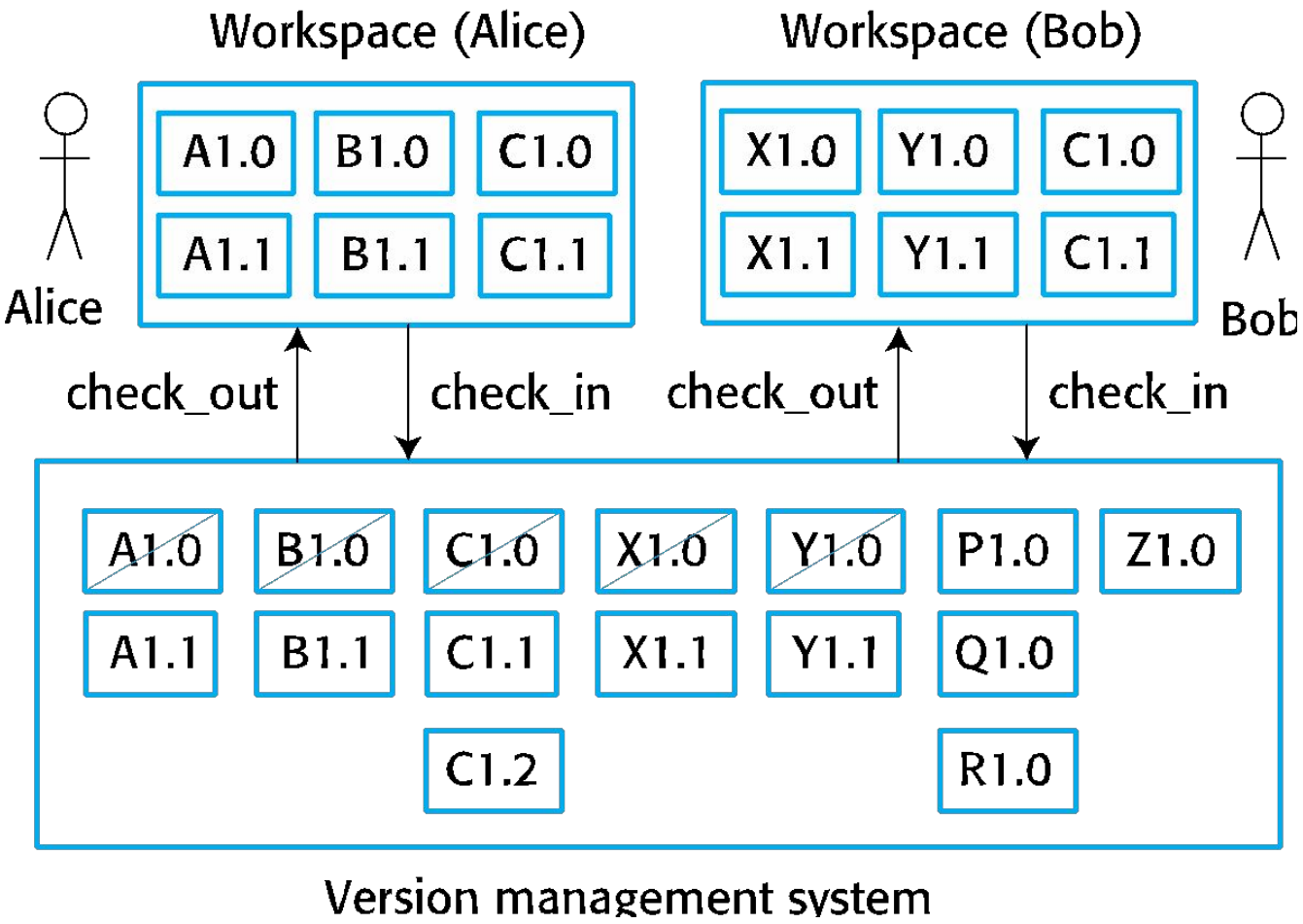
# Public repository and private workspaces

- To support independent development, VCSs use the concept of a project repository and a private workspace.
- Project repository maintains the 'master' version of all components. It is used to create baselines for system building.
- When modifying components, developers first copy (check-out) these from the repository into their workspace.
- When they have finished their changes, the changed components are returned (checked-in) to the repository.

# Centralized version control

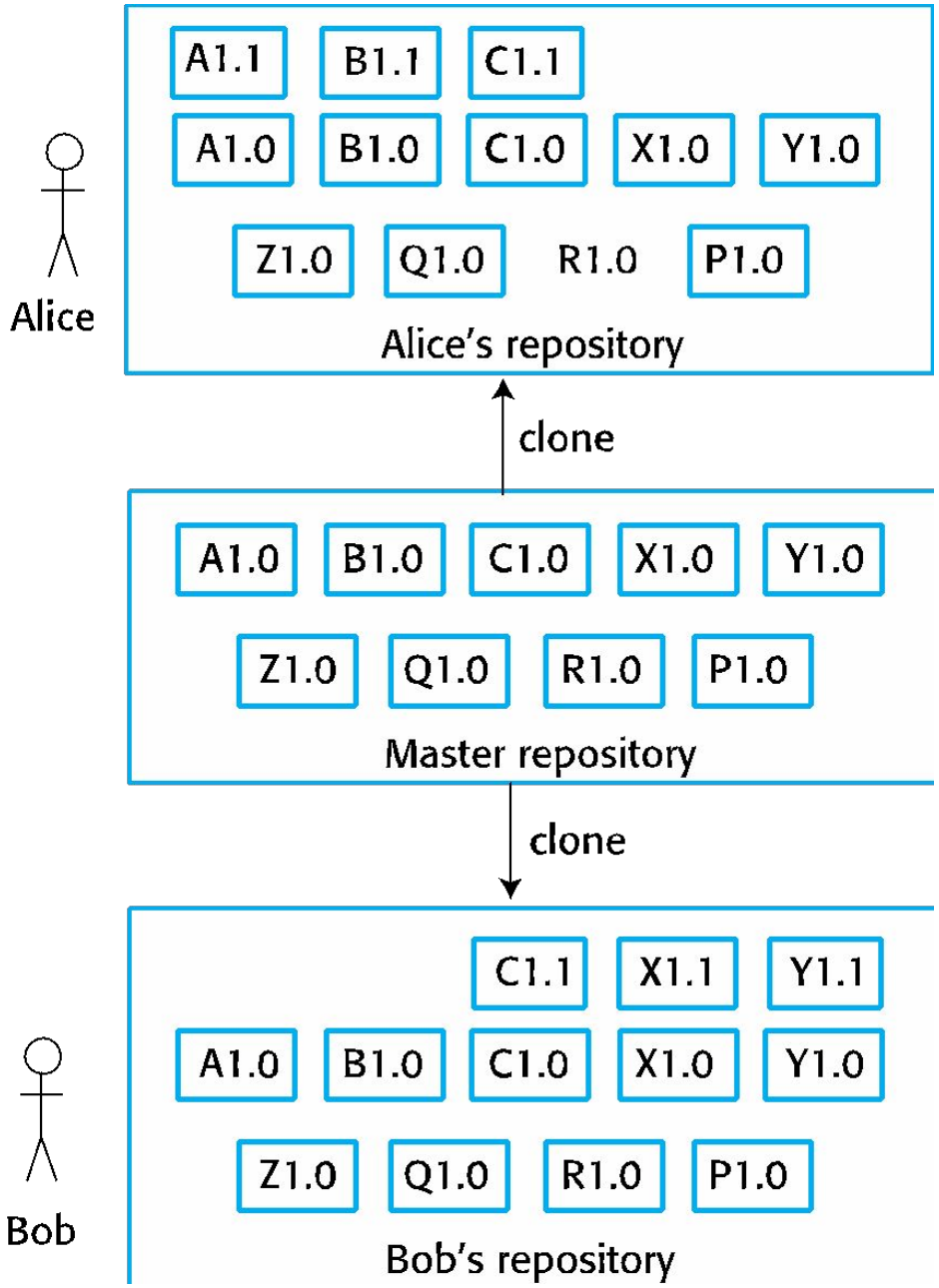
- Developers check out components from the project repository into their private workspace and work on these copies in their private workspace.
- When their changes are complete, they check-in the components back to the repository.
- If several people are working on a component at the same time, each check it out from the repository.
- If a component has been checked out, the VC system warns other users wanting to check out that component that it has been checked out by someone else.

# Repository Check-in/Check-out



# Distributed version control

- A ‘master’ repository is created on a server that maintains the code produced by the development team.
- A developer creates a clone of the project repository that is downloaded and installed on their computer.
- Developers work on the files required and maintain new versions in their private repository on their computer.
- When changes are done, they ‘commit’ these changes and update their private server repository.
- They may then ‘push’ these changes to the project repository.




# Repository cloning

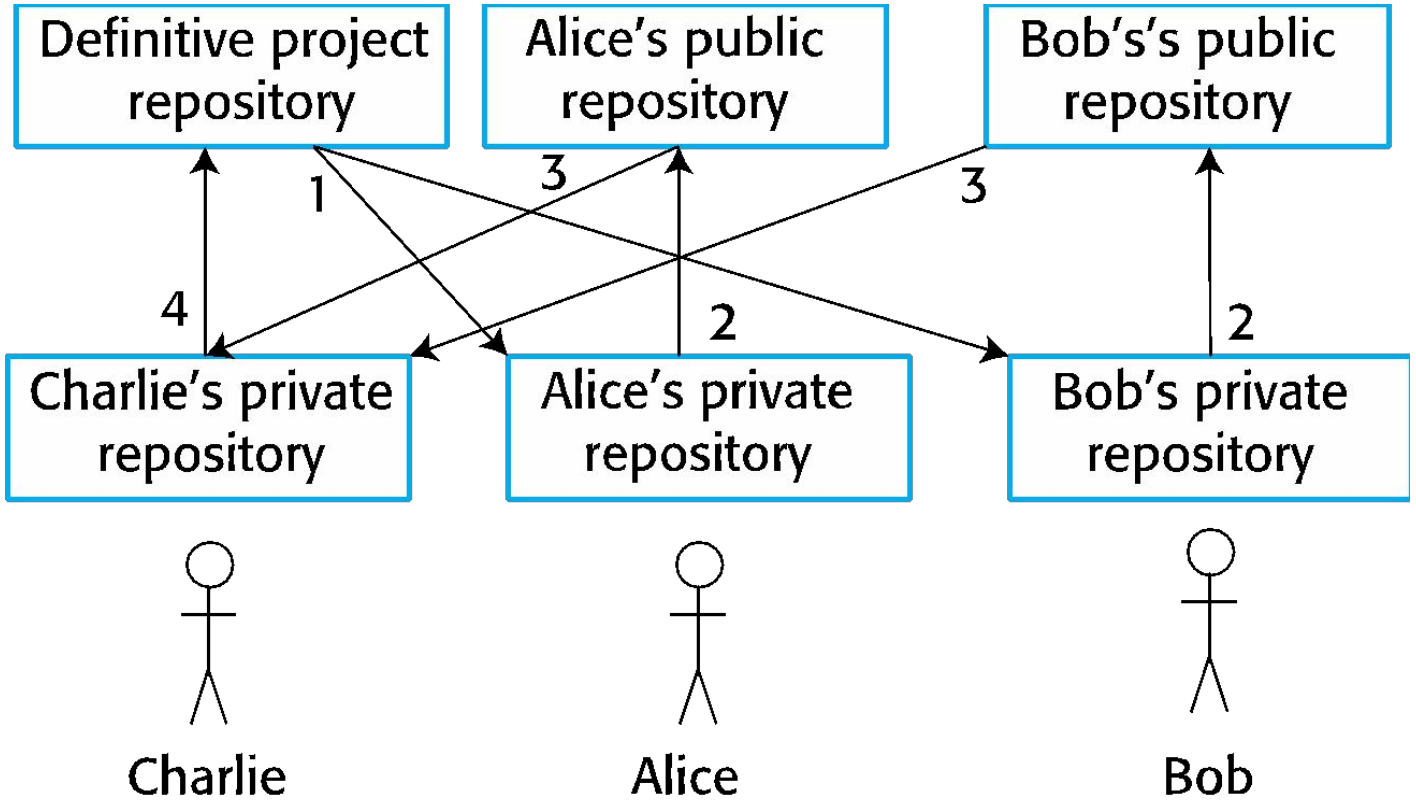
# Benefits of distributed version control

- It provides a backup mechanism for the repository.
  - If the repository is corrupted, work can continue and the project repository can be restored from local copies.
- It allows for off-line working
  - developers can commit changes if they do not have a network connection.
- Project support is the default way of working.
  - Developers can compile and test the entire system on their local machines and test the changes that they have made.

# Open source development

- Distributed version control is essential for open source development.
  - Several people may be working simultaneously on the same system without any central coordination.
- Beside a private repository on their computer, developers maintain a public server repository to which they push new versions of components they have changed.
  - It is then up to the open-source system ‘manager’ to decide when to pull these changes into the definitive system.

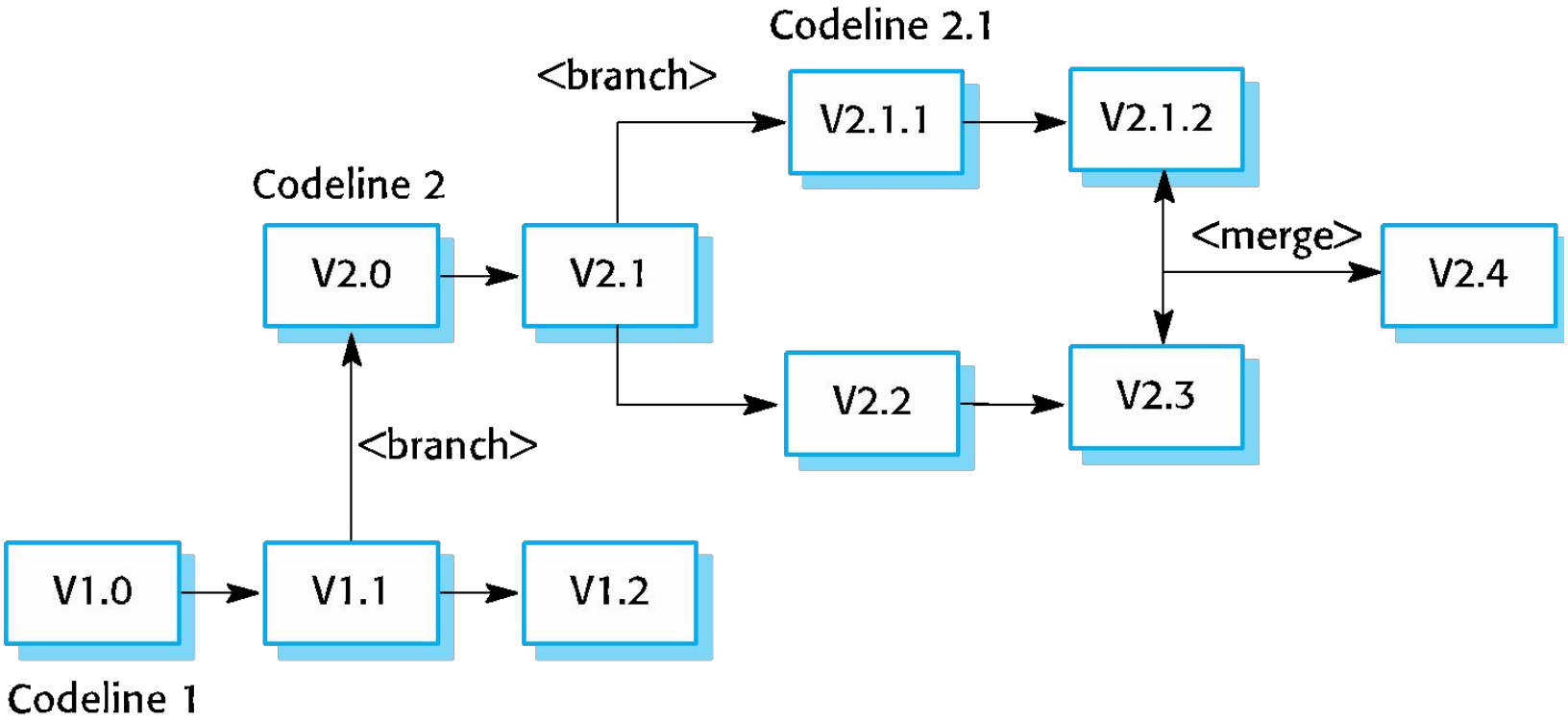
# Open-source development



# Branching and merging

- There may be several independent sequences of versions that reflect changes to a component over time.
  - This is normal in system development, where different developers work independently on different versions of the code.
- At some stage, it may be necessary to merge codeline branches to create a new version of a component that includes all changes that have been made.
  - If the changes made involve different parts of the code, the component versions may be merged automatically by combining the “deltas” that apply to the code.

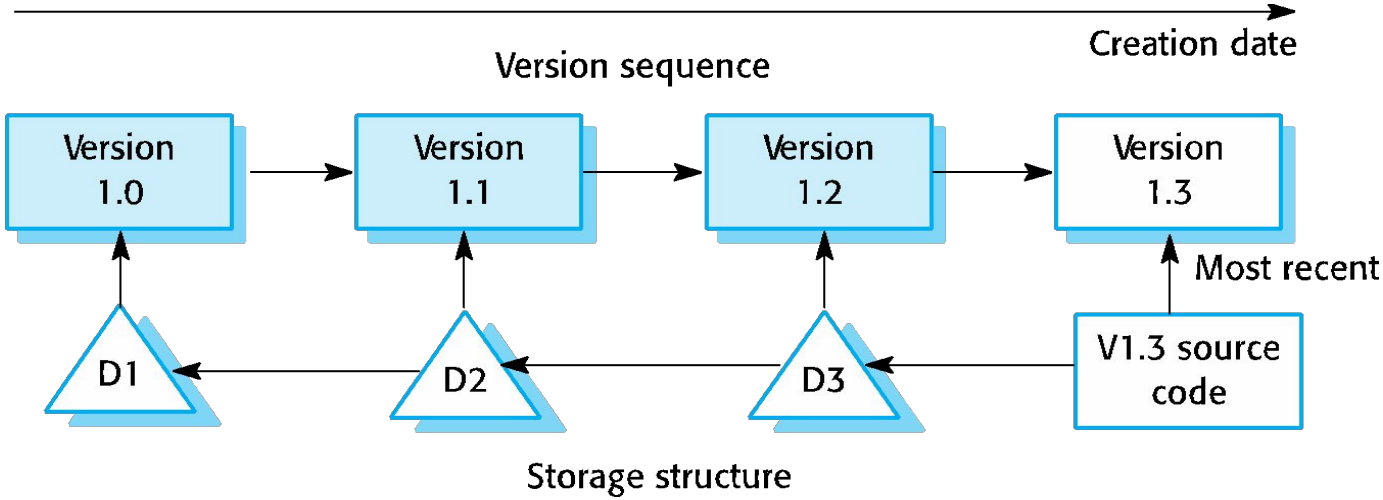
# Branching and merging



# Storage management

- When VCSs were first developed, storage management was one of their most important functions.
- Disk space was expensive and it was important to minimize the space used by different copies of components.
- Instead of keeping a complete copy of each version, the system stores a list of differences (deltas) between one version and another.
  - By applying these to a master version (usually the most recent version), a target version can be recreated.

# Storage management using deltas



# Storage management in Git

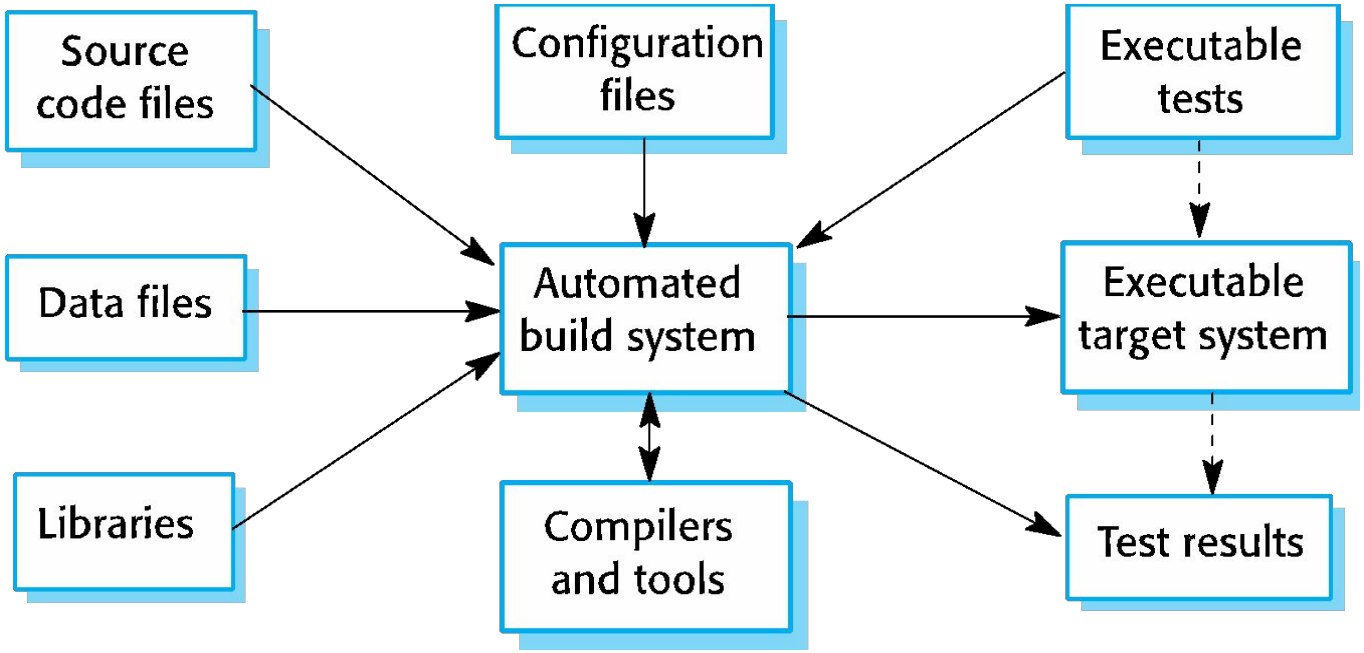
- As disk storage is now relatively cheap, Git uses an alternative, faster approach.
- Git does not use deltas but applies a standard compression algorithm to stored files and their associated meta-information.
- It does not store duplicate copies of files. Retrieving a file simply involves decompressing it, with no need to apply a chain of operations.
- Git also uses the notion of packfiles where several smaller files are combined into an indexed single file.

# System building

# System building

- System building is the process of creating a complete, executable system by compiling and linking the system components, external libraries, configuration files, etc.
- System building tools and version management tools must communicate
  - the build process involves checking out component versions from the repository managed by the version management system.
- The configuration description used to identify a baseline is also used by the system building tool.

# System building



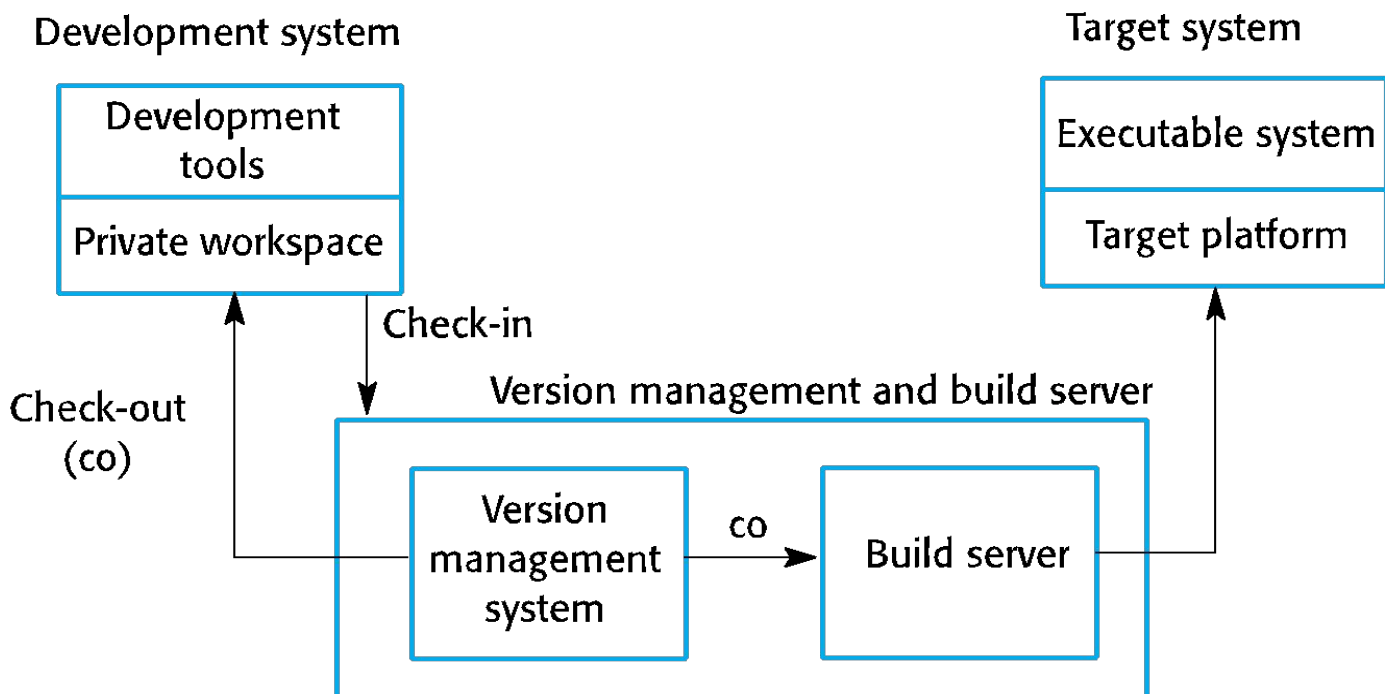
# Build system functionality

- Build script generation
- Version management system integration
- Minimal re-compilation
- Executable system creation
- Test automation
- Reporting
- Documentation generation

# System platforms

- The development system, which includes development tools such as compilers, source code editors, etc.
- The build server, which is used to build definitive, executable versions of the system.
- The target environment, which is the platform on which the system executes.
  - For real-time and embedded systems, the target environment is often smaller and simpler than the development environment (e.g. a cell phone)

# Development, build, and target platforms



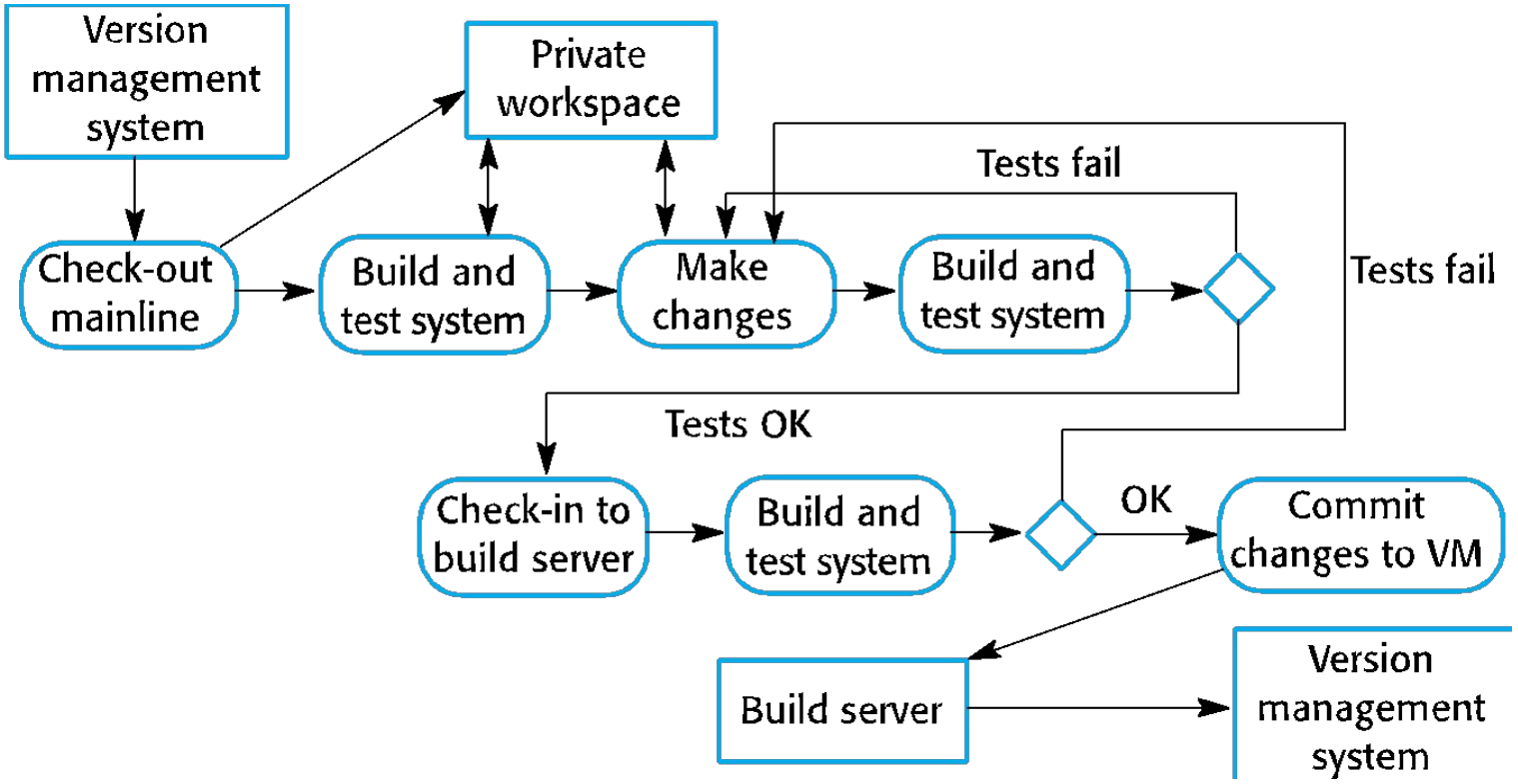
# Agile building

- Check out the mainline system from the version management system into the developer's private workspace.
- Build the system and run automated tests to ensure that the built system passes all tests.
  - If not, the build is broken and you should inform whoever checked in the last baseline system so they can fix the problem.
- Make the changes to the system components.
- Build the system in the private workspace and rerun system tests. If the tests fail, continue editing.

# Agile building

- Once the system has passed its tests, check it into the build system but do not commit it as a new system baseline.
- Build the system on the build server and run the tests.
  - You need to do this in case others have modified components since you checked out the system.
  - If this is the case, check out the components that have failed and edit these so that tests pass on your private workspace.
- If the system passes its tests on the build server, commit your changes as a new baseline in the system mainline.

# Continuous integration



# Pros and cons of continuous integration

- Pros
  - It allows problems caused by the interactions between different developers to be discovered and repaired ASAP.
  - The most recent system in the mainline is the definitive working system.
- Cons
  - If the system is very large, it may take a long time to build and test, especially if integration with other systems is involved.
  - If the development platform ≠ target platform, it may not be possible to run system tests in developer's private workspace.

# Daily building

- The development organization sets a delivery time (say 2 p.m.) for system components.
  - If developers have new versions of the components that they are writing, they must deliver them by that time.
  - A new version of the system is built from these components by compiling and linking them to form a complete system.
  - This system is then delivered to the testing team, which carries out a set of predefined system tests
  - Faults discovered during testing are documented and returned to the developers.
  - They repair these faults in a subsequent version of the component.

# Minimizing recompilation

- Tools to support system building are usually designed to minimize the amount of compilation that is required.
- They do this by checking if a compiled version of a component is available.
  - If so, there is no need to recompile that component.
- A unique signature identifies each source and object code version and is changed when code is edited.
- By comparing the signatures on the source and object code files, it is possible to decide if the source code was used to generate the object code component.

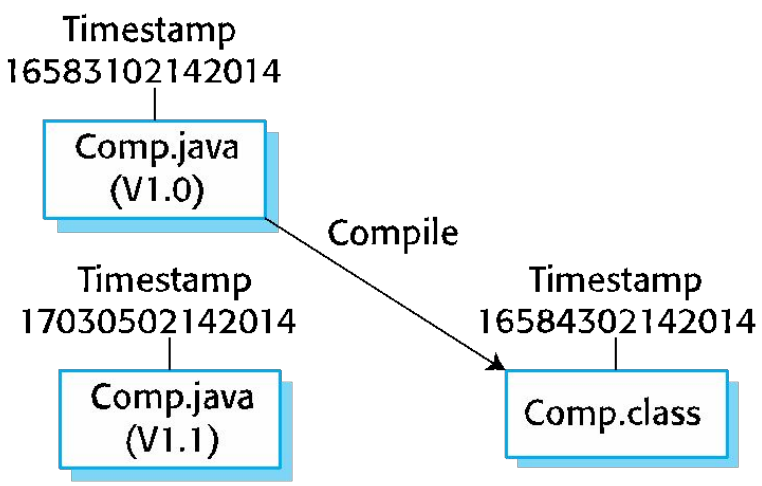
# File identification

- Modification timestamps
  - The signature on the source code file is the time and date when that file was modified.
  - If the source code file of a component has been modified after the related object code file, the system assumes that recompilation to create a new object code file is necessary.
- Source code checksums
  - The signature on the source code file is a checksum calculated from data in the file.
  - A checksum function calculates a unique number using the source text as input.
  - If you change the source code, this will generate a different checksum.

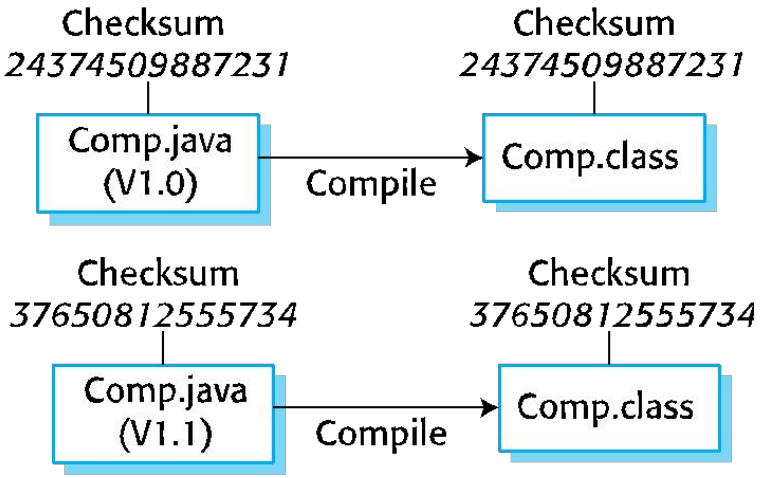
# Timestamps vs checksums

- Timestamps
  - Because source and object files are linked by name, it is not possible to build different versions of a source code component into the same directory at the same time, as these would generate object files with the same name.
- Checksums
  - When you recompile a component, it does not overwrite the object code, as would normally be the case when the timestamp is used.
  - Rather, it generates a new object code file and tags it with the source code signature.
  - Parallel compilation is possible and different versions of a component may be compiled at the same time.

# Linking source and object code




Time-based identification

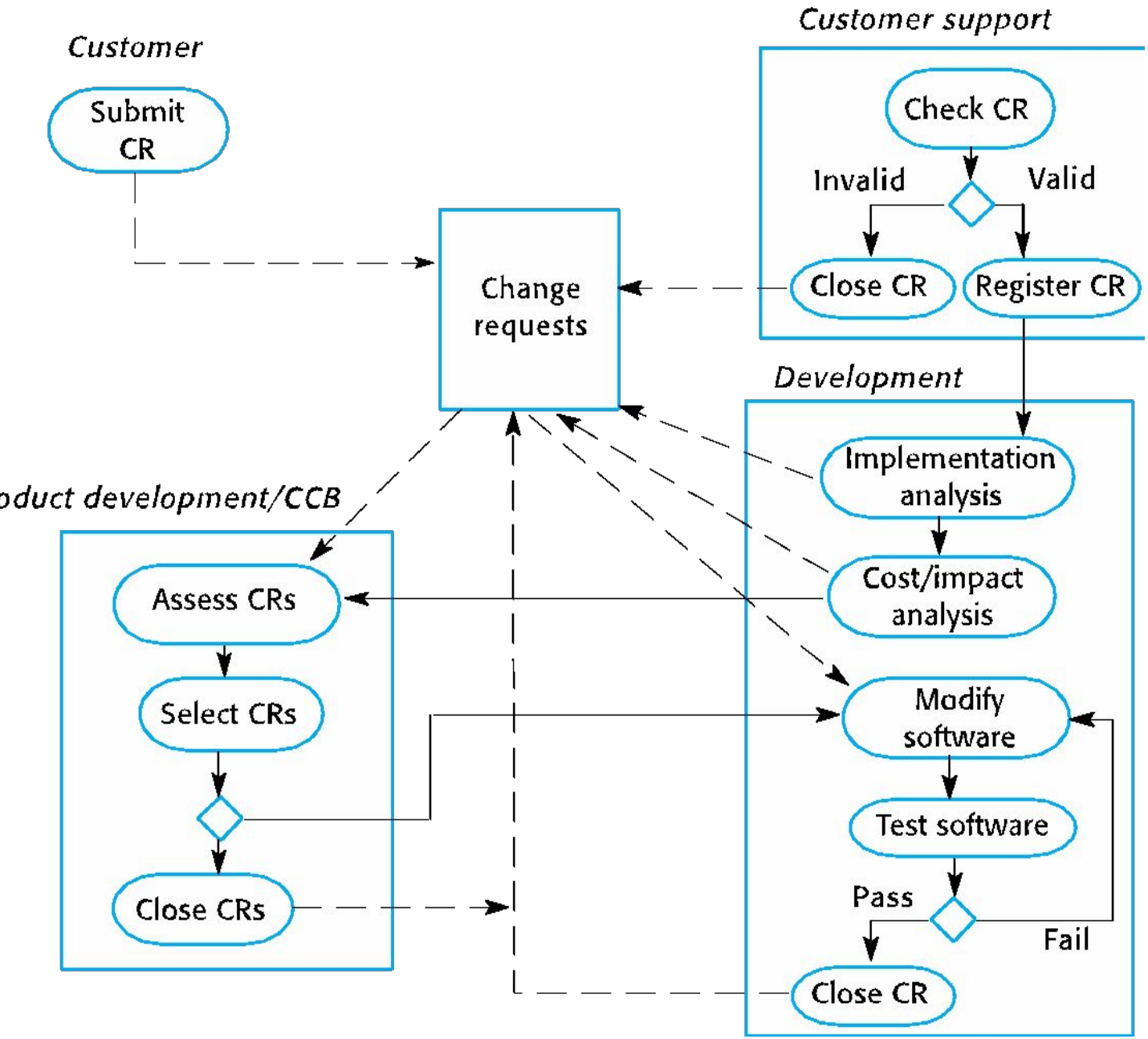



Checksum-based identification

# Change management

# Change management

- Organizational needs and requirements change during the lifetime of a system, bugs have to be repaired and systems have to adapt to changes in their environment.
- Change management is intended to ensure that system evolution is a managed process and that priority is given to the most urgent and cost-effective changes.
- The change management process is concerned with
  - analyzing the costs and benefits of proposed changes,
  - approving those changes that are worthwhile, and
  - tracking which components in the system have been changed.




**The change management process**

# A partially completed change request form (a)

**Change Request Form**

**Project:** SICSA/AppProcessing **Number:** 23/02
**Change requester:** I. Sommerville **Date:** 20/07/12
**Requested change:** The status of applicants (rejected, accepted, etc.) should be shown visually in the displayed list of applicants.

**Change analyzer:** R. Looek **Analysis date:** 25/07/12
**Components affected:** ApplicantListDisplay, StatusUpdater

**Associated components:** StudentDatabase

# A partially completed change request form (b)

**Change Request Form**

**Change assessment:** Relatively simple to implement by changing the display color according to status. A table must be added to relate status to colors. No changes to associated components are required.

**Change priority:** Medium
**Change implementation:**
**Estimated effort:** 2 hours
**Date to SGA app. team:** 28/07/12 **CCB decision date:** 30/07/12
**Decision:** Accept change. Change to be implemented in Release 1.2
**Change implementor:** **Date of change:**
**Date submitted to QA:** **QA decision:**
**Date submitted to CM:**
**Comments:**

# Factors in change analysis

- The consequences of not making the change
- The benefits of the change
- The number of users affected by the change
- The costs of making the change
- The product release cycle

# Derivation history

```
// SICSA project (XEP 6087)
//
// APP-SYSTEM/AUTH/RBAC/USER_ROLE
//
// Object: currentRole
// Author: R. Looek
// Creation date: 13/11/2012
//
// © St Andrews University 2012
//
// Modification history
// Version Modifier    Date        Change        Reason
// 1.0J. Jones   11/11/2009    Add header    Submitted to CM
// 1.1R. Looek  13/11/2012    New field     Change req. R07/02
```

# Change management and agile methods

- In some agile methods, customers are directly involved in change management.
- They propose a change to the requirements and work with the team to assess its impact and decide whether the change should take priority over the features planned for the next increment of the system.
- Changes to improve the software are decided by the programmers working on the system.
- Refactoring, where the software is continually improved, is not seen as an overhead but as a necessary part of the development process.

# Release management

# Release management

- A system release is a version of a software system that is distributed to customers.
- For mass market software, it is usually possible to identify two types of release
  - major releases deliver significant new functionality
  - minor releases repair bugs and fix problems that have been reported.
- For custom software or software product lines, releases of the system may have to be produced for each customer
  - individual customers may be running several different releases of the system at the same time!

# Release components

- Beyond the executable code of the system, a release may also include:
  - configuration files defining how the release should be configured for particular installations;
  - data files, such as files of error messages, that are needed for successful system operation;
  - an installation program that is used to help install the system on target hardware;
  - electronic and paper documentation describing the system;
  - packaging and associated publicity that have been designed for that release.

# Factors influencing system release planning

| Factor | Description |
|---|---|
| Competition | For mass-market software, a new system release may be necessary because a competing product has introduced new features and market share may be lost if these are not provided to existing customers. |
| Marketing requirements | The marketing department of an organization may have made a commitment for releases to be available at a particular date. |
| Platform changes | You may have to create a new release of a software application when a new version of the operating system platform is released. |
| Technical quality of the system | If serious faults are reported which affect the way in which many customers use the system, it may be necessary to issue a fault repair release. Minor system faults may be repaired by issuing patches that can be applied to the current release. |

# Release creation

- The executable code of the programs and all associated data files must be identified in the version control system.
- Configuration descriptions may have to be written for different hardware and operating systems.
- Update instructions may have to be written for customers who need to configure their own systems.
- Scripts for the installation program may have to be written.
- Web pages have to be created describing the release, with links to system documentation.
- When all information is available, an executable master image of the software must be prepared and handed over for distribution to customers or sales outlets.

# Release tracking

- In the event of a problem, it may be necessary to reproduce exactly the software that has been delivered to a particular customer.
- When a system release is produced, it must be documented to ensure that it can be re-created exactly in the future.
- This is especially important for customized, long-lifetime embedded systems, such as those that control complex machines.
  - Customers may use a single release of these systems for many years
  - They may require specific changes to a particular software system long after its original release date.

# Release reproduction

- To document a release, you have to record the specific versions of the source code components that were used to create the executable code.
- You must keep copies of the source code files, corresponding executables and all data and configuration files.
- You should also record the versions of the operating system, libraries, compilers and other tools used to build the software.

# Release planning

- Beside the technical work in creating a release distribution, advertising and publicity materials and marketing strategies must be put in place to convince customers to buy the new release of the system.
- Release timing
  - If releases are too frequent or require hardware upgrades, customers may not move to the new release, especially if they have to pay for it.
  - If system releases are too infrequent, market share may be lost as customers move to alternative systems.

# Software as a service

- Delivering software as a service (SaaS) reduces the problems of release management.
- It simplifies both release management and system installation for customers.
- The software developer is responsible for replacing the existing release of a system with a new release and this is made available to all customers at the same time.