HEP Project Status Report –June 2019

Large Synoptic Survey Telescope (LSST) Camera

HOST LABORATORY: SLAC
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FEDERAL PROJECT DIRECTOR: Hannibal Joma
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1. SCORECARD AS OF May 2019

Current CD:	3	Date of Current CD approval:	Aug 27, 2015
Next CD:	4	Forecast/Planned:	Mar 17, 2021
Percent Complete:	92.8%	Baseline:	Mar 31, 2022
ETC:	$12.2	TPC or Cost Range:	$168M
Contingency:	$2.6M (EAC)	Float to CD-4:	252 Days
Cumulative CPI:	0.97	Cumulative SPI:	0.97

2. NEAR-TERM MILESTONES

May 19 Forecast Finish	Activity Name	Float[1]	Comment
7-Jun-19	COMP: Cryostat Chamber & I&T Refrigeration System Ready for Integration	-18	Completed successfully in June. This is the main driver for the 18 days schedule delay.
14-Jun-19	COMP: Commissioning Camera Shipped to Tucson	678	Completed on June 19th.
21-Jun-19	COMP: Corner Raft Tower Ready for Integration	2	This could be impacted due to the glows found on 3 guide sensors. The project is reviewing the impact if these defects. If a sensor has to be replaced, insertion of the corner raft will be shifted to after insertion of all science rafts.
25-Jun-19	START: Science Raft Tower Integration	-18	This is currently planned to start by end of June assuming the project makes the decision to proceed with the lost washer not found.
28-Jun-19	COMP: Camera L3 Lenses Ready for I&T	121	This has been delayed by several week to address the de-centering measured during the environmental testing
28-Jun-19	COMP: Chile Compressor System Ready for Pathfinder	615	This is on track with testing of the Cold Cabinets being under way.
1-Jul-19	START: Filter Exchange System Testing	64	This is on track at IN2P3. Work has re-started as planned after the safety incident corrective actions being implemented.
10-Jul-19	COMP: Filter Coating 1st Article	124	The r-band filter is expected to arrive back at Materion on July 8th for the final full-size testing
30-Jul-19	COMP: Camera Body & Purge Unit Ready for Integration	33	This is on track with purge testing expected to start last week of June
31-Jul-19	COMP: L1-L2 Assembly - I&T Phase 5	184	This is on track with the L1-L2 acceptance review currently planned for July 9th
16-Sep-19	START: Camera I&T	0	This is on track and dependent on receiving the filter exchange system from IN2P3 as currently planned.
19-Sep-19	COMP: Integration of 9 SR into Cryostat	0	This is on track
2-Oct-19	COMP: Shutter Ready for Integration	45	This is on track per this forecast date. Work has re-started now that the long lead linear bearing have been received at SLAC

1) Float to early Camera delivery need date of 11/19/2020.

3. STATUS HIGHLIGHTS

General Summary:

As reported, an injury accident in April caused about a two-month delay in integration of the filter-exchange carousel with the Camera back flange. The person injured is recovering rapidly and is expected to return to work by late June. On May 22-24, the project conducted a review at LPNHE to assess corrective safety measures and future carousel testing. While the filter exchange work is now near critical path, the project does not expect the carousel delay to impact Camera early delivery.

Currently, eight Raft Tower Modules (RTMs) have been re-verified at SLAC and deemed ready for integration with the cryostat. The project is addressing a few minor issues found during re-verification. The issues include additional contamination and occurrence of shorts between the shroud and side walls in some of the RTMs. The shorts can be addressed by addition of a simple spacer. Other production RTMs are in queue for re-verification or are still undergoing refurbishing.

As reported, four Corner Raft Tower Modules (CRTMs) were constructed for the focal plane in 2018. Acceptance-testing of the four was completed in early June at SLAC. One CRTM was deemed available for integration with the cryostat. The other three CRTMs were found to have guide-sensor glow issues.

The project is investigating impact of the glow issues. If replacement of guide sensors becomes necessary, CRTM availability may be delayed as much as two months. The project expects to complete the investigation by the end of June and to make a decision then whether the affected sensors must be replaced.

In early June, Arizona Optical Systems (AOS) completed testing of the integrated L1-L2 lens assembly. After measuring excess astigmatism during initial assembly, AOS implemented a simple change to shims that adjust the L1-L2 alignment co-planarity, and the L1-L2 assembly is now completed.

Delivery of the L1-L2 assembly is scheduled for July with an acceptance review currently planned for July 9, 2019. The remaining scope of work at AOS is limited to the accessories (lens covers, and shipping container), which have made some progress despite limited resources available at AOS to accommodate a DX-rated contract.

Thales SESO (TSESO) completed integration of the L3 lens with its titanium barrel and environmental testing is underway. Test results are mostly successful, except for some de-centering that has occurred during thermal cycling under gravity. TSESO is investigating the de-centering.

The first units of the production auto-changer and filter loader were delivered to LPNHE by, respectively, CPPM and LPSC. When the carousel is available, the filter-exchange components will undergo combined interoperability tests using the full-scale test bench at LPNHE.

Assemblies of the Camera body housing and Camera body shroud were completed at the SLAC IR2 Cleanroom Facility. The shroud is currently at the painting vendor. When the shroud returns, it will be attached to the housing. As reported, long lead time for fabrication of shutter-blade linear guides has delayed assembly of the two production shutters. The vendor delivered the guides to SLAC in early June, and assembly of the two shutters is underway. The shutter delay does not impact Camera schedule.

All four power-cabling feedthroughs and all six Optical Translation Modules (OTMs) were installed on the cryostat in May. After installation, leaks were detected in seals for a few of the feedthroughs. The time required to repair leaks caused a small delay in completion of Bench for Optical Testing (BOT) electro-optical (EO) testing. I&T accomplished final EO testing in mid-June. The delay contributed to a slip of the Camera early delivery date by three weeks.

I&T has opened the sealed cryostat to remove the two engineering test units (ETU) rafts, which were used for final EO testing. Once removed, the cryostat and ETUs will be exposed for a search for a washer that has been missing since the feedthroughs were installed. Pending location of the washer and favorable review of I&T refrigeration test results, I&T can begin RTM integration.

I&T will integrate RTMs in two stages. The first stage currently is on track to begin in late June. In the first stage, nine RTMs will be installed incrementally within the cryostat. One or more CRTMs may also be installed, pending resolution of guide-sensor glow issue. I&T expects that the first stage will continue through the summer of 2019.

The commissioning camera (ComCam) team held a successful pre-ship review May 29-30 at SLAC, and the dewar was been delivered to Tucson. Delivery of the ComCam dewar accomplished a major project goal.

Status by Camera subsystem:

- **Systems Integration.** The Systems Integration team continued work on verification and test plans and acceptance reviews for various Camera subsystems.
- **Sensors.**
  ITL and e2v have completed and delivered all sensors per their contracts.
- **Science Raft.** Raft Tower Module (RTM) channel-loss mitigation activities continued at BNL and SLAC (Figure 1). Currently eight RTMs have been re-verified and are deemed ready for integration within the cryostat. Minor issues found during re-verification are being addressed (additional contamination and a short between shroud and side wall that the team is addressing with a simple spacer). The remainder of the production RTMs are in the queue for re-verification or are still undergoing refurbishing.

Table 1 summarizes current status of each RTM and describes the mitigation plan that applies to each.

Table 1: Summary of RTM status as of June 25, 2019.

RTM	Sensors	Location	Original State[1]	Plan[2]	Current Status
RTM1	ITL	SLAC	4 dead channels	B	RTM refurbished and returned to SLAC 5/17. Pending reverification.
RTM2	e2v	SLAC	1 dead channel	C	Received at SLAC 5/17 but particulate contamination remains. Will go back to BNL
RTM3	e2v	SLAC	0 dead channels	C	RSA refurbished and returned to SLAC 6/19 for final re-assembly
RTM4	e2v	SLAC	1 dead channel	C	RSA refurbished and returned to SLAC 5/31 for final re-assembly
RTM5	e2v	SLAC	0 dead channels	C	RSA refurbished and returned to SLAC 5/31 for final re-assembly
RTM6	e2v	SLAC	Several shorts	A	RTM refurbished and returned to SLAC 5/31. Pending reverification.
RTM7	e2v	SLAC	0 dead channels	C	RSA refurbished and returned to SLAC 6/19 for final re-assembly
RTM8	ITL	SLAC	1 dead channel	D	COMPLETE. Ready for integration. One dead channel remains
RTM9	e2v	SLAC	1 glowing sensor/ (sensor will be removed)	A	COMPLETE. Ready for integration.
RTM10	ITL	SLAC	3 high noise sensors	A	COMPLETE. Ready for integration.
RTM11	ITL	SLAC	3 dead channels	B	COMPLETE. Ready for integration.
RTM12	e2v	SLAC	0 dead channels	C	RSA refurbished and returned to SLAC 6/19 for final re-assembly
RTM13	e2v	SLAC	0 dead channels	C	RSA refurbished and returned to SLAC 6/19 for final re-assembly
RTM14	ITL	SLAC	1 dead channel	D	COMPLETE. Ready for integration. One dead channel remains
RTM15	ITL	SLAC	1 dead channel	D	Pending dis-assembly and cleaning at SLAC
RTM16	e2v	BNL	0 dead channels	C	At BNL under cleaning. Expect to ship 6/28
RTM17	e2v	SLAC	0 dead channels (complete on hold)	B	COMPLETE. Ready for integration.
RTM18	ITL	SLAC	0 dead channels	D	Pending dis-assembly and cleaning at SLAC
RTM19	ITL	BNL	1 high CTE sensor (sensor will be removed)	A	Refurbishment complete at BNL. Awaiting final acceptance. Expect to ship 6/28.
RTM20	ITL	SLAC	0 dead channels (complete on hold)	B	COMPLETE. Ready for integration. One dead channel remains.

RTM21	e2v	SLAC	0 dead channels (complete on hold)	B	Received at SLAC in 5/29 and being re-verified.
RTM22	e2v	SLAC	Incomplete (not constructed yet)	A	COMPLETE. Ready for integration.

1) State prior to channel-loss mitigation.
2) Migration plans A through D:
A. RTM to be disassembled, cleaned, retrofitted, re-assembled and qualified at BNL and then re-verified at SLAC: Applies: to 1) RTMs that were returned to BNL that require sensor replacement due to permanent damage or performance issues; and 2) incomplete RTMs at BNL that are currently on hold. There are five RTMs in this category, all of which will be re-verified at SLAC.
B. RTM to be disassembled, cleaned, retrofitted, re-assembled at BNL, and then re-verified at SLAC: Applies to 1) RTMs that were returned to BNL that do NOT require sensor replacement; and 2) completed/tested RTMs at BNL that were never shipped to SLAC and are currently on hold at BNL. There are six RTMs in this category, all of which will be re-verified at SLAC.
C. (e2v only) RTM to be disassembled at SLAC and the RSA will be shipped to BNL for cleaning and retrofitting, and then returned to SLAC for re-assembly and re-verification at SLAC: Applies to e2v-based RTMs currently at SLAC (e2v-based RTMs require sensor removal due to limited access to the wire bonds while installed on the RSA). There are eight RTMs in this category, all of which will be re-verified at SLAC.
D. (ITL only) RTM to be disassembled, cleaned, retrofitted, reassembled and re-verified at SLAC: Applies to ITL-based RTMs already at SLAC. There are four RTMs in this category.

- **Corner Raft.** As reported, four Corner Raft Tower Modules (CRTMs) were constructed for the focal plane in late 2018. Acceptance-testing of the four was completed in early June at SLAC. One CRTM has been deemed available for integration within the cryostat. The other three CRTMs are found to have guide-sensor glow issues.

  Seriousness of the glow issues is under investigation. Three guide sensors are affected with one glowing channel each. If the project determines that science impact is negligible, the four CRTMs can be available for integration by July as planned. However, if replacement of guide sensors is necessary, CRTM availability may be delayed as much as two months.

  The project expects to complete its assessment of the glow-issue impact to Camera schedule by end of June and to make a decision then whether the affected sensors must be replaced.

- **Optics.** Arizona Optical Systems (AOS) completed attachment of the L1 lens to the L1-L2 assembly in May (Figure 2). L2 was attached last summer. After measuring excess astigmatism during the initial assembly, AOS implemented a simple change to shims that adjust the L1-L2 alignment co-planarity, and the L1-L2 assembly is now completed.

  Delivery of the L1-L2 assembly is scheduled for July with an acceptance review currently planned for July 9, 2019. The remaining scope of work at AOS is now limited to the accessories (lens covers, and shipping container), which have made some progress despite the limited resources available to accommodate a DX rated contract.

  Thales SESO (TSESO) completed integration of the L3 lens with its titanium barrel and environmental testing is underway. Test results have been successful except for some de-centering occurring during thermal cycling under gravity. TSESO is investigating the de-centering issue but the impact on performance, as reviewed by the project, is expected to be negligible and easily managed using the active optics system.

  TSESO expects to finish polishing of the z-band filter glass by late June. Processing of the u-band, g-band, and y-band glass continued at TSESO. Materion, the filter-coating vendor, is underway with qualification of the r-band filter coating.

  As reported, early results confirmed that the r-band filter-coating was successful; however collection of the full as-built measurement at Materion has been impaired by calibration issues of the metrology system.

The impact of the delay required shipping the r-band filter to TSESO un-measured to complete the as planned coating stress verification step and returning the filter to Materion after this issue is resolved. The coating stress on the r-band filter conducted concurrently with a filter mount stress on the un-coated i-band confirmed no issues on optical performance as expected by the design analysis.

- **Filter Exchange**. As reported, a serious injury accident in April delayed integration of the filter-exchange carousel with the Camera back flange. The person injured continues to recover rapidly and is expected to return to work by late June. The project determined that the incident will cause about a two-month delay in the carousel schedule.

  The project conducted a review at LPNHE May 22-24 to assess corrective safety measures and plans for ongoing carousel testing (Figure 3). Recommendations from the safety review are contained in a report currently circulating. Currently, the project does not expect the carousel delay to impact Camera early delivery, although this set of activity is now near critical path.

  The first of two units of the production auto-changer and the filter loader were shipped to LPNHE for combined testing by, respectively, CPPM and LPSC (Figures 4 and 5). Work on the carousel was restarted in early June, and the team expects to start combined testing at LPNHE by the end of June. The filter exchange full system except for the spare auto-changer is expected to ship to SLAC by the end of August.

- **Camera Body and Mechanisms.** Assemblies of the Camera body housing and Camera body shroud were completed at IR2. The shroud currently is at the painting vendor. When the shroud is returned, the team will attach it to the housing.

  As reported, assembly of the production shutter at SLAC was delayed due to long lead time for delivery of shutter-blade guides, which were custom-made by a vendor in Japan. The vendor delivered the guides to SLAC in early June (Figure 6). Assembly of the two production shutters is under way. The shutter delay caused by long lead time for the guides will not impact Camera schedule or cost.

  Work on the Camera purge system cabinets continued. Test procedures for the purge systems have been released. There are two purge systems: a Camera volume purge system and a mechanism purge system. The two control temperature and flow of air around critical components in the Camera housing.

- **Cryostat and Refrigeration.**

  - **Utility Trunk**: As reported, the team installed four of the power-cabling feedthroughs between the utility trunk and the cryostat. The four feedthroughs, which enable rafts to be powered in the sealed cryostat, were needed for final BOT EO testing. The team also installed all six Optical Translation Modules (OTMs). OTMs translate electrical signals from the RTMs to optical signals available for processing off-Camera.

    After installation, the team detected vacuum leaks in seals for a few of the feedthroughs. The time required to repair the leaks caused a small delay in completion of BOT EO testing, which requires a sealed, cooled cryostat. I&T accomplished final EO testing in mid-June. This delay in EO testing has contributed to the slip of the Camera early delivery date.

    Purchase orders have been issued for the utility trunk vacuum chambers, including some correction to address structural reinforcement needed after some further integrated analysis. The chambers will contain refrigeration heat exchangers and purge-system components inside thermally-isolated areas. Delivery of the chambers is expected in July.

    Drawings for utility trunk front-end assembly, panels, and doors have been released and approved.

  - **Refrigeration:** All I&T heat exchangers and refrigeration cabinets have been operating successfully at IR2. Verification testing of the I&T refrigeration system has been completed and analysis of results is underway.

    Work on the Telescope Mount Assembly (TMA) refrigeration system is progressing well. The vendor

delivered parts for the TMA cold-system heat exchangers to SLAC in early June (Figures 7 and 8). Cleaning and inspection of the parts is underway. The vendor will begin phased-delivery of the cryo-system parts in early July and complete delivery in August.

Assembly of TMA refrigeration cabinets continued at SLAC. The two cold-system cabinets, expected to be completed in early June, have been delayed a few weeks to correct minor fabrication issues. Completion of the two cryo-system cabinets currently is on track for July. Currently, verification of the TMA refrigeration system is anticipated within the third quarter of 2019.

Following is a table that summarizes current status of refrigeration components.

Table 2: Summary of Refrigeration Status as of June 25, 2019.

Component	System	Circuit	Status	Location
Evaporator	Camera Cryostat	2 Cold circuit	Formal acceptance test completed	SLAC
		6 Cryo circuit	Formal acceptance test completed	SLAC
	Pathfinder Chamber	2 Cold circuit	Chamber lid and vessel received at SLAC 5/24	SLAC
		2 Cryo circuit	Chamber lid and vessel received at SLAC 5/24	SLAC
Heat Exchangers	I&T (to become Chile maintenance system)	Vacuum can 1: 2 Cold and 2 Cryo circuits	Formal acceptance test completed	SLAC
		Vacuum can 2: 4 Cryo circuits	Formal acceptance test completed	SLAC
	Pathfinder	Vacuum can 1: 2 Cold and 2 Cryo circuits	Assembly with the load under way	SLAC
	On-Telescope (Chile)	Vacuum can 1: 2 Cold and 2 Cryo circuits	Cold received and under cleaning. Delivery of cryo expected July 2019	SLAC/Eden
		Vacuum can 2: 4 Cryo circuits	Fabrication in progress at Eden. Delivery expected July 2019	Eden
Compressor cabinets	I&T (to become Chile maintenance system)	2 Cold Cabinets, each supporting 1 Cold circuit.	Formal acceptance test completed	SLAC
		2 Cryo cabinets, each supporting 3 Cryo circuits.	Formal acceptance test completed	SLAC
	On-Telescope (to be used in Chile with pathfinder first)	2 Cold Cabinets, each supporting 1 Cold circuit.	Assembled at SLAC awaiting acceptance test	SLAC
		2 Cryo cabinets, each supporting 3 Cryo circuits.	In Assembly at SLAC	SLAC

- **Integration and Test (I&T).** I&T continued activities related to RTM refurbishment and to preparations for RTM integration using the BOT. I&T also continued assembly of the Camera integration stand and the procurement of fixtures for positioning Camera subassemblies during Camera construction (Figures 9 through 11).

  As mentioned, teams at IR2 installed power-cabling feedthroughs and OTMs. During installation of one of the feedthroughs, I&T discovered that some fasteners and washers were missing from the feedthrough terminal block. All but one washer was found on the floor near the BOT. The washer is still missing. If the washer is not found on the floor, the team may have to search within the cryostat.

I&T has opened the sealed cryostat to remove the two engineering test units (ETU) rafts, which were used for final EO testing. They were removed, leaving the cryostat and ETUs exposed for a search for the washer and correction of a few other maintenance problems (including a heater short-circuit).

Originally, I&T had planned to start RTM integration by late May. However, there was a delay due to more time required than expected for refrigeration testing and for repair of feedthrough seal leakage. I&T currently is on track to begin RTM integration by late June. The project is forecasting an 18-day delay to Camera early delivery date, which is still within the schedule float available for when the Camera must be available to mount on the telescope.

In the first stage of RTM integration, nine RTMs will be installed incrementally within the cryostat. One or more CRTMs may also be installed, pending resolution of the guide-sensor glow issue. I&T expects that the first stage will continue through the summer of 2019.

I&T continues to support about half of the RTM channel-loss mitigation activities described in the Science Raft section of this report. UC-Davis and SLAC teams trained by BNL are qualified to disassemble and clean rafts at SLAC. Table 1 contains current status of RTMs set to undergo processing at SLAC. The RTM refurbishment is maintaining schedule and remains ahead of the planned integration need date.

- **Commissioning Camera (ComCam).** Final testing of the commissioning camera (ComCam) dewar was completed at IR2 in May. The testing used ComRaft, an RTM constructed in support of commissioning schedule mitigation. The ComCam team held a successful pre-ship review May 29-30 at SLAC. The dewar was packed for shipment to Tucson on June 19 (Figures 12 through 15). The dewar has been received at Tucson, which accomplishes a major project goal.
- **Commissioning.** As reported, the MIE project forecasts that the Pathfinder compressor cabinets will be available at the end of June 2019. Storage tanks for Pathfinder cryo-system refrigeration were filled at SLAC in preparation for shipment to the summit.

  Also at SLAC, work on Pathfinder heat exchangers and heat loads continued. Construction of the vacuum vessel that will contain the heat exchangers was completed, and the vendor delivered the vessel to SLAC.

4. ISSUES

- Recent Risk: The injury incident related to the work on carousel in France is being investigated. The lessons learned will be applied at SLAC since similar verification work is planned at IR2 after delivery of the carousel from LPNHE. The incident is expected to affect carousel schedule by about two months; although this delay is not expected to impact Camera early delivery at this time, any delays beyond two months will place this element on or near critical path.
- Existing Risk continuation: The impact of metallic particulate contamination leading to loss and potential damage of some sensor channel has strained the level of contingency on the project. While significant progress has been made in refurbishing the rafts, there is significant risk related to the additional handling of the rafts as evidenced by several small issues discovered on recently refurbished rafts.
- The read-noise issue with ITL RTMs remains a concern as is the appearance of glows on some sensors, which is not fully understood yet. The project has reviewed impacts on science requirements allowing the use of some sensors that have degraded performance, which is reducing the risk of not having enough sensors available. The risk will remain high until performance-testing is completed at the integrated Camera level.
- Existing Risk continuation: Manufacturing issues with the on-telescope heat exchangers still remains even though significant effort has been invested in simplifying the design. Refrigeration performance remains a risk as well, although it is reduced based on the recent successes demonstrated with the first heat exchanger canister.
- Existing Risk continuation: The vacuum-system remains a technical risk regarding initial pump down time, capacity and lifetime based on early results with the cryostat. A tiger team was assembled and has completed the plan to address these issues. Current results of full cryostat pumping in May with 2 ETUs

and all cabling are reducing this risk significantly as the new pump down procedure is now estimated to take less than 8 days on a fully loaded cryostat to reach acceptable pressure based on early measurement as opposed to 3 weeks from the previous measurements.

5. COST AND SCHEDULE SUMMARY ($M)

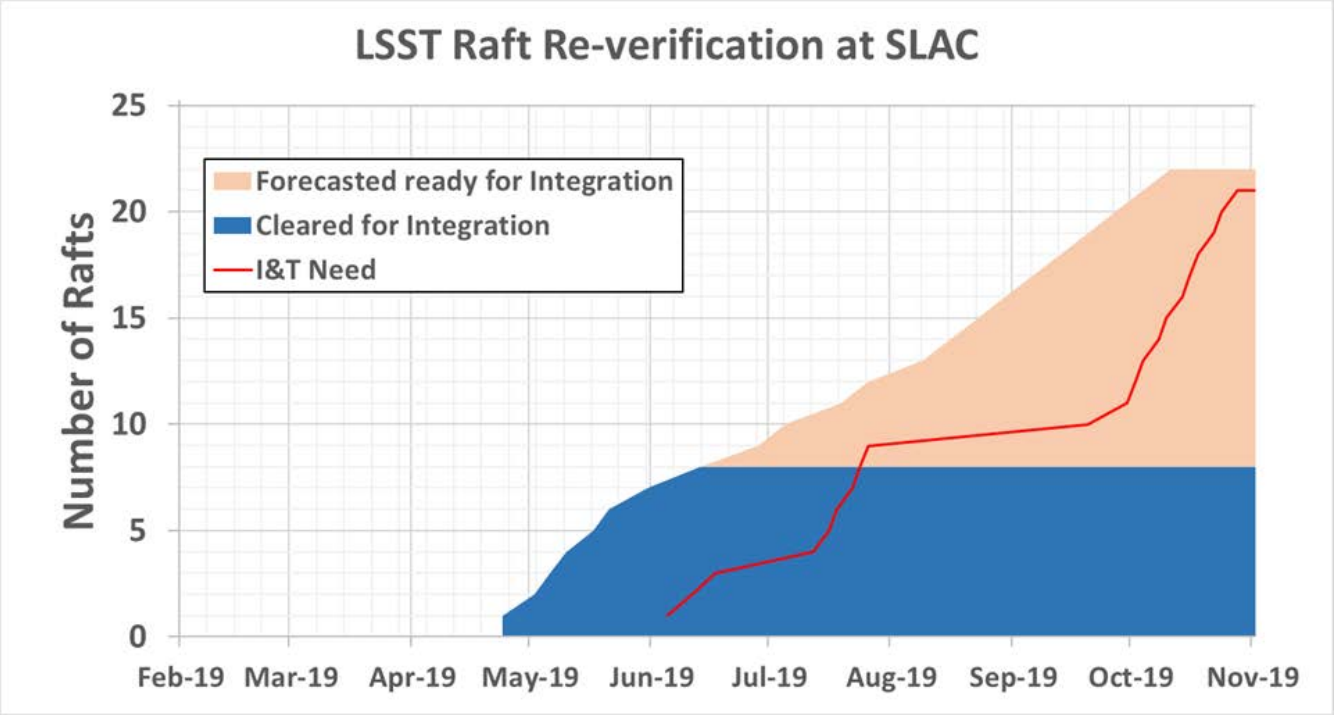
	WBS	BAC	CTG	EAC	Contingency	Actuals
TEC	3	$143.1	$12.2	$148.0	$2.6	$135.8
Management	3.01	$12.2	$1.7	$11.8		$10.1
Systems Integration	3.02	$7.1	$0.9	$6.8		$5.9
Science Sensors	3.03	$30.0	$0.0	$29.7		$29.7
Science and Corner Raft System	3.04	$22.5	$0.5	$22.3		$21.8
Optics	3.05	$26.5	$4.6	$26.5		$21.9
Camera Body, Mechanisms, Cryostat	3.06	$20.3	$0.8	$24.4		$23.6
CCS, DAQ, Auxiliary Electronics	3.07	$12.0	$0.8	$13.6		$12.8
Integration and Test	3.08	$12.5	$2.9	$12.9		$10.0
OPC	3	$17.2	$0.0	$17.4	$0.0	$17.4
Management	3.01	$3.0	$0.0	$3.0		$3.0
Systems Integration	3.02	$2.2	$0.0	$2.2		$2.2
Science Sensors	3.03	$4.0	$0.0	$4.1		$4.1
Science and Corner Raft System	3.04	$2.1	$0.0	$2.1		$2.1
Optics	3.05	$1.6	$0.0	$1.6		$1.6
Camera Body, Mechanisms, Cryostat	3.06	$2.9	$0.0	$3.0		$3.0
CCS, DAQ, Auxiliary Electronics	3.07	$1.1	$0.0	$1.1		$1.1
Integration and Test	3.08	$0.3	$0.0	$0.3		$0.3
TEC+OPC	3	$160.3	$12.2	$165.4	$2.6	$153.2
TPC	3	$168.0		$168.0		

[1)] Camera level 3 designation based on LSST Project WBS.

Schedule Summary:

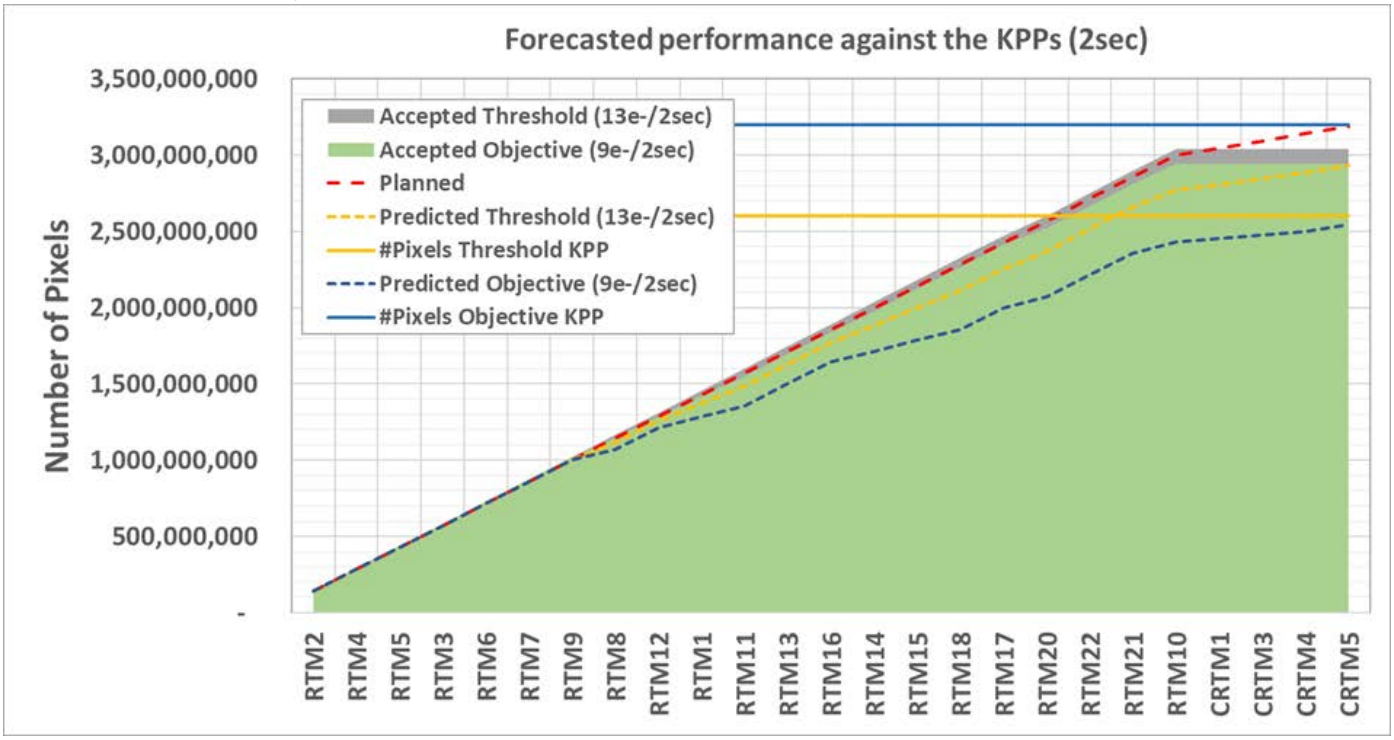
Level	Milestone	Actual & **Forecast**	Baseline Finish
L1	COMP: CD-0, Approve Mission Need	20-Jun-11 A	06/20/11
L1	COMP: CD-1, Approve Alternative selection and Cost Range	11-Apr-12 A	04/11/12
L1	COMP: CD-3a, Approve Start Long Lead Procurements	05-Jun-14 A	06/05/14
L1	COMP: CD-2, Approve Performance Baseline	07-Jan-15 A	01/30/15
L1	COMP: CD-3, Approve Start of Construction	27-Aug-15 A	01/29/16
L1	COMP: CD-4, Approve Project Completion	03/17/21	03/31/22
L2	COMP: Conceptual Design Complete (Ready for CD-1)	30-Nov-11 A	11/30/11
L2	COMP: Prototype Science Sensors Received	03-Jan-12 A	01/03/12
L2	COMP: Vertical Slice Test - Phase 1	16-May-13 A	05/16/13
L2	COMP: Sensor Final Design Complete (Ready for CD-3a)	31-Mar-14 A	03/31/14
L2	COMP: First Article Sensor Contract Placed	24-Apr-14 A	04/24/14
L2	COMP: Performance Baseline Established (Ready for CD-2)	16-Oct-14 A	10/16/14
L2	START: ASIC production (IN2P3)	25-May-15 A	03/31/16
L2	COMP: Award L3 Assembly Phase 1 Contract	08-Jun-15 A	07/31/15
L2	COMP: Camera Design Complete (Ready for CD-3)	12-Jun-15 A	09/30/15
L2	COMP: L1-L2 Assembly Phase 2 FDR	30-Oct-15 A	02/29/16
L2	COMP: First Sensor Tested	27-Jan-16 A	02/29/16
L2	COMP: First article 2Kx4K Wavefront Sensor (Phase 1)	16-May-16 A	12/16/16
L2	COMP: Award Sensor Lot 2	02-Aug-16 A	08/31/16
L2	COMP: First RTM Ready for Integration	26-May-17 A	05/31/17
L2	COMP: Sensor Production is 50% complete (end of lot 2)	29-Sep-17 A	02/28/18
L2	COMP: L1 & L2 Pre-Coating Metrology (Phase 4b)	16-Feb-18 A	02/28/18
L2	COMP: Sensor Production Complete	16-Nov-18 A	03/29/19
L2	COMP: Cryostat Chamber & I&T Refrigeration System Ready for Integration	06/07/19	12/13/18
L2	COMP: Commissioning Camera Ready to Ship for Testing	06/14/19	05/31/19
L2	COMP: L3 Assembly Ready for Integration	06/28/19	04/30/19
L2	COMP: 1st Filter Coated and Ready for Integration	07/10/19	08/30/19
L2	COMP: L1/L2 Assembly Ready for Integration	07/31/19	10/31/19
L2	COMP: Early Hardware & Software Ready for Summit	09/24/19	10/31/19
L2	COMP: Filter Exchange System Ready for Integration (IN2P3)	10/10/19	01/31/19
L2	COMP: Loaded Cryostat Ready for Integration	01/30/20	02/28/20
L2	COMP: Camera Fully Integrated & Ready for Verification Testing	07/17/20	08/31/20
L2	COMP: PSR/ORR - Camera Pre-Ship/Operations Readiness Review Complete	12/17/20	02/26/21
L2	COMP: KPPs achieved (Camera Readiness Review, Ready for CD-4)	12/17/20	10/29/21

Raft Status as of June 25, 2019



Raft re-verification at SLAC after refurbishment progress against late need date to maintain Camera schedule.

KPP status as of June 25, 2019



Progress against the KPP for raft accepted at BNL regardless of channel loss retrofit. Includes now 21 rafts.

7. FIGURES

Figure 1: RTM6 during original assembly in the LSST cleanroom at BNL. RTM6 was refurbished earlier this year per the plan for channel-loss mitigation and is in the queue for delivery to SLAC for re-verification. RTM refurbishment at SLAC and BNL is maintaining schedule and remains ahead of the planned need date for integration within the cryostat.

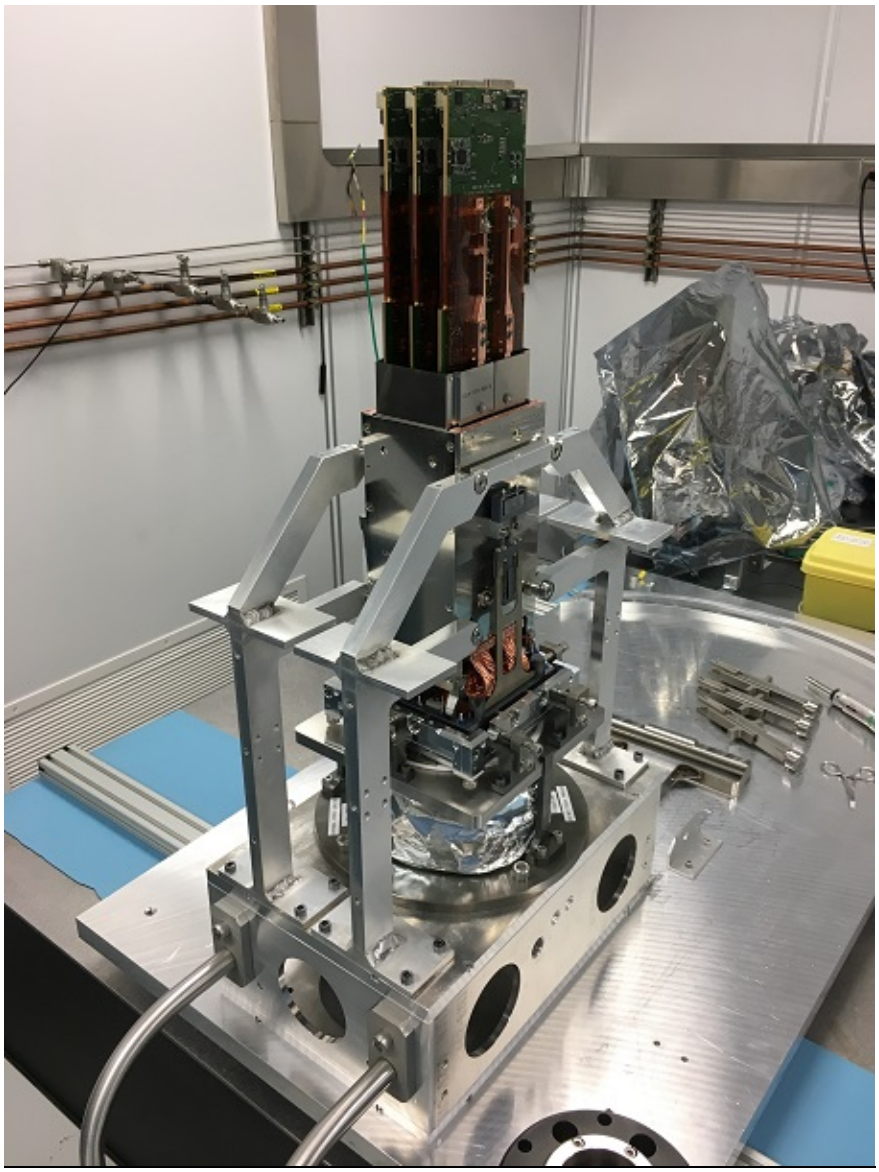


Figure 2: The L1-L2 lens assembly integrated at Arizona Optical Systems (AOS). The assembly is a lightweight structure that holds L1 and L2 in position at the front of the Camera and maintains correct separation between the two lenses. AOS found a minor astigmatism issue during initial Transmitted Wavefront Error (TWE) testing of the assembly. The plan is to address the issue by a simple change to shims that adjust L1-L2 alignment.

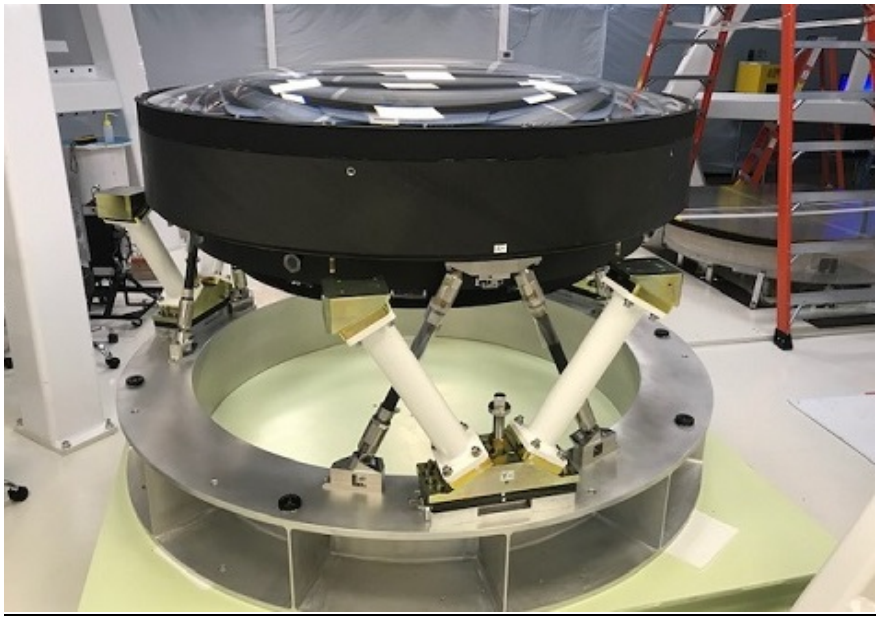
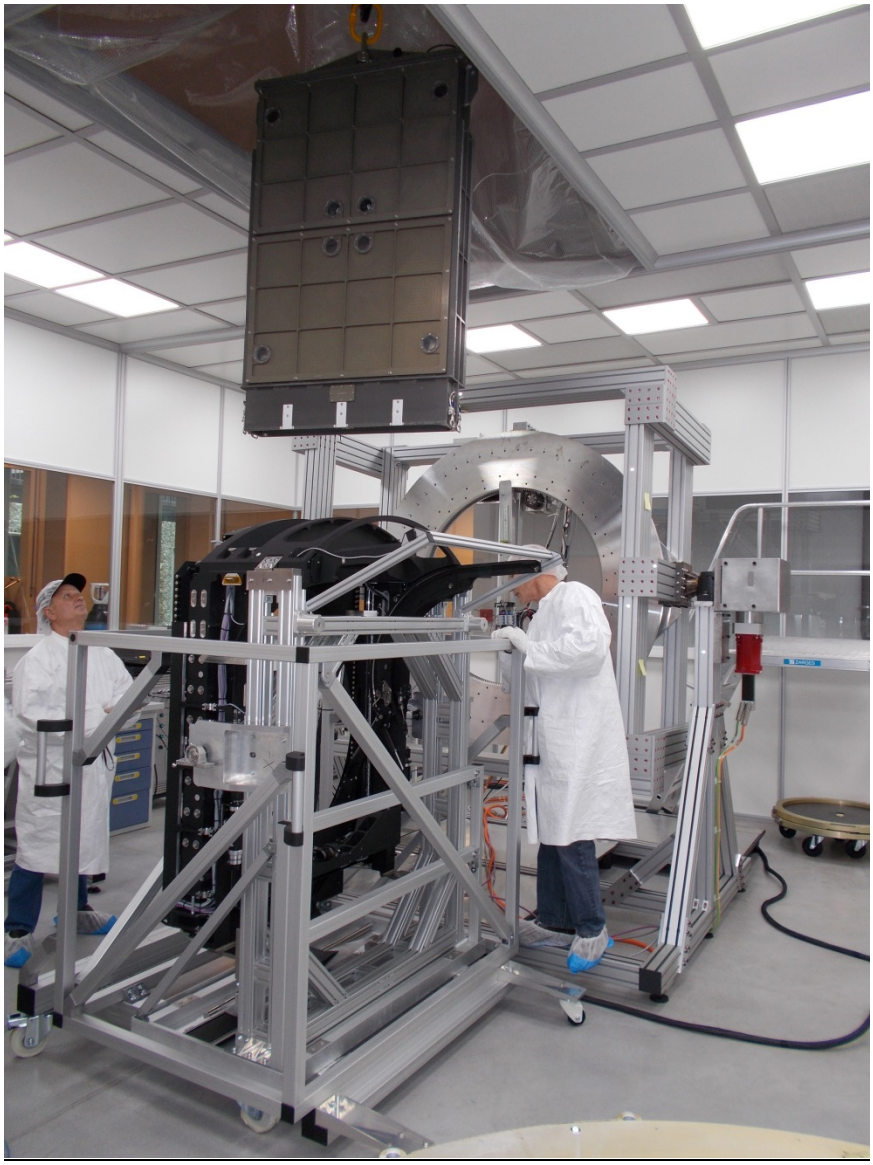
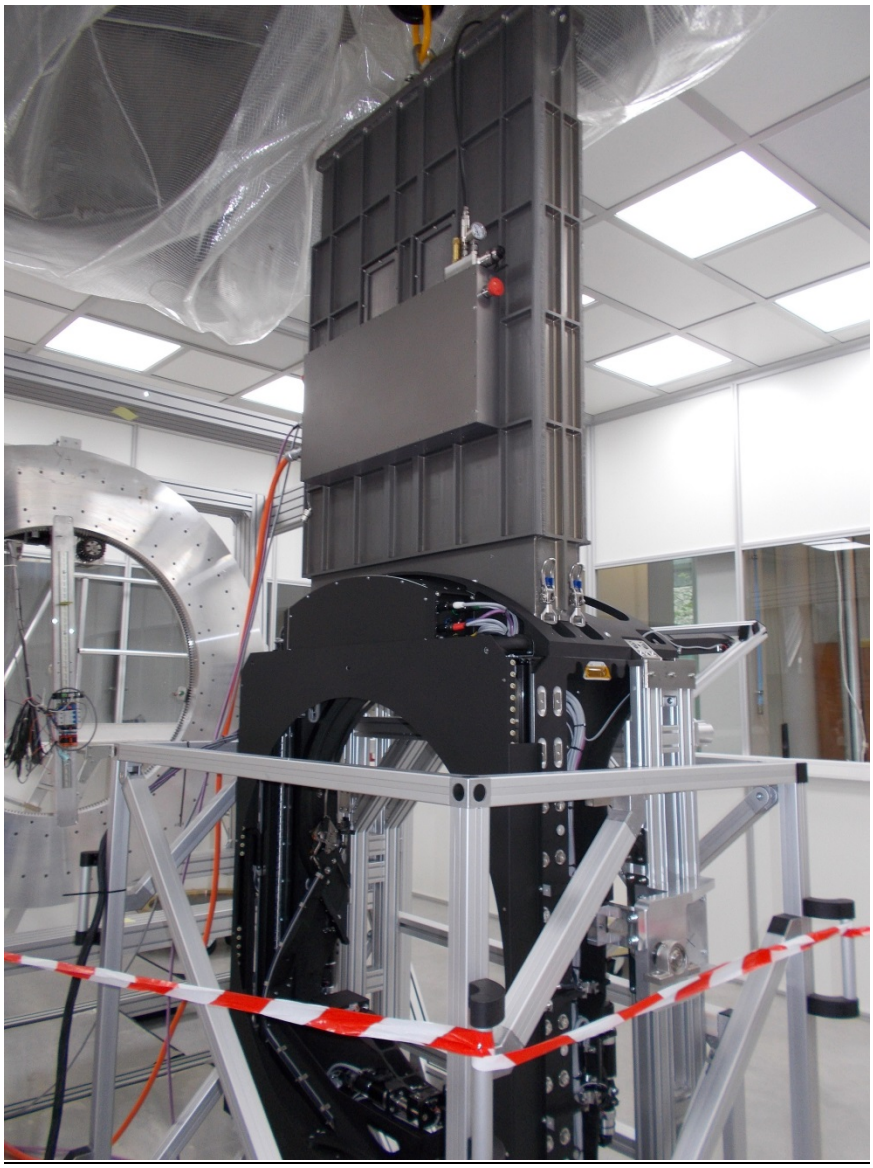


Figure 3: The filter-exchange carousel integrated with the Camera back flange at LPNHE. Corrective safety measures were implemented in response to a serious injury accident that occurred during carousel testing in April. The safety measures include installation of protective shielding and an emergency stop switch.

Figure 4: Preparations are underway for combined testing of the first units of the auto-changer and filter loader at the LPNHE cleanroom. Here the auto-changer is attached to its standalone test bench with the loader suspended overhead. Behind the auto-changer is the full-scale filter-exchange test bench that will be used for combined testing. The full-scale bench allows interoperation of filter-exchange components in all expected Camera orientations.



<u>Figure 5:</u> The loader in position to install a filter into the auto-changer, which is attached to its standalone test bench. The circular structure at left is a base assembly that will attach the integrated carousel-back flange unit (not shown) to the full-scale filter-exchange test bench. The base assembly simulates the front of the cryostat.



<u>Figure 6:</u> The drive-side linear guide assembly for the production shutter was delivered by the vendor to SLAC in early June. The guide carriages (eight square structures in the lower-half of photo) attach to shutter blade stacks and shutter-drive belts. The belts pull the carriages over the guide to open and close shutter blades.

<u>Figure 7:</u> At SLAC, coils for cold-circuit heat exchangers of the Telescope Mount Assembly (TMA) refrigeration system. The coils are undergoing inspection and cleaning at SLAC before assembly into heat exchanger units. The TMA refrigeration system will be identical to the I&T refrigeration system currently operating at IR2. The TMA system will be used by the on-summit Camera. When it is no longer needed for testing at IR2, the I&T refrigeration system will be transferred to the Camera maintenance room on summit.

Figure 8: Measurement of parts of cold-circuit TMA heat exchangers prior to delivery to SLAC by the vendor. Phased delivery of cryo-circuit parts is expected to start this month and be completed in August. Experienced gained by the vendor during manufacturing of components for I&T heat exchangers has significantly improved quality of the TMA system parts.

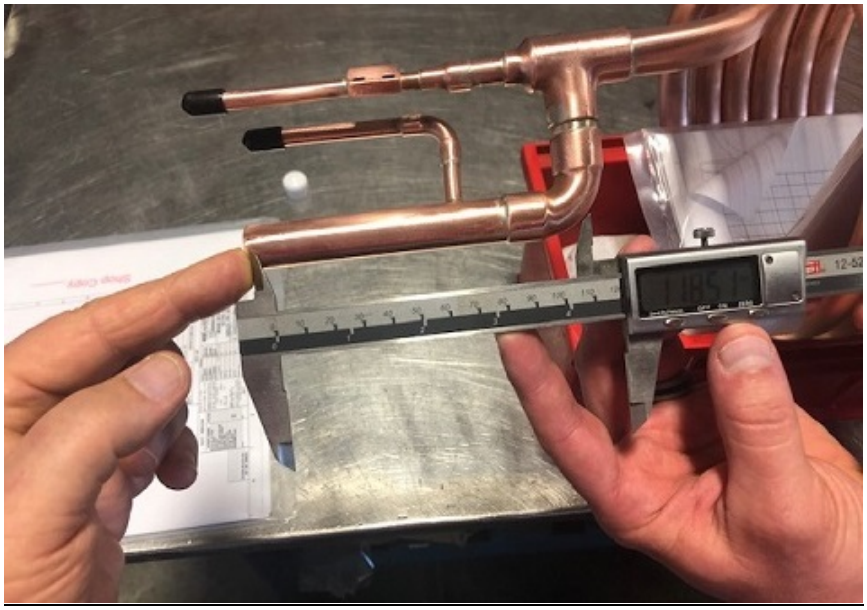


Figure 9: A recent view of activity in the main (high bay) area at the SLAC IR2 Cleanroom Facility. The camera faces the north side of the room. A technician at left stands on an access platform at the top side of the Bench for Optical Testing (BOT). The cryostat is contained in the BOT and currently holds two engineering test rafts (ETUs). The BOT will be used to integrate production RTMs within the cryostat in two stages; the first stage will install nine RTMs and the second stage the remaining 12. RTMs will be installed incrementally in each stage, and a stage will conclude with electro-optical (EO) testing to verify performance of the focal-plane array.

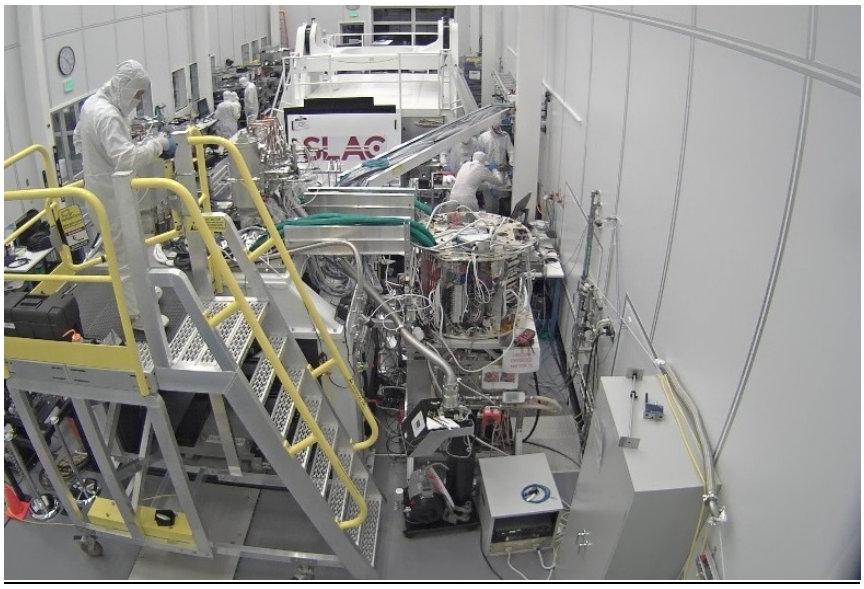


Figure 10: A view of the high-bay area at IR2 from a camera that faces the south side. In the foreground is the Camera body housing on an assembly bench. The housing is a protective structure that will enclose the cryostat assembly, L3 lens, Camera shutter, and filter-exchange components. The large white structure directly beyond the housing is the Camera integration stand, which will cradle the Camera assembly during construction. In this view, the platform of the stand is not installed yet and sits on the floor to the right of the stand. At the back of the room, technicians work in the BOT area.

Figure 11: A view of the high-bay area at IR2 that shows the Camera integration stand with platform installed. The technicians in the view show the scale of the integration stand, which is the largest structure that will occupy IR2. The I&T team will use several other fixtures not shown to construct or store Camera subassemblies during the Camera integration process.

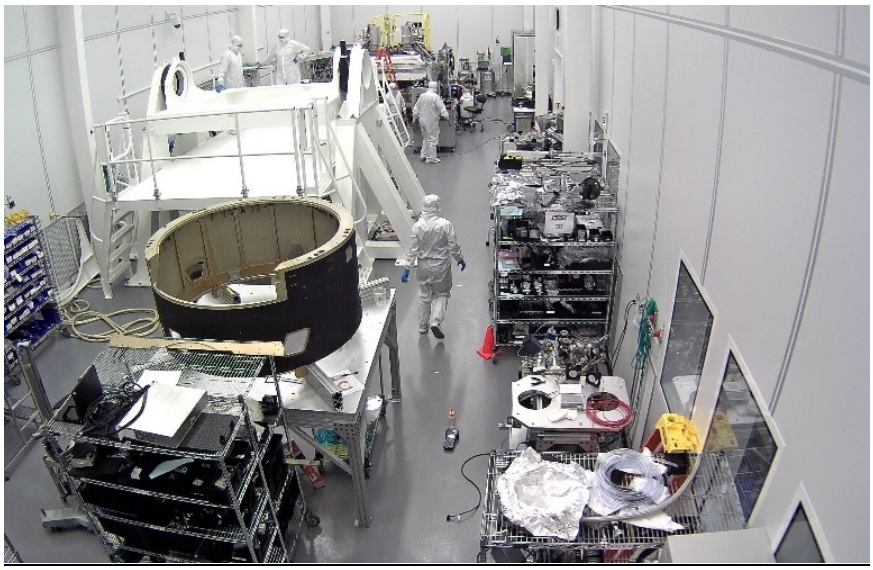


Figure 12: The completed ComCam dewar at IR2 in early June waiting to be packaged for shipment to Tucson. In late May, the ComCam team held a successful pre-ship review that resulted in no significant action items. ComCam is a single-raft imaging instrument that will be operated as a surrogate for the full-science Camera during early integration and testing activities at the summit. The Camera project is responsible for delivering the ComCam dewar, raft, and software that supports the imaging system.

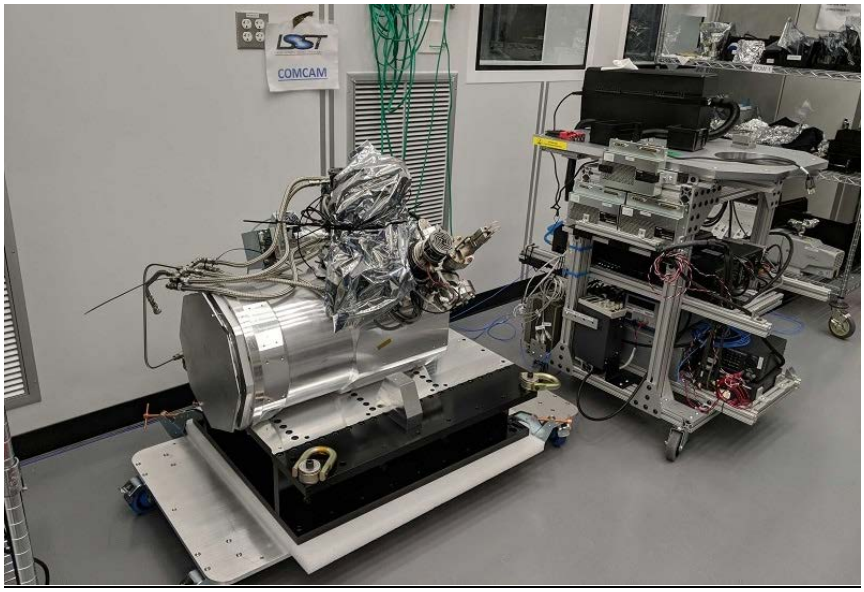
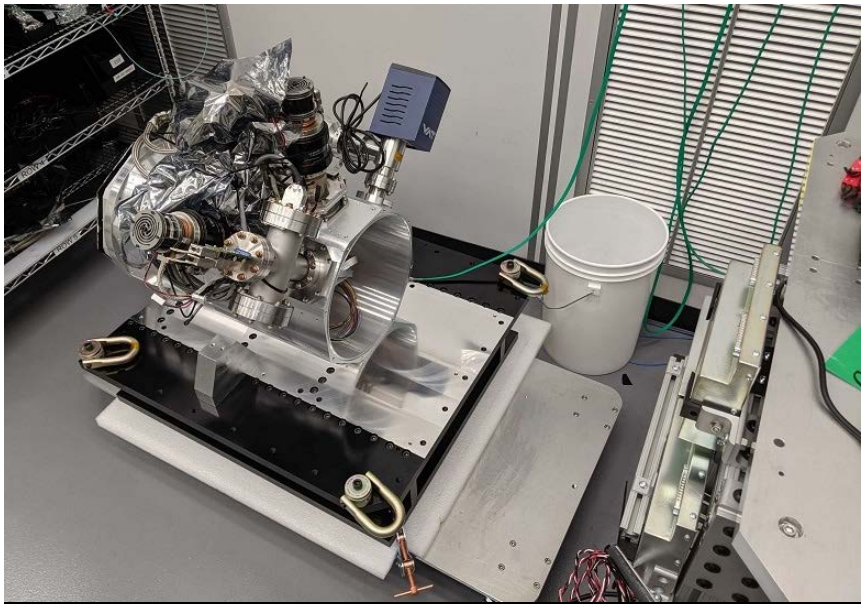


Figure 13: A view of the front of the ComCam dewar at IR2. The ComCam raft will be attached to a cradle assembly inside the front opening. Long-term the raft is expected to be one of the two engineering test units (ETUs) that have been used by I&T to verify BOT EO test instrumentation. The ComCam dewar was shipped to Tucson the ComRaft installed.



<u>Figure 14:</u> A view of the ComCam dewar outside the IR2 main area during packaging for shipment to Tucson. The two small black boxes attached to the base of the shipping container contain sensors to record conditions inside the container during shipment.

Figure 15: A view of the ComCam dewar packed and ready for delivery to Tucson. The delivery of ComCam accomplishes a major goal of the Camera project. The dewar will undergo integration and testing with other ComCam components at Tucson before delivery to the summit for commissioning activities.