Modelling Safety-Critical Java Level 2 in *Circus*

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Outline

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Introduction

Aims

- Produce a model of the SCJ Level 2 paradigm
- Devise a formal translation strategy to convert SCJ Level 2 programs to this model

SCJ Level 2

SCJ Level 2 Features

- Concurrent Missions with concurrent Managed Schedulables
- Level 1 Managed Schedulables: `PeriodicEventHandler`, `AperiodicEventHandler`, `OneShotEventHandler`
- Level 2 Managed Schedulables: *`ManagedThread`*, *`MissionSequencer`*
- Access to `Object.wait` and `Object.notify`

SCJ Level 2

Mission Sequencers as Schedulables

- Mission Sequencers may be nested inside Missions
- Nested Mission Sequencers allow multiple Missions to be active...
  - One active Mission per Mission Sequencer
  - Managed Schedulable Objects from any running Mission may preempt, based on their priorities
  - No assumption of Schedulable Objects from a particular mission having priority

SCJ Level 2

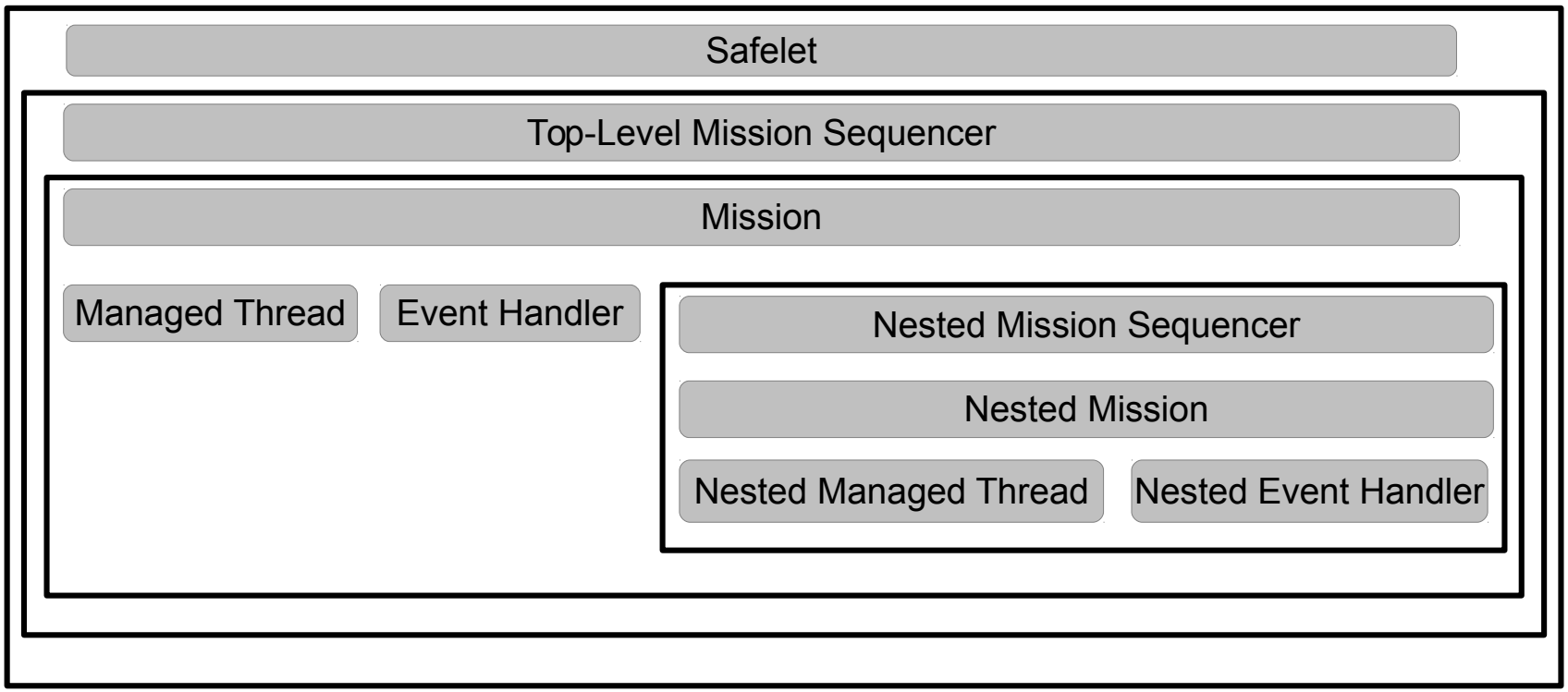


Figure 1: Possible Structure of a Level 2 Program

SCJ Level 2

Spacecraft Example

- Three modes: Launch, Cruise, Land
- Each has its own specific Schedulable Objects
- There are also Schedulable Objects which run throughout all the modes...
  - Monitoring the craft's environment
  - Handling the craft's controls

SCJ Level 2

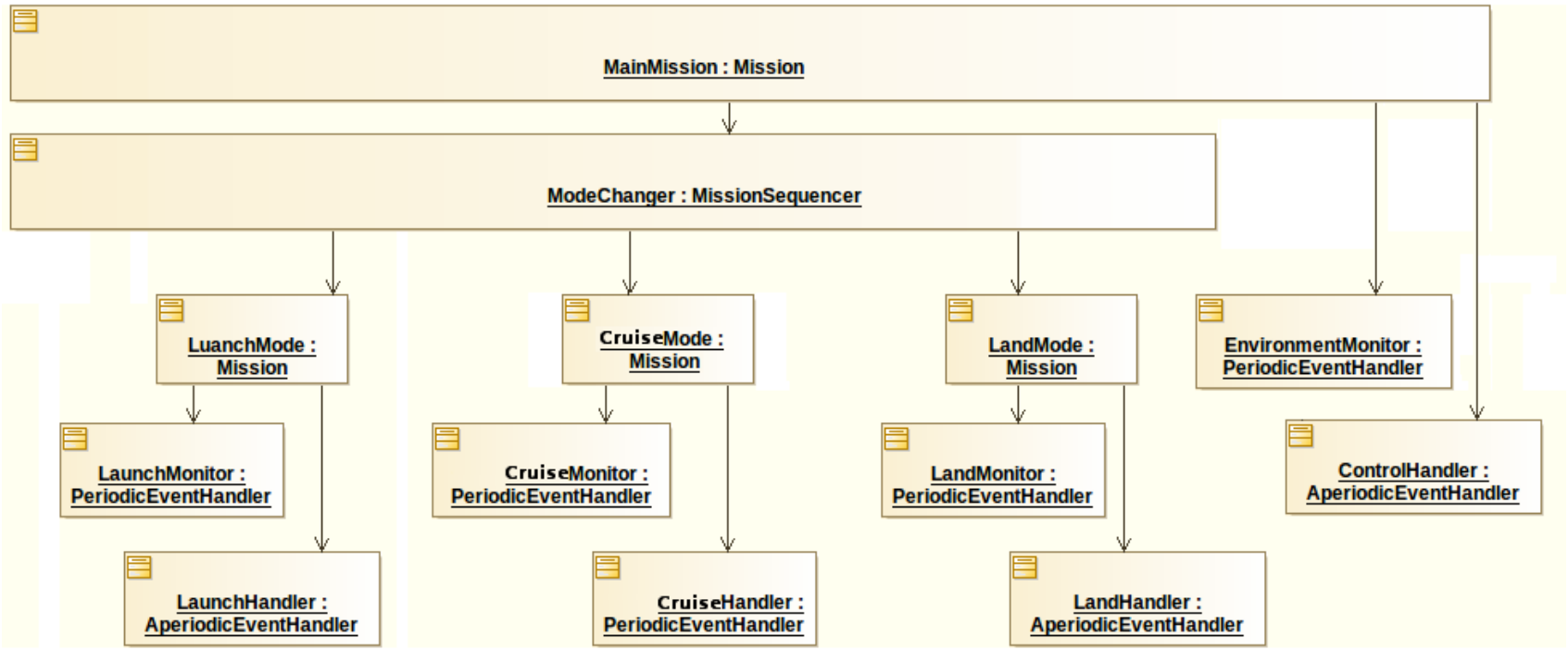


Figure 2: Object Diagram of the Spacecraft example application

Circus Family

Circus Language

- Combination of **Z** and **CSP**
  - Captures both State and Behaviour
- Organised around Processes
  - Similar to Java classes
  - State component (**Z**) to hold variables
  - Actions (free combination of **Z** and **CSP**) to perform behaviours
  - Main action to specify the overall behaviour of the process
  - Communication through **CSP** channels
    - $channel \longrightarrow A$
    - $channel.parameter \longrightarrow A$

Circus Family

Circus Variants

Our model also uses features from other members of the *Circus* family

- *OhCircus*...
  - Classes based on Java classes
  - Inheritance
  - Used to model simple data objects in the Application Model
- *Circus* Time
  - Notion of (relative) time
  - $\mathbf{wait}\ t$
  - $channel@time \longrightarrow A$

Circus Family

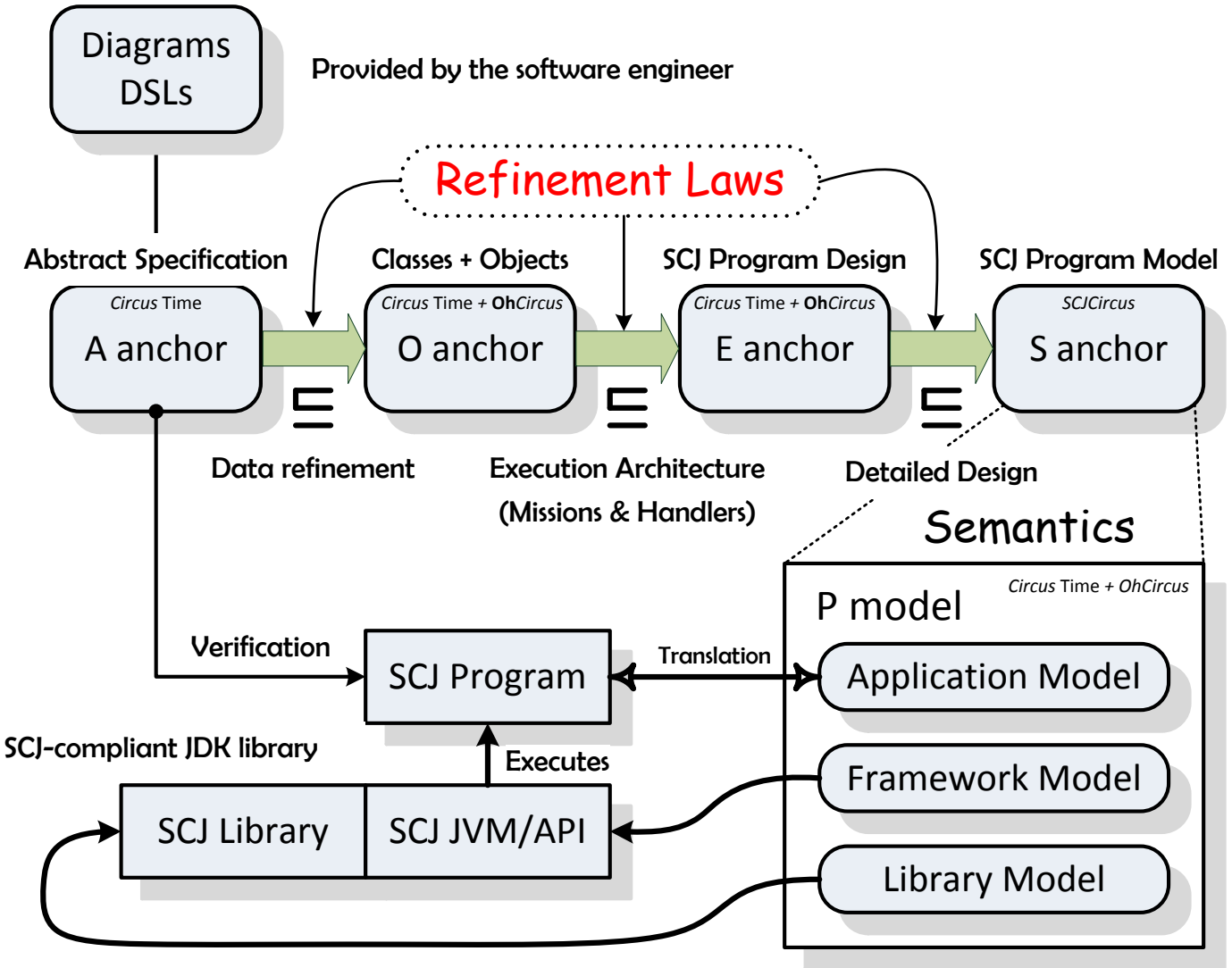
However...

- Model checker for *Circus* still in development
- Leads to converting *Circus* specifications into **Z** and **CSP**...
  - using ProB to check the **Z**
  - using FDR to check the **CSP**
- Causes obvious overheads

Why Use *Circus*?

- Previous work using *Circus* and Java/SCJ...
  - Existing model of SCJ Level 1
- Refinement-based development

Context of Work



Context of Work

Top-Down

Target for refinement-based development of SCJ programs

- Refinement from abstract to concrete specifications...
  - Concrete specifications that capture the SCJ paradigm
- Correctness by construction

Bottom-Up

Allows translation from SCJ code to model

- Catches certain program errors...
  - Deadlock
  - Divergence
  - Some exceptions
- Will not catch memory errors

Modelling Challenges

SCJ Challenges

- Changing or untested language specification
- Complexity of the unique features of Level 2
- No complete Level 2 implementation...
  - Use RTSJ to simulate SCJ structure
  - 'Flatten' programs with nested missions to test them using a Level 1 implementation

Circus Challenges

- Model checker still in development so convert to CSP...
  - Feature set does not match that of *Circus*
  - Modelling state becomes complicated
    - Large state process to model variables
    - Allows remote access to a process' state

Developing the Model

Approach

- Based on current Level 1 model
- Separate model of SCJ into...
  - **Framework**, which captures the infrastructure classes
  - **Application**, which captures application-specific code using...
    - *Circus* processes
    - *OhCircus* classes
- Translation strategy to capture the application-specific information and output the Application model
- Tool to automate this translation

Developing the Model

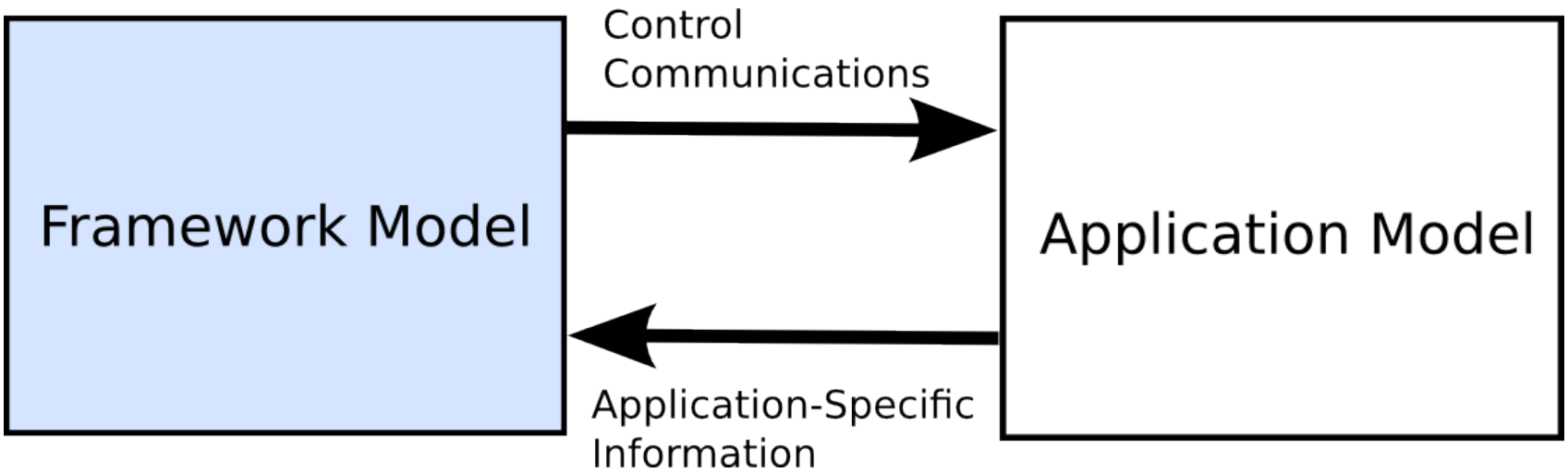


Figure 3: High-Level Framework and Application Models

Developing the Model

Coverage

- Model ignores...
  - Priorities
  - Resources (E.g. Memory)
- Model Captures...
  - Behaviour and State of Objects
  - Limited treatment of some Exceptions
- Exceptions ...
  - Causes $\mathbf{Chaos}$ in the specification
    - Built-in process that diverges
  - Memory Exceptions not covered

Developing the Model

Object model

- Each object is modelled by up to four components...
  - **Object**: concerns derived from `Object`
    - If the class is used as a lock
  - **Thread**: identifies the thread of control
    - If the class has a controlling thread
  - **Framework**: concerns of the SCJ class being extended
  - **Application**: program-specific information
- Composed to form one process
  - Parametrised with an ID
- If a class has two instances, each has its own model

Developing the Model

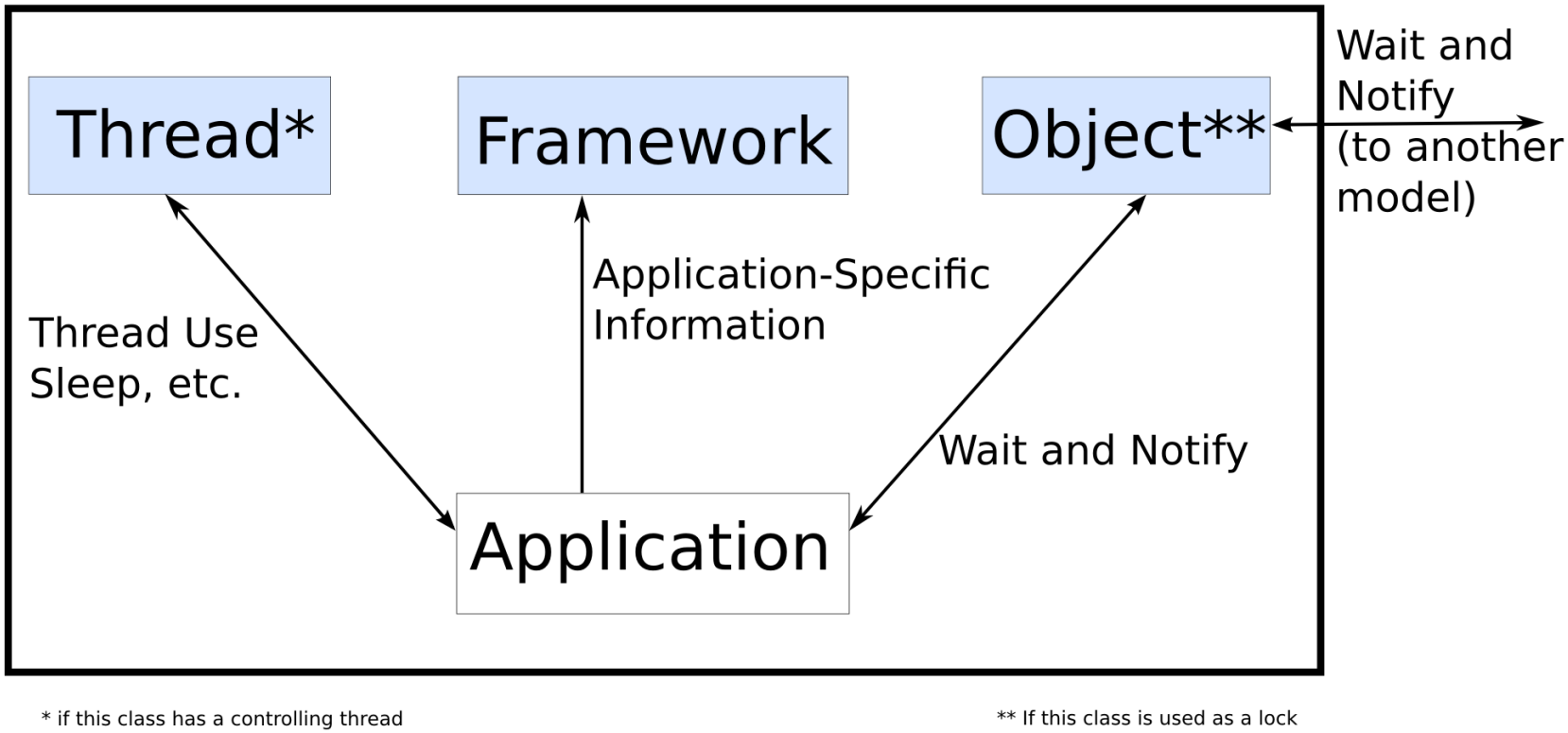


Figure 4: Potential components of an Object's Model

Developing the Model

Communication

- Free communication across each model and between Framework and Application models
- Components communicate with components that are...
  - Of a different type
    - Querying concrete information
    - E.g. Mission Sequencer Framework communicating with the Mission Sequencer Application to get the next mission
  - Of the same type
    - Objects communicating with other Objects
    - E.g. Mission Sequencer Framework calling the Mission Framework's `Initialize` action

Developing the Model

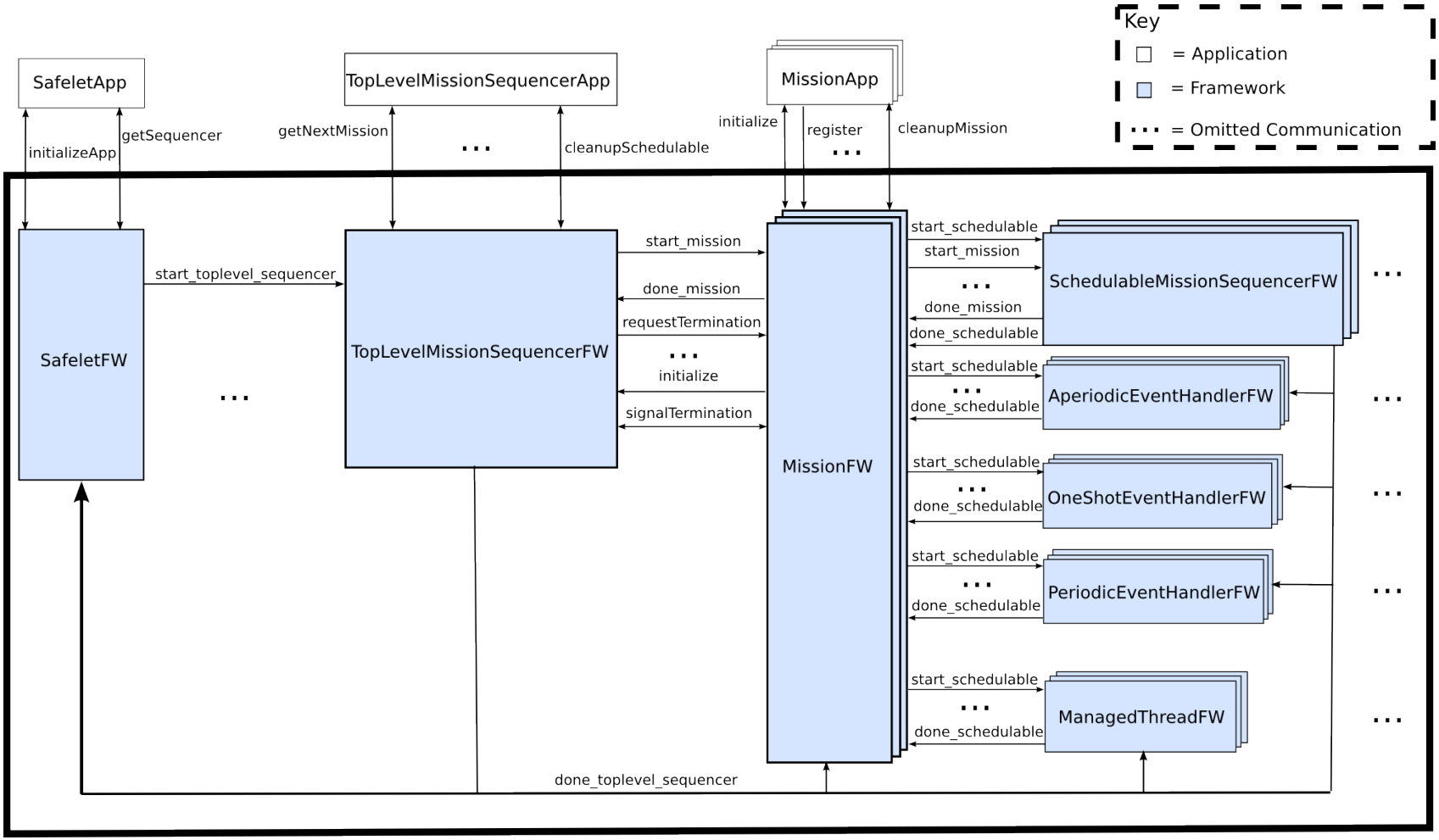


Figure 5: Framework Processes structure

Developing the Model

Model

- Framework model in Figure 5 remains the same for each program
- Application model is similar but is generated afresh for each program
- Translation strategy only needs to extract application-specific information from the program

Summary and Further Work

Summary

- Model SCJ Level 2 paradigm as **Framework** and **Application** combination
- Model of SCJ Level 2 contributes to ...
  - **Top-down** development as a refinement target
  - **Bottom-up** development as verification tool

Further Work

- Devise Application model
- Translation strategy to convert application code to Application model
- Tool to automate translation

Thank you for listening.
Any Questions?