



Content

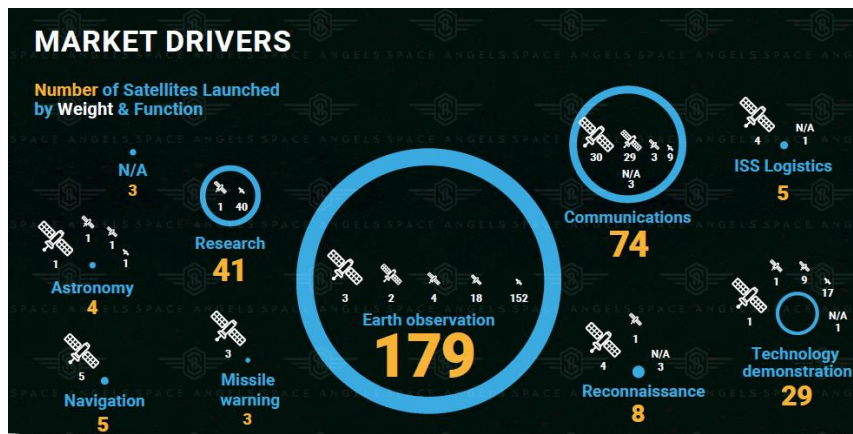


- ❑ Introduction – Why Small Launcher?
- ❑ NASA Flight Opportunities Program
- ❑ Small Launcher Technologies – Public Private Partnership
- ❑ Area of Opportunities
 - ❑ Announcement of Collaborative Opportunities (ACO)
 - ❑ Tipping Point
 - ❑ Small Business Innovative Research (SBIR)
- ❑ Technology Development Trends - A personal observation

Need for Dedicated Small Launcher



- “Small Sat” is not just for science anymore!
- It has become a viable business for investors
 - A global phenomenon
- Demands for dedicated Small Sat Launcher
 - Go WHERE you want to go, WHEN you want to go, at a PRICE you can afford,
 - WHEN to start booking revenues!
- Need to maintain U.S. competitiveness in commercial space access

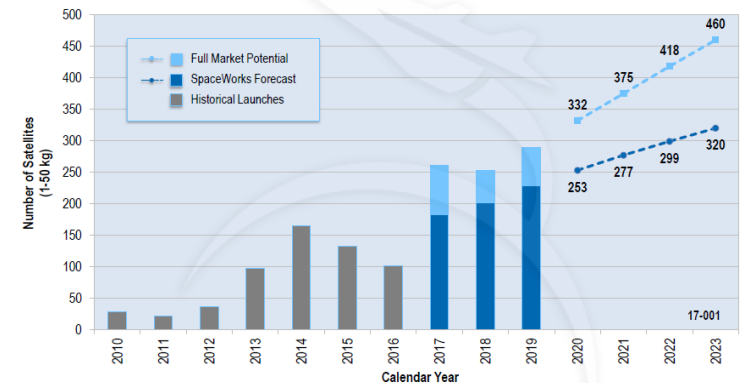


Space Angels, “Space Investment Quarterly”, Q3, 2017

SpaceWorks 2017 Nano/ Microsatellite Forecast

2017 Nano/Microsatellite Launch History and Forecast (1 - 50 kg)

Projections based on announced and future plans of developers and programs indicate nearly 2,400 nano/microsatellites will require a launch from 2017 through 2023



MARKETS

US EU ASIA OIL BONDS GOLD

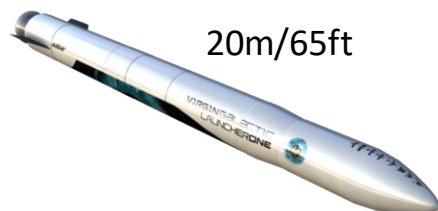
Space companies are receiving billions from venture backers, report says

- Investment firm Space Angels said that over \$2 billion in private investment has flowed into space industry companies this year.
- The number of venture firms investing in space reached 59 this year, up from five in 2011.

Michael Sheetz | @thesheetztweetz
Published 4:23 PM ET Wed, 1 Nov 2017



Sample of Small Launchers in Development



20m/65ft



23m/77ft



17m/56ft



13m/43ft



9.75m/32ft

Green = ACO/TP partners

Vehicle	LauncherOne	Firefly Alpha	Electron	Vector-R	Spyder
Launch	Air	Land	Land	Land	Land
Expected	2018	2020	2018	2018	-
P/L LEO	500kg @ 230km*	360kg @ 400km [#]	224kg @ 300km [^]	70kg @ 200 km	8kg @ 370 km
P/L SSO	300kg @ 500km	200kg @ 500km	150kg @ 500km	30kg @ 450 km	-
Cost/kg	\$33K/kg	\$50K/kg	\$40K/kg	\$33K/kg	\$125K/kg
Price	<\$10M	\$10M	\$6M	\$1M	\$1M

SSO : Sun-Synchronous Orbit

* circular 0deg incl.

[#] circular +45deg incl.

[^] apogee with 180km perigee +45deg incl.

Investments in U.S. Small Launch Providers



Vehicle	LauncherOne	Firefly Alpha	Electron	Vector-R	Spyder			
Company	Virgin Orbit	Firefly Aerospace	Rocket Lab USA	Vector Space Systems	UP Aerospace	Relativity	Ventions	Generation Orbit – Launch Services
Corporate Structure	Subsidiary of Virgin Group	Private	Private	Private	Private	Private	Private	Private
Founded	2017	2017 (restart)	2006	2016	2004	2015	2004	2011
HQ Location	Los Angeles, CA	Cedar Park, TX	Long Beach, CA	Tucson, AZ	Denver, CO	Los Angeles, CA	SF, CA	Atlanta, GA

Private Funding*

Latest Round	-	\$19M Venture (June 2016)	\$75M Series D (March 2017)	\$21M Series A (June 2017)	?	tbd	?	?
Total	-	\$21.76M	>\$75M	\$27.75M	?	>\$10M^	?	?

U.S. Government – NASA only**

VCLS	\$4.7M	-	\$6.9M	-	-	-	-	-
ACO2017	\$1.2M	-	-	-	\$1.2M	\$1.2M	-	-
TP2016	-	-	-	\$1.9M#	\$2M	-	\$2M	-
ACO2015	\$1M	-	-	\$0.6M	\$1M	-	-	\$3.1M
SBIR/STTR***	-	-	-	\$3.7M	-	-	\$3.1M	\$1M
	\$6.9M	-	\$6.9M	\$6.2M	\$4.2M	\$1.2M	\$5.1M	\$4.1M

* source: <https://www.crunchbase.com>

^ source: <https://www.geekwire.com/2017/relativity-space-raises-curtain-bit-stealthy-rocket-venture/>

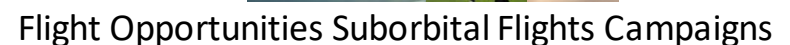
** source: https://www.nasa.gov/sites/default/files/atoms/files/active_domestic_private_sector_saas_as_of_12-31-2016.pdf

*** source: NASA/DoD awards 2011-2017 from <https://www.sbir.gov/sbirsearch/detail/171983?page=1>

: sub contractor to HRL

Green = ACO/TP partners

-
- REVITALIZING NASA'S SUBORBITAL PROGRAM**
ADVANCING SCIENCE, DRIVING INNOVATION, AND DEVELOPING A WORKFORCE
- The infographic illustrates several suborbital flight paths relative to Earth's horizon:
- ECOSPHERE:** 479 - 60,000 M.
 - TREASURER:** 31 - 479 M.
 - MEDUSA:** 8 - 31 M.
 - SEACRUISE:** 6 - 8 M.
 - TRIPOLI:** 3 - 6 M.
 - GOOSE:** 400 MI.
 - SUNGLASS:** 100 MI.
 - SP-2:** 10 MI.
 - ORCA:** 70 MI.
- NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

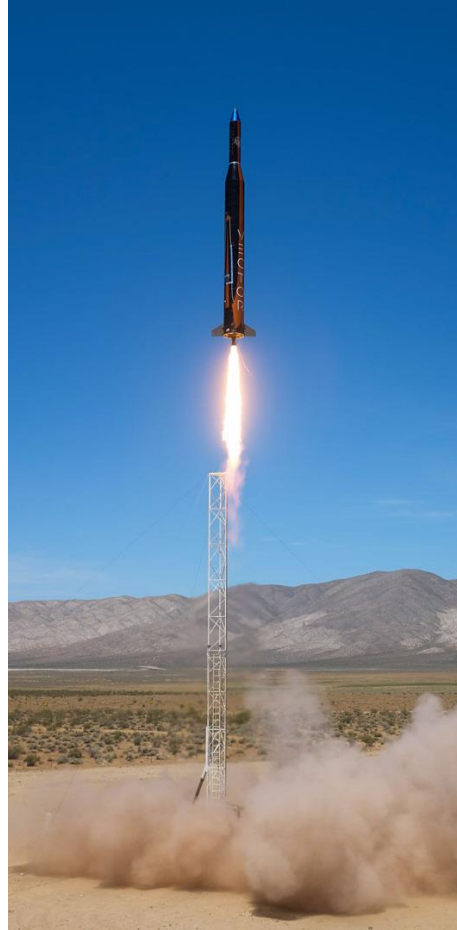




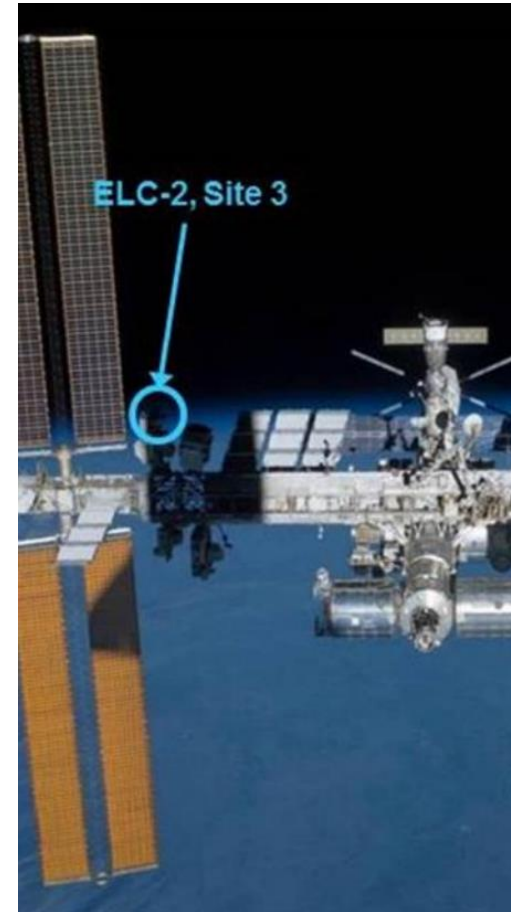
Commercial Suborbital – Small Launch – LEO



Commercial
Suborbital Flight
Platforms



Commercial Small
Orbital Launch Vehicles



Commercial Materials ISS
Experiment Flight Facility

nasa-flightopportunities@nasa.gov



Small Launcher Technology – Public Private Partnership



Objective: Support the development of commercial small orbital launch capabilities.

Mechanism: Competitive selection – Proposal evaluation process

- ***Announcement of Collaborative Opportunity (ACO) - Every Other Year***
 - ACO enables NASA Centers to provide technical expertise and test facilities, as well as hardware and software, to commercial companies for the purpose of accelerating the development of promising technologies.
 - ACO 2015 executed in June 2016.
 - 5 companies selected at total value of \$7M
 - ACO 2017 awarded in September 2017, awaiting execution.
 - 3 companies selected at total value of \$3.5M
- ***Tipping Point - Every Year***
 - Firm-fixed-price contracts awarded to both flight service providers and vendors/suppliers/support service providers that can significantly improve the prospects of the emerging small launch vehicle market.
 - 2016 - 6 companies selected at total value \$12M. (June 2017)
 - 2018 solicitation open (see next page)

<https://www.nasa.gov/directorates/spacetech/solicitations>



Tipping Point Solicitation

- **What is it?**
 - Firm Fixed Price FAR Contract
 - Period of Performance: up to 24 months
 - Contract Award: up to \$2M/ea.
 - Company must cost share at least 25%
- **Goal/Intent:** To stimulate the commercial space industry while leveraging those same commercial capabilities through public-private partnerships to deliver technologies and capabilities needed for future NASA, other government agency, and commercial missions.
- **Tipping Point 2018 Solicitation Schedule**

Key Dates:

Appendix Release Date:	November 30, 2017
Mandatory Preliminary Proposal Due:	January 30, 2018
Invitation for Full Proposals/Feedback Provided:	by March 30, 2018 (target)
Full Proposals Due:	May 30, 2018 (target)
Selection Announcement:	September 2018 (target)
Award Date:	February 2019 (target)



NASA SBIR Program



Subtopic Z9.01: *Small Launch Vehicle Technologies and Demonstrations*

- Key Dates
 - 2018 Phase I SBIR
 - Solicitation Release: 1/11 – 3/14/2018
 - Phase I award: 5/04/2018
 - 2017 Phase II SBIR
 - Solicitation Release: 10/27 – 12/30/2017
 - Phase II award: 3/06/2018

<https://sbir.nasa.gov/>

Phase I Contract	SBIR	STTR
Maximum Contract Value	\$125,000	\$125,000
Period of Performance	6 months	12months
Phase II Contract	SBIR	STTR
Maximum Contract Value	\$750,000	\$750,000
Maximum Period of Performance	24 months	24 months

Small Launch Capabilities

Technology Development Partners



ACO15

6 awards



Tipping Point 16

6 awards



SBIR17

5 awards



STTR17

4 awards



ACO17

3 awards



ACO 2015 Example: Vector Space



May 3, 2017

Vector-R launch with
3D-printed injector.



December 8, 2016

Vector Space (VS) test of 5,000 lbf
first stage engine using Liquid
Oxygen and Liquid Propylene
(LOX/LC3H6) in collaboration with
MSFC developed all aluminum 3D
printed injector.



ACO 2015 Example: Generation Orbit

Flight Test of GoLauncher1 Inert Test Article (ITA)



Technology Maturation and Flight Validation for Air Launched Liquid Rockets (ACO-15)

Generation Orbit Launch Services of Atlanta, GA

- This project focuses on a single stage liquid rocket, GoLauncher 1, launched from a NASA owned and piloted Gulfstream III, capable of delivering payloads up to 1,000 pounds on high-altitude suborbital and suppressed hypersonic trajectories.
- Generation Orbit Launch Services is partnering with the NASA Armstrong Flight Research Center (AFRC)
- December 11 – 12/ 2017: Completed flight test simulated abort release of ITA.



Take off: <https://www.youtube.com/watch?v=dzbdptNT7qc>

Landing: <https://www.youtube.com/watch?v=ayAr7CUBQzg>



Technology Development Trends

- A personal observation



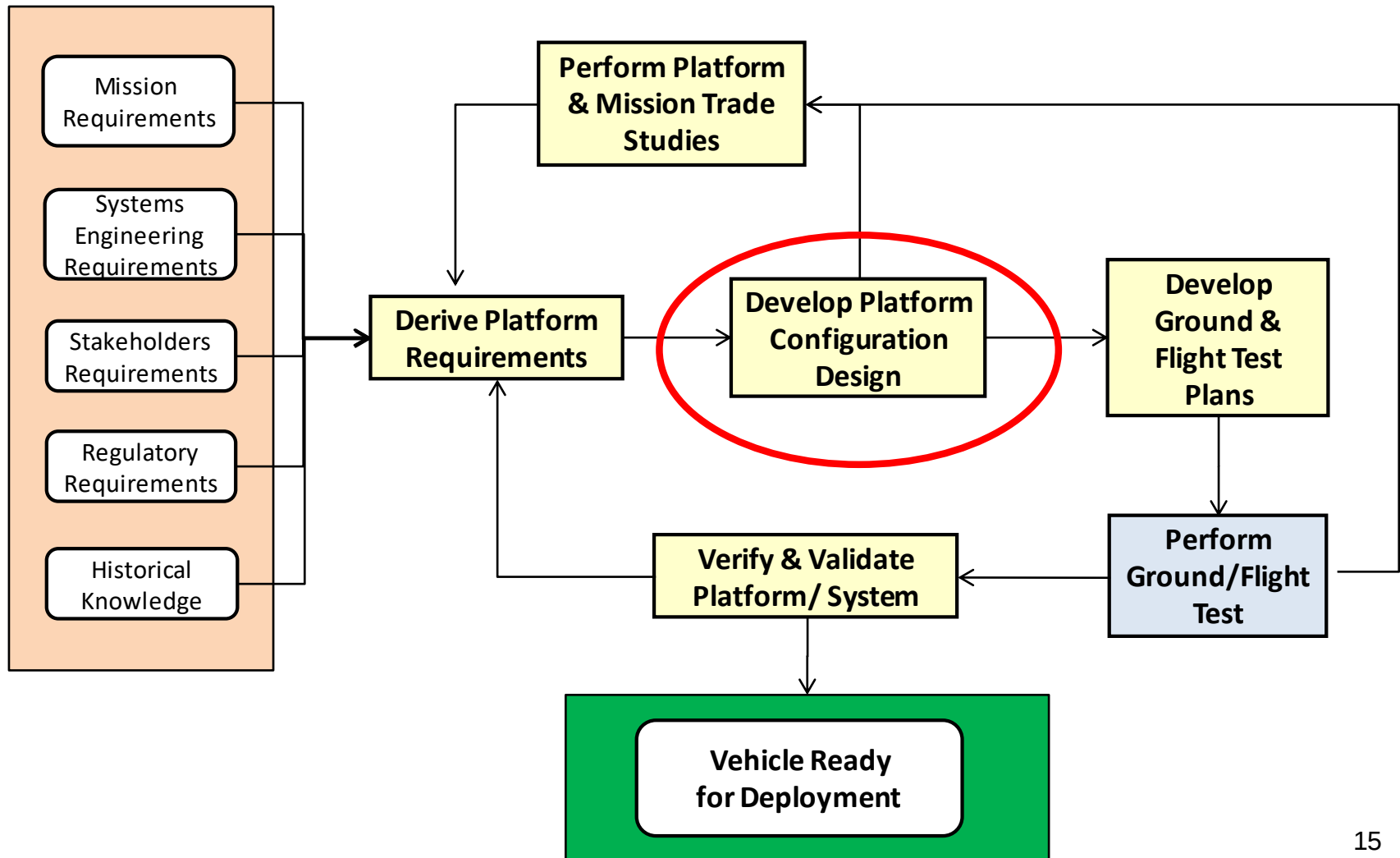
- **Reduce Total Cost of a Launch System**
 - Companies understand cost drivers and find ways to eliminate or minimize
- **Reduce Development/ Manufacturing/ Acquisition Cost**
 - Eliminate turbopump-fed liquid rocket engines (good performance/ high cost)
 - *Opportunity: Develop low cost turbopump using additive manufacturing techniques*
 - Find/ develop low-cost solid propellant manufacturers
 - Develop alternatives to high cost flight computer guidance/navigation/control and flight termination system
 - *Opportunity: Eliminate traditional flight termination system. Develop alternatives.*
 - Reduce traditional aerospace component suppliers – Make vs. Buy
- **Reduce Infrastructure Cost**
 - Eliminate a permanent launch pad. Use of mobile launch pad concept.
- **Incorporation of Reusable/ Partially Reusable Systems**
- ***It is a race!!***
 - Time to market is perhaps the most important metric



Final Thought



It's a Launch System – more than just a Rocket!





Questions?