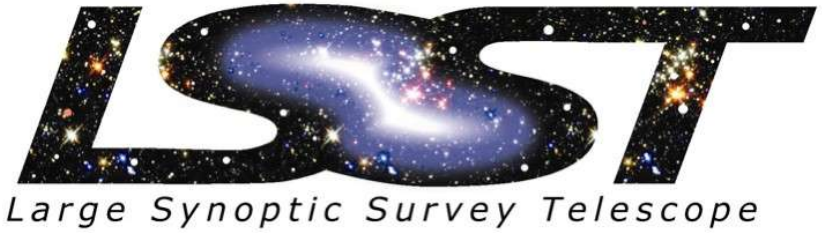
Camera Body and Mechanisms Design Update

13 June 2007



Martin Nordby

Pierre Antilogus, Walter Bertoli, Gordon Bowden, Guillaume Daubard, Mike Foss, John Ku, Sandy Williams

SLAC

Outline

- Current Design of Camera Body and Mechanisms
- Plans for servicing and removal of components

- Status of lens sensitivity analysis
- Status of light baffling design

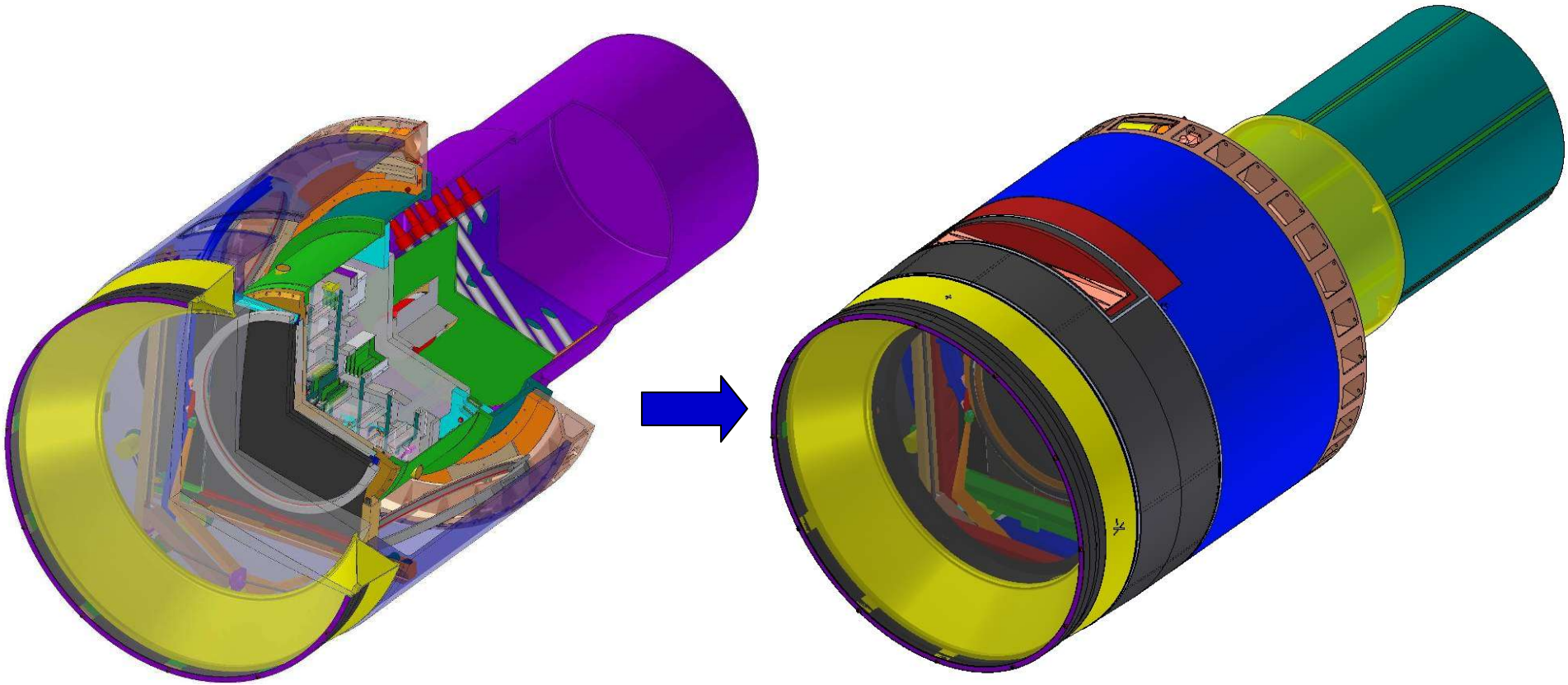
- Detailed component design status
  - Camera housing
  - L1/L2 Assembly
  - Auto Changer
  - Manual Changer
  - Carousel
  - Shutter

Evolution Since the Reference Design

- **Problems with the Reference Design motivated much of the design evolution over the past 9 months**
  - **Mounting of L1/L2 Assembly**
    - The Reference design did not include a support for the L1/L2 Assembly
    - Support must hold the mount ring around its periphery to reduce lens distortions and motions
  - **L1 and L2 thermal motions were large**
    - We moved to an aluminum housing to save weight
    - However, this significantly increased thermal motions of the lenses
  - **Access for servicing was very poor**
    - There was little access or room for even the simplest work
    - On-camera maintenance or troubleshooting would need to be done through small access ports in the housing
    - Nearly all servicing and maintenance would require the camera to be removed from the telescope
  - **Little thought to removal plans**
    - The Auto Changer was built in-place within the camera housing
    - This completely blocked access to the Shutter for removal
    - Significant servicing and alignment verification of the Auto Changer was not possible with the camera on the telescope

- **Our focus over the past six months has been to make the design more modular, more serviceable, and structurally more stable, to address the 4 problems described above**

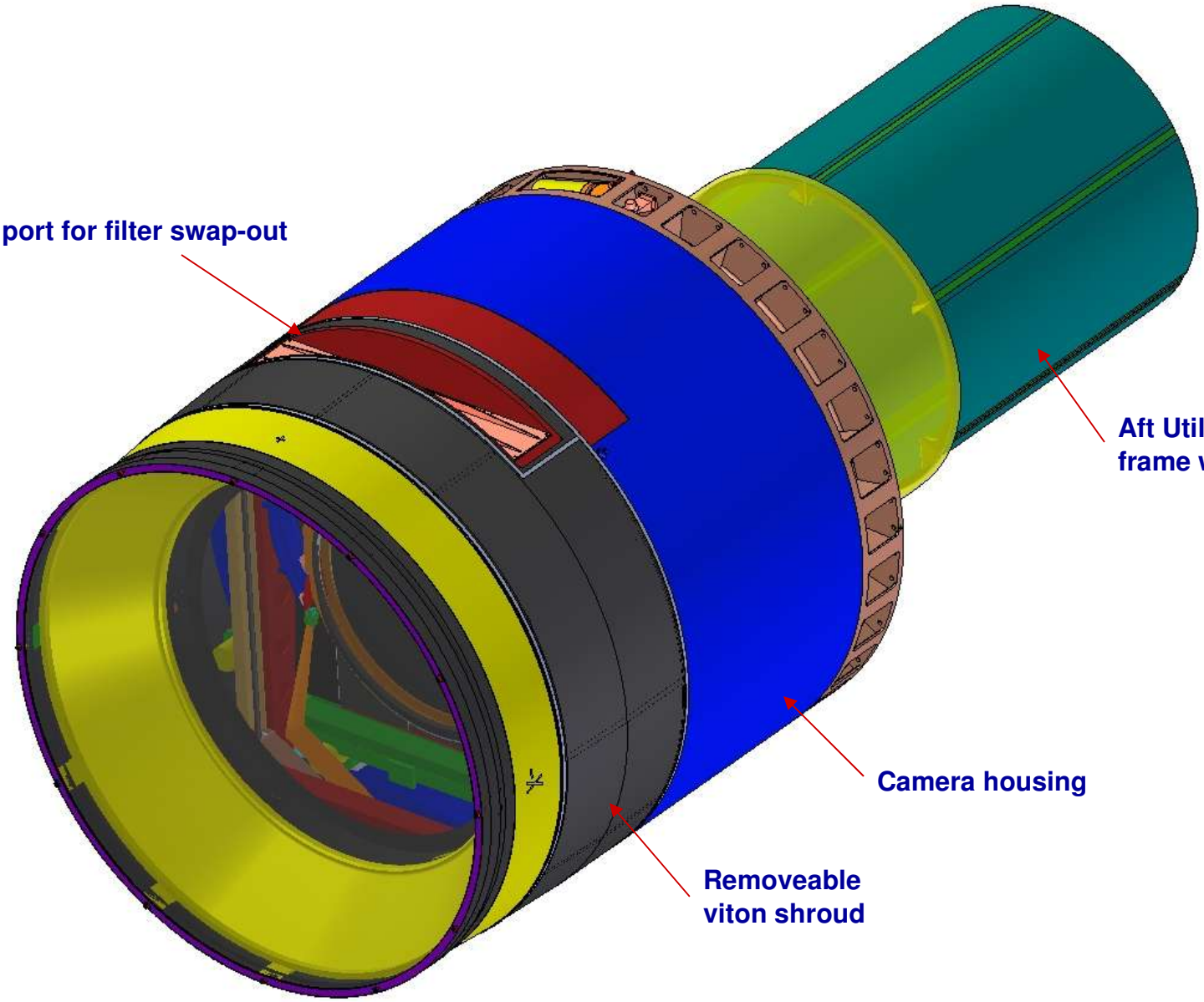
Camera Conceptual Design



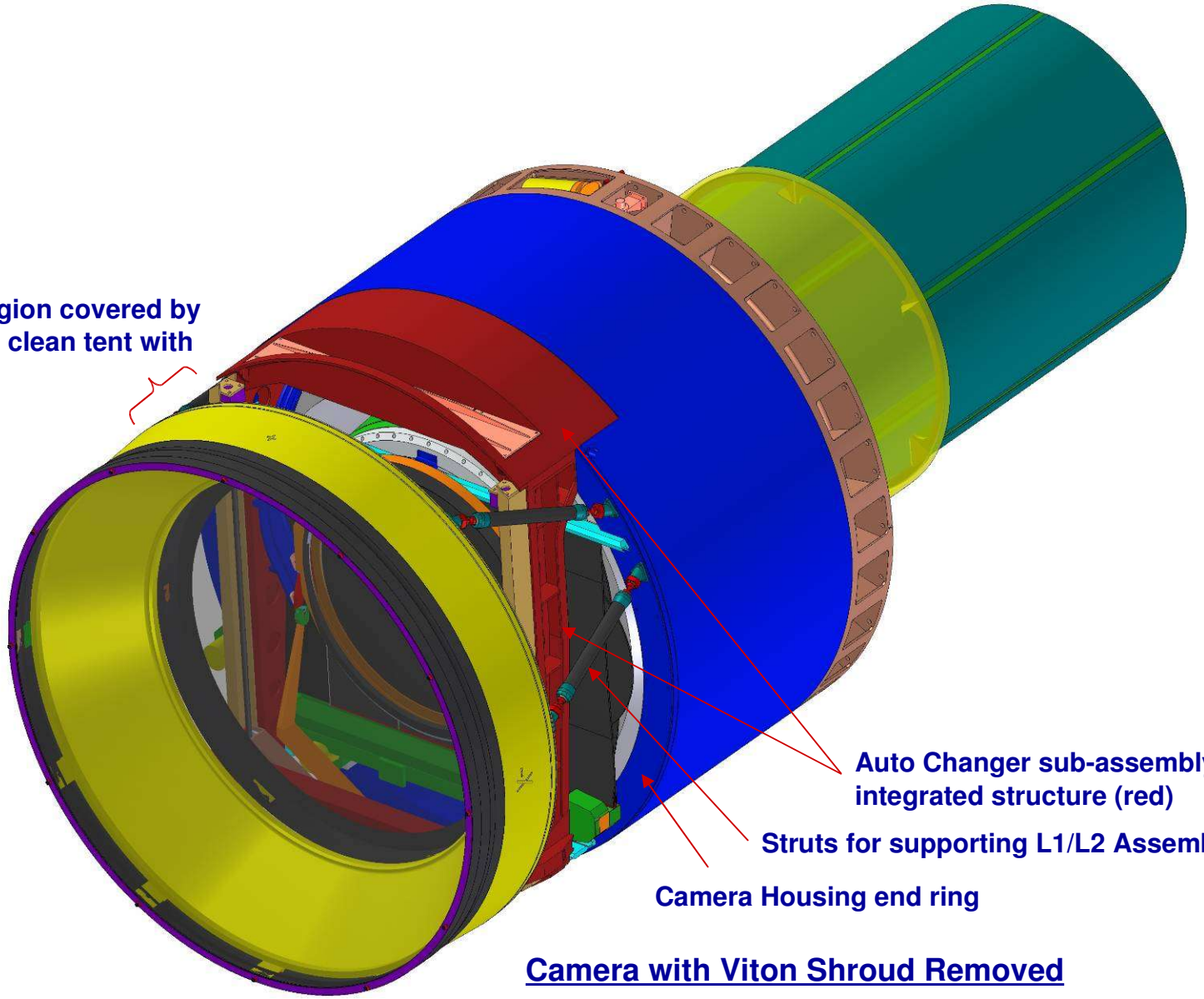
Camera Reference Design
August 2006

Camera Conceptual Design
June 2007

Fully-Integrated Camera

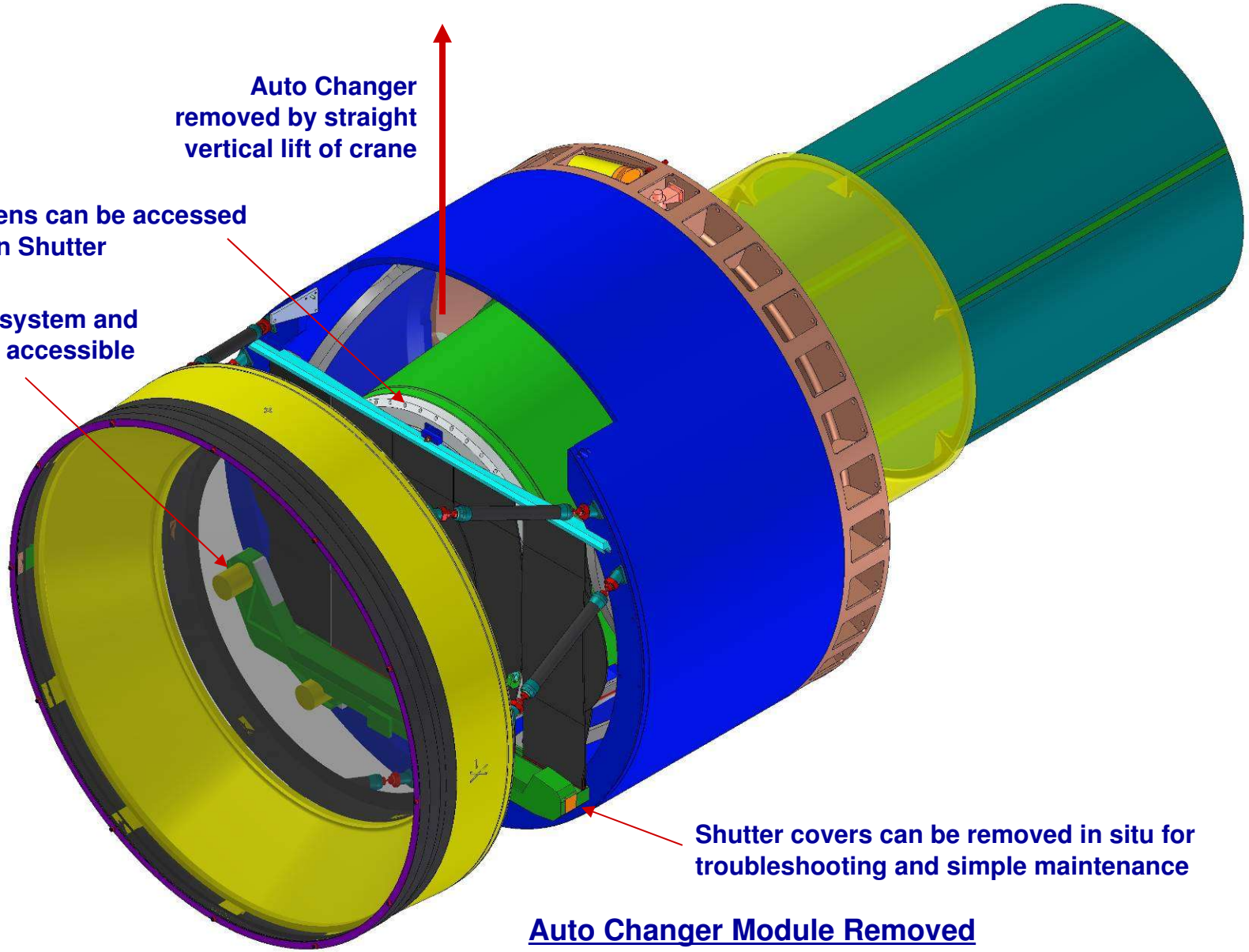


Camera Open for Servicing



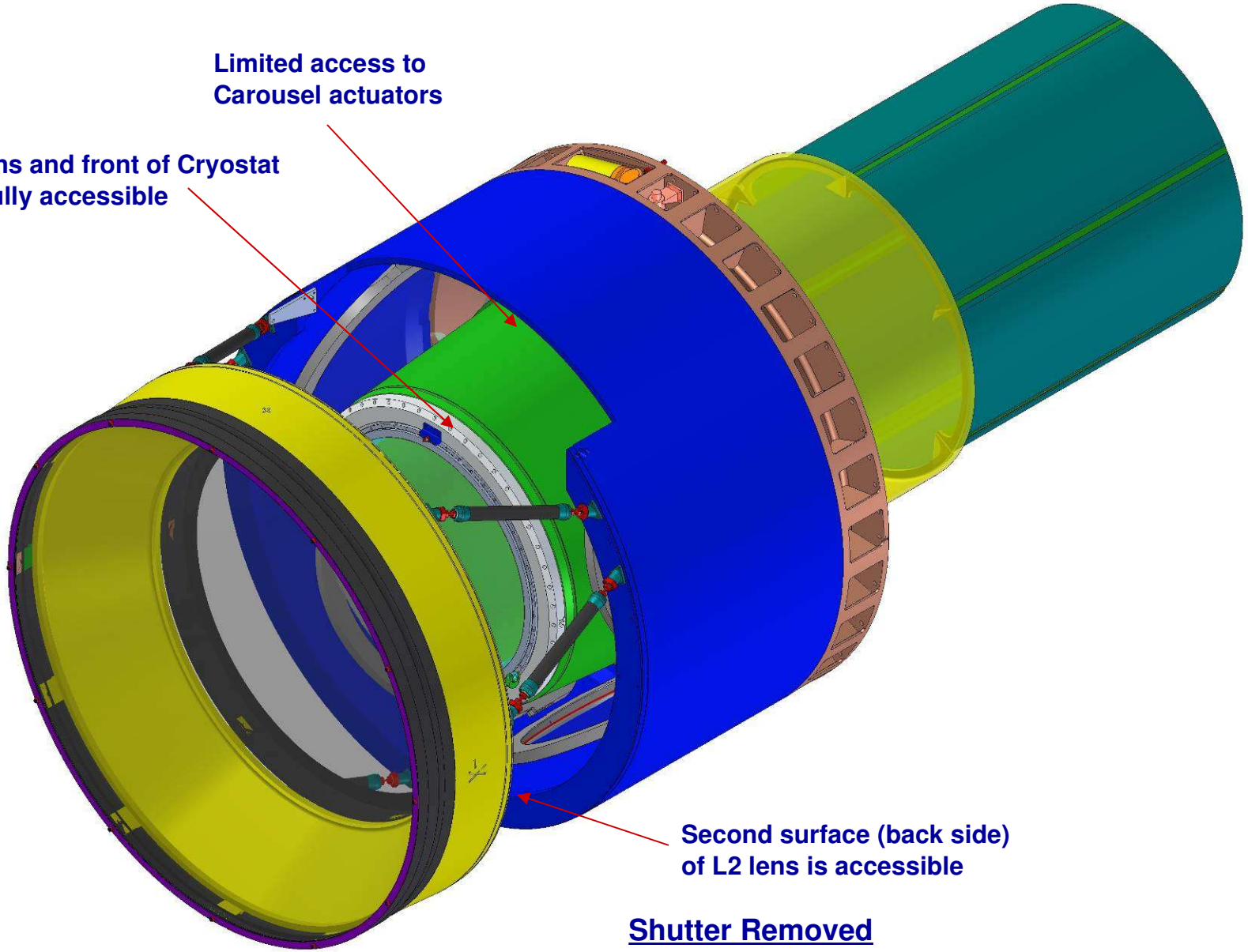
Camera with Viton Shroud Removed

Access for Shutter Servicing



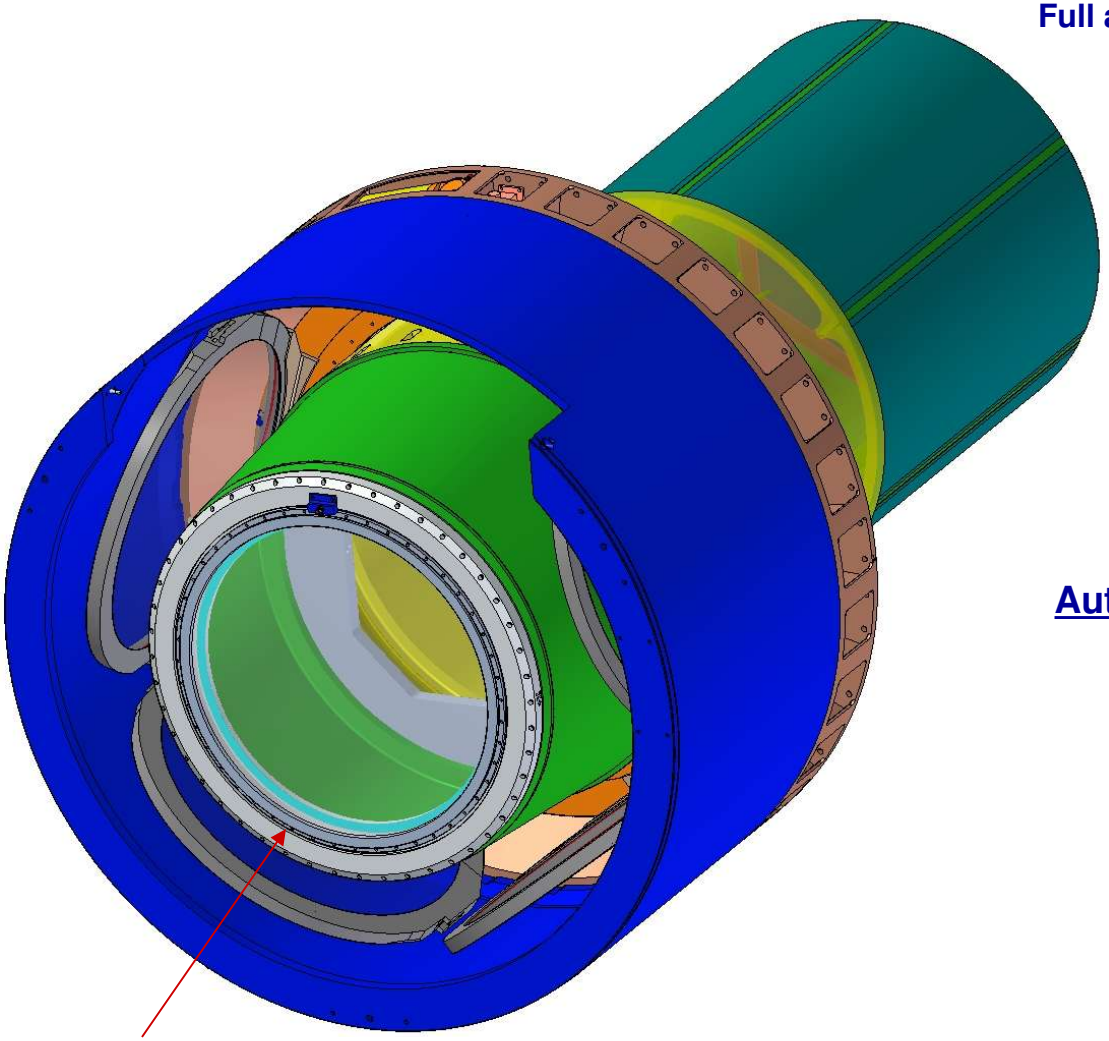
Auto Changer Module Removed

Access for L3 and Carousel Servicing

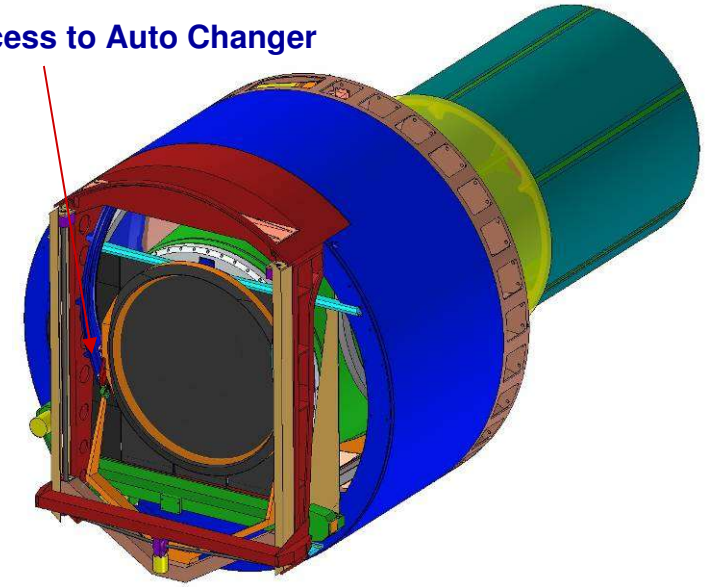


Shutter Removed

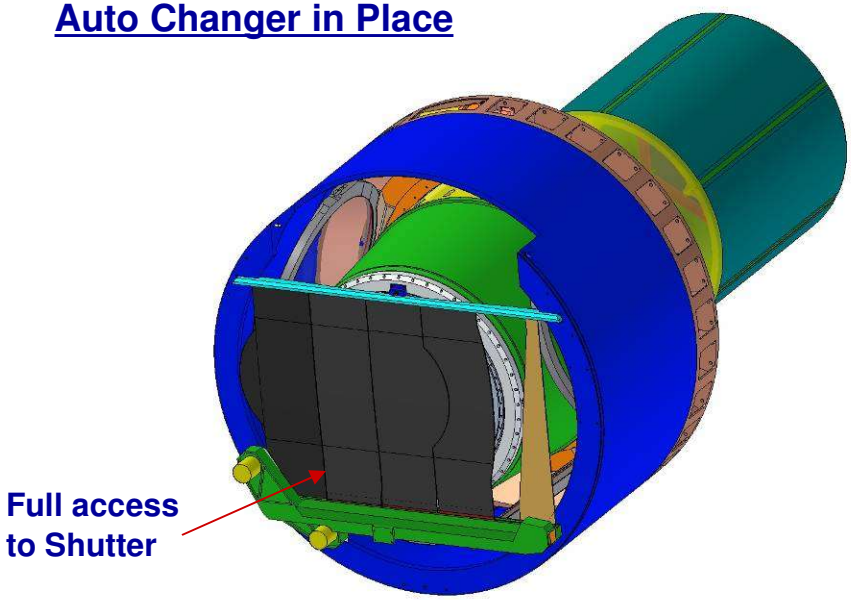
L1/L2 Assembly Removed for Full Access



L1/L2 Assembly Removed



Auto Changer in Place

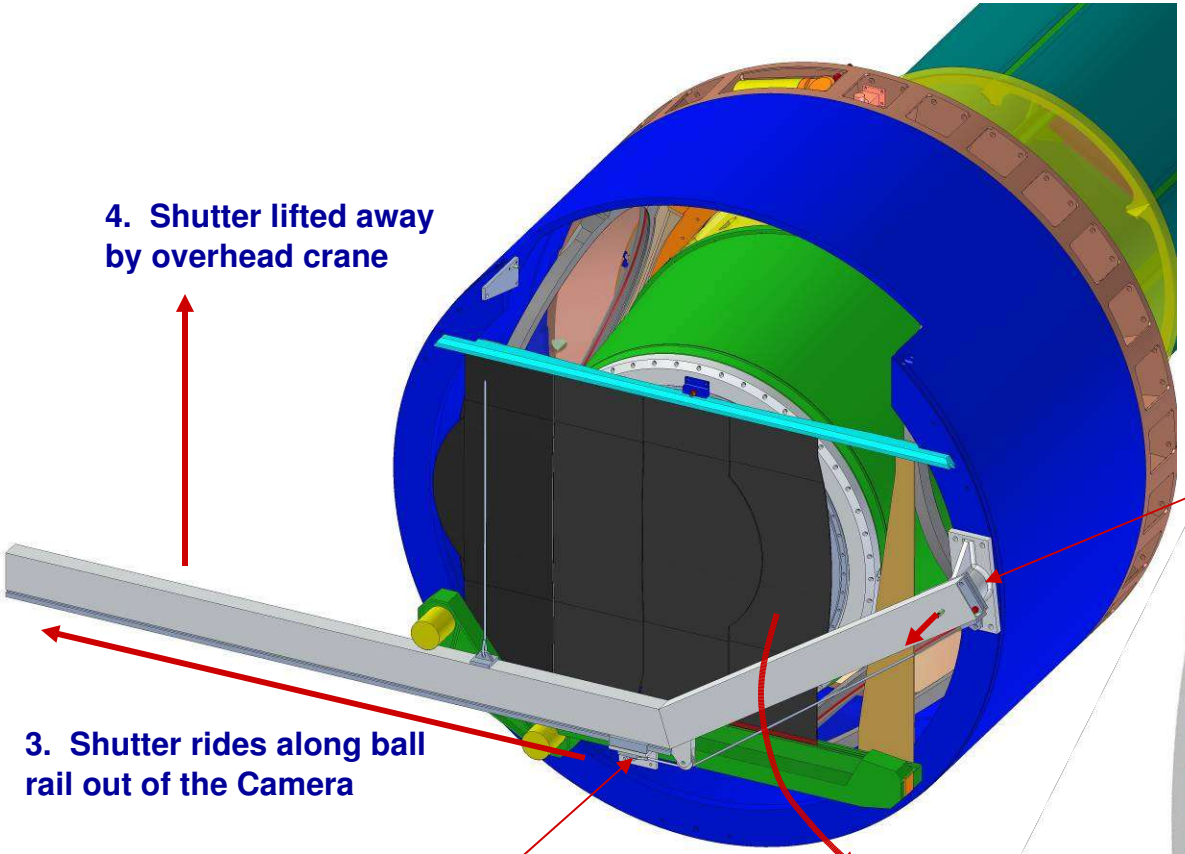


Auto Changer Removed

Plans for Servicing and Removal

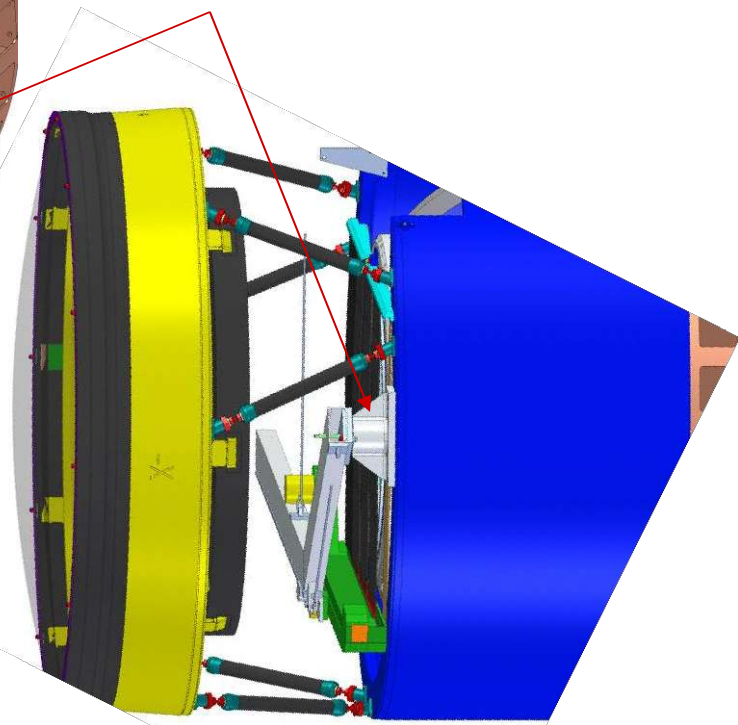
- **Component access for servicing**
  - **Modular design allows for much easier access to camera mechanisms for troubleshooting and making simple repairs**
  - **We are designing the mechanisms to allow for field-removal and replacement of most moving parts**
    - Shutter: drive bands, motors, pulleys
    - Auto Changer: trucks, motor, linear slide and ball screw
    - Carousel: motor, clamp actuator
- **Component removal**
  - **Auto Changer sub-assembly is integrated and removed as a near-complete assembly**
    - This allows for full alignment and drive system verification on the bench prior to integration
    - It opens up the possibility of being able to swap units for preventive maintenance
    - Flipper rails at back end of Auto Changer are pre-aligned and never removed
  - **Shutter unit is integrated as a complete assembly**
    - We should be able to swap out a Shutter during a day shift
    - Testing and troubleshooting can be done with or without the Auto Changer in place
- **Thoughts on alignment stability and verification**
  - **Modular design attempts to preserve the alignment of L1 and L2 with respect to the Cryostat**
    - L1/L2 Assembly, Auto Changer, and Shutter are all mounted to camera housing in a near-kinematic way
    - This maximizes the chance that the lenses will stay aligned after the camera is serviced and a module removed
    - Since the L1/L2 Assembly mounting struts provide a kinematic interface to the camera housing, we should be able to remove and replace the lens assembly and still return very close to our original alignment
  - **We still have work to do on developing a method to verify lens and filter alignment**
    - We do not yet have a working plan for doing this in the lab or on the telescope
    - However, these design changes provide many options for optically sighting the cryostat from the outside

Shutter Removal



Shutter Removal Beam

(L1/L2 Assembly not shown)



Shutter Removal

(View from personnel access platform)

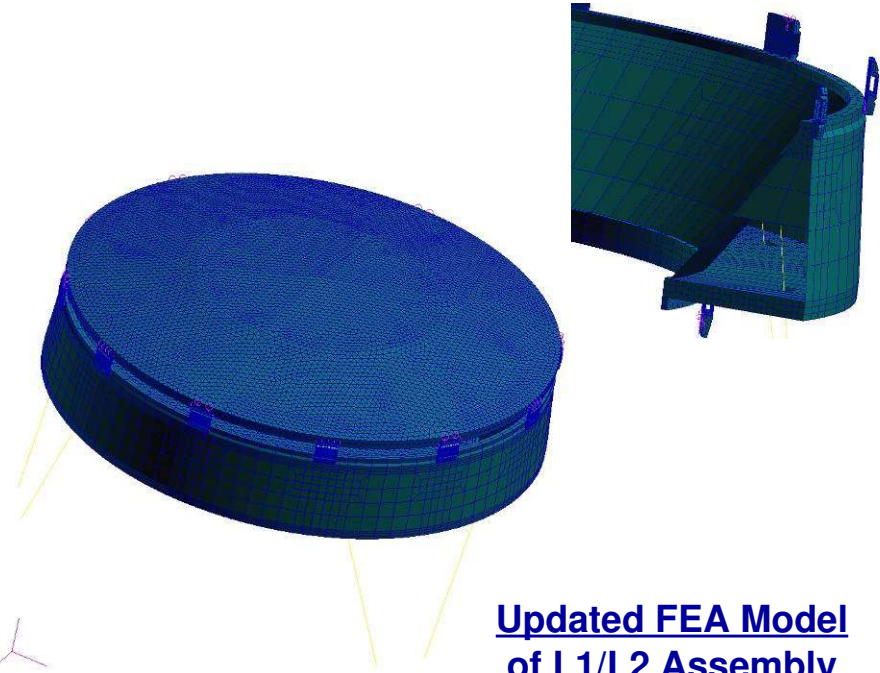
Camera FEA Development and Lens Sensitivity Analysis

- A sensitivity analysis using the camera design as of April 2007 produced promising optical performance
- Although promising, the analysis is preliminary because it did not incorporate three key design evolutions
  - L1/L2 Assembly and kinematic mount design
  - Shortened camera housing
  - New, optimized grid and flexure mount design
- Current plan to incorporate these three design evolutions will produce new results by the end of June
  - L1/L2 Assembly new baseline model nearing completion → ECD = 6/15
  - Camera housing update → ECD = 6/15
  - Grid modifications complete
  - Flexure design concept complete
  - Integrate updated component models into full camera model → ECD = 6/20
  - Sensitivity analysis update → ECD = 6/22

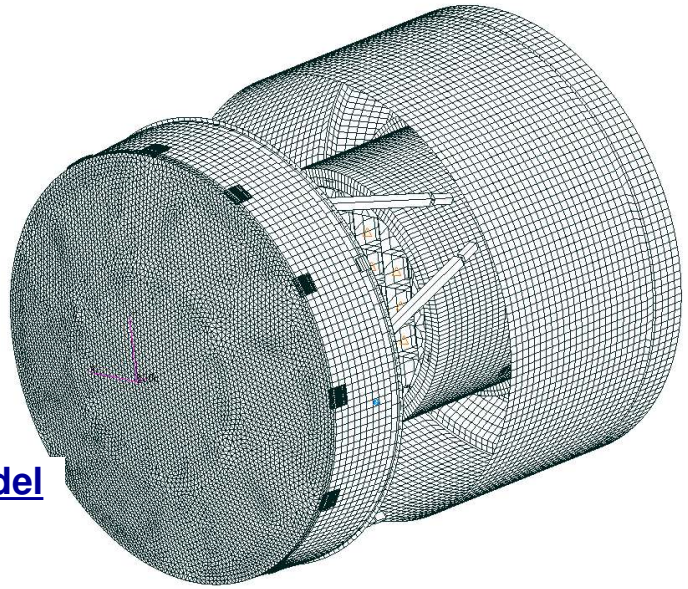
- With the next round of sensitivity analyses complete, we will be able to predict with some confidence the expected optical performance
  - Optical performance due to rigid body distortions (sensitivity analysis)
  - Optical performance due to lens shape distortion (we will provide lens shape distortions to Scot Olivier's group)

L1/L2 Assembly and Camera Housing Analysis

- **L1/L2 Assembly and mounting struts**
  - Model update nearly complete → ECD = 6/15
  - 6 CFC struts create a kinematic mount
  - Assembly attaches near focal plane Z-position
  - Low CTE of CFC minimizes thermal motion
  - Struts attach to structural ring near center of gravity (to be confirmed through analysis)
  - Lens surface distortions will be provided to optics group for evaluation
  - We are also using the analysis to optimize the location and angles of the mounting struts and to lighten the mounting ring as much as possible
- **Camera housing**
  - Current camera housing has large cutout for manual filter changer interface
  - New shortened camera body gets rid of opening, creating a near-axisymmetric body, resulting in more uniform distortion when rotated about the camera axis
  - New camera body model nearly complete → ECD = 6/15



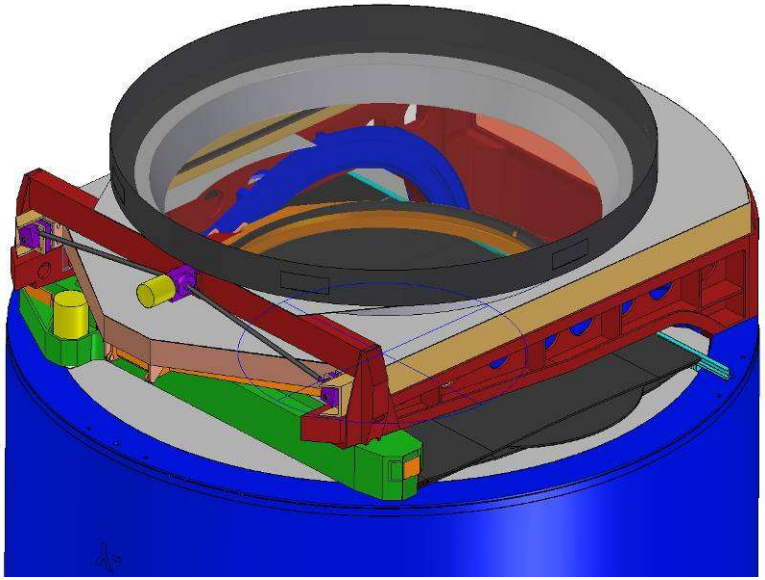
Updated FEA Model of L1/L2 Assembly



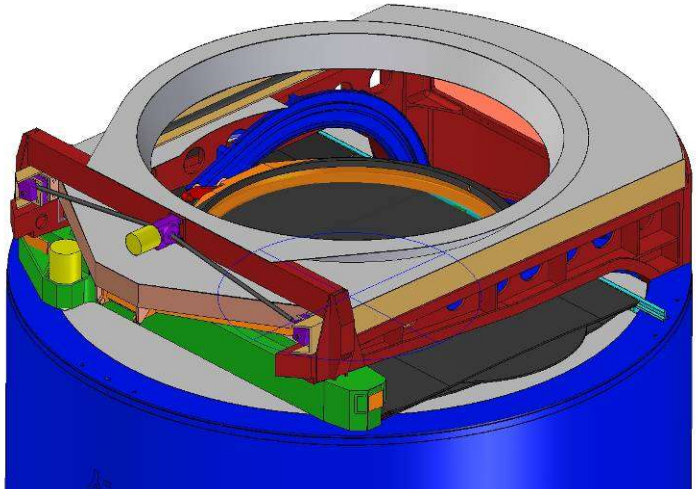
Camera FEA Model

Light Baffling

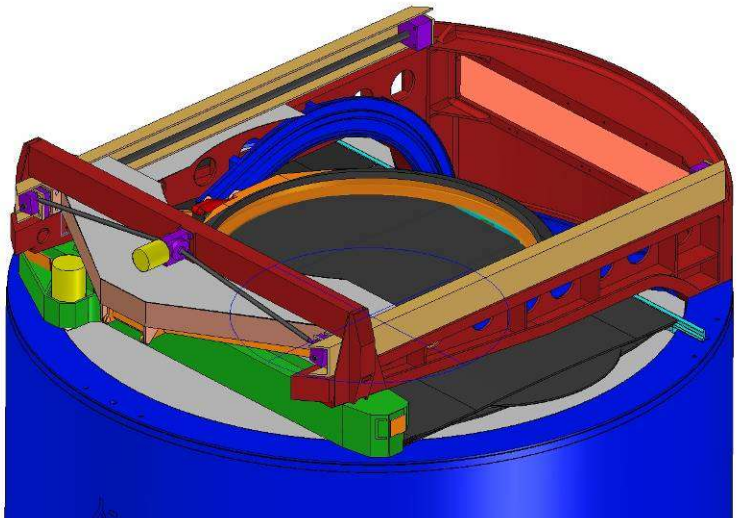
- Requirements of baffles inside camera
  - Reduce/eliminate glancing-angle views of camera components from incoming light cone
  - Shield as many camera components as possible with optically black shrouds or coatings
  - Provide aperture-defining rings all along light path to catch low-angle scattered light
- Issues still needing addressing
  - Optimize design of stepped cones and annular rings for L1/L2 cone and between L2 and filter
  - Develop conceptual design of light trap around perimeter of L2 lens
  - Iterate design with scattered light analysis



L1 and mount ring removed, showing L2

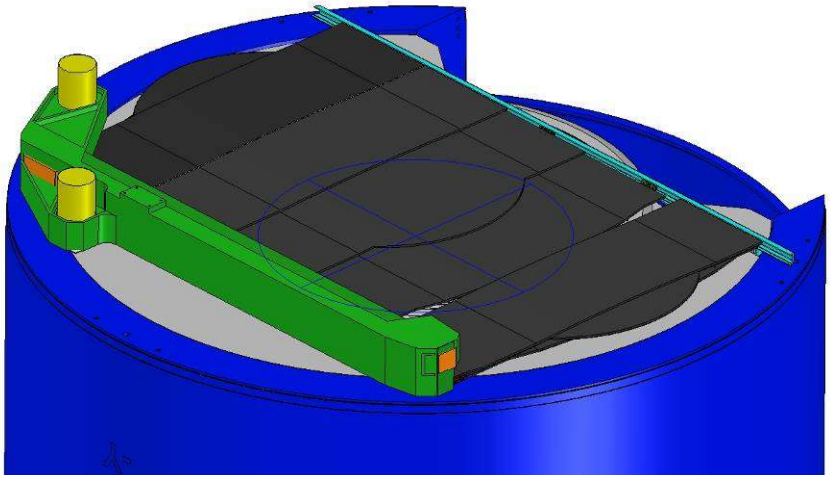


L2 removed, showing forward baffle ring and cone

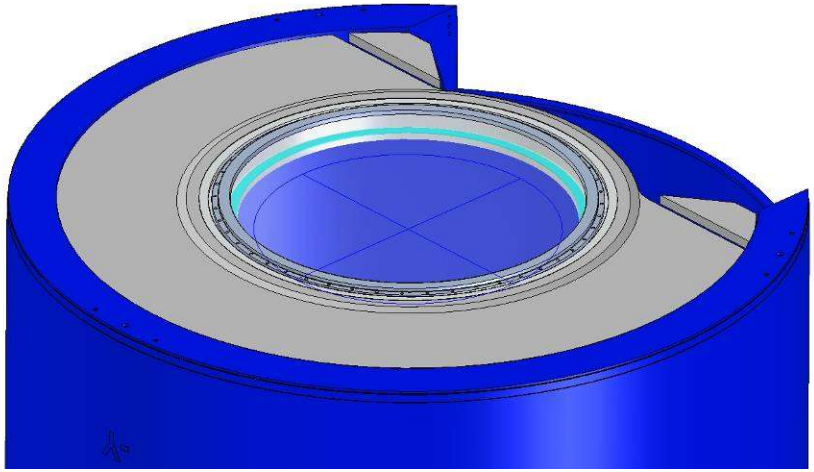


Forward baffle removed, showing Changer

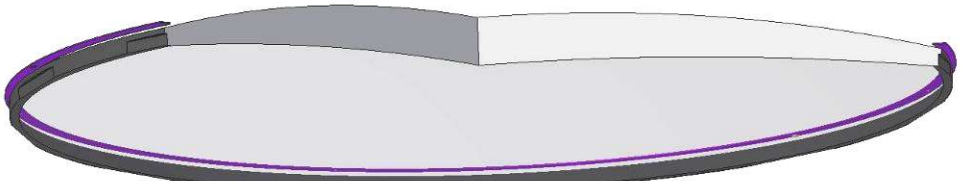
Light Baffling

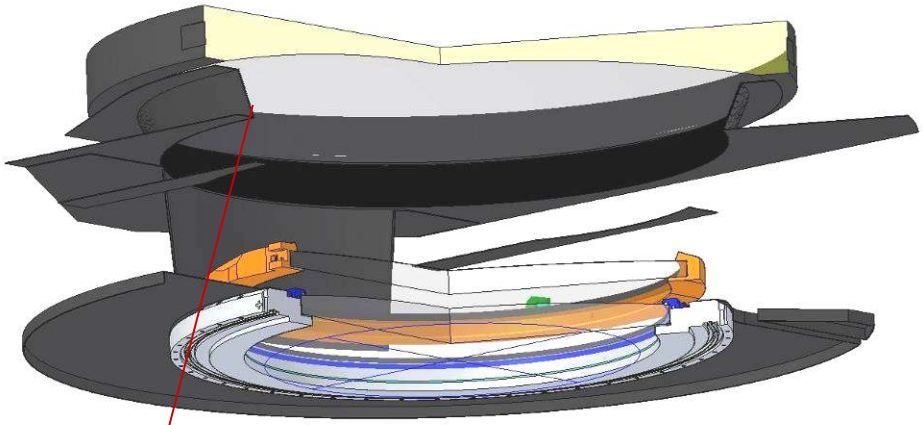


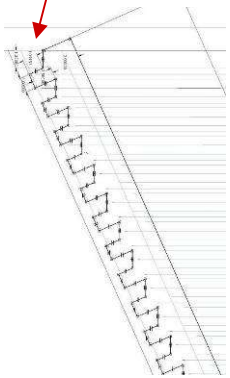
Filter Changer removed, showing Shutter



Shutter removed, showing L3 and L3 shroud





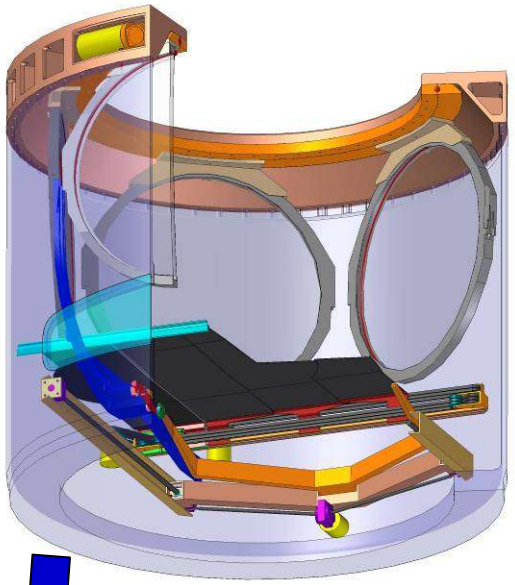


Light baffles

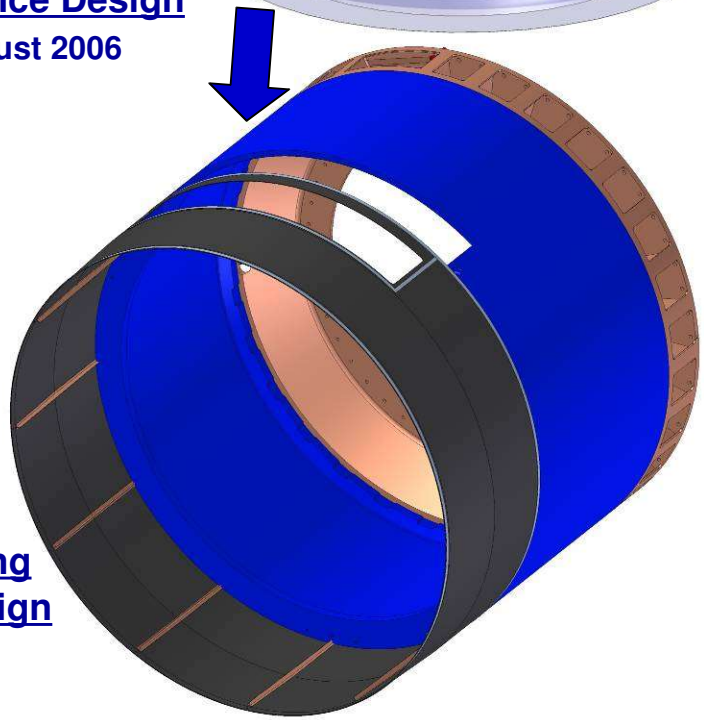
Stepped-cone design
to trap light

Camera Housing Status

- **Design Status**
  - Shortened housing
  - Changed from steel to aluminum to save weight
  - Modified Cryostat-to-back flange joint to stiffen it and reduce cryostat motion
  - Re-designed housing for manufacturability
  - Integrated housing design with modular Auto Changer concept
  - Completed initial structural FEA analysis of housing
- **Work still to complete for CoDR**
  - None—ready for CoDR
- **Work to complete for CD-1 Review**
  - Develop integration and alignment scheme for components in the housing
  - Re-analyze housing and back flange with all secondary structures included (Auto Changer, L1/L2 Assembly, and Shutter)
  - Incorporate cable ways and access ports for servicing cables and Carousel actuators

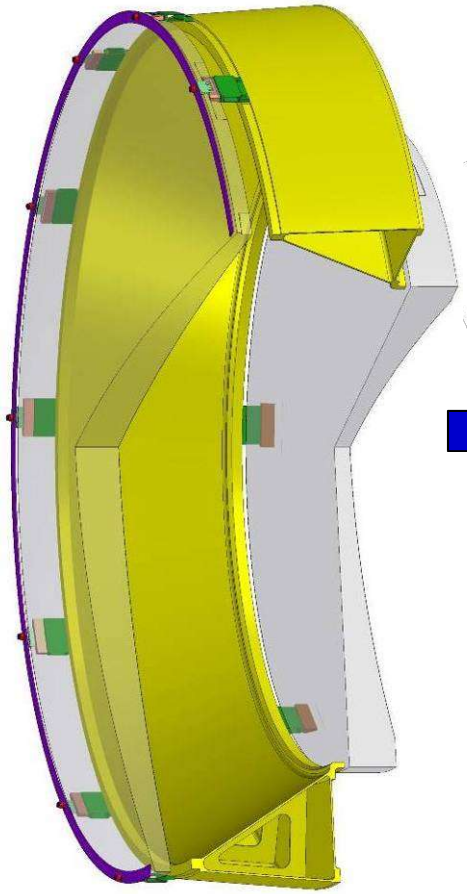


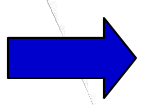
Camera Housing Reference Design
August 2006

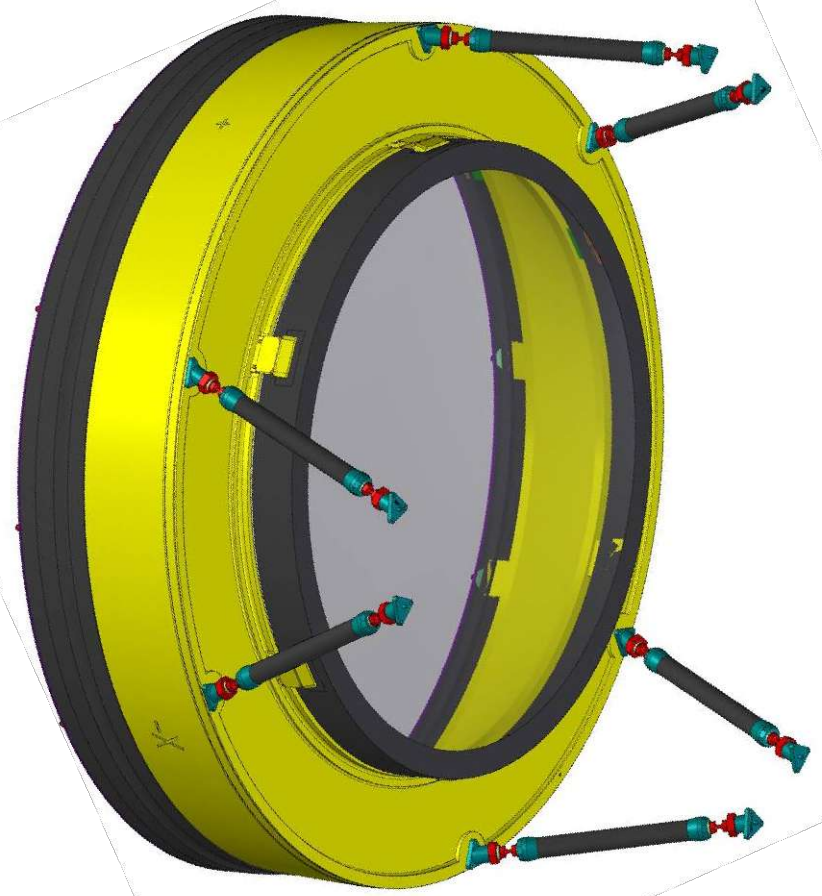


Camera Housing Conceptual Design
June 2007

L1/L2 Assembly Design







L1/L2 Assembly Reference Design
August 2006

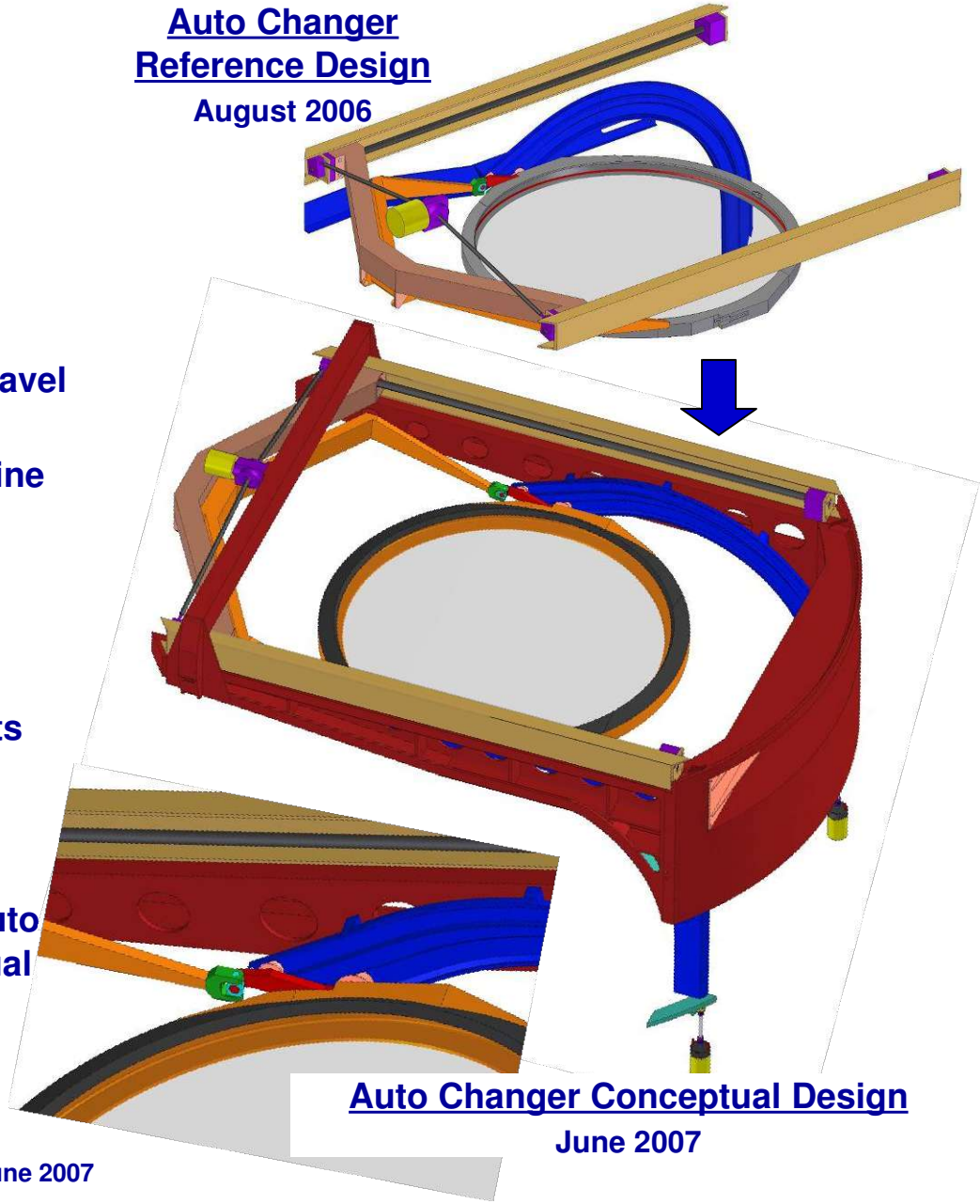
L1/L2 Assembly Conceptual Design
June 2007

L1/L2 Assembly Status

- **Design status**
  - **Added struts to mount L1/L2 Assembly**
  - **Changed material from steel to aluminum**
- **Work still to complete for CoDR**
  - **Complete L1/L2 Assembly FEA analysis**
    - Incorporate completed structural design into overall camera FEA model, for lens sensitivity analysis (to John Ku and Doug Neill)
    - Export L1 and L2 lens distortion analysis for optical tolerance analysis (to Scot Olivier and Lyn Sepala)
  - **Modify strut length and mount locations to minimize lens deflections**
  - **Modify mount ring design**
    - Add support bosses for mounting struts
    - Add light baffle rings on inside sloped surface
    - Re-design for manufacturability and to allow for re-cleaning after fabrication
- **Work to complete for CD-1 Review**
  - **Complete strut and mounting boss stress analysis**
  - **Complete strut design**
  - **Develop concept for L1/L2 Assembly alignment on the camera**

Auto Changer Status

- Design status
  - Re-designed Auto Changer to be fully modular
  - Added Manual Changer access port
  - Added Aluminum support structure
  - Modified rail path and interface to Carousel
  - Added “flipper rails” at back end of travel to clear the Carousel motion
  - Completed kinetic analysis to determine Changer design loads
- Work still to complete for CoDR
  - None—ready for CoDR
- Work to complete for CD-1 Review
  - Run stress analysis on all components and size components accordingly
  - Size and select linear rail, ball screw, motor, and transmissions
  - Develop strategy for hand-off from Auto Changer to Carousel clamp and Manual Changer clamp, including truck compliance

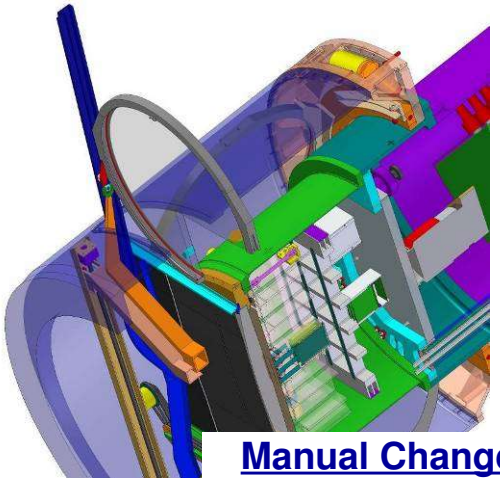


Auto Changer Reference Design
August 2006

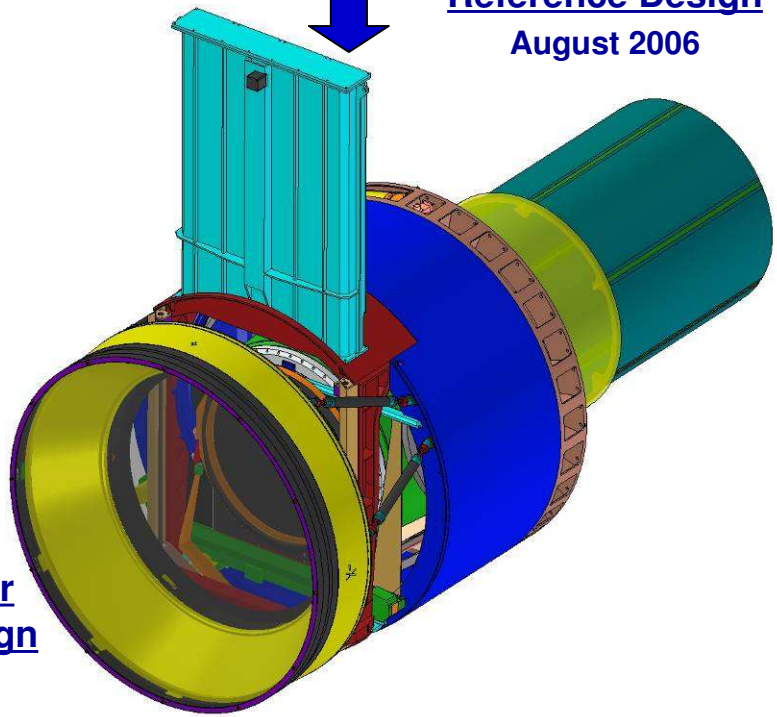
Auto Changer Conceptual Design
June 2007

Manual Changer Design

- The Manual Changer is a piece of ground support equipment, but it is sufficiently integrated with the camera design and operations that we need to design it and plan for its operation along with working on the on-camera Auto Changer design
- For the Reference Design, we had only vague sketches of the functionality of a Manual Changer
  - We now have a completed conceptual design
  - The design fully integrates with the camera housing and Auto Changer
- Manual Changer conceptual design features
  - One Manual Changer per filter
  - Manual Changer is installed by crane, then mounts to the camera during a filter swap-out, to ensure accurate alignment
  - Filter swap-out is done in a fully clean environment with no exposure to outside air
  - The Manual Changer is controlled by the Auto Changer controller, ensuring that all filter motions are fully safe, controlled, and fail-safe

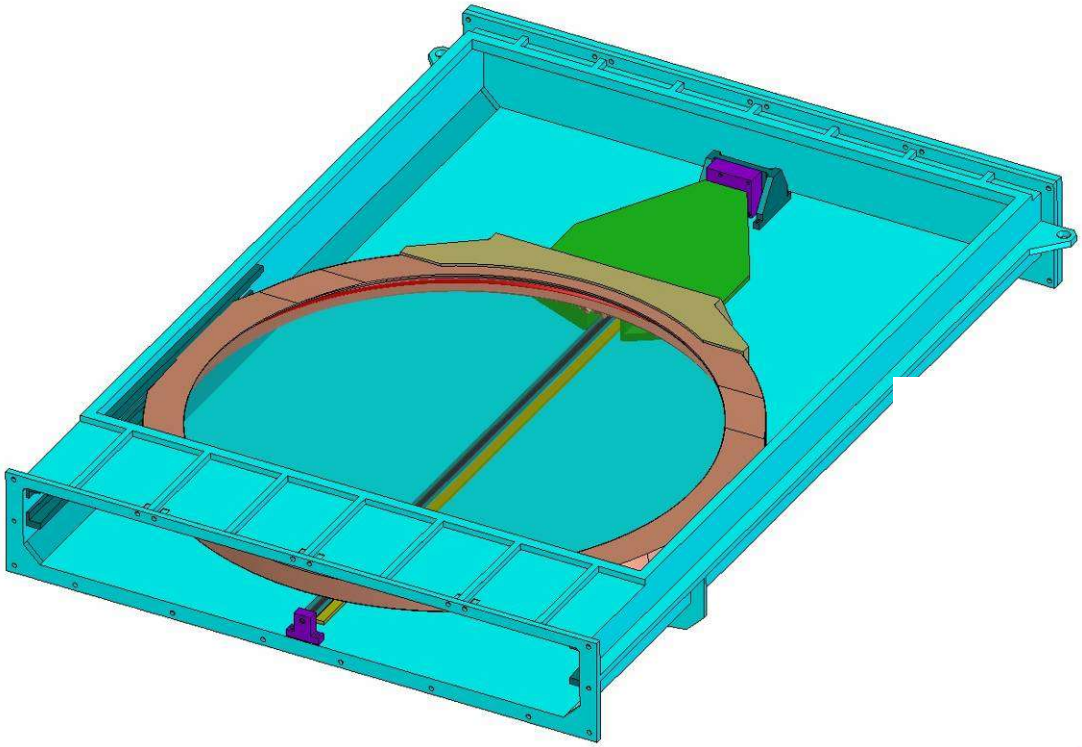


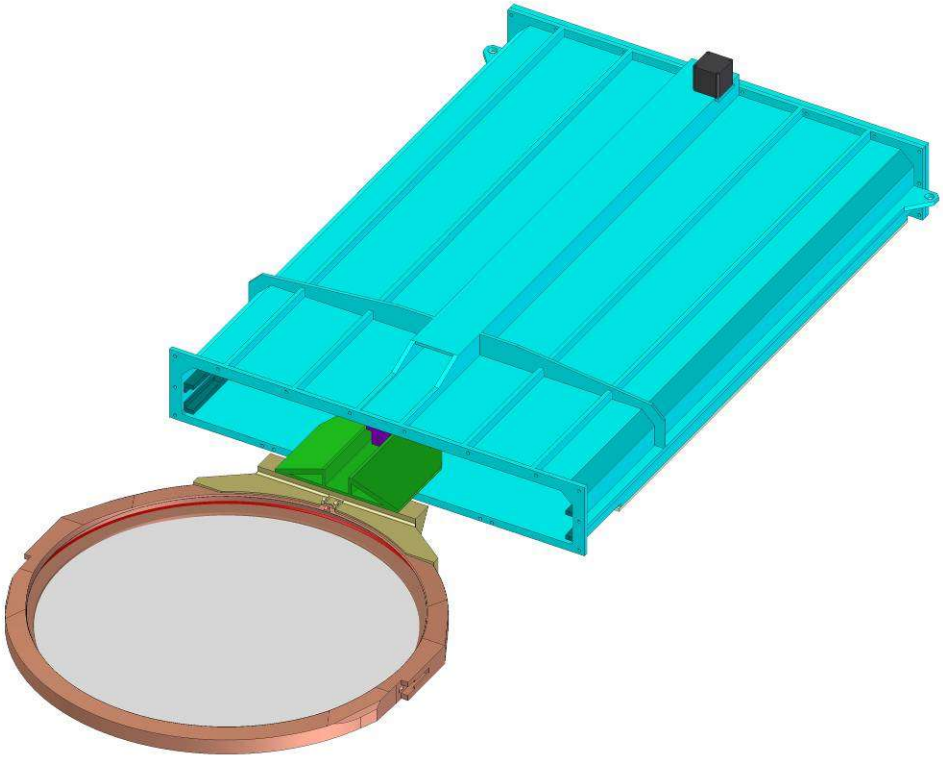
Manual Changer Reference Design
August 2006



Manual Changer Conceptual Design
June 2007

Manual Changer Design Details

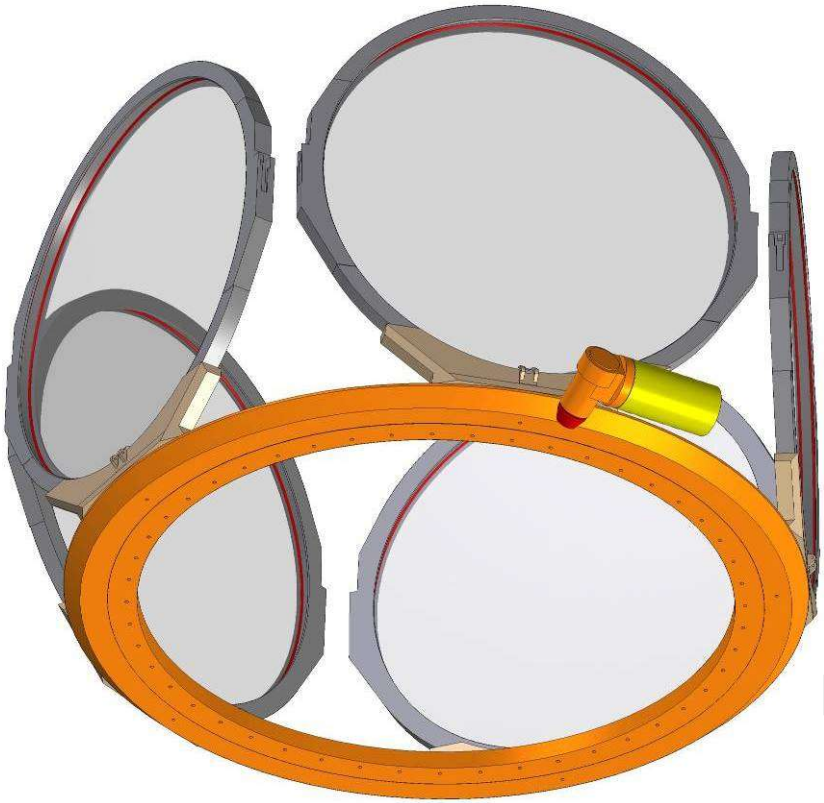




Manual Changer Status

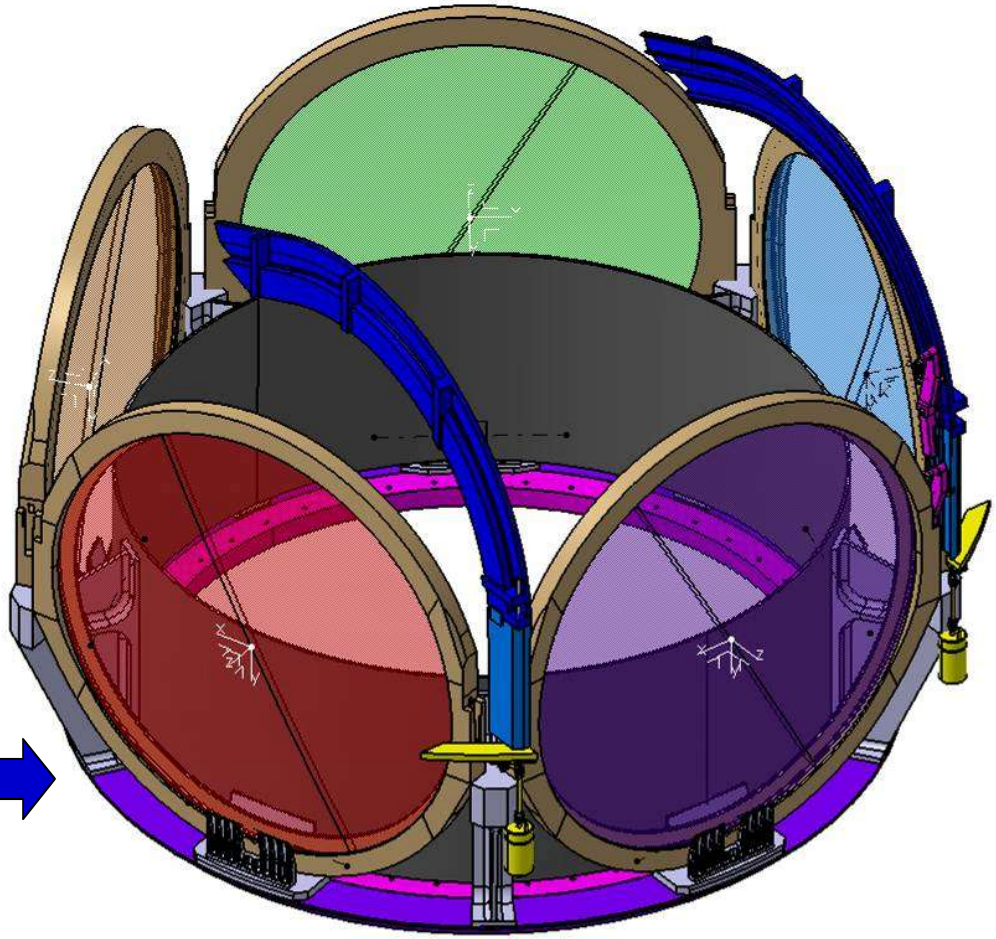
- **Design status**
  - **Completed a conceptual design**
  - **Fully integrated the design with the design of the rest of the camera**
  - **Reviewed the Manual Changer design and operations plans with the Telescope team**
    - Verified that we have suitable crane hook height
    - Verified that the Manual Changer can be positioned as needed and that its weight can be supported by the telescope hexapod and rotator
    - Checked that the Telescope platforms provide adequate personnel access for operating the Manual Changer during a filter swap-out
- **Work still to complete for CoDR**
  - **None—ready for CoDR**
- **Work still to complete for CD-1 Review**
  - **Size and select linear rail, ball screw, motor, and transmission**
  - **Develop clamp design, based on Carousel clamp**
  - **Modify filter exchange control logic and instrumentation plans to include manual changer**

Carousel Design



Carousel Reference Design

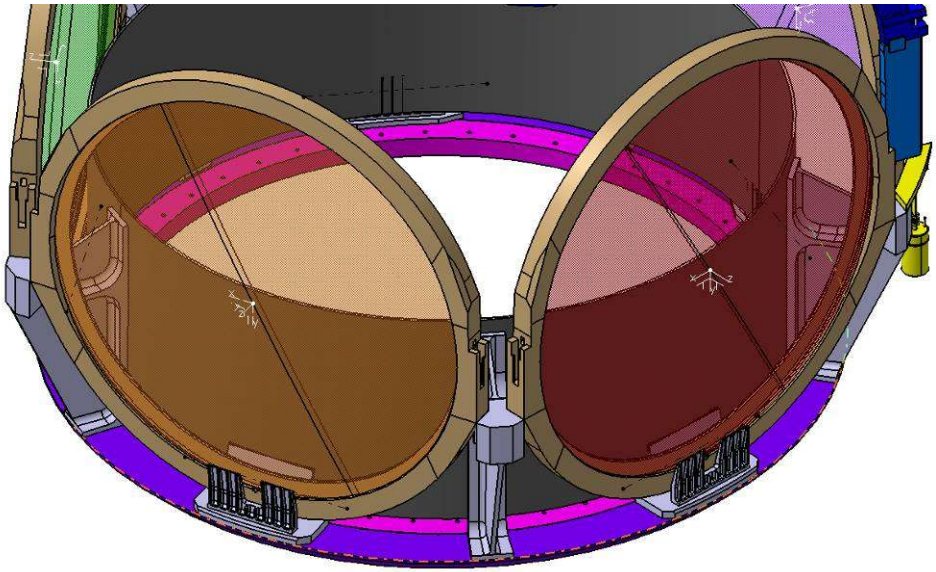
August 2006



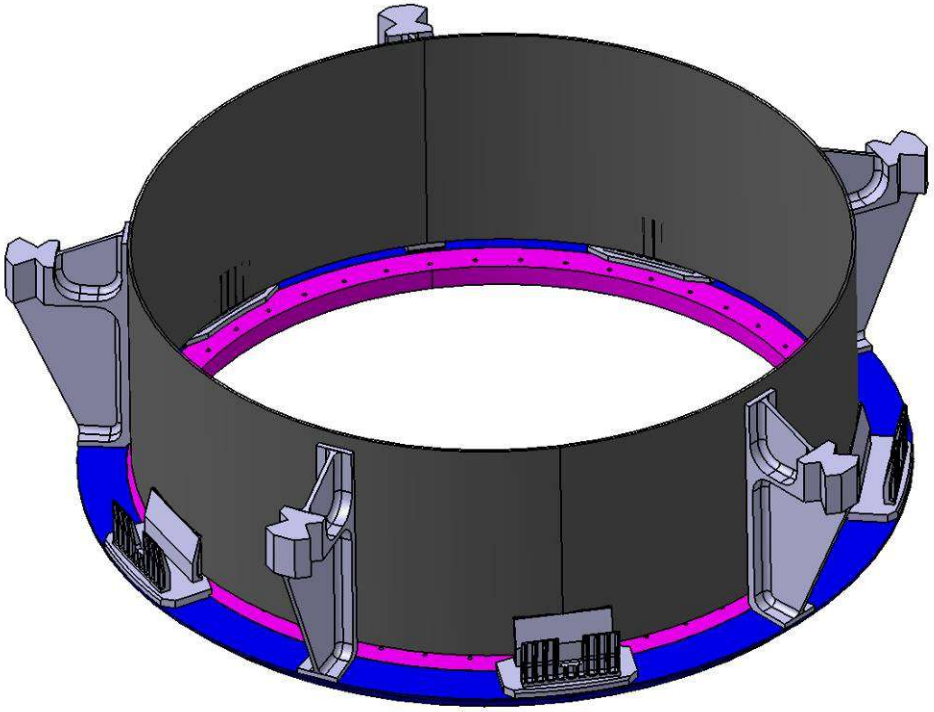
Carousel Conceptual Design

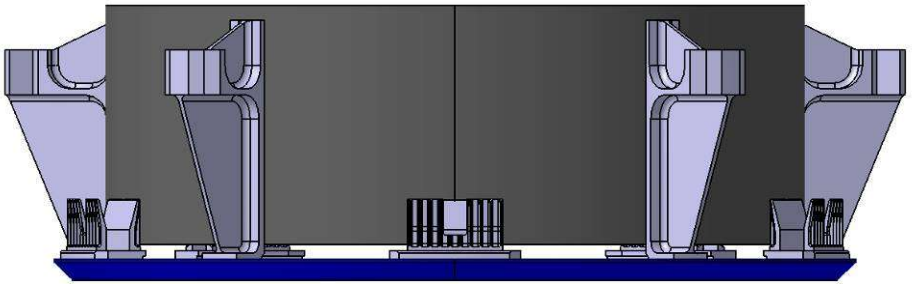
June 2007

Carousel Design Details

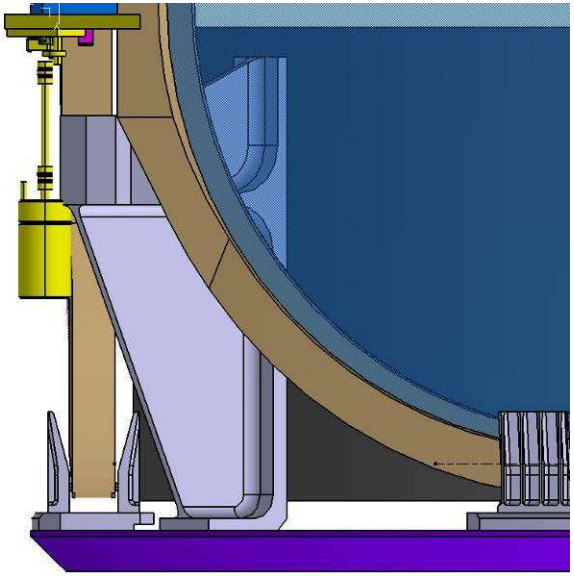


Filter and Clamp Detail





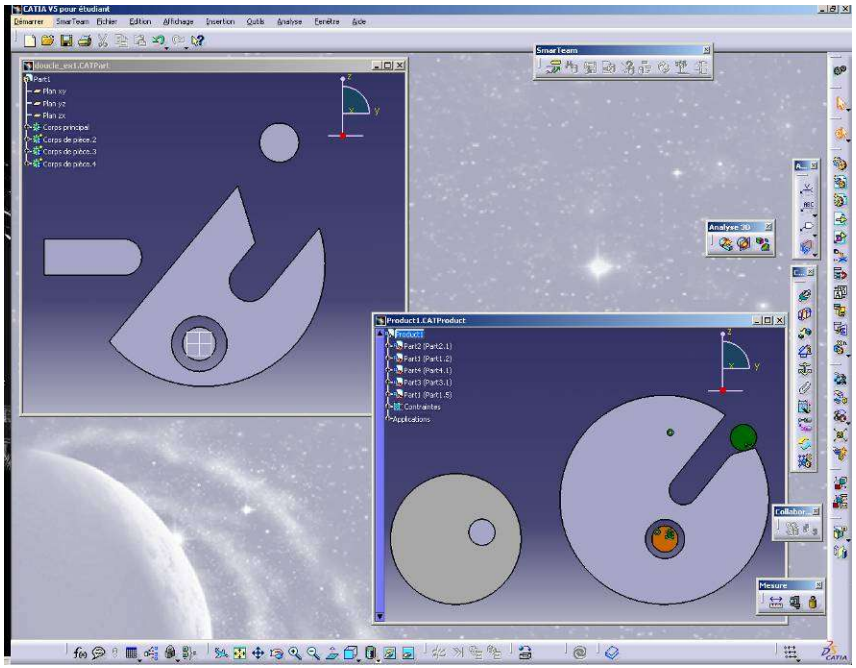
Side View of Empty Carousel



Detail of Filter Engaged in Clamp

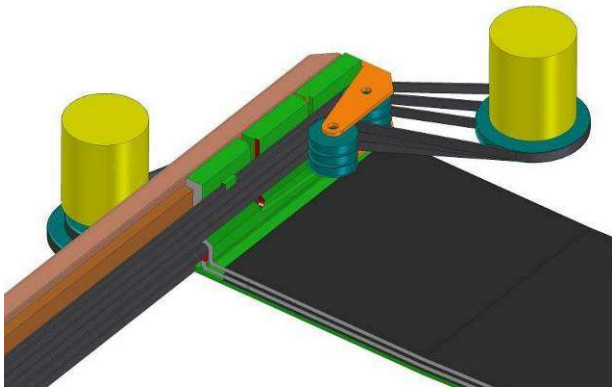
Carousel Design Status

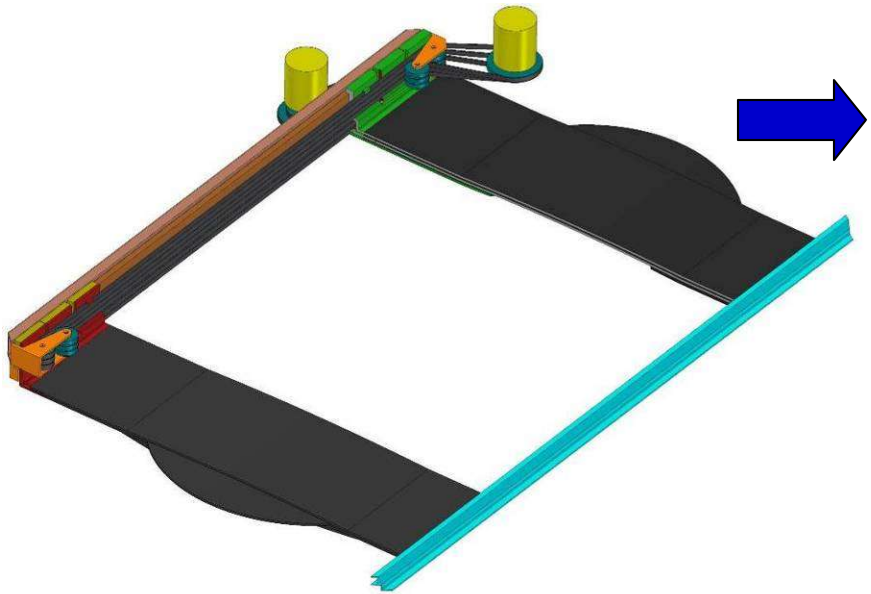
- **Design status**
  - **Completed Carousel and Filter stayclear models and drawings**
  - **Transferred Carousel work to University of Paris**
  - **Modified Carousel design**
    - Developed integrated clamp and Carousel ring design to improve accuracy of clamp placement and stiffen Carousel ring
    - Changed filter support concept to significantly reduce bending stresses in filter frame and glass
  - **Currently investigating alternate clamp mechanisms for holding the filter in place**
- **Work still to complete for CoDR**
  - **Complete clamp conceptual design**
  - **Integrate Carousel design into Camera model**
- **Work to complete for CD-1 Review**
  - **Develop and test prototype of clamp design**
  - **Analyze tolerances of Carousel/Changer mate-up and develop details of compliance and run-in features**

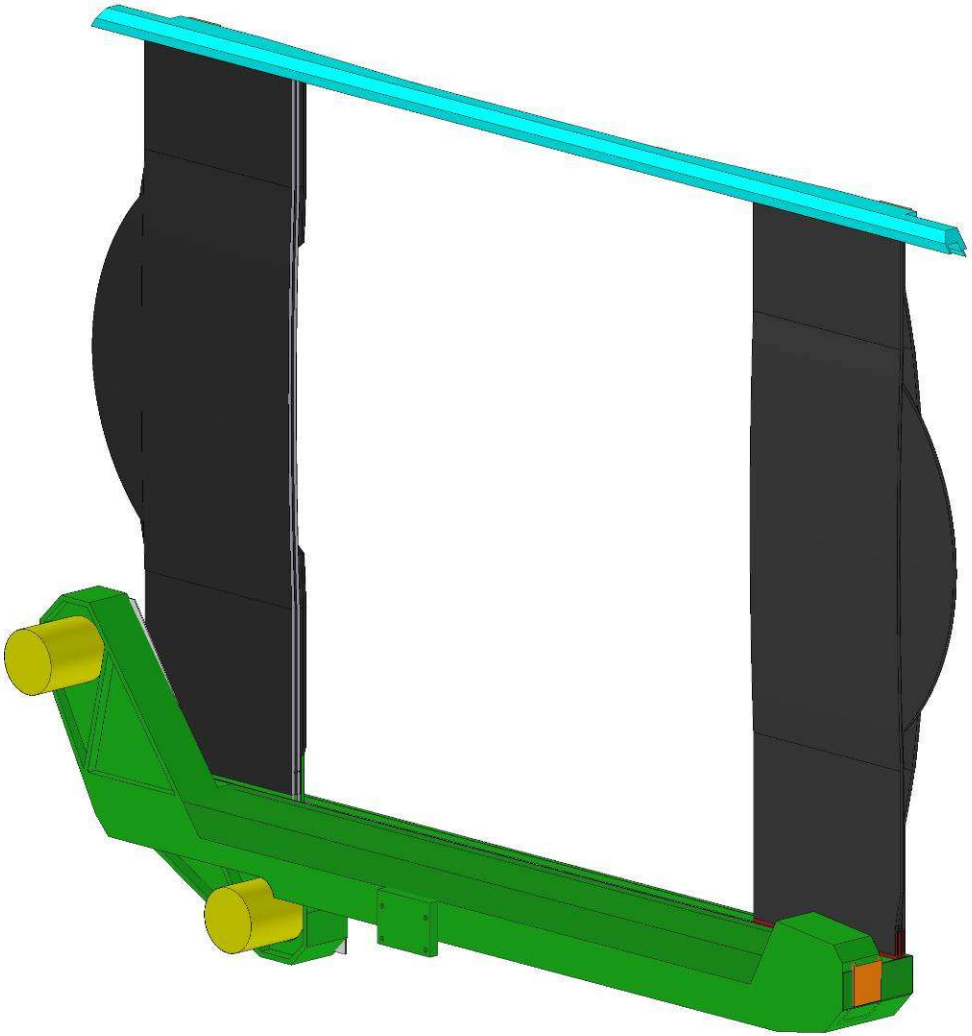


Clamp Latch Concept

Shutter Design







Shutter Reference Design
August 2006

Shutter Conceptual Design
June 2007

Shutter Status

- **Design status**
  - **Specified belt type, pulleys and motor size**
  - **Developed dynamic analysis model of the shutter drive system**
    - This was used to understand the influence of the stiffnesses of various shutter components on the overall system dynamics
    - We expect to correlate this model with test data to develop a more accurate dynamic model
    - This has also been used to estimate the effect of faster shutter closing times on shutter dynamics and loads
  - **Designed a support frame and enclosure for the Shutter drive system**
  - **Developed a mounting method and servicing/removal concept for the Shutter**
  - **Designed and detailed a prototype of the Shutter drive train**
    - This prototype is currently on-hold, due to funding constraints
- **Work still to complete for CoDR**
  - **None—ready for CoDR**
- **Work to complete for CD-1 Review**
  - **Agree on where Shutter will be developed and re-start work**
  - **Complete prototype testing and incorporate design changes**
  - **Investigate light-tightness of the Shutter and refine design as-needed**

Conclusions

- Camera Body and Mechanisms subsystem is very nearly ready for CoDR
- Summary of work to be done prior to CoDR
  - Complete L1/L2 Assembly structural analysis and update L1/L2 mounting ring accordingly
  - Complete lens sensitivity analysis
  - Complete Carousel design update and integrate into Camera assembly
- We expect to complete all subsystem preparations for CoDR in mid- to late-July
- We can then turn our attention to preparations for prototyping and the CD-1 Review