Motivation

Credit: NASA
Motivation
Prior Work

- Government Missions
  - Near Earth Asteroid Rendezvous
  - Rosetta and Philae
  - Asteroid Redirect Mission

- Commercial
  - Planetary Resources
  - Deep Space Industries

- Verification
  - Monte Carlo methods
  - Lunar landing
  - Satellite rendezvous in low earth orbit
Initial Assumptions

- 2 DOF system – approach axis translation and rotation
- Constant acceleration due to gravity
- Constant mass spacecraft
- Fixed braking acceleration
- Time-triggered controller
- No orbital mechanics
Control & Invariant

- Derive safety from equations of motion

\[ v_f^2 = v_i^2 + 2a(p_f - p_i) \]

\[ p \geq \frac{-v^2}{2(g - B)} \]

- Predict forward and check braking condition

\[ p - v \cdot T - \frac{1}{2}gT^2 > \frac{-(v + g \cdot T)^2}{2(g - B)} \]
Fuel Use — Key Variables

- $dm$ – dry mass of the satellite (no fuel)
- $M$ – fuel mass
- $mi$ – initial mass of the satellite, $mi = dm + M$
- $m$ – current mass of satellite, initially $mi$
- $f$ – constant force output of the thruster
- $I_{sp}$ – specific impulse, “engine efficiency”
Fuel Use – Key Equations

- Dynamic braking acceleration
  \[ B \equiv \frac{f}{m} \]

- Dynamic mass
  \[ m = \frac{f}{I_{sp} * g_e} \]

- Conservative fuel mass bound
  \[ m - dm \geq \frac{f}{I_{sp} * g_e} * \frac{\sqrt{v^2 + 2gp}}{g} \]
Fuel Use – Application

- NEAR Shoemaker
  - $l_{sp}=325$ Seconds
  - $f = 450$ Newtons
  - $d_m$ (dry mass) = 478 Kilograms
  - $M$ (fuel mass) = 300 Kilograms
  - $p_i = 1000$ Meters
  - $v_i = 3$ Meters/Second
  - $g = 0.0059$ Meters/Second$^2$
  - Predicts 735 Kilograms of fuel
Fuel Use – Application

NEAR Shoemaker Final Descent from 35-km Orbit

View from Sun

Credit: NASA
Questions?