NAVSEA WARFARE CENTERS DAHLGREN

# Integrating Dynamic Systems Simulation into the Design process of a 105mm Gun's Recoil System

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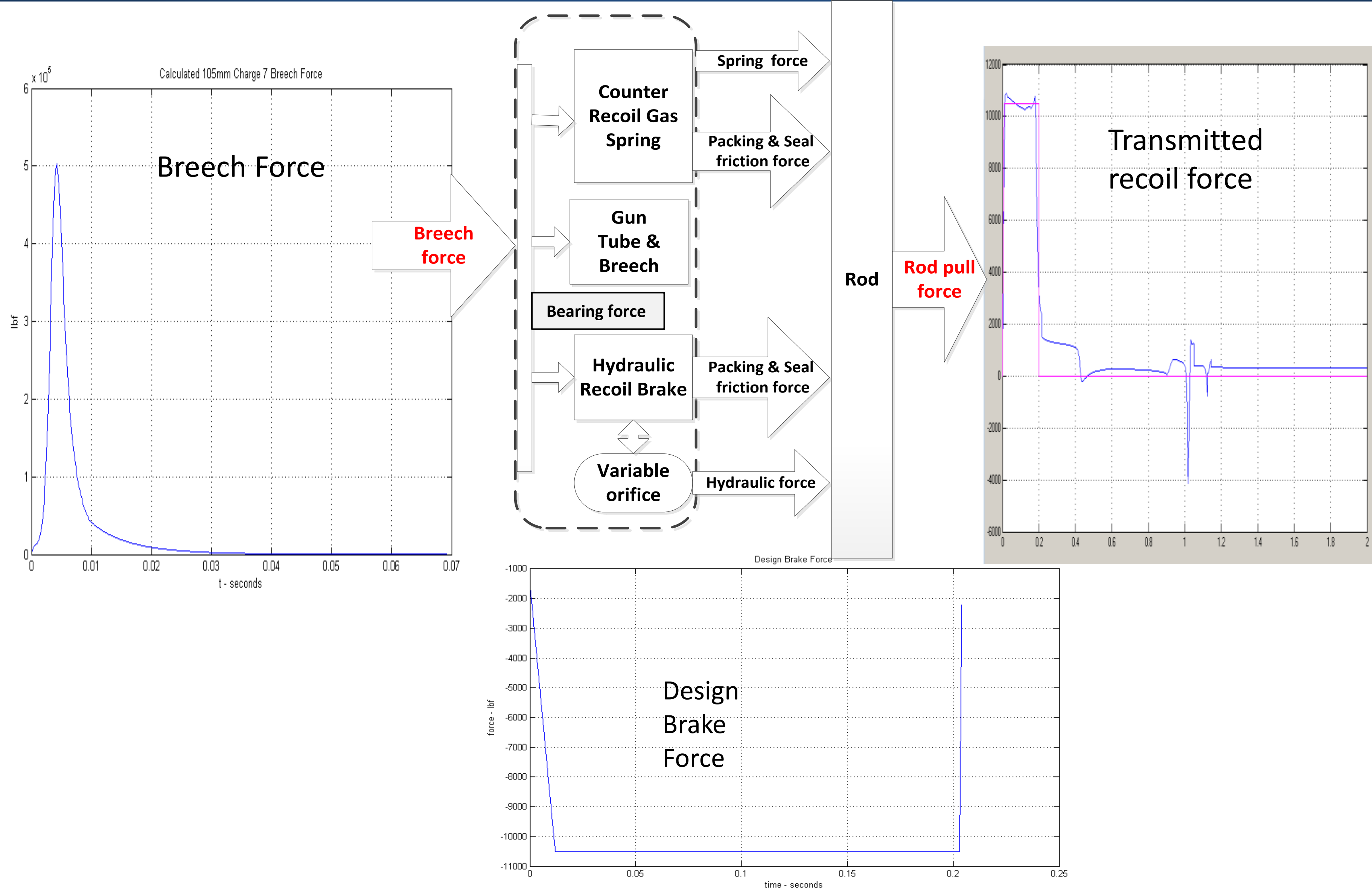
# Problem Description: Recoil System

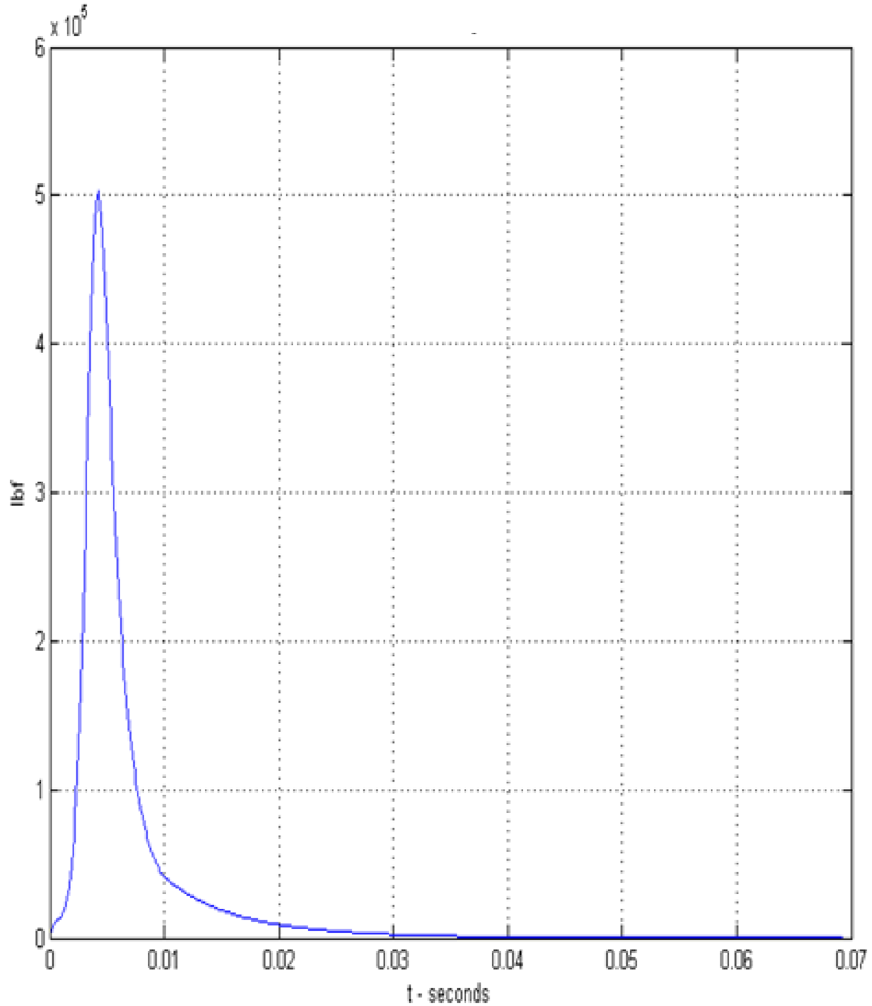


# Objectives

- Develop and simulate models of recoil system functionality to:
  - Generate hydraulic orifice area design specifications,
  - Generate buffer area design specifications,
  - Generate hydraulic and pneumatic pressure and friction forces for cylinder packing, and seal design specifications,
  - Verify suitability of dimensional design specifications, and
  - Verify and predict system performance.
    - Target recoil and force requirements at nominal T&P, charge 7  based breech force at zero elevation
- Key References
  - DOD-HDBK-778(AR) RECOIL SYSTEMS (1988)
  - MIL-HDBK-785(AR) DESIGN OF TOWED ARTILLERY WEAPON SYSTEMS (1990)
  - RHEINMETALL Handbook on Weaponry (1982)

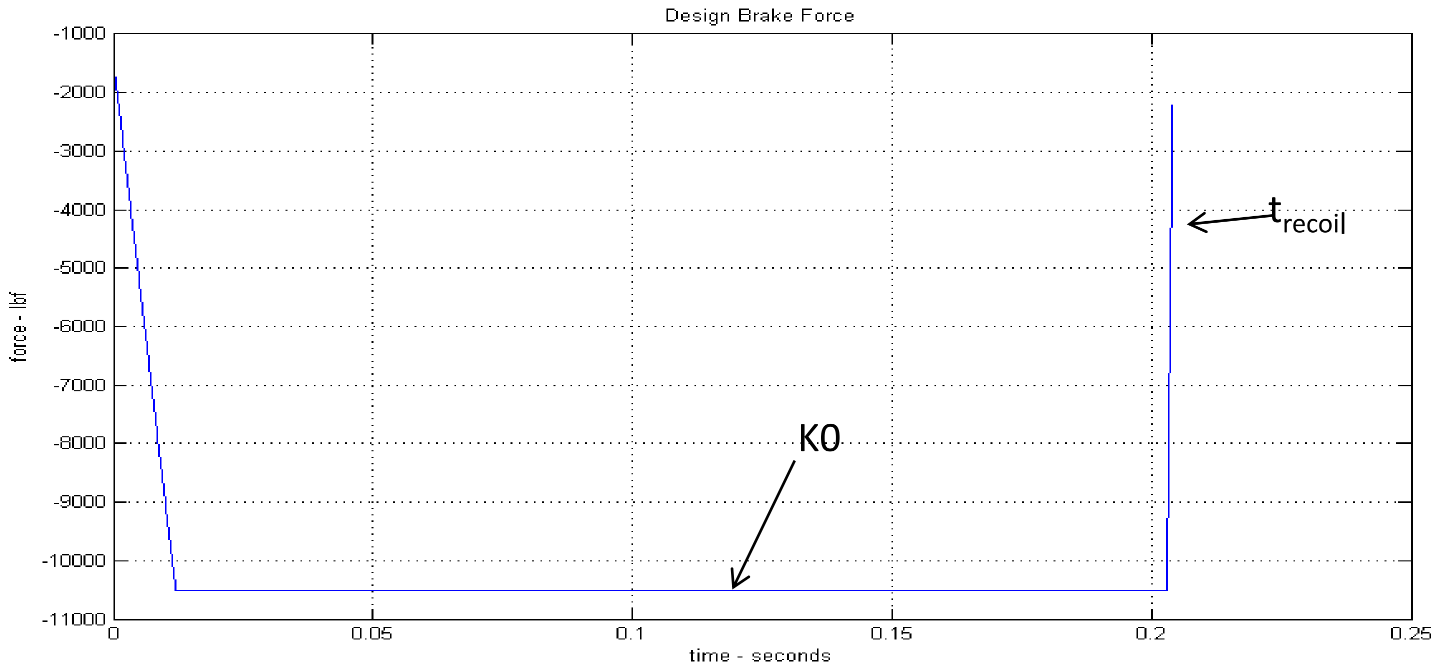
# Breech Force

- Driving force for recoil system
- Impulse (I)
  - Integral of breech force curve
  - Used to design brake force function



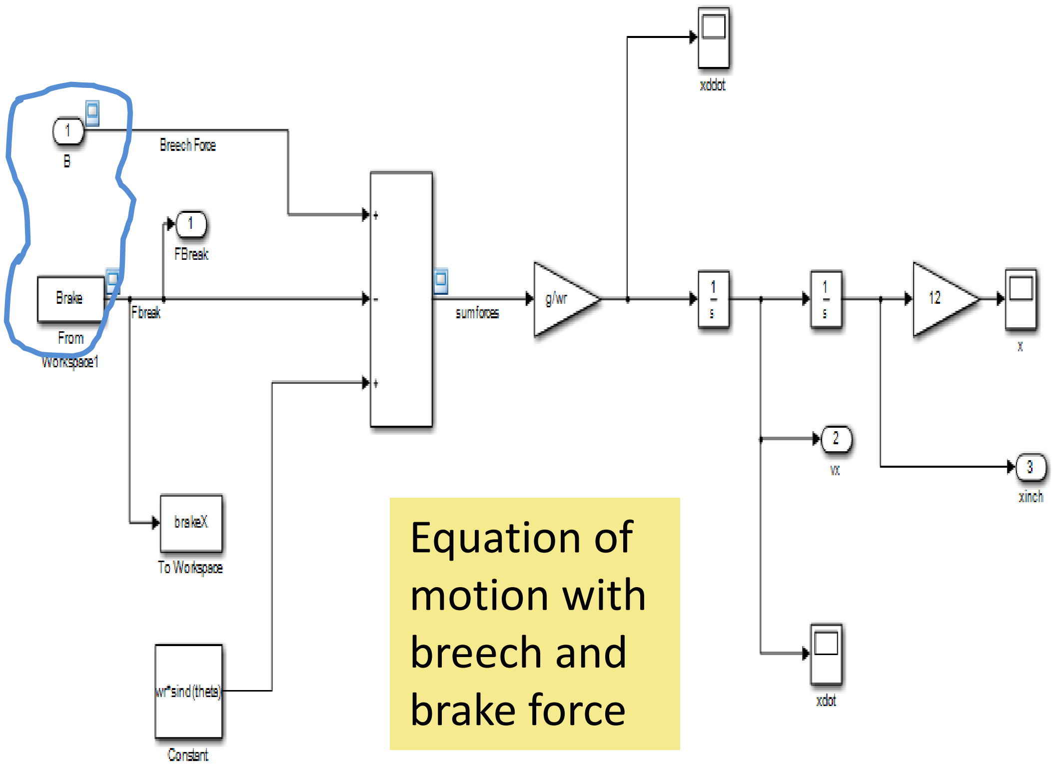
# Brake Force Functions

- Brake force curve design
  - Average Brake Force: $K0 = I^2 /(2 * m_{recoil} * L_{recoil})$
  - Recoil time: $t_{recoil} = I / K0$
  - Estimate friction and gas spring forces
  - Design trapezoidal FBrake(t), over recoil duration

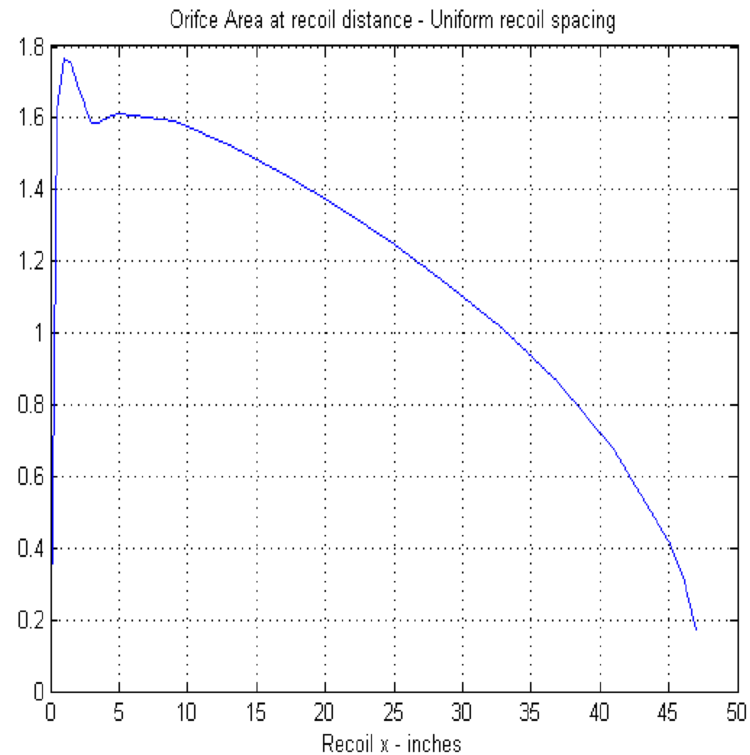


# Designing Variable Orifice

- $ae(x) = ao(x) * Cd = A_{hyd} * \mathbf{v(x)} * \sqrt{\frac{density * A_{piston}}{2 * \mathbf{F_{orifice}(x)}}}$
- Simulate: B(t) and Brake(t) ➔ v(t), $F_{orifice}$(t), x(t) ➔ **v(x) ,$F_{orifice}$(x)**



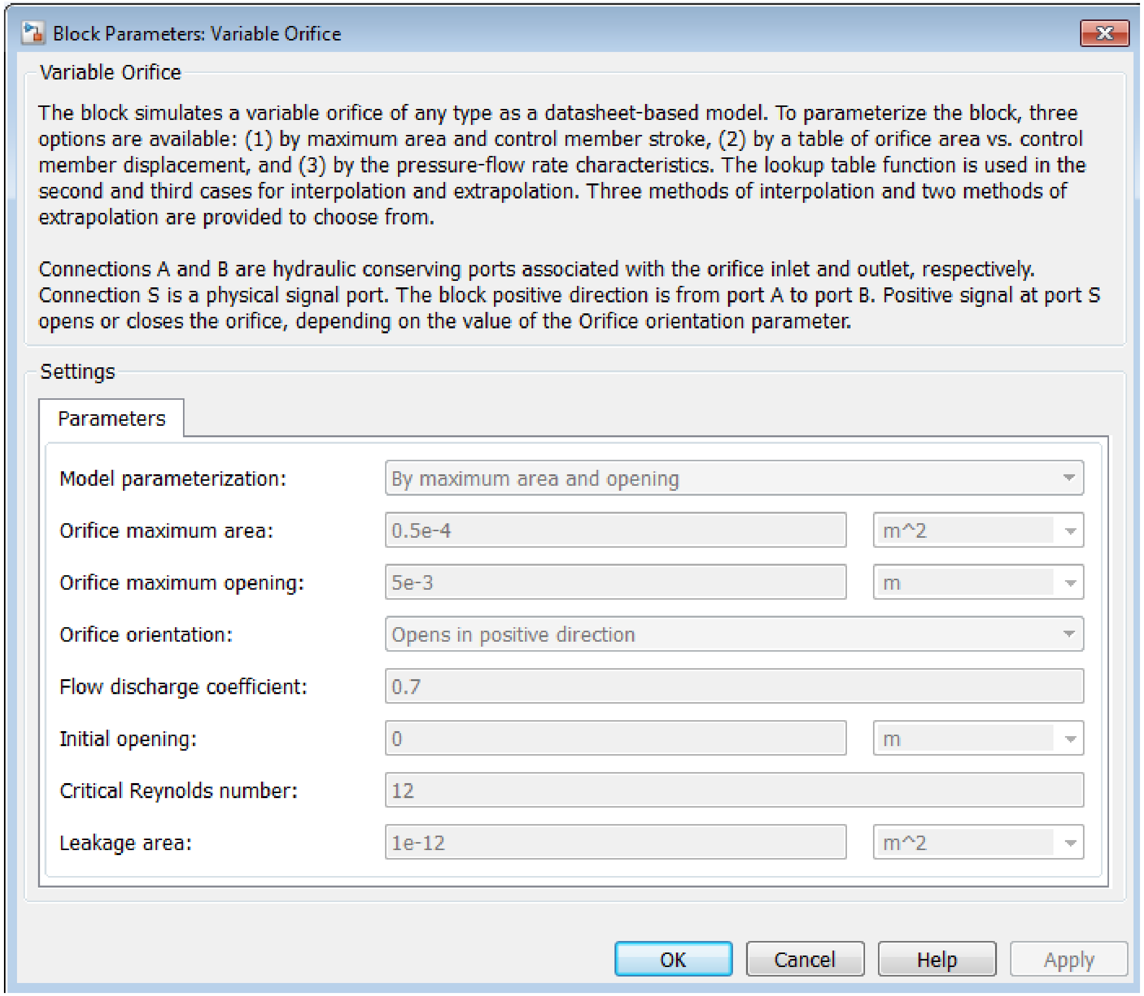

Equation of motion with breech and brake force



# Simulink and Simscape

- Simulink
  - Graphical numerical programming
  - Numerically solve differential equations
  - Directional flow -  evaluation order
- Simscape (and Simhydraulics)
  - Graphical ***physical modeling***
    - Through and across variables bidirectional
  - Encapsulate equations for all behaviors of components

# Simhydraulics Variable Orifice




$$q = C_D \cdot A(h) \sqrt{\frac{2}{\rho}} \cdot \frac{p}{\left(p^2 + p_{cr}^2\right)^{1/4}}$$

$$p = p_A - p_B$$

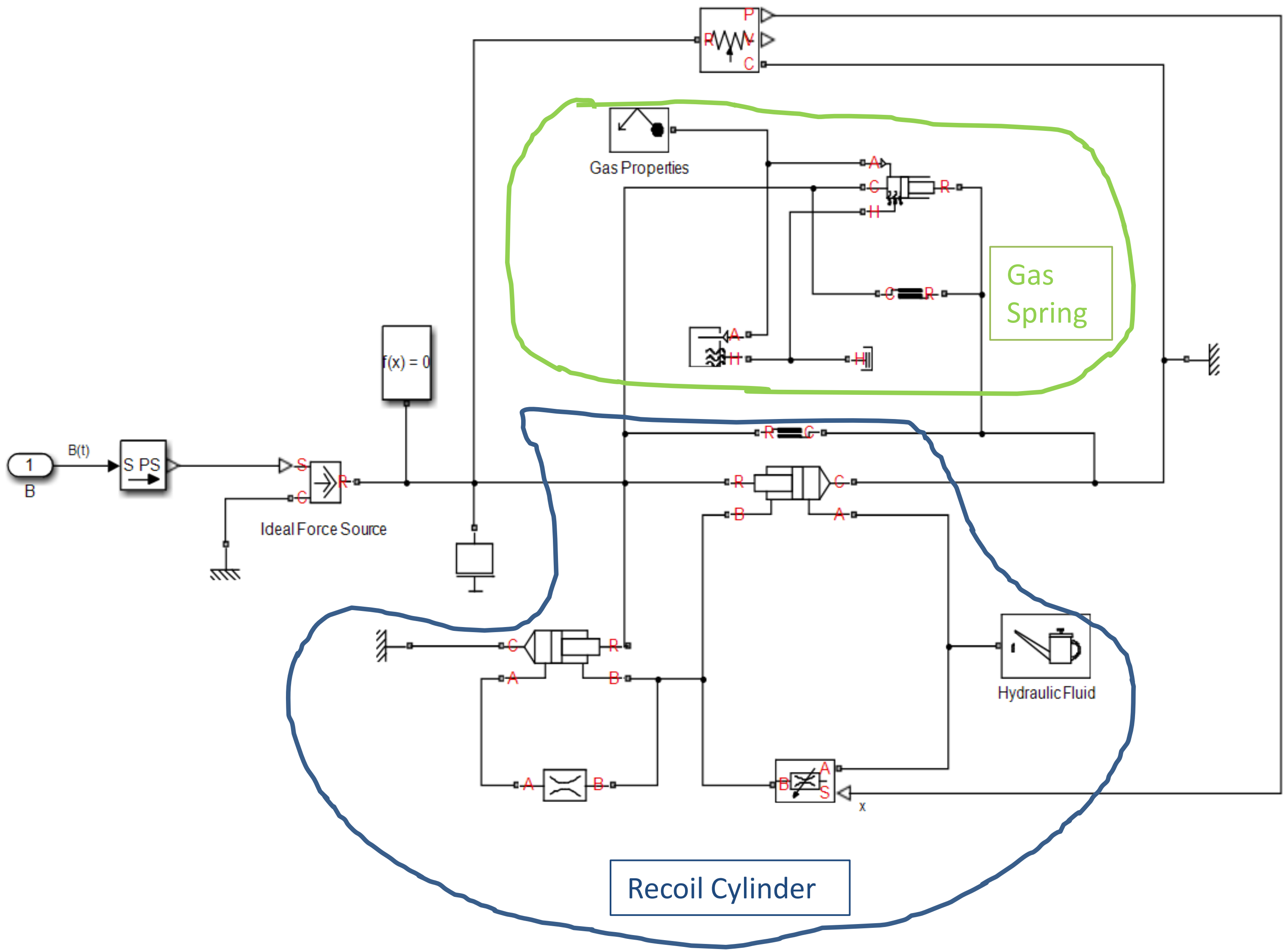
$$p_{cr} = \frac{\rho}{2}\left(\frac{\mathrm{Re}_{cr} \cdot \nu}{C_D \cdot D_H}\right)^2$$

$$h = x_0 + x \cdot or$$

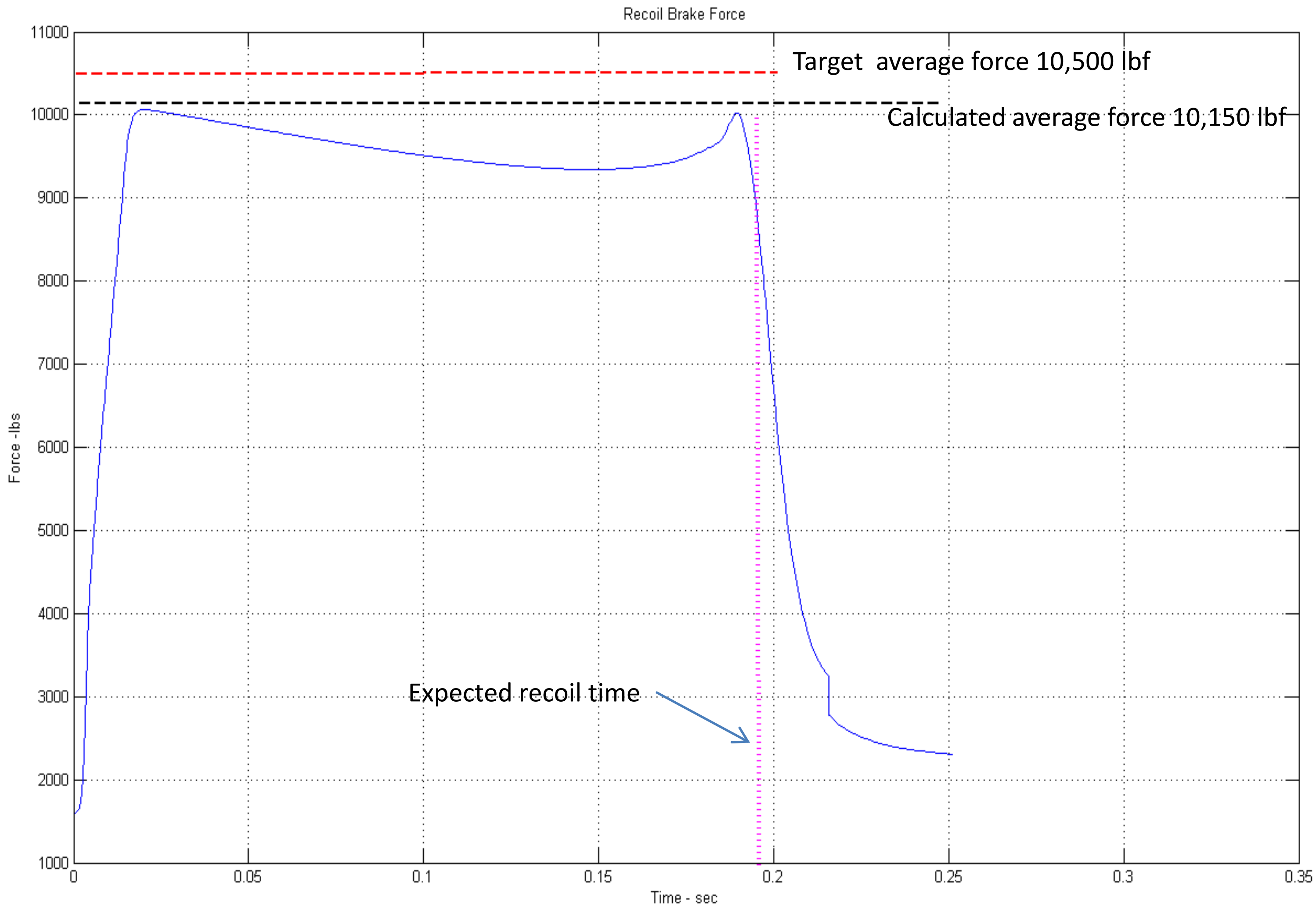
$$A(h) = \begin{cases} h \cdot A_{max}/h_{max} + A_{leak} & \text{for } h > 0 \\ A_{leak} & \text{for } h <= 0 \end{cases}$$

$$D_H = \sqrt{\frac{4A(h)}{\pi}}$$

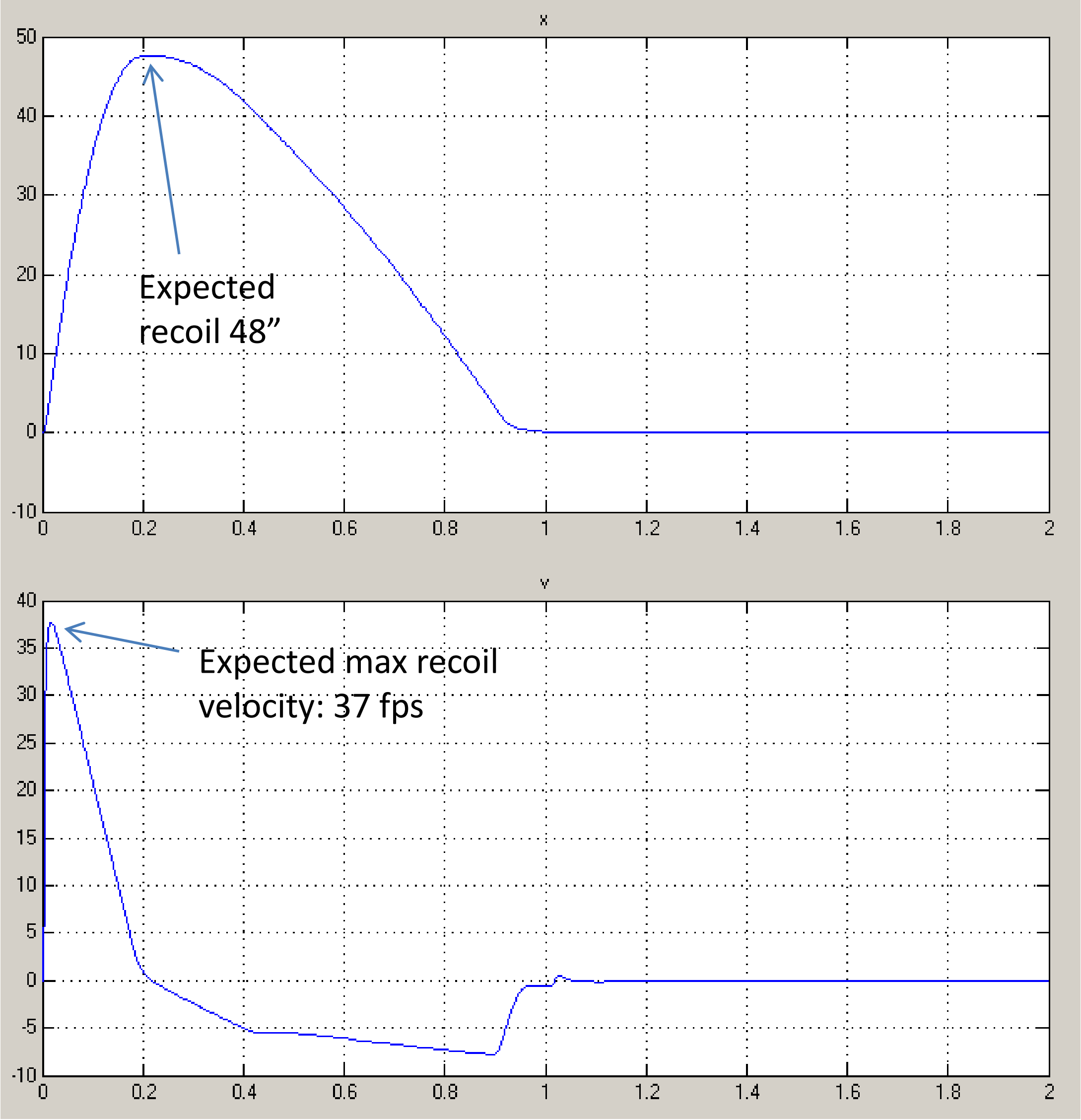
# Recoil System Model



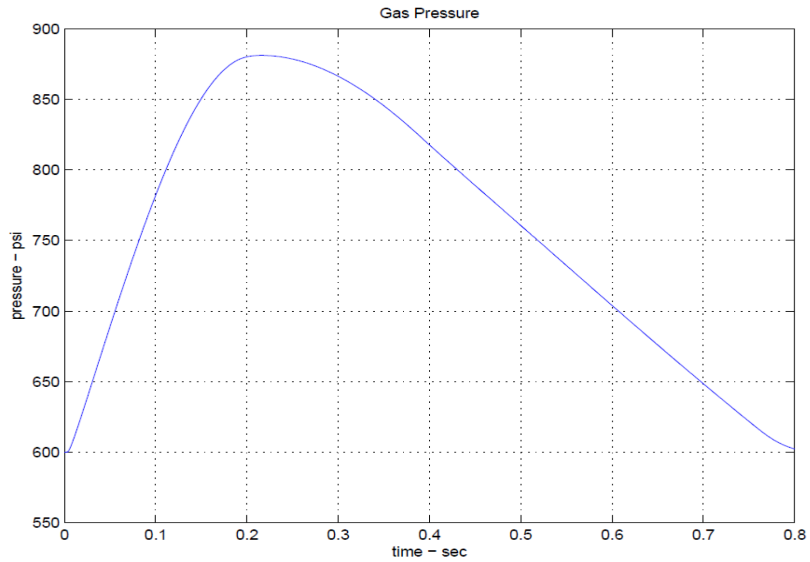
# Simulation: Force

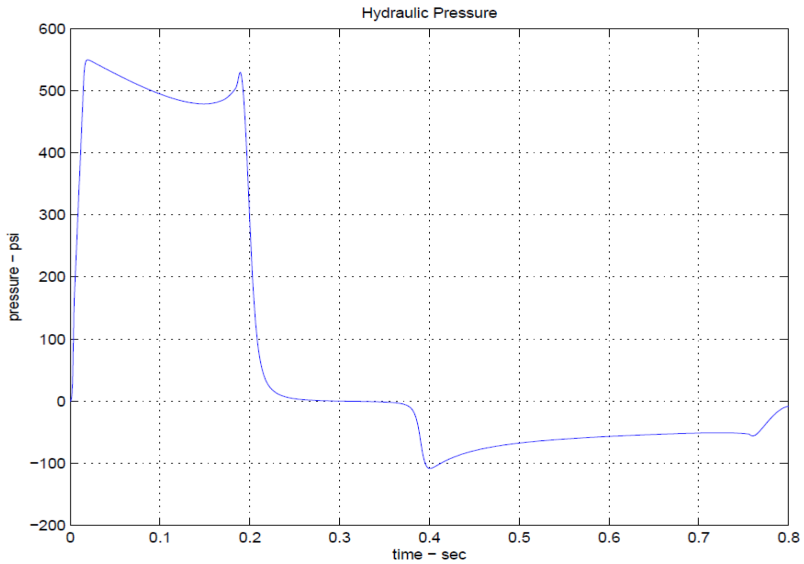


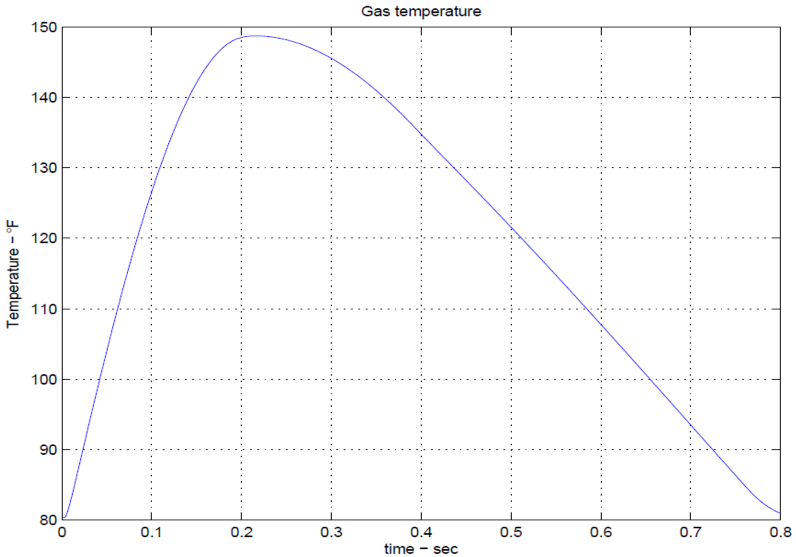
# Validation: Recoil and Velocity



# Design Information From Simulation




- Maximum hydraulic pressure: 550 psi
- Maximum gas pressure: 880 psi
- Maximum gas temperature: 150°F

# Conclusions and Continuing Work

- **Dynamic system simulation critical to design process**
  - Highly interdependent interacting subsystems
  - Exploration of design variables and trade studies
  - Actual dimensional design of subsystems (buffer, replenisher)
  - Sensitivity analysis
- **Continuing work**
  - Continue refining model detail
  - Explore and complete counter recoil buffer design
  - Conduct environment and operational mode sensitivity analysis
  - Validate model
    - Tests prototype subsystems
    - Range test development gun-recoil system
  - Iterative design adjustments using test and simulation results