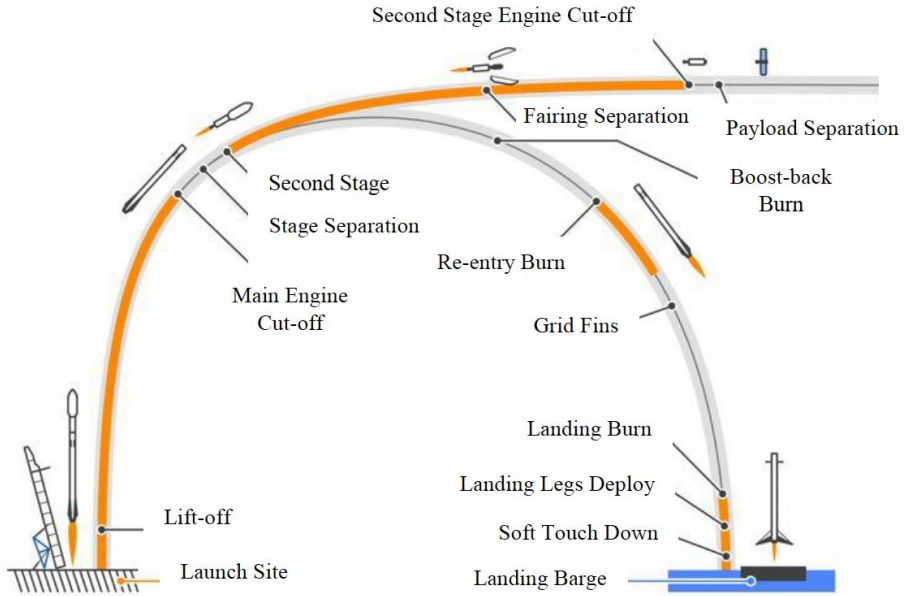
Computational control

Project Announcement

Rocket-landing



Rocket-landing

State: $[x_i, \dot{x}_i, z_i, \dot{z}_i, \theta_i, \dot{\theta}_i]$

Other variables:

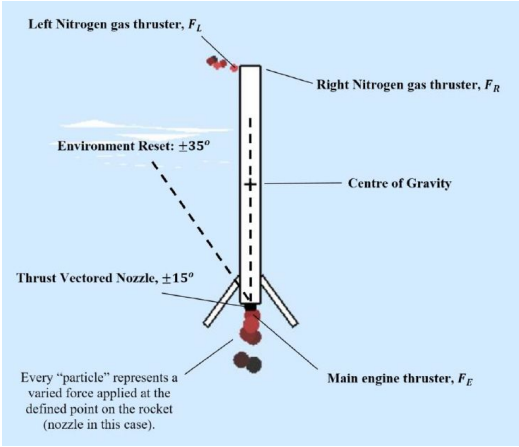
$F_E = Main\ Thruster\ Force$
$F_R = Right\ Thruster\ Force$
$F_L = Left\ Thruster\ Force$
$F_S = F_L - F_R$
$\theta = Angle\ between\ the\ z-axis\ and\ the\ longitudinal\ axis\ of\ the\ rocket$
$\varphi = Angle\ between\ the\ Nozzle\ and\ the\ longitudinal\ axis\ of\ the\ rocket$
$l_1 = Londigutdinal\ length\ between\ the\ Center\ of\ Gravity\ (COG)\ and\ F_E$
$l_2 = Longitudinal\ length\ between\ the\ COG\ and\ F_R, F_L$
$l_n = Nozzle\ length$
$m = Rocket\ Dry\ Mass + Fuel\ Mass$
$x = Horizontal\ Position\ of\ the\ Rocket$
$z = Vertical\ Position\ of\ the\ Rocket$
$\alpha = Real\ Constant$

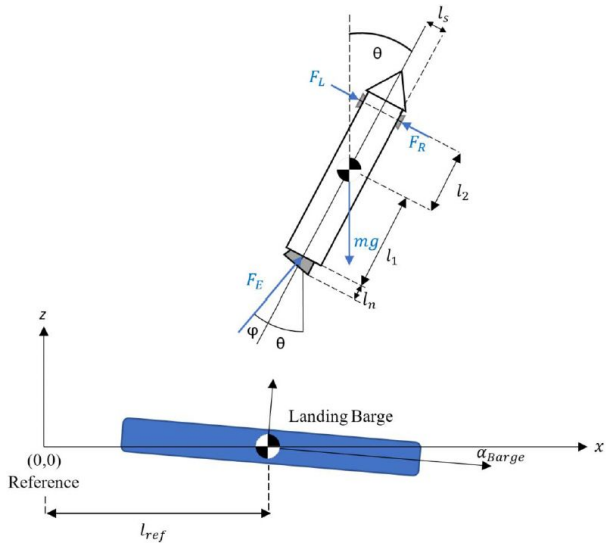
Actuators:

- Main engine thrust, F_E
- Side Nitrogen gas thrusters, F_L, F_R
  - Summarized in a single input $F_S = F_L - F_R$
- Nozzle angle, φ.

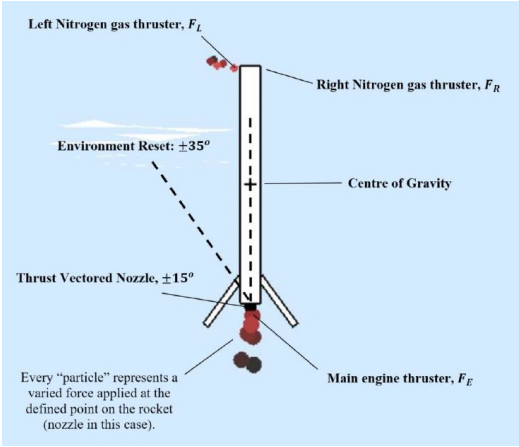
Terminal constraints:

$$-Left\ Barge\ Edge \le x_\tau \le Right\ Barge\ Edge$$
$$-2\ m/s \le \dot{x}_\tau \le 2\ m/s$$
$$z_\tau = Barge\ Height$$
$$\dot{z}_\tau = 0\ m/s$$
$$-10^o \le \theta_\tau \le 10^o$$
$$-2^o/s \le \dot{\theta}_\tau \le 2^o/s$$





Rocket-landing with PID control



State:

$[x_i, \dot{x}_i, z_i, \dot{z}_i, \theta_i, \dot{\theta}_i]$

Actuators:

- Main engine thrust, F_E
- Side Nitrogen gas thrusters, F_L, F_R
  - Summarized in a single input $F_S = F_L - F_R$
- Nozzle angle, φ.

Dynamics equations:

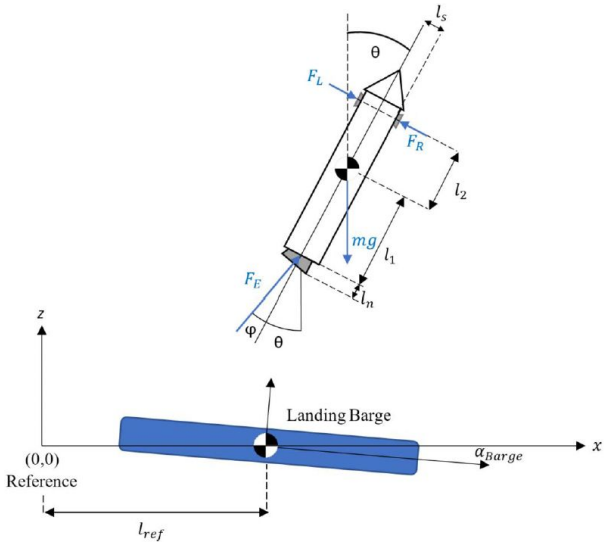
$$m\ddot{x} = F_E \sin(\theta + \varphi) + F_s \cos(\theta)$$

$$m\ddot{z} = F_E \cos(\theta + \varphi) - F_s \sin(\theta) - mg$$

$$J\ddot{\theta} = -F_E \sin(\varphi)\,(l_1 + l_n \cos(\varphi)) + l_2 F_S$$

SISO approximations:

$$\frac{X}{F_S} = \frac{1}{ms^2} \qquad \frac{Z}{F_E{}'} = \frac{1}{ms^2} \qquad \frac{\theta}{\varphi} = -\frac{c}{Js^2}$$



The Pitch

Elon Musk (your boss) is impressed by the simulation of the rocket landing and wants to put your PID controller on the Falcon 9.

Do you feel comfortable putting your PID controller on the Falcon 9?

If not, put together a pitch for Elon to justify more design time and budget. You have five minutes.

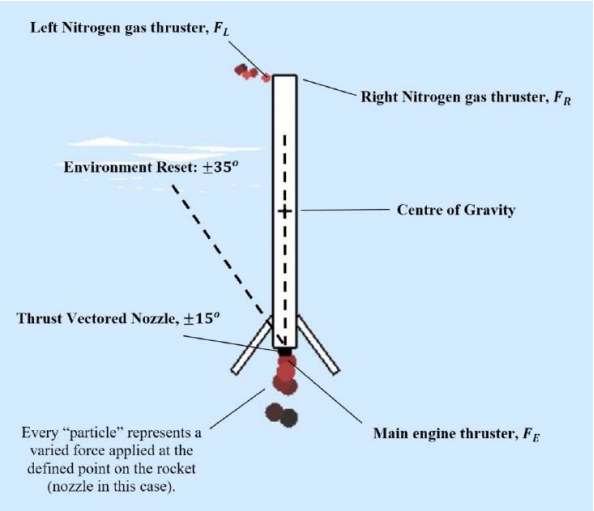
The Project

You will design four different controllers for the rocket landing using the control methods we will cover in class

1. Model Predictive Control
2. Data-enabled Predictive Control
3. Reinforcement Learning
4. [A method or improvement of your choice]

You will submit a report that includes

- your code,
- a well-informed explanation of each technique, and
- a controller (controller 4) that improves upon the base techniques we cover (controllers 1-3).



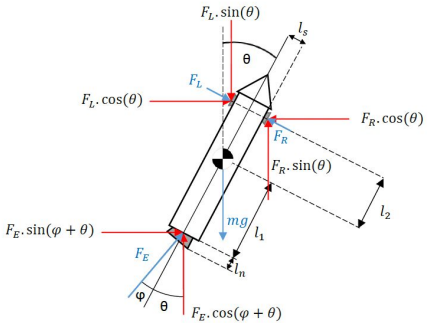


Figure 12 Free body diagram showing all forces considered.