Satellites in civil protection

STEM Projects

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***Abstract*—In today's world, satellites fulfil many tasks helping people in difficult situations like earthquakes and fires. They can decrease the damage by sending their observations before and after the disaster. So people are warned beforehand and rescuers have a better overview of the situations afterwards. The contribution of this paper is to show different situations where satellites can help rescuers in ecological disasters and map out danger zones as early as possible.**

***Index Terms*—satellites, first aid, civil protection**

I. Introduction

When an ecological disaster happens, many basic questions have to get answered for the aid agencies. How many people need help? What villages are destroyed? What is the best way to get to the area? Is it safe for the rescuers to get there? All maps of the area are outdated immediately and new ones have to be made for the actual situation. Every year, ecological disasters cost millions of lives. This year's Botball competition is about disaster management. With our thoughts on this topic, we did not stay on earth. Satellites have huge potential to keep the damage lower.

II. State of the Art

A. Origin and Meaning

The expression "satellite" comes from the Latin word "satelles", which means companion, bodyguard. Satellites are objects, that orbit other objects in space. There are two different types of satellites: natural and artificial ones. Natural satellites are objects, which are not human made such as the moon. It orbits the earth, so it's a natural satellite of our planet. Artificial satellites are made and sent to space by humans. Now (15.02.2019) there are 1957 active satellites from different countries orbiting earth. There are many more out there, but they are no longer useful, so they are not active. The first artificial satellite was Sputnik 1. It was launched by the Soviet Union on 4th October 1957. There are many earth observation programs, whose goal is to study the earth's surface. The major ones are EOS (Earth Observing System) by NASA (National Aeronautics and Space Administration) and Copernicus by ESA (European Space Agency). They aim at combining ground and space based observations in order to develop a civil protection network. [1]

B. Different Metrology

1) Synthetic-aperture radar (SAR): The synthetic aperture radar is used to measure the distance between the satellite and the surface of a planet. The SAR, as it is also called, creates a two dimensional image of the height of the surface of a planet. With this two dimensional image a three dimensional image can be reconstructed. The SAR uses a beam forming antenna, which is an antenna array, to send and receive the signals. Because of the beam forming antenna the resolution is much higher. The area where it captures data is parallel to the flight track as shown in figure 1. The black line on the top of the image shows the flight track. The two green lines mark the area where the data is captured. The spacecraft or aircraft sends waves to the planet (blue arcs) and measures how much time the signals need to return. With this value the distance between the satellite and the area is calculated. This value is then used to create a two dimensional image. The wavelength of the radio waves is in the range of a meter down to a few millimetres. A SAR is not affected by thunderstorms and all other types of weather. It also works at night because it needs no light. The synthetic aperture radar is used in the topography, oceanography, glaciology, geology and forestry. It has so many use cases because of its high resolution. This technology is also able to monitor the environment, for example it can help when a flooding happens. [2] The SAR technology is used in the two Senitel-1 satellites, which are part of the Copernicus Programme of the ESA. [3]

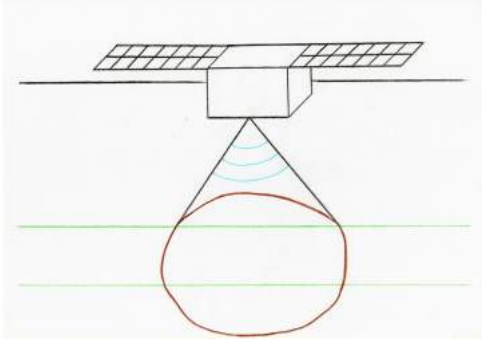

Figure 1. SAR

2) Interferometric synthetic aperture radar (InSAR): The interferometric synthetic aperture radar which is normally named InSAR uses two or more SAR images from the same place and combines them to create an interferometric synthetic aperture radar image. The InSAR technology is used to measure differences down to a millimetre on the earth's surface. It can also be used to measure movements of a pipeline to prevent that the pipeline from breaking and thus an ecological disaster from happening. After earthquakes it can help to evaluate how many buildings are collapsed and how the rescuers get to the building as fast as possible to rescue as many people as possible. [4] [5] By the two Senitel-1 satellites every place on the earth is overflown and monitored within six days. [3]

3) Infrared atmospheric sounding interferomter (IASI): The infrared atmospheric sounding interferometer, which is also named IASI, is based on the Michelson interferometer, with an integrated imaging system. The Michelson interferometer uses two mirrors, a beam splitter and a detector to measure the wavelength of the light. [6] There exist three bands. The first band is used to measure the temperature of the surface and the clouds. The second band is used to measure the humidity and the last band measures the temperature of the surface and clouds and also the amount of CO, CO_2, N_2O and CH_4. The IASI has three data layers (0, 1, 2). The level 0 is the raw output of the sensor data. Level 1 and 2 produce the final image. After the second level the image shows for example the temperature on the surface or the rate of CO in the air. The IASI needs cloud free conditions and has an accuracy of 1 kelvin. It is used in the MetOp-A and MetOp-B satellites. The infrared atmospheric sounding interferometer, for example, is used to detect wildfires. [7] [8]

4) Optical imaging: The optical imaging process captures the light in different wavelengths. This technique needs reflected sunlight to work as shown in figure 2. There exist several bands on which data can be captured. Only a few bands of them are normally visible to the human eye. One of the other bands is for example the infrared band, which is not normally visible to the human eye. [9]

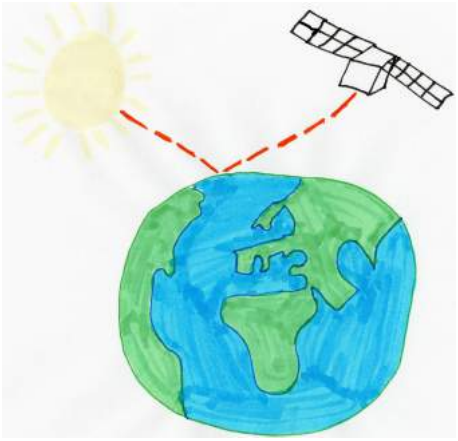

Figure 2. Optical Imaging

III. Usecases of the satellite technology

A. Mini satellites or nano satellites

Today companies like planet [10] or spire [11] help to decrease the time until a satellite crosses the same area where for example a natural disaster happened. They have a lot of very small satellites around the earth, which operate like swarms. The NASA purchased last year data from these companies to evaluate how accurate the private sector Earth observation data is. [12]

B. Prevent solar storms

Solar storms are not only a problem for satellites as shown in V-C but also for the power grids on earth. If a solar storm happens the NASA's twin Stereo satellites or the SOHO satellite will detect this and the operators of the power grids are then informed to keep the damage as low as possible. [13]

C. Satellite communication

These days there are a lot of communication satellites which are used by the military, internet service provider and other sectors. They are also used to transmit for example television signals direct to the home. There are three orbits, the low earth orbit (altitude between 160 km and 1600 km), the medium earth orbit (altitude between 10000 km and 20000 km) and the geostationary or geosynchronous orbit (altitude is 35786 km). The geostationary or geosynchronous orbit is used if a huge area needs to be covered. Another advantage of the geostationary or geosynchronous orbit is that it does not need to be tracked because the satellite stays on the same place. If a low delay time communication is needed, the low Earth orbit or the medium Earth orbit are used. A problem with these two orbits is, that the satellites must be tracked to do not lose all connection to them because they orbit around the earth. This type of communication is especially helpful if the local service is down in case of an natural disasterfor excample. [14]

IV. Possible applications in different thematic areas

In many different situations, satellites can provide data to help humans to decrease the extent of the damage disasters come with. Next, we describe some of them. [15]

A. Earthquakes

Earthquakes are caused by movements in the earth's tectonic plates. Many of them are so small that they do not cause any harm and often go unnoticed. But sometimes there are so enormous ones, that they destroy whole cities. The strength of earthquakes is declared by the Richter magnitude scale and the moment magnitude scale. Theoretically, the Richter scale starts at 0 and has no real end, but at values bigger than 6.5 this scale loses validity, wherefore then the moment magnitude scale is used. This is because the energy increases much faster than the magnitude. So the severity increases faster, too. Anyway in most news, the Richter scale is used for all earthquakes. The yet most intense earthquake which was measured was 9,5 on the moment magnitude scale. At a value of 10,6 the earth

would break apart. [16] But this is not the only coefficient that affects how much damage is done. Another important point is the hypocentre. There the earthquake arises. The further this point is away from every civilisation, the better.

Satellites like Sentinel 1 can measure terrain displacements using the above described SAR interferometry technique.

B. Flood waters

Snow melts in spring and extremely heavy rain are typical causes for inundations. These can damage buildings and other structures, including transport infrastructure, power transmission or generation, to list a few. Satellites can help to lower the damage. The earth observation program Copernicus intends, among other projects, to combine ground- and space-based observations to develop an integrated flood monitoring service for national civil protection agencies. It supports providing pre- and post-disaster situation maps and reliable information for flood damage. It helps to produce almost real-time maps of the flooded areas.

C. Fires

Especially in the Mediterranean regions, fires are a huge problem. Satellites can not only track the smoke from wildfires, but also alternations of the landscape can be mapped. This helps firefighters to locate the process of the fire to make fast and safe plans to rescue as many people as possible. The information is also useful to observe the recovery of the vegetation. For example, Sentinel 3, a satellite of Copernicus, is used for that. It can provide exact temperature data by infrared atmospheric sounding interferometry to locate forest fires.

D. Storms

Storms are caused by differences in air pressure. Wind force can be stated on the Beaufort scale. It ranges from 0, calm, to 12, hurricane. Many storms develop in the sea. Satellites like Sentinel 1 can measure the sea surface temperature, whereby the force of the storm can be estimated. Furthermore, they collect data about velocity of the wind and wave height, whereby forecasts about the process of the disaster can be constructed. So, people can recognise, if, and where the storm will hit the mainland, whereby the population can be warned. So the affected areas can be evacuated in time.

E. Epidemics

Mainly in West Africa, outbreaks of epidemics like Ebola and Malaria are always an important topic. The more we know about the sprawl of these diseases, the better. The Ebola virus can be transmitted between humans and from animals, primarily fruit bats, to humans trough body fluids. Satellites can oversee parameters like land cover, water bodies, wind and dust. That helps experts to find the possible directions in which the epidemic spreads.

F. Droughts

Droughts have a longer advance warning time than most other disasters. Satellite pictures show them weeks before they reach a dangerous level. Water saving measures can be enacted and farmers can prevent harvest losses. [17] Last summer (2018) was a long try period. This would have been especially relevant. [18]

V. Open Problems

Although there are so many benefits of using satellites to reduce economical disasters, there are still some points to improve for example the following ones. [19]

A. Data

One problem of satellites is that they produce a huge amount of data. This data must be sent to the earth station. On earth this data is then saved. The Copernicus project alone produces 20 Terabyte worth of data each day. This data also has to be analysed. The analysis process needs a huge amount of compute power. Therefore there are several data centres dedicated for this process.

B. Time

Unfortunately, it is still impossible to observe every area at once. In the worst case, scientists have to wait many hours until a satellite is above the place they want to study. It is not possible to just change its trajectory – it would need a lot of fuel to make big changes. In extreme situations this is a huge problem, because there is no time for waiting – the people need help immediately. Time often makes the difference between life and death. Furthermore the satellite has to be in visual contact with a tracking station to even get the commission and data to track the requested area. It is also necessary to get the information from the satellite down to the ground station. To solve this problem, more satellites have to be built, so that the probability, that a satellite is near the requested area, is higher. In figure 3 and 4 you see pictures of a satellite (green), which is able to communicate with a tracking station (violet) and one (red), which is not, because it is “behind” the earth and has no visual contact with the tracking station. The yellow area on figure 3 shows the “black angle” of the tracking station. Satellites which are in this area are not able to send or get any data from the ground from this tracking station. In reality, there is more than one tracking station on earth.

C. Solar storms

Solar storms are also a problem for satellites. Solar storms are high-energy particles originating in the sun. These particles can damage solar cells. For example, the satellite SOHO has lost 25% of his solar cell power in the last 24 years. The particles of a solar storm can also blind the sensors of the satellites or can cause a computer crash. Fortunately, in many cases no lasting damage to computers is done and after rebooting the computers usually work again. There exist satellites to detect these storms and help to keep the damage

on the power grids on earth and on the satellites as low as possible as described here III-B. [20]

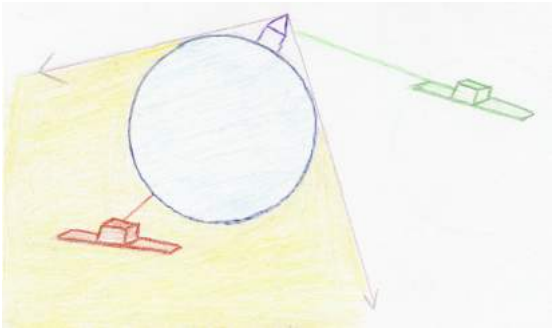

Figure 3. Earth with 2 satellites

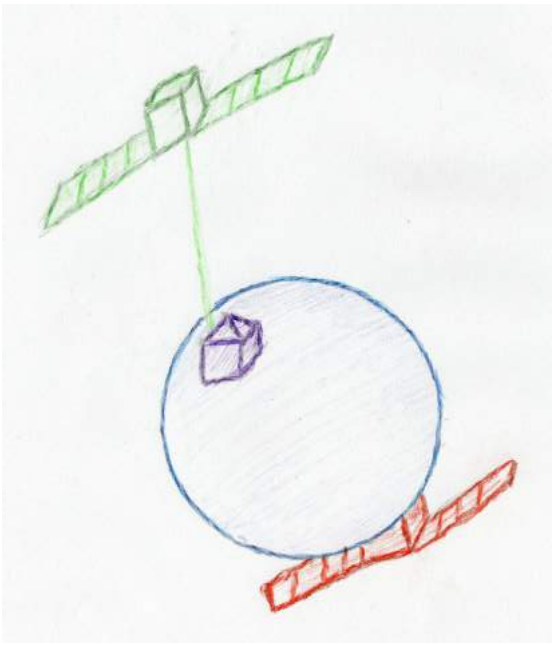

Figure 4. Earth with 2 satellites

VI. Conclusions

Satellites have a great importance for today's world. This paper focuses on their functions in civil protection and which metrology is used for that. In the future – of course, many new inventions and technologies will be developed. For example, NASA announced that they will launch a satellite named SWOT (Surface Water and Ocean Topography) to survey the earth's surface water in 2021. SWOT will survey 90 percent of the rivers, oceans and lakes at least twice every 21 days to make weather and climate predictions and oversee changes in the water's surface. [21]

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