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MOX Fresh Fuel Transportation Package Designs

NRC Dockets 71–9353 and 71–9354

Gary L. Clark, P.E.
MOX Packaging Technical Advisor
NRC, Rockville MD August 14, 2012

Meeting Purpose

- Review previous certification testing of the Type B Package Base Designs
- Present the current designs for both PWR and BWR MOX fresh fuel packages
- Planned approach to comply with 10 CFR 71 requirements
  - Containment
  - Criticality Control
- Estimated Schedule

Previous Fresh Fuel Package Testing

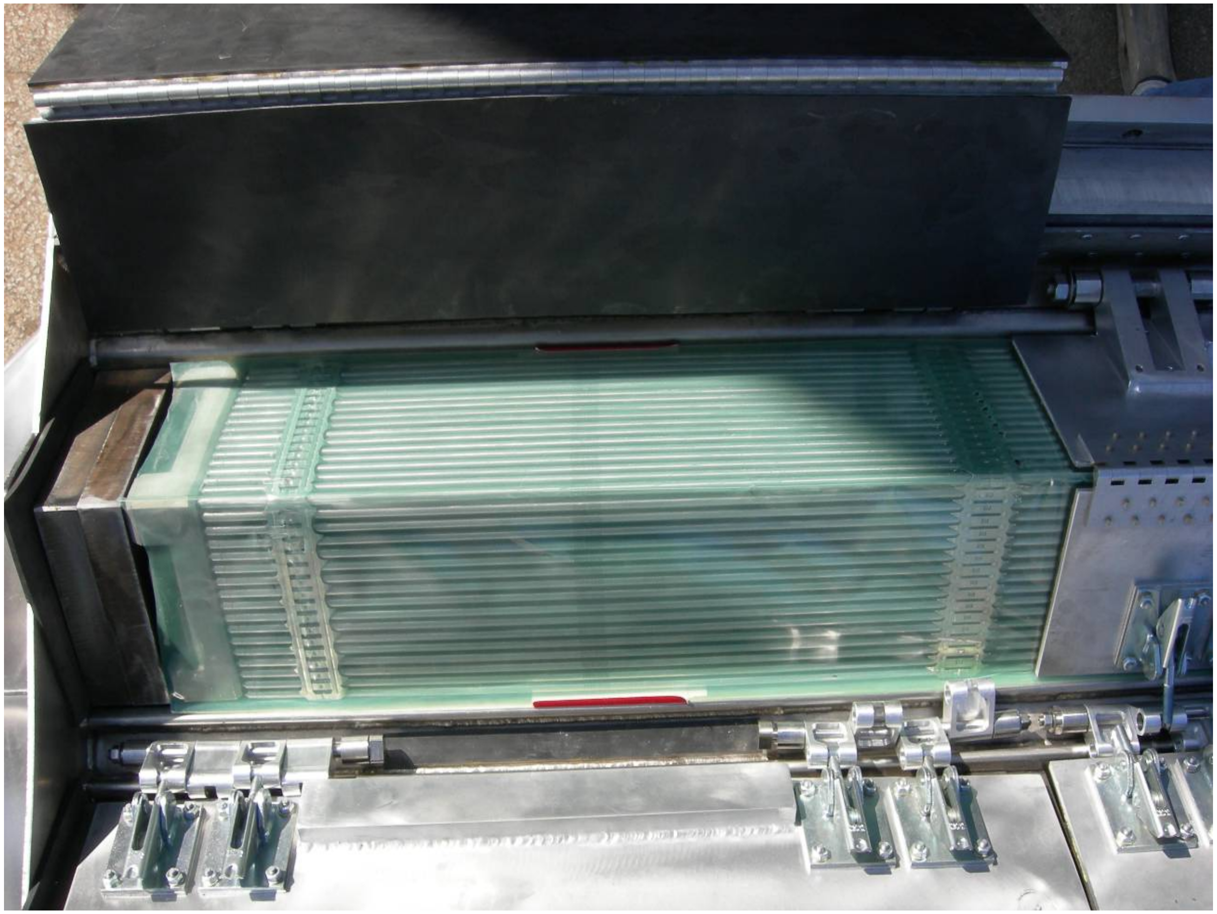
- **Previous Type B Packages Tested**
  - **MAP–12: (2) PWR Fuel Assemblies (FAs)**
  - **RAJ–II: (2) BWR FAs**
- **Test Payloads**
  - **Prototypic FA**
  - **Dummy/Mock FA**
- **Both Packages Underwent Full–Scale Certification Testing**
  - **Free and Puncture Drops**
  - **Fire (MAP–12 only)**

MAP–12 CTU Testing

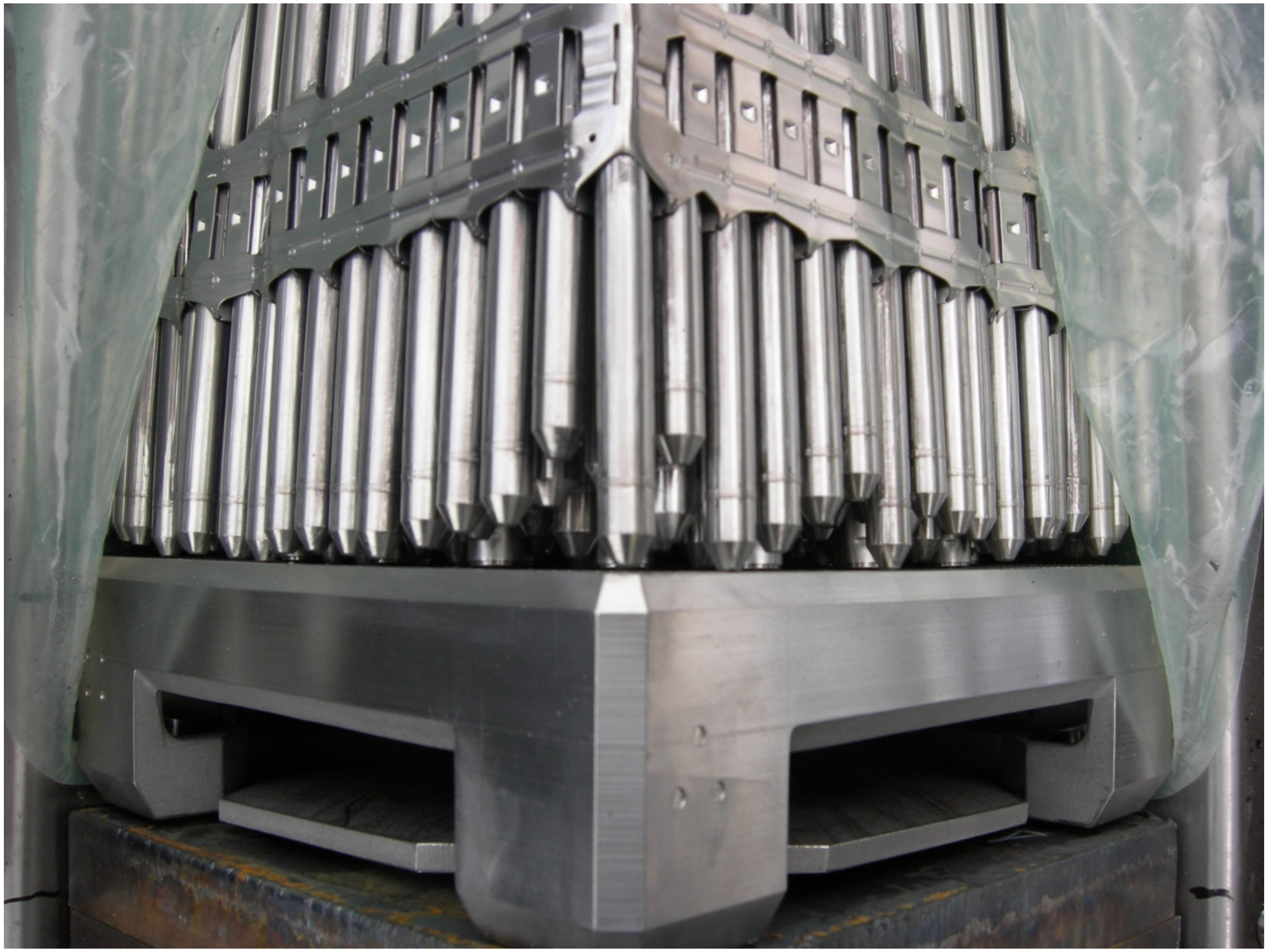
- (1) Prototypic and (1) mock FA utilized in Certification Test Unit (CTU) tests
- HAC Free Drop orientations tested
  - Bottom End (longitudinal axis 90° relative to horizontal)
  - Slap–Down on Front End , Lid down, (longitudinal axis 30° relative to horizontal)
  - Top (Lid) Down (longitudinal axis 0° relative to horizontal)
- Puncture Drop
  - Oblique, Lid down (longitudinal axis 0° relative to horizontal, lateral axis 20° relative to horizontal)
  - Side Closure (longitudinal axis 0° relative to horizontal)
- Fire Test
  - Performed on CTU w/ damage from top down, horizontal free drop, oblique puncture
- Results demonstrated no apparent failure of the fuel rod cladding due to any of the free or puncture drops and fire test.

MAP–12 CTU Testing
After End Drop

MAP–12 CTU Testing
PWR Fuel Assembly After End Drop



MAP–12 CTU Testing
PWR Fuel Assembly After End Drop



MAP–12 CTU Testing
After Bottom Down Slap Down

MAP–12 CTU Testing After Top Down Drop

MAP–12 CTU Testing
After Oblique Puncture Drop on Bottom

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MAP–12 CTU Testing
Fuel Assembly After Thermal Test

MAP–12 CTU Testing
Moderator After Thermal Test

RAJ–II CTU Testing

- (1) Prototypic and (1) mock FA utilized in CTU tests
- HAC Free Drop orientations tested
  - Bottom End (longitudinal axis 90° relative to horizontal)
  - Bottom Corner (longitudinal axis 0° relative to horizontal)
  - Oblique Slap–Down, Lid down (longitudinal axis 15° relative to horizontal)
  - Top (Lid) Down (package longitudinal axis 0° relative to horizontal)
  - CG–Over–Bottom Corner (package longitudinal axis near 90° relative to horizontal)
- Puncture Drop
  - Oblique, Lid down (package longitudinal axis 25° relative to horizontal)
- Results demonstrated that the package met the allowable A_2 release limits of 10 CFR §§71.51(1) [NCT] and 71.51(2) [HAC].

RAJ–II CTU Testing
After Bottom End Drop

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RAJ–II CTU Testing
BWR Fuel Assembly After End Drop

Lessons Learned: Type B Fresh Fuel Packages

- Fuel cladding remained visually intact under worst–case HAC test conditions

- Design features provide protection of fuel rods from damage
  - Side drops result in no observable damage to fuel rods
  - Slap down drops affect the package closure, but fuel rods only experience minor (elastic) bending
  - Puncture drops result in localized damage to the thermal protection, but fuel rods remain undamaged

Lessons Learned: Type B Fresh Fuel Packages (cont.)

- **End drops present potential for buckling of fuel rods and sharp bends at interface between cladding and tie plates**
- **Cladding can experience significant elastic bending without permanent damage, but is susceptible to cracking if deformed cladding undergoes reverse bending**
- **Effect of end drops are adequately mitigated by design features (e.g., properly sized end impact limiters to reduce acceleration and use of internal "doors" to ensure that fuel rod buckling potential is eliminated**

MOX Fresh Fuel Package Designs

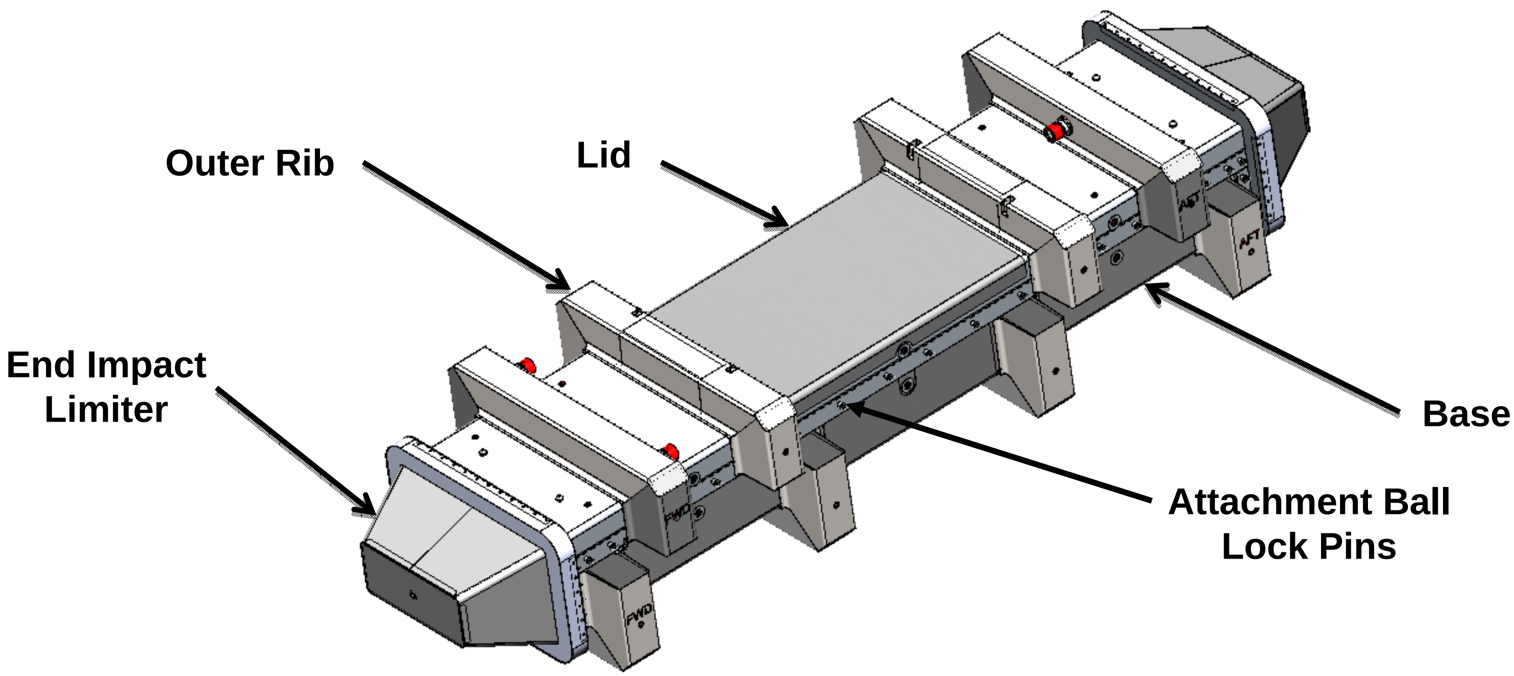
- **Package Identifications**
  - **PWR MOX Fuel Package (PMFP), assigned NRC Docket 71–9354**
  - **BWR MOX Fuel Package (BMFP), assigned NRC Docket 71–9353**
- **Package designs based on MAP–12 package design w/ design enhancements to address safety functions:**
  - **Containment**
  - **Criticality Control**
- **Payloads**
  - **PMFP: (2) Advanced W17 HTP FAs**
  - **BMFP: (2) ATRIUM 10A or ATRIUM 10XM FAs**
  - **Maximum Enrichment of 6.0 wt% fissile plutonium (Pu)**

PMFP Design

- **Package Details**
  - **Overall Dimensions: 39” high × 62” wide × 214” long**
  - **Gross Weight: 9,500 lbs**
  - **Payload Weight: 3,400 lbs**
  - **Primary Materials of Construction:**
    - Stainless steel – structural
    - Polyurethane foam – impact and thermal protection
    - Alumina silica paper – thermal protection
    - Aluminum – fuel doors
    - Nylon & Borated Aluminum – neutron moderator & poison
- **Criticality Control**
  - **Poison, moderator, and geometry control ensures package is subcritical**
- **Maximum Package Thermal Load: 160 Watts**

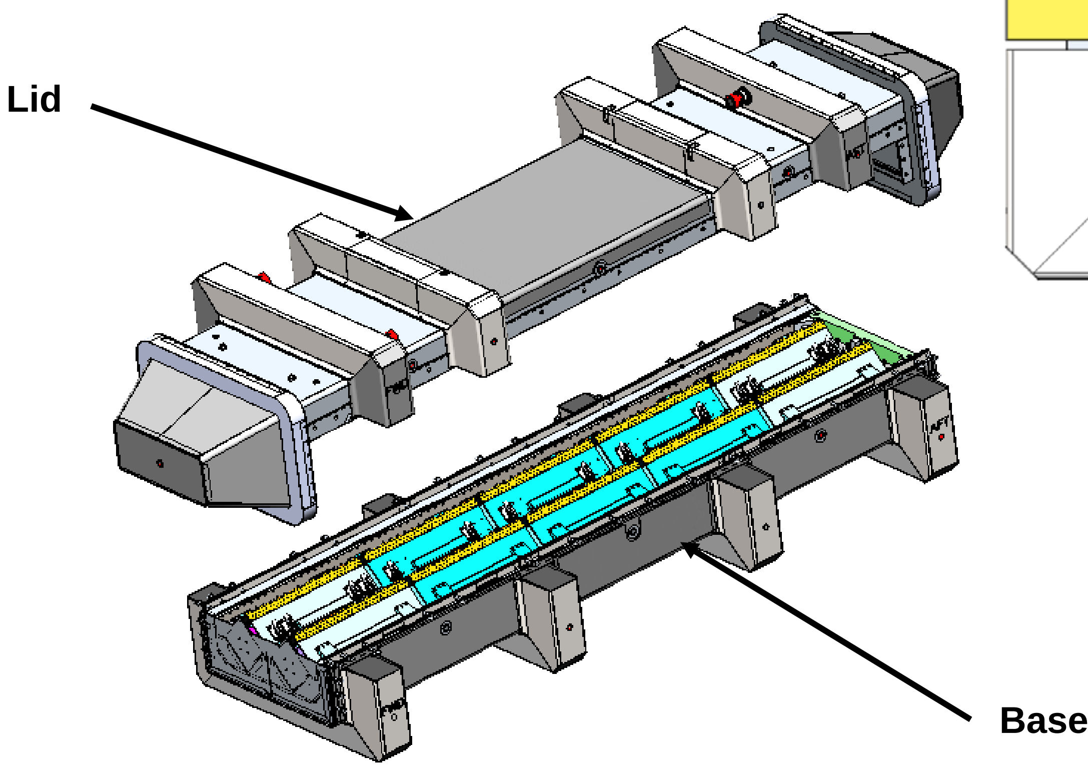
PMFP Design (con't)

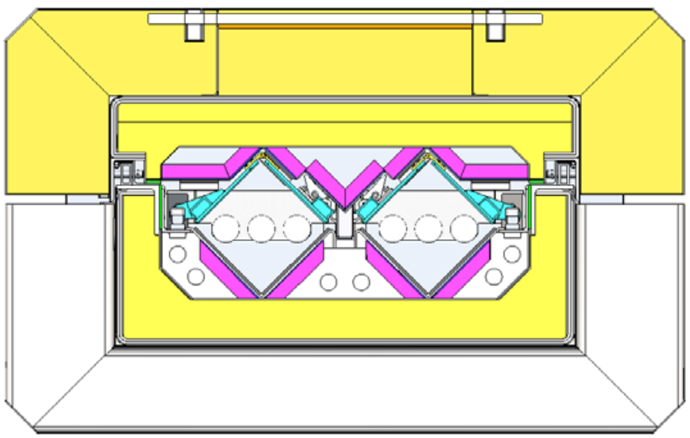
- **Package Assembly**



PMFP Design (con't)

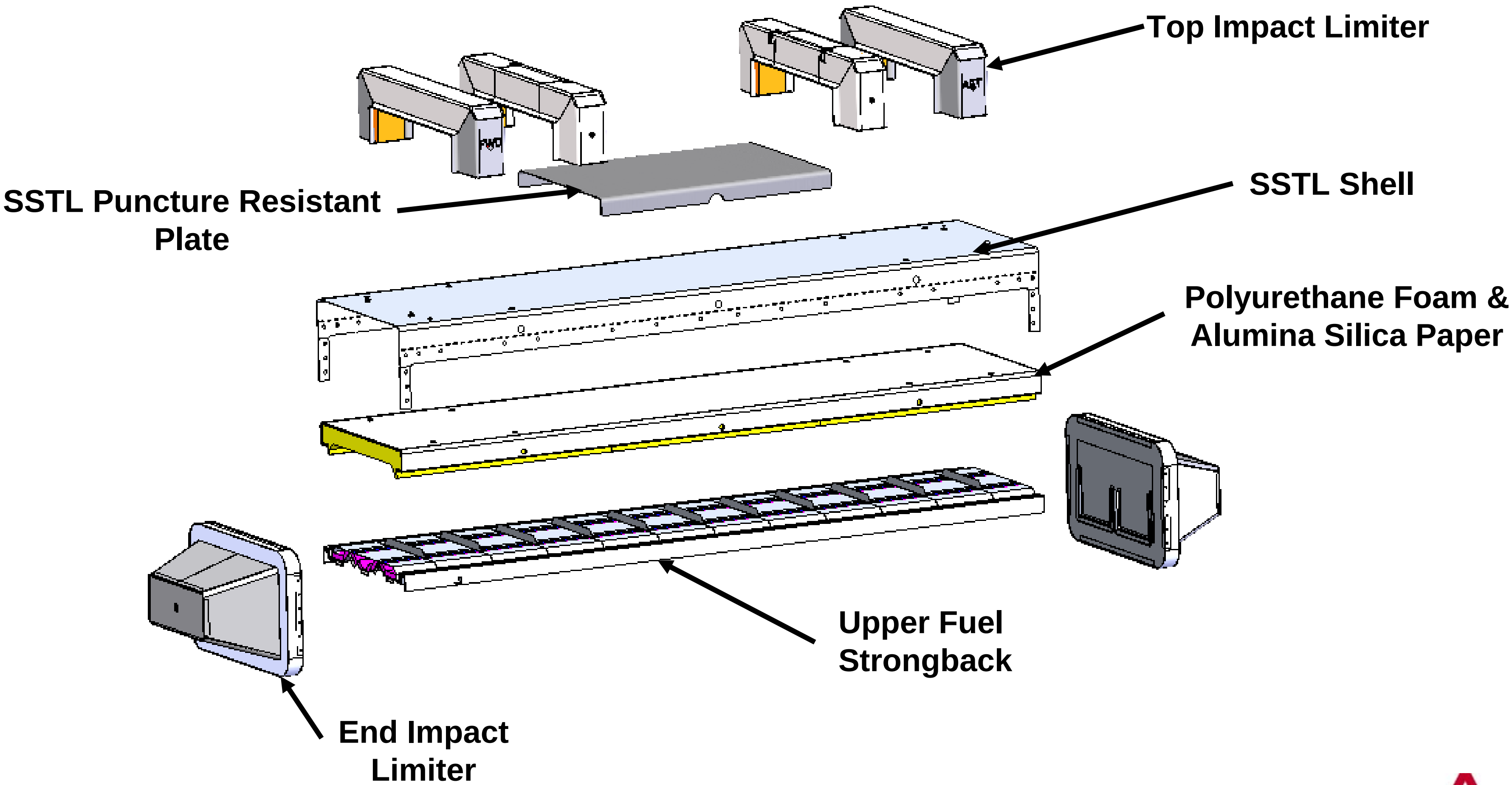
▶ Package Assembly (con't)





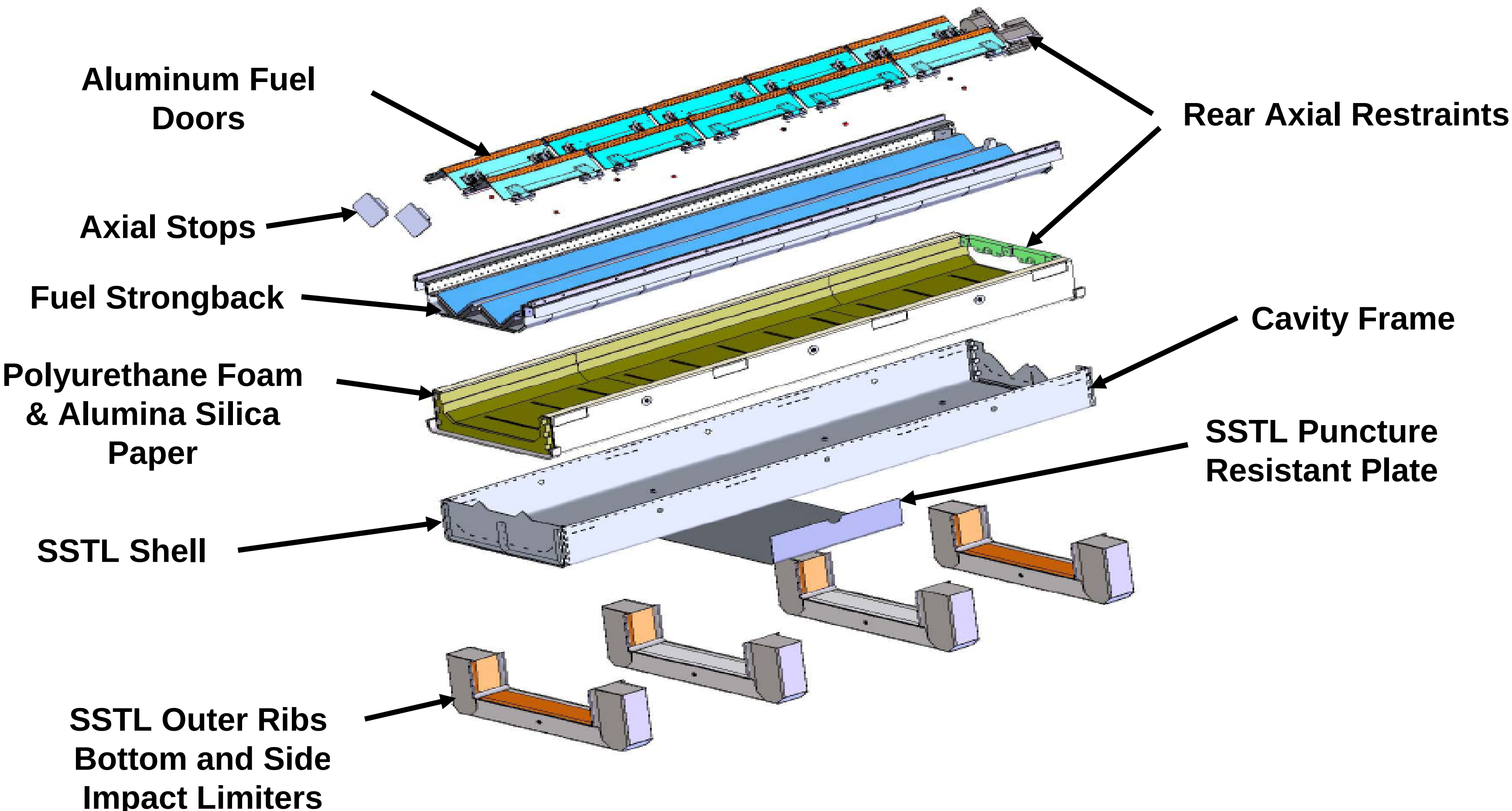
PMFP Design (con't)

- **Exploded View of Lid Assembly**



PMFP Design (con't)

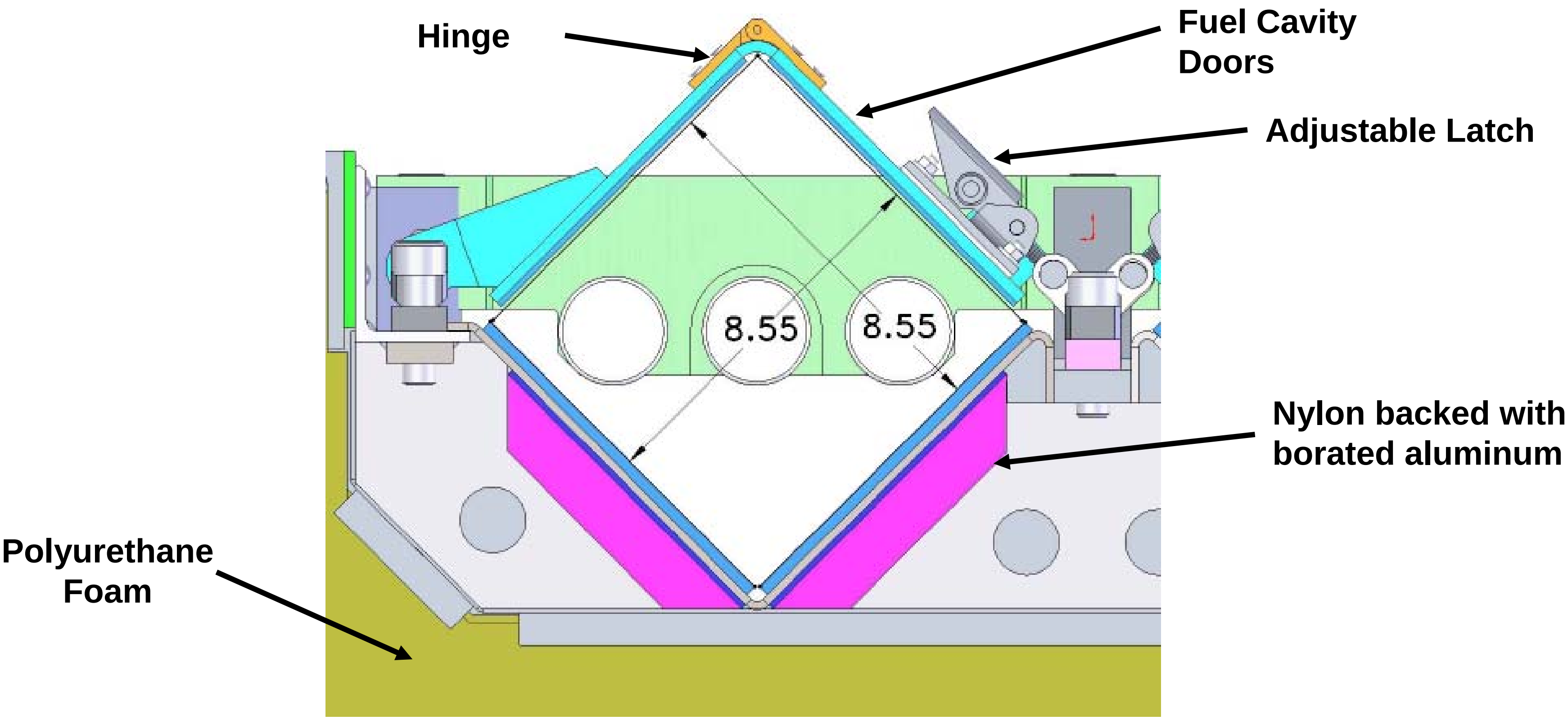
- **Exploded View of Base Assembly**



PMFP Design (con't)

Fuel Cavity Details

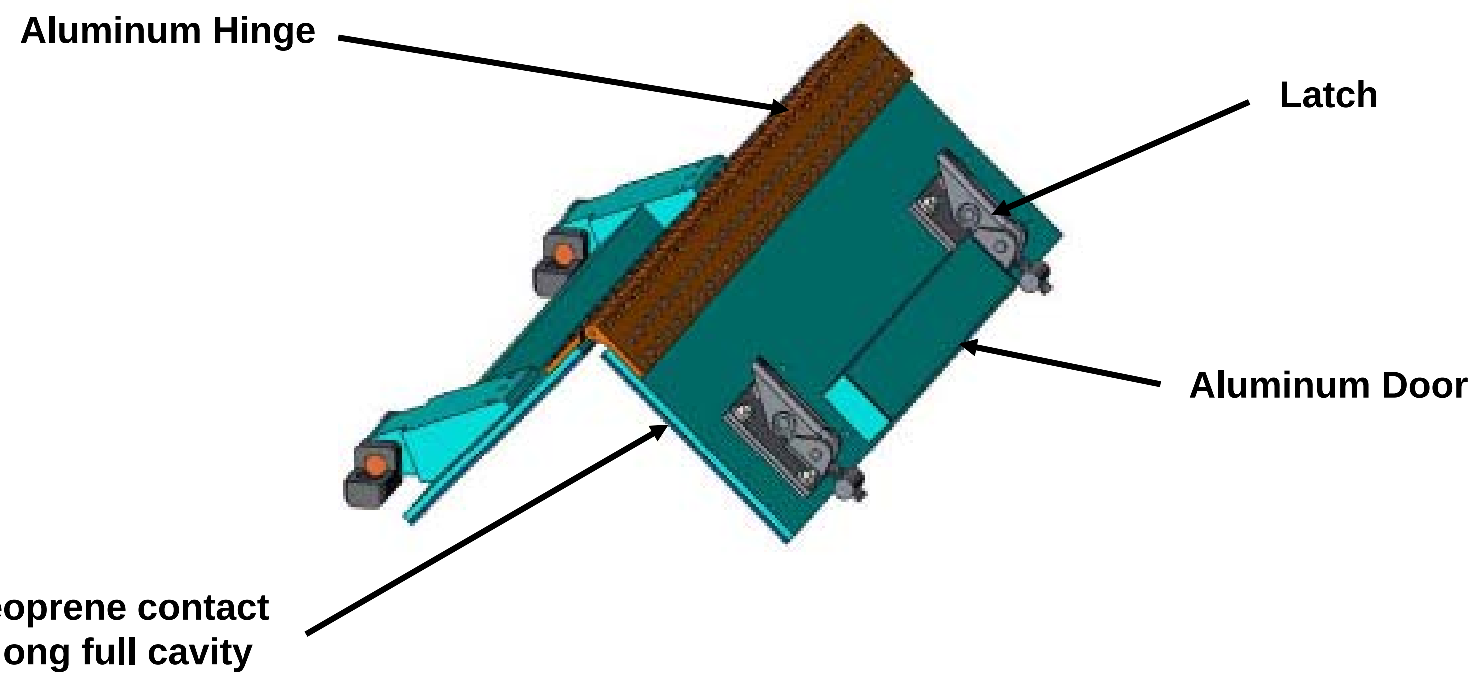
- Diagonal fuel cavity door provides structural support and constant pressure clamping



PMFP Design (con't)

▶ Fuel Door Details

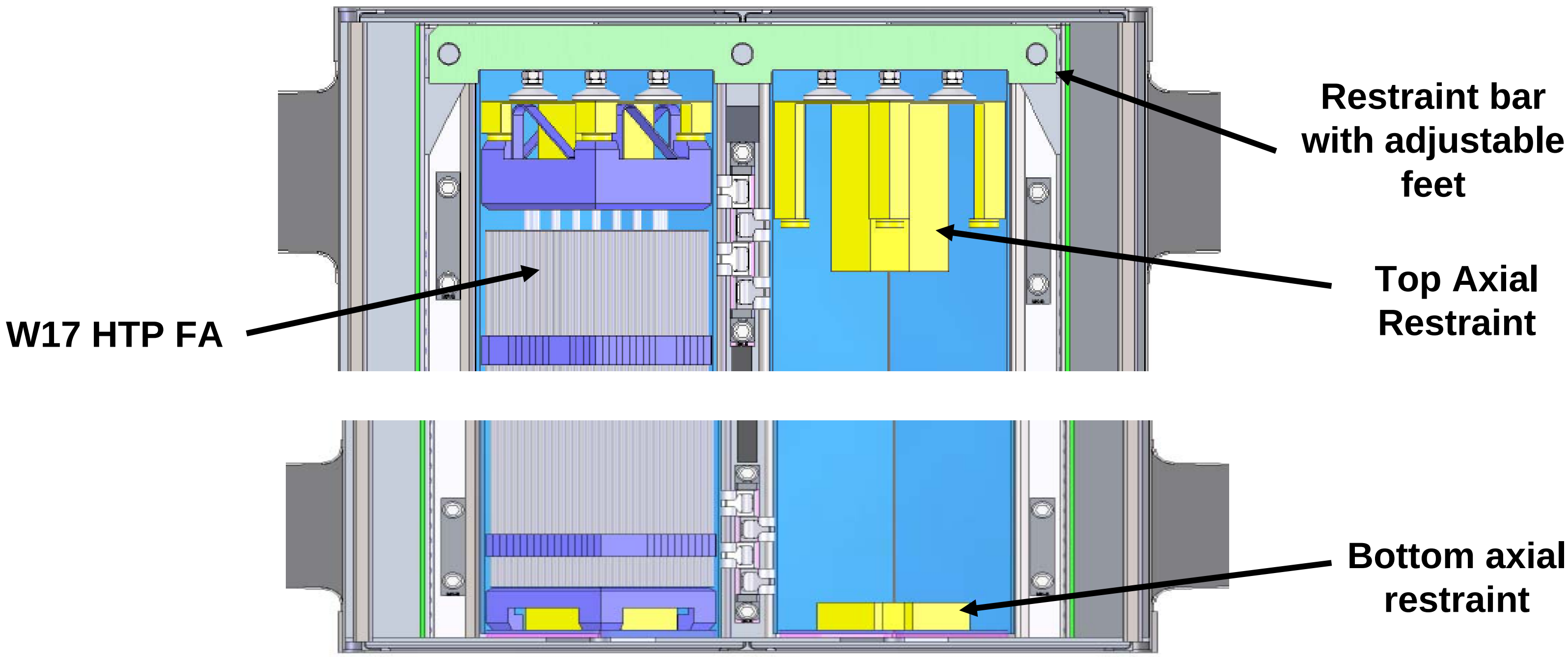
- Five doors provide cavity closure down axial length of FA
- Each end doors have four (4) latches.



PMFP Design (con't)

▶ Fuel Interface Details

- **Axial restraints –** Nylon spacers at each end and adjustable feet at the top end of the fuel assemblies



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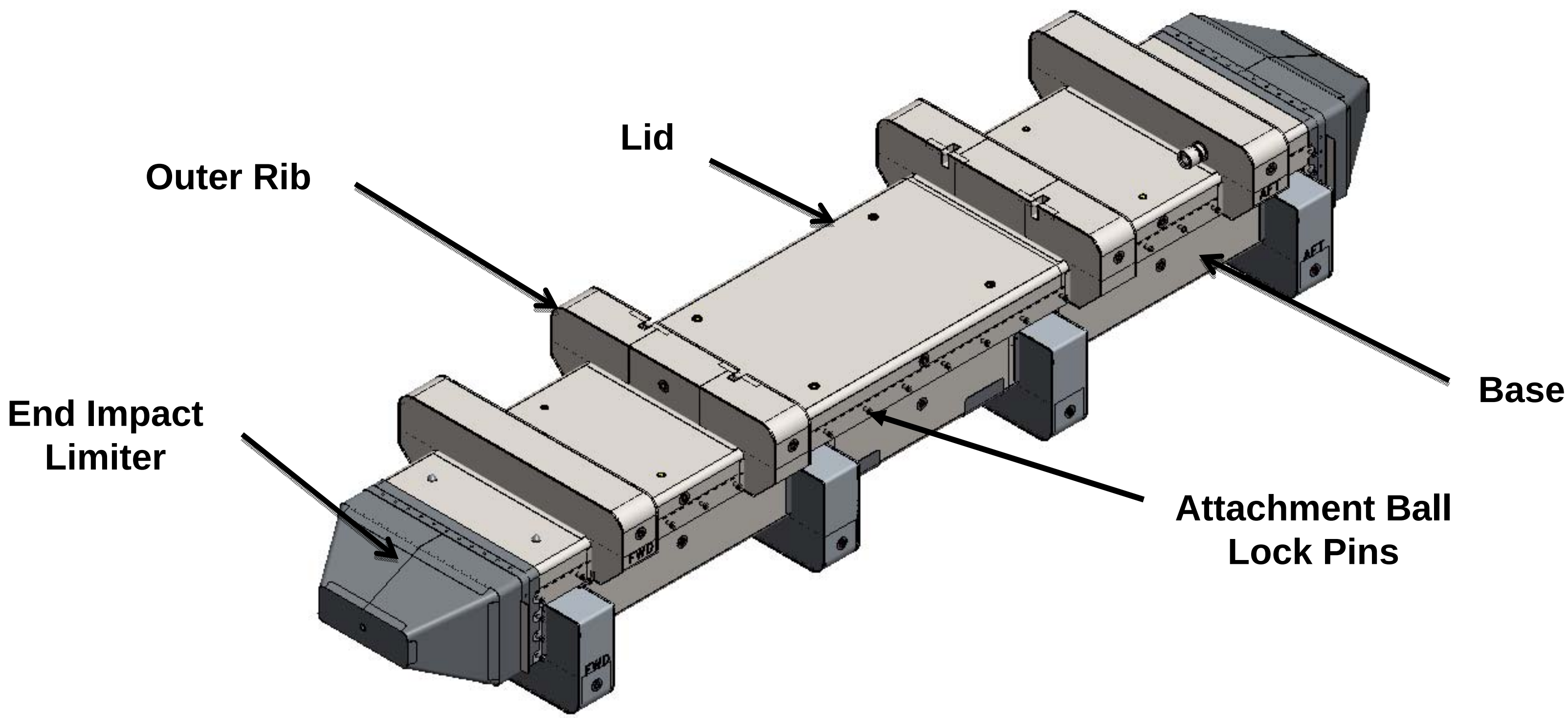
BMFP Design

- **Package Details**
  - **Overall Dimensions: 35¾" high × 53¾" wide × 226" long**
  - **Gross Weight: 6,500 lbs**
  - **Payload Weight: 1,300 lbs**
  - **Primary Materials of Construction:**
    - Stainless steel – structural
    - Polyurethane foam – impact and thermal protection
    - Alumina silica paper – thermal protection
    - Aluminum – fuel doors
- **Criticality Control**
  - **No poison or moderator required for BWR fuel**
  - **Geometry control ensures package is subcritical**
- **Maximum Package Thermal Load: 50 Watts**

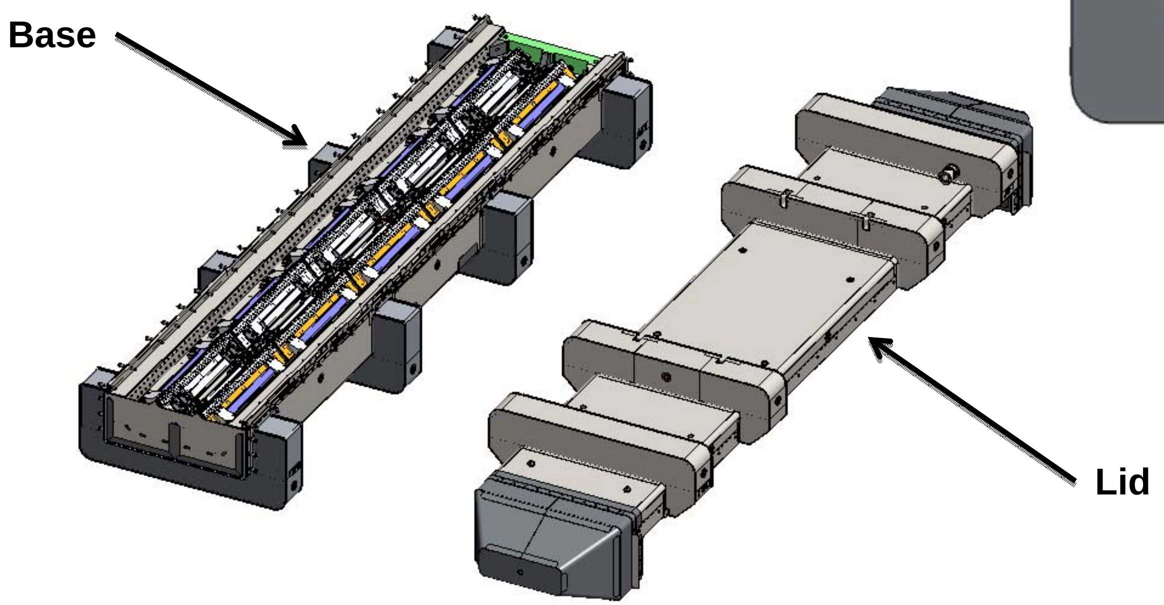
BMFP Design (con't)

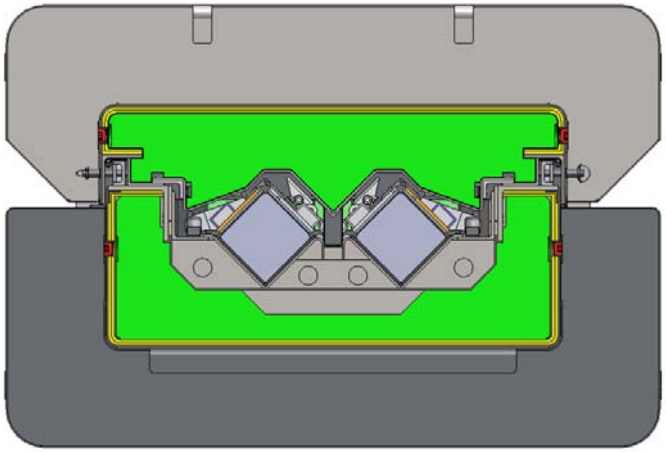
▶ Package Assembly



BMFP Design (con't)

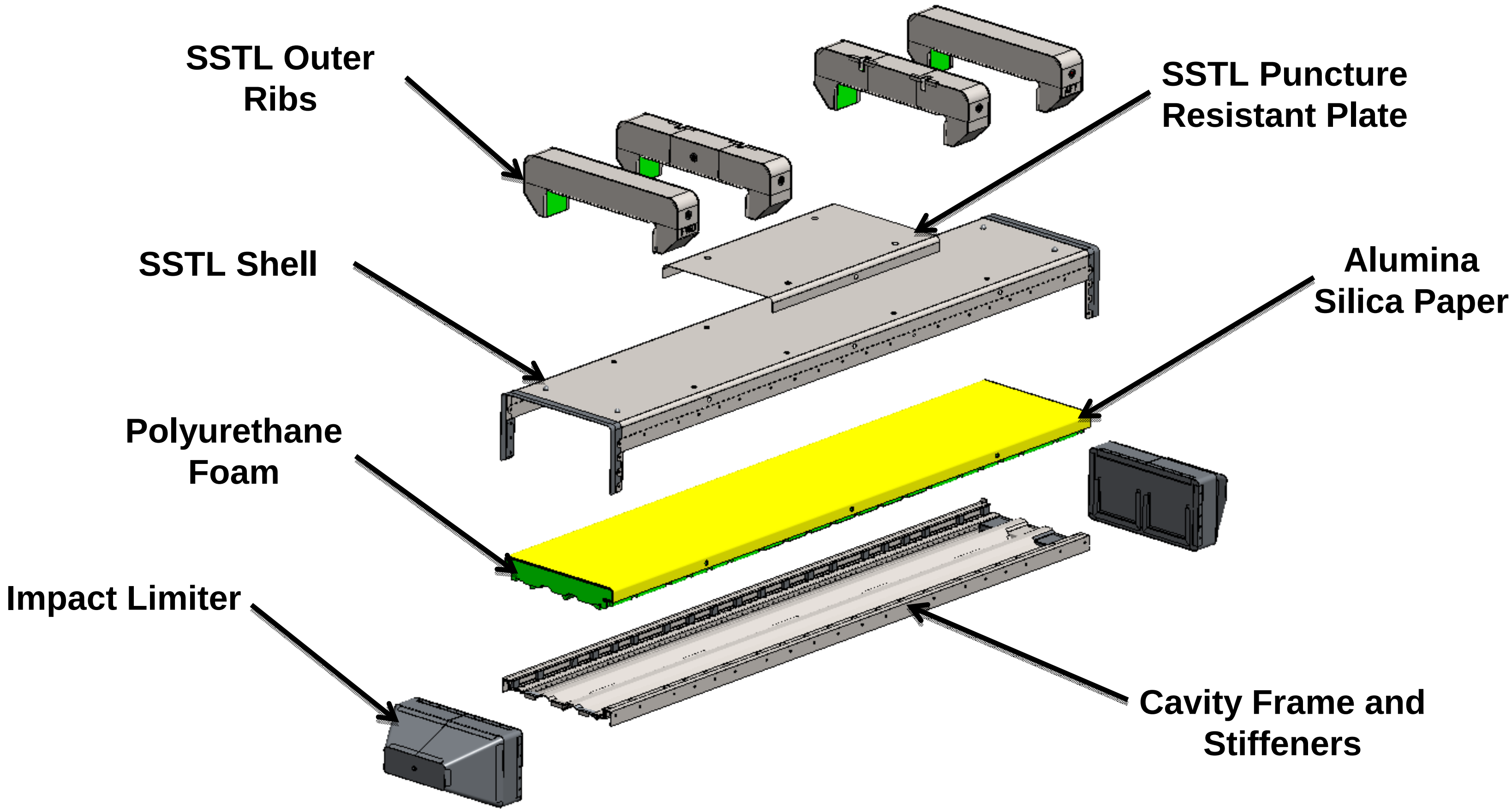
- **Package Assembly (con't)**





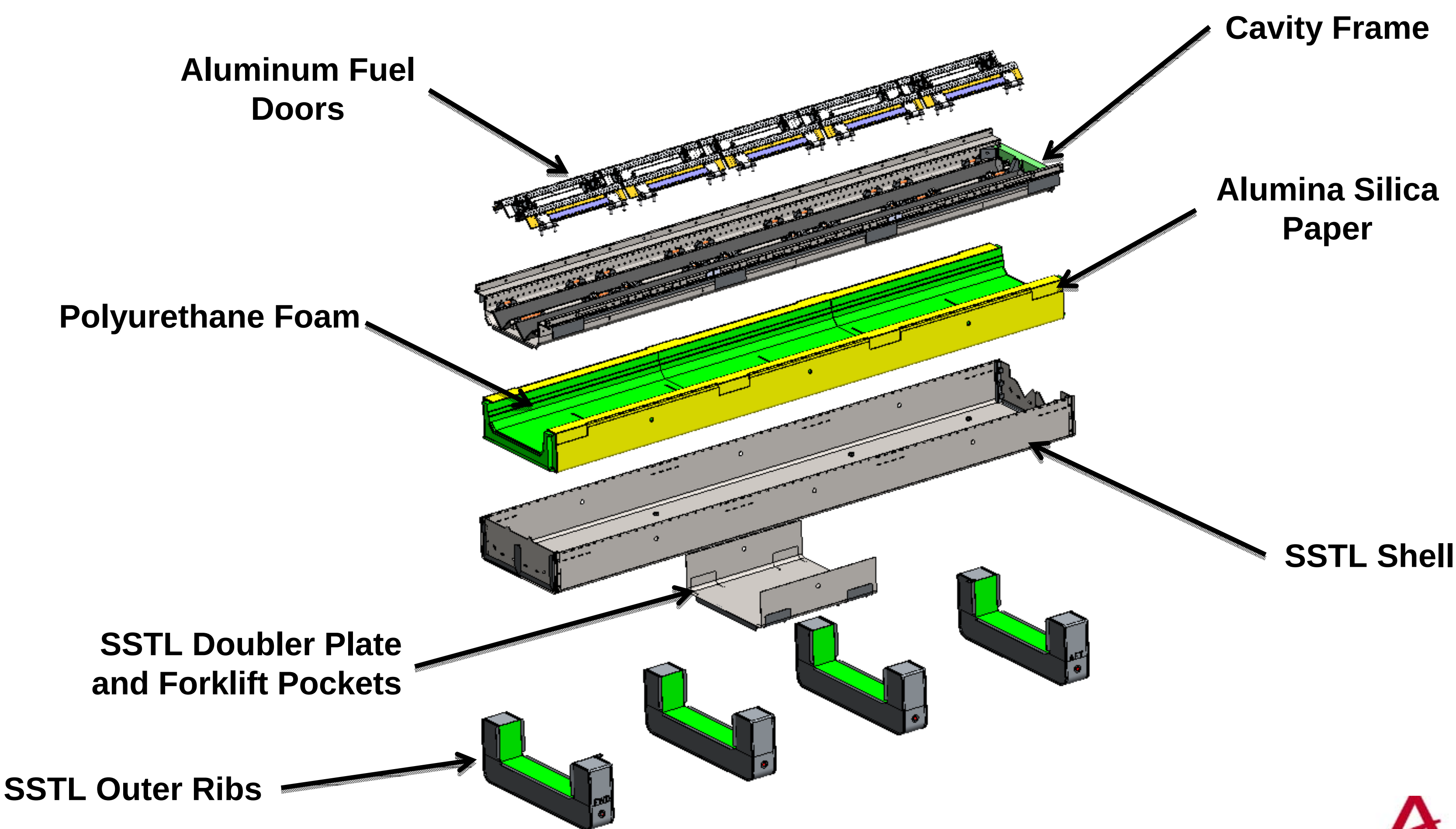
BMFP Design (con't)

- **Exploded View of Lid Assembly**



BMFP Design (con't)

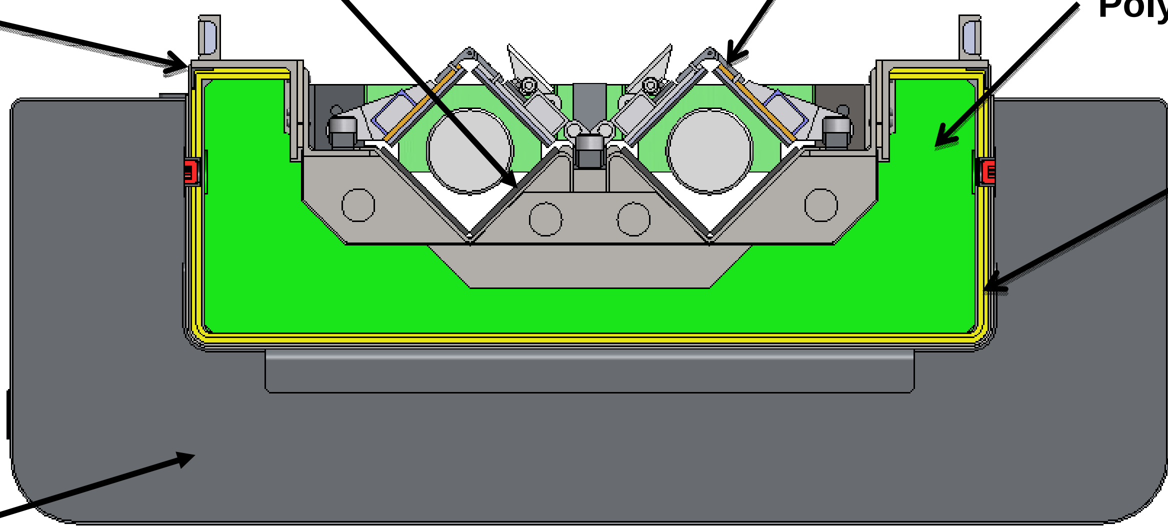
- **Exploded View of Base Assembly**



BMFP Design (con't)

▶ Fuel Cavity Details

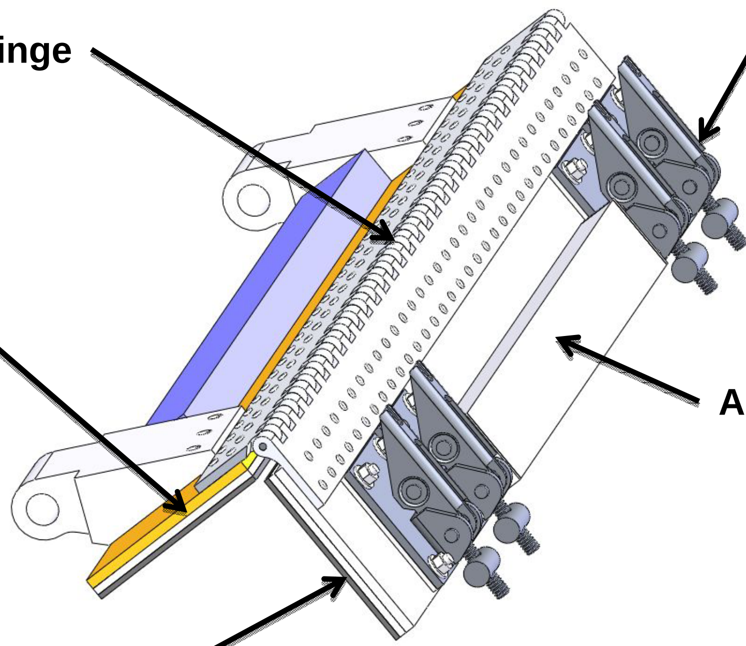
- Diagonal fuel cavity door provides structural support and constant pressure clamping
- Fuel assemblies clamped by door assemblies. Longitudinal clearance provided by grid strap thickness



BMFP Design (con't)

Fuel Door Details

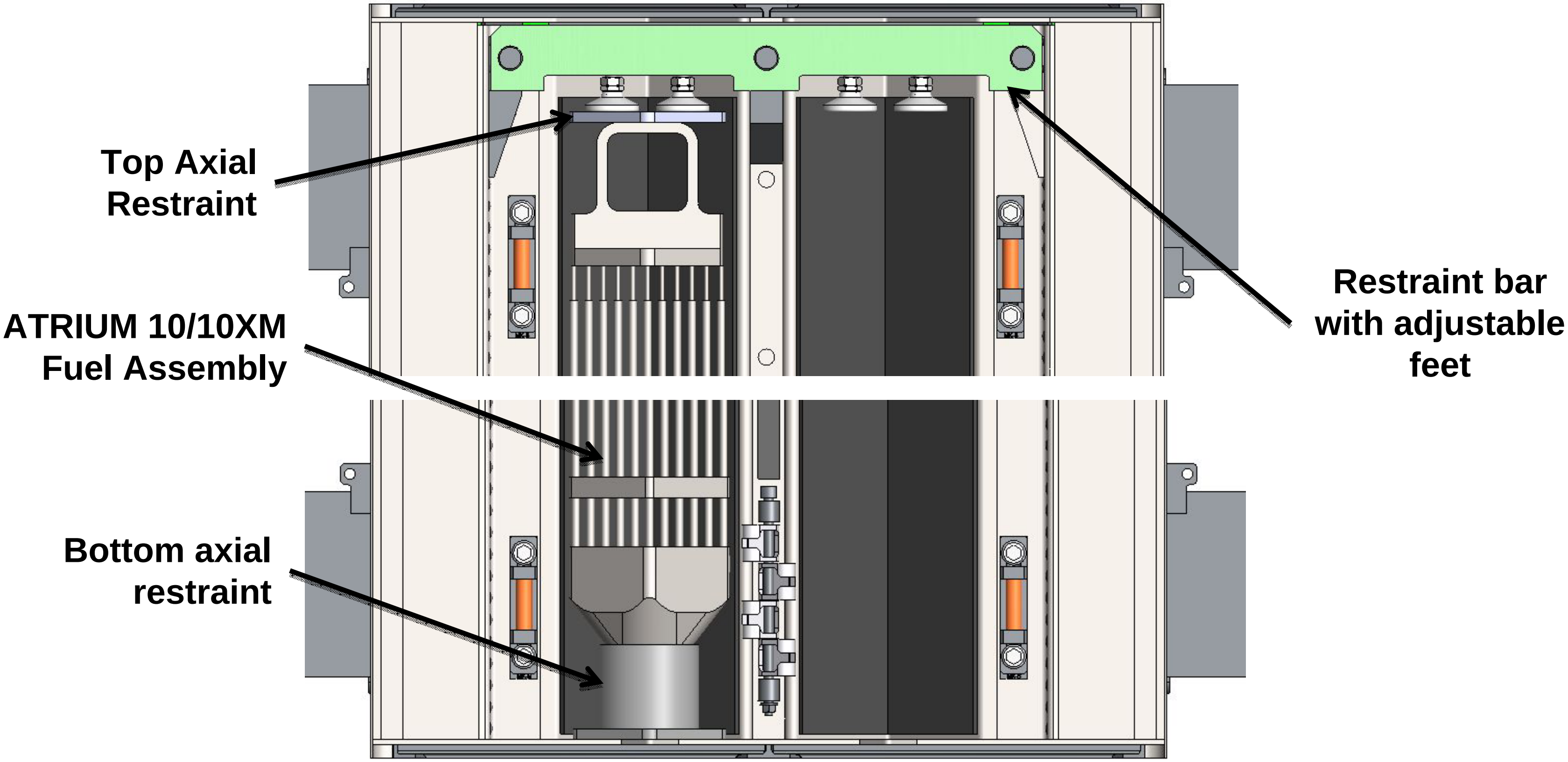
- Delrin® shims provide cavity size adjustment
- Five doors provide cavity closure down axial length of FA



BMFP Design (con't)

Fuel Interface Details

- **Axial restraints – Nylon Spacers at each end and adjustable feet at the top end of the fuel assembly**



Thermal Performance

- Fuel is designed for high temperature operation in the reactor with large margins of safety.
  - Fuel has been heated to failure and only has failed at temperatures over 800 °C (1,475 °F)
  - All packaging protects the fuel to below the 800 °C (1,475 °F) of the HAC thermal event
- For PWR package, thermal protection will protect both moderator and neutron poison material.

Certification Testing

- Engineer Test Units (ETUs) for each package design
  - Identify features that may need changing
  - Two full–sized packages to be tested to assist in determining worst–case free and puncture drop orientations for the FAs
  - (1) Prototypic FA and (1) dummy FA to be utilized
- Certification Test Units (CTUs) for each package design
  - Two full–sized packages that will be tested at the worst–case orientations
  - CTU with most severe free and puncture drop damage will be exposed to fire per 10 CFR §71.73(c)(4)
  - Verification of leaktight containment of prototypic FA performed after fire test

Certification Testing (cont.)

- **Currently Planning Certification Test Unit Fabrication**
  - **Road Tests and back–up should additional testing be required**
  - **Series of Free Drop and Puncture tests to be spaced over a minimum of two CTUs**
    - End Drops for attacking fuel rod containment
    - Slap down and side drops with puncture for determining maximum damage
    - Thermal (Fire) Test
      - PWR FA requires testing for protection of neutron poison and moderator
      - BWR FA has no neutron poison or moderator, but containment function will be demonstrated

Certification Testing (con't)

- **Certification Test program will be developed based on testing of the ETUs.**
- **Test Plan to be discussed with NRC prior to testing.**
- **Various Environmental Conditions will be considered to determine worst conditions.**

Demonstration of Fuel Cladding Integrity as Containment Boundary

- **Helium leakage rate testing of FAs both pre– and post–test**
  - **Fuel integrity and helium content verified at fabrication**
  - **Leakage rate testing of prototypic FAs using a vacuum chamber after HAC testing**
  - **Methodology currently being developed to detect and verify presence of helium**
    - Under both NCT & HAC, the containment boundaries (cladding) will be demonstrated to be "leaktight" in accordance with ANSI N14.5, i.e., 1×10^{-7} ref–cc/sec, air $\cong 2.7 \times 10^{-7}$ cc/sec, He.
    - Fuel rods will be tested to verify the presence of helium after HAC testing.

Demonstration of Fuel Cladding Integrity as Containment Boundary (cont.)

- **Leakage rate testing and verification methodology will be reviewed with NRC prior to certification testing.**
- **Certification testing will be conducted with simulated fuel assemblies using rods that are pressurized with helium, sealed, and leakage rate tested similar to actual fuel rods prior to testing.**
- **Fuel assemblies will be leakage rate tested post–HAC testing per ANSI N14.5.**

License Applications

- Separate applications will be submitted for the PMFP and BMFP designs
- Applications will be specific to MOX project fuel
- Applications will demonstrate compliance with all applicable 10 CFR 71 requirements
  - Compliance will be demonstrated primarily through physical testing of prototypic fuel assemblies
  - Design based on using the fuel cladding as containment

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Estimated Schedule

▶ ETU Testing	6 – 7 months
▶ CTU Testing	9 – 11 months
▶ Applications to the NRC	13 – 15 months
▶ Expected NRC approvals	16 – 18 months after Submittal

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