Aerospace Design:
A Purely Digital Affair

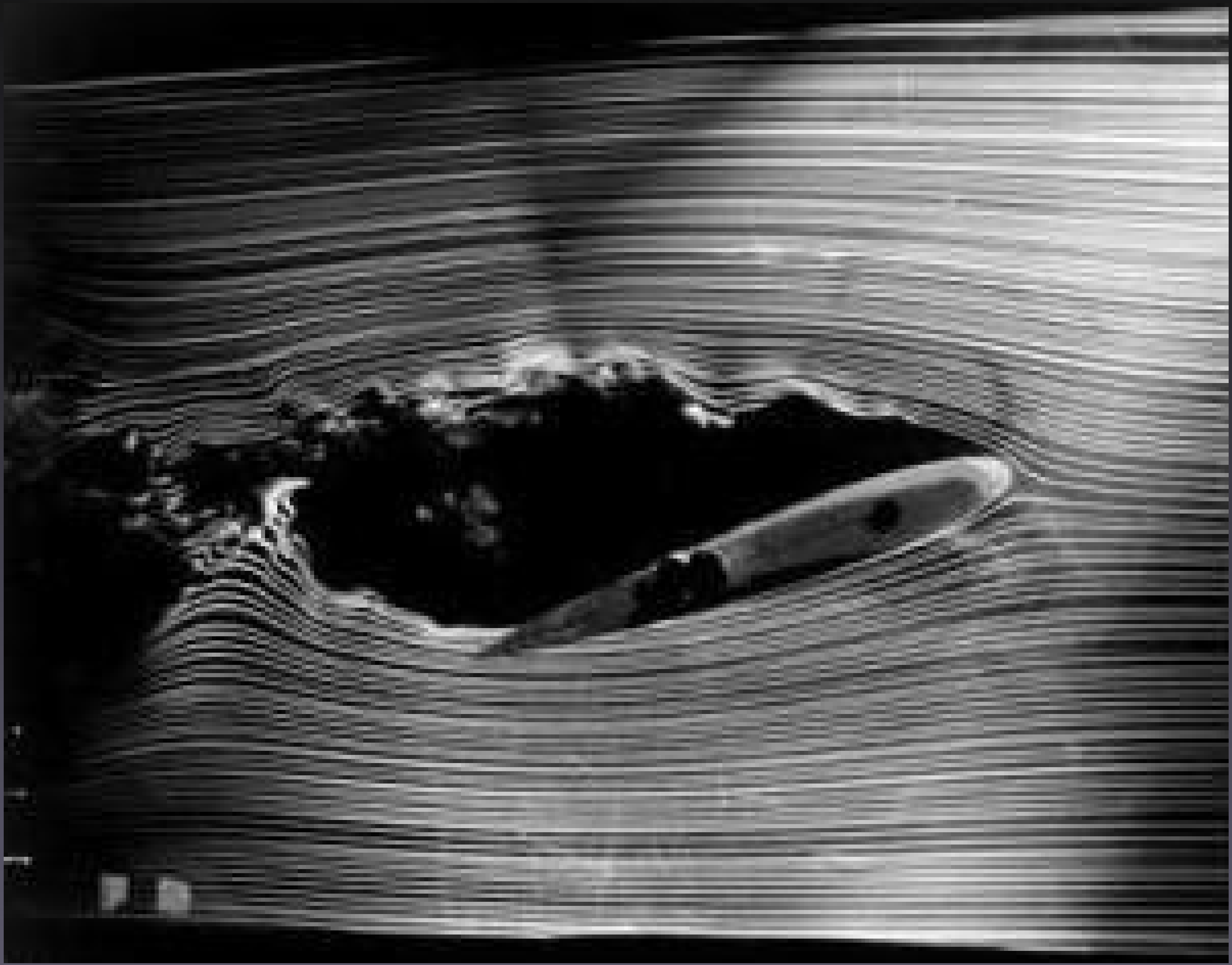
Ben Keller

Physics 715 Final Project

Build a Better Air Trap

- Can an airfoil placed in a square duct improve the flow qualities through that duct?

How Do I Test This?



$$\frac{Du}{Dt} = -\nabla P + \frac{\nu}{UL} \nabla^2 u$$

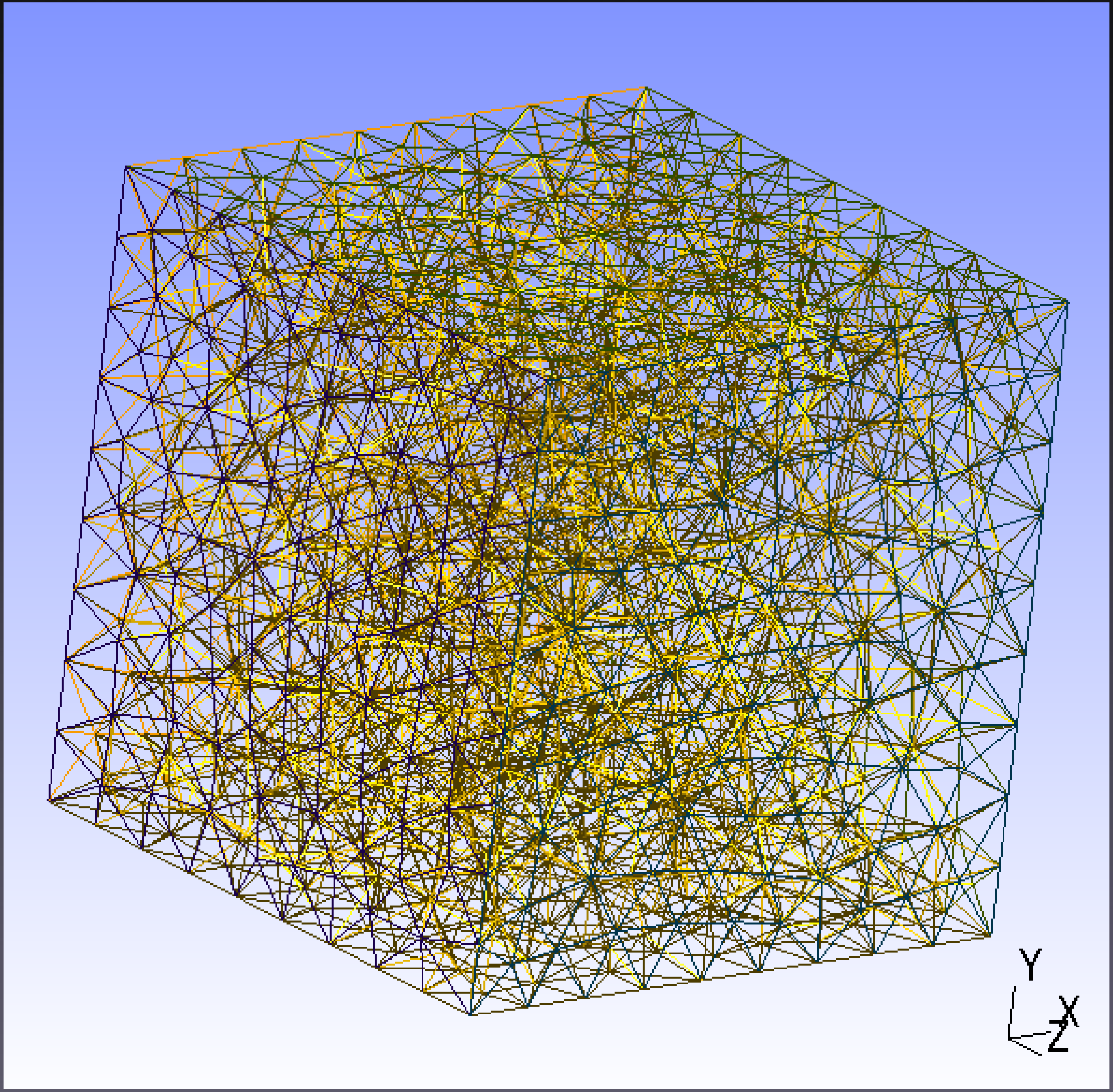
Computers are Discrete!

$$\Phi = physical\ properties$$

$$\Phi^{n+1} = 2\Phi^{n} - \Phi^{n-1}$$

$$\frac{\rho}{\Delta t}\left(f^{n+1} - f^{n}\right) + \nabla\cdot\left(\left(\rho\vec{u}\right)f^{n+1}\right) - \nabla\cdot\left(K\nabla f^{n+1}\right) = .$$

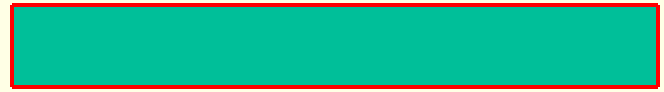
$$\left[S\left(\Phi\right)f\right]^{n+1} + \nabla\cdot\left(\rho\vec{u}\right)f^{n+1}$$


Y
X
Z

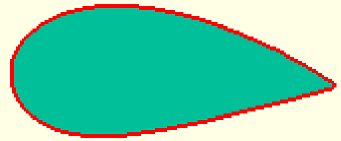
NACA Airfoils

- Name Format NACA MPTT
- M is 1st digit of maximum camber percentage
- P is 1st digit of maximum camber position
- TT is 1st & 2nd digit of maximum thickness percentage

Cylinder



NACA5440



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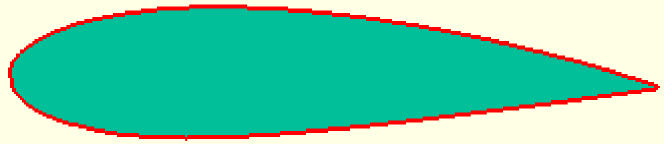
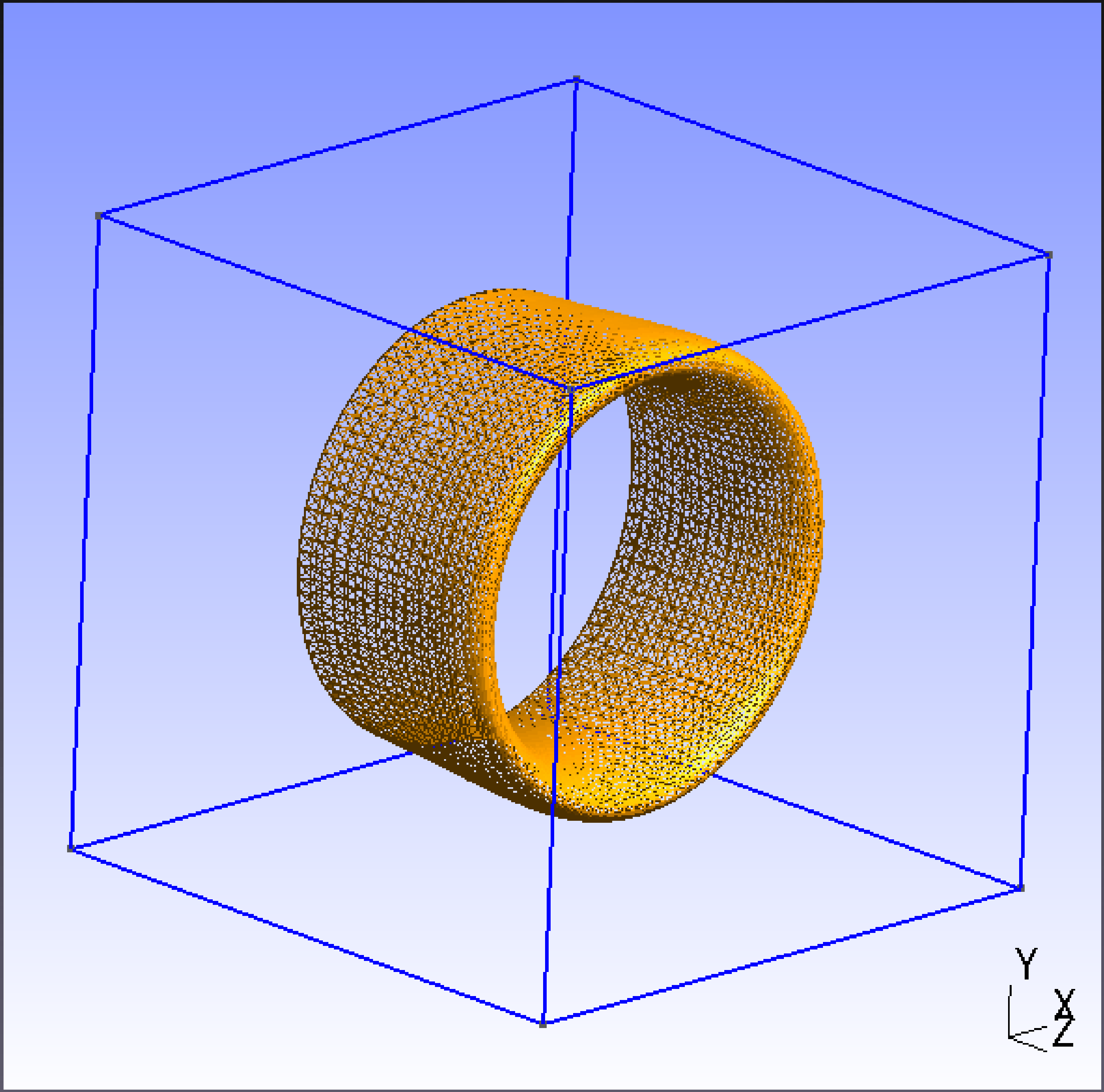


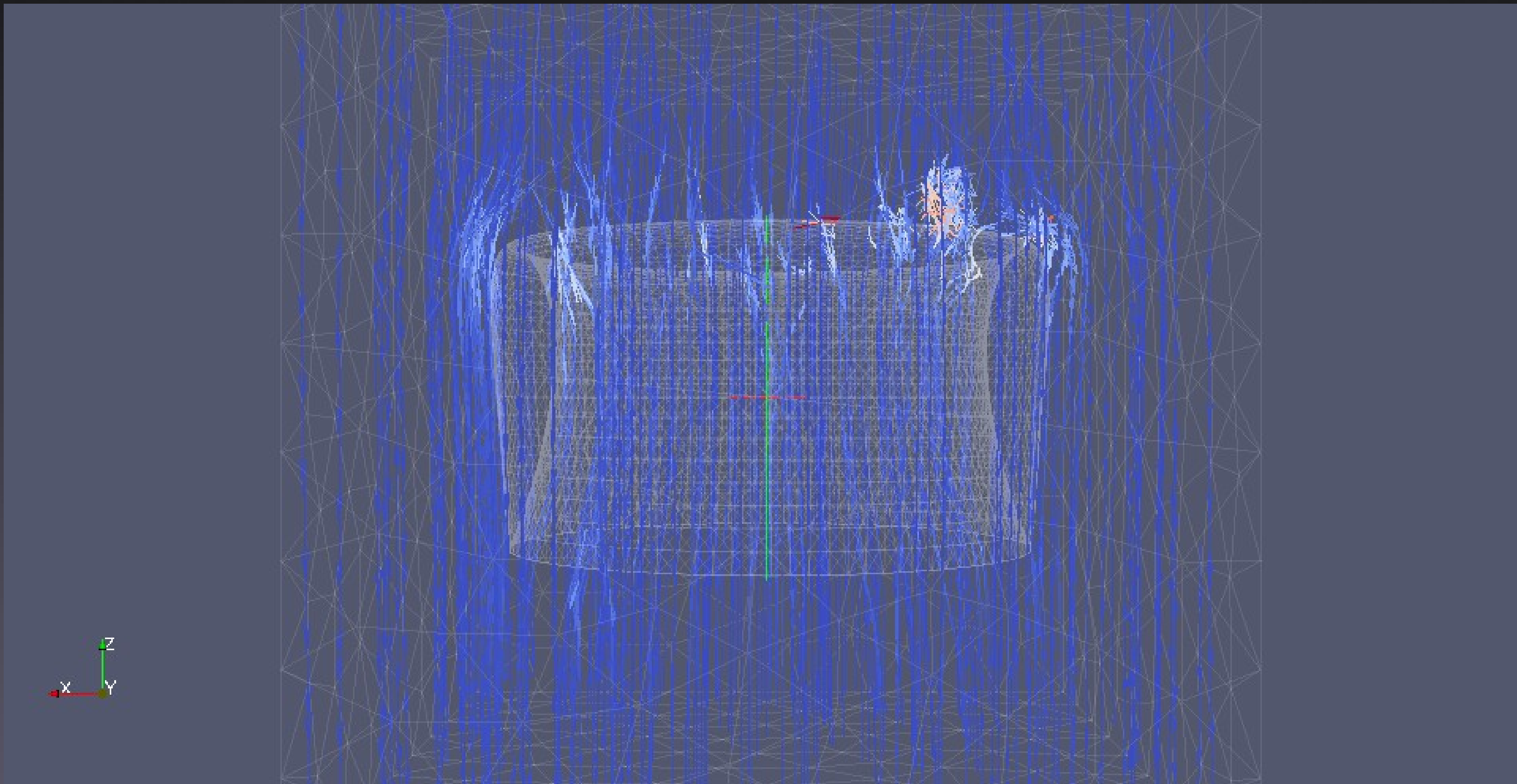
Turbulence Model

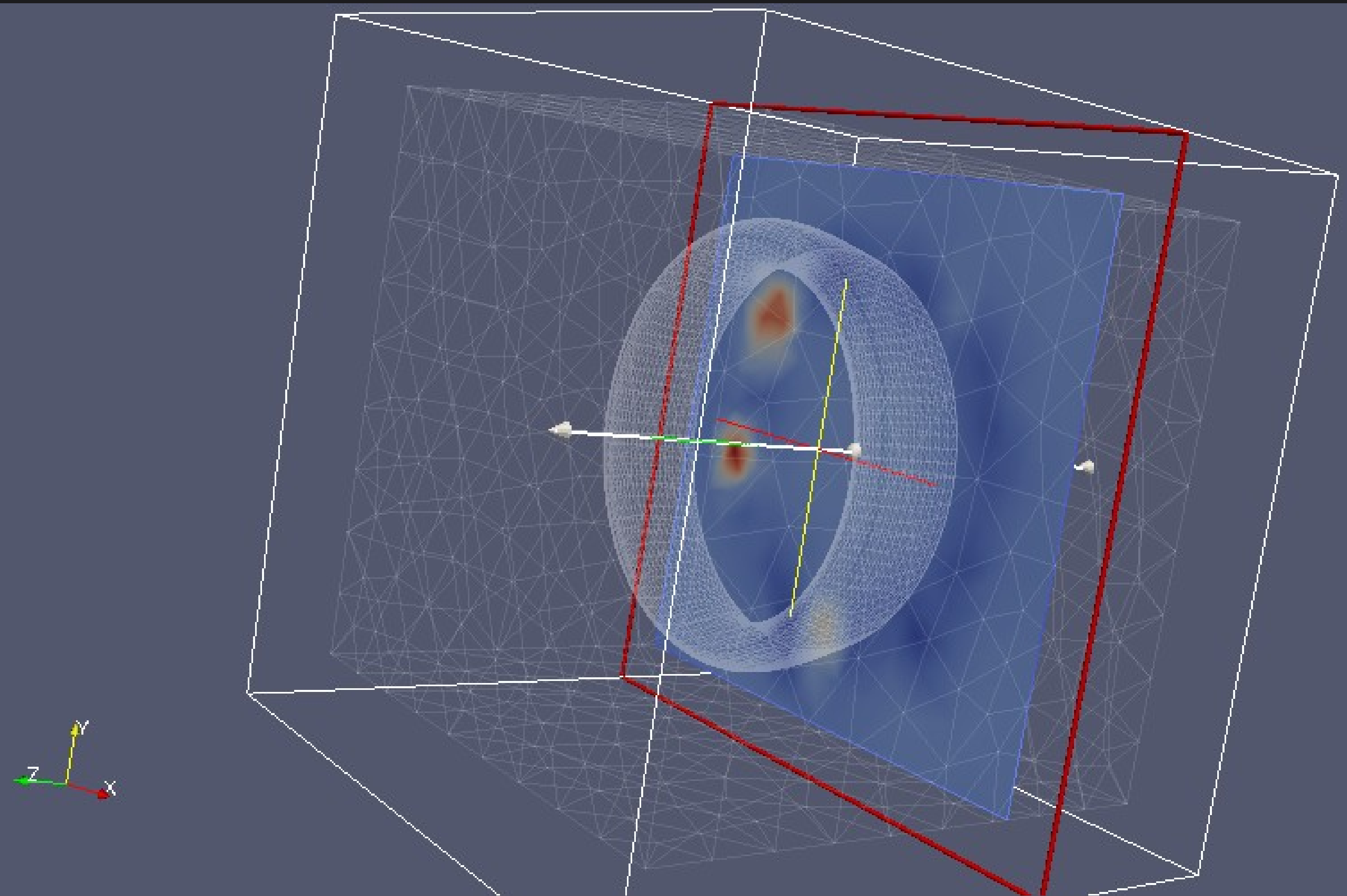
$$\frac{Dk}{Dt}=\left(\mu+0.009\left(\frac{k^2}{\epsilon}\right)\nabla k\right)+P-\rho\epsilon$$

$$\frac{D\epsilon}{Dt}=\left(\mu+0.007\left(\frac{k^2}{\epsilon}\right)\nabla\epsilon\right)+1.44\left(\frac{\epsilon}{k}\right)P-1.92\rho\left(\frac{\epsilon^2}{k}\right)$$

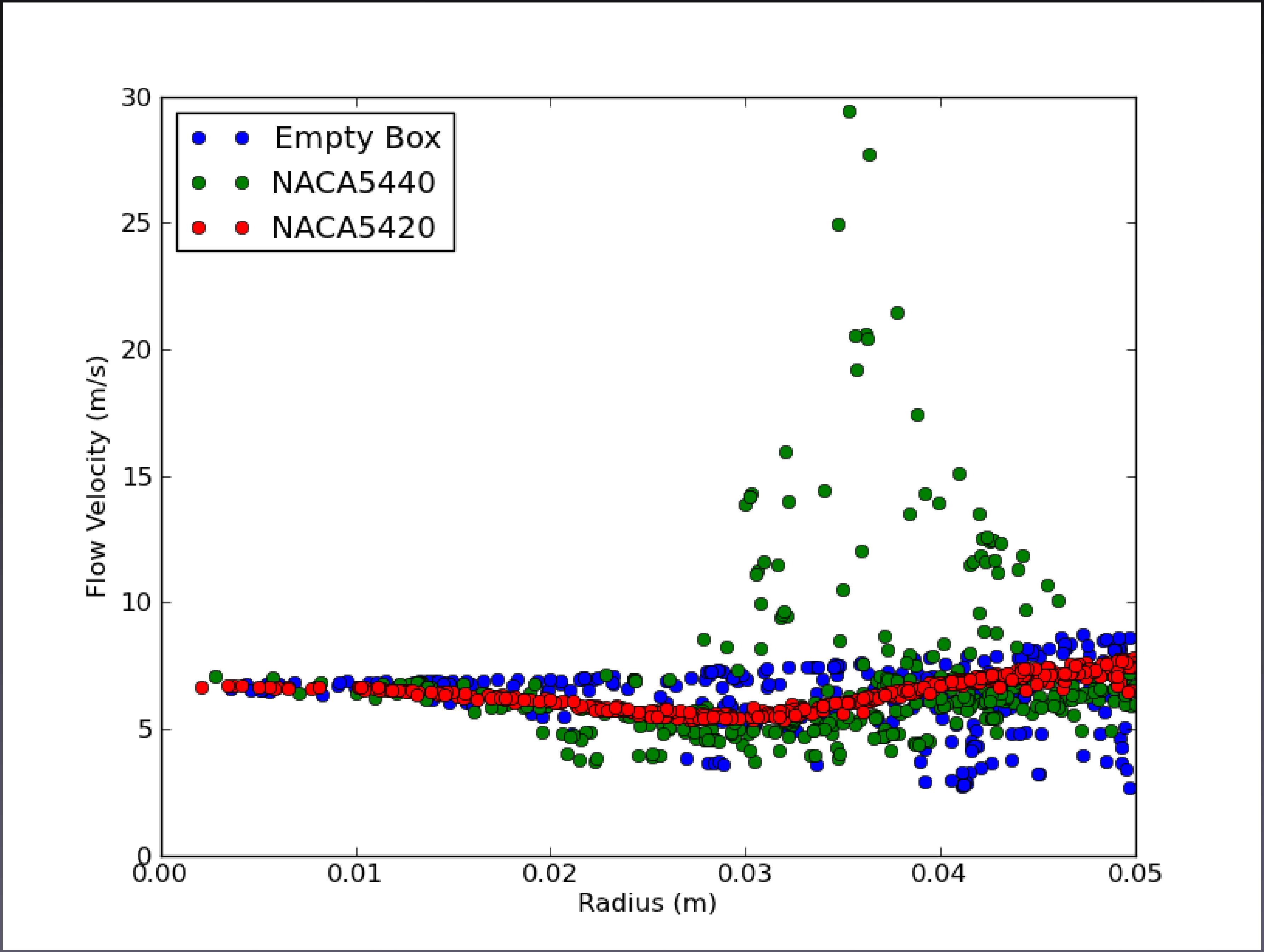
$$k=\left(\frac{1}{2}\right)R_{ij}\qquad P=\left(\frac{1}{2}\right)R_{ij}\frac{\partial u_i}{\partial x_j}\qquad \mu_t=0.009\rho\frac{k^2}{\epsilon}$$


Y
X
Z

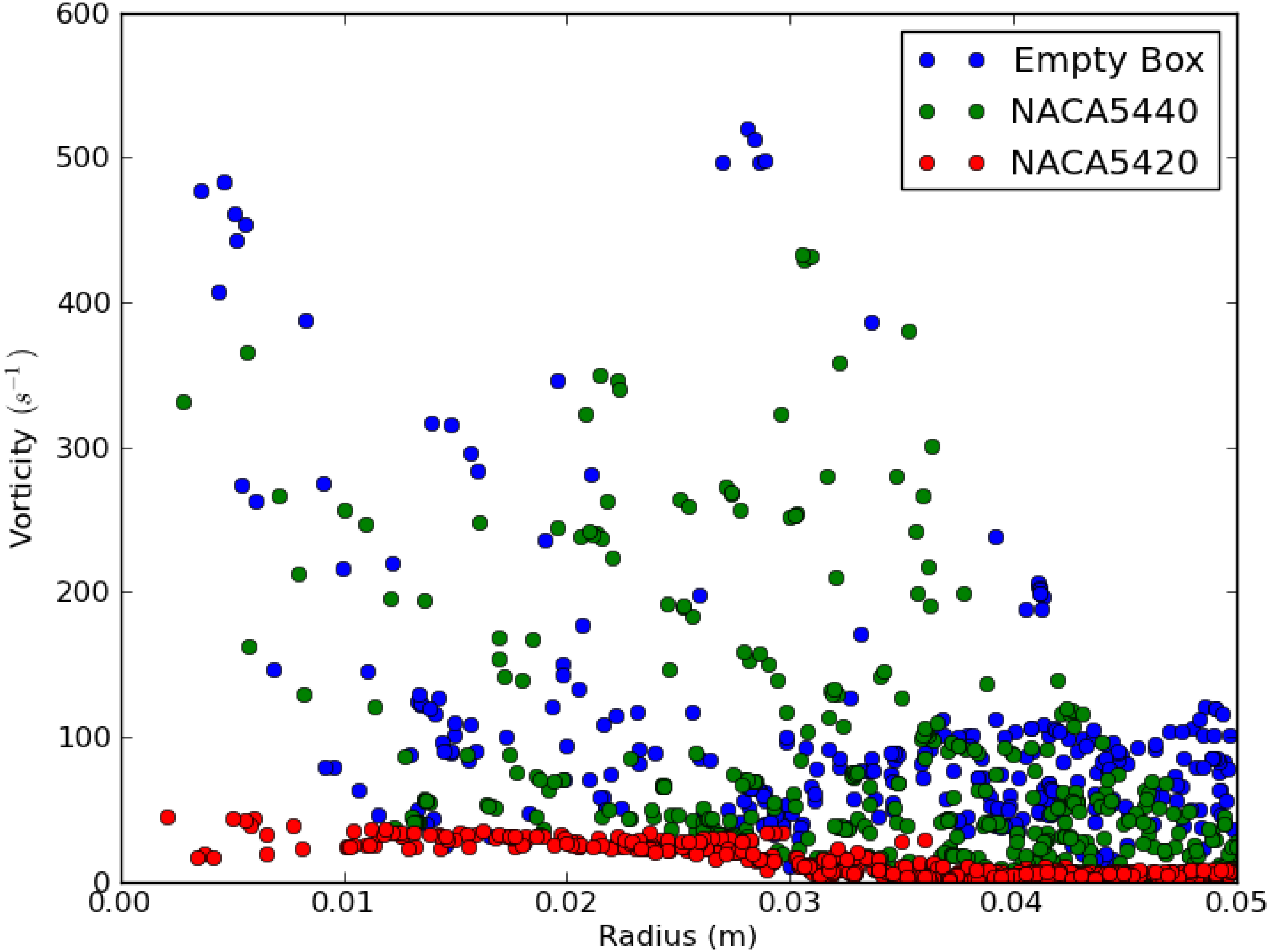

Z
X
Y



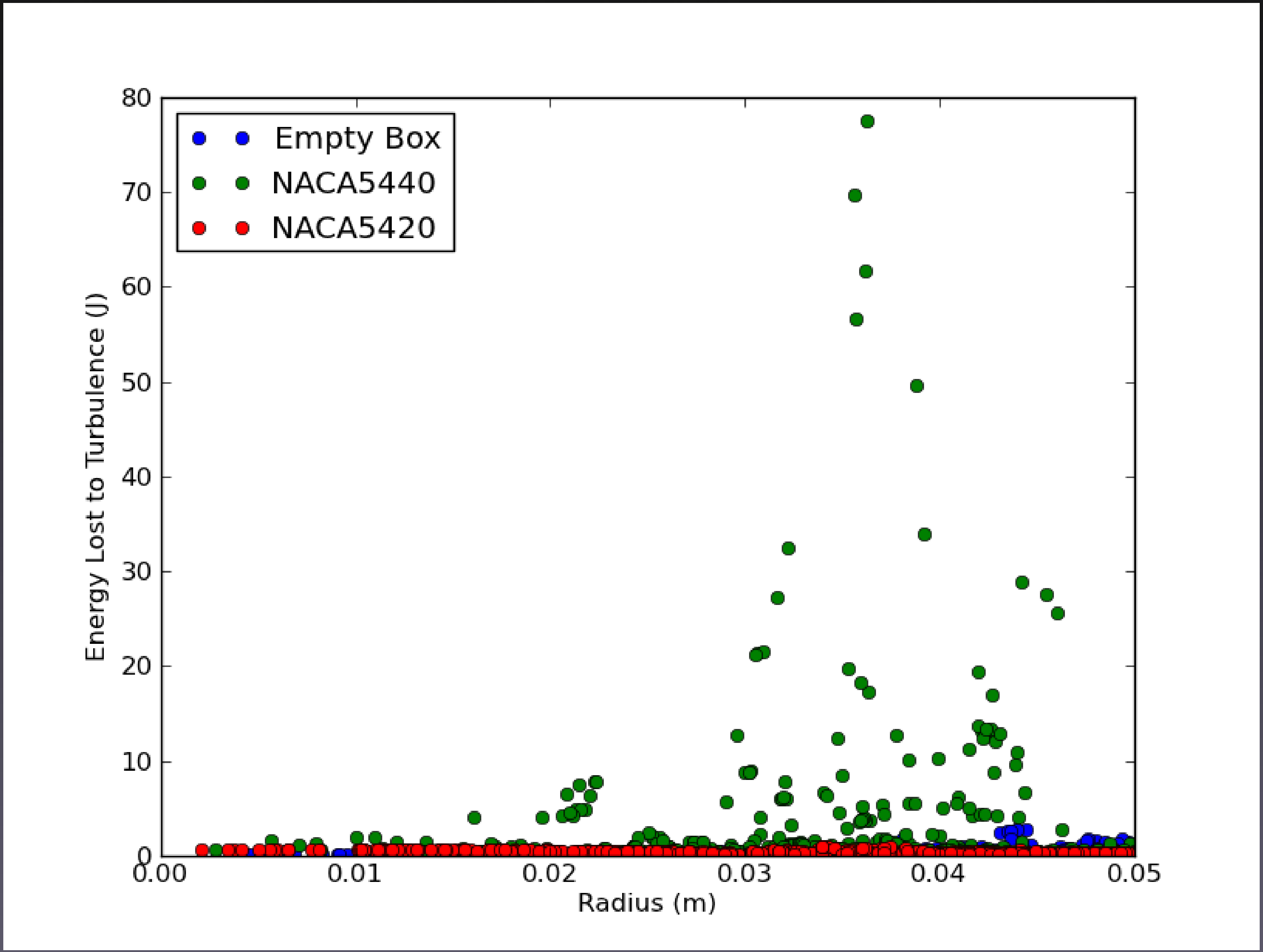
Y
Z
X



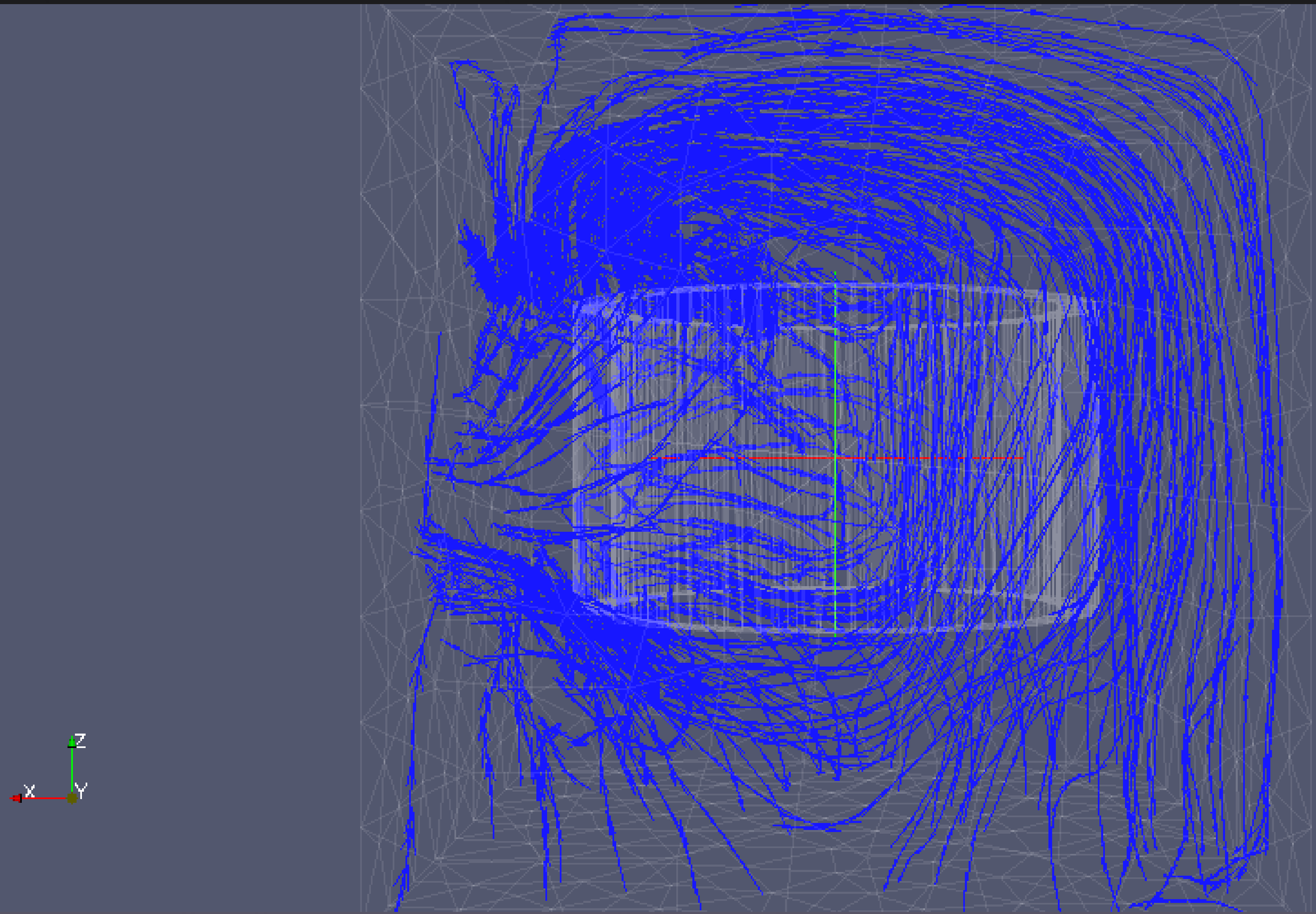
Empty Box
NACA5440
NACA5420
Flow Velocity (m/s)
Radius (m)
0
5
10
15
20
25
30
0.00
0.01
0.02
0.03
0.04
0.05

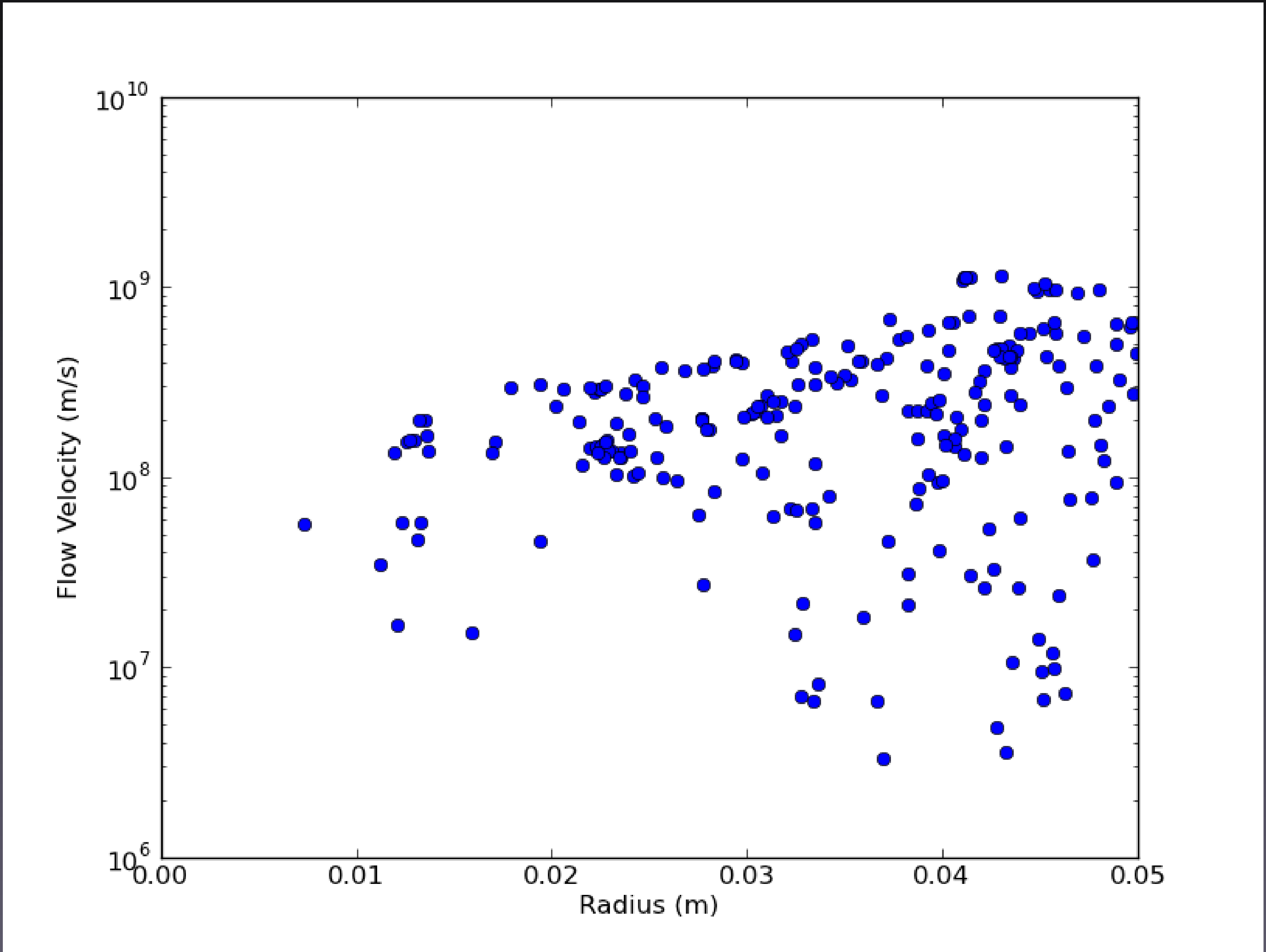


Empty Box
NACA5440
NACA5420
Vorticity (s^{-1})
Radius (m)
0
100
200
300
400
500
600
0.00
0.01
0.02
0.03
0.04
0.05



Empty Box
NACA5440
NACA5420
Energy Lost to Turbulence (J)
Radius (m)
0
10
20
30
40
50
60
70
80
0.00
0.01
0.02
0.03
0.04
0.05


Z
X
Y



10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
0.00
0.01
0.02
0.03
0.04
0.05
Flow Velocity (m/s)
Radius (m)


MakerBot
Thing-O-Matic
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INDUSTRIES