Component-based software engineering

Objectives

- To explain that CBSE is concerned with developing standardised components and composing these into applications
- To describe components and component models
- To show the principal activities in the CBSE process
- To discuss approaches to component composition and problems that may arise

Topics covered

- Components and component models
- The CBSE process
- Component composition

Component-based development

- Component-based software engineering (CBSE) is an approach to software development that relies on software reuse.
- It emerged from the failure of object-oriented development to support effective reuse. Single object classes are too detailed and specific.
- Components are more abstract than object classes and can be considered to be stand-alone service providers.

CBSE essentials

- Independent components specified by their interfaces.
- Component standards to facilitate component integration.
- Middleware that provides support for component inter-operability.
- A development process that is geared to reuse.

CBSE and design principles

- Apart from the benefits of reuse, CBSE is based on sound software engineering design principles:
  - Components are independent so do not interfere with each other;
  - Component implementations are hidden;
  - Communication is through well-defined interfaces;
  - Component platforms are shared and reduce development costs.

CBSE problems

- Component trustworthiness - how can a component with no available source code be trusted?
- Component certification - who will certify the quality of components?
- Emergent property prediction - how can the emergent properties of component compositions be predicted?
- Requirements trade-offs - how do we do trade-off analysis between the features of one component and another?

Components

- Components provide a service without regard to where the component is executing or its programming language
  - A component is an independent executable entity that can be made up of one or more executable objects;
  - The component interface is published and all interactions are through the published interface;

Component definitions

- Councill and Heinmann:
  - *A software component is a software element that conforms to a component model and can be independently deployed and composed without modification according to a composition standard.*
- Szyperski:
  - *A software component is a unit of composition with contractually specified interfaces and explicit context dependencies only. A software component can be deployed independently and is subject to composition by third-parties.*

Component as a service provider

- The component is an independent, executable entity. It does not have to be compiled before it is used with other components.
- The services offered by a component are made available through an interface and all component interactions take place through that interface.

Component characteristics 1

Standardised	Component standardisation means that a component that is used in a CBSE process has to conform to some standardised component model. This model may define component interfaces, component meta-data, documentation, composition and deployment.
Independent	A component should be independent Š it should be possible to compose and deploy it without having to use other specific components. In situations where the component needs externally provided services, these should be explicitly set out in a Õequires Õinterface specification.
Composable	For a component to be composable, all external interactions must take place through publicly defined interfaces. In addition, it must provide external access to information about itself such as its methods and attributes.

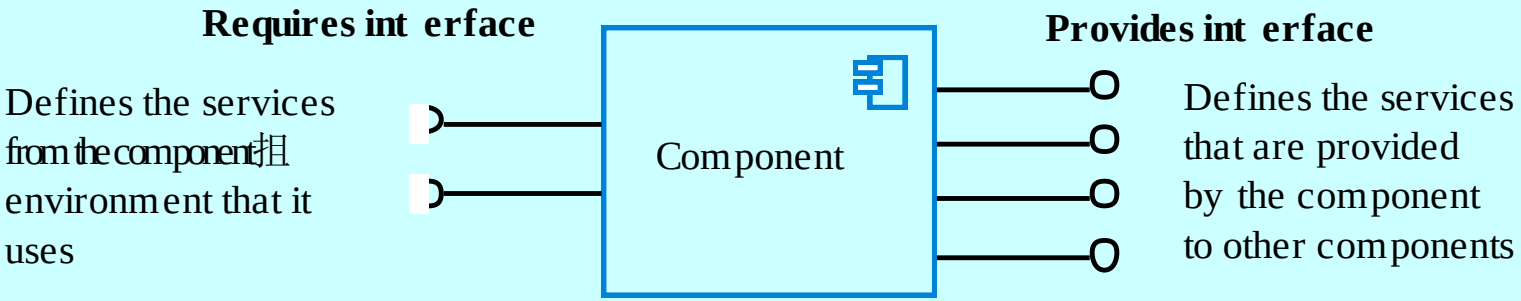
Component characteristics 2

Deployable	To be deployable, a component has to be self-contained and must be able to operate as a stand-alone entity on some component platform that implements the component model. This usually means that the component is a binary component that does not have to be compiled before it is deployed.
Documented	Components have to be fully documented so that potential users of the component can decide whether or not they meet their needs. The syntax and , ideally, the semantics of all component interfaces have to be specified.

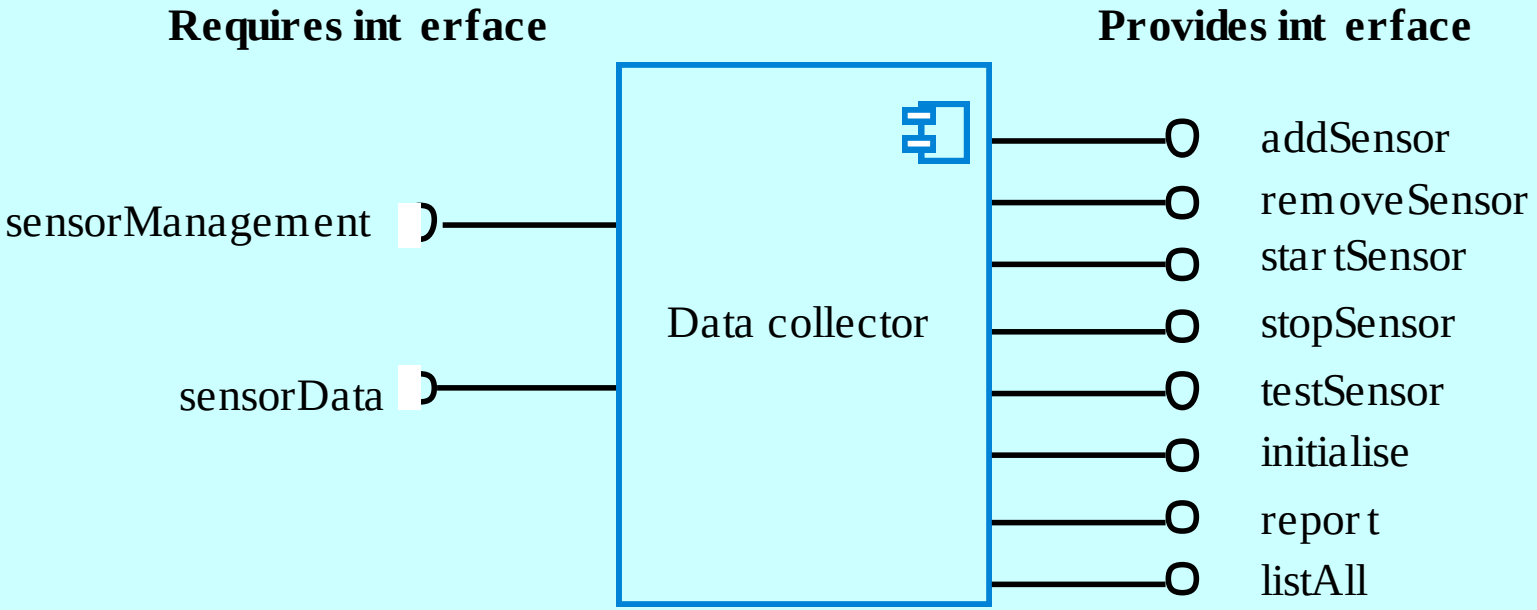
Component interfaces

- Provides interface
  - Defines the services that are provided by the component to other components.
- Requires interface
  - Defines the services that specifies what services must be made available for the component to execute as specified.

Component interfaces



A data collector component



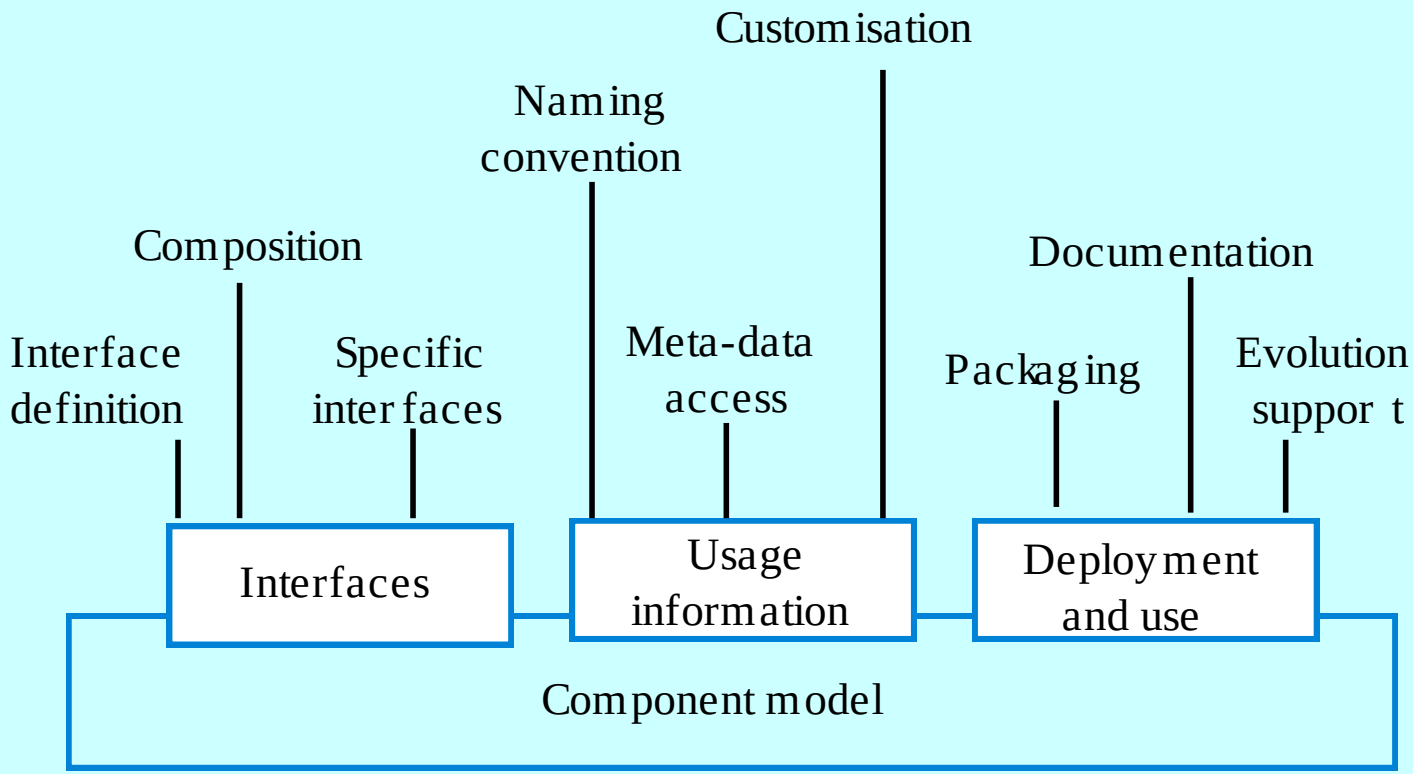
Components and objects

- Components are deployable entities.
- Components do not define types.
- Component implementations are opaque.
- Components are language-independent.
- Components are standardised.

Component models

- A component model is a definition of standards for component implementation, documentation and deployment.
- Examples of component models
  - EJB model (Enterprise Java Beans)
  - COM+ model (.NET model)
  - Corba Component Model
- The component model specifies how interfaces should be defined and the elements that should be included in an interface definition.

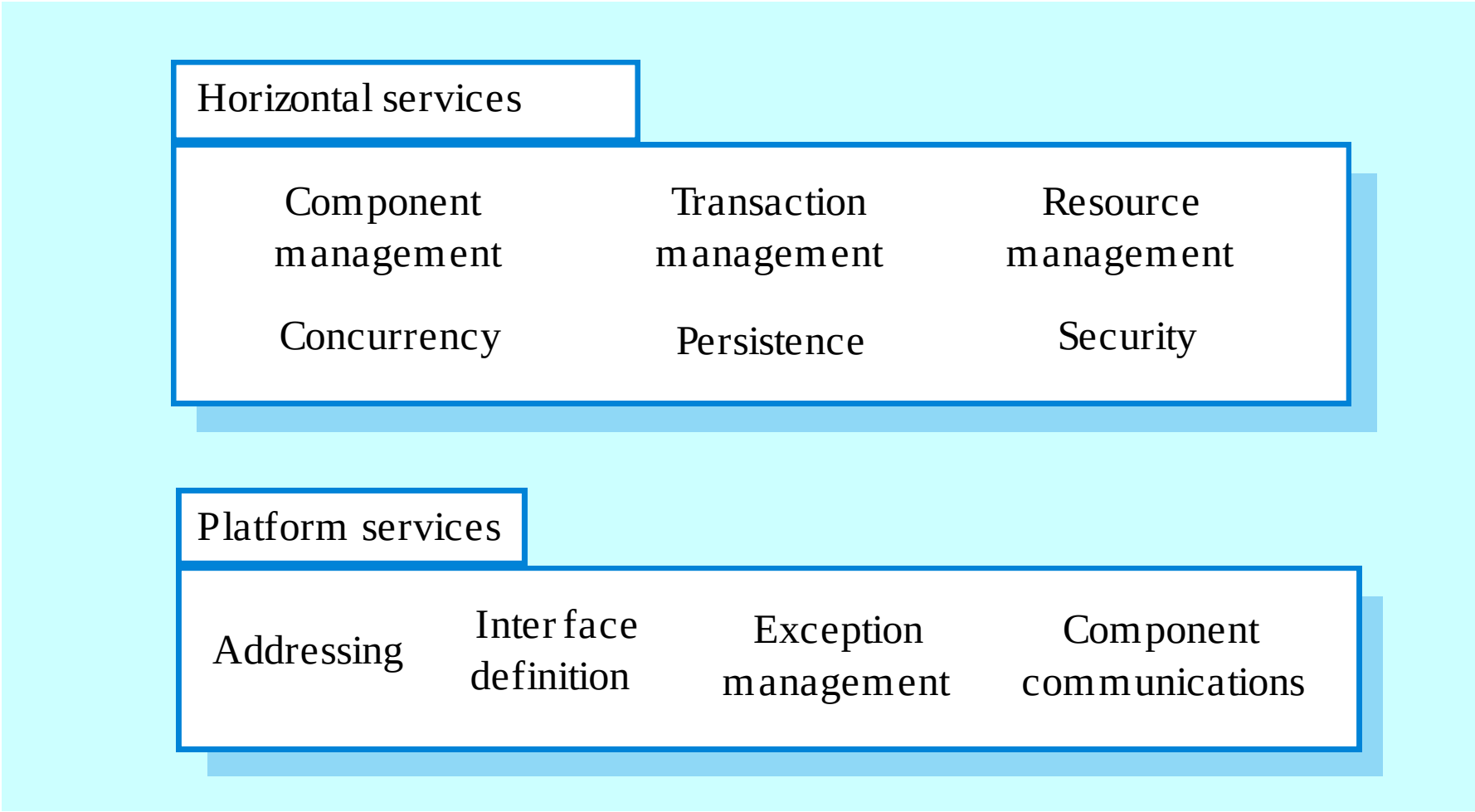
Elements of a component model



Middleware support

- Component models are the basis for middleware that provides support for executing components.
- Component model implementations provide:
  - Platform services that allow components written according to the model to communicate;
  - Horizontal services that are application-independent services used by different components.
- To use services provided by a model, components are deployed in a container. This is a set of interfaces used to access the service implementations.

Component model services



Component development for reuse

- Components developed for a specific application usually have to be generalised to make them reusable.
- A component is most likely to be reusable if it associated with a stable domain abstraction (business object).
- For example, in a hospital stable domain abstractions are associated with the fundamental purpose - nurses, patients, treatments, etc.

Component development for reuse

- Components for reuse may be specially constructed by generalising existing components.
- Component reusability
  - Should reflect stable domain abstractions;
  - Should hide state representation;
  - Should be as independent as possible;
  - Should publish exceptions through the component interface.
- There is a trade-off between reusability and usability
  - The more general the interface, the greater the reusability but it is then more complex and hence less usable.

Changes for reusability

- Remove application-specific methods.
- Change names to make them general.
- Add methods to broaden coverage.
- Make exception handling consistent.
- Add a configuration interface for component adaptation.
- Integrate required components to reduce dependencies.

Legacy system components

- Existing legacy systems that fulfil a useful business function can be re-packaged as components for reuse.
- This involves writing a wrapper component that implements provides and requires interfaces then accesses the legacy system.
- Although costly, this can be much less expensive than rewriting the legacy system.

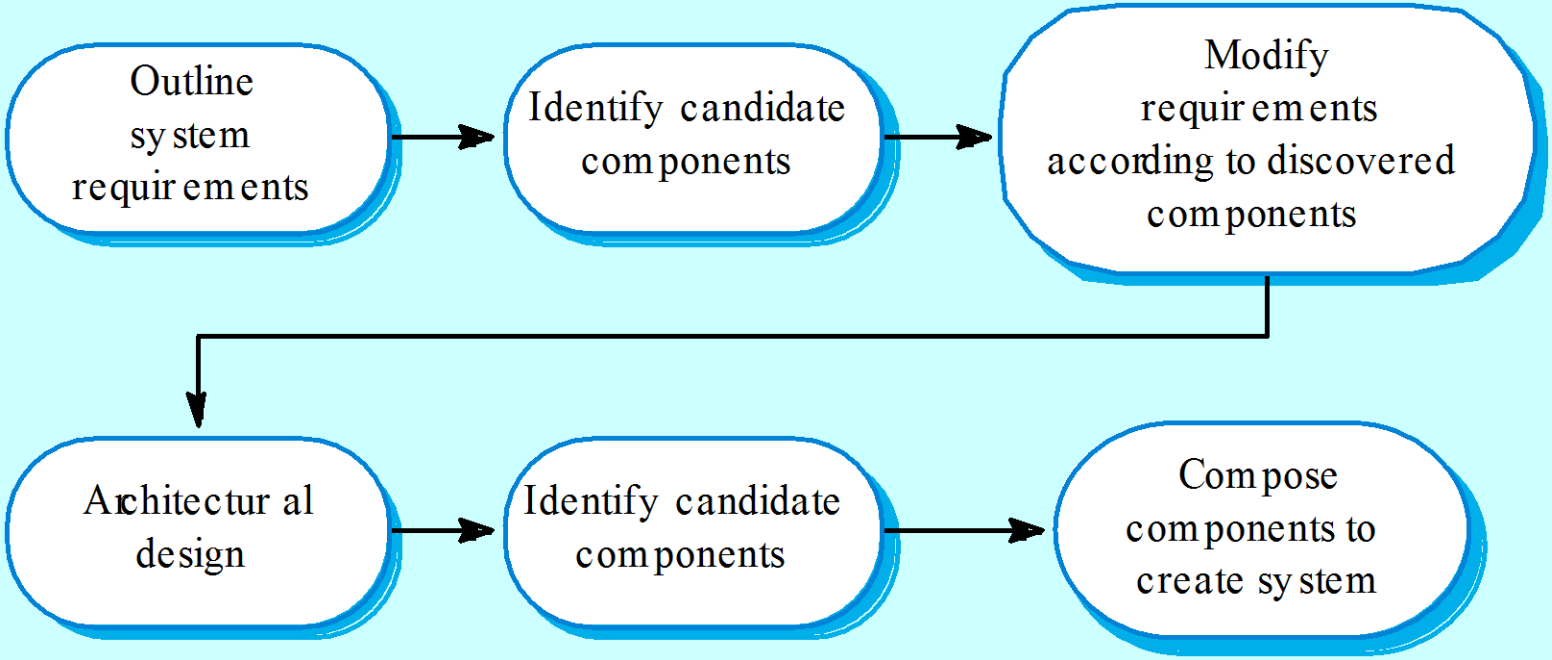
Reusable components

- The development cost of reusable components may be higher than the cost of specific equivalents. This extra reusability enhancement cost should be an organization rather than a project cost.
- Generic components may be less space-efficient and may have longer execution times than their specific equivalents.

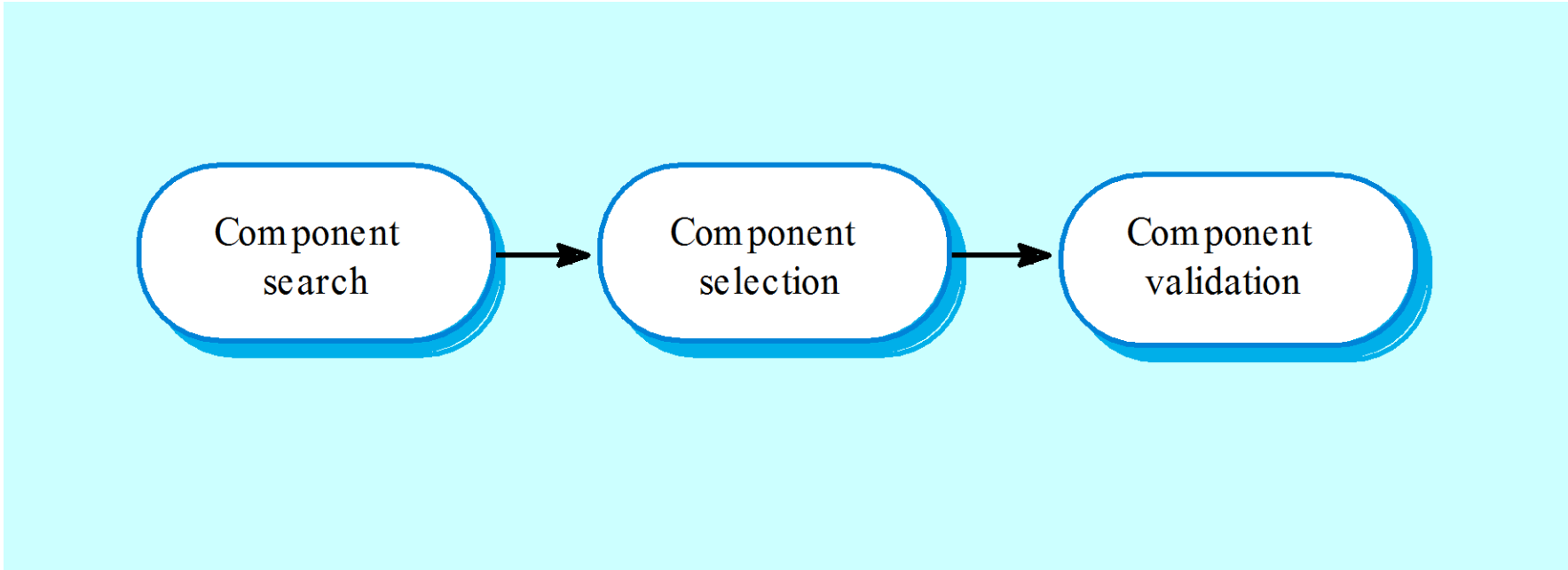
The CBSE process

- When reusing components, it is essential to make trade-offs between ideal requirements and the services actually provided by available components.
- This involves:
  - Developing outline requirements;
  - Searching for components then modifying requirements according to available functionality.
  - Searching again to find if there are better components that meet the revised requirements.

The CBSE process



The component identification process



Component identification issues

- Trust. You need to be able to trust the supplier of a component. At best, an untrusted component may not operate as advertised; at worst, it can breach your security.
- Requirements. Different groups of components will satisfy different requirements.
- Validation.
  - The component specification may not be detailed enough to allow comprehensive tests to be developed.
  - Components may have unwanted functionality. How can you test this will not interfere with your application?

Ariane launcher failure

- In 1996, the 1st test flight of the Ariane 5 rocket ended in disaster when the launcher went out of control 37 seconds after take off.
- The problem was due to a reused component from a previous version of the launcher (the Inertial Navigation System) that failed because assumptions made when that component was developed did not hold for Ariane 5.
- The functionality that failed in this component was not required in Ariane 5.

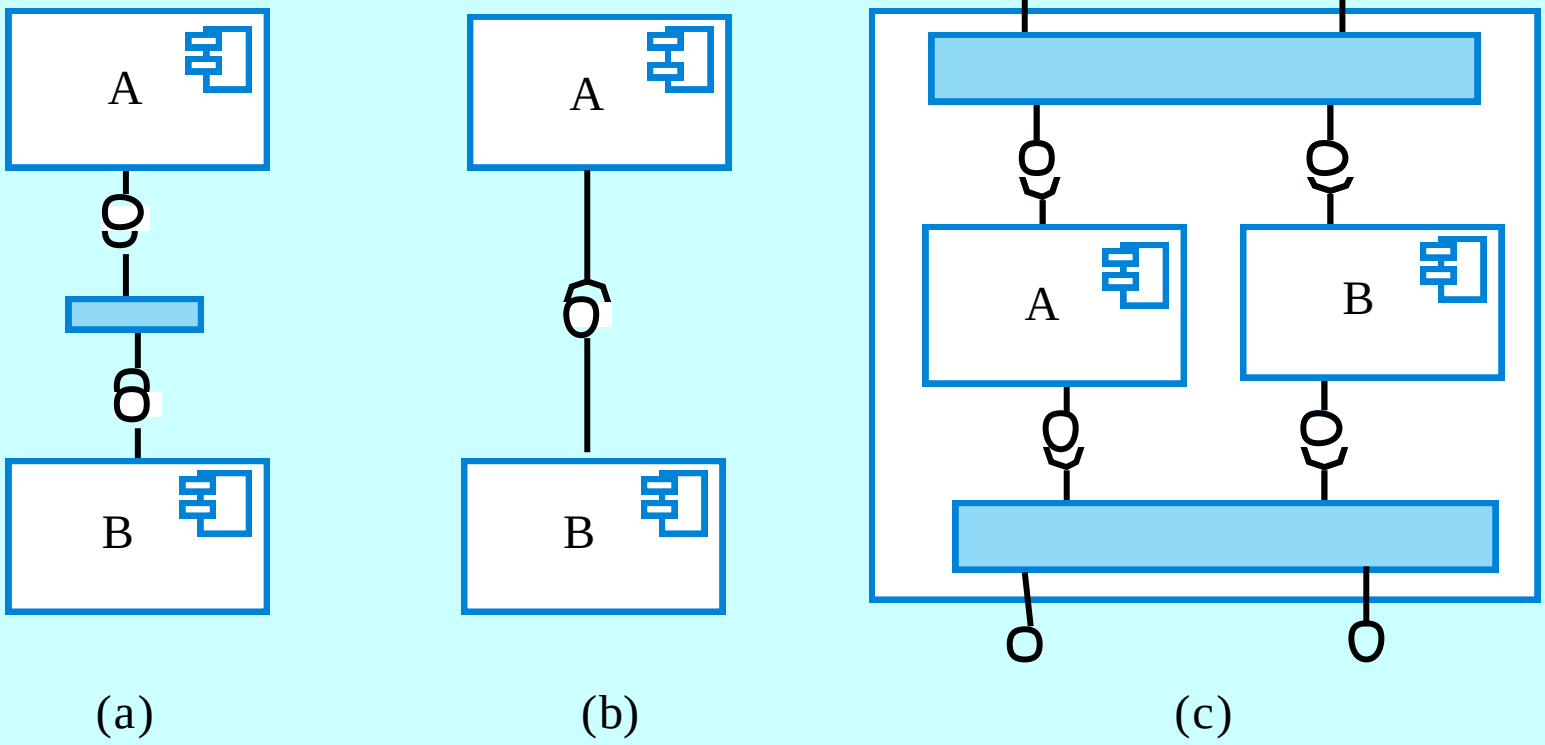
Component composition

- The process of assembling components to create a system.
- Composition involves integrating components with each other and with the component infrastructure.
- Normally you have to write ‘glue code’ to integrate components.

Types of composition

- Sequential composition where the composed components are executed in sequence. This involves composing the provides interfaces of each component.
- Hierarchical composition where one component calls on the services of another. The provides interface of one component is composed with the requires interface of another.
- Additive composition where the interfaces of two components are put together to create a new component.

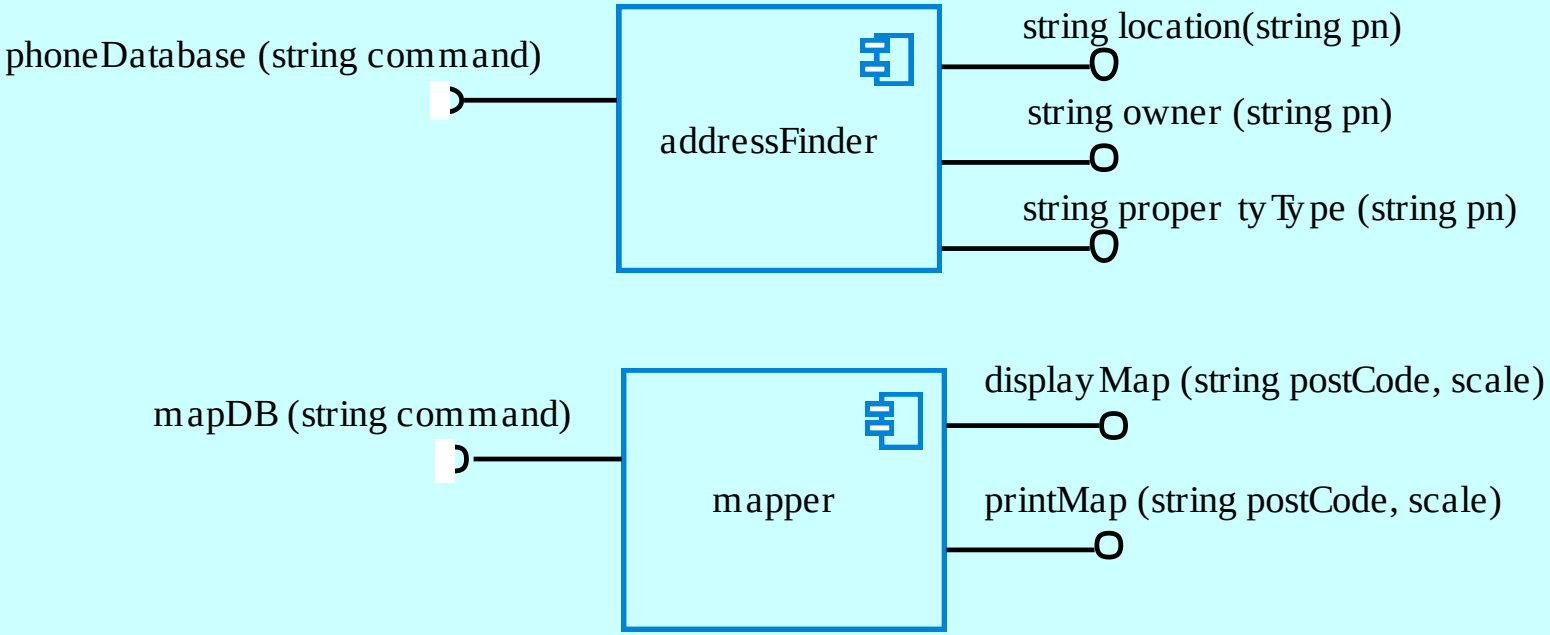
Types of composition



Interface incompatibility

- Parameter incompatibility where operations have the same name but are of different types.
- Operation incompatibility where the names of operations in the composed interfaces are different.
- Operation incompleteness where the provides interface of one component is a subset of the requires interface of another.

Incompatible components



Adaptor components

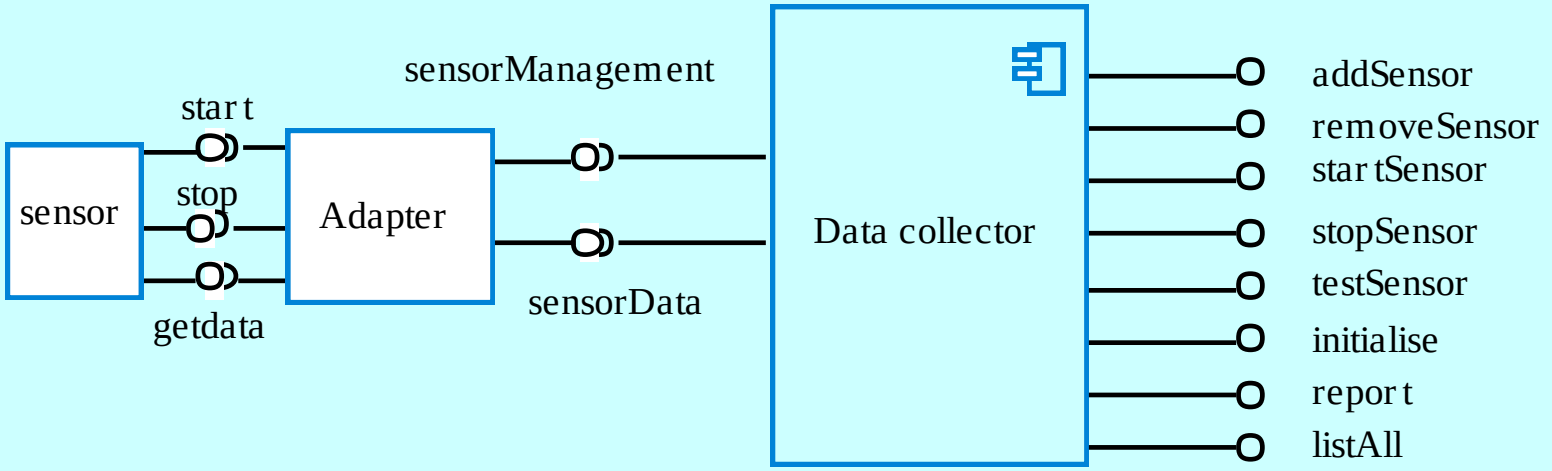
- Address the problem of component incompatibility by reconciling the interfaces of the components that are composed.
- Different types of adaptor are required depending on the type of composition.
- An addressFinder and a mapper component may be composed through an adaptor that strips the postal code from an address and passes this to the mapper component.

Composition through an adaptor

- The component postCodeStripper is the adaptor that facilitates the sequential composition of addressFinder and mapper components.

```
address = addressFinder.location (phonenumber) ;
postCode = postCodeStripper.getPostCode (address) ;
mapper.displayMap(postCode, 10000)
```

Adaptor for data collector



Interface semantics

- You have to rely on component documentation to decide if interfaces that are syntactically compatible are actually compatible.
- Consider an interface for a PhotoLibrary component:

```
public void addItem (Identifier pid ; Photograph p; CatalogEntry photodesc) ;
public Photograph retrieve (Identifier pid) ;
public CatalogEntry catEntry (Identifier pid) ;
```

Photo library composition

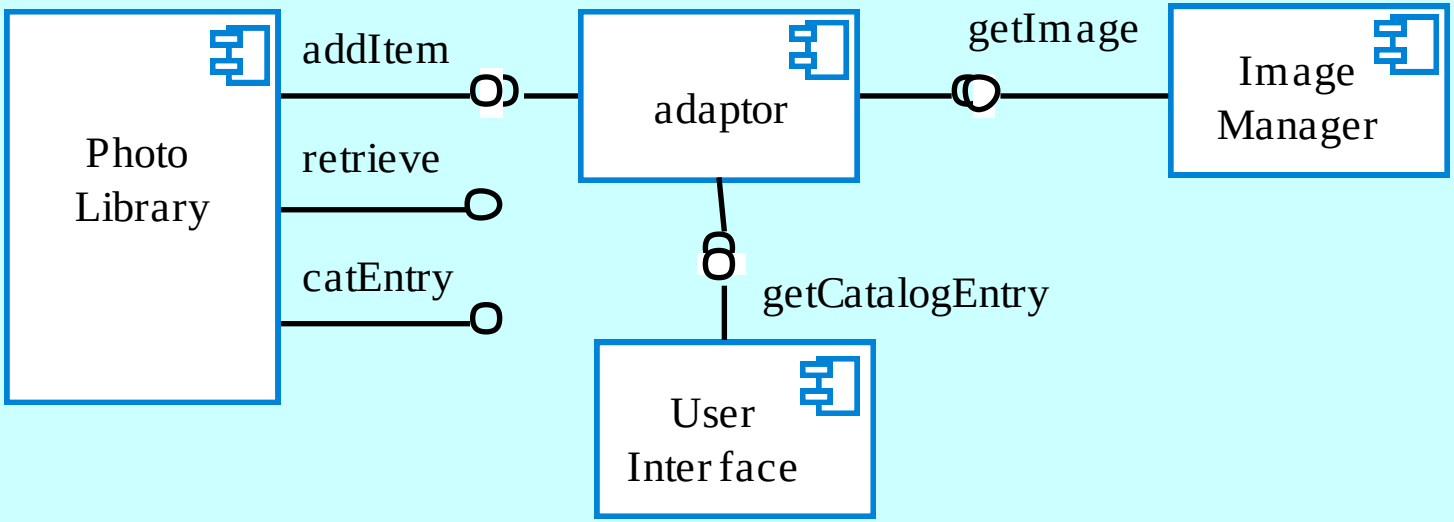


Photo Library documentation

"This method adds a photograph to the library and associates the photograph identifier and catalogue descriptor with the photograph."

"what happens if the photograph identifier is already associated with a photograph in the library?"
"is the photograph descriptor associated with the catalogue entry as well as the photograph i.e. if I delete the photograph, do I also delete the catalogue information?"

The Object Constraint Language

- The Object Constraint Language (OCL) has been designed to define constraints that are associated with UML models.
- It is based around the notion of pre and post condition specification - similar to the approach used in Z as described in Chapter 10.

Formal description of photo library

```
-- The context keyword names the component to which the conditions apply
context addItem

-- The preconditions specify what must be true before execution of addItem
pre:    PhotoLibrary.libSize() > 0
        PhotoLibrary.retrieve(pid) = null

-- The postconditions specify what is true after execution
post:   libSize () = libSize()@pre + 1
        PhotoLibrary.retrieve(pid) = p
        PhotoLibrary.catEntry(pid) = photodesc

context delete

pre: PhotoLibrary.retrieve(pid) <> null ;

post: PhotoLibrary.retrieve(pid) = null
      PhotoLibrary.catEntry(pid) = PhotoLibrary.catEntry(pid)@pre
      PhotoLibrary.libSize() = libSize()@pre - 1
```

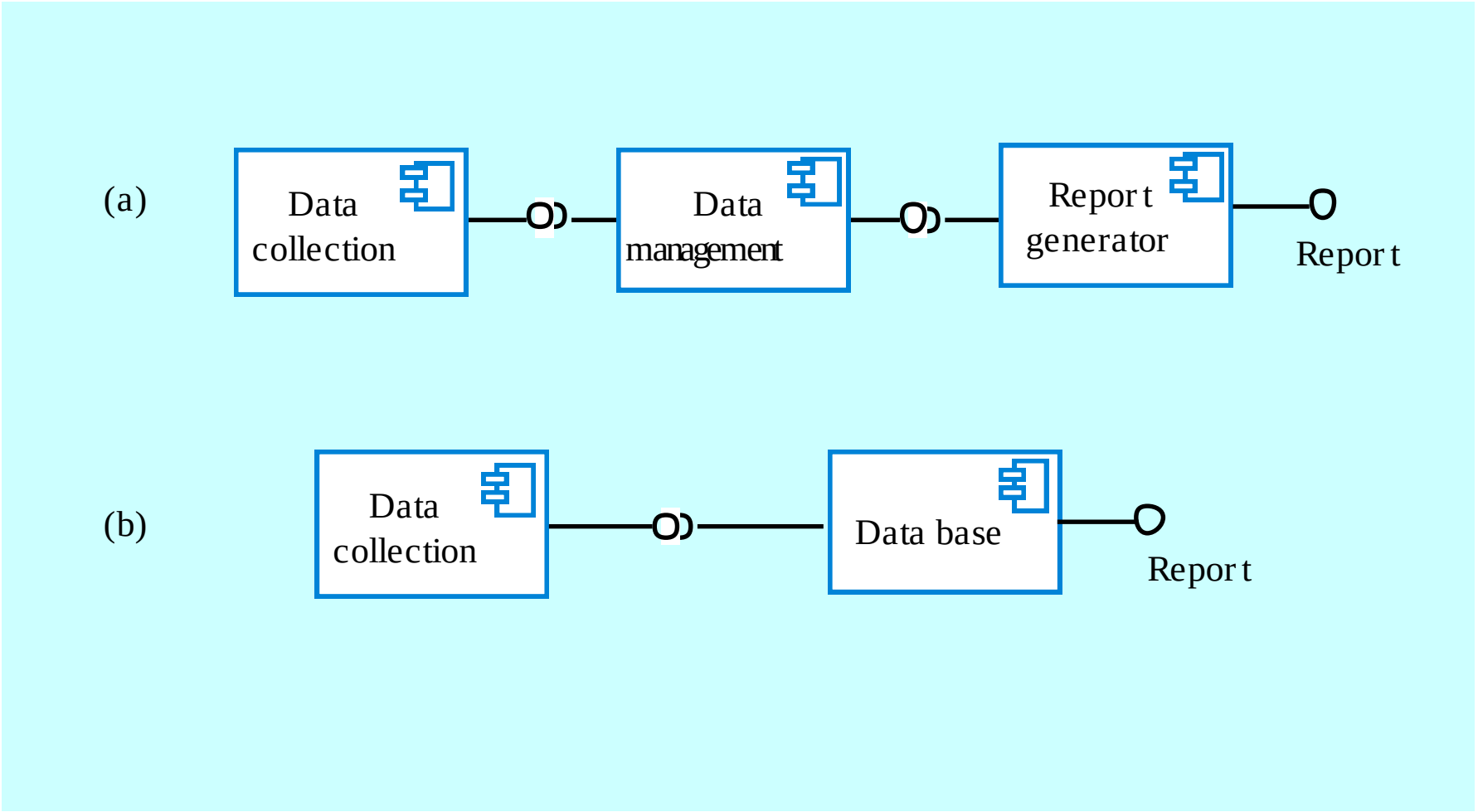
Photo library conditions

- As specified, the OCL associated with the Photo Library component states that:
  - There must not be a photograph in the library with the same identifier as the photograph to be entered;
  - The library must exist - assume that creating a library adds a single item to it;
  - Each new entry increases the size of the library by 1;
  - If you retrieve using the same identifier then you get back the photo that you added;
  - If you look up the catalogue using that identifier, then you get back the catalogue entry that you made.

Composition trade-offs

- When composing components, you may find conflicts between functional and non-functional requirements, and conflicts between the need for rapid delivery and system evolution.
- You need to make decisions such as:
  - What composition of components is effective for delivering the functional requirements?
  - What composition of components allows for future change?
  - What will be the emergent properties of the composed system?

Data collection and report generation



Key points

- CBSE is a reuse-based approach to defining and implementing loosely coupled components into systems.
- A component is a software unit whose functionality and dependencies are completely defined by its interfaces.
- A component model defines a set of standards that component providers and composers should follow.
- During the CBSE process, the processes of requirements engineering and system design are interleaved.

Key points

- Component composition is the process of ‘wiring’ components together to create a system.
- When composing reusable components, you normally have to write adaptors to reconcile different component interfaces.
- When choosing compositions, you have to consider required functionality, non-functional requirements and system evolution.