



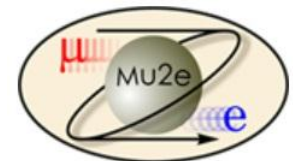
Mu2e Remote Handling Review Baseline Horizontal Design

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L4 Engineer/Designer – Target Remote Handling

3-3-2015



Outline:

- A. Requirements, Assumptions, and Design Constraints
- B. Basic Layout of the RH (Remote Handling) System
- C. Sequence of Operation
- D. Detailed look at the robot design and how it works
- E. Summary

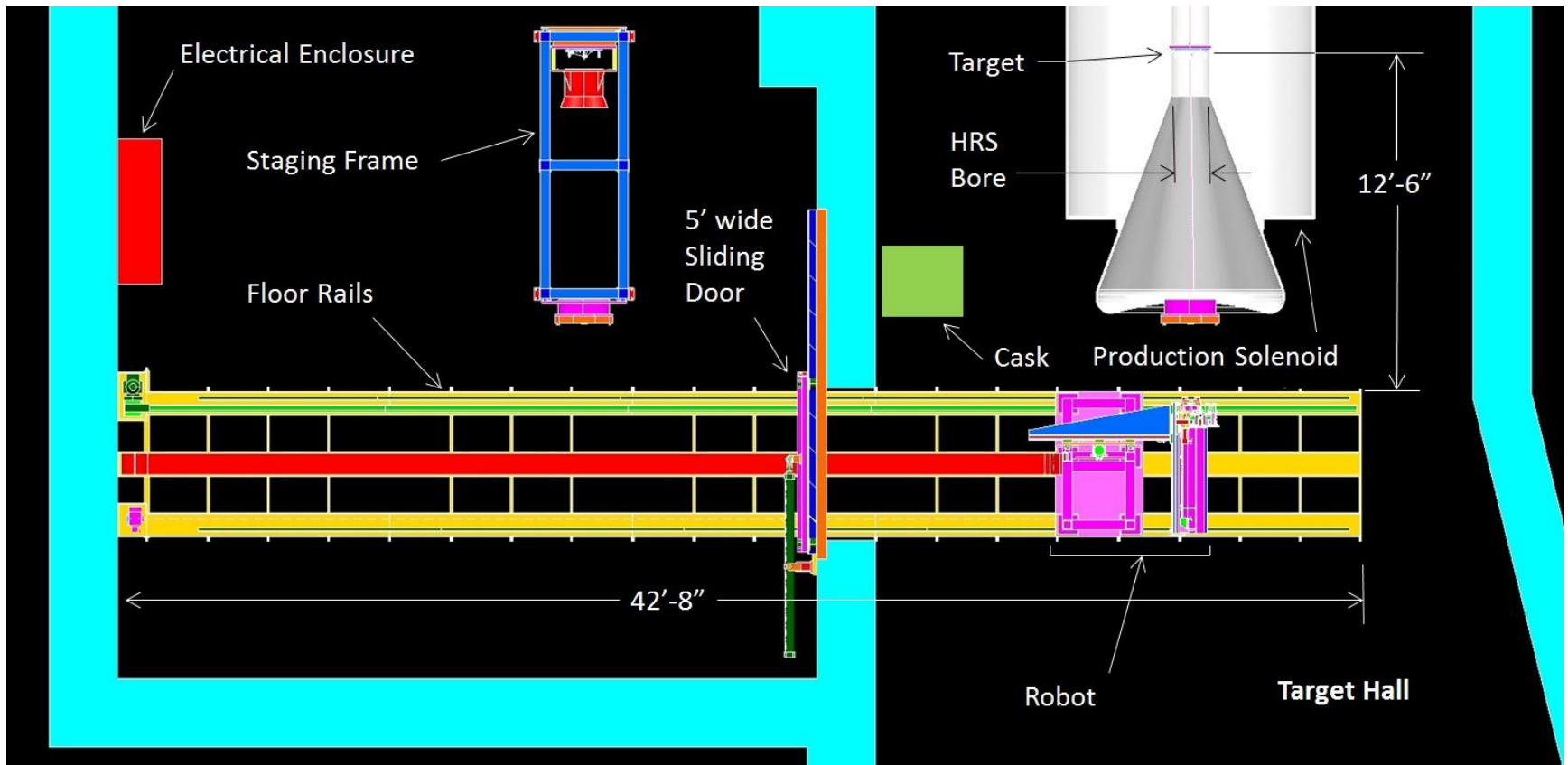
Requirements, Assumptions, and Design Constraints:

1. RH system to remove the old window and target, dispose them into a storage cask, place new target and window, re-make vacuum seal
2. RH system to handle the Radiation-Cooled (RC) target
3. Enter / exit the Target Hall (TH) from a separate RH room on floor rails
4. Pass through a doorway with a sliding, shielded door between the TH and RH room
5. Concrete floor (along w/ the embedded floor rails) can/will move over time relative to the location of the work being done
6. Autonomous or remote control operation
7. RH system interface with the cask occurs in the TH
8. Planned usage: Replace window and target once per year
9. TH has a ceiling hatch to the outside, not intended to access for target exchange
10. RH system should also be able to remove/dispose/replace 2 additional windows:
(A) proton beam exit window, (B) extinction monitor window

How Those Requirements / Assumptions / Design Constraints Drive the Baseline Horizontal Design:

- A. The target access window is roughly the size and weight of a man-hole cover and must make a high vacuum seal to its' mounting flange - thus has 36 bolts around its' perimeter. The best way to put a bolt-driver on this many positions is to use X / Y / Z programmable robotic positioning.
- B. Since the floor is assumed to shift over time, the robot's move coordinates cannot be preset. The robot must be machine-vision guided, meaning: it must "find" the bolt locations using a video camera and machine-vision software before it can move to the required X / Y / Z coordinates.
- C. The reach distance into the Production Solenoid (PS) to pick / place the target is approx. 12-1/2 ft., but the robot must pass through a much narrower width doorway. Thus the arm that handles the target must have a telescoping reach.

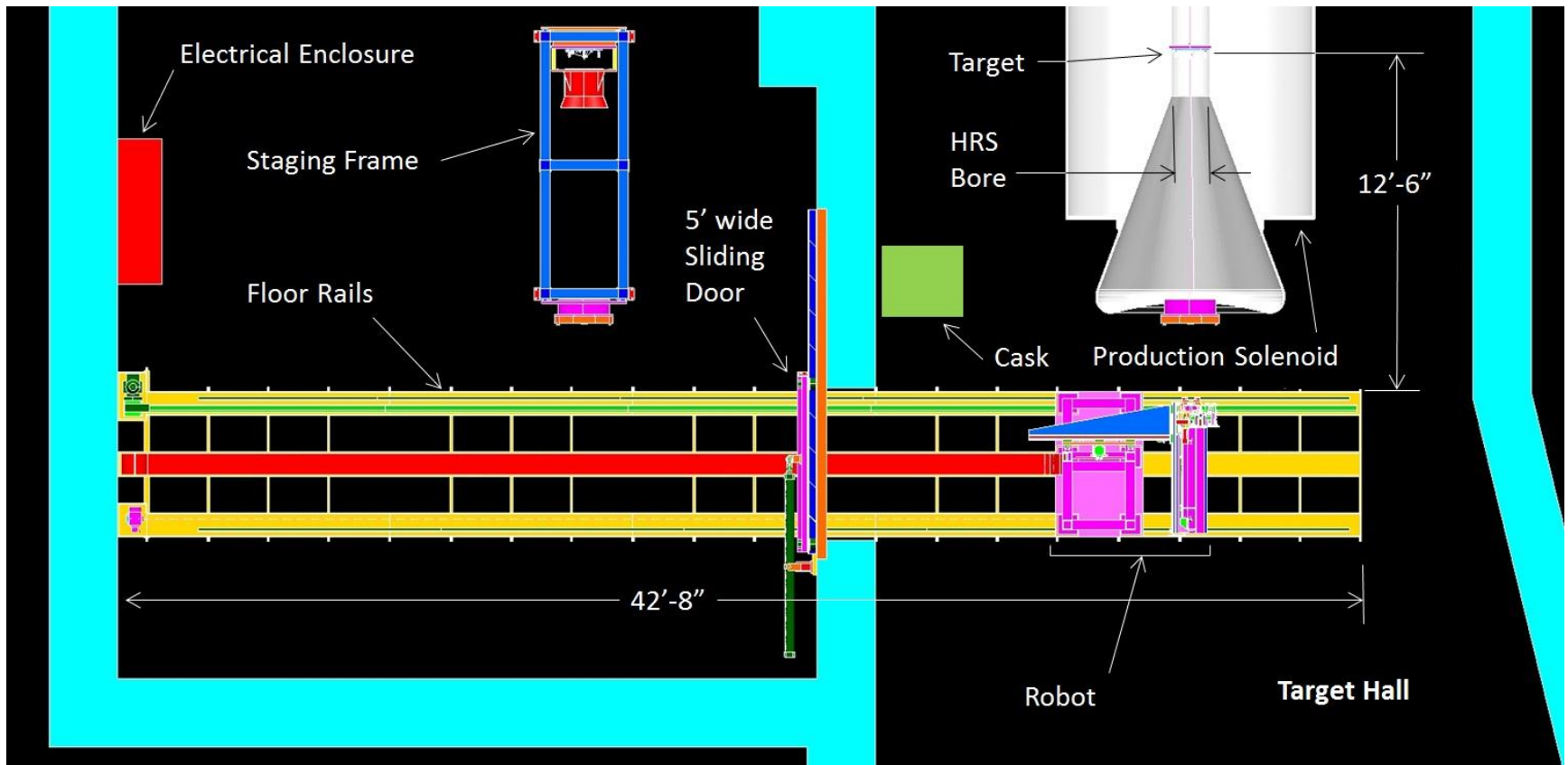
The Baseline Horizontal Design:



The basic layout is shown above.

Note that the robot is autonomous, but does have a control desk in the RH room, plus a possible second control desk at a further remote location. Control desk(s) would include interface to machine control computer, video screen(s) for operators to watch

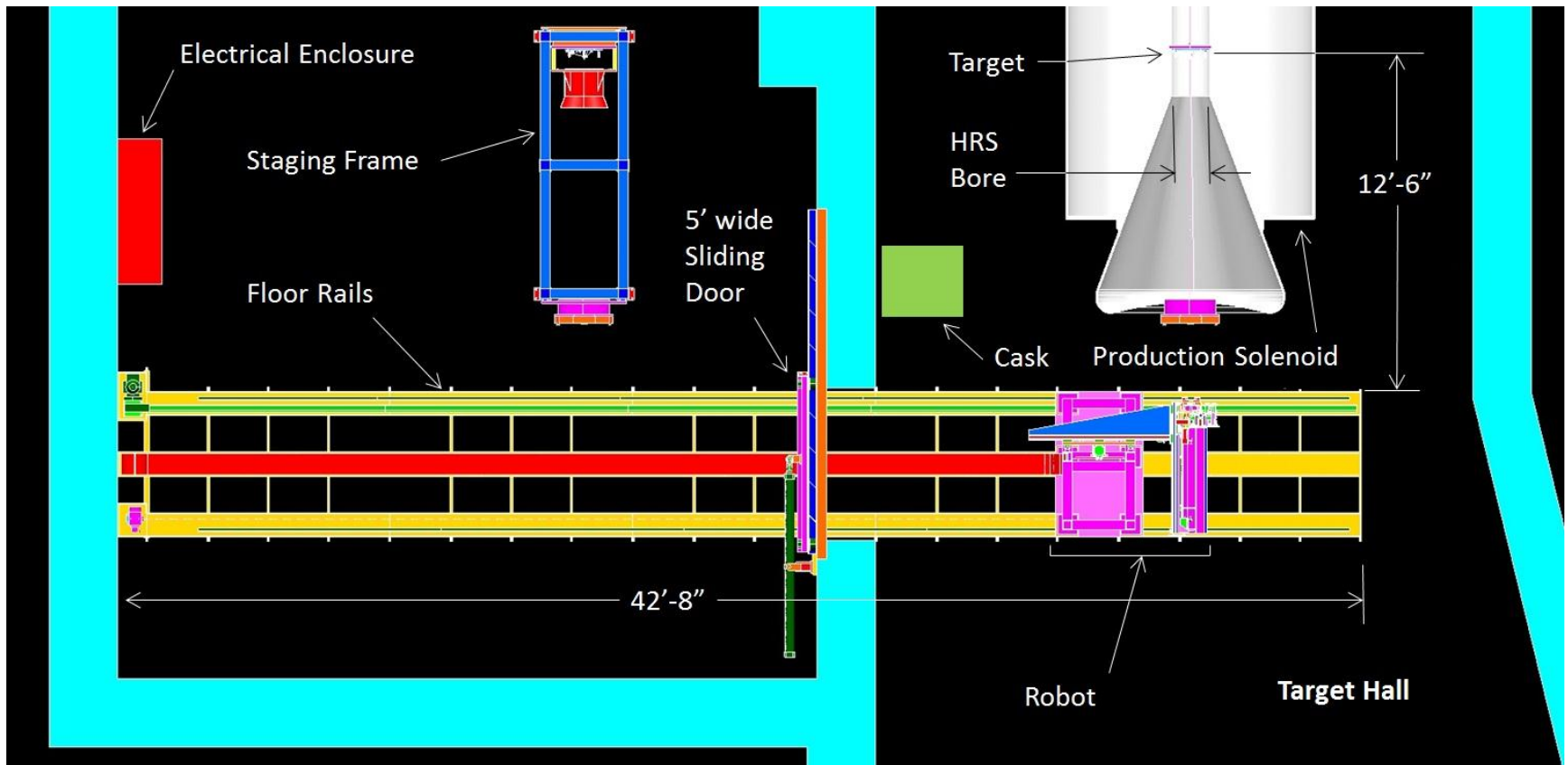
The Baseline Horizontal Design:



Sequence of Operation . . .

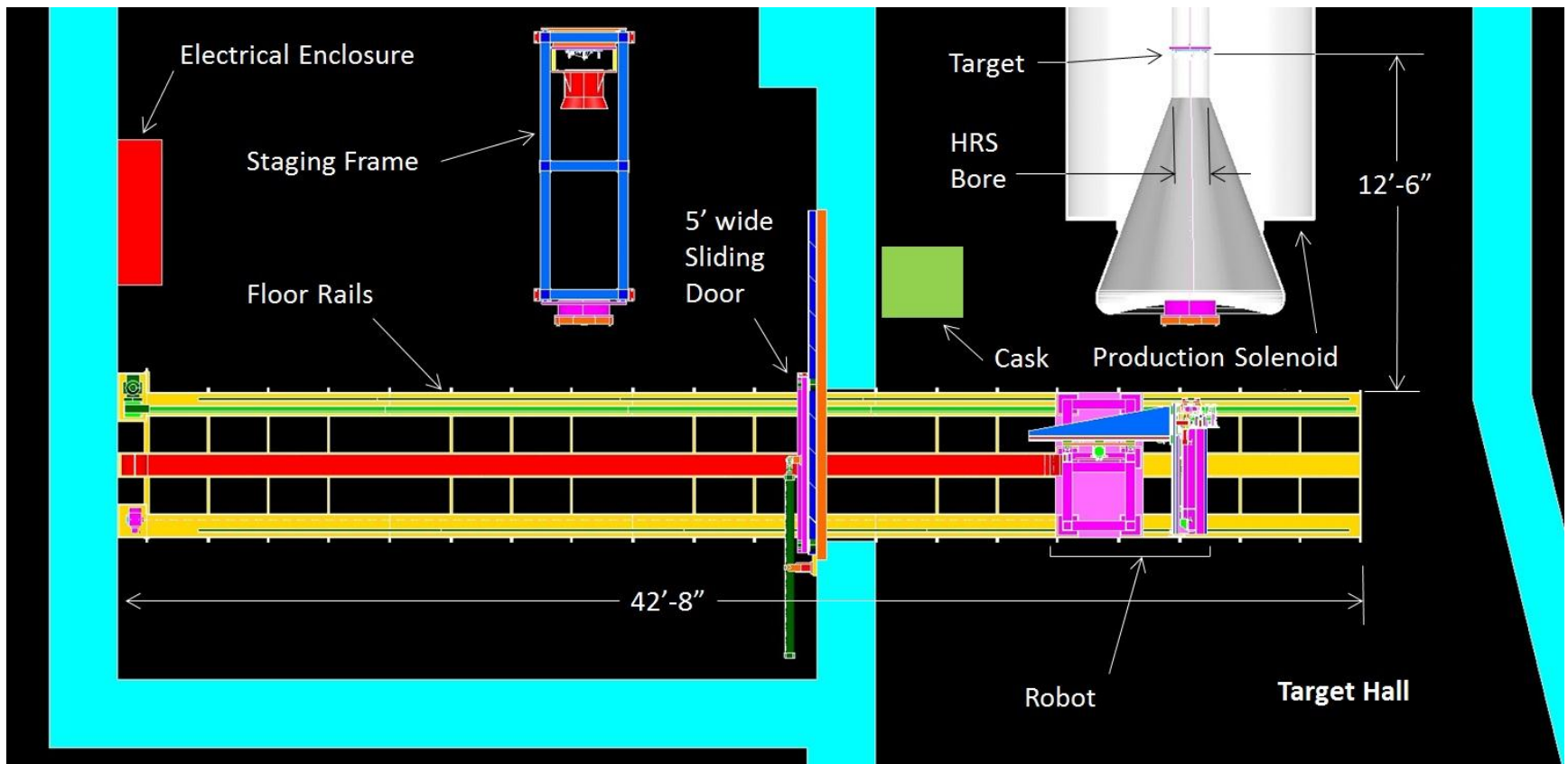
1. The sliding shield door opens, the robot moves into the TH on its' floor rails to position behind the PS, and the door closes.

The Baseline Horizontal Design:



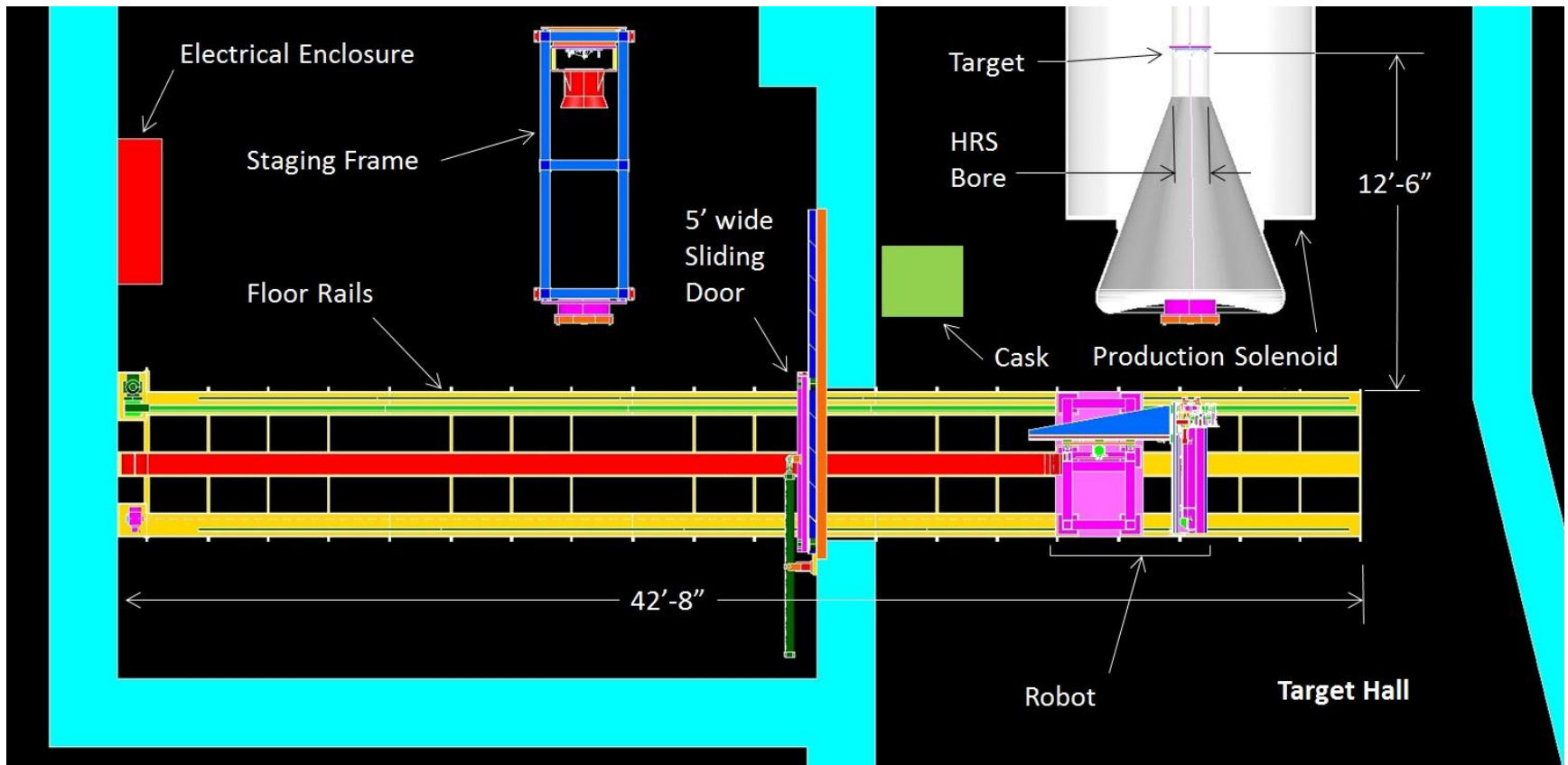
2. Using machine vision and X / Y / Z linear servo / screw-driven motions, the robot moves its' bolt driver to all bolt locations and removes bolts (retained in holes)
3. Robot retracts the bolt driver, extends its' gripper arm, grips, and removes window

The Baseline Horizontal Design:



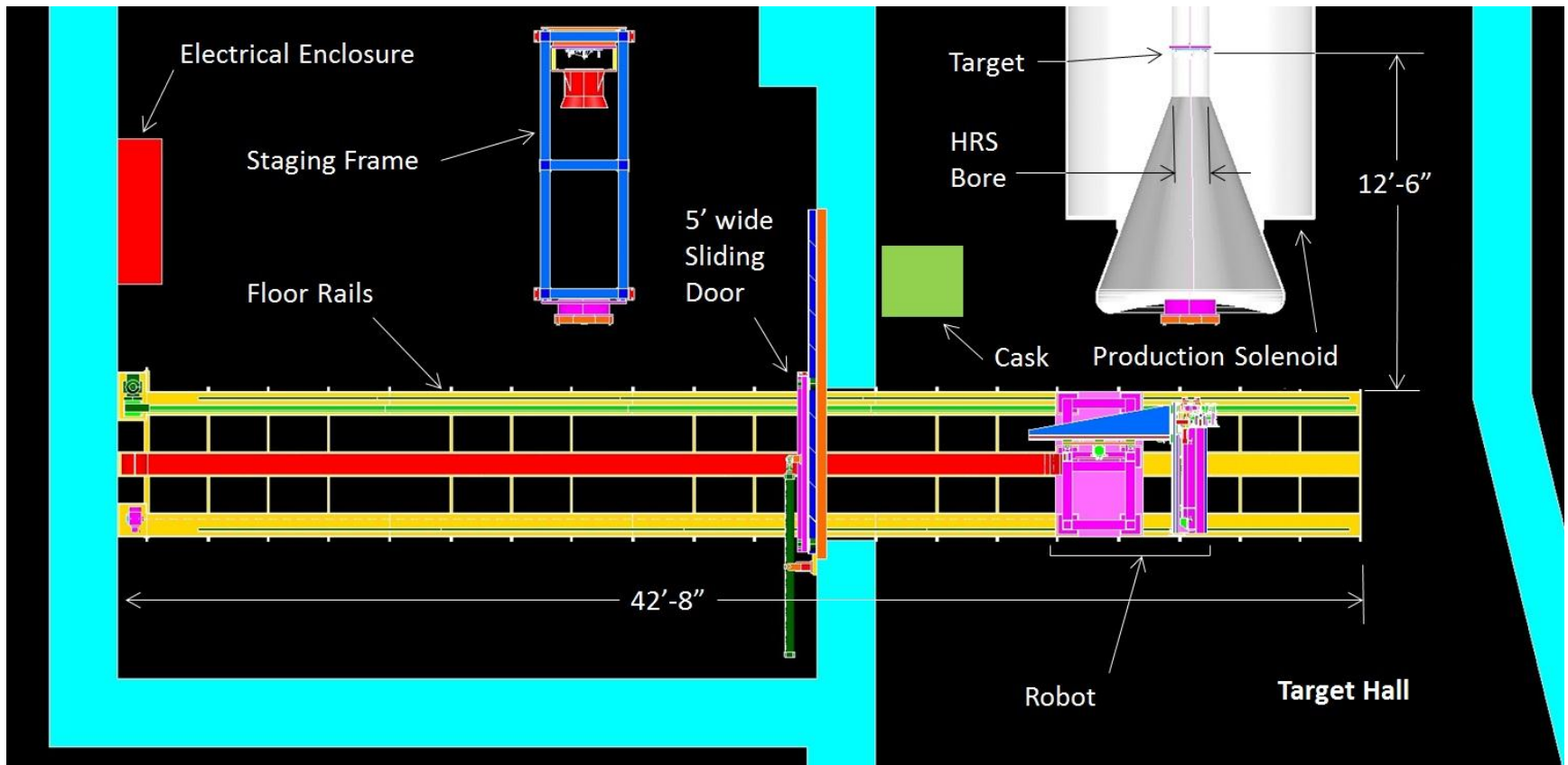
4. Robot moves on its' floor rails to position behind cask, cask door is already open
5. Robot places window into cask (upper half of chamber), releases it, retracts arm
6. Robot moves back to position behind PS, uses vision to find the target access hole

The Baseline Horizontal Design:



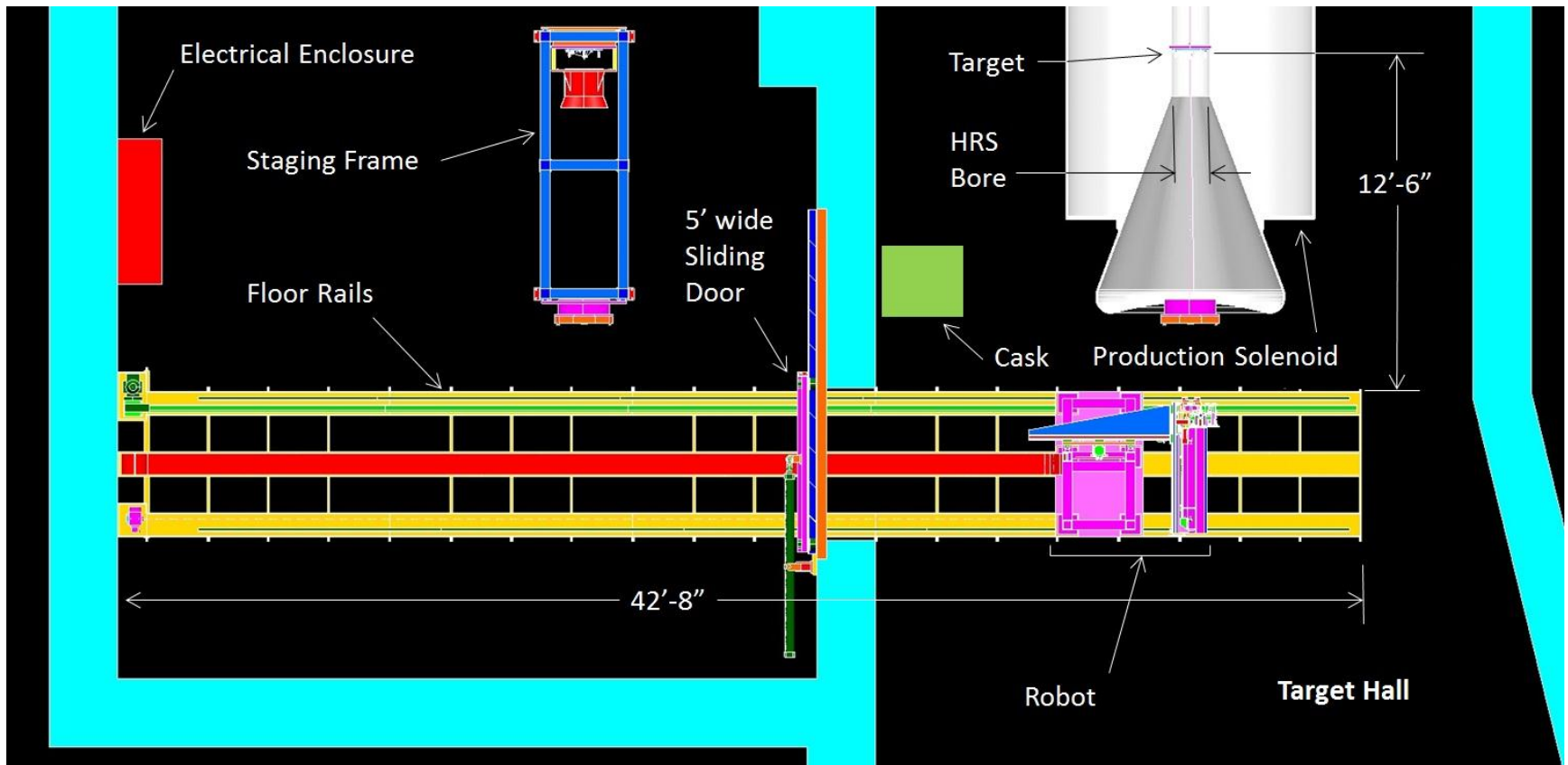
7. Robot positions its' telescoping target handling arm on center with the access hole
8. Robot extends the arm to reach the target assembly, end of arm tooling grips target
9. End of arm tooling turns 3 latches to release target from its' mounting surface

The Baseline Horizontal Design:



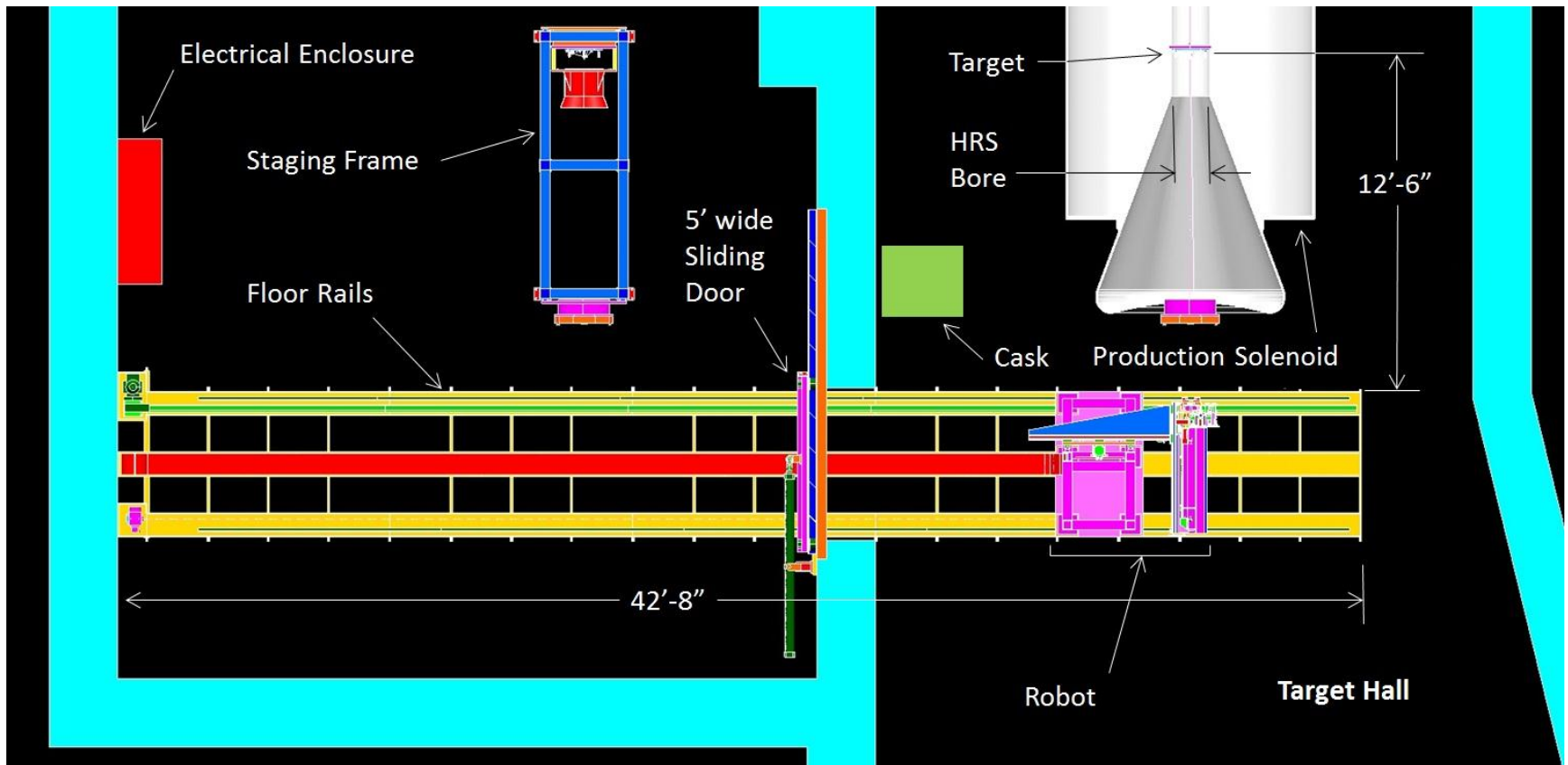
10. Robot retracts its' telescoping target handling arm to remove target assembly
11. Robot moves on its' floor rails to back position behind cask
12. Robot places target into cask (lower half of chamber), releases it, retracts arm

The Baseline Horizontal Design:



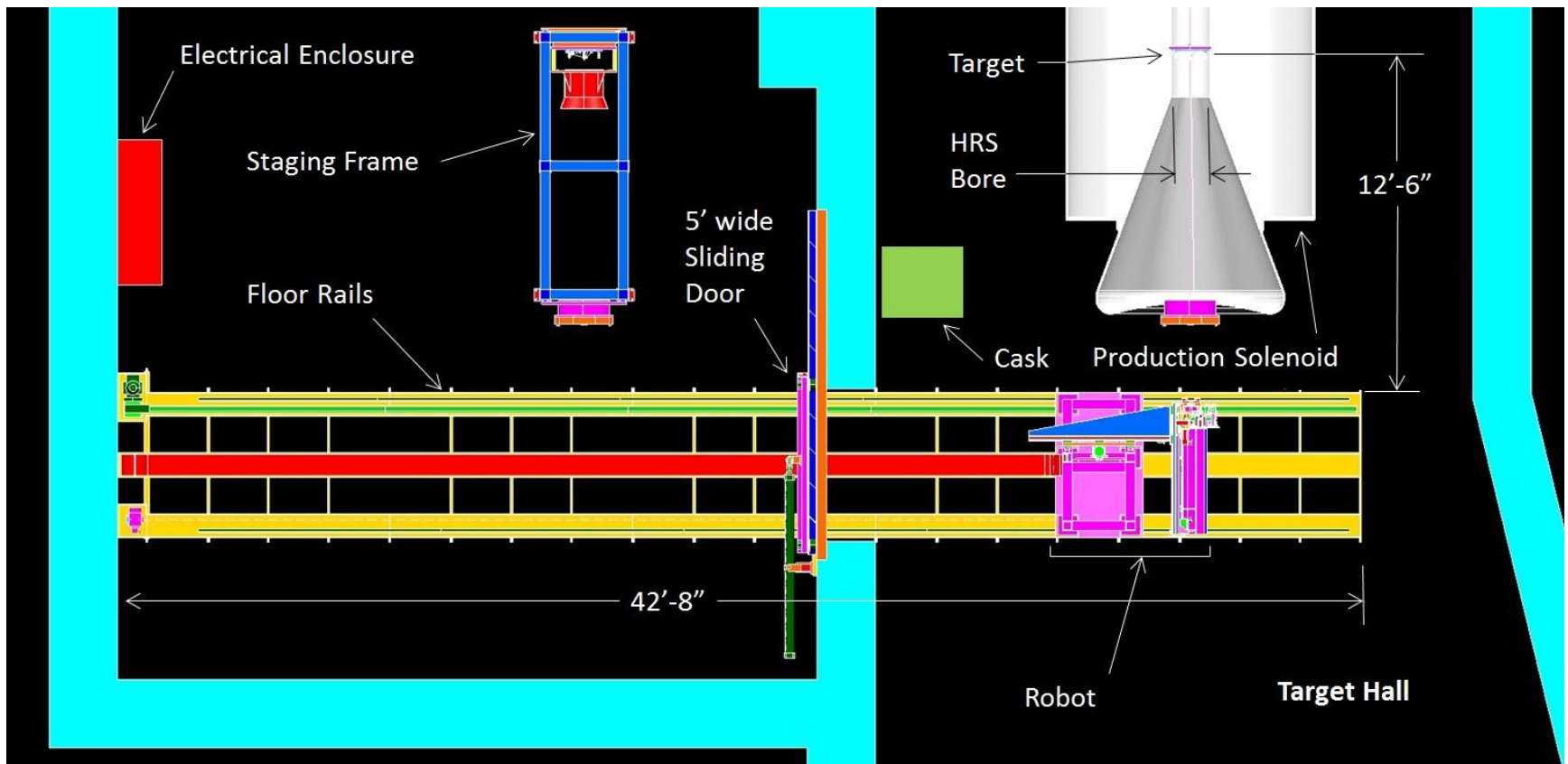
13. The sliding shield door opens and the robot returns to the RH room, positioning itself behind the staging frame, the sliding shield door then closes
14. A new target assembly will have been pre-staged in the staging frame as part of the RH task set-up. Using its' camera and arm, the robot retrieves the new target

The Baseline Horizontal Design:



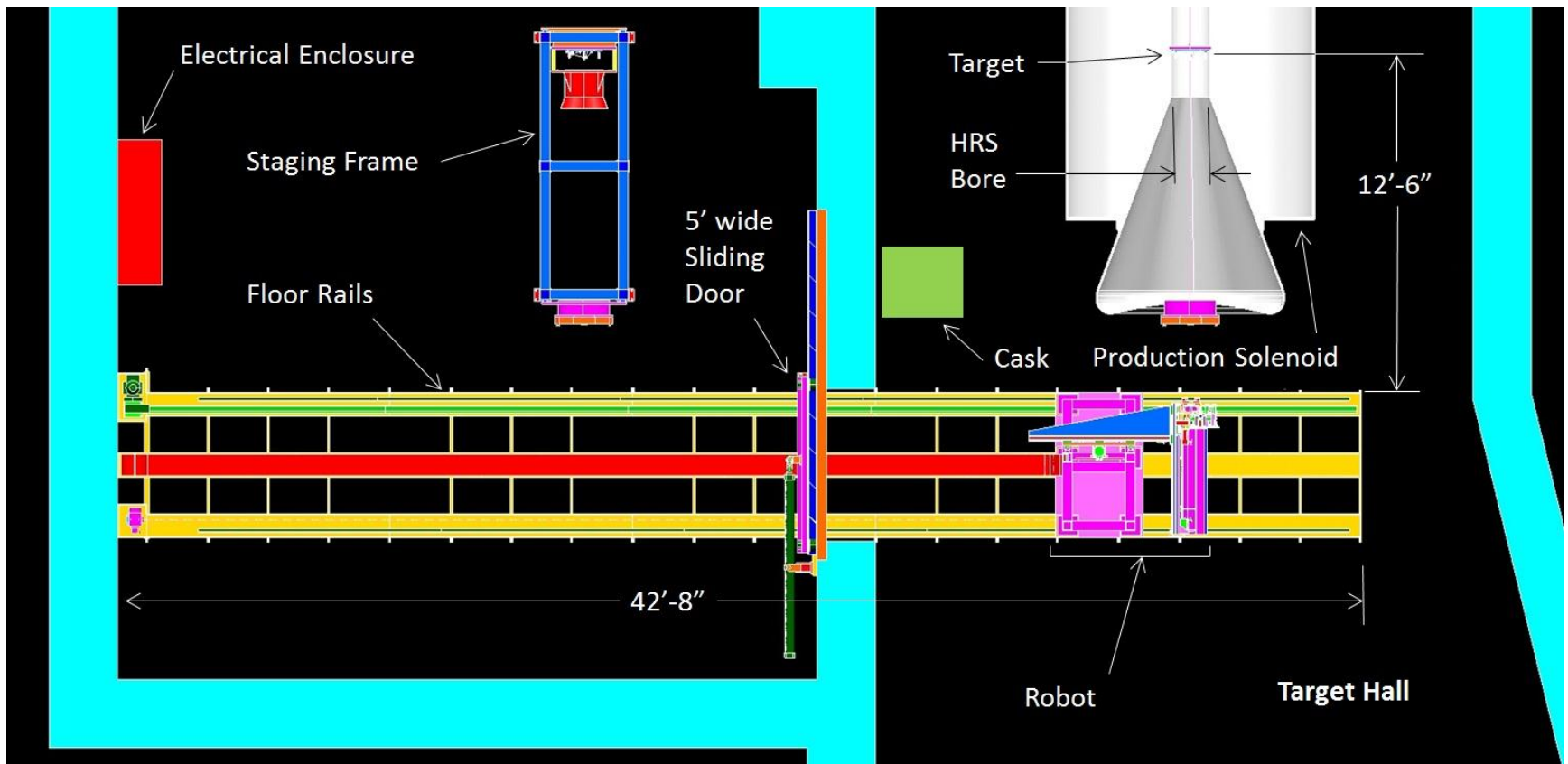
15. The sliding shield door opens and the robot returns to the TH, positioning itself again behind the PS, the sliding shield door then closes
16. Using its' camera and arm, the robot places the new target, latching it into place on the mounting surface using its' end of arm tooling

The Baseline Horizontal Design:



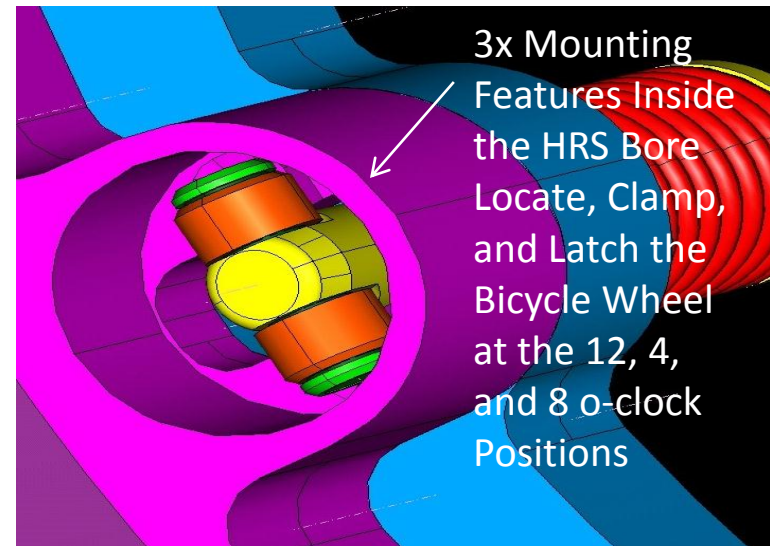
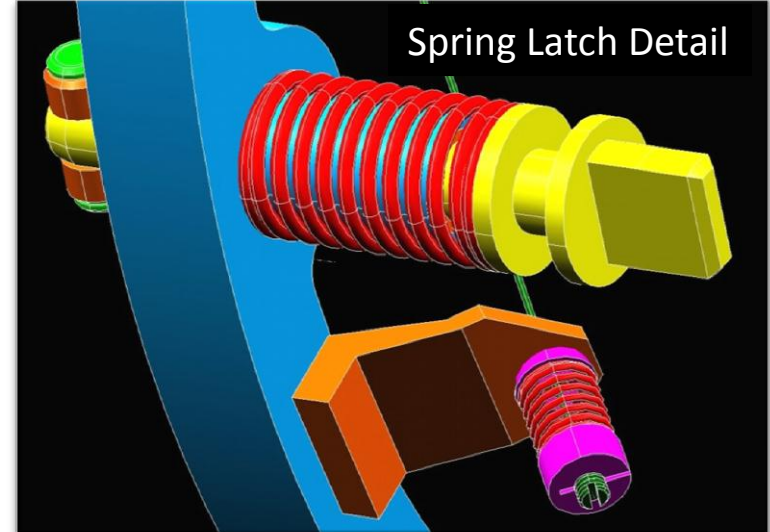
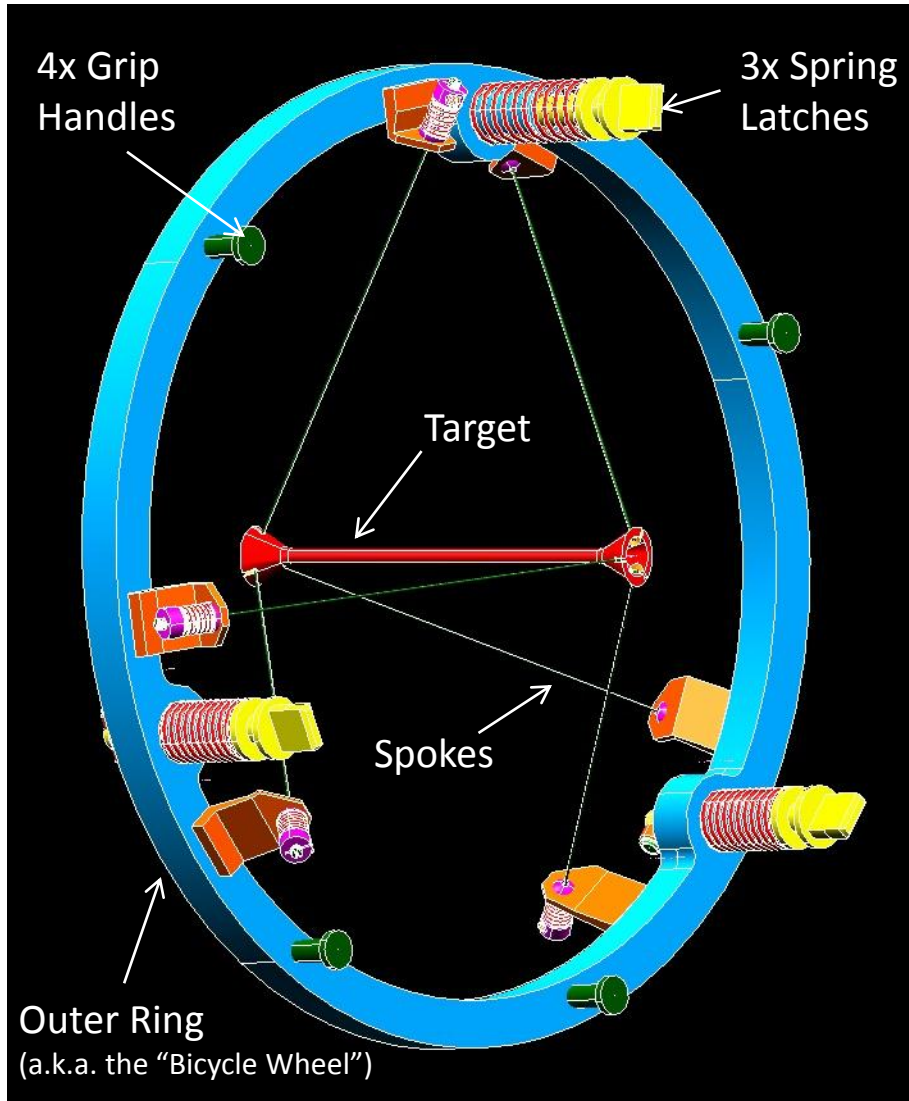
17. Similar to before, the robot returns to the RH room through the doorway, retrieves the new window, then travels back to its' position behind the PS in the TH
18. Robot places the new window, then proceeds to tighten the bolts around the perimeter. Any desired star pattern tightening sequence can be programmed

The Baseline Horizontal Design:

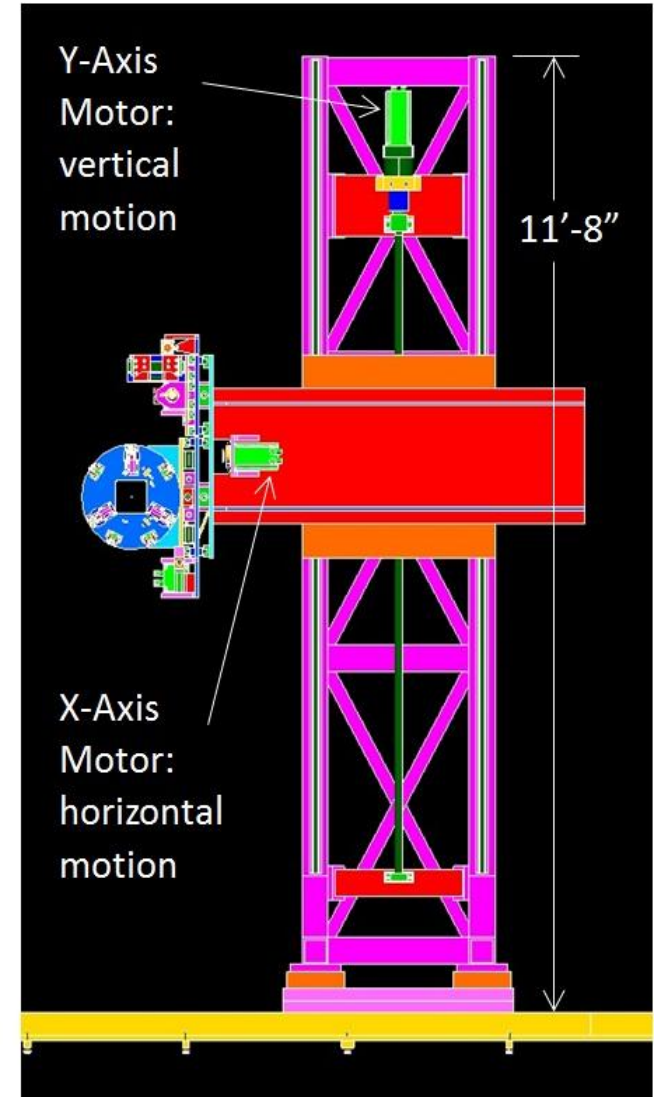
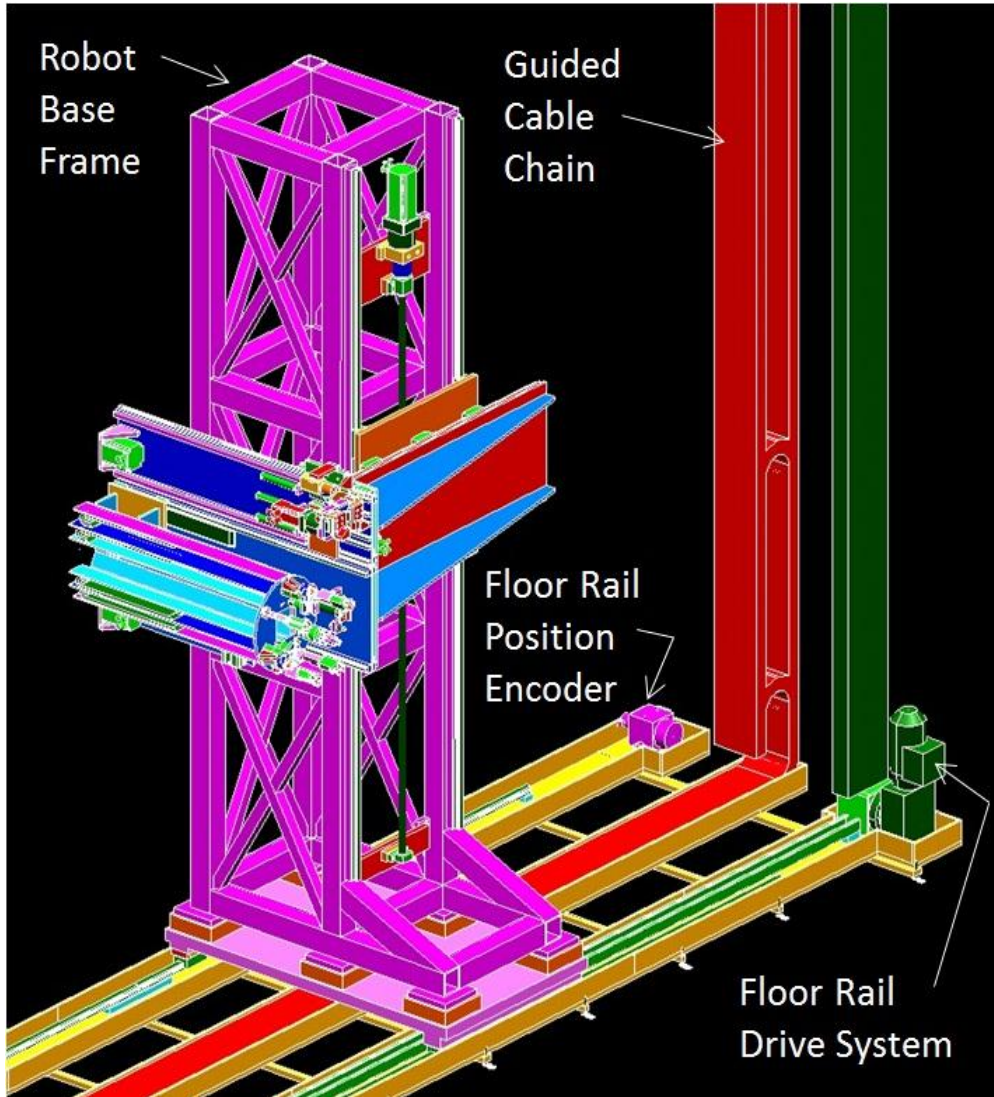


19. The sliding shield door opens, the robot returns to the RH room, and the door closes
20. The cask is manually pulled back toward the M4 beamline. Once under crane coverage there, the cask front door is placed onto it. The target exchange process is now complete

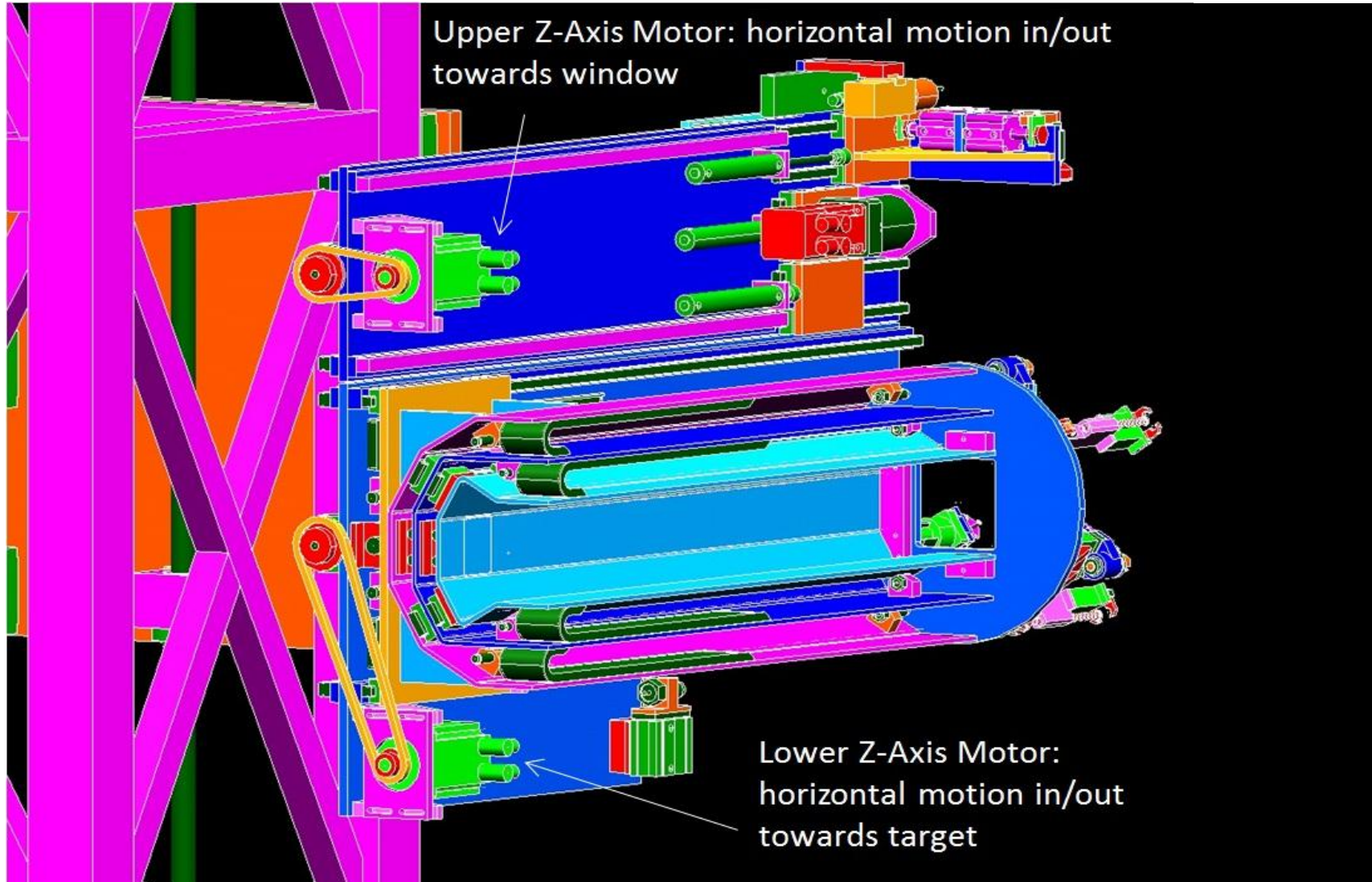
Design Details: The RC Target Assembly and its' Mount Inside the PS / HRS



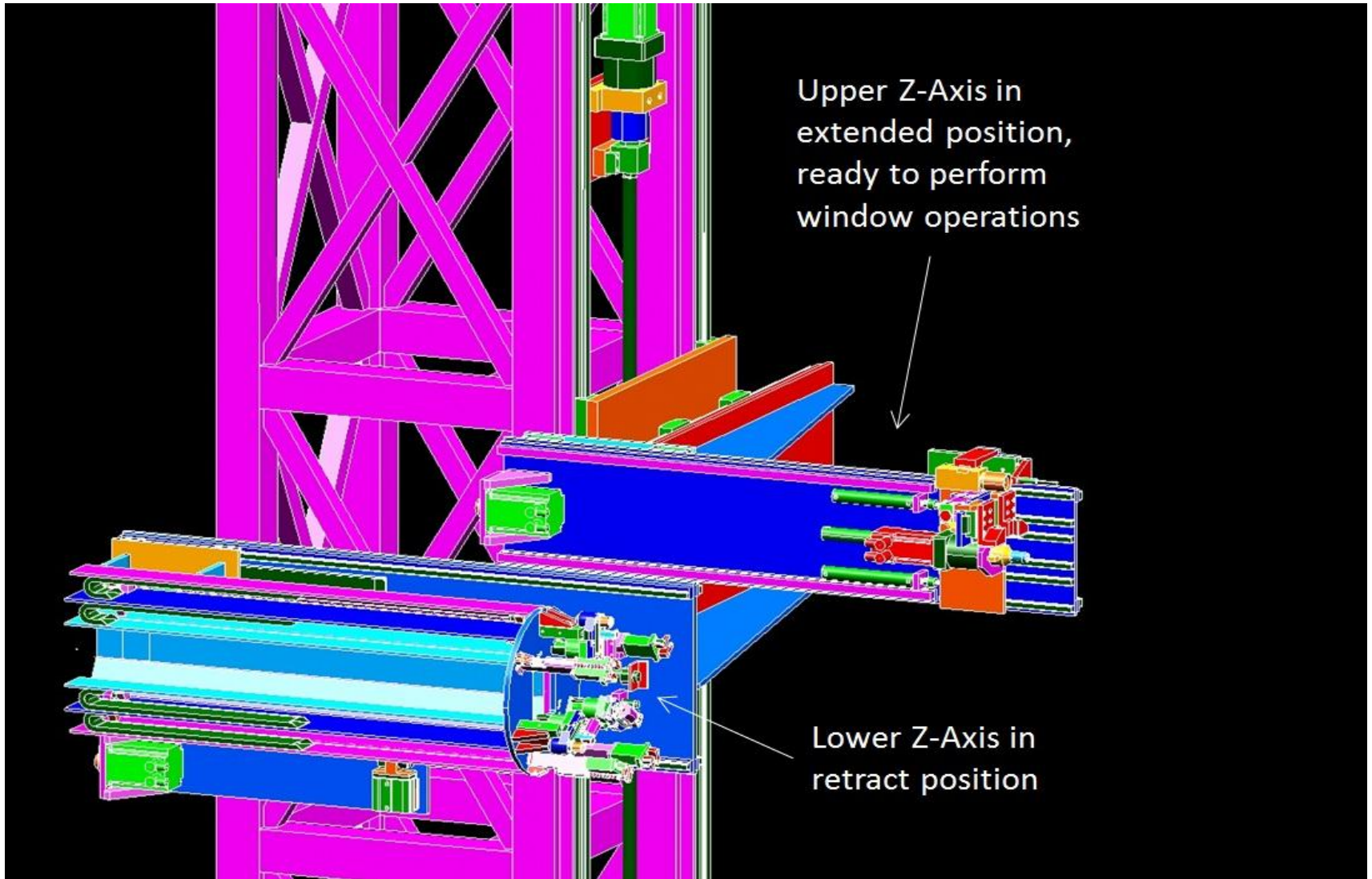
Design Details: The Robot Basic Structure and Its' X / Y Motion Axes



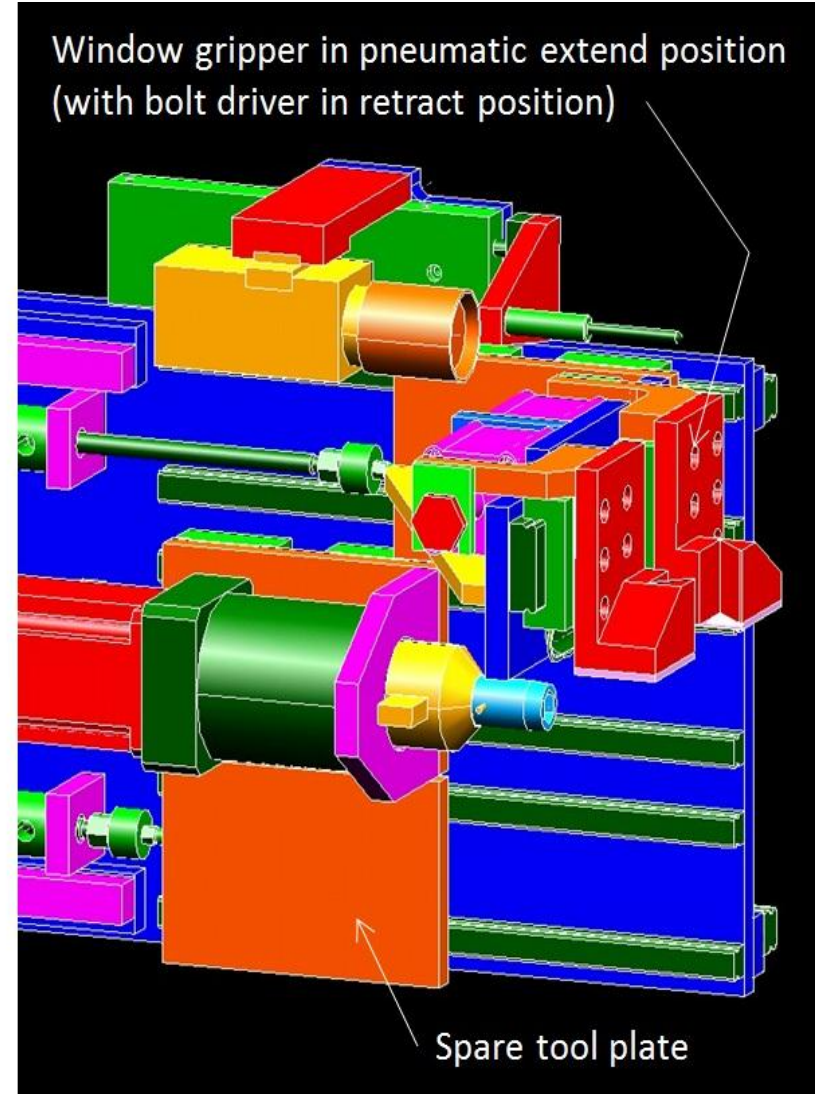
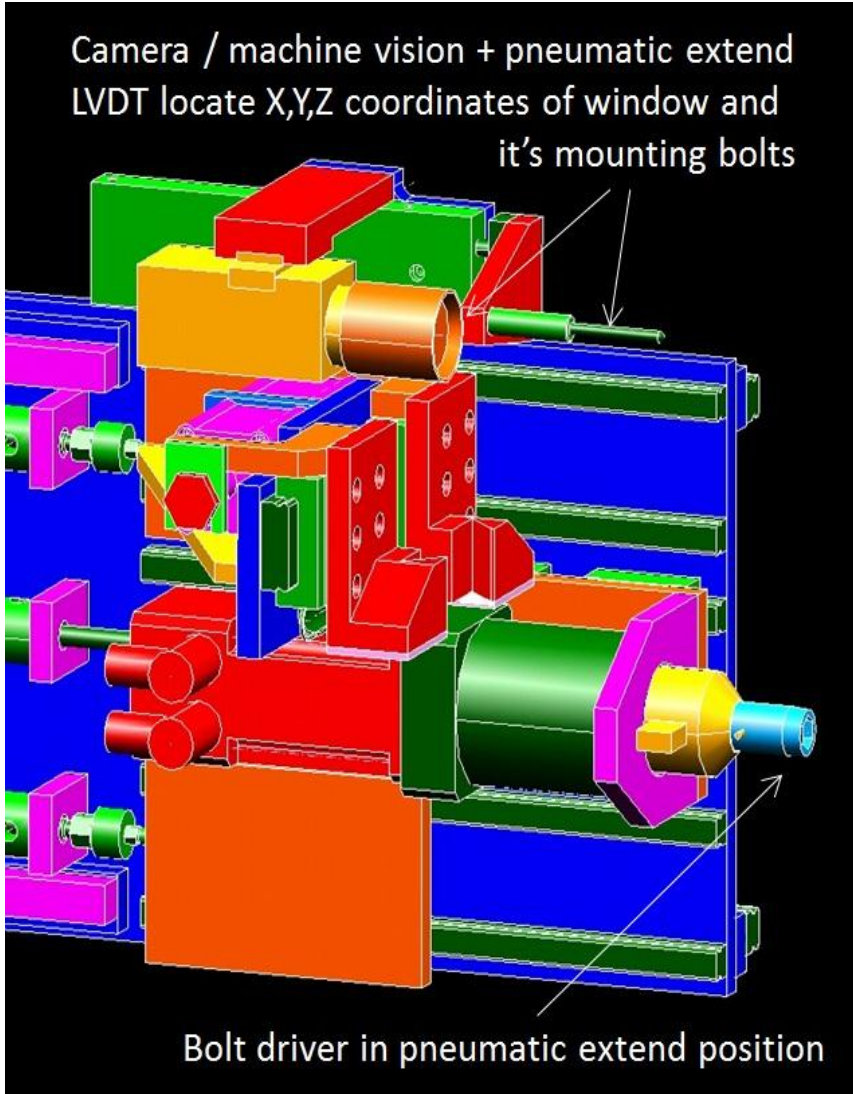
Design Details: The Robot Dual Z Motion Axes



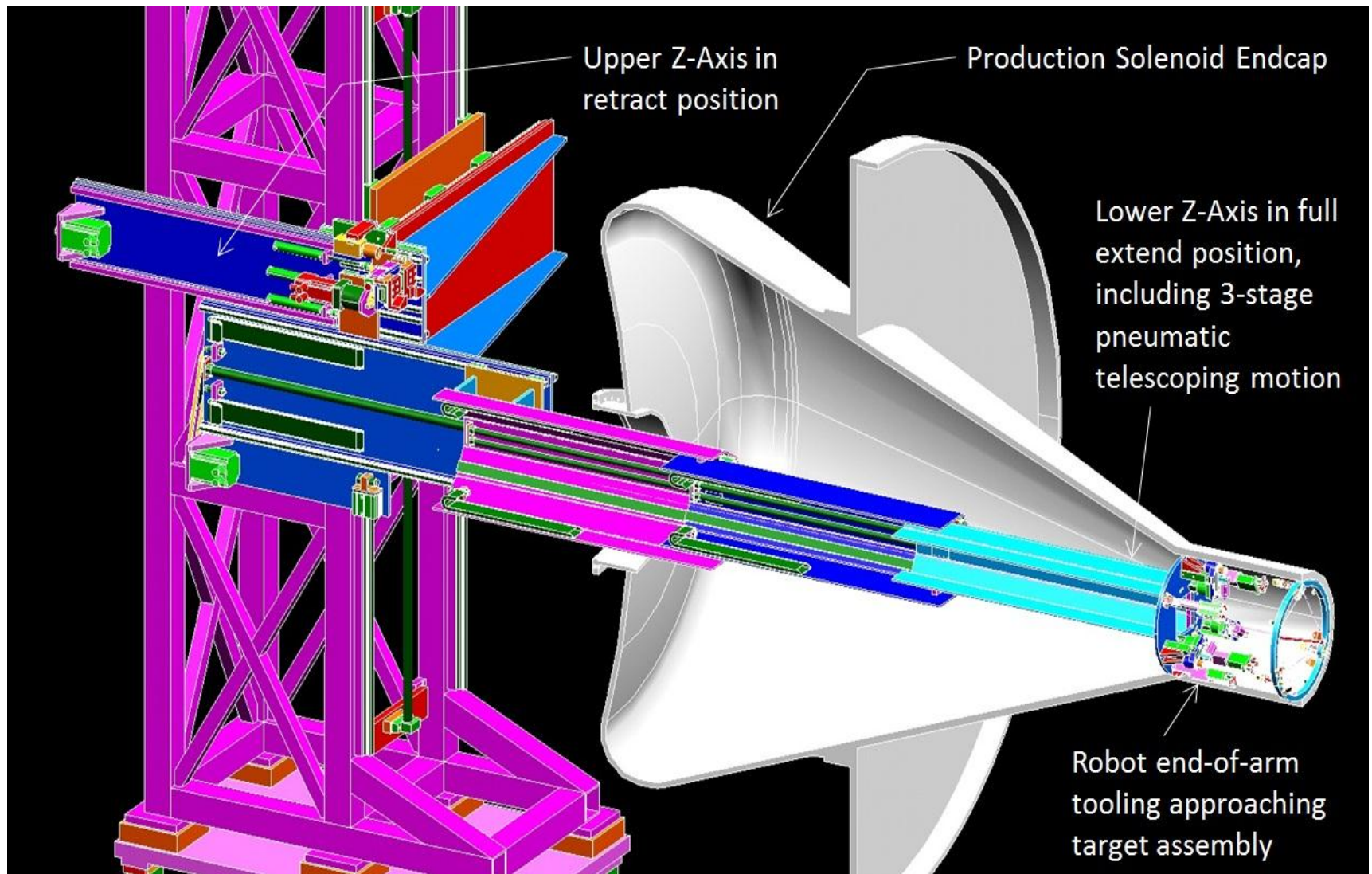
Design Details: Upper Z Axis – Handles the Target Access Window



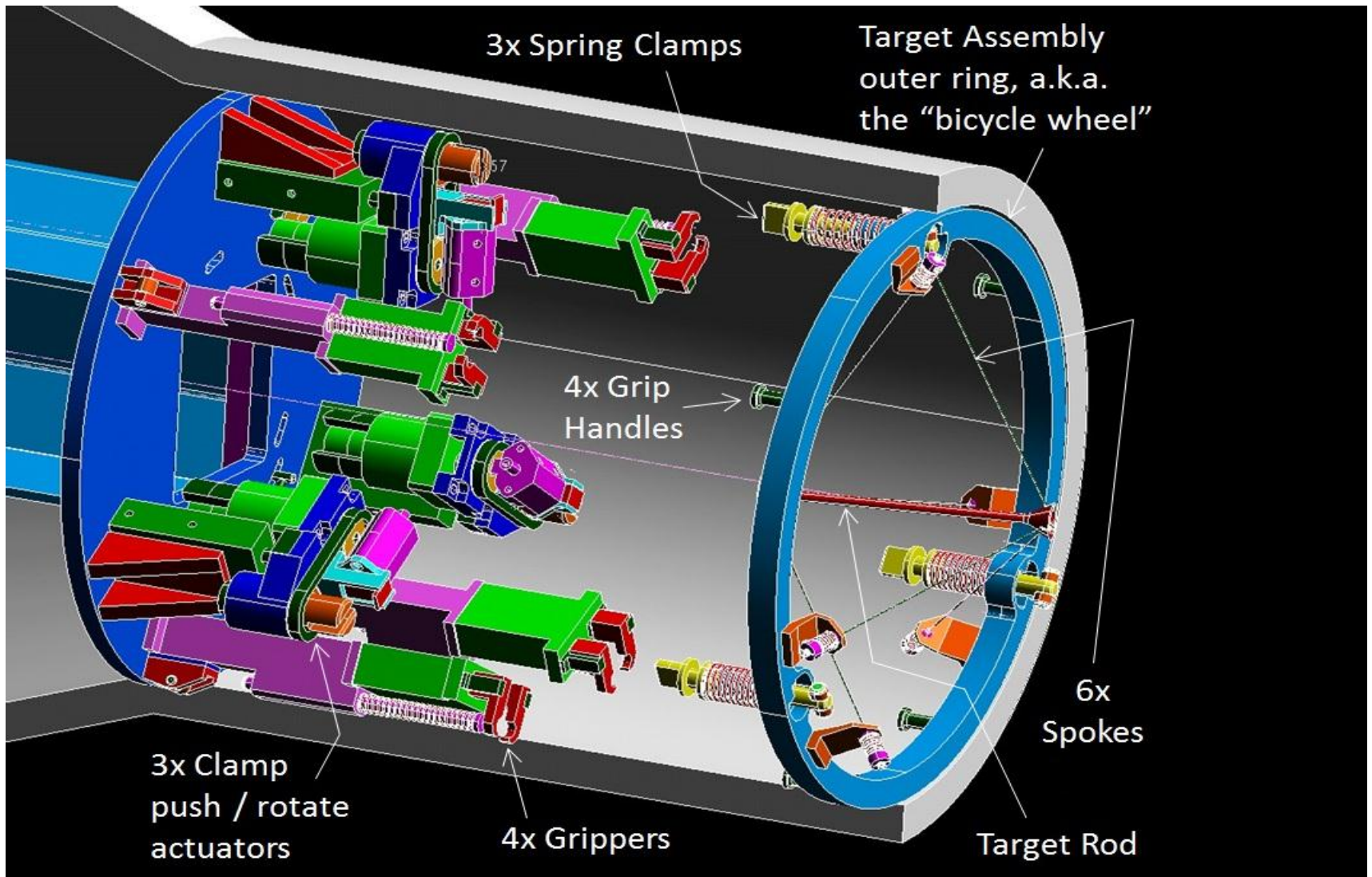
Design Details: Upper Z Axis – Handles the Target Access Window



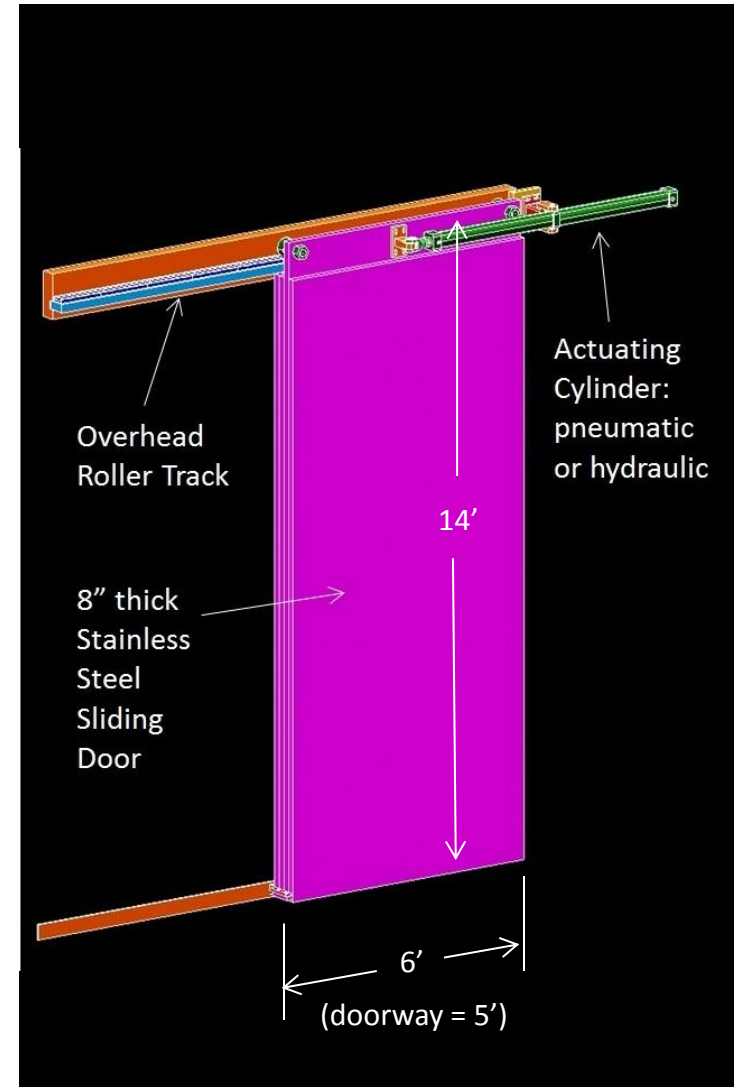
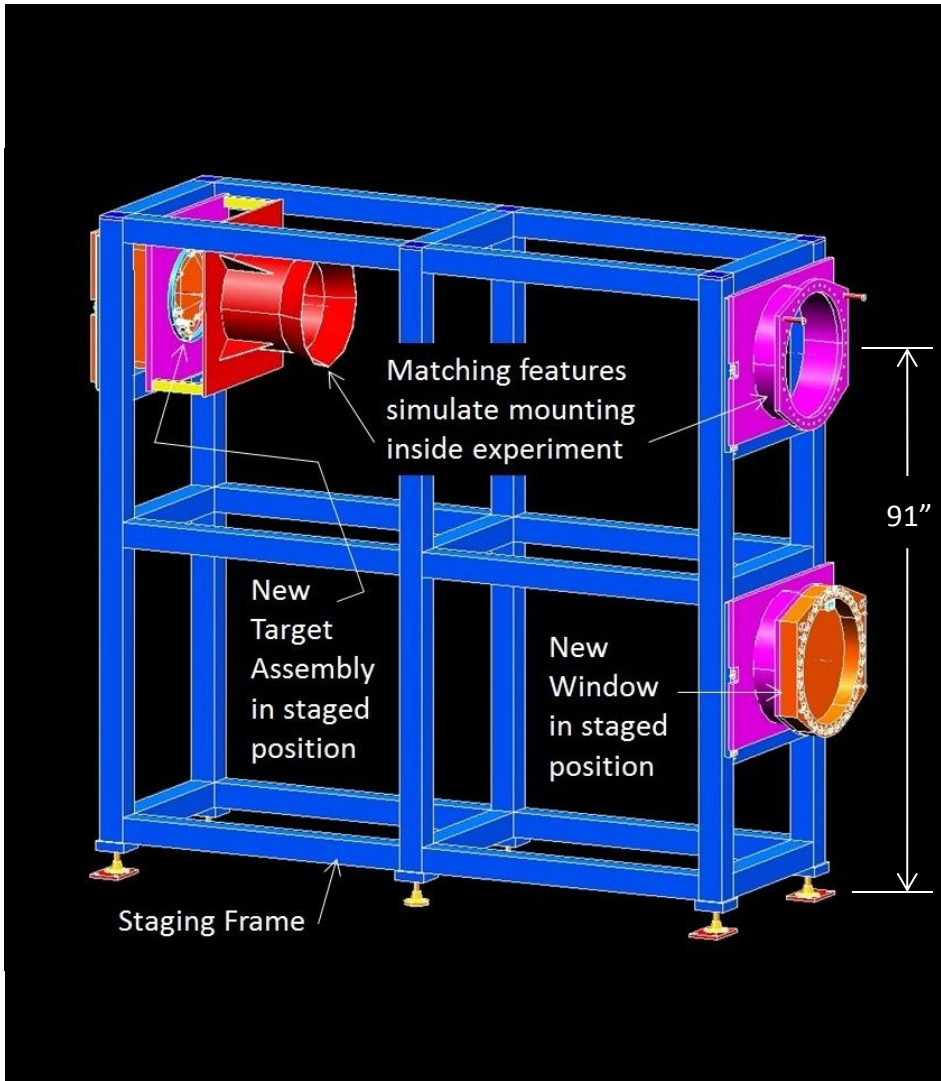
Design Details: Lower Z Axis – Handles the Target Assembly



Design Details: Lower Z Axis – Handles the Target Assembly



Design Details: Other System Components – Staging Frame and Sliding Door



Summary:

The horizontal RH scheme utilizes a robotic machine that:

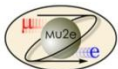
1. Removes & replaces the RC target and window
2. Travels between the TH and RH room on floor rails
3. Contains 5 servo motion axes, the floor rail drive axis, & 20 pneumatic motions
4. Uses a camera and machine-vision system to “find” its’ move coordinates
5. Utilizes a 4-stage telescoping arm to cover the 12-1/2’ reach distance to the target

End of Main Presentation

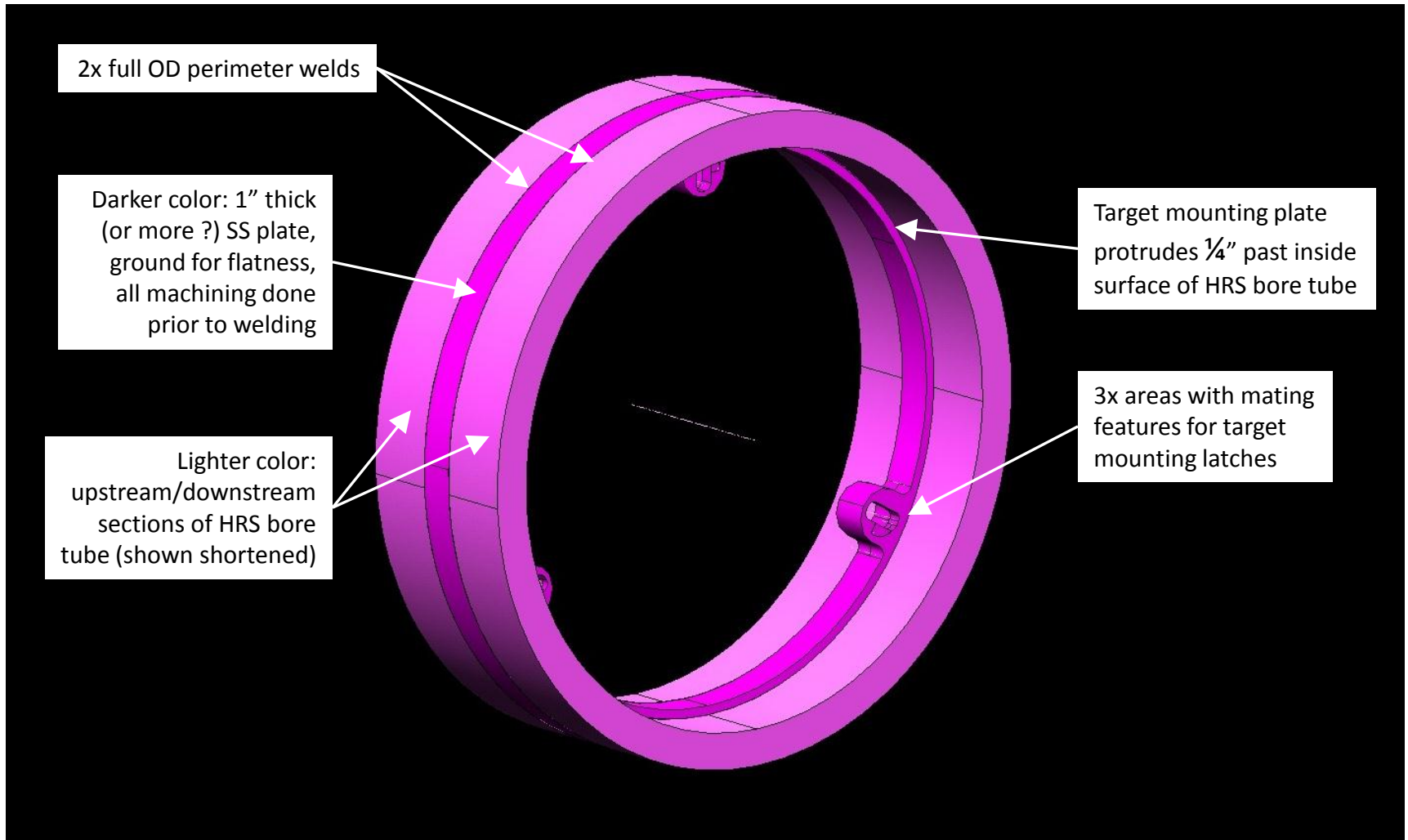
Back-up Slides Following . . .

Robot Component Selection Details

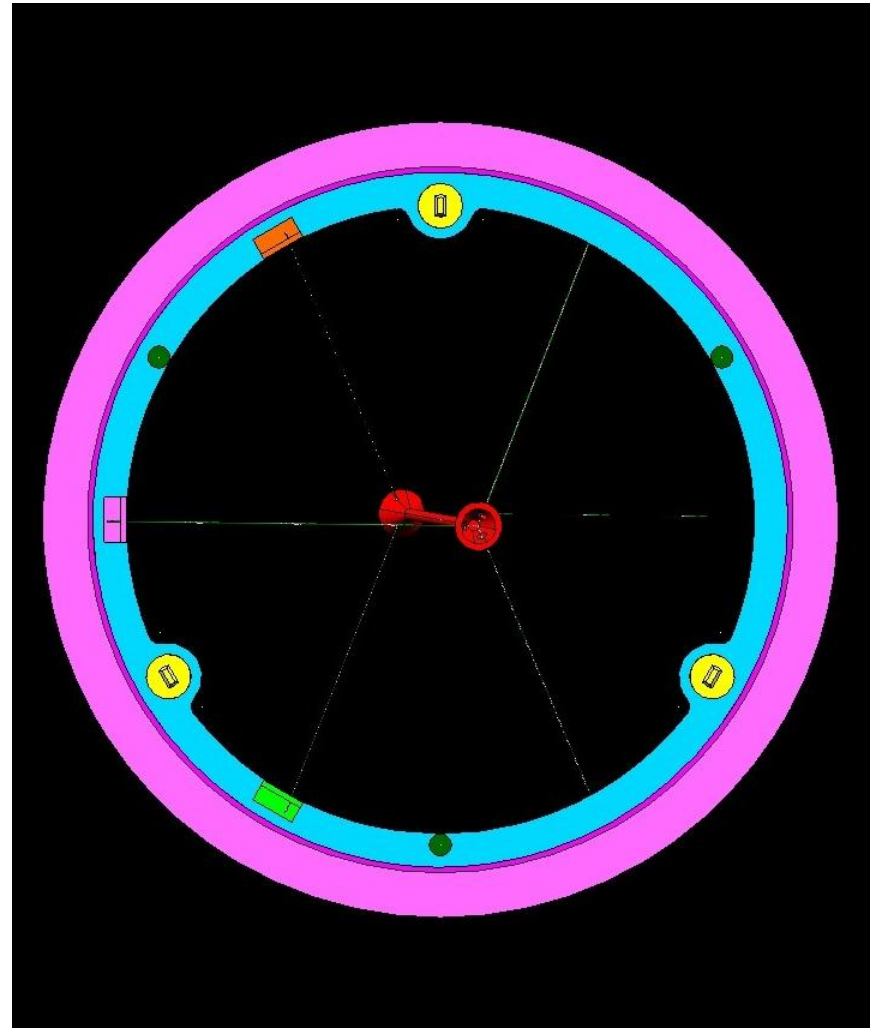
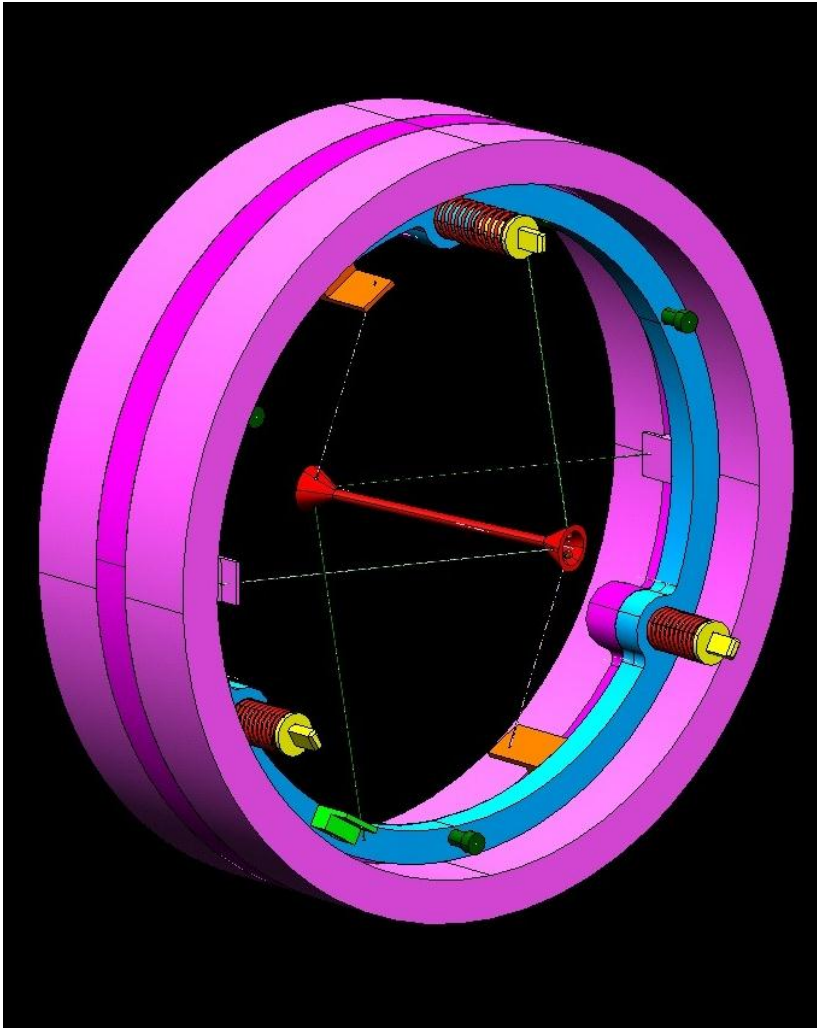
1. Stainless steel for both: NSK Ballscrews, THK square-rail linear bearings
2. SMC Pneumatics – actuators, solenoid valves, other pneumatic system components
3. Igus cable carrier chains, chainflex cabling
4. Stainless steel Serapid push/pull chain and AC gearmotor drive for floor rails
5. Linear pull-wire encoder for floor rails – TR Electronics (optical / absolute), ~2mm resolution, not specifically rad tolerant, will be removed when not in use
6. Symphotic Tii Megarad-3 camera - good image at $1E5$ rad/hr, $3E6$ rads total (gamma)
 - > planning to use standard (~ \$500) lens and replace as needed
 - > interface to vision-system software via iPORT Analog-Pro frame grabber module
7. Measurement Specialties LVDT and remote signal conditioner module
8. Wittenstein rad-hardened brushless servo motors (total dose limit = $1E9$ rads)
 - > resolver feedback, also from Wittenstein: planetary gearbox, couplings
9. Motion controls: National Instruments CompactRIO controller, servo drive modules, other various modules, NI Labview software with NI vision module



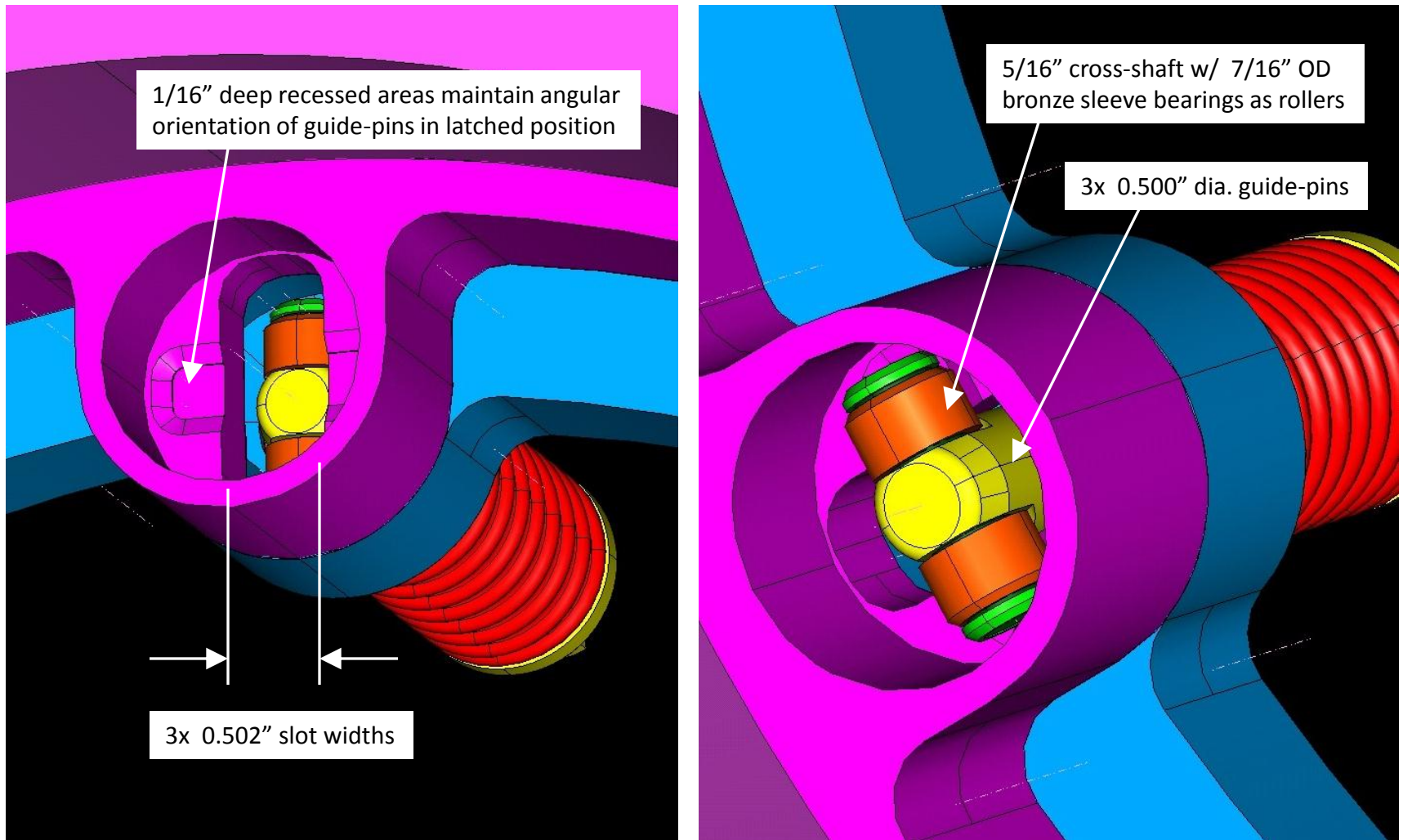
HRS Bore Tube Detail Showing Target Assembly Mounting Features



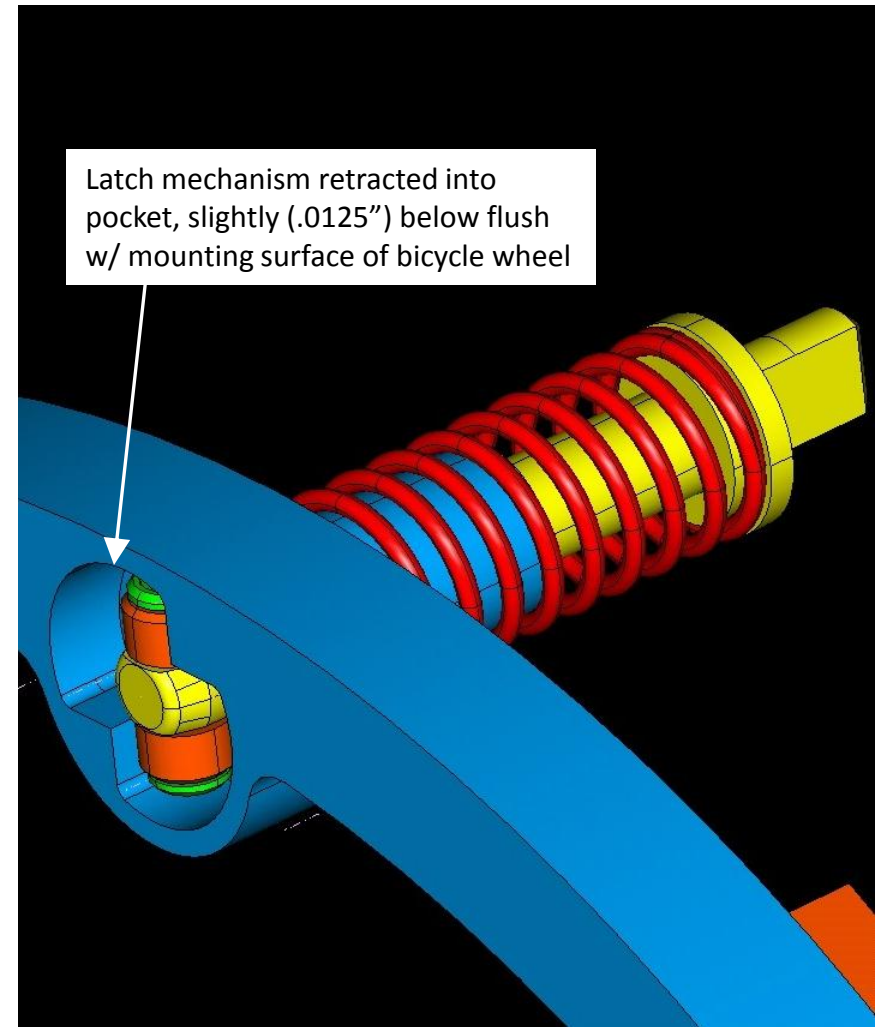
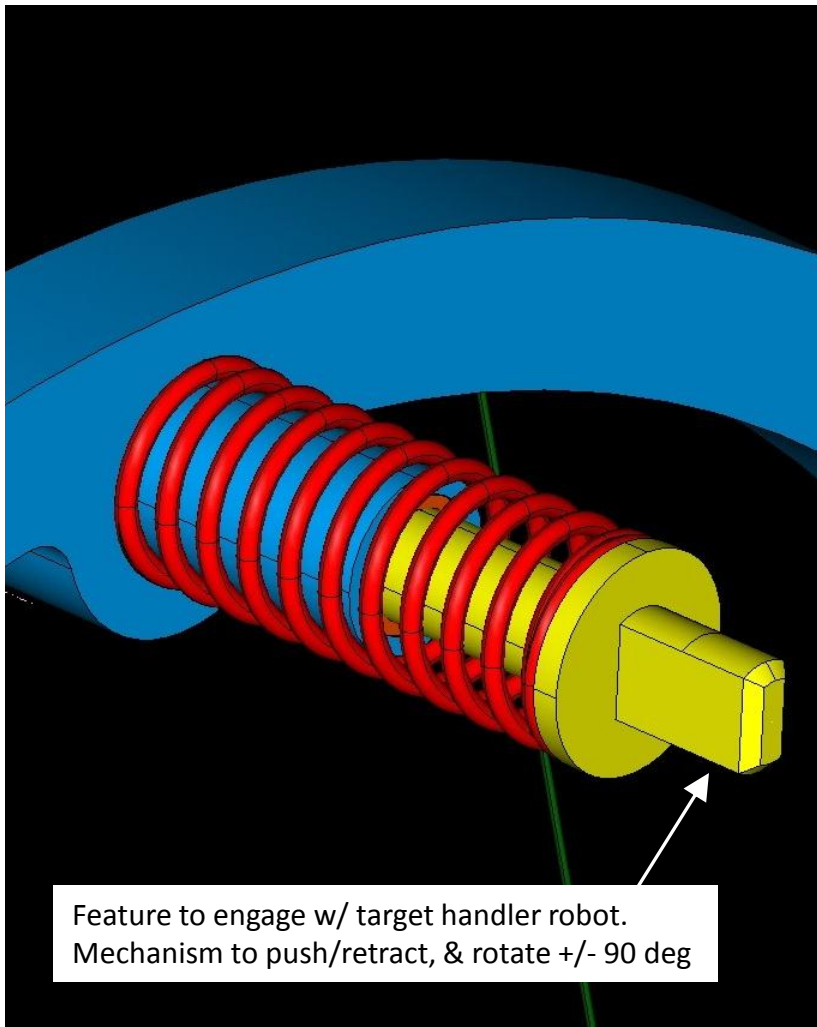
Target Assembly Shown Mounted in HRS Bore



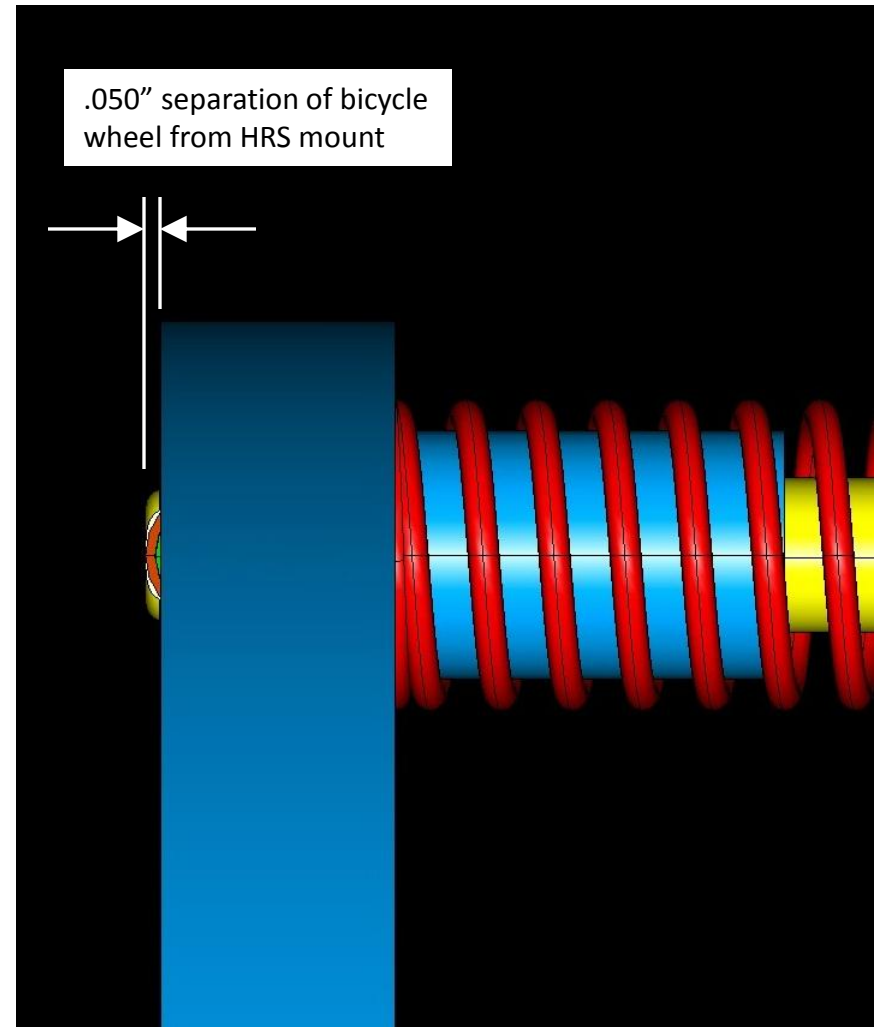
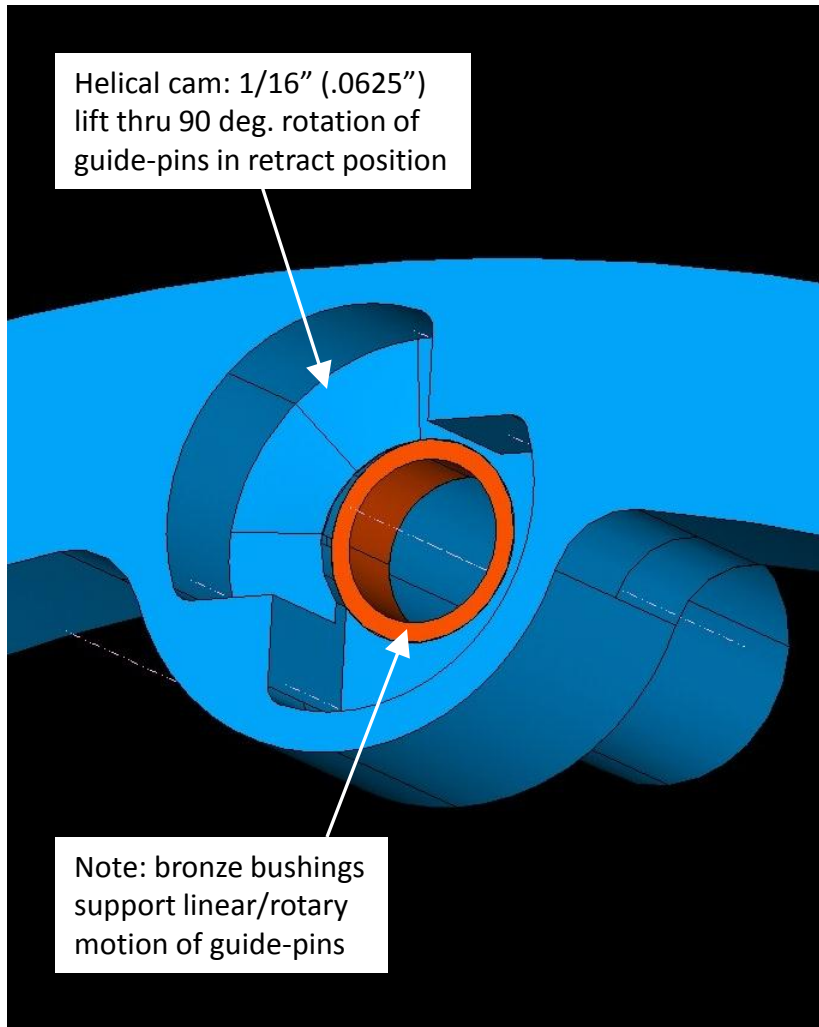
Target Latch Mechanism Detail – unlatched (left), latched (right)



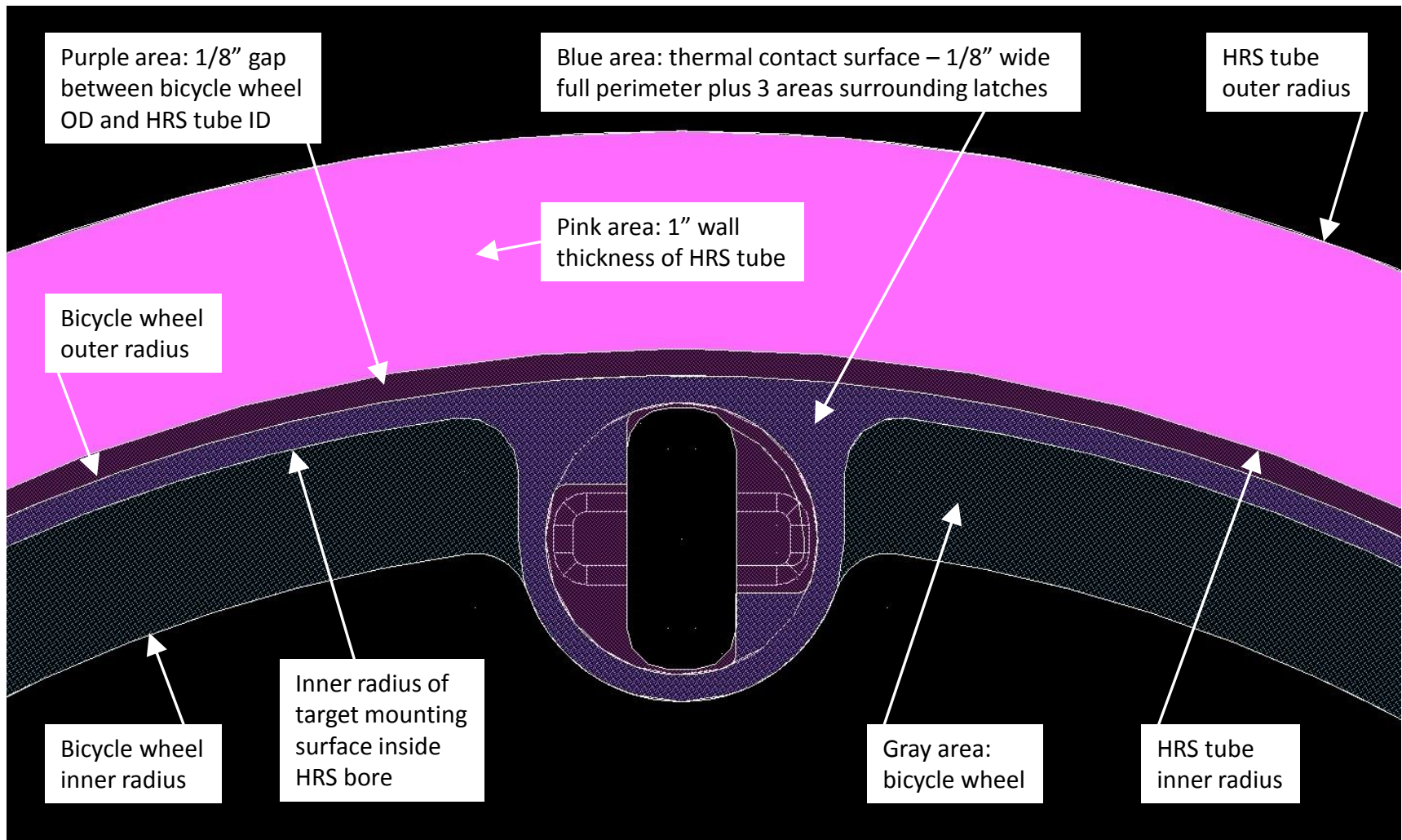
Target Latch Mechanism Detail – shown retracted in pocket features of bicycle wheel



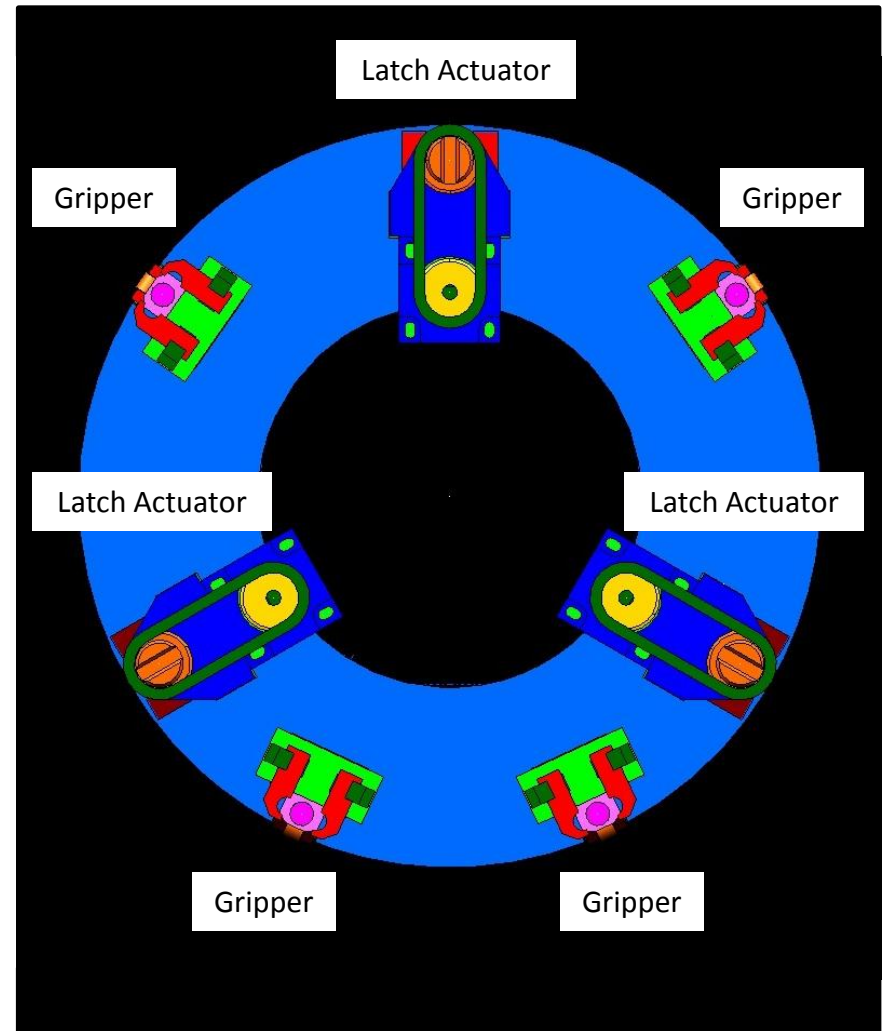
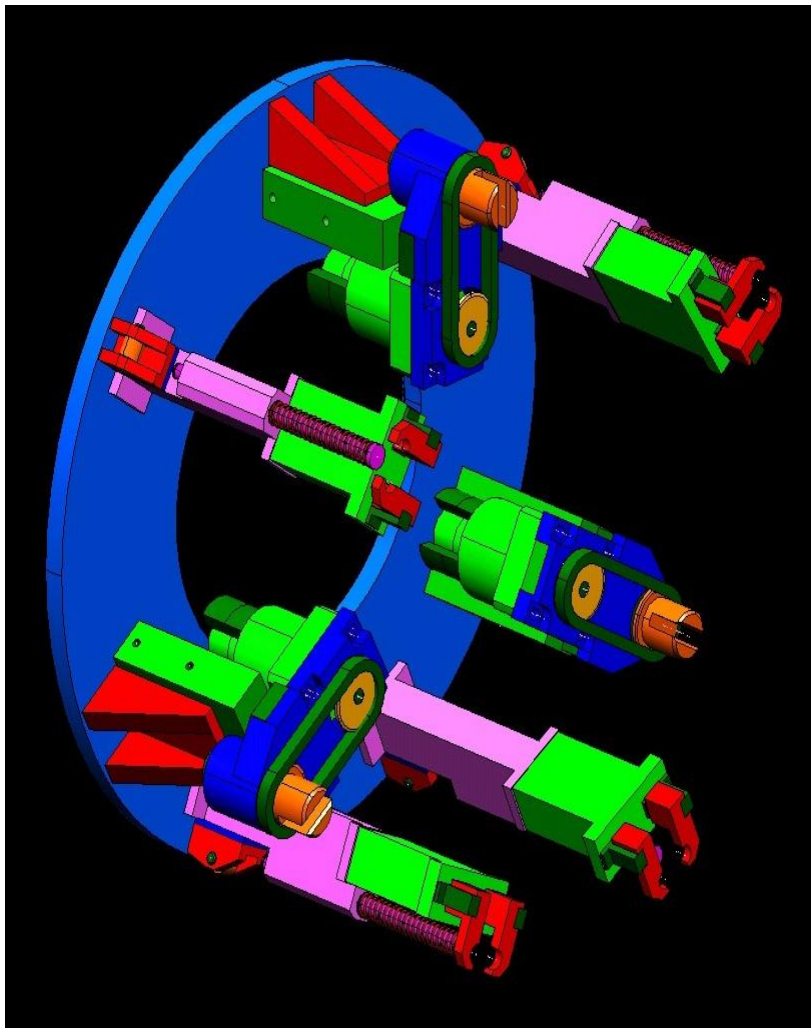
Target Latch Mechanism Detail – showing push-off feature (1/16" lift cam in pocket)



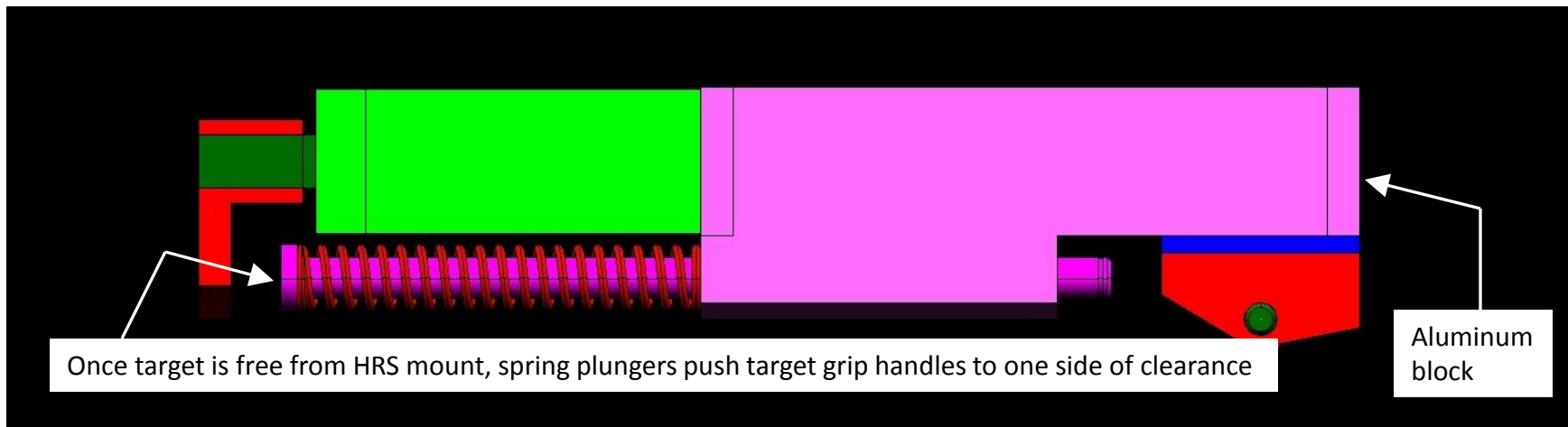
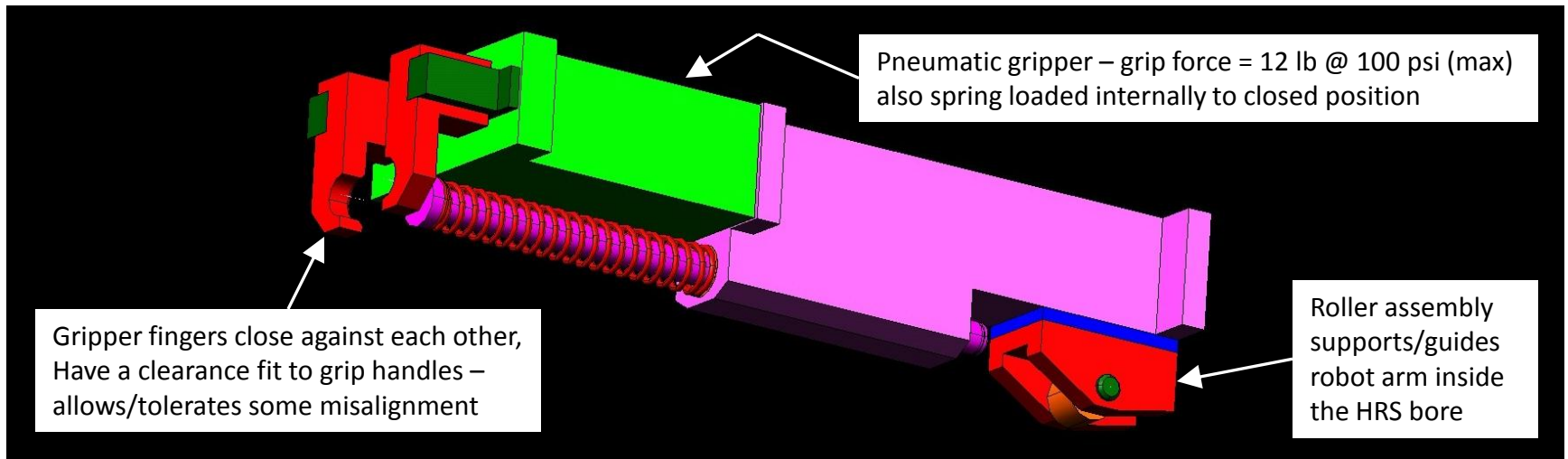
Target Mounting Detail Showing Thermal Contact Area



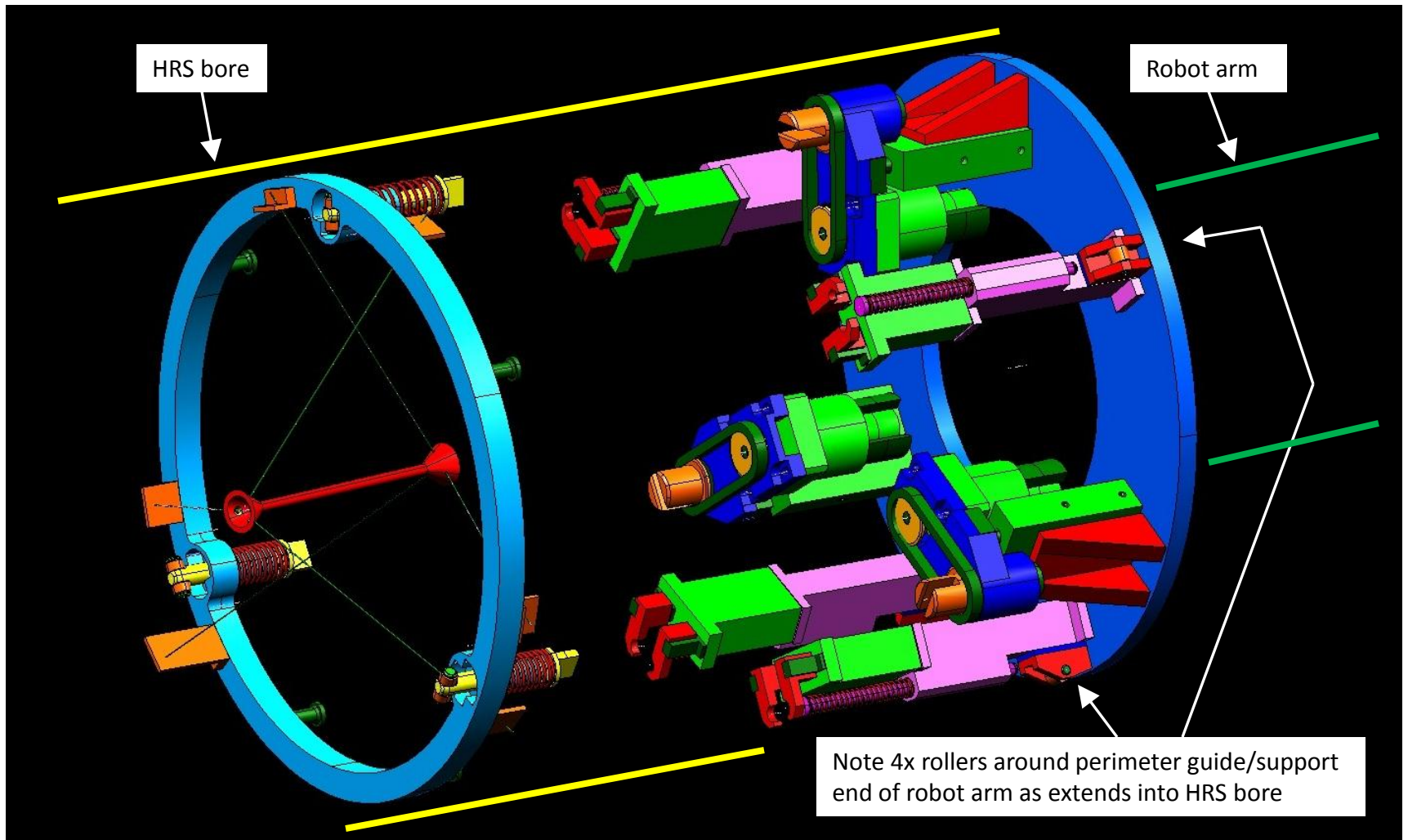
Target Interface Mechanism Conceptual Design - Overview



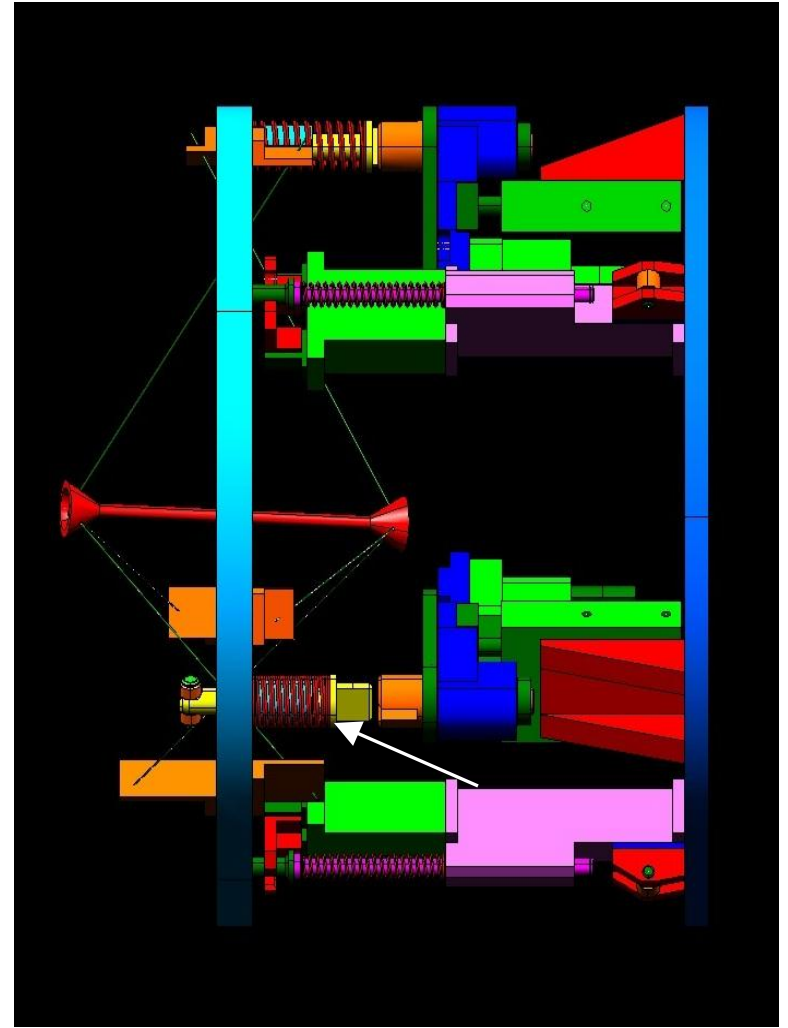
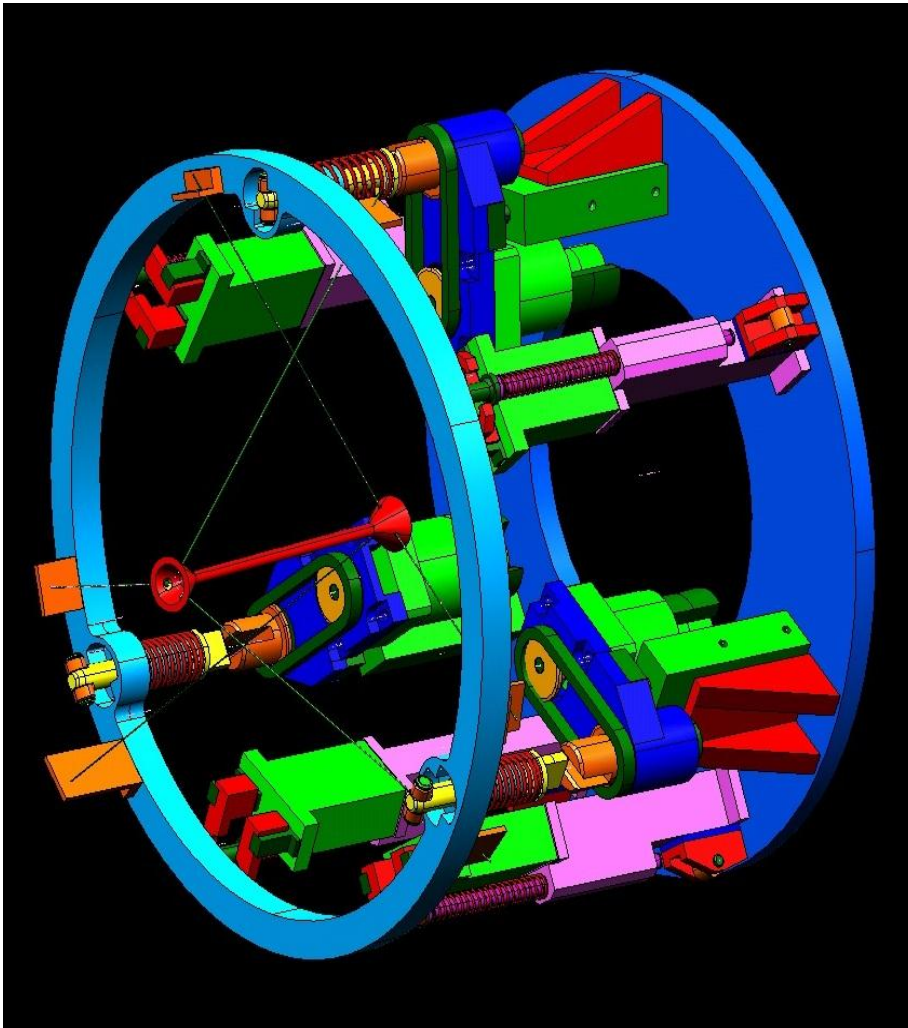
Target Interface Mechanism Conceptual Design – Gripper Mechanism



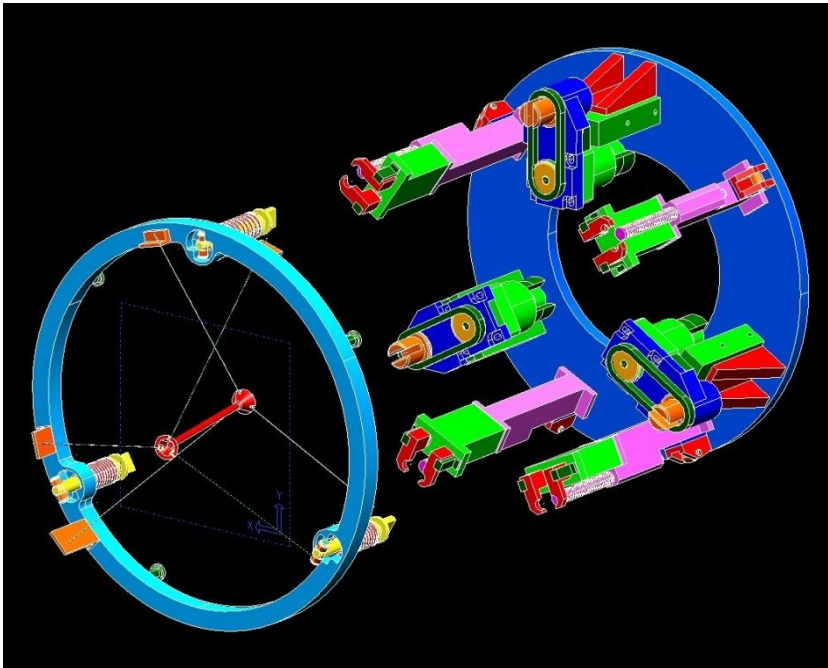
Target Interface Mechanism Conceptual Design – Just Prior to Engaging Target Assembly



Target Interface Mechanism Conceptual Design – Engaged with Target Assembly

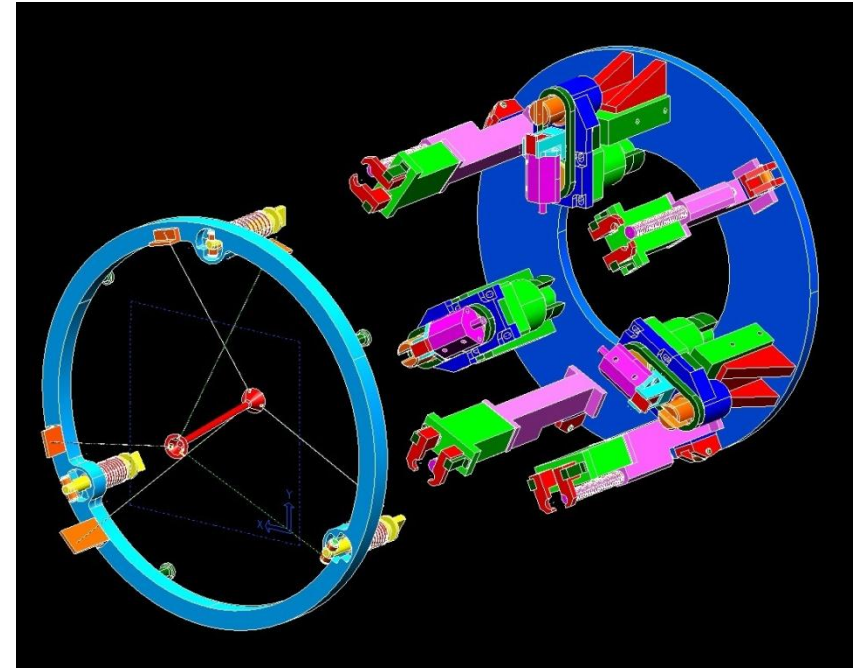


1. Bicycle wheel latch mechanism design update



Previous Design

Shows 3 latch actuators that each push and rotate the latches 90°.



Latest Design

Shows pneumatic cylinders added to each latch actuator – cylinders extend to hook the latches, insures they retract.

1. Bicycle wheel latch mechanism design update

