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Synchronizing Orbits and Deep Learning Algorithms: Satellite Surveillance and Civil Sea Rescue Missions in the Mediterranean

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Introduction: Mind the gap

When I began fieldwork at the Regensburg-based non-governmental organization (NGO) Space-Eye, Walter Wissenschaftler,[1] a physics professor who played a crucial role in launching the Space-Eye project around 2018 and now acts as its scientific advisor, asserted:

> If we say we can look from above and document, then naturally half the population complains because they say, 'Well, then you can see me too when I'm in a bikini in my garden sunbathing'. Of course, we can't do that, and that's not our goal. But between what is actually fact, and what the population fears, there is quite a gap.

In the following, I explore this 'gap' when it comes to doing satellite surveillance 'for the good' as a civilian actor. I undertook ethnographic fieldwork between April 2021 and March 2022 on the voluntary work of Space-Eye members in Regensburg, Stuttgart, and Berlin, who deploy optical satellites and deep learning algorithms with the goal of supporting civil search-and-rescue (SAR) missions in the Mediterranean.

In this chapter, I show that within their coding practices, Space-Eye members must negotiate what Lefebvre (2009) called *polyrhythmia* – understood as multiple rhythmic demands that coexist simultaneously. Space-Eye members must synchronize the realities and rhythms of their (in)organic collaborators on land and sea, and in (cyber)space. The following paragraphs examine the polyrhythmia of these monitoring technologies, in the socio-technological practices necessary to operationalize them, and where organic and inorganic temporalities interact (Peacock, Introduction, this volume). By doing so, I problematize assumptions about the smoothness of (quasi-)real-time data processes in relation to satellite surveillance (Pollozek, 2020, p 678).

First, this chapter introduces the Space-Eye project, how and why it came about, and what socio-technological approaches Space-Eye members are working with. Second, it focuses on the kinds of temporal challenges that emerge in the technical encounters between Space-Eye members, optical satellites, and deep learning algorithms. These challenges show that Space-Eye's work is as much about compressing time as it is about compressing space. Thirdly, using the example of the 'European Data Relay Satellite System', I show that (quasi-)real-time satellite surveillance constitutes an active achievement that depends on overcoming temporal challenges, by patching together sets of unresolved temporal patterns and mechanical tempos, through specific infrastructural investments. In conclusion, I propose a preliminary politics of lag, that stresses the importance of being attentive to the infrastructural investments in satellite and artificial intelligence, and raises questions about ownership, funding, access, and who is being left out.

Space-What?

The Space-Eye project is part of other civil SAR techniques, which include ships, planes, (optical and radar) satellite data, and drone data. Satellites and drones offer the advantage that they can widen the search radius of ships by offering clues on where to look for boats in distress, compared with the view from ships, which is limited and weather dependent.

Sea-Watch started using the aircraft Moonbird (from 2017 to 2022 in collaboration with Swiss Humanitarian Pilot Initiative), Seabird 1 (since 2020), and Seabird 2 (since 2022) to help detect boats in distress and report them to the Maritime Rescue Coordination Centres and nearby vessels.[2] In 2017, civil SAR organizations such as Sea-Watch, Mission Lifeline, and Sea-Eye became subject to increasing criminalization and legal obstructions, resulting in the blockade of ships and planes. The Space-Eye project was initially conceived as a response to this hostile environment. Gerd Gründer, founder of Space-Eye, thought of using satellites to document what was happening in the Mediterranean while ships and planes were blocked.

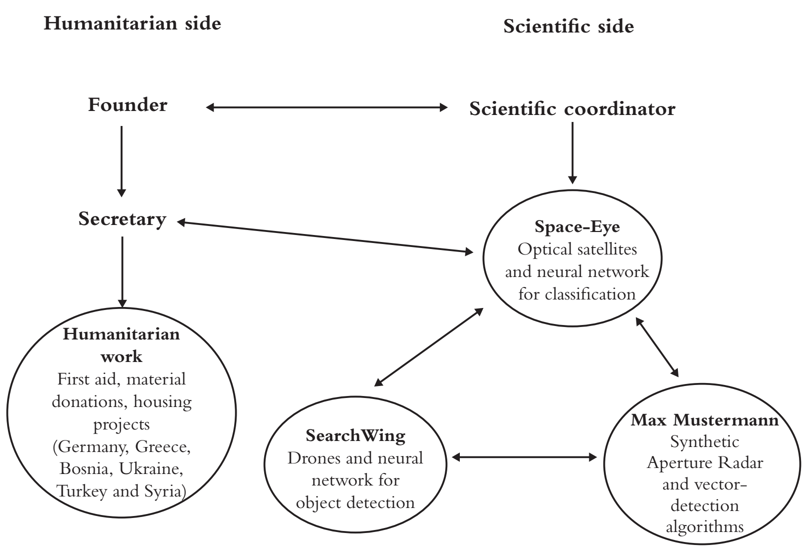
The Space-Eye project started in 2018, with a technological and scientific focus on satellites and artificial intelligence. Rosa Roboter became the unofficial lead on the project. The idea was to train deep learning algorithms that were capable of processing satellite images of the Mediterranean to identify refugee boats. Space-Eye would then be able to cover the whole Mediterranean, and quickly filter out possible refugee boats in distress to give their approximate whereabouts to SAR ships nearby. Additionally, Space-Eye could sort through past satellite images, and look for images depicting push/pullbacks or human rights abuses.

However, members of Space-Eye struggled to gain access to data with which they could train their deep learning algorithms, and faced difficulties while attempting to operationalize the satellite images. During my fieldwork I noticed how a division between what we might call a humanitarian and a scientific side within the NGO emerged. They started to pick up on tasks such as first aid, material donations, and housing projects, which meant finding immediate solutions to problems that were manageable within a shorter timeframe through direct action. The 'humanitarian side' can make things happen within three weeks. Meanwhile, the work of the project's 'scientific side' requires years of building a socio-technological network and infrastructure (Figure 6.1).

The scientific work of Space-Eye is not restricted to the NGO itself. It is currently constituted by collaborations with the Augsburg- and Berlin-based NGO SearchWing and the Berlin-based PhD student Max Mustermann. They share the goal of supporting SAR missions through technological methods. There are four main socio-technological approaches.

Firstly, members based in Regensburg, and previously in Stuttgart, attempt to train a neural network on image classification instead of object detection

Figure 6.1: First attempt to trace the Space-Eye network



or facial recognition.[3] A neural network is a subset of machine learning and at the centre of deep learning algorithms. It is worth quoting Rosa Roboter at length to understand this further:

> Artificial intelligence is the really big umbrella term that stands above everything. Even a simple decision can fall into this category. Like 'if the power is too high, then my device switches off'. That can also be included as long as we would describe it as intelligent. One level below is machine learning. Machine learning can be defined as making decisions based on data. We no longer say that if the power is too high, you must switch off, but that the system learns for itself what 'too high' means. …
>
> Under machine learning there are many different applications and one of them is neural networks or deep learning [algorithms]. …] Neural networks are simply a connection of different so-called neurons, and they are *very* abstractly modelled on the human [brain] and consist of several layers of neurons. … It is precisely this part of deep learning neural networks that is known for its black box, because there is very little information about what is actually happening between data input and output. A neuron simply processes its input data and produces an output. [It] is really just a mathematical component.

The term 'neural network' describes: a 'computational learning system that uses a network of functions to understand and translate a data input of one form into a desired output, usually in another form'.[4] In other words, a neural network constitutes 'a set of algorithms, modelled loosely after the human brain, that are designed to recognize patterns'.[5] Neural networks depend on training data to fine-tune their accuracy in the ways they classify and cluster data at high speed, and can be used for speech or image recognition. Image classification means the trained neural network in the case of Space-Eye would ideally be able to distinguish and classify refugee boats, as a distinctive pattern deviating from the blue water surface within satellite images. In the case of object detection, the trained neural network could sort out pictures with a pattern deviating from the blue water surface *and* show their geographical position for the ship to navigate to. Members of Space-Eye could use their neural network to skim faster through satellite images, spot potential refugee boats, and inform SAR ships and other actors nearby about the boat's geolocation. The nearby rescue ships can then navigate to the boat in distress.

Secondly, members of SearchWing build their own drones for usage by SAR ships. These drones start from the boats and fly a limited range while taking pictures automatically that are uploaded to an on-board computer. Then a neural network trained on object detection sorts out pictures with potential refugee boats and their geographical position, or other patterns other than the blue water surface. Thirdly, Max Mustermann uses synthetic aperture radar data from satellites and combines them with a machine learning model, similar yet distinct from the first approach due to the nature of the 'pictures' used and produced. Radar 'images' constitute a collection of microwave frequency ranges, representing returned radiation of material objects on the ground.

Fourthly, a group of Space-Eye members facilitate an 'Automatic Identification Signal' (AIS) as a sorting-out tool for their searches. AIS is used for navigating and securing naval traffic. Any 'official' boat has AIS to communicate its position, to secure smooth traffic or in instances of an emergency. Later, I focus on optical satellites and neural networks, and investigate the kinds of rhythms and mechanical tempos that Space-Eye members have to reconcile in their coding practices.

Reconciling polyrhythmia

Recent anthropological work has complicated our understanding of time and temporality. Time and temporality had been somewhat taken for granted and under-theorized (Munn, 1992; Guyer, 2007; Bear, 2016). However, anthropologists increasingly acknowledge 'composite and hierarchically assembled temporalities of most of the phenomena that [anthropology] explores' rather than seeing time as a universal singularity (Ssorin-Chaikov, 2017, pp 3–4).

Felix Ringel's concept of 'temporal agency' offers a starting point to study 'knowledge (about time) and the temporal dimensions of knowledge [practices]' (Ringel, 2018, p 29) as part of technical activities. Through Space-Eye's coding practices, space, time and movement have to be coordinated and assembled. The temporal dimension of these knowledge practices – or Space-Eye members' temporal agency –involves synchronizing the polyrhythmia resulting from the interaction of Space-Eye members with satellites, neural networks, and SAR ships through their coding practices.

I began my research in Germany during the COVID-19 lockdown in April 2021. Interviews with members of Space-Eye were therefore initially conducted via video chat. I asked my interlocutors about their past and current practices, as well as their future goals. Depending on who I was talking to, the answers (including the technological tools, collaborating actors, and infrastructures involved) would differ tremendously. It gradually became apparent that with each of the situated, socio-technological practices of Space-Eye, SearchWing and Max Mustermann, different relational and composite organic and inorganic temporalities were being negotiated. This led to distinct temporal progressions and rhythms of their individual monitoring tools.

The voluntary work of Space-Eye members can be seen as 'a temporary rhythm made up of a set of unresolved [bio-, physio-, and social] temporal patterns' (Mirmalek, 2020, p 93) that makes it susceptible to lags and delays. The resulting rhythms of these knowledge practices stem from bio-temporal patterns, meaning from the temporal properties and mechanical tempos of the technologies, such as satellites in orbit or digitally trained neural networks. They are furthermore connected to getting access to the infrastructures these technological elements rely on, the collaborations with actors and actants, and the actual temporal work patterns of Space-Eye members and its associates to bring them all together.

In the case of Space-Eye members, the 'indissolubility of space, time, and movement' becomes even starker. Members have to organize their digital knowledge practices to visualize, monitor, and enact the Mediterranean to support civil SAR ship crews around orbiting satellites in space, and therefore have to adapt to the physio-temporal patterns tied to the earth's axial rotation and Low Earth Orbits. A great deal of their digital work means taking into account, and attempting to merge, the local experiences of both orbiting satellites and roaming ships on the Mediterranean, as these constitute the primary sets of conditions around which Space-Eye's work must be ordered. But what does it mean to order one's voluntary work around the mechanical tempos of orbiting satellites in practice?

Between the temporal and the technological: orbits, pathways, and pipelines

Debates around technologies like artificial intelligence, big data, or satellite surveillance can be associated with a utopian vision, in the form of 'technological solutionism' (Morozov, 2014), or the opposite – a dystopian vision of techno-determinism (Fisch, 2018). Both narratives fall short when confronted with specific situated practices, such as Space-Eye members trying to combine satellite images and artificial intelligence to support SAR missions in the Mediterranean with their current access to academic research infrastructures.

Scholars have stressed the importance of situating and contextualizing where and how technological applications are *practised* (Mol, 2002) and the different actors (be they human or non-human), places, and times when technologies are used (Oppenheim, 2007). These 'encounters' with technology (Bissell, 2021) bear the potential for individual creativity, affective relationality, collective contestation, and organizational 'tinkering' that inhabit the potentiality to practise technology *differently*. Yet it is also within these situated practices of human–technology encounters that an interaction between place, time, and the expenditure of energy (Peacock, this volume, Introduction) takes place. An ethnographic engagement with the work of Space-Eye offers not only insights about the local practices of how one '*does*' artificial intelligence and satellite surveillance, but furthermore how within these practices a 'garland' of rhythms of human as well as the mechanical tempos of non-human bodies interact.

Space-Eye members' voluntary work therefore does not simply occur in time, but rather '[mediates] diverse temporal rhythms, representations, and technologies in an orchestration of human action towards their temporary reconciliation' (Bear, 2014, p 73). This process of achieving 'temporary reconciliation' of these diverging rhythms and temporal patterns tied to orbiting satellites, the training of neural networks, and the voluntary working capacities of individual Space-Eye members must be further synchronized with the rhythms of civil SAR missions on the Mediterranean with their own work 'rotations' resulting from the interactions of crew members, ships, and technological applications on board while searching for people in distress.

Investigating Space-Eye members' work centring around satellites and neural networks, Michael Fisch's concept of 'technography' offers us a starting point to understand human–machine relations not as a binary. Instead, he proposes to view them as 'iterations of a collective distributed across a technologically mediated milieu' and urges us to think '*with*, not just *about* technology' (Fisch, 2018, p 6, emphasis in original). Machines are, in other words, integral to human thinking and social becoming.

The Space-Eye project can be understood as a collective brought about by co-constitutional interactions through contextualized practices, materialities, and their rhythms between humans and machines. To do so raises our attention to how and where certain qualities of technologies enable, sustain, constitute, and restrict specific relations within the broader technological becoming of the Space-Eye project. To understand the possibilities and restrictions of Space-Eye and the temporal patterns, mechanical tempos, and rhythms that arise by collaborating with technological elements of earth observation and artificial intelligence, let us engage with the main qualities of optical satellites and artificial intelligence, specifically neural networks trained for classification.

Possibilities and restrictions

Optical satellites

What is the gap between the promise of constant satellite surveillance anywhere, anytime, and its possibilities and restrictions in practice? The sensor in optical satellites is passive to save energy and can only record the sunlight reflecting from the earth's surface.[6] If the satellite passes at night, the resulting image remains black, which means that optical satellites must be in a 'sun-synchronous orbit' (SSO).

These satellites roam within a 'Low Earth Orbit (under 2,000 km altitude)'[7] and are synchronous with the sun. The earth rotates around its own axis and orbits the sun, while satellites simultaneously orbit earth. A satellite in an SSO remains in the same 'fixed' position relative to the sun, while the earth rotates 'under' the orbiting satellite. It takes the earth around 90 to 120 minutes to rotate around its own axis 'under' a satellite in SSO to its 'starting point', as Daniel Düsentrieb, an aerospace engineering student based in Stuttgart, explained. These 90 to 120 minutes constitute the SSO's 'temporal resolution' as 'the time it takes for a satellite to complete an orbit and revisit the same observation area'.[8] The satellite thus passes different local spots on earth at the same local hour, either in the morning or in the afternoon.[9] While the earth itself is rotating, it also rotates around the sun. As Daniel elaborates:

> While the earth is rotating around the sun, I have to rotate the orbit of my satellites so that I always have the same angle to the sun. Then I always get the same exposure or the same lighting conditions for my photo …. Conveniently, the earth is not round, and the earth's gravitational field is not uniform, but is rather egg-shaped, or more precisely, elliptical. Even more precisely, it's more like a potato. I can conveniently adjust to fly through this gravitational field in such a way that with each orbit I get a little kick in the right direction to turn with the sun. In other words, I need to rotate my entire orbit by 360 degrees in a year. And in return, I can get through the earth's gravitational field at a [98 degree] angle, in a certain way, and I get this rotation for free. This is the so-called sun-synchronous orbit, which defines a very specific [north-west] direction of flight.[10,11]

Yet here a challenge arises. As Daniel specifies:

> I would expect to see the satellite again directly above me after 120 minutes. But unfortunately, the earth continues to rotate beneath the satellite during these 120 minutes. As the satellite is in orbit, it is detached from the earth's rotation and the earth rotates away from under the satellite …. This means that the next time you see your satellite again [at the exact same spot] will be after 12 hours …. While the earth rotates under the satellite, a certain distance is travelled, so to speak, during which I have not taken a photo. And the next time the satellite passes by, I will not be able to photograph the entire route. I can only ever photograph a narrow strip of 20 or 30 kilometres.[12,13] And that also determines how many satellites I need.

Here we can witness Lefebvre's (2009) principle that repetition is not synonymous with replication. New rhythms arise as the earth continues to rotate under the satellites. As Space-Eye members' work centres around the inorganic temporality of optical satellites, with each orbit this temporality changes. This inorganic temporality is a composite. It consists of the satellites' mechanical tempos which stem from their passive sensors, their temporal resolutions, and the physio-temporal pattern of their sun-synchronous orbits. Yet as the earth continues to rotate under the satellites in orbit, the satellite's trajectory differs with every iteration. This means that Daniel never gets exactly the same recorded strip of the earth's surface. Rather, he has to wait 12 hours until his satellite passes the same local spot. The result is that the narrow strips the satellite can record change with each repetition after 12 hours. It is to these changes to which the members of Space-Eye have to adjust their knowledge practices.

For Space-Eye and the case of the Mediterranean, the satellite of their current provider passes 'at a rough estimate 11:27 o'clock' each day, according to Rosa. This could be expanded to other satellites being located on different orbits while still being sun-synchronous. Space-Eye could get more pictures by purchasing from different providers. As Daniel explains:

> You can increase the temporal resolution by flying lower. But if you fly lower, a satellite doesn't last very long. Or you have many satellites and that's what [Space-Eye's commercial satellite image provider] does …. If you make constellations, then you get a lot of satellites that can come one after the other on the same orbit and then within … about half an hour, you always get a picture. But then, if you want to have a picture every day, it has to fly staggered, which is done with Sentinel [satellite missions developed by the European Space Agency for the EU's space programme 'Copernicus'], where they fly exactly opposite each other.[14] They have more or less the same orbit, but one is on one side of the earth and the other on the other side. And then they have a very good temporal resolution.[15]

As Daniel explained, Space-Eye is limited to a timeframe of pictures taken between 8 o'clock and 12 o'clock in the morning, when there are fewer clouds. Another factor slowing down the process of working with optical satellites is the 'downlink'. Downlink describes the delay because data can only be transmitted to the ground if the satellite in orbit is in visual range of a ground station.[16] A further delay is brought about by the difference between the recording of an image after it was sent 'down', and its provision by Space-Eye's commercial provider, which can take from four to 48 hours.

Let us return to Mirmalek's understanding of temporal rhythm and unresolved temporal patterns (2020). We witness the interplay of the 'bio'-temporal patterns of interacting organic and inorganic actors and the physio-temporal patterns tied to orbits and the axial rotation of the earth. The results are distinct mechanical tempos resulting from the 'lifespan' of optical satellites, their passive sensors, their temporal resolution, if they fly in a staggered way or not, how their orbit translates to strips on the map, their delay caused by the downlink and how clouds might interfere. The result is the 'indissolubility of space, time, and movement' (Peacock, this volume, Introduction) that must be temporarily reconciled within the social temporal patterns of Space-Eye members' work.

Ultimately, the work of Space-Eye members is as much about compressing time as it is about compressing space, exemplified by the issues of both temporal and spatial resolution inherent to optical satellites. Satellite surveillance epitomizes the very idea of successful 'time-space compression' (Harris, 2021, p 85). The work of Space-Eye is organized around technologies in space to support technologies and their crews in the Mediterranean, to offer them near 'real-time' information for their civil SAR missions. In the process it shows all the hidden boundaries and temporal challenges that arise for everyone involved. Compressing time becomes a vital issue. When it comes to connecting the reality of orbiting satellites to that of roaming ships, any lag or delay of information about a potential boat in distress might lead to a civil SAR ship not getting there in time to rescue people who would otherwise drown.

Neural networks

Space-Eye are limited to one picture per day. They are constrained by the inorganic temporalities of resolution and downlink, of their sun-synchronous satellites. This still offers a starting point to train the neural network. But here a new temporal challenge arises from how neural networks are trained. Space-Eye carries out supervised training of a neural network, rather than unsupervised training or enforcement training. The focus is on computer vision (pictures rather than audio) to enable the network to identify refugee boats in the images of Space-Eye's satellite image provider. Supervised learning means that Rosa submits pictures to the network that she has labelled. Rosa defines different categories that she relates to a numerical, quantitative value (0, 1), thereby making it processable for the neural network.

In the process, Rosa 'presents' the network with various images as input data, some labelled, others not. The network will work out its own criteria or pattern of how to distinguish the categories and then apply this to the unlabelled data. Rosa will then check if it has done so correctly or not. The network does not 'see' the image but just a summation of data points and sums. As Rosa mentioned, a classic example of a supervised neural network for computer vision is a network that is taught to distinguish pictures of cats and dogs. In this case, one would 'show' a neural network labelled images, meaning one assigned them a number for each category. Cats would be labelled '0', dogs '1'. Next to the labelled data, one would provide the network with thousands of other pictures of cats and dogs. Rather than predefining certain features, one would let 'it' figure out how to distinguish the two categories according to 'its' own criteria or pattern.

As part of training a neural network for the task of distinguishing boats from the surface of the Mediterranean, three core challenges arise: access to data, (spatial) resolution, and verification. For a neural network to be reliable, Rosa would need to show the neural network thousands of images. The first challenge for Rosa and the Space-Eye team was to put together their own dataset. Because of the specificity of their task, they could not rely on any of the standard datasets used in academic research. Furthermore, they had not found an example of a satellite image with a refugee boat in it.

The spatial resolution – meaning 'how big is a pixel on the ground' – currently available to Space-Eye via their commercial provider and the open-source data on the internet is around 3 metres × 3 metres per pixel. This means that the types of rubber boats commonly used by refugees (10–12 metres long and 3–4 metres wide) would be three pixels on the satellite images. Or, as Walter phrases it:

> We are currently working with resolutions that are atrocious, so something like three metres per pixel. In the military field, and technically possible, the resolution is less than 30 centimetres .... So, you have the following challenges in principle: There are satellites that are freely accessible or that are scientifically freely accessible. But these satellites usually have a poor resolution, or they don't have the spectral range that you want .... The moment I want something better, I either need money or I'm a military man.

During Space Eye's first labelling phase in August 2021, which I took part in, I found it challenging to distinguish anything from the blue background in the square sections of the processed satellite images, whereby the visualization with near-infrared spectroscopy can help.[17] But it is still nearly impossible to verify what it is that I had labelled, as there were not many ways to follow up on who or what was there. This generated creative approaches, in order to attempt to provide clarity on how a potential refugee boat might look on the images at Space-Eye's disposal. One of the members documented their time and GPS position while being out with their sailing boat on holiday, and Space-Eye members tried to find him via satellite.

Gaining access to satellite images with the resolution of Google Maps, for instance, is possible but is costly. This requires requesting and ordering satellite imagery for a specific region in advance, and buying pictures from multiple providers. Another way to gain access to satellite images with better spatial resolution is by applying to research institutes, like the European Space

Agency. This requires writing research proposals with academic researchers and their infrastructures, and waiting for these proposals to be accepted, which may take months.

The challenges that Space-Eye are dealing with in their work – for example, their attempt to successfully compress both time and space and to enhance their temporal and spatial resolution within socio-technological coding practices – were explained to me as a consequence of being 'merely' scientists and NGO actors on the project. The work of Space-Eye raises our awareness about certain 'temporal hierarchies' (Harris, 2021, p 96), 'temporal politics' (Ringel, 2018, p 11), or 'power-chronography' (Sharma 2013, p 14), that are related to the infrastructures of earth observation and artificial intelligence, and constitute limits to their usage for civilian ends. These boundaries can be both in relation of scientific use compared to military or corporate use, but also within the scientific field.

It is here that the multiple temporalities of global capitalism as well as military/security interest steps to the fore as being intertwined with these infrastructures. While Space-Eye members struggle to gain access, private corporations able to pay the price or military actors with the golden ticket walk by freely. In this case, we witness how military and global capitalist temporalities come *before* scientific temporality, both in abstract terms and additionally when it comes down to who gets their satellite images first, or '(near) real-time'. Or rather, we witness how the promise of speed as a universalized condition is contrasted with a reality of 'temporally experienced privilege and difference' (Sharma, 2013, p 19), whereby some forms of knowledge practice are advanced and accelerated if they are favourable to certain economic or military interests.

While there are challenges, there have been major leaps forward. Harry Hacker took the principle explained here and turned it on its head. Reaching out to SAR organizations, they agreed to share some of their logbooks in which they documented information about their sightings of refugee boats in distress. By scanning through the logbooks, he noted times, dates, and locations of sightings. Knowing where to look, and considering how the boat might have drifted in the time between the noted sightings and the time a satellite picture was taken, he gained access to satellite images of the surrounding area and built a tool for object detection. Object detection is a combination of *identifying* as in classifying into 'water' and 'not-water' and *locating* as in detecting the geolocation of objects.

While the former approach was 'We have a satellite image, find me the boats', Harry's approach is to say, 'I know whereabout the boat is, find me the satellite image'. By combining different algorithmic tools for this kind of object detection into a data pipeline, he was successful in finding various pictures of boats, which can further be used to train Space-Eye's classification-neural-network.

Circumventing temporal challenges through infrastructures

Throughout the fieldwork, I investigated the ways the same technological objects (satellites, drones, and artificial intelligence) are used by 'the other side', namely Frontex. One infrastructure that constitutes an interface between the work of Space-Eye and that of protecting EU borders is the EU satellite programme Copernicus. It consists of six satellite missions called 'Sentinel 1–6', that enable land, sea and atmosphere monitoring and observation through high-resolution optical imagery, radar imaging, and atmospheric spectrometry.[18] Most of the Copernicus data is advertised as free and open access for researchers and the wider public.[19] This led Space-Eye members to apply for access to Sentinel's higher-resolution optical data. Copernicus was formerly known as 'Global Monitoring of Environment and Security' (GMES), exemplifying the dual-use inherent to the programme. However, nowadays its environmental applications are foregrounded while its security applications are pushed into the background (Monroy, 2021).[20]

Frontex is one of the EU's fastest growing agencies, and supports EU member states with their surveillance and border control (see Kasparek, 2021). The agency researches and invests in the latest technological innovations for potential future application. Frontex started to use Copernicus satellites in 2014 as part of their border surveillance services 'in fighting cross-border crime and in countering terrorism'. The satellites provide 'near-real-time data on the EU's external land and sea borders, supporting the EU's external border surveillance information exchange framework (EUROSUR)'.[21] EUROSUR is based on optical and radar satellite data from the Copernicus programme and further (inter)national satellite providers. This (ideally) enables EUROSUR to automatically track and detect vessels. Through this system and platform, Frontex can allegedly calculate and detect anomalies, and predict vessel positions based on precise weather and oceanographic forecasts.[22]

To deal with the issue of downlink, meaning the delay due to data only being transmitted to the ground if the satellite in orbit is in visual range, Frontex uses the European Data Relay Satellite System (EDRS).[23,24] EDRS is part of the Copernicus framework and ideally ensures communication at all times. Three laser satellites facilitate a kind of 'space data highway' that 'establish[es] a connection between lower-flying observation satellites with a ground station over distances of 80,000 kilometres', resulting in a quasi-real-time transmission of satellite images anywhere on earth (Monroy, 2021, pp 19–20). The price for this space data highway is 'at least €520 million and is subsidized with large public sums as a public-private partnership between Airbus and the European Space Agency …. However, the owner of the 'space data highway' is Airbus, so the company markets the services alone' (Monroy, 2021, p 20).

What the EDRS exemplifies is that (quasi-)real-time satellite surveillance constitutes an active achievement *for some* rather than a given. EDRS constitutes one of various infrastructural investments in the fields of earth observation and artificial intelligence. Such infrastructures do not constitute a new overarching surveillance system. Rather they signify a 'patching together' of the multiple temporalities and paces to enable interoperability between existing data infrastructures (Pollozek, 2020, p 678). It constitutes a site where 'politics is translated from a rationality to a practice' (Appel et al, 2018, pp 15, 20). We can observe the divergence between the promise of 'real-time' satellite surveillance anytime anywhere, and its reality, which consists of all the composite and hierarchically assembled practicalities, rhythms, and temporal patterns that must be synchronized and patched together in the process.

Yet we can see that this patching together is only accessible for some. The 'same' satellite infrastructure(s) of the Copernicus programme play quite different roles in the collective brought about by the Space-Eye-project compared to that of the EUROSUR network. Both collectives are brought about by different contextualized practices and materialities involving interacting humans and machines and their (in)organic temporalities. The technological objects of optical satellites and neural networks entail the promise of speed and 'time-space compression'. Yet if one is neither a military person nor has unlimited financial capabilities, this promise dissolves and one is stuck with dealing with 'lags' and 'delay(s)'.

What we are left with are certain possibilities with simultaneous restrictions, be it due to the inorganic temporalities of optical satellites being tied to the physio-temporal pattern of sun-synchronous orbits, their passive sensors, the issues of temporal and spatial resolution, and further being 'slowed down' by the issue of downlink. Or it could be due to the inorganic temporality of training a neural network by providing a certain quantity of pictures with a decent resolution to 'speed up' the mechanical learning tempo of a neural network, to come up with its own criteria and pattern to distinguish refugee boats from the sea and for Space-Eye members to check up on its training's progression.

Thinking about Space-Eye's volunteer work, organized around satellites and neural networks with their organic and inorganic temporalities, makes us aware of the issue of access to certain infrastructures for better temporal and spatial resolution.This resonates with Marilyn Strathern's argument on the role of ownership in 'cutting the network' (Strathern, 1996). Positioned as as a critique of the open-endedness of networks within Actor-Network Theory she submits: 'Ownership is powerful because of its double effect, as simultaneously a matter of belonging and of property […]. So where technology might enlarge networks, proprietorship can be guaranteed to cut them down to size' (Strathern, 1996, p 531).

Turning to these infrastructures of earth observation prompts the questions of 'Who knows?', 'Who decides?' and 'Who decides who decides?'. These questions relate to knowledge, authority, and power, and the 'axial principle of social order in an information civilization' (Zuboff, 2019, p 168). They reflect upon the ability to share or withhold knowledge, and who is in charge of such decisions, that is tied to earth observation infrastructures. These questions become quite concrete in the case of Space-Eye and earth observation infrastructures, where 'knowing' constitutes a specific, situated, socio-technological, practical achievement involving the reconciliation of multiple rhythms in the process.

We observe how these questions gain temporal importance, as being denied access to these infrastructures slows down Space-Eye members in their attempt at time-space compression 'for the good'. It slows down those in front of their screens, and those on board trying to find people in the water. They pose a closure of the future on the question of of how, and for whom, it is accessible in relation to the technologies of satellites and artificial intelligence, which involves 'not only the deceleration of technical advancements in certain domains but also an entrenchment of the same old visions of future societies, of power relations and ways of living' (Hong, 2022, p 373). In this case, the usage of satellites for military, corporate, and border security purposes is taken as a given, while we encounter various (temporal) challenges that arise when these technologies are enacted for a different kind of future and collective.

It is a closure that impacts the (techno)future(s) in the making, by members of Space-Eye within their alternative socio-technological practices. It further impacts the form of social becoming – and belonging – that is potentially brought about by this co-constitutional interaction in the future and the here-and-now. The collective that is brought about by the current hegemonic dialogical interactions of the EUROSUR-network does not seem to include people on the move as worth saving. Rather, people on the move are enacted as a security risk (Kasparek, 2021), exemplified by Frontex's research into future border technology applications. For people on the move this signifies a quite lethal closure, not of *the*, but of *a* future and who gets the opportunity to have one.

With the EDRS we get a glimpse from the 'other B-series' (Ssorin-Chaikov, 2017, p 15), the one that comes first. Or rather, the one that not only has the 'authority to share or withhold knowledge' (Zuboff, 2019, p 168), but also has the power to create the socio-technological and material basis through which knowledge is circulated, the speed of its circulation, and who gets access. It shows how the 'infrastructural ordering of time', as a 'macrophysics of power' (Crawford, 2021, p 81), is not solely given but can be actively reformulated through specific socio-technological or material investments and the creation of new infrastructural elements, in this case four satellites roaming geostationary orbit. It is the power to create new socio-technological infrastructural elements that 'configure time, enable certain kinds of social time while disabling others, and make some temporalities possible while foreclosing alternatives' (Appel et al, 2018, p 15).

We can witness here how spatialization constitutes a 'temporal act and activity' (Appel et al, 2018, p 16). It is through temporal agency that consistent 'near-real-time data on the EU's external land and sea borders' is brought about. Temporal agency relying on a socio-technological network transcending orbits and downlink through three laser satellites at the bargain price of €520 million of partly public money. The result is an infrastructural constellation that manages to watch in near real time how people on the move drown, while retrieving Frontex missions at sea were justified by 'framing the 'problem' as merely a lack of EU resources' (Mainwaring and DeBono, 2021, p 1034).

Conclusion: The politics of lag

Temporality – or arrhythmia – itself has become a tool and weapon in the context of EU migration control (Andersson, 2014). The EDRS offers a glimpse into the machinery, or rather the growing infrastructural 'hybrid collectif' (De León, 2015, pp 38–44), of EUROSUR and its temporalities of control. It constitutes an element in an 'economics of illegality' that facilitates technological innovations for all kinds of new policing applications. Because of that, defence contractors and border authorities are provided with ever more resources leading to 'precisely the opposite reality for those who are targeted: a world of slowness and stasis' (Andersson, 2014, p 806–7). Returning this to the reality of SAR missions, we encounter how lag and delay constitute the result of socio-material state actions such as criminalization that become a tool to target SAR organizations, slowing them down in their practices, whereby in the context of SAR, where compressing time signifies a vital issue, any lag becomes potentially fatal.

Faced with this discrepancy within both the means and ends of the 'other side' to the Space-Eye project, it is hard not to feel confronted with a cybernetically enhanced hydra, solely equipped with an Atari console. But getting access and being reliant on these infrastructures does not keep members, as exemplified by Harry Hacker's tool, from crafting unique pathways through their own forms of temporal agency. In the spirit of a cyborgian retelling of David versus Goliath, the image of their original encounter gracing the walls of the 'Goliathhaus' in the middle of Regensburg (Figure 6.2), what better place to spark hope?

A first step is to pragmatically develop the idea that where technology enlarges networks, ownership cuts them down. This means addressing these emerging satellite and artificial intelligence infrastructures, asking who has legal ownership over them and who is left out of decision-making. How could they nurture a different kind of collective? It would mean using situated socio-technological practices, and the infrastructures they rely on,

Figure 6.2: The 'Goliathhaus' in Regensburg

as a gateway to investigate 'lag' as the consequence of political decisions and infrastructural investments. These are manifested in composite and hierarchically assembled and patched-up rhythms, temporal patterns, mechanical tempos, and interacting (in)organic temporalities that signify (near) real-timeness for some, and the denial of a future for others.

It further raises our awareness to questions of technical/temporal imagination(s) and investigate how the *promise* of '(near) real-timeness' is tied to a specific kind of technofuture that constitutes a 'dominant formulation of temporality' (Ringel, 2018, p 27), one that 'enact[s] a hegemony of closure and sameness' and postulates 'the closure of possible worlds and temporalities to the one and only kind of progress' (Hong, 2022, pp 372–4). It thus forces us to investigate how time is folded within these infrastructures and how they fold time. It involves asking who (more in a network-, constellation-, or organization-sense rather than merely tied to specific individuals) is capable of, responsible for, and in charge of newly developing infrastructural elements that constitute an active achievement of time-space compression for some. How are these infrastructures funded? Whose time are they folding or accelerating? Whose are they slowing down? For what purposes?

This further involves tracing how our imagination of time is marked by dominant formulations of temporality, where the future is left to be colonized and occupied only by certain groups claiming the hegemony over its means and form(ulation) (Andersson, 2014). Hence it is crucial to engage actively with a 're-appropriation of the future [as] a political right, a right to aspire and to participate in the social practice of the imagination' (Ringel, 2018, p 30). Space-Eye offers a starting point for such a re-appropriation of the future, a technofuture which, although it has not happened yet, is already effective in the virtual (Fisher, 2014). In the case of Space-Eye, this technofuture is not even merely limited to the realm of the virtual, but *already* a future enacted within present socio-technological and infrastructural practices and as part of Space-Eye members' temporal agency. It is through their coding practices that Space-Eye members already enact surveillance more in the image of Big Mother (Peacock, this volume, Introduction). It is through their practices that surveillance acts as an anticipatory act which has the differential capacity to protect rather than to neglect in real time. While the Space-Eye project faces its limits in scope and resources, let us hope it can be one of many tears in the fabric of the closing curtain of securitized technofutures, a contribution to an alternative horizon of how technological progress and border practices could be, and *already are*, done differently.

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Notes

[1] All names are pseudonyms.

[2] https://sea-watch.org/en/mission/airborne/ (Accessed: 25 October 2024).

[3] https://www.datacamp.com/tutorial/introduction-to-convolutional-neural-networks-cnns (Accessed: 25 October 2024).

[4] https://deepai.org/machine-learning-glossary-and-terms/neural-network (Accessed: 25 October 2024).

[5] https://wiki.pathmind.com/neural-network (Accessed: 25 October 2024).

[6] See online supplementary figure S1 at https://bristoluniversitypress.co.uk/rhythm-and-vigilance.

[7] https://privacyinternational.org/explainer/4595/satellite-and-aerial-surveillance-migration-tech-primer (Accessed: 25 October 2024).

[8] https://www.earthdata.nasa.gov/learn/backgrounders/remote-sensing#:~:text=Temporal%20resolution%20is%20the%20time,temporal%20resolution%20is%20much%20finer (Accessed: 25 October 2024).

[9] See online supplementary figure S2 at https://bristoluniversitypress.co.uk/rhythm-and-vigilance.

[10] For a visualization of the SSO, see https://www.youtube.com/watch?v=ylvgxNF3C0c (Accessed: 25 October 2024).

[11] See online supplementary figure S3 at https://bristoluniversitypress.co.uk/rhythm-and-vigilance.

[12] For a visualization, see https://www.youtube.com/watch?v=y_jM_BxQGvE (Accessed: 25 October 2024).

[13] See online supplementary figure S4 at https://bristoluniversitypress.co.uk/rhythm-and-vigilance.

[14] See online supplementary figure S5 at https://bristoluniversitypress.co.uk/rhythm-and-vigilance.

[15] For a visualization of Sentinel-2 'flying staggered' see https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-2/Satellite_constellation (Accessed: 25 October 2024).

[16] See online supplementary figure S6 at https://bristoluniversitypress.co.uk/rhythm-and-vigilance.

[17] See online supplementary figures S7 and S8 at https://bristoluniversitypress.co.uk/rhythm-and-vigilance.

[18] https://sentiwiki.copernicus.eu/web/copernicus-programme (Accessed: 25 October 2024).

[19] https://www.copernicus.eu/de/ueber-copernicus; https://www.esa.int/Applications/Observing_the_Earth/Copernicus/The_Sentinel_missions (Accessed: 9 June 2022).

[20] For the English version of the study from which quotes were taken, see https://digit.site36.net/2021/07/22/border-drones-part-1-unmanned-surveillance-of-the-eus-external-borders-by-frontex/ (Accessed: 9 June 2022).

[21] https://insitu.copernicus.eu/FactSheets/CSS_Border_Surveillance (Accessed: 25 October 2024).

[22] https://frontex.europa.eu/media-centre/news/news-release/frontex-to-implement-border-surveillance-services-as-part-of-copernicus-Z1r4A0 (Accessed: 25 October 2022).

[23] https://artes.esa.int/european-data-relay-satellite-system-edrs-overview (Accessed: 25 October 2024); for a visualization, see https://www.youtube.com/watch?v=_TnNmtm8l0I (Accessed: 25 October 2024).

[24] See online supplementary figure S9 at https://bristoluniversitypress.co.uk/rhythm-and-vigilance.

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