Potential LEO Markets

- Commercial human spaceflight and accommodation (tourism)
- Basic and applied research
- Aerospace test & demo
- Education
- Media and public relations
- Remote sensing (vehicle/platform based)
- Satellite deployment and operation
- On-orbit transportation
- Infrastructure support (servicing, propellant depots, midware)
- Resource acquisition/utilization
- Manufacturing
- Point-to-point transportation
Today’s Commercial LEO Economy

**SUBORBITAL TRANSPORT**
- Blue Origin
- Virgin Galactic
- XCOR

**ORBITAL TRANSPORT**
- Boeing CST-100 Starliner
- SpaceX Dragon
- SNC Dream Chaser
- Blue Origin Space Vehicle
- ISS
- Bigelow Aerospace BEAM, BA 330

**OTHER SERVICES**
- Payload Integrator NanoRacks
- Launch/Payload Broker Spaceflight Industries
- Satellite Servicing ViviSat
- Payload Integrator NanoRacks
- Launch/Payload Broker Spaceflight Industries

**DESTINATIONS**
- Golden Spike
- Space Adventures
- Planetary Resources Arkyd
- SpaceX

**Satellites**
- Telecommunications, remote sensing, weather, navigation
- Satellites
- Satellite Servicing ViviSat
SUBORBITAL MARKETS
# Suborbital Commercial Human Spaceflight Providers

<table>
<thead>
<tr>
<th>Company</th>
<th>Suborbital Reusable Vehicle</th>
<th>Seats*</th>
<th>Locker Equivalents (estimated)</th>
<th>Cargo (kg)</th>
<th>Price per Seat</th>
<th>Ticket Reservations</th>
<th>Expected Operational Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue Origin</td>
<td>New Shepard</td>
<td>6</td>
<td>5</td>
<td>120**</td>
<td>Not announced</td>
<td>Not announced</td>
<td>2017</td>
</tr>
<tr>
<td>Virgin Galactic</td>
<td>SS2</td>
<td>6</td>
<td>36</td>
<td>600</td>
<td>$200K</td>
<td>700+ (as of October 2015)</td>
<td>2017</td>
</tr>
<tr>
<td>XCOR Aerospace</td>
<td>Lynx Mark I</td>
<td>1</td>
<td>3</td>
<td>120</td>
<td>$150K***</td>
<td>300+ (as of July 2015)</td>
<td>2016</td>
</tr>
<tr>
<td></td>
<td>Lynx Mark II</td>
<td>1</td>
<td>3</td>
<td>120</td>
<td>$150K***</td>
<td></td>
<td>2017</td>
</tr>
<tr>
<td></td>
<td>Lynx Mark III</td>
<td>1</td>
<td>28</td>
<td>770</td>
<td>$150K per seat, $500K for small sat launch***</td>
<td></td>
<td>2018</td>
</tr>
</tbody>
</table>

* Maximum number of space flight participants, exclusive of crew (several vehicles are piloted)

** Net of payload infrastructure

*** Effective January 1, 2016
Suborbital Demand

Basic and Applied Research

Technology Demonstration

Education

Satellite Deployment

Media and Public Relations

Commercial Human Spaceflight

Additional potential demand
(not estimated)

- Game changing unknowns: price reductions, research discoveries, commercial applications, major sponsorships, others
- Growth: Multiple flights per day, $1.6B over 10 years
- Increased demand from marketing, research successes, and flight operations
- Baseline: Daily flights, nearly $600M over 10 years
- Today’s consumer demand and research budgets
- Constrained: Multiple flights per week, $300M over 10 years
- If there is a significant drop from today’s demand

Growth: Multiple flights per day, $1.6B over 10 years

Approximate Annual Flight Revenue (Bil)

Year 1: Year 2: Year 3: Year 4: Year 5: Year 6: Year 7: Year 8: Year 9: Year 10

0 $50 $100 $150 $200
ORBITAL MARKETS
# Commercial Human Orbital Spaceflight Providers

<table>
<thead>
<tr>
<th>Company</th>
<th>Orbital Vehicle</th>
<th>Launch Vehicle(s)</th>
<th>Max. Crew</th>
<th>First Flight</th>
<th>NASA Funding Awarded to Date</th>
<th>2015 Highlights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue Origin</td>
<td>Space Vehicle</td>
<td>Atlas V Blue Origin RBS</td>
<td>7</td>
<td>TBD</td>
<td>$25.6M</td>
<td>Orbital launch vehicle announced, with site selected at Cape Canaveral</td>
</tr>
<tr>
<td>Boeing</td>
<td>CST-100Starliner</td>
<td>Atlas V Delta IV Falcon 9</td>
<td>7</td>
<td>2017</td>
<td>$4.8B</td>
<td>Completed processing facility at KSC (formerly OPF-3) and announced new name of vehicle</td>
</tr>
<tr>
<td>Sierra Nevada Corp.</td>
<td>Dream Chaser</td>
<td>Atlas V</td>
<td>7</td>
<td>2019</td>
<td>$363.1M</td>
<td>Still developing crewed vehicle, but focusing on cargo version in anticipation of CRS-2. Established science mission partnership with OHB System</td>
</tr>
<tr>
<td>SpaceX</td>
<td>Dragon (Cargo)</td>
<td>Falcon 9</td>
<td>0</td>
<td>2012 (actual)</td>
<td>$396M (COTS) $1.5B (CRS)</td>
<td>Conducted 3 cargo missions, one lost in launch failure</td>
</tr>
<tr>
<td></td>
<td>Dragon (Crew)</td>
<td>Falcon 9</td>
<td>7</td>
<td>2017</td>
<td>$3.1B</td>
<td>Successful pad abort test</td>
</tr>
</tbody>
</table>

NASA currently drives LEO demand for human spaceflight
- NASA demand is well understood in near to mid term;
- Contracts are in place

Limited systematic assessment of non-NASA markets available publicly
- Most commonly targeted potential customers (non NASA) appear to be
  - ISS partners (research, tech demo)
  - Other nations (training, space experience, research, tech demo)
  - Satellite launch
- Anecdotal information about other potential applications

Source: NASA HQ (May 2015), updated to reflect actual flights
ON-ORBIT DESTINATIONS
## On-orbit Destinations for Commercial Human Spaceflight

<table>
<thead>
<tr>
<th>Destination</th>
<th>Mission Profile</th>
<th>Company</th>
<th>Launch Vehicle(s)</th>
<th>On-orbit Transportation Vehicle</th>
<th>First Flight</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEO</td>
<td>Genesis I</td>
<td>Bigelow Aerospace</td>
<td>Dnepr</td>
<td>N/A</td>
<td>2006</td>
</tr>
<tr>
<td>LEO</td>
<td>Genesis II</td>
<td>Bigelow Aerospace</td>
<td>Dnepr</td>
<td>N/A</td>
<td>2007</td>
</tr>
<tr>
<td>LEO</td>
<td>BEAM</td>
<td>Bigelow Aerospace</td>
<td>Falcon 9</td>
<td>Dragon CRS-8 (trunk)</td>
<td>2016</td>
</tr>
<tr>
<td>LEO</td>
<td>BA 330</td>
<td>Bigelow Aerospace</td>
<td>Atlas V</td>
<td>Dragon, CST-100 Starliner</td>
<td>2017</td>
</tr>
<tr>
<td>LEO</td>
<td>BA 2100</td>
<td>Bigelow Aerospace</td>
<td>Falcon Heavy, SLS</td>
<td>Dragon, CST-100 Starliner</td>
<td>TBD</td>
</tr>
<tr>
<td>LEO</td>
<td>ISS</td>
<td>Space Adventures</td>
<td>Soyuz</td>
<td>Soyuz CST-100</td>
<td>1998 TBD</td>
</tr>
<tr>
<td>LEO</td>
<td>ISS</td>
<td>Space Adventures</td>
<td>Soyuz</td>
<td>Soyuz CST-100</td>
<td>1998 TBD</td>
</tr>
<tr>
<td>Moon</td>
<td>Surface</td>
<td>Golden Spike</td>
<td>TBD</td>
<td>Lunar Lander (Northrop Grumman)</td>
<td>TBD</td>
</tr>
<tr>
<td>Moon</td>
<td>Orbit</td>
<td>Space Adventures</td>
<td>Soyuz</td>
<td>Soyuz and habitation module</td>
<td>2018</td>
</tr>
<tr>
<td>Mars</td>
<td>Mars</td>
<td>SpaceX</td>
<td>Future large vehicle</td>
<td>TBD</td>
<td>2030s</td>
</tr>
</tbody>
</table>

**Images:**
- ISS
- Bigelow Aerospace BEAM
- Bigelow Aerospace BA 330
- Space Adventures DSE-Alpha
- Golden Spike
- SpaceX on Mars
On-Orbit Destination Demand

- **LEO Platforms**
  - **ISS**
    - New demand may be associated with availability of commercial transportation
    - May be concern regarding potential procedural barriers to use
    - Limited demand to date for ISS availability for research; may be related to transportation access
  - **Bigelow**
    - Appears to have targeted national actors as customers; MOUs with 7 governments
    - Recent NASA contract
    - No other announced sales to date

- **Moon/Mars**
  - One reported ticket sale to date
  - Target customers (when characterized) typically high net worth individuals or national actors
Potential Benefits to Government of a Commercial LEO Economy

- Enhanced capability
- Buy by the yard
- More opportunities to test
- Researchers and citizen scientists
- Increased visibility of space activities
- Reduced costs
  - Launch
    - Competition
    - Launch rate
  - Technologies
  - ISS
Market Dynamics/Reality Check

- Proposed systems largely viewed as technically credible
- Mix of business experience, from global entrepreneurial superstars to technologists building companies
- Meaningful investment with potential for more
- Business case not proven; uncertain demand and revenue potential
  - Significant commercial demand for suborbital services, demonstrated ticket sales; supply side somewhat uncertain
  - Potential commercial demand for orbital services and LEO destinations, limited analysis
  - Unknown demand for Moon/Mars destinations, very little data
- Major challenges: magnitude of investment is massive, technology is complex, timelines are long
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