New Visionary Entrepreneurs Are Privatizing Space

The Next Big Thing

University of Colorado Boulder
Colorado Space Grant Consortium Seminar

Dr. James R. Stuart
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1 Dec 2016
- **Brief History of Space** (#3-13)
  - NASA - Technology, Planetary Exploration (Water, Tube Caves)

- **Commercial Space Achievements** (#15-16)
  - by DARPA and Disruptive Entrepreneurs (Big Corporations)

- **Entrepreneurial Space Privatization Beginnings** (#17-28)
  - Anselmo, Space Industries, Orbital, LEO Constellations, Launchers

- **Entrepreneurs’ Space Visions/Projects** (#28-76)
  - Zero G flights (#30-32)
  - Space Prizes (X-Prize, Google, FL, Bigelow) (#33-38)
  - Space Tourism (Suborbital Orbital, Lunar, Mars) (#41-58)
  - New Space Launchers (#59-69)
  - Private Commercial Spaceports (#70)
  - Constellations Revolution (#71-73)
  - Asteroid Mining (#74)
  - Exoplanet/Stellar Flyby (#75)

- **Front Range Space Companies** (#77-78)
1813 **William Moore**

1903 **Konstantin Tsiolkovsky**

Tsiolkovsky foresaw: Space Elevator, Space Solar Power, etc.

1915 **NACA** formed during WWI:

1926 **Robert Goddard** - first liquid rocket

1938 **Wernher von Braun** - V2 rocket

1945 **Arthur C. Clarke** - “Extra-Terrestrial Relays”

1947 supersonic **Chuck Yeager** – (Bell to) NACA’s X-1 from B29

1957 **USSR Sputnik 1 and 2**

1958 **NASA** formed from NACA
1957 Vanguard
- Navy launch failure 12/6/57
  - settled back down on pad
  - fuel tanks exploded
  - Vanguard thrown clear, landed on ground - beacon transmitter going

1958 NASA/JPL’s Explorer-1
Done in 84 days - Launched 2/1/58
on JPL- modified Army Redstone rocket

1960 von Braun - Director of NASA MSFC

1961 Yuri Gagarin - 1st orbital human

1961 Alan Shepard - 1st USA suborbital

1962 Scott Carpenter 2nd Mercury astronaut
raised corner Aurora Ave /7th St.
Boulder High School (class ’43)
CU Aerospace Engineering, ΔΤΔ
Aquanaut (Sealab), Astronaut

1962 John Glenn - 1st USA orbital
1962 AT&T Telstar satellite
High altitude nuke ‘Starfish Prime’ set-off day before launch

1963 Joe Walker - X-15 to 67 miles
Astronaut ‘Space Tourist’ per UN list of ~540 people who’ve been in space (≥62 miles)

1964 Intelsat formed - 11 countries
100 countries in 2001, privatized in 2001, sold in 2005
Largest fleet today (52 GEO’s)

1969 MOON LANDING
- **4/81** First Shuttle Launch
- **11/84** First Satellite Retrievals

**Discovery**
- 1st Launch 8/84
- 2 PAM-D deployment failures
- stranding
- Palapà B2, Westar 6

**Enterprise**
- 8/77-11/77: 5 glide flights

**Columbia**
- 4/81-2/03: 28 flights

**Challenger**
- 4/83-1/86: 10 flights

**Endeavor**
- 3/92-5/16/11:
  - To LA CA Sci Center
  - 25 flights

**Atlantis**
- 10/85-7/6/11:
  - To KSC, FL Visitor Center
  - 32 flights

**Dr. Joe Allen**

**Discovery**
- 2nd Launch 11/84
- 2 PAM-D Deployments
- 2 Satellite Retrievals

**To NY Manhattan SA&S Museum**

**To Chantilly, VA A&S Museum**

**To KSC, FL Visitor Center**
1986-2001 USSR/Russian MIR Space Station

Soyuz historic failure rate: 88/1800 ~5%
1998-Present International Space Station

- **Raffaello module** added 2011
- **Cupola Observatory** added 2010

- **SpaceX Dragon**
  - 1st Arrives: 5/25/12

- **5th Dragon Delivery to ISS**: 10/22/13

- **Progress M-25M**
  - 57th **Soyuz** flight to ISS launched 10/29/14 3AM EDT
  - Able to launch with 8 hours notice (was moved up from 11/4/14 after Antares explosion 10/28/14 6:22PM EDT)

- **OSC Cygnus**
  - 1st Departs: 10/22/13
  - 4th Cygnus Launch to ISS 10/28/14
  - 4th re-Launch on Atlas V 12/6/15

- **Progress M-25M**
  - 57th **Soyuz** flight to ISS launched 10/29/14 3AM EDT

- **Antares**
  - FAILED

- **Dragon Commercial CREW Contract** (2-6 flights) 2.6 B$ 11/23/15

- **3/26/16**
  - 1 Cygnus
  - 2 Progress
  - 2 Soyuz TMA

- **4th re-Launch on Atlas V 12/6/15**
Planetary Exploration Achievements – Mars Surface:

- 1975 Mars Landers - Viking 1 and 2
- 1997 Mars Rover - Pathfinder
- 2004 Mars Rovers - Spirit and Opportunity
- 2004 Mars Lander - Phoenix
- 2012 Mars Rover - MSL Curiosity

Scoreboard

Mars 28
Earth 24

Mars Fly-bys, Orbiters, and Landers

<table>
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<th>Country</th>
<th>Average</th>
<th>Attempts</th>
<th>Fail</th>
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<td>21</td>
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<tr>
<td>India</td>
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* ESA ExoMars 10/19/16 Mars Orbit Insertion
* ESA Schiaparelli 10/19/16 Mars Landing

10/16 NASA: Future Mars spacecraft/landers could be operated like astronomical observatories, with scientists applying for time on the spacecraft to carry out specific studies.

Curiosity ‘Sky Hook’ Landing
8/5/12
Mercury (ice in polar craters)
Earth (liquid oceans)
Moon (ice in polar craters)
Mars (ice, seasonal salty dark liquid water trickles, and CO₂ slides)
  - Subsurface Ice deposit found 11/16 ~ Lake Superior (Utopia Planitia region)
  - Surface soil: can extract 1 liter per cubic foot
Asteroid Belt (20-30% ice + metals, rock, carbon)
  - Ceres (25% ice - global layer, internal liquid water ocean, water geysers, ice volcanoes)
  - Vesta (buried ice, past internal liquid water ocean and flowing surface water)
Jupiter (deep internal liquid water ocean)
Jupiter Moons (mostly all ice)
  - Europa (ice, internal liquid water ocean, maybe melted pocket lakes near surface, water spouts)
    - Water Geysers (S. Pole)!
    - Ice Plate Tectonics - Europa has MORE WATER than EARTH
  - Ganymede (ice, internal liquid water ocean layers)
    - Flooding, More water than on Earth!
  - Callisto (100km ice shell, internal liquid water ocean 10km deep)
Saturn (deep internal liquid water ocean)
Saturn Moons (mostly all ice)

- Enceladus (30 km ice shell, internal global liquid water ocean 10 km deep)
  - Alkaline – like Mona Lake (super biologically productive aquatic environment)
  - Hydrothermal Vents! Water Geysers (S. Pole)! More water than on Earth
- Titan (50 km ice shell, surface methane lakes, tides, salty internal liquid water ocean)
  - Ice volcanoes, organic-rich atmosphere and surface
  - Giant Ices cloud - South Polar Vortex in winter
- (Dione - ice, maybe km’s deep liquid water ocean 62 km down)
- Mimas (25 km ice shell, internal liquid water ocean)
- (Tethys, Rhea; and Iapetus: ice, subliming water)

- Uranus (deep internal liquid water ocean)
- Neptune (deep internal liquid water ocean)
- Neptune Moons (mostly all ice)
  - Triton – (ice shell, LN geysers, thin atmosphere, past internal liquid ocean and ice volcanoes)
- Pluto (ice shell/bedrock, past internal liquid ocean, 2 huge ice volcanoes)
- Kuiper Belt Objects (billions of icy objects: asteroids, comets)
  - Comets (ice, dirty snowballs)
- Oort Cloud Objects (billions of icy objects: comets)
Visible Surface Tubes and Skylights

- **Lava tubes (and Ice tubes past frost line)**
  - Future Robotic and Human missions
  - Preexisting sheltered environments
    - Pressurizable
    - Ice
    - Radiation protection

- **Moon**
  - ~700 Tube Caves
  - Tubes: 100m's to km's wide
  - Skylights: 10m - 100m's wide
  - Stable temp: -20° C (-4° F)

- **Mars**
  - ~2000 Tube Caves

- **Jupiter, Saturn, Neptune Moons**
  - Vents and fissures (water ice plumes)

- **Pluto**
  - Primary Vents of Cryovolcanos
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Front Range Space Companies (#77-78)
**DARPA’s GPS**
- > 70 B$ global commercial revenues in 2015

**DISRUPTIVE** (Still run by DARING FOUNDERs):
- Liberty, WildBlue, EchoStar, ViaSat

**Dr. John Malone** (72) Yale BA EE/Econ, JHU MSIM, PhD OR
- 1973 CEO of TCI (at 32)
- 1998 sold for 48B$ (Comcast)
- 12/14: Donated 42.5M$ to CSU Vet. Regenerative Medicine

**Charlie Ergen** (60) MBA, Professional Gambler
- 1970’s: sold Big TV dishes in Littleton
- 1980 founded EchoStar (at 27) Value >6B$

**Mark Dankberg** (58) BS/MSEE, Rice
- 1986: ViaSat - 25k$ in MD’s spare room (at 31)
- 2009 bought WildBlue, 2012 invented HTS: ViaSat-1 Value ~3B$

**Orbital Sciences Corp.** (Still led by a Founder)
- Founded 1982 (JRS founding Chief Engineer)
- Rounds: 500k$, 3M$, 50M$
- No Longer DISRUPTIVE (risk adverse, career management, etc)

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1960’s ARPA TRANSIT (NavStar)
1995 AFSPC Full Operational Capability

Vet. Regenerative Medicine

1960’s ARPA TRANSIT (NavStar)
1995 AFSPC Full Operational Capability
**XS-1** Rapid Turn-around Reusable Space Plane
- 2,250 kg LEO capability
- Reusable 1st Stage, Expendable 2nd
- Rapid turn around (>10 flights/year)
- \( \leq 5.0 \) M$ per launch (1k$/lb)

**X-37B** Rapid Turn-around Reusable Space Plane
- Remote piloted, Autonomous
- >12 month on-orbit capability
- 2 week turn around
- Pick-up bed-size cargo bay
  - Holds 2 several hundred kg satellites

**X-37C** LARGER Rapid Reusable Space Plane
- 165%-180% bigger
- Holds 6 astronauts
- Highly Maneuverable

**XS-1**
- Boeing (+ Blue Origin)
- Northrup (+ Virgin Galactic)
- Masten (+ XCOR)

**X-37C**
- SpaceX Dragon v2
- Boeing CST-100
- SNC DreamChaser

- NASA 7 Crew Capsule Contracts 9/14:
  - SpaceX Dragon v2
  - Boeing CST-100
  - SNC DreamChaser

- ULA Contract 9/14:
  - Blue Origin BE-4
  - Reusable rocket engine
  - partnering with ULA for Atlas 5 replacement
Rene Anselmo - Maverick Privatized Sat Com Industry

- 1963 Founded Spanish International Network (37)
- 1984 Founded PANAMSAT (58)
- 1987 Sold SIN (UNIVISION) for 80M$ (61)
- 1988 Launched PAS-1 1st PRIVATE COMSAT (62)
  - Refurbished Satellite, 1st Ariane 4 Launch
  - Blocked/Fought by INTELSAT Monopoly
  - Engraved in stone over his Greenwich, CT office building entrance:
    “Truth and Technology will Triumph Over Bullshit and Bureaucracy”
- 1991 NYT full page Cartoon Ad - ‘My Dog Spot’
  Urinating on legs of problem politicians, lobbyists

Broke INTELSAT Monopoly – 1st private comsat business

- 1995 Died at 69 (2 days before IPO)
- 2004 PANAMSAT sold for 2.6B$
1991 NYT full page Cartoon Ad - ‘My Dog Spot’ - Urinating on legs of problem politicians, lobbyists

Rene Anselmo:
Maverick Who Privatized the SatCom Industry
Drs. Joe Allen, Max Faget - First Private Space Station effort

- Joe Allen-1982 and 1984 Shuttle Astronaut
- 1985 Joined Space Industries Inc.
  - Founded 1982 by Max Faget,(at 61)
  - INDUSTIAL SPACE FACILITY
  - Private/Government Partnership
- 1988 Reagan requested 700M$
  - No Congress Approval
- **FAILED VISION**
  - NASA IG: US ISS costs ~75B$ thru’ 2013
    (ISS ~44B$ + STS flights ~21B$)
  - Wiki: ISS costs ~150B$ thru’ 2013
    (US ISS ~59B$ + STS flights ~51B$)
Orbital Sciences Corp - Privately funded Launchers, GSOs

- 1982 Founding (DWT 28, JRS 36)
- 1984 50M$ LP Private Raise
  - Largest Aerospace Round ever at time
- 1986 160M$ in TOS Sales
- 1990 Pegasus 1st Launch
- 1990 IPO (NYSE: ORB)
- 2009 start Antares from Wallops Island
  - (Competitor: LMA/ATK’s resumed Athena 1c, 2c)
- 2010 acquires GD sat mfg (Gilbert, AZ)
- 2013 Antares: Cygnus docks with ISS
- 2014 Merges with ATK: Orbital ATK 4.5B$ rev, 13,000 employees

Kodiak Launch Site: 21 M$ For MLV - Proposals 11/25/14 (Orbital and LMA)

AJ-26 (NK33) Turbo Explodes

5th Launch (Cygnus to ISS) 10/28/14 Explodes

OSC’s Antares Wallops Island, VA 4/21/13

Mars Observer

LMA/ATK’s Athena II was to launch from Kodiak 2016
- Failed Visions

- Low Earth Orbit Constellations BUBBLE in late 1990’s
  - Big Corporations - Spent $ Billions
  - Dot-com and Technology BUBBLES BURST 1999-2000
  - Economy went into RECESSION in 2001
  - Then Telecom BUBBLE BURST - No Market Uptake - $Billions Lost

- 1991 Iridium – Motorola (voice)
    - Iridium Next (replacement constellation) to begin launching in 2016

- 1991 Globalstar - Loral and Qualcomm (voice)
    - Globalstar 2nd-Generation (replacement constellation) launched 2010-13

- 1991 Orbcomm - Orbital Sciences (M2M)
  - 1996 Service Start 2000 Bankruptcy  (2014 ~100M$ Annual Revenues)
    - OG-2 (replacement constellation) 1/3 lost 10/12, 1/3 lost 7/14, Next F9 launch 2/16
    - 11/14: acquires Canada’s SkyWave (250k subsc: ~GLOBAL M2M ~1.2M subsc)
Entrepreneurial Space Privatization Beginnings
- Failed Visions (cont'd)

- **Teledesic - 10B$ Mega Constellation**
  - 1990 Founded
  - 1997 Licensed Granted
  - 1998 IPO scheduled
  - 2003 Liquidated

- **Bill Gates** (was 35) and **Craig McCaw** (was 41)
  - JRS Chief Architect, Head of Space

- CU Aerospace (Mark Balas, et. al) lead Teledesic Dynamics and Control

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Bill Gates (now 59)

Craig McCaw (now 65)
1993 Léo ONE PANAMERICA (M2M)
- Jose Manuel Villalvazo Baz (was 38)
- Mexico License granted 1995 Closed 2002

1994 Leo ONE USA (M2M)
- David A. Bayer (was 51)
- USA License granted 1998 Closed 2002

1995 KiTcomm (M2M)
- H. James Kennett (was 36)
- Australian License granted 1997 Closed 2004

New Launchers Caught in Bubble

1993 Athena 1, 2 Launcher
- Lockheed Martin/ATK (Corporate funded)
- 7 Launches 1995-2001 Cancelled 2001
- Re-started 2011 to compete with SpaceX, Orbital
Innovative Launchers Caught in Bubble

- Rotary Rocket Corp.

XCOR (scrappy start-up) formed by former RRC rocket engine team

XCOR picked by ULA for new Atlas/Delta upper stage 3/11

XCOR booked by SwRI for 6 Lynx Spaceplane Flights 2/11

XCOR produces EZ-Rocket for Rocket Racing League
Innovative Launchers Caught in Bubble (cont’d)

- American Rocket Company
  - 1985: George A. Koopman (1944-89)
  - Founder: Insgroup Inc. (was 34)
  - Produced: Movies, Books, Albums
  - Founder: AmRoc (was 41)
  - 20M$ invested: 300 rocket tests

1998 IP Sold to SpaceDev (rockets: 2004 X-prize, Virgin Galactic)
2008 SD Sold to Sierra Nevada Corp

Virgin Galactic used SNC’s HTPB, changed, now back to HTPB

Hydroxyl-terminated polybutadiene (HTPB) with N2O oxidizer (nitrous oxide)
Innovative Launchers Caught in Bubble (cont’d)

- Kelly Space & Technology Astroliner

Mike Kelly (was 39)
Was Chief Engineer
FAA’s Office of Commercial Space Transportation (FAA/AST)
Since 6/15: DARPA Program Manager

San Bernadino, CA
www.kellyspace.com
Innovative Launchers Caught in Bubble (cont’d)

- **VentureStar X-33**
  - Dave Urie, Proj Mngr
  - NASA took over 1996
  - NASA Cancelled in 2001
Basis of Jeff Bezos’ Blue Origin ‘New Shepard’ Tourist SS vehicle (Kent, WA factory)

Bezos also doing: 2-stage Orbital Launch Vehicle Using Turbo/LNG BE-4 rocket engine + partnering with ULA for Atlas 5 replacement

Innovative Launchers Caught in Bubble (cont’d)

- DARPA’s DC-X Delta Clipper (1991-93)
  - Given to NASA (DC-XA) in 1993
    - NASA Cancelled ~ 2001
Entrepreneurs' Space Visions
(and their Projects)

- **Zero G flights** (#30-32)
- **Space Prizes** (#33-38)
  - X-Prize, Google, FL, Bigelo
- **Space Tourism** (#41-58)
  - Suborbital Orbital, Lunar, Mars
- **New Space Launchers** (#59-69)
  - Falcon, New Shepard/ Glenn, StratoLaunch, LauncherOne, etc.
- **Private Commercial Spaceports** (#70)
- **Constellations Revolution** (#71-73)
  - Deja Vu
- **Asteroid Mining** (#74)
- **Exoplanet/Stellar Flyby** (#75)
Zero-G Corp Founders
Dr. Byron Lichtenberg (68)
Dr. Peter Diamandis (55)

- Zero-G Sold to Space Adventures in 2008
- Swiss Space Systems (S3 ZeroG) to compete from KSC 2016
Peter Diamandis (55)
- Co-Founder of SEDS (at 19)
- Founder of International Space University (at 26)
- Co-Founder Zero-G (at 32)
- Co-Founder of Angel Technologies (at 35)
- Founder of X-Prize Foundation (at 35)
- Co-Founder of Space Adventures (at 37)
- Founder X-Cup (at 44)
- Founder Rocket Racing League (at 45)
- Co-Founder Singularity University (at 46)
- Co-Founder Planetary Resources Inc. (at 49)

Formed 2005, PLAN: 4 team event in 2006 then 10 team event 2007
Financial Difficulties
7/09 VC round: 5.5M$
4/10 Tulsa 1st Time 2 RACERS IN AIR
No events occurred since

Same XCOR (scrappy ex-Rotary Rocket start-up)
100 Aviation Prizes offered 1905-1935
- 25k$ Orteig Prize: 1927 Charles Lindbergh to Paris

1-9M$ Space Prizes
- NASA Centennials: CubeQuest Challenge (5.5M$)
  - Cubesat to orbit the Moon or send to deep space
- SFF Cheap Access to Space (CATS) Prize
- Heinlein Prize
  - 7/11 Altius Space Machines (Louisville, CO)
- Planetary Society Asteroid Tagging Prize
- Northrop Grumman Lunar Lander Prize:

10M$ X-Prize
- 3 people to 100 km (≥62 miles), Repeat within 2 weeks
  - 10/04 Paul Allen, Burt Rutan (Scaled Composites)

30M$ Google Lunar X-Prize
- Land on Moon, Traverse, Snap Photos, Transmit

40M$ Florida RLVII Prize
- Most significant advancement toward designing and building a reusable space vehicle [for FL] (2009 through 2015)

50M$ Space America Prize
- 5 people to 400km, 2 orbits, Repeat within 60 days

Full list: http://spaceprizes.blogspot.com, etc
2004 10M$ won by Paul Allen and Burt Rutan
- **Paul Allen** (now 63)
  - Co-Founder Microsoft (at 22)
  - Experience Music Project
  - Sci Fi Museum
  - Co-Founder **Space Ship Company**
  - Owns Trailblazers, Seahawks and Sounders
  - Co-Founder **Stratolaunch Systems**
Burt Rutan (73)
- Founder Rutan Aircraft Factory (at 31)
- Founder Scaled Composites (at 39)
- Co-Founder Space Ship Company (at 62)

Rutan built 47 novel airplane designs

2011: '367 BiPod'

Steve Fossett

Retired 4/11 to do "one last innovative design: ‘SkiGull’
Harsh environments: sea, snow, dirt patches, fields
No Alum: all composites, Ti

11/15: Maiden Flight ‘SkiGull’

Angel Technologies
Failed Vision
Repurposed

Flying car/roadable airplane

N375BT

Dec. 1, 2016 JRS slide 36 of 79
Larry Page (43)
Google Founder at 26

- Land on the Moon
- Move 500 meters and
- Send back video, images and data

30 M$ Prize (1/15: 5.25 M$ in early ‘milestone’ prizes)
20 M$ for the winner
5 M$ for second place
4 M$ in technical bonuses
1 M$ diversity award

- Deadline: (extended to) end of 2017
- provided ≥1 launch contract in 2015: 3 So far
- otherwise competition over: no winner

2017: Moon Express MX-1
#2: launch (booked 4.9M$) on Rocket Lab's ELECTRON ROCKET

2017: Astrobotic Lander/Rover
+ AngelicvM rover
+ 2 Team Hakuto rovers
“Formula One-style race”
(+ payloads by Mexican Space Agency and Lunar Mission One)
On SpaceX Falcon 9

2017: Moon Express MX-1
#2: launch (booked 4.9M$) on Rocket Lab's ELECTRON ROCKET

2nd half 2017: SpaceIL (Israel)
#1 Booked/Verified launch On SpaceX Falcon 9

#3: 2nd half 2017: Synergy Moon Launch on Interorbital’s NEPTUNE 8 ROCKET

Boulder Entry: Next Giant Leap (Subsidiary of Moon Express)

Live TV:
Science Channel and Discovery Chanel will cover
the moon race from testing to the finish to the
live lunar landing of the winning team

2016: JRS slide
Bob Bigelow (now 71)

- Founder Budget Suites of America (at 34)
- Founder Bigelow Aerospace (at 54)
- Founder National Institute for Discovery Science (at 55)
Suborbital Space Tourism
- Virgin Galactic SpaceShipTwo
- Blue Origin New Shepard

Orbital Space Tourism
- SpaceX Falcon/Dragon
- Blue Origin New Glenn
- Bigelow Aerospace BEAM

Lunar Tourism
- Bigelow Aero BEAM Surface Hotel

Mars Tourism
- SpaceX Falcon Heavy/Dragon
- Inspiration Mars SLS/Cygnus flyby

Satellite Constellations
- TBD (global internet)
- BlackSky Global (global imaging)
- OneWeb (global internet)
Commercial Spaceports
- Texas (Boca Chica), ASDS
  - Elon Musk
- Texas (Van Horn)
  - Jeff Bezos

New Space Launchers
- Falcons
  - Elon Musk
- New Shepard, New Glenn
  - Jeff Bezos
- LauncherOne
  - Sir Richard Branson
- Stratolauncher
  - Paul Allen

Asteroid/Lunar Mining
- Moon Express
  - Naveen Jain
- Planetary Resources
  - Larry Page, etc.

Exoplanet/Stellar Flyby
- Breakthrough Starshot
  - Yuri Milner
1990’s Russians sold 5-10 trips to MIR
- Foreign Astronauts, Japanese Reporter, UK Contest Winner

Space Adventures - **Eric Anderson** (42)
- Co-Founder **Space Adventures** 1997 (at 23)
- Co-Founder **Cosmopolis XXI** 2007 (at 33)
- Co-Founder **Planetary Resources** 2010 (at 36)
2001 **Dennis Tito** (at 61) paid **15 M$**
- Ex-JPL, Orbit Analysis Software
- Founder Wilshire Associates (at 32)
- Funded Rocketplane Tourist vehicle (2000)

2002 **Mark Shuttleworth** (at 29) paid **20M$**
- UK, born South Africa
- Founder Thawte (at 25)
  - Sold to VeriSign for 575M$

2005 **Greg Olsen** (at 60) paid **20M$**
- Founder Sensors Unlimited (at 47)
  - Sold for 750M$, Bought Back for 7M$
  - Resold to Goodrich during launch

2006 **Anousheh Ansari** (at 40) paid **20M$**
- Co-Founder Telecon Technologies (at 27)
  - Sold for 550M$ to Sonus Networks
- Founder Prodea Systems (at 39)
- Ansari X-Prize

2007, 2009 **Dr. Charles Simonyi** (at 59 and 61) paid **25M$**
- Microsoft since 1981 (WORD, EXCEL)
- 3/09 2nd flight to ISS (FRONT OF LINE) paid **35M$**
2007 Sheikh Muszaphar Shukor (at 37)
- Malaysian Space Agency
- Malaysian Orthopedic Surgeon
- Angkasawan Spaceflight program
  Bundled with 18 Russian SU30 MKM Fighter Jet deal

2008 Richard Garriott (at 47)
- Co-Founded ORIGIN (Ultima) (at 22)
- Sold to Electronic Arts

2009 Guy Laliberté (at 50)
- Founder Cirque du Soleil (at 24)
- Backup: Barbara Barrett
  - certified as a ‘fully trained cosmonaut’
  - Husband ex-Chairman, CEO Intel
  - Former Deputy Administrator FAA, Ambassador to Finland
  - first civilian woman to land in an F/A-18 Hornet on an aircraft carrier

3/10/10 End of Soyuz tourist rides
- 9/2/15 ride (no Sara Brightman) declined by 2 others

Will resume ~2017
Price of Russian Soyuz rides to ISS

- NASA 2001-10 R/T’s at 15-35 M$/seat
- NASA 2011/12 R/T’s at 51 M$/seat
- NASA 2013/14 6 R/T’s at 55.8 M$/seat
- NASA 2015/16 12 R/T’s at 62.7 M$/seat
- Space Adventure 20015/16 R/T’s at 52 M$/seat
- NASA 2017/18 R/T’s at 76 M$/seat
- NASA 2018/19 R/T’s at 88 M$/seat (5/16 contract reduced min #)
- Price drops expected with 2018 USA competition (e.g. Falcon 9/Dragon)

- Late 2015 Sarah Brightman (56) – 5/15 dropped out after several months training at StarCity
  - Actress, Songwriter and Dancer
  - 180 Gold and Platinum sales awards in over 40 different countries

- ~2017 Vladimir Gruzdev (49)
  - Founder Largest Retailer in Russia
  - Explorer, Parliament

- ~2017 Sergey Brin (43)
  - Co-Founder Google (at 25)
  - Space Adventures Investor
  - Cosmopolis XXI
Virgin Galactic (HTHL)

First flight use of NEW polyamide-based plastic rocket motor (Was Sierra Nevada’s HTPB motor) Now Back to HTPB
8s after ignition (> Mach 1):
Co-pilot MIS-DEPLOYED re-entry FEATHER

10/31/14 SpaceShip CRASH

4/16: $250k → $300k/ride
‘Price will come down with more vehicles and sites
>700 seats sold
4/13: $200k → $250k/ride

Richard, Sam and Holly
On first commercial flight: 2017
Prime time special night before + 3 hour live coverage on TODAY show

Silicon Valley Goes to Space
(Youtube, 25m)

Sir Richard Branson (66)
Blue Origin New Shepard (VTVL) - Jeff Bezos (52)
- Founder Amazon (at 30)
- Founder Blue Origin (at 40)

Launch - Land - REPEAT!

6/19/16
REUSABLE BOOSTER
4th Flight + Return
100.7 km, Mach 3.72
- Crew Capsule: parachuted to landing
- Propulsion module: powered vertical landing

West Texas Launch Site

New Shepard Capsule 6 passenger

Launch - Land - REPEAT!

Jeff Bezos (50)

his Blue Origin investment as of 1/16: >700M$
BSC Dream Chaser (VTHL) - Jim Benson
- Founder CompuSearch (at 38)
- Founder ImageFast (at 44)
- Founder Space Development Corp (at 52)
- Founder Benson Space Company (at 61)

Sierra Nevada Corp’s Dream Chaser (Louisville, CO)

Dream Chaser purchased with SDC by Sierra Nevada Corp. (SNC)
Fatih Ozmen, CEO (now 56, joined SNC 1981 at 23)
SNC acquired 1994 at 36
Eren Ozmen, President / CFO

1/16 ISS Cargo contract (~1.5 B$)
ESA investment (36M$)
10/14 Stratolaunch partner:

Jim Benson (died at 63)
- **George French**
  - Founder **Space Explorers**
  - **Rocketplane** (HTHL)
  - Kistler
XCOR’s Lynx Spaceplane (HTHL)

- Formed by former Rotary Rocket rocket engine development team
- Carries: 1 pilot + 1 passenger (+1 small sat or sci payload)
  - 150 k$ per passenger (was 100 k$)
- SwRI books 6 flights at 95 k$/ea (3/11)
  - 1 passenger +1 sci payload
  - 3 minutes of microgravity below 0.01 g
- First test flight early 2017
  - From Mojave Air and Spaceport
World View Enterprises (AZ)

- High altitude balloon + parasail 30 km
- 2 hr balloon up, 2 hr at altitude, 1 hr parasail down
  - 50-60k$ in He
    - Balloon ½ size of Red Bull Balloon - 39 km sky dive
- Luxury ‘Voyager’ Capsule
  - ‘free to stroll around capsule and order drinks from a bar’
- 2 pilots, up to 6 passengers (shirtsleeve)
- 75k$/passenger, start ~2018

Capsule designed by UK firm Priestmangoode

Formed by Paragon Space Dev. Corp 2013
Co-founders PSDC, WV (Biosphere 2):
Jane Poynter, Taber MacCallum (67)
+ Alan Stern (56)
Sierra Nevada Corp.’s DreamChaser

- 6 space business areas, 35 location, 16 states. 2k people
- HQ: Sparks, NV  www.sncorp.com
- Fatih Ozmen, CEO, Eren Ozmen, President /CFO;
- 7 passenger, VTHL
- 9m long, 7m wingspan

2016 Resumes Flight Tests (unpowered)

Just missed cut for NASA CCP

- DreamChaser (Atlas V) for ~ 3B$
- SpaceX (v2 on F9) got 2.6B$
- Boeing (CST-100 on Atlas 5) got 4.2B$

Launch on Atlas V

3/15 New foldable wings

3/15 Bid CRS-2
Cargo competition

9/14 cut from CCiCap
10/14 partnered with Stratolaunch

Fits inside 5m shrouds
Orbital Technologies **CSS** (Russian Firm: Eric Anderson founder)

- JV Announced 9/10
  - Orbital Technologies + RSC Energia
  - Working with Space Adventures, OSC
- Commercial Space Station (CSS) ~2016

4/13: New COO

Joining 2 cosmonauts

Nothing since 2013

~ Failed Vision
Excalibur ALMAZ

- Founded 2005 (Isle of Man) Art Dula CEO
- ALMAZ derived Space Station and re-entry modules
  - Using existing Russian ALMAZ and TKS modules
    will have ‘largest windows on a spacecraft
- Teamed with Space Launch Services, PlanetSpace
  - To Purchase SÈA LAUNCH out of Bankruptcy (6/09)
    24.5 M$ in DIP financing 2010, 2011
  - Chapter 11 to Russian Interests 10/10

6/12: ‘Moon trips 150M$ in 2015’ + initiating ‘Asteroid Mining’ expedition
9/12: Investor SUES Art Dula for FRAUD - ‘Had no technical readiness’
5/14: ALMAZ auctioned in Belgium - ‘secondhand Soviet-era space capsule that
  launched into space twice’

RESURRECTED again: Excalibur Almaz Limited (Isle of Man) now owns:
- 2 ALMAZ modules + 4 RRV’s (Reusable Reentry Vehicle) Capsules
- “Alliance” - NPOM, EADS Astrium, Untied Space Alliance, Paragon Space Dev.
**Space Orbital Hotel**

- **Bigelow Aerospace Corp. - Bob Bigelow (71)**
  - 180 M$ invested by 2010 (up to 500M$ to 2015)
  - Sundancer to launch on Falcon 9 ~2016
    - 3 person space station module: 60 days @ 26.25 M$
  - NASA purchase of B.E.A.M. for ISS (17.8 M$) 1/13

**Genesis 1**
Launched 7/06 on Dnepr (SS-18)

**Genesis 2**
Launched 6/07 on Dnepr

**Space Complex Alpha**
3x BA-330 modules

**Sundancer**
To launch 2014

**SpaceX Dragon v2**

**Boeing CST-100**

**10d-60d tourist visits:**
- 27M$ w/Dragon v2
- 37M$ w/CST-100

**BEAM**
Space Complex Alpha
3x BA-330 modules

**Personal Quarters**

**Bridge**

**Entertainment Display**

**Fitness Equipment**

**Personal Hygiene Equipment**

**Vitality Boxes**

**Imaging Postage**

**Soil Box Equipment**

**Bigelow Expandable Activities Module (BEAM) launch to ISS April’16**
**Space Adventures**  
**Eric Anderson (42)**

**Lunar swingby:** $150M$ per 1 seat  
- 2 paid deposits 6/14, offer declined by Jeff Bezos 4/16

**Mission:** 2 paying seats (+1 Russian cosmonaut commander) '8 potential candidates ready to pay' (9/16)

**17 day Mission:**
- Crew fly on Soyuz to ISS for few days
- Undock and rendezvous with a habitation module and Block DM propulsion stage launched separately on Proton
- Block DM burn to lunar swingby and Earth return

Russia’s Rocket and Space Corp (RSC)  
**ENERGIA Modified SOYUZ**  
1st trip may be by 2020
Golden Spike – Alan Stern (59) VP at SwRI (1050 Walnut, Boulder, CO)
- Roundtrip Lunar landing: $1.5B per 2 seats
  - Raised $20k of $240k goal (Kickstarter crowd funded 4/13), No Billionaires
  - $7-8B needed
    - NGST Conceptual Design Study.

Bigelow Aerospace
Bob Bigelow (now 68)
- LUNAR HOTEL (open to NASA, etc.)
- 11/13 Call for Lunar Property Rights
SpaceX - Elon Musk (45)
- Mars landing: 500 k$ per seat roundtrip
- Refuel at Mars, Fully reusable spacecraft

METHANE FUEL: hydrolysis of water by electricity to create hydrogen and the addition of carbon dioxide CO2 (Sabatier process) to create methane.

\[ \text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O} \]

In-Situ Mars Production of METHANE FUEL:

- Red Dragon (Mars landing variant)
- 1/16 Red Dragon Hover test
- 4/16: Musk unveiled plans to Launch Unmanned MARS MISSION as soon as 2018! and 1st MANNED by 2024!

Elon: Reusable Mars Transfer Vehicles
Mars Methane Fuel Production
First landing in 10-15 years
500 k$ roundtrip ticket price
R/T: 180d + 600d + 180d
80,000 person permanent Mars Colony

Interplanetary Transport
RAPTOR Engine Test 9/16

Dec. 1, 2016 JRS slide 57 of 79
Inspiration Mars  USA  501(c)3 non-profit
- Founder: Dennis Tito (76)
- Mars Flyby – 501 day Free-Return opportunity (~once/15 years)
  - Launch 4/5/18 – Return 5/21/19 (NOW 2021: +80 days + Venus slingshot)
  - 2 passengers: man + woman
- Cygnus Capsule on SLS first demo flight (2017/18)
- ‘Proposed Funding: 300M$ (private) + 700M$ (Gov’t) – ‘NASA reacted cooly’

Mars One  Dutch  NO RETURN
- Founders: Bas Lansdorp (MSME) Arno A. Wielders (MSPhysics)
- No billionaires - funding delays - slipped schedules
  - 11/16 reverse merger (with public traded shell) – access to capital?
  - One way trip starting 2020? – 1st Crew landing 2025? 2nd Crew 2027?

Mars Polar  UAE, et al  RETURN a possible option
- Polar settlement 1st Crew 2029
  - No billionaires
Orbital
- SpaceX Falcons
- Blue Origin New Glenn
- Vulcan Aerospace Stratolaunch
- Orbital Science Corp Antares
- Elon Musk
- Jeff Bezos
- Paul Allen

Suborbital and Orbital (Smallsats)
- Virgin Galactic LauncherOne
- Generation Orbit Launch Services GoLauncher GO-2, GO-1
- Armadillo Aerospace Stig-B
- Up Aerospace Spyder, SpaceLoft
- FireFly Space Systems Alpha (all 160 staff let go 10/16)
- Rocket Lab Electron
- Vector Space Systems Vectors
- CubeCab Cab-3A
- XCOR Aerospace Lynx
- Sir Richard Branson
- John Carmack
- Failed Vision
- Failed Vision?
SpaceX - Elon Musk (45)
- Co-Founder Zip2 (at 24)
- Co-Founder PayPal (at 27)
- Founder Space Exploration Technologies (at 31)
- Co-Founder Tesla Motors (at 32)
- Co-Founder Solar City (at 35)

8/13:  Elon’s reveals HYPERLOOP
11/13:  Hyperloop Transportation Technologies Inc (crowd funding)
11/14:  "SpaceX is developing advanced micro-satellites operating in large formations.
1/15:   Elon’s 4026 LEO sat constellation w/Google, Fidelity Investments ~1B$
  +Musk building disruptive low-cost high volume satellite manufacturing facility in Redmond, WA


**Falcon 9**

- **12/21/15** First landing reusable F9v1.1 booster (Bezos first 11/23/15)
- **11/20/15** NASA Commercial Crew Contract 2.6B$ (D2 on F9) astronauts to ISS
  - Boeing (CST-100 on Atlas 5) got 4.2B$, Dream Chaser (Atlas 5) got cut
- **11/22/13** First Launch to GTO (F9v1.1 SES-8)
- IRIDIUM Launch contract 492 M$ deal
  - 6.8 M$ per 800 kg sat (<4k$/lb)
- **10/10/12** First Commercial Cargo
  - Dock with ISS (F9v1.0)
  - NASA Commercial Resupply to ISS contract 1.6 B$$ deal

**SpaceX: Falcon**

Falcon 9 v1.1 Reusable
Returnable 1st Stage
Tail Landing
Cape Canaveral
12/21/15

Russian ROSCOSMOS
Proton, Progress
can’t compete with
Falcon, Dragon

Manned Dragon Capsule

Falcon 9 v1.0 + Elon Musk
ALCC ETR 6/10

Merlin Rocket Engine
RP-1/LOX Turbo-pumped

F9 v1.0  F9 v1.1
60% longer

Raptor engine
Methane, LOx
6x thrust of Merlin

SpaceX:  Falcon

Falcon 9 v1.1 Reusable Returnable 1st Stage Tail Landing Cape Canaveral 12/21/15

Russian ROSCOSMOS Proton, Progress can’t compete with Falcon, Dragon

Manned Dragon Capsule

Non NASA 2.6B$ Crew (CCP) Contract 9/16/14

Mars One: 5 m diam variant (~2020, 25)
SpaceX: Falcon HEAVY

Debut 2017
First ETR Launch early ’17

Falcon Heavy can deliver 53 metric tons (117,000 lb) to Low Earth Orbit

Falcon Heavy’s first stage will be made up of three nine-engine cores, which are used as the first stage of the SpaceX Falcon 9 launch vehicle.

Cross-feeding of propellant leaves core stage nearly full on booster separation

Advertised Price: 80M$-95M$

At lift-off the upgraded Merlin engines generate over 3.8 million pounds of thrust — equal to fifteen 747’s at full power.

World’s Largest Launcher since Saturn 5
Twice the Lift of Shuttle, Delta 4 or Atlas V

Record low price/pound: < $1,000 per pound to LEO

- New RAPTOR methane/LOX reusable staged combustion rocket engine
  - First launch scheduled for 11/16
- SpaceX 4 Launch sites: VAFB LC4E, CCAFS LC40, KSC LC39A, Boca Chica, TX

Musk 2014: SpaceX MARS project: roundtrip ticket to Mars for 500K$
Blue Origin: New Glenn Launch System

- **Blue Origin - Jeff Bezos (52)**
  - Founder **Amazon** (at 30)
  - Founder **Blue Origin** (at 40) 500M$ Invested by Bezos

**BLUE ORIGIN**

- **Blue Origin Factory floor** (Kent, WA)

**1st Reusable Tail landing 11/23/15**

- **Suborbital 1st flight Mar’15**

- **Test vehicle**
- **Suborbital vehicle**

- **New Glenn Launch System**
- **Lox/LNG**
Vulcan Aerospace: Stratolaunch System

Development Costs: ~ 300 M$

- Paul Allen (62) Co-Founder
- Burt Rutan (71) Co-Founder

Orbital 3-stage Booster (Solid-Solid-Liquid) ‘Thunderbolt’

10/16 Orbital ATK’s Pegasus XL contract:
1000 lbs to LEO

2 Pegasus XL’s

World’s Largest Wingspan
“Fully Operational”: < 2020
Orbital Science Corp’s Antares and Cargo Vehicle

Antares first Launch 4/13
Cygnus unmanned COTS cargo vehicle first launch 9/13
5th Antares Launch FAILURE - Return to flight 10/16

Orbital’s Antares at M-ARS (Wallops Island, VA)

Cygnus Cargo Capsule
Built by Thales Alenia

2,000 kg
2,700 kg

After explosion – Atlas V Launch of Cygnus OA-4 to ISS 12/3/15

Failed Vision

4/11 Stopped developing a commercial crew vehicle

Dec. 1, 2016
Virgin Galactic: LauncherOne (with ‘Cosmic Girl’)  

1. The LauncherOne rocket will be mounted to the Boeing 747-400 under the left wing.  
2. By ‘piggybacking’ on the Boeing jet, it can be deployed from commercial airports.  
3. LauncherOne will be released at an altitude of approximately 35,000ft (10,668 metres).  
4. Once released, the rocket will fire up its single main stage engine called the ‘Newton Four’ for three minutes.  
5. After stage separation, the single upper stage engine, called the ‘Newton Four’, will carry the on-board satellite into orbit.  
6. Typically the second stage will burn multiple times for almost six minutes.  
7. At the end of this sequence, LauncherOne will deploy the on-board satellite into its orbit.  
8. Both stages of LauncherOne will be safely deorbited, and the jet will return to the airport.  

Cosmic Girl 747-400  

Sir Richard Branson  

Pilot  

Kelly Latimer
Generation Orbit Launch Services Founded 2011
(former professor/grad students from Georgia Institute of Technology)

- Won SBIR II from AFRL for GOLauncher 1 testbed (8/4/15)
- Won NASA launch contract 2.1 M$ 9/13 - three 3U CubeSats to a 425 km orbit
  Sched Aug. 2016: 1st Mission Launch from Cecil Field Spaceport (Jacksonville, FL)
- Won 100 k$ Grand Prize 11/13 (NASA-sponsored NewSpace Business Plan Competition)
- Won 150 k$ SBIR (hypersonic flight research, AFRL) 11/13

GOLauncher 1: Suborbital (μgravity ~7 min)
- Gulfstream T3 business jet
- Rocket stage: ~existing solid missile

GOLauncher 2: 40 kg to LEO
- Gulfstream T3 business jet
- 1st stage Rocket: ~existing solid missile
- 2nd stage Rocket: Ventions Kerosene motor
John Carmack (46)

Co-founder id Software (at 21)
Games: Doom 1-4, Rage, Quake 1-4, etc.
Doom RPG for iPhone
Engines: Half-Life, Call of Duty, Medal of Honor, etc.
4th person inducted into AIAS Hall of Fame
(Academy of Interactive Arts and Sciences)

Founder Armadillo Aerospace (2000)
Lunar Lander Challenge:
Won 350k$ prize 10/08
Qualified for 1M$ prize 9/09
Stig-A Launch (95km) 12/11 from Space America, NM
Put in "hibernation mode" (8/13)
following crash of STIG-B rocket

Reformed by team as EXOS Aerospace (5/14)
Developing SARGE from Stig-A rocket
- Up Aerospace Spyder, SpaceLoft
- FireFly Space Systems Alpha *Failed Vision?*
- Rocket Lab Electron
- Vector Space Vector-R, -H
- CubeCab Cab-3A
- XCOR Aerospace Lynx
**Private Commercial Spaceports**

**FAA Licensed (10):** Alaska, Arizona, California (2), Florida (2), New Mexico – Virgin Galactic, Oklahoma, Texas (2) – XCOR, SpaceX, SNC, Virginia (1), (Kwajalein Atoll)

**Proposed for FAA Licensing:** next - **Colorado** (Spaceport Colorado at Front Range Airport SE of DIA), Hawaii (Kona, HI), Indiana, Wisconsin, Alabama, Wyoming (Greater Green River Intergalactic Spaceport), Georgia, Tucson (World View)

**Proposed International:** Dubai, Singapore, UK, Malaysia, Sweden, Curaçao, etc

- NM invests 200M$ in infrastructure
- BIG PROBLEM after SS2 crash when Virgin Galactic (anchor, only tenant) takes >1 year delay in ops

Currently FOR SALE by NM
SpaceX - TBD (Internet) - Elon Musk (45)
2825 LEO 1100-1300 km constellation ($10B, laser) raised 1B$ from Google, Fidelity Investment + Musk building disruptive low-cost high-volume sat. manufacturing facility in Redmond, WA

OneWeb (Internet) - Greg Wyler (47)
Google’s 100% SES’s O3B (32 MEO) + WorldVu (360 LEO) now OneWeb (720 LEO), O3BN (+24 MEO)
9/14 Wyler left Google (after 1 yr) with Ku spectrum rights (~Skybridge)

▪ 720 LEO (1,200km, 200kg, 6Gbps, 5 yr, 0.5M$ ea) ~2B$ ≤2019
▪ 1/15: OneWeb raised 500M$: Branson/Virgin, Qualcomm, Intelsat, Coca-Cola
▪ 6/15 contracts: 900 sat Airbus (outside KSC), 21 Soyuz, 39 (+100) LauncherOne

LeoSat (Internet) - (founders/funders not disclosed)
▪ 108 Hi power Ka Sats 1,400 km LEO, targeting top 3,000 businesses ~2.5-3B$

Boeing - TBD (Internet 5G)
▪ 6/16: 1,396 + 1,560 LEO 1200km constellation (V-, C-band)

BlackSky Global (Imaging) - Paul Allen (63)
▪ Imaging 60 satellites 450-600km LEO 98.7° ‘pay per picture’ ‘hourly’

Planet (Imaging, was P. Labs) - no billionaires (6/16 name change)
▪ 100’s Imaging disposable 5kg cubesat flocks 475 km LEO
▪ 1 photo/sec, raised 183 M$ (95M$ raised 1/15)
▪ Test in orbit vs ground: 131 launched with 87 working – 12 complete redesigns in past 3 years
  ▪ Acquired RadipEye (5 sats) + geospatial business 6/15
  ▪ 11/15: Launch 250 sats in 2016, 7/16: 3 Rocket Lab Electron launches (~75 sats) starting in 2017

Hera Systems (Imaging) - no billionaires
▪ 48 Imaging cubesat constellation (in 2016) sunsync and inclined LEO

Terra Bella (Imaging, was SkyBox) – GOOGLE Subsidiary
▪ 13 LEO 83 kg (180 cubesats) constellation sunsync and inclined LEO
**Constellations Revolution**

- **Constellation Filings flooding ITU**
  - at 40k$ filing fees each constellation (or each GSO sat)
  - USA: O3b (32 MEO’s, 12 in orbit), SpaceX (4026 LEO’s), OneWeb (648 LEO’s), Planet Labs (42 EOC’s)
  - ViaSat (24 MEO’s), Telesat (117 LEO’s), upstarts: Audacy, Karousel, Kepler, Space Norway, Theia
  - Canada: CANPOOL-2 (72 sats), COMSTELLATION (794 sats), UrtheCast (16 sats: 8+8 SAR)
  - France: MCSat (800-4,000 sats)
  - Australia: Sky and Space Global (200 nanosats) 2018 on LauncherOne
  - Norway: ASK-1 (10 sats), STEAM (4,257 sats)
  - Lichtenstein: 3ECOM-1 (264 sats)
  - Russia: Yaliny (144 sats)
  - China: CASIC (156 LEO sats)
  - India: Astrome (160 LEO sats)
  - (USA+withheld): LeoSat LLC (120-140 LEO HTS big sats)

- **Loon - Balloons (Internet) - Google**
  - 6/13: High-altitude balloons (20 mi up) connecting with LTE cell phones (3G)
    - Inter-Balloon links (IBL’s), Partnered with CNES

- **SkyBender - Drone/UAV’s (5G Internet + mapping) - Google**
  - Solar Powered high-altitude drones ‘Titan Solara’ (165’ wingspan)
    - FCC licensed Testing since 3/8/15 E of Albuquerque (1st flight crash 5/15)

- **Drone/UAV’s (5G Internet) - Facebook**
  - 9/14: Solar Powered high-altitude drones ‘Aquila’
    - Altitude 60k-90k ft, ~737 wingspan (147’), stay up months, 38-39.5 GHz, Lasercom
  - 10/15 sat contract: +Eutelsat, Lease Ka spectrum from Amos-6 (start 1/17)
GPS Occultation weather forecasting constellations

- **PlanétIQ** (12-18 LEO's), Bethesda, MD
  - being built by Blue Canyon Technologies, Boulder

- **GeoOptics** (24 LEO's) Pasadena, CA – partner with LASP

- **Spire** (100 LEO's) Built/launched first crowd-funded satellite (ArduSat, 2013)
  - San Francisco, Glasgow, Singapore 7/15: 40M$ raised for 100 sats
  - 20 sats by 12/15, 100 by 2017
Moon Express
- Co-Founders: Naveen Jain (54), Barney Pell (45), Robert Richards (47) 8/10
- Investors: Naveen Jain (54) (INFOSYS – was billionaire), Klee Irwin
- Acquisitions: Next Giant Leap, Rocket City Space Pioneers
- Google Lunar X-Prize, ILO-X

Planetary Resources Inc.
- Co-Founders: Peter Diamandis (55), Eric Anderson (42)
- Investors: Larry Page (43), Charles Simonyi (68), Ross Perot, Jr. (58), Eric Schmidt (67)
- Formed as Arkyd Astronautics 11/10 Acquired and Renamed PRI 9/12
- 11/21/13 NASA SAA – for crowd sourced: ‘Asteroid Grand Challenge’
  Raised 1.5M$ (1.0M$ goal Kickstarter crowd funded 7/13)
  12M$ (20M$ goal 10/15), 21M$ (5/16)
  28M$ (11/16, Luxembourg)

Deep Space Industries Inc.
- Co-Founders: Rick Tumlinson, David Gump 1/13
- Investors: no billionaires

TransAstra
- Founder: Joel Sercel (JPL) 9/15
- Investors: no billionaires

Galactic Mining Inc. (founded 1990)
- Founder: Richard Westfall
- JRS, Lawyers (Law of the Sea, Space Treaty)
- CO School of Mines WAAAY TOO EARLY
Breakthrough Starshot Founder: Yuri Milner (54)

- Russian Billionaire Entrepreneur, Venture Capitalist, Physicist
- Breakthrough Prizes: Life Sciences, Fundamental Physics, Mathematics
  - 3 M$ to Laureates – “the LARGEST SCIENTIFIC AWARDS in the world” (Nobel: 1.1 M$)
  - As of 1/15: 168.1 M$ in prize-money awarded to 70 individual scientists and 4 large research teams
- Milner initial investment 100 M$
  - Total project cost ~ 5-10 B$
- Board of Directors: Stephen Hawking, Mark Zuckerberg, Yuri Milner
  - Project Manager: Pete Worden
  - Advisors: Avi Loeb, Martin Rees, Saul Perlmutter, Ann Drunyan, Freeman Dyson, Mae Jemison
- Alpha Centari – 4.37 light-years, 20 year trip, 0.2 speed of light
  - Launch Mother ship with FLEET of ~1000 iPhone-sized light sail craft
  - Once in orbit, probes unfold thin sails
  - Propelled by 100 GW laser beams from earth
    - In ≤2 minutes, probes > 600,000 miles from earth
    - In 3 days, probes past Pluto’s orbit
    - Arrival AC exoplanet in 20 years
  - Then a miracle occurs 😊
- Safe arrival message+flyby images rec’d 4.37 years later
Many Space Companies around Front Range Area

Colorado is 3rd-largest Space Economy in USA (behind CA and FL)

#1 Region in USA
Nine-county Metro Denver region
Ranks #1 for Private Sector Aerospace Employment (out of the 50 largest metro areas)

#1 County in USA
Jefferson County ranked #1 for Private Sector Aerospace Employment

Lists of Space Companies around Front Range Area:
- [http://www.metrodenver.org/industries/aerospace/](http://www.metrodenver.org/industries/aerospace/)
- [http://www.denverchamber.org/Aerospace?keywords=aerospace&ysort=true](http://www.denverchamber.org/Aerospace?keywords=aerospace&ysort=true)
- [http://www.spacecolorado.org](http://www.spacecolorado.org)
- [www.manta.com/mb_43_G0_06/aerospace/colorado](http://www.manta.com/mb_43_G0_06/aerospace/colorado)
- [http://aerospace.regionaldirectory.us/colorado.htm](http://aerospace.regionaldirectory.us/colorado.htm)
- [http://www.advancecolorado.com/key-industries/aerospace/aerospace-map](http://www.advancecolorado.com/key-industries/aerospace/aerospace-map)

LMSS Commercial Space HQ and A2100 comsat production moved to Waterton facility 11/14
Many Space Companies in Boulder Area (partial list):

- **ABSL Space Products** (Li-ion batteries) 2602 Clover Basin Drive, Suite D, Longmont, CO 80503 303.848.8081
- **Altius Space Machines** (Mechanisms, Docking) 511 E. South Boulder Road, Louisville, CO 80027 303.827.1574
- **Ball Aerospace & Technologies** (Satellites, etc.) 1600 Commerce Street, Boulder, CO 80301 303.939.6100
  Internship Program: http://www.ballaerospace.com/page.jsp?page=48
- **DigitalGlobe** (Space Imaging) 1601 Dry Creek Drive, Suite 260, Longmont, CO 80503 303.684.4561
- **Google Boulder** (Software, Navigation) 2590 Pearl Street, Suite 110, Boulder, CO 80020 303.245.0086
- **Laboratory for Atmospheric and Space Physics (LASP)** (Space science, operations) 1234 Innovation Drive, Boulder, CO 80303 303.492.6412
- **National Center for Atmospheric Research (NCAR)** 3090 Center Green Drive, Boulder, CO 80301 303.497.1000
- **National Oceanic and Atmospheric Administration (NOAA)** 325 Broadway, Boulder CO 80305 303.497.4600
- **Next Giant Leap** (Moon Express subsidiary) 4401 Discovery Drive (#290), Boulder, CO 80301 605.591.3915
- **PlanetiQ** (Global weather data constellation) 2425 55th Street (Suite A-150), Boulder, CO 80301 571.364.7238
- **Sierra Nevada Corp. (SNC)** (Satellites, Dreamchaser, etc.) 1722 Boxelder Street, Suite 102, Louisville, CO 80027 303.530.1925
- **Southwest Research Institute (SwRI)** (Space studies, operations) 1050 Walnut St, Suite 300 Boulder, CO 80302 303.446.9670
- **Space Science Institute (SSI)** (Space studies, operations) 4750 Walnut Street, Suite 205, Boulder, CO 80301 720.974.5888
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Dr. James R. Stuart is an independent, internationally recognized space consultant specializing in the development of new technologies, advanced systems and commercial businesses, an inventor, an author and a serial entrepreneur. He has consulted to over 110 companies in 12 countries over the past 37 years. Dr. Stuart has 21 patents granted in space vehicles design, satellite telecommunications, launchers, personal computing, wireless communications, digital rights management and RFID’s (another 4 are pending). He is currently a Board Director of 2 entrepreneurial, high-technology companies, and of 2 civic and non-profits. He has been a Board Director of 39 companies, and an Advisory Board member of 49 companies. Dr. Stuart has been a professional expert witness in 8 major space industry litigations.

Dr. Stuart is currently CEO of Space Tug Corp. (developing commercial high-power thorium electric space vehicles). He has held positions as the CEO and President of IOSTAR Corp. in Salt Lake City, UT, the CEO of SkyVault Secure Digital Distribution, Inc. in Carmel, CA, the CEO and President of Kitcom Satellite Communications Ltd. in Hamilton, Bermuda, as the Vice President and Chief Architect of Teledesic Corp. in Bellevue, WA ($15 billion satellite broadband venture by Craig McCaw and Bill Gates), and the Chief Engineer and the Chief Scientist of Ball Aerospace in Boulder, CO. He was previously the founding Chief Engineer of Orbital Sciences Corp. (now Orbital ATK, NYSE: OA), the Assistant Laboratory Director of the Laboratory for Atmospheric and Space Physics (LASP), and the Development and Flight Programs Manager at Caltech NASA Jet Propulsion Laboratory (JPL) of both the Solar Mesosphere Explorer (launched 1981) and the Mars Observer (launched 1992).

Dr. Stuart was a member of three graduate engineering faculties of the University of Colorado at Boulder for 19 years, in the Electrical Engineering, the Telecommunications and the Aerospace Engineering Sciences Departments. He has been a regular lecturer at various universities, including the Stanford University Graduate School of Business and the Naval Postgraduate School. He received his Ph.D. in Systems Engineering (1979), M.S. in Operations Research (1977), and M.S. in Electrical Engineering (1974) from the University of Southern California, and his B.S. in Physics (1968) from the University of Washington.

Dr. Stuart has received numerous professional awards, including NASA's Exceptional Service Medal for his project management of JPL’s Solar Mesosphere Explorer Project. He has been listed in Via Satellite magazine’s "Top 100 Executives in the Satellite Communications Industry". He has presented invited technical lectures in 13 countries. He is the author of a graduate engineering, two-volume text entitled Satellite Communications Systems, co-author of Telecommunications: An Interdisciplinary Text, paid magazine features; and over 200 professional technical papers.