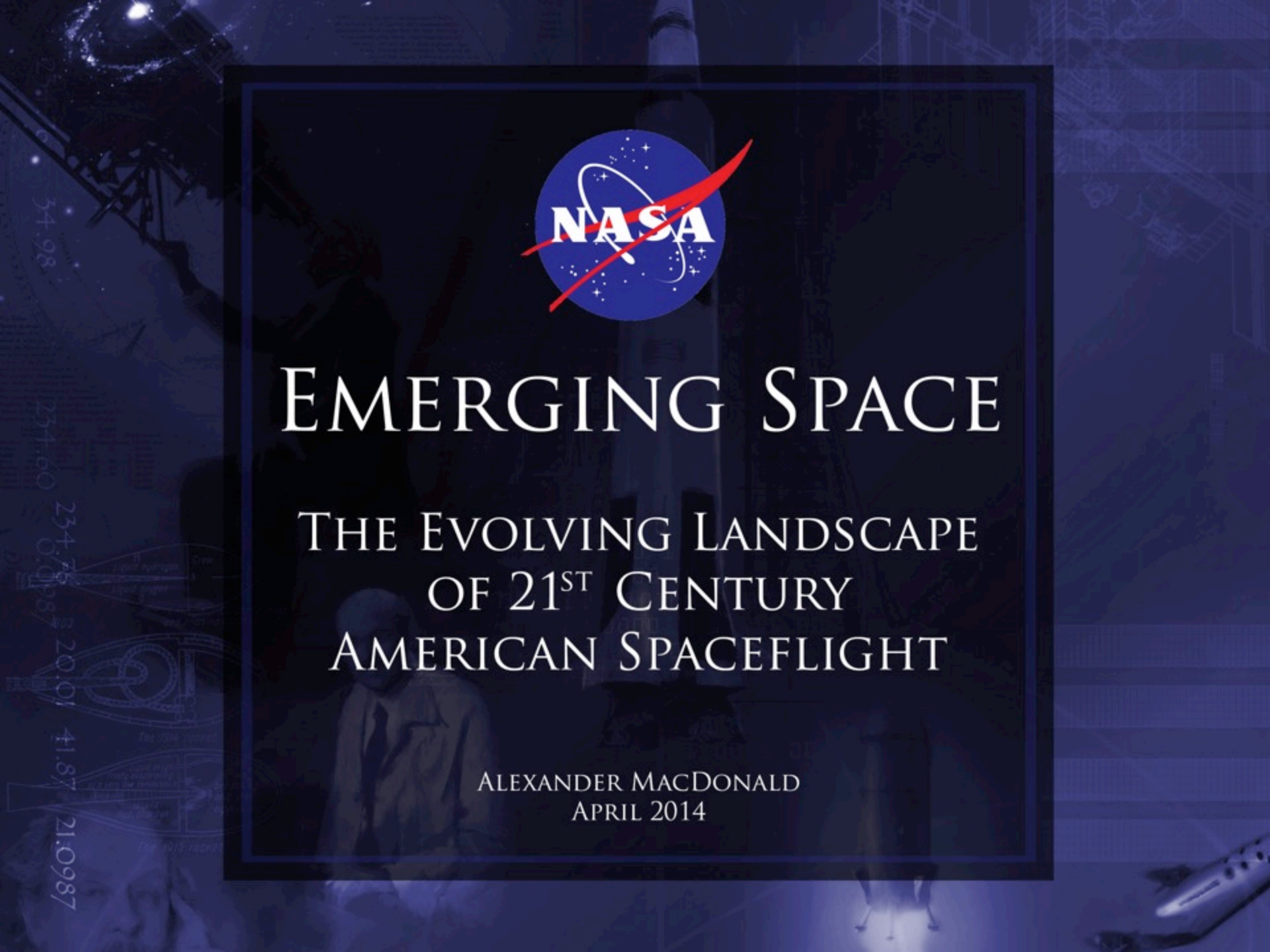


Emerging Space

The Evolving Landscape of 21st Century American Spaceflight

Alexander MacDonald

April 2014

Overview

- Evolving Landscape of 21st Century American Spaceflight
- NASA Engages with Emerging Space
- New Landscape of Space Exploration
- Building a Future Space Economy
- Exploring Space Forever

Evolving Landscape of 21st Century American Spaceflight

- The U.S. stands at opening of "Second Space Age"
- Innovative NASA programs and American entrepreneurs together are transforming the space industry
- NASA is directed "to encourage, to the maximum extent possible, the fullest commercial use of space"
- Total committed investment in the commercial human spaceflight industry ~$2.5B since 2004
  - Individuals are the dominant funding source
  - 2012 revenue was about $800M

When NASA was founded, only a government program could undertake a voyage from the Earth to the Moon. *This may not be true in the future*

Forging the New Space Economy

- NASA has been the chief enabler of expanding human presence in space for over 50 years
- Sustaining this expansion requires fresh ideas and new approaches
  - NASA has embraced the emerging space industry, which focuses on creating new markets for goods and services
  - Cargo and crew transportation to low Earth orbit (LEO) is the first major effort between NASA and emerging space companies
  - As expansion beyond LEO proceeds, the complexity and scope of this process will require that we habitually learn to incorporate and encourage new industrial and international partnerships

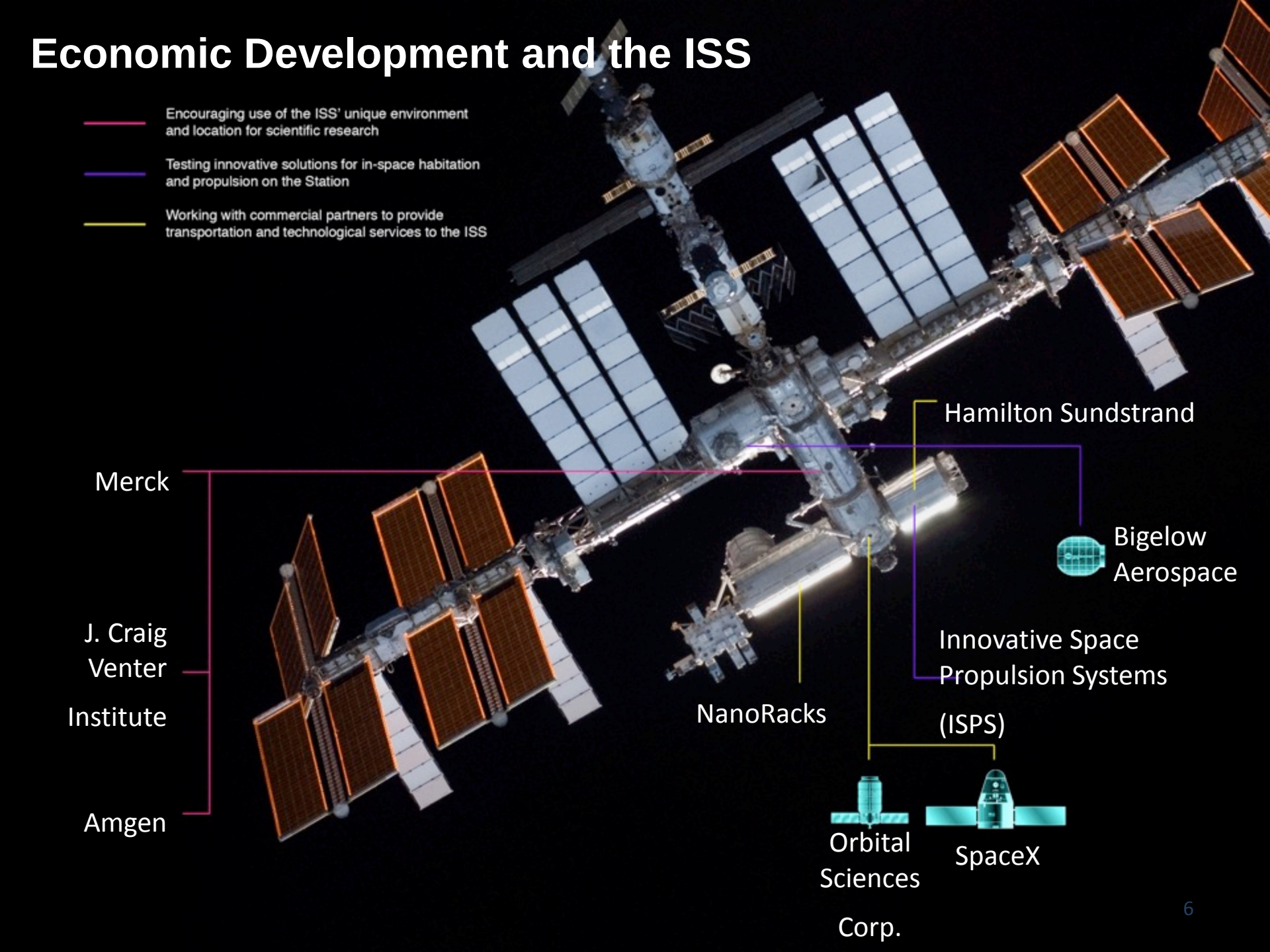
A robust and competitive commercial space sector is vital to continued progress in space

Economic Development and the ISS

- The ISS is the first international economic system in space. We are learning to foster economic development through space utilization
  - International government collaboration
  - Enabled emerging space companies to pursue LEO cargo and crew transportation services
    - $1.5B in future commercial revenue from Falcon 9 and Antares launches booked by the private sector
  - Research facility provided to any qualified individual or group across all sectors
    - 1,500 scientific investigations since 1998
    - 1,400 peer-reviewed papers featuring ISS research from 1998 to 2013
    - 42 million students reached through ISS educational events from 1998 to 2013
- NASA is actively welcoming a broader array of emerging space partners for ISS, extending the life of the station to at least 2024

The ISS is becoming a frontier industrial and development hub for the nation

Economic Development and the ISS



Enabling Commercial Crew and Cargo

- NASA now purchases flight services to ISS, a departure from the previous model of NASA owning and operating its own vehicle
- Development of commercial cargo transportation
  - Successfully produced two new U.S. launch vehicles and two new cargo spacecraft
  - Cargo development cost about $900M, followed by cargo transportation contract valued at $3.4B
  - Non-NASA payload operators now seeking these two new vehicles, with estimated backlog of $2.5B (includes commercial and outstanding NASA CRS contract amounts)
- Three new crew spacecraft under development and planned for introduction in 2017
- Commercial cargo and crew program highlighted as an example of a successful NASA-industry partnership that produces low-cost, high-quality competitive capabilities for the nation

Through competition, NASA is encouraging development of commercial crew and cargo access to LEO and beyond

Enabling Commercial Crew and Cargo

NASA has distributed more than $5.7B in contracts and Space Act Agreements for commercial crew and cargo

Agreement or Contract	Investment to Date	Partners	Scope
Commercial Orbital Transportation Services	$891M	Orbital and SpaceX	Cargo transportation system technologies and concepts
Commercial Resupply Services	$3.4B	Orbital and SpaceX	Cargo resupply services to the ISS
Commercial Crew Development Round 1	$50M	Blue Origin, Boeing, Paragon, Sierra Nevada, and ULA	Crew transportation system technologies and concepts
Commercial Crew Development Round 2	$315M	Blue Origin, Boeing, Sierra Nevada, and SpaceX	Elements of a crew transportation system
Commercial Crew Integrated Capability	$1.1B	Boeing, Sierra Nevada, and SpaceX	Integrated crew transportation systems
Certification Products Contract	$29.6M	Boeing, Sierra Nevada, and SpaceX	Early certification products

Commercial companies developing vehicles under commercial cargo or commercial crew contracts with NASA include (top to bottom) SpaceX for its Dragon vehicle, Orbital Sciences Corporation for the Cygnus, Boeing for the CST-100, and Sierra Nevada Corporation (SNC) for Dream Chaser.

Advancing Space Technology

- NASA mission of exploration and discovery necessitates development of new technologies and capabilities
  - More than 1,600 new technology inventions in FY 2013
  - More than 2,150 domestic technology transfers in FY 2013, including software usage agreements, copyrights, and licenses
- NASA's community of innovators includes
  - NASA workforce
  - Small businesses
  - Established and emerging space companies
- To advance space technology in areas such as solar electric propulsion, cryogenic propellant storage transfer, laser communications, and small satellites, NASA is partnering with emerging space companies

NASA's Space Technology portfolio includes critical technologies for expanding American activities in the solar system as well as technologies that will benefit the public and our economy

NASA Facilities and Expertise

- NASA's infrastructure and expertise are invaluable resources for emerging space companies
- NASA, and its predecessor organizations like the NACA and the Army's Redstone Arsenal, have allowed the agency to provide almost a century's worth of facilities and expertise
  - Over 1,000 requests by U.S. industry for human spaceflight technologies since the Apollo Program
  - Following retirement of the Space Shuttle, NASA is pursuing unique opportunities to lease or provide in-kind capabilities and expertise that would otherwise be latent
  - Keeping these assets and professional services active means the U.S. aerospace industrial base remains vigorous and competitive
- Facilities being considered for partnerships at KSC alone total nearly 630,000 square feet with a replacement value of $762M

NASA's facilities and expertise represent opportunities for emerging space companies to build upon a legacy of success

NASA Facilities and Expertise Advance Space Development

NASA leases facilities no longer used due to retirement of the Space Shuttle to a variety of private sector partners. In addition, NASA provides facility use and expertise to companies developing new technologies, typically in the form of Space Act Agreements

Goddard Space Flight Center

Ames Research Center

Glenn Research Center

Headquarters

Wallops Flight Facility

Armstrong Flight Research Center

Langley Research Center

Jet Propulsion Laboratory

Marshall Space Flight Center

Kennedy Space Center

Johnson Space Center

Stennis SpaceCenter

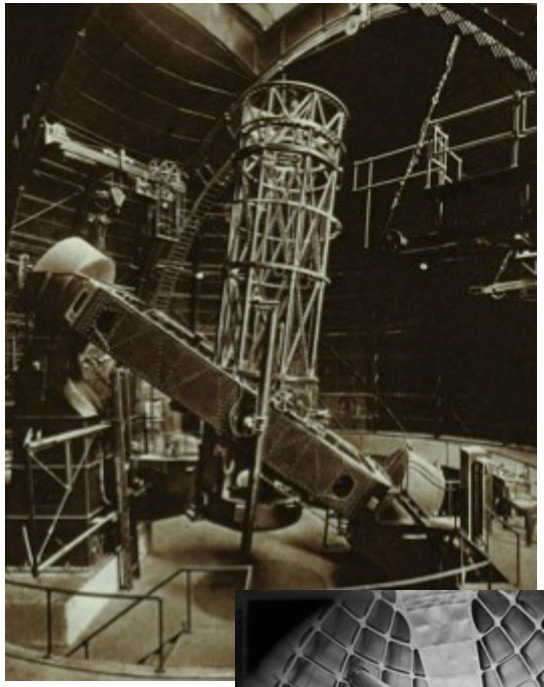
Origins of the American Space Economy

- By the time NASA formed in 1958, private investment in over 40 U.S. observatories totaled ~$8 billion (2012 dollars), and rocket clubs and test sites nationwide laid the first foundations of the American space community
- NASA's core centers came from the National Advisory Committee for Aeronautics (NACA), the Army's Redstone Arsenal, and the Naval Research Lab's Vanguard group
- Private-sector rocket engineers were also contributing to the field of rocketry, with their efforts pursued at the privately endowed GALCIT (later JPL) and Reaction Motors, Inc.
- After WWII, the Air Force pursued development of the Atlas and Thor missiles. The German rocket team behind the V-2, lead by Werner Von Braun, arrived in America, adding their technological expertise, culture, and spaceflight vision to the mix

Even before the formation of NASA, American citizens were working, organizing, and investing in order to make spaceflight a reality

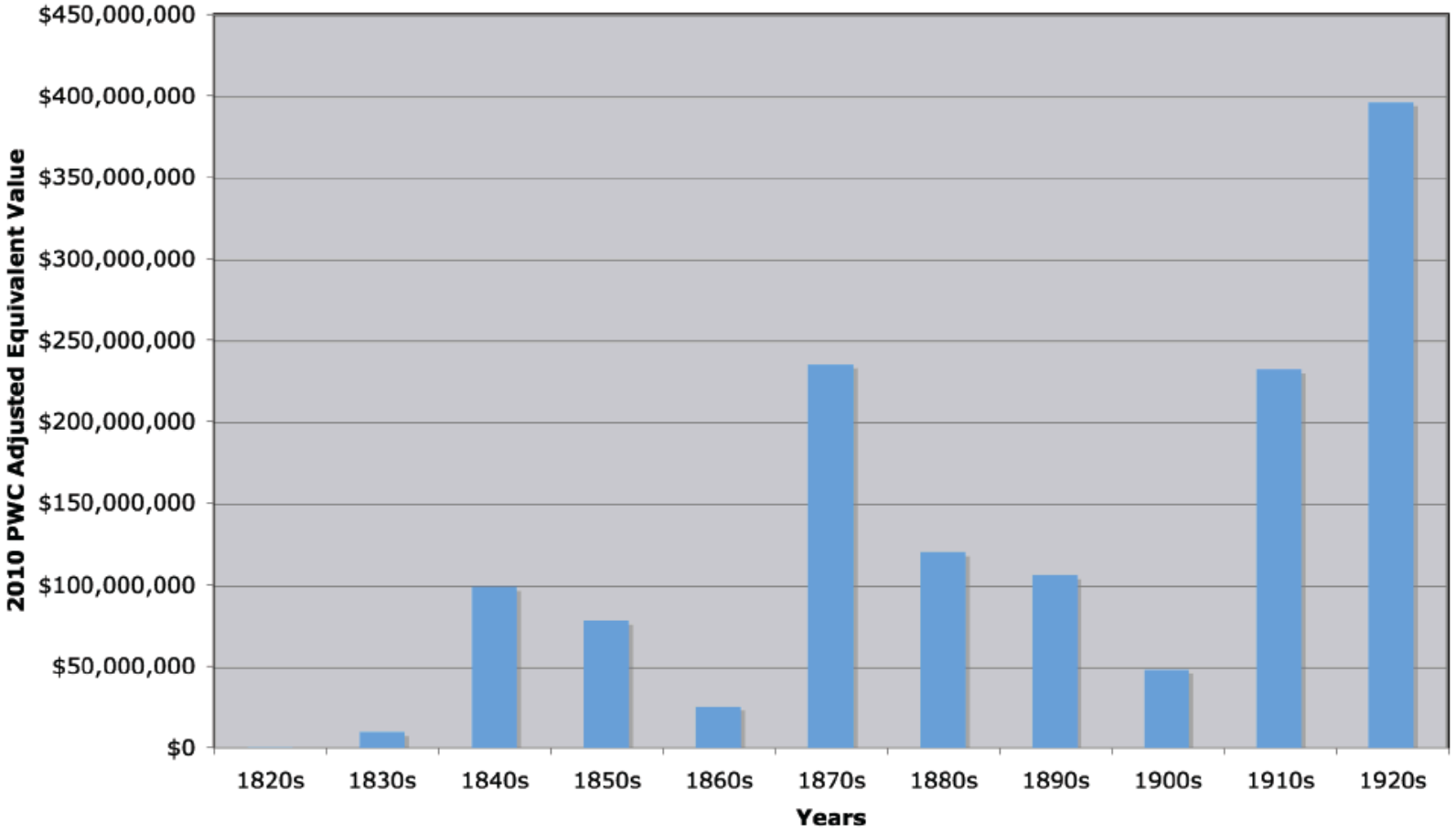
Origins of the American Space Economy

Project	Year	Current Prices in U.S Dollars ($)	Constant Prices in U.S. Dollars ($) adjusted by PWC index, base year 2010*	GDP-ratio Equivalent Value in U.S. Dollars ($) adjusted by ratio to GDP, base year 2010**
Yale College Observatory	1828	1,200	661,000	19,600,000
University of North Carolina Observatory	1831	6,400	3,020,000	89,200,000
Hopkins Observatory	1836	6,100	3,100,000	60,500,000
Western Reserve College Observatory	1836	4,000	2,030,000	39,700,000
Philadelphia High-School Observatory	1837	5,000	2,170,000	47,200,000
West Point Academy	1842	5,000	2,070,000	45,300,000
U.S. Naval Observatory	1842	25,000	10,300,000	227,000,000
Cincinnati Observatory	1843	16,000	7,550,000	150,000,000
Harvard College Observatory	1844	50,000	23,200,000	431,000,000
Georgetown Observatory	1844	27,000	12,500,000	233,000,000
Jackson Observatory	1845	4,000	1,860,000	31,600,000
Edward Philips Endowment - Harvard	1848	100,000	40,700,000	604,000,000
Shelby College Observatory	1848	3,500	1,420,000	21,200,000
Detroit Observatory	1852	22,000	8,680,000	105,000,000
Shattuck Observatory	1852	11,000	4,340,000	52,600,000
Litchfield Observatory	1854	50,000	19,400,000	198,000,000
Dudley Observatory	1854	119,000	46,300,000	470,000,000
Allegheny Observatory	1862	32,000	9,300,000	80,300,000
Vassar College Observatory	1865	14,000	3,310,000	20,600,000
Dearborn Observatory	1865	56,000	13,200,000	82,300,000
Winchester Observatory	1871	100,000	22,800,000	191,000,000
Halsted Observatory	1872	60,000	13,600,000	106,000,000
Morrison Observatory	1874	100,000	22,400,000	171,000,000
Lick Observatory	1876	700,000	162,000,000	1,220,000,000
Washburn Observatory	1876	65,000	15,100,000	114,000,000
Warner Observatory	1880	100,000	23,800,000	140,000,000
McCormick Observatory	1881	135,000	32,400,000	169,000,000
Kenwood Physical Observatory	1888	25,000	5,160,000	26,200,000
Elias Loomis Endowment - Yale	1889	300,000	59,600,000	315,000,000
Goodsell Observatory	1890	65,000	12,900,000	62,600,000
Chamberlin Observatory	1890	56,000	11,110,000	54,000,000
Ladd Observatory	1891	30,000	5,960,000	28,300,000
Yerkes Observatory	1895	349,000	73,200,000	325,000,000
McMillan Observatory	1895	16,000	3,360,000	14,900,000
New Allegheny Observatory	1906	300,000	48,700,000	140,000,000
Mount Wilson Observatory	1910	1,450,000	219,000,000	630,000,000
Griffith Observatory	1919	225,000	13,800,000	41,700,000
Perkins Observatory	1925	379,000	19,900,000	60,800,000
Mount Palomar Observatory	1928	6,550,000	334,000,000	977,000,000
McDonald Observatory	1929	840,000	43,000,000	118,000,000



MacDonald, Alexander, "The Long Space Age: An Economic Perspective on the History of American Space Exploration" Doctoral Dissertation, University of Oxford, 2013

Origins of the American Space Economy



Decadal Expenditure on U.S. Observatories, 1820s to 1920s: Constant Prices in 2010 U.S. Dollars-PWC Adjusted

MacDonald, Alexander, "The Long Space Age: An Economic Perspective on the History of American Space Exploration" Doctoral Dissertation, University of Oxford, 2013

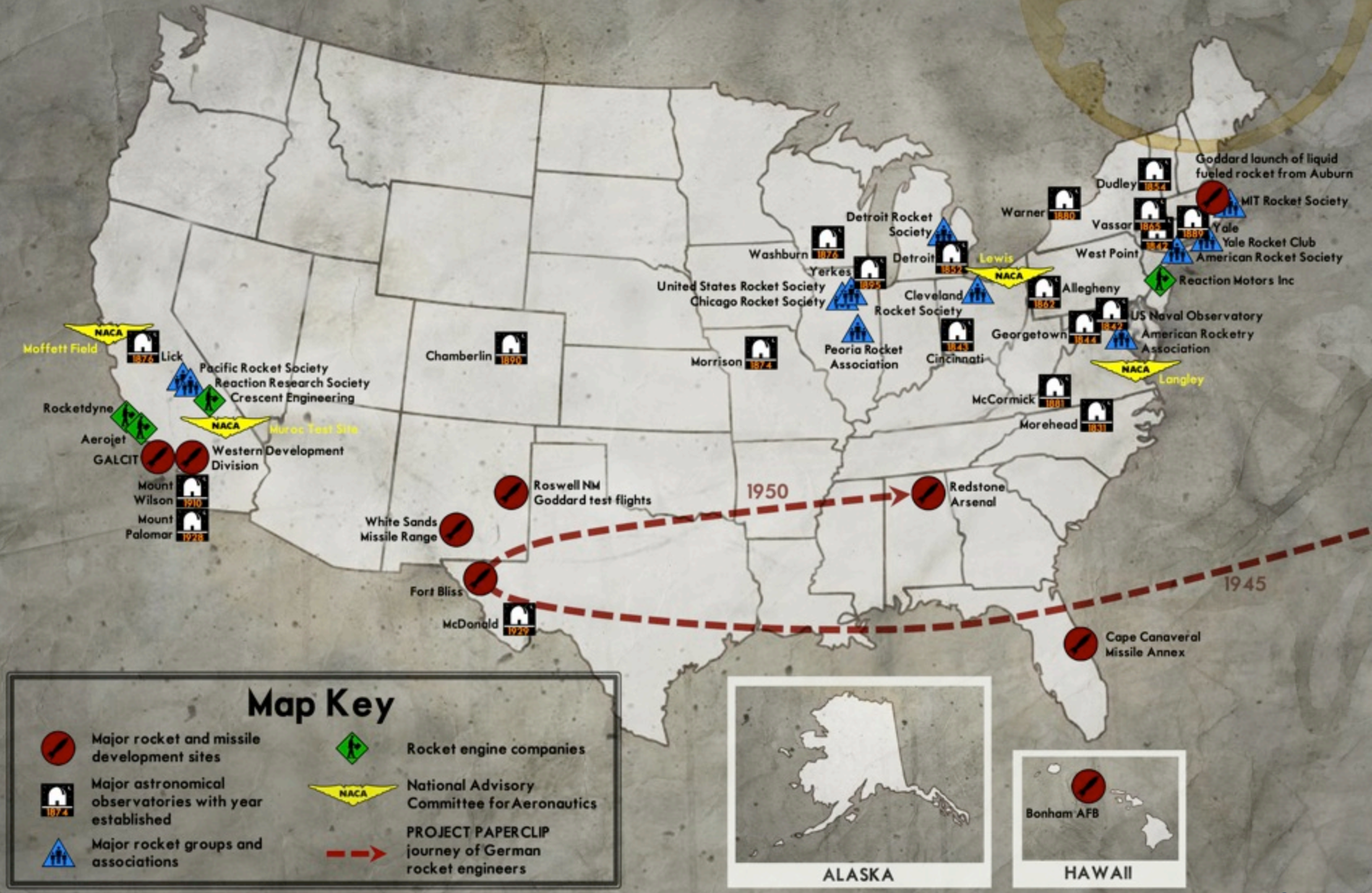
Origins of the American Space Economy

Year	Source	Amount	2010 PWC	2010 GDP-Ratio Equivalent
1917	Smithsonian (Hodkins Fund)	$5,000	$464,000	$1,220,000
1918	U.S. Army Signal Corp	$25,000	$1,850,000	$4,790,000
1921	Clark University	$2,500	$137,000	$493,000
1922	Clark University	$1,000	$59,500	$198,000
1924	Smithsonian (Cottrell Fund)	$5,000	$261,000	$835,000
1924	AAAS	$190	$9,910	$31,700
1928	Smithsonian (Operations)	$1,750	$89,200	$261,000
1929	Smithsonian (Research Corporation)	$2,500	$128,000	$351,000
1929	Smithsonian (Operations)	$2,500	$128,000	$351,000
1930	Carnegie Institute of Washington	$5,000	$251,000	$796,000
1931	Daniel Guggenheim	$50,000	$2,580,000	$9,490,000
1932	Smithsonian (Hodgkins Fund)	$250	$14,800	$61,900
1933	Guggenheim Foundation	$2,500	$150,000	$644,000
1934	Guggenheim Foundation	$18,000	$903,000	$3,960,000
1935	Guggenheim Foundation	$18,000	$878,000	$3,570,000
1936	Guggenheim Foundation	$20,000	$961,000	$3,470,000
1937	Guggenheim Foundation	$20,000	$839,000	$3,160,000
1938	Guggenheim Foundation	$20,000	$826,000	$3,370,000
1939	Guggenheim Foundation	$20,000	$826,000	$3,150,000
1940	Guggenheim Foundation	$20,000	$789,000	$2,870,000
1941	Guggenheim Foundation	$3,000	$107,000	$344,000
1942	Army Air Force	$13,000	$400,000	$1,170,000
1942	Navy Bureau of Aeronautics	$87,267	$2,680,000	$7,830,000
1943	Navy Bureau of Aeronautics	$104,600	2,820,000	$7,650,000
	Private Sources	$217,190	10,401,410	38,626,600
	Military	$229,867	7,750,000	21,440,000
	Total	$447,057	18,151,410	60,066,600

Robert Goddard in his workshop in Roswell, NM (1935)

MacDonald, Alexander, "The Long Space Age: An Economic Perspective on the History of American Space Exploration" Doctoral Dissertation, University of Oxford, 2013

Origins of the American Space Economy

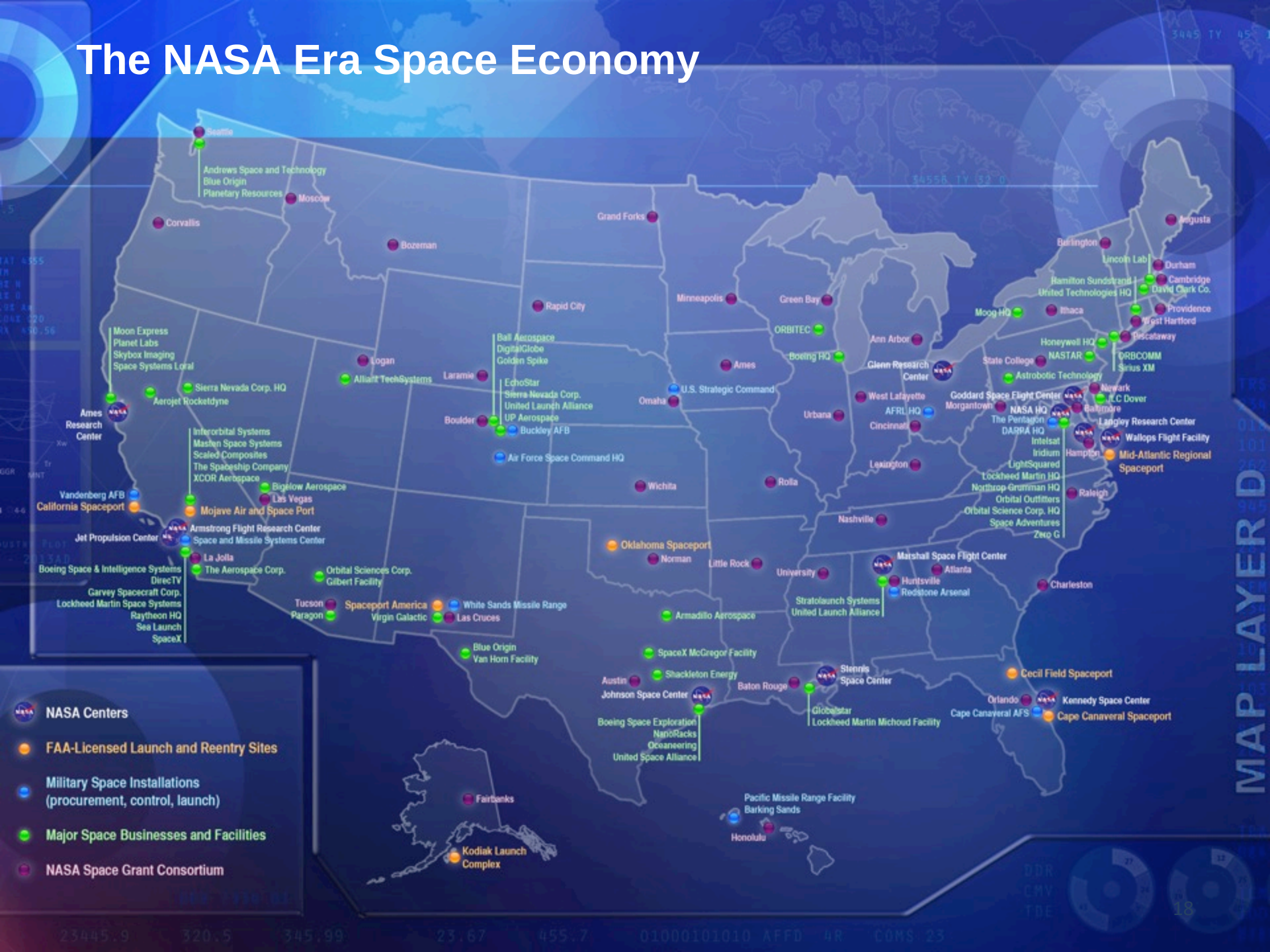


The NASA-Era Space Economy

- The U.S. space economy grew substantially following the establishment of NASA
- NASA played an integral role in the development of satellite communications, remote sensing, digital flight controls, integrated circuits, and inertial navigation
- The U.S. space industry now employs about 240,000 people across thousands of companies
- Over the decades, NASA has transformed the pursuit of spaceflight from the private domain of a few to a national endeavor, creating a vibrant space industry in the process

The formation of NASA as a federal agency expanded spaceflight activities to the whole of the nation

The NASA Era Space Economy



Private Investors and Entrepreneurs

- Participation by individuals is characteristic of how space exploration began in the U.S.
  - Private capital contributed to the construction of most observatories during the 19th century and many early rockets in the 20th century
  - Established in 1958, NASA becomes a catalyst for an enormous boost in space capabilities, forming an impressive space industrial base
  - In the 21st century, emerging space companies are being established by proven business professionals, often with contributions from philanthropists and angel investors
- Adjusted for inflation, these investments have been similar in scale
  - Lick Observatory (1876) and Mount Palomar (1928) cost about $1B each in 2010 dollars, equivalent to NASA's New Horizons ($670M), MESSENGER ($420M), and Mars Exploration Rover ($850M) missions

Entrepreneurs and philanthropists, past and present, have played a critical role in advancing and investing in our nation's space exploration capabilities

Emerging Space Companies

- Today, emerging space companies aim to provide human spaceflight and space habitation services, once the domain of governments only
- Emerging space companies see the provision of services not as singular accomplishments, but as investment in a sustainable space economy
  - Requires new capabilities enabled by new technologies
  - But also existing capabilities, like lower-cost space access, something enabled by NASA through its commercial crew and cargo program
  - Planetary Resources raised over $1M to develop a space-based telescope using crowdfunding
- Other companies seek to provide more efficient space-based services or higher fidelity, rapidly disseminated data to users
  - Planet Labs raised $52M in capital for development of a constellation of remote sensing microsatellites
  - Skybox Imaging raised $90M to develop a series of small remote sensing satellites

Re-emergence of private investment during the 21st century, coupled with ongoing NASA investment, combines for a promising future in space exploration

List of Emerging Space Companies, Grouped by Destination

	Company	Vehicle(s) or Spacecraft	Services
Space Access	Blue Origin	New Shepard, Biconic Spacecraft	Suborbital and orbital launch
	Masten Space Systems	Xaero, Xogdor	Suborbital and orbital launch
	Virgin Galactic	SpaceShipTwo, LauncherOne	Suborbital and orbital launch
	XCOR Aerospace	Lynx	Suborbital and orbital launch
	Orbital Sciences Corp.	Pegasus, Minotaur-C. Antares, Cygnus	Orbital launch, cargo transport
	SpaceX	Falcon 9, Falcon Heavy, Dragon	Orbital launch, cargo and crew transport
	Stratolaunch Systems	Stratolauncher	Orbital launch
Remote Sensing	Planet Labs	Flock	Remote sensing
	Skybox Imaging	Skysat	Remote sensing
LEO Human Spaceflight	Bigelow Aerospace	BA 330	Modular orbital and planetary habitats
	Boeing	CST-100	Crew transport
	Sierra Nevada Corp.	Dream Chaser	Crew transport
	Space Adventures	Soyuz	Crew transport
Beyond LEO	B612 Foundation	Sentinel	Hazardous asteroid detection
	Inspiration Mars Foundation	Inspiration Mars	Crewed Mars flyby
	Moon Express	Moon Express	Lunar prospecting
	Planetary Resources	Arkyd	Asteroid prospecting

Spacefaring Nation to Nation of Spacefarers

- Several emerging space companies are aiming to provide suborbital space access for anyone who can afford it, and the price is within reach of millions worldwide
  - Since 2001, 7 individuals paid tickets to orbit
  - By 2014, 850 reservations made by individuals for suborbital flights with Blue Origin, Virgin Galactic, and XCOR
  - If successful, these companies will launch more people into space within five years than have flown between 1961 and 2014 (~500 people)
- There is growing demand in the American public for access to space, and no single provider can address that demand
- Access to millions of potential customers for spaceflight means more opportunities for people to develop new ideas about how to use space, in turn establishing future emerging space capabilities

As more people learn more about space, and as new capabilities emerge enabling wider participation in space exploration and development, demand and enthusiasm for direct access to orbit and beyond will grow

Garage Inventors

- The earliest American spaceflight pioneers, like Robert Goddard and members of the American Rocket Society, were backed by private investment; their successes helped lay the foundation for what became the U.S. space industrial base
- The legacy continues today as hackers, makers, and hobbyists tinker with space technologies, improving and elaborating upon them
  - Some have helped found new rocket companies focused on affordable space access
  - Others have pursued satellite development, producing capabilities based on standardized cubesats to constellations of small satellites
  - Over 500 satellites with masses below 200 kg launched over the past decade, 30% of these launched in 2013, primarily cubesats

Once an area of research and development for a few, now space is becoming an area for many to actively participate and contribute to the nation's knowledge and industrial base

Citizen Scientists and Crowdfunding

- NASA's team extends well beyond the agency's professional cadre of employees and contractors
- NASA uses crowdsourcing, enabling large numbers of people to contribute services or ideas with an aim toward advancing the agency's mission. The benefits are mutual:
  - NASA receives much needed help to sort through huge volumes of data
  - Citizen scientists receive valuable education and experience, becoming the foundation for tomorrow's emerging space companies
- Crowdfunding has emerged as another means for citizens to engage space
  - Citizens can pool resources, usually via the Internet, to develop new technologies and capabilities
  - Crowdfunding offers space organizations alternative funding options beyond traditional institutional methods
  - About $1.9M raised for various space projects via Indiegogo, Kickstarter, and other venues
  - In May 2014, crowdfunding enabled reacquisition and control of NASA's International Sun-Earth Explorer-3 (ISEE-3), launched in 1978

Citizen Scientists

Project	Citizen Scientist Role	Participants
Be a Martian	Tag rover images and map craters from satellite pictures	1,230,000
HiTranslate	Help translate NASA's HiRISE project captions into different languages	1,021 new in 2012
International Space Apps Challenge	Develop mobile applications, software, hardware, data visualization, and platforms to address current challenges relevant to space exploration and social need	2,083 from 17 countries in 2012
Lunar Impacts	Indpendent observers can monitor the rates and sizes of large meteoroids striking the far side of the Moon	26 impact candidates
Rock Around the World	Help Mars scientists better understand the red planet by sending rocks to NASA for analysis	12,461 rocks received
Stardust at Home	Search for the first samples of solid matter from outside the solar system	30,649 from 2006 to 2012
Target Asteroids!	Observe asteroids, to help scientists refine orbits and determine the composition of near-Earth objects (NEOs) in support of the OSIRIS-Rex mission	104 registered users from 23 countries

More than 1.2 million people from 80 countries have participated in NASA's citizen science projects. This table captures just a few of them.

Crowdfunding

Year	Company	Description	Funding Goal	Funding Raised	Backers	Platform
2011	KickSat	Develop spacecraft the size of two postage stamps	$30,000	~$75,000	> 300	Kickstarter
2012	ArduSat	Launch the ArduSat (Arduino satellite) and allow the public to design and run space-based applications, games, and experiments and take pictures on demand	$35,000	$103,330	676	Kickstarter
2012	Uwingu	Help create “The Uwingu Fund” for space research and education	$75,000	~$80,000	> 800	Indiegogo
2012	STAR Systems	Develop a full-size rocket motor for the Hermes spacecraft	$20,000	$20,843	> 300	Kickstarter
2012	LiftPort Group	Space elevator research and demonstration	$8,000	> $110,000	3,468	Kickstarter
2012	Hyper-V	Demonstrate a prototype electric pulsed plasma jet thruster	$69,000	~$73,000	1,101	Kickstarter
2013	Aerospace Industries Association	Run a 30 second trailer about the space program before the new Star Trek movie	$33,000	> $50,000	> 1,600	Indiegogo
2013	Lunar Orbiter Image Recovery Project	Identify changes in the lunar surface over time using photos from NASA’s Lunar Orbiter program	$75,000	$62,585	549	Rockethub
2013	Planetary Resources	Development and launch of an asteroid-hunting telescope by 2015	$1M	$1.5M	17,614	Kickstarter
2014	Skycorp, Inc.	Regaining control of ISEE-3, which NASA launched in 1978	$125K	$160K	2,238	RocketHub

Thousands of people have directly contributed to developing space projects by donating funds.

Challenges and Prizes

- Garage inventors and small companies are often inspired by grand challenges and open competition
- The use of challenges and prizes to seek innovative technical solutions dates back to the 18th century. Examples:
  - Longitude Prize for improved ship navigation (1714)
  - Warner Prize for discovering comets (1881)
  - Orteig Prize for solo, non-stop trans-Atlantic flight (1919)
- NASA's Centennial Challenges
  - Drives progress in aerospace technology
  - Encourages participation in aerospace research and development
  - Finds the most innovative solutions to technical challenges
  - Funded at about $4M per year
  - $6M awarded to 16 teams since 2007
- Some prizes are not federally-funded, like those established by The X PRIZE Foundation
  - The Ansari X PRIZE led to the successful development of the world's first spacecraft using no government funds ($10M)
  - The Google Lunar X PRIZE seeks to put the Moon into focus, providing a means for small teams to find innovative and cost effective ways to land on the Moon ($30M)

Challenges and prizes provide incentives for innovation, a relatively low-cost investment that can yield high returns for the nation's space industry

Challenges and Prizes

CHALLENGE	CITIZEN INVENTOR ROLE	PARTICIPANTS	AWARDED $
Power Beaming	Practical demonstration of wireless power transmission.	10 teams	$900,000
Strong Tether	Materials engineering challenge to advance tether strength-to-weight ratio. Strong, ultra-light tethers.	7 teams	No winner
Lunar Lander	Building and flying a rocket-powered vehicle that simulated the flight of a vehicle on the moon.	11 teams	$2 million
Astronaut Glove	Improve glove design to reduce the effort to perform tasks in space and improve durability of the glove.	2 teams	$550,000
Regolith Excavation	Teams designed and built robotic machines to excavate simulated lunar soil (regolith).	34 teams	$750,000
Personal Air Vehicle	Improve personal aircraft in performance, noise reduction, handling, efficiency, short takeoff and top speed.	4 teams	$250,000
General Aviation Tech.	Demonstrate innovations that would lead to safer, more affordable, easier to fly and greener aircraft.	3 teams	$ 97,000
Green Flight	Create a efficient, quiet, safe aircraft that could average 100 mph at 200 passenger miles per gallon.	4 teams	$1.47 million
Sample Return Robot	Build an autonomous robot that can nagivate a natural landscape and collect samples in a timed event.	26 teams	$ 5,000 (open)
Unmanned Aircraft Sys.		7 teams	TBD (open)

Emerging States

- U.S. states have recognized the economic benefits of space activities within their borders
- Several have invested in space transportation infrastructure and passed legislation to attract space businesses
  - $80M from State of Virginia for development of Mid-Atlantic Regional Spaceport (co-located with NASA Wallops Flight Facility), which became fully operational in 2013
  - $31M by the State of Alaska for the Alaska Aerospace Corporation since 1991 for Kodiak Launch Complex, with additional $150M from the federal government
  - $20M budget authorized by State of Florida for spaceport infrastructure
  - $15M in approved funds from the Midland Development Corp. (Texas) for relocation and establishment of a California-based space suit company
  - $1.3M in appropriated funds from the State of Hawaii for lunar robotic systems and analog site development through the state-run Pacific International Space Center for Exploration Systems (PISCES)
  - CO, FL, NM, TX, and VA passed legislation to limit liability to certain space businesses

States have recognized the economic benefits of space and have become involved at the state level

Emerging States

Emerging Space in 2044

- The president has directed that by the mid-2030s, NASA's human exploration wavefront will have reached Mars, with an asteroid mission along the way
- The ISS will remain operational at least through 2024
- These factors, and many others, are helping to create a fertile environment for a sustainable space industry, one in which new capabilities and companies will continually emerge

NASA and private industry will together expand the American economic sphere into the solar system

Emerging Space in 2044

"Mars has been the greatest challenge of American space exploration of the age. The American private-sector has mustered significant expenditure and investment in order to advance the date of this achievement through partnership with NASA and enable long-term habitation following NASA's initial missions." – *New York Daily Mail, June 15, 2044*

"The ISS served as a stepping stone to the establishment of new commercial stations. Space traffic management and active debris removal and mitigation were introduced to address the greater amount of orbital activity. Propellant depots and spacecraft servicing systems were also built, located in GEO and Lagrangian Libration Points to provide support for the growing interplanetary transportation system. Some of these facilities were established by governments as independent public authorities, authorized to raise funds and issue their own bonds, as do some seaports on Earth. These serve as gateways to points beyond." – *Economy Today, May 1, 2044*

"NASA's near-earth asteroid explorations begun in the late 2010s paved the way for regular government and private-sector activity involving near-earth asteroids. With the support of NASA partnerships, companies started extracting water ice, metals and rock from several NEAs identified as viable candidates for mining." – *London Herald, April 27, 2044*

"The Moon has become a primary destination for exploration and technology development, particularly for the development of robotic planetary surface systems. Prospecting, extraction, and processing of lunar volatiles and metals have begun scaling to support activities on the Moon and other locations. The costs of working on the Moon have fallen due to investment in space transportation infrastructure and local production. Exploration of the Moon are supplemented by privately financed expeditions with NASA partnerships." – *Washington Daily, February 8, 2044*

Exploring Space Forever

- Fifty years after the creation of NASA, the long-term goal is no longer about reaching a destination
- The long-term goal has become the creation of capabilities that will lead to a sustainable path for exploration and economic development in outer space
- NASA will play an integral role, as it has in the past, of leading the wavefront of exploration, pioneering the planets, and enabling private industry and American citizens to live, work, and play in space

Exploring Space Forever