Theatre of the World: The history of maps

by

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PREFACE

All the world’s a stage

\*

Oslo, Norway

59° 56' 38'' N

10° 44' 0'' E

Human beings took a bird’s-eye view of the world long before learning to fly. Since pre-historic times, we have drawn our surroundings as seen from above to better understand where we are – rock carvings of houses and fields provide early evidence of this need. But it was only relatively recently that we were able to see how everything really looked. On Christmas Eve 1968, the three astronauts aboard Apollo 8 orbited the Moon and became the first humans to see the entire Earth at once. ‘Here’s the Earth coming up. Wow, that is pretty! [...] Hand me that roll of colour quick’, said astronaut William Anders, before taking a photograph of our planet hovering beautiful, lonely and fragile in the infinite vastness of space.

Apollo was the Greek god who rode across the sky each day, pulling the Sun behind him. When Flemish cartographer Abraham Ortelius published the world’s first modern atlas in 1570, just four hundred years before Apollo 8 orbited the Moon, a friend of his composed a tributary poem in which Ortelius sits beside the god in order to see the whole world: ‘Ortelius, who the luminous Apollo permitted to travel through the high air, beside him in his four-horse chariot, to behold from above all the countries and the depths that surrounds them’\*.

Ortelius’s atlas opens with a world map, with clouds drawn aside like stage curtains to reveal the Earth. With the book open before us, we look down on *Noruegia*, *Bergen*, *Suedia*, *Aegyptus*, *Manicongo*, *Iapan*, *Brasil*, *Chile* and *Noua Francia*. Ortelius called the book *Theatrum Orbis Terrarum* – *Theatre of the World* – because he believed the maps enabled us to watch the world play out before our eyes, as if in a theatre.

Regarding the world as a theatre was common in Ortelius’s time. The year after *Theatrum* was published, English playwright Richard Edwardes had one of his characters say that ‘this world was like a stage, / Whereon many play their parts’ – a formulation so admired by William Shakespeare that he used it in *As You Like It* some years later: ‘All the world’s a stage, / And all the men and women merely players; / They have their exits and their entrances’. Shakespeare also named his theatre the Globe.

Ortelius was no original cartographer. Nor was he an astronomer, geographer, engineer, surveyor or mathematician – in fact he had no formal education within any discipline. He did, however, know enough about cartography to understand what made a good map and what made a poor one, and with his sense of quality, thoroughness and beauty – in addition to a large network of contacts and friends, who either drew maps themselves or knew others who did so – was able to collate a refined selection of maps for inclusion in the world’s first atlas.

Writing a book about the history of maps is somewhat reminiscent of Ortelius’s work with *Theatrum*. This book also builds upon the prior work of many others, and I have studied a considerable number of books, texts and films to identify the most important and interesting material. It has also been necessary to make certain choices – no map can cover the whole world, and no book can contain cartography’s entire history, since the history of maps may be said to be the history of society itself. Maps are of political, economic, religious, everyday, military and organisational significance, and this has necessitated some difficult decisions regarding what to include. The hardest decisions have been those relating to material closest to our present time, since scarcely any aspect of society is unaffected by cartographic questions.

Throughout history, the creation of maps has been guided by value judgements as to what is worthy of inclusion. Maps have always given us more than geographical information alone – as illustrated by the clear contrast between an Aztec map of the city of Tenochtitlan, which only provides details of the rulers of each district, and Cappelen’s *Norgesatlas* (*Atlas of Norway*) from 1963, where the publisher, due to social considerations, has ‘chosen to include too many place names, rather than too few’. The Aztec map reflects the hierarchy of a strictly class-based society, while the *Norgesatlas* represents the golden age of social democracy in which everyone must be included. Both maps were influenced by the values of the age in which they were created.

[...]

In 1969, American cartographer Waldo R. Tobler formulated what is known as the first law of geography: ‘Everything is related to everything else, but near things are more related than distant things.’ When looking at a new map, the first thing most people seek out is their home town. ‘Some will perhaps search this theatre of ours for a performance of a particular region (since everyone, because they love their place of origin, would like to see it among the rest)’\*, wrote Ortelius in his preface to *Theatrum*, so the phenomenon is an old one. And yet once we have found our home town, many of us experience a thrill as we journey through an atlas – pausing to look at Takoradi, Timbuktu and Trincomalee; running our finger along the route taken by the Orient Express, the Silk Road, the Western Front and the boundaries of Ancient Rome – and realise that we are an equally exotic and inevitable part of the world as any other.

Distance and nearness are relative. Seen from space, the Earth must have seemed like the home town of all humanity. As astronaut William Anders said: ‘We came all this way to explore the Moon, and the most important thing is that we discovered the Earth’.

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THE FIRST ATLAS

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Antwerp, Belgium

51° 13' 6'' N

4° 23' 53'' E

With her brush, Anne Ortel carefully applies light green paint to an area of woodland, then uses pale and darker brown to indicate the lowlands of *Brabantia*, *Flandria*, *Hannoia* and *Hollandia*. Two shades of blue denote the water; light for the vast ocean, and dark for the rivers, lakes and navigable waterways along the coast. She paints the ships brown and dark yellow, then dips her brush in red to colour the cities, one by one: *Brueßel*, *Utrecht*, *Louen* and *Oosterwijck*; *Amsterdam*, *Delft*, *Eyndhouen* and *Antwerpen* – her home town. In 1570, Antwerp is the richest city in the world thanks to the trade that takes place along the river Schelde. The significance of this waterway is clear, as a five-metre-long map of it was created in 1486. In Antwerp, the Spanish and Portuguese purchase copper and silver mined in Southern Germany, before transporting it to India and Africa where they exchange it for spices, ivory and slaves. English cloth, Flemish embroidery and German leather goods are traded here, and the city itself exports luxury products such as glass, gems and wallpapers.

The Antwerp of Ortel’s time is a cosmopolitan city. If you take a walk beside the port, where over 2,500 ships dock each year, you might hear merchants speaking Dutch, English, French, Italian, Yiddish, Portuguese, Spanish and German, in addition to African and Oriental languages. Traffic to the city is so great, and the new, modern cranes so numerous, that Antwerp even has its own crane operators’ guild. A network of canals spreads from the port to the city’s many warehouses, and then further out into the Brabantian countryside. The similarities to Alexandria 1,500 years earlier are striking – both cities are trading hubs with a significant interest in geography and the wider world. Antwerp has no major library or renowned educational institution, but makes up for this with its many printing houses, booksellers and publishers – since German printer Johannes Gutenberg began producing books in the 1450s, the book market has developed at such a pace that the need for libraries has reduced. Dutch humanist Erasmus praised a printer friend by asserting that he was ‘building a library with no limits but the world itself’\*, and Antwerp’s printing houses act as libraries, booksellers, publishers, workshops and meeting places for scholars of all kinds. Most of them are located in Kammenstraat, including Europe’s biggest and most important printing house at this time, *De Gulden Passer* (The Golden Compass), where business has increased to such an extent that the premises now span seven buildings located side by side.

Anne Ortel was named after her mother, who taught her how to colour maps. Her grandfather moved to Antwerp from the German city of Ausberg after hearing about the opportunities Antwerp had to offer, and did well for himself – the Ortel family were highly regarded in the city. Anne’s father, Leonard, became an antiques dealer, and inherited his father’s propensity for religious reflection. Like the rest of the city, which at this time was controlled by the Spanish crown, Anne’s parents officially professed to follow the Catholic faith, but like many other Antwerpians held Protestant sympathies. In 1535, Leonard was forced to flee the city due to his involvement in the printing of reformist Myles Coverdale’s English translation of the Bible.

Charles V, ruler of both the Spanish and Holy Roman empires, had little time for Protestantism, and the Inquisition burned both books and heretics with zeal. When Leonard fled Antwerp, he left behind his wife and children – including Anne’s older brother, Abram, who was just eight years old. The Inquisition stormed the house, looking for forbidden, heretical books, but found none.

Anne’s father died just four years later, leaving her mother to diligently and successfully continue the antiques business and instruct Anne, Abram and their younger sister Elizabeth in the art of colouring maps. Maps had always been part of their father’s collections, and young Abram showed a keen interest in geography. There was a large market for maps in the Netherlands at the time, which expanded alongside the country’s international trading activities – even outdated maps were desirable, and many of the period’s artists painted everyone from the bourgeoisie to humble shoemakers in settings featuring maps on the walls. Maps were bought and sold at all price levels – and in the Netherlands, coloured maps were particularly in demand.

Abram and his sisters purchased black-and-white maps, which they glued onto linen canvases before stretching them over wooden frames to be coloured. They sold the coloured maps to private individuals, publishers and booksellers – a coloured map usually cost around a third more than an uncoloured one. Each map’s appearance was dictated by the client – if someone wanted their home town coloured a bright shade of pink, well, their wish was granted. But colours could also be used to convey information. As early as the year 1500, German cartographer Erhard Etzlaub recommended the use of different colours to indicate where different languages were spoken. Later in life, however, Abram would disclose a preference for uncoloured maps. In a letter to his nephew, Jacob, dated 1595, he wrote: ‘You ask me for a coloured copy; in my opinion an uncoloured copy is better; you may decide for yourself’\*.

Abram never gained an education – presumably because he had to work. Perhaps Leonard had hoped for his son to go to university – he had at least done his best to educate him in Latin and Greek – but according to a friend who referred to him in a letter after his death, Abram was ‘hampered by his circumstances, since he had a mother who was widowed and two sisters to care for’\*. The University of Leuven, around sixty kilometres away and one of just two universities in Europe offering cartography as a discipline, must have seemed almost within reach and yet a distant dream. Another friend wrote that Abram ‘studied and practised [mathematics] on his own without an instructor or teacher, and through his own hard work and strife, for which others admired him, eventually understood the subject’s greatest and deepest mysteries’\*.

What books might Abram have read? The professor teaching cartography at Leuven in Abram’s time was Gemma Frisius – an orphaned cripple who grew up under the care of his poor stepmother before being offered a place at the university reserved for talented students of limited means. He made the most of the opportunity, and became an astronomer, mathematician, doctor and instrument maker, creating a globe and publishing *De principiis astronomiae et cosmographiae* (*Of the Principles of Astronomy and Cosmography*) as a supplement to it in 1530, in addition to a small volume on surveying three years later. Both books were printed in Antwerp – the most important city in Europe for geographical publications and maps – and it is not improbable that the young Abram read both of them from cover to cover.

Abram also read travelogues and historical works: Herodotus, Strabo, works about Marco Polo and Ptolemy’s *Geographia* – probably in the editions published by Sebastian Münster in 1540, 1542 and 1545, the most recent of many versions published since the first translation into Latin over one hundred years earlier.

PTOLEMY RETURNS | The European Renaissance began in 1397, when Greek scholar Manuel Chrysoloras arrived in Florence to teach Greek to the Florentine monks. Greek had been studied little by European scholars over the previous 700 years, and the monk Jacopo d’Angelo invited Chrysoloras to Italy after meeting him in Constantinople while he was there to study Greek. D’Angelo returned to Florence with a number of Greek manuscripts including a copy of Ptolemy’s *Geographia*, and a certain anticipation spread through the city’s humanist circles when Chrysoloras began to translate it – so far scholars had only heard rumours about the work, and been able to read only fragments from it. Jacopo d’Angelo took it upon himself to complete the translation when Chrysoloras moved on to other cities.

 In the introduction to the translation of the *Geographia*, d’Angelo wrote that Ptolemy showed us how the world looks (‘*orbis situm ... exhibuit*’). He also emphasised that the Greek scholar offered something that was lacking in the Latin cartographic tradition – methods for transferring the geography of a sphere onto a flat piece of paper. But d’Angelo lacked the mathematical skills necessary to translate Ptolemy’s somewhat complex instructions about how such projections should be created, and consequently the methods were poorly understood by Renaissance readers.

 D’Angelo changed the title of the work from *Geographia* to *Cosmographia*. In the Middle Ages, the Europeans had no separate term for geography, and a definition of the word therefore had to be given every time it appeared in a translation – usually as ‘that having to do with describing the world’\*. *Cosmographia*, used by some Roman authors, often served as a synonym, although cosmography describes both the Earth and the heavens. Readers must not forget, d’Angelo reasoned, that the book was primarily concerned with the celestial bodies, since Ptolemy’s longitudes and latitudes are based on observations of the Sun, Moon, stars and planets, and therefore show how these bodies influence the Earth. He thereby located the *Geographia* in a tradition where astrology and astronomy were two sides of the same coin, and this is how we must understand Ptolemy as being read by early-Renaissance readers: the *Geographia* did not suddenly provide the Europeans with a new world view, nor a method of drawing maps that was more scientific than the ones they already had. Instead, they used Ptolemy in the same way as they used other maps and astronomical observations – to adjust their existing ideas of the world based on the works of Pliny and the travelogues of the Middle Ages.

 We do not know exactly when Florentine scholars started drawing maps based on Ptolemy’s list of coordinates, but an undated letter from the early 1400s states that a Francesco di Lapacino was among the first individuals to produce one: ‘He did it in Greek, with the names in Greek, and in Latin, with the names in Latin, and nobody had done it before him’\*. In 1423, a Poggio Bracciolini purchased ‘some maps from Ptolemy’s *Geographia*’\* from a Florentine statesman.

 Ptolemy was rediscovered at a time when the Southern Europeans were starting to venture out into the world. The Portuguese set out on expeditions along the African coast to find gold, supplementing their old, heavier ships with caravels – light, manoeuvrable vessels that could also sail up rivers and in shallow waters. In 1418, two Portuguese ships were blown ashore on the island of Madeira in the Atlantic Ocean; they reached the Azores in 1427 and sailed past Cape Bojador on the coast of Western Sahara – known for its fog and inclement weather – in 1434. The Portuguese had long believed that nobody lived any further south than this, but when they reached the Gambia River, on the other side of the Sahara, they had sailed the full length of the Arab trade routes that cut through the desert, and gold and slaves could be transported directly to European ports.

 The Europeans now found themselves in the part of the world antiquarian sources claimed was uninhabitable due to the intense heat. After a church meeting in Florence in 1439, at which the Ethiopian delegates were asked a long list of questions about how far south their country was, the Italian Flavio Biondo wrote that ‘this Ptolemy, who only knew the smallest initial part of Ethiopia – that contained within Egypt – could not but be ignorant of the regions and kingdoms that lie beyond’.

 To the north, Ptolemy’s world map stretched no further than the mystical island of Thule at a latitude of 63 degrees north. In 1427, after the *Geographia* had reached scholarly circles in Paris, Cardinal Guillaume Fillastre published an edition including the northern regions. Of the map, Fillastre wrote: ‘Beyond that which Ptolemy put here, there are Norway, Sweden, Russia and the Baltic Sea dividing Germany from Norway and Sweden. This same sea, further to the north, is frozen for a third part of the year. Beyond this sea is Greenland and the island of Thule, more to the east. And this fills all the northern region as far as the unknown lands. Ptolemy made no mention of these places, and it is believed that he had no knowledge of them. So that this eighth map might be more complete, a certain Claudius Cymbricus outlined the northern regions and made a map of them which is joined to the other maps of Europe, and thus there are eleven maps (instead of ten)’. This map expanded the Ptolemaic world view to include the countries up to a latitude of 74 degrees north.

Pages 239-248

AS SEEN FROM THE AIR

\*

Neuve­Chapelle, France

50° 35' 4'' N

2° 46' 5'' E

When the battle was over, more than 20,000 soldiers were dead, injured, missing or taken prisoner from the battlefield, and the village of Neuve­Chapelle was just a name on a map. Wednesday 10 March 1915 dawned with a light snowfall that soon thickened into damp fog; nonetheless, British aircraft took to the air to fly over enemy positions, bombing railway lines and advancing reinforcements while the artillery aimed their guns at the German targets. At 07.30 am the British launched the biggest artillery attack in history, pulverising the German trenches. In his diary, British Officer Herbert Steward wrote: ‘The earth shook and the air was filled with the thunderous roar of the exploding shells. To the watching thousands the sight was a terrible one: amidst the clouds of smoke and dust they could see human bodies with earth and rock, portions of houses, and fragments of trench hurtling through the air.’ In just 35 minutes, the artillery fired off more ammunition than that used by 500,000 British soldiers during the three-year duration of the Boer War fifteen years earlier.

 The First World War was not like previous wars. Industrialisation had given rise to a broad range of new, powerful weapons such as machine guns, grenades and poison gas, in addition to new vehicles including tanks, submarines – and planes. Prior to the battle, the Royal Flying Corps – the British Air Force – had defied the weather to take a vast number of aerial photographs of the German positions. ‘My table is covered with photographs taken from aeroplanes. We have just developed this method of reconnaissance, which will I think develop into something very important’, wrote Brigadier General John Charteris a few days before the attack.

 The photographs were placed side-by-side to create a mosaic of the landscape. The army – and the Royal Engineers in particular – then assisted the anti-aircraft artillery in creating a map based on the photographs, with red and blue lines denoting attack plans and artillery targets. This was the world’s first map based on aerial photographs.

THE WRIGHT BROTHERS | On 17 December 1903 a cold, light breeze blew across the long, flat beaches of Kill Devil Hills in North Carolina, USA, where four men and a teenage boy stood observing a group of inventors attempting to make a spindly-looking plane take flight. The inventors succeeded – Orville Wright covered a stretch of 37 metres in 12 seconds in history’s first-ever powered flight.

 Did Orville and Wilbur – the Wright brothers – consider this breakthrough the start of what would take human beings ever higher, until we would eventually crash through the atmosphere and travel out into space? Or were they simply two inventors with a good idea? Probably both. The plane which took flight on that Thursday was the result of work the brothers started as young boys in 1878, when they were given a toy by their father – a kind of helicopter made from paper, bamboo and cork, operated by an elastic band. After they played with it so much that it fell to pieces, they made their own.

 The idea of humans learning to fly was in the air when the Wright brothers were growing up, and many inventors were experimenting with various devices. Hot air balloons were already well-established – the first successful hot air balloon flight took place in 1783. Eleven years later, the French army sent a man up in a balloon to obtain an overview of enemy positions, and in 1859 French Officer Aimé Laussedat developed the first camera specifically created for mapping purposes. Clambering up and onto the church towers and roofs of Paris, he photographed easily-identifiable locations at least twice and from various angles, and used the images to draw reasonably accurate maps. This work laid the foundations for photogrammetry – the science of making measurements from photographs. During the American Civil War, the Northern states established the Union Army Balloon Corps, whose leader demonstrated photogrammetry techniques to President Abraham Lincoln in 1861 by floating 150 metres above the White House lawn. The Northern states’ Topographical Engineering Corps used the view from hot air balloons to draw maps based on aerial observations.

 Many people lost their lives during the first experiments with various aircraft. The Wright brothers concluded that an effective steering mechanism was the key to successful flight – Wilbur studied birds, and noticed that they changed the angle of their wingtips when turning to the left or right. The brothers believed that the same principle would work on airplanes, and after experimenting with gliders developed a system which enabled them to turn left and right, move up and down, and roll from side to side – a system still in use today.

 In 1908, the brothers travelled across the Atlantic – by boat – to demonstrate their invention to sceptical Europeans. During a demonstration for the King of Italy, a film camera was attached to an aircraft for the first time and recorded a film clip, just under two minutes in length, of what almost nobody had seen before: the world – in this case an Italian village with cows, a man on horseback and the ruins of a Roman aqueduct – as seen from above.

 The Italians were the first to use aircraft in warfare. After declaring war on the Ottoman Empire, they launched a reconnaissance mission beyond enemy lines in October 1911, and in the following November released the world’s first bombs from a plane. A year later, they took the first aerial reconnaissance photograph – the pilot was only able to take one image, since it was impossible for him to simultaneously operate the plane and change the glass plate (the period’s film).

 The French were the first to develop an aircraft specifically for aerial photography. In 1913, the British magazine *Flight* reported from Paris Aero Salon that one of the planes in the exhibition was named the ‘Parasol’, because its wings were attached in a higher position than on other aircraft: ‘This arrangement has, of course, the very great advantage that an excellent view of the country is obtained, as the planes are above the pilot’s head, and he thus has an unrestricted view in a downward direction [...] behind the observer’s seat is situated a special camera, which is pointed straight downward, so that photographs may be taken while the machine is in flight. The camera is operated from the observer’s seat by means of a single string, which serves the double purpose of actuating the shutter and the plate-changing mechanism.’

AERIAL PHOTOGRAPHY | The First World War started with the Germans marching through Belgium and Luxembourg, before they defeated French attacks and moved quickly towards Paris, where they took up a position just 70 kilometres from the outskirts of the city. British and French aircraft noticed that the German forces had split in two and so attacked in the gap, forcing the Germans to retreat to north of the river Aisne where they dug trenches to hold their ground – establishing both the Western Front and trench warfare, with each side locked into positions stretching hundreds of kilometres from the North Sea and Belgium, through France to Switzerland.

The British forces who arrived in France in August 1914 possessed three maps based on surveys performed during the Napoleonic wars 100 years earlier: two of Belgium and north-eastern France and one of France alone. They planned to update the maps using traditional methods: ‘I hope none of the men here are so stupid as to think that aeroplanes will be of any use in reconnaissance during the war’\*, said a General with the cavalry.

 Members of the cavalry were used to acting as the army’s spies – venturing behind enemy lines and reporting on movements and reinforcements – but static warfare in the trenches provided no such freedom of movement. The plane therefore became the answer to the question of how to keep the enemy under surveillance.

 Not that this was easy. The first British reconnaissance planes got lost because visibility was poor and the pilots poorly acquainted with the area. One pilot wondered whether it would be ‘impolite to land and ask people the way’\* – something he ended up having to do – while another flew over Brussels without recognising the city. Often, the only thing the pilots were able to report on with certainty was where the Germans were *not* to be found – or they might spend half the day attempting to find the enemy and the rest finding their way back – but aerial reconnaissance gradually assumed the cavalry’s former role. In September 1914 a British General lauded the ‘fantastic air report’\* which had exposed the movements of the German troops. Information gained from the aircraft was noted on the maps. As a French pilot wrote: ‘I discovered the positions of twenty-four guns on the line to the west of Vitry. I marked them on the map [...] and informed the corps concerned’.

 Strategic aerial photography began rather incidentally – the first images were taken by pilots who photographed cities, landmarks and beautiful landscapes using their personal cameras to have something to show to their family and loved ones. Despite this, nobody had thought of using systematic aerial photography in map-making – when French Captain Georges Bellenger established a dedicated aerial photography division and presented his superior with images he believed could be used to create maps, his superior informed him that he ‘already had a map’\*. Nonetheless, Bellenger developed a technique for creating maps from photographs – this required a good understanding of the landscape and the ability to interpret black-and-white photographs taken from a vibrating plane with unsteady hands.

 The winter of 1914-1915 was characterised by a cold standstill in soaking-wet trenches, and the landscape was so heavily bombed that this alone made it difficult to advance. Behind the front lines, however, intensive work was underway to enable the aircraft – the only things able to move to any great extent – to take better pictures, and with the war’s first spring came the first movements in the lines.

NEW MAPS | Neuve­Chapelle is situated in the French lowlands, close to the Belgian border. The town is neither large nor important, but as fate would have it Neuve-Chapelle became part of the northern Western Front, and therefore a strategic target. If the allied forces could pass through the town and make it to the larger city of Lille, they would also be able to intercept the railway lines, roads and canals used as transport routes by the Germans.

 British planes photographed the town and surrounding countryside in detail prior to the planned attack – the obtained images formed the basis for a map that was printed in 1,500 copies and distributed to the troops who would go into battle. The information was invaluable – the allied forces could now study the battlefield and analyse where a German counter-attack was most likely to occur. For the first time in British military history, the army was able to stage an attack with a full overview of the enemy’s defence lines, positions and hideouts.

‘Our intelligence show was successful, in that we found the Germans exactly as we had located them, and their reinforcements arrived to the exact hour that we had predicted they would’, wrote Brigadier General Charteris afterwards. The fact that the attack was not a complete success, since a number of the German reinforcements managed to stop the advance, forcing the British to dig new trenches not so far from where they started, was of little consequence – the preparations were deemed a huge step forward. From this point onwards, maps based on aerial photographs became an integrated part of the allied strategy, and a system was established in which the day’s aerial photographs were submitted to the cartographers at 20.30 each evening – the cartographers then worked flat-out through the night to prepare and print up a hundred maps for the troops by 06.00 the next morning.

Before the war, nobody had received training in how to take photographs from a plane, but as the need for images increased the armies scoured their ranks to find men who knew their way around a camera – who understood how to take a photograph and what an image could convey. One described the recruitment process as follows: ‘I had a camera when I was a kid, and had taken, developed and printed some fairly amateur photographs. Based on this I was appointed the squadron’s official aerial photographer’\*. The British founded the School of Photography, Mapping and Reconnaissance to cover their forces’ needs.

Aerial photography was demanding. Both the pilot and photographer occupied the plane’s cold, wet, wind-battered cockpit, while the enemy attempted to kill them. The pilots had to fly steadily back and forth along straight lines at a constant altitude to enable the photographers to work as methodically as possible – this predictable course made the reconnaissance aircraft easy targets for those tasked with shooting them down from the ground. One pilot wrote: ‘Photography again. I’m getting tired of this job. It’s the hardest and most dangerous work a pilot can get’\*. Another wrote simply: ‘Photography’s a good job when you don’t get hurt’\*.

For their part, the photographers were tasked with operating a large camera in a confined space. They had to figure out when to take the photographs to achieve the desired overlapping pattern – most often by counting in their heads – and change the glass plate after each image with fingers stiffened by the cold. And then there was the turbulence to deal with. But one of the photographers described braving the harsh conditions and difficulties as worth it: ‘There was something enormously satisfying about this work… Moving behind the lines and looking vertically down on the enemy’s most valuable and private assets, and knowing that it was in your power to make sure that they were either destroyed or captured, was in truth work that was worth doing’\*.

On the ground were those who drew the maps based on the photographs. James Barnes, who held the unofficial title of aerial photograph interpreter, wrote in his biography:

Reading and interpreting a photograph taken from a plane requires a special mind – the kind of mind that can solve chess problems, or, in our time, difficult crossword puzzles. To the uninitiated, an image of trenches or myriad bomb craters means very little, but to the problem-solver who studies the photograph with a magnifying glass, the shadows, lines and possible gradients mean a lot. They tell a story. The imagination is often ignited by a strange, small thing, something he does not immediately recognise; and then, suddenly, he understands it. The curious little dots are iron fence posts supporting strong wires. The men who walked over to the large crater left no tracks because they could reach the hidden machine gun by walking on the bottom wire. The path to a location some hundred metres away, which leads to another crater, is an attempt to mislead us – there is no weapon there. The battle was fought between the camera and camouflage – it was like being in a poker game with an ace up your sleeve.\*

In the wastelands of the First World War a new kind of cartographer was born – one who occupied a dark room and used advanced optical instruments to interpret images, rather than going out into the world to view its physical geography.

 The increasing need for aerial photographs forced the civil camera industry to produce increasingly better cameras, with ever-improving lenses that could be used for cartographic purposes. Of course, the higher the planes could fly while still obtaining a detailed image, the less the risk of being shot down, and cameras that could reproduce the ground in sharp detail from a height of 6,000 metres were soon developed. During 1918 – the last year of the war – aerial mapping was such an important part of the strategy that the allied forces took more than ten million photographs. The maps of the Western Front were updated twice daily using new information obtained from the air. The Germans estimated that they had taken enough images to cover the country six times over.

 ‘The First World War paved the way for aerial mapping – the creation of entirely modern, accurate maps with the addition of contour lines – with the senseless loss of human life and unlimited consumption of funds possible only in war’, wrote Topographer and Captain Thorolf Ween in 1933. ‘Developments steamed ahead at the tempo the war demanded. And then came peace, and it became necessary to find a use for all these new inventions and branches of industry.’

Pages 295-307

THE DIGITAL WORLD

\*

Baikonur, Kazakhstan

45° 57' 54'' N

63° 18' 18'' E

It was visible, high up in the sky, after the Sun had set: a tiny moon moving faster than any other celestial body. Across the world, people took out their binoculars and set up their telescopes on roofs and in parks to observe the technological marvel of the age – using an amateur radio, it was also possible to hear the *beep-beep-beep* of the radio transmitters it carried. ‘Until two days ago, that sound had never been heard on this earth. Suddenly it has become as much a part of twentieth century life as the whir of your vacuum cleaner’, said a reporter’s voice from the television set. On these autumn evenings in 1957, Sputnik – the world’s first artificial satellite – ushered in the space age as humankind looked on, astonished.

 Sputnik was launched from the Soviet Cosmodrome in Baikonur, Kazakhstan, and orbited the earth in just 96 minutes and 12 seconds at a speed of 29,000 kilometres an hour. It was only 58 centimetres in diameter and at its highest point travelled 940 kilometres above the ground, but was still visible due to its polished surface designed to reflect the Sun’s rays. Sputnik’s engineers wanted the world to be able to follow the tiny metal ball’s progress – a victorious feat of propaganda in a world characterised by the rivalry between two superpowers. During its second day, the satellite passed over Berlin 13 times, New York seven times, and Washington six times – where the Americans were forced to bitterly admit that their arch rival had reached space before them.

 On Monday morning, after Sputnik had dominated the news since Friday evening, physicists William H. Guier and George C. Weiffenbach were eating lunch in the cafeteria of the Applied Physics Laboratory (APL) in Baltimore, USA. They thought it was strange that nobody had studied the radio signals emitted by the satellite, and in the laboratory found a receiver and a small cable they used as an antenna. Late in the afternoon they heard Sputnik’s signals – *beep-beep-beep* – and started to record and analyse them, with no particular intention other than to save the data for posterity.

 After a while, Guier and Weiffenbach discovered something interesting – the signals they heard when Sputnik first appeared on the horizon changed as the satellite came closer, only to change again as it passed over them and journeyed onwards – similar to the way the sound of a bell changes as you travel past it on a train at night. Using the changes in sound, the scientists were able to predict Sputnik’s trajectory and ascertain the satellite’s position at any given time.

 One day, Guier and Weiffenbach were asked to come into their boss’s office and close the door behind them. He wondered whether it was possible to turn the finding on its head: using a satellite, was it possible to determine one’s position on Earth?

GPS | Today, we are often a part of our maps in the form of a tiny, moving dot – whether we have asked our car to find the fastest route to the local amusement park or are looking for a bakery in an unfamiliar city, we can use our GPS, tablet or mobile to view where we are and understand the direction in which we are moving. Geography is digitised – above us, satellites constantly send out signals indicating their positions; our receiver obtains information from four of these to work out where we are. One satellite provides us with the latitude, another with the longitude and a third the altitude – while the fourth satellite performs the calculations that enable the GPS to provide us with an accurate position.

 The maps we use are also often based on images taken by satellites. From 800 kilometres above the Earth, satellites are capable of photographing two dogs playing in a garden in Fetsund, and we use them to map the weather, air quality, ice conditions, desertification, urbanisation and deforestation. One of the benefits of using satellites is that they orbit the Earth in fixed trajectories and therefore take photographs of the same areas over and over again, making it easy to observe changes even in deserted and isolated areas. A satellite can photograph the entire Earth in just 16 days. ‘Man must rise above the Earth – to the top of the atmosphere and beyond – for only thus will he fully understand the world in which he lives’, said the Greek philosopher Socrates, and at the time of writing around 1,100 satellites are currently orbiting above us. They survey the Earth in such detail that we are now able to update our maps faster than ever before in history.

 The first person to imagine a man-made satellite orbiting the Earth was British scientist Isaac Newton. In his *Philosophiæ Naturalis Principia Mathematica* (*Mathematical Principles of Natural Philosophy*), published in 1687, he described an experiment in which a cannon shoots a ball from the top of a high mountain. If the ball travels at a low velocity, it will fall to earth, but if it travels at a high velocity, it will continue out into space. And if the velocity of the cannonball is just right, the Earth’s gravity will pull it into orbit.

 In 1865, French author Jules Verne wrote a book based on Newton’s theory, *From the Earth to the Moon*, in which people travel around the Moon in a projectile shot from a cannon. In 1903, Russian rocket scientist Konstantin Tsiolkovsky enjoyed calculating how long Verne’s cannon would have to be, and the pressures the people in the projectile would be forced to withstand. Not unsurprisingly, Tsiolkovsky’s conclusion was that a cannon would be useless for putting people into space. Instead, he developed the principle of multi-stage rockets, in which the fuel tanks are disconnected as they are emptied. At the final stage, enough fuel remains to puff a small projectile into orbit. This was the principle which, 54 years later, gave us the first satellite as part of the space race between the two superpowers of the USA and the Soviet Union.

V-2 | The race between the Americans and the Soviets started towards the end of the Second World War as a race to acquire German missile technology. During the last phase of the war, the Nazis introduced a new weapon which sent shockwaves through the allied forces – the V-2 rockets.

 The missiles were first launched from occupied Netherlands on a September morning in 1944 – people on the English side of the Channel saw three ribbons of smoke disappearing into the stratosphere. The missiles travelled 80 kilometres above the ground at supersonic speed – meaning that they crashed down in Paris and London just five minutes later, killing three people. The V-2 was the world’s first space rocket.

 In the 1920s, the lead architect behind the V-2 programme, Wernher von Braun, was one of several amateur rocket enthusiasts based at a disused warehouse just outside Berlin – a location known locally as *Raketenflugplatz*. After a time, the group made so much progress that the German army began to take an interest in their work, and in 1932 – the year before the Nazis came to power – the amateur rocket scientists became part of the army’s development programme, with von Braun in the role of technical director. In 1942, the group managed to launch a rocket to such an altitude that it left the atmosphere, before landing 200 kilometres away. ‘We have invaded space with our rocket, and for the first time used space as a bridge between two points on Earth’, an excited German general wrote in his report.

 The V-2 rockets never achieved great military significance, and more people died as a result of the forced labour used to create them – 20,000 prisoners from the Nazi concentration camps – than from being hit. But both the Americans and the Soviets understood that this was the weapon of the future, and each side established specialist groups to gain access to German rocket engineers and drawings.

 In February 1945, von Braun heard the Red Army’s artillery advancing towards the rocket laboratory. He and several hundred other employees gathered up everything they could carry and set out southwest towards the American army – believing, quite rightly, that with the knowledge they possessed they were simply too valuable to be imprisoned. In early May, the Americans made their way to the V-2 factory, which in accordance with allied agreements would be deemed on Soviet territory from June onwards. Several tonnes of rocket parts were transported to Antwerp by rail convoy, and then on to the USA by sea. Von Braun and his colleagues also made the journey.

KOROLEV VS. VON BRAUN | The Americans had won the first round – leaving little behind for the Soviets at the V-2 laboratory and factory – and so the Soviets decided to release Sergei Korolev, a brilliant rocket researcher who had been imprisoned on the basis of false accusations and sent to Siberia before the war. In August 1945, after a period of convalescence, Korolev was sent to Germany to discover how a V-2 rocket was constructed. ‘You must understand’, a commissioner said to him, ‘that the Americans are not lazing about. After the atomic bombs over Hiroshima and Nagasaki, they are continuing to work on nuclear weapons. And now they have only one enemy – us’\*. The Soviets did not like the idea of the Americans enjoying sole possession of both nuclear weapons *and* missiles – and Korolev was therefore assigned to make up some of the ground lost to von Braun’s head start.

 Due to the Cold War, the space race and arms race became two sides of the same coin – leaving both Korolev and von Braun frustrated at having to prioritise work on rockets intended for use in missile attacks rather than those that would put satellites into orbit. To varying degrees, both men were dreamers who had far more desire to send people into space than to design ways to kill them. In an interview, von Braun described how the Earth would look from above, echoing Socrates’ description from over two thousand years earlier: ‘a gigantic and shining globe [where] the continents will be delineated as grey and brown shadows bordering the brilliant blue sea [...] while the whole Earth will be framed by the total darkness of space’\*. Both von Braun and Korolev attempted to convince their respective countries’ governments and militaries that satellites could be used to map the enemy – and in 1946 the Americans’ first V-2 rocket launches hinted at this. The space usually used to hold the explosives was instead used for the installation of scientific instruments and a camera, resulting in the first images of the Earth taken from space – a collage covering an area stretching from Mexico to Nebraska.

 Korolev argued that satellites would act as the perfect spies for the Soviet military – capable of orbiting the Earth like a photographic eye, they would be able to observe even the tiniest details. He was told, however, that the Soviet army was interested in obtaining weapons – not toys. Von Braun used the same arguments before the American military when he claimed that satellites would be able to ‘lift any iron curtain, wherever it may fall’\*.

 In 1955, the American military published a report recommending the use of reconnaissance satellites – but first, they reasoned, it would be wise to send up a civil satellite and thereby establish the freedom to pass through space above any country. President Dwight Eisenhower announced that the USA planned to launch a satellite – a new moon – in 1957.

 Eisenhower’s speech sent a tremor through the Soviets. They had already been panicked three years earlier, when the Americans changed Pacific geography by blasting the Eniwetok Atoll off the map with the detonation of the world’s first hydrogen bomb – a bomb many times more powerful than the atomic bomb. After the Soviets detonated their hydrogen bomb in 1954 and decided to develop something even more powerful, Korolev was tasked with developing a rocket capable of carrying a warhead weighing five tonnes. Korolev immediately understood that such a rocket would easily have the power to put a satellite into orbit, and when he presented his proposed satellite to General Secretary Nikita Khrushchev in February 1956, his idea was approved at the highest level – Khrushchev liked the idea of celebrating the fortieth anniversary of the Russian revolution with the world’s first satellite.

COMPUTING | Performing the calculations necessary to put a satellite into orbit might be routine today, but those for the first-ever man-made satellite were anything but, and required the Soviets’ most powerful computing technology. The Strela computer at Moscow University filled a 400-square-metre room, and was capable of performing up to 3,000 calculations per second. The machine would now be responsible for ensuring that a colossal rocket would nudge a tiny satellite out into space with just the right amount of force. Everything needed to be exact – and many test launches resulted in complete disaster.

 The use of computers had increased during the Second World War as a means of both creating coded messages and cracking them. The computers were huge – there was a reason that the allied forces’ best code-cracking machine was named ‘Colossus’ – but developments in the field were rapid. In 1948, American electrical engineer Claude Shannon described how all information could be transferred digitally. ‘If 2 is the base’, he wrote, ‘the units may be called binary digits, or bits for short’\*. With this, Shannon described the age of digital information, which would later give us both maps created using computers and online maps. Today, all computerised data is encoded using two digits, 0 and 1, and data capacity is measured in bits.

 The transistor – a device that enabled electrical impulses to travel with unprecedented speed – was invented a year before Shannon presented his theory. In 1957, the year in which Sputnik was launched, American electrical engineer Jack Kilby had the idea of linking a number of transistors in an integrated circuit to form the microchip – thereby laying the foundations for all personal computers, smartphones and tablets.

 But in the 1950s, computers were reserved for universities, laboratories, government agencies, large companies and the military. Strela was the first computer used by the Soviets in data programming, and Korolev and his team watched Sputnik’s launch with pounding hearts, anxious to see whether the machine’s calculations would prove correct. Late in the evening on Friday 4 October, white-gloved technicians placed the diminutive Sputnik atop a gigantic launch vehicle, and an hour and a half before midnight the ground shook as the engines lifted the rocket from a sea of flames up into the night sky. On the ground, observers nervously watched what appeared to be the perfect launch, until it suddenly seemed as if the rocket was returning to Earth. ‘It’s falling, it’s falling!’ several people exclaimed, before they realised that due to the satellite the rocket had been programmed to follow a different course to that of the test rockets. The engines shut down and sent Sputnik into orbit at 230 kilometres above the ground. Korolev smoked frantically while he and his team waited for the satellite to complete its first full orbit. When they finally received its signal – *beep-beep-beep* – Korolev asked everyone to listen: ‘This is music no one has ever heard before’.

TRANSIT | On the following Monday, Guier and Weiffenbach sat in their laboratory in Baltimore listening to Sputnik’s signals, and two weeks after the launch, when Sputnik’s batteries were depleted and the radio signals silenced, started to analyse the information using a computer. The results confirmed that it was possible to determine a satellite’s location by listening to the signals it emitted.

 Head of the laboratory, Frank McClure, asked Guier and Weiffenbach whether they could turn this finding on its head, as he was assisting the marines with a project to equip submarines with atomic missiles. The idea was that the enemy would never know just how close they were to a nuclear attack because they were unaware of the submarines’ locations – but the problem was that the submarines themselves were also often unsure of exactly where they were. This was vital information if the missiles were to hit the desired targets – and ideally, the submarines would like to be able to ascertain their location without having to resurface to check the stars. McClure asked Guier and Weiffenbach how accurately they could calculate a position using satellites – they estimated that it should be possible with a margin of error of around 160 metres.

 The Applied Physics Laboratory (APL) was thereby established, and work began on the Transit navigation programme – the frontrunner of today’s GPS. But first, the Americans had to prove that they too were capable of launching a satellite.

 On the evening of Sputnik’s launch, Wernher von Braun had arranged a party for the new Secretary of Defense. A tense silence settled over the gathering when someone came in with news of the Soviet triumph – von Braun, rather ungraciously, said: ‘I could have done this a year ago’\*. After Eisenhower announced the USA’s intention to launch a satellite, the army, navy and air force competed for the contract. Von Braun worked for the army, but despite the fact that von Braun had the best solution some thought it problematic to allow the first American satellite to be created by Germans – particularly Germans with a Nazi background – and the contract was awarded to the navy. Paradoxically, the American authorities had originally taken control of von Braun’s experiments to prevent him launching a satellite for anyone else.

 Sputnik made the entire world look to the skies, and Khrushchev claimed the historic event was proof of communism’s superiority to capitalism. Time magazine called it a ‘red triumph’, and many feared that the Soviets were now capable of using atomic missiles against the USA. The Americans felt under pressure – which only increased when, two months later, Sputnik 2 was launched with Laika the dog on board – the first living being ever to enter space.

 This mounting pressure caused the Americans to declare that they would launch their satellite on the sixth of December. Millions watched the events unfolding live on television as the engines started, spewing out flames and billowing smoke, before the rocket rose exactly 1.2 metres into the air and tipped over onto its side, exploding on the launch pad. The tiny satellite lay on the ground beside the wreckage, mournfully sending out its signals.

The next morning, von Braun – with a touch of *schadenfreude* – read newspapers filled with headlines such as ‘kaputnik’, ‘flopnik’, ‘goofnik’ and ‘oopsnik’. The navy’s failure gave him an opportunity – and on 31 January 1958, von Braun and his team put the first American satellite – Explorer 1 – into orbit.

The navy and APL launched the Transit satellite from Cape Canaveral, Florida, the following year, and the satellite passed over the Atlantic Ocean for 25 minutes before it dropped into the sea just off the coast of Ireland. The rocket’s third stage had failed to ignite, but despite this the mood was positive – during its short flight, the satellite had emitted its signals exactly as planned.

Many test satellites had to be launched before the Transit navigation programme could finally be put into operation. The project’s engineers discovered one thing after another that disturbed both the satellites’ signals and their trajectories, including the Earth’s irregular shape, which results in variations in gravity as the satellites pass above it. The satellites jumped around without the engineers understanding why, until they discovered that the Earth was more uneven than first thought, in addition to being slightly more pointed in shape in the north than in the south. The engineers had to combine technology with geodesy – the study of the Earth’s shape and size – and studied the work of Marie Tharp and Bruce Heezen, which showed how the Earth’s surface is in constant motion due to continental drift, and how this affects gravity, which in turn affects the satellites. All irregularities had to be mapped and programmed.

Right from the experimental stage the scientists realised that localisation using satellites was more accurate than old-fashioned triangulation – discovering, for example, that ordinary maps put the islands of Hawaii several kilometres away from their true location.

With the successful launch of Transit 5c1 in June 1964, the system was complete – three satellites orbiting the Earth, sending out signals that were received by the navy’s ships and submarines. Three years later, Transit was made available for both public and commercial use, and Norway was one of the system’s early adopters. During the first year in which the country had access to the system, Transit was used to determine positions on the mainland; in 1971 the Norwegian Polar Institute was able to determine positions on Svalbard, and measurements taken of Jan Mayen in 1979 showed that the island was situated 350 metres closer to Norway than previously believed. The Continental Shelf Office used the system to precisely calculate the dividing line between Norway and Scotland out in the North Sea, and to determine the exact positions of oil platforms. Even leisure boats installed the Transit system when receivers became smaller and more affordable. The system had a margin of error of just 25 metres.

SPY MAPS | In the shadow of the space race, the American military developed spy satellites. Although they had equipped their U-2 aircraft with cameras in 1954 – cameras that could photograph objects measuring just a metre across from altitudes of over 21,000 metres – they knew it was only a matter of time before the Soviets managed to shoot the aircraft down. The Soviets detected and shot down a U-2 in 1960, but that same summer the Americans were also able to recover a roll of film containing images taken by a satellite.

 The images taken by digital cameras at the time were nowhere near detailed enough for reconnaissance purposes, and so the spy satellites had to use rolls of film. At 9,600 metres in length these were somewhat longer than usual, and dropped from the satellite in what was known as a ‘film bucket’ – a capsule which plummeted 140 kilometres before the heat shield released at 18 kilometres above ground level, triggering a parachute. A plane was then sent out to catch the falling bucket mid-flight – if the plane was unsuccessful, searches were initiated on the ground or in the sea.

 The satellites travelled at a speed equivalent to eight kilometres per second at ground level. Each image covered an area of 16 x 190 kilometres, and so the satellites took one photograph every other second – enabling the entire enemy territory to be photographed in just a day or two. The first roll of film contained images of 64 Soviet airports and 26 launch sites for anti-aircraft missiles. The Soviets launched their first spy satellite, Zenit, in 1962.

 The Cold War made its mark on the period’s maps. A Soviet map of the British city of Chatham, for example, clearly showed the dockyard where the Royal Navy was building submarines, while on the British map the same location was simply a blank space. The Soviet map also featured information about the size and load capacity of the bridges in the dockyard’s surrounding area.

 The two superpowers had different mapping strategies which reflected the differences in their militaries. The Americans’ command of the air meant that maps of areas of strategic interest showing more detail than that provided at a scale of 1:250,000 were rarely necessary. The Soviet Union, on the other hand, was at the forefront of tank warfare and possessed the world’s largest army, so required detailed maps that provided information such as road widths, the load capacity of bridges, river depths and forest topography – many of them also featured meteorological information. The Soviets therefore mapped some parts of the world right down to building level, and Soviet military maps of Western Europe and American terrain were often more detailed than those possessed by the countries themselves. They were also fiercely guarded – personnel were required to sign out any maps needed for exercises, and if a map was destroyed, the pieces had to be returned. At the same time, the Soviet Union’s civil maps were almost useless – not only did they lack detail, but they were also deliberately distorted using a special projection process that resulted in random variations. Famous landmarks such as rivers and cities were included, but the specified coordinates, directions and distances were completely wrong. The point was to prevent Western spies from being able to get hold of an accurate map of Soviet territory from any local newsagents or kiosk. The cartographer who developed this system received an award from Stalin for his efforts.

 After Stalin’s death in 1953 the Soviet military had global ambitions – Khrushchev saw fertile ground for communism in a world where former European colonies were becoming independent states. The Soviet military therefore dispatched cartographers to survey and map a broad range of developing countries, and here too they were extremely thorough in their activities – so thorough, in fact, that previously classified Soviet maps of these areas were purchased and used by telecommunications companies in setting up mobile networks. This work requires a topographical overview so that cell towers can be erected in appropriate locations, and the Soviet maps provided the best available overview of hilly regions in these parts of the world.

 The Soviet Union used maps to systematise their knowledge of the globe. Their maps were like an analogue database – much like those of the Middle Ages – and provided more than geographical information alone. The Soviets presented extensive and varied information through the creation of a visual hierarchy, in which the most important aspects were emphasised and the less important remained in the background. Their maps prefigured the digital method of organising geographical information in several layers, which is used today.