Vera C. Rubin Observatory
Rubin Observatory Operations

The Rubin Observatory Target-of-Opportunity Mock Data Challenge

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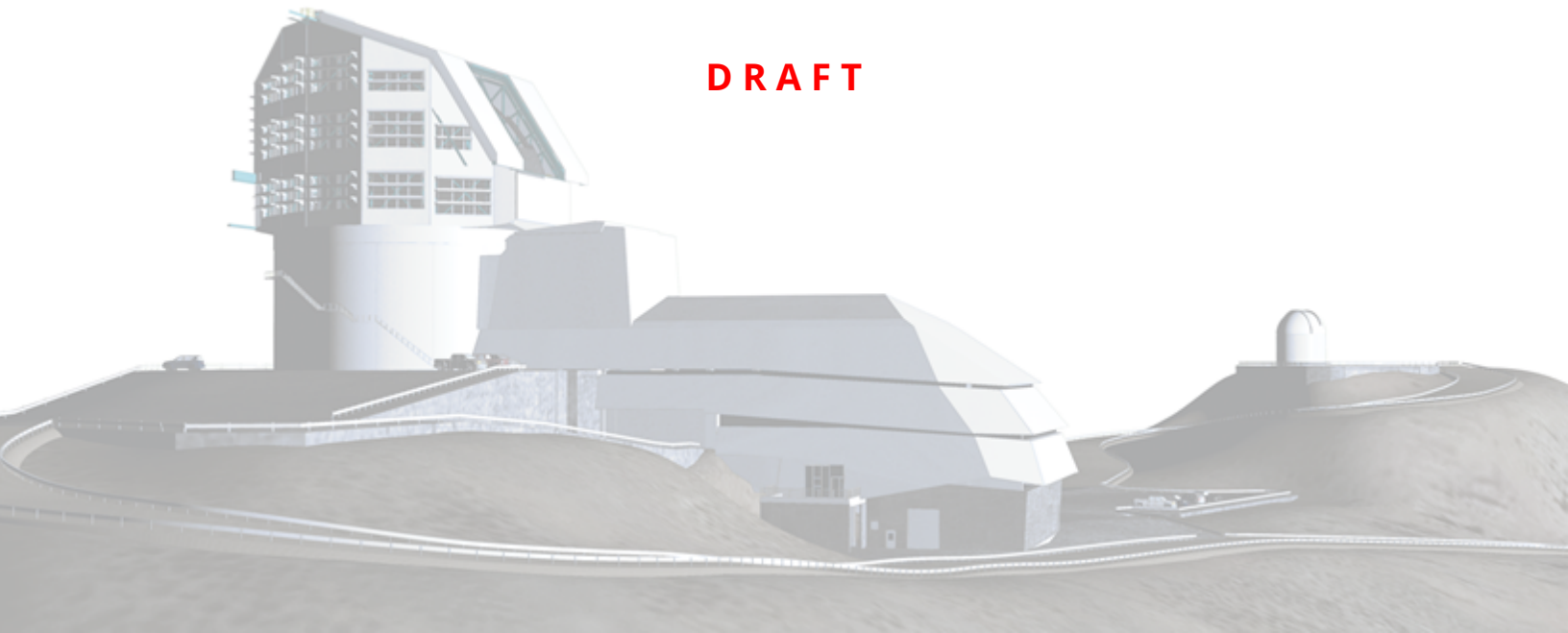

Abstract

We describe the activities of the Target-of-Opportunity mock data challenge, taking place from Sep 22 2025 - Oct 18 2025. We center this activity in four questions that are critical for maximizing the scientific output of the ToO system:

- How quickly can Rubin Observatory start observing after a ToO alert is received?
- How efficient is Rubin Observatory at recovering the host of a ToO event?
- How accurate are the observing strategies that the community has created for the ToO program?
- How can expert ToO scientists interact effectively with the ToO system, where many processes are fully automated?

In this challenge, and the report summarized herein, we aim to answer the aforementioned questions to better the Rubin ToO program.

Change Record

Version	Date	Description	Owner name
1	2025-09-18	Introduction + Abstract.	MacBride

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The Rubin Observatory Target-of-Opportunity Mock Data Challenge

1 Introduction

Rubin Observatory will enable many scientific discoveries, including target-of-opportunity (ToO) observations of GW, high energy neutrino, potentially hazardous asteroids, and galactic supernova.

The $\sim 10\,\mathrm{deg}^2$ field-of-view of the Rubin optical system allow ToO observations to survey a wide area, while the single-visit depth of the LSST-Camera allows single observations to rapidly observe the southern sky for faint transient phenomena. The combination of the large FOV and deep observations make Rubin Observatory an ideal tool for discovery of ToO phenomena.

The Rubin ToO program encompasses 3% of the LSST. Each target has a different observing strategy based on observing conditions, the conditions of the astrophysical event, and other parameters. The observing strategies are the product of community input, and were revised in 2024 (Andreoni et al. (2024)). These recommendations were accepted by the survey cadence optimization committee in January 2025 (Rubin's Survey Cadence Optimization Committee et al., PSTN-056).

The Rubin ToO mock data challenge was spawned out of necessity to properly characterize the infrastructure and scientific potential of 3% of the LSST. This challenge has included coordination with the LVK collaboration and the IceCube collaboration, who will be sending simulated data that is syntactically identical to real alerts. The action on the Rubin Observatory side is to parse and process these alerts as if we were in operations to obtain a better understanding of the ToO system.

The deliverables of the mock data challenge are grounded in characterizing the technical and scientific outcomes of the ToO program. They are the following:

- **How quickly can Rubin Observatory start observing after a ToO alert is received?** While there will be variance in ToO response time due to slew time being non-uniformly distributed, many aspects of the ToO time-to-response can be adequately measured with many additional ToO alerts.

- **How efficient is Rubin Observatory at recovering the host of a ToO event?** Previous forecasts of candidate discoverability have been grounded in simulations, while this exercise utilizes data from the on-sky performance of Rubin observatory during the SV survey.
- **Are changes to the community designed observing strategies necessary?** To adequately serve the Rubin ToO community, the observing strategies must reflect the desired outcomes of the multi-messenger community as requested.
- **How can expert ToO scientists interact effectively with the ToO system, where many processes are fully automated?** This includes pursuing ToO's that were outside of the original alert criteria, stopping a ToO observation after it has begun, and gathering sufficient information to assess a specific ToO alert.

We describe the events and results of the first Rubin Observatory Target-of-Opportunity mock data challenge. In section 2, we describe the involvement of different experiments, and describe how they interact with the Rubin ToO ecosystem. In section 3, we describe the events and activities of the data challenge itself. In section 4, we describe analyses of alert latency. In section 5, we describe analyses of observing efficiency. In section 6, we describe analyses of observing strategy generation. In section 7, we describe the interaction between scientists and ToO infrastructure. Finally, in section 8, we conclude on the results herein and reflect ahead of future ToO activities.

2 Organization

Here, describe LVK involvement, IceCube involvement, SCiMMA, Rubin infrastructure.

3 The challenge

Here, we describe the events of the MDC

4 Alert latency

Here, we describe the analyses of the alert latency

4.1 LVK Alerts

4.2 IceCube Alerts

5 Observing efficiency

Here, we describe the analyses on the observing efficiency and candidate discoverability.

5.1 LVK Alerts

5.2 IceCube Alerts

6 Strategy generation

Here, we describe the analyses of observing strategy generation

6.1 LVK Alerts

6.2 IceCube Alerts

7 The Human Component

Here, we describe the human component of this activity

8 Conclusion

Here, we review the collected results, and assess the status and readiness of the ToO program.

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B References

Andreoni, I., Margutti, R., Banovetz, J., et al., 2024, arXiv e-prints, arXiv:2411.04793 (arXiv:2411.04793), doi:10.48550/arXiv.2411.04793, ADS Link

[PSTN-056], Rubin's Survey Cadence Optimization Committee, Bianco, F.B., Jones, R.L., et al., 2025, *Survey Cadence Optimization Committee's Phase 3 Recommendations*, Project Science Technical Note PSTN-056, NSF-DOE Vera C. Rubin Observatory, URL https://pstn-056.lsst.io/, doi:10.71929/rubin/2585402

C Acronyms

Acronym	Description
AST	NSF Division of Astronomical Sciences
AURA	Association of Universities for Research in Astronomy
DE-AC02	Department of Energy contract number prefix
FOV	field of view
GW	Gravitational Wave
LSST	Legacy Survey of Space and Time (formerly Large Synoptic Survey Telescope)
LSST-DA	LSST Discovery Alliance

LVK	LIGO-Virgo-KAGRA
PSTN	Project Science Technical Note
RTN	Rubin Technical Note
SLAC	SLAC National Accelerator Laboratory
SV	Science Validation
ToO	Target of Opportunity