Sputnik, The Beep-Beep-Beep Heard Around the World: An Analysis of the Orbital Trajectory of *Sputnik* and its Reception in the Soviet Union

Independent Study Thesis

Presented in Partial Fulfillment of the Requirements for the Degree Bachelor of Arts in the Departments of Mathematics and Russian Studies at the College of Wooster

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2019

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Abstract

The purpose of this undergraduate thesis in the fields of Mathematics and Russian Studies at the College of Wooster is to explore the mathematical and cultural significance of the launch of the first artificial Earth satellite, *Sputnik 1*, and how it was perceived by the Soviet Union and the rest of the world. The historical perception of this launch is established through discussion of the connected series of scientific achievements that led to the inevitable launch of the first artificial Earth satellite made by the Soviets as well as the analyzation of the initial press coverage after the launch. Focus is also given to the theory of orbits and Kepler Laws to establish a more technical understanding of the complications faced in order to launch a satellite into orbit.

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Chapter One

The First Artificial Earth Satellite, *Sputnik 1*

The year is 1957 and the Soviet Union has just launched *Sputnik 1*, an artificial Earth satellite, into the atmosphere, shocking the world and kicking off the competition between the USSR and the USA in space exploration[1]. It is the culmination of months of hard work and ingenuity at the hands of Soviet scientists and marks, for the Soviet Union, the beginning of their establishment as a world superpower. Tensions between the USSR and the USA have been high as they both race to be the first to enter space.

In December of 1954, Sergei Korolev, the chief Soviet rocket scientist, proposed a new plan for an artificial satellite to Dimitri Ustinov, the Minister of the Defence Industry. It summarized a report made by Mikhail Tikhonravov, a Soviet aerospace engineer and scientist, that described similar projects abroad. Tikhonravov believed that the launch of an orbital satellite was an inevitable next step in the development of rocket technology. Not even seven months later, in June 1955, US President Dwight D. Eisenhower announced that during the International Geophysical Year[2] the United States would launch an artificial satellite. Within a week following

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[1] For more information see Levine, Alan J. *After Sputnik: America, the World, and Cold War Conflicts*. New York: Routledge, 2018.

[2] The International Geophysical Year was an international scientific project from July 1, 1957 to December 31, 1958 that marked the end of the period of the Cold War where scientific exchange between the East and the West had been seriously interrupted.

this announcement, on 8 August, the Politburo of the Communist Party approved Korolev's proposal for the creation of an artificial satellite, jumpstarting the space race into high gear.

On January 30th 1956, the Council of Ministers approved the practical work that had been done on an artificial satellite that would orbit the Earth. They called this satellite, *Object D*, and its completion was expected in 1957-1958. In their book *Russian Space Probes: Scientific Discoveries and Future Missions*, Brian Harvey and Olga Zakutnyaya describe the specifics of *Sputnik 1*'s design as well as the history behind its creation. Its planned mass was to be of 1,000 to 1,400 kg and it would be able to carry between 200 to 300 kg of scientific instruments (Harvey). Its first test was planned for 1957. Its preliminary designs included plans for the scientific tasks that the satellite was expected to complete, like: measuring the density of the atmosphere and its ion composition, the solar wind, magnetic fields, and cosmic rays. All of these calculations would aid in the further development and creation of future artificial satellites. All the data collected was to be transmitted back to a system of ground stations that would observe the satellite's orbit and transmit commands to the satellite. However, as 1956 came to its close it soon became clear that due to the complexity of *Object D*'s design and the many scientific tasks it was expected to complete, it would be unlikely that it would be able to be launched in time because of the difficulties that scientists and engineers were encountering in creating scientific instruments. Therefore, its launch was rescheduled for April 1958.

Due to the setbacks they were experiencing with *Object D*, the USSR feared that the US would be able to launch a satellite before it was completed. Because of this, a new satellite design was suggested in May 1957 before the International Geophysical Year began in July 1958. This new satellite would not be as technologically advanced as *Object D* and would, therefore, weigh much less and be easy to construct. All of the scientific instruments were scrapped and replaced with a simple radio transmitter. In February 1957, the much simpler satellite, now known as *Object PS*, was approved by the Council of Ministers of the USSR. One interesting fact about this new satellite is that Earth-based observers would be able to track the satellite visually and hear the tracking signals it transmitted to ground-based receiving stations.

In order to launch this revolutionary satellite into space, Sergei Korolev decided to modify the intercontinental ballistic missile, R-7, and use it as *Sputnik*'s carrier vessel, although it was originally meant to launch *Object D* into space, which Asif Siddiqi details in his article "Korolev, Sputnik, and the International Geophysical Year" (43-72). The R-7 rocket was first launched on May 15, 1957. However, it was not entirely successful as a fire broke out inside the rocket mere seconds after it had lifted off from the ground, causing it to crash 98 seconds into its flight. The second launch of the rocket was attempted three times before it proved to be entirely unsuccessful due to an assembly defect in June. On July 12, the third attempted launch was also unsuccessful due to an electrical short that caused the vernier engines to put the missile into an uncontrolled roll. This roll forced the rocket's strap-ons to become loose 33 seconds into the launch and ultimately ended in the rocket crashes 7 km from the launch site. On August 21, the fourth launch of the rocket proved to be successful.

1.1 The Design of *Sputnik 1*

According to Harvey and Zakutnyaya, *Sputnik* was primarily constructed by Mikhail S. Khomyakov. It was 585-mm in diameter sphere (see Fig. 1.1)[3]. It was built from two hemispheres that were hermetically[4] sealed with o-rings and connected by 36 bolts. It's mass was approximately 83.6 kilograms. The hemispheres were 2 mm thick and covered with a 1-mm thick heat shield made of an aluminum-magnesium-titanium alloy that was highly polished. The satellite had two pairs of antennas that extended from the bottom of the satellite. Each antenna consisted of two whip-like parts that 2.4 and 2.9 meters in length with an almost spherical radiation pattern (Harvey).

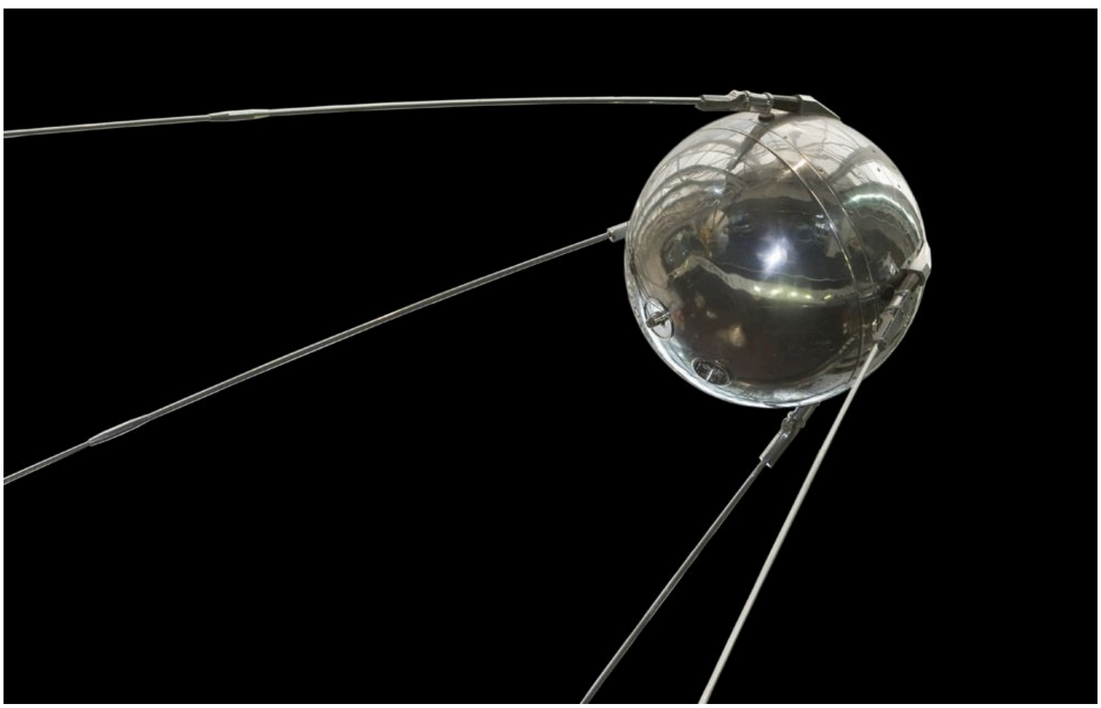

Figure 1.1: The first artificial Earth satellite, *Sputnik 1*

[3] Source: Mark Thiessen, "Oct 4, 1957 CE: USSR Launches Sputnik." *National Geographic*, https://www.nationalgeographic.org/thisday/oct4/ussr-launches-sputnik/.

[4] A hermetic seal is any type of sealing that ensures a given object is airtight, that is, it excludes the passage of air, oxygen, or other gases.

Sputnik's power supply weighed about 51 kg and was shaped like an octagonal nut with the radio transmitter in its hole. *Sputnik* was powered by three silver-zinc batteries, two of which powered the radio transmitter and the other powered the temperature regulation system. The batteries were expected to last two weeks; however, they operated for 22 days (see Fig. 1.2)[5]. The power supply turned on automatically the moment that *Sputnik* separated from the second stage of the rocket.

Sputnik's radio transmissions were carried out by a one-watt, 3.5 kg radio transmitting unit that was housed inside the satellite. The transmitter worked on two frequencies, 20.005 and 40.002 MHz. Signals from the first frequency were transmitted in 0.3 second pulses with pauses of the same duration filled by pulses on the second frequency. These radio signals were used to collect data on the electron density of the ionosphere, with temperature and pressure encoded in the duration of the radio beeps.

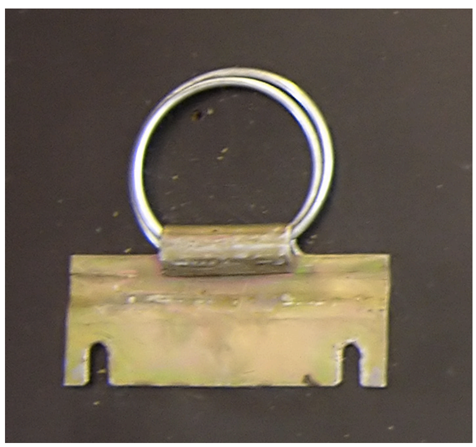

Figure 1.2: The last remaining piece of *Sputnik 1*. It is a metal arming key that prevented contact between the batteries and the transmitter prior to launch.

[5] Source: "Sputnik 1." *Wikipedia*, https://en.wikipedia.org/wiki/Sputnik_1.

The satellite also contained a temperature regulation system that consisted of a fan, a dual thermal switch[6], and a control thermal switch. This was a crucial component of the satellite's design as it controlled the temperature inside the satellite in order to maintain the scientific instruments on board. If the temperature inside the satellite exceeded 36°C the fan was turned on and if the temperature fell below 20°C the fan turned was turned off by the dual thermal switch. However, if the temperature began to exceed 50°C or fell below 0°C , another control thermal switch activated, changing the duration of the radio signal pulses.

Sputnik 1 was filled with dry nitrogen that was pressurized to 1.3 atm. It had a barometric switch that activated if the pressure inside the satellite fell below 130kPa, as this would indicate failure of the pressure vessel or a puncture by a meteor, and would, therefore, have changed the duration of the radio signal impulse (Harvey). While *Sputnik 1* remained attached to the rocket, it was protected by a cone-shaped payload fairing, that was approximately 80 cm tall. This fairing separated from both *Sputnik* and the rocket at the same time as the satellite was ejected from it.

1.2 Before *Sputnik*: A Historical Overview

The Soviet Union's dream of space exploration did not start in 1957 but in fact many years before, most significantly with the birth of Konstantin Eduardovich Tsiolokovskiy in 1857, who once said "Humankind will never stay on Earth forever but in pursuit of flight and living in space it will, cautiously at first, go beyond the atmosphere and then conquer for itself the whole Solar System" (Mozzhorin 22). Tsiolokovskiy was a Soviet rocket scientist who is widely

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[6] A thermal switch is a device which normally opens at a high temperature and re-closes when the temperature drops. Thermal switches are used in powers supplies in case of overload, or in some heating and cooling systems such as thermostats.

regarded as one of the founding fathers of modern rocketry and astronautics. Tsiolokovskiy outlined how to build multi-stage rockets, construct space stations, and travel through the solar system.[7] He developed a formula, known as "Tsiolokovskiy's Equation," a formula for rocket propulsion that is still the basis for all rockets. This equation demonstrated that the final acceleration of the rocket would depend on such factors as the initial masses of the rocket and the propellant as well as the speed of exhaust gases from rocket engines (Gorin 14). Before the development of the rocket was completed, the only other possible avenue open to space science was the balloon. Gavril Tikhov, a Soviet astronomer, born in 1875, while apprenticing in France, ascended in a balloon over Paris with fellow Russian astronomer Alexei Gansky and their French colleagues in order to observe meteors (Harvey 3-14). It was this flight that sparked the desire of the Soviets to also send a balloon into the atmosphere in order to investigate its composition which led to the further development of rocketry in the Soviet Union and eventually the push to launch a satellite into space. All of these technological advancements can be traced back to the Vladimir Lenin's push towards modernizing Russia following the October Revolution in 1917.

Following the 1917 revolution, OSOAVIAKHIM, the Society for the Promotion of Air Travel, developed a new method of transportation, ballooning. OSOAVIAKHIM built the first scientific balloon in Russia that was equipped with scientific instruments allowing for the measurement of cosmic rays, atmospheric temperature, winds, the ozone layer, the Sun, and the stars. This was the dawn of a new age of space science. The scientists rode in a sealed, pressurized, and heated gondola that contained oxygen bottles and carbon dioxide removers, a vehicle that could be considered the precursor to the modern spaceship. The gondola featured

[7] For more information see Tsiolokovskiy's *Issledovaniya mirovykh prostranstv reaktivnymi priborami (Exploration of Space by Reactive Devices).*

eight 80-mm windows that the scientists used to conduct their observations. The gondola was also equipped with long-range radios in order for the balloon travelers to maintain contact with ground control.

The first official balloon developed in the Soviet Union was *USSR-1*, a hydrogen-filled Soviet Air Forces high-altitude balloon. It was the first Soviet scientific balloon to make its ascent into the atmosphere. On September 30, 1933 two pilots, Georgi Prokofiev and Ernest Birnbaum, and one rubber technologist, Konstantin Godunov were propelled into the air over Moscow's Frunze Airport, adorned with protective suits, a radio transmitter, and communications soft-hats. Their aim was to take samples of the atmosphere and trap cosmic rays as well as study the Earth's atmosphere using barographs, thermometers, altimeters, and variometers. As they rose into the sky the trio of aeronauts studied the Sun using special light filters and collected air samples. Their findings were the first attempts that were made to reach space previously unknown. While the connection between this balloon flight and the first flights into space might not seem immediately apparent to most, it was to Tsiolokovskiy. It was also the first time that the Soviet Union was recognized by the rest of the world for their advancement in space science. The *New York Herald Tribune* hailed the flight of the *USSR 1* as "a historic achievement of Soviet science." (Harvey 6).

Following the launch of the *USSR 1*, Sergei Korolev pursued a new line of thought that would eventually lead to the launch of the first artificial Earth satellite. He persuaded the Soviet Academy of Sciences to allow him to present a paper which detailed the next advancement in stratospheric studies, a high-altitude rocket. According to Harvey, the Academy was open to the idea and the next year a follow-up conference was organized on the theme of "The Uses of

Rocket-Propelled Craft for the Exploration of the Stratosphere"(8). It was here that Korolev outlined a rocket ascent into the atmosphere with both scientific instruments and pilots on board. The Academy of Sciences proceeded to establish an Astronomy Council in 1936, more commonly known as Astrosoviet. While the academics deliberated on how to move forward with Korolev's presented ideas, a further three balloons were made to continue their scientific observations of the atmosphere: *OSOAVIAKHIM 1*, *USSR 1*bis, and *Komsomol*. Further work on balloons was halted in the late 1930s, when Stalin unleashed the Great Purge. Very few of the leading scientists and rocketeers escaped. Some were shot, many, including Korolev, were sent to the GULAG while others continued their work under house arrest. Any talk of space science risked the accusation of treason as it diverted attention away from where it was most needed, meeting the threat of counter-revolution. When the Germans invaded the Soviet Union during World War II, the country needed all of its workers and citizens attention on defeating Hitler and his troops. Therefore, research into new technology, like rockets, was severely limited as it had little practical application in the USSR at the time, and further advancement into long-range guided cruise missiles was halted a few years before with the arrest of Korolev (Gorin 28-29).

Once the war concluded, space science was allowed to progress once more. After the war, the Soviets were allowed to reap the benefits of their victory and transferred all of the Germans' rocket hardware, technology, and personnel to the Soviet Union. Stalin, seeing the rapid advancement of German rocketry, decided to build up rocket industry within the Soviet Union. New facilities were built in Moscow, a launching range opened near Stalingrad called Kapustin Yar, and a design council was formed, led by Sergei Korolev, who was appointed chief designer. On October 18th 1947, the Soviet Union launched its first captured German A-4 rocket and, a year later on 10th October 1948, launched its own domestically built version, the R-1.

According to Harvey and Zakutnyaya, the R-1 was the first example of a rocket adapted and used for scientific purposes (14-20). Despite Stalin's interest in rockets being limited only to how they would aid the Soviet Union in war, Korolev was able to continue to fly them for scientific purposes on the basis that something useful could be added into the nose cone. These rockets adapted to scientific purposes were known as the *Akademik* tests and there were five subsets, named A, B, V, D, and E after the first five letters of the Cyrillic alphabet. The first of the *Akademik* series, the R-1A, launched on 21st April and 24th May 1949, quickly followed by the R-1B in 1950 and the R-1D and R-1E in 1955. The R-1D and R-1E rockets had side containers weighing 65 kg that measured the chemical composition of the atmosphere. Once they reached altitude, the containers would separate and parachute down, with the two falling from the sky parallel to one another. The nose cone would also detach from the rocket.

The *Akademik* series carried out experiments for solar, ultraviolet, and X-ray measurements, chemical, and mass spectrometer analysis of the atmosphere and tested for micrometeorites. Such observations made it possible to measure cosmic rays, the atmosphere, and its ionospheric parameters, like content and temperature. This information was especially pertinent to rocket engineers, as winds, temperature, gaseous content, and radio wave propagation were significant for rocket and missile development. These rockets provided around 10 minutes of flight time above the atmosphere.

The *Akademik* series continued to develop more and more rockets that ascended further and further in altitude as the years progressed. The observations conducted using these rockets allowed science and technology to progress further. In 1949, Sergei Korolev had the idea of putting animals into these rockets (20-23). It was decided that dogs were the preferred animal to be launched into space as they are small in size, light in weight, easy to handle, and "the best predictor as to how humans might respond in such key areas as breathing, blood circulation, and reaction to stress," (Harvey 20). Another point in their favor is that they are small enough to fit inside rockets.

It was decided to fly two dogs at the same time in order to eliminate any differences their personalities might have on their reactions. For their flights into the atmosphere, the rockets were fitted with cameras in order to observe the dogs' responses, like how they would react to acceleration, deceleration, noise, weightlessness, and vibration. The first dogs, Tsygan and Dezik, were launched into the atmosphere on July 22, 1951 on an R-1V from Kapustin Yar. Their launch and subsequent recovery was observed by Korolev. As the dogs were launched before dawn, the early morning light illuminated the sky making it easy to watch the rocket as it ascended to 100 km. After the main rocket impacted with a bright bang, the parachute carrying the nose cone and the dog container was clearly visible floating gently back to Earth. The Soviets had beat the Americans to the first biological launch by two weeks. The following two missions were classified as failures when both dogs on each launch died before returning back to Earth. These missions carried on throughout the summer of 1951 and were picked back up from 1954 to 1956 and the results of these missions were published in Paris at an international conference in December 1956 as "Vital Activity of Animals during Rocket Flights into the Upper Atmosphere."

Due to the success the Soviets experienced with these missions, they decided to push their efforts even further by using a more powerful rocket for higher and longer missions. The

R-2 rocket, whose scientific version was called the R-2A, was able to reach orbital height, 180 km. The nose cone was able to house two dogs in a hermetically sealed cabin with a film camera installed overhead for observation. Radio telemetry, called *Tral*, was used to transmit blood pressure, pulse, respiration, and electrocardiograms. The first flight was made by Ryzhaya and Damka on May 16 1957 and proved to be successful with the dogs experiencing weightlessness for 6 minutes, twice as long as the first flight made in 1951. The second was disastrous in comparison with the loss of both dogs on board. The descents from the R-2A caused much higher G forces, up to 8G, which caused the animals to experience some bleeding which was a warning of the possible effects on cosmonauts. The next three series of flights proved to be successful and even launched the animals to an altitude of 400 km, far out into space, when using the new R-5A rocket. These dog tests indicated that it would be possible to put dogs into orbit, which could lead to further information as to how humans might respond to space travel, which was the ultimate goal. However, before this could be achieved, more data had to be collected on the Earth's atmosphere and space before a human could safely be launched into orbit. This lead to the creation of satellites, like *Sputnik*, that were used in order to gather this information and further the realization of this dream.

1.3 The Reception of *Sputnik 1*

Despite the Soviet Union providing details of *Sputnik 1* before its launch, few people outside the Soviet Union paid much attention to it. Its launch came as a shock to experts and observers in the United States, as they had hoped the United States would be the first to accomplish such a feat. The fact that it was the Soviet Union who had been the first to achieve this scientific advancement fed into the fears of the United States that they were falling behind in the development of new technology. It is because of this mindset that the launch of *Sputnik 1* resulted in the intensifying of the arms race and an increase in Cold War tensions. The Soviets successfully launched two additional satellites not long after, one even including a dog. Together they orbited the Earth every 90 minutes, and with every revolution increased the fear that the United States had started to fall behind in technological capability.

President Dwight D. Eisenhower tried to downplay the significance of the successful launch *Sputnik 1* to the American people, but his actions betrayed his words as he started to funnel additional funds and resources into the space program in the hope of catching up with the rapidly advancing Soviets. The United States suffered a severe setback and embarrassment when their first artificial satellite, *Vanguard*, exploded before it even left the launch pad. This served as a very stark and painful reminder of how much the United States still had to achieve in order to compete with the advancements being made by the Soviets. However, on January 31, 1958 the United States was finally able to launch its first satellite, the *Explorer*, into space, though it was still a smaller satellite than those launched by the USSR. Remarkably, the *Explorer* was launched much deeper into space than *Sputnik*, and so the space race continued on, with each side competing with the other in order to lead the world in scientific achievement.

Sputnik had a significant impact on relations between the United States and the Soviet Union, and therefore on the Cold War itself. It pushed the United States to accelerate space and weapons programs in the fear that they had fallen behind. In his book *After Sputnik: America, the World, and Cold War Conflicts*, Alan Levine states that in the late 1950s, the Soviet Premier, Nikita Khrushchev, repeatedly boasted about Soviet technological superiority and their growing stockpiles of ICBMs, which caused the United States to furiously work to develop its own mass amount of ICBMs in a hope of countering this supposedly growing stockpile of Soviet weapons directed against the United States (55-74). In this way the launch of *Sputnik* fueled both the space race and the arms race as it caused both sides to fear the scientific advancements of the other and then led them to develop further technology in an attempt to outdo one another.

Of course the reactions of the American people and the rest of the world did little to diminish this fear as they believed that the launch of *Sputnik* had two meanings: defeat and discovery. The Soviet's satellite by far exceeded the expectations people had for it, it was heavier than anything being developed by the Americans, which indicated higher rocket capabilities, and the satellite flew higher than any American scientist thought possible. As scientists around the world turned on their equipment to track *Sputnik* and radio stations and amateur astronomers alike turned on their radios in search of that iconic sound -- a sound that TIME magazine called "those chilling beeps," simultaneously acknowledging the remarkable scientific achievement made by the USSR as well as the concrete proof of Communist success in the Cold War world where technological advancement was seen as a proxy for military might (Rothman).

While Americans viewed this launch as a defeat and feared the rising power of the Soviet Union, the Soviets saw this as the culmination of decades of hard work by Soviet scientists, engineers, and workers as well as a validation of the superiority of communism over capitalism. In fact, the article announcing the successful launch of *Sputnik* in the Soviet state newspaper *Pravda* is titled, " A Great Victory in the Peaceful Competition with Capitalism" (*Pravda* 1-2). For the purpose of this project, this article has been translated from Russian into English in order to fully analyze the language used by the official state newspaper of the Soviet Union in describing their success. The reception of *Sputnik 1* in the Soviet Union was very politically charged and celebratory, as it was symbolic of communism triumphing over capitalism. Therefore, this article is central to this IS because of its discussion of how the Soviet Union as whole viewed the launch of the first artificial Earth satellite into orbit as well as their critique of the rest of the world who doubted their ability to make extraordinary scientific advancements. This article written for the masses, which makes its inclusion of such a technical description of the mechanics behind construction of *Sputnik* truly unique. *Sputnik* was not just extraordinary in the context of world history but also in the scientific sphere as it was the culmination of centuries of hard work made by countless physicists, scientists, and mathematicians.

Chapter Two

The Preliminaries of Orbits

For centuries, astronomers have attempted to unravel the complexities of space and the motion of celestial bodies. The orbit of celestial bodies around one another are not so different from satellites orbiting a planet. In order to analyze the orbits of satellites, like Sputnik, it is important to understand the basic concepts of orbital motion and celestial mechanics, starting with conic sections (see Fig. 2.1).[8]

2.1 Conic Sections

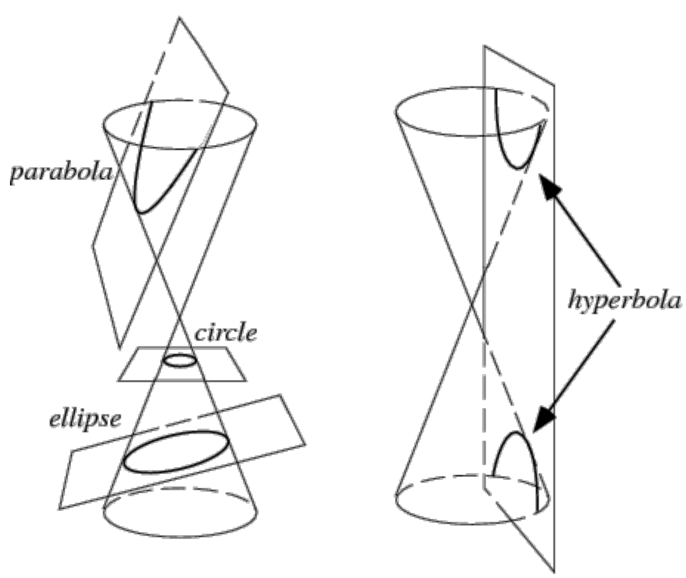

Figure 2.1: Conic sections in relation to right circular cones

[8] Source: "Conic Section." *Wolfram - MathWorld,* http://mathworld.wolfram.com/ConicSection.html.

Conic sections are figures or curves that are formed by the intersection of a plane with a right circular cone (Smail 271). Conic sections can be placed into four separate groups: circles, ellipses, parabolas, or hyperbolas, depending on the angle of the plane with respect to the cone. These conics are specified by their *eccentricity*.

Definition: *An **orbital eccentricity**, e, of an astronomical object, is a parameter that determines the amount by which its orbit around another body deviates from a perfect circle* (Finney 434).

So, conic sections (see Fig 2.2)[9] can be defined based upon their orbital eccentricity, denoted '*e*':

- If $e = 1$, the orbit is circular.
- If $0 < e < 1$, the orbit is elliptical.
- If $e = 1$, the orbit is parabolic.
- If $e > 1$, the orbit is hyperbolic.

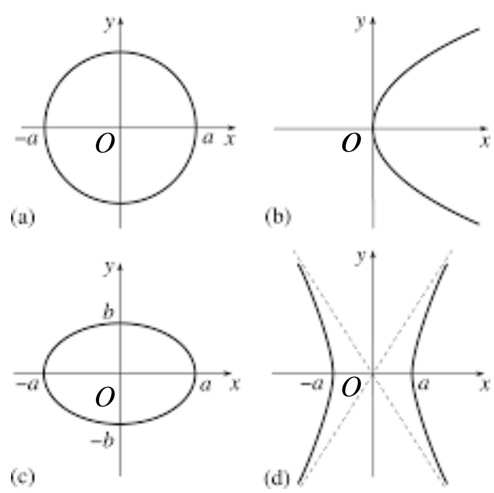

Figure 2.2: Conic Sections (a) circle, (b) parabola, (c) ellipse, (d) hyperbola centered at the origin *O*

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[9] Source: https://www.open.edu/openlearn/science-maths-technology/mathematics-and-statistics/vectors-and-conics/content-section-4.1.

When Johannes Kepler was attempting to explain the orbit of Mars around the Sun, he rediscovered the notion of an ellipse that had first been defined by the Greek geometers (Caperdou 2). From there, in conjunction with Newton's theory, astronomers proved that the trajectory of a body subject to a gravitational force could not only form an ellipse, but also a parabola or even a hyperbola (see Fig. 2.3)[10].

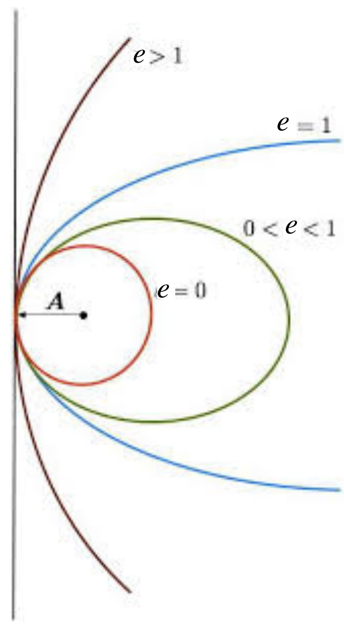

Figure 2.3: Hyperbolic, parabolic, elliptic, and circular orbits as defined by eccentricity.

When observing satellites, circular and elliptical conics are the most prominent as they are bounded curves that form closed orbits, mirroring the motion of satellites orbiting the Earth. Hyperbolic and parabolic conics describe bodies that are not permanently in the system, like asteroids, or bodies that gain enough momentum to escape the orbit.

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[10] Source: "Chapter 9: Central Forces and Orbital Mechanics." https://courses.physics.ucsd.edu/2010/Fall/physics110a/LECTURES/CH09.pdf.

2.1.1 Ellipses

For satellites, like *Sputnik*, the ellipse is the most important of all of the conic sections, as it constitutes the only periodic trajectory, or closed trajectory as it is a closed curve (Caperdou 2). In this case, the ellipse, the orbit of the satellite, will be viewed as a geometrical object localized by its focus and specified by its eccentricity *e*. We can now define an ellipse and specify its properties.

Definition: *An **ellipse** is the locus of points M in the plane such that that the sum of the distances MF and MF' to two fixed points F and F′, called the foci, is constant* (see Fig. 2.4)[11] (Caperdou 2).

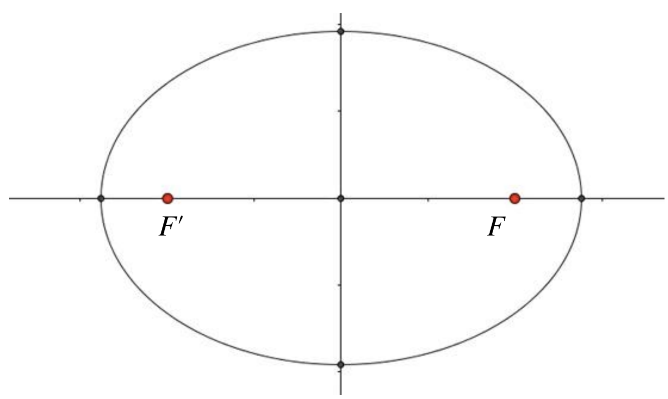

Figure 2.4: Ellipse of two fixed points *F'* and *F*

From this definition, specifically for an ellipse with foci F and F', we have

$$F'P_1 + FP_1 = F'P_2 + FP_2 \tag{2.1}$$

for any P_1 and P_2 on the ellipse. There is a straight line that passes through the two foci that is known as the *principal axis* of an ellipse, and the midpoint of this line is called the *center* of the ellipse (Smail 246). So, the center is the intersection of the major and minor axes. That is, the *major axis* is the maximum diameter of the ellipse and the *minor axis* is

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[11] Source: “The 9 Elements of the Ellipse.” https://www.lifepersona.com/the-9-elements-of-the-ellipse.

its minimum diameter. Therefore, the *semi-major axis* (a) is half of the major axis and the *semi-minor axis* (b) is half of the minor axis. These two values represent the maximum and minimum radii of the ellipse as they are half of the maximum and minimum diameter of the ellipse.

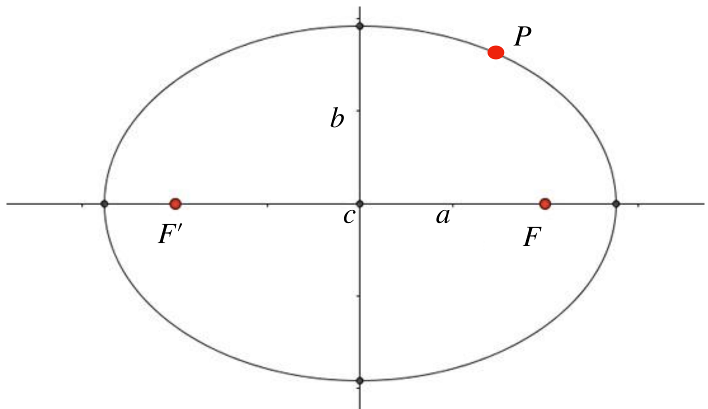

Figure 2.5: Ellipse where P is any point on the ellipse, b is the semi-minor axis, a is the semi-major axis, c is the center, and F' and F are the foci.

In order to obtain the standard form of the equation of an ellipse, we will let the principle axis to be the *x-axis* with the origin at the center. Let $F(c,0)$ and $F'(c,0)$ be the foci of the ellipse and allow $P(x, y)$ to be any point on the ellipse. We will also define the endpoints of the semi-major and semi-minor axes to be $A(a,0)$ and $B(0,b)$, respectively. By the definition of an ellipse we have that $F'P_1 + FP_1 = F'P_2 + FP_2$ for any P_1 and P_2 on the ellipse. So, we know $FP + F'P = FA + F'A$ by substitution. Using the distance formula, we have

$$\sqrt{(x-c)^2 + y^2} + \sqrt{(x+c)^2 + y^2} = 2a\ . \qquad (2.2)$$

By subtracting the second radical and squaring both sides of the equation, we obtain

$$\begin{aligned}
\sqrt{(x-c)^2+y^2}+\sqrt{(x+c)^2+y^2} &= 2a \\
\sqrt{(x-c)^2+y^2} &= 2a-\sqrt{(x+c)^2+y^2} \\
\left(\sqrt{(x-c)^2+y^2}\right)^2 &= \left(2a-\sqrt{(x+c)^2+y^2}\right)^2 \\
(x-c)^2+y^2 &= 4a^2-4a\sqrt{(x+c)^2+y^2}+(x+c)^2+y^2 \\
4a\sqrt{(x+c)^2+y^2} &= 4a^2+(x+c)^2+y^2-(x-c)^2-y^2 \\
4a\sqrt{(x+c)^2+y^2} &= 4a^2+x^2+2cx+c^2+y^2-x^2+2cx-c^2-y^2 \\
4a\sqrt{(x+c)^2+y^2} &= 4a^2+4cx \\
a\sqrt{(x+c)^2+y^2} &= a^2+cx\,.
\end{aligned}$$

Now, by squaring both sides once more, we have

$$\begin{aligned}
a\sqrt{(x+c)^2+y^2} &= a^2+cx \\
a^2(x^2+c^2+y^2)+2a^2cx &= a^4+2a^2cx+c^2x^2 \\
a^2x^2+a^2c^2+a^2y^2 &= a^4+c^2x^2 \\
x^2(a^2-c^2)+a^2y^2 &= a^2(a^2-c^2)\,.
\end{aligned}$$

Because $0 < c < a$ by the definition of an ellipse, therefore it is also true that $0 < c^2 < a^2$. So, we know that a^2-c^2 must be a positive number. Suppose we allow $b^2 = a^2 - c^2$ to be this positive number, then we get

$$b^2x^2+a^2y^2 = a^2b^2\,. \tag{2.3}$$

Since a^2 and $b^2 = a^2 - c^2$ are both non-zero, we are able to divide both sides of the equation by a^2b^2 in order to obtain

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1 \,, \tag{2.4}$$

which is the standard equation for an ellipse (Smail 247).

Theorem 1: *If the foci are on the x-axis and the origin is midway between the foci, the equation of the ellipse is*

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1 \,, \tag{2.5}$$

where $2a$ *is the sum of the distances of any point on the ellipse from the foci, and b is defined by* $b^2 = a^2 - c^2$ *where* $2c$ *is the distance between foci* (see Fig. 2.6) (Smail 247).[12]

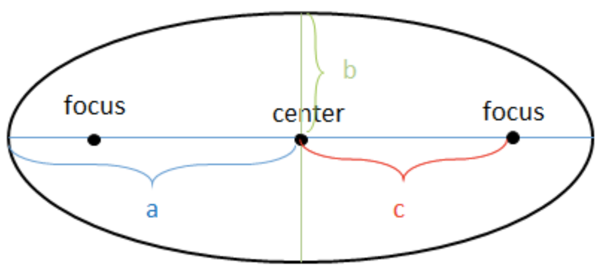

Figure 2.6: Ellipse where *2a* is the sum of the distances of any point on the ellipse from the foci, and *2c* is the distance between foci.

[12] Source: "Finding the Foci of an Ellipse." http://www.softschools.com/math/calculus/finding_the_foci_of_an_ellipse/.

2.2 Kepler Laws

In attempting to understand the orbital trajectory of the first artificial Earth satellite, commonly referred to as *Sputnik 1*, that was made by Soviet scientists and engineers in 1957, it is important to have a concrete understanding of Kepler Laws, the laws of planetary motion. Johannes Kepler was a German mathematician, astronomer, and astrologer that lived from 1571 to 1630. He is best known for his laws of planetary motion that laid the foundations for Isaac Newton's theory of universal gravitation Dreyer). Before the 16th and 17th centuries, the motion of any planet was believed to follow a completely circular geocentric path in accordance with the teachings of Greek philosophers Aristotle and Ptolemy. Any observed variations in the motion of planets were explained away by smaller circular paths that were overlaid on the larger path. During Kepler's time there was no clear distinction between the fields of astronomy and astrology as there is today; however, there did exist a formidable division between the fields of astronomy and physics. Kepler called his new astronomy "celestial physics," stating that it transformed the "ancient tradition of physical cosmology by treating astronomy as part of a universal mathematical physics" (Kepler 845). Kepler's laws of planetary motion were not well received at first. Many significant historical figures such as Galileo Galilei and René Descartes did not even acknowledge Kepler's *Astronomia nova*. They did not agree with Kepler's inclusion of physics into his astronomy, as they were regarded as two completely distinct fields.

Johannes Kepler's work with planetary motion was essential to the early histories of astronomy, like the 1758 work *Historie des mathématiques* by Jean-Étienne Montucla, a French mathematician and historian and *Historie de l'astronomie moderne,* written in 1821 by Jean-Baptiste Delambre, a French mathematician and astronomer. Kepler has become a symbol of scientific modernity and is regarded as a man ahead of his time. He has been described by Carl Sagan as "the first astrophysicist and the last scientific astrologer."[13]

Although Kepler designed his laws of planetary motion specifically with the movement of planets and the Sun in mind, his ideas can also be applied to the movement of other orbiting bodies, like the moon, comets, and satellites. According to James Stewart in his textbook *Calculus: Early Transcendentals*, these ideas can be derived and proven using calculus.

When contemplating astronomical phenomena, such as orbit, it is easiest to think of an ellipse in terms of its eccentricity and its semi-major axis, with length a (Stewart 666). Then we can express the distance d, from the focus to the directrix, the fixed line (see Fig 2.7)[14], in terms of a.

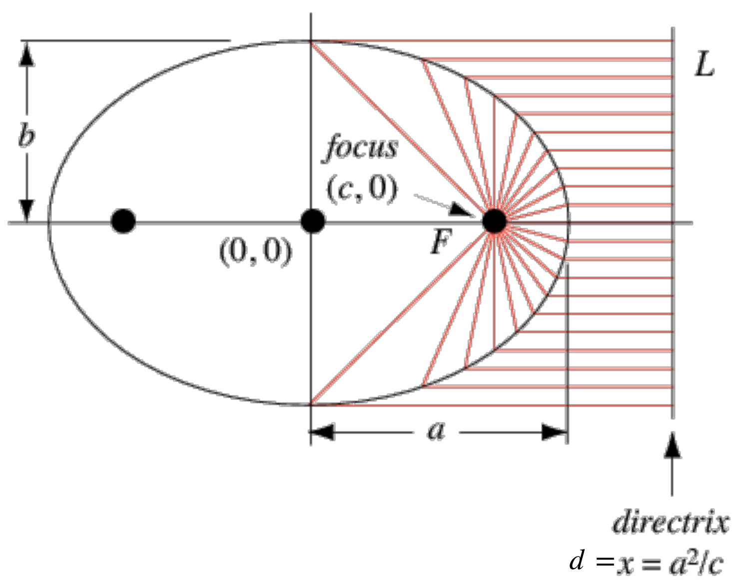

Figure 2.7: Directrix of an Ellipse centered at the origin.

[13] Quote from Carl Sagan, *Cosmos: A Personal Voyage*, episode III: "The Harmony of the Worlds".

[14] Source: Eric W. Weisstein, "Ellipse." *MathWorld — A Wolfram Web Resource*, http://mathworld.wolfram.com/Ellipse.html.

Suppose that the focus, F, is located at a pole and the directrix, l, a vertical line with the Cartesian equation $x = d$, where $d > 0$ and P has polar coordinates (r, θ), then we have $|PF| = |Pl|$ where $|PF| = r$ and $|Pl| = d - r\cos\theta$ (see Fig. 2.8)[15] while $|PF| = e|Pl|$, so

$$r = ed - er\cos\theta \tag{2.6}$$

(Stewart 663). Therefore, by solving for r, we have $r = \dfrac{ed}{1+\cos\theta}$.

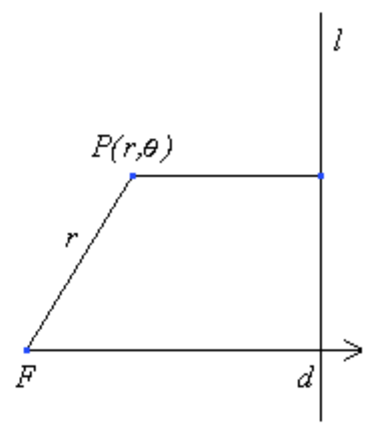

Figure 2.8: Graph of the polar equation *r*.

Now, we can square both sides of $r = ed - er\cos\theta$, to find

$$r^2 = e^2(d - r\cos\theta)^2. \tag{2.7}$$

Then, converting to rectangular coordinates, we have

$$\begin{aligned} x^2 + y^2 &= e^2(d-x)^2 \\ &= e^2(d^2 - 2dx + x^2) \\ &= e^2d^2 - 2e^2dx + e^2x\,. \end{aligned} \tag{2.8}$$

[15] Source: "11.8 Polar Equations of Conics," https://colalg.math.csusb.edu/~devel/IT/main/m11_conic/src/s08_polar-conics.html.

Now, we can rearrange Equation (2.8) in order to find $(1-e^2)x^2 + 2e^2dx + y^2 = e^2d^2$. Thus, if we complete the square we have

$$\left(x + \frac{e^2d^2}{1-e^2}\right)^2 + \frac{y^2}{1-e^2} = \frac{e^2d^2}{(1-e^2)^2}. \tag{2.9}$$

If we let $e < 1$, then we find that Equation (2.9) is the equation of an ellipse, so we have

$$\frac{(x-h)^2}{a^2} + \frac{y^2}{b^2} = 1, \tag{2.10}$$

where $h^2 = \dfrac{e^2d}{1-e^2}$, $a^2 = \dfrac{e^2d^2}{(1-e^2)^2}$, and $b^2 = \dfrac{e^2d^2}{1-e^2}$. Therefore, because the foci of the ellipse is at a distance, c, away from the center, we have

$$\begin{aligned} c^2 = a^2 - b^2 &= \frac{e^2d^2}{(1-e^2)^2} - \frac{e^2d^2}{1-e^2} \\ &= \frac{e^4d^2}{(1-e^2)^2} \end{aligned} \tag{2.11}$$

and, thus, we take the square root of Equation (2.11), to find $c = \dfrac{e^2d}{1-e^2}$.

So, from Equation (2.10), we have

$$\begin{aligned} a^2 = \frac{e^2d^2}{(1-e^2)^2} &\Rightarrow a^2(1-e^2)^2 = e^2d^2 \\ &\Rightarrow \frac{a^2(1-e^2)^2}{e^2} = d^2 \Rightarrow d = \frac{a(1-e^2)}{e} \Rightarrow ed = a(1-e^2)\,. \end{aligned} \tag{2.12}$$

If the directrix is $x = d$, then we can find the polar equation, $r = f(\theta)$. The *polar equation* is denoted $r = f(\theta)$, where r is the distance between the origin O and P, if P is any other point on the plane and θ is the angle between the polar axis, a ray starting at the origin, and the line *OP* (see Fig. 2.9)[16].

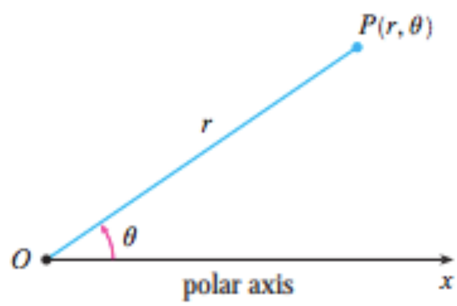

Figure 2.9: Polar axis and the line *OP*.

So, because $e = \dfrac{c}{a}$ and $d = x = r\cos\theta, y = r\sin\theta$ and we have defined the directrix as $x = d$, then we set

$$d = r\cos(\theta). \tag{2.13}$$

Therefore, we can substitute Equation (2.13) into Equation (2.12), and find

$$ed = er\cos\theta = a(1 - e^2). \tag{2.14}$$

Then, we find that the polar equation is

$$r = \frac{ed}{1 + e\cos(\theta)} = \frac{a(1 - e^2)}{1 + e\cos(\theta)} \tag{2.15}$$

with focus at the origin by Equation (2.6).

Now, if we recall from calculus, there is a theorem that states if θ is the angle between $\overrightarrow{a}$ and $\overrightarrow{b}$ (with $0 \leq \theta \leq \pi$), then $\|\overrightarrow{a} \times \overrightarrow{b}\| = \|\overrightarrow{a}\|\|\overrightarrow{b}\|\sin\theta$, we will use this theorem later on to derive Kepler's First Law of planetary motion. Now, before moving on we must prove another property of cross products, in 3-space,

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[16] Source: James Stewart, "10.3 Polar Coordinates," *Calculus: Early Transcendentals*, p. 639.

$$\vec{a} \times (\vec{b} \times \vec{c}) = (\vec{a} \cdot \vec{c})\vec{b} - (\vec{a} \cdot \vec{b})\vec{c}\,. \tag{2.16}$$

<u>*Proof:*</u> Suppose we have $\vec{a} \times (\vec{b} \times \vec{c})$, we can find the x component of this by:

$$\begin{aligned}(a \times (b \times c))_x &= a_y(b_x c_y - b_y c_x) - a_z(b_z c_x - b_x c_z)\\ &= b_x(a_y c_y + a_z c_z) - c_x(a_y b_y + a_z b_z)\\ &= b_x(a_y c_y - a_z c_z) - c_x(a_y b_y + a_z b_z) + (a_x b_x c_x - a_x b_x c_x)\\ &= b_x(a_x c_x + a_y c_y + a_z c_z) - c_x(a_x b_x + a_y b_y + a_z b_z)\\ &= (\vec{a} \cdot \vec{c})b_x - (\vec{a} \cdot \vec{b})c_x\,.\end{aligned} \tag{2.17}$$

Now, we can find the y and z components of $a \times (b \times c)$ similarly, and obtain

$$\begin{aligned}(a \times (b \times c))_y &= (\vec{a} \cdot \vec{c})b_y - (\vec{a} \cdot \vec{b})c_y\\ (a \times (b \times c))_z &= (\vec{a} \cdot \vec{c})b_z - (\vec{a} \cdot \vec{b})c_z\,.\end{aligned} \tag{2.18}$$

Therefore, by combining the x, y, and z components, we find

$$\vec{a} \times (\vec{b} \times \vec{c}) = (\vec{a} \cdot \vec{c})\vec{b} - (\vec{a} \cdot \vec{b})\vec{c}. \tag{2.19}$$

Q.E.D

With this property of cross products in mind, according to Stewart, we can follow Isaac Newton's steps in deriving Kepler's First Law of planetary motion (844).

A particle will move through space so that it has a position vector of $\vec{r}(t)$ at time t. So, for small values of h, the vector

$$\frac{\vec{r}(t+h) - \vec{r}(t)}{h} \tag{2.20}$$

approximates the direction that the particle is moving along the curve $\vec{r}(t)$. This vector, defined in Equation (2.20), is the average velocity over a length of time h. Its limit is called the *velocity vector* at time t, and is defined as

$$\overrightarrow{v}(t) = \lim_{h \to 0} \frac{\vec{r}(t+h) - \vec{r}(t)}{h} = \vec{r}'(t) \tag{2.21}$$

(Stewart 839). The speed at which the particle is moving along the curve at time *t* is given by the magnitude of the velocity vector, that is $\|\overrightarrow{v}(t)\|$. This is because

$$\|\overrightarrow{v}(t)\| = \|\vec{r}'(t)\| = \frac{ds}{dt} = \text{rate of change of distance with respect to time.} \tag{2.22}$$

Therefore, the acceleration of the particle as it moves along the curve will be defined as the derivative of the velocity, that is

$$\overrightarrow{a}(t) = \overrightarrow{v}'(t) = \vec{r}''(t). \tag{2.23}$$

In 1687, Sir Isaac Newton proved in his book *Principia Mathematica* that Kepler's Laws are consequences of his own laws, the Second Law of Motion and the Law of Universal Gravitation. It is interesting to note that Newton's work came after Kepler's own ideas, which were published between 1609 and 1619.

The gravitational pull, or the force of gravitation of the sun on a planet, is so much stronger than the force of other celestial bodies that the pull of these bodies on the planet is negligible when compared to the force of the sun (844). So, we can construct a coordinate system where the sun is at the origin and $\vec{r} = \vec{r}(t)$, the position vector of the planet. Then the velocity vector is $\overrightarrow{v} = \vec{r}'$ and the vector of the acceleration is $\overrightarrow{a} = \vec{r}''$, as previously defined. Thus, we can define Newton's Laws. Given $\overrightarrow{F}$ is the gravitational force, *m* and *M* are the masses of the planet and the sun respectively, *G* is the gravitational constant, $r = \|\vec{r}\|$, and $\overrightarrow{u} = \left(\frac{1}{r}\right)\vec{r}$ is the unit vector in the direction $\vec{r}$, then Newton's Second Law of Motion is defined as

$$\overrightarrow{F} = m\overrightarrow{a}, \tag{2.24}$$

and Newton's Law of Universal Gravitation is defined as

$$\overrightarrow{F} = \frac{-GMm}{r^3}\vec{r} = \frac{-GMm}{r^2}\overrightarrow{u}, \tag{2.25}$$

(844).

Now, we can see that the planet moves in one plane. So, we can equate $\overrightarrow{F}$ in Newton's Laws to each other

$$\begin{aligned} \overrightarrow{F} = m\overrightarrow{a} &= \frac{-GMm}{r^3}\vec{r} \\ \overrightarrow{a} &= \frac{-GM}{r^3}\vec{r}\,. \end{aligned} \tag{2.26}$$

So, $\overrightarrow{a}$ is parallel to $\vec{r}$ because they are scalar multiples of each other, (see Fig. 2.10)[17].

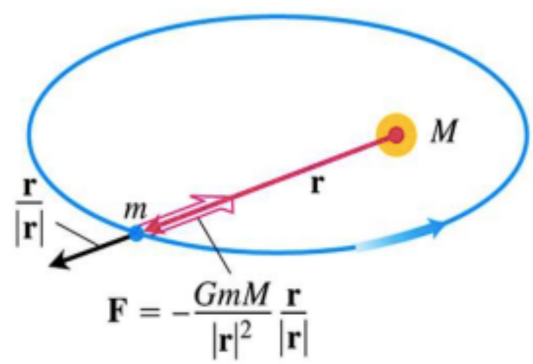

Figure 2.10: Acceleration and position vectors are parallel, where |**r**| = ||**r**|| and the acceleration vector is expressed as it is in Equation (2.26).

Because $\overrightarrow{a}$ is parallel to $\vec{r}$, then $\vec{r} \times \overrightarrow{a} = \overrightarrow{0}$. Now, we find

$$\begin{aligned} \frac{d}{dt}(\vec{r} \times \overrightarrow{v}) &= (\vec{r}' \times v) + (r \times \overrightarrow{v}') \\ &= (\overrightarrow{v} \times \overrightarrow{v}) + (\vec{r} \times \overrightarrow{a}) \\ &= \overrightarrow{0} + \overrightarrow{0} = \overrightarrow{0}\,. \end{aligned} \tag{2.27}$$

---

[17] Source: "13.6 Velocity and Acceleration in Polar Coordinates," http://faculty.etsu.edu/gardnerr/2110/notes-12e/c13s6.pdf

Hence, $\vec{r} \times \vec{v} = \vec{h}$, where $\vec{h}$ is a constant vector because we assume that $\vec{h} \neq \vec{0}$, so $\vec{r}$ and $\vec{v}$ are not parallel since their cross product does not have magnitude zero (845). This means $\vec{r} = \vec{r}(t)$ is perpendicular to h for all t (see Fig. 2.11)[18] because by definition of a cross product, $\vec{h}$ is perpendicular to both $\vec{r}$ and $\vec{v}$. Therefore, the planet, or satellite, will remain in the plane through the origin perpendicular to $\vec{h}$. Thus, the orbit of a planet, or satellite, is a *plane curve*, a curve that lies in a single plane.

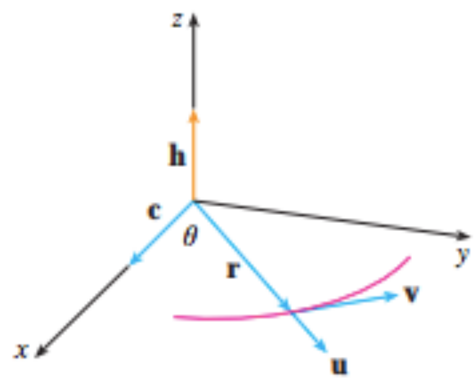

Figure 2.11: The position vector is perpendicular to *h* for all *t*. Note that *h*=*a*, the semi-major axis.

2.2.1 Kepler's First Law of Planetary Motion

Kepler's First Law states that "a planet revolves around the sun in an elliptical orbit with the sun at one focus" (Stewart 844). In order to prove Kepler's First Law, we need to define the vector $\vec{h}$. Recall that we have defined h, the constant vector, as $\vec{r} \times \vec{v} = \vec{h}$, the velocity vector as $\vec{v} = \vec{r}'$, and the unit vector as $\vec{u} = \left(\frac{1}{r}\right)\vec{r}$. Hence,

[18] Source: James Stewart, "13.4 Motion in Space: Velocity and Acceleration," *Calculus: Early Transcendentals*, p. 845.

$$\begin{aligned}\overrightarrow{h} = \vec{r} \times \overrightarrow{v} = \vec{r} \times \vec{r}' &= r\overrightarrow{u} \times (r\overrightarrow{u})' \\ &= r\overrightarrow{u} \times (r\overrightarrow{u}' + r'\overrightarrow{u}) \\ &= r^2(\overrightarrow{u} \times \overrightarrow{u}') + rr'(\overrightarrow{u} \times \overrightarrow{u}) \\ &= r^2(\overrightarrow{u} \times \overrightarrow{u}')\end{aligned} \tag{2.28}$$

and from there we can apply what we know about Newton's Laws. So, we find

$$\begin{aligned}\overrightarrow{a} \times \overrightarrow{h} &= \frac{-GM}{r^2}\overrightarrow{u} \times [r^2(\overrightarrow{u} \times \overrightarrow{u}')] \\ &= -GM\overrightarrow{u} \times (\overrightarrow{u} \times \overrightarrow{u}') \\ &= -GM[(\overrightarrow{u} \cdot \overrightarrow{u}')\overrightarrow{u} - (\overrightarrow{u} \cdot \overrightarrow{u})\overrightarrow{u}']\end{aligned} \tag{2.29}$$

because of the triple vector product that we proved in equations (2.27), (2.28), and (2.29). Since $\overrightarrow{u} \cdot \overrightarrow{u} = \|\overrightarrow{u}\|^2 = 1$, as $\overrightarrow{u}$ is a unit vector, and because $\|\overrightarrow{u}(t)\| = 1$, so $\overrightarrow{u} \cdot \overrightarrow{u}' = 0$ (845). Thus, applying these conditions, we observe

$$\begin{aligned}\overrightarrow{a} \times \overrightarrow{h} &= GM[0 \cdot \overrightarrow{u} - (1) \cdot \overrightarrow{u}'] \\ &= GM\overrightarrow{u}'.\end{aligned} \tag{2.30}$$

Therefore, we can find $(\overrightarrow{v} \times \overrightarrow{h})'$, but first we must define the first derivative of the vector $\overrightarrow{h}$,

$$\begin{aligned}\overrightarrow{h} &= \vec{r} \times \overrightarrow{v} \\ \overrightarrow{h}' &= \vec{r}' \times \overrightarrow{v} + \vec{r} \times \overrightarrow{v}'\end{aligned} \tag{2.31}$$

because of the product rule of vector calculus. Now, we observe that

$$(\vec{r}' \times \overrightarrow{h})' = (\overrightarrow{v} \times \overrightarrow{h})' = (\overrightarrow{v}' \times \overrightarrow{h}) + (\overrightarrow{v} \times \overrightarrow{h}'), \tag{2.32}$$

where

$$\begin{aligned}\overrightarrow{v} \times \overrightarrow{h} &= \overrightarrow{v} \times [(\vec{r}' \times \overrightarrow{v}) + (\vec{r} \times \overrightarrow{v}')] \\ &= \overrightarrow{v} \times (\vec{r}' \times \overrightarrow{v}) + (\overrightarrow{v} \times \vec{r}) \times \overrightarrow{v} \\ &= \overrightarrow{v} \times (\vec{r}' \times \vec{r}') + (\vec{r}' \times \vec{r}) \times \vec{r}'' \\ &= \overrightarrow{0} + \overrightarrow{0}.\end{aligned} \tag{2.33}$$

Equation (2.33) has $\overrightarrow{v} \times \overrightarrow{h} = \overrightarrow{0} \times \overrightarrow{0}$ because it is constant. Hence, we find, from Equation (2.32), that

$$(\overrightarrow{v} \times \overrightarrow{h})' = \overrightarrow{v}' \times \overrightarrow{h} = \overrightarrow{a} \times \overrightarrow{h} = GM\overrightarrow{u}'. \tag{2.34}$$

In order to undo this operation, we will integrate both sides of Equation (2.34) in order to find

$$\begin{aligned} \int (\overrightarrow{v} \times \overrightarrow{h})' dt &= \int GM\overrightarrow{u}' dt \\ \overrightarrow{v} \times \overrightarrow{h} &= GM \int \overrightarrow{u}' dt \\ &= GM\overrightarrow{u} + \overrightarrow{c} \end{aligned} \tag{2.35}$$

and $\overrightarrow{c}$ is a constant vector.

Now, we will define the coordinate axes in such a way that $\overrightarrow{k}$, the *standard basis vector* defined as $\overrightarrow{k} = \langle 0,0,1 \rangle$ that has length 1 and points in the direction of the positive z-axis (775), points in the direction of $\overrightarrow{h}$. So, the planet, or satellite, moves in the xy-plane. Because $\overrightarrow{v} \times \overrightarrow{h}$ and $\overrightarrow{u}$ are perpendicular to $\overrightarrow{h}$, it follows from Equation (2.35) that $\overrightarrow{c}$ lies in the xy-plane. Now, we can define the x and y axes so $\overrightarrow{i}$ lies in the direction of $\overrightarrow{c}$ (845).

One important cross product property that is important to mention before moving forward is the theorem that gives the geometric description of its length, $\|\overrightarrow{a} \times \overrightarrow{b}\|$ (788). So, if θ is the angle between $\overrightarrow{a}$ and $\overrightarrow{b}$ where $0 \leq \theta \leq \pi$, then

$$\|\overrightarrow{a} \times \overrightarrow{b}\| = \|\overrightarrow{a}\| \|\overrightarrow{b}\| \sin\theta. \tag{2.36}$$

There is a similar dot product theorem that we will use in the following steps (780). This theorem states that if θ is the angle between the vectors $\overrightarrow{a}$ and $\overrightarrow{b}$, then

$$\overrightarrow{a} \cdot \overrightarrow{b} = \|\overrightarrow{a}\| \|\overrightarrow{b}\| \cos\theta. \tag{2.37}$$

So, suppose θ is the angle between $\overrightarrow{c}$ and $\vec{r}$, then we define (r, θ) as the polar coordinates of the planet, or satellite, in the ellipse. Then, from Equation (2.35) and (2.37), we have,

$$\begin{aligned}\vec{r}\cdot(\overrightarrow{v}\times\overrightarrow{h}) &= \vec{r}\cdot(GM\overrightarrow{u}+\overrightarrow{c}) \\ &= GM\vec{r}\cdot\overrightarrow{u}+\vec{r}\cdot\overrightarrow{c} \\ &= GMr(\overrightarrow{u}\cdot\overrightarrow{u})+\|\vec{r}\|\|\overrightarrow{c}\|\cos\theta \\ &= GMr+rc\cos\theta \\ &= r(GM+c\cos\theta)\end{aligned} \tag{2.38}$$

where $c = \|\overrightarrow{c}\|$ (846). Thus, from Equation (2.15), Equation (2.26), and Equation (2.37)

$$r = \frac{\vec{r}\cdot(\overrightarrow{v}\times\overrightarrow{h})}{GM+c\cos\theta} = \frac{1}{GM}\frac{\vec{r}\cdot(\overrightarrow{v}\times\overrightarrow{h})}{1+e\cos\theta} \tag{2.39}$$

where $e = \dfrac{c}{GM}$ because $e = \dfrac{c}{a}$ and acceleration is $a = GM$. However,

$$\begin{aligned}\vec{r}\cdot(\overrightarrow{v}\times\overrightarrow{h}) &= (\vec{r}\times\overrightarrow{v})\cdot\overrightarrow{h} \\ &= \overrightarrow{h}\cdot\overrightarrow{h} \\ &= \|\overrightarrow{h}^2\| \\ &= h^2\end{aligned} \tag{2.40}$$

where $h = \|\overrightarrow{h}\|$. Therefore, from Equation (2.39) and because $\vec{r}\cdot(\overrightarrow{v}\times\overrightarrow{h}) = h^2$ from Equation (2.40), we have

$$r = \frac{1}{GM}\frac{h^2}{1+e\cos\theta} = \frac{\frac{h^2}{GM}}{1+e\cos\theta} = \frac{e\left(\frac{h^2}{c}\right)}{1+e\cos\theta} \tag{2.41}$$

because $GMe = c$. Now, we define $d = \dfrac{h^2}{c}$, which we know is also $d = \dfrac{a^2}{c}$ from Fig 2.11, so $h = a$, to get

$$r = \frac{ed}{1 + e\cos\theta}. \tag{2.42}$$

This is the polar equation of a conic section with focus at the origin and eccentricity e. We know that the orbit of a planet is a closed curve, thus the conic must be an ellipse. This is Kepler's First Law of Planetary Motion.

2.2.2 Kepler's Second Law of Planetary Motion

Kepler's Second Law of Planetary Motion states that a planet, or satellite, moves in a plane, and the radius vector (from the sun to the planet, or from the planet to the satellite) sweeps out equal areas in equal times. According to Stewart, we can use Newton's Second Law of Motion and Newton's Law of Universal Gravitation to prove Kepler's Second Law (848). Stewart has outlined a few steps that will aid in the derivation of Kepler's Second Law that we will follow. So, we will use the same notation we used in proving Kepler's First Law. Note, that we are using polar coordinates, so

$$\vec{r} = (r\cos\theta)\vec{i} + (r\sin\theta)\vec{j} \tag{2.43}$$

where $\vec{i} = \langle 1,0,0\rangle$ and $\vec{j} = \langle 0,1,0\rangle$ (848). Recall that $\overrightarrow{k} = \langle 0,0,1\rangle$.

Now, Stewart states that then first step of this proof is to show that $\overrightarrow{h} = r^2\dfrac{d\theta}{dt}\overrightarrow{k}$ (848).

So, recall that we defined in Equation (2.28) that $\overrightarrow{h} = \vec{r} \times \overrightarrow{v}$, which is the same as

$$\overrightarrow{h} = \vec{r} \times \vec{r}'. \tag{2.44}$$

Thus, we can substitute $\vec{r}$ into Equation (2.44) with the equation we defined in Equation (2.43) for $\vec{r}$. But, before we do, let's make clear what these components of $\overrightarrow{h}$ will be. So, $\vec{r} = (r\cos\theta)\vec{i} + (r\sin\theta)\vec{j}$. Therefore, $\vec{r} = \langle r\cos\theta, r\sin\theta, 0\rangle$ and $\vec{r}' = \langle r'\cos\theta - r\sin\theta\dfrac{d\theta}{dt}, r'\sin\theta + r\cos\theta\dfrac{d\theta}{dt}, 0\rangle$. So, now we can find $\overrightarrow{h} = \vec{r}\times\vec{r}'$. Thus,

$$
\begin{aligned}
\overrightarrow{h} &= \vec{r}\times\vec{r}' \\
&= [(r\cos\theta)\vec{i} + (r\sin\theta)\vec{j}\,]\times\left[\left(r'\cos\theta - r\sin\theta\frac{d\theta}{dt}\right)\vec{i} + \left(r'\sin\theta + r\cos\theta\frac{d\theta}{dt}\right)\vec{j}\,\right] \\
&= \langle r\cos\theta, r\sin\theta, 0\rangle \times \langle r'\cos\theta - r\sin\theta\frac{d\theta}{dt}, r'\sin\theta + r\cos\theta\frac{d\theta}{dt}, 0\rangle \\
&= \langle r\sin\theta\cdot 0 - 0\cdot\left(r'\sin\theta + r\cos\theta\frac{d\theta}{dt}\right), 0\cdot\left(r'\cos\theta - r\sin\theta\frac{d\theta}{dt}\right) - r\cos\theta\cdot 0, r\cos\theta\left(r'\sin\theta + r\cos\theta\frac{d\theta}{dt}\right) - r\sin\theta\left(r'\cos\theta - r\sin\theta\frac{d\theta}{dt}\right)\rangle \\
&= \langle 0, 0, r\cos\theta\left(r'\sin\theta + r\cos\theta\frac{d\theta}{dt}\right) - r\sin\theta\left(r'\cos\theta - r\sin\theta\frac{d\theta}{dt}\right)\rangle \\
&= \langle 0, 0, rr'\cos\theta\sin\theta + r^2\cos^2\theta\frac{d\theta}{dt} - rr'\cos\theta\sin\theta + r^2\sin^2\theta\frac{d\theta}{dt}\rangle \\
&= \langle 0, 0, r^2\cos^2\theta\frac{d\theta}{dt} + r^2\sin^2\theta\frac{d\theta}{dt}\rangle \\
&= \langle 0, 0, r^2\frac{d\theta}{dt}(\cos^2\theta + \sin^2\theta) \\
&= \langle 0, 0, r^2\frac{d\theta}{dt}\rangle\,.
\end{aligned}
$$

Hence,

$$\overrightarrow{h} = r^2\frac{d\theta}{dt}\overrightarrow{k} \tag{2.45}$$

because $\overrightarrow{k} = \langle 0,0,1\rangle$.

The next step outlined by Stewart is to deduce that $r^2\dfrac{d\theta}{dt} = h$ (848). Recall that we said that $h = \|\overrightarrow{h}\|$. This becomes a scalar as opposed to a vector. So, we apply this to Equation (2.45), and yield

$$h = \|\vec{h}\| = r^2\left|\frac{d\theta}{dt}\right|. \tag{2.46}$$

According to Stewart, "if $A = A(t)$ is the area swept out by the radius vector $\vec{r} = \vec{r}(t)$ in the time interval $[t_0, t]$, like in the figure (see Fig. 2.12)[19], we need to show that

$$\frac{dA}{dt} = \frac{1}{2}r^2\frac{d\theta}{dt}. \tag{2.47}$$

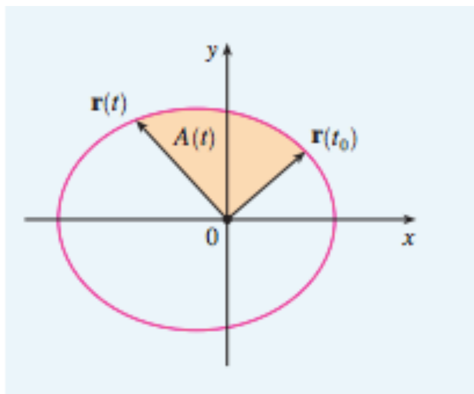

Figure 2.12: *A(t)* is the area swept out by the radius vector.

Using the equation for the area of a wedge $A = \dfrac{1}{2}r^2\theta$, we have that

$$A(t) = \frac{1}{2}\int_{\theta_0}^{\theta} \|\vec{r}\|^2 d\theta. \tag{2.48}$$

Since our notation uses polar coordinates, we rewrite Equation (2.48), to find

$$A(t) = \frac{1}{2}\int_{t_0}^{t} r^2\frac{d\theta}{dt}. \tag{2.49}$$

Thus, by the Fundamental Theorem of Calculus, we have

[19] Source: James Stewart, "13.4 Motion in Space: Velocity and Acceleration," *Calculus: Early Transcendentals*, p. 848.

$$\frac{dA}{dt} = \frac{1}{2}r^2\frac{d\theta}{dt}. \tag{2.50}$$

Finally, Stewart states that in order to finish proving Kepler's Second Law, we need to show that $\frac{dA}{dt} = \frac{1}{2}h$ = constant (849). This shows that A is swept out at a rate that is constant. So, from Equation (2.50), we have $\frac{dA}{dt} = \frac{1}{2}r^2\frac{d\theta}{dt}$. Now, recall from Equation (2.46) that $h = r^2\frac{d\theta}{dt}$. So, we have

$$\frac{dA}{dt} = \frac{1}{2}h\,. \tag{2.51}$$

Thus, we need to show that $\frac{1}{2}h$ is a constant. Hence, recall from Equation (2.28), that $\overrightarrow{h} = \vec{r} \times \overrightarrow{v}$, and from Kepler's First Law, recall Equation (2.27) that states $\overrightarrow{h}\,' = \frac{d}{dt}(\vec{r} \times \overrightarrow{v}) = (\overrightarrow{v} \times \overrightarrow{v}) + (\vec{r} \times \overrightarrow{a}) = \overrightarrow{0}$, because $(\vec{r} \times \overrightarrow{a})$ is constant. Hence, because $\overrightarrow{h}\,' = \overrightarrow{0}$, h must be a constant independent of t. Therefore, $\frac{1}{2}h$ is also a constant as it is a scalar multiple. Thus,

$$\frac{dA}{dt} = \frac{1}{2}h = \text{ a constant.} \tag{2.52}$$

This is a proof of Kepler's Second Law of Planetary Motion.

2.2.3 Kepler's Third Law of Planetary Motion

Kepler's Third Law of Planetary Motion states that the "square of the period of revolution of a planet is proportional to the cube of the length of the major axis of its orbit" (Stewart 848). Stewart has outlined a proof of Kepler's Third Law. In order to set up such a proof, let T be the orbit of a planet about the sun, remember that this can also be applied to satellites. Then, T is the time necessary for a planet to complete one revolution around its elliptical orbit. Suppose that the lengths of the major and minor axes of the ellipse are $2a$ and $2b$, respectively (see Fig. 2.13)[20] (849). Then, we can follow Stewart's steps.

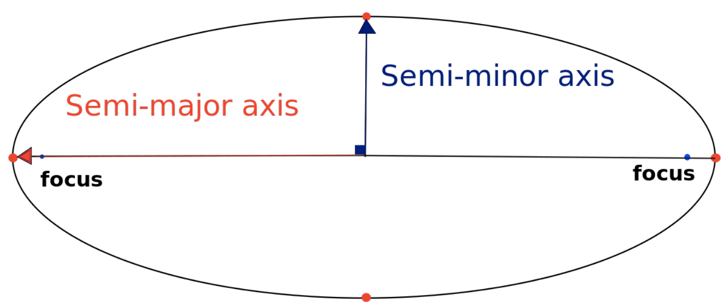

Figure 2.13: Semi-major and semi-minor axes of an elliptical orbit.

First, Stewart states that we should use part 4 of the proof of Kepler's Second Law to show that $T = 2\pi \dfrac{ab}{h}$ (849). Recall that the area of an ellipse is $A = \pi ab$, where $a =$ major axis and $b =$ minor axis. Recall from Kepler's Second Law, Equation (2.51) that states $dA = \dfrac{1}{2} h\,dt$. We can undo this operation by integrating the equation with respect to A and t, in order to find

$$A = \int_0^T \frac{1}{2} h\,dt \Rightarrow A = \frac{1}{2} hT \tag{2.53}$$

[20] "Astronomical unit." *Wikipedia*, https://simple.wikipedia.org/wiki/Astronomical_unit.

because dA is integrated over a period T. Thus, because $A = \pi ab$, we have

$$\begin{aligned} \pi ab &= \frac{1}{2}hT \\ 2\pi ab &= hT \\ \frac{2\pi ab}{h} &= T. \end{aligned} \tag{2.54}$$

Next, Stewart advises we show that $\frac{h^2}{GM} = ed = \frac{b^2}{a}$ (849). So, we recall from Equation (2.12) that $a^2 = \frac{e^2 d^2}{(1-e^2)^2}$ and $ed = a(1-e^2)$, when we express the directrix d in terms of the semi-major axis with length a. We also recall from Equation (2.15) that $r = \frac{ed}{1 + e\cos\theta}$ and from Equation (2.41) that $r = \frac{\frac{h^2}{GM}}{1 + e\cos\theta}$. So, because of Equation (2.15) and Equation (2.41), we see that

$$r = \frac{ed}{1 + e\cos\theta} = \frac{\frac{h^2}{GM}}{1 + e\cos\theta} \Rightarrow ed = \frac{h^2}{GM}. \tag{2.55}$$

Hence, we have that $\frac{h^2}{GM} = ed$, and now we want to show that $ed = \frac{b^2}{a}$. We can define the semi-minor axis, b, with regards to the semi-minor axis, a, and the eccentricity, e. Therefore, the semi-minor axis is

$$b = a\sqrt{1-e^2}. \tag{2.56}$$

So, we can proceed forwards from Equation (2.12) where $ed = a(1-e^2)$. Thus,

$$\begin{aligned} ed &= a(1-e^2) \\ &= \frac{a^2(1-e^2)}{a} \\ &= \frac{(a\sqrt{1-e^2})^2}{a} \end{aligned} \tag{2.57}$$

and from Equation (2.56), which states that $b = a\sqrt{1-e^2}$, we have that

$$ed = \frac{b^2}{a}. \tag{2.58}$$

Therefore, we have

$$\frac{h^2}{GM} = ed = \frac{b^2}{a}. \tag{2.59}$$

Now, Stewart recommends that we use the two previous parts of this theorem to show that $T^2 = \frac{4\pi}{GM}a^3$ (849). From step one and Equation (2.54), we have that $T = \frac{2\pi ab}{h}$. By squaring both sides of this equation, we find

$$T^2 = \frac{4\pi^2 a^2 b^2}{h^2}. \tag{2.60}$$

From step two and Equation (2.59), we have that $\frac{h^2}{GM} = ed = \frac{b^2}{a}$, so $\frac{h^2}{GM} = \frac{b^2}{a}$. We can rearrange this equation to find

$$h^2 = \frac{b^2 GM}{a}. \tag{2.61}$$

Now, we substitute Equation (2.61) into Equation (2.60), in order to find

$$\begin{aligned} T^2 &= \frac{4\pi^2 a^2 b^2}{h^2} \\ &= \frac{4\pi^2 a^2 b^2}{\frac{b^2 GM}{a}} \\ &= \frac{4\pi^2}{GM} a^3 \end{aligned} \tag{2.62}$$

which shows that the square of the period of revolution, T, of a planet is proportional to the cube of the length of the major axis of its orbit, a. This proves Kepler's Third Law.

2.2.4 Satellite Orbits

Although Kepler wrote his Laws of Planetary Motion with the orbit of planets about the Sun in mind, these Laws are also applicable to the movement of satellites about a planet. This is because the mass of a planet in comparison to the mass of the Sun, and the mass of a satellite compared to the mass of a planet is much, much smaller. These small masses orbit much larger masses. So, say a satellite of mass m orbits a planet with a much larger mass M. Then, we can view this motion as if M was stationary without much significant error. Now, we can reexamine Kepler's Laws under the frame of satellite orbit. So, Kepler's First Law would be that satellites have elliptical orbits with the primary body at one of the foci, the primary body being Earth in this case. Kepler's Second Law with regards to satellites is that satellites will cover equal areas in equal intervals of time. Kepler's Third Law for satellites is that the orbital period of a launched satellite depends only on one of its parameters, the distance of the satellite from Earth.

So, in order to really examine the orbital trajectory of a satellite like Sputnik, it is important to focus on Kepler's Third Law that describes the orbital period of an orbiting body. When proving Kepler's Laws, we started with Newton's Law of Universal Gravitation and Newton's Second Law of Motion. The point of this was to show that the force of gravity acting upon an orbiting body is the cause for Kepler's Laws, this is because at a given location all masses orbit with the same acceleration. If we look specifically at Kepler's Third Law, we will recall from Equation (2.62) that $T^2 = \frac{4\pi^2}{GM}a^3$. We can determine from this Law, that the further away a satellite is from the body it is orbiting, the longer its orbital period. Even though Kepler died many years before the launch of the first artificial Earth satellite in 1957, he would have been able to determine the time that *Sputnik* needed to orbit the Earth using his Third Law of Planetary Motion. We can do this calculation ourselves.

Again, recall Equation (2.62), $T^2 = \frac{4\pi^2}{GM}a^3$, where the gravitational constant is $G = 6.67408 \cdot 10^{-11}\ \mathrm{m^3kg^{-1}s^{-2}}$, the mass of the Earth is $M = 5.972 \cdot 10^{24}$ kg, and the semi-major axis of *Sputnik*'s orbit is $a = 6{,}955$ km or $a = 6{,}955{,}000$ m. So, we find

$$\begin{aligned} T^2 &= \frac{4\pi^2}{GM}a^3 \\ &= \frac{4\pi^2}{6.67408 \times 10^{-11} \cdot 5.972 \times 10^{24}} \cdot (6{,}955{,}000)^3 \end{aligned} \tag{2.63}$$

which is equal to $T^2 = 3.332268078 \times 10^7$. Therefore, the time necessary for *Sputnik* to complete one revolution around its elliptical orbit is $T = 5772.580080$, which is approximately 96.2 minutes (*Pravda* 2). Kepler's Laws of Planetary Motion have allowed us to calculate the period of revolution for *Sputnik*'s orbit, and now we can move forward into the classification of its orbit.

Chapter Three

The Theory of Orbits

3.1 Geocentric Orbit

On October 4th 1957, the Soviet Union successfully launched its first artificial Earth satellite, referred to around the world as *Sputnik I*, into a low Earth orbit. *Sputnik* zipped across the surface of the Earth at an altitude that fluctuated between 132-582 miles. It completed a full revolution around the planet every 96.2 minutes, this is what is referred to as the period of a satellite (*Pravda* 2). *Sputnik 1* zoomed across the sky from horizon to horizon so quickly that it was not visible from any point on Earth under its orbit for any significant amount of time. Communications with the satellite ceased as soon as its line of sight was broken and they would not resume until its return on the next overhead pass. As *Sputnik* was the first artificial Earth satellite to be launched into orbit, it can be expected that it was perhaps not the most ideal model of a satellite as it was the first of its kind. In order to understand the peculiarities of *Sputnik's* orbit, it is important to first understand the different types of orbits of satellites as well as the ideal orbit of a communications satellite such as *Sputnik.*

The best type of communications satellite is one that remains fixed overhead, appearing to hover in the sky. However, this is only achieved when the satellite is launched so high that its orbital period is synchronized to the rotational period of the Earth. This is called *geosynchronous orbit*. A geosynchronous orbit is a satellite's orbit around the Earth with an orbital period that matches the Earth's rotation on its axis, which takes one sidereal day, which is approximately 23 hours, 56 minutes, and 4 seconds. For an observer on Earth, this synchronization of rotation and orbital period means that an object that is in geosynchronous orbit will return to exactly the same position in the sky after a period of one sidereal day. Ultimately, over the course of a day, the orbiting object's position in the sky will trace out a path that is typically in the form of a figure-8. The precise characteristics of this form depend on the orbit's inclination and eccentricity. Orbital inclination measures the tilt of an object's orbit around a celestial body. A satellite with a geosynchronous orbit hovers so high above the Earth, actually 35,786 km, that it experiences practically no atmospheric drag, and its orbit remains stable (see Fig. 3.1)[21].

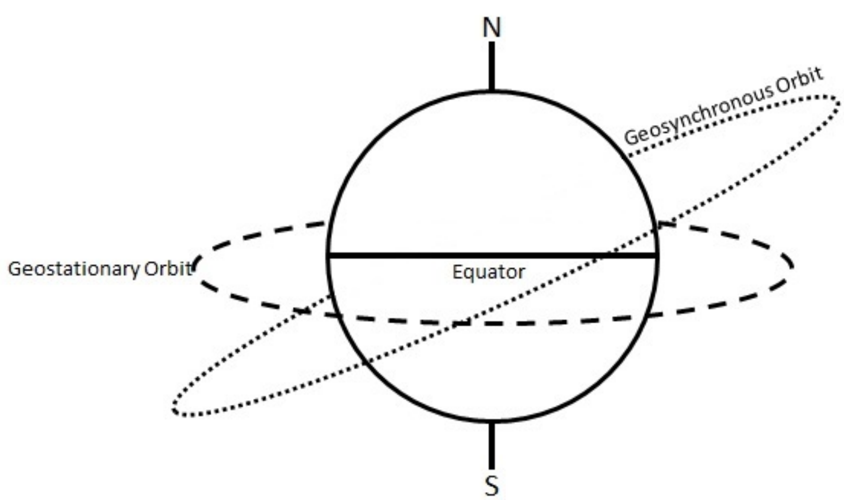

Figure 3.1: Geosynchronous and geostationary orbits

[21] Source: "Geostationary Orbit." *Geospatial Education Platform*, http://www.polyu.edu.hk/proj/gef/index.php/glossary/geostationary-orbit/.

There is a special form of geosynchronous orbit that is classified as geostationary. *Geostationary orbit* is a circular geosynchronous orbit in the Earth's equatorial plane, that is directly above the Equator. As one might deduce from its name, a satellite in geostationary orbit appears to be stationary, or rather always at the same point in the sky, to observers on the surface of the celestial body that the satellite is orbiting. Communications satellites, like *Sputnik*, are often launched into geostationary or close to geostationary orbits, this is so the satellite antennas that communicate with them do not have to move, but rather can be permanently pointed at the fixed location in the sky where the satellite appears.

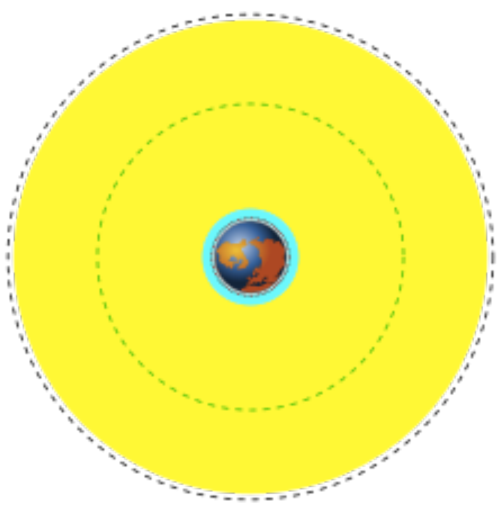

Figure 3.2: Geocentric Orbit Model, cyan=Low Earth Orbit, Black dotted line= Geosynchronous Orbit.

Orbits, like geosynchronous and geostationary, can be classified as *geocentric orbits*. That is, geocentric orbits are Earth orbits that involve any object orbiting the Planet Earth, like artificial satellites (see Fig. 3.2)[22]. Geocentric orbits can be classified using a wide variety of characteristics like altitude, inclination, eccentricity, and more.

[22] Source: "Geocentric Orbit." *Wikipedia*, https://en.wikipedia.org/wiki/Geocentric_orbit.

For the purposes of classifying Sputnik's orbit we will restrict ourselves to classifications of altitude and eccentricity.

3.2 Low Earth Orbit

Now, as stated above, *Sputnik* was the first satellite launched into orbit, so it is expected that it didn't achieve ideal orbit. However, as *Sputnik* orbited the Earth it can still be classified as having geocentric orbit, despite not being the desired geostationary satellite. *Sputnik*'s orbit is classified as having a Low Earth Orbit, which falls under the orbital classification of altitude (see Fig. 3.3)[23]. Low Earth orbit is a geocentric orbit that ranges in altitude from 160 kilometers to 2,000 kilometers above the mean sea level. It has at least 11.25 periods per day, which indicates an orbital period of 128 minutes or less. Low Earth Orbit also indicates an orbiting body of having an eccentricity less than 0.25.

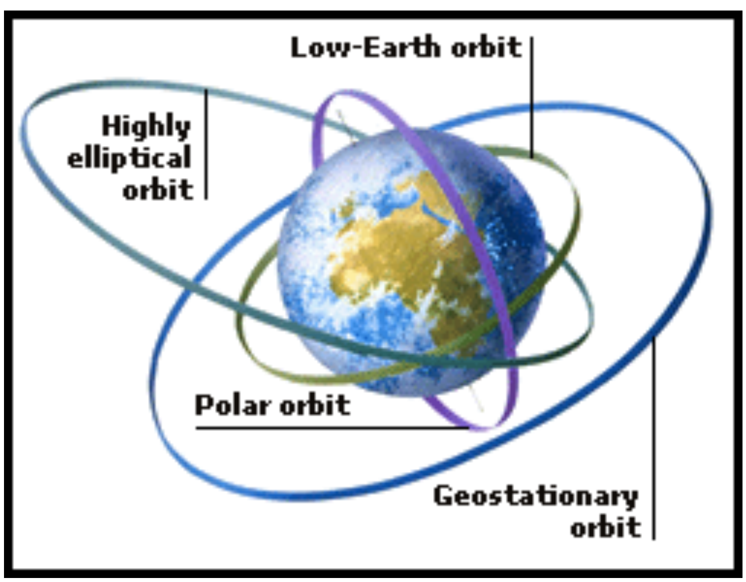

Figure 3.3: Low Earth Orbit model

[23] Source: "Space Acquisitions: Geosynchronous Equatorial Orbit (GEO)." *AcqNotes*, http://acqnotes.com/acqnote/careerfields/geosynchronous-equatorial-orbit-geo.

We mentioned that Low Earth orbit can be defined in terms of altitude. This is because the altitude of an object in an elliptical orbit can vary significantly along the orbit. Even for circular orbits, the altitude above ground can differ as much as 30 kilometers due to the flattening of the Earth's spheroid figure. Definitions in terms of altitude are inherently ambiguous; however, most of them are within range specified for an orbital period of 128 minutes. This occurs because, according to Kepler's third law, this corresponds to a semi-major axis of 8,413 kilometers. For circular orbits, this corresponds to an altitude of 2,042 kilometers above the mean radius of the Earth. This is consistent with some of the upper limits in the Low Earth Orbit definitions in terms of altitude.

In addition to Low Earth Orbit, there is also the Low Earth Orbit region, which is the region in space that Low Earth Orbit orbits occupy. It is possible for highly elliptical orbits to pass through the Low Earth Orbit region near their perigee but they are not classified as being in Low Earth Orbit because their apogee is greater than 2,000 kilometers. On the other hand, it also happens that sub-orbital objects, that is objects that reach outer space but their trajectory intersects the atmosphere or surface of the gravitating body from which it is launched, so it does not complete one orbital revolution, can also reach the Low Earth Orbit region without actually having Low Earth Orbit as they re-enter the atmosphere. In terms of satellites, Low Earth Orbit is an especially important term as all crewed space stations as well as the majority of satellites have been in Low Earth Orbit. Objects in Low Earth Orbit experience atmospheric drag caused by gases in the thermosphere, which is approximately 80-500 kilometers above the surface, or exosphere, which approximately 500 kilometers and up, depending on the height of the orbit. It is because of this atmospheric drag that satellites do not usually orbit below 300 kilometers.

For satellites, Low Earth Orbit seems to be ideal as it requires the lowest amount of energy for satellite placement and provides high bandwidth and low communication latency. Earth observation satellites and spy satellites orbit the Earth in Low Earth Orbit as they are able to see the surface of the Earth clearly due to their close location to it. However, Low Earth Orbit is not without its disadvantages for satellites. Satellites that experience Low Earth Orbit have a relatively small momentary field of view in that they are only able to observe and communicate with a fraction of the Earth at a time. Because of this, a collection of satellites is required in order for continuous coverage to be provided. Satellites that are located in the lower regions of Low Earth Orbit also experience fast orbital decay that either periodic rebooting in order to maintain a stable orbit or launching replacement satellites when old ones re-enter the atmosphere.

3.3 The Specifics of *Sputnik*'s Orbit

The Soviet Union launched *Sputnik* into an elliptical low Earth orbit in October 1957, where it remained orbiting for three weeks before its batteries died continuing on for a further two months before falling back into the atmosphere. The control system of the *Sputnik* rocket was calibrated for the originally intended orbit of 223 by 1,450 kilometers, with an orbital period of 101.5 minutes. This trajectory had been calculated by Georgi Grechko, a Soviet cosmonaut with a doctorate in mathematics, using the USSR Academy of Sciences' mainframe computer.

The satellite had a 65° inclination which along with the duration of its orbit caused its flight path to cover virtually the entire Earth. It travelled at about 29,000 kilometers per hour, taking 96.2 minutes to complete each orbit around the Earth. *Sputnik*'s orbit had a semi-major axis of 6,955 kilometers and an eccentricity of $e = 0.05201$. The perigee of the orbit was at 215 kilometers and its apogee was at 939 kilometers, placing it well within the bounds of Low Earth Orbit (see Fig. 3.4)[24].

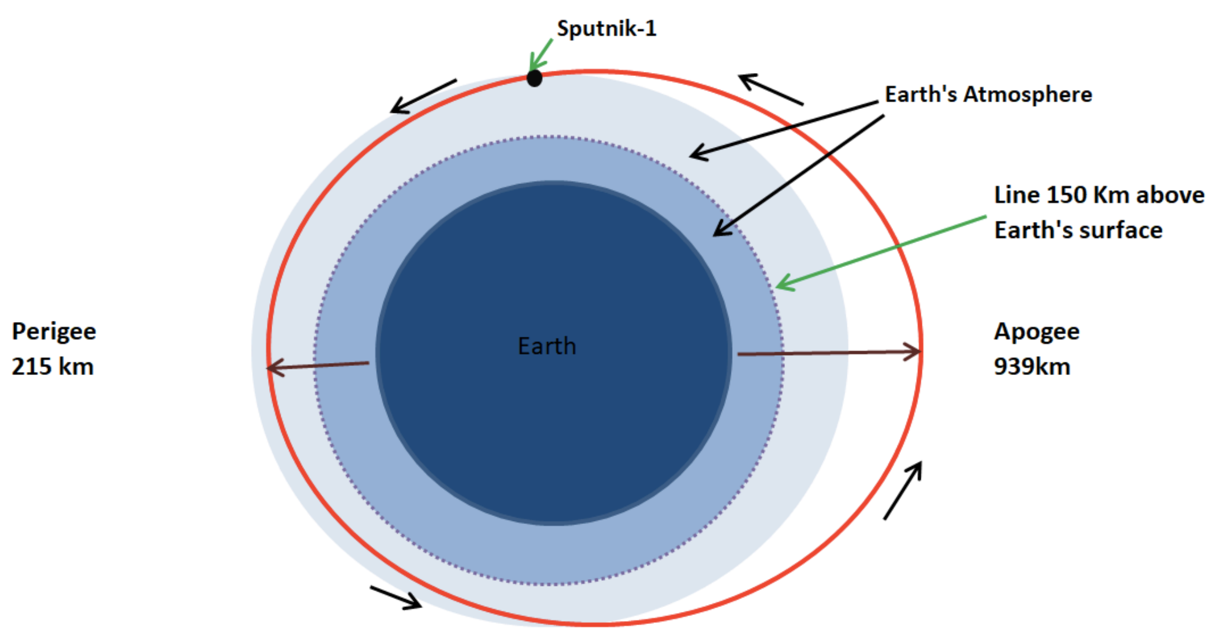

Figure 3.4: Model of Sputnik's orbit around the Earth

The satellite's transmitter batteries remained in operation for 21 days before they eventually died out on October 26, 1957. The satellite's mission was completed after it stopped transmitting signals back to Earth and was disposed of due to orbital decay.

[24] Source: "4 October 1957 - The start of the space age." *The Science Geek*, https://thesciencegeek.org/2017/10/04/4-october-1957-the-start-of-the-space-age/.

When *Sputnik* burned up upon reentry into the Earth's atmosphere on January 4, 1958 it had completed 1440 orbits of the Earth and travelled a distance of about 70 million kilometers. *Sputnik* provided scientists with valuable information about through tracking and study. It allowed them to deduce the density of the upper atmosphere from its drag on the orbit, and the propagation of its radio signals gave data about the ionosphere. An interesting feature of atmospheric drag on a satellite is that instead of slowing down its orbit, as one might guess, it, in fact, increases the speed of a satellite, which *Sputnik* provides a very fitting example of. The launch of *Sputnik* signified the beginning of a new era of political, military, technological, and scientific developments. It was an event that echoed across the Earth and sparked peaceful competition between two great superpowers, the United States and the Soviet Union, pitting capitalist against communist.

Chapter Four

Introduction to the Translation

On October 9, 1957, the Soviet state newspaper *Pravda* published an articled announcing their triumph in space exploration to the world. Entitled "A Great Victory in the Peaceful Competition with Capitalism," the article details the journey of the world's first artificial Earth satellite as it orbits the Earth and informs its audience of how the satellite came to be. In the Soviet Union a great deal of importance was placed on modernization and with that came a focus on science as leaders like Lenin and Stalin hoped to change the worlds perception of the Soviet Union as a country of illiterate peasants to one of the world's superpowers, like the United States.

In fact, scientific analysis and technological advancements were an important part of the Soviet Union's approach to becoming a world superpower. They intended to force the eyes of the world onto them and their scientific achievements. This drive to modernization largely started following the 1917 Revolution with Lenin calling for the education of the Russian people and implementing new policies that were meant to fix the socio-economic backwardness of Imperial Russia. He facilitated rapid and intensive industrialization that led to a united, working-class proletariat in a largely rural, agrarian, peasant society. However, perhaps the largest push to modernization and industrialization of the Soviet Union began with Stalin, who brought rocket industry back to the USSR after their triumph over Germany and with it forged the Soviet Union's path to their victory in the peaceful competition with capitalism.

Not only does this article remark on their journey to launching the first artificial Earth satellite into space and emphasize the fact that they were the first to do so, clearly proving communist superiority, it also discusses the science and math behind such a feat in surprisingly great detail. It is interesting that a Soviet news article has such an in depth review of the particulars of *Sputnik*'s orbit and design using such mathematical language as this article was for the average Soviet. It was the article announcing this scientific marvel to their nation, as such one would expect it to be easily understood by the average citizen. However, this article defies all expectations as it waxes on about the perigee and apogee of the satellite's orbit as well as the rotation of the satellite about the earth and the data it collected on its journey. It is probably from this importance placed on showcasing their scientific advancements that the Soviet Union's article detailing the launch of *Sputnik 1* and its particulars is so dense with mathematical analyses and specific explanations of the satellite's launch and orbit, as well as the observations made around the world of this modern marvel. After all, if this article is for the masses, then surely they are no longer the illiterate peasants that the rest of the world perceives them to be, especially since they have just cemented their place in the history of space exploration, beating out their capitalist rivals, the United States, and shocking the world.

Chapter Five

Translation of the Article

“Великая Победа в Мирном Соревновании с Капитализмом”	“A Great Victory in the Peaceful Competition with Capitalism”
Первый в мире искусственный спутник Земли, созданнuый советскими учеными, инженерами, рабочими, совершает свой полет вокруг нашей планеты. День 9 октября он встретил в Тунисе, через две минуты он пролетел над Римом, еще через четыре минуты появился над Москвой, а затем через восемнадцать минут промелькнул над Токио и направился к Западной Европе. Крупнейшие ученые современности говорят о наступлении новой эпохи, того периода в истории цивилизации, когда сделан гигантский шаг вперед в освоении межпланетного пространства. В этом историческое значение советского открытия. С того времени, когда человек впервые натянул тугую тетиву лука и пустил в воздух стрелу, прошли тысячелетия. Мечта уже тогда летела вперед, опережая действительность. Появилась сказка о	The first artificial earth satellite in the world, constructed by Soviet scientists, engineers, and workers, has made its first flight around our planet. On the ninth of October it passed over Tunisia, two minutes later it was flying over Rome, after another four minutes it appeared over Moscow, and then eighteen minutes later it flashed over Tokyo and headed off to Western Europe. The greatest scientists of our time talk about the dawn of a new era, of a period in the history of civilization, when a gigantic step forward is made in the exploration of interplanetary space. In this lies the historical significance of Soviet innovation. Thousands of years have passed since the time when man first pulled on the tight string of a bow and shot an arrow into the air. The dream was already flying forward, outpacing reality. A tale appeared of man flying like a

полете человека, подобно птице, в воздушном океане. Сказка о ковре-самолете прошла через всю историю человечества. Сказание об Икаре, сделавшем себе крылья и поднявшемся в небо, -- жемчужина в сокровищнице мировой культуры.	bird through the ocean of air. The tale of the flying carpet has been told throughout the entire history of mankind. The tale of Icarus, who made himself wings and flew into the sky, is a pearl in the treasury of world culture.
Но огромный исторический период отделяет полет орудия, пущенного в воздух рукой человека с помощью простейшего механизма, от полета самого человека, оторвавшегося от земли. В эпоху Возрождения Леонардо да Винчи умом ученого и глазом художника изучал полет птиц. Люди не оставляли мечту и попытки сравняться с птицей. Однако прошли века, пока человек поднялся в воздух на построенном им аппарате. Сначала это был воздушный шар. Но уже Ломоносов трудился над моделью геликоптера с часовым механизмом, предчувствуя закат эры воздушных шаров. Вновь минуло более столетия, пока начали строить летательные аппараты тяжелее воздуха. Первая половина XX века стала временем бурного развития авиации.	But a huge historical period separates the flight of a projectile, propelled into the air by the hand of man using the simplest mechanism, from the flight of man himself, detached from the ground. In the Renaissance era Leonardo Da Vinci, studied the flight of birds with a scientist's mind and with an artist's eyes. People kept dreaming and attempting to catch up with birds. However, centuries passed before man took to the air on a mechanism he built. At first it was the hot air balloon. But already Lomonosov[1] labored on a helicopter model with a clockwork mechanism, anticipating the decline of the era of hot air balloons. More than a century passed, before aircrafts heavier than air began to be built. The first half of the twentieth century was a time of rapid development of aviation.
И снова мечта опережала действительность, мечта о полете за пределы воздушного пространства.На этот раз это была мечта научная, обоснованная математическим расчетом, подкрепленная изучением физических явлений. Перед	And again dream outpaced reality, the dream of flight outside of airspace. This time it was a scientific dream, based on a mathematical calculation, supported by the study of physical phenomena. Before mankind stood the task of turning this dream into

человечеством встала задача и эту мечту превратить в действительность. Запуск в Советском Союзе искусственного спутника Земли -- важнейший шаг в осуществлении этой мечты.	reality. The launch of an artificial Earth satellite in the Soviet Union was a crucial step in the realization of this dream.
В нашей стране жили и трудились Н. Е. Жуковский -- один из великих создателей аэродинамики, К. Э. Циолковский -- основоположник теории полета с помощью реактивного двигателя. Они и многие другие готовили своими трудами нашу сегодняшнюю великую победу. Но между ними и этой победой лежат десятилетия упорного труда советских рабочих, инженеров, техников, ученых. Год за годом Коммунистическая партия воспитывала кадры авиаконструкторов и самолетостроителей, взращивала во всем народе огромную любовь к летному делу, создавала авиационную культуру страны.	In our country lived and labored N. E. Zhukovskiy[2] -- one of the great creators of aerodynamics, and K. E. Tsiolkovskiy[3] -- the father of jet engine. They and many others set the stage with their work for our great victory today. But between them and this victory lies a decade of hard labor of Soviet workers, engineers, technicians, and scientists. Year after year the Communist Party reared the personnel of aircraft designers and aircraft builders, cultivated in all people a great love for aviation, and created the country's aviation culture.
Путь к сегодняшним достижениям в нашей науке и технике начинается 7 ноября 1917 года. И когда Ленин в России, едва освещенной керосиновой лампой, разрабатывал план электрификации, план ГОЭЛРО, тогда уже были посеяны семена нынешних наших побед. И когда в лютые морозы бетонщики Волховстроя сооружали плотину первой нашей гидроэлектростанции, когда огромным напряжением воли и всех наших сил мы	The path to today's achievements in our science and technology began on the 7th of November 1917. And when Lenin, in Russia, which was barely lit with a kerosene lamp, developed a plan for electrification, the GOELRO plan[4], it was already then that the seeds of our present victories were sown. And when in severe frosts the concrete workers of Volkhovstroi constructed the dam of our first hydroelectric power station, when with a tremendous strain of will and all of our

создавали индустриальные центры, когда воздвигали новые заводы и энергетическую базу Советской страны, когда враги и просто путаники или маловеры лезли под руку и твердили, что-де не надо строить тяжелую промышленность, тогда в суровых сражениях первых пятилеток закладывались основы всех достижений нашего сегодняшнего дня.	strength we were creating industrial centers, when we were erecting new factories and the energy base of the Soviet state, when enemies and skeptics or simply the misguided were putting spokes in our wheels and asserting that there was no need to build heavy industry, it was then, in the harsh battles of the first five-year plans, that the foundations of all achievements of our present day were laid.
Сегодня все население Земли видит великую победу нашей советской науки и техники, высокоразвитой промышленности, нашу техническую мощь, которую год за годом в течение пятилеток по строгому научному плану, последовательно проводя ленинскую генеральную линию в социалистическом строительстве, создал великий советский народ под руководством Коммунистической партии. Запуск искусственного спутника Земли -- это победа советского человека, который с большевистской смелостью и целеустремленностью, настойчивостью и энергией умеет идти вперед. Это победа коллективного труда, который только и может совершать в мире подлинные чудеса.	Today the Earth's entire population witnesses the great victory of our Soviet science and technology, of highly developed industry, our technological power, which year after year for five years through a strict scientific plan, consistently pursued the Leninist general line in socialist construction, created by the great Soviet people under the direction of the Communist party. The launch of an artificial satellite of Earth is a great victory of Soviet man, who with Bolshevik courage and purposefulness, perseverance and energy can go forward. It is the victory of collective labor, which alone can perform genuine miracles in the world.
С удивительной силой и наглядностью еще раз доказано, что советский социалистический строй является лучшей формой организации человеческого труда, который освобожден от пут эксплуатации. На свой лад преимущества	With miraculous strength and visibility it was once again proven that Soviet socialist foundation is the best form of human labor organization, of human labor that is freed from the fetters of exploitation. In its own way, even the capitalist press is forced to recognize

социалистического строя вынуждена признать и капиталистическая печать. Газета “Нью-Йорк джорнэл-Америкэн”, анализируя состояние работ по созданию искусственного спутника в США, горько сетует на “распри между отдельными видами вооруженных сил, которые задержали наше развитие”. Грызня между различными видами вооруженных сил США является лишь фасадом, за которым скрывается борьба мощных монополий: королей стали, выступающих за строительство в первую очередь и во что бы то ни стало морских кораблей, магнатов алюминиевой промышленности, стремящихся оттеснить морской флот на второй план и добиться заказов на самолетостроение.	the advantages of the socialist system. The newspaper, “New York Journal-American,” analyzing the status of work on the creation of an artificial satellite in the USA, bitterly complains about “the feuds between separate types of armed forces, which hindered our development.” The squabbles between various types of armed US forces are only a facade, behind which lies the struggle of powerful monopolies: kings of steel, advocating in favor of constructing, first and foremost, of any kind of naval ships, and magnates of the aluminum industry, seeking to push the navy into the background and attain orders for aircraft construction.
Мир корысти и наживы со своей хваленой “свободой предпринимательства” ставит преграды на пути развития производительных сил. В советском обществе нет этих преград. Вот почему газета “Нью-Йорк геральд трибюн” и вынуждена сделать вывод: “Наша страна понесла поражение в эпическом соревновании XX века”. Без хвастовства, без шума и рекламы, присущей капитализму, советские люди, руководимые Коммунистической партией, разрабатывают грандиозные планы и претворяют их в жизнь, строят, изобретают, удивляют мир своим творческим одухотворенным трудом. За последнее время на западе придумали	The world of greed and profit with its vaunted “free enterprise” sets obstacles in the path of the development of production forces. In Soviet society there are no such obstacles. This is why the newspaper, “New York Herald Tribune” was forced to conclude: “Our country suffered a defeat in the epic competition of the twentieth century.” Without boasting, without the noise and advertising inherent in capitalism, the Soviet people, led by the Communist party, are developing ambitious plans and implementing them in life, they are building, inventing, astonishing the world with their creative, inspired work. Recently, in the West they have fabricated many false tales about the fate of scientists

много лживых небылиц о судьбе деятелей науки и техники, изобретателей, новаторов в Советском Союзе. Вы хотите знать, господа, судьбу ученых, новаторов и изобретателей в Стране Советов? Следите за полетом спутника Земли!	and technicians, inventors and innovators in the Soviet Union. Do you want to know, dear sirs, the fate of scholars, innovators and inventors in the Soviet State? Then follow the flight of the Earth Satellite!
В наше время научный и технический прогресс стал важнейшей составной частью мирного соревнования двух систем. Новый, социалистический мир овладевает мощной техникой, создает новую, свою технику, неуклонно идет вперед по пути прогресса. Мы не боимся мирного соревнования с капитализмом и охотно на него идем. Из новой победы Советского Союза в этом соревновании необходимо сделать серьезные политические выводы. Надо отбросить те рассуждения, которым вопреки логике жизни предаются сейчас реакционные политические круги на Западе. Эти круги стараются мирное соревнование между двумя системами в области технического прогресса свести… к гонке вооружений. Американская газета “Дейли ньюс” пишет, например, что “запуск русскими искусственного спутника означает, что конгресс -- если не правительство -- потребует более быстрого осуществления различных программ Пентагона (военное министерство США).	In our time scientific and technological progress has become an important, integral part of the peaceful competition of two systems. The new, socialist world takes possession of powerful technology, creates new technology of its own, and steadily moves forward along the path of progress. We are not afraid of peaceful competition with capitalism, rather we willingly go for it. It is necessary to draw serious political conclusions from the new victory of the Soviet Union in this competition. It is necessary to discard those arguments, in which reactionary political spheres in the West now indulge, contrary to the logic of life . These spheres are trying to reduce the peaceful competition between two systems in the field of technological progress … to an arms race. The American newspaper, “The Daily News,” writes, for example, that “the launch of the Russian’s artificial satellite means that congress -- if not the government -- will require faster implementation of various Pentagon (the war ministry of the USA) programs.
Не пора ли, однако, американским правящим кругам выйти из того порочного	Isn’t it time, however, for the American governing spheres to get out of that vicious

круга, в который они сами себя завели? Ведь они начинали гонку вооружений, заявляя о своей монополия на атомное оружие. Но их расчеты потерпели крах. Они продолжали гонку вооружений, крича о монополии США на водородную бомбу. И снова их расчеты провалились. Они отвергали советские предложения о разоружении, хвастаясь своим ракетным оружием. И снова потерпели провал, когда СССР создал межконтинентальную баллистическую ракету. Не довольно ли предметных уроков? Не пора ли более здраво и трезво оценивать реальные факты современной жизни? Газета "Нью-Йорк таймс" теперь жалуется, что в политике США давала себя знать "неуклонная тенденция недооценивать советские возможности". Газета призывает отбросить "традиционное стереотипное мнение Соединенных Штатов и Запада, будто большинство русских -- это невежественные и безграмотные крестьяне". Давно пора покончить с этой глупейшей выдумкой. По-видимому, кое-кто в США, ослепленный своей ненавистью к коммунизму, проглядел Великую Октябрьскую социалистическую революцию, не заметил сорокалетнего опыта победоносного социалистического строительства в Советской стране, бурного развития ее экономики, науки и культуры. Теперь и в США раздаются некоторые трезвые голоса, предупреждающие, что нельзя слепоту делать фактором мировой политики.	cycle, into which they led themselves astray? After all they began the arms race, declaring their monopoly on atomic weapons. But their calculations suffered a failure. They continued the arms race, shouting about the United States' monopoly on the hydrogen bomb. And again their calculations collapsed. They rejected Soviet disarmament proposals, showing off their missile weapons. Yet again they miscalculated, when the USSR developed intercontinental ballistic missiles. Are these lessons not sufficient enough ? Isn't it time to more sensibly and soberly assess the real facts of modern life? The newspaper, "The New York Times" now complains, that in politics the US made itself known to possess "a steady tendency to underestimate Soviet capabilities." The newspaper calls to reject "the traditional, stereotypical opinion held by the United States and the West that the majority of Russians are ignorant and illiterate peasants." It has long been time to do away with this silliest of fictions. Apparently, some in the United States, blinded by their hatred for communism, overlooked the Great October Socialist Revolution, didn't notice the forty year experiment of victorious socialist construction in the Soviet state, or the rapid development of its economy, science, and culture. Now, in the US, some sober voices ring out a warning that it is impossible to make blindness a factor in world politics.

Столбовая дорога развития современных международных отношений ясна. Это -- мирное сосуществование двух различных систем, их мирное соревнование в области экономики, науки и техники. Именно этот путь предлагают капиталистическому лагерю избрать Советский Союз, все страны социалистического лагеря. И лучшим пропагандистом за этот путь является советский искусственный спутник, вращающийся вокруг нашей планеты, на которой расположены ныне и социалистические, и капиталистические страны.	The main road of development of modern international relations is clear. It is the peaceful coexistence of two different systems, their peaceful competition in the area of economics, science and technology. It is this path that the Soviet Union and all countries of the socialist bloc suggest for the capitalist camp to choose. And the best propagandist for this path is the Soviet artificial satellite, rotating around our planet, which now hosts both socialist and capitalist countries.
О ДВИЖЕНИИ ИСКУССТВЕННОГО СПУТНИКА ЗЕМЛИ Весь мир следит за полетом первого искусственного спутника Земли. Сообщения о визуальных и радиотехнических наблюдениях поступают из множества путников Советского Союза и из различных стран. Дальности, на которых принимаются радиосигналы спутника, значительно превзошли ожидаемые. В отдельных случаях дальность наблюдения на частоте 20 мегагерц (длина волны 15 метров) достигает 10 тысяч километров. Это свидетельствует о том, что материалы наблюдений помогут существенно уточнить научные данные, связанные с вопросами распространения радиоволн и строения ионосферы.	ON THE MOVEMENT OF THE ARTIFICIAL EARTH SATELLITE The whole world is following the flight of the first artificial Earth satellite. Messages about the visual and radio observations are received from many travelers of the Soviet Union and from different countries. Distances at which satellite radio signals are received, significantly surpassed what was expected. In some cases distance observations at a frequency of 20 megahertz (wavelength 15 meters) reach 10 thousand kilometers. This suggests that observation materials will help significantly clarify scientific data, related to questions of radio wave propagation and the structure of the ionosphere.

На 6 часов московского времени 9 октября спутник облетел вокруг земли уже 63 раза. Изменения расстояния между спутником и движущейся за ним по орбите ракетой-носителем пока не обнаружено.	At 6 o'clock Moscow time on the 9th of October the satellite had already circled around the earth 63 times. Changes in the distance between the satellite and the carrier rocket orbiting around it have not yet been detected.
Публикуемые прогнозы прохождения спутника помогают наблюдателям следить за ним. В поступающих сообщениях отмечается хорошее соответствие истинных времен прохождения и их предвычисленных значений. Так, наблюдателя из штата Аризона (США) визуально наблюдали его прохождение точно по расписанию. В это же время были ими приняты и радиосигналы со спутника. Однако радионаблюдателям следует иметь в виду, что передача сигналов со спутника через некоторое время может прекратиться вследствие израсходования ресурса источников питания.	Published satellite passage forecasts will help observers to monitor it. In the incoming messages there is a good correspondence between the real transit times and their predicted values. Thus, observers from the state of Arizona (USA) visually observed its passage exactly on schedule. At the same time, they also received radio signals from the satellite. However, radio observers should be aware, that the transmission of signals from a satellite may cease after some time due to the death of the battery.
Задачи, поставленные программой работ по запуску искусственного спутника Земли, рассчитанные на определение параметров орбиты с помощью массовых наблюдений радиопеленгаторными станциями и радиолюбителями, выполнены. Получен ценный материал. После прекращения передач сигналов со спутника наблюдения будут продолжаться с помощью оптических средств в радиолокационных станций.	Tasks set by the work program on the launch of the artificial Earth satellite, intended to determine the parameters of orbit using mass observations by radio direction-finding stations and radio amateurs, have been completed. Valuable material has been received. After the termination of satellite transmissions, the observation will continue using optical systems in radar stations.

Для проведения наблюдений за движением спутника 9 и 10 октября сообщается перечень основных пунктов земного шара, над которыми он будет проходить (время московское):	For observations of the satellite’s movements on October 9th and 10th, a list of the main points of the globe over which it will pass (Moscow time) has been compiled:
9 октября Аддис-Абеба — 8 час. 45 мин., Ванкувер — 9 час. 53 мин., Корал-Харбор — 10 час. 00 мин., Мадрид — 10 час. 12 мин., Алжир — 10 час. 14 мин., Ситка (Аляска) — 11 час. 32 мин., Лейк-Харбор — 11 час. 40 мин., Канарские о-ва — 11 час. 53 мин., Фритаун (Африка) — 11 час. 59 мин., Мельбурн — 12 час. 42 мин., Порт-Гаррисон — 13 час. 18 мин., о-в Ньюфаундленд — 13 час. 22 мин., земля Кемпа — 14 час. 04 мин., Калгурли (Австралия) — 14 час. 19 мин., о-в Новая Гвинея — 14 час. 26 мин., Фербенкс — 14 час. 48 мин., Оттава — 14 час. 59 мин., Нью-Йорк — 15 час. 00 мин., Джорджтаун — 15 час. 10 мин., Сан-Пауло — 15 час. 20 мин., Джакарта — 16 час. 02 мин., Владивосток — 16 час. 15 мин., Шелтон (Аляска) — 16 час. 25 мин., Фербенкс — 16 час. 27 мин., Оклахома — 16 час. 38 мин., Новый Орлеан — 16 час. 40 мин., Сан-Хосе — 16 час. 46 мин., Ибарра (Южная Америка) — 16 час. 49 мин., Росарио — 17 час. 00 мин., Рангун — 17 час. 45 мин., Лос-Анжелес — 18 час. 15 мин., Рио-Гранде (Южная Америка) — 18 час. 44 мин., Бомбей — 19 час. 22 мин., Дели — 19 час. 25 мин., Кызыл — 19 час. 31 мин., Братск — 19 час. 32 мин., Вилюйск— 19	**October 9th** Addis Ababa — 8 hr. 45 min., Vancouver — 9 hr. 53 min., Coral Harbor — 10 hr. 00 min., Madrid — 10 hr. 12 min., Algeria — 10 hr. 14 min., Sitka (Alaska) — 11 hr. 32 min., Lake Harbor — 11 hr. 40 min., Canary Islands — 11 hr. 53 min., Freetown (Africa) — 11 hr. 59 min., Melbourne — 12 hr. 42 min., Port Garrison — 13 hr. 18 min., Newfoundland — 13 hr. 22 min., Kemp land — 14 hr. 04 min., Kalgoorlie (Australia) — 14 hr. 19 min., New Guinea — 14 hr. 26 min., Fairbanks — 14 hr. 48 min., Ottawa — 14 hr. 59 min., New York — 15 hr. 00 min., Georgetown — 15 hr. 10 min., Sao Paulo — 15 hr. 20 min., Jakarta — 16 hr. 02 min., Vladivostok — 16 hr. 15 min., Shelton (Alaska) — 16 hr. 25 min., Fairbanks — 16 hr. 27 min., Oklahoma — 16 hr. 38 min., New Orleans — 16 hr. 40 min., San Jose — 16 hr. 46 min., Ibarra (South America) — 16 hr. 49 min., Rosario — 17 hr. 00 min., Rangoon — 17 hr. 45 min., Los Angeles — 18 hr. 15 min., Rio Grande (South America) — 18 hr. 44 min., Bombay — 19 hr. 22 min., Deli — 19 hr. 25 min., Kyzyl — 19 hr. 31 min., Bratsk — 19 hr. 32 min., Vilyuysk — 19 hr. 36 min., Ashgabat — 21 hr. 04 min., Barabinsk — 21 hr. 08 min., Seymchan — 21 hr. 17 min., Cabinda (Africa) — 22 hr. 27

час. 36 мин., Ашхабад — 21 час 04 мин., Барабинск — 21 час 08 мин., Сеймчан — 21 час 17 мин., Кабинда (Африка) — 22 час. 27 мин., Александрия — 22 час. 37 мин., Краснодар — 22 час. 41 мин., Саратов — 22 час. 43 мин., Пермь — 22 час. 45 мин., Якутск — 22 час. 54 мин., Курильские о-ва — 22 час. 59 мин.	min., Alexandria — 22 hr. 37 min., Krasnodar — 22 hr. 41 min., Saratov — 22 hr. 43 min., Perm — 22 hr. 45 min., Yakutsk — 22 hr. 54 min., Kuril Islands — 22 hr. 59 min.
10 октября Рим — 0 час. 17 мин., Будапешт — 0 час. 18 мин., Минск — 0 час. 19 мин., Москва — 0 час. 21 мин., Котлас — 0 час. 22 мин., Хабаровск — 0 час. 35 мин., Токио — 0 час. 38 мин., Рио-де-Жанейро — 1 час 34 мин., Лондон — 1 час 55 мин., Гетеборг — 1 час 57 мин., Архангельск — 2 час. 01 мин., Енисейск — 2 час. 07 мин., Иркутск — 2 час. 10 мин., Улан-Батор — 2 час. 11 мин., Пекин — 2 час. 14 мин., Сидней — 2 час. 37 мин., Сант-Яго — 3 час. 07 мин., Архангельск — 3 час. 39 мин., Омск — 3 час. 44 мин., Семипалатинск — 3 час. 46 мин., Ханой — 3 час. 55 мин., Панама — 4 час. 54 мин., Петрозаводск — 5 час., 18 мин., Вологда — 5 час. 19 мин., Куйбышев — 5 час. 21 мин., Сталинабад — 5 час. 26 мин., Кабул — 5 час. 27 мин., Мадрас — 5 час. 33 мин., Мехико — 6 час. 34 мин., Детройт — 6 час. 41 мин., Осло — 6 час. 55 мин., Вильнюс — 6 час. 57 мин., Минск — 6 час. 58 мин., Киев — 6 час. 59 мин., Керчь — 7 час. 00 мин., Багдад — 7 час. 04 мин., Лос-Анжелос — 8 час. 14 мин., Виннипег (Канада) — 8 час. 19 мин., Глазго	**October 10th** Rome — 0 hr. 17 min., Budapest — 0 hr. 18 min., Minsk — 0 hr. 19 min., Moscow — 0 hr. 21 min., Kotlas — 0 hr. 22 min., Khabarovsk — 0 hr. 35 min., Tokyo — 0 hr. 38 min., Rio de Janeiro — 1 hr. 34 min., London — 1 hr. 55 min., Gothenburg — 1 hr 57 min., Arkhangelsk — 2 hr. 01 min., Yeniseysk — 2 hr. 07 min., Irkutsk — 2 hr. 10 min., Ulaanbaatar — 2 hr. 11 min., Peking[5] — 2 hr. 14 min., Sydney — 2 hr. 37 min., Santiago — 3 hr. 07 min., Arkhangelsk — 3 hr. 39 min., Omsk — 3 hr. 44 min., Semipalatinsk[6] — 3 hr. 46 min., Hanoi — 3 hr. 55 min., Panama — 4 hr 54 min., Petrozavodsk — 5 hr., 18 min., Vologda — 5 hr. 19 min., Kuybyshev — 5 hr. 21 min., Stalinabad[7] — 5 hr. 26 min., Kabul — 5 hr. 27 min., Madras[8] — 5 hr. 33 min., Mexico — 6 hr. 34 min., Detroit — 6 hr. 41 min., Oslo — 6 hr. 55 min., Vilnius — 6 hr. 57 min., Minsk — 6 hr. 58 min., Kiev — 6 hr. 59 min., Kerch — 7 hr. 00 min., Bagdad — 7 hr. 04 min., Los Angeles — 8 hr. 14 min., Winnipeg (Canada) — 8 hr. 19 min., Glasgow — 8 hr. 32 min., Brussels — 8 hr. 34 min., Munich — 8 hr. 35

8 час. 32 мин., Брюссель — 8 час. 34 мин., Мюнхен — 8 час. 35 мин. (ТАСС).	min. (TASS[9]).
Первый в мире Заявление профессора Бернала ЛОНДОН, 8 октября (Корр. “Правды”). Первый в мире искусственный спутник Земли, созданный в Советском Союзе, прочно вошел в быт и жизнь английской столицы. Вот уже четвертый день “советская Луна” не сходит с первых страниц всех лондонских газет.	*First in the world* Statement by Professor Bernal LONDON, 8th of October (Correspondent of “Pravda”). The first artificial Earth satellite in the world, made in the Soviet Union, firmly entered everyday life of the English capital. For the fourth day in a row, the “Soviet moon” has not left the front pages of all London newspapers.
Огромная научная ценность этого достижения, заявил вчера выдающийся английский физик профессор Бернал, самоочевидна. Запуск первого в мире сделанного человеком спутника Земли открывает путь к пониманию солнечной системы, звезд и Галактики. Более того, подчеркнул Бернал, самым важным уроком этого события является тот факт, что только Советский Союз смог проявить такую способность полностью координировать и использовать достижения теоретической и прикладной науки и инженерного мастерства.	The outstanding scientific value of this achievement is self-evident, declared yesterday by the eminent English physicist Professor Bernal. The launch of the first man-made Earth satellite in the world opens the way to understanding the solar system, stars, and galaxies. Moreover, Bernal emphasized, the most important lesson of this event is the fact that only the Soviet Union was able to display such an ability to fully coordinate and use the achievements of theoretical and applied science and engineering skill.
“Пусть ваша страна продолжает вести за собой мир в научных достижениях” Поздравления из США ВАШИНГТОН, 8 октября. (ТАСС). В посольство СССР в Вашингтоне поступают телеграммы от американских организаций	**“May your country continue to lead the world in scientific achievements”** Congratulations from the USA WASHINGTON, 8th of October. (TASS). Telegrams from American organizations and individuals arrive at the USSR Embassy in

и отдельных граждан, поздравляющих Советский Союз с созданием первого искусственного спутника Земли. В телеграмме Американо-Русского института, подписанной его председателем Х. Робертсом, говорится:	Washington, congratulating the Soviet Union on the creation of the first artificial Earth satellite. A telegram from the American-Russian institute, signed by its chairman H. Roberts, states:
“Поздравляем вас, ваших ученых, работников культуры и советской народ, которые запустили первый искусственный спутник Земли. Это эпохальное достижение подчеркивает замечательный успех Советского Союза в области науки и культуры. Советский искусственный спутник Земли является сияющим символом мирных целей Советского Союза. Прошу принять нашу горячую благодарность и наилучшие пожелания дальнейших успехов советскому народу. Он является лучшей гарантией мира и своей преданностью, благородной работой увеличивает безопасность, благосостояние и счастье народов всех стран”.	“Congratulations to you, your scientists, cultural workers, and the Soviet people, who launched the first artificial Earth satellite. This epoch-making achievement underlines the remarkable success of the Soviet Union in the field of science and culture. The Soviet artificial Earth satellite is a shining symbol of the peaceful goals of the Soviet Union. Please accept our warm thanks and best wishes for continued success to the Soviet people. They are the best guarantee of peace, and their devotion and noble work increase the security, well-being and happiness of the peoples of all countries.”
Американец Т. Уэллес из Глендейла в штате Калифорния, сообщая, что он слушает с помощью своего коротковолнового радиоприемника сигналы, посылаемые советским спутником Земли, выражает пожелание, чтобы “ваше великое достижение объединило наши страны в дальнейших исследованиях неизведанного”.	American T. Welles from Glendale in the state of California, informing that he is listening to the signals sent by the Soviet Earth satellite with the help of his shortwave radio receiver, expressed the wish, that “your great achievement will unite our countries in further studies of the unknown.”

От Американской федерации астронавтов посольство СССР получило следующую телеграмму: “Позвольте мне от имени Американской Федерации астронавтов передать самые искренние поздравления ученым и народу Советского Союза в связи с научным подвигом — созданием первого искусственного спутника Земли”. Телеграмму подписал президент федерации Норрис Ферри.	The Embassy of the USSR received the following telegram from the American Federation of Astronauts: “Allow me, on behalf of the American Federation of Astronauts, to convey my most sincere congratulations to the scientists and the people of the Soviet Union on their scientific achievement — the creation of the first artificial Earth satellite.” The telegram was signed by the president of the federation Norris Ferry.
Теплую телеграмму прислали Поль Робсон-старший и Поль Робсон-младший. “Поздравляем советских ученых и советский народ с запуском первого искусственного спутника Земли, — говорится в телеграмме. — Это огромный вклад в работы геофизического года”.	A warm telegram was sent by Paul Robson Sr. and Paul Robson Jr. “Congratulations to the Soviet scientists and the Soviet people on the launch of the first artificial Earth satellite, — the telegram says. — This is an enormous contribution to the work of the geophysical year.”
Известный ученый и общественный деятель США д-р Б. Дюбуа пишет: “Позвольте мне поздравить Советский Союз с его огромным научным достижением, заключающимся в том, что он первый запустил искусственный спутник Земли. Пусть же ваша страна продолжает вести за собой мир в научных достижениях”.	The famous scientist and US public figure Dr. B. Dubois writes: “Allow me to congratulate the Soviet Union for its great scientific achievement, that is, on the launch of the first artificial Earth satellite. May your country continue to lead the world in scientific achievements.”
ОПРОБОВАНИЕ 19-го ГИДРОАГРЕГАТА КУЙБЫШЕВСКОЙ ГЭС	**TESTING OF THE 19TH HYDRO AGGREGATE OF THE KUIBYSHEV HPP**

ЖИГУЛЕВСК (Куйбышевская область), 8. (ТАСС). Сегодня вечером поставлен на холостые обороты 19-й гидроагрегат Куйбышевской ГЭС. Завершена сборка последнего, 20-го гидроагрегата. В ближайшее время он также будет поставлен на холостые обороты.	Zhigulevsk (Kuibyshev region), 8. (TASS). Tonight, the 19th hydraulic unit of the Kuibyshev hydroelectric station is set on idle rotation. The assembly of the last, 20th, hydraulic unit has been completed. In the near future, it will also be set on idle rotation.
Советский искусственный спутник Земли 4 октября 1957 г. весь мир стал свидетелем выдающегося события — в Советском Союзе был осуществлен успешный запуск первого искусственного спутника Земли. Сообщение о запуске спутника было получено во всех уголках земного шара. Прохождение его зарегистрировано многими наблюдателями на всех континентах. Создание спутника явилось результатом длительной упорной исследовательской и конструкторской работы, в которой приняли участие большие коллективы советских ученых, инженеров, работников промышленности.	**Soviet artificial Earth satellite** On October 4th, 1957 the whole world witnessed an outstanding event — in the Soviet Union, the first artificial Earth satellite was successfully launched. The message about the launch of the satellite was received in all corners of the globe. Its passage was registered by many observers on all continents. The creation of the satellite was the result of long persistent research and design work done by large teams of Soviet scientists, engineers, and industrial workers.
Теоретически вопрос о возможности посылки космического корабля за пределы земной атмосферы был решен в начале двадцатого столетия выдающимся русским ученым К. Э. Циолковским, доказавшим, что средством для космического полета должна быть ракета. В трудах К. Э. Циолковского был разработан ряд кардинальных проблем межпланетного	Theoretically, the question of the possibility of sending a spacecraft beyond the limits of the Earth's atmosphere was resolved at the beginning of the twentieth century by the eminent Russian scientist K. E. Tsiolkovsky, who proved that it is rocket that should serve as a means for space flight. In the works of K. E. Tsiolkovsky a number of cardinal problems of interplanetary flight were

полета должна быть ракета. В трудах К. Э. Циолковского был разработан ряд кардинальных проблем межпланетного полета и было указано, что создание искусственного спутника Земли явится первым и необходимым этапом.	developed and it was stated that the creation of an artificial Earth satellite would be the first and necessary stage.
Создание искусственного спутника Земли потребовало решения ряда сложнейших и принципиально новых научно-технических проблем. Наибольшие трудности встретились при разработке ракеты-носителя для вывода спутника на орбиту. Для запуска спутника создана ракета-носитель, обладающая высоким конструктивным совершенством. Созданы мощные двигатели, работающие при трудных термических условиях. Разработаны оптимальные режимы движения ракеты, обеспечивающие наиболее эффективное ее использование. Для обеспечения заданного закона движения ракеты, необходимого для выведения спутника на орбиту, разработана весьма точная и эффективная система автоматического управления ракетой.	The creation of an artificial Earth satellite required solving a number of the most complex and fundamentally new scientific and technological problems. The greatest difficulties were encountered in developing a launch vehicle for launching a satellite into orbit. A carrier rocket with high structural perfection has been made for the launch of the satellite. Powerful engines have been made, operating under difficult thermal conditions. Optimal modes of rocket movement have been developed, ensuring its most effective usage. To assure a given law of rocket movement, necessary for launching a satellite into orbit, a very precise and effective system of automatic control has been developed.
Решение этих, а такие многих других сложнейших задач оказалось возможным лишь в результате использования новейших достижений науки и техники в самых различных областях и в первую очередь благодаря высокому техническому уровню ракетостроения в СССР. Создание	The solution of these, and so many other complex tasks, was possible only as a result of the use of the latest achievements in science and technology in the most diverse fields and primarily due to the high technical level of rocket production in the USSR. The creation of an artificial Earth satellite in such a short

искусственного спутника Земли в столь короткие сроки было обеспечено высоким уровнем научно-технического потенциала в нашей стране, четкой и организованной работой научно-исследовательских институтов, конструкторских бюро и промышленных предприятий.	time was ensured by a high level of scientific and technological potential in our country, clear and organized work of research institutes, construction design offices and industrial enterprises.
Запуск первого спутника открывает широкую программу научных исследований, которая будет продолжена в течение Международного геофизического года на ряде последующих искусственных спутников, при создании которых предусматривается дальнейшее увеличение их веса и размеров. Создание спутника является первым шагом в завоевании межпланетного пространства и осуществлении космических полетов.	The launch of the first satellite opens a broad program of scientific research, which will be continued in the International Geophysical Year on a number of subsequent artificial satellites, the development of which provides for a further increase in their weight and size. The creation of the satellite is the first step in the conquest of interplanetary space and the implementation of space flight.
Спутник имеет форму шара. Он был размещен в передней части ракеты-носителя и закрыт защитным конусом. Ракета со спутником стартовала вертикально. Через небольшое время после старта при помощи программного устройства ось ракеты начала постепенно отклоняться от вертикали. В конце участка выведения на орбиту ракета находилась на высоте нескольких сот километров и двигалась параллельно земной поверхности со скоростью около 8.000 метров в секунду. После окончания работы двигателя ракеты защитный конус был сброшен, спутник отделился от ракеты и начал двигаться	The satellite has the shape of a ball. It was placed in front of the launch vehicle and closed with a protective cone. The rocket with the satellite lifted off vertically. A short time after the launch, with the help of a software device, the rocket axis began to gradually deviate from the vertical. At the end of the launch phase, the rocket was at a height of several hundred kilometers and moved parallel to the earth's surface at a speed of about 8,000 meters per second. After the rocket's engine stopped, the protective cone was dropped, the satellite separated from the rocket and began to move independently.

самостоятельно.	
В настоящее время вокруг Земли движется снабженный аппаратурой спутник, а также ракета-носитель и защитный конус. Так как скорость отделения конуса от спутника и спутника от ракеты невелика, носитель и конус в течение некоторого времени находились от спутника на сравнительно небольшом расстоянии, двигаясь вокруг Земли по орбите, близкой к орбите спутника. Затем, вследствие разности периодов обращения, получающейся как за счет относительной скорости в момент отделения, так и за счет различной степени торможения в атмосфере Земли, все три тела разошлись и в процессе дальнейшего движения в один и тот же момент времени могут оказаться находящимися над совершенно различными точками земной поверхности.	At present, an equipped satellite is moving around the Earth, and also a launch vehicle and protective cone. Since the speed of separation of the cone from the satellite and the satellite from the rocket is small, the carrier and the cone were for some time located at a relatively short distance from the satellite, moving around the Earth in an orbit that was close to the orbit of the satellite. Then, due to the difference in the orbital periods, resulting from both relative velocity at the time of separation, as well as the varying degree of drag in the Earth's atmosphere, all three bodies were separated and in the process of further movement at the same moment of time they may be located above completely different points on the Earth's surface.
ОРБИТА СПУТНИКА Орбита спутника представляет собой в первом приближении эллипс, один из фокусов которого находится в центре Земли. Высота полета спутника над поверхностью Земли не остается постоянной, а периодически изменяется, достигая наибольшего значения, примерно тысячи километров.В настоящее время перигей орбиты (ее наинизшая точка) находится в северном полушарии Земли, а апогей (наивысшая точка орбиты) — в	**SATELLITE ORBIT** The satellite's orbit is approximately an ellipse, one of the foci of which is in the center of the Earth. The height of the satellite's flight over the surface of the Earth does not remain constant, but rather periodically changes, reaching the highest value about a thousand kilometers. Currently, the perigee of the orbit (its lowest point) is in the Earth's northern hemisphere, and the apogee (the highest point of the orbit) is in the southern hemisphere.

южном полушарии.	
Ориентация плоскости орбиты относительно неподвижных звезд остается почти постоянной. Так как Земля вращается вокруг своей оси, то на каждом следующем витке спутник должен оказываться над другим районом, смещаясь за один виток примерно на 24° по долготе. Фактическое смещение по долготе будет несколько больше, так как вследствие отклонения поля тяготения от центрального плоскость орбиты будет медленно поворачиваться вокруг оси Земли в направлении, противоположном ее вращению. Это движение плоскости орбиты невелико и составляет примерно четверть градуса по долготе за один оборот. В результате относительного движения Земли и плоскости орбиты каждый следующий виток будет проходить западнее предыдущего на широте Москвы примерно на 1.500 км. В экваториальной области смещение больше и будет составлять около 2.500 километров.	The orientation of the orbital plane relative to fixed stars remains almost constant. Since the Earth rotates around its axis, then at each following orbit, the satellite must appear above another region, becoming displaced in one revolution approximately 24° in longitude. The actual displacement in longitude will be slightly larger, since due to the deviation of the gravitational field from the central orbital plane, it will slowly rotate around the Earth's axis in the direction opposite to its rotation. This movement of the orbital plane is small and amounts to approximately a quarter of a degree in longitude per revolution. As a result of the relative motion of the Earth and the orbital plane, each following orbit will pass to the west of the previous one at the latitude of Moscow by approximately 1,500 kilometers. In the equatorial region, the displacement is greater and will be about 2,500 kilometers.
Плоскость орбиты наклонена к плоскости земного экватора под углом 65°. В связи с этим трасса спутника проходит над районами Земли, находящимися приблизительно между Северным и Южным полярными кругами. Вследствие вращения Земли вокруг оси угол наклона трассы к экватору отличается от угла	The orbital plane is tilted towards the plane of the Earth's equator at an angle of about 65°. In this regard, the satellite route passes over the regions of the Earth, situated approximately between the Northern and Southern polar circles. Due to the rotation of the Earth around its axis, the angle of the slope of the route to the equator differs from the

наклонения плоскости орбиты. Приходя в северное полушарие, трасса пересекает экватор под углом 71,5° в направлении на северо-восток. Затем трасса постепенно заворачивает все больше на восток и, коснувшись параллели, отвечающей 65° северной широты, отклоняется к югу и пересекает экватор в направлении на юго-восток под углом 59°. В южном полушарии трасса касается параллели, отвечающей 65° южной широты, после чего отклоняется к северу и снова переходит в северное полушарие.	angle of the slope of the orbital plane. Coming into the northern hemisphere, the route crosses the equator at an angle of 71.5° towards the northwest. Then the route gradually turns more and more to the east and, after having touched the parallel corresponding to 65° north latitude, deviates to the south and crosses the equator in a direction to the south-east at an angle of 59°. In the southern hemisphere, the route touches a parallel, corresponding to the 65° south latitude, after which it deviates to the north and again passes into the northern hemisphere.
С течением времени, вследствие торможения спутника в верхних слоях атмосферы Земли, форма и размеры орбиты спутника будут постепенно изменяться. Так как на больших высотах, где происходит движение спутника, плотность атмосферы чрезвычайно мала, эволюция орбиты будет происходить вначале весьма медленно. Высота апогея будет убывать быстрее высоты перигея, и орбита будет все более приближаться к круговой. При вхождении спутника в более плотные слои атмосферы, торможение спутника станет весьма сильным. Спутник раскалится и сгорит, подобно метеорам, приходящим из межпланетного пространства и сгорающим в атмосфере Земли.	Over time, due to the deceleration of the satellite in the upper layers of the Earth's atmosphere, the shape and size of the satellite's orbit will gradually change. Since at high altitudes, where the satellite is moving, the density of the atmosphere is extremely small, the evolution of the orbit will occur very slowly at first. The height of the apogee will decrease faster than the height of the perigee, and the orbit will increasingly approach a circular one. When the satellite enters the denser layers of the atmosphere, the deceleration of the satellite will become extremely strong. The satellite will heat up and burn, like meteors coming from interplanetary space and combusting in the Earth's atmosphere.
В настоящее время плотность верхней	Currently, the density of the upper

атмосферы известна недостаточно точно. Поэтому дать точный прогноз о времени существования спутника на орбите пока не представляется возможным. Данные о плотности верхней атмосферы, имеющиеся в настоящее время, а также результаты проведенных траекторных измерений позволяют утверждать, что спутник будет двигаться вокруг Земли длительное время.	atmosphere is not classified completely. Therefore, it is not yet possible to give an accurate forecast of the lifetime of a satellite in orbit. Data on the density of the upper atmosphere that is currently available, and also the results of the conducted trajectory measurements suggest that the satellite will move around the Earth for a long time.
Период обращения спутника составляет в настоящее время 96 мин. По мере понижения орбиты период будет уменьшаться. Скорость изменения периода будет служить указанием на быстроту изменения формы орбиты. Поэтому точное измерение периода обращения спутника является чрезвычайно важной и ответственной задачей.	The revolution period of the satellite is currently 96 minutes. As the orbit decreases, the period will decrease. The rate of change of the period will serve as an indication of the speed of change of the shape of the orbit. Therefore, accurate measurement of the satellite revolution period is an extremely important and crucial task.
Параметры орбиты советского искусственного спутника позволяют наблюдать его на всех континентах в большом диапазоне широт. Это открывает большие возможности для решения различных научных проблем. Можно указать, что запуск спутника на такую орбиту является более трудной задачей, чем запуск на орбиту, близкую к экваториальной плоскости. При запуске по экватору имеется возможность использования в большей степени для разгона ракеты скорости вращения Земли вокруг оси.	The parameters of the orbit of the Soviet artificial satellite make it possible to observe it on all continents in a large range of latitudes. This opens up many opportunities for solving various scientific problems. It can be demonstrated that the launch of a satellite into such an orbit is a more difficult task, than the launch into an orbit close to the equatorial plane. When launched at the equator, it is possible to use the speed of the Earth's rotation around its axis to a greater extent to accelerate a rocket.

НАБЛЮДЕНИЯ ЗА ДВИЖЕНИЕМ СПУТНИКА	OBSERVATIONS OF THE MOTION OF THE SATELLITE
Весьма важной составной частью исследований, проводимых с помощью искусственного спутника Земли, является наблюдение за его движением, обработка наблюдений и предсказание по результатам обработки дальнейшего движения спутника. Наблюдение за спутником ведется с помощью радиотехнических средств, а также в обсерваториях с помощью оптических инструментов. Наряду со специалистами с их средствами к наблюдениям широко привлечены радиолюбители, а также группы астрономов-любителей, ведущие наблюдения на астрономических площадках с помощью специально изготовленных для этих целей оптических инструментов. В настоящее время в СССР наблюдения за спутником регулярно ведут 66 станций оптических наблюдений и 26 клубов ДОСААФ с большим количеством средств радионаблюдения. Кроме того, наблюдения за спутником ведут индивидуально тысячи радиолюбителей.	A very important part of research, conducted with the help of an artificial Earth satellite, is the observation of its movement, the processing of observations and the prediction of the results of processing further movement of the satellite. The observation of the satellite is carried out using radio equipment, as well as in observatories using optical instruments. Along with specialists and their equipment, amateurs are widely involved in observations, as well as groups of amateur astronomers conducting observations at astronomical sites using optical instruments specially manufactured for this purpose. Currently in the USSR, 66 optical observation stations and 26 DOSAAF[10] clubs with a large amount of radio observation devices regularly monitor the satellite. In addition, observations of the satellite are individually conducted by thousands of radio amateurs.
Научные станции ведут наблюдения с помощью радиолокаторов и радиопеленгаторов. Ведутся также наблюдения оптическими методами и фотографирование движения спутника.	Scientific stations conduct observations using radars and direction-finders. Optical observation and photographing of satellite motion are also being conducted.
Остановимся на методах наблюдения	Let us dwell on the methods of

астрономами-любителями и радиолюбителями, так как эти методы доступны широким кругам, интересующимся движением спутника. В распоряжении астрономов-любителей имеется большое количество специально изготовленных астрономических трубок, обладающих совершенной оптикой с широким углом зрения. На наблюдательных станциях имеются также комплекты оборудования, позволяющие определять положение спутника на небесной сфере в определенный момент времени.	observation by amateur astronomers and radio amateurs, since these methods are available to wide circles, interested in the movement of the satellite. Amateur astronomers have a large amount of specially made astronomical tubes, possessing perfect optics with a wide angle of view at their disposal. At observation stations, there are also sets of equipment that allow for the determination of the position of a satellite on the celestial sphere at a specific point in time.
Имеющаяся аппаратура, с помощью которой оптическая станция отмечает положение спутника на небесной сфере, позволяет производить измерения с точностью до одного градуса, а момент времени, в который отмечается это положение, с погрешностью не более одной секунды. Оптическая станция наблюдает искусственный спутник в утреннее или вечернее время, когда поверхность Земли погружена в темноту, а сам спутник, находясь на большой высоте, освещен Солнцем.	The available equipment, by means of which the optical station marks the position of the satellite on the celestial sphere, allows measurements to be made with an accuracy up to one degree and the point in time at which this position is noted, with an error of no more than one second. The optical station observes the artificial satellite in the morning or evening, when the surface of the Earth is darkened, and the satellite itself, being at a high altitude, is illuminated by the Sun.
Следует отметить, что наблюдения за спутником с помощью астрономических инструментов представляют известную трудность и не похожи на наблюдения обычных астрономических объектов, так	It should be noted that observations of the satellite, with the help of atmospheric instruments, present a certain difficulty and are not similar to observations of ordinary atmospheric objects, since the satellite moves

как спутник движется по небу очень быстро, со скоростью в среднем около одного градуса в секунду.	through the sky very quickly, at an average speed of about one degree per second.
Для обеспечения надежности наблюдений каждая оптическая станция устраивает один или два “оптических барьера” из трубок, расположенных в меридиане и по вертикальному кругу, перпендикулярному видимой орбите спутника. Кроме того, при поиске спутника применяется метод, основанный на так называемом “правиле местного времени”. Этот метод использует то обстоятельство, что орбита спутника не участвует в суточном вращении Земли, а сам спутник будет проходить через заданную широту в местное звездное время, медленно меняющееся при вращении орбиты в абсолютном пространстве вокруг земной оси за счет отклонения поля тяготения от центрального. Благодаря этому для данной станции спутник в процессе своего движения будет проходить через последовательность точек на небесной сфере, которые можно назвать точками ожидания. Если регулировать ось оптического прибора таким образом, чтобы она была направлена в заранее рассчитанную на небесной сфере очередную точку ожидания, то рано или поздно неизбежно произойдет обнаружение спутника.	To ensure the reliability of observations, each optical station arranges one or two “optical barriers” from the tubes located in the meridian and in the vertical circle, perpendicular to the visible orbit of the satellite. In addition, when searching for a satellite, the method based on the so-called “local time rule” is applied. This method uses the fact that the satellite’s orbit does not participate in the Earth’s daily rotation, and the satellite itself will pass through a given latitude at local celestial time, varying slowly as the orbit rotates in absolute space around the Earth’s axis due to the deviation of the gravitational field from the center. Because of this, for a given station, the satellite, in the course of its movement, will pass through a sequence of points on the celestial sphere, which can be called waiting points. If the axis of the optical device is adjusted in such a way that it is angled towards the next waiting point, calculated in advance, on the celestial sphere, sooner or later the satellite will inevitably be detected.

Наблюдения за спутником ведет большое число радиолюбителей с помощью специально для этой цели сконструированных радиоприемников. Схемы этих приемников, а также схемы пеленгационных приставок к ним были опубликованы в научно-популярном радиотехническом журнале “Радио” задолго до запуска спутника. Информацию о движении спутника, даваемую радиолюбителями, можно использовать не только для изучения законов прохождения радиоволн через атмосферу, но также, особенно в случае, если радиолюбитель использует пеленгационную приставку, для грубого определения элементов орбиты спутника.	Observations of the satellite are conducted by a large number of radio amateurs using specially designed radio receivers. The diagrams of these receivers, as well as the diagrams of direction finding consoles for them, were published in the popular scientific radio technology journal “Radio,” long before the launch of the satellite. Information about satellite motion, given by radio amateurs, can be used not only for studying the laws of radio waves through the atmosphere, but also, especially if the radio amateur uses a direction finding attachment, to approximately distinguish the elements of the satellite’s orbits.
Уже к настоящему времени имеется большое количество наблюдений спутника радиолюбителями. В ряде мест прохождение спутника зарегистрировано астрономами-любителями. В ряде других мест, к сожалению, до сих пор облачность не дала возможности вести оптические наблюдения.	Already in our time there are a large number of observations of the satellite by radio amateurs. In some places the passage of the satellite is registered by amateur astronomers. In a number of other places, unfortunately, cloudiness has so far not made it possible to conduct optical observations.
Все данные научных станций, а также радио-и оптических наблюдений любителей собираются и обрабатываются. В результате обработки этих данных определяются как элементы орбиты, так и их вековые уходы. При обработке используются новейшие вычислительные	All data from scientific stations, as well as radio waves and optical observations, is collected and processed. As a result of processing this data, both the elements of the orbit and their secular drifts are determined. The processing uses the latest computing tools, such as electronic counting machines.

средства, такие, как электронные счетные машины. В результате обработки уточняются параметры орбиты и предсказывается движение спутника. Кроме того, данные, поступающие с наблюдательных станций, используются для ряда геофизических исследований, проводимых с помощью спутника, таких, например, как определение плотности атмосферы по эволюции параметров орбиты спутника и т. д.	As a result of processing, the parameters of the orbit are refined and the motion of the satellite is predicted. In addition, data from observation stations are used for a number of geophysical surveys conducted by the satellite, such as, for example, determining the density of the atmosphere from the evolution of satellite orbital parameters, and etc.
ХАРАКТЕРИСТИКА СПУТНИКА Как уже указывалось, спутник имеет форму шара. Диаметр его равен 58 сантиметрам, вес -- 83,9 килограмма. Герметичный корпус спутника изготовлен из алюминиевых сплавов. Поверхность его полирована и подвергнута специальной обработке. В корпусе размещается вся аппаратура спутника вместе с источниками энергопитания аппаратуры. Перед пуском спутник заполняется газообразным азотом.	**FEATURES OF THE SATELLITE** As already mentioned, the satellite has the shape of a sphere. Its diameter is 58 centimeters, weight -- 83.9 kilograms. The hermetic satellite body is made of aluminum alloys. Its surface is polished and underwent special treatment. All of the satellite's equipment is located in the housing along with the equipment's power supply sources. Before launching, the satellite is filled with gaseous nitrogen.
На внешней поверхности корпуса установлены антенны в виде четырех стержней длиной от 2,4 до 2,9 метра. Во время выведения спутника стержни антенн прижаты к корпусу ракеты. После отделения спутника антенны поворачиваются относительно своих шарниров и занимают положение, изображенное на фотографии. (См. фотоснимок на 1 странице).	Antennas in the form of four rods, from 2.4 to 2.9 meters long, are installed on the outer surface of the case. During the launch of the satellite, the antenna rods are pressed against the body of the rocket. After the separation of the satellite, the antennas are rotated relative to their hinges and occupy the position depicted in the photo. (See photo on page 1).

Двигаясь по орбите, спутник периодически подвергается резко переменным тепловым воздействиям -- нагреванию лучами Солнца в период нахождения над освещенной стороной Земли, охлаждению при полете в тени Земли, термическим воздействиям атмосферы и т. д. Кроме того, при работе аппаратуры в спутнике также выделяется известное количество тепла. В тепловом отношении искусственный спутник является самостоятельным небесным телом, находящимся в лучистом теплообмене с окружающим пространством. Поэтому обеспечение в течение длительного времени нормального температурного режима на спутнике, необходимого для работы его аппаратуры, является принципиально новой и достаточно сложной задачей. Поддержание необходимого температурного режима на первом спутнике обеспечивается приданием его поверхности соответствующих значений коэффициентов излучения и поглощения солнечной радиации, а также регулированием теплового сопротивления между оболочкой спутника и размещаемой в нем аппаратурой за счет принудительной циркуляции азота внутри спутника.	Moving in orbit, the satellite is periodically exposed to sharply varying thermal effects -- heating by the sun’s rays while remaining above the illuminated side of the Earth, cooling when flying in the shadow of the Earth, thermal effects of the atmosphere, etc. In addition, when working equipment in the satellite also produce a known amount of heat. Thermally, an artificial satellite is an independent celestial body in radiant heat exchange with the surrounding space. Therefore, securing, for a long time, the normal temperature regime on the satellite, which is necessary for the operation of its equipment, is a fundamentally new and rather complicated task. Maintaining the required temperature regime on the first satellite is provided by imparting to its surface the corresponding values of radiation coefficients and absorption of solar radiation, as well as regulation of the thermal resistance between the satellite envelope and the equipment placed in it due to forced circulation of nitrogen inside the satellite.
На спутнике установлены два радиопередатчика, непрерывно излучающие сигналы с частотами 20,005 и 40,002 мегагерца (длина волн -- 15 и 7,5	Two radio transmitters were fixed to the satellite, continuously emitting signals at frequencies of 20.005 and 40.002 megahertz (wavelengths of 15 and 7.5 meters,

метра соответственно). Следует отметить, что на созданном в СССР искусственном спутнике в связи с его относительно большим весом оказалось возможным установить радиопередатчики большой мощности. Это позволяет производить прием сигналов со спутника на весьма больших расстояниях и дает возможность включиться в наблюдения за спутником самым широким кругам радиолюбителей во всех частях земного шара. Первые сутки наблюдения за полетом спутника подтвердили возможность уверенного приема его сигналов обычными любительскими приемниками на расстояниях нескольких тысяч километров. Зафиксированы отдельные случаи приема сигналов спутника на расстояниях до 10.000 километров.	respectively). It should be noted, that it was possible to install high-power radio transmitters on an artificial satellite created in the USSR due to its relatively large weight. This allows you to receive signals from the satellite at very large distances and makes it possible for the widest circles of radio amateurs in all parts of the globe to join in the observations of the satellite. The first days of observation of the satellite's flight confirmed the possibility of confident reception of its signals by ordinary amateur receivers at distances of several thousand kilometers. There have been separate cases recorded receiving satellite signals at distances of up to 10,000 kilometers.
РАДИОСИГНАЛЫ СПУТНИКА	**RADIO SIGNALS OF THE SATELLITE**
Сигналы излучаемые радиопередатчиками на каждой из частот, имеют вид телеграфных посылок. Посылка сигнала одной частоты производиться во время паузы сигнала другой частоты. В среднем длительность сигналов на каждой из частот составляет около 0,3 секунды. Эти сигналы используются для наблюдения за орбитой спутника, а также для решения ряда научных задач. Для регистрации процессов, происходящих на спутнике, на нем установлены чувствительные элементы, меняющие частоты телеграфных посылок и соотношения между	The signals emitted by radio transmitters at each of the frequencies are in the form of telegraphic packages. The transmission of a signal of one frequency occurs during a pause of a signal of another frequency. On average, the duration of the signals at each frequency is about 0.3 seconds. These signals are used to monitor the orbit of the satellite, as well as solve a number of scientific problems. To register the processes occurring on the satellite, sensitive elements are installed on it, changing the frequencies of telegraph packages and the relationship between the duration of these packages and pauses when

длительностью этих посылок и пауз при изменении некоторых параметров на спутнике (температуры и др.). При приеме сигналов со спутника производится их регистрация для последующей расшифровки и анализа.	changing some parameters on the satellite (temperatures, etc.). When receiving signals from a satellite, they are registered for subsequent decoding and analysis
Следует учитывать, что через некоторое время радиопередатчик прекратит свою работу. Это может, например, произойти, если метеорная частица пробьет корпус спутника или повредит антенну. Кроме того, спутник имеет ограниченный запас электроэнергии. После прекращения работы передатчика наблюдение за спутником будет вестись оптическими методами и радиолокаторами.	It should be taken into account that after some time the radio transmitter will stop its work. This may, for example, occur if a meteor particle breaks through the satellite body or damages the antenna. In addition, the satellite has a limited supply of electrical energy. After the termination of the transmitter, the observation of the satellite will be conducted by optical methods and radars.
Большое значение имеют наблюдения за распространением радиоволн, излучаемых со спутника. До сих пор основные сведения об ионосфере были получены изучением радиоволн, посылаемых с Земли и отраженных от областей ионосферы, лежащих ниже максимальной ионизации ионосферных слоев. В настоящее время по существу не известно, на каких высотах лежит верхняя граница ионосферы. Запуск спутника создает возможность получать в течение длительного времени радиосигналы с двумя различными частотами из областей ионосферы, ранее недоступных для длительных наблюдений, лежащих выше максимума ионизации, а	Observations of the propagation of radio waves emitted from a satellite are of great importance. So far, basic information about the ionosphere has been obtained by studying radio waves sent from the Earth and reflected from the ionospheric regions that lie below the maximum ionization of the ionospheric layers. Currently, it is essentially not known at what altitudes the upper limit of the ionosphere lies. The launch of a satellite makes it possible to receive for a long time radio signals with two different frequencies from the regions of the ionosphere that were previously inaccessible for long-term observations that lie above the ionization maximum, and maybe above the ionosphere in general.

может быть, над ионосферой вообще.	
Измерение уровней принимаемых сигналов и углов рефракции радиоволн с различными частотами позволяет получить данные о затухании радиоволн в ранее не исследованных областях ионосферы и некоторые сведения о структуре этих областей.	Measuring the levels of received signals and the angles of refraction of radio waves with different frequencies allows us to obtain data on the attenuation of radio waves in previously unexplored areas of the ionosphere and some information about the structure of those areas.
Программа научных измерений на искусственных спутниках Земли весьма обширна и охватывает многие разделы физики верхних слоев атмосферы и изучения космического пространства около Земли.	The program of scientific measurements on artificial Earth satellites is very extensive and covers many branches of the physics of the upper layers of the atmosphere and the study of outer space near the Earth.
К этим вопросам относятся: изучение состояния ионосферы, ее химической структуры, измерения давления и плотности, магнитные измерения, изучение природы корпускулярного излучения Солнца, первичного состава и вариаций космических лучей, ультрафиолетового и рентгеновского участков спектра Солнца, а также электростатических полей верхних слоев атмосферы и микрочастиц. Уже первый спутник даст сведения по ряду из этих вопросов.	These areas include: studying the state of the ionosphere, its chemical structure, measuring pressure and density, magnetic measurements, studying the nature of solar corpuscular radiation, the primary composition and variations of cosmic rays, the ultraviolet and x-ray sections of the solar spectrum, and the electrostatic fields of the upper atmosphere and microparticles. Already the first satellite will provide information on a number of these issues.
В области изучения космических лучей программа предусматривает получение	In the field of cosmic ray studies, the program provides for obtaining data on the

данных по относительному количеству в составе первичного космического излучения различных ядер. В частности, будет произведено определение относительного количества ядер лития, берилия и бора, а также ядер с весьма большим зарядом. В этом отношении можно будет получить данные, недоступные для ранее применявшихся методов исследований.	program provides for obtaining data on the relative amount of the various cosmic rays in the primary cosmic rays. In particular, the relative number of lithium, beryllium and boron nuclei will be determined, as well as nuclei with a very large charge. In this regard, it will be possible to obtain data that were not available in previously used research methods.
Устанавливаемая на спутниках аппаратура позволяет также произвести изучение вариаций полного потока космических лучей, изучение которых затрудняет большая толща атмосферы, находящейся над аппаратурой при установке ее на Земли. Полученные данные позволят выявить суточные, полусуточные и двадцатисеми-суточные вариации и изучить их связь с явлениями на Солнце. Спутник позволяет провести указанные измерения по всему земному шару.	The equipment that is being installed on satellites also makes it possible to study the variations in the total flux of cosmic rays, the study of which complicates the large thickness of the atmosphere located above the equipment when it is installed on the Earth. The obtained data will allow us to reveal diurnal, semi-diurnal and twenty-seven-diurnal variations and study their connection with the phenomena on the Sun. The satellite allows you to carry these measurements around the globe.
Вследствие поглощения атмосферой коротковолновой радиации Солнца она до сих пор еще не изучена. Большие высоты, на которых обращается спутник, позволят с помощью разработанной нашими физиками аппаратуры изучить ультрафиолетовый и рентгеновские участки спектра Солнца и выявить вариации интенсивности излучения. Это важно, так как по современным представлениям	Due to the absorption by the atmosphere of the short-wave radiation of the Sun, it has not yet been studied. The high altitudes at which the satellite is drawn, will allow, using the equipment developed by our physicists, to study the ultraviolet and x-ray portions of the solar spectrum and to reveal variations in the radiation intensity. This is important because, according to modern concepts, the short-wave radiation of the Sun causes ionization of the

коротковолновое излучение Солнца вызывает ионизацию верхних слоев атмосферы. Следовательно, эти результаты прольют новый свет на процессы образования ионосферы. Поскольку коротковолновое излучение Солнца вызывается солнечной короной, данные о нем позволят получить новые результаты о структуре солнечной короны.	upper layers of the atmosphere. Consequently, these results will shed new light on the formation of the ionosphere. Since the short-wave radiation of the Sun is caused by the solar corona, data on it will make it possible to obtain new results on the structure of the solar corona.
Наряду с коротковолновой радиацией Солнца огромную роль в процессах, происходящих в верхних слоях атмосферы, играет корпускулярное излучение Солнца. С этой целью важно решить вопрос о природе корпускулярного излучения, его интенсивности, энергетическом спектре частиц, выбрасываемых Солнцем, и выяснить роль корпускулярного излучения Солнца в образовании полярных сияний. Эти вопросы также удастся решить с помощью созданной аппаратуры и устанавливаемой на искусственных спутниках Земли.	Along with the short-wave radiation of the Sun, the corpuscular radiation of the Sun plays a big role in the processes occurring in the upper layers of the atmosphere. To this end, it is important to resolve the issues of the nature of corpuscular radiation, its intensity, the energy spectrum of particles emitted by the Sun, and clarify the role of corpuscular radiation of the Sun in the formation of auroras. These issues can also be resolved with the help of the equipment created and installed on artificial Earth satellites.
***	***
Полет спутника над ионизированными слоями атмосферы позволяет проверить ряд выводов, сделанных на основании тех или иных гипотез, относительно круговых токов, существующих в верхних слоях атмосферы. Искусственные спутники	The flight of a satellite over the ionized layers of the atmosphere allows you to check a number of conclusions made on the basis of certain hypotheses, relative to circular currents that exist in the upper layers of the atmosphere. Artificial satellites also make it

позволяют также произвести изучение быстрых вариаций магнитного поля Земли.	possible to study the rapid variations of the Earth's magnetic field.
Представляет значительный интерес изучение на больших высотах (порядка 1.000 километров) электростатических полей и решение вопроса -- является ли Земля вместе со своей атмосферой заряженной или нейтральной системой. Наряду с изучением ионосферы косвенными методами путем наблюдения за прохождением радиоволн программа исследований на спутниках предусматривает непосредственные замеры ионной концентрации на различных высотах, а в дальнейшем также химического состава ионосферы масс спектрометрическими методами. Если справедливы современные представления о том, что на больших высотах отсутствуют отрицательные ионы, эти опыты дадут полные сведения о составе ионосферы.	It is of considerable interest to study at high altitudes (about 1,000 kilometers) electrostatic fields and to determine whether the Earth, together with its atmosphere, is a charged or neutral system. Along with the study of the ionosphere by indirect methods by observing the passage of radio waves, the program of research includes direct measurement of ionic concentration at various altitudes, and further also the chemical composition of ionosphere by mass spectrometer methods. If contemporary understanding that negative ions are absent at high altitudes is correct, these experiments will give complete information about the composition of the ionosphere.
Не останавливаясь на всех научных наблюдениях, которые производятся и будут произведены на спутниках в течение Международного геофизического года, мы упомянем еще об исследованиях метеорной материи, находящейся в верхних слоях атмосферы. Намечено получение спектра масс и скоростей микрочастиц, попадающих в атмосферу из космического пространства.	Without dwelling on all of the scientific observations that are being made and will be made on satellites during the International Geophysical year, we will also mention the studies of meteoric matter located in the upper layers of the atmosphere. It is planned to obtain a spectrum of masses and velocities of micro-particles entering the atmosphere from outer space.

Искусственный спутник есть первый шаг в завоевании космического пространства. Для перехода к осуществлению космических полетов с человеком необходимо изучить влияние условий космического полета на живые организмы. В первую очередь это изучение должно быть проведено на животных. Так же, как это было на высотных ракетах, в Советском Союзе будет запущен спутник, имеющий на борту животных в качестве пассажиров, и будут проведены детальные наблюдения за их поведением и протеканием физиологических процессов.	The artificial satellite is the first step in conquering outer space. In order to transition to implementing manned space flights it is necessary to study the influence of spaceflight conditions on living organisms. First of all, this study should be conducted on animals. Just as it was done on high-altitude rockets, the Soviet Union will launch a satellite that has animals on board as passengers, and will conduct detailed observations of their behavior and the course of physiological processes.
Можно с уверенностью сказать, что осуществление намеченной программы научных исследований с помощью искусственных спутников Земли сыграет революционизирующую роль во многих вопросах физики, геофизики и астрофизики.	It is safe to say, that the implementation of the planned program of scientific research using artificial Earth satellites will play a revolutionary role in many issues in the fields of physics, geophysics, and astrophysics.
С успешным запуском искусственного спутника Земли наука и техника делают новый качественный скачок, перенося прямые методы научных измерений в недоступное до настоящего времени космическое пространство и прокладывая широкие пути будущим межпланетным путешествиям.	With the successful launch of an artificial Earth satellite, science and technology have made a new qualitative leap, transferring direct methods of scientific measurements to outer space unavailable to date and paving the way for future interplanetary travel.

5.1 Notes on Translation

[1] Mikhail Vasilyevich Lomonosov (1711-1765) was a Russian polymath. In 1754, he developed a working model of a proto-helicopter. It was a flying apparatus that was lifted up by two propellers.

[2] Nikolai Yegorovich Zhukovsky (1847-1921) was a Russian scientist, mathematician, and engineer. He was one of the founding fathers of modern aero- and hydrodynamics. He was the first to undertake the study of airflow.

[3] Konstantin Eduardovich Tsiolkovsky (1857-1935) was a Russian and Soviet rocket scientist. He is considered one of the founding fathers of modern rocketry and astronautics. His work contributed to the success of the Soviet space program.

[4] Abbreviation for the “State Commission for the Electrification of Russia.”

[5] Now, Beijing.

[6] Now, Semey.

[7] Now, Dushanbe.

[8] Now, Chennai.

[9] Abbreviation for the “Telegraph Agency of the Soviet Union."

[10] Abbreviation for the “Volunteer Society for Cooperation with the Army, Aviation, and Navy.” It was a paramilitary sport organization in the Soviet Union, mainly dealing with weapons, automobiles, and aviation. It was established in 1927 as OSOAVIAKhIM before adopting the name of DOSAAF from 1951 to 1991.

Chapter Six

Analysis of the Article

On February 25 1956, Nikita Khrushchev, the General Secretary of the Communist Party of the Soviet Union at the time, gave a secret speech entitled, “On the Cult of Personality and its Consequences” to the 20th Congress of the Communist Party of the Soviet Union. It was a speech that criticized Joseph Stalin and denounced his actions. The speech was an attempt by Khrushchev to draw the Communist Party back to Leninism and put Stalinism behind them. Because of this, communist propaganda started to highlight more of Vladimir Lenin’s contributions to the advancement of the Soviet Union rather than those of Joseph Stalin. While Lenin did lead the Soviet Union into a new age of technological advancement after the October Revolution in 1917, most of the Soviet Union’s spectacular innovations came under the leadership of Stalin. According to Harvey and Zakutnyaya, it was Stalin that pushed for further development of rocketry in the Soviet Union, the construction of an atomic bomb in an effort to catch up with the advancements being made by Americans, and set unrealistic goals in the development of heavy industry.

However, despite all of these contributions, Stalin is not mentioned once throughout the entire article, “A Great Victory in the Peaceful Competition with Capitalism.” This article was written in October of 1957, more than a year following Khrushchev’s speech. No mention is made of the scientific advancements conducted under Stalin that contributed to the launch of the first artificial Earth satellite into space. Innovations like the balloon are barely touched on, while all of Stalin's advancements in the rocket industry are outright ignored, despite their key role in the launch of *Sputnik*. Instead, Lenin is praised for his actions in leading Russia, at this time the Soviet Union, into a new era. The article mentions that the "path to today's achievements in [Soviet] science and technology began on the 7th of November 1917" (59). That is to say, all of the advancements made in the Soviet Union were made because of the Bolshevik Revolution that was instigated by Lenin. He began the process of technological advancement with his GOELRO plan, the State Commission for Electrification of Russia. He brought the Soviet Union into the future and started its modernization. The article states that it was here that the "seeds of [their] present victories were sown" (59). It was Lenin's hard work on modernizing the Soviet Union that set the stage for Soviet innovation, and the article's description of this almost evokes the image of Lenin as a farmer cultivating his land and planting the seeds of future Soviet victories with his hard labor.

As the article goes further and further in emphasizing Lenin's contributions to the Soviet Union and ignores the innovations made under Stalin's rule, they mention the five-year plans. The article states that "it was then, in the harsh battles of the first five-year plans, that the foundations of all achievements of [their] present day were made" (60). This excerpt comes from the same paragraph that mentions how Lenin's work set up the basis for Soviet advancement, connecting Lenin to the first five-year plans. The five-year plans mentioned where the plans for the development of the national economy of the Soviet Union. They consisted of a series of nationwide centralized economic plans and were based on the production forces that were an integral part of the Soviet ideology. While Lenin was the chief mastermind behind the New Economic Plan that led to the five-year plans being put into place, it was Stalin that inherited the NEP from Lenin and was the driving force behind their implementation in the Soviet Union. However, this fact is completely ignored by the article and instead all credit is given to Lenin. The article is an example of the Soviet Union leaving Stalinism in the past and returning to core ideals of Leninism, bringing about a revolution in the world, albeit not exactly the one that he had hoped for. Of course the announcement of the culmination of Lenin's hard labor and the labor of countless Soviet workers must be done in a decidedly Soviet manner. Not only by its content but in its narrative style, the article is a prime example of socialist journalism at the time.

This article exemplifies the artistic style of the Soviet Union at the time, which was socialist realism. Socialist realism was the state-enforced artistic style of the Soviet Union and is characterized by the glorified depiction of communist values, like the emancipation of the proletariat. During the Communist Party Congress of 1934, four guidelines were outlined for the characteristics of the socialist realist style (Juraga 68). In order for a work to be characterized as socialist realist it must be: relevant and understandable to workers, depict scenes of everyday life to the people, be realistic in representation, and supportive of the aims of the State and the party. The article emphasizes the equal contributions that were made in the development of the satellite, which was a collaborative effort by all different types of Soviet workers.

The first sentence of the article states that the first artificial Earth satellite in the world was "constructed by Soviet scientists, engineers, and workers" (57). This highlights the fact that all different types of workers contributed equally, going from those with an advanced degree (scientists), to those with degrees (engineers), to finally the average Soviet who could be anyone (workers). This is not the only instance where the contributions made by Soviet workers are highlighted in the article. In fact, there is an entire passage that chronicles the contributions made by great Soviet engineers and innovators to the realm of aerospace science, like the work of Zhukovskiy and Tsiolokovskiy. Following their introduction in the article, the work of other nameless Soviet workers is highlighted and we, the audience, are reminded that "between [Zhukovskiy and Tsiolokovskiy] and this great victory, lies a decade of hard labor of Soviet workers, engineers, technicians, and scientists" (59). It is a reminder that the launch of *Sputnik* was decades in the making and was an important milestone in the history of Soviet innovation. It is something that exemplifies the Soviet work ethic, the unrelenting push towards modernization and innovation that led to so many extraordinary feats in Soviet history, like the remarkable mobilization of factories during World War II.

Nothing can stall the well-oiled machine of Soviet innovation as it continues to churn forward and bring about new scientific achievements. In fact, as Lenin brought electricity into Russia as Prometheus did fire to mankind, the article reinforces the fact that nothing would stop this drive to modernization. The concrete workers of Volkhovstroi constructed the dam of the first hydroelectric station in the Soviet Union through severe frosts and workers labored to continue the industrialization of Russia, building new factories and the energy base of the Soviet state despite the opposition they faced from enemies and skeptics who said there was no need to build such heavy industry. Hard labor persists even in the worst conditions as nothing will stall the wheels of the Soviet machine. This is an idea that echoes throughout Soviet history, once again exemplified in the Soviet mobilization of factories during World War II and the quick turn around they experienced in fighting off the Germans following their development of heavy industry and machinery. Following World War II, the Soviet strove to prove their might on the world stage, hoping to compete with the technological marvels coming out of the United States. So, hoping to establish the Soviet Union as a world superpower equal or superior to the West, Stalin turned to scientists and workers to develop technological advancements in order to draw the global attention to the superiority of communist ideals. The only tools needed by Soviets to bring about scientific miracles is hard work and strength of will.

In "A Great Victory in the Peaceful Competition with Capitalism," a great deal of importance is placed on the fact that *Sputnik* was the first artificial Earth satellite in space. The very first paragraph of the article emphasizes this fact by starting off with the phrase "first in the world" (57). This underlines the fact that in one day this small Soviet satellite was able to traverse many major cities around the world, like Rome, Moscow, and Tokyo. It looks at the satellite's journey through a geographical scope rather than a scientific one, reminding everyone that it is the Soviet Union that is looking down at the world from above. In fact, this portion of the article brings to mind one of the core goals of Leninism, a worldwide revolution of workers. When Lenin came to power in the Soviet Union following the October Revolution, he spoke on his dream of a worldwide revolution, one that didn't just stop with the establishment of the Soviet Union, but rather one that spread communism around the world. This satellite is symbolic of Lenin's dream for the Soviet Union, of the Soviets extending control over different parts of the world. The satellite is a symbol of this dream almost turning into reality. Although there has been no worldwide revolution of workers, communism has indeed spread to parts of the world, like North Korea and the People's Republic of China. One could argue that instead of inciting a communist revolution like Lenin dreamed, the Soviet Union instead led a revolution of technological advancement as the launch of *Sputnik* propelled the space race between the USSR and the USA into high gear.

This article uses poetic language in order to situate the significance of *Sputnik*'s launch in the context of world history. Indeed the launch of the world's first artificial Earth satellite is a momentous and extraordinary feat of technological advancement, and no one is more proud and celebratory of this fact than the Soviet Union itself. This historic event signified the "dawn of a new era" (57) where the competition between world superpowers was played out on an even bigger stage with even higher stakes. The launch of *Sputnik* marked the beginning of a new competition in space where extraordinary feats were no longer the creation of devastating atomic bombs but rather being the first to explore space previously unknown. It is the beginning of an age where science fiction stories are no longer just fiction. The Soviets are quick to announce to everyone that this extraordinary step is made by the well-oiled machine of Soviet innovation. The Soviets saw it as their mission to turn this idea of flight outside airspace from a dream into reality. The first attempt at such a feat was with the balloon previously mentioned in the first chapter of this project. However, the Soviets were not satisfied by merely reaching the stratosphere. They had a bigger and brighter vision, one were the sky was no longer the limit. In fact, even before the balloon age started its inevitable decline "Lomonosov labored on a helicopter model with a clockwork mechanism" (58). The Soviets pushed themselves further and further in the pursuit of space flight. They yearned for the "realization of this dream" (59) into reality. This phrase is used again and again to describe the idea of flight outside airspace, highlighting this dream that was something long sought after by both the Soviets and the rest of the world. However, the article is once again quick to remind everyone that it was the Soviets that made this dream into reality.

In order to emphasize this realization of mankind's dream into Soviet reality, the article starts to mythologize the whole endeavor, poetically comparing the launch of *Sputnik* to the first innovations of mankind and the different myths surrounding human flight in different cultures around the world. Since "man first pulled on the tight string of a bow and shot an arrow into the air" (57) mankind has dreamed of flight, of flying through the "ocean of air" (58). As the article suggests, oftentimes the imagination of man is too advanced for technology to keep up with, like the ever enduring tale of the flying carpet. Then there is the ultimate dream of flight for man, the tale of Icarus, "who made himself wings and flew into the sky" (58). Mankind's dream is to fly like birds in the sky, and with technological advancements this can become a reality. For example, in the fifteenth century Leonardo Da Vinci studied the flight of birds and proposed mechanisms for flight by machine. However, his inventions never lifted a man into the atmosphere. In fact, centuries passed before a man was ever lifted into the air by a mechanism he built.

The first to do so was the hot air balloon; however, Mikhail Lomonosov, a Russian polymath, anticipated the decline of the era of hot air balloons and in 1794 developed a working model of a proto-helicopter. Another century would pass before "aircrafts heavier than the air" would be constructed. Interestingly enough, the article glosses over the technological advancements made by non-Russians in the field of aviation. No mention is made of the Wright Brothers who were the first to fly the world's first successful airplane. In 1903, they made the first controlled and sustained flight of a powered, heavier-than-air aircraft in Kitty Hawk, North

Carolina. Nor is any mention made of the balloons sent into the stratosphere nor the rocket tests done during Stalin's time. Instead, they are all vaguely hinted at in the line declaring the first half of the twentieth century as the "time of rapid development of aviation" (58). However, this paragraph is quickly followed by the reminder that mankind had still not achieved its dream of flight outside airspace. Now though, the dream has changed from an abstract idea and popularized myth to an actual scientific dream that is based on concrete work. Bringing back the elements of Socialist Realism, the article is quick to point out that the Soviets' dream is based on mathematical calculations and is supported by the study of physical phenomena, basing it in reality.

Of course, all of these scientific and technological advancements would not have come about without the support of the Communist party. It is with their backing that this dream of space flight is being turned into reality. Starting in 1917 when Lenin led the October Revolution and brought about a new age of modernization and industrialization, the Communist party, according to the article, has always supported its scientists and workers in their scientific and technological ambitions. In the pursuit of space flight, the Communist party has again and again "reared the personnel of aircraft designers and aircraft builders, cultivated in all people a great love for aviation, and created the country's aviation culture" (59). The Communist party encouraged the technological advancement made by the workers of the Soviet Union, applauded the pursuit of the dream of flying like birds, and fostered within its people a profound love for technological advancement. With the launch of *Sputnik*, the Earth's entire population is able to witness the great victory of Soviet science and technology, of highly developed industry, and their technological power "created by the great Soviet people under the direction of the

Communist party" (60). It is communist ideals that have led to the "victory of collective labor, which alone can perform genuine miracles in the world" (60). The article again and again reinforces the fact that the Communist party is the driving force behind the development of ambitious plans made by the Soviet people and their implementation in life that has allowed them to build, invent, and astonish the world with their creative and inspired work. The West would have you believe that scientists and technicians, inventors and innovators in the Soviet Union are met will fates. However, the article states this is all hear-say made up by the capitalist press, and that if one wishes to know the fate of scholars, innovators and inventors in the Soviet State, then follow the flight of the world's first artificial Earth satellite.

As Neil Armstrong took his first steps on the surface of the moon in 1969, he cemented his place in world history and uttered the now famous phrase, "one small step for a man, one giant leap for mankind" emphasizing the significance one small action can have in the history of civilization. Although stepping off a ladder onto the ground doesn't seem like a defining moment in history, it was, in fact, the culmination of decades of work made by scientists and mathematicians that got him there. It is a significant leap forward for technological advancement. However, while Neil Armstrong was the man that popularized this phrase, he is not the first to use this kind of terminology in reference to extraordinary scientific achievements. In fact, he almost verbatim repeated the phrase that the Soviets used more than a decade earlier when discussing *Sputnik 1*'s launch. When discussing the "dawn of a new era, of a period in the history of civilization" (57) the article states that a "gigantic step forward" had been made in the exploration of interplanetary space. Although not exactly the words coined by Neil Armstrong in 1969, the language is undoubtedly similar. Armstrong's use of this language supports the idea that the space race was politicized and that even American astronauts were speaking the language of propaganda. It emphasizes the extraordinary bounds forward that have been made by technology in recent years. Within the span of a few decades, mankind has gone from fighting wars with tiny guns and cannons to using atomic bombs and nuclear missiles. Now, a new age has dawned where the sky is no longer the limit.

A few paragraphs later, the article once again utilizes this language when describing the launch of *Sputnik* as a "crucial step in the realization of this dream" (59) of flight outside of airspace. It is interesting that the first to use such language was the Soviet Union more than a decade before Neil Armstrong took his first steps on the surface of the moon. The moon landing is a significant event in the history of the United States and the world. Numerous movies and documentaries chronicle the struggle that American scientists and workers had to face in putting a man on the moon. Not unlike the Soviets, this defining moment in history was used by the Americans as a way to showcase to the world the might of the United States. Neil Armstrong further supported this with his words that day. In fact, his appeal to the same idea is evidence that this peaceful competition between countries did indeed have something peaceful about it. It united humans in their quest for scientific and technological advancement, while also setting the stage for a different kind of war, one without the loss of lives but rather with scientific achievements and discoveries.

This new avenue of peaceful competition was quickly pursued by both countries as they endeavored to show their own individual superiority over the other. In fact, the launch of *Sputnik 1* is a consequence of this very competition. In the late 1950s, both the Soviets and the Americans were developing models for the first artificial Earth satellites. However, the Soviets scrapped their original plans for their satellite because of their fear that they would not be able to finish its construction before the Americans were able to launch their own version of a satellite. Obsessed with becoming the "first in the world" in launching a satellite into orbit, the Soviets designed a much simpler satellite in its place, ensuring their victory. During this time, scientific and technological advancement had become an important, integral part of the peaceful competition between the Soviet and American systems. The Soviets viewed *Sputnik* as their triumph, an event that cemented their belief that "the new, socialist world takes possession of powerful technology, creates new technology of its own, and steadily moves forward along the path of progress" (62). The article is alluding to Stalin bringing rocket industry back to the Soviet Union from Germany and further developing from it the rockets that would eventually lead to the creation of *Sputnik*. The Soviets were eager to continue this peaceful competition in order to prove themselves and their ideals to the rest of the world, specifically the skeptics in the West.

The article reminds everyone that "with miraculous strength and visibility, it was once again proven that Soviet socialist foundation is the best form of human labor organization" (60). Soviets believe that with their successful launch, the rest of the world, even the capitalist press, is "forced to recognize the advantages of the socialist system" (60-61). After all, it is from this hard work and determination that such a miraculous event has sprung forth. The socialist system calls for collaborative work from its workers and is not hindered by the "feuds between separate types of armed forces" (61), behind which lies the "struggle of powerful monopolies" (61), that stalled the development of an artificial satellite in the USA. The events surrounding the launch of the first artificial Earth satellite in both the US and the USSR proves, at least to the Soviets, that the world of greed and profit that is capitalism sets “obstacles in the path of the development of production forces” (61). With their socialist system, the Soviet society is faced with no such obstacles. Instead, they focused on working towards realizing their dream of space flight “without boasting, without the noise and advertising inherent in capitalism” (61). The Soviet Union doesn’t boast about their accomplishments like the United States, instead they care only about the advancements they are working on and the astonishment of the world is merely a consequence of their work, not their reasoning behind it. They don’t feel the need to broadcast their hard work in order to receive praise. The only acknowledgement they need of their hard work is watching the flight of the Earth Satellite, which will be the only thing boasting the technological advancement of the Soviet Union.

For the Soviets, the article states that this need to match and surpass the technological and scientific advancements coming out of the United States was nothing more than a peaceful competition between two opposing systems. With the launch of *Sputnik*, it is necessary to analyze the serious political conclusions that come with the victory of the Soviet Union in this competition. The article addresses the misconceptions made by the reactionary political spheres in the West that are “trying to reduce the peaceful competition between two systems in the field of technological progress … to an arms race” (62). The American newspaper, “The Daily News” believes that *Sputnik*’s launch will force the government to quickly implement various Pentagon programs in order to catch up with Soviet progress. However, the Soviets believe that is high time for American governing spheres to “get out of that vicious cycle, into which they led themselves astray” (62-63). There is no such arms race, if anything they began this arms race by declaring their monopoly on atomic weapons and the hydrogen bomb, by rejecting Soviet disarmament proposals and showing off their missile weapons. They miscalculated and underestimated the might and hard work of the Soviet Union who developed intercontinental ballistic missiles and ultimately the first artificial Earth satellite. The article goes on to highlight the fact that in politics the US has made itself known to have “a steady tendency to underestimate Soviet capabilities” (63), even referencing *The New York Times*’s call to reject “the traditional, stereotypical opinion held by the United States and the West that the majority of Russians are ignorant and illiterate peasants” (63). The United States have become blinded by their hatred for Communism and overlooked key features of Soviet success, like: the Great October Socialist Revolution, or the rapid development of Soviet economy, science, and culture. Now the United States must acknowledge the extraordinary advancements made by a country they had previously believed to be underdeveloped. The main road of development of modern international relations that will led to the peaceful coexistence of two different systems is a peaceful competition in the areas of economics, science, and technology. And, as the article states, “the best propagandist for this path is the Soviet artificial satellite, rotating around our planet, which now hosts both socialist and capitalist countries” (64).

Chapter Seven

Conclusion

On October 4, 1957 the Space Race was kicked into gear by a silver ball zipping across the sky. This was the Soviet artificial Earth satellite known as *Sputnik 1.* It was a symbol of the communist victory over capitalism, the triumph of Soviet ideals over American superiority. This feat of Soviet innovation proved the USSR's technological prowess and spurred the United States into advancing its own space program. One could say that the Space Race was a tug of war between the United States and the Soviet Union over being "first in the world" that started that day in October 1957. The Soviets left the world gapping in shock with their beeping metal ball orbiting the Earth, striking fear in the United States that they were falling behind the Soviets in technological capability. Many feared that *Sputnik* was merely beginning of a whole range of technological firsts. A fear that was further cemented merely a month later when the Soviets launched another satellite on November 3, 1957, a satellite that was much heavier and even carried a dog, Laika, within it (Levine 55). It appeared that the Soviets had beaten the West, particularly the United States, at its own game — technology. They were the ones that were attributed the glory of launching what was dubbed the Space Age.

While the Soviets had already succeeded in launching two separate satellite for the International Geophysical Year, the Americans' own attempt, *Vanguard*, failed spectacularly on

December 6, 1957 (65-66). Fearing that this would give support to the claim that the US could not keep up with Soviet advancement, the Americans turned to another project, *Explorer 1*, to propel themselves into the Space Race. It successfully launched on February 1, 1958, going further than both Soviet satellites and even discovering the Van Allen Belts, a radiation field that surrounds the Earth (66). Now, the Soviets and Americans were once again on an even playing field and both heavily invested in spacecraft development in the following decade. More satellites and animals made their journey into space, testing out spacecraft parameters, like life support and re-entry in order to help researchers better understand how space would affect animals and humans.

Now that both countries had successfully launched a satellite into orbit a new race had begun. The race to put the first man into space. Once again the Soviets came out the victor in this competition, launching Yuri Gagarin into orbit on April 12, 1961. The Americans, however, were not far behind, launching their own astronaut, Alan Shepherd, three weeks later on May 5, 1961. Now, a new race for astronaut milestones quickly followed, the countries competing to be the first to send two people into space simultaneously, send three people into space simultaneously, perform a spacewalk, or dock two spacecraft in space. The next feat to be accomplished in space exploration was putting a man on the moon, something that President John F. Kennedy famously declared in 1961 that the United States would do by the end of the 1960s in a move partly designed to reestablish US technological superiority. On July 20, 1969, the United States' *Apollo 11* successfully touched down on the moon's Sea of Tranquility and Neil Armstrong was the first to ever step foot on the surface of another planet. Of course, not even a year later, the Soviet Union had its own first to counter with, launching the first space station, Salyut 1, on April 19,

1971. They developed expertise in long-term spaceflight across several space stations, most notably, space station Mir of the the 1980s and 1990s.

The launch of *Sputnik 1* was a defining moment in the history of mankind and represented the dawn of a new era in technological advancement. It's biggest impact was the incredible legacy of space exploration achievements that it inspired. *Sputnik* sparked a race to be "first" in space. The stakes in the race lay in prestige and general technological and scientific advancements. *Sputnik* was more than a tiny ball of metal that orbited around the Earth, it was the culmination of centuries of work made by astronomers, physicists, mathematicians, and engineers who desired to understand the workings of the universe. It was the realization of a dream that has survived for centuries, a dream of flight.

Throughout this project, we have discussed the history behind the launch of *Sputnik 1*, how it came to be, and its reception in both the Soviet Union and around the world as well as the math behind the theory of orbits, *Sputnik*'s orbital trajectory around the Earth, and the specifics of its own orbit. As the scope of this project was rather broad, so too were the conclusions that were drawn from it. In detailing the story of *Sputnik 1*, I have attempted to fit together the details of a complex history together in a narrative of the cultural and scientific implications of space exploration, as well as the significance *Sputnik* had in the context of the Space Race. By focus on the Soviet perspective and interpretation of the launch, I have come to understand how significant space exploration was to the Soviet identity and what it represented to a country that was again and again underestimated by the rest of the world. In terms of the mathematics behind orbits, I am impressed that the basis for such a contemporary idea like space exploration has such significant roots in the ideas of centuries past, and how our understanding of the universe has grown from these ideas.

In considering the launch of the first artificial Earth satellite through both a cultural and scientific lens, we are able to understand the entire impact space exploration had on Soviet and global culture. The Space Race was more than a struggle of technological superiority, it was an ideological one, as well. For this project, I have tried to broaden discussion of the launch of the first artificial Earth satellite by taking both a qualitative and quantitative approach by analyzing the reception of *Sputnik 1* and describing the mathematics that supported its orbit. In the process of this, I have come to appreciate the significance such an event had on the history of space exploration and I have gained a better understanding of the intricacies of orbital calculations.

In conclusion, it is clear that the launch of *Sputnik 1* was the dawn of a new era in the history of civilization, the beginning of the Space Age, and it shaped the future of space exploration. It kickstarted a race to be the “first” in space that allowed for more rapid development of technology and scientific understanding. *Sputnik 1* was born from the work of countless scientists and mathematicians who all worked together in order to realize mankind’s dream of spaceflight. Since the launch of *Sputnik* in 1957, mankind has advanced further and further in their understanding of the workings of the universe. However, none of this progress would have been made without the perseverance of Soviet scientists and workers whose innovation started a global revolution of technology, something that Konstantin Tsiolkovsky started decades earlier with a revolutionary idea. In the words of Johannes Kepler, “the ways by which men arrive at knowledge of celestial things are hardly less wonderful than the nature of these things themselves."[25]

[25] Gould, Alan. "Johannes Kepler: His Life, His Laws and Times." *NASA*, 3 August 2017. https://www.nasa.gov/kepler/education/johannes.

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