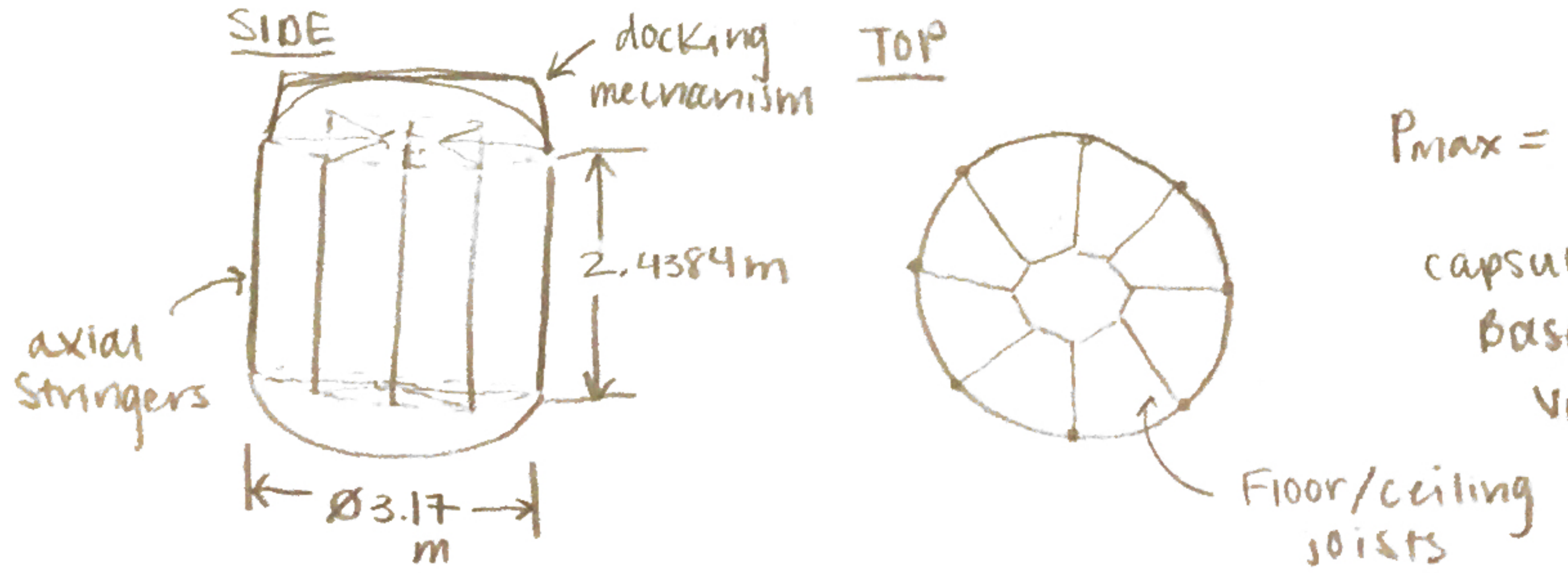
Preliminary Design

Crew capsule



$P_{max} = 14.7\ psi = 101353\ Pa$

capsule height & diameter calculated based on habitable & pressurized volume requirements

For 2000 series Aluminum Alloys:

$\sigma_y = 290 \cdot 10^6\ Pa$

with SF = 1.4 (According to NASA-STD-5001A) $\rightarrow \sigma_{allow} = 207.14 \cdot 10^6\ Pa$

$$\sigma_{hoop} = \frac{pd}{2t} \rightarrow t = \frac{pd}{2\sigma}$$

$$t_{min} = \frac{(101353)(3.17)}{2(207.14 \cdot 10^6)} = \boxed{7.755 \cdot 10^{-4}\ m} = 0.7755\ mm$$

Axial stringers

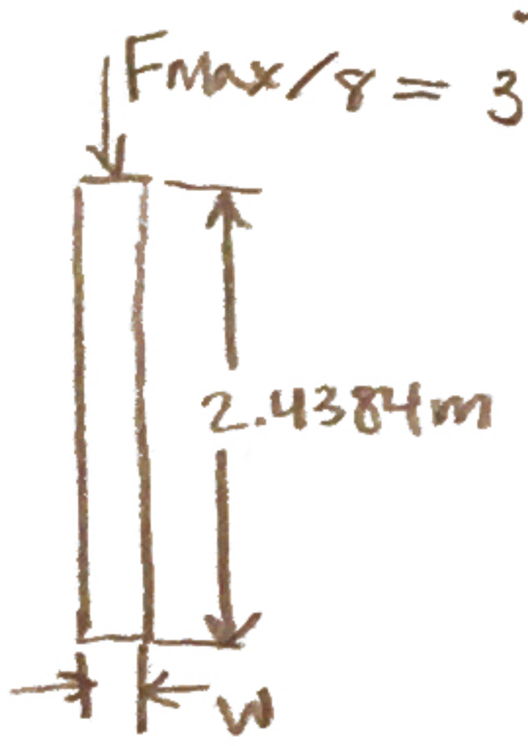
max acceleration during SLS launch $= 5g = 49.05\ m/s^2$

Mass docking mechanism = 200 kg

Mass Avionics & wiring = 438.7 kg (estimated based on maximum mass of passive common berthing mechanism used on ISS)

$M_{tot} = 492.47\ kg \rightarrow F_{max} = \underline{24155.5\ N}$

Assume 2/3 m wiring & avionics in ceiling



*note: stringers will also experience point moments & shear forces from other attatchments. For preliminary design these are accounted for by using a SF of 5.0 *

Buckling

$$P_{crit} = \frac{\pi^2 E I}{(KL)^2} = \frac{\pi^2 E w^3 L}{12 (KL)^2} \rightarrow w = \sqrt[3]{\frac{12 F (KL)^2}{\pi^2 E L}}$$

$E = 72 \cdot 10^9\ Pa$, $K = 1$ (Fixed-Fixed ends)

$$w = \sqrt[3]{\frac{12(3019.4)(5.0)(2.4384)^2}{\pi^2 (72 \cdot 10^9)(2.4384)}} = \boxed{0.008535\ m} = 8.535\ mm$$

Ascent Stage (all mass estimates from preliminary design mass budget)

LOX tank

$m_{LOX} = 5925.3$ kg

$\rho_{LOX} = 1141$ kg/m^3

$V_{LOX} = 4.383$ m^3 — cylinder w/ elliptical end caps

$d = 3.17$ h = cylinder height , $c = \frac{1}{2}h$ = "height radius" of ellipsoid

$a = b = d/2$ (major & minor radius)

$$V = \frac{4}{3}\pi\left(\frac{d}{2}\right)^2\left(\frac{1}{2}h\right) + \frac{\pi}{4}d^2 h \rightarrow h = \frac{V}{\frac{4\pi}{6}\left(\frac{d}{2}\right)^2 + \frac{\pi}{4}d^2}$$

LH_2 tank

$m_{LH2} = 1975$ kg

$\rho_{LH2} = 70.8$ kg/m^3 $V_{LH2} = \frac{m_{LH2}}{\rho_{LH2}}$ Assume end cap height $= \frac{1}{3}h$

$$h = \frac{V_{LH2}}{\left(\frac{4\pi}{9}\right)\left(\frac{3.17}{2}\right)^2 + \frac{\pi}{4}(3.17)^2}$$

interstage/intertank structure

"truss"

$m_{capsule} = 5000$ kg

$F_{intertank} = 5000\,(5g)$

$F_{intertank}/8$

Descent stage

LOX tank

$m_{LOX} = 20330$ kg Assume end cap height $= \frac{1}{4}h$

$\rho_{LOX} = 1141$ kg/m^3

$V_{LOX} = \frac{m}{\rho}$

$$h = \frac{V_{LOX}}{\frac{4\pi}{12}\left(\frac{3.17}{2}\right)^2 + \frac{\pi}{4}(3.17^2)}$$

CH_4 tank

$m_{CH4} = 6777$ kg

$\rho_{CH4} = 430$ kg/m^3 Assume end cap height: $\frac{1}{3}h$

$$h = \frac{V_{CH4}}{\left(\frac{4\pi}{9}\right)\left(\frac{3.17}{2}\right)^2 + \frac{\pi}{4}(3.17)^2}$$