The Returning Rocket

Friend or Foe?

David Franklin & Philip Massey
Outline

● Introduction
  ○ Motivation
  ○ Safety
  ○ Physics

● Controllers
  ○ Strategy
  ○ Descent
  ○ Balance

● Conclusion
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● **Conclusion**
Introduction

How do we make space exploration less expensive?

Possible answer:
- Reusability of launch vehicles
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
  \[ \ddot{a} = \dot{g} + \frac{F_d}{m} \]
Introduction - Physics

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

- **Balance**
  - $\dot{\theta} = a \sin \theta + F_t$
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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 $v < v_{\text{safe}}$

- **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?