



Small Launch Vehicles A 2015 State of the Industry Survey

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- Overview of Small Launch Vehicles
- Launch Method/Locations
- Launch Performance
- Projected Launch Costs
- Individual Rocket Details

- Have a **maximum capability** to LEO of 1000 kg (definition of LEO left to the LV provider).
- The effort must be for the development of an **entire launch vehicle system** (with the exception of carrier aircraft for air launch vehicles).
- Mentioned through a web site update, social media, traditional media, conference paper, press release, etc. **sometime after 2010**.
- Have a stated goal of completing a **fully operational space launch (orbital) vehicle**. Funded concept or feasibility studies by government agencies, patents for new launch methods, etc., do not qualify.
- Expect to be **widely available** commercially or to the U.S. Government
- No specific indication that the effort has been cancelled, closed, or otherwise disbanded.

*Corrections, additions, and comments are **welcomed and encouraged!***

We did not ...



- ... Talk to the individual companies
- ... Rely on any proprietary/confidential information
- ... Verify accuracy of data found in public resources
 - Primarily relied on companies' web sites
- Funding sources, when listed, are not implied to be the vehicles sole or even majority funding source.

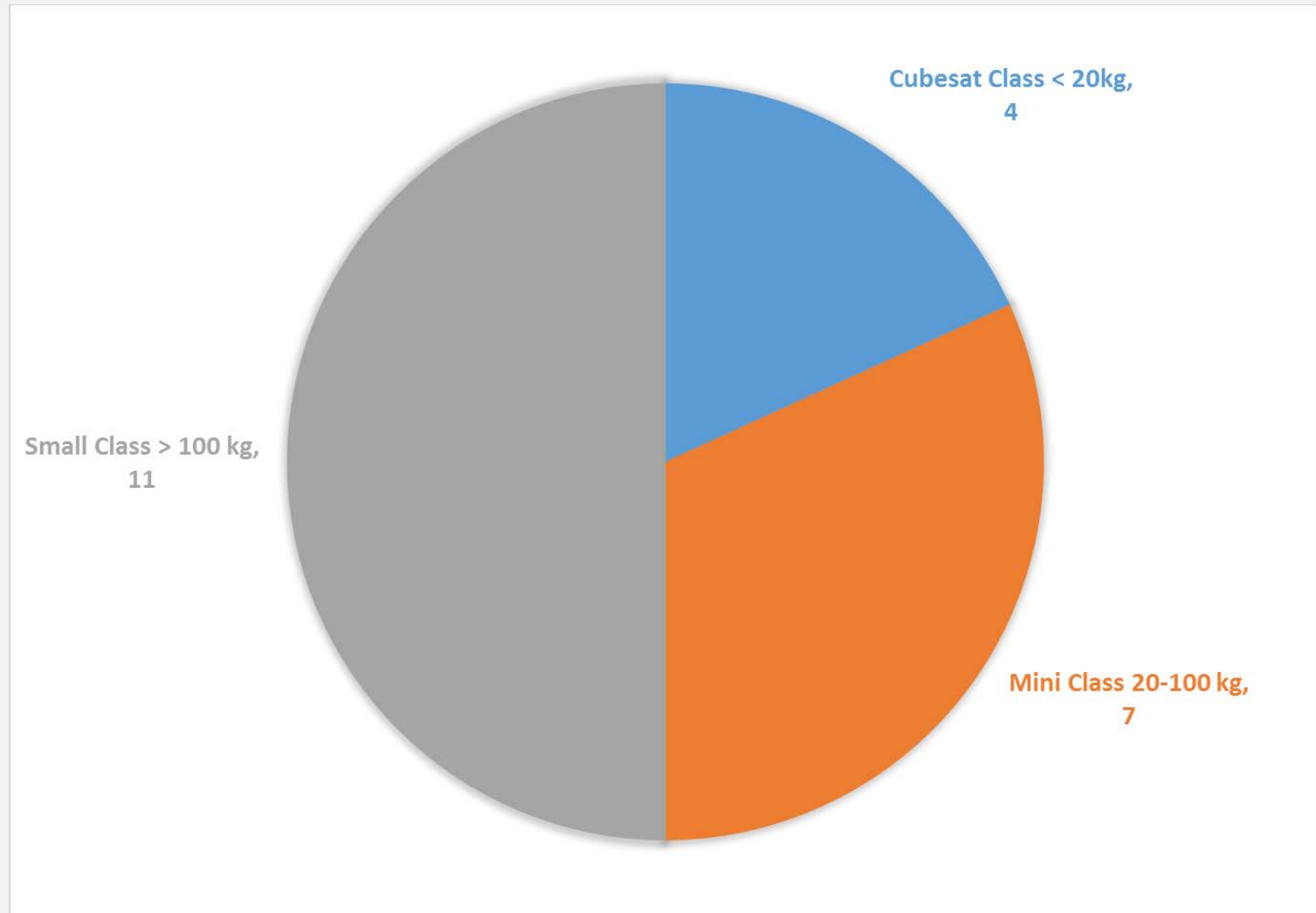
We do not make any value judgements on technical or financial
credibility or viability

Vehicle Overview

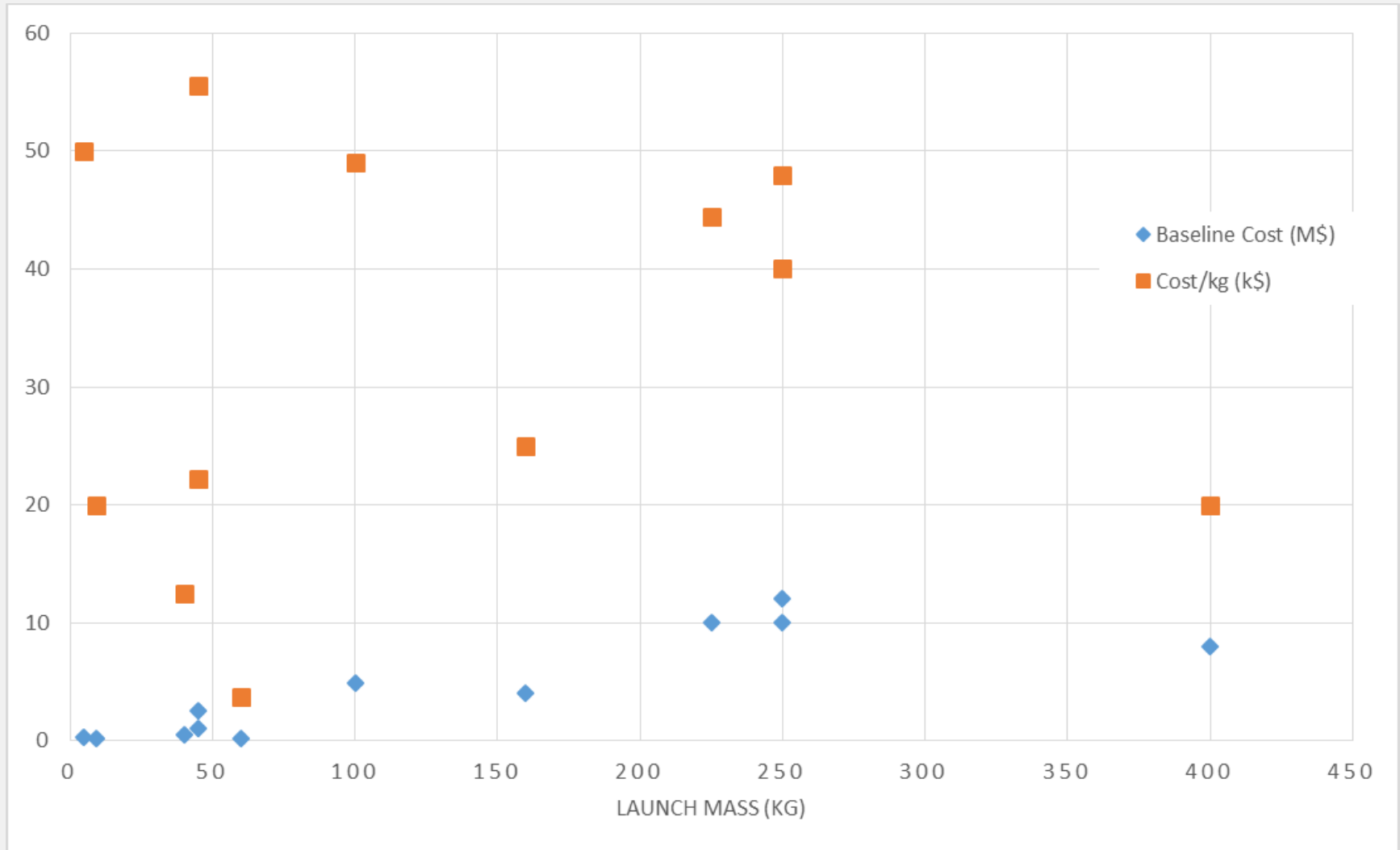


Organization	Vehicle Name	Country of Origin	First Launch Date
Boeing	ALASA	USA	Q1 2016
Lockheed Martin	Athena Ic	USA	After contract award
zero2infinity	Bloostar	Spain	
CubeCab	CubeCab	USA	July 2017
Scorpius Space Launch Company	Demi-Sprite	USA	
Rocket Lab	Electron	USA/New Zealand	2015
Firefly	Firefly α	USA	2017
Generation Orbit	GO Launcher 2	USA	Q4 2016
ARCA Space Corporation	Haas 2C	Romania/USA	
Virgin Galactic	LauncherOne	USA	Q4 2016
XCOR Aerospace	Lynx Mark III	USA	2017+
MISHAAL Aerospace	M-OV	USA	
Orbital ATK	Minotaur I	USA	2000
Garvey Spacecraft Corporation	Nanosat Launch Vehicle	USA	
Interorbital Systems	NEPTUNE N5	USA	Q4 2015
Open Space Orbital	Neutrino I	Canada	
Orbital ATK	Pegasus	USA	1990
Celestia Aerospace	Sagittarius Space Arrow	Spain	Q1 2016
Ventions	SALVO	USA	2015
Swiss Space Systems	SOAR	Switzerland	2017
U. Hawaii, Aerojet Rocketdyne, Sandia	Super Strypi	USA	October 2015
Lin Industrial	Таймыр	Russia	

How Small is Small?



Next Generation Launch Costs



Please see paper for assumptions



Boeing Artist's Concept

- Two Stage Air-Launched (F-15) Rocket
 - First and second stage share engines
 - Unmodified F-15
 - Each stage uses a monopropellant
 - Nitrous Oxide/Acetylene
- Funded by DARPA
- **Boeing** Prime Contractor
- \$1M/Launch Goal
- 45 kg Performance Goal

<http://www.boeing.com/space/advanced-space-access/>

- Derivative of Athena I
 - New Second Stage Solid Motor
- Two Stage Ground-Launched Rocket
 - Two Primary Stages are Solid
- Smallest in Athena Line of Modular Launch Vehicles
- **Lockheed Martin** Prime Contractor
- 700 kg Performance Goal



Athena I; Lockheed Martin

<http://www.lockheedmartin.com/content/dam/lockheed/data/space/documents/athena/Athena%20Fact%20Sheet%20Review%20vers%204.pdf>

- Three Stage Balloon Launched Rocket
- Concentric, Toroidal Stages
 - Identical Pressure-Fed Cryogenic Liquid Motors
- **Zero 2 Infinity** Prime Contractor
- 45 kg Performance Goal



Zero 2 Infinity

<http://www.bloostar.com/>



- Air-Launched (F-104) Rocket
- Winner of 2014 New Space Lightning Pitch Competition
- **CubeCab** Prime Contractor
- \$250K/Launch Goal
- 3U Cubesat (5 kg) Performance Goal

<http://cubecab.com/launch-services.html>



Demi-Sprite Model; Microcosm,

- Three Stage, Modular Ground Launched Vehicle
 - First and Second stages share core design
 - Jet-A/LOx engines with no turbopumps
 - Launch on demand within 8 hours
- **Scorpius Space Launch Company** Prime Contractor
- \$4M/Launch Goal
- 160 kg Performance Goal

<http://smad.com/launch/scorpius>



Rocket Lab

- Two Stage Ground Launched Vehicle
 - Each Stage Uses Identical, Additive Manufactured Engines
 - Engines Utilize Electric Turbopumps
- Funded by NZ Government, Kholsa, VBP, KIWI, Lockheed Martin
- **Rocket Lab** Prime Contractor
- \$4.9M/Launch Goal
- 100 kg Performance Goal

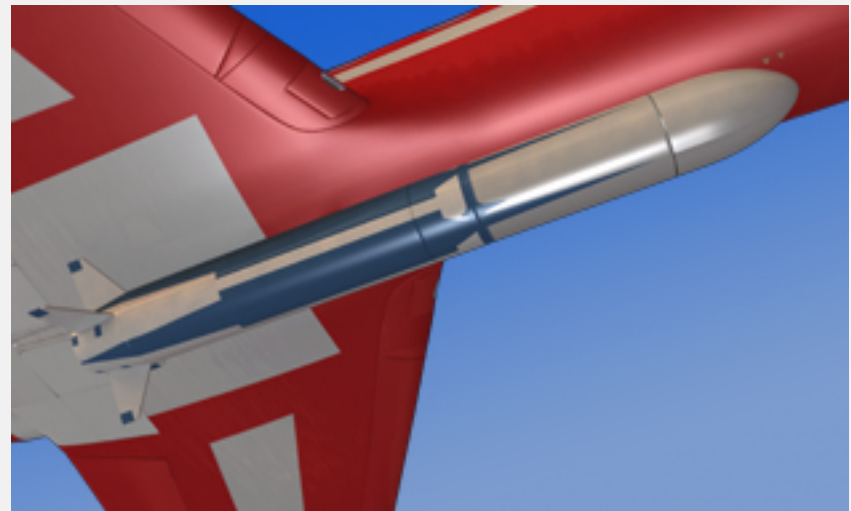
<http://www.rocketlabusa.com/index.html>

- Two Stage Ground Launched Vehicle
 - Each stage uses Identical Lox/Methane or Kerosene Engines
 - First Stage has 12 Engine Around Aerospike
 - Second Stage has Single Engine
- Funded by Local Government Grants
- **Firefly** Prime Contractor
- \$8-9 M/Launch Goal
- 400 kg Performance Goal



<http://www.fireflyspace.com/vehicles/firefly-a>

- Two Stage Air-Launched (Gulfstream IV-SP) Rocket
 - First Stage Tactical Solid
 - Second Stage Liquid
- Funded by SBIR Contracts
- **Generation Orbit** Prime Contractor
- \$2.5M/Launch Goal
- 40 kg Performance Goal



Generation Orbit

<http://www.generationorbit.com/golauncher2.html>

- Two Stage Rocket
 - Each Stage uses a LOx/RP-1 Engine
- Orbital LV evolved from SSTO engine demo
- **ARCA Space Corporation** Prime Contractor
- 400 kg Performance Goal



ARCA Space Corporation

<http://www.arcaspace.com/en/haas2c.htm>



Virgin Galactic

- Two Stage Air-Launched (White Knight 2) Rocket
 - Lox/Kerosene Engines
 - Leverage Spaceship-2 experience
- Funded Primarily by Virgin Group
- **Virgin Galactic** Prime Contractor
- \$10M/Launch Goal
- 225 kg Performance Goal

<http://www.virgingalactic.com/satellite-launch/>



XCOR Aerospace

- Two Stage Air-Launched (Lynx Mark III) Rocket
 - Reusable suborbital space plane
 - Liquid Propellant Two Stage Vehicle
- Funded by NASA/Haiyin Capital
- **XCOR Aerospace** Prime Contractor
- 15 kg Performance Goal

<http://aerospace.xcor.com/reusable-launch-vehicles/lynx-spacecraft/>



- Two Stage Ground Launched Rocket
 - Hybrid (HTPB/Nitrous Oxide)
- Part of LV family that also includes suborbital and lunar launchers
- **MISHAAL Aerospace** Prime Contractor
- 454 kg Performance Goal

<http://www.mishaalaerospace.com/orbital-vehicle>

Minotaur I



- Four Stage Solid Rocket
 - Lower 2 Stages Minuteman Based
 - Upper 2 Stages Pegasus Based
- 11 Launches with 100% Reliability
- Funded by USAF
- **Orbital ATK Prime** Contractor
- 584 kg Performance Goal

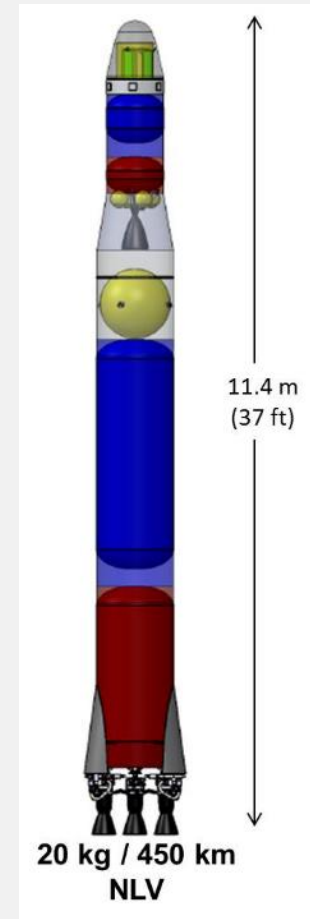


NASA

<http://www.orbitalatk.com/flight-systems/space-launch-vehicles/minotaur/>

Nanosat Launch Vehicle

- Two Stage Ground Launched Rocket
 - Liquid Powered Rocket Engines
- Funded by NASA
- **Garvey Spacecraft Corporation** Prime Contractor
- 20 kg Performance Goal



Garvey Spacecraft
Corporation

<http://www.garvspace.com/NLV.htm>



Neptune test vehicle; Interorbital

- Multi-Stage Ground Launched Rocket
 - Lower Stage Built of Bundled Common Propulsion Modules (CPM)
 - CPM's use White Fuming Nitric Acid and Turpentine
 - Upper Stages can be Solid
- Funded by Pre-sales
- **Interorbital** Prime Contractor
- \$0.25M Cost Goal
- 40 kg Performance Goal

http://www.interorbital.com/interorbital_06222015_012.htm

- Ground Launch Rocket
 - Hybrid Engines
- Open Space Orbital Prime Contractor
- 50 kg Performance Goal



<http://www.openspaceorbital.com/#!/launchvehicle/cipy>

Pegasus XL



- Three Stage Air-Launched (L-1011) Rocket
 - All Stages Solid Propellant
 - First Stage Aero Control
 - Second, Third Stage Thrust Vector Controlled
- 42 launches from 7 different launch sites
- Funded Orbital/Hercules
- **Orbital ATK** Prime Contractor
- 460 kg Performance Goal

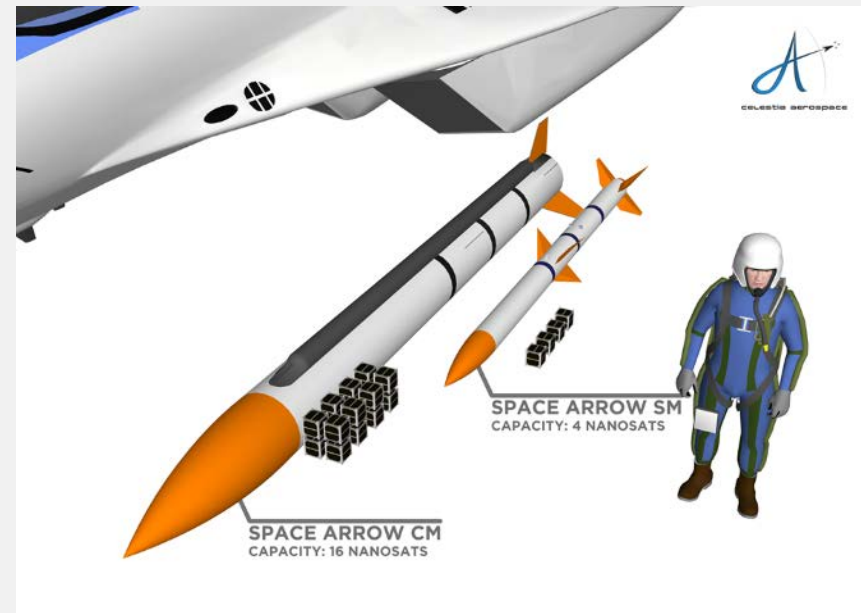


Orbital ATK, Inc

<http://www.orbitalatk.com/flight-systems/space-launch-vehicles/pegasus/>

Sagittarius Space Arrow

- Multi-stage Solid Air-Launched (Mig-29UB) Rockets
 - Utilizes existing aircraft and modified missiles
 - Option for 4 small rockets or 1 larger rocket
- Funded by DARPA
- **Celestia Aerospace** Prime Contractor
- \$0.24M/Launch Goal
- 4-16 Nanosat Performance Goal



Celestia Aerospace

<http://celestiaaerospace.com/>

- Two Stage Air-Launched (F-15E) Rocket
 - Battery Powered pumps
 - LOx/RP-1 Engines
 - Unmodified F-15
- Funded by DARPA/Precursor to ALASA program
- **Ventions** Prime Contractor
- 4 kg Performance Goal



DARPA via AmericaSpace.com

No website available



Swiss Space Systems

- Two Stage Air-Launched (A-300) Rocket
 - Suborbital Space Plane
Launched from Top of A-300 Carrier Aircraft
 - Lox\RP-1 Engine
 - Orbital Insertion Upper Stage
- Funded by Breitling
- **Swiss Space Systems** Prime Contractor
- <\$10M/Launch Goal
- 250 kg Performance Goal

<http://www.s-3.ch/en/mission-goals>



Sandia National Labs

- Three Stage Solid Ground Rail-Launched Rocket
 - Spin-Stabilized
 - Reorient Prior to Third Stage Ignition
- Funded by USAF
- **Sandia** Prime Contractor
- \$12M/Launch Goal
- 250 kg Performance Goal

[No website available](#)



Lin Industrial

- Multi stage Hydrogen Peroxide /RP-1 Ground Launched Rocket
 - Hydrogen Peroxide /RP-1
 - Multi-Core Options
 - No turbopumps
- Funded by Sergei Burkatovsky
- Lin Industrial Prime Contractor
- \$0.18M Goal
- 9 kg Performance Goal

<http://www.spacelin.ru/#!taymyr/c1wuk>

- Applied Thermal Sciences – VALT
<http://www.appliedthermalsciences.com/pages/hypersonics.html>
- Masten Space Systems – Xephyr
<http://masten.aero/>
- MicroLaunchers LLC – ML1
<http://www.microlaunchers.com/7816/L3/sa09/sa09.html>
- Newton Launch Systems
<http://www.newtonlaunchsystems.com/default.aspx>
- RocketStar, LLC
<http://www.rocketstar.nyc>
- Swedish Space Corporation – Rainbow Smallsat Express
- Unreasonable Rocket – Unreasonable Rocket
<http://unreasonablerocket.blogspot.com/>
- Whittinghill Aerospace – Minimum Cost Launch Vehicle