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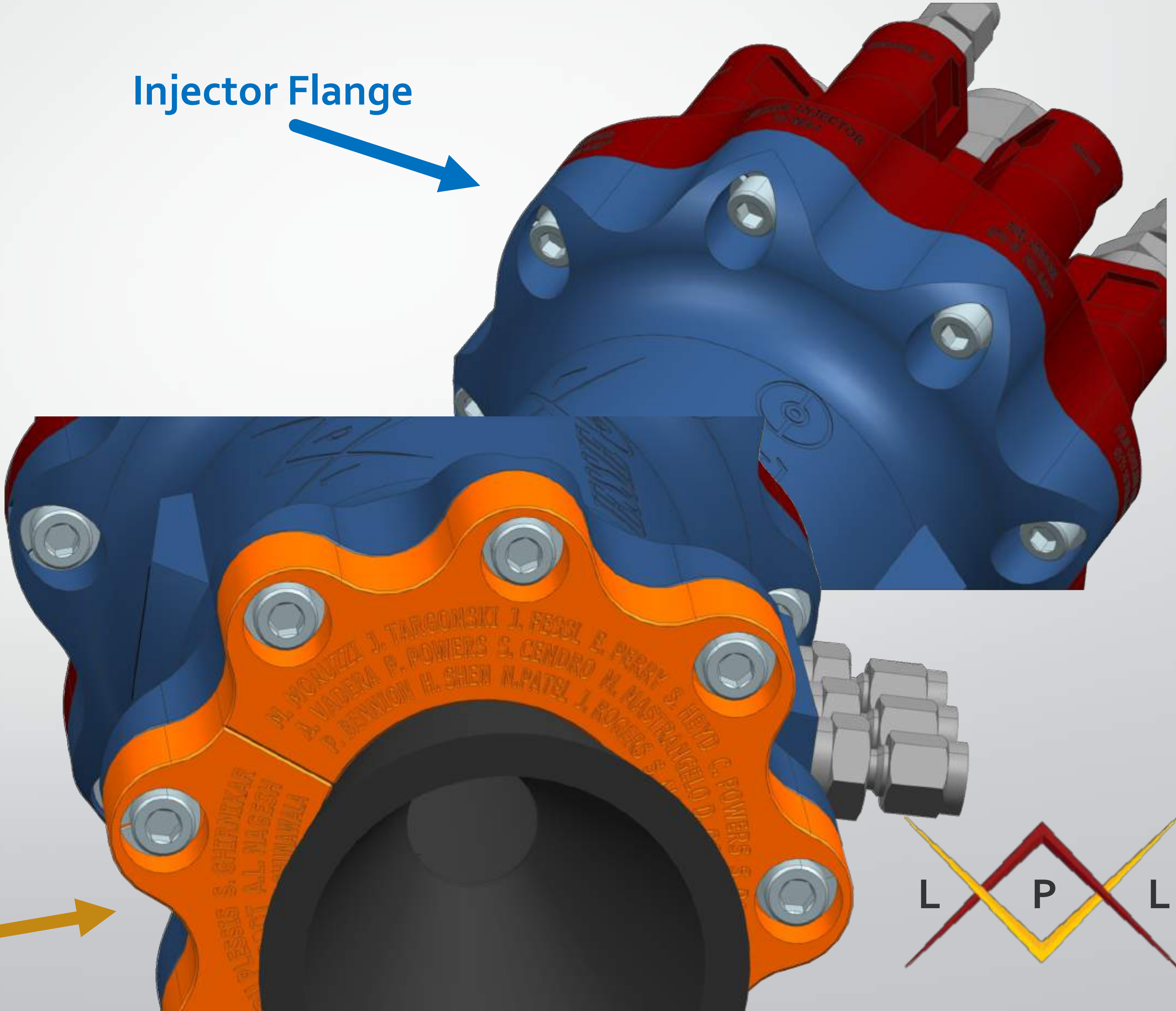
J&J Fasteners

J&J will feature a total of 16 ¼-28 5/8" fully threaded socket head screws

The first set of 8 will secure the injector to the chamber and the second set of 8 will secure the nozzle to the chamber with a 3D printed retention ring.

Injector Flange



Nozzle Retention Ring Flange

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J&J Fasteners & Washer Material Properties

Screws

Used for both retention ring and injector side
Type: ¼-28

Length: $\frac{3}{4}''$

Material: 18-8 Stainless Steel

(fully threaded socket head screw)

Tensile Area: 0.03640”

Ultimate Strength: 70 ksi

Young's Modulus: 28500 ksi

Lock washers

Used for both retention ring and injector side

18-8 Stainless Steel Mil. Spec. Split Lock Washer

ID: 0.260”

OD: 0.487"

Thickness: 0.062”

Ultimate Strength: 73.2 ksi

Young's Modulus: 28500 ksi

Yield Strength: 31.2 ksi

L P L

J&J Fasteners & Retention Ring Material Properties

Retention Ring, Injector, Chamber

Material: EOS Maraging Steel MS1

Yield Strength: 145 ksi (1000 MPa)

(in Z direction – lower then the XY direction)

Modulus of Elasticity: 22 Msi (150 Gpa)

(in Z direction – lower then the XY direction)

Keensert (Lightweight Insert)

Only Using on Retention Ring Side

Non-locking (Part # KN428J)

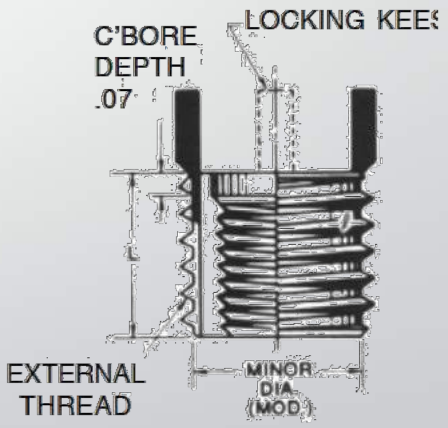
Internal Thread Class 3B ¼-28

Material: 303 CRES (passivated)

External Thread: 3/8 – 16

Shear Engagement: 0.2371"

L: 0.37"



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Screw Preload Force

$$Preload\ Force = 0.75\ (\sigma_{proof})A_t$$

Where $A_t = Tensile\ Area$

(0.75 is coefficient used for reusable screws)

$$Preload\ Force = 0.75\ (80\ ksi)0.0364in^2$$

$$\boldsymbol{Preload\ Force = 2184\ lbf\ (9.610\ kN)}$$

Screw Torque Equation

$$T = K_t F_i D$$

Where : T= torque (in-lb, ft-lb, or N-m)

K_t= torque coefficient (**0.15 lubed**)

F_i= Initial preload Force in the bolt

D= nominal diameter of bolt

$$T = (0.15)(2184)lbf(0.25)\text{in}$$

Torque Preload = 81.9 in-lbf (9.25 N-m)

For screws on both the injector and nozzle side

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Screw Stiffness

$$K_{screw} = \frac{A_t E_{screw}}{L_{joint}} \text{ (Fully Threaded screw)}$$

E_{bolt} = 28500 ksi

L_{joint} = 0.35 inch

$A_t = 0.0364 in^2$

$$K_{screw} = \frac{0.0364 in^2 \, 28500 \text{ ksi}}{0.35 \text{ inch}}$$

$$\boldsymbol{K_{screw}} = \textbf{2.964 Msi}$$

Joint Stiffness

$$K_{joint} = \frac{\pi E_{joint} d_{shank}}{2 ln\left(5\left(\frac{L_{joint} + 0.5 d_{shank}}{L_{joint} + 2.5 d_{shank}}\right)\right)}$$

E_{joint} = 22000 ksi (entirely marging steel)

$d_{shank} = 0.281$ inch

$$K_{joint} = \frac{\pi(22000E3)(0.281)}{2 ln\left(5\left(\frac{0.35 + (0.5)(0.281)}{0.35 + (2.5)(0.281)}\right)\right)}$$

$$\boldsymbol{K_{joint}} = \textbf{11.5 Msi}$$

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Joint coefficient of screw-load factor, C

$$C = \frac{k_{screw}}{k_{screw} + k_{joint}}$$

$$C = \frac{2.964\ Msi}{2.964\ \text{Msi} + 11.5\ Msi}$$

$$\boldsymbol{C} = \mathbf{0.20}$$

The required minimum preload to prevent gapping is then

$$F_i = P(1 - C)$$

Factor of Safety against gapping

$$FS_{gap} = \frac{F_i}{P(1 - C)}$$

Where P = load

Now need to determine the load on the joint for both ends of the engine…

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Fastening - Retention Ring Side

Determining Load on Fasteners

$$P_{Retention\ Ring} = (P_0)(A_c - A_t)$$

$$P_{Retention\ Ring} = (1000\ psi)(3.55in^2 - 0.466in^2)$$

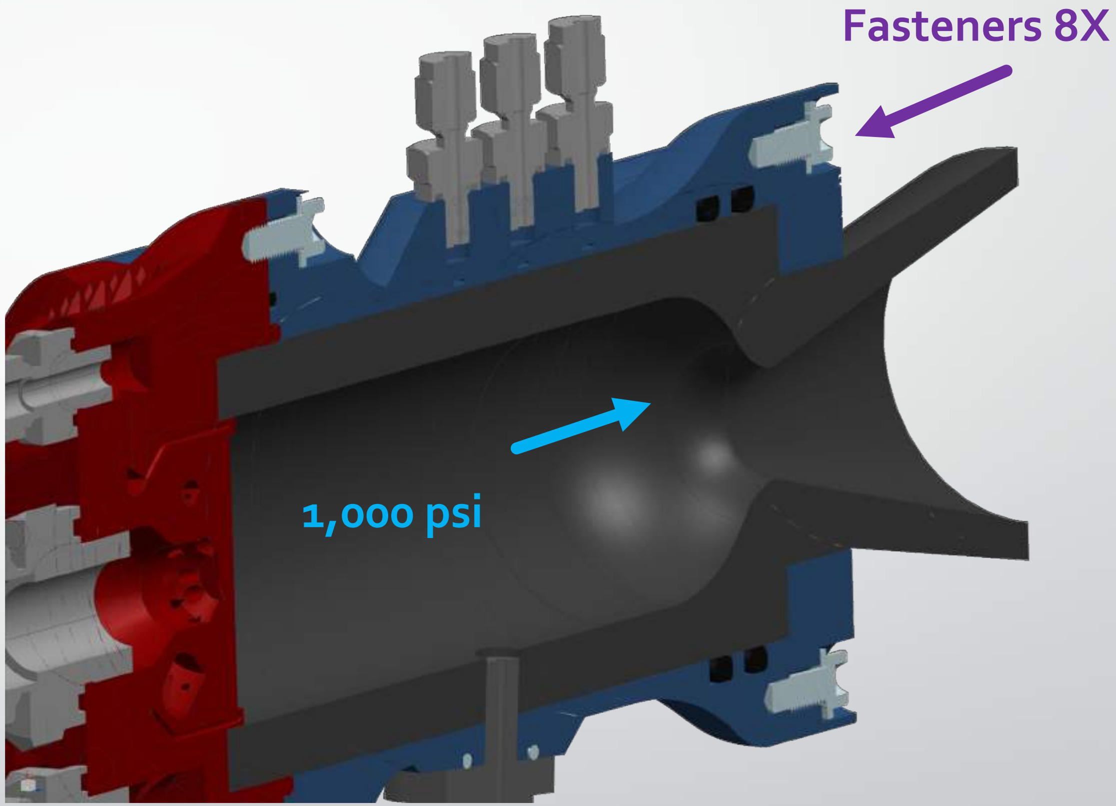
$$\boldsymbol{P_{Retention\ Ring}} = \textbf{3084 lbf}$$

$$P_{screw} = \frac{P_{Retention\ Ring}}{\#\ of\ Screws}$$

$$\#\ of\ Screws = 8$$

$$P_{screw} = \frac{3084\ \text{lbf}}{8}$$

$$\boldsymbol{P_{screw} = 385.5\ lbf}$$



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Fastening - Retention Ring Side

$$\sigma_{screw} = \frac{P_{screw}}{Tensile\ Area}$$

$$\sigma_{screw} = \frac{385.5\ lbf}{0.0364 in^2}$$

$\boldsymbol{\sigma_{screw}}$ **= 10.6 ksi**

$$FS = \frac{\sigma_{ult}}{\sigma_{screw}}$$

$$FS = \frac{80\ ksi}{10.6\ ksi}$$

$$\boldsymbol{FS = 7.55}$$

Failure in tension is NOT predicted!

The required minimum preload to prevent gapping is then

$F_{i,min} = P(1 - C)$ = 385.5 lbf (1-0.20)

$F_{i,min}$ = 308 lbf

$\boldsymbol{Preload\ Force = 2184\ lbf}$ ✓

Factor of Safety against gapping

$$FS_{gap} = \frac{F_i}{P(1 - C)} = \frac{2184\ lbf}{385.5\ lbf(1-0.20)}$$

$\boldsymbol{FS_{gap}}$ **= 7.08**

Gapping is NOT predicted!

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Fastening - Injector Side

Determining Load on Fasteners

$$P_{Injector} = (P_0)(A_c)$$

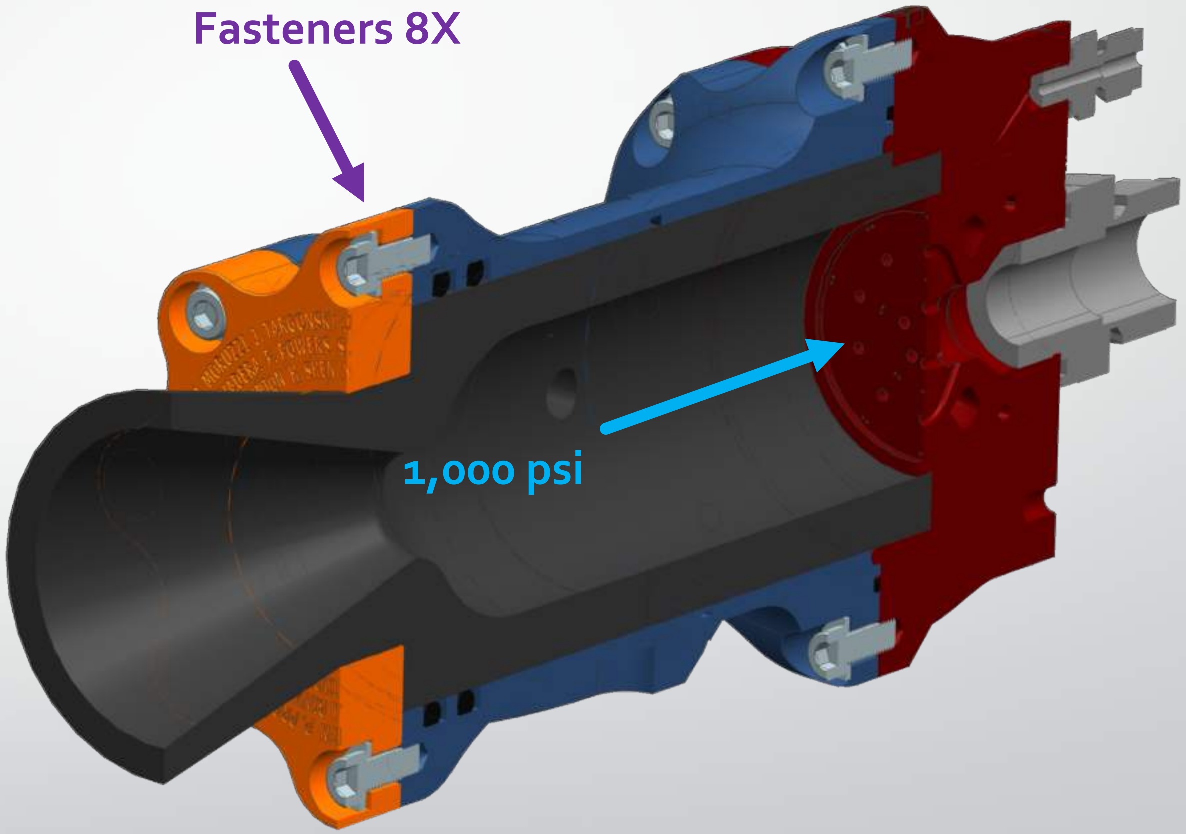
$$P_{Injector} = (1000\ psi)(3.55 in^2)$$

$$\boldsymbol{P_{Injector}} = \mathbf{3550\ lbf}$$

$$\#\ of\ Screws = 8$$

$$P_{screw} = \frac{3550\ \text{lbf}}{8}$$

$$\boldsymbol{P_{screw} = 444\ lbf}$$



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Fastening – Injector Side

$$\sigma_{screw} = \frac{P_{screw}}{Tensile\ Area}$$

$$\sigma_{screw} = \frac{444\ lbf}{0.0364 in^2}$$

$\boldsymbol{\sigma_{screw}}$ = **12.2 ksi**

$$FS = \frac{80\ ksi}{12.2\ ksi}$$

$$\boldsymbol{FS = 6.56}$$

Failure in tension is NOT predicted!

The required minimum preload to prevent gapping is then

$F_{i,min} = P(1 - C)$ = $444\ lbf$(1-0.20)

$F_{i,min} =$ 355 lbf

$\boldsymbol{Preload\ Force = 2184\ lbf}$ ✓

Factor of Safety against gapping

$$FS_{gap} = \frac{F_i}{P(1 - C)} = \frac{2184\ lbf}{444\ lbf(1-0.20)}$$

$\boldsymbol{FS_{gap}}$ = **6.15**

Gapping is NOT predicted!

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Checking Minimum Length of Engagement on Retention Ring Side, Not using Keenserts here

Minimum Screw Length of Engagement

$$L_{e,min} = \frac{(2)A_t}{K_n \max \pi\,(\frac{1}{2} + 0.5775n(E_s min - K_n \max\,)}$$

$$L_{e,min} = \frac{2(0.0364)}{(0.1857)\pi(\frac{1}{2} + 0.5775(28)(0.1904 - 0.1857)}$$

$\mathbf{L_{e,min}}$ = **0.217 inch**

Since different materials need to get the J value

$$J = \frac{A_s\sigma_{ult,ext}}{A_n\sigma_{ult,int}}$$

A_s = *Shear area of external thread (screw)*
A_n = *Shear area of internal thread (hole)*

If $J > 1$ then the minimum length of engagement needs to be extended to:

$$L_{e,min\,new} = J \times L_{e,min\,org}$$

$$A_s = \pi\, n\, L_{e,min} k_n \max(\frac{1}{2n} + 0.57735(E_s \min - k_n \max\,))$$

$k_n \max$ = *Maximum minor diameter of internal thread*

$E_s \min$ = *Minimum pitch diameter of external thread*

n = *number of threads per inch*

$$A_s = \pi\,(28)\,(0.217)(0.1857)(\frac{1}{2(28)} + 0.57735(0.1904 - 0.1857\,))$$

A_s = *0.073 in²*

$$A_n = \pi\, n\, L_{e,min} D_s \min(\frac{1}{2n} + 0.57735(D_s \min - E_n \max\,))$$

$E_n \max$ = *Maximum pitch diameter of internal thread*

$D_s \min$ = *Minimum major diameter of external thread*

$$A_n = \pi\,(28)(0.217)(0.2095)(\frac{1}{2(28)} + 0.57735(0.2095 - 0.1959))$$

A_n = *0.103 inch²*

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Checking Minimum Length of Engagement on Retention Ring Side, Not using Keenserts here

Minimum Screw Length of Engagement cont.

Since different materials need to get the J value

$$J = \frac{(0.073\ in^2)(70\ ksi)}{(0.103\ in^2)(145 ksi)}$$

$J = 0.34$

Since J < 1:

$L_{e,min} = 0.217$ inch

Our length of Engagement On Retention Ring Side:

Length of Thread Engagment

$$L_e = L_{screw} - (t_{retention_{ring}} - d_{counter\ bore}) - t_{washer}$$

$$L_e = 0.75'' - (0.75'' - 0.4'') - 0.062''$$

$$L_e = 0.338''$$

On retention ring side both internal and external threads are NOT predicted to fail!

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Using Keenserts on Injector Side

Insert Internal Thread Failure Check

$$A_s = \frac{3\pi L_e D_{major,ext}}{4}$$

Where $A_s = Thread\ Shear\ Area$

$L_e = Length\ of\ Thread\ Engagment$

$D_{major,ext} = Major\ Diameter\ of\ the\ mating\ external\ thread$

$$A_s = \frac{3\pi(0.338)(0.375)}{4}$$

$$A_s = 0.30\ in^2$$

Insert Internal Thread Failure Check

$P_{ult} = 12370\ lb$ (MS51830E-202L)

$$FS_{shear\ thread\ failure} = \frac{P_{ult}}{P_{joint}}$$

For Injector Side

$$FS_{shear\ thread\ failure} = \frac{12370\ lbf}{444\ \ lbf}$$

$FS_{shear\ thread\ failure}$ =27.9

Insert Internal Thread Failure is NOT predicted!

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Using Keenserts on Injector Side

Insert External Thread Failure Check

$P_{ult} = 8630\ lb$ (MS51830E-202L)

$A_s = 0.30\ in^2$

For injector side

$$FS_{shear\ thread\ failure} = \frac{8630\ lbf}{444\ lbf}$$

$FS_{shear\ thread\ failure}$ =19.4

Insert External Thread Failure is NOT predicted!

Insert Parent Material Thread Failure Check

$P_{ult} = (\mathbf{0.103\ in^2})(\mathbf{145ksi})$

$P_{ult} =$ 14,935 lbf

For injector side

$$FS_{shear\ thread\ failure} = \frac{14935\ lbf}{444\ lbf}$$

$FS_{shear\ thread\ failure}$ =33.6

Insert Parent Material Thread Failure is NOT predicted!

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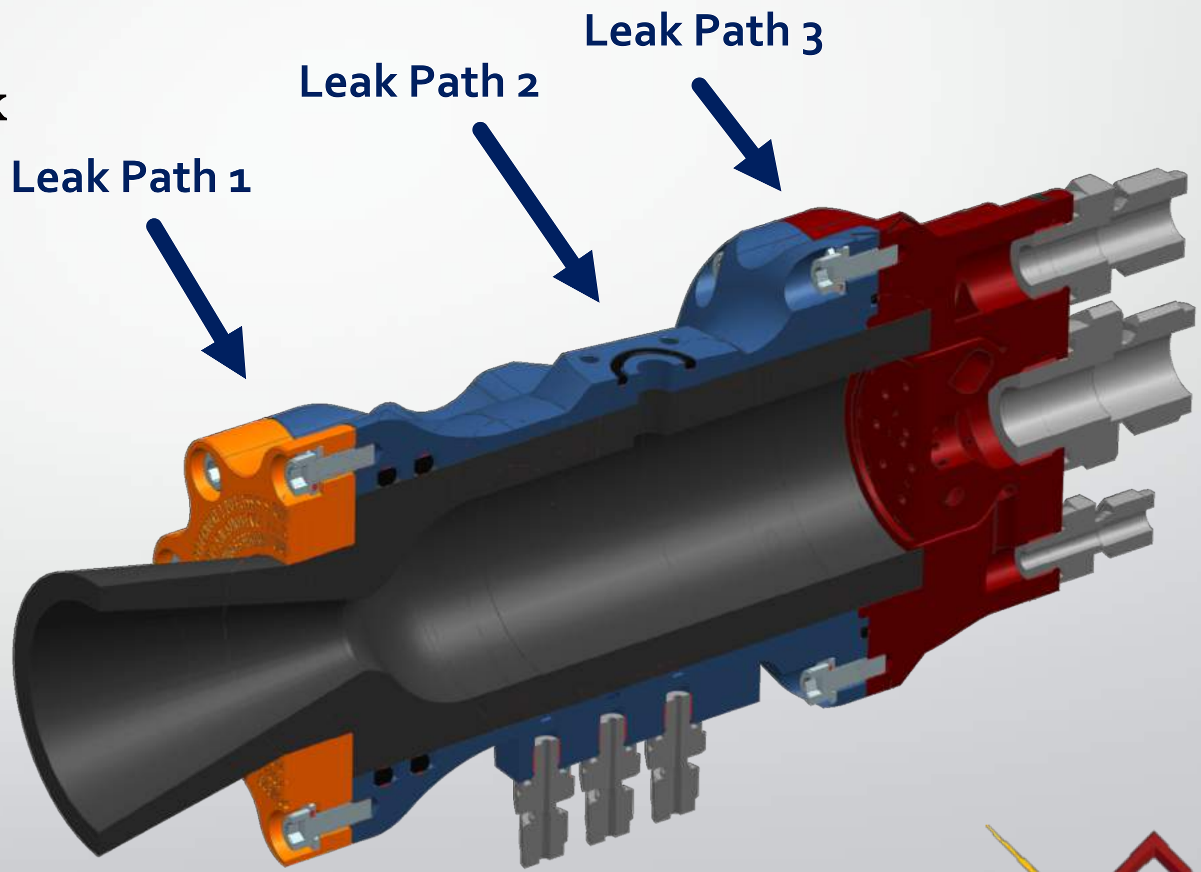
Sealing Features

Jessie & James each have 3 potential leak paths

1. *Nozzle & Chamber interface*
2. *Ignitor & Chamber interface*
3. *Injector & Chamber interface*



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Sealing Features

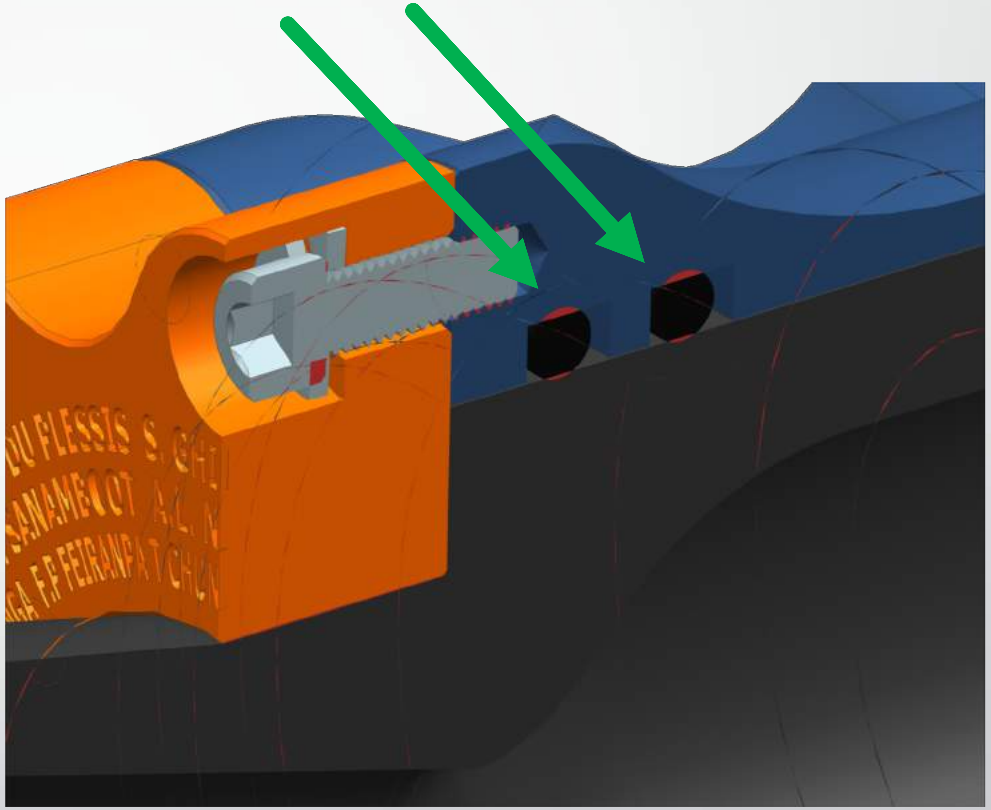
Nozzle & Chamber interface

Will feature two female gland piston seals

Two for redundant purposes, fine surface finish on nozzle may be hard to achieve

Multiple nozzles will be printed during Jessie & James lifetime, so O-ring groove has been placed on chamber side (less machining)

2 Female Gland Piston Seals



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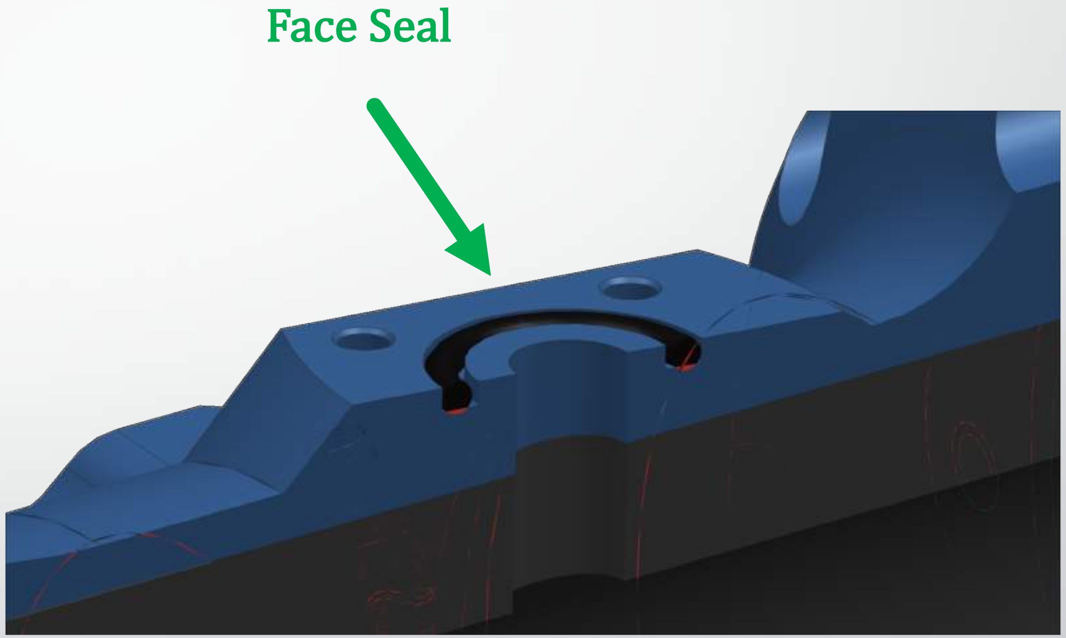
Sealing Features

Ignitor & Chamber interface

Will Feature a Face Seal

Because it is more likely to print future iterations of the ignitor, the O-ring groove has been placed on the chamber side (less machining labor)



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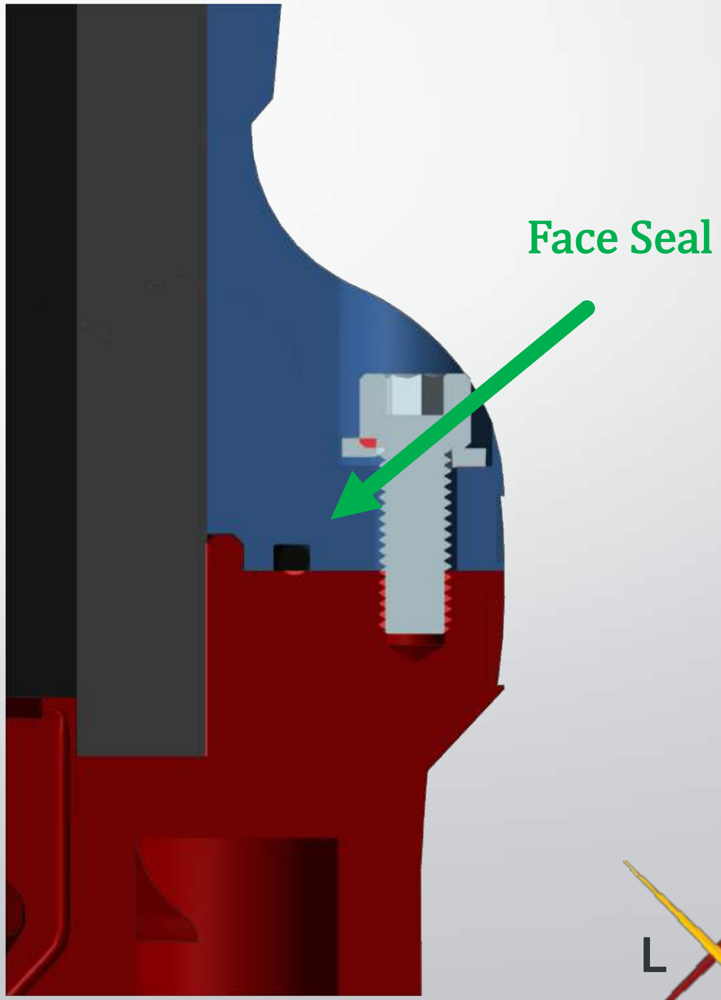
Sealing Features

Injector & Chamber interface

Will Feature a Face Seal

Because it is more likely to print future iterations of the injector, the O-ring groove has been placed on the chamber side (less machining)



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Injector-Chamber

Face Seal O-ring

Dash Number 153

Qty: 1

Size: 3/32”

Material : Viton

Nozzle-Chamber

Piston Seal O-rings

Dash Number 337

Qty: 2

Size: 3/16”

Material Viton

Ignitor-Chamber

Face Seal O-ring

Dash Number 115

Qty: 1

Size: 3/32”

Material : Viton