The Returning Rocket

Friend or Foe?

David Franklin & Philip Massey

Outline

- Introduction
  - Motivation
  - Safety
  - Physics
- Controllers
  - Strategy
  - Descent
  - Balance
- Conclusion

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Introduction

How do we make space exploration less expensive?

Possible answer:

- Reusability of launch vehicles

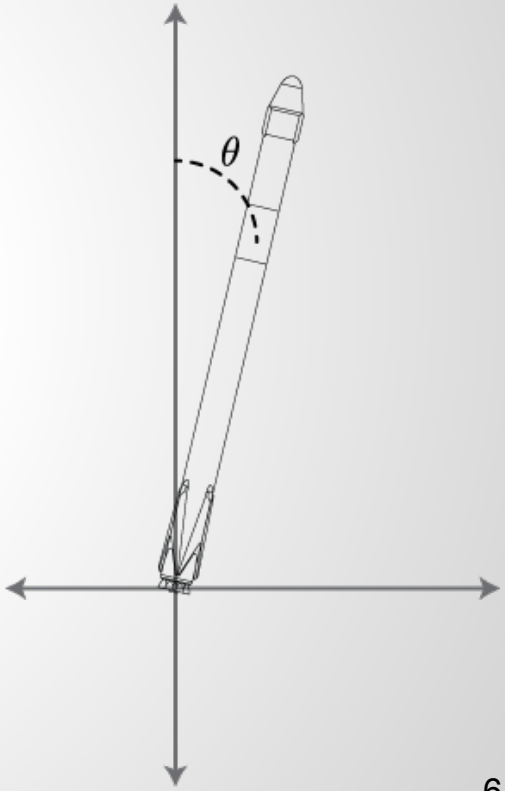
"Atlas EELV Family" Public Domain, US Gov FFA

Introduction - Problem

http://youtu.be/0UjWqQPWmsY?t=40s

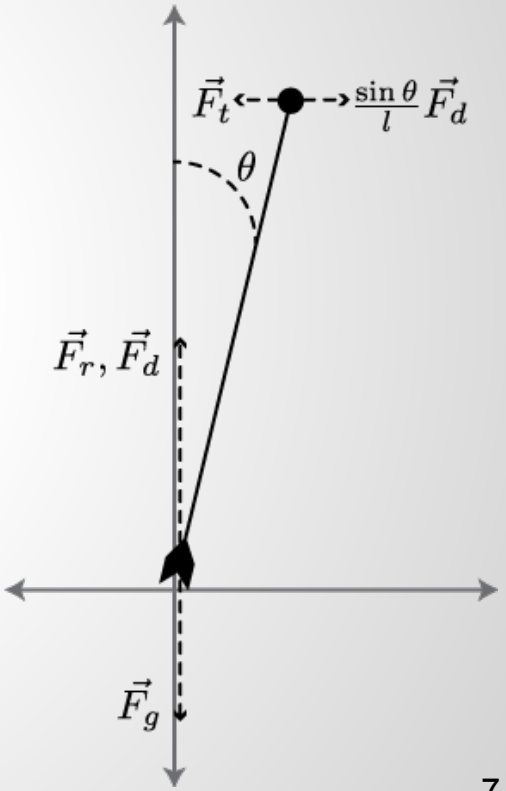
Introduction - Safety

- Descent
  - Must land with safe velocity
- Balance
  - Maintain a safe rotation



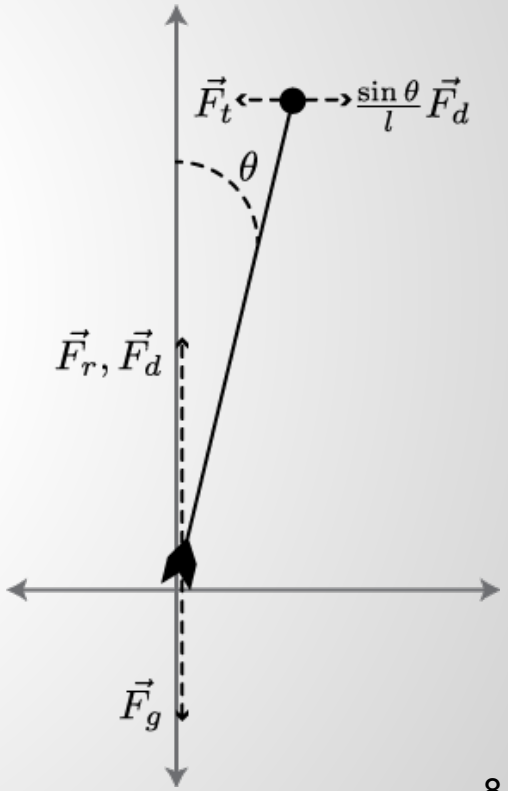
Introduction - Physics

- Descent
  - $\frac{d\vec{p}}{dt} = \vec{F}_g + \vec{F}_d + \vec{F}_r$



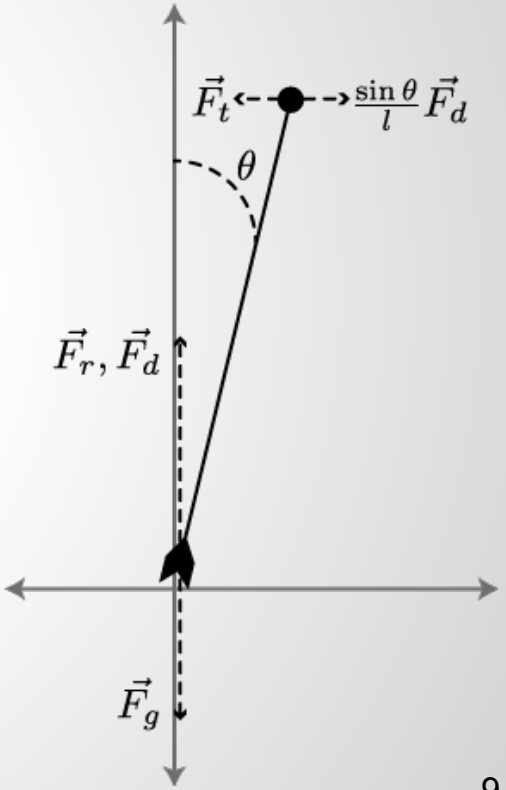
Introduction - Physics

- Descent
  - $\vec{a} = \vec{g} + \frac{\vec{F_d}}{m}$



Introduction - Physics

- Descent
  - $\vec{a} = \vec{g} + \frac{\vec{F_d}}{m}$
- Balance
  - $\ddot{\theta} = a \sin\theta + F_t$



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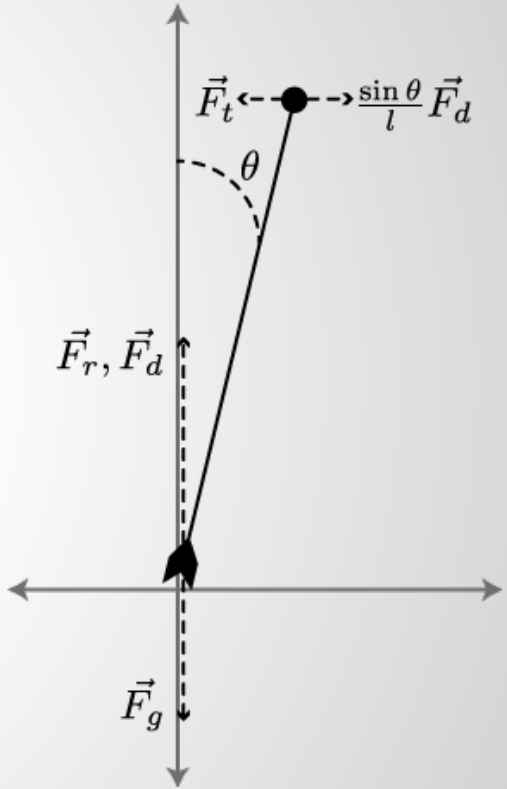
Controllers - Strategy

- Use two time-based controllers
  - One controller for descent
  - One controller for balance
  - Either can be changed without need to reprove other controller.
  - Cannot take advantage of particular descent strategy.

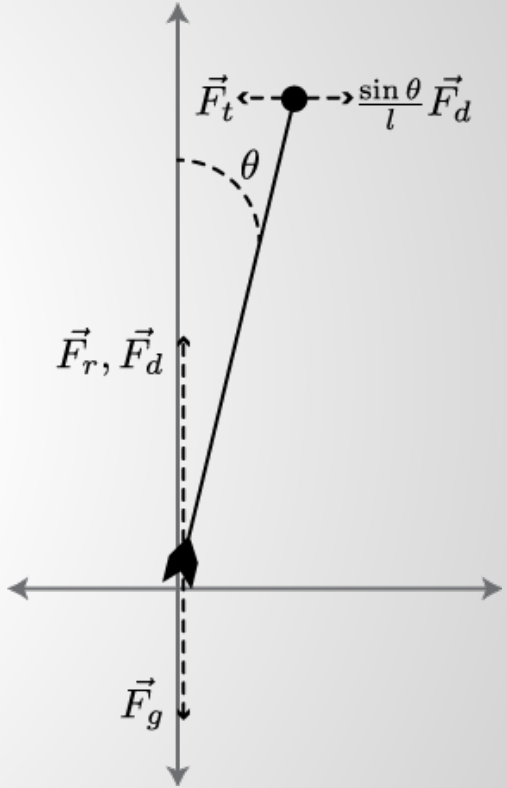
Controllers - Descent

- Safety:
  - At height h = 0, ensure v < v_{safe}
- Cased solution:
  - If speed greater than max:
    - $F_d := m \cdot \left(\frac{v_{\text{safe}}^2 - v^2}{2h} + g\right)$
  - Else if speed less than max and can free fall:
    - $F_d := 0$
  - Else:
    - $F_d := m \cdot \left(\frac{v - v_{\text{safe}}}{T} + g\right)$



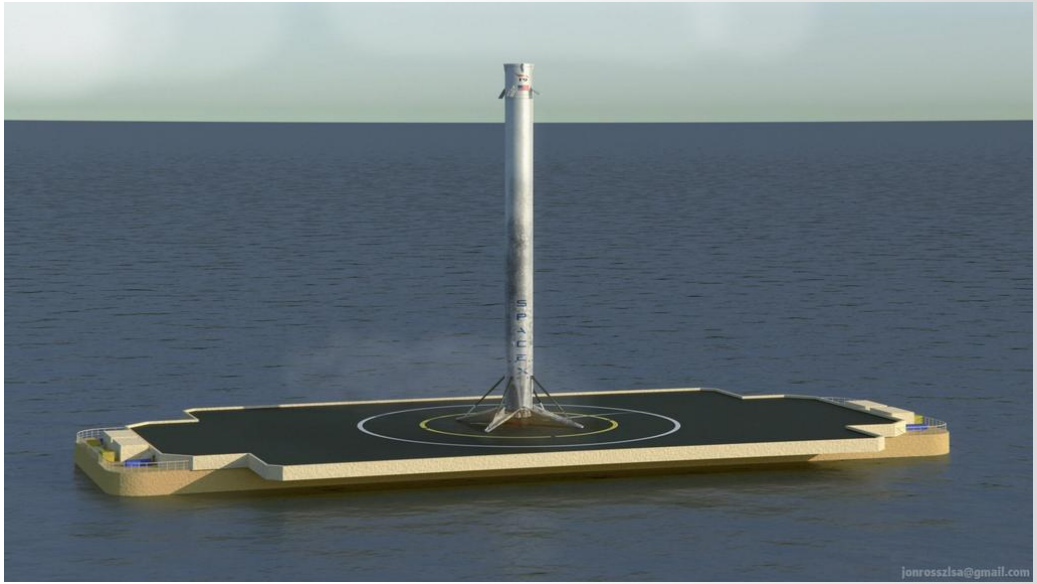
Controllers - Balance

- Safety:
  - Maintain a bound on rotation
- Idea:
  - Non-deterministically assign F_d
- Simple Solution:
  - Set $F_t = \frac{\sin\theta}{l} F_d$
  - Keep $\dot{\theta} = 0$
  - Use $\sin\theta \approx \theta$



Conclusion

- Safety
- Physics
- Controllers
  - Strategy
  - Descent
  - Balance
- Importance



"SpaceX Landing Rendering" Jon Rosszlsa

Questions?