

UML modeling of the LINC-NIRVANA software

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ABSTRACT

LINC-NIRVANA is a Fizeau interferometer for the Large Binocular Telescope (LBT) doing imaging in the near infrared (J,H,K - band). Multi-conjugated adaptive optics is used to increase sky coverage and to get diffraction limited images over a 2 arcminute field of view. The control system consists of five independent loops, which are mediated through a master control. Due to the configuration, LINC-NIRVANA has no delay line like other interferometers. To remove residual atmospheric piston, the system must control both the primary and secondary mirrors, in addition to a third, dedicated piston mirror. This leads to a complex and interlocked control scheme and software. We will present parts of the instrument software design, which was developed in an object-oriented manner using UML. Several diagram types were used to structure the overall system and to evaluate the needs and interfaces of each sub-system to each other.

Keywords: Instrument Software, UML, Fizeau Interferometer, Interferometer, Adaptive Optics, MCAO

1. INTRODUCTION

Software projects grow bigger and get more complex in the last thirty years. Hence software development was undergoing an evolution from functional programming to object oriented design to handle the new dimensions and larger complexity. The visualization of the software structure and the software functionalities are important for the design process to explore and validate the software. The method of visualization changed from simple data flow charts to several sophisticated diagram types which each look with different perspective on the software.^{1,2} The Unified Model Language (UML) is the approach to define a standard³ for such diagrams and their usage. The goal of UML was to provide a ready to use modeling language which is independent of a particular method and supports object oriented design.

Current astronomical instruments are often very versatile, highly complex, multi-purpose instruments. Likewise the dimensions of the telescopes and instruments are getting larger. Therefore elements and sub-systems of the instruments and telescopes have to be actively controlled. All this together gives the software more and more importance.

LINC-NIRVANA⁴ (LN) will be a first kind of 23m class instrument as it is combining the two 8.4m telescopes of the LBT⁵ into an interferometric imager over a larger field of view. The instrument exist of several sub-systems built at different places spread over Germany and Italy. The complexity of the instrument as well as the distributed development was a motivation to use a common standard to design and document the software. UML is therefore a natural choice. Currently there is no plan to generate the code automatically from an UML tool.

After introduction of the UML tool we utilize, we will show a short overview of the instrument and its software structure. Than we will discuss some UML diagrams in detail and emphasize how and what we use them for.

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2. THE UML TOOL

There are more than hundred UML tools for different operation systems available.⁶ A number of these tools are open source or free for science institutes. We evaluated several tools within a LINUX environment and decided finally for INNOVATOR from MID. The advantage of this tool is the large selection of diagrams, the fast response time (all the JAVA based tools were quite slow), the availability under LINUX and the price (it is free for scientific institutes). INNOVATOR also features version control and supports distributed development. The disadvantage of this UML builder is the not very intuitive handling.

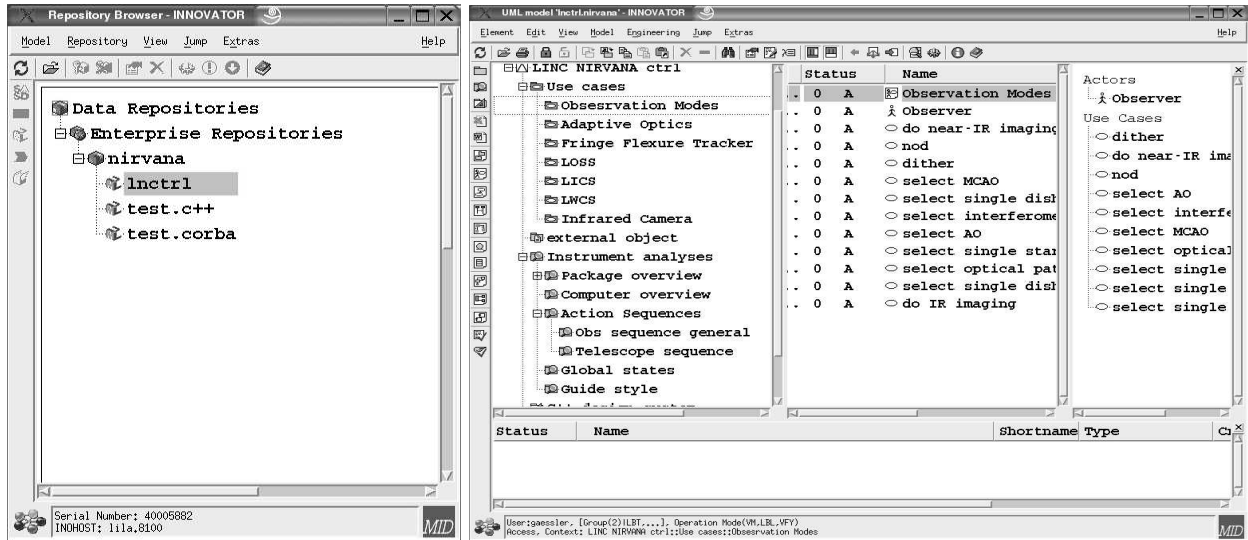


Figure 1. Left: INNOVATOR repository browser. Right: INNOVATOR model browser. In the left column the model structure is shown. In the middle column the selected diagrams with its components is displayed and in the right column the components are listed according to the related object class (Actors, Use Cases, etc.).

Multiple repositories where each can handle several different models are managed with a repository browser (see Figure 1 left). A second browser, the model browser (Figure 1 right), allows to navigate through the diagrams of a model. This browser has three columns. The left column of the browser displays the model structure, similar a directory tree. In the middle column the selected diagram with its components is listed. A click on the name launches the diagram in a separate window, where it can be modified. The right column shows all the components of a diagram according to its object class (Actors, Use Cases, etc.). On the top is a menu bar and on the bottom a status window. Icons help to short cut commands.

3. LINC-NIRVANA OVERVIEW

Figure 2 gives an overview of the instrument. The optical bench is about 5m wide, 3.6m deep and the structure below is 2.5m high with additional 1.50m of the wavefront sensors on top of the bench.

The cryostat, below the bench, contains the infrared science camera (IRC) and a Fringe and Flexure Tracker (FFT). The FFT measures the optical path difference between the right and left arm of the system and drives a piston mirror to reduce it.

The Adaptive Optics (AO)⁷ system exists of four sensors, two for each arm. It is a Multi-Conjugated AO (MCAO)⁸ system correcting the turbulence of the ground layer with the adaptive secondary mirror of the telescope and the mid and high layer turbulence with deformable mirrors on the bench. The two rings on the right and left side of the bench are the Ground Layer Wavefront Sensors (GWS) and the two towers in the back are the Mid-High Layer Wavefront Sensors (MHWS). The MCAO is used to exceed the Field of View (FoV) for the FFT guide star up to 2' diameter.

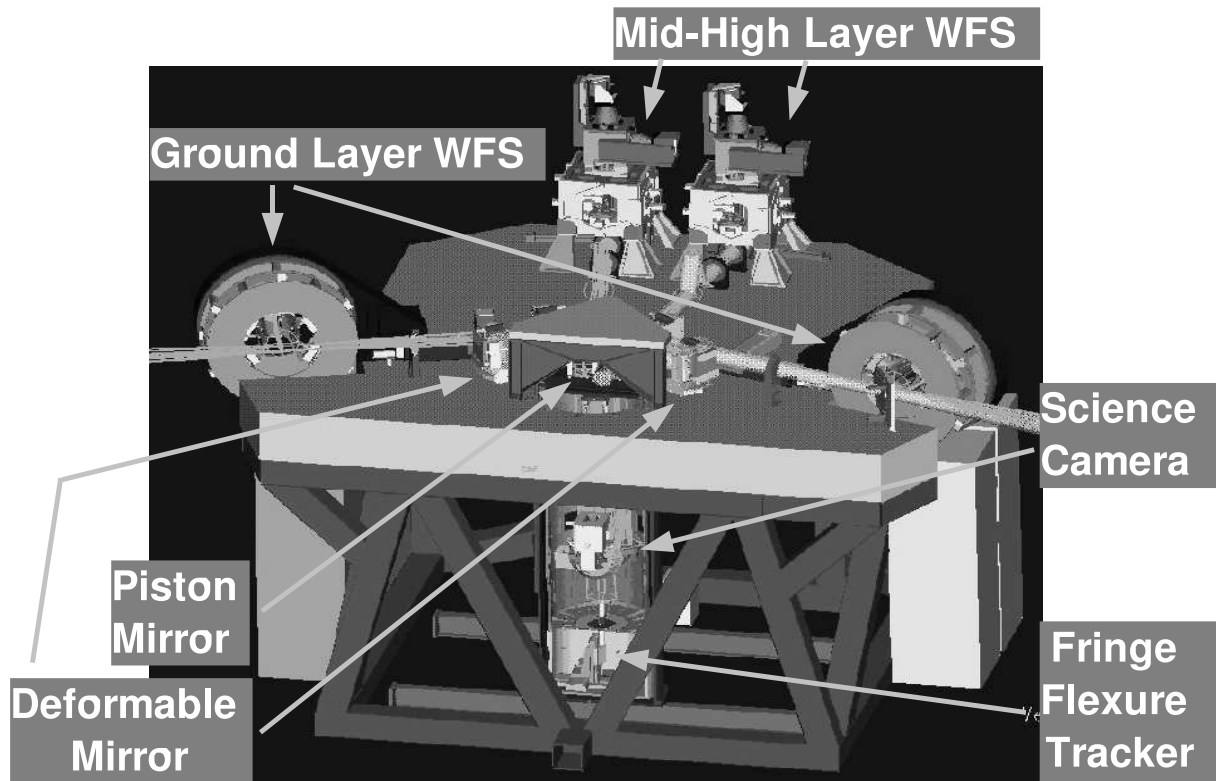


Figure 2. Overview of LINC-NIRVANA. All the major components are named. The overall dimensions of the instrument is about 3.5m x 5m x (2.5m + 1.5m) (D x W x H).

LBT is an altazimuth telescope with two off axis mirrors. The folded beams from right and left side have different chirality. Therefore the field de-rotation, as needed for an altazimuth telescope, can not be done at any place. LN de-rotates each sub-system (GWS, MHWS, FFT, IRC) separately .

In opposite to other interferometric instruments LN is doing real imaging, not fringe visibility measurements. LN will obtain an image over a 10" x 10" FoV with the resolution of a 23m telescope in the horizontal and a 8.4m telescope in the vertical direction. This gives a diffraction limited point like source (e.g. a star) such strange shape as shown in Figure 3.

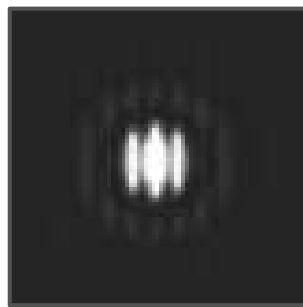


Figure 3. Simulated diffraction limited image of a star as obtained with LINC-NIRVANA. In the horizontal direction a resolution of a 23m telescope can be reached, while in the vertical direction only the resolution of 8.4m telescope can be reached.

An image with the full 23m telescope resolution of 8mas in Z and 20mas in K can be reconstructed from minimum three images at different parallactic angles of 60 degree distance each. This puts certain constrains on the preparation of observations and hence on the software.

4. SOFTWARE BREAKDOWN

Considering the number of sub-system, the complexity of the instrument and the needs to operate the instrument, a breakdown of the software in different packages was done. The structuring is shown in Figure 4 in a non UML conform fashion.

Three software levels are defined. The top level is the observation level, than the system level and on the bottom the sub-system level. In the observation level the software deals with supporting the astronomer to prepare and execute his observations at home and at the telescope. Two main packages are identified for the observation level. The Observation Preparation Software (OPS) which is used by the astronomer at the home institute to select the instrument setup and the guide stars for MCAO and fringe tracker and the Observation Support Software (OSS) which executes the observations with help of a scheduler. The performance of the instrument depends strongly on the guide star geometry and atmospheric condition at the night of observation. The OPS provides estimations of a certain parameter space to evaluate interactively the optimum setup and the acceptable atmospheric constrains to obtain images useful for a certain scientific application, further it gives suggestions when to observe the targets best. As there is need of a minimum of three images of the same target at different parallactic angles to reconstruct the full 23m telescope resolution the scheduling of observations is

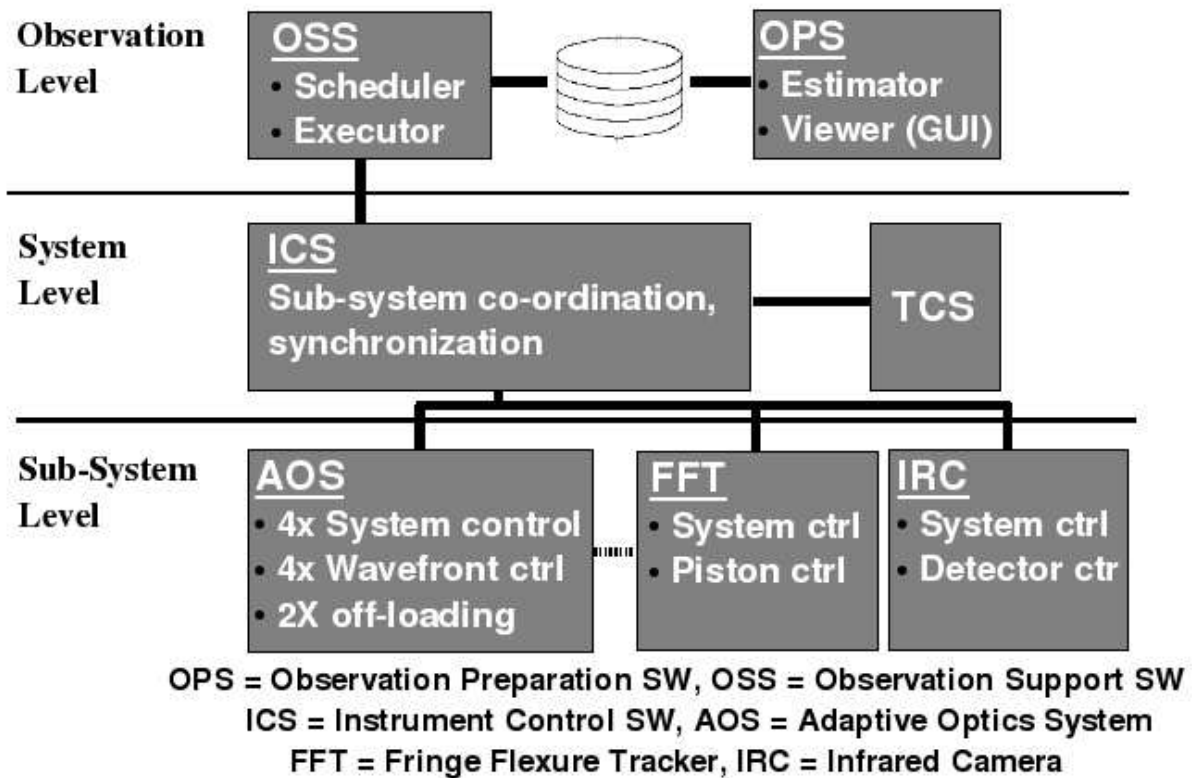


Figure 4. LINC-NIRVANA software structure. Three software levels with altogether 7 system packages are identified. A repository will store the outcome of the OPS created at the home institute. The OSS will load the observations from this repository. The ICS will breakdown the executed observation and co-ordinate between the sub-systems (AOS, FFT, IRC) and the TCS.

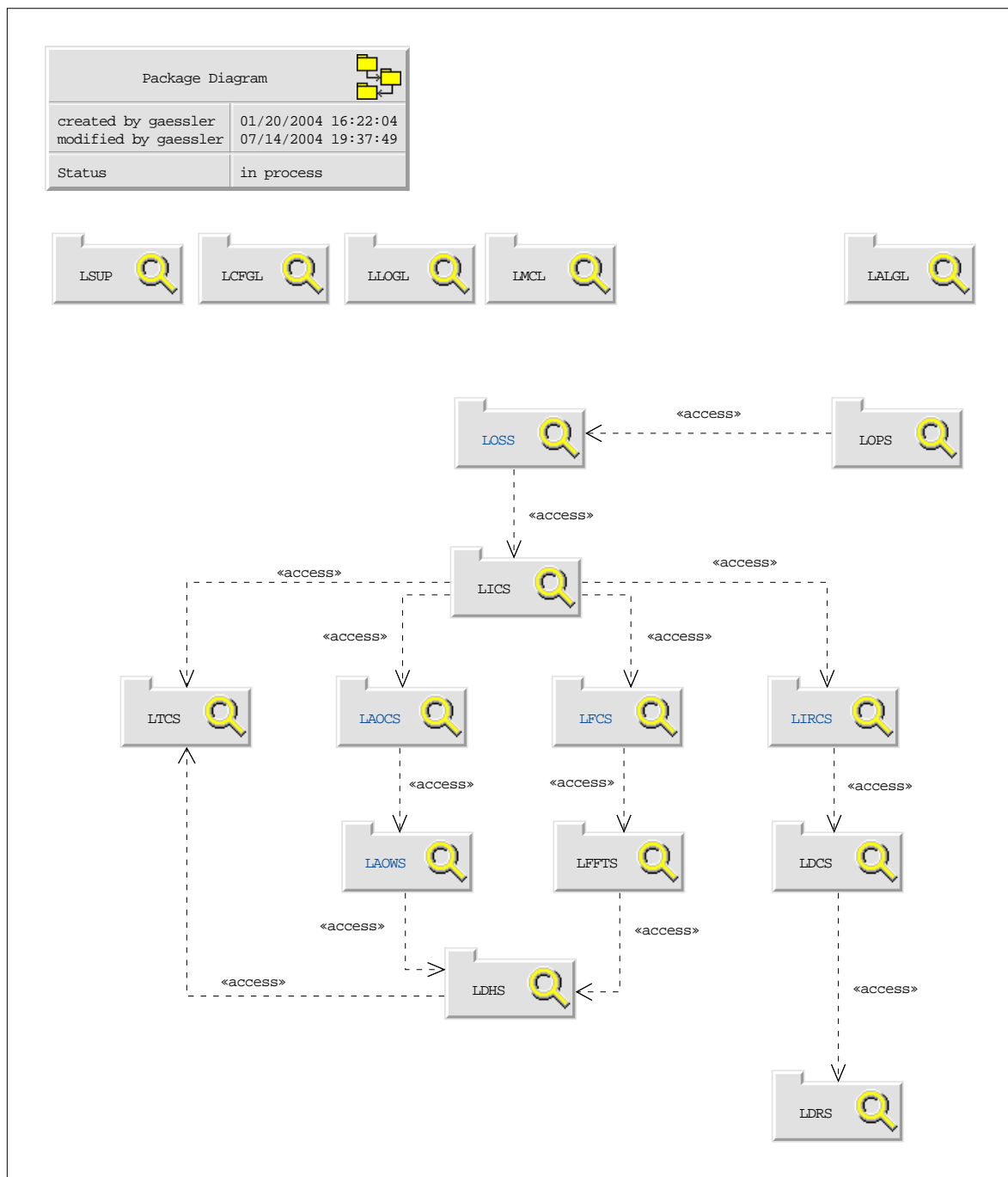


Figure 5. Package diagram of LN. All package names start with 'L' as acronym for LINC-NIRVANA. Common libraries (LSUP, LCFGL, LLOGL, LMCL, LALGL) are kept separate. Interfaces between the packages are indicated by an arrow. Table 1 gives a short description of all packages.

not trivial. In one night it is difficult to obtain a full set of images for all the targets started with after the first third of the night. The scheduler of the OSS will take track of the observation programs and optimize their

Package name	Description
LSUP	Software installation and management scripts
LCFGL	Configuration file library (reading, writing, query)
LLOGL	Logging and error handling library
LMCL	Motor control library
LALGL	Common algorithms library (de-rotation)
LOPS	Observation Preparation Software
LOSS	Observation Support Software
LICS	Instrument Control Software
LAOCS	Adaptive Optics Control Software (command handler, motors, etc.)
LFCS	Fringe and Flexure Tracker Control Software (command handler, motors, etc.)
LIRCS	Infrared Camera Control Software (command handler, motors, etc.)
LTCS	Telescope Control Software Interface
LAOWS	Adaptive Optics Wavefront Control Software (closed loop)
LFFTS	Fringe and Flexure Tracker Software (closed loop)
LDCS	Science Detector Control Software
LDHS	Data Handling Software. The LDHS combines all the loops and off loads from one to the other.
LDRS	Data Reduction Software

Table 1. Short description of the software packages in Figure 5

execution until they are finished.

The second level is the system level. In this level exist two packages: the Instrument Control Software (ICS) and the Telescope Control Software (TCS). The TCS is provided by LBT with a generic communication interface for instruments. The ICS is part of LN and has as main task to co-ordinate and synchronize all the sub-systems of LN and the telescope system.

The bottom level - sub-system level - contains all the LN sub-systems. There are four similar working AO wavefront sensor systems driven by different instances of the Adaptive Optics Software (AOS), than there is a software for the Fringe and Flexure Tracker (FFT) and finally the software of the Infrared Camera (IRC). The AOS takes care off all motor control and command handling as well as the wavefront control (in real-time) and off loading between units (GWS, MHWS, FFT, Primary mirror, etc.). The FFT software moves the translation stages to follow the guide star and also drives the piston mirror.

The package diagram of Figure 5 shows the same as the software breakdown of Figure 4 but in UML. Some more details like additional library packages and the data reduction software (LDRS) are added. All names start with 'L' as acronym for LINC-NIRVANA. The sub-systems are all divided into a common control and command handling layer and a layer for wavefront control, fringe/flexure control or detector control, respectively.

5. USE CASE AND ACTIVITY DIAGRAM

Use case diagrams are taken to identify functionalities, actors and relationships between the actors of a system. Activity diagrams are used to display the flow and dynamics of a system.

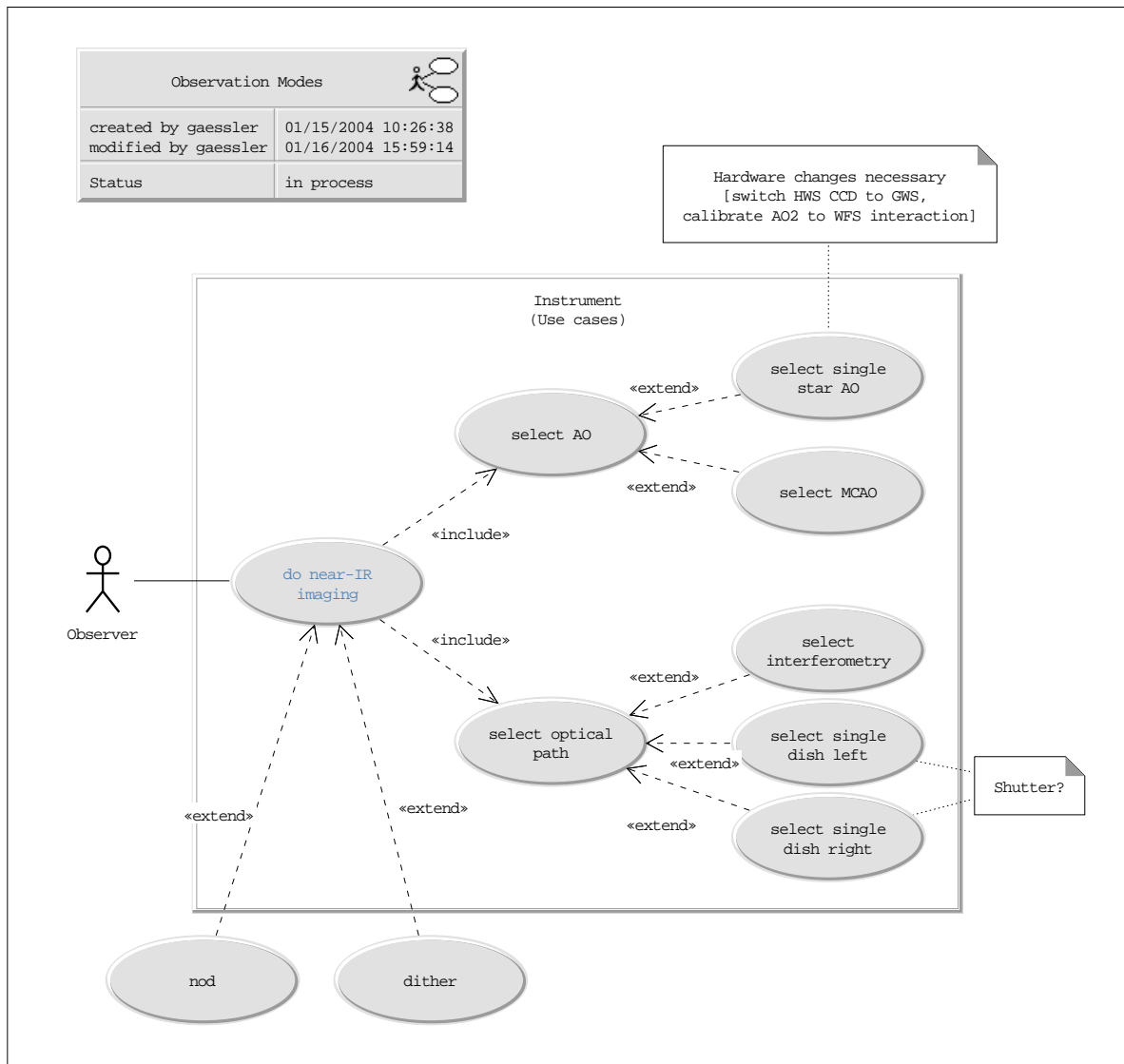


Figure 6. Use case diagram for the modes of LINC-NIRVANA.

Figure 6 shows the use case diagram of the observation modes. The instrument has as primary functionality to take near-infrared images. The actor is the observer. There are two extensions of the use case 'do near-IR imaging': dither and nod. The dither mode offsets the telescope keeping the AO loops closed while the nodding mode opens the loops during movement. The primary use case includes also two further cases. First the AO has to be selected. The options are MCAO or single guide star AO. Second the optical path has to be selected, either interferometric, single dish right or single dish left. Important comments and notes are written directly within the diagram into a note box as e.g. for the use case 'select single star AO'.

The activity diagram in Figure 7 displays the observation flow of LN. As LN exists of several sub-systems which can run alone but the performance of others depend on each other it is important to understand how the system works and where synchronization points are needed. Each sub-subsystem has its own column. Actions which are on the same horizontal level can be executed at the same time in parallel, like 'set star enlargers', 'point telescope', 'set-up IR camera'. The horizontal lines give synchronization points. At such points sub-systems have

to wait for others to go on with the next action. The white boxes (e.g. 'Start GWS') are action containers. Further actions are hidden inside and displayed in a different diagram to simplify this current diagram.

6. CONCLUSIONS

LINC-NIRVANA is a complex instrument with several sub-systems to be co-ordinated. The observations can not be done as linear as for other instruments because of the certain constrains on the parallactic angle. UML is a good tool to model such complexity and visualize it from different perspectives. The UML tool we are using was introduced and example diagrams for LN were presented. Currently the software design of LN is in the analysis phase after requirement gathering. The final idea is to model the instrument with UML down to detailed class diagrams but not to create the code with the UML tool. Starting with UML and still learning it, we experienced that, even UML is a standard, the description of this standard can vary from author to author. Therefore it was important to find in several discussions an agreement within the team how we use the diagrams.

Acknowledgment

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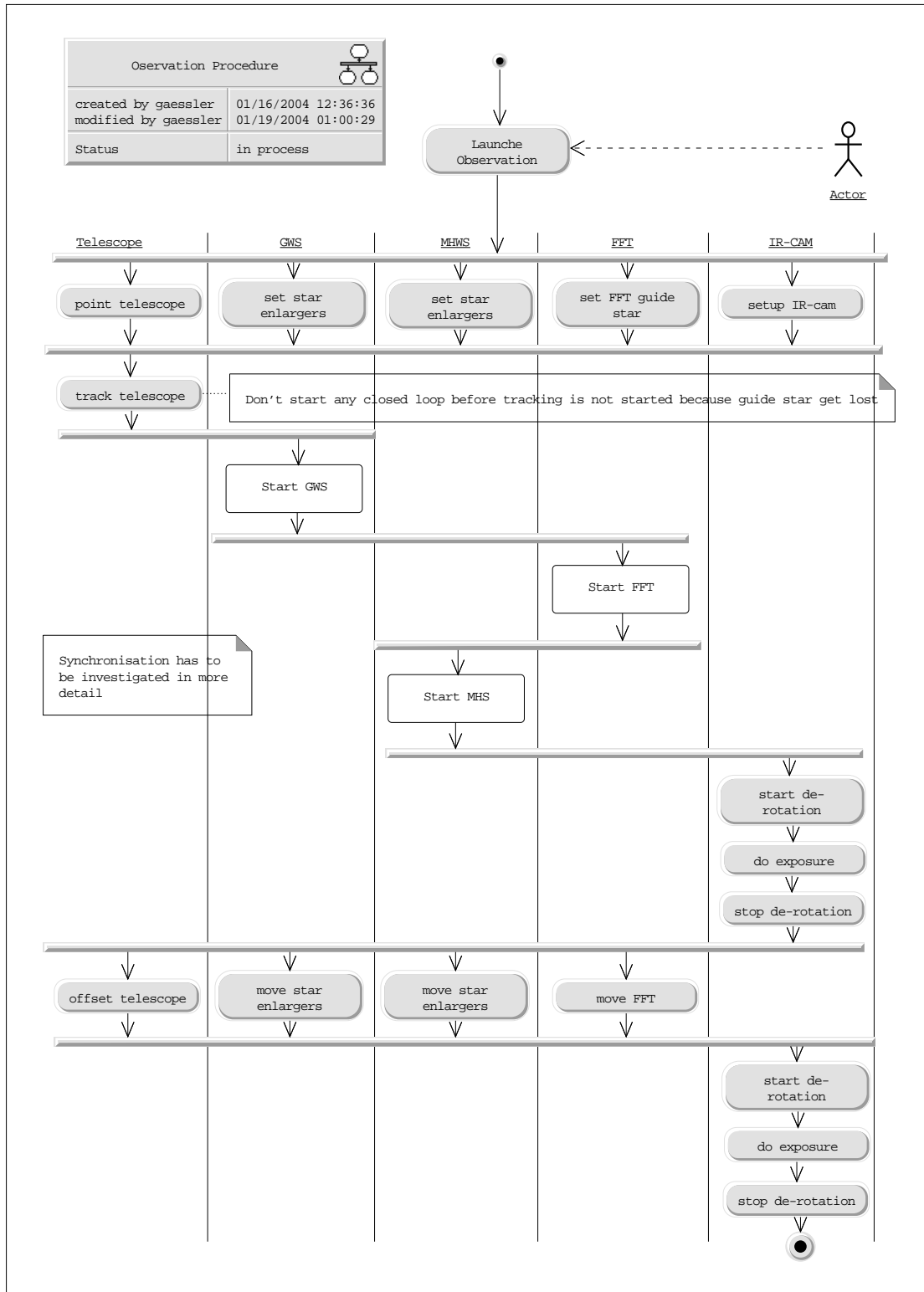


Figure 7. Activity diagram of the observation flow of LINC-NIRVANA.