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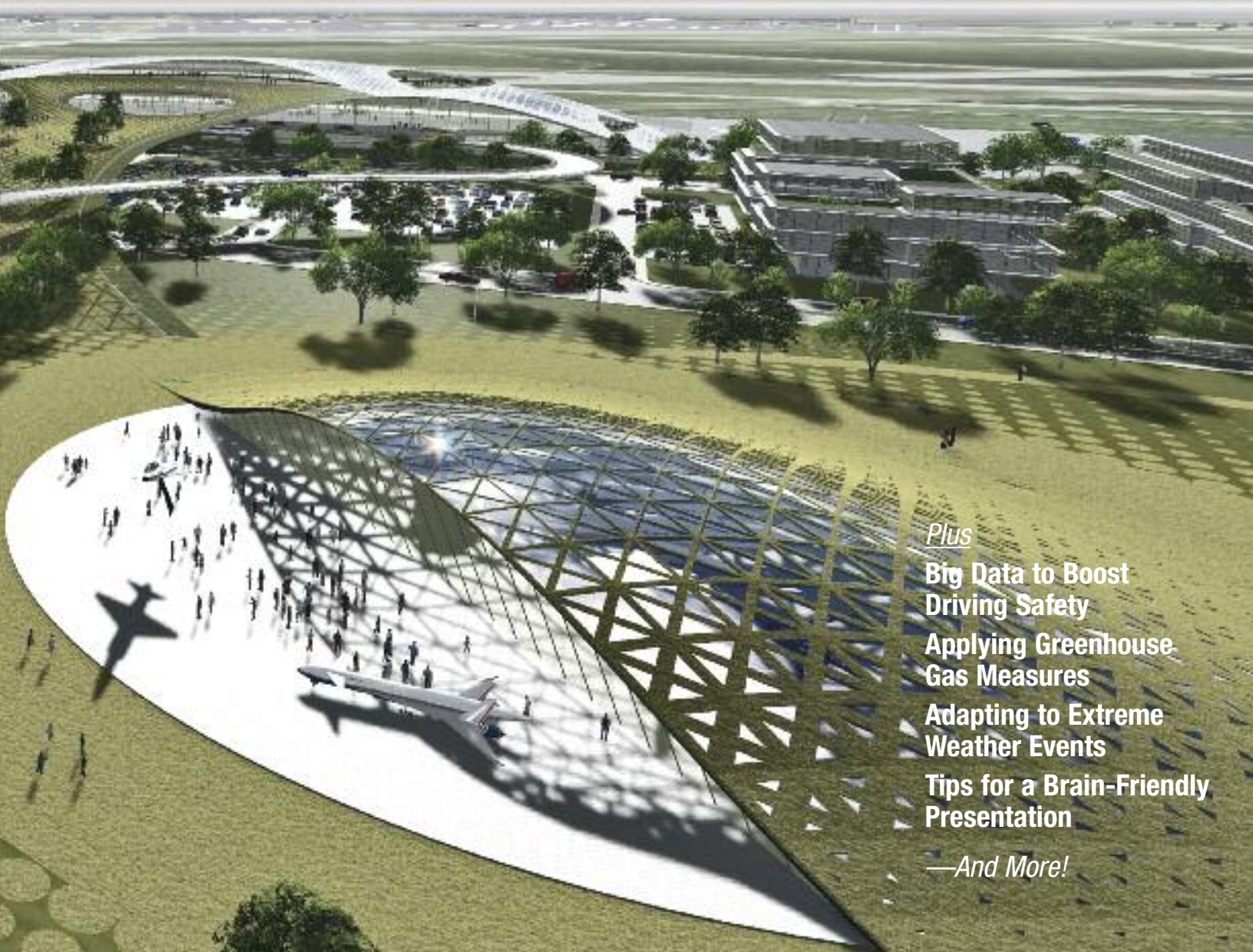
Commercial Spaceports



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Commercial Spaceports

Building the Foundation of a Commercial Space Transportation Network

RICHARD M. ROGERS

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PHOTO: NASA/MASTEN

(Above:) Xombie, a vertical-takeoff, vertical-landing experimental rocket, lifts off from Mojave Air and Space Port in a test for the National Aeronautics and Space Administration's Jet Propulsion Laboratory; the project is evaluating an algorithm for planetary pinpoint landing of spacecraft. *(Below:)* Commercial spaceports may expedite the recreational space travel imagined in the 1902 French silent film *A Trip to the Moon.*

IMAGE: WIKIMEDIA COMMONS

The word "spaceport" may trigger visions of some far-off place, millennia into the future, with spacecraft zipping around between planets. Yet spaceports are here, on Earth, and are inching ever closer to the spaceports envisioned in the imagination and depicted in the movies. In the not too distant future, spacecraft will be zipping people from the surface of the Earth into space and back again. Space flight no longer will be the privilege of a few astronauts. The Commercial Space Transportation Network is in development now.

Diversified Space Race

Traditionally, spaceports were federally owned facilities for launching large government rockets. Kennedy Space Center and Cape Canaveral Air Force Station in Florida and Vandenberg Air Force Base in California are the primary government facilities that have managed rocket launches in the United States for more than 60 years.

In the past two decades, the U.S. Congress has passed several pieces of legislation that are ushering in a new commercial space race. The legislation promotes the use of government assets for access to space, including commercial launch facilities, rockets, personnel, and missions.

After the retirement of the Space Shuttle in 2011, NASA programs—such as Commercial Crew and Cargo—have inspired several private companies to fill the gaps in space access. Some companies are building on past designs; others are working for a cheaper, more accessible, way to space by applying new ideas, new designs, and unique engineering. New designs in development are attempting to build-in significant cost savings. Some of the innovations are revolutionary—such as stage reusability, vertical takeoff–vertical landing, and horizontal reusable launch vehicles.

The Federal Aviation Administration (FAA) Office of Commercial Space regulates many aspects of the commercial space sector. FAA has licensed 10 commercial spaceports, each with a unique role and capability.

The U.S. spaceport network includes several types of facilities, government- and commercially owned. Some require large expanses of land with gigantic

After its retirement in 2011, the Space Shuttle was flown over Washington, D.C., on delivery to the Air and Space Museum. Private companies now are working to fill the gaps in space access.

steel infrastructure; some only need small pads of concrete. Some are located at airports, mostly on the coasts, although recently some are inland. Each serves a specific purpose and a specific subset of launch vehicles.

Types of Launch Sites

For spaceports, one size does not fit all. The addition of commercially owned and operated launch facilities to the repertoire of federal launch sites has allowed diverse missions and users to gain access to space. Commercial launch facilities and operations can be more businesslike than their government counterparts. Each of the following types of launch sites has commercial and federal versions:

- **Traditional vertical launch sites** require an infrastructure specific to the rocket. Many of the vehicles are large and require substantial storage depots for propellants, as well as secure safety areas.
- **Sites for vertical takeoff–vertical landing vehicles** also require specific infrastructure for launches and a clear area for landing. Smaller traditional rockets and vertical takeoff–vertical landing rockets require a similar type of infrastructure with an expanse of land. The rocket-specific infrastructure of these sites limits the number of users.
- **Launch facilities that cater to large rockets** also occasionally handle the smaller sounding rockets. A sounding rocket does not require as much room, but if the rocket is unguided and launched with a rail launcher, a location near a coast may be necessary. These types of launches do not receive the media coverage that launches of larger satellites attract but are important to the scientific community, enabling short, recoverable, suborbital flights into microgravity at a much lower cost.
- **Sites for winged launch vehicles**—or horizontal takeoff-and-land launch vehicles—have gained interest, and many are in development. The Virgin Galactic SpaceShipTwo and XCOR Aerospace Lynx aim to conduct space tourism, carrying passengers and payloads into suborbital space flight. Other versions of these horizontal takeoff-and-land launch vehicles use an expendable second stage to insert payloads into orbit. Winged launch vehicles take off horizontally via a runway and operate similarly to an airplane until rocket ignition.

A spaceport that can support horizontal takeoff-and-land launch vehicles typically is colocated at an airport and is known as an aerospaceport. FAA has licensed four spaceports at active airports: Cecil Spaceport in Jacksonville, Florida; Houston Spaceport in Texas; Oklahoma Air and Space Port in Burns

PHOTO: HOUSTON AIRPORT SYSTEM

A rendering of the Houston Spaceport at Ellington Airport in Texas, which was approved by the Federal Aviation Administration in June to host the 10th licensed commercial spaceport in the United States.

Photo: Tony Gray and Tim Powers, NASA

The SpaceX Falcon 9 rocket carries NOAA's Deep Space Climate Observatory spacecraft from a traditional launch site at Cape Canaveral Air Force Station in Florida.

Flat; and Midland International Air and Space Port in Texas. Sometime in the future, aerospaceports also will be used for high-speed, point-to-point transportation.

Spaceport Services

Spaceports offer much more than the infrastructure to launch a rocket. A spaceport offers a range of services to users and to the supporting aerospace industry:

- Aerospace design and manufacturing capabilities, to support the launch vehicle and the payload providers;
- Range support and telemetry services for safe launches and for the transmission of data during a launch or test;
- Payload processing and integration facilities, to support satellite development, manufacturing, and testing; and
- Other services, such as propellant supply and storage, secure facilities, weather monitoring, lightning protection, and more.

These same manufacturing, integration, and engineering services also may extend beyond the aerospace industry to support research and development for the Department of Defense, universities, and commercial manufacturers.

Many transportation modes play a role at a spaceport. Large rocket components, such as propellant tanks or solid boosters, commonly are fabricated at locations away from the launch site. Delivery of these components requires a coordinated logistics effort that often spans every mode—air, ground, ship, and rail. The commercial spaceport network relies on the local transportation infrastructure to support launch operations.

Several secondary industries also are associated with spaceports, such as spaceflight and pilot training, museums, tours, education, and retail outlets. As the commercial spaceflight network grows, the neighboring aerospace industries increase, helping to build the community economically and socially.

Inspiration and Motivation

The array of services and capabilities offered by a spaceport also inspires the growth of the commercial space network. High technology, science, and engineering

Photo: 24oranges.nl

A model of an XCOR Aerospace Lynx on display at Mediamarkt Amsterdam, Netherlands. XCOR and other winged launch vehicles are being developed to conduct payloads into suborbital space flight.

PHOTO: KIM SHIFLETT, NASA

The NASA Railroad train transports the final set of solid rocket booster segments for the Space Shuttle to the Kennedy Space Center. A multimodal infrastructure is required to move equipment and parts to launch sites.

jobs are often abundant in the area surrounding a spaceport and provoke community interest in space. A spaceport and related aerospace industry can inspire local children to pursue studies in science, technology, engineering, and mathematics through tours, launches, and classroom experiments.

The Department of Defense, NASA, and communications companies are interested in putting satellites into orbit for the Global Positioning System, telecommunications, and weather research. But the motivations for space flight are more extensive. The biomedical industry, for instance, seeks access to space to research new medicines, biological products, and medical devices. Other industries, such as aerospace, technology, optics, and materials, want to use space to research and develop new manufacturing techniques, materials, and devices. University researchers, scientists, and students may need to conduct microgravity experiments on a suborbital or orbital mission. As the number of spaceports within the commercial spaceport network increases, so does the access to space.

Regulations and Standards

Originally, government organizations such as the Department of Defense and NASA exclusively operated spaceports. The commercialization of space has involved FAA in licensing and regulations for spaceport operators and for launch vehicle operators.

Commercial space regulations in the *Code of Federal Regulations* (CFR) cover safety, launch sites, launch vehicles, experimental permits, and human space flight requirements.[1] The CFR section titled

[1] 14 CFR Part 411 through Part 461.

What Happens at a Spaceport?

WAYNE FINGER

Everything necessary for a flight into space comes together at a spaceport. Components arrive by air, rail, water port, or highway. The major parts of the rocket are integrated to create the fully assembled launch vehicle. Propellants—both fuels and oxidizers—arrive at the spaceport and are stored, awaiting transfer to the launch vehicle just before the launch. Space flight participants, crew, and their families arrive, complete orientation, and prepare for the flight. Cargo and experiments arrive and are stored in a controlled environment. Researchers, educators, and students participate in the final preparations, and the experiments are loaded on board.

The space flight mission originates at the spaceport, which monitors the weather and coordinates with air traffic control to ensure that the flight corridor has accounted for public safety. Some launch vehicles eventually may go beyond earth orbit and not return. For now, most will return intact to a spaceport, will have components that return to a spaceport, or will fall into the ocean.

In essence, a spaceport is a multimodal transportation facility that integrates air, water, ground, and space transportation. This span of responsibilities requires special technological, safety, and environmental approaches for successful operations—and opens vast opportunities for research.

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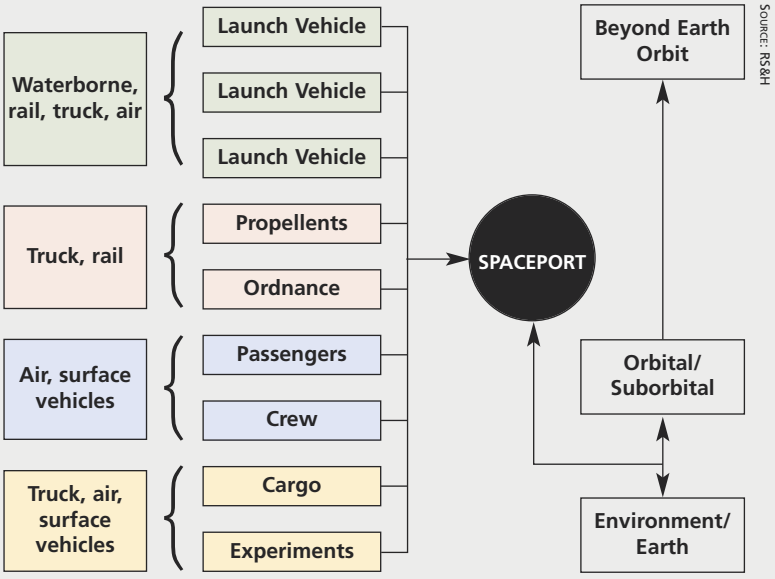

Figure 1 What happens at a spaceport.

"License to Operate a Launch Site" specifically governs spaceports.[2]

The section describes a detailed application process to ensure the safe operation of a launch vehicle. The application requires analyses that consider hazardous chemicals, safety operations, security, airspace and flight paths, risk, and environmental assessments. Updates and revisions to the regulations are continual, reflecting the approval and implementation of new industry standards.

Depending on the mission and launch site, other regulations may apply. Launches that use the Department of Defense Launch and Test Range System, which provides support for commercial spacecraft launches and for aeronautical testing missions, must meet specific safety guidelines. Government-sanctioned launches follow the department's guidelines, and launches for a NASA program must meet the appropriate NASA standards. Many of the requirements overlap or mimic each other but are necessary for fulfilling a specific mission.

Advisory Groups

Several ongoing industry efforts are attempting to bridge the gap between users and regulators. The Commercial Space Transportation Advisory Committee (COMSTAC) was established to provide FAA with information, advice, and recommendations on issues related to the commercial space transportation network. COMSTAC consists of industry representatives who meet biannually in sessions open to the public. The membership and the working groups discuss industry concerns and develop recommendations for FAA.

The Commercial Spaceflight Federation (CSF) is an industry group that includes the major spaceport operators, launch vehicle operators, and aerospace companies. The federation addresses industry issues, policies, and regulations; promotes industry growth; and engages in public outreach.

The industry also has pursued other avenues to raise awareness, establish standards, advocate for regulatory changes, and discuss challenges. Many professional societies and groups have formed standing committees, subcommittees, and working groups to explore issues and interests in commercial space—notably the American Institute of Aeronautics and Astronautics and the Transportation Research Board (TRB). Many of these groups are focusing on specific industry issues.

Regulators and industry users have been working together to build the commercial spaceport network. The openness of regulators to recommendations and to change, along with the collaborative efforts of industry users through COMSTAC, CSF, and other groups, are contributing to the growth of commercial spaceflight activities.

[2] 14 CFR Part 420.

PHOTO: NASA

Space opens many new possibilities for research in a range of fields; NASA Flight Engineer Tracy Caldwell Dyson works on experiments requiring cryogenic refrigeration aboard the International Space Station.

Spaceport Research Needs

The rapid growth of the commercial spaceflight network offers many opportunities for research to assist and benefit the industry. Many research needs relate to facilities and operations for horizontal takeoff-and-land and for vertical takeoff–vertical landing vehicles. Nevertheless, research to support the development and establishment of vertical rocket launch sites that can support a variety of users is also needed.

Another key subject for research involves the integration of spaceport operations into an airport—license applications for aerospaceport arrangements are increasing. Reviewing the lessons learned from the two recently licensed aerospaceport facilities could identify challenges and solutions that would be instructive for other facilities and that could identify operations approaches that are common throughout the commercial spaceport network.

For example, vertical takeoff–vertical landing launch vehicles offer challenges not encountered with expendable launch vehicles. Developing and publicizing safe operating procedures, methods, and analyses for vertical takeoff–vertical landing could enhance system and public safety.

Additional topics for research on the integration of a spaceport with an airport include propellant storage, loading methods and mechanisms, aircraft rescue and firefighting procedures, modifications to airport design standards to accommodate a spaceport, and the development of passenger processing operations.

PHOTO: DAVID C. BOWMAN, NASA LANGLEY

A prototype of the GL-10, a hybrid diesel–electric tiltwing aircraft with vertical takeoff–vertical landing (VTOL) ability, hovers after takeoff. Research into VTOL vehicles can open up new avenues of launch site design.

A New Phase

This is a new phase in U.S. spaceflight history: NASA is producing a new Space Launch System that is larger and more powerful than the Saturn V rocket that took astronauts to the moon. Commercial companies regularly are carrying cargo into space and soon will carry people. Regularly scheduled commercial space tourism is imminent.

The industry is evolving into a commercial spaceport network; competition and innovation will drive launch costs down and the frequency of launches up. Pushing the boundaries of spaceflight will open many possibilities and benefits.

As the U.S. space launch landscape undergoes changes, TRB has a role in providing advice and research to support an emerging commercial spaceport network. Adopting an excited, interested, and solution-focused attitude to industry changes related to commercial spaceflight may result in a spaceport nearby.

Advising on Aerospace Technology

Informing Policies, Procedures, and Research Agendas

MICHAEL H. MOLONEY

The Aeronautics and Space Engineering Board (ASEB) at the National Academies of Sciences, Engineering, and Medicine was established in 1967 "to focus the talents and energies of the engineering community on significant aerospace policies and programs." In fulfilling this charge, ASEB oversees ad hoc report-writing committees that recommend priorities and procedures for achieving aerospace engineering objectives and brings engineering and other related expertise to bear on aerospace issues of national importance.

Issues include the research and development aspects of the Next-Generation Air Transportation System, or NextGen; NASA's aeronautics research program; national aeronautics research and development policy and its implementation; space policy and programs, with a focus on human spaceflight, space technology, and space operations; commercial space activities; and other aerospace engineering topics.

PHOTO: NASA

Commander Barry (Butch) Wilmore holds a science sample container that took 2 hours to make with a 3-D printer on the International Space Station; NASA seeks to make objects in space instead of delivering them. The Aeronautics and Space Engineering Board is advising NASA on 3-D printing in space and other research.

Recent activities have included studies on 3-D printing in space, a research agenda for autonomy in civil aviation, a major review of the goals and direction of human spaceflight, NASA's flight research program, and priorities for NASA's space technology development roadmaps. Current studies include the establishment of a research agenda for low-carbon propulsion and energy systems for civil aviation and a review of changes to NASA's space technology development road maps.

ASEB also oversees the work of the Aeronautics Research and Technology Roundtable and the Space Technology Industry, Government, and University Roundtable. The roundtables convene senior-level representatives from industry, universities, and government to define and explore critical issues of shared interest related to NASA's research agendas for aeronautics and space technology; to frame systems-level research issues; and to explore options for public–private partnerships that could support rapid, high-confidence knowledge transfer. These forums facilitate a candid dialogue among the participants, foster greater partnership within the NASA-related aerospace community, and—when appropriate—convey awareness of the consequences to the wider public.

The author is Director for Space and Aeronautics, Aeronautics and Space Engineering Board and Space Studies Board, Division of Engineering and Physical Sciences, National Academies of Sciences, Engineering, and Medicine, Washington, D.C.