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Development of a state machine sequencer for the Keck Interferometer: evolution, development & lessons learned using a CASE tool approach

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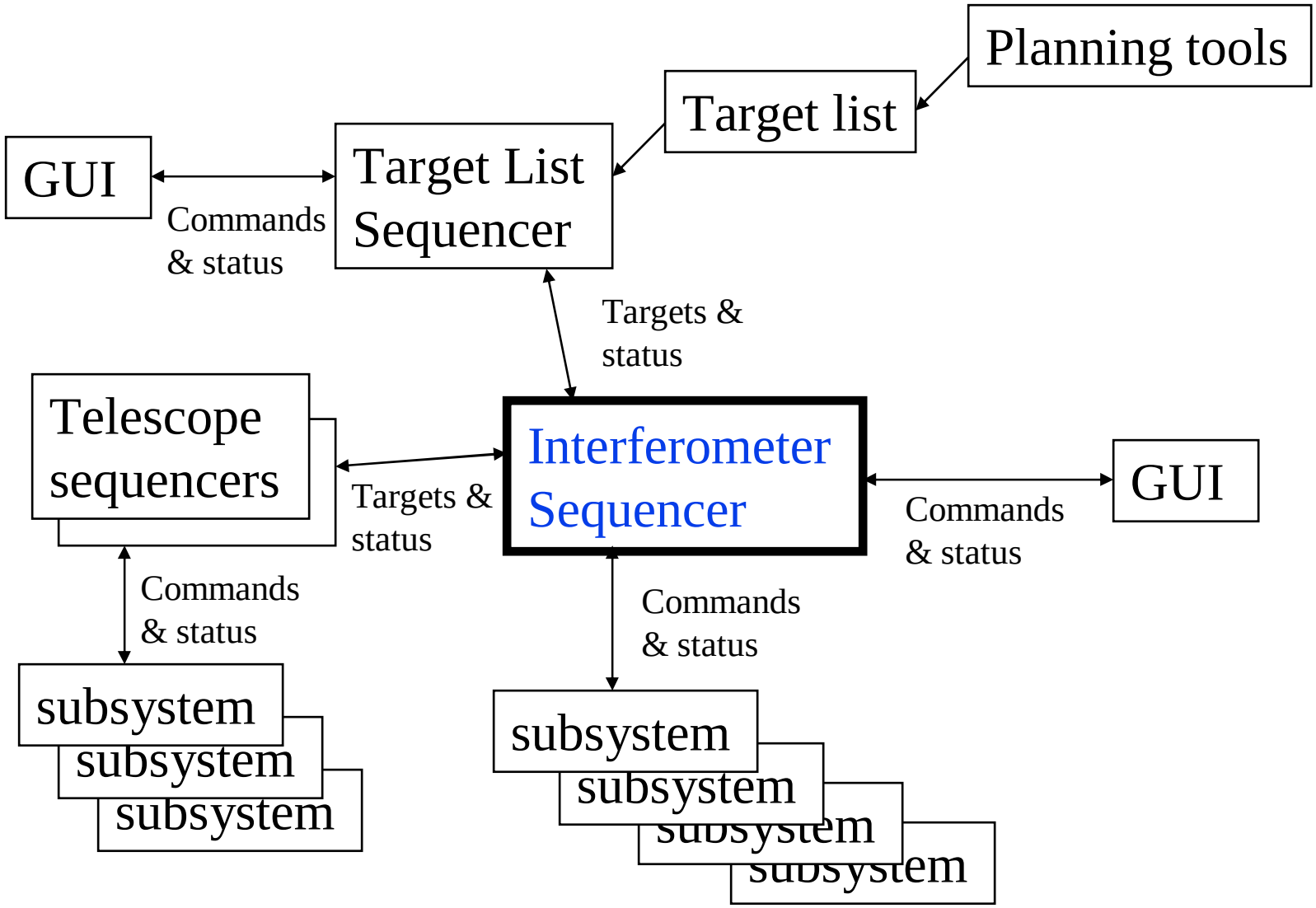
Keck Interferometer

- 2 Keck 10m telescopes with full adaptive optics
- Wavelengths 1.2 um to 10 um
  (AO operates in visible)
- Science: nulling, differential phase, astrometry, imaging
- First fringes with Keck Telescopes March, 2001

What I will talk about

- Interferometer (IF) Sequencer within overall software
- What is the CASE Tool?
- Interferometer Major Components
- Rhapsody and IF Sequencer Design
  - Static Class and Harel Statechart Diagrams
- Lessons Learned

Target/Observation Sequencing Hierarchy



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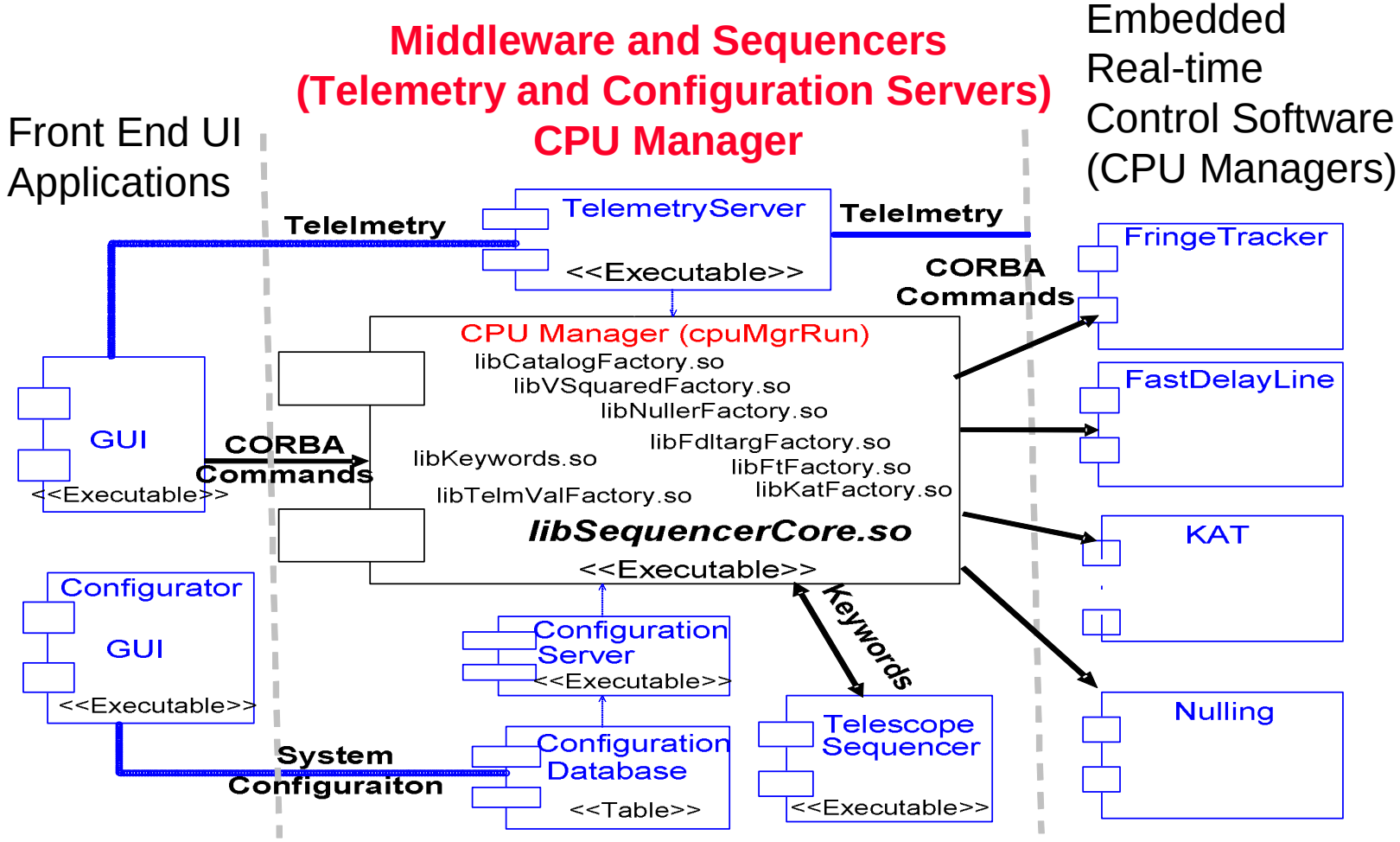
Interferometer Sequencer

- Provide high-level control for observing
  - Send commands via CORBA to JPL RTC software
  - Control Keck Telescope Sequencers via Keywords API
  - Support Science modes: nulling, differential phase, astrometry, imaging (multi-baseline)
- ***State-machine classes running in separate threads***
- Multi-mode Science Ops
  - CPU Manager allows load, instantiate and desroy objects
  - Utilized Rhapsody internal shared infrastructure for state machine to state machine event passing
  - Configurable from common RTC database
  - New more flexible Python GUI using CORBA

Component diagram of IF Sequencer Configuration with JPL RTC Toolkit



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Rhapsody: What is the tool?

- It is a CASE (Computer Aided Software Engineering) Tool

- One uses UML (Unified Modeling Language) to design object structures and state machines

- The tool generates C++ code from the UML

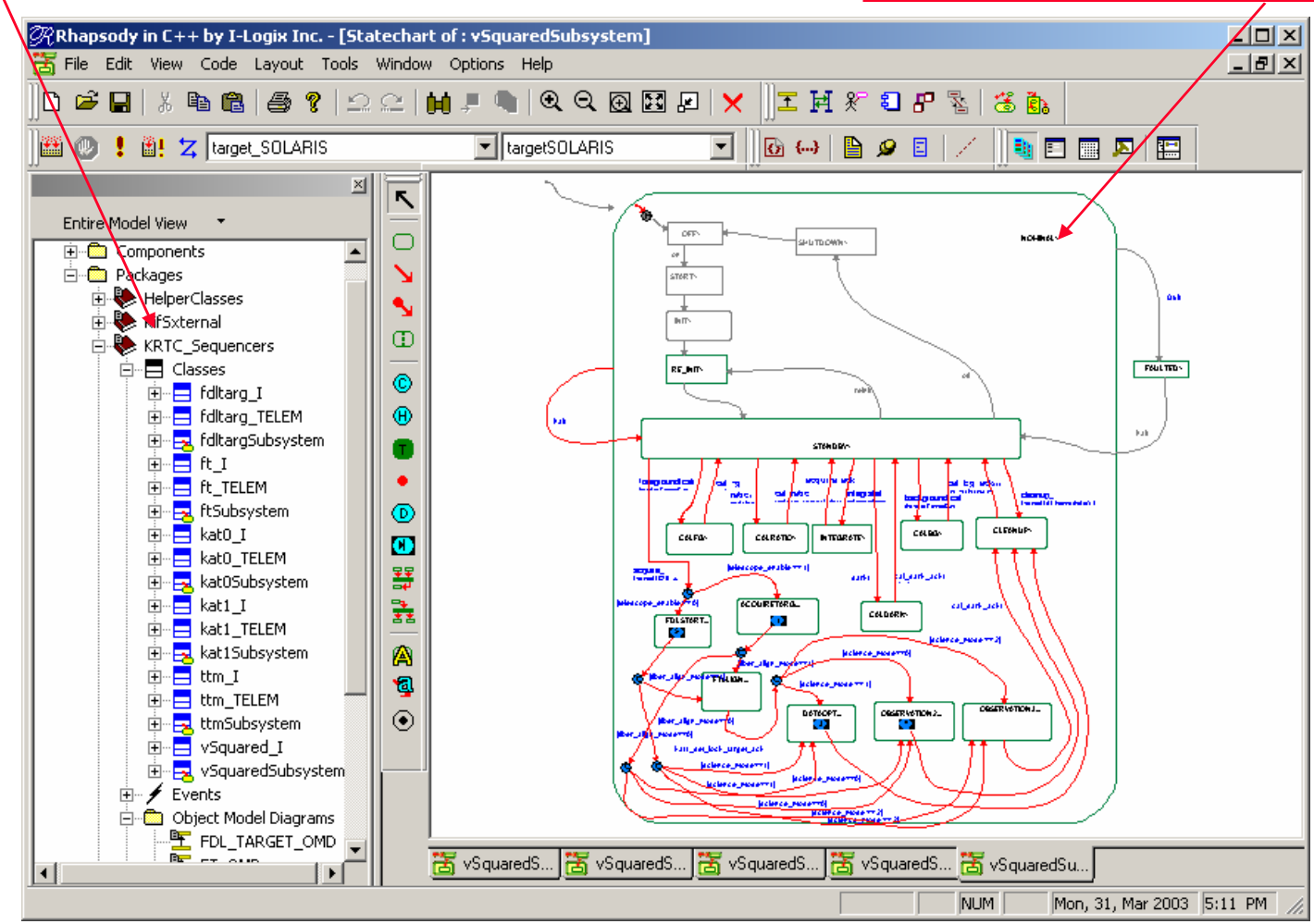
- **Our main use of Rhapsody is to automatically generate multi-threaded state machine code!**

- One can specify state machine behavior for some classes using UML style state machine diagrams

Screenshot showing Rhapsody CASE Tool

Model View

State Machine or Object Model Graphical Views



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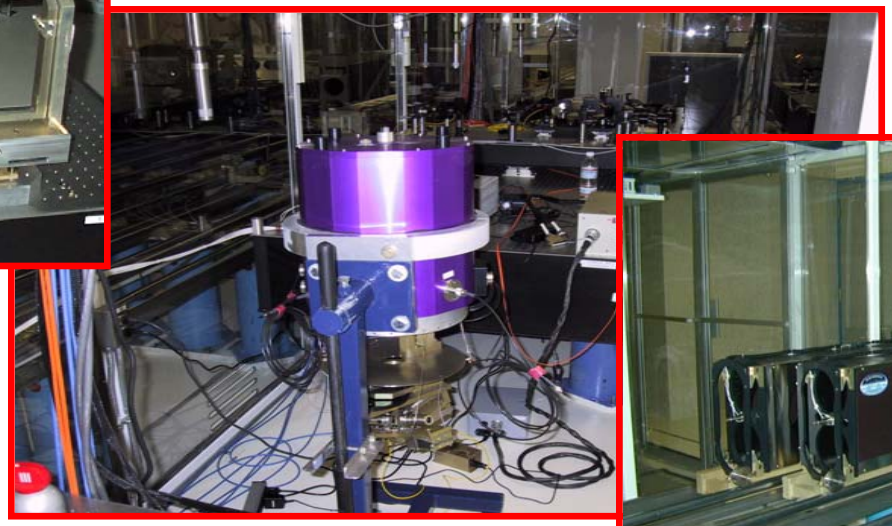
Interferometer Major Components

Beam Transport Optics (Coude Train)



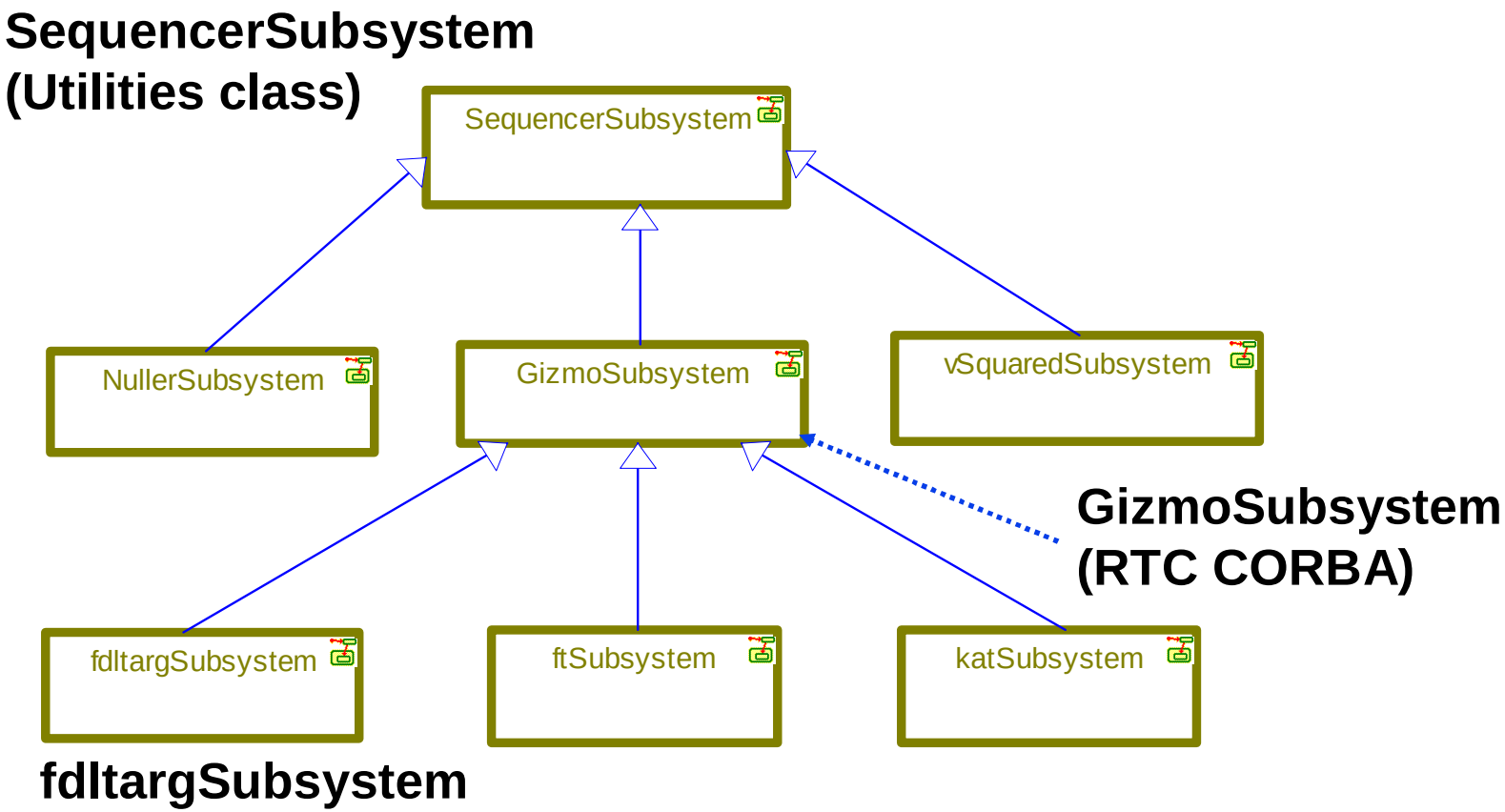
Fringe Tracker (FATCAT)

Fast Delay Lines (FDL)

Angle Tracker (KAT)

Long Delay Lines (LDL)

Static Class Diagram of Subsystems Class Hierarchy



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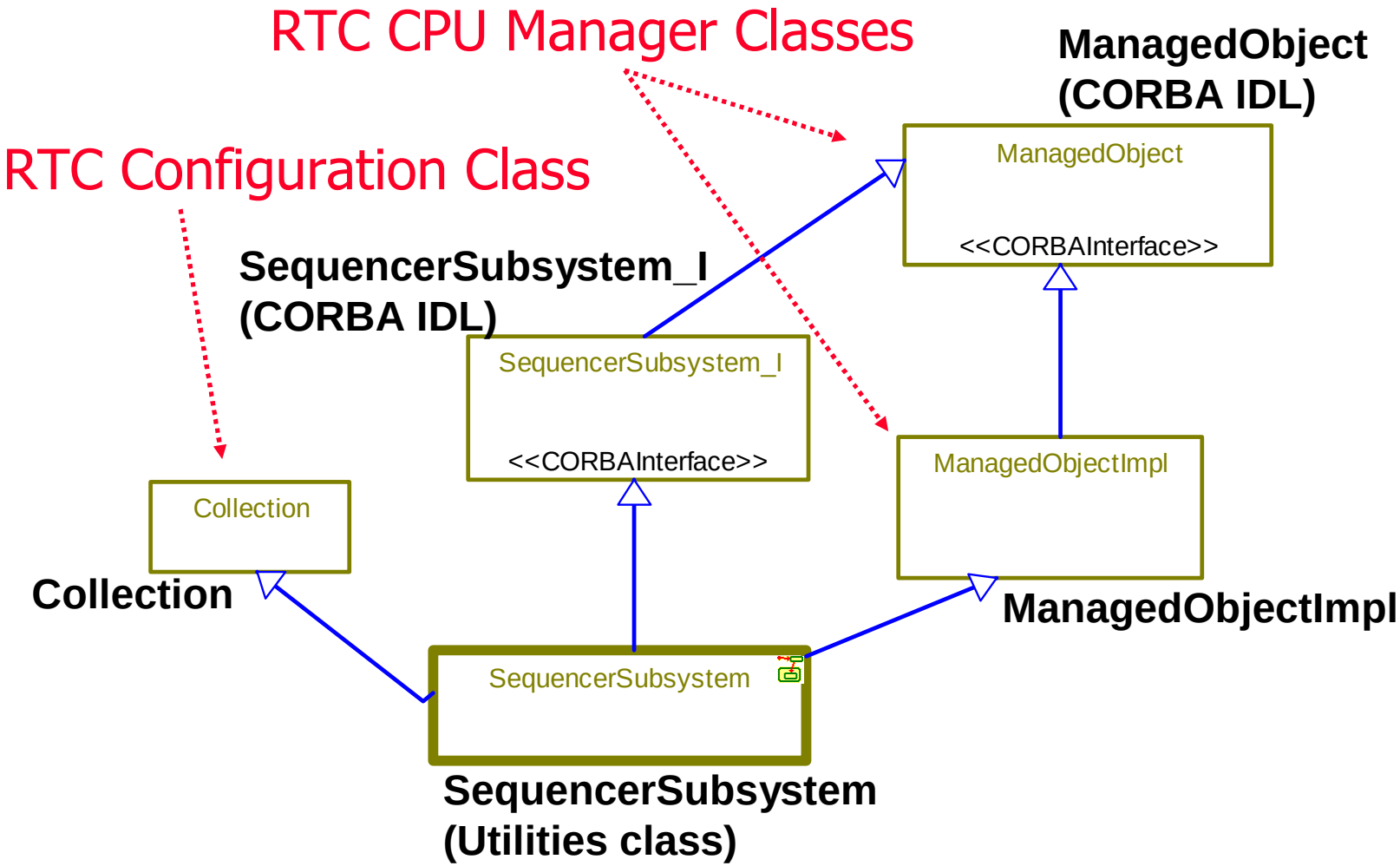
SequencerSubsystem Utility Class Relationship to RTC Toolkit



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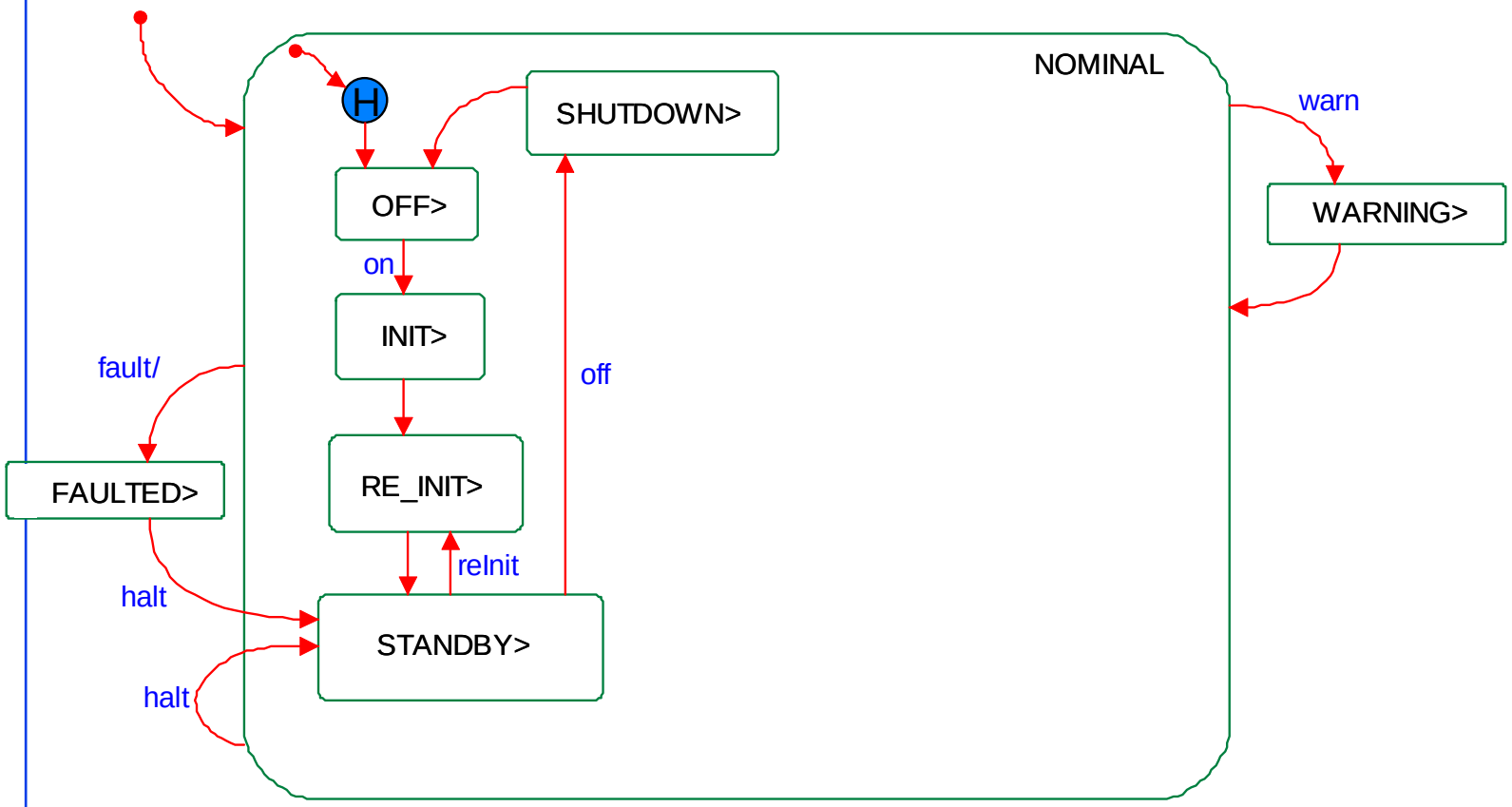
Harel State Machine-Based Design (Class)

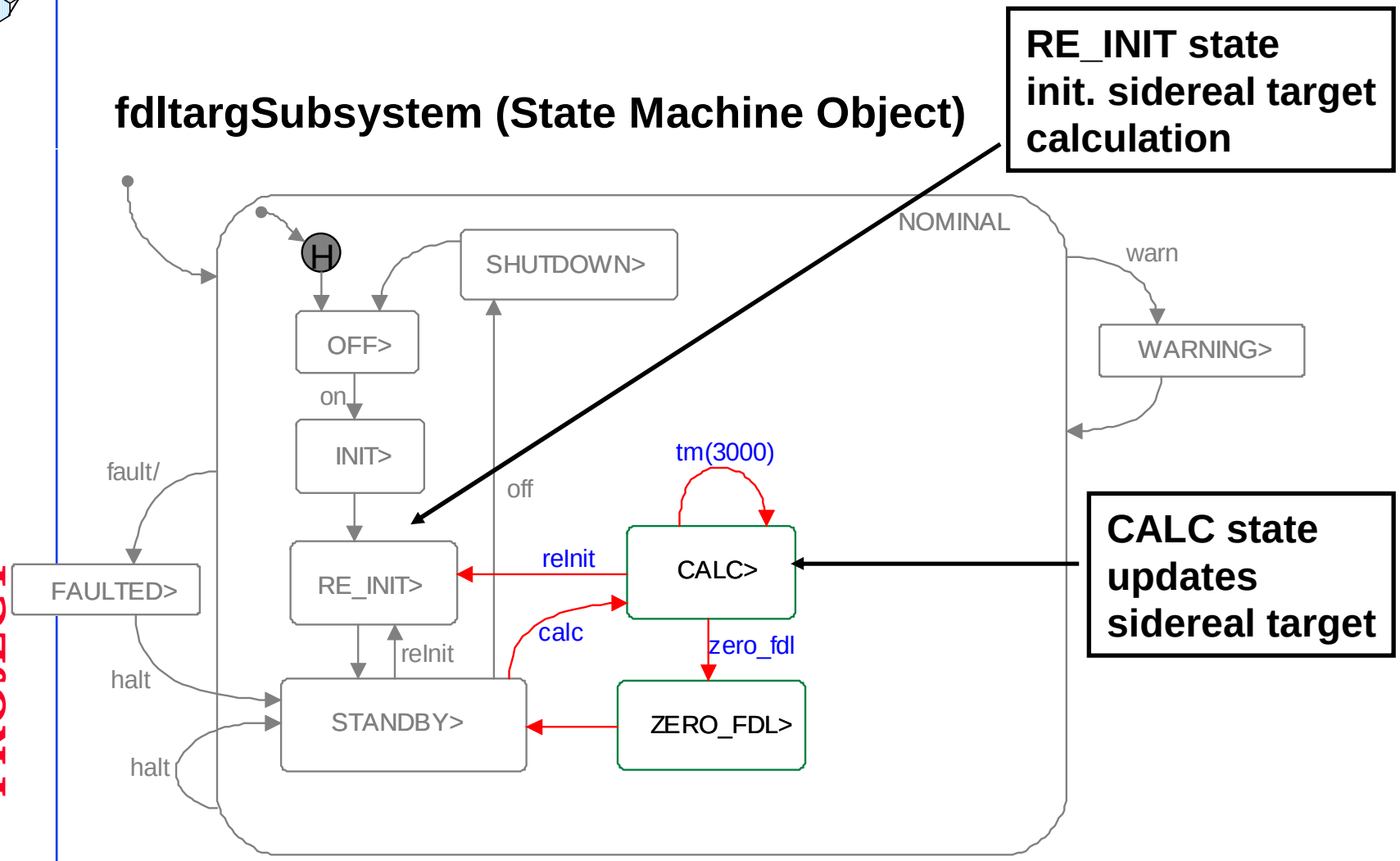
- All state machines inherit this class

SequencerSubsystem (Utilities class)



Fast Delay Line Target Generator
Harel State Machine

fdltargSubsystem (State Machine Object)



RE_INIT state init. sidereal target calculation

CALC state updates sidereal target

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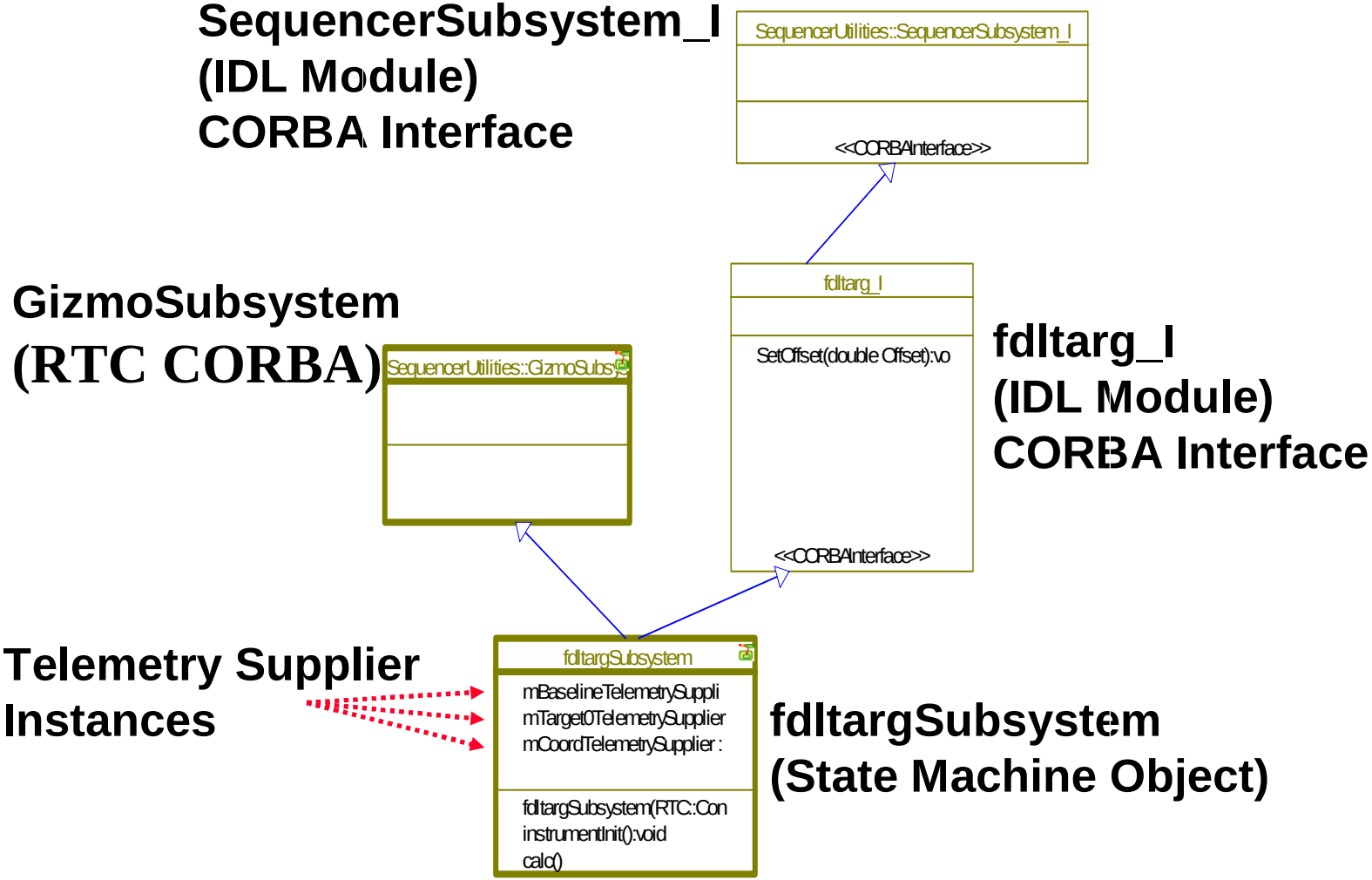
Fast Delay Line Target Generator (fdltargSubsystem) Static Class Diagram



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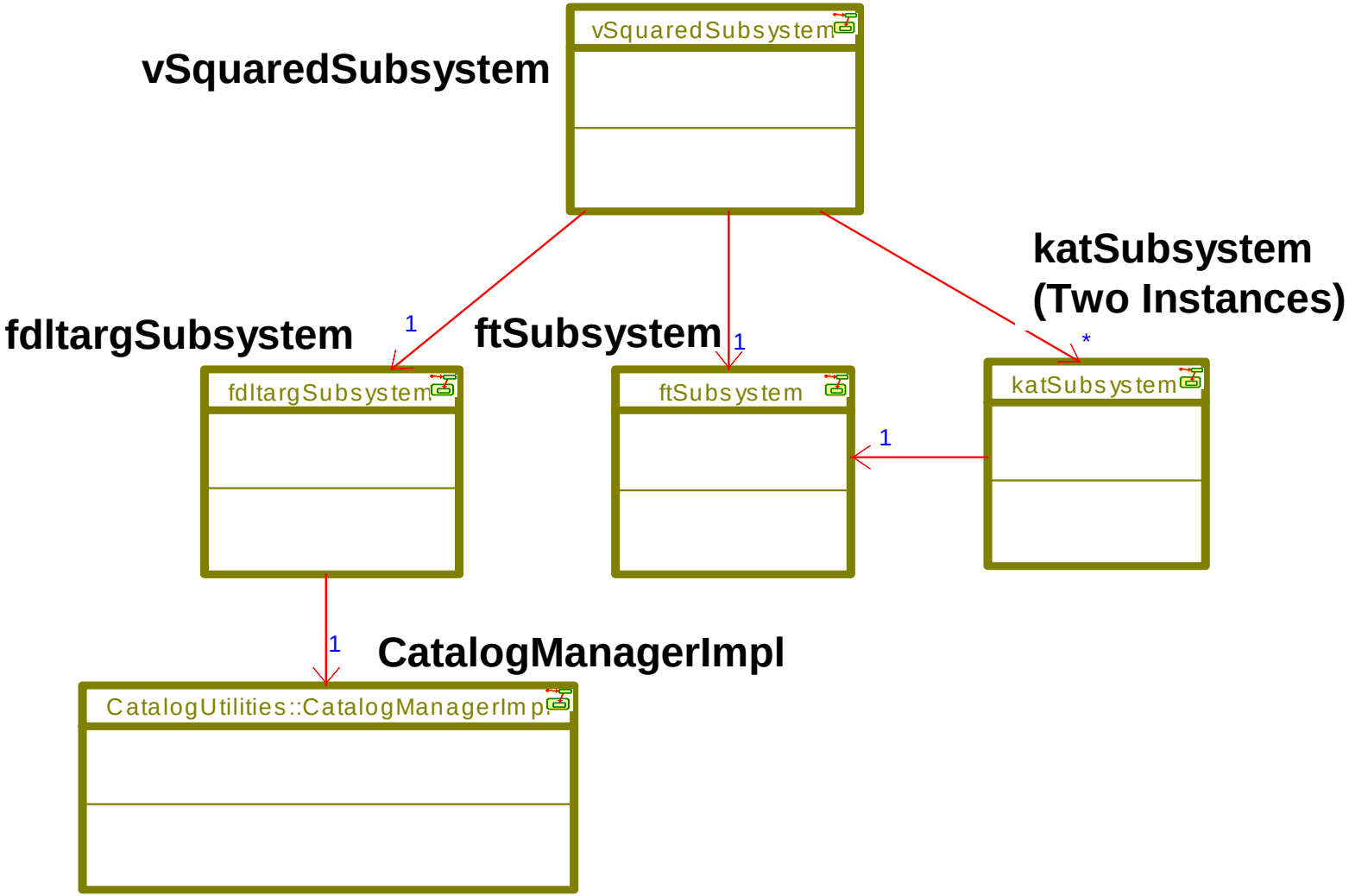
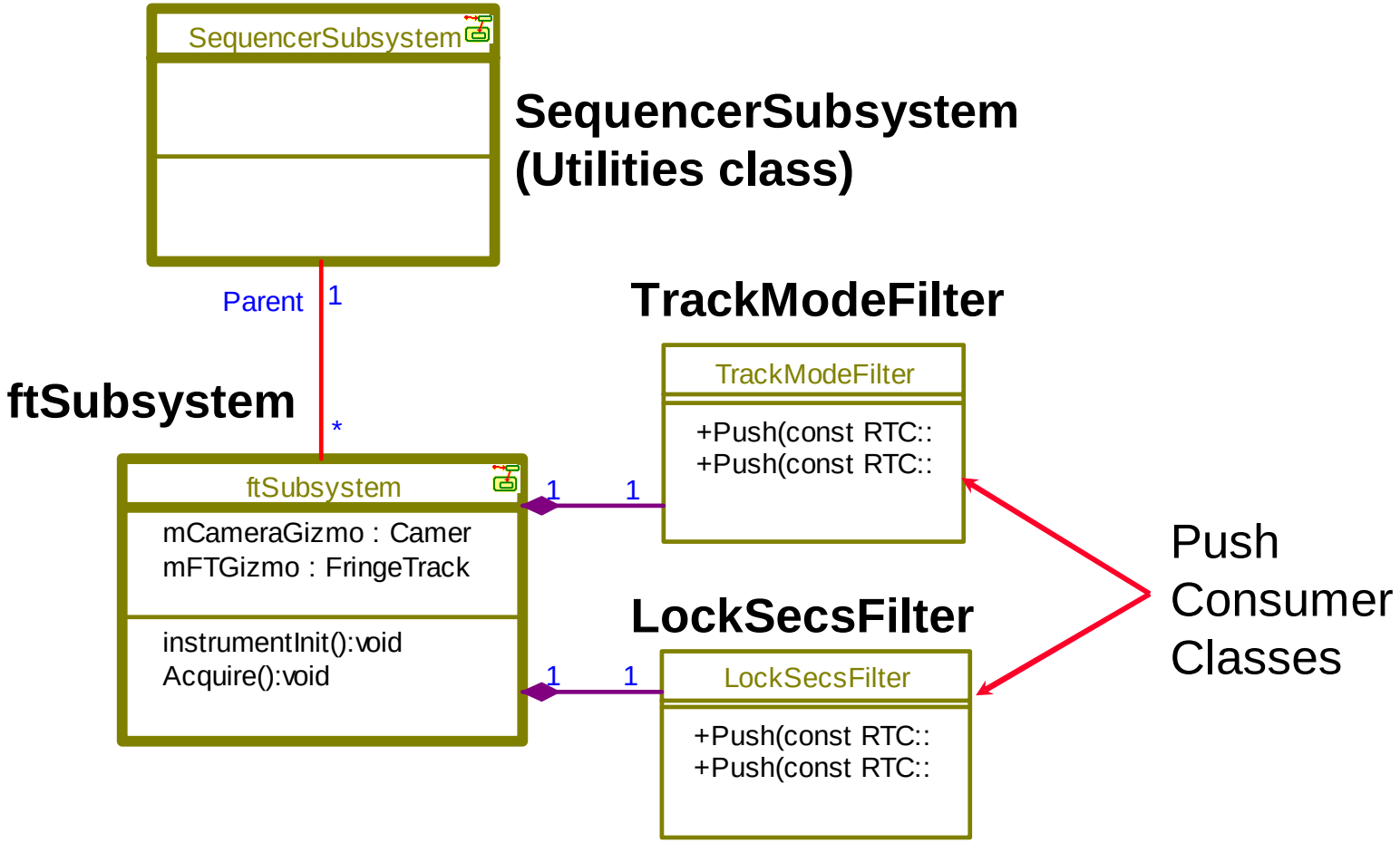
Static Class Diagram of Subsystem Associations for Visibility Operation



Fringe Tracker UML
(Shows Telemetry Consumers)



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Lessons Learned (1)

1) For CASE tool to be significantly beneficial requires an overall commitment and investment.

a. Consider a process for development and then a tool.

2) Hard to integrate multiple infrastructures!

a. Even harder to integrate them into a CASE tool.
b. Ideally, on new projects try not to mix infrastructures.
c. Legacy code is inevitable so minimize mixing.

3) "Old programming habits die hard" [Douglas Schmidt, UCLA Ext. 2002].

a. It is hard to learn graphical/coding UML methodology of the CASE tool environment if you have been a line-by-line coder for years.

Lessons Learned(2)

4) Maintainability of code is vastly improved.

a. C++ code is coupled to a UML graphical model so it is more understandable.

b. Automatically limits the amount of reverse engineering of code required later in software lifecycle!

5) Standardized auto-generated code leads to better infrastructure.

a. Design can be rapidly changed graphically with only a minimum amount of coding required.

6) Templates were not included with the Rhapsody case tool so we implemented them externally and hooked them into the tool. This is a kludge and is confusing to a new developer. This effectively defeats rule 4 above.

Lessons Learned (3)

7) The urge to use many of Rhapsody's framework features has sometimes overwhelmed the wiser inclination to use more standardized tools such as the STL (C++ Standard Template Library).

8) Features in a tool may look good during a sales demo, but be careful!

9) When starting, one should evaluate and not guess at a CASE tool to use; there are lots of choices today.

10) Version control of UML models can be problematic even between only a few developers.

Summary

- Implemented a multi-threaded state machine based, high-level, control capability for the Keck Interferometer

- State-machine classes have been designed to be highly configurable and flexible while reusing a basic state-machine initialization and error handling scheme

- CASE tool approach is superior to hand line-by-line coding
  - Improved maintenance over the life-cycle is realized
  - Dealing with third party infrastructures outside of the Rhapsody tool is problematic at first
  - After significant effort at integration it becomes easy to graphically add states and additional software architecture

- Rhapsody is an excellent tool, especially for state machine design and the problem fits nicely into the infrastructures provided by I-logix and the JPL developed RTC toolkit

Interferometer Sequencer User Interface

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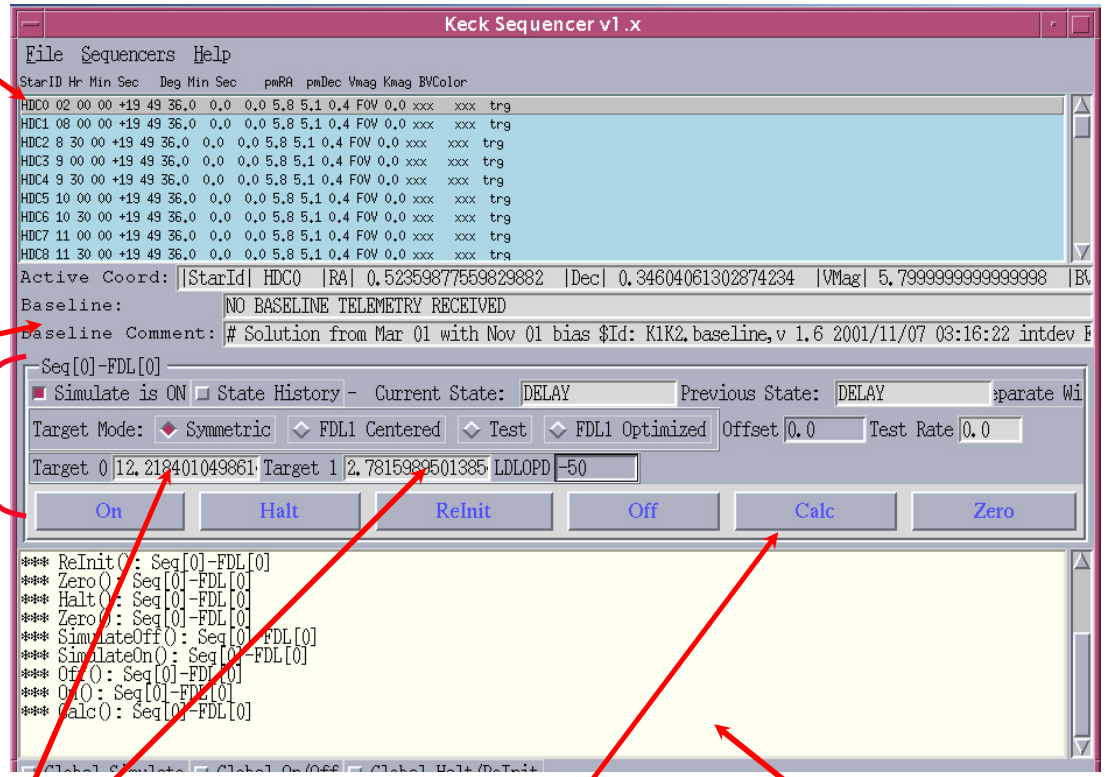
Selected observation record

Current observation & baseline vector

Optional State Machine Control Panel



Generated Delay Line Sidereal Targets

Sequencer observing controls

Text Status