SENSING AT EARTH MAGNITUDE

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INTRODUCTION

"Suppose we were equipped with the right senses and sensors, and looked at Earth from outer space. What we would see would resemble a giant Christmas tree, a planet that is brightly 'lit-up', not only with enormous amounts of visible light, but also with electromagnetic radiation, radio waves, infrasound and wireless telecom frequencies." [1]

For us humans, it is difficult to perceive these phenomena since we are equipped with a limited set of senses and our human perception is limited to vision, sound, touch tase, smell and our immediate surroundings. In order to reveal such phenomena to the human, there needs to be a transformation from one state of energy to another state that is perceivable by the human. This transformation is done through the notion of the sensor. A sensor is a device that detects changes in its physical environment and translates it into data that can be perceived by the human. The sensor allows us to perceive energies and entities which were previously invisible to us and which we are generally not aware of. Our contemporary world is filled with sensors, from weather stations to satellites, infrasound stations and seismic monitoring stations. These sensors form a very specific spatial part of our environment; they generate a specific architectural infrastructure, have a precise relation to their territory and operate on scales beyond our human perception. However, The sensor is often overlooked in architectural discourse and production.

This paper investigates the notion of the sensor for the development of an architectural project. It addresses earth magnitude as a hyperobject filled with energy and activity made visible through the sensor. Moreover, it encourages us to think at earth magnitude; at the true extend of earth's range, from its core to outer space, and beyond the human perspective. The argument is developed through examination of the Kazakhstan international monitoring system, how they reveal earth magnitude, what it means to think at earth magnitude and how the sensors constitute a specific spatial reality in the critical zone. Finally this paper discusses the potential of thinking at earth magnitude in architectural production and how the notion of the sensor can inform an architectural project in the Borders & Territories MSc 3/4 studio.

INTERNATIONAL MONITORING SYSTEM

In order to gain an insight in the sensors on the territory of Kazakhstan, we will first look at the sensors of the International Monitoring System (IMS). The IMS is a worldwide network of monitoring stations that detect events that might indicate violations of the 1996 Comprehensive Nuclear-Test-Ban Treaty (CTBT). The CTBT is a multilateral treaty, that bans all nuclear tests, for both civilian and military purposes, in all environments. The International Monitoring System includes seismic, infrasound, radionuclide and hydro-acoustic stations located on the territory of 90 countries around the world, including Kazakhstan. The Kazakhstan monitoring stations network consists of seismic and infrasound stations (figure 1). The data from these stations are acquired and processed at the Kazakhstan National Data Center (KNDC) in Almaty. These stations, on the one hand, participate in the International Monitoring System, and on the other hand, monitor the seismic and infra-acoustic activities on the territory of Kazakhstan.

[1] Van der Velden, L., & Altena, A. (2015). The Geologic Imagination. Sonic Acts - The Geologic Imagination, 11–16.

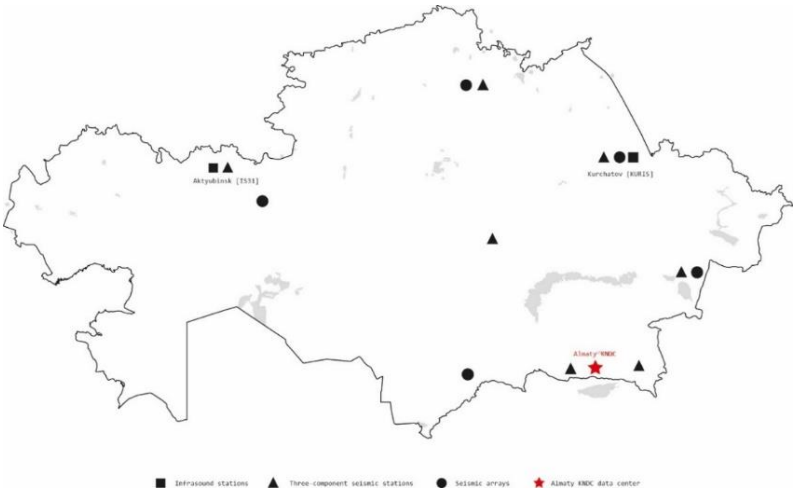

Figure 1 Kazakhstan IMS Stations

SEISMIC OBSERVATION

The Kazakh monitoring stations of the IMS record a variety of human, natural, and geological activities through infrasound recording and seismic observation. The seismic stations in Kazakhstan measure seismic activity 24 hours a day through seismometers. These seismometers are installed hundreds of meters deep in the earth's skin through boreholes and are connected to solid rock. Seismometers reveal seismic activity through the monitoring of seismic waves, which can have several sources such as earthquakes, explosions, drilling and tectonic movement. In his 1991 project *'The Skin of the Earth'*, architect Raoul Bunschoten elaborates on this seismic activity by writing *"Slow time. The time of geological movement. Movement of the crust that we call ground. Ground that reaches into the depths of our imagination, deceives us into trusting it as solid, heavy, static – ground to build upon, ground to deposit objects on."* [2]. This suggests the earth as a dynamic and moving entity, slowly changing over millions of years.

The earth is structured by several layers; a solid thin crust, a liquid asthenosphere, a solid mantle and a liquid core which generates earth's magnetic fields. Earth's crust accounts for less than 1% of earth's volume and ranges from 5-70km in depth. The composition of the crust is built up out of several layers such as igneous rocks like basalt and silicate rocks like granite. These different layers of the composition correspond to different geological times such as the Tertiary (10 – 66 mya) and Cretaceous (66 – 145 mya) periods [3]. According to Bunschoten, we scratch, incise and articulate earth's crust in order to place and orient ourselves. We build cities that hug the crust, drawn to, but also alienated from it, as a second skin which mimics the first one with its slowly shifting features and sudden ruptures [2].

The crust the city of Almaty is built upon contains a huge active seismic fault which, according to Geologist Christoph Grützner is likely to rupture one day. In its young history, Almaty has been hit by multiple devastating earthquakes in 1887 and 1911 [4]. All along the fault, Holocene fault scarps have been found which offset the terrain with heights between 5 and 50m. Some of these fault scarps stem from single large earthquakes while others are so big that they must have been formed by repeated earthquakes millions of years ago. Moreover, relatively young uplift and deformation has been found in the forelands of Almaty, indicating that several seismic sources may be active at the same time[5]. These findings reveal the earth as a dynamic and moving entity filled with seismic activity of both today and millions of years ago, made visible through the seismic sensors.

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[2] Bunschoten, R. (1992). The skin of the earth. AA Files, 1992(23), 97–98.

[3] Dastrup, R. (2020). The Composition and Structure of Earth. Lumen physical geography. https://courses.lumenlearning.com/geophysical/chapter/the-composition-and-structure-of-earth/

[4] Grützner, C. (2017). Almaty sits on a huge active fault, and here is why we know. paleoseismicity.org. https://paleoseismicity.org/almaty-sits-on-a-huge-active-fault-and-here-is-why-we-know/

[5] Grützner, C., Walker, R. T., Abdrakhmatov, K. E., Mukambaev, A., Elliott, A. J., & Elliott, J. R. (2017). Active Tectonics Around Almaty and along the Zailisky Alatau Rangefront. Tectonics, 36(10), 1. https://doi.org/10.1002/2017tc004657

INFRASOUND

Next to seismic observation stations, the IMS network in Kazakhstan contains infrasound observation stations. Infrasound, often referred to as low-frequency sound, describes sound waves with a frequency below the lower limit of audibility (generally 20 Hz)(figure 2). Infrasound was first discovered after the eruption of the Krakatoa volcano in 1883. Barographs around the world measured small air pressure fluctuations that corresponded to the event. Due to the low frequency of the soundwaves, they hardly experience any attenuation which makes them travel the world multiple times at atmospheric altitudes of over 100km [6]. Due to the low frequency but high sound pressure characteristics of infrasound, the vibrations can be felt in the body and the sound gets a physical dimension. Due to this physical dimension, the soundwaves territorialize an area and they creates acoustic territories [7].

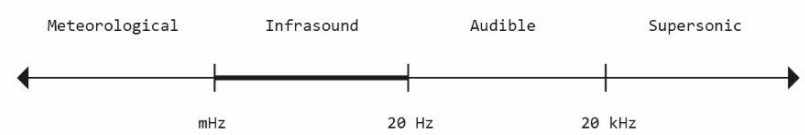

Figure 2 Frequency spectrum infrasound

Infrasound waves are being caused by a wide variety of sources. Natural sources of infrasound include earthquakes, avalanches, solar storms and meteors. Human sources of infrasound include quarry explosions, oil flares, rocket launches and nuclear tests (figure 3). Sonologist Raviv Ganchrow terms this 'the bandwith of the Anthropocene' [7]. The Anthropocene is a proposed epoch of geological time in which human activity started to have a large scale impact on earth's geology and ecosystems. The start date of the Anthropocene is often discussed. A growing group of scientists argue that the Anthropocene should follow up the Holocene (11,700 years ago – present) and start in the year 1945 with the detonation of the first atomic bomb and its peak in radionuclide fallout [8]. Due to infrasound waves traveling the earth multiple times, they can be monitored thousands of kilometers away from their original sources. Infrasound reveals human activity as an anthropogenic geological force capable of interacting with the scale of topography and even the earth [7].

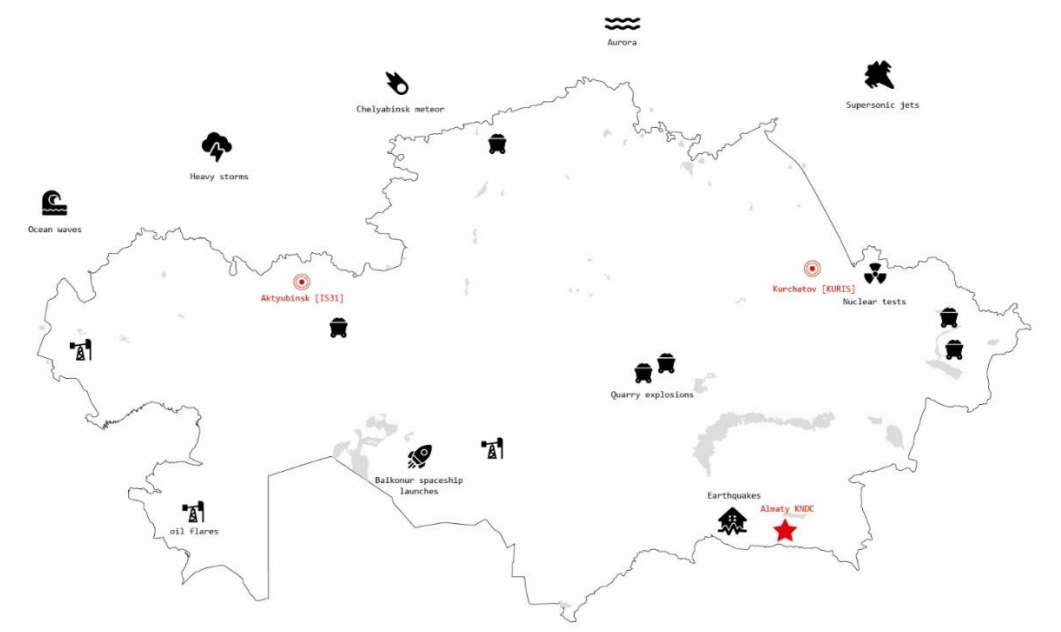

Figure 3 Kazakhstan infrasound sources

[6] Evers, L. (2009). KNMI - Infrasound and seismology in the Low Frequency Array LOFAR. KNMI. https://www.knmi.nl/kennis-en-datacentrum/achtergrond/infrasound-and-seismology-in-the-low-frequency-array-lofar

[7] Ganchrow, R. (2015). On Long-Wave Synthesis. Sonic Acts - The geologic imagination, 180–198.

[8] Rafferty, J. P. (2020). Anthropocene Epoch | Definition & Evidence. Encyclopedia

EARTH MAGNITUDE

The sensors of the IMS reveal human and seismic activity as geological forces operating at the scale of the earth; at the scale of earth magnitude. However, what is earth magnitude? And what does it mean to think at earth magnitude? Earth magnitude is first introduced by academic Douglas Kahn in his book *'Earth Sound Earth Signal: Energies and Earth Magnitude in the Arts'* (2013). In this book, Kahn uses the term earth magnitude to relate energies to the scales of the earth — from sound at local and long distances, to the effects of electrical atmospheres, to electromagnetic activities occurring at the speed of light at earth magnitude [9]. Kahn investigates several energy related artistic and scientific projects, such as the natural radio of Alvin Lucier, Gordon Mumma's seismic music and the whistler phenomenon. A whistler is a low frequency wave generated by bursts of lightning. Although they are electromagnetic waves, they occur at audio frequencies, and can be converted to audio using a suitable receiver [10]. Whistlers bounce back and forth between the earth and the ionosphere. At a height of 600km, they arch over the equator and form globetrotting signals; earth magnitude signals in their truest sense [9]. Whistler science evolved out of the military communications of World War I and, along with geophysical sciences generated new scientific means of sensing physical phenomena and energetic states of the earth at a geophysical scale [9]. In a late nineteenth-century contest to sense the scale of the earth, the main contenders were of acoustical nature: the eruption of the Krakatoa was heard thousands of kilometers away from its source and seismic signals from an earthquake in Japan hit seismographs in Germany. Both were means to sense the 'whole earth' long before technological surveillance aircraft and 'blue marble' photographs from space took over [9]. Through the investigation of energy related artistic and scientific projects, Kahn reveals earth magnitude as a large scale, dense entity filled with electromagnetic currents, weather systems, terrestrial activity and radio waves, made visible through years of artistic expression.

Philosopher Timothy Morton elaborates further on earth magnitude by stating that thinking at earth magnitude is thinking at a scale sufficient to open the concept of earth to the true extend of its range [11]. Global climate does this, as terrestrial weather events are caused by a massive entity that exists at earth magnitude. Solar storms do this as they interact with earth's magnetic shields and produce aurora's. Human thought at Earth magnitude is human thinking that is as 'large' as the aurora. It is a thought that can think the aurora in such a way that its vastness is witnessed and opened in us [11].

According to Morton, at earth magnitude, anthropocentric distinctions don't matter anymore. These distinctions include binaries such as here vs there, person vs thing, individual vs group and life vs non-life. Thinking at earth magnitude allows us to see human species and activity not as a thing we can ontically point to, but as something like the aurora, a mysterious yet distinct entity. Morton proposes to see human activity, with all its dense energies as an hyperobject that is real, yet inaccessible [11]. Morton uses the term 'hyperobjects' to describe vast entities that are massively distributed in time and space and transcend spatiotemporal specificity; such as global warming and the atmosphere [12]. It is the notion of the hyperobject that provides a way to think entities at earth magnitude, hyperobjects are real entities that cannot be seen, touched or grasped. They are beyond the human, but they are not infinite or abstract, they are just very, very big [11].

Ultimately, the notion of the Hyperobject reveals earth magnitude as a massive entity that is filled with energy and activity and is massively distributed in time and space. The sensors of the IMS expose earth's atmosphere as filled with anthropogenic human activity and the earth itself as filled with geological-time seismic activity. Moreover, earth magnitude allows us to think at the true extend of earth's range, from its core to outer space, and beyond the human perspective.

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[9] Kahn, D. (2013). Earth Sound Earth Signal: Energies and Earth Magnitude in the Arts. University of California Press.

[10] Helliwell, R. A. (2006). Whistlers and Related Ionospheric Phenomena. Dover Publications.

[11] Morton, T. (2015). Human Thought at Earth Magnitude. Sonic Acts - The geologic imagination, 163–178.

[12] Morton, T. (2013). Hyperobjects: Philosophy and Ecology after the End of the World. University of Minnesota Press.

THE SENSOR IN THE CRITICAL ZONE

Now that we have defined Earth Magnitude as a hyperobject filled with anthropogenic human activity in its atmosphere and geological-time seismic activity within the earth, made visible through the sensor, we can look at where these two intersect; the Critical Zone. As theorized by Bruno Latour, the critical zone is a thin layer of several kilometers thick above and below the surface of our planet in which human activity has a significant impact on earth's geology and ecosystems [13]. Lying at the interface of geological time and the Anthropocene, at the intersection of earth and atmosphere, the critical zone is a complex entity where multiple scientific disciplines such as geology, hydrology, climatology and ecology come together [13]. According to Latour, if we were to look at earth magnitude purely through the notion of the globe, it obliges you to squeeze the atmosphere, the earth and it's critical zone into nothing. The notion of the critical zone encourages us to see the earth from within, free our imagination from the blue marble as shot from outer space and break down the cartographical view of our planet [13]. It is through the notion of the sensor that allows us to see things from within and generate an insight in the entities at earth magnitude.

It is in the critical zone that these sensors constitute a specific spatial reality. Even though the sensor reveals immaterial conditions to the human, the sensor in itself is a very physical object, with sophisticated forms and precise territorialization. In order for a sensor to operate properly, it requires a specific environment, an infrastructure, electrical power, a data transmitter and perhaps protection from the weather. All of these technical conditions generate a very specific architectural manifestation. In order to gain an understanding of these architectural manifestations, we will examine two sensors of the Kazakh IMS; the seismometer and the infrasound monitoring station.

As previously discussed, a seismometer (figure 4) is a sensor that is connected to solid rock and is installed hundreds of meters deep in the earth's skin through a borehole. However, the data from the seismometer needs to be brought up to a computer processor. This equipment is very sensible so it has to be protected from the weather and the public. This protection is offered by an archetypical equipment vault, an architectural manifestation defined by technical requirements and framed by fences in a desolate territory. From here, the data is transmitted to a recording facility by an antenna. The infrasound station (figure 5) contains multiple micro-barometers which are connected to a spider-like steel pipe structure that reduces surrounding noise and amplifies the sound signal. This structure is elevated from the terrain to reduce the interference of surrounding vibrations. The spatial composition of the array allows for accurate source location. Next to this specific spatial structure, an archetypical equipment vault protects the data transmitter.

Figure 4 Seismometer station

Figure 5 Infrasound station

As mentioned earlier, our contemporary world is filled with sensors and isn't just limited to the sensors of the IMS. All these sensors with their specific architectural infrastructure and precise relations to their territory introduce the idea of the territory as a sensing device, spatialized in the critical zone.

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[13] Latour, B., & Weibel, P. (2020). Critical Zones: The Science and Politics of Landing on Earth (Illustrated editie). The MIT Press.

THE STACK

Finally, another entity that exists at earth magnitude has been theorized by philosopher Benjamin Bratton as 'The Stack'. The Stack is a political design theory of planetary scale computation that forms an accidental megastructure. Within this megastructure, Bratton proposes various information orders stacked on top of each other, operating as a whole and forming both a computational apparatus and a new governing architecture. The stack consists out of the layers earth, cloud, city, address, interface and user. Planetary scale computation distorts and deforms traditional logics of nation states and its political geography and produces new territories in its own [14]. However, the stack should not be understood only through its virtuality but also through its physicality. The stack is an energy intensive megastructure with physical manifestations of the virtual in the form datacenters, oil refineries, powerplants and sensing devices. Moreover, the stack is based on rare earth minerals, pulled from mountain streams in central Africa that go into all of the electronics that we use. *"The stack terraforms its host planet by drinking its elemental juices."* [14]. In the atmosphere, the stack forms a vast and specific infrastructure of cloud computing, data, addresses and interfaces existing all over the earth. The stack creates a new subdivision of territories by stacking vertical layers on top of the existing horizontal territory, generating the corresponding jurisdictional complexity [14]. Ultimately, the stack forms a vast and specific megastructure that is part of earth magnitude and is manifested by physical infrastructure on earth.

DISCUSSION / POSITIONING

In this paper, earth magnitude is defined as a hyperobject filled with energy and activity and that is massively distributed in time and space. The sensors of the IMS expose earth's atmosphere as filled with anthropogenic human activity and the earth itself as filled with geological-time seismic activity. Moreover, earth magnitude encourages us to think at the true extend of earth's range, from its core to outer space, and beyond the human perspective. It is the notion of the sensor that allows us to perceive the dense energies and activities at earth magnitude. These sensors constitute a specific spatial and architectural reality in the critical zone and introduce the idea of the territory as a sensing device.

Thinking at earth magnitude in architectural production allows us to create an architectural project that is not limited by traditional human perspective. It opens up our thought to the true extend of earth's range and encourages us to position an architectural project in a dense hyperobject that is beyond the human. Thinking at earth magnitude allows us to connect an architectural project to entities and energies we are generally not aware of and provide a new scale for thinking about architecture. Moreover, thinking at earth magnitude is related to relatively new philosophical thinking where the human perspective is no longer privileged and human activity is seen as a geological force of the Anthropocene. This places the project in a contemporary philosophical debate about our relationship to the planet.

Our contemporary world is filled with sensors, from weather stations to satellites and the seismic and infrasound monitoring stations. The sensor forms a very spatial part of our environment, however, they are often overlooked in architectural discourse and production. The sensor generates new types of spatial components and architectural manifestations as a result of our contemporary reality. By taking the sensor and their spatial components highly serious, a new kind of departure point for an architectural project in the Borders & Territories MSc 3/4 project can be laid out. In our ever growing world of sensors and data, such a project would deal with contemporary and further emerging conditions, contribute to a field of experimental architectural production and makes us aware of the impact and scale of sensing at earth magnitude. By mapping out the sensors in the critical zone, the spatialization of the sensor and the territory as a sensing device can be revealed.

[14] Bratton, B. H. (2016). The Stack: On Software and Sovereignty. The MIT Press.

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IMAGES

Figure 1 – Kazakhstan IMS Stations
Drawing by author Menno Brouwer

Figure 2 – Frequency spectrum infrasound
Drawing by author Menno Brouwer

Figure 3 – Kazakhstan infrasound sources
Drawing by author Menno Brouwer

Figure 4 – Seismometer station
http://publications.isc.ac.uk/index.php/summary/article/view/28/29

Figure 5 – Infrasound station
https://en.wikipedia.org/wiki/Infrasound#/media/File:Infrasound_Arrays.jpg