Reusable Launch Vehicle (RLV)
Mission/Market Model

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Mission Model

- Assess the Vehicle’s Capabilities to Support ISS Servicing
- Determine the Potential to Leverage the Commercial Marketplace to Reduce NASA Cost
- Evaluate the Vehicle’s Ability to Expand the Space Economy
Mission Model Methodology

Data Sources
- ISS: JSC and LaRC Studies
- NASA Science: Architecture Study Guidelines and the National Mission Model
- DoD: National Mission Model
- Commercial LEO: FAA Associated Administrator for Commercial Space Transportation
- Commercial GTO: COMSTAC Report
- Emerging Markets: Commercial Space Transportation Study (CSTS)

Payload Classification
- Two Classes of ISS Servicing
  - Shuttle or Shuttle Equivalent
  - 25K lbs to ISS
- National Mission Model Approach used for NASA Science and DoD Missions
- Commercial LEO Classifications same as FAA
- All GTO Missions (Commercial and USG) Classified Consistent with COMSTAC

Multiple Manifesting
- No Multiple Manifesting of NASA Scientific or DoD LEO Payloads
- Multiple Manifesting of Commercial LEO Missions Built into Source Material
- GTO Payloads Multiple Manifested in Market Analysis Model
ISS Servicing Mission Models

25K Vehicle Flight Rate
- Assumed IOC in 2005
- Crew & Cargo Carried Separately

Common Assumptions
- One CRV Rotation Flight Every 3 Years
- One Contingency Flight Per Year

Shuttle Flight Rate
- ISS Assembly Complete in 2005
- USG Portion Only
<table>
<thead>
<tr>
<th>Year</th>
<th>LEO Vehicle Classification</th>
<th>GTO Vehicle Class</th>
<th>Medium: Medium + Med-Lite (TBD)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Small &lt; 4,000 lbs</td>
<td>Medium 4,000 - 22,400 lbs</td>
<td>Heavy &gt; 22,400 lbs</td>
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<tr>
<td>2020</td>
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<td>5</td>
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Estimated as a Repeat of 2008, 2009 & 2010

Bantam Flights Not Inc.
## DoD Mission Model

<table>
<thead>
<tr>
<th>LEO Vehicle Classification</th>
<th>GTO Vehicle Classification</th>
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<tr>
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<td>&gt; 22,400 lbs</td>
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<td>Estimated repeat of 2008, 2009 &amp; 2010</td>
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From the DoD National Mission Model (NMM)

NMM Classes Used for LEO, COMSTAC Classes Used for GTO
COMSTAC
Commercial GTO Mission Model

Prepared by an Industry Advisory Group for FAA
Worldwide Commercial GTO Satellite Mission Model

“Addressable Payloads” Open to International Competition

Three Vehicle Classes
- MLV: 2,000 - 4,000 lb.
- ILV: 4,000 - 9,000 lb.
- HLV: >9,000 lb.
Prepared by the FAA Associate Administrator for Commercial Space Transportation (AST)

Graph Represents Baseline LEO Scenario

Four Big Systems
Three Little Systems
Two Broadband Systems
Captures Remote Sensing and Foreign Scientific Missions

Two Launch Vehicle Classes
Small (<5,000 lb. to LEO)
Medium to Heavy (>5,000 lb. to LEO)
Commercial Mission Model

- 689 Payloads
  - Commercial GTO
    - 669 Flights
  - Commercial LEO
  - DoD
    - 195 Payloads
    - 126 Payloads

## Emerging Market

<table>
<thead>
<tr>
<th>$5000/lb to LEO</th>
<th>$1000/lb to LEO</th>
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<tbody>
<tr>
<td><strong>Vehicle</strong></td>
<td><strong>High</strong></td>
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<tr>
<td>10K</td>
<td>3 Flts</td>
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<td>4 Flts</td>
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<td>55K</td>
<td>2 Flts</td>
</tr>
<tr>
<td>100K</td>
<td>1 Flts</td>
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</table>

<table>
<thead>
<tr>
<th>$600/lb to LEO</th>
<th>$400/lb to LEO</th>
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</thead>
<tbody>
<tr>
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<td>55K</td>
<td>41 Flts</td>
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<tr>
<td>100K</td>
<td>25 Flts</td>
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</table>

Data from the Commercial Space Transportation Study Final Report

Only Known Source of Emerging Market Data (Future Spacelift Requirements Study Confirmed and Repackaged)

Problem with Commercial Market Overlap

Used High Probability Flight Rates to Develop Parametric Model using PPF (Converted from $/lb) and Vehicle LBS to LEO as the Drivers
Mission Model Analysis

- Flight Rate
- Mass (10k lbs)
- Revenue ($B)
Market Analysis Model

Purpose: Estimate Annual Flight Rate for a Conceptual Vehicle Driven by Vehicle Capability and Price Per Flight (PPF)

Competitive Base: Current and Future ELV’s and RLV’s

Data on Commercial Launch Vehicle Capabilities and Prices
- International Space Industry Report, 9 November 1998
- EELV Program Office

Three Market Segments
- ISS Servicing
- Commercial: Today’s Commercial GTO and LEO Market plus Unmanned USG Missions
- Emerging: New (and Speculative) Business Opportunities
Market Model Inputs and Process

**Inputs**
- Vehicle LEO Capability, PPF (by Market Segment, IOC, Upper Stage, F and Weight, ISS Capability and Transition Years, Select/Deselect Market Segment)

**Model Functions**
- Market Capture Analysis
- Market Penetration
- Emerging Market Model
- Multiple Manifesting

**Model Databases**
- Mission Model
- Commercial Competitors

**Economic Analysis**
- NASA Scientific Flight Rate
- Commercial LEO Flight Rate
- Commercial GTO Flight Rate
- ISS Flight Rate
- DoD Flight Rate
- Emerging Market Flight Rate
ISS Servicing Market Model

Flight Rates Based on JSC/LaRC Analysis

If the Vehicle is Capable, Assumed to Capture all Flights (PPF Not a Factor)

Transition Rate Assumed to be Linear

IOC Date and Years in Transition can be Varied for Sensitivity Analysis
Commercial Market Model

Our Market Segments
- Commercial GTO
- Commercial LEO
- DoD
- NASA Scientific

Market Driven by Demand for On-Orbit Services (Communications) and US Budgets
Currently a Thriving Commercial Market to Supply Launch Services

Any New Vehicle Must Take Market Share from Existing Competitors

Market Capture Model Based on Economic Theory (Oligopoly)

Model Uses Mass to Orbit and Price to Determine Capture; Volume, Reliability, etc. are Not Factored into the Analysis

**Inputs:**
- LBS to Orbit (LEO & GTO)
- PPF
- Upper Stage Weight and PPF
- IOC
# Commercial Market Model

## Competitive Market Segments

<table>
<thead>
<tr>
<th>Vehicle Class</th>
<th>Weight Range (lbs)</th>
<th>Price per Flight ($M)</th>
<th>Number of Companies</th>
<th>Representative Vehicles</th>
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</thead>
<tbody>
<tr>
<td>Commercial GTO</td>
<td></td>
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</tr>
<tr>
<td>Medium</td>
<td>2,000 - 4,000 GTO</td>
<td>$36</td>
<td>4</td>
<td>Delta 2, CZ-4B, M-5</td>
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<tr>
<td>Intermediate</td>
<td>4,000 - 9,000 GTO</td>
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<td>6</td>
<td>Ariane 4, Atlas II, Delta 3, CZ-3A</td>
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<tr>
<td>Heavy</td>
<td>&gt; 9,000 GTO</td>
<td>$93</td>
<td>5</td>
<td>Ariane 5, CZ-3B, Proton, Zenit 3SL</td>
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<tr>
<td>Commercial LEO</td>
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<td>Ariane, Atlas, Delta, H-2A, Soyuz</td>
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<tr>
<td>Government GTO</td>
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<td>Small</td>
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<tr>
<td>Heavy</td>
<td>&gt; 22,400 LEO</td>
<td>$140</td>
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<td>EELV Heavy</td>
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</tbody>
</table>

Average Price Per Flight used to Establish Market Equilibrium
Commercial Market Model
Market Capture Function

\[ y = -16.957x^5 + 84.787x^4 - 171.64x^3 + 175.77x^2 - 91.395x + 19.436 \]

RLV PPF Relative to Market Equilibrium
Commercial Market Model
Market Penetration Assumption

• Assumes 5 Years to Build Customer Base

• Expressed as a Percent of the Maximum Market Share the RL can Capture

• Initial Market Penetration is 20% and Grows at a 50% Rate


• Also Applied to the Emerging Market
Commercial Market Model
Market Capture Analysis

US Government GEO/LEO
Low Earth Orbit Commercial
GEO Commercial Communications
Vehicle Class | Price Per Flight
---|---
Medium | $36
Intermediate | $70
Heavy | $93

Competitive Market

If Number of Competitors is 4,
Market Share Per Competitor
At Equilibrium is $1/4 = 25%$

Market Behavior Function

![Graph showing market behavior function]

The RLV PPF of $50M is Divided by Market Equilibrium PPF ($50/$70 = 0.72),
and Input into the Market Behavior Function, the Market Behavior Function is Added to the Equilibrium Market Share and then Multiplied by the Demand Projection: $22\% + 25\% = 47\% * 17 Flights Per Year
Emerging Market Model

Plot of Flight Rate Curves
For Selected Vehicle Classes

Price Per Flight

Business Opportunities Created by a Significant Reduction in the Price to Orbit

Based on an Analysis of CSTS Data, Curve Fitted to Summary Data (Drivers are Weight
(F) with an $R^2 = 0.875$

Disabling Price ($/lb) can be Adjusted to Reflect a Conservative Bias

Assume Vehicles Creating this Market Capture all Flights
Market Capture for a Conceptual TSTO Vehicle

TSTO Market Capture

- Emerging Market
- Commercial GEO
- Commercial LEO
- DoD
- NASA Scientific
- ISS Servicing

Graph showing market capture from 2001 to 2020.
Market Model Sensitivity Analysis

- Mission Model Sensitivity
  - Vary Number of Existing Commercial Flights

- Market Capture Sensitivities
  - Increase or Decrease Effect of the Market Capture Function
  - Vary Equilibrium Price
  - Vary Number of Competitors

- Emerging Model Sensitivities
  - Vary Number of Emerging Flights
  - Change Enabling $/lbs
Sensitivity Analysis
Commercial Market

Baseline Number of Flights

- 40Klbs to LEO
- 20Klbs Upper Stage Weight
- $50M Vehicle PPF
- $20M Upper Stage Price
- IOC Year: 2007

- 20Klbs to LEO
- 15Klbs Upper Stage Weight
- $30M Vehicle PPF
- $15M Upper Stage Price
- IOC Year: 2007