Why do humans explore space?

Humans pursue space exploration for five basic reasons. The first emphasizes the gains to be made through science, the second reason favors national defense. The third deals with what commentators call signaling. The fourth is commerce.

Science fiction and popular histories abound with stories about people who got rich exploiting the resources and opportunities available in what appear to be new and distant places. The stories help justify the widespread belief that outer space is becoming a significant outpost for new economic activity.

Conjuring images of past gold and silver rushes on the Earth, humans in the 2009 film *Avatar* travel to the Alpha Centauri star system to remove a rare superconductive mineral called unobtanium. In Fritz Lang's classic 1929 film *Frau im Mond*, industrialists finance a voyage to the Moon in quest of gold. They find a cave full of precious material. Filmmakers repeat the theme in the 2009 film *Moon* in which a sole employee oversees removal of Helium-3 from the lunar surface for use in powering fusion reactors back on Earth.

Science fiction author Isaac Asimov describes life on a space-based solar power beaming station. On the station, an artificial intelligence robot concludes that its human companions could not have created it since they are so clearly inferior at aiming energy beams to their home planet. The 1941 short story is titled "Reason." In *Destination Moon* (1950), industrial leaders finance an expedition to the lunar surface after government executives refuse to support what they view as an excessively risky venture.

Such stories recall similar tales about real people, often embellished. California's "big four" amassed personal fortunes of mythic proportions by investing earnings from their mining supply and department stores in the US transcontinental railroad. William Boeing turned his personal investments in Pacific Northwest timberlands into the large aircraft company that bears his name. Fortunately for Boeing, spruce trees proved to be a valuable resource for manufacturing early airframes.

Story telling often turns into space reality. In 1945, a 27-year-old engineer wrote an article for *Wireless World*, published one dozen years before the first Earth orbiting satellites appeared. The article was written by Arthur C. Clarke, soon to be a famous science fiction writer. The subject was communication satellites. Clarke pointed out that three strategically placed satellites could provide communication channels to nearly all the Earth's population.

Scarcely one and one-half decades later, after a brief period of experimentation, the newly formed National Aeronautics and Space Administration (NASA) encouraged the formation of a commercial satellite industry. The US Congress passed the Communications Satellite Act of 1962 which in turn led to the formation of the Communications Satellite Corporation (COMSAT) and its international counterpart, the International Telecommunications Satellite Organization (INTELSAT). COMSAT received public funding, raised additional capital from private investors, and owned the satellites they designed and flew.

Today communication satellites form the backbone of the commercial space industry. Satellites transmit telephone calls, television and radio broadcasts, cable and network

programs, financial and commercial information, and an increasing variety of internet services. The constellations of communication satellites along with their associated ground equipment are a multi-billion-dollar operation.

It is worth noting that Clarke envisioned the need for human crews on board what he called relay stations. The relay stations, he predicted, would provide "living quarters, laboratories and everything needed for the comfort of its crew, who would be relieved and provisioned by a regular rocket service."[1] The cost of any such astronaut-based system, however, would have been prohibitive. Fortunately for people pursuing profits in space, advances in robotic and automated technologies rendered unnecessary the need for on-board crews.

To be profitable and grow, communication satellite companies had to be competitive with ground-based carriers like cell phone towers and fiber optic cables. An early Intelsat III satellite launched in 1969 into a geostationary orbit 22,000 miles above the Earth's surface could transmit four television channels or 2,400 telephone calls. It had a mass of 646 pounds.[2] By 2023, communication satellite companies like Hughes Network Systems were ready to loft 12,800-pound satellites capable of transmitting 500 gigabits per second into geostationary orbits, where they communicated with ground stations and internet users.

To attain further improvements, entrepreneurs moved their communication satellites from geostationary orbits to pathways much closer to the Earth. Diminished orbits reduced launch costs and increased transmission speeds, a clear advantage. But diminished orbits also required more satellites to cover a given service area, a cost disadvantage.

In 1997, the Iridium Company, a spin-off from the Motorola Corporation, began the task of launching 75 communication satellites into 485-mile high-orbits (technically known as low-Earth orbits). Each having a mass of 1,412 pounds, the satellites were launched on relatively lower-cost Delta rockets, several on each launch vehicle.

The overall system provided nearly worldwide user coverage, but the technology was bulky and hard to use. The company went bankrupt in 1998.[3]

Commercial interests withdrew to time-established business strategies for reducing their cost of operations – make satellites smaller and reduce transportation costs. When rocket designers failed to reduce launch costs with winged spacecraft like the NASA space shuttle and the privately-owned X-33/VentureStar, communication engineers worked to make satellites smaller.

Smaller, less expensive satellites allowed more equipment in low-Earth constellations. In 2016, representatives from Elon Musk's SpaceX company appeared before the US Federal Communications Commission with a request to place up to 42,000 small communication satellites in orbits close to the Earth. Flight engineers packed sixty individual satellites on top of one Musk Falcon 9 rocket. Stacked vertically like kernels on an ear of corn, early versions of the

[1] Arthur C. Clarke, "Extra-Terrestrial Relays," *Wireless World* (October 1945): 306.
[2] Francis A. Gicca, "Communication Satellites – Success in Space," *Electronics World* (August 1969).
[3] Craig Mellow, "The Rise and Fall and Rise of Iridium," *Air & Space Magazine* (September 2004).

individual satellites weighed as little as 570 pounds (Earth mass).[4] Concurrently, the cost of a Falcon 9 fell relative to other launchers.

The large number of satellites allowed designers to shift their attention to the lucrative business of transmitting information available on the internet. Competitors like Jeff Bezos' Blue Origin and the Amazon Corporation followed**.**

In the late 1990s, commercial space spending crossed an important threshold. Based on reported data, the size of the commercial space industry exceeded the amount of money reportedly spent by governmental bodies on space. The government figure probably omitted some defense expenditures, but the symbolic importance of the event was incontrovertible. Commercial space had or was about to overtake government space, solidifying a trend relatively unbroken since then. Barring a major international conflict, commercial investors would not look back.

By 2022, the commercial global space sector held a four-to-one lead. Estimated government space spending world-wide reached at least $119 billion that year, including reported outlays directed into national defense. The commercial sector reached $428 billion. Forecasters predicted that the two-sector total would top $1 trillion soon.[5]

To cross the $1 trillion two-sector total, industry analysts anticipated growth in the following commercial sectors in addition to more conventional communications satellite market.

The information provided by PNT or what are called position, navigation, and timing satellites is providing a large revenue source for private sector firms. PNT satellites began as a technology used by military units such as ships at sea that needed a precise methodology for locating their position. The technology quickly found a wide range of commercial applications once military officers made signals available to the general public. Signals dispatched from PNT satellites provide information used for global navigation, guidance for automated driving vehicles, pathways for precision agriculture, and highly accurate statements of time. The latter supports a global financial system that requires exact time-based registrations to process large financial transactions.

Information transmission: spread around the globe, the communication satellite remains the most efficient method for achieving universal access to all information such as that available on the internet.

Resources: the mining of space for valuable resources will probably begin with the extraction of goods for sale in space, such as water ice processed into hydrogen and oxygen rocket fuel, breathing oxygen, and drinking water. Likely customers could include the astronauts working at various research stations including the Moon and Mars. Should retrieval expenses

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[4] Stephen Clark, "SpaceX unveils first batch of larger upgraded Starlink satellites," *Spaceflight Now* (February 27, 2023). Plans called for the satellites to grow to 1,760 pounds.

[5] Space Foundation, *The Space Report* (Colorado Springs, CO, 2023 Q2). See also Simon Seminari, "Global government space budgets continues multiyear rebound." spacenews.com (November 24, 2019) accessed September 29, 2022; Michael Sheetz, "The space industry is on its way to reach #1 trillion in revenue by 2040." cnbc.com (May 21, 2022) accessed September 29, 2022.

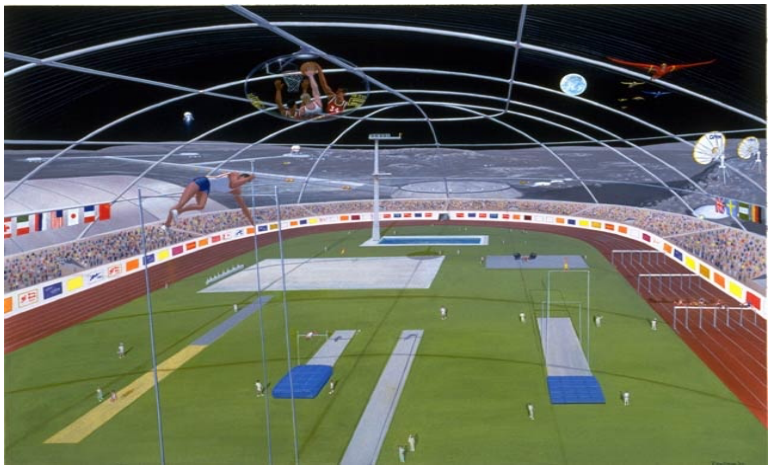
continue to fall, elements like helium 3 could be prepared for shipment back to Earth. The substance is rare on Earth but thought to be abundant on the surface of the Moon.

Micro-gravity manufacturing: since the early discussion in 1983 of what became the International Space Station, business leaders have anticipated a hefty market for substances manufactured in space. Practically everything made on Earth is manufactured or grown under the conditions of one Earth gravity. Scientists anticipated that alternative levels of gravity (including hardly any gravitational force at all) could yield an abundance of materials such as strange metal alloys and pharmaceutical products unknown on the Earth.

For an industry running out of exotic locations to entice visitation on the Earth, outer space offers an endless tourist frontier.

For decades, imaginative writers have envisioned the challenges of collecting the energy lost to the endless vacuum of space and redirecting it toward the Earth and other objects in the solar system.

Business entrepreneurs anticipate a market for supplying lunar stations and other destinations with commodities like food and water, sources of energy, services like transportation, housing, recreation, and even a visitor center. One artist cleverly envisioned a lunar Olympics in one-sixth gravity.[6]



Credit: Pat Rawlings/NASA

Antarctic and South Pole stations offer the most analogous Earth-based models for these services and the opportunities that grow up around them.

Finally, the commercial sector will probably find a way to profit from trash collection in outer space, from the removal of Earth orbital debris to the disposal of waste products from lunar stations and places beyond. Half of all earth orbiting satellites are now non-functioning – the equivalent of an orbiting junk yard for dead automobiles and a major obstacle to expansion.

Commercial opportunities provide the fourth major justification for space travel.

Dr. Howard McCurdy, September 9, 2023

[6] Leonard David, "Moon Olympics," (December 7, 2019) artwork by Pat Rawlings.