Camera Body and Mechanisms

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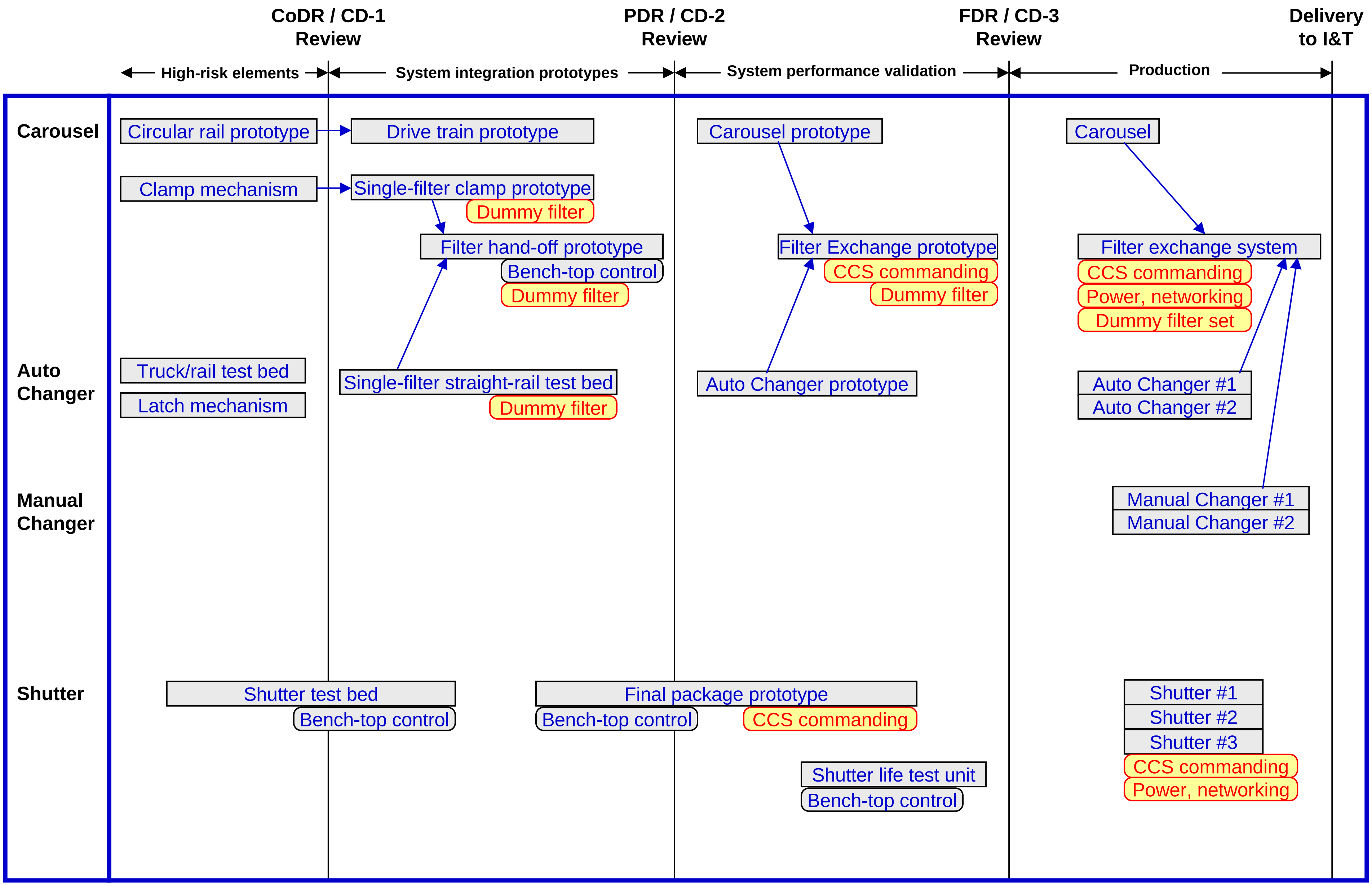
Outline

- Current plan and schedule for delivery to I&T
- Key technical milestones
- Highlight specific technical development activities
- Test requirements/equipment at each phase
- Task interdependencies with other subsystems
- What is the subsystem self-protection plan/features

Filter Exchange System Development Activities



Filter Exchange System Prototyping Goals (1)

- **High-risk design element prototyping (prior to CD-1 review)**
  - **Carousel circular rail prototype**
    - Evaluate THK circular rail system: loading, accuracy
  - **Carousel clamp mechanism test**
    - Demonstrate full performance of the fail-safe clamp mechanism on the carousel
    - Proof-test the clamp design
  - **Auto changer truck/rail test bed**
    - Load-test the truck design
    - Evaluate truck and rail performance for varying rail angles, bend radii, fits, and gaps
  - **Auto changer latch mechanism test**
    - Demonstrate full performance of the fail-safe latch mechanism on the auto changer trucks
    - Load-test the latch design
- **System integration prototyping (prior to CD-2 review)**
  - **Carousel drive train prototype**
    - Test and proof test the entire drive train, including motor(s) and ring gear, with circular rails
  - **Carousel single-filter clamp prototype**
    - Demonstrate performance of clamp/release mechanisms
    - Select sensors for monitoring state of clamps and filter
  - **Auto changer single-filter straight-rail test bed**
    - Demonstrate performance of the auto changer rail and latch systems
    - Select sensors and finalize truck and rail design
  - **Filter hand-off prototype**
    - Combined test of carousel and auto changer prototypes
    - Test the mechanics, tolerances, and fault-tolerance of the highest-risk step of the exchange process
    - Test fault-tolerance and failure recovery scenarios

Filter Exchange System Prototyping Goals (2)

- **Complete system performance validation (prior to CD-3 review)**
  - **Carousel prototype**
    - Full system performance demonstration
    - Test sensors, fault-tolerance, and failure recovery
    - Load-test system
  - **Auto Changer prototype**
    - Full system performance demonstration
    - Test drive-train sensors and actuators
    - Load-test the drive-train
    - Demonstrate filter positioning accuracy
  - **Filter Exchange system prototype**
    - Test the complete system, along with its control system
    - Run life testing and contamination assays to establish particulate-control requirements and servicing periods
    - Develop servicing procedures

Shutter Prototyping Goals

- **High-risk design element prototyping (prior to CD-1 review)**
  - **Shutter test bed**
    - Test performance of timing belt drive system: acceleration, vibration, yaw
- **System integration prototyping (prior to CD-2 review)**
  - **Shutter test bed**
    - Demonstrate dynamic performance of 3-capstan drive system with 3 carbon fiber blades
    - Test candidate materials and components for the drive train
    - Run initial life and wear testing
  - **Final packaging prototype**
    - Qualify drive train components
    - Validate system design and packaging
    - Select and test sensors
- **Complete system performance validation (prior to CD-3 review)**
  - **Final packaging prototype**
    - Demonstrate shutter performance
    - Test fault-tolerance and failure recovery
    - Finalize instrumentation and telemetry
  - **Life test unit**
    - Characterize component wear, particulate generation over lifetime
    - Establish long-term monitoring and troubleshooting procedures
    - Establish servicing schedule

Filter Exchange Hardware Protection System

- **Failure scenarios and fault protection**
  - **Hardware protection is handled 100% locally in hardware, with no CCS response needed**
  - **Fault conditions are communicated to the camera control system**
- **"All" known modes of the systems will be detected by one or more sensors**
  - **Before or during an action, if any sensor trips or goes out-of-range, the action is immediately aborted (we need a "standard" stop sequence)**
  - **Out-of-sequence steps are prevented by requiring system enables with an "and-ed" combination of binary switches**
  - **Failure in of any one actuator or sensor will prevent enabling of any other system**
- **Actuators are fail-safe to loss of power**
  - **All actuator drive trains either have power-off brakes or are non-back-drive-able**
  - **Some clamp/registration solenoid pins have two stable positions, so they hold their current position if power is lost**
  - **Brakes and other pins must be actuated against a spring force, so a loss of power will re-engage them**
- **Loss of a sensor or loss of signal from a sensor**
  - **If this happens prior to an action, then action is disabled since it requires a positive signal to enable the action**
  - **If this happens during an action, then action is stopped when "enable" status drops due to loss of a sensor signal**
  - **We need to look at whether we need redundant sensors at key places**
    - This is generally not done for system-safety, but may be warranted for a few key sensors

Filter Exchange Operations

- **Four operating states of the filter exchange system**
  - **"Standard" operations**
    - Steps needed to exchange one filter for another that is stored in the carousel
    - In this operating state, all systems and sensors are actively used to protect the system
  - **"Non-standard" operations**
    - Steps taken to perform an action that is not typically done
    - Examples: swapping out a filter with the manual changer, turning system off/on, identifying filters in the carousel
    - In this operating state, some select sensor signals may be overridden, or additional sensors used (as is the case for the manual changer)
  - **Fault-recovery operations**
    - Actions to either recover the system from a fault or safe the system to protect it, prior to repair or servicing
    - Not all of faults and fault-recover actions have been identified
    - In this operating state, some sensors or actuators are not functioning correctly, so there is incomplete knowledge about the system
  - **Integration and servicing operations**
    - Not all sensors and actuators may be functioning, or even present

Filter Exchange Personnel Protection System

- **Mechanisms include many pinch/crush points**
  - **The speed is slow, but these are considered personnel hazards when the camera is open**
- **During normal operations**
  - **Need sensors to confirm that camera (and access hatches) are closed**
  - **Could this be done with a simple "standard operations" enable from the CCS?**
  - **During filter swap-out with manual changer**
    - No personnel access is needed or possible during swap-out
    - The manual changer design prevents any hand access to the camera volume
  - **During integration or servicing**
    - In this state, people may be physically near, and working on the hardware, so personnel protection becomes important
    - Are additional sensors needed for personnel protection during servicing?
    - What administrative controls and add-on guards are needed?
    - What lock-out tag-out system is needed to both protect personnel and provide the operating functionality during and access for troubleshooting or servicing?

Shutter Hardware Protection System

- Sensors determine the correct static configuration of the shutter before each actuation
  - These signals form a latch chain permissive to the next actuation
- Failure scenarios and fault protection
  - Hardware protection is handled locally in hardware, with no CCS intervention needed
  - Fault conditions are communicated to the camera control system
- Actuators are fail-safe to loss of power
- Loss of a sensor or loss of signal from a sensor disables any action since it requires a positive signal to enable the action