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Rubin observatory commissioning camera: summit integration

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ABSTRACT

The Rubin Observatory Commissioning Camera (ComCam) is a scaled down (144 Megapixel) version of the 3.2 Gigapixel LSSTCam which will start the Legacy Survey of Space and Time (LSST), currently scheduled to start in 2024. The purpose of the ComCam is to verify the LSSTCam interfaces with the major subsystems of the observatory as well as evaluate the overall performance of the system prior to the start of the commissioning of the LSSTCam hardware on the telescope. With the delivery of all the telescope components to the summit site by 2020, the team has already started the high-level interface verification, exercising the system in a steady-state model similar to that expected during the operations phase of the project. Notable activities include a simulated "slew and expose" sequence that includes moving the optical components, a settling time to account for the dynamical environment when on the telescope, and then taking an actual sequence of images with the ComCam. Another critical effort is to verify the performance of the camera refrigeration system, and testing the operational aspects of running such a system on a moving telescope in 2022. Here we present the status of the

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interface verification and the planned sequence of activities culminating with on-sky performance testing during the early-commissioning phase.

Keywords: Instrumentation, direct imager, telescope construction, Rubin Observatory, commissioning

1. INTRODUCTION

The Vera C. Rubin Observatory (Rubin Observatory), formerly the Large Synoptic Survey Telescope,[1] is designed to systematically survey the southern sky and currently is in its latter stages of construction. The observing facility is located on Cerro Pachon, Chile and is now being integrated with the optical elements of the system. During the late stages of System Integration, Testing, and Commissioning (SIT-Com,,[2] the Commissioning Camera (ComCam) will be used to test the performance of the major subsystems, and interfaces between them, prior to the installation of the 3.2 Gpixel LSSTCam,[3] including the Telescope & Site,[4] Data Management,[5] and Camera Components.[6]

Here we present an update to previous articles on the ComCam.[7,8] In Section 2 we will briefly describe the design of the ComCam system, along with the associated Refrigeration Pathfinder components. Section 3 covers the mechanical integration of the ComCam assembly with the other summit sub-systems, followed by the system-wide testing that has been achieved to date in Section 4. In Section 5 we finally conclude with a summary of the current schedule of planned activities leading up to the start of on-sky observations.

2. DESIGN OVERVIEW

The ComCam design (see Figure 1) is essentially a scaled-down version of the LSSTCam. It utilizes a single 9-CCD (sensors from ITL) raft assembly, identical to the 21 individual science rafts in LSSTCam,[9] with the same readout electronics and auxiliary subsystems with a few notable exceptions. The cryostat is a re-purposed test stand vacuum chamber from early in the LSSTCam development stages. This was modified to accept a system of three Sunpower CryoTel GT coolers which provide stable temperatures for the CCDs and readout electronics inside the cryostat. A simple computer-controlled 3-position filter slide, a 236mm square double-blade shutter by Bonn Shutters, and three lens field-flattening corrector assembly are all mounted to the front of the cryostat. The auxiliary support electronics are housed aft of the cryostat in the utility trunk of same dimensions and similar layout to the LSSTCam utility trunk. The entire system is mechanically housed in a support structure that precisely represents the total mass, center of gravity, and dimensional limits of LSSTCam. All interfaces (mechanical and utilities) to the telescope are made in the same manner as LSSTCam.

2.1 Refrigeration Pathfinder

In order to validate the LSSTCam refrigeration system functionality and performance prior to the actual installation, a separate cryostat with heat exchangers with electric heat loads was designed and built to mimic the behavior of the final configuration at the observatory. There are also dedicated pumps to evacuate and maintain the vacuum of the system. The entire "Refrigeration Pathfinder" cryostat assembly and refrigeration lines are installed inside the ComCam utility trunk and also share some of auxiliary systems with the imager. The refrigeration lines are then routed out of the utility trunk through the bulkhead connections in the camera cable wrap interface with the telescope. This will allow a close approximation of how the refrigeration systems will behave on a moving telescope.

3. SUMMIT INSTALLATION

After the summit arrival of the imager, utility trunk, and support structure in late 2020, the ComCam was unpacked, re-assembled, and verified in the facility cleanroom (Figure 2) to confirm that the system had survived the transportation.

The Refrigeration Pathfinder was installed into the utility trunk (Figure 3) and mounted onto the support structure along with the ComCam imager (Figure 4) in early 2021. Then the integration and functional testing of the Refrigeration Pathfinder proceeded, and by July 2021 the assembly was complete and ready to integrate with the other telescope subsystems.

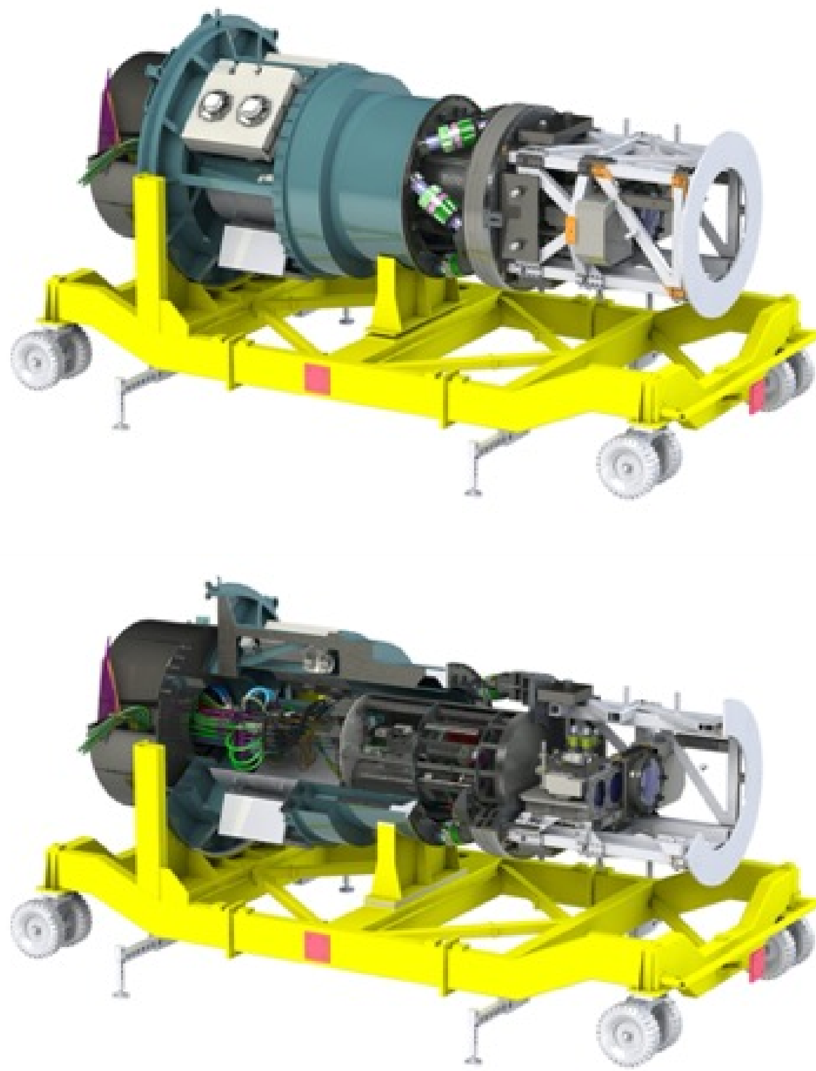

Figure 1. Solid model of the ComCam system installed on the telescope top end structure on the installation cart.

The ComCam assembly was first lifted and installed onto the camera support assembly in early August 2021 (Figure 5). The camera support assembly consists of the camera rotator (which includes the mounting flange for the camera), camera hexapod, the camera cable wrap, and associated electronics, safety systems, and thermal control systems. This entire assembly is able to be moved from the 3rd floor of the support facility building to the telescope platform on a cart on steerable wheels, and can be driven by a electrical tug or lifted by overhead crane. The system then was subject to extensive testing for about 6 months under similar conditions expected when on the telescope. During this initial testing, a few issues were uncovered that required the removal of the ComCam assembly. These issues mostly concerned the operation of the Refirgeration Pathfinder, which was only just put in operation for the first time. The removal happened in Feburary, 2022, and the issues were quickly resolved and re-installation of the ComCam was completed a two weeks later.

The interface and functional testing is ongoing, culminating with a full system-wide testing campaign, currently underway and will continue into the near-term.

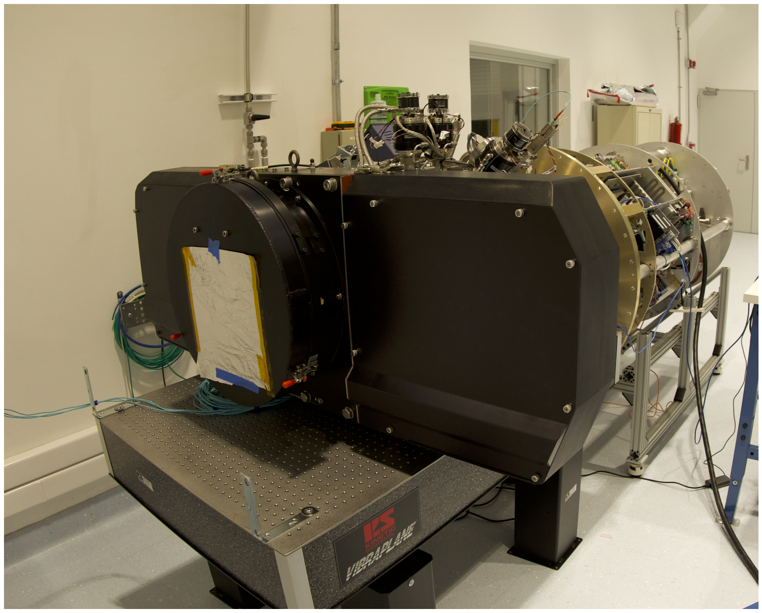

Figure 2. The ComCam imager reassembled and under testing in summit cleanroom.

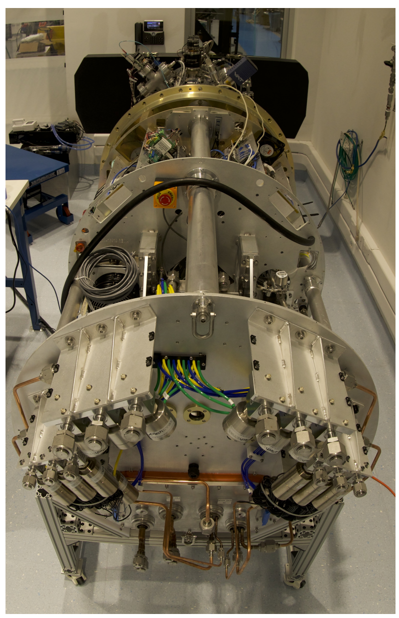

Figure 3. The Refrigeration Pathfinder installed in the ComCam utility trunk in the summit cleanroom.

4. SYSTEM INTEGRATION

The first integration tasks of the ComCam system with a telescope subsystem was with the camera cable wrap. The ComCam itself is mechanically positioned by both the camera rotator and hexapod, independent of the camera cable wrap. As such the software for these sub-systems must synchronize the rotations of the wrap and camera to avoid excessive twisting or flexing of the utility lines. One of the main safety systems are limit switches on the camera bulkhead plate, which will trip if the synchronicity deviates more than acceptable. Once the switches were adjusted and connected, the full range of rotator and hexapod positioning were tested with the ComCam mass to verify loaded performance. Then the ComCam was to be integrated into the observatory's software architecture. Over time, this architecture has grown to include several individual components that

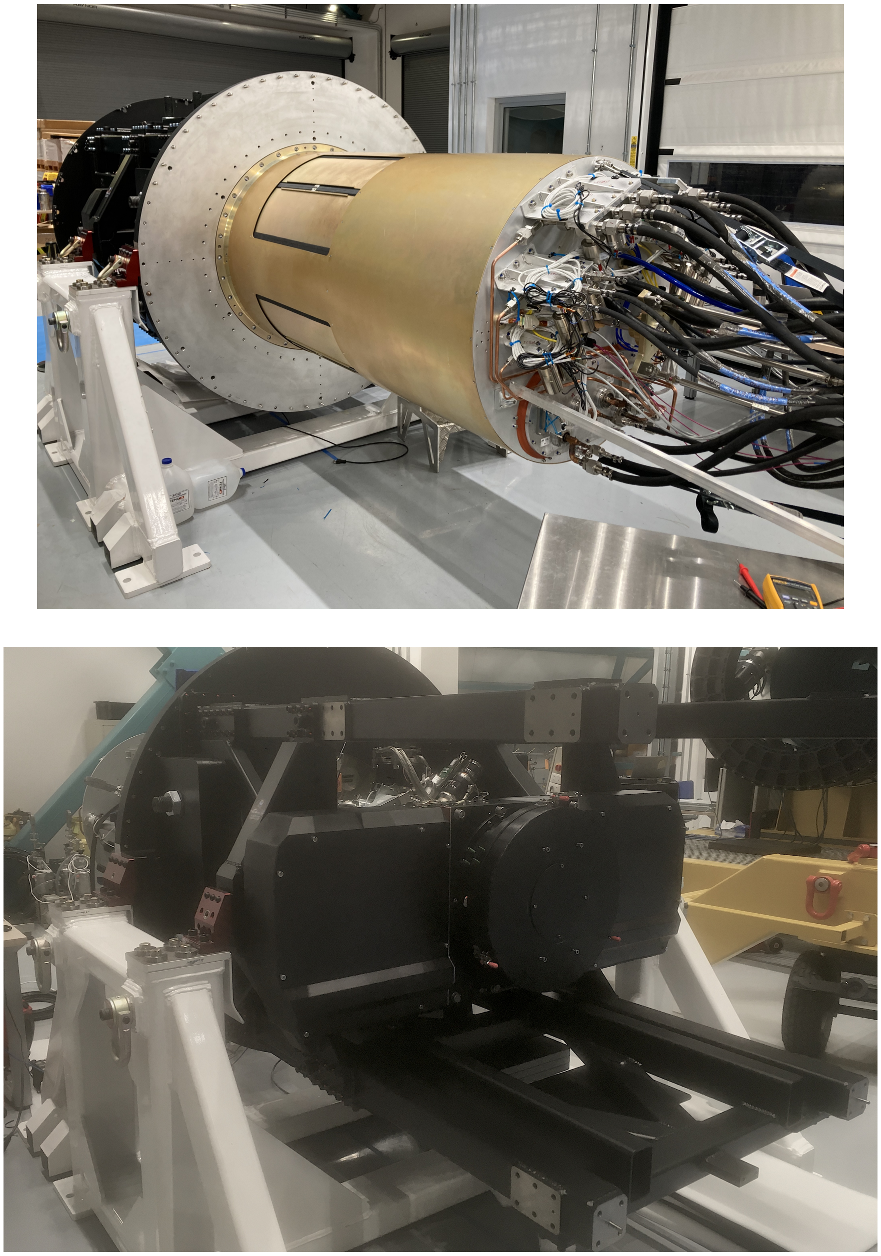

Figure 4. (TOP) The utility trunk, with environmental enclosure installed on the support structure at the summit facility. (BOTTOM) The ComCam imager being mounted inside the support structure.

coordinate the execution of the system which includes a queue executor, high-level python scripts and classes (to more easily access commonly used functionality), and interfaces for these aspects so users can interact. All telemetry and software commands are currently streamed over a publisher-subscriber Data Distribution Service (DDS) based interface called the Services Abstraction Layer (SAL), and all summit-related telemetry and communication data are saved in an influx database, called the Engineering Facility Database (EFD) which is then archived with the image data in the U.S.

As of mid-2022, the integration efforts have continued, and now include the M1M3 and M2 support subsystems, the Global Interlock System, the Mount Control System, and the pointing trajectory planners for the telescope. The latest integration tests have included a closed-loop feedback test of the Active Optics System

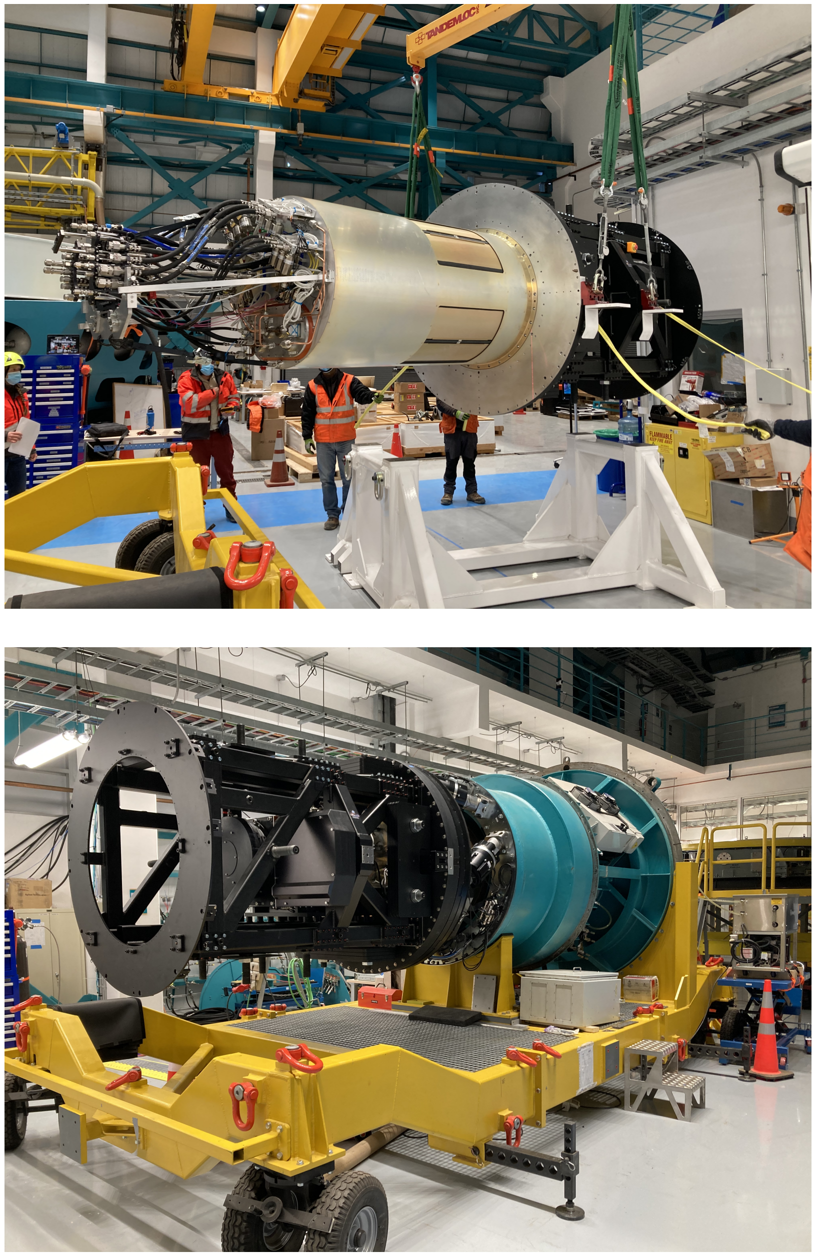

Figure 5. (TOP) The active process of the mechanical lift of the ComCam onto the camera support assembly. (BOTTOM) The ComCam installed on the camera support assembly.

(AOS)[10] which is a wavefront sensing algorithm to actively control all of the degrees of freedom in the mirror support systems and hexapods. Although the ComCam is not currently on-sky, the Rubin team has simulated in-focus and out-of-focus images using imsim to feed the system. Utilizing a "playback" function of the camera's data acquisition system, the simulated images appear (from the AOS perspective) to come from the sky (Figure 6) with valid on-sky metadata being properly populated by the other sub-systems. The AOS then applies a wavefront sensing technique to arrive at a delivered zernike-basis set of coefficients for the sampled focal plane. These zernike coefficients are then fed back through a model of the system to arrive at a new solution to apply to the optics through differential-forces and actuator positions. AOS software architecture is described in a previous paper.[11]

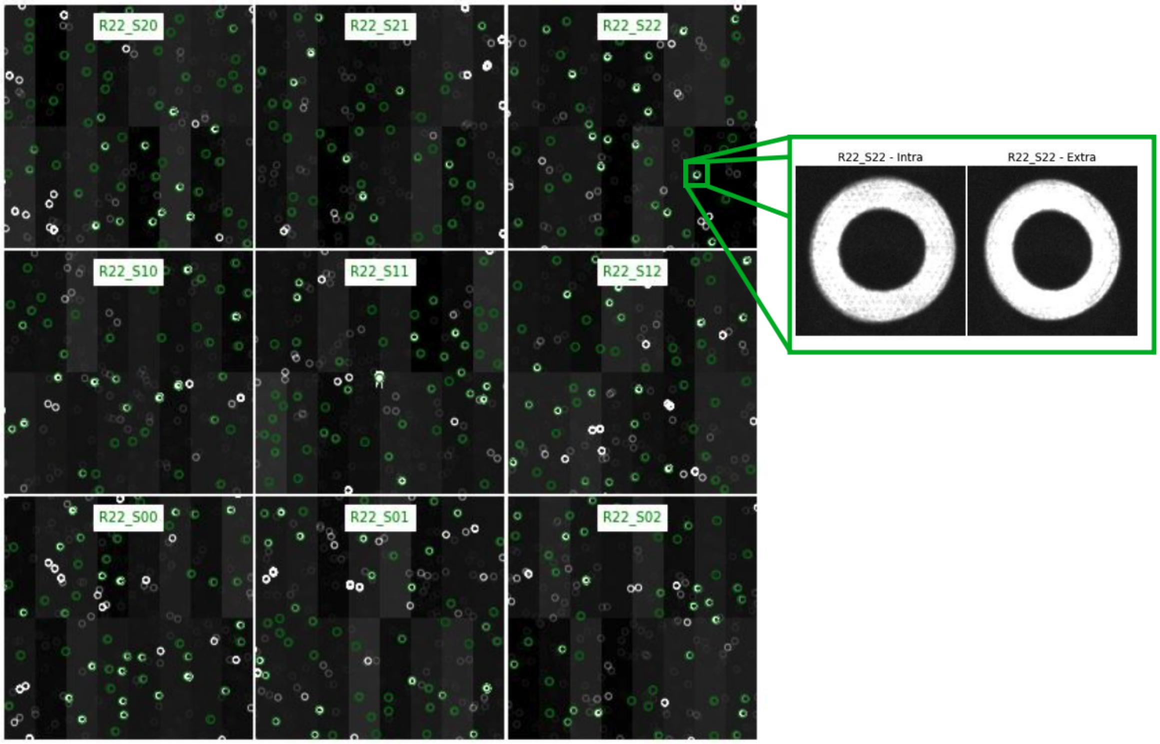

Figure 6. Example of a simulated ComCam image used for integration tests. This image is designed to be what is expected for a 1.5mm out-of-focus 30-second exposure for wavefront sensing. (INSET) Example of one out-of-focus point source, at -1.5mm and +1.5mm from nominal focus.

5. FUTURE SCHEDULE

Final readiness for installing the ComCam on the telescope is planned for July 2022 and safety reviews are already scheduled. This entire sequence of a safety demonstration (with surrogate masses and envelope volume simulators), followed by the installation, connection, cooldown and functional re-verification of the ComCam will take several weeks and is collaboratively shared responsibility between the Rubin team and the telescope contractors.

Once installed and re-verified on the telescope around August/September 2022, the ComCam will remain in place until the active M2 support system is ready to be installed (requires the ComCam to be removed for this activity), currently scheduled for late 2022. After a few months of downtime, the ComCam will be reinstalled, awaiting the commissioning of the telescope's 3-mirror optical system. During these months, the ComCam imager will continue integration tests with more system components (including the dome), and simultaneously the Refrigeration Pathfinder will be testing the refrigeration system with the compressors and lines that will be used eventually for LSSTCam. Long-term stability and performance are important studies with the moving telescope, so as much active run time is needed as possible.

Following the commissioning of the mirrors, engineering "first-light" on-sky observations will commence, starting with pointing, tracking, slewing tests, as well as the final control loop testing of the AOS to control the mirror figure and position the optics precisely for optimized image quality. Subsets of the ComCam images will be collected into a publicly-accessible "Data Preview" for the astronomical community to analyze and prepare for the LSSTCam and the Science Survey.

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