Chapter 2
Understanding the Nature of Space Business

In November 1984, Dale Gardner and Joseph Allen stepped outside their vehicle to retrieve two broken pieces of equipment. This could have been a very unremarkable task if not for the location of the work: 340 km from the surface of Earth. The mission of Gardner and Allen and their fellow crew members aboard the space shuttle *Discovery* (STS 51-A) was to deploy two telecommunication satellites and to retrieve two other ones that were stranded in LEO. At the time, this commercial mission was seen as a testament to the original vision of the space shuttle – a versatile spacecraft capable of carrying crew and cargo for scientific, military and commercial missions. The "For Sale" sign held by Gardner gave the impression that spaceflight was now a routine, albeit costly activity (Fig. 2.1).

Designed as a multi-purpose vehicle, the space shuttle was indeed open for business in its early days of operation. Between 1981 and 1986 various commercial missions were flown, serving multiple customers. In 1985 alone, *Discovery* flew four separate missions, a remarkable performance underlining the reusable nature of the vehicle. However, the shuttle never became the "space truck" that was originally promised. Just over a year from the successful mission of Gardner and Allen, another mission with a similar designation, STS 51-L, took off from Cape Canaveral. A minute after takeoff, the space shuttle *Challenger* disintegrated midair, taking with it not only the lives of its seven crew members but also the promise of safe and routine human spaceflight.

The *Challenger* accident brought an abrupt end to consideration of the shuttle as a commercial carrier, and many pending commercial launches were canceled. But, what if the *Challenger* accident had not happened? Would the private sector use of the shuttle have been a resounding success? For the reasons we'll explore below, the answer is "Probably not."

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Fig. 2.1 Astronaut Dale Gardner holds up a For Sale sign after EVA (Image courtesy of NASA)

Review of Key Concepts

The space industry is markedly different from other sectors of economic activity. Some of these differences stem from the challenging technical requirements demanded by the harsh environment of space. Other differences are related to the origins of the space industry and the strong military rationale that is still an important part of global space activities.

It is not a surprise that the early days of space exploration were dominated by policy imperatives and the intense competition of the Cold War. However, as the space "firsts" were claimed one by one, starting with the world's first artificial satellite, Sputnik, followed by Yuri Gagarin's historical flight and by Neil Armstrong's footsteps on the Moon, the political momentum had slowed down. Today, national pride still plays a significant role, but justifying the economic benefits of space investments in practical terms is becoming more and more important. Thus, mastering the key concepts of space economics helps us to understand the "economic rationale" of space exploration.

The Fundamental Forces of Economics: Demand and Supply

Our review of core concepts will start with demand and supply. It is hardly possible to exaggerate the importance of these two forces that shape the nature of any industry. The formal definition of demand in economics is the quantity of a good or service an individual or group desires at a given price. Supply, on the other hand, is the quantity of a good or service that an individual or group is willing to provide at a given price. Although most people are introduced to the concepts of demand and supply as part of their formal education, very few make use of these concepts to understand the actual behavior of their economic surroundings.

Very simply put, price acts as a lever that determines the actions of buyers and sellers. If the price falls, the quantity demanded rises and the quantity supplied falls. If the price increases, the quantity demanded falls and the quantity supplied rises. This continuous adjustment in the market shapes the quantity and variety of goods and services available. If supply exceeds demand, producers' inventories will increase, forcing them to reduce the price they are willing to accept until supply and demand are equal again.

Sound economic policy and successful business decisions are all based on a careful analysis of the trends that affect the supply and demand for space-related goods and services.

Now let's put these concepts to work and apply them to the space industry.

Elasticity of Launch Services

The sensitivity of consumers to a change in the price of a product or service is measured by the price elasticity of demand. If the demand is inelastic, changes in the price don't have a big impact on the quantity demanded (e.g., cigarette consumption, drinking water). If the demand is elastic, changes in price have a significant impact on the quantity demanded (e.g., hospitality services, luxury items, electronics).

One of the fundamental cost drivers in the space industry is the cost of launching payloads to LEO and beyond. In order to compare the cost of different launch vehicles, one convenient metric is cost per pound or cost per kilogram. A study conducted in 2005 concluded that the oversupply in the launch vehicle market in the last two decades resulted in significant price drops, in some cases as much as 50 %.[1] This price signal would normally cause the demand to increase; however the demand was stable. One explanation for this lack of "demand response" is the long lead times associated with developing new payloads and building spacecraft. Just because there is a cheaper launch available doesn't mean that there will be spacecraft ready for launch. The other, perhaps more fundamental reason, is the limited amount of demand for launch services even in the best of times.

Cost Versus Price

At first glance, the concepts of cost and price are deceptively simple. The former is the total amount of expenses incurred for producing a good or service while the

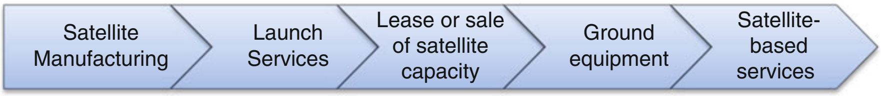

Fig. 2.2 The value chain of satellite applications

latter is the amount a customer is prepared to pay to acquire this very same good or service. Most importantly, from the seller's point of view, the difference between the price she charged and the costs she incurred is the profit – the lifeblood of a market-based economy. Understanding the distinction between the cost and price of a product or service isn't always easy in the space sector, since there is a strong heritage of cost-plus contracts. These types of contracts entitle the contractor to a total reimbursement of all the project costs plus a certain amount of profit, generally based on a percentage of the cost base. Thus, historically, there has been little incentive to control the project costs. It is important to note that the most "commercial" of the space industries, namely the commercial communications satellite industry, was among the first to migrate away from cost plus contracts. By demanding a fixed price bidding process whereby competing satellite manufacturers assumed the risk of cost overruns, satellite operators successfully moved away from a cost-plus business model.

For a private enterprise in a competitive market, the cost of producing a good or service has to be below its market price, so that the firm can make a profit and stay in business. For most government-run projects, the same constraint doesn't apply, so the governments can keep subsidizing very expensive projects because of other priorities, such as national security.

The Space "Value Chain"

Just like any other sector of economic activity, products and services in the space industry reach their final customers after successive rounds of inputs from contributors. In economics, the term "value-added" refers to the additional value created at each phase of production, as raw materials are transformed into finished goods and services by applying factors of production (e.g., labor and capital) (Fig. 2.2).

This value chain may be entirely transparent to a viewer enjoying a live sports broadcast on satellite TV, but it has to operate flawlessly for the customer to enjoy reliable and affordable service. The broadcast signals, coming all the way from GEO, are provided by a TV content provider who has leased satellite capacity from a satellite operator. The operator ensures that the satellite functions optimally by maintaining its orbit and various subsystems. In turn, satellite operators are dependent on many suppliers as well. These include ground equipment manufacturers, satellite manufacturers and launch service providers. Their collective effort is required to design, test, manufacture and deliver satellites in the proper orbit.

Meanwhile, all of these activities are supported by hundreds, if not thousands, of other firms who provide all the necessary hardware and software elements as subsystem suppliers. Unbeknownst to TV viewers who flip on a television set, each satellite-based broadcast from space reaches their living room thanks to this value chain.

The value chain concept applies to all satellite applications, from remote sensing to satellite navigation. Since the value chain captures every essential contribution of the industry participants, it is a very useful gauge to assess the economic activity in the space industry. By summing up all the value-added products and services in each industry segment, we can have a fairly accurate idea about the size of each segment.

The Economic Footprint of Space

Just as in any other branch of science, measurement plays a key role in economics and business, as we cannot truly understand what we cannot measure. For many years, it has been particularly difficult to find reliable and detailed statistics on the space industry. This situation improved drastically in the last few years. Today, some of the leading sources of information that compile industry statistics on the space industry include the following: (i) the Global Forum on Space Economics of the OECD, (ii) various reports published by the Satellite Industry Association in the United States (as compiled by the Futron Corporation), (iii) “Industry Facts & Figures” published by Eurospace and (iv) “The Space Report” published by the Space Foundation. It is interesting to note that global industry statistics are not always in agreement, and cross-checking key indicators is always a good idea.

The inconsistencies may be a result of various factors. One issue is the time period for which the statistics are compiled (i.e., calendar year versus fiscal year). Another issue is the difficulty in combining the figures of largely “wholesale” suppliers such as Intelsat and Eutelsat with the sales figures of retail suppliers. The line between a space-based service and a terrestrial one is not always clear. In some satellite services, such as in broadcasting and telecommunications, for instance, it is not exactly clear where the satellite service has transitioned to a terrestrial telecommunications service or an Internet transaction. Finally, there can be double counting or improper accounting of revenues in a supply chain.

In this section – despite these difficulties – we’ll attempt to illustrate the economic footprint of the space industry. As we’ll see, when we only consider economic metrics, space is neither a giant industry nor a fringe one. However, some of the most important benefits of space activities are also the ones hardest to quantify. Without key satellite services, thousands of lives might be lost due to storms or hurricanes, airline operations would not be as reliable, financial institutions would not be able to function as efficiently and the reach of the Internet would be severely curtailed – particularly in a number of developing countries. The importance of satellite services ripple across the global economy.

Some of the main factors that determine the size of the space industry are government space budgets. These budgets can give us a good idea about the inputs to

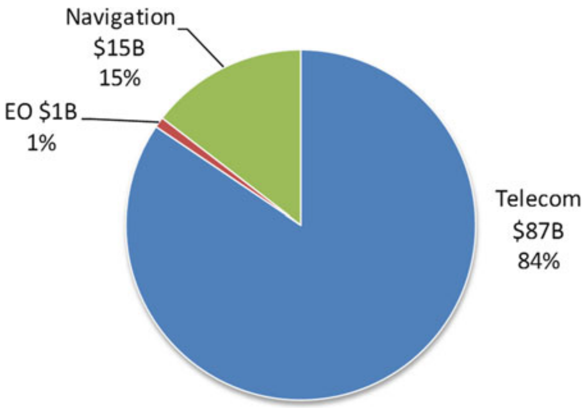

Fig. 2.3 Distribution of satellite services revenues (in billion dollars) between the three main types of satellite applications in 2009 (Source: OECD 2011)

the industry. The OECD regularly publishes reports on government space budgets around the world. The 35 spacefaring nations covered by the OECD invested a total of $64.4 billion in 2009, and an estimated $ 65.3 billion in 2010, including both civilian and military spending.[2] The Space Foundation also publishes statistics for worldwide government space budgets with an estimate of $87.12 billion for 2010. The discrepancy is mostly due to the way U. S. space budgets are calculated, the restricted release of information regarding military satellite activities and lack of standards when it comes to the definition of "space activities".[3]

It is not an exaggeration to say that the United States dwarfs other nations when it comes to space spending. For each dollar spent by the rest of the world on space activities, the United States spends more than $2 (including both civilian and military spending). However, budgetary amounts can be deceiving when making international comparisons regarding the capability of different spacefaring nations. Labor is by far the biggest expense category in space programs, and labor costs are much lower in BRIC countries and other emerging space nations. Therefore, one needs to always check if purchasing power parity (PPP) is used when international budgets are compared.

Another key indicator of space industry statistics concerns the revenues of the commercial sector. Although commercial revenue estimates vary significantly, comparing various sources gives us a range of $170–190 billion for 2010[4,5] This figure includes the combined annual revenues of satellite applications (satellite telecommunications, Earth observation and satellite navigation) and the rest of the value chain (i.e., satellite manufacturing, launch services, ground equipment and support services including launch insurance) (Fig. 2.4).

Tallying up the revenue estimates of the commercial sector can be tricky. It is very easy to double count various revenues. Thus, it is critical to map out the value chain and account for the incremental revenues from one stage to the other properly. Otherwise we can easily overestimate the total volume of the industry. For example, a satellite manufacturer generally subcontracts the many subsystems that go into a satellite. If we tally up the cost of all subsystems to the prime

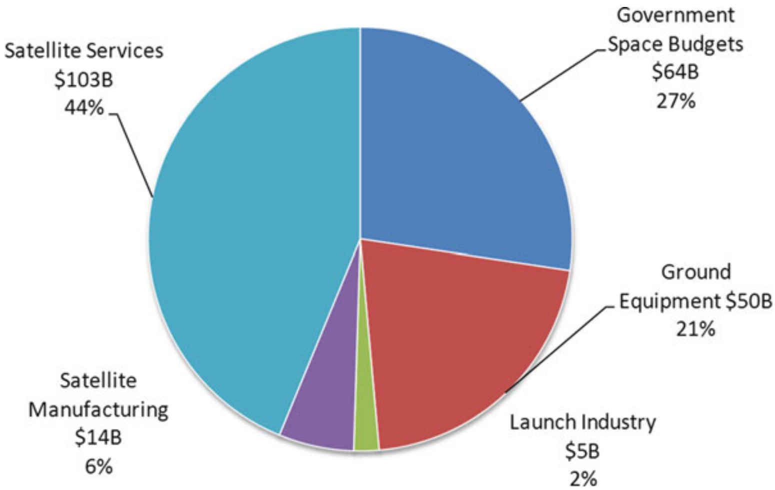

Fig. 2.4 The economic footprint of the space industry in 2009 (Source: OECD and SIA)

contractor and then add the total value of the satellite on top of that, we will be double counting the total value.

The breakdown of the commercial space sector revenues also provides some interesting facts. Satellite applications are by far the leading segment in the space industry, and about 84 % of the aggregate revenues come from a single application, satellite telecommunications. In recent years, the satellite navigation segment has grown at a rapid pace, as location-based services started gaining more importance. In terms of growth rates, direct-to-home broadcast and satellite navigation segments are the two leading segments. Earth observation (EO), a relatively mature segment of the space industry, accounts for about 1 % of the total commercial sales (Fig. 2.3). (This figure does not include the EO products and services purchased by governments).

In order to get a global estimate of the direct economic value of the space sector for any given year, we can add up the public space budgets and private sector revenues. Of course care is needed to avoid double counting. A good portion of the public space budgets flow to the private sector in the form of contracts. For 2010, this global figure encompassing all space activities was in the range of $235–277 billion, depending on which sources we use. This figure excludes indirect benefits (such as spin-offs) as well as the book value of the assets in the sector (e.g., launch pads). So, to sum up, the global economic footprint of the entire space industry is in the range of a quarter trillion dollars.

The workforce of space professionals can also be seen as a key indicator of the global space industry. OECD reports that about 170,000 employees work in space manufacturing in the United States, about 31,000 in Europe and 50,000 in China.[6] Just like for space budgets, different sources don't always agree on these numbers; for example the Space Foundation reports that the U. S. space workforce was composed of 250,000 individuals in 2010.[4] Although it is harder to get statistics for other spacefaring nations, such as India, Brazil, Turkey and other emerging economies, a conservative estimate would be at least another 50,000–70,000 space professionals.

Satellite Applications: Meet the Three Musketeers

Satellite applications have become so ubiquitous today that they may be the victim of their own success. Various types of infrastructure in space support many activities in our daily lives that we easily take granted. From withdrawing cash from ATMs to regulating traffic lights, signals from space drive millions of transactions in our economy. Our quality of life is critically dependent on the flawless operations of a thousand satellites circling the globe.

Satellite Telecommunications

In 1945, a young British engineer published an article in *Wireless World* magazine proposing to cover the entire globe using three telecommunications satellites. This elegant concept, based on these "stationary" orbital points in the sky with respect to the rotating Earth below (GEO orbit) spurred a brand new industry: satellite telecommunications. Sir Arthur C. Clarke's vision, not taken very seriously when it was introduced, became a reality within 20 years with the launch of the experimental commercial satellite, Telstar, in 1962 and the launch of Intelsat I Early Bird (the first commercial geostationary communication satellite) in 1965. Since then, especially GEO – sometimes called "Clarke orbit" in honor of Sir Clarke – has become prime real estate in space, with hundreds of commercial satellites now strategically placed to cover the globe with their signals.

Since the early 1990s, the private sector has been evolving into a more prominent role. At the height of the dot.com boom, satellite telecommunications saw an unprecedented amount of interest for ambitious projects involving hundreds of new satellites, especially in LEO. Mobile satellite telecommunication systems such as Iridium, ICO, Globalstar, and Orbcomm, plus proposed broadband systems such as Astrolink and Teledesic, attracted billions of dollars of private investment. These projects envisioned a dense constellation of satellites providing mobile telecommunications services on a global basis. Unfortunately, just like the sudden rise of these projects, their collapse was also spectacular. Many of them never moved beyond blueprints, and only a few made it to orbit. Some of these new mobile satellite systems have managed to survive, but as a shadow of their original vision. These systems went through bankruptcy proceedings and were typically bought on a distress sale basis for a small fraction of their original valuations.

These past episodes have made it very difficult for space ventures to raise funding, and the drama in the capital markets seems far from over. More recent examples are two companies based in the United States, LightSquared and Terrestar, which planned to combine satellites with broadband mobile terrestrial services as a "hybrid network" principally for the U. S. market. After spending billions of dollars building and launching some of the most massive and sophisticated communications satellites ever conceived, both of these companies have declared bankruptcy. Only the Inmarsat and Thuraya ventures, employing geosynchronous satellite technology, has managed to maintain consistently profitable mobile satellite operations for a sustained period of time.

In stark contrast to the mobile segment, fixed satellite services evolved into a stable and profitable business. This business model is akin to commercial real estate. Satellite operators lease capacity to content providers and telecommunications companies on a long-term basis. The leased capacity is used to provide a host of services, including TV and radio broadcasting and long-distance telephony.

Global Navigation Satellite Systems

Global Navigation Satellite Systems (GNSS) is the generic term that refers to satellite navigation constellations in Earth's orbit. These constellations provide accurate positioning, navigation and timing information to users around the globe.

Currently, there are only two systems that offer global coverage: the U. S. Global Positioning System (GPS) and the Russian GLONASS system. Although other countries have operational navigation satellites, such as the European Galileo, the Indian Regional Navigational Satellite System, the Japanese Quazi-Zenith Satellite System and the Chinese BeiDou/Compass systems, none of these systems provides global coverage at this time.

Originally designed as a military navigation system, satellite navigation has branched out to business-to-business applications (such as surveying) and business-to-consumer applications (such as car navigation). In recent years, the widespread adoption of smart phones with built-in satellite navigation capability has dramatically increased the number of people who regularly use GPS signals as part of their daily lives. The timing function is also vital for a number of scientific and governmental applications. This precision timing capability, enabled by the on-board atomic clocks, has also been used for various applications such as security verification.

Since the GPS signals are provided for free, developing a business case around the space segment is fiendishly difficult. Thus, business opportunities are to be found elsewhere, closer to the end user (also known as the downstream part of the market). Not surprisingly, the lion's share of the GNSS revenues comes from the sales of receivers and associated services to end users. The development of competing GNSS systems is thus largely due to national security reasons rather than an economic rationale. In fact, one can argue that there will be an oversupply of satellite navigation signals once the European, Japanese, Chinese and Indian systems become operational.

A key milestone in the evolution of the satellite navigation was in May 2000, when the U. S. federal government disabled the Selective Availability feature, instantly boosting the precision of the GPS signals for civilian users. In 2007, the U. S. Department of Defense, which procures and operates the GPS satellites, permanently disabled the intentional degradation of the satellite signals.[7] This policy decision significantly reduced the uncertainty surrounding high precision GPS signals for civilian and commercial applications. It has big implications for critical operations such as air traffic control, and it is likely to increase the adoption of GPS-enabled operations in many economic sectors.

Europe is currently deploying its own satellite navigation system, Galileo. When it becomes fully operational towards the end of this decade, Galileo will provide high-precision satellite navigation capability on a global basis.[8] Galileo is designed to be interoperable with GPS and GLONASS and, unlike the GPS, it will be entirely under civilian control. When Galileo joins GPS and GLONASS as an operational satellite navigation system, users will have access to more than 75 satellites.

Certainly such a level of coverage will create a well-developed and reliable upstream segment for the market with a high degree of redundancy. This would virtually guarantee the integration of satellite navigation and timing-based products and services in our daily lives, including in sensitive application areas such as air traffic control and driverless cars.

Remote Sensing

Remote sensing, also known as Earth observation, is one of the most important space-based capabilities at our disposal. Today, thousands of spaceborne instruments are orbiting around Earth, taking the pulse of our environment with precise measurements across the electromagnetic spectrum.

Holding the higher ground has always been a strategic objective throughout history. Successive technological developments such as observation towers, balloons and aircraft were employed to keep an eye on our surroundings. In this sense, remote sensing is nothing new. However, access to space, coupled with advances in electro-optics has opened up a wide variety of orbits around the Earth and carried us to the ultimate higher ground.

The bits of information flying back and forth from these orbiting satellites to Earth provide crucial scientific, military and commercial capabilities. Some of the primary applications of remote sensing include agriculture (e.g., crop classification), forestry (e.g., monitoring deforestation), geology (e.g., mineral exploration), hydrology (e.g., flood mapping and monitoring), meteorology (e.g., numerical weather prediction) and security (e.g., missile launch detection).

On the commercial front, many companies are actively working on developing innovative products and services using remote sensing data. Once the exclusive domain of top secret government operations, high-resolution optical systems are now widely available for commercial applications. Access to high-resolution remote sensing data at a reasonable cost has rapidly increased the scope and variety of these products and services. For example, by using satellite imagery, Remote Sensing Metrics, a U. S. company, is able to create economic activity indicators that are then used as part of economic forecasts. These indicators cover many different economic sectors, such as the number of cars in the parking lot of a shopping mall, the number of shipping containers stockpiled in a port, or the height of the storage tanks in refineries. By observing the changes in these indicators over time, remote sensing analysts can literally see economic cycles in action.[9]

Big Data and Satellite Applications

Another recent development that vastly expanded the use of satellite applications in business is "big data." Although there is no formal definition of big data, it largely refers to our ability to collect, store and analyze vast volumes of data and identify patterns and underlying trends in our economic, natural and political systems.

Vast reductions in the price of digital storage devices, the emergence of cloud computing and virtualization of computer systems have enabled the emergence of big data. A recent report published by McKinsey notes that the amount of data in the world has been exploding, and analyzing large volumes of data will become a central theme of the twenty-first century economic enterprise, unleashing new waves of productivity growth and innovation.[10]

Together, the three main satellite applications collect terabytes of data every day from a wide variety of sensors. Analyzing this "satellite big data" and combining it with other sources of information can create many new business opportunities.

One remarkable example is the Climate Corporation, a company founded by two former Google employees. This company acquired 60 years of crop yield data from the Department of Agriculture, including terabytes of information on soil types for the entire United States. Then, they merged this information with weather forecasts and other climate data from the National Weather Service to calculate the weather-related risks for corn, soybeans and winter wheat. This combined capability enabled the company to track these risks on a continuous basis and develop weather insurance products for farmers.

Another interesting example comes from the solar energy sector. Availability of solar irradiance at a project site is one of the primary factors which affect the profitability of a photovoltaic project. Solar irradiance, in turn, is affected by various atmospheric effects, such as cloud cover, water vapour and aerosols. Therefore, determining the characteristics of these effects at a project site is essential for conducting a profitability analysis and tracking the performance of a photovoltaic investment over time.[11] The imagery from meteorological satellites is very useful for this purpose.

Meteorological satellites, perched in GEO, such as the GOES series of NOAA or the METEOSAT series of EUMETSAT, are capable of imaging the entire disk of

Earth at frequent intervals. Typically, these satellites carry imagers operating at the visible and thermal infrared bands, ideal for detecting clouds.[12] In order to conduct a 10-year historical analysis of solar irradiance, more than 100,000 images need to be analyzed. Today, thanks to advances in data storage and processing power, this type of analysis can be conducted within hours, turning raw satellite imagery into insights for business decisions.

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