

# Error and Exception Handling



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**ADAP B05**

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# Agenda

1. The common bug
2. A system model
3. Error detection
4. Error signaling
5. Error handling
6. Service failure

Homework

# Focus

In this lecture, we focus on a subset of [A+04], specifically

- Errors caused by software faults that are
  - Always development, internal, human-made faults
  - Typically non-malicious, non-deliberate
- Error detection by concurrent detection
- Error handling using any matching strategy

In other words, errors caused by the common bug

[A+04] Avižienis, A., Laprie, J. C., Randell, B., & Landwehr, C. (2004). Basic concepts and taxonomy of dependable and secure computing. IEEE Transactions on Dependable and Secure Computing 1(1), 11-33.

# **1. The Common Bug**

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# Catching the Common Bug

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Best done during development (earlier is better)

But you can't avoid errors at runtime

# Deliberately Bad Java Example [1]

```
public int readInt(File f, Buffer b) throws ParseException {
    int result = 0;
    try {
        FileInputStream fis = new FileInputStream(f);
        fis.read(b);
        result = Integer.parseInt(b.toString());
    } catch (Exception ex) {
        // do nothing
    }
    if (result == 0) {
        // there should never be "0" in file
        System.out.println("something went wrong!");
        return -1;
    }
    return result;
}
```

# Things Wrong With Example

## General programming errors

- Unclear preconditions; no assertions
- No need for external buffer variable
- No clean-up after resource use

## Specific bad practices of error handling

- Overloading of purpose of return value
- Mismatch between method signature and behavior
- System exception swallowed without logging
- Inconsistent use of error codes and exceptions
- Unprofessional logging / error message useless

# Dependability and Fault Tolerance

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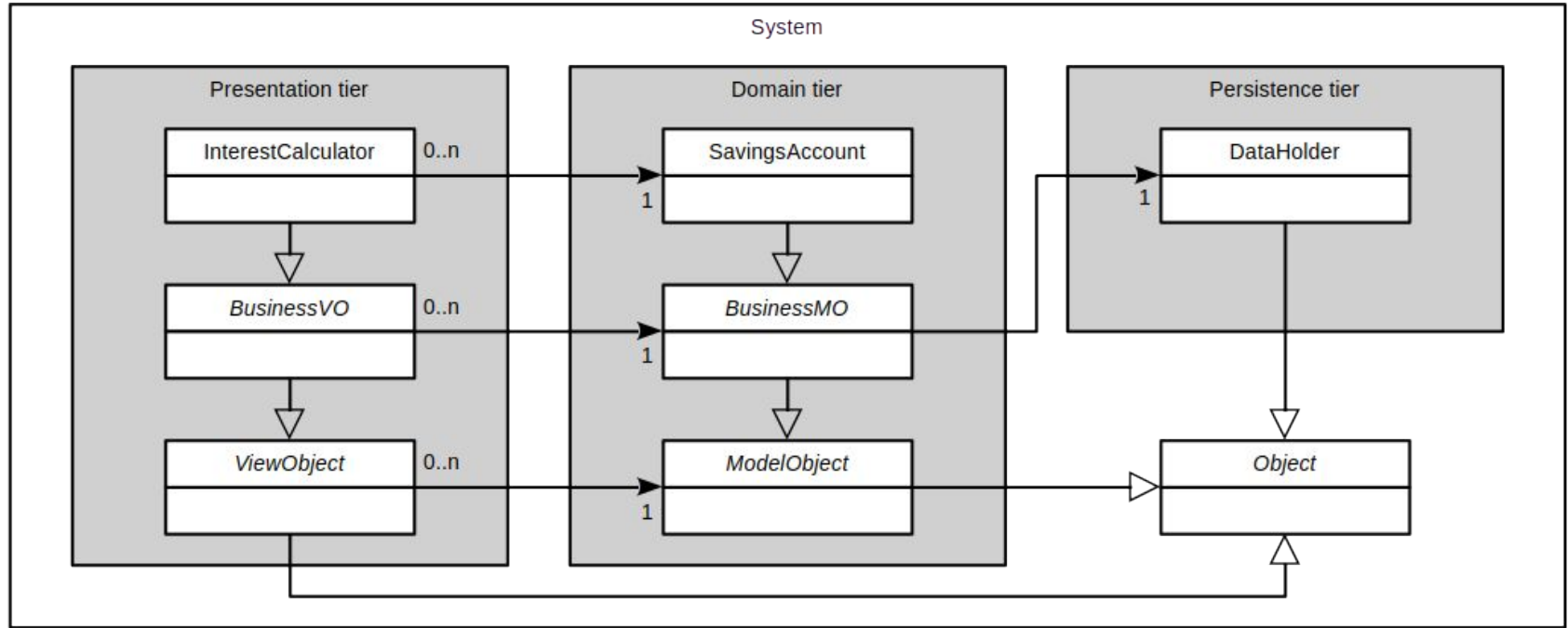
If bugs are inevitable, how to handle them?



## **2. A System Model**



# System Architecture (Runtime Tiers)



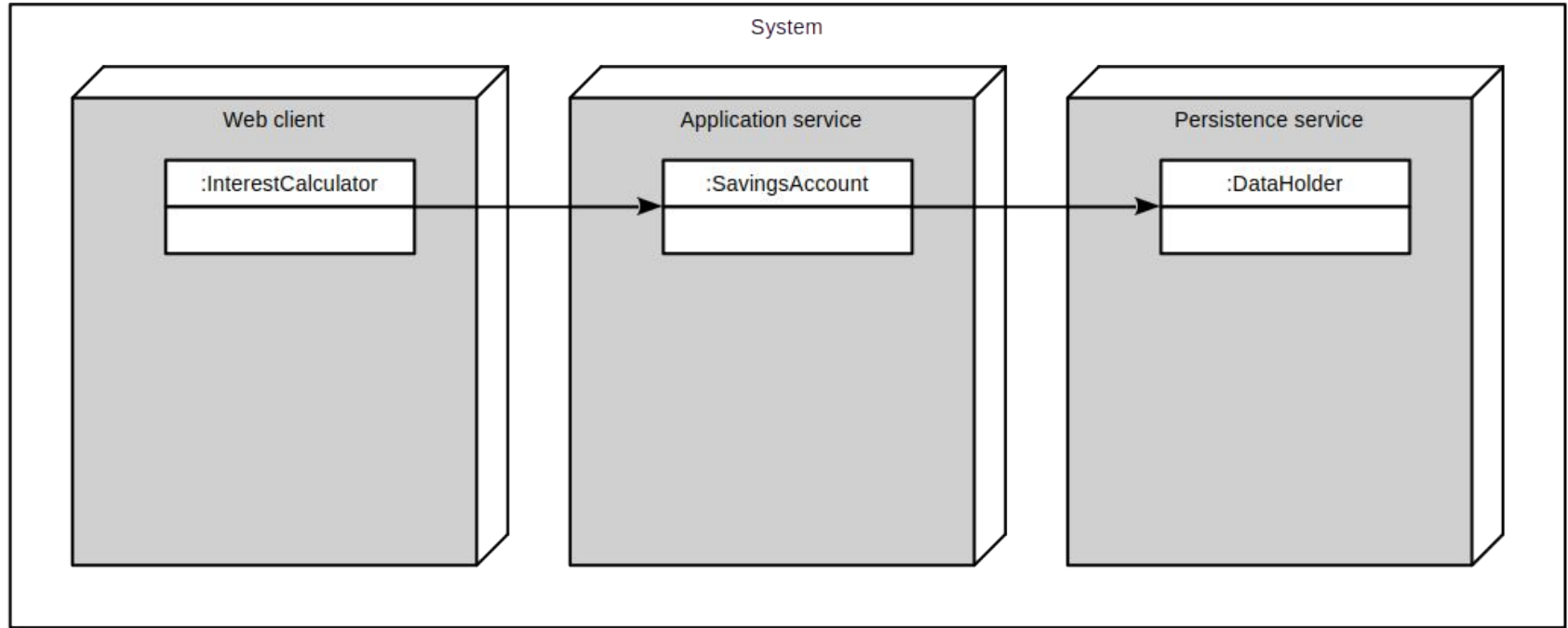
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# How Many Objects at Runtime? [1]



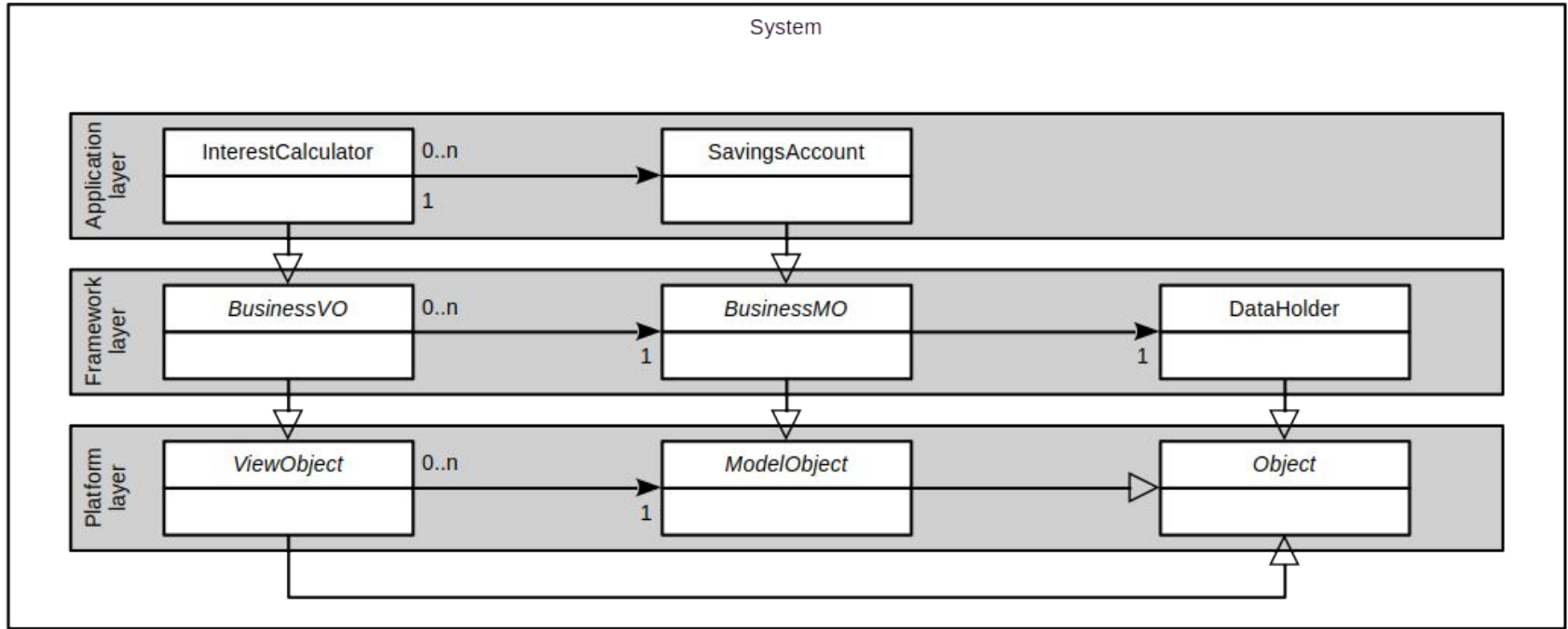
[1] Also <https://forms.gle/aV3yF6KTM1odzJRFA>

# Runtime Objects



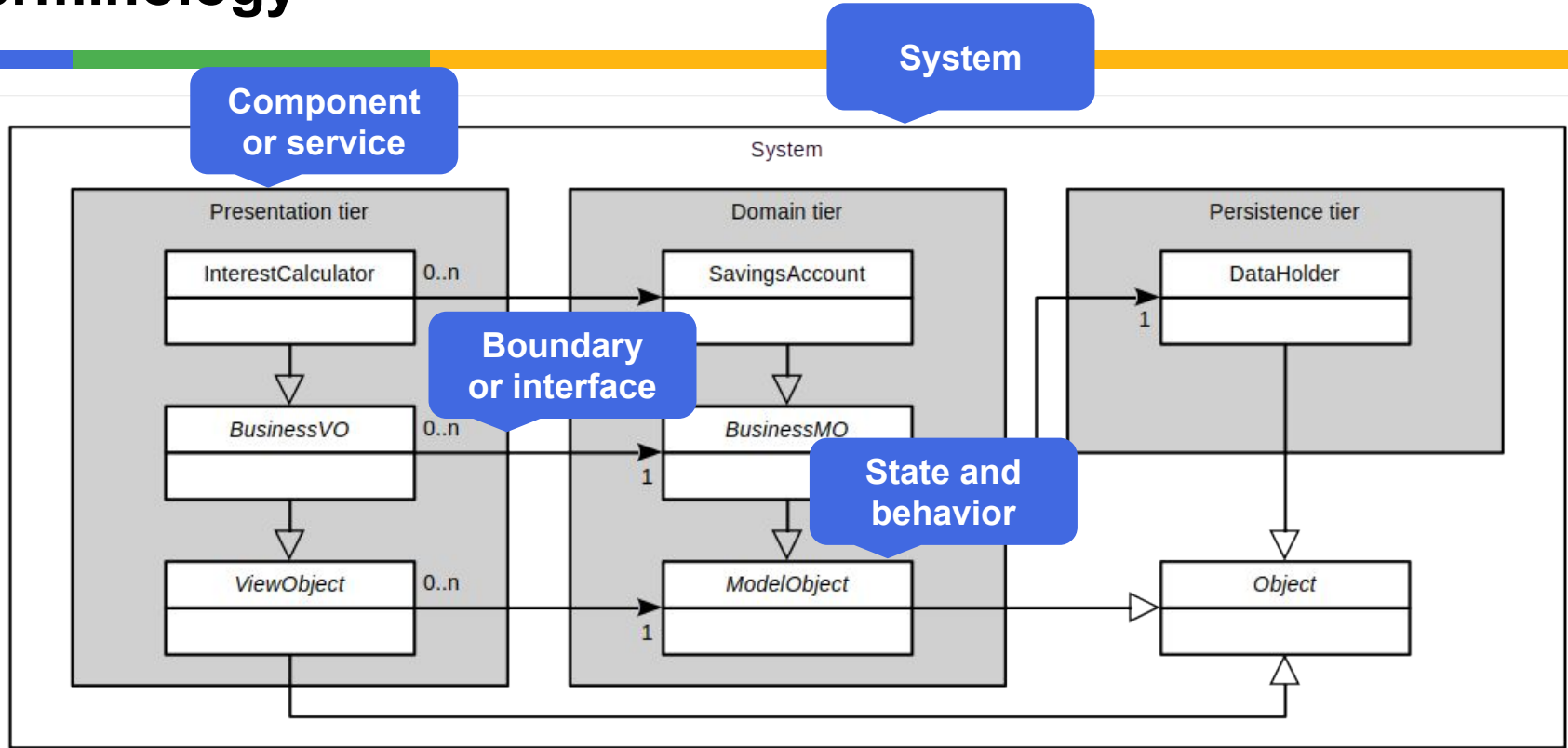
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# Code Layers



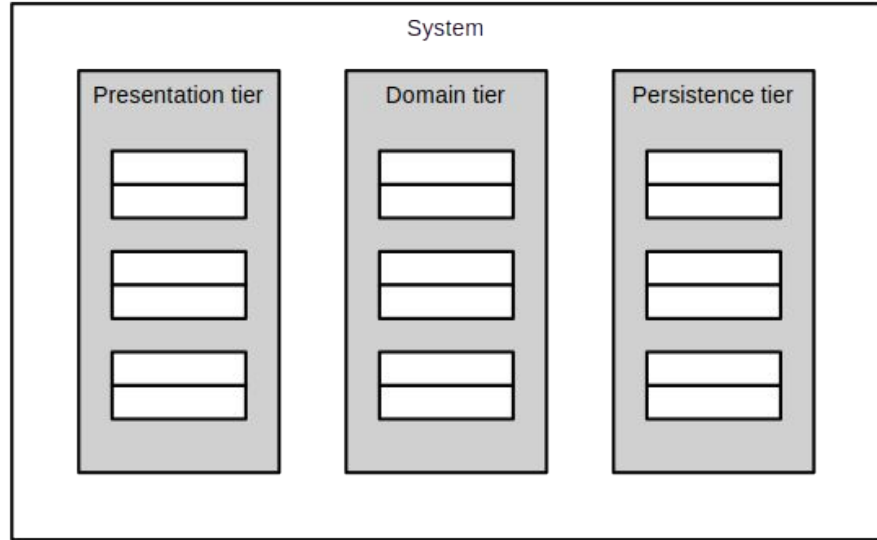
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# Terminology



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# Operator (User) Interaction [1]



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# System Terminology

- A runtime component is
  - Some runtime data encapsulated (bounded) by an interface
  - Typically does not stand alone and cannot be deployed independently
- A service is a runtime component that
  - Has business value and maybe composed of other components
  - Typically does not stand alone (has clients), but can be deployed independently
- A system
  - Is a combination of services and operators (yeah, really)
  - Has business value and has stakeholders to who this value accrues
- Operators are stakeholders but not all stakeholders are operators



# Fault

A fault is

- A condition that can cause an error
  - A fault is **dormant**, if it has not yet caused an error
  - A fault is **active**, if it causes an error

A fault

- Can be classified by eight independent dimensions [A+04]

# Fault Classification

	Option 1	Option 2
Phase of creation / occurrence	Developmental	Operational
System boundaries	Internal	External
Phenomenological cause	Natural	Human-made
Dimension	Hardware	Software
Objective	Malicious	Non-malicious
Intent	Deliberate	Non-deliberate
Capability	Accidental	Incompetence
Persistence	Permanent	Transient

# How to Classify the Common Bug? [1]



[1] Also <https://forms.gle/DuNNXR2VghcaRHK48>

# Error

An error is

- A state of the system that may lead to a failure
  - An error is **latent**, if it has not been detected
  - An error has been **detected**, if regular code identifies an erroneous state

An error

- Can be categorized by the failures it may cause

# Failure

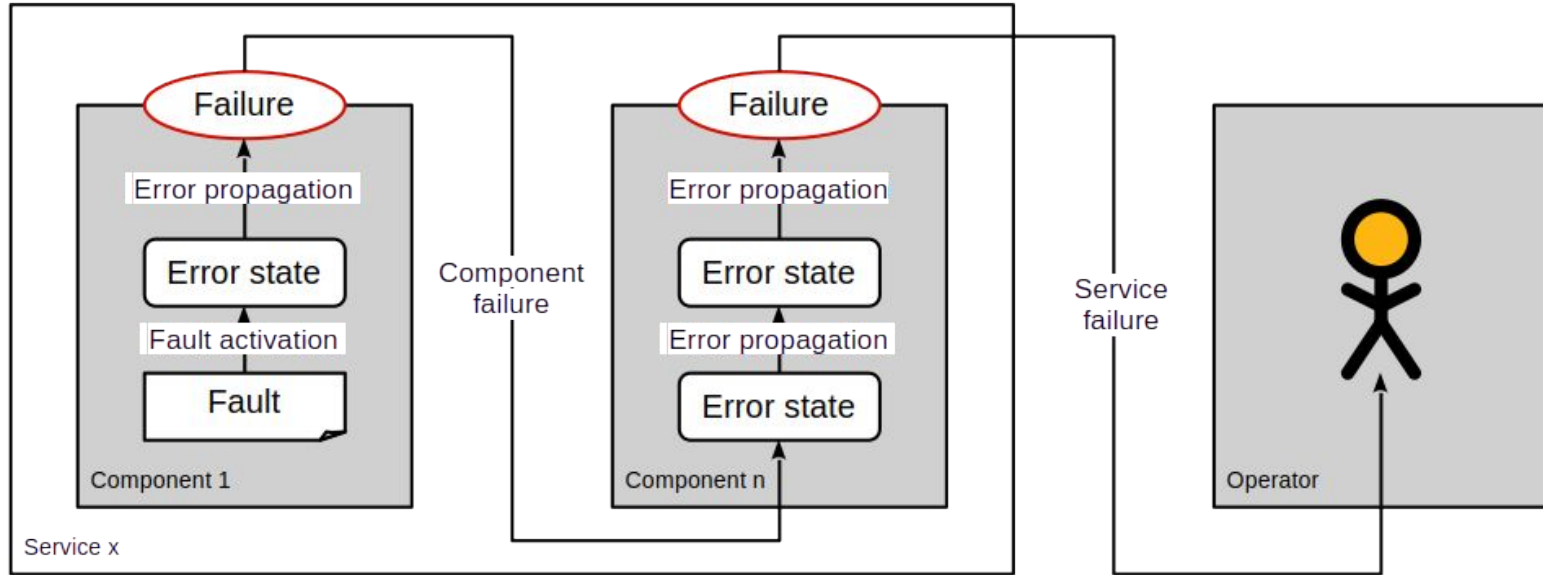
A failure is

- An event that transitions the system from correct to incorrect service

A failure

- Has a (failure) mode
- Can be categorized by four independent dimensions
  - Domain (content, early timing, late timing, halt, and erratic failures)
  - Detectability (signaled and unsignaled failures)
  - Consistency (consistent and inconsistent failures)
  - Consequences (minor to catastrophic failures)
- Can be ranked by severity (consequences)

# Illustration of Process that Leads to Service Failure



# Three Steps to Error Handling

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1. Error detection
2. Error signaling
3. Error handling

# 3. Error Detection





# How to Detect an Error (State)

If an error is an erroneous state of the system

- You need to explicitly check for that state

Assertions that fail identify an error (state)

- Assertions are regular code in normal processing state

Use design by contract

# Example Name Instance (= Component) Failure

```
public insert(i: number, c: string): void {
    this.assertIsValidIndex(i);
    this.assertIsProperlyMasked(c);

    const oldNoComponents: number = this.getNoComponents();
    this.doInsert(i, c);

    this.assertClassInvariants();

    const condition: boolean = this.getNoComponents() == (oldNoComponents + 1);
    MethodFailedException.assertCondition(condition);
}
```

# Typical Information to Capture / Gather

## Meta information

- Error id (instance)
- Error type

## Error-specific information

- Stacktrace
- Source objects
- Affected objects
- Explanatory message

# How to Represent Error Information

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- Error codes
- Error objects
- Exceptions

## 4. Error Signaling



# How to Signal an Error?



A detected error state needs to be logged and signaled

Transition the system from normal to abnormal program / processing state

# Normal vs. Abnormal Processing State

## Normal processing state (NPS)

- Method performed its services
- Control flow returns via return statement

## Abnormal processing state (APS)

- Method failed to perform service
- Control flow returns via raising an exception

# Methods for Error Signaling

Using normal control flow (but in abnormal processing state)

- Use return statement but include error code in return value

Using abnormal control flow

- Raise an exception and include information in exception object



# Error Code Conventions

0 = no error

-1 = generic error

1..n = specific error

# Return Objects

A return object is

- An object that provides both
  - A possible error code, if any
  - The actual return results

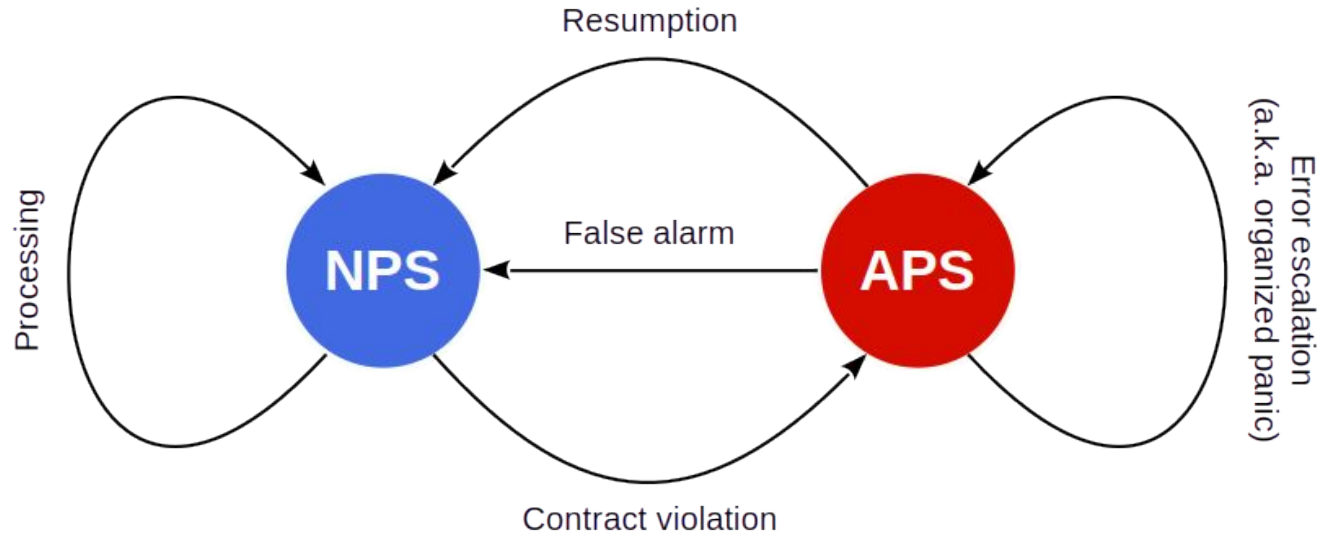
# Error Codes vs. Return Objects vs. Exceptions

	Pros	Cons
Error codes	Simple	Return values need to be passed back separately
Return objects	A solution if you have no good exception mechanism	Mix normal with abnormal processing state
Exceptions	Separate normal with abnormal processing state	—

## 5. Error Handling



# Error Handling State Model



# Error Handling

A false alarm is

- An erroneously identified error state

Resumption is

- When you try again, possibly after fixing something

Escalation (a.k.a. organized panic) is

- When you give up and signal the error to your caller

# How to Handle Component Failures?

```
public read(noBytes: number): Int8Array {
    let result: Int8Array = new Int8Array(noBytes);
    // do something

    let tries: number = 0;
    for (let i: number = 0; i < noBytes; i++) {
        try {
            result[i] = this.readNextByte();
        } catch(exception) {
            tries++;
            // Oh no! What @todo?!
        }
    }

    return result;
}
```

1

```
if (tries == 3) {
    // ignore
}
```

2

```
if (tries == 3) {
    throw exception;
}
```

3

```
if (tries == 3) {
    result = {
        errorCode: -1,
        errorMessage: "couldn't finish"
    }
}
```

4

```
MethodFailedException.assertCondition(tries < 3);
```

# What Should You Do? [1]



[1] Also <https://forms.gle/kw7eHQpnUgTLwnU59>



# How to Escalate an Error

First, clean up

- Leave the component in a viable state
  - Restore component invariants
- Release any unneeded resources
  - Use finally block to ensure this

Then, escalate

- Enhance original error information
  - Keep chaining exceptions

# Checked vs. Unchecked Exceptions

Use unchecked exceptions within a component

- You also can use checked exceptions, but human psychology suggests that you won't be able to follow through

Use checked exceptions at a service's boundary

- Typescript does not have checked exceptions, so you may have to find alternative ways of dealing with service boundaries

## **6. Service Failure**

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# Service Failure

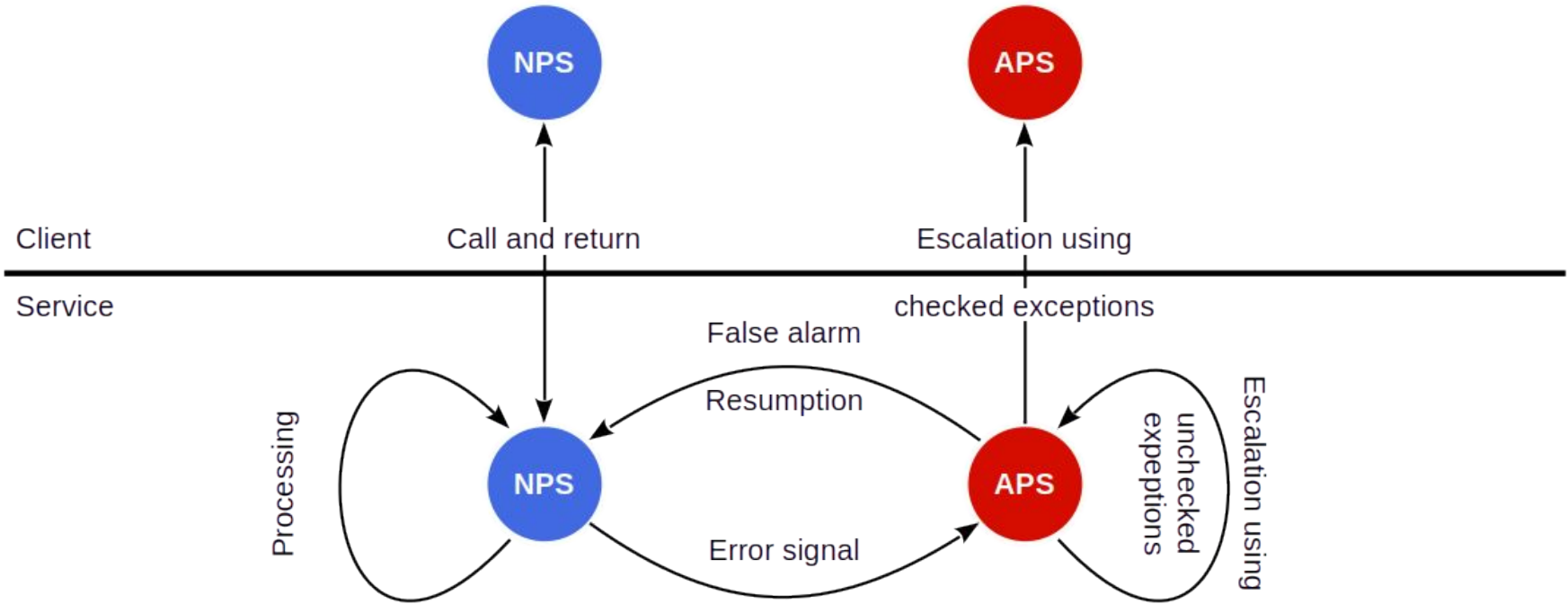
A service failure is a component failure

- At the interface to the calling client

Use checked exceptions to signal service failure

- Only use exceptions specific to the failure

# Client / Service Error Handling State Model



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# Service Failure Exceptions to Use [1]

On the service side, for service failures, use

- `ServiceFailureException`

To be interpreted as a “to check” (checked) exception

# Error Escalation of Failure Signal

On the client side, if you need to escalate a service failure

- Wrap the checked exception in an unchecked exception

The game may repeat itself at the next service boundary

# Service Failure at the User (Operator) Interface

Rather than display in text, a checked exception

- Convert the error into human-readable form and display it



Sorry!  
We will be back soon.

**Don't panic.** It's not you, it's us.

Most likely, our engineers are updating the code, and it should take a minute for the new code to load into memory.

Try refreshing after a minute or two.



# Homework

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# Homework

- Implement findNodes() for the Node class hierarchy
  - View a file system as a service with the root node as its interface
  - View the names as just a component used within the file system
- Make the buggy file setup test work as intended
  - Please see the injected fault in BuggyFile.ts
  - No need to complete the file implementations
- Adapt your previous work to this homework as you see fit
- Commit homework by deadline to homework repository

# The Final Word on Exceptions

```
let up: Exception = new Exception("something is wrong");  
throw up; // haha
```

# Summary

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1. The common bug
2. A system model
3. Error detection
4. Error signaling
5. Error handling
6. Service failure

# Thank you! Any questions?



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