AST Commercial Space Transportation

Commercial Space Transportation State of the Industry UNOOSA ICAO Symposium August 2017

Federal Aviation Administration

Highlights

- U.S. Regulatory Approach
- International Perspective
- Economics of Commercial Space Transportation
- Research and Development
- Air and Space Traffic Management
- Collaborations

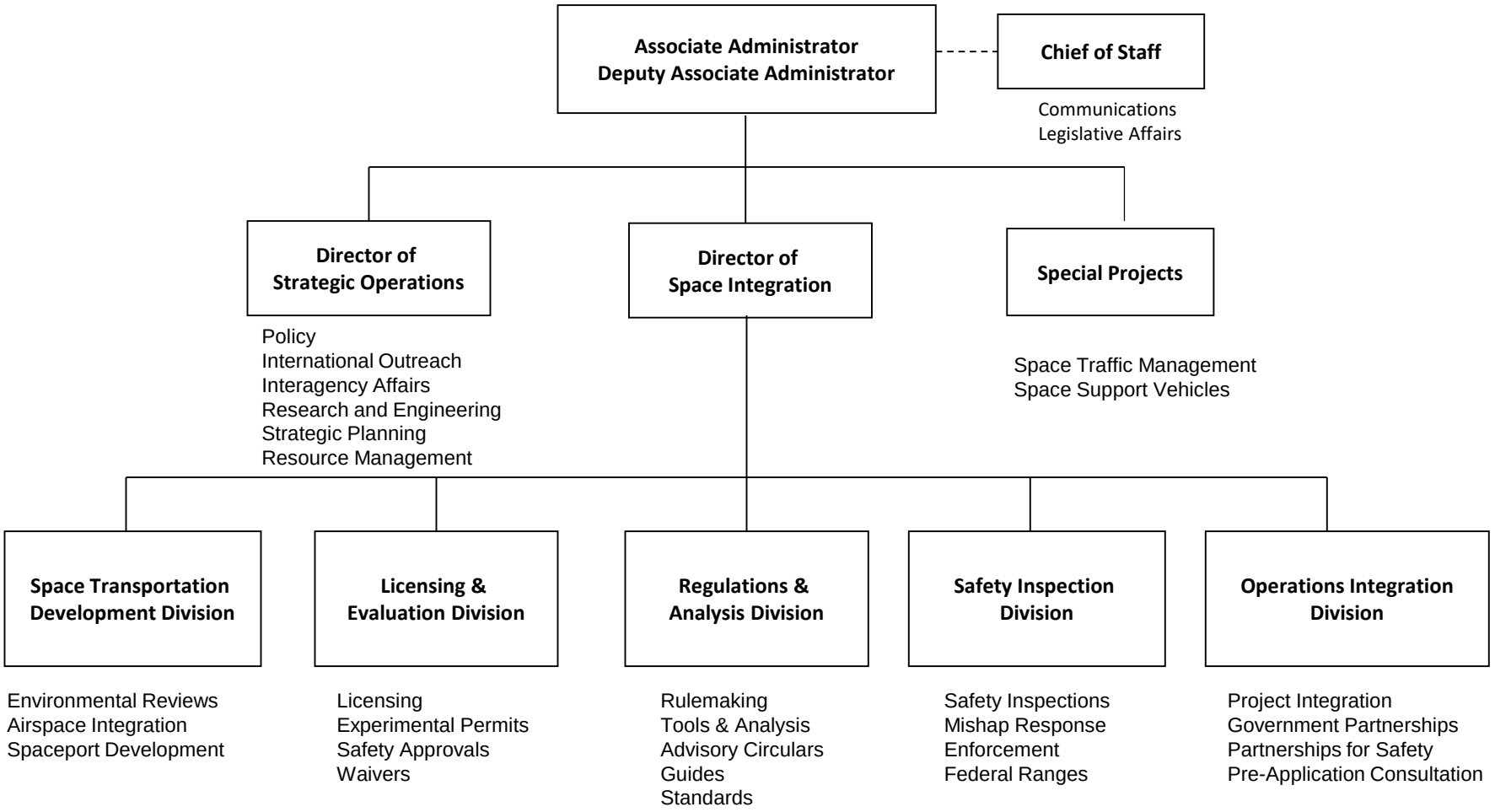
Department of Transportation, Federal Aviation Administration- Statutory Authority

51 U. S. C. Chapter 509 (formerly the Commercial Space Launch Act of 1984, as amended)

- Authorizes the FAA* to license commercial launch and reentry activities and the operation of launch and reentry sites as carried out by U.S. citizens or within the United States.
- Directs the FAA to:
  - Exercise this responsibility consistent with ***public*** health and **safety**, safety of property, and the national security and foreign policy interests of the United States, and
  - **Encourage, facilitate, and promote** commercial space launches and reentries by the private sector.

* The Secretary of Transportation's licensing authority has been delegated to the Administrator of the FAA and further assigned to the Associate Administrator for Commercial Space Transportation (AST)

AST Organization



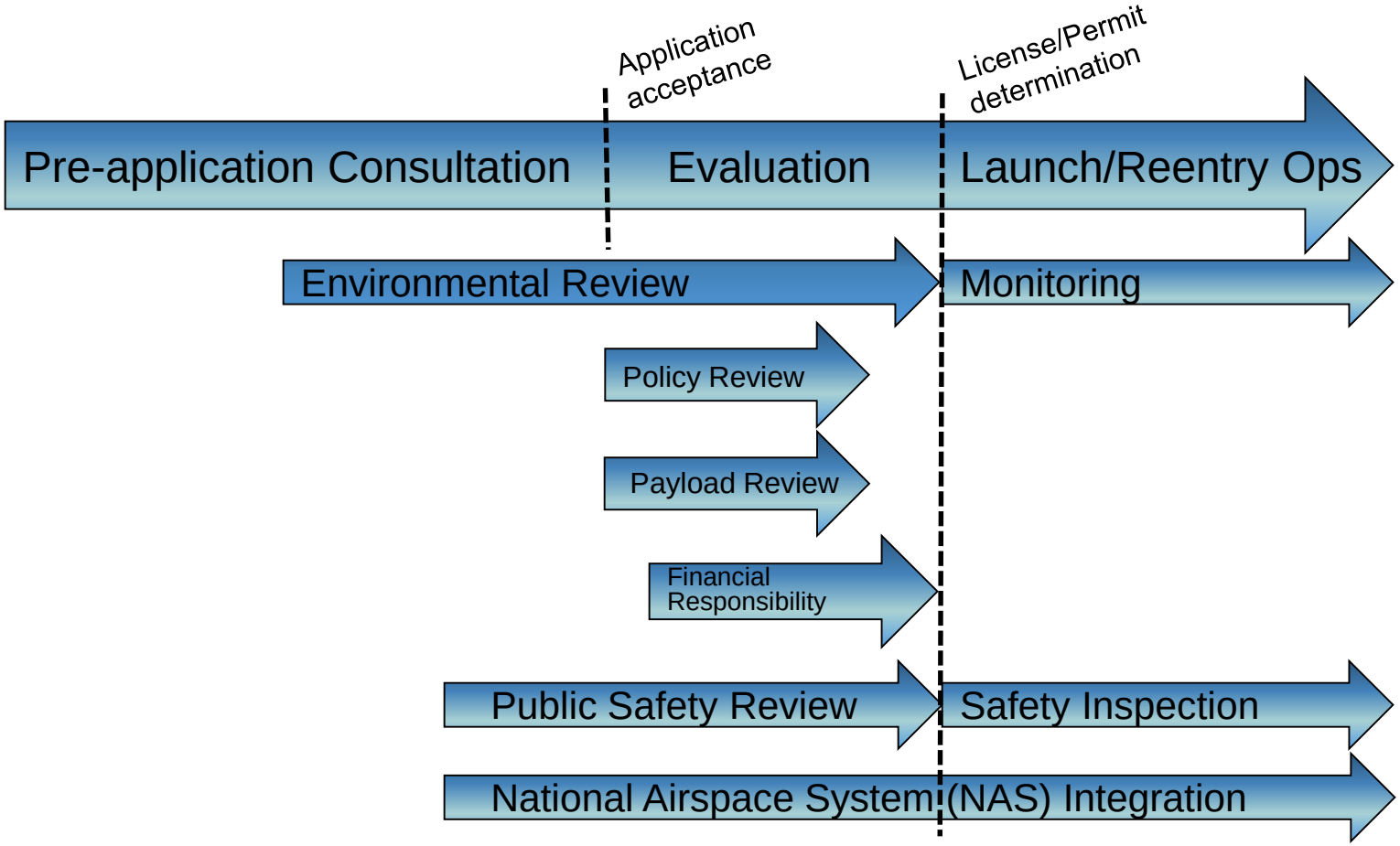
Who Must Obtain A License

- An entity must obtain a license:
  - To ***launch*** a launch vehicle from the United States;
  - To ***operate*** a launch site within the United States;
  - To ***reenter*** a reentry vehicle in the United States; or
  - To ***operate a reentry site*** within the United States.

- A U.S. citizen or an entity organized under the laws of the United States or any State must obtain a license:
  - To launch a launch vehicle *outside* the United States;
  - To operate a launch site *outside* of the United States;
  - To reenter a reentry vehicle *outside* of the United States; or
  - To operate a reentry site *outside* of the United States.

- FAA does <u>not</u> license launches or reentries "the Government carries out for the Government"
  - NASA and the Department of Defense typically carry out their own launches.

FAA License Process Overview

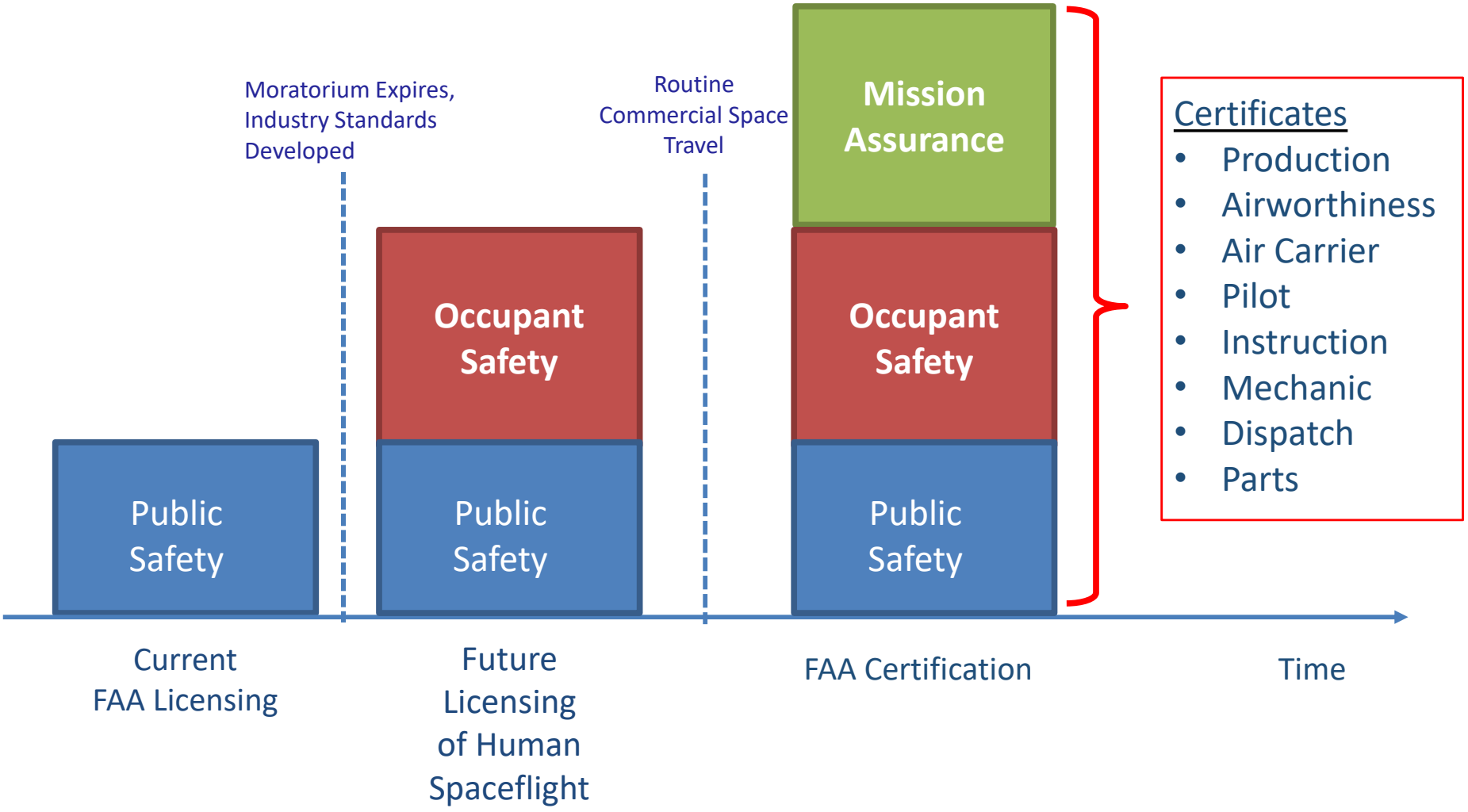


FAA has 180 days to respond to a "complete enough" application for a license, 120 days for a permit

Limits in Regulatory Authority

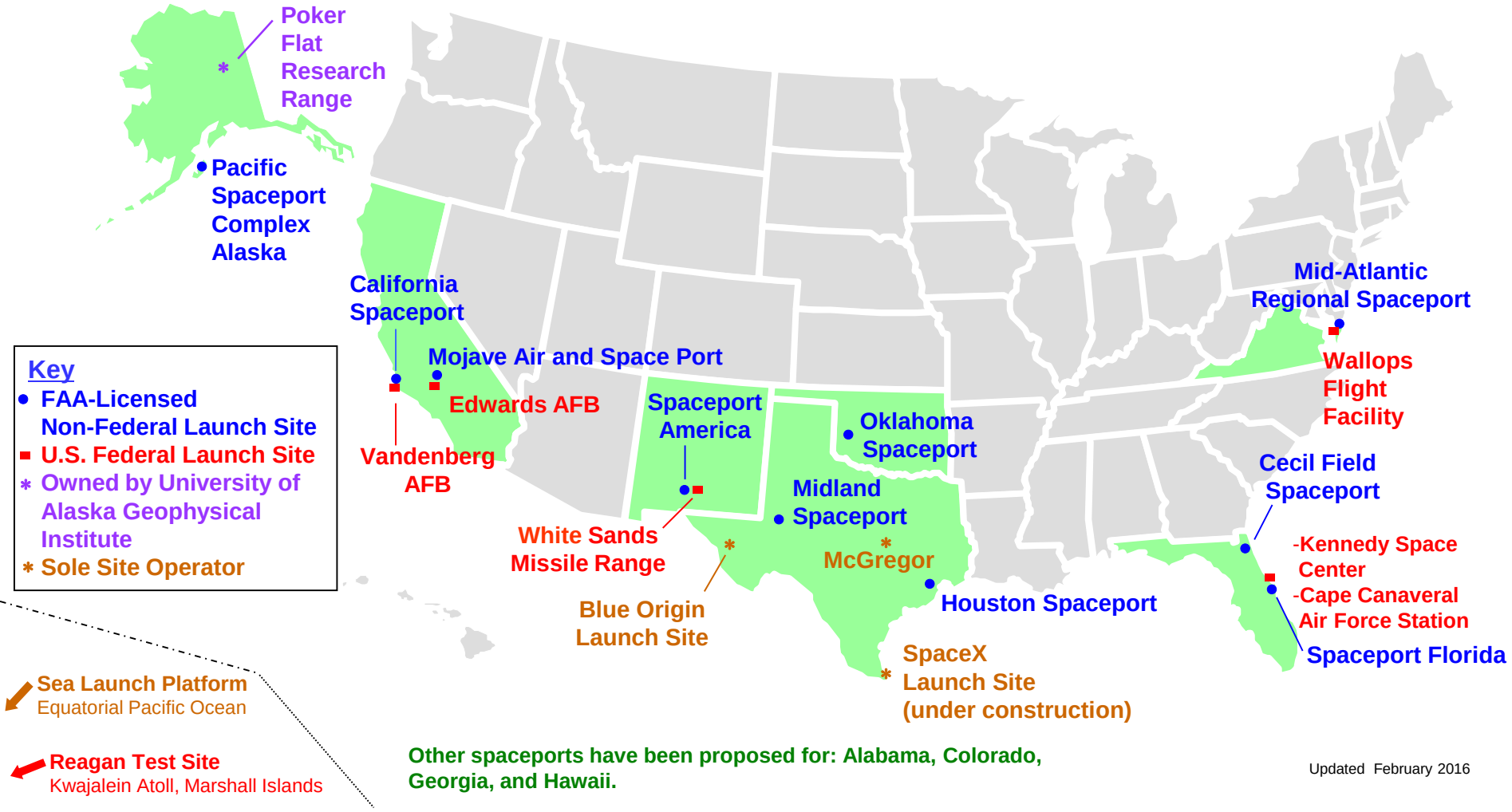
- The U.S. Congress has only incrementally expanded DOT/FAA authority over commercial space transportation
  - 1984 included launch authority
  - 1998 added reentry authority
- U.S. law contains limitations on FAA authority:
  - The FAA can only regulate "to the extent necessary"
    - The FAA does not certify space launch vehicles; it licenses the launch operation
      - Mission success is the responsibility of the commercial launch operator
- Included in the 2004 Commercial Space Launch Amendments Act (CSLAA): "…the regulatory standards governing human space flight must evolve as the industry matures so that regulations neither stifle technology development nor expose crew or space flight participants to avoidable risks as the public comes to expect greater safety for crew and space flight participants from the industry."
- Thus, FAA cannot protect people onboard space vehicles
  - Congress extended industry "Learning Period" to September 30, 2023
    - No new regulations related to human safety can be introduced
  - Informed Consent regime

Potential Regulatory Path



U.S. Spaceports

Commercial/Government/Private Active and Proposed Launch Sites



Other spaceports have been proposed for: Alabama, Colorado, Georgia, and Hawaii.

Updated February 2016

International Commercial Launch Activity

- Independent orbital launch capability

  Russia, United States, Europe, Japan, China, India, Israel, Iran, South Korea, North Korea

- Competing in the commercial market

  Russia, United States, Europe, Japan, China, and India

- Reusable launch vehicles in development (both suborbital and orbital)

  United States (Virgin Galactic, Blue Origin), Europe (Airbus), United Kingdom, Spain, others

- Small Satellite market is driving small launch vehicle development

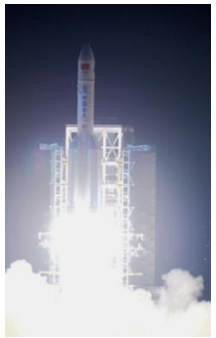
  Of 22 new global small launch orbital vehicles in development, 17 originate with U.S. companies (Source: Niederstrasser, Frick AIAA Utah paper 2015)

- Several countries in various stages of considering/developing new legislation and/or national frameworks for commercial suborbital launch (human space flight), orbital launch, and launch sites
  - *UK, Curacao, Japan, UAE, New Zealand, Sweden, Spain, France*

Rocket Lab USA's Electron. First launch attempt, May 25, 2017 in New Zealand.

Virgin Galactic's SpaceShipTwo with WhiteKnightTwo. Powered tests in 2017.

Europe's Ariane 6.
First launch scheduled in 2020



Long March 5. First launch from China was in November 2016. 14,000 kg to GTO.

FAA/AST International Goals

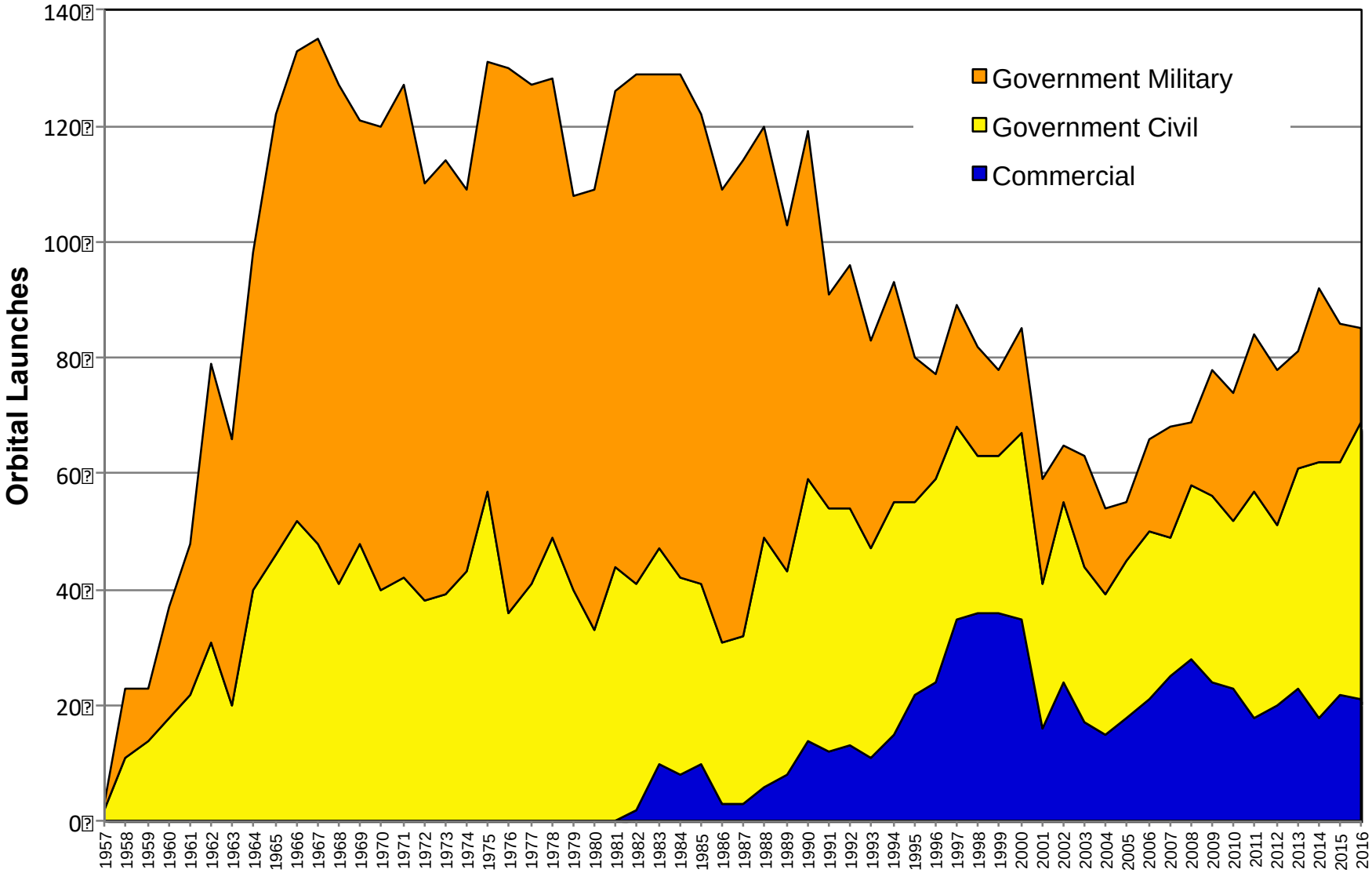
- The 2013 National Space Transportation Policy directs the Secretary of Transportation and other appropriate agencies to:

  "Advocate internationally for the adoption of United States Government safety regulations, standards, and licensing measures to enhance global interoperability and safety of international commercial space transportation activities."

- The FAA is promoting its commercial space transportation regulations for adoption by other countries—the goals of AST's outreach are to:

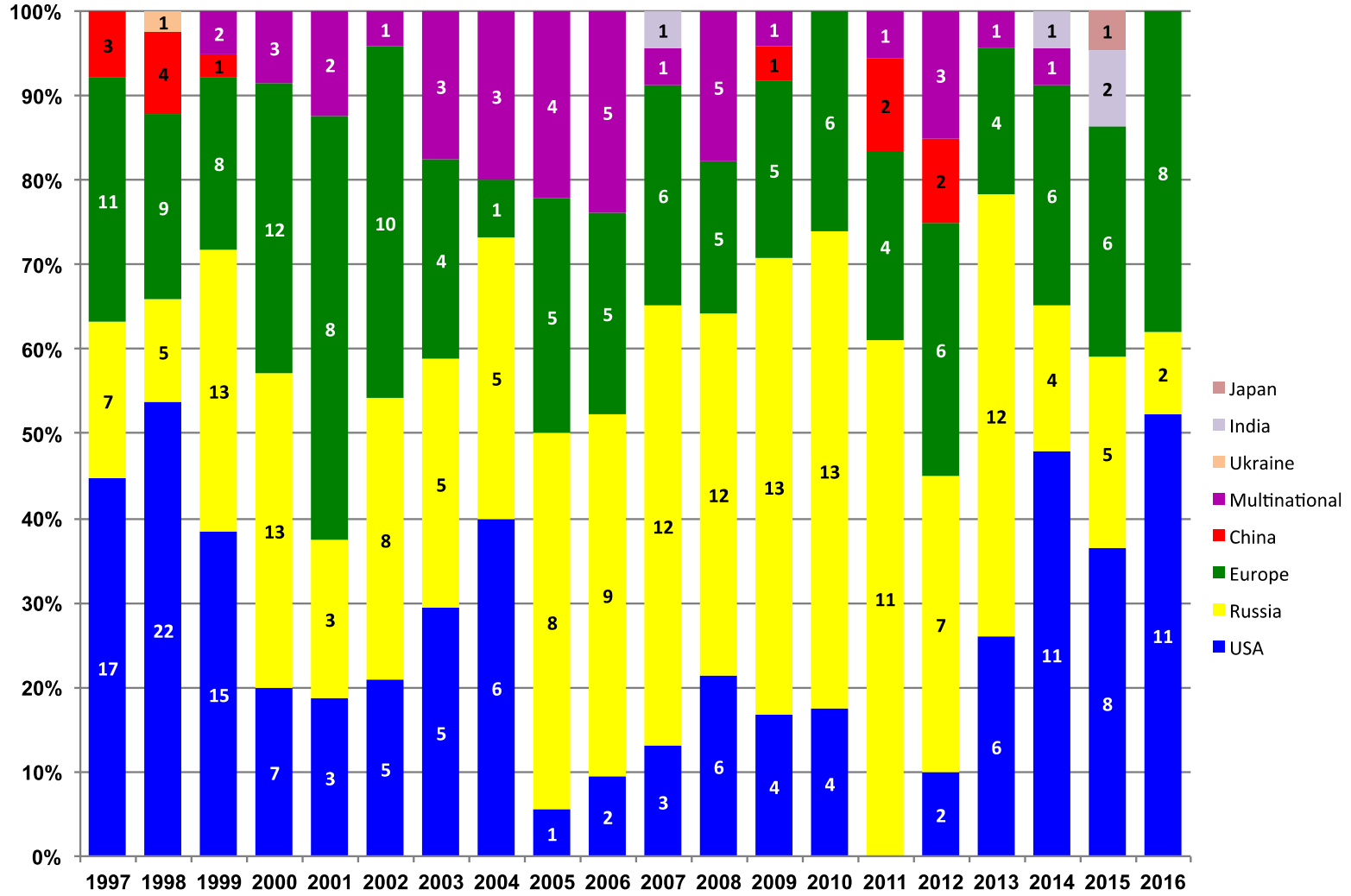
  1. **Provide international leadership and assistance;**
  2. **Support U.S. industry activities;**
  3. **Establish international relationships; and**
  4. **Prepare for future interoperability between countries**

Worldwide Orbital Launch Events, 1957 - 2016



Source: FAA January 2017

Commercial Orbital Launches by Market Share, 1997 - 2016

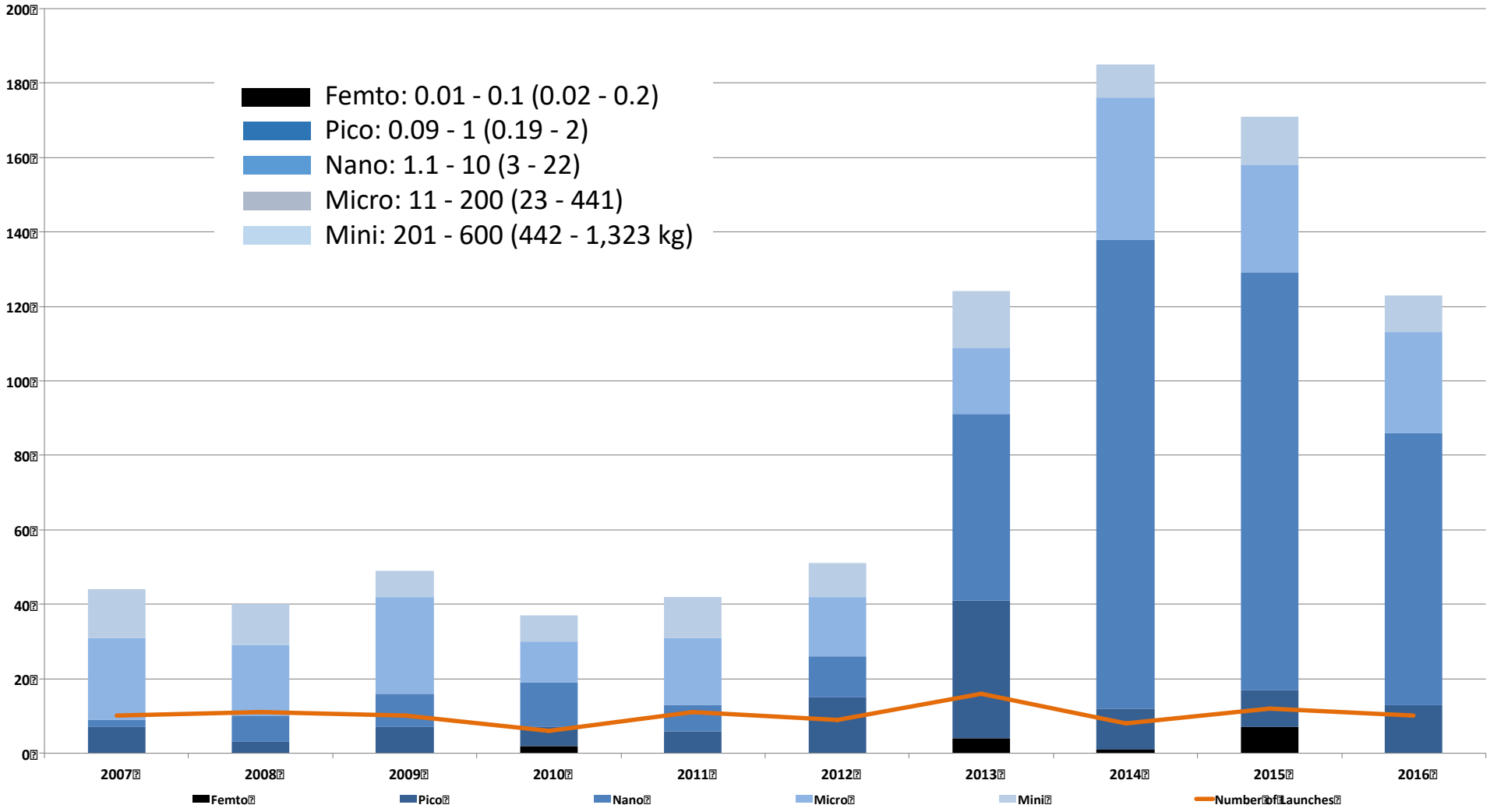


Includes Geosynchronous Orbit and Non-geosynchronous orbits launches that are internationally competed, commercially sponsored, or FAA-licensed. Since 1989, DOT/FAA has licensed 50 launches of U.S. Government payloads

U.S. total includes U.S.-manufactured vehicles only. Multinational denotes Sea Launch.

Source: FAA January 2017

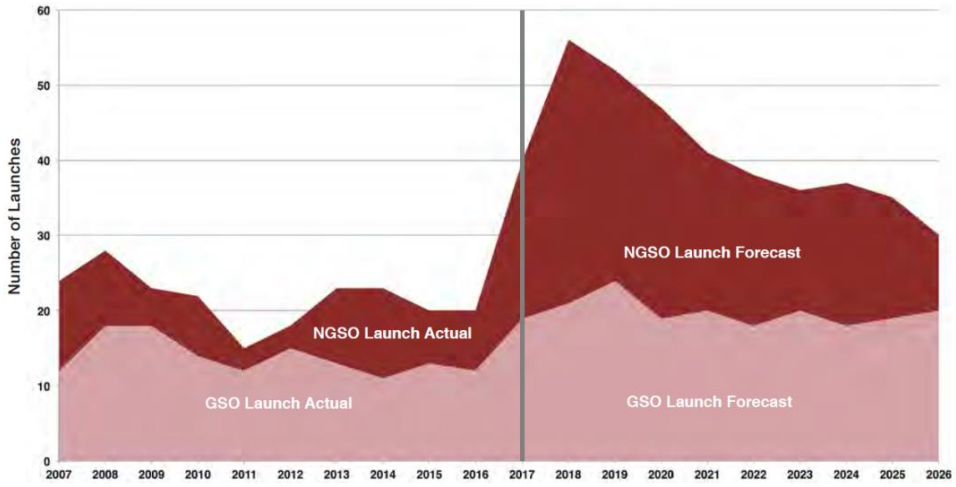
Small Satellites Launched (2007-2016)



Source: FAA July 2017

2017-2026 International Orbital Commercial Launch Demand Forecast

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	Total	Avg.
Payloads												
GSO Forecast (COMSTAC)	25	25	26	21	22	22	22	22	22	22	229	22.9
NGSO Forecast (FAA)	242	300	300	244	256	249	206	252	206	135	2,390	239.0
Total Payloads	***267***	***325***	***326***	***265***	***278***	***271***	***228***	***274***	***228***	***157***	***2,619***	***261.9***
Launches												
GSO Medium-to-Heavy	19	21	24	19	20	18	20	18	19	20	198	19.8
NGSO Medium-to-Heavy	16	25	15	17	16	16	11	15	11	9	151	15.1
NGSO Small	5	10	13	11	5	4	5	4	5	1	63	6.3
Total Launches	***40***	***56***	***52***	***47***	***41***	***38***	***36***	***37***	***35***	***30***	***412***	***41.2***



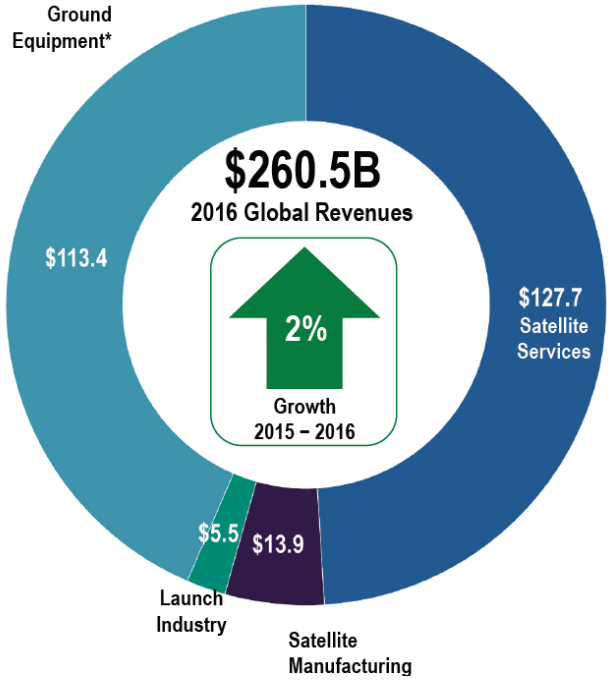
The 2017 forecast shows an increase to 41 launches per year compared to 30 (16 GSO, 14 NGSO) in the 2015 forecast.
GSO market is stable with increase in + 5,400kg satellites.
NGSO increase in satellite demand for telecom, ISS resupply, and small remote sensing satellites. Small launch demand was only 1.4 per year in 2015 forecast compared to 6.3 in 2017.

COMSTAC- Commercial Space Transportation Advisory Committee
GSO- Geosynchronous Orbit
NGSO- Nongeosynchronous Orbits
Medium-to-Heavy vehicles - more than 2,268 kg (5,000) to 28.5^0 incl.
Small vehicles - less than 2,268 kilograms (5,000 pounds) to 28.5^0 incl.

Source: FAA Compendium, January 2017
Prepared by COMSTAC and FAA

Revenue

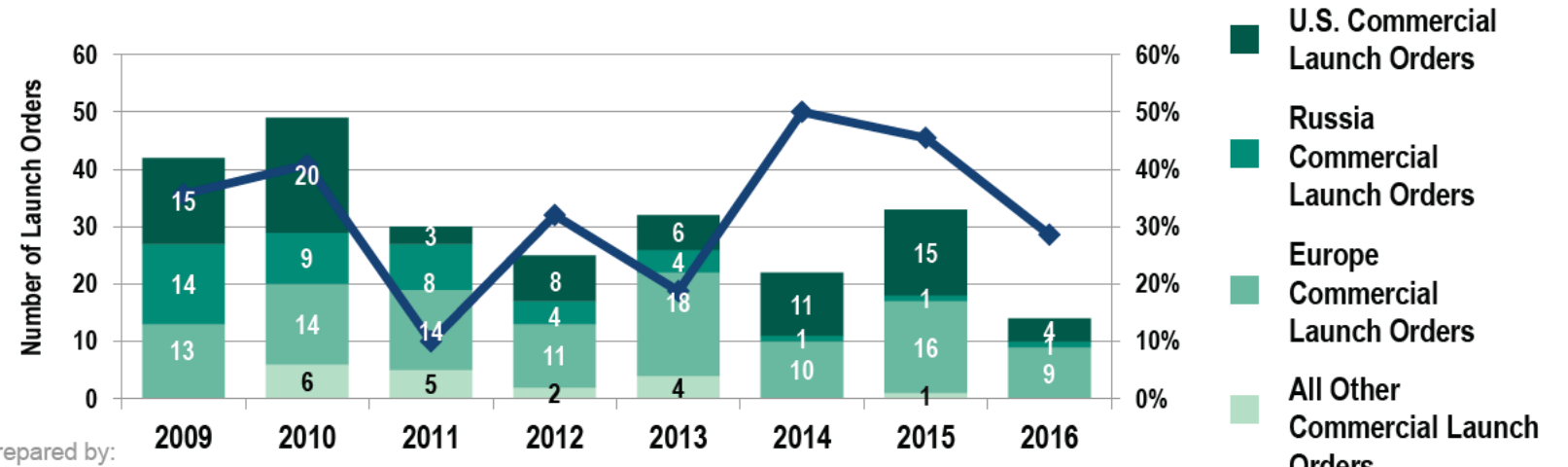
- Revenue from global space activity was about $**260 billion in 2016.**
- If you want to make money in space, *think Satellite Services*
  - Delivering direct to home television via satellite totaled $97.7 billion in revenue.
- U.S. Share of Global Revenue
  - Satellite Services 40% U.S.
  - Ground Equipment 42% U.S.
  - Launch 40% U.S. ($2.2 billion)
  - Satellite Manufacturing 64% U.S.
  - 74% of U.S. revenue is from government contra
  - The U.S. won 59% of new GEO commercial satellite orders in 2016, Europe 29%



Source: Satellite Industry Association, July 2017

Orders for Commercial Launches

- 14 commercial satellite launch orders placed in 2016, down from 33 in 2015
- 4 (29%) satellite launch orders won by U.S. companies, down significantly from 15 (45%) in 2015
- U.S. market dropped from 45% in 2015 to 29%
  - Typical year for Arianespace, though not as robust as previous years
  - Inmarsat and ViaSat shift satellites from SpaceX to Arianespace
- Note: 11 orders for government payloads not counted here



Prepared by:

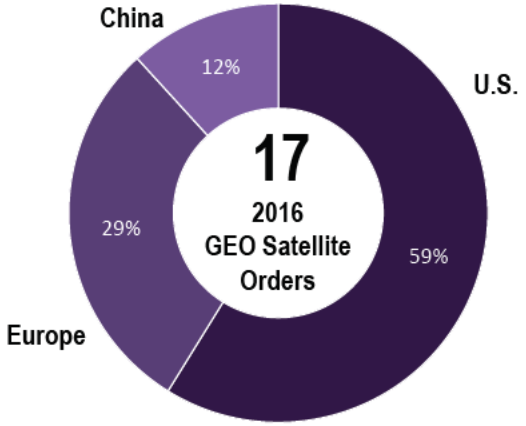
BRYCE
Formerly Tauri Group Space and Technology

NOTE: A single launch contract may cover the launch of more than one satellite (each described as an "order").

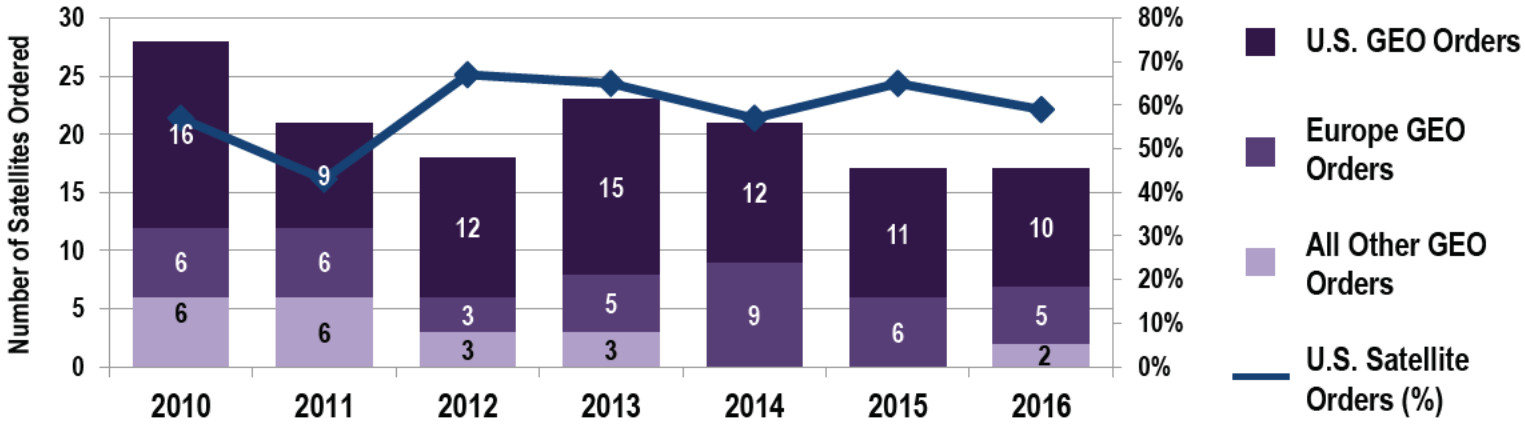
26

Source: Satellite Industry Association, July 2017

Orders for GEO Commercial Satellites



- Orders for 17 commercial GEO satellites announced in 2016
- 10 orders won by U.S. manufacturers
- 59% share of orders won by U.S. firms, down from 65% in 2015



Source: Satellite Industry Association, July 2017

Investment in New Markets

- Private investment in commercial space overall has increased
  - Study found that more venture capital was invested in space in 2015 ($1.8 billion) than the prior 15 years combined.
    - Over 250 investors in global start-up companies were identified in the study– 66% are located in the United States
  - Cumulative investment (including debt financing) in start-up space ventures (both satellite and launch companies) from 2000-2015 totaled $13.3 billion.

(Source: “Start-Up Space” Tauri Group, 2016)

New Markets: Vehicles

A combination of innovative entrepreneurs, private investment, flexible government policy (buying services and/or co-investment), and safety regulations have put the U.S. in a good position to capture new international markets

1) NASA co-investment has enabled U.S. companies to develop International Space Station resupply vehicles and commercial crew vehicles

- Allows industry to use same vehicles for commercial markets like satellites, LEO space stations, Moon resource mining/exploration, deep space, Mars, of future NASA exploration (cargo beyond LEO)

2) Suborbital reusable launch vehicles for space tourism with private funding

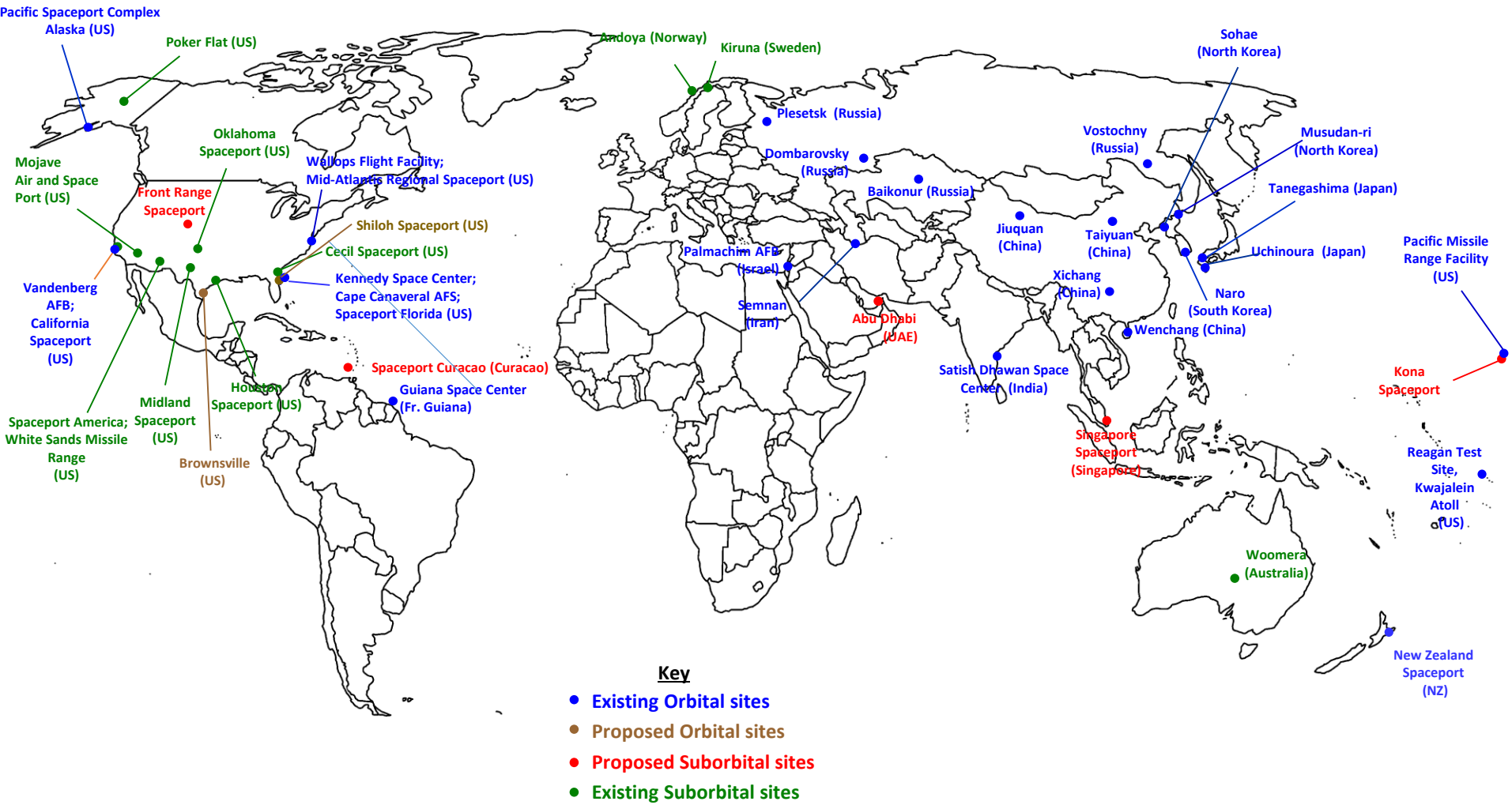
- Virgin Galactic's SpaceShipTwo, Blue Origin's New Shepard
- European companies (ie Airbus) have also proposed new RLVs

3) Small launch vehicles to compete for increased demand to launch small satellites

- Rocket Lab USA's Electron (with New Zealand), Virgin Galactic's LauncherOne, Firefly's Alpha, others
- Of 22 new global small launch vehicles in development, 17 originate with U.S. companies (Source: Niederstrasser, Frick AIAA paper 2015)

4) Earth orbit and beyond low Earth orbit missions – asteroid mining, Moon surface resources, orbital satellite servicing, Mars exploration.

Existing and Proposed Global Launch Sites



Source: FAA June 2017

FAA Research in Commercial Space Transportation

1. Space Traffic Management & Spaceport Operations
   - 1.1 Air/Space Traffic Management
   - 1.2 Space Situational Awareness
   - 1.3 Spaceport Operations
2. Space Transportation Vehicles
   - 2.1 Ground System & Operations Safety Technologies
   - 2.2 Vehicle Safety Analysis
   - 2.3 Vehicle Safety Systems & Technologies
   - 2.4 Payload Safety
   - 2.5 Vehicle Operations Safety
3. Human Spaceflight
   - 3.1 Aerospace Physiology & Medicine
   - 3.2 Personnel Training
   - 3.3 ECLSS
   - 3.4 Habitability & Human Factors
   - 3.5 Human Rating
4. Industry Viability
   - 4.1 Market
   - 4.2 Policy
   - 4.3 Law
   - 4.4 Regulation
   - 4.5 Cross-Cutting Topics

- FAA Center of Excellence with U.S. universities in four areas: STM & Spaceports, Human Spaceflight, Vehicles and Industry Viability
- Other AST Research, Engineering, & Development projects and FAA Technical Center

Air and Space Traffic

Current Approach: Accommodation

- Generally, the FAA protects aircraft against potential hazards posed by launch and reentry vehicles using preemptive airspace closures (i.e., segregated airspace)
- Relatively large, static volumes of airspace (i.e., aircraft hazard areas) are closed in advance of a launch, reentry, or amateur rocket operation to protect air traffic from hazards of vehicle failures, including falling debris

Future Approach: Integration

- Launch and reentry vehicles and aircraft will share airspace
- Air traffic management will focus on preventing collisions between vehicles and aircraft (i.e. separation) rather than collisions between aircraft and falling debris (i.e. segregation)

Space Data Integrator

- Prototype tool to enable real-time monitoring of space launch/reentry vehicle transitions through the National Airspace (NAS).

Orbital Space Traffic Management

- US DoD historically collects and shares space situational awareness information
- Evolving Philosophy
  - A civilian agency focuses on civil and commercial aspects
  - US military focuses on national security and defense aspects
- FAA identified STM concept of operations as a 2017 priority
- FAA/AST is working with US DoD to develop a pilot program

Government and Industry Partnerships

- Space Learning Group
- COMSTAC
- Aviation Rulemaking Committees
  - Airspace Integration
  - Spaceport Categorization
- Center of Excellence for Commercial Space
- Innovation Initiative

Summary

- Commercial space transportation is an innovative global industry
- Public and private sectors are working together in new ways
- States can learn from each other and help each other

BACKUP

Virgin Group

- Virgin Galactic's SpaceShipTwo –suborbital vehicle for space flight participants
  - 4 drop tests as of May 2017, powered tests scheduled in 2017
  - Around 700 tickets sold as of early 2017. Ticket price raised to $300,000 in 2016.
- Virgin Orbit's Launcher One – orbital vehicle for small satellites
  - Could be test-launched by the end of 2017
  - Price goal of less than $10 million per launch, up to 500 kg payload to Low Earth Orbit

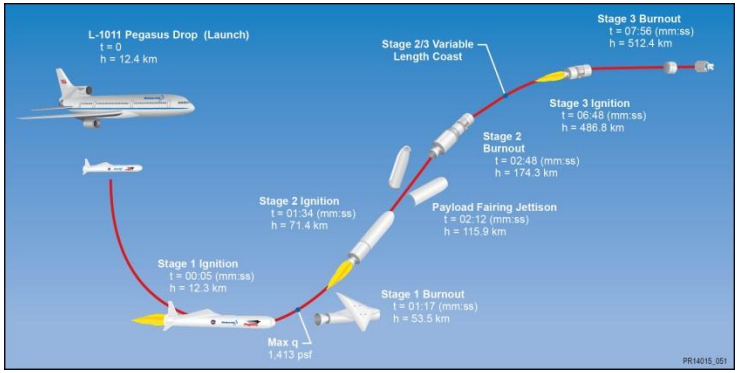
SpaceShipTwo (VSS Unity), unpowered glide test May 1, 2017.
Carries 6 space flight participants, operations in 2018?
Air-launched at 50,000 feet (15km) to altitude of 100km
from White Knight II aircraft.

LauncherOne (concept art). Two-stage, LOX-kerosene rocket,
air-launched from a 747-400 at 35,000 feet (9km).

Orbital ATK

- A variety of suborbital and orbital vehicles from Orbital ATK are available
- Pegasus XL has done over 40 launches since 1990
  - 1,000 pounds (450 kg) payload to low Earth orbit
  - Launches from the U.S., Marshall Islands, and Spain

Vehicles for orbital space launch

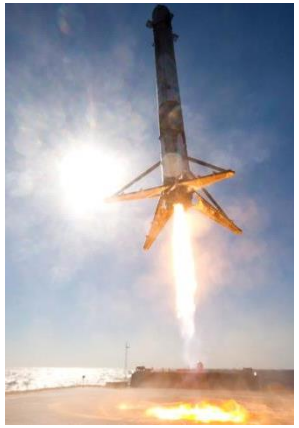


Pegasus XL launch profile

SpaceX

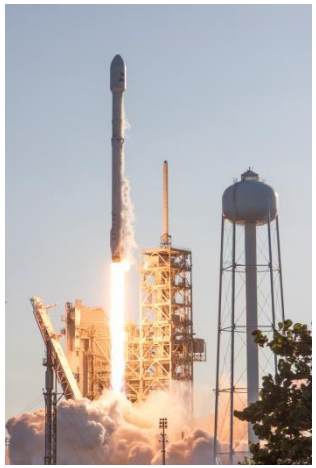
- SpaceX has revitalized U.S. market share in global commercial launch services
  - Over 35 launch orders on SpaceX manifest, more than half for commercial customers
  - 7 launches in 2016, 10 launches so far in 2017 (January-July)
  - Of 21 commercial launches worldwide in 2016: 50% US, 40% Europe, 10% Russia
  - New Falcon Heavy vehicle scheduled in 2017
- Autonomous Flight Termination System – first U.S. launch was Falcon 9 (February 19, 2017)
- First commercial crew flight for NASA scheduled for mid-2018
- Developing a constellation of 800 satellites for broadband communications
- Proposed mission around Moon in 2018 with people, unmanned "Red Dragon" to Mars, and future people to Mars

Falcon 9 liftoff April 8, 2016
(CRS-8 to ISS) Cape Canaveral

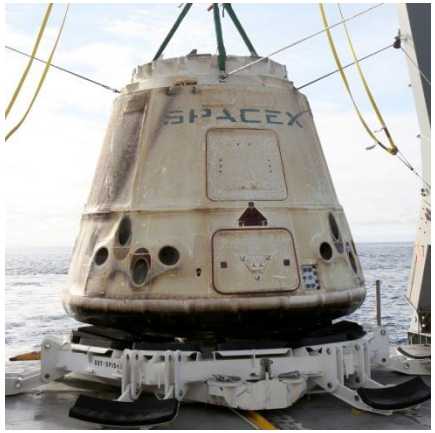


First stage barge landing
April 8, 2016

Refurbishing a first stage
from Falcon 9
[*photo from Jan 2016]*

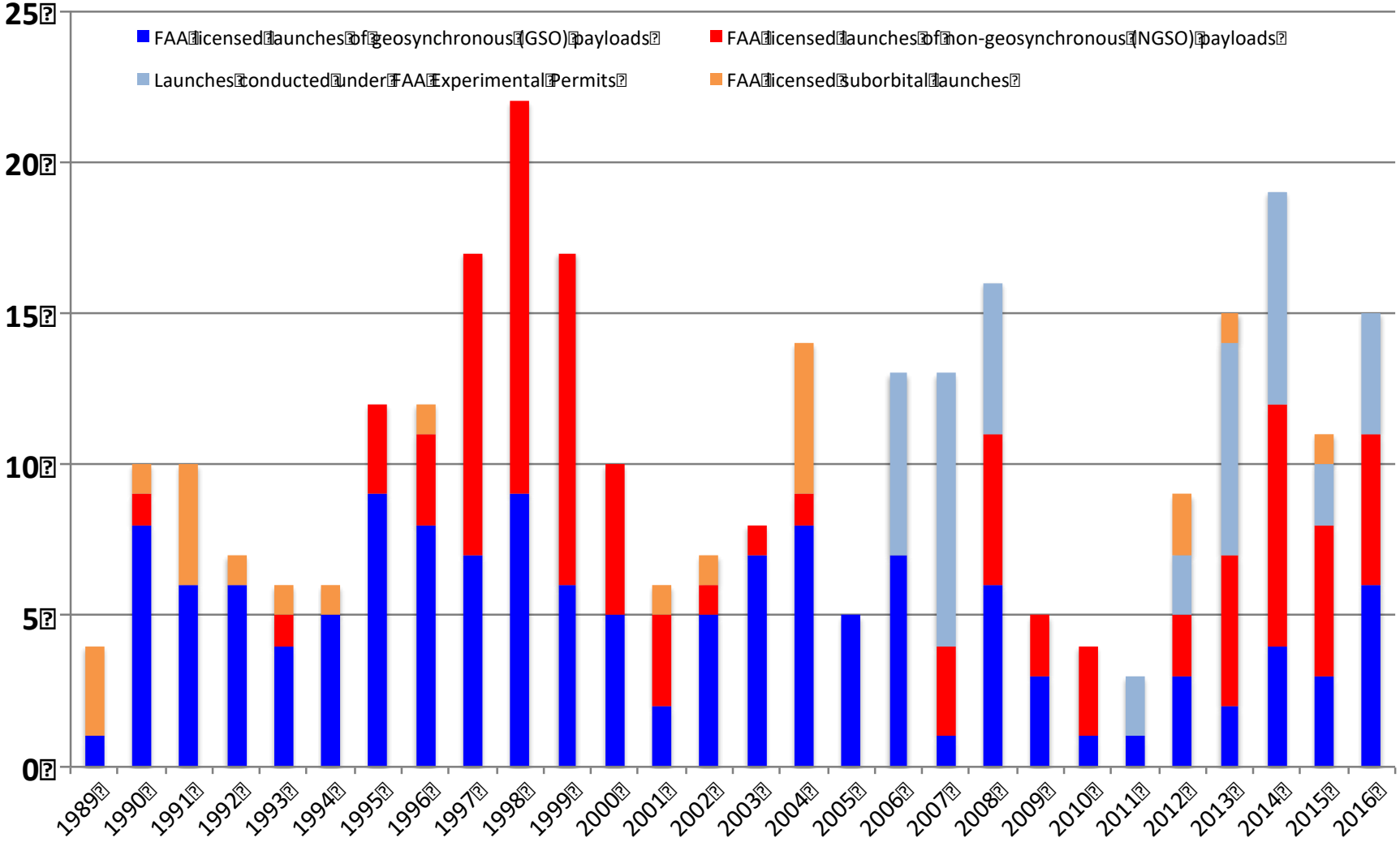


Falcon 9 launch of SES 10 satellite,
March 30, 2017 [32nd launch of F9]



Dragon capsule after reentry,
CRS-10 mission (launched Feb 19)
March 19, 2017

FAA-Licensed and Permit Launches 1989 - 2016

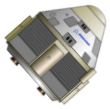


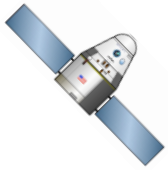
252 FAA-licensed launches 1989 - 2016 (138 GEO, 91 NGSO, 23 Suborbital)
44 Permit launches 2006 – 2016 (all suborbital)
Includes 50 launches for U.S. Government (NASA [ISS], NOAA, and DoD)

Source: FAA January 2017

Active and Future Licensed or Permit Vehicles

- There are about 72 industry projects in “pre-application consultation” with the FAA/AST (as of June 2017)
  - Launch and reentry vehicles
  - Launch sites
  - Safety Approvals
  - Payload reviews including those intended for destinations beyond Earth orbit


CST-100 Starliner


Dragon

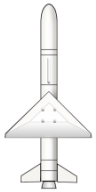

SpaceShipTwo

New Shepard


Atlas V


Delta IV

Falcon 9


Pegasus XL


Minotaur C


Antares

Zenit 3SL

Electron

Expanding Commercial Capabilities

ELVs, Suborbital RLVs, Orbital Systems, Habitats

Virgin Galactic

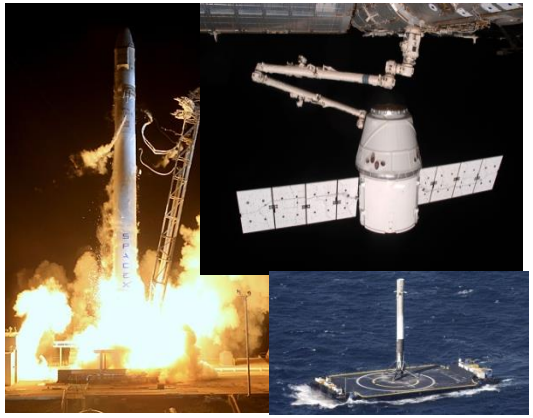
Sierra Nevada Corp

Boeing

Rocket Lab USA

Blue Origin

Orbital Sciences ATK



SpaceX

Bigelow Aerospace