COE CST Third Annual Technical Meeting:

Task SU-193: Opportunities for Secondary & Hosted Payloads on NASA Missions

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COE CST
Center of Excellence for Commercial Space Transportation

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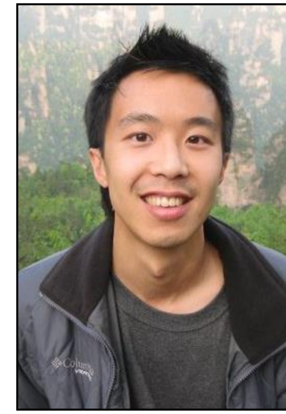


Stanford University
Graduate School of Business
MBA

Industry Partners

ULA United Launch Alliance

LOCKHEED MARTIN

Scitor Corporation

Orbital

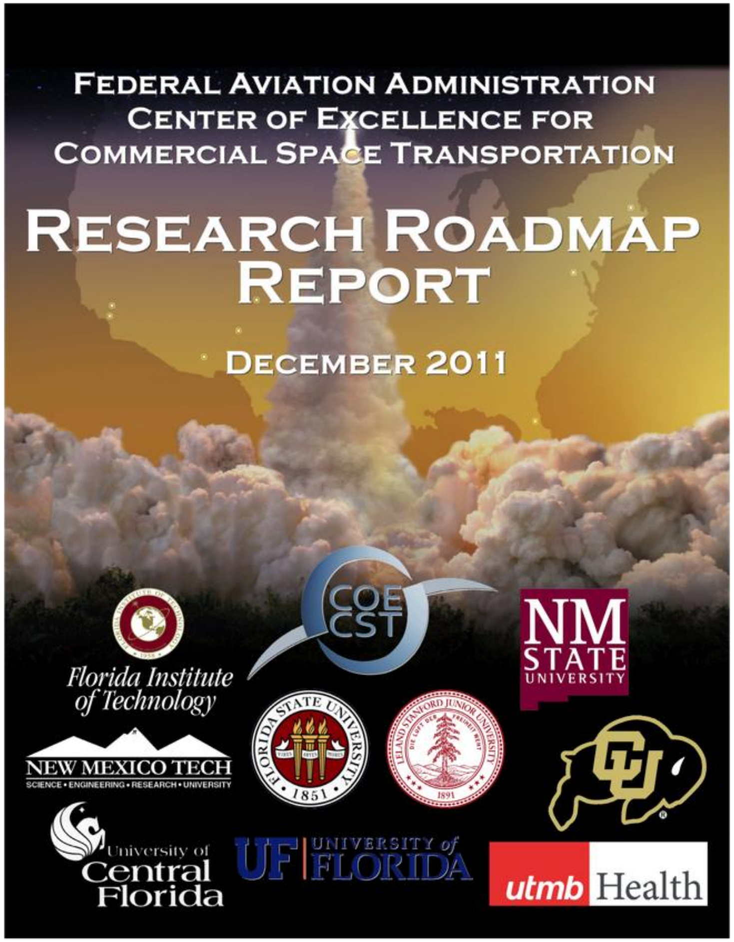
SPACE SYSTEMS LORAL

Motivation

- Results of research roadmapping work for the COE:

  "What is the market?" remains an open question to the CST industries. Identifying and verifying the suborbital and orbital microgravity commerce and research opportunities is of prime importance.

- Focusing on secondary and hosted orbital payloads represents a tractable portion of this task
  - Topic was strongly suggested by several industry partners during roadmap workshop

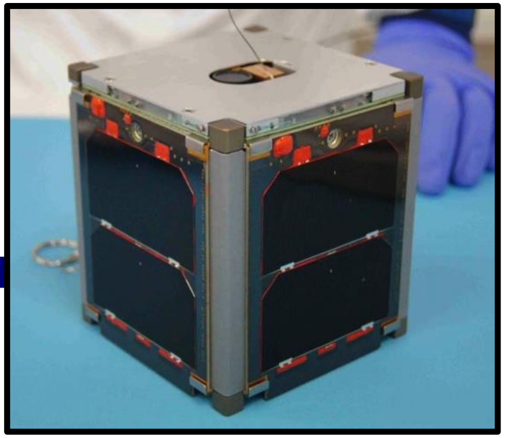


Secondary & Hosted Payloads

Terminology:

- **Secondary Payloads:** independent satellites that are carried into orbit on the same vehicle as the primary, utilizing any excess capability of the launch vehicle
- **Hosted Payloads:** small payloads that are directly affixed to the primary satellite, using its bus for power and communications

Title	Payload Size
Mini	100kg-500kg
Micro	10kg-100kg
Nano	1kg-10kg
Pico	100g-1kg



ZACUBE-01 (CPUT, South Africa)

The Opportunity

- Nearly every launch has some unused vehicle capacity
- Secondary and hosted payloads can use this resource
  - Low cost access to space for a small payload has many appealing applications and missions
  - Missions can be enabled by having distributed architectures across numerous small satellites or hosted payloads
    - e.g. communications networks, space situational awareness, earth observation, navigation

Commercially Hosted Infrared Payload (CHIRP)
USAF tech demo (SAIC) on SES-2 (Orbital)

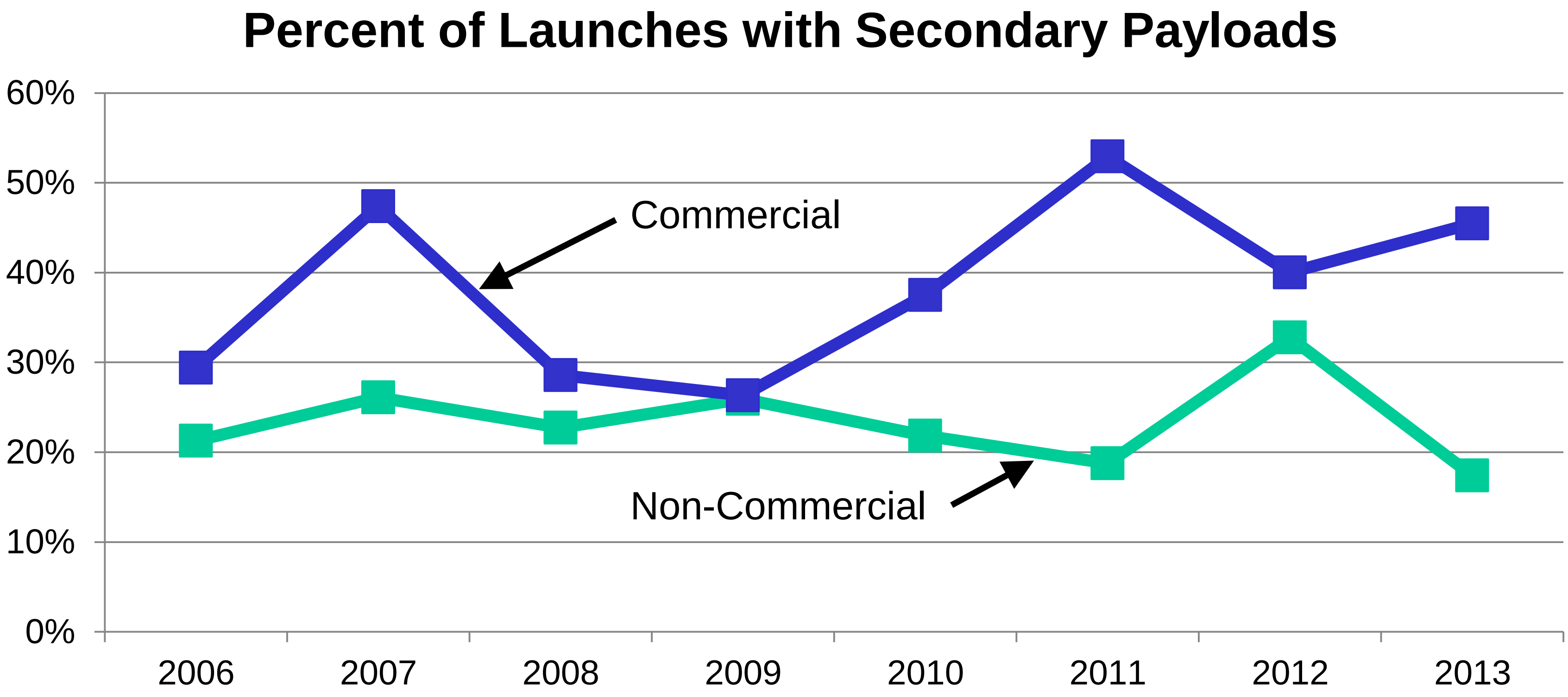
- 13% of the cost of a dedicated mission
- 80% of the mission objectives accomplished

(Office of Space Commercialization)

Commercial vs Non-Commercial

Launches with a commercial satellite are more likely to have secondary payloads

- Worldwide average over 7.5 years: 38% vs 24%



What Can We Do?

- Commercial launches
  - Already taking advantage of secondary payloads
  - New companies are working to aggregate payloads
- Military launches
  - Information unavailable
- Civil government (NASA) launches
  - Public information
  - Launches organized by centralized authority
  - Many established contacts at NASA

Policy Impact

Impact on Future Policy

- If there is a convincing argument a new policy could be introduced
- For example, require that excess launch capacity be identified at the time of a strategic mission assignment or Announcement of Opportunity
- Utilize excess capacity for technology demonstration or science investigation

Current Policy (Launch Services Program "Path to the Future")

- *"Determine the best way to implement PPOD/Ridesharing/Dual Manifest opportunities"*
- *"Develop LSP's (small class) launch services strategy"*

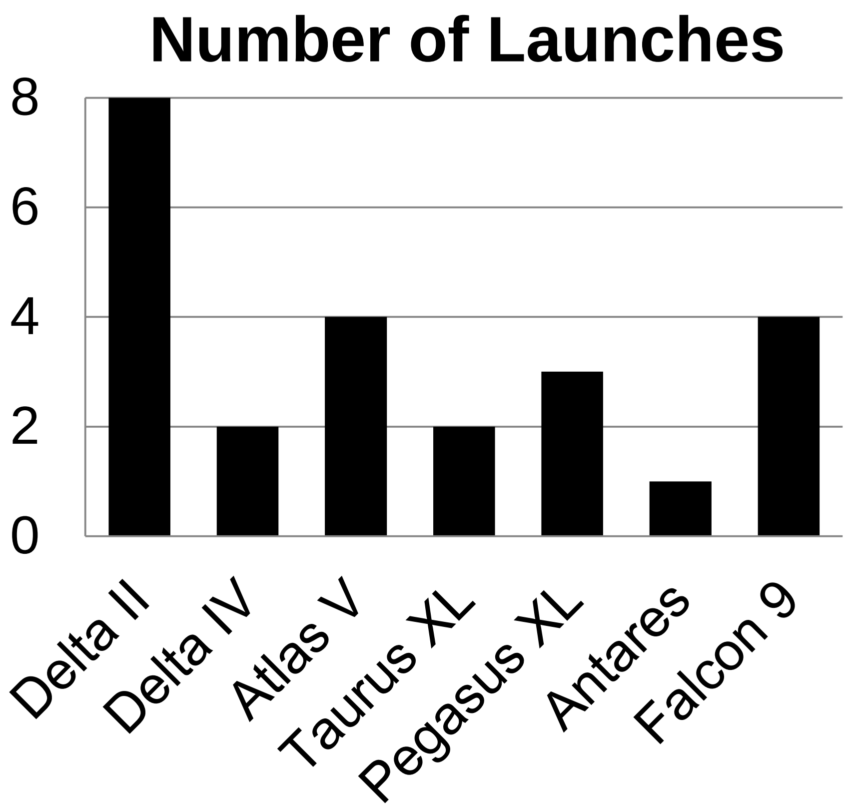
Approach

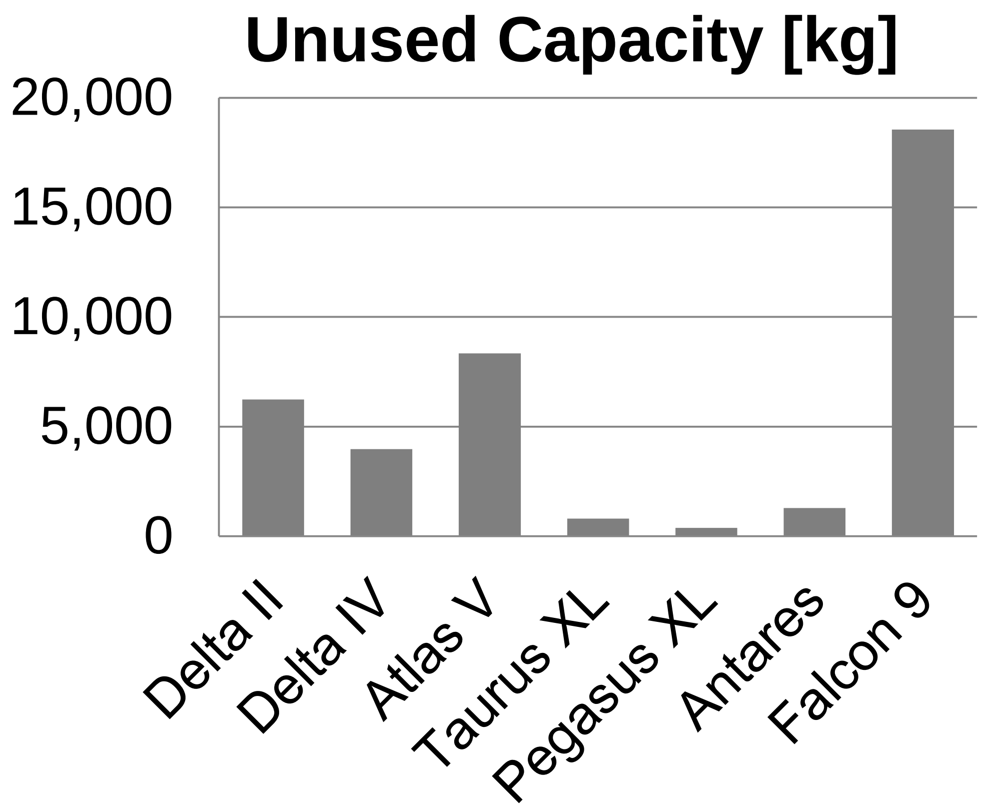
- Research and Document Key Elements of Argument:
  1. **Prove that there is excess capacity**
  2. Demonstrate that this capacity is a valuable resource
  3. Use case studies to show that the capacity could be useful for high-return missions
- Present results to NASA policy makers, for example:
  - Launch Services Office, NASA HQs
  - Science Mission Directorate
  - Space Technology Mission Directorate

Demonstrate Excess Capacity

- Compiled database of recent NASA launches
  - For each, determine payload mass and launch vehicle payload capacity
  - 34 launches from January 2006 to August 2013
  - 10 (29%) are to orbits with no published launch vehicle payload capacity
  - Of the 24 launches we have numbers for
    - 55,600 kg worth of payload launched
    - 39,600 kg worth of payload unused (42%)
    - 5,280 kg per year
    - 1,650 kg per launch

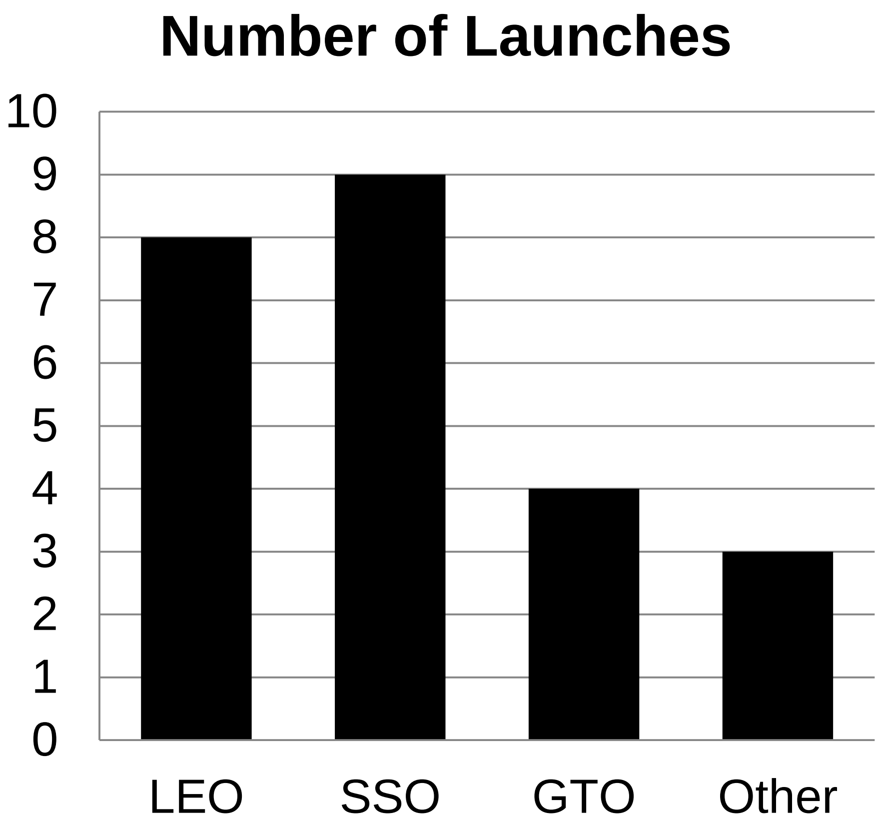
Breakdown by Launch Vehicle

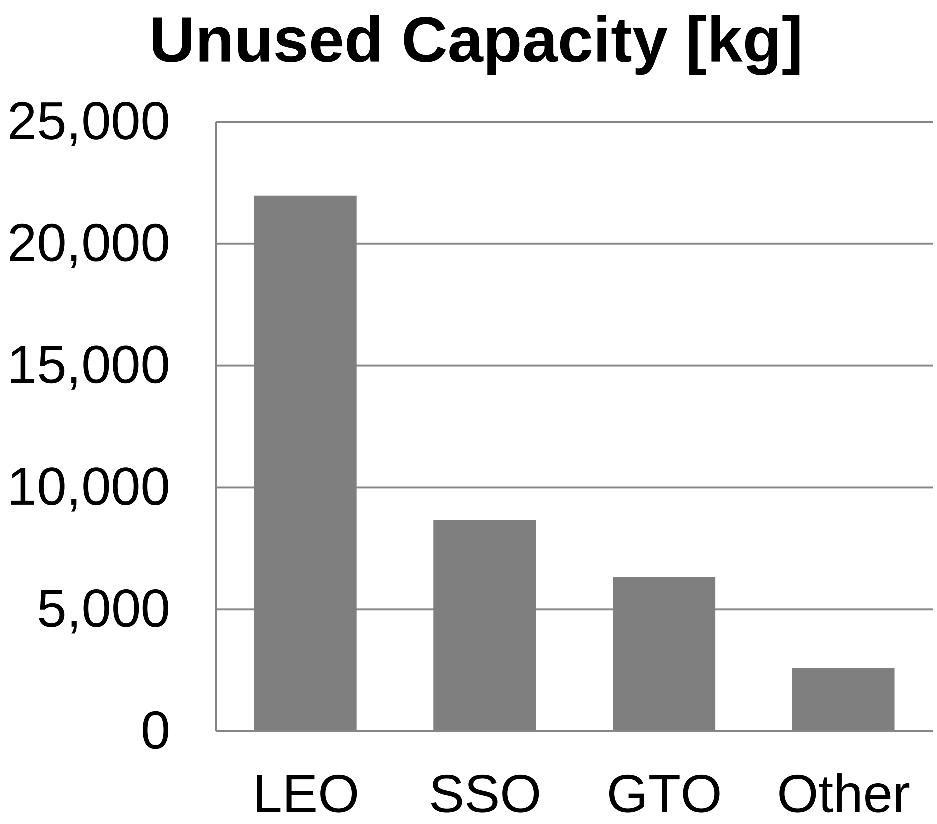




SpaceX and ULA have most unused capacity

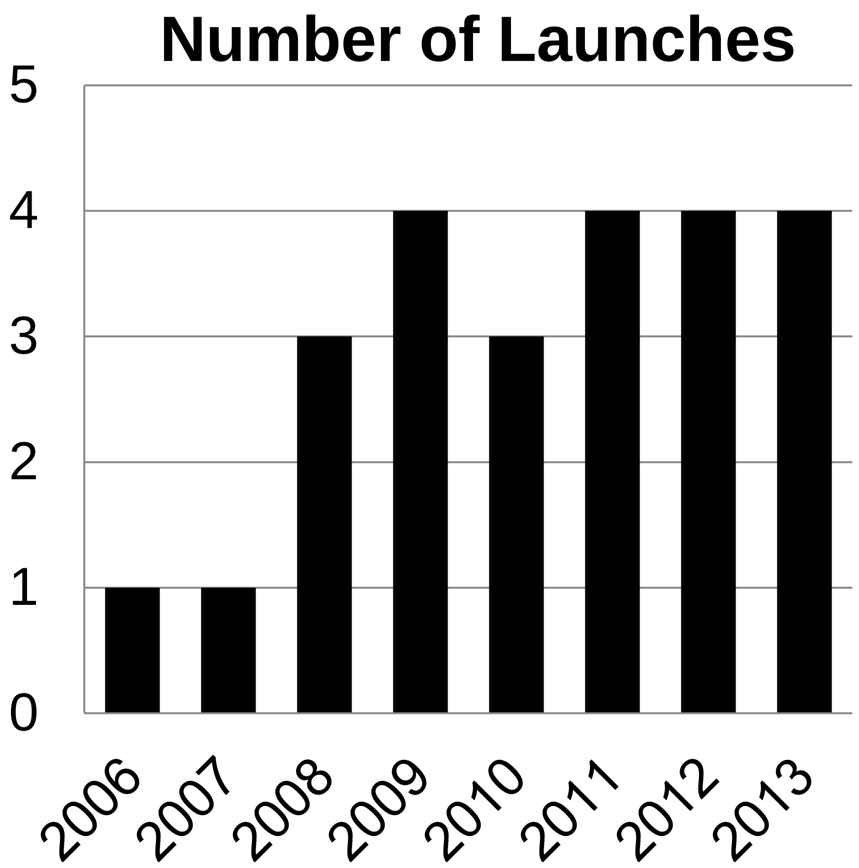
Breakdown by Orbit

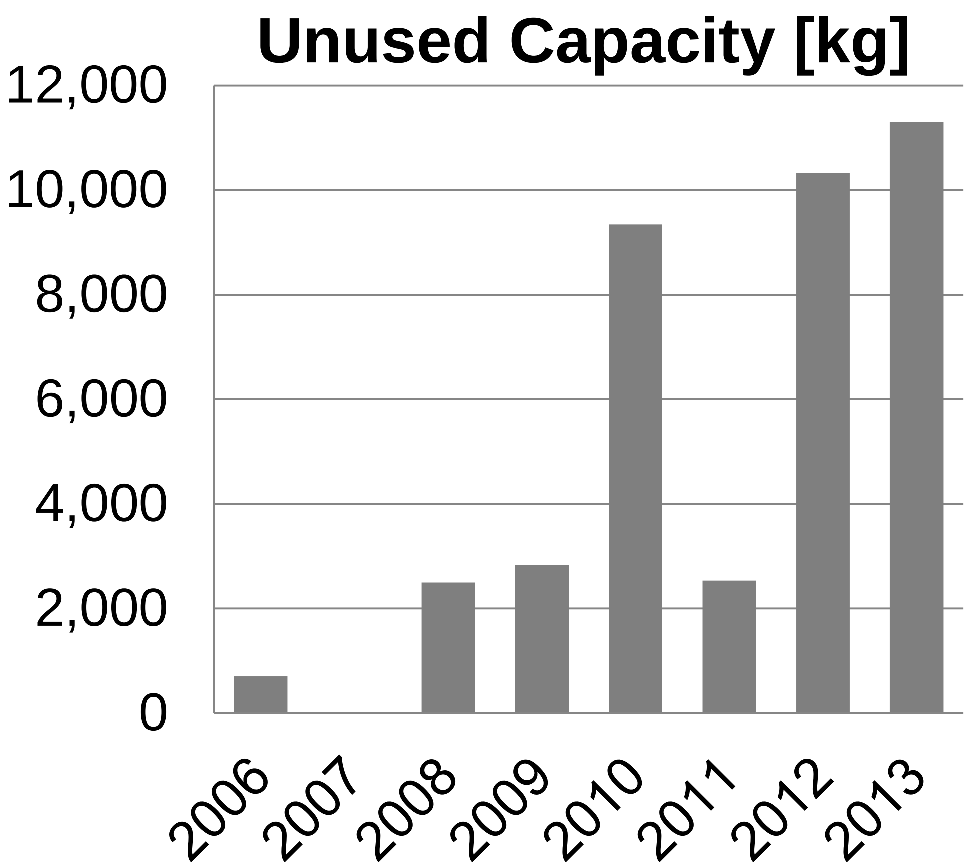




LEO has most unused capacity

Breakdown by Year





It's getting worse with time

Caveats

Uses for Excess Capacity

- Wider launch windows
- Trajectory optimization possible
- Increase primary lifetime
- Larger margin on the launch vehicle

Reasons Not to Have SHPs

- Scheduling
- No adapter available
- Risk
- Volume constrained

Results should be interpreted as an upper bound on actual unused capacity

Value of Excess Capacity

- 2002 study by the Futron Corporation on space transportation costs:

Price per kilogram (2000 dollars)

Vehicle Class	LEO	GTO
Small (Pegasus, Taurus)	$18,642	$41,591
Medium (Delta II, Antares)	$11,024	$26,783
Heavy (Atlas V, Delta IV, Falcon 9)	$9,801	$37,598

- Applied to NASA launch database (2013 dollars):
  - $900M total
  - $117M per year
  - $37.5M per launch

Conclusions and Future Work

- Three point plan:
  1. ~~Prove that there is excess capacity~~
  2. Demonstrate that this capacity is a valuable resource
  3. Use case studies to show that the capacity could be useful for high-return missions
- Estimate payload capacity for orbits with no published values
- Identify missions to use for case study
- Present case to NASA policy makers

Acknowledgements

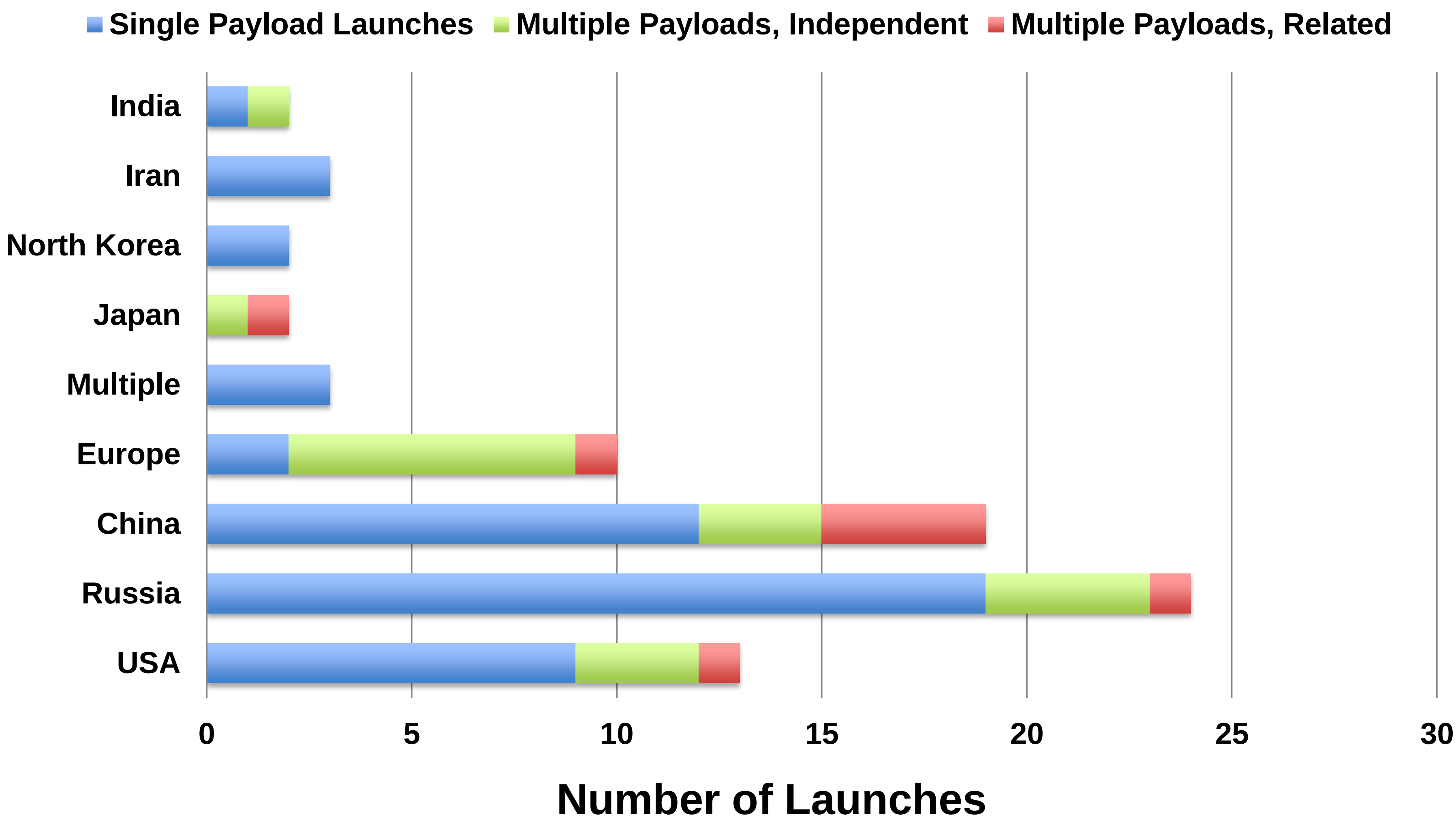
- Primary funding:
  - This work was funded by the Federal Aviation Administration Office for Commercial Space Transportation (FAA-AST) under cooperative agreement 10-C-CST-SU-002.
- Some of our industry partners:

ULA United Launch Alliance · LOCKHEED MARTIN · Scitor Corporation · Orbital · SPACE SYSTEMS LORAL

- Others:
  - Patrick Shannon
  - Tom Komarek

Backup Slides

2012 Secondary Payloads



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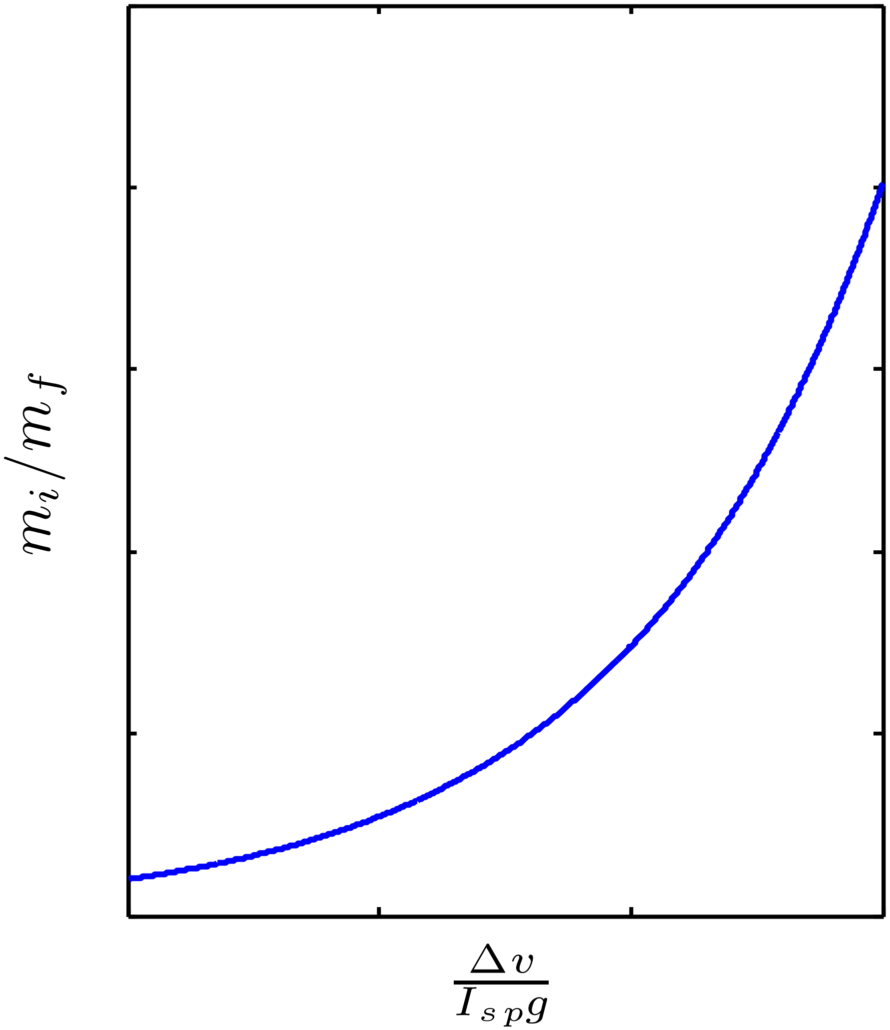
A Little Math

$$T = m\frac{dv}{dt}$$

$$\frac{dv}{dt} = \frac{I_{sp}g}{m}\frac{dm}{dt}$$

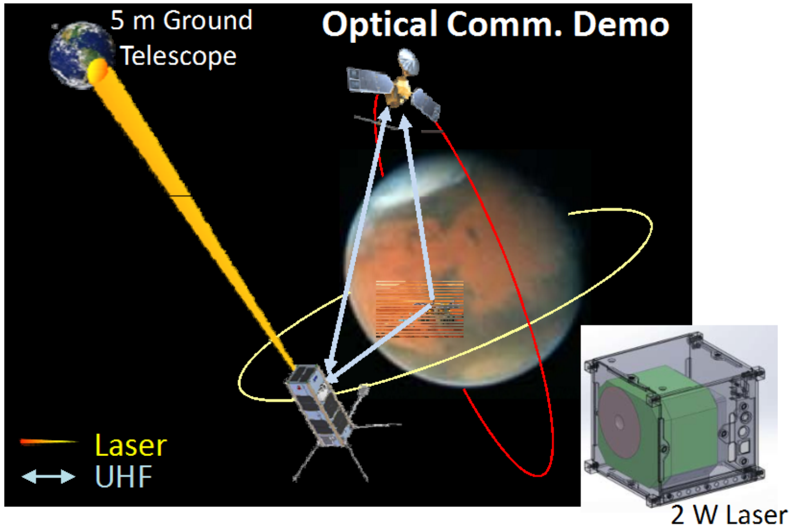
$$\Delta v = I_{sp}g \ln\left(\frac{m_i}{m_f}\right)$$

$$\exp\left(\frac{\Delta v}{I_{sp}g}\right) = \frac{m_i}{m_f}$$

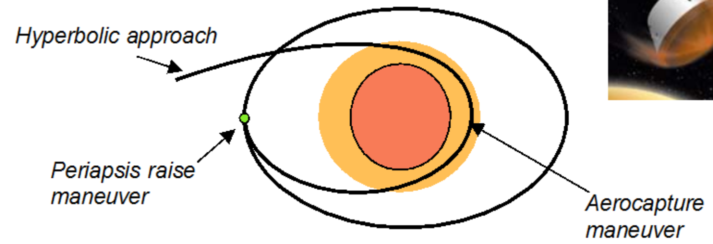


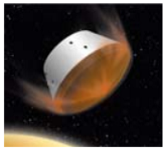
Three Example Mission Concepts

Tom Komarek
JPL



Aerocapture Demo

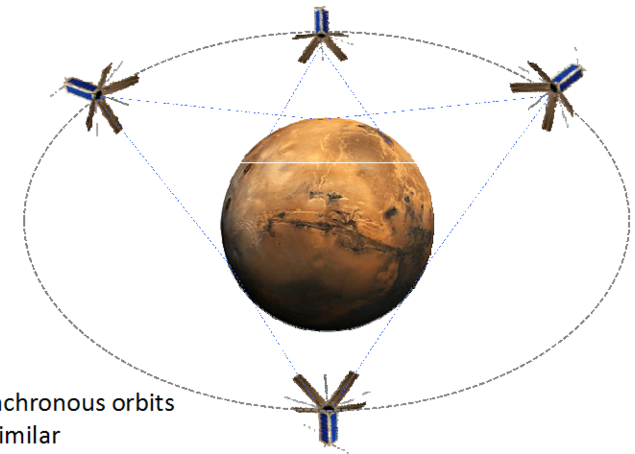




- Aerocapture replaces chemical propulsion as a method of insertion into Mars orbit
- Released on hyperbolic trajectory ~4 days prior to closest approach

- **Optical Comm. Demo:** 5 kbit/s from Mars at 2 AU
- **Aerocapture Demo:** Enables Mars orbit insertion without chemical propulsion
- **Mars CubeSat Network:** Enables spatially distributed continuous coverage for atmospheric or gravity science

Mars CubeSat Network



- 3 Equatorial Synchronous orbits
- 1-2 Polar sats (similar observation, lower orbit)