



# MARVEL Technology Review: Reactivity Control System (RCS)

Control Drum and Shutdown Rod (Central Insurance Absorber)

March 2026

Presenter: Anthony L. Crawford

Assembly: Casey White, Rowdie Shepherd, Peter Ritchie

Engineering: Peter Ritchie, Carl Baily, Tom Pfeiffer, Ben Coryell, Bob Spears

Project Management: Justin Johnson, Stephan Wilkins, Stacie Strain

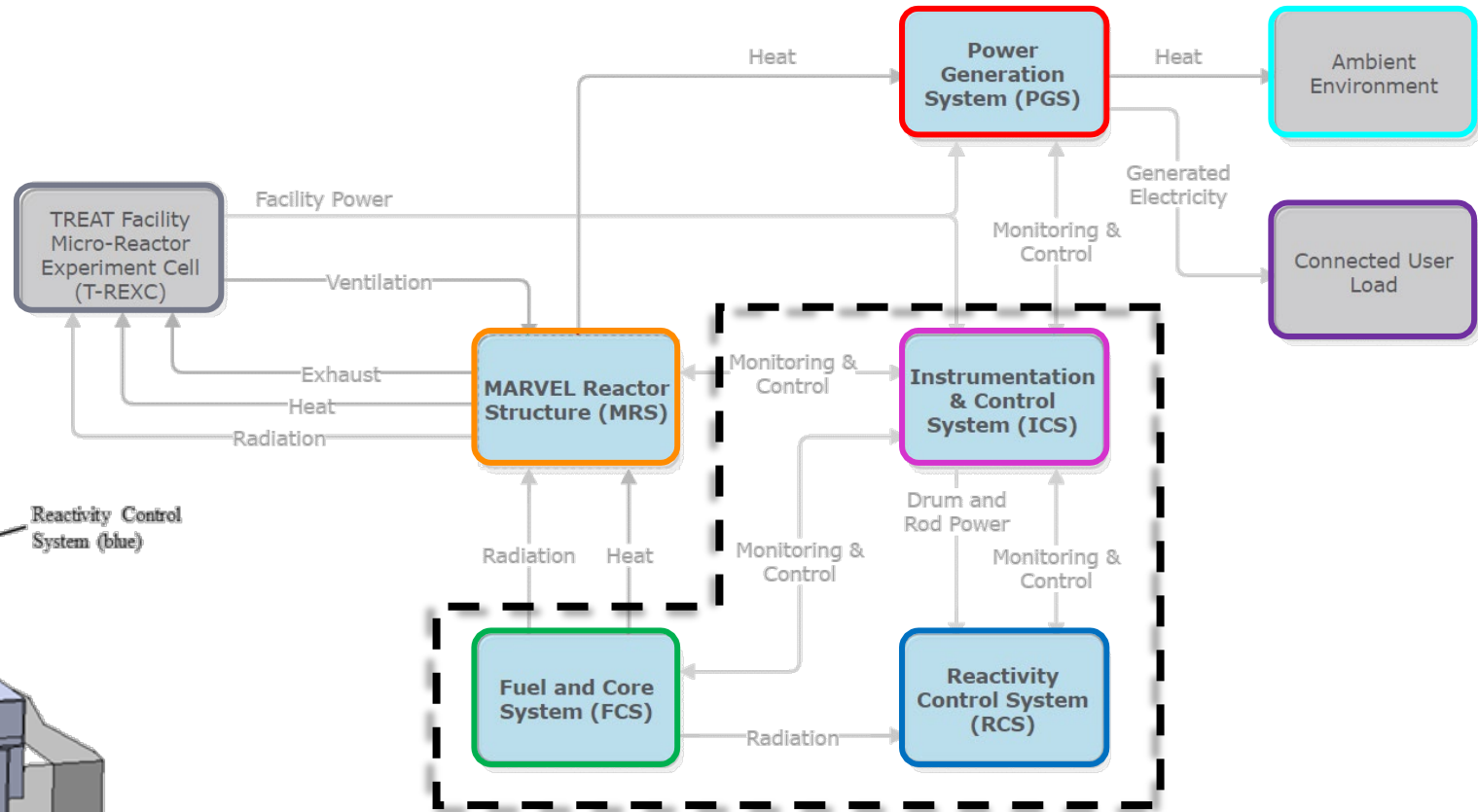
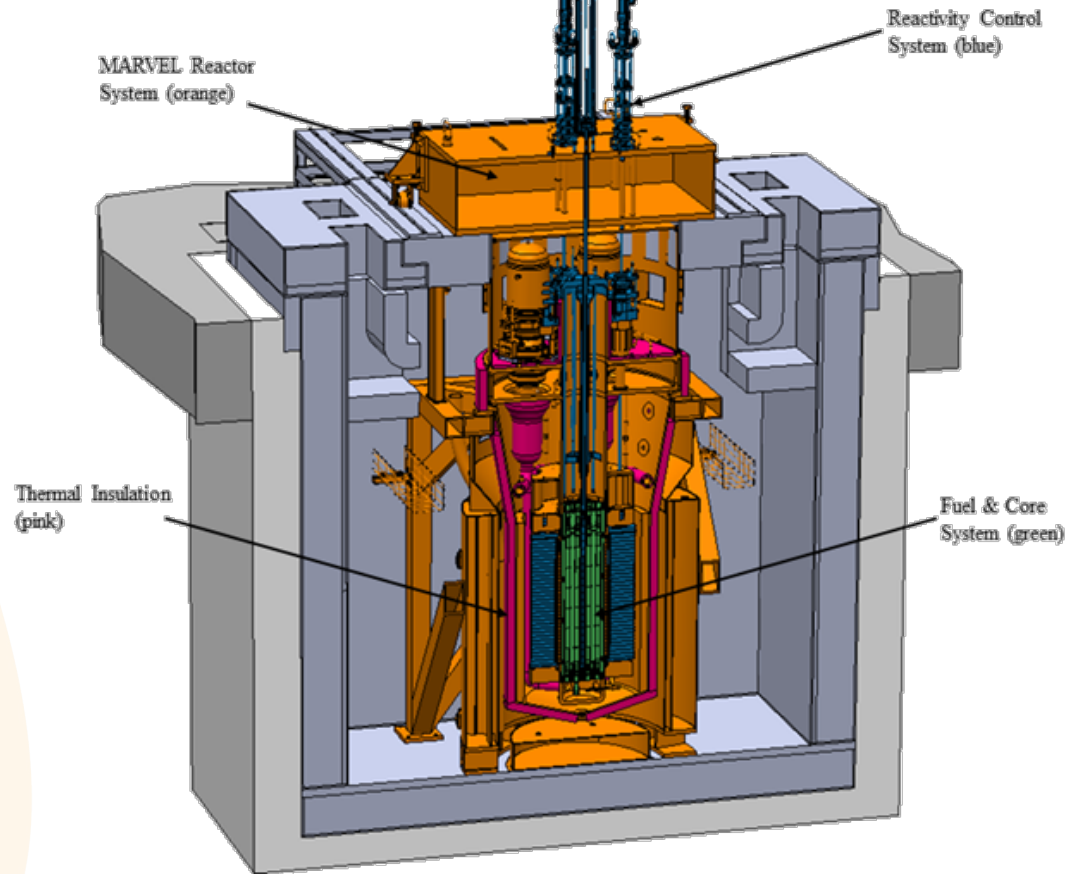
Fabrication: Derek Sommer, John Burchtorf, Brandon Ferguson, Cameron Criddle, Lance Seward

Procurement: Carl Longacre, Avery Hartvigson

Quality: Jen Davlin, Raymond Clark, Tasha Stacey

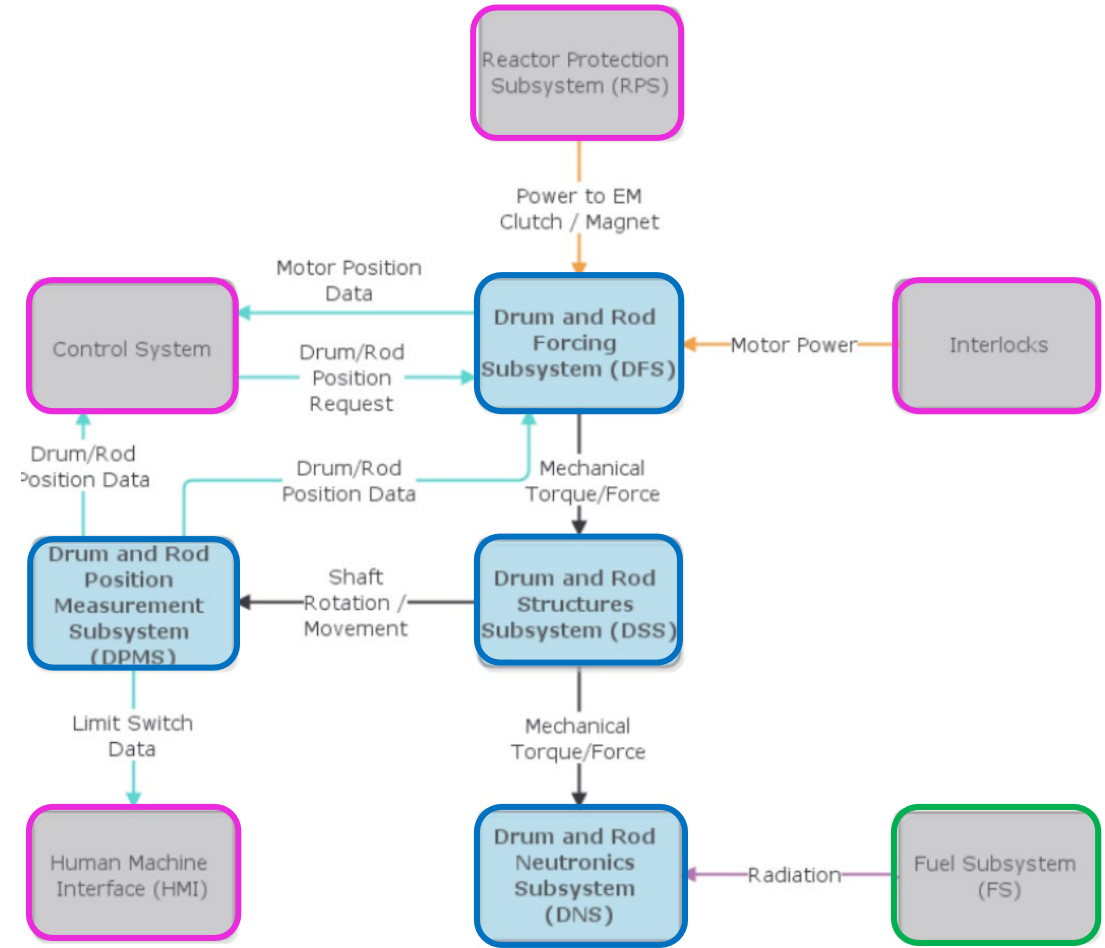
Software: Andrew Heim, Ben Baker

# MARVEL Overview



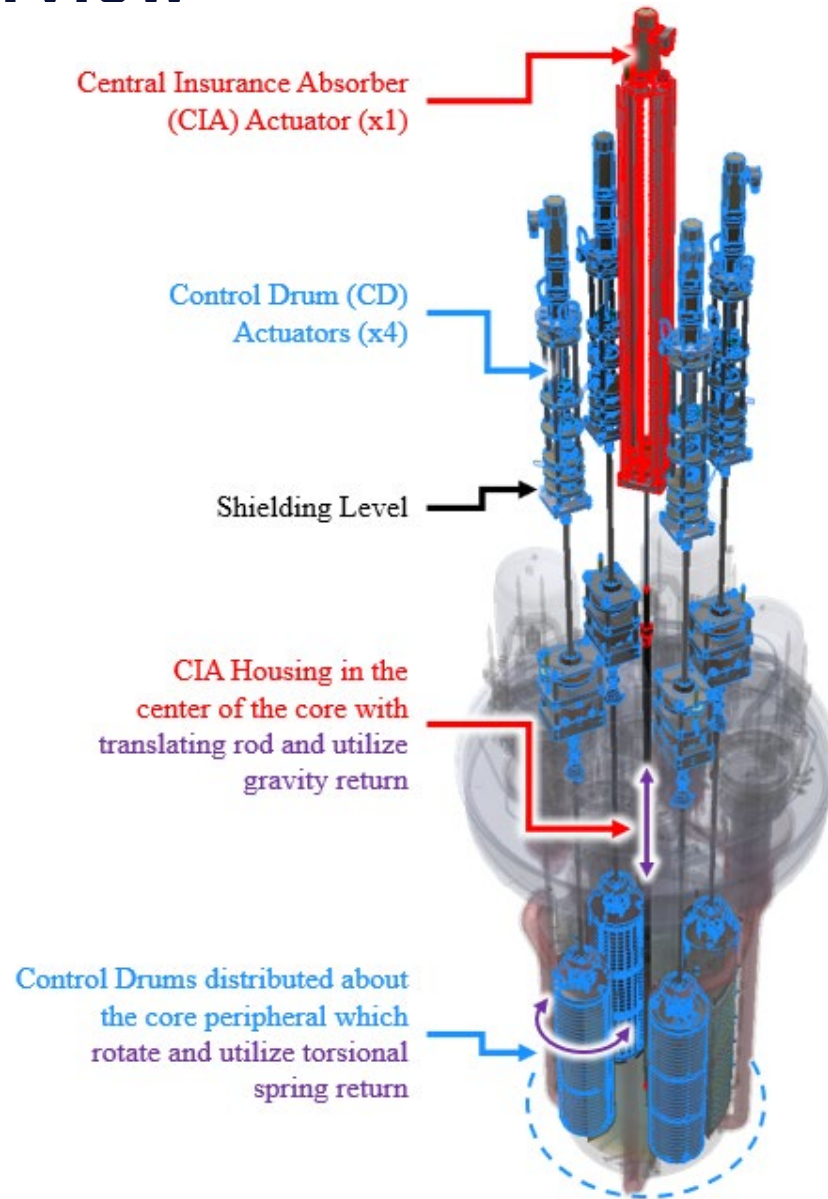
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# MARVEL Overview

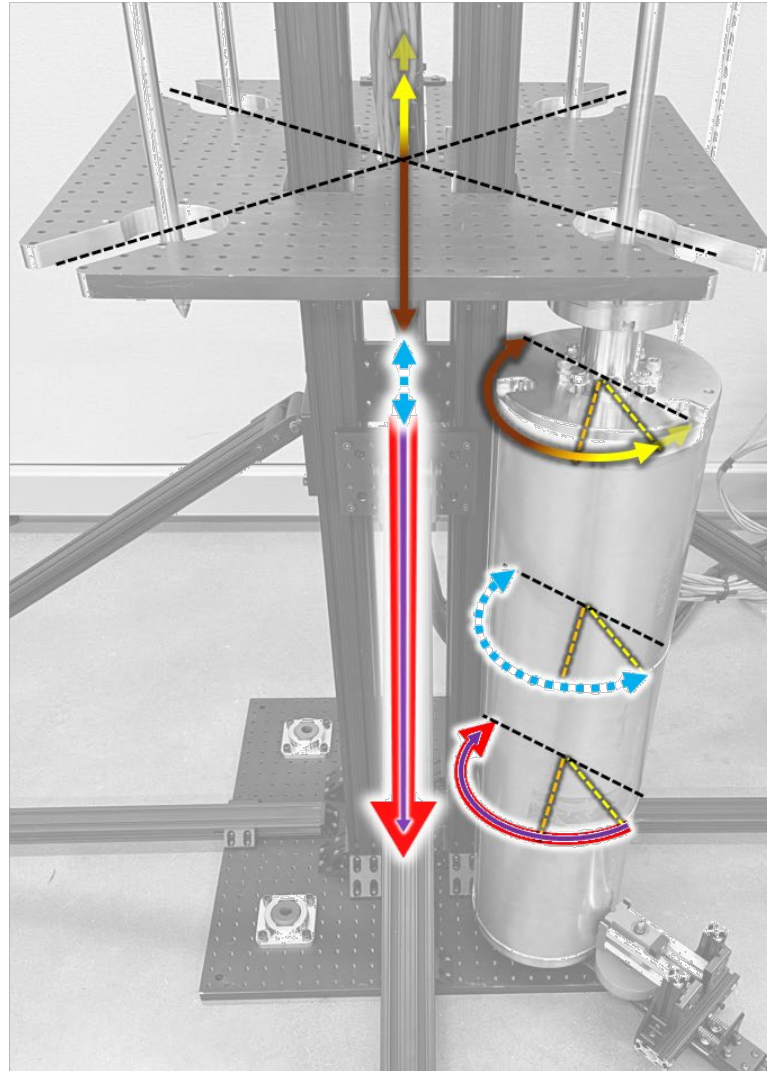


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# MARVEL Overview



# Graphical Requirements



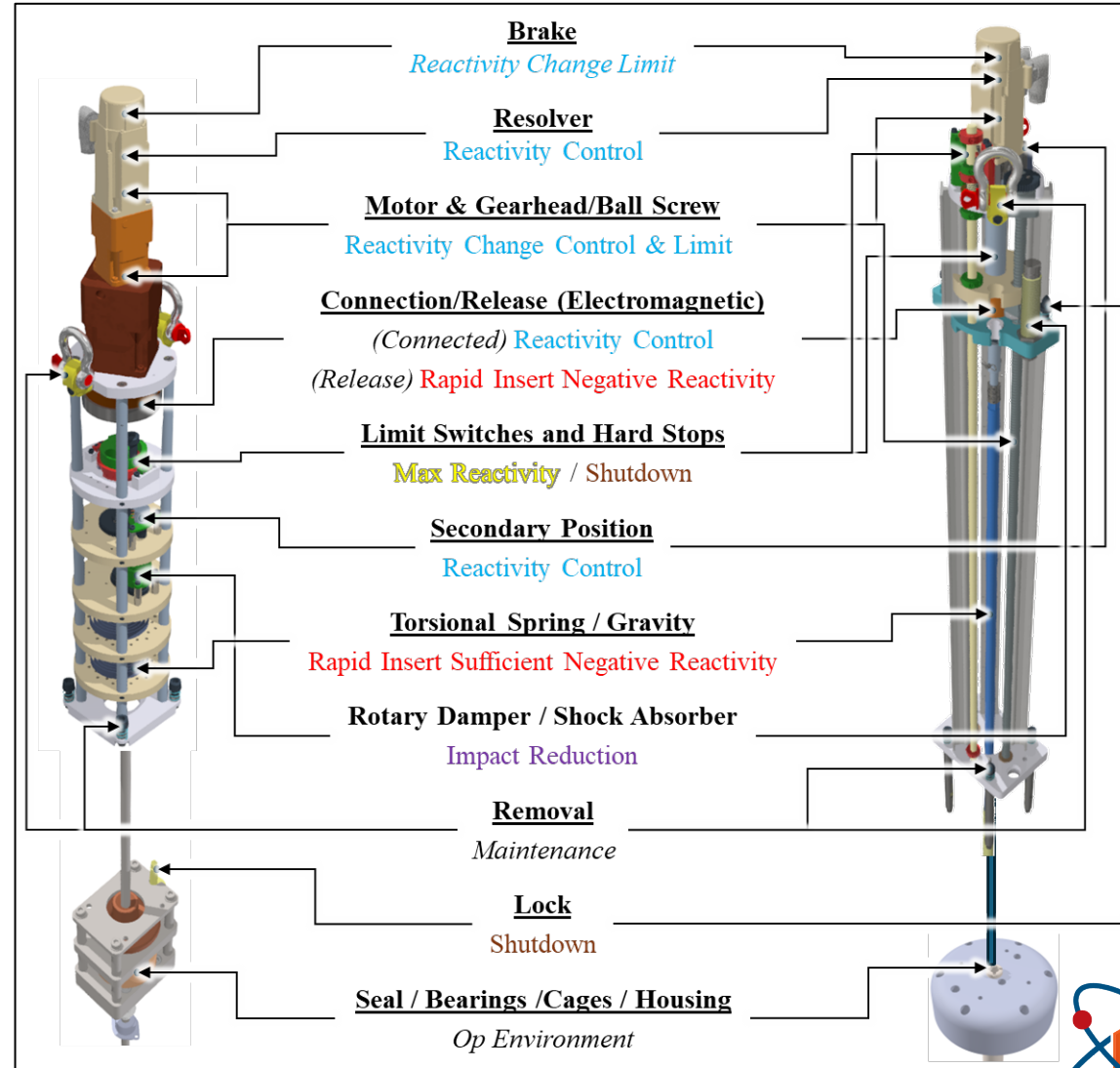
- **Beyond Hard Stop Limit**
  - **Max Reactivity**
    - **Critical**
    - **Shutdown**
- **Reactivity Change Rate Limits**
- **Rapid Neg Reactivity Insertion Duration**
  - **Max via Seismic**
  - **Min via Impact**
- **Operating and Seismic Environment**
- **Durability, Maintenance, and Testing**

Position

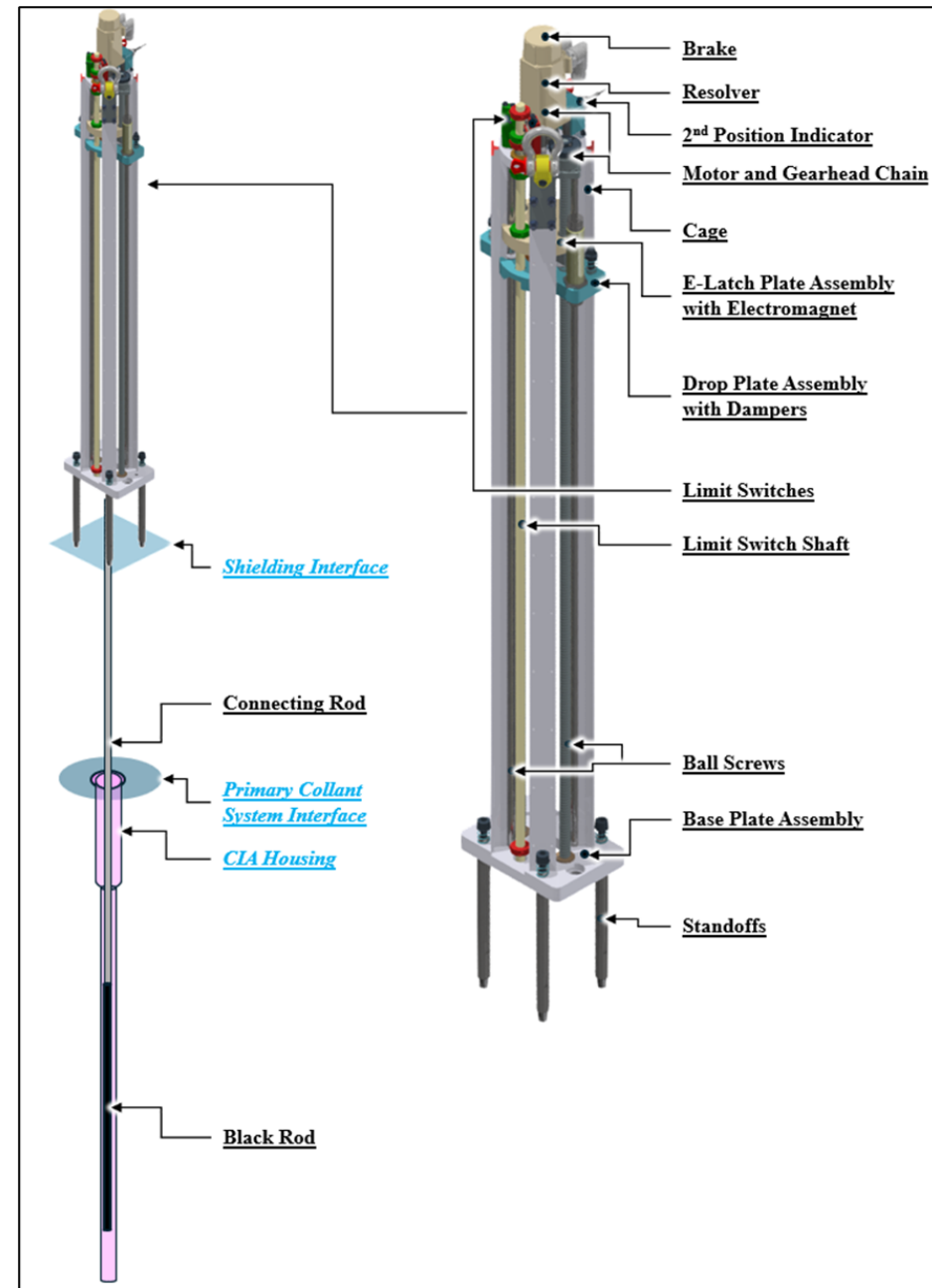
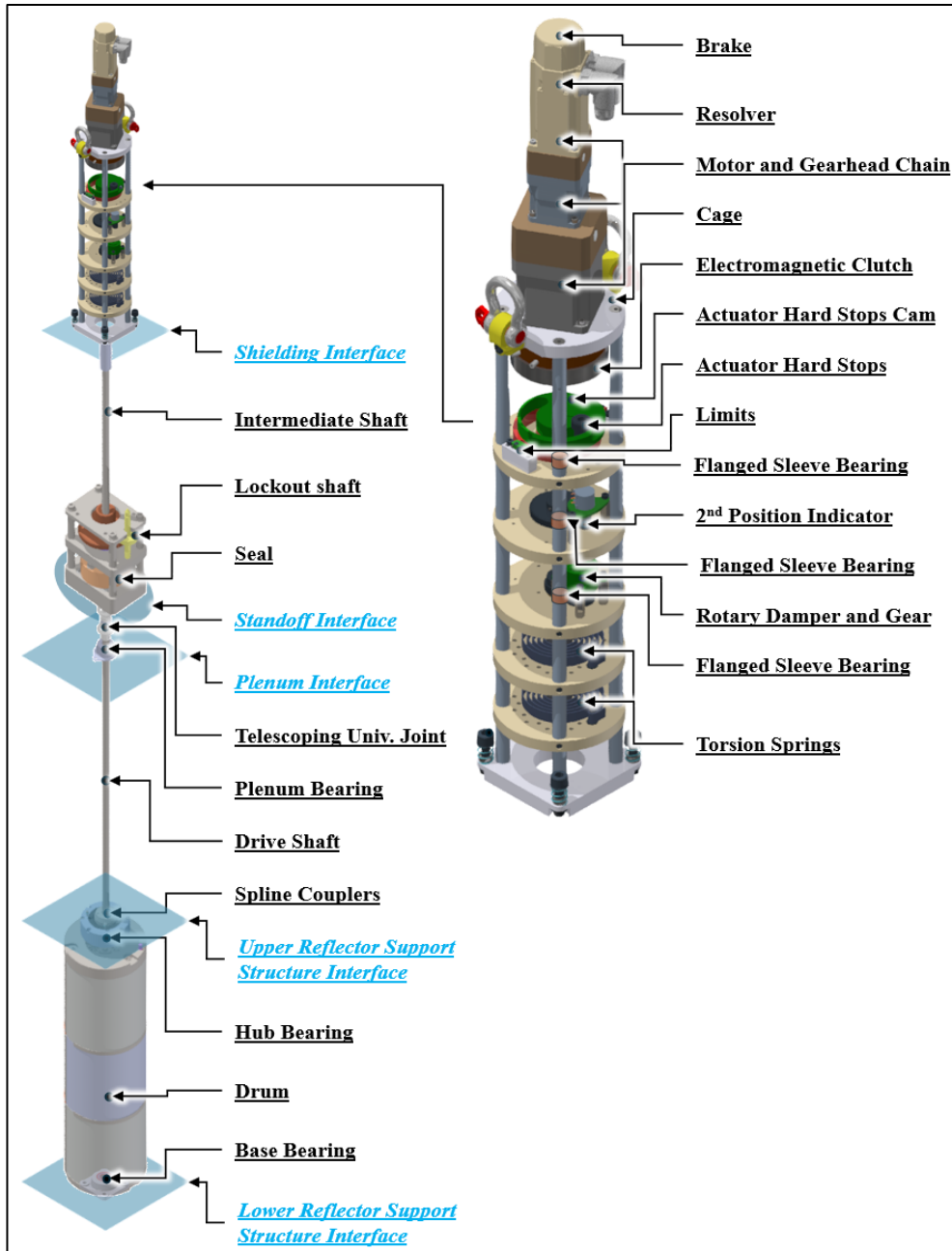
Forcing



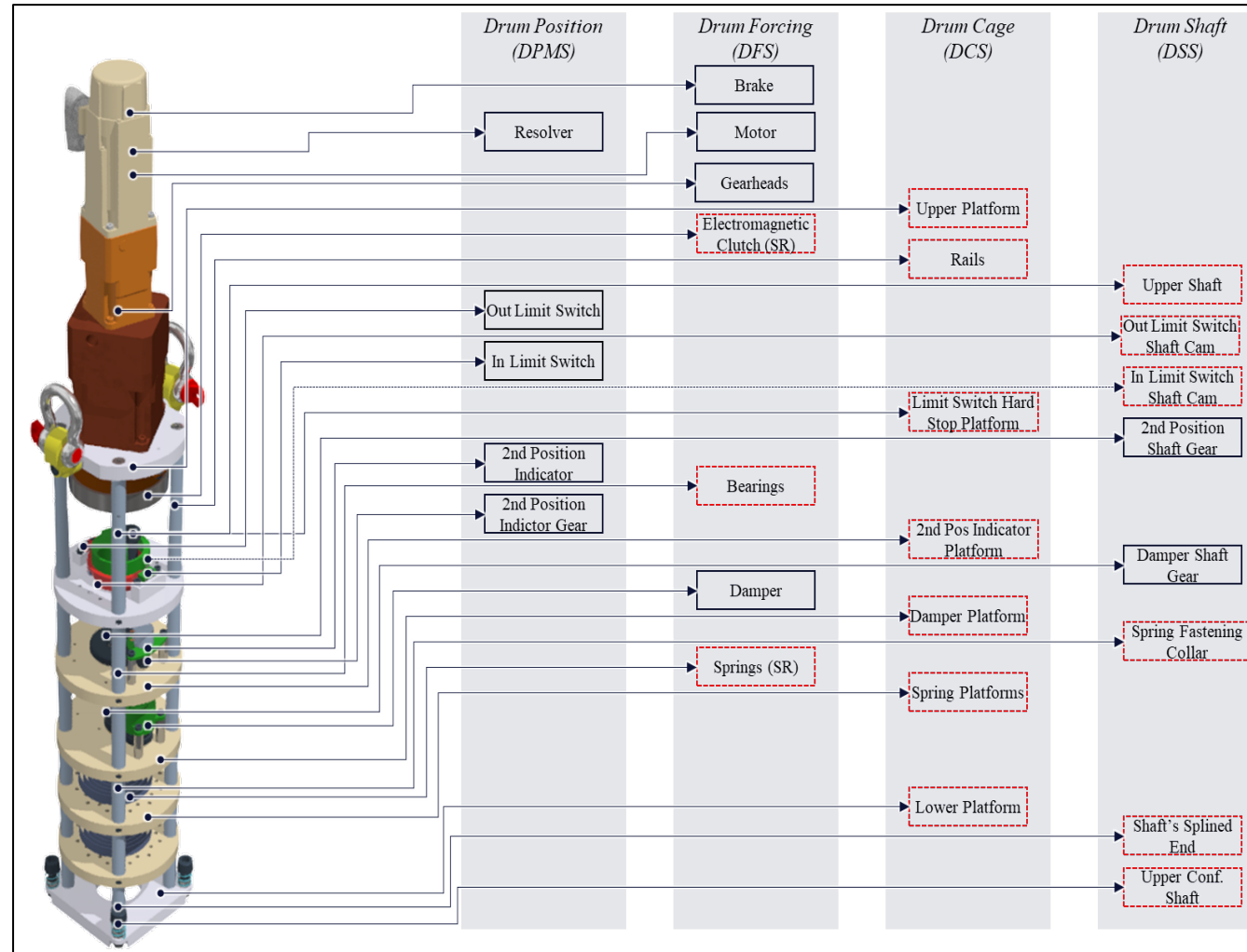
# Requirements to Primary Component Relationships



# MARVEL RCS Overview

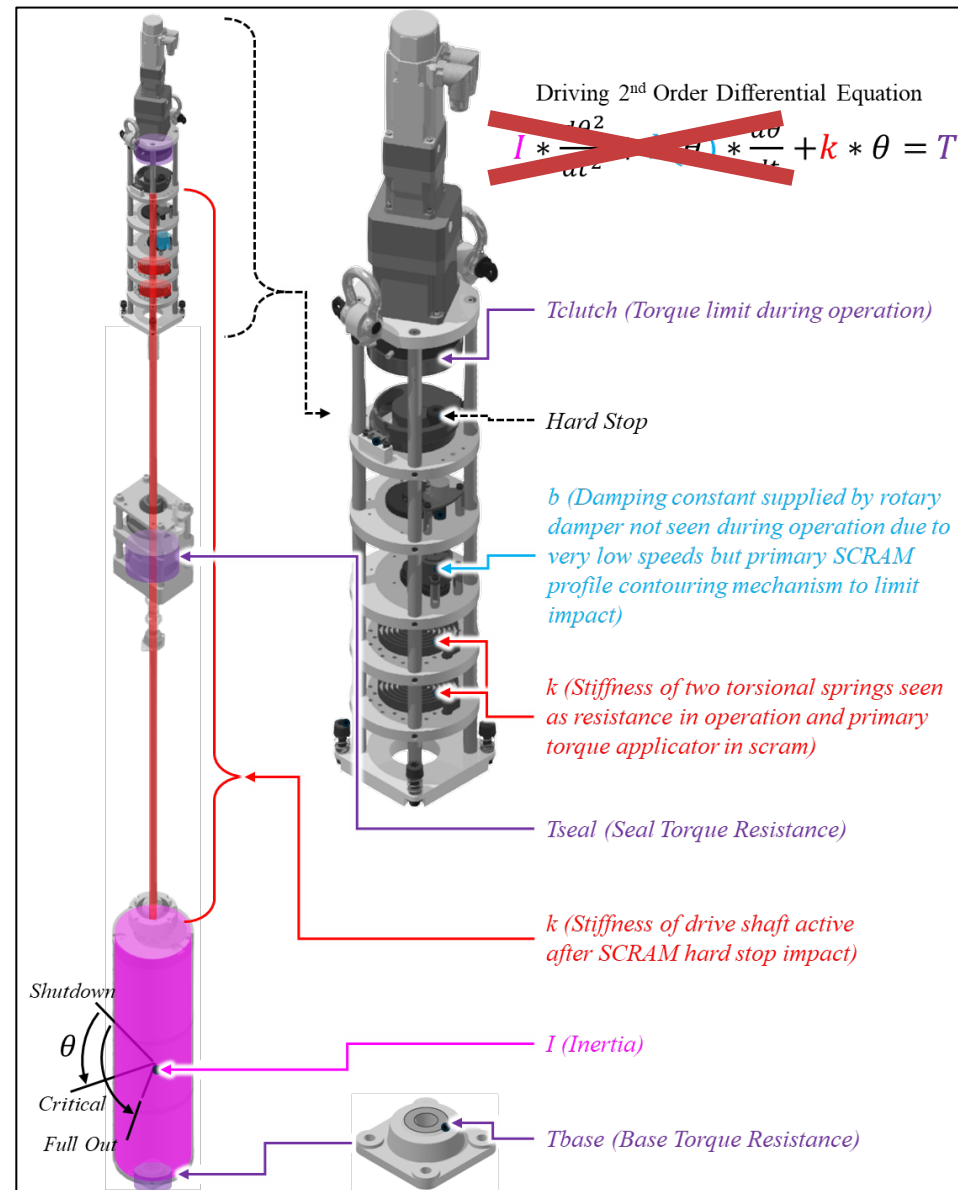


# CD Actuator System Dispersed into Subsystems



# CD System's Requirements

- SCRAM
  - < 3 Seconds
  - Min Impact
- Operating
  - Max Speed
  - Precision



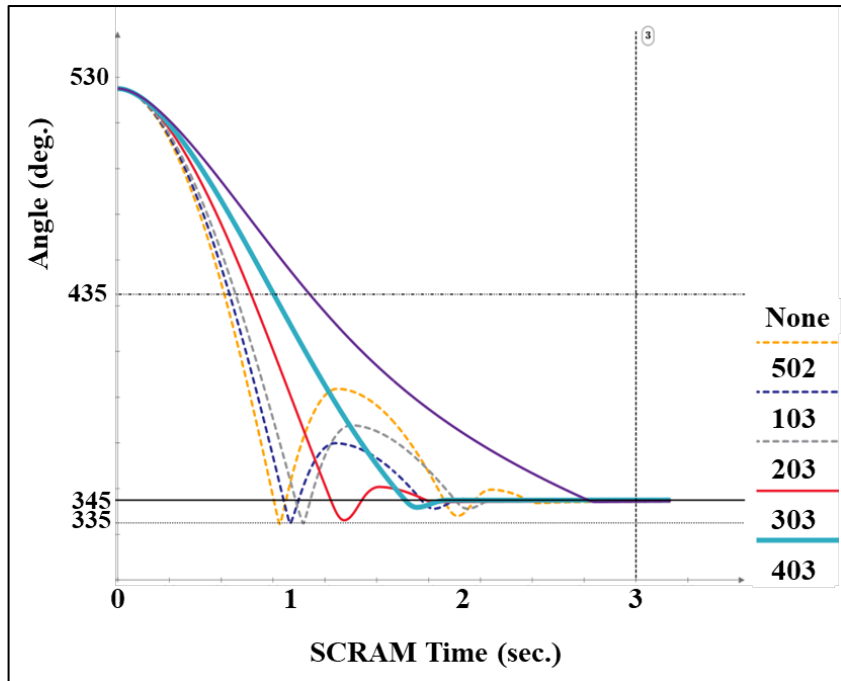
# CD System's SCRAM Requirements

- SCRAM
  - < 3 Seconds
  - Min Impact

Driving 2<sup>nd</sup> Order Differential Equation

$$I * \frac{d^2\theta}{dt^2} + b(\theta) * \frac{d\theta}{dt} + k * \theta = T$$

## Component Selection



## Tolerancing

**Primary Components Whose Variability Can Influence SCRAM**

**Rotary Damper:**

- Impact+: -b via -Tol
- Time+: +b via +Tol

**Torsion Springs:**

**Stiffness**

- Impact+: +k via +Tol
- Time+: -k via -Tol

**Preload\***

- Impact+: T<sub>max</sub> via maximum  $\theta_{Preload}$
- Time+: T<sub>min</sub> via minimum  $\theta_{Preload}$

**Drive Shaft:**

- Impact+: -k via Temp+
- Time+: k via Temp Amb

**Resistance via Bearings and Seal\*:**

\* System resistances are compensated by Torsion Spring Preload and thus variations to Coefficient of Friction, etc. are compensated by Torsion Spring Preload adjustment.

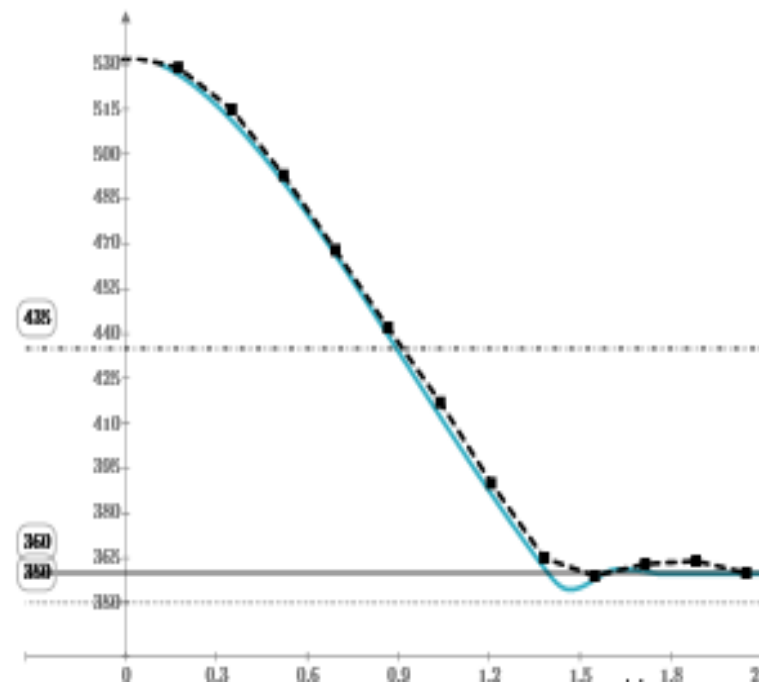
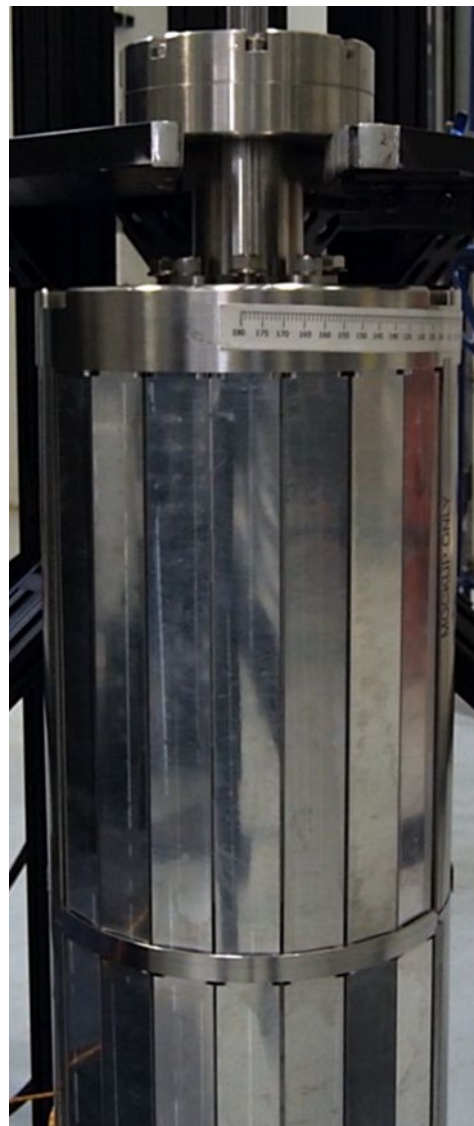
**Qualitative Representation of Tolerance Influence**

Shutdown

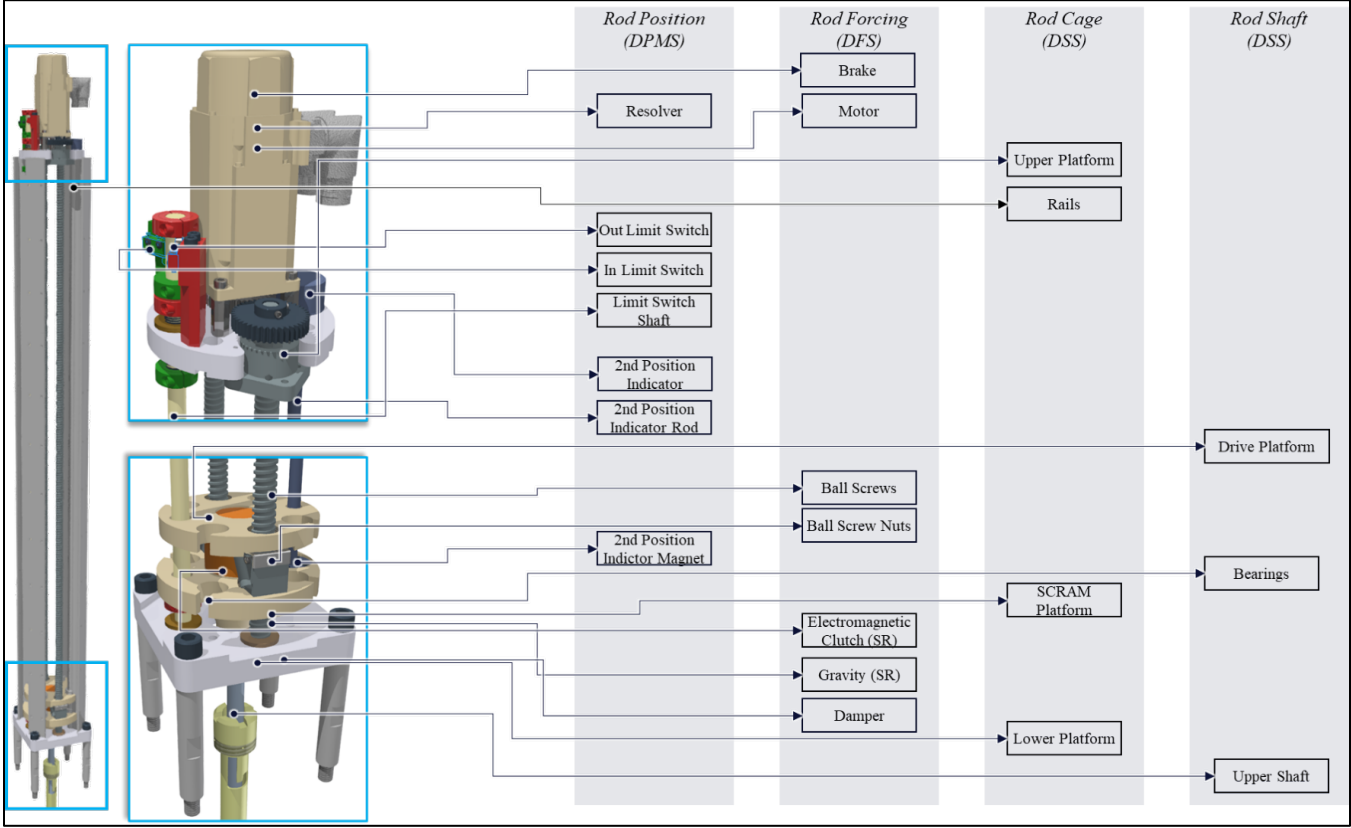
- High Impact
- Target Response
- Long Duration

# CD Testing Results and Model Validation

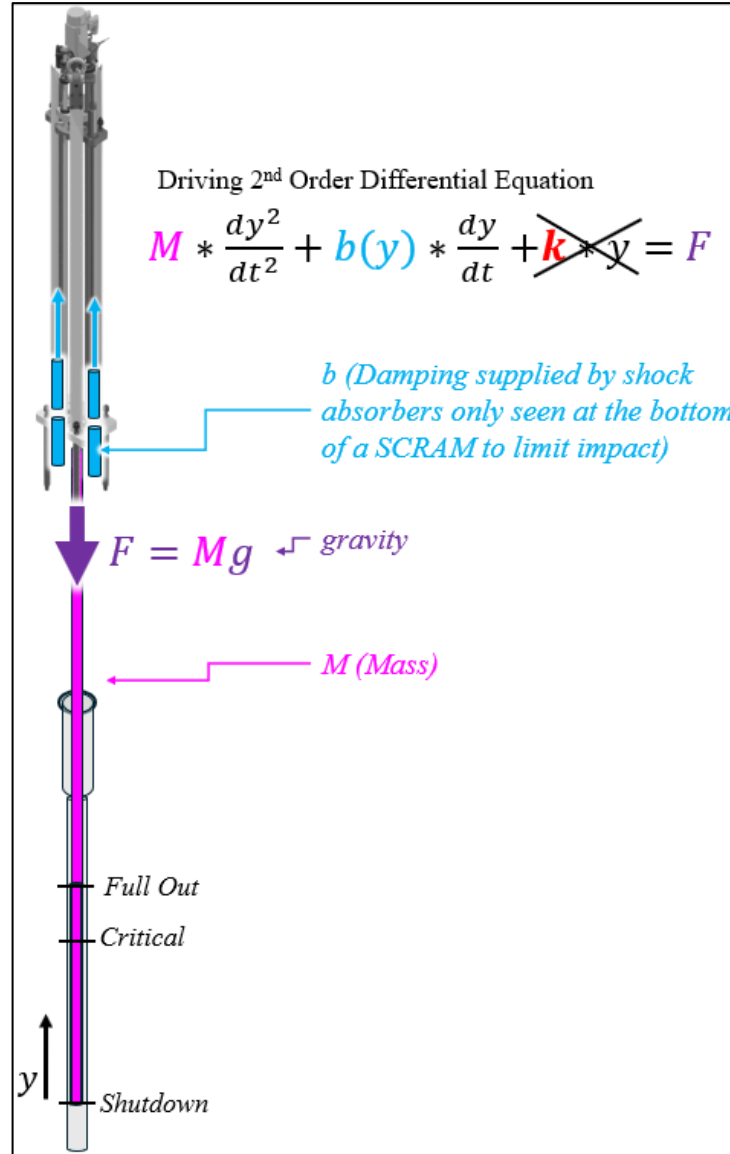
- Move Out
- SCRAM



# CD Actuator System Dispersed into Subsystems

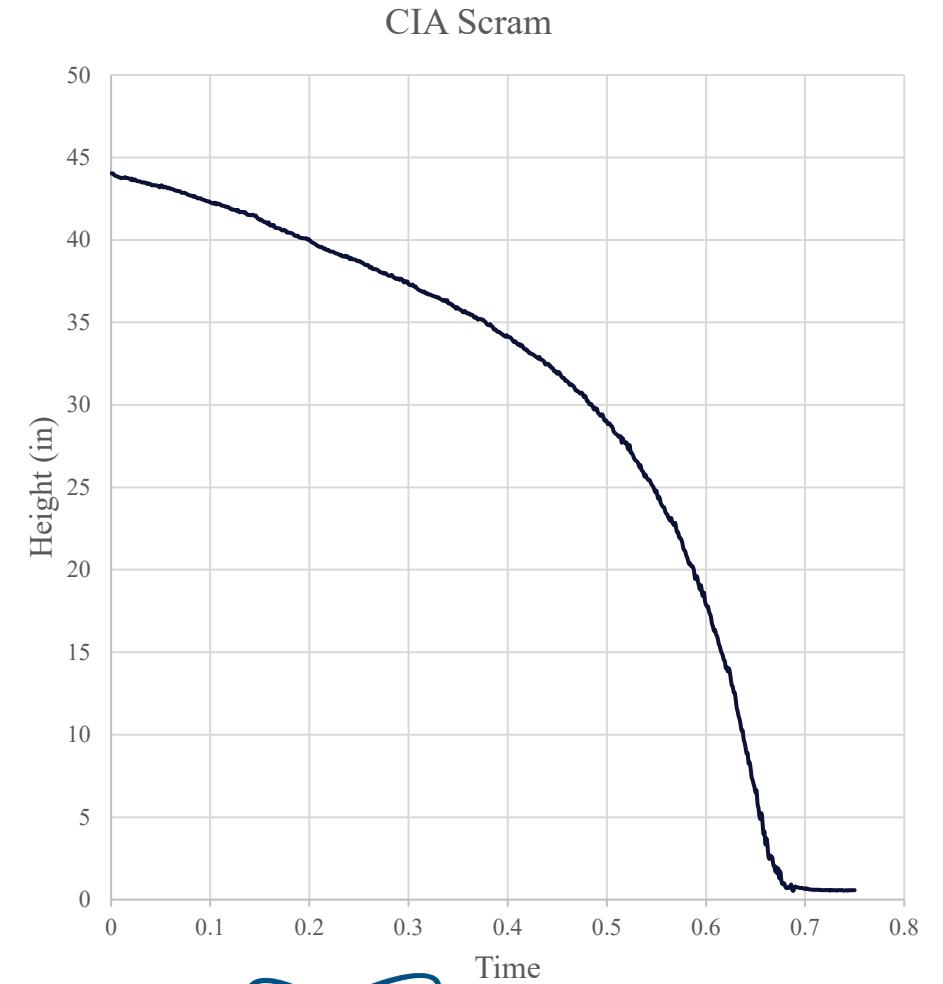
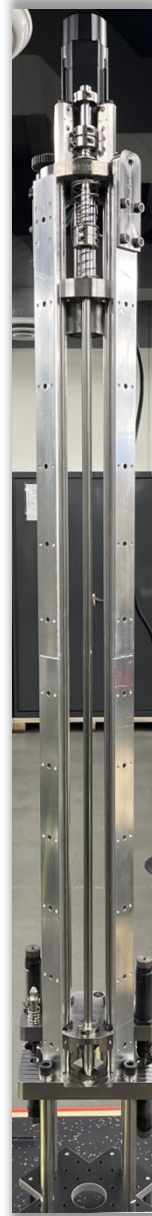


# CIA System's Driving Mathematics

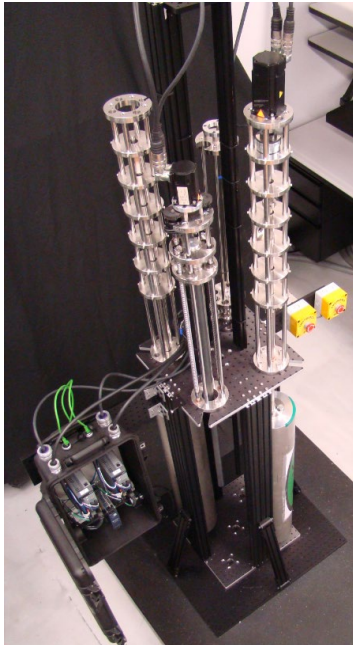


# CIA Testing Results and Model Validation

- Move Up
- SCRAM

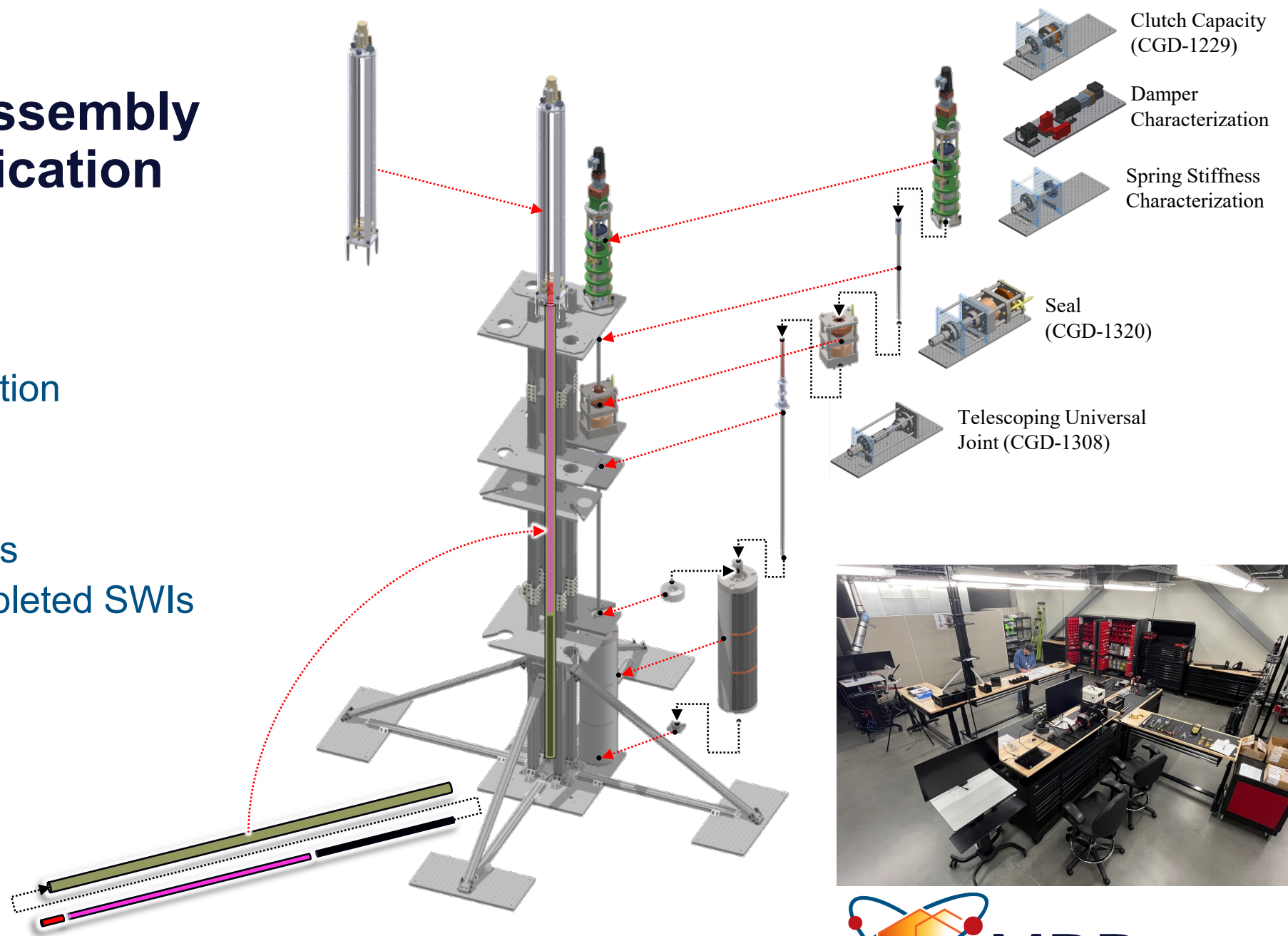


# Iterative Development



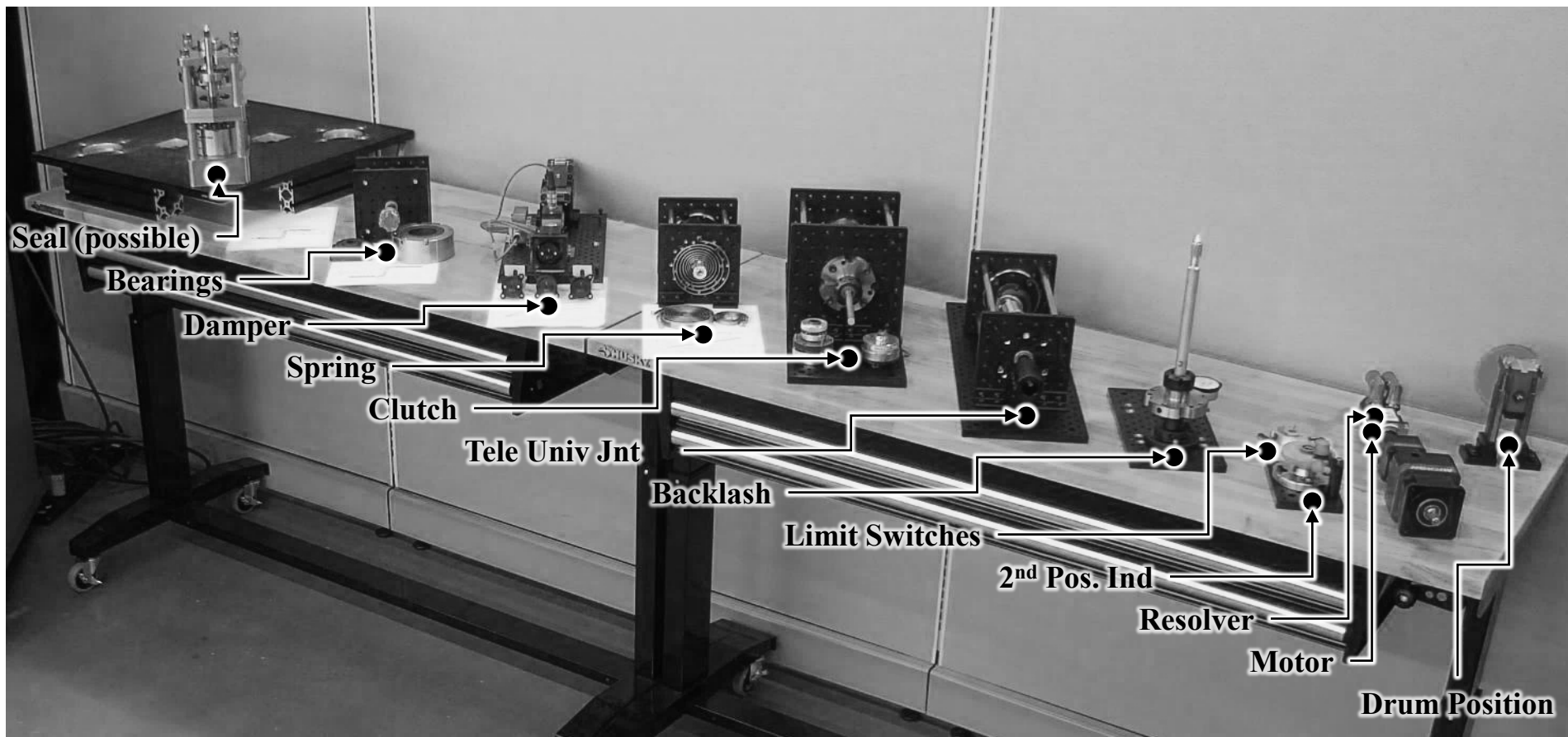
# Iterative Assembly and Qualification

- Analyses
  - Sizing
- Characterization
  - 60+ Tests
- Assembly
  - 2586 Parts
  - 37+ Completed SWIs
- Qualification



# Component Characterization

- For a system that is rarely implemented, there are expectedly few commercial options, so we had to assess the critical characteristics of all parts and characterize them for proof of operation.

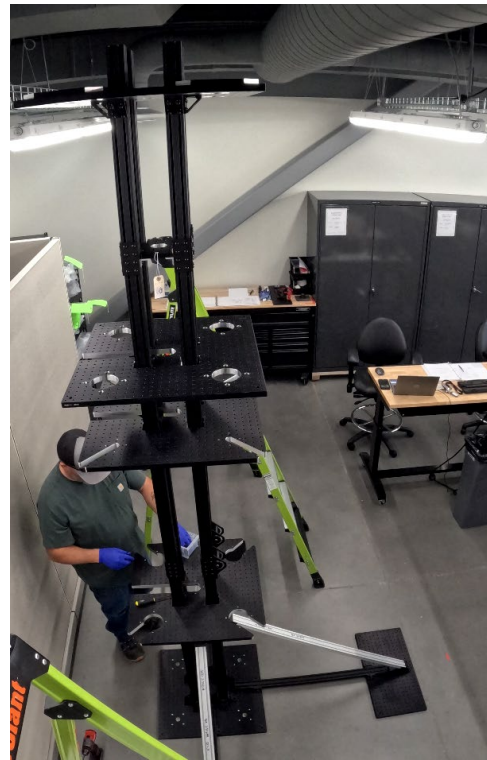
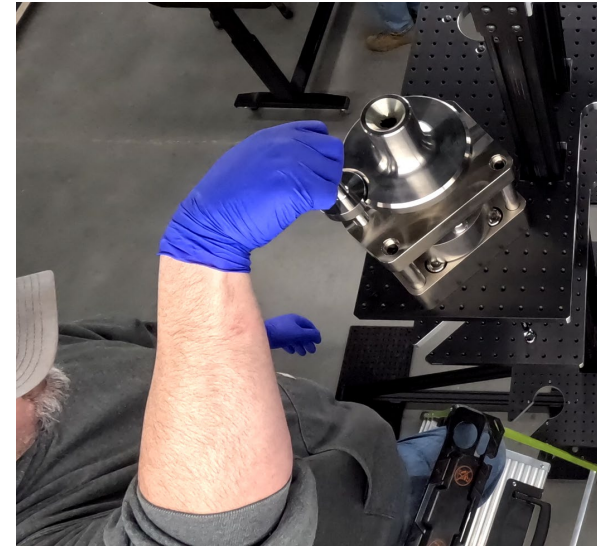
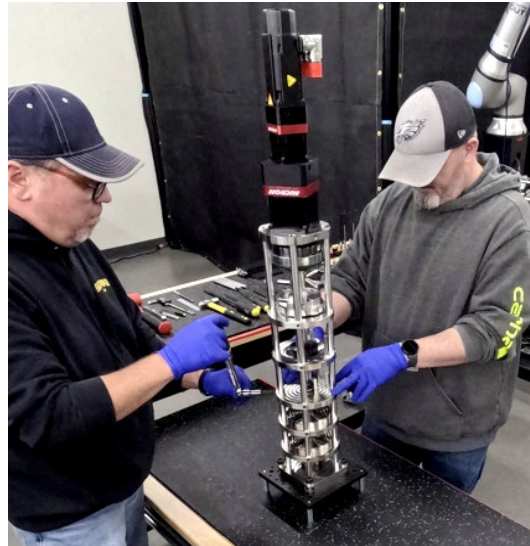


# RCS Assembly



# RCS Assembly

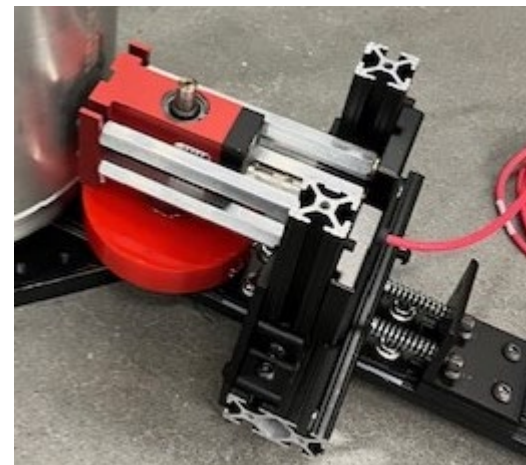
- Time Lapse Videos
  - CD Actuator
  - Seal
  - CIA Actuator
  - Test Stand



# CD System Qualification

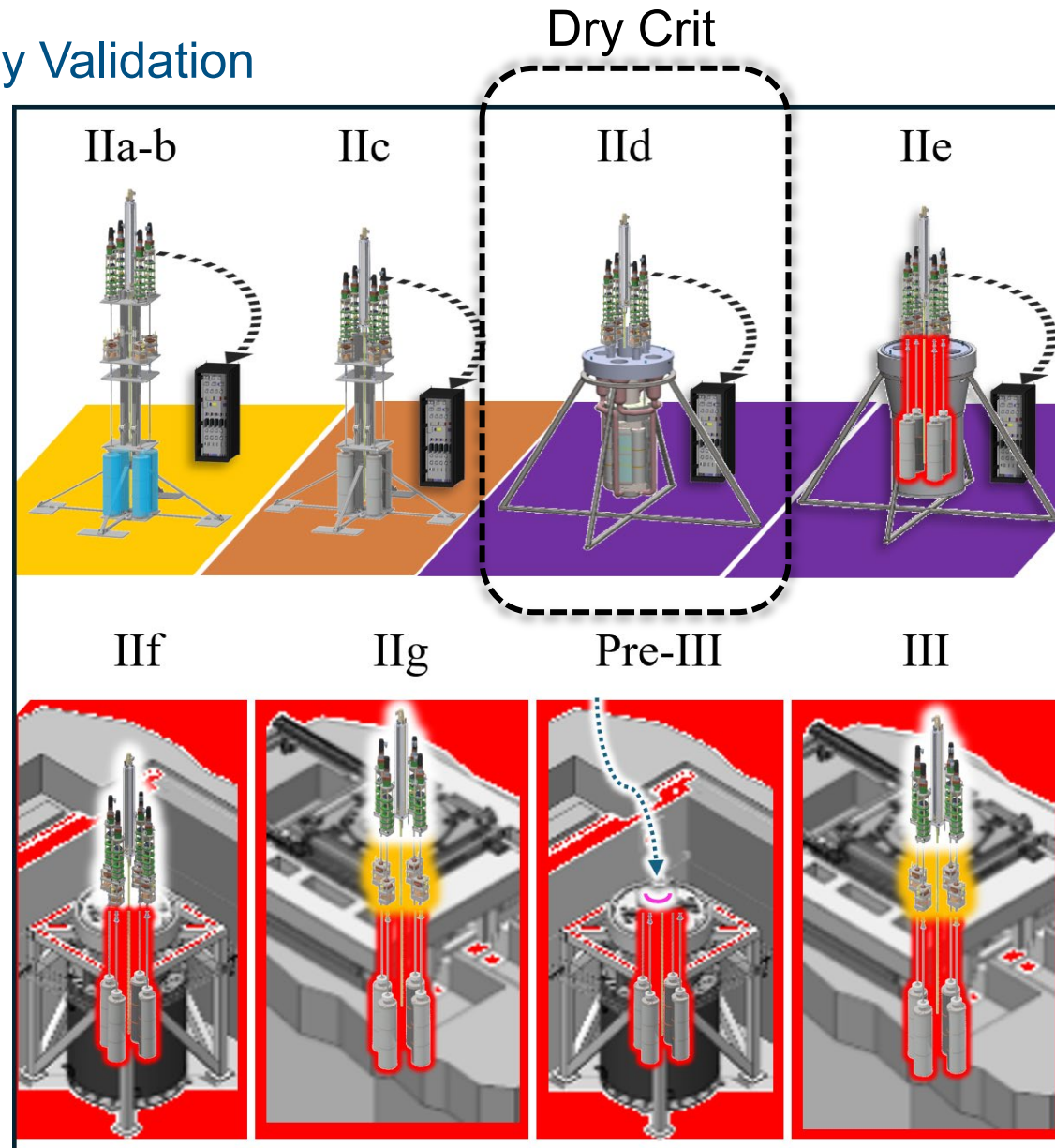
- Thorough initial qualification
- Reduces to simple move full out and then SCRAM

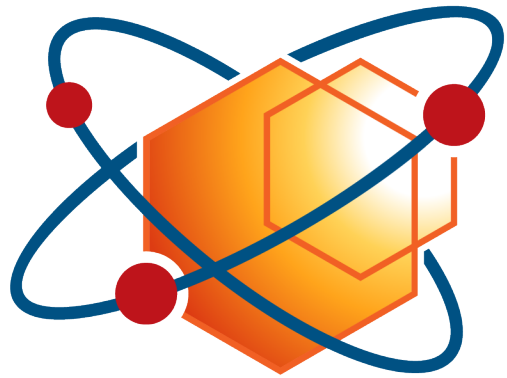
• Verify General System Setup: (Support Structure, Actuator, Shaft Chain, Drum, Cabinet)	<input type="checkbox"/>
• Verify Clearances:	<input type="checkbox"/>
• IN Limit Switch (Manual Check)	<input type="checkbox"/>
• OUT Limit Switch (Manual Check)	<input type="checkbox"/>
• Potentiometer (Manual Check)	<input type="checkbox"/>
• Resolver (Base AKD drive Software Check)	<input type="checkbox"/>
• Motor Status (Base AKD drive Software Check)	<input type="checkbox"/>
• Brake Status (Base AKD drive Software Check)	<input type="checkbox"/>
• Motor Motion Out Check with De-energized Clutch/Electromagnet	<input type="checkbox"/>
• Motor Toggle, Relative, Absolute (slow)	<input type="checkbox"/>
• Motor Toggle, Relative, Absolute (fast)	<input type="checkbox"/>
• Motor Max Speed Identification	<input type="checkbox"/>
• Energize Clutch/Electromagnet	<input type="checkbox"/>
• Lock Strength Check	<input type="checkbox"/>
• Hard Stop (IN) Strength Check	<input type="checkbox"/>
• System SCRAM Just Barely Off IN Limit Switch	<input type="checkbox"/>
• System Motion OUT Check with Energized Clutch (Resolver, Potentiometer, Limit Switch, and Calibrated Direct Rod System Position Monitoring)	<input type="checkbox"/>
• System Toggle, Relative, Absolute (slow)	<input type="checkbox"/>
• System Toggle, Relative, Absolute (fast)	<input type="checkbox"/>
• System Max Speed Identification	<input type="checkbox"/>
• System Motion IN Check with Energized Clutch (Resolver, Potentiometer, Limit Switch, and Calibrated Direct Rod System Position Monitoring)	<input type="checkbox"/>
• System Toggle, Relative, Absolute (slow)	<input type="checkbox"/>
• System Toggle, Relative, Absolute (fast)	<input type="checkbox"/>
• System Max Speed Identification	<input type="checkbox"/>
• Hard Stop (IN) Strength Test	<input type="checkbox"/>
• SCRAM Iteratively (25%, 50%, 75%, 100%)	<input type="checkbox"/>
• SCRAM repeatedly at 100% until target statistics achieved with max environment loads applied (e.g., thermally induced deflections)	<input type="checkbox"/>



# Iterative Qualification

- Ila: RCS Qualification
- Iib+: Assembly Validation





**MRP** Microreactor  
Program