Analyzing the AO Operational Behavior of Non-sidereal Tracking on the Thirty Meter Telescope using SysML

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Introduction

We have modeled the functional and physical architecture, behavior, requirements, and parametric relationships through system-level simulation of observation workflows, using OMG's Systems Modeling Language (SysML), to validate use-case scenarios and verify timing requirements early in the life-cycle phase. This paper presents preliminary results for non-sidereal tracking scenarios, especially for fast targets where the on-instrument wavefront sensors must hand off from one guide star to another. Operational modes and behavior are modeled using activity diagrams. Scenarios are captured primarily using sequence and activity diagrams. Verifiable requirements are formally captured using constraints on properties. This type of modeling can be particularly useful when investigating the effect of parallelizing or re-ordering sequence tasks.

Non-Sidereal Tracking

TMT supports non-sidereal tracking rates of up to 1.5 arcsec/s relative to the fixed stars. Fast-moving near-Earth objects ($\gtrsim$ 0.08 arcsec/s) will typically be bright enough to guide on directly using just the NFIRAOS Pyramid WFS in either NGSAO mode or at least in tip/tilt/focus mode.

For slower-moving targets in LGS MCAO mode, the IRIS OIWFS probe arms perform a "crab walk" maneuver across the field, exchanging guide stars as they move out of the field, while maintaining lock on at least one guide star. AO performance will vary as the asterism geometry changes and stars drop in and out of the AO loop during the observation.

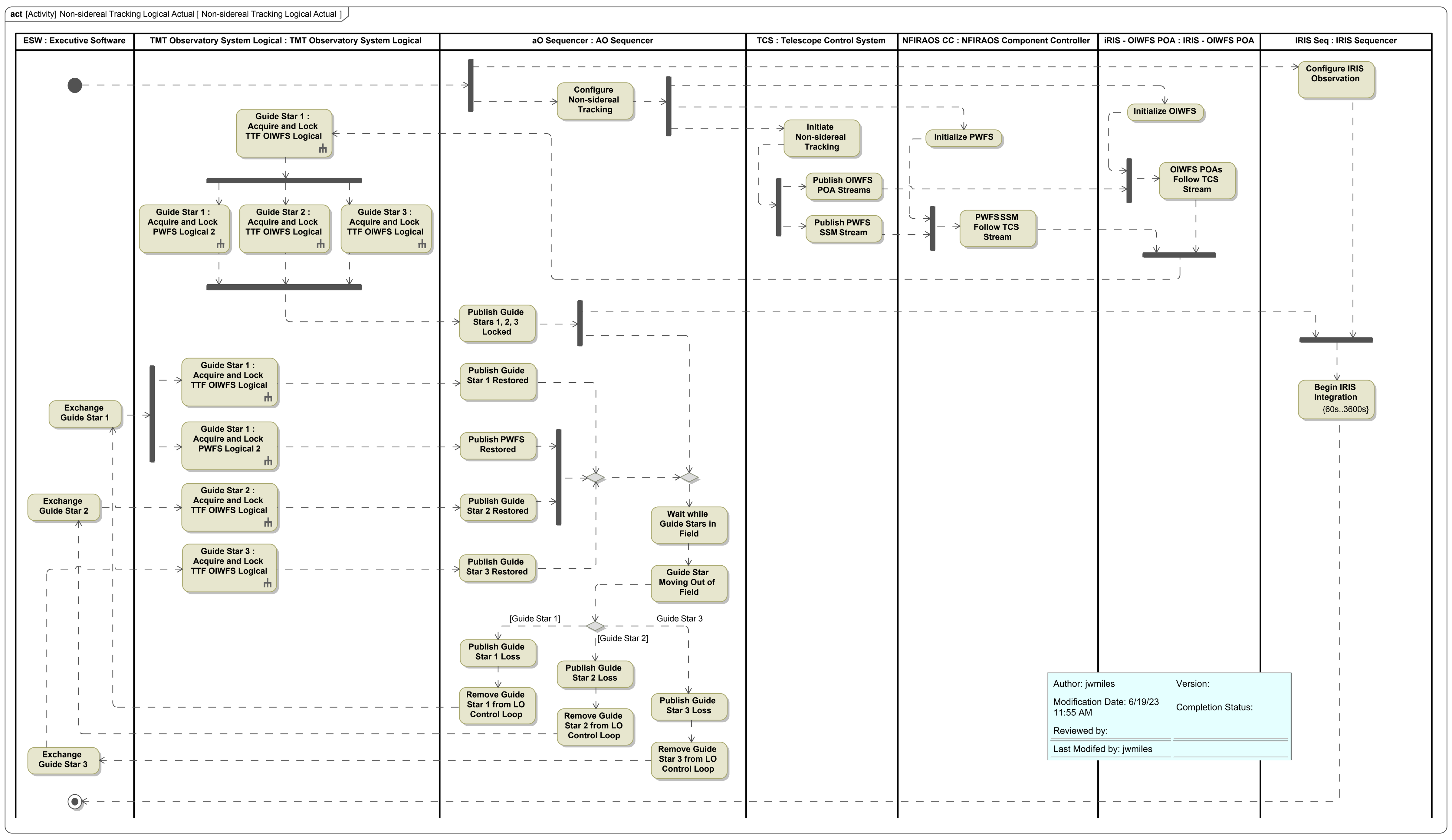
Simulation

This simulation assumes a specified probability that each attempted guide star is successfully acquired, and switches as needed to a new guide star, up to four stars per acquisition. It also assumes the same probability of achieving AO lock, once acquired, allowing for one additional guide star acquisition if the lock fails.

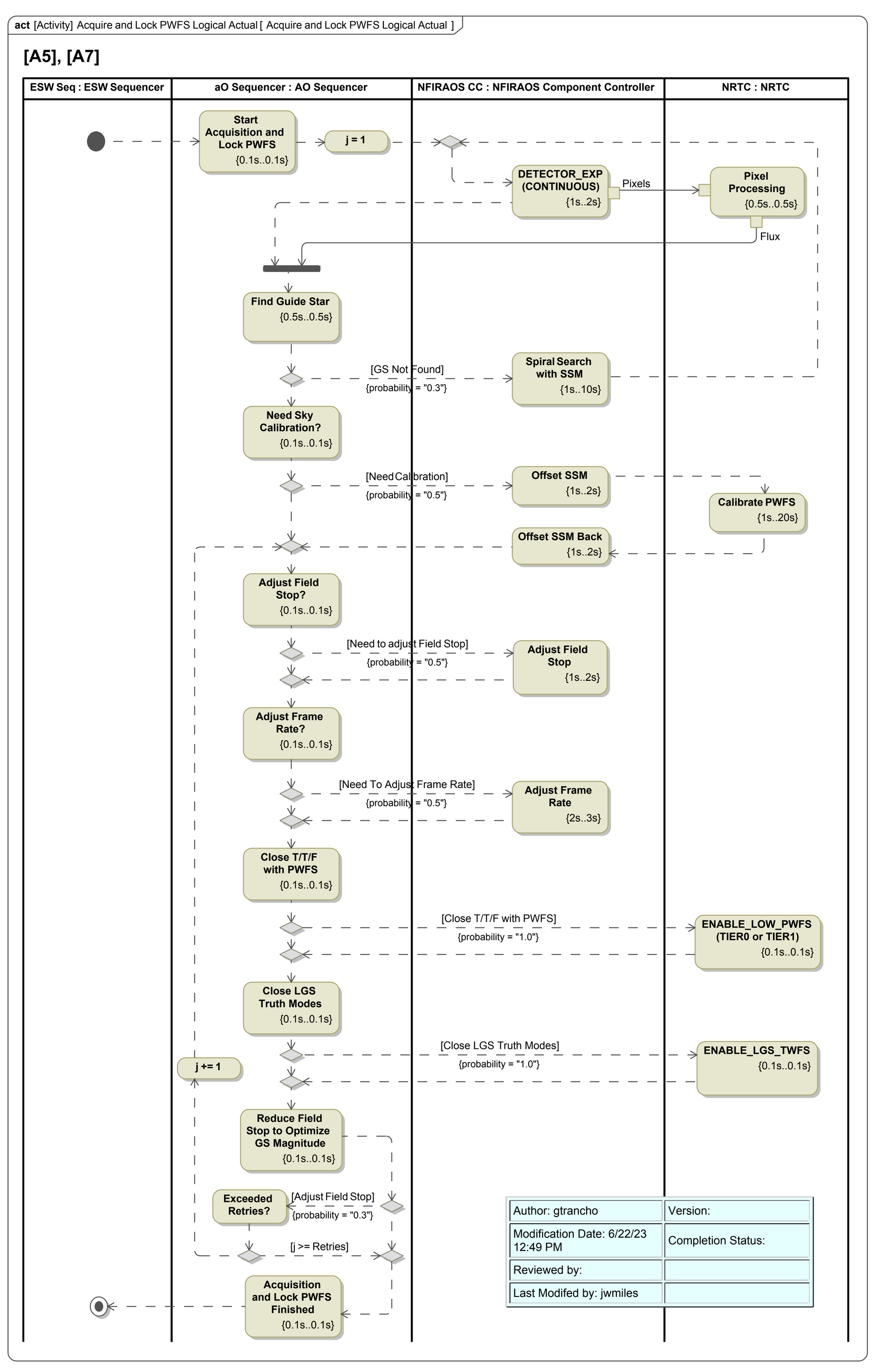
Monte Carlo simulation (N = 1000) results for the length of time a guide star drops out of the AO loop until another one is acquired are shown in the table below. The probabilities give an indication of the impact that field star density has on the dropout time.

Probability Guide Star Acquired	Guide Star Dropout Time (s)	
	OIWFS	OIWFS + PWFS
50%	100 ± 59	110 ± 60
70%	53 ± 42	63 ± 43
90%	21 ± 18	31 ± 20

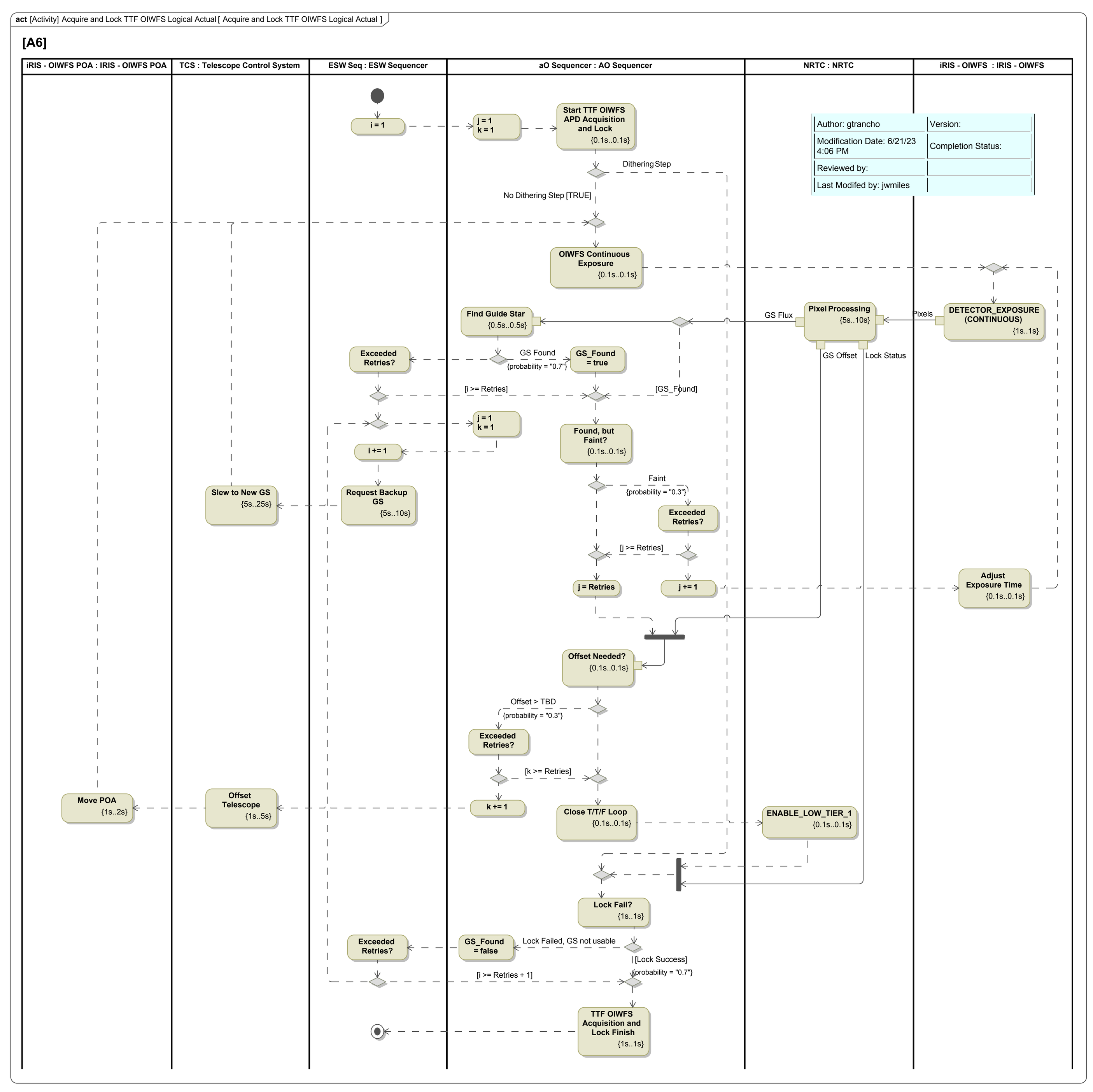
Non-sidereal Tracking Model

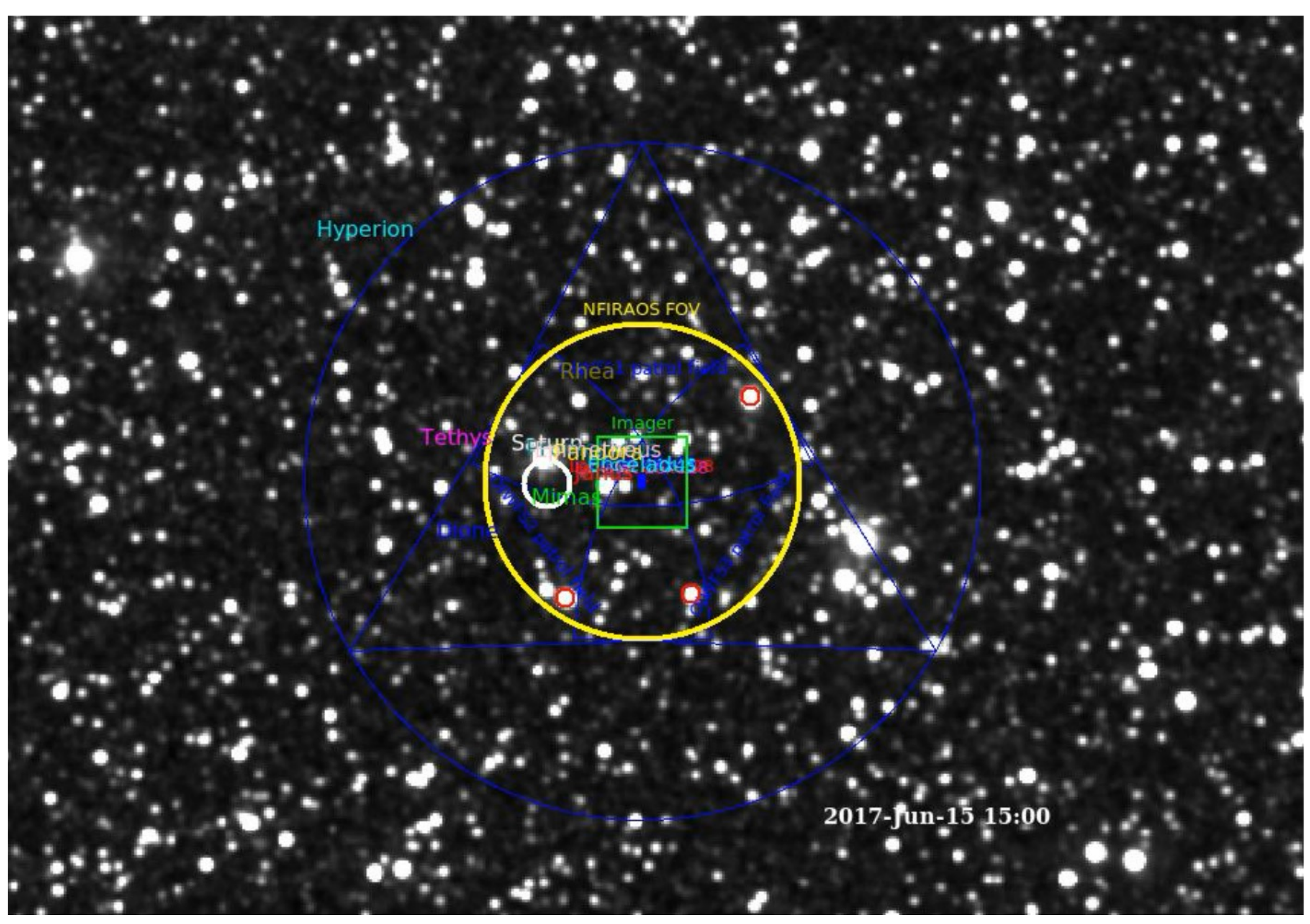


PWFS Acquisition



OIWFS Acquisition





This Enceladus tracking sky simulation shows three OIWFS guide stars circled in red.

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