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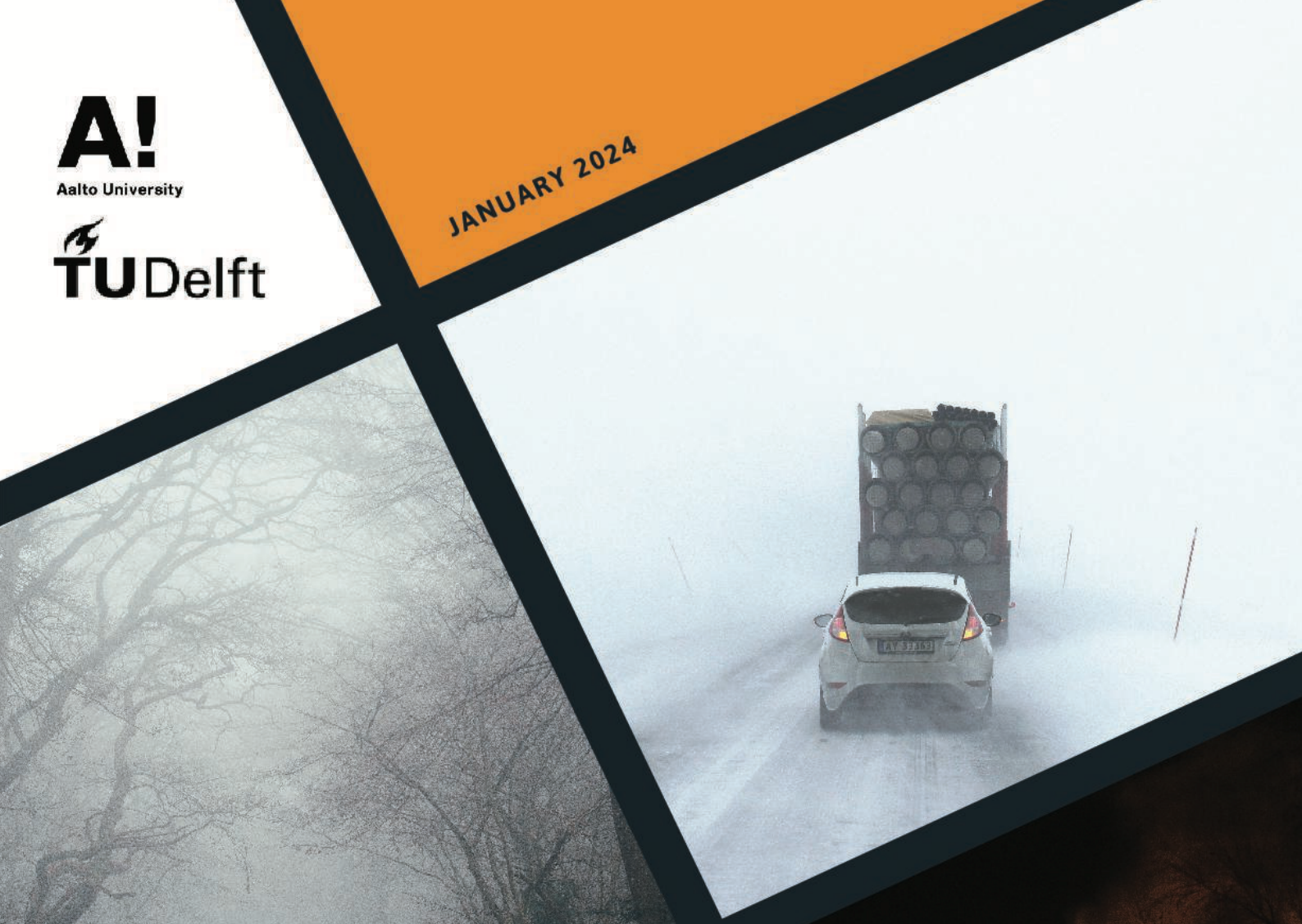

SPOT

SOCIETAL PERSPECTIVES TO INNOVATION OPPORTUNITIES IN TECHNOLOGY

EXPLORING VISIR2

TECHNOLOGICAL, LEGAL & ENVIRONMENTAL DIMENSIONS

ATTRACT

Report:

SOCIETAL PERSPECTIVES: TECHNOLOGICAL, LEGAL & ENVIRONMENTAL DIMENSIONS

Student perspectives

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VISIR2

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Introduction

Students were tasked to consider the technological and environmental factors, relating to a PESTEL analysis. A PESTEL analysis is a strategic tool that examines the external macro-environmental factors affecting an organisation. A PESTEL analysis offers a comprehensive view of the external environment by assessing Political, Economic, Social, Technological, Environmental, and Legal factors. This holistic perspective helps in understanding the broader context in which an organisation operates.

A focus on technological factors enabled students to recognise emerging trends and technological advancements, while a focus on environmental factors is crucial in today's business landscape. By analysing environmental aspects within PESTEL, students identified ways in which the organisation can operate sustainably and incorporate environmental responsibility.

This compilation of student insights draws from the 14 analyses submitted. Students were introduced to both the VISIR2 technology card and a description of the technology case prior to the analysis.

Student insights were collated into emerging themes for technological, environmental, and legal factors.

The main technological themes include accident prevention, AI, materials science and engineering, self-driving and autonomous vehicles, power consumption, search, and rescue technologies as well as solid state imaging. Environmental themes include energy consumption, global warming, greener construction, plastic waste management, responsible material choices and wildfire detection. Finally, the main legal factors included copyright, patent law, export control, democratization of night vision and IR imaging, evolving automotive legislation and regulations, Privacy concerns, regulating harmful or dangerous materials, responsibility, and liability.

Technological Dimensions & Considerations

Accident Prevention

"Almost all new cars have some technology that helps to recognize the environment around it. There are many reasons for that. According to the World Health Organization's report in 2016, road accidents ranked as the eighth leading cause of death worldwide and, in Europe alone, road accidents incur an estimated cost of 130 billion Euros annually.
However, image-based environmental detection is not the only technology that detects the environment. For example, the LIDAR (Light Detection and Ranging) is used for estimating distances between objects (NOAA 2019). LIDAR is a method for determining ranges by targeting an object or a surface with a laser and measuring the time for the reflected light to return to the receiver. Many image-based detection systems are not always completely accurate, and the possibility of errors is greater. The distance can be measured much more precisely when it is measured from surfaces alone (Rangwala, 2022)."

"The combination of infrared and visible light provides valuable insights, which neither one can provide on its own. One great example of such novel use cases is improving the driver's visibility in low light condition such as night or haze and fog on the road (ATTRACT, 2021). The European Road Safety Observatory reveals that 41% of accidents occur between 6:00 PM and 6:00 AM. VISIR2 can help to enhance visibility in the dark during night-time driving (Krebs et al., 1999). The efficient production of VISIR2 imagers can help improve and democratize technologies such as the *Audi Night vision assistant*, available in the larger Audi models (Audi Technology Portal, 2023). VISIR2 can impact such technologies by making them more available and better."

"Another way in which VISIR2 imagers can impact technology, also in the car industry, is by offering significant improvements to driver fatigue monitoring systems. Currently, systems for fatigue detection often utilize CMOS to capture infrared light reflected from the driver's body or face. VISIR2 imagers could improve this technology by ensuring robustness in difficult lighting conditions. Importantly, VISIR2 technology could bring improvement without increasing camera size, which is important in the automotive industry."

"The automotive industry will benefit from VISIR2 for example in safety measures VISIR2 will be testing its technology assist ing driving in bad weather such as heavy rain, smoke, or fog and monitoring ddrivers' sleepiness by eye movement. (Attract, 2021). This would be possible through VIS/SWIR technology thus it can scan eye movement and it allows you to see far more than usually in bad conditions. The ability of VISIR2 to remove sunlight interference is a valuable feature, especially in the automotive industry. Sunlight can cause glare and make it hard to see, particularly during sunrise and sunset. VISIR2 technology can identify and eliminate these glare issues, which improves a driver's visibility and overall

road safety. This is vital because traffic accidents are still a major cause of fatalities worldwide. (European Commission, 2022)."

"In the vehicular industry, effectiveness of various advanced driver assistance systems has been studied (Masello, 2022). One of the technologies being used is Blind Spot Warning (BSW) system. A camera-based warning system uses a compact video camera mounted on the side or bottom of the sideview mirrors of the vehicles (Vision Zero, 2020). In this case, the VISIR2 can provide more reliable object detection than a conventional camera in low light condition because the adopted near infrared detector will not be affected by visible light level and the presence of fog in the environment, thus it will work well at night. The VISIR2 based BSW system will also have a faster response time compared to ultrasound based BSW system because a light wave travel faster than an ultrasound wave. It means the VISIR2 based BSW system can notify the driver sooner compared to ultrasound-based system."

Artificial Intelligence

"Image-based system has own weaknesses, and it slows the adoption of the technology. The combining the AI and image-based detection system could be a ground-breaking innovation if it works without errors. Many applications use image-based detection system but there are many variables involved. Identification becomes considerably more difficult when the scale of things to be identified increases. Shapes, colours, light, and background may all vary. This means that the possibility of error is inevitable. If errors are possible, you don't necessarily want to put the equipment into use."

Materials science and engineering

"The previously used in SWIR detector systems have many drawbacks, that VISIR2 will attempt to overcome. The case study itself mentions that detectors based on InGaAs and InSb technologies are incompatible by themselves with silicon-based semiconductor technologies. Thus, the integration technology needed balloons the price of these devices. Another type of sensor is based upon lead (Pb) which is well known for its harmful health effects (World Health Organisation, 2023). The ability to combine the positive aspects of each of the aforementioned technologies is a huge advancement with a new, novel solution is a credit to the amount of research being done into materials science."

Self-Driving and Autonomous Vehicles

"The use of VISIR2 will benefit hugely the self-driving sector of automotive industry. Self-driving cars rely fully on sensor input that the onboard computer digests, and based on this input makes the appropriate decision to control the car. These self-driving cars use a wide range of sensors to gather as much data of the traffic and road conditions as possible, but at the forefront are cameras, with algorithms that can detect traffic signs and lights. Self-driving cars of course have headlights as all other cars do too, but these are not nearly as bright as compared to daylight, nor are they invulnerable to failure. VISIR2 cameras, that can see both VIS and SWIR

can be of huge advantage in the automotive industry as they are much better equipped to "see" in both daylight and darkness. This is due to a phenomenon called Spectral Irradiance. Spectral Irradiance is caused by Airglow, which results in many times more intense electromagnetic radiation in the SWIR band as compared to visible light (Danny De Gaspari, 2012)."

"Autonomous driving and sensors in transport vehicles are on the rise. The sensors in the field are currently struggling with different weather conditions. Snow, dust and sun glare are major difficulties and blinding to current sensors. As SWIR spectrum deals with non-visible light, sun glare is not a problem. SWIR is also very effective in detecting objects behind fog or dust particles. This is direct result of scattering theory, where longer wavelength has less scattering than shorter. Because the sensor detects infrared light, at night-time mostly emitted by stars, the night vision capabilities are also excellent. With stronger computation and machine learning, in the future VISIR2 could help autonomous vehicles get more data from their surroundings and majorly increase safety (Medium, 2022)."

Power Consumption

"Reduction of system complexity by combining multiple vision systems into one and thereby reduction in total power consumption with reduced hardware need."

"In the automotive industry, the physical size and power consumption of the VISIR2 product are very critical technological features. To seamlessly integrate the VISIR2 into an automobile would require miniaturization and low-power design without affecting the system of the automobile. The compact form and compatible dimensions of the VISIR2 allow it to be perfectly integrated into an automobile. Since miniaturization is possible with advanced processes like etching and photolithography, therefore, VISIR2 can be incorporated into vehicles without compromising their design and functionality."

"The power draw of a sensor system can be an important consideration as systems that require more power can be significantly harder to engineer around and are less sustainable. In automotive applications specifically, a camera that draws a significant amount of power would reduce the range of an electric car or require a larger alternator in an internal combustion-based vehicle. This becomes more critical the more cameras are integrated into a single system. As self-driving cars can have dozens of cameras, power requirements must be considered (Davies, 2018)."

Quality Control and Sorting Technologies

"VISIR2 technology will improve quality control and sorting systems in agricultural and manufacturing industry. SWIR spectrum penetrates water poorly due to its longer wavelength than visible light. On the other hand, this gives SWIR advantage when it comes to some solid and semi-solid materials, as it can see through them (Edmund optics, 2023). These properties enable detection over rotten or bruised agricultural products, which will allow sorting them better separately thus reducing waste and improving quality.

Closed containers can also be scanned through to see the content levels for example."

"Combining Visible Spectrum and Short-Wave Infrared allows us to see things or objects that we can't see with eye. This kind of technology can be utilized in quality inspection, food detection, recycling, plastic sorting, and security. For example, in quality inspection you can possibly see underneath opaque plastic packaging, which can be used to make sure of the content. (Emberion 2023)."

Search & Rescue technologies

"The SWIR sensor can paint scenes illuminated by only Airglow, but it is important to note that anything that is warm, emits heat in the form of radiation, IR radiation. In general, the wavelength of light emitted by humans is of wavelength 1200nm (Lee, 2010). Essentially, this means that humans are "light sources" to this sensor. Using these VISIR2 sensors on drones allows the user of the drone to see people illuminated in the dark, useful for search-and-rescue missions. This is a positive influence on technological capabilities."

Solid State Imaging

"The principle of operation of the VISIR2 sensor is solid-state imaging, which is essentially using an array of phototransistors that when individually excited by photons output a signal which can be processed into images, or in real-time to live video."

"VISIR2 employs cutting-edge solid-state imaging technology. The case discusses the three basic types of solid-state imagers - photodiode arrays, charge injection devices, and charge-coupled devices. Solid-state imaging has come a long way since its inception, and it has revolutionized various industries, including automotive, surveillance, and healthcare. The use of Ge-on-Si back-to-back photodiodes in VISIR2 reflects the continual advancement of semiconductor technology, improving performance and reducing costs. This innovation allows for the coverage of both the visible and short-wave infrared spectral ranges with a single sensor, enhancing the capabilities of imaging systems in low-light and adverse conditions."

System Integration, Scalability and Cost

"Traditional VIS-SWIR imagers often utilize costly materials such as Indium Gallium Arsenide (InGaAs) and Lead Sulfide (PbS) quantum dots, limiting their application to specialized markets like defense and astronomy. These units can cost upwards of 10,000 euros each. In contrast, VISIR2 employs materials and manufacturing techniques from fully qualified CMOS pilot lines, commonly found in consumer microelectronics, to significantly reduce production costs."

"VISIR2 imager will be realized on a proper production line, using the same materials, processes, and methods that are commonly used in the production of consumer microelectronics. This will significantly aid in bring the down the cost of dual-band imagers. The efficient production of VISIR2 imagers will help to revolutionize the applications of dual-band

imagers. The range of applications is currently severely limited by the cost of these sensors. Quantum dots-based products like InGaAs and PbS already exist but the cost to consumer of a single sensor is well above 10k€ per device."

"Combining the two different sensors into one is a very cost-effective solution. Using only one sensor saves money in the fewer sensors needed itself as well as with less lenses and other components needed with the new technology. Currently one SWIR sensor is priced at 5000€ and up. Combining two sensors from different spectrums into one similarly priced is a huge advantage. The cost reduction means, that SWIR technology can be used in the future much more widely in different fields. (Frigerio et al., 2022)."

Technical Features

"The pixel size and resolution will add overall complexity to the imager since the wavelength of SWIR is longer than that of visible light. This can influence the optimal pixel sizes for the short-wave infrared band and require balancing of the resolution between the two different ranges. Optics compatibility faces the same issue since optics needs to be balanced for both VIS and SWIR ranges in order to minimize loss and distortion across the combined spectral range. The result of the optimization for these two considerations must not make the imager too large in order to enable for mobile applications or installation with limited space in consumer-level products. Considering the VISIR2 project's goal of having such imagers installed in cars to record both the road and the driver, the physical size must not be too large."

"While there are many different technologies that can detect SWIR light, many of them have important technological considerations. For example, the cooling requirements of the sensor system is very important. InSb sensors are a technology that can detect light from the range of 1 – 5.5µm (Infrared detectors, 2023) and some InSb based photodetector require extreme cooling with liquid-nitrogen based systems ("InSb photovoltaic detectors," no date). This is an important factor as the power and space requirements of the cooling system may be significant. There are other sensor technologies such as InGaAs ("InGaAs amplified photodetector with Thermoelectric Cooler," no date) and HgCdTe ("HgCdTe (MCT) amplified photodetectors," no date) that do not require as extreme of cooling. However, as with the InSb systems, they cannot detect SWIR and VIS light. This means that multiple cameras would be required. This also affects the power requirements of the sensor system."

Environmental Dimensions & Considerations

Energy Consumption

"The production and use of electronic devices in cars require a significant amount of energy, electronics of modern cars consume a significant part of the vehicle's energy. Further the constant technological updating and the lack of modular systems in the automotive industry requires constant manufacturing of new vehicles and new production and automation systems."

"Due to the possibility of miniaturization of the VISIR2 technology, less material is utilized during its manufacturing, so requiring less energy for its production. Many of the imaging devices that are available right now consume a lot of power during its manufacturing and during its use due to being less efficient. This high energy consumption contributes directly to global warming as well as greenhouse gas emissions. To help tackle this problem, energy efficient technology solutions are required which can help in reducing the energy usage and the carbon footprint. VISIR2 has a lot of emphasis on low power design, and it is not only important for its integration into various applications, but it also aligns well with environmental goals. By reducing the power consumption during its usage, it will also reduce the overall climate impact."

Global Warming, Environmental Hazards and Pollution

"The production and disposal of electronic devices in cars as well as the outdated cars require a vast industry ecosystem to support this practice, leading to a system which is bigger than necessary and further polluting air, water, and soil due to the problems of energy and resource needs."

"Like the other type of semiconductor's manufacturing, the fabrication process of silicon and germanium lead to substantial greenhouse gas emissions, primarily in the form of carbon dioxide. In 2021, the total carbon emissions for the semiconductor industry worldwide are estimated at 76.5 Mtons of CO2 equivalent, breaking down into 30.6 Mtons CO2 direct emissions and 45.9 Mtons of CO2 emissions induced by the energy consumption of manufacturing (Pelcat, 2023). Additionally, the mining and refining process contribute to air and water pollution, impacting local ecosystems and human health (Nature World News, 2023). In terms of resource availability in the nature, germanium is not as abundant as silicon. There are only about 1.5 ppm of elements in the Earth's crust (Wafer World, 2022), meanwhile silicon makes up 27.7% of the Earth's crust by mass and is the second most abundant element (Royal Society of Chemistry, 2023). Increase in demand of Ge-on-Si photodetector can lead to resource scarcity and potential supply chain issues. Higher demand with limited supply will also result in higher retail price"

Greener Construction

"Construction has a major environmental impact and very large renovations have to

be done due to water damage going unnoticed for a long time. VISIR2 allows scanning of buildings in case of water damage easily. The data received doubles with regular images from the dual sensors taken from the same spots as the SWIR images where water damage can be seen. This way moisture can be detected very early. SWIR is also abled to differentiate between different liquids such as oil and water, helping the troubleshooting."

Plastic Waste Management

"Every year 19-23 million tonnes of plastic waste leaks into aquatic ecosystems, polluting lakes, rivers, and seas (UN Environment Programme, 2023). Plastic waste is the world's common problem. They can disrupt ecological balance of our nature by reducing ecosystems' ability to adapt to climate change, directly affecting millions of people's livelihoods, food production capabilities and social well-being. The VISIR2's SWIR vision would have immensely positive impact on mitigation towards abundant plastic waste in the nature. For example, installing a SWIR detector on UAV offers low-cost platform for plastic waste detection in the shoreline (Cocking, 2022). The example proves the usability of VISIR2's SWIR imagery in plastic waste detection and can be further implemented in various automation system, such as automatic sorting plastic item machine in the recycling centre and automatic plastic waste picking robot."

"VISIR2's ability to differentiate between various types of plastics through imaging presents an innovative application with significant environmental implications. Given the escalating global challenge of plastic waste management, effective sorting mechanisms are crucial for streamlining recycling processes. Utilizing its state-of-the-art technology, VISIR2 has the potential to transform waste management by facilitating more accurate and automated sorting of plastics. This capability could prove particularly advantageous for recycling systems, as it would enable the conversion of waste into valuable resources."

"There are many environmental possibilities with image-based detection system. The VISIR2 prototype can be used to showcase a potential use case and effectiveness in automatically identifying plastic waste in natural environments. Even if this is not the final use of the prototype, it opens a lot of new possibilities. This detection system could be used in many recycling operations and machines. The plastic waste might be a big problem in the future because we don't know how microplastics will affect environment and humans."

"SWIR technology is a big part of waste sorting systems. Paired with visible light imaging, sensors could detect and sort waste even better. Recycling materials more efficiently is critical for sustainability. SWIR technology is most critical in the detection of textiles as well as differentiating between different plastics. From the waste conveyor, VISIR2 sensors can use shape-based sorting with visible light scanning and in problematic situations switch to SWIR scanning to increase successful sorting. (Lynred. 2021)."

"Another application of this technology, with a great environmental impact, is in cleaning up natural environments from plastic waste. By combining the

information from visible and infrared imagers, machines could better distinguish plastic waste from natural materials. This facilitates more effective and efficient plastic clean up in natural environments. This would facilitate a positive impact on the environment."

"VISIR2's ability to automatically identify plastic waste in natural environments is another key environmental consideration. Plastic pollution is a major environmental concern due to its long-lasting impact on ecosystems and wildlife. The technology's potential to autonomously detect plastics underscores its significance in addressing environmental issues. By facilitating the automated collection and management of plastic waste, VISIR2 contributes to reducing pollutant emissions, promoting sustainability, and helping transform waste into a resource. This aligns with the global imperative to tackle plastic pollution and minimize its ecological footprint (ATTRACT, 2021)."

"Another important environmental consideration that is being influenced by the VISOR2 case is the challenge of plastic pollution. The ecosystem nowadays is full of plastics, especially the ocean water contains large amount of micro plastics. These micro plastics are not only harmful for humans, but they are especially harmful to sea creatures. The reason plastics are harmful is because they are not biodegradable and when they are ingested by fish, these micro plastics get stuck in the gills of fill and are largely responsible for its death. According to an article(a) that is published in PLOS ONE, in 2023 over 170 trillion plastic particles were floating in the ocean. With the use of VISIR2, we can detect and sort plastics and by utilizing this technology in robots, we can enable the robot to automatically collect the waste. This waste can then be utilized in the recycling industry promoting a sustainable economy while reducing pollutant emissions."

Raw Materials

"Modern car materials and electronics need a multitude of raw materials which inadequately recycled if discarded and never reused, dismantling practices do not account for alloys and trace materials which leads to weak recycle-ability, trace materials as well as pure raw materials must be added to recycling waste to sustain material quality. Only 19% of plastics from end-of-life vehicles are recycled in Europe, while most metals, composite materials and electronics are not recycled."

"The long-term ecological implications of VISIR2 are also noteworthy. Particularly in the automotive sector, the device holds the potential to improve road safety significantly. Fewer road accidents would likely translate to a reduction in environmental hazards, such as oil spills and wreckage. However, as VISIR2 technology gains broader adoption across multiple sectors, it will be crucial to monitor any unforeseen environmental impacts."

Responsible material choices

"The development of these technologies that can image infrared light are heavily affected by environmental factors. As mentioned above, the negative effects due to lead exposure are well documented.

Thus, with some of the sensors not compatible with silicon, and the lead-based sensors liable to cause health issues, there is a huge environmental drive to find a solution to the challenge of a silicon-compatible non-lead based infrared imaging sensor."

"The drawback now is the use of lead-based material, which is not compatible with many certifications. Lead based material is also not good for the environment, neither during fabrication, nor as a waste. The production and use of lead-based products have contributed to environmental pollution. Lead is a persistent environmental contaminant, and its presence in soil, water, and air can have detrimental effects on ecosystems (World Health Organization 2023). Even if no harmful substances are used in the products, many electronic components contain materials which mining and processing cause a large impact on environment, like cobalt or lithium. When the need for equipment increases, more materials are also needed. The effects may not be visible in our own environment, but the mining of many metals causes great destruction in Africa and Asia (Murray, 2022)."

"Most imaging technologies that are available nowadays are utilizing lead, which is a heavy metal and has very harmful effects. If this lead is leached into the environment, it causes loss in biodiversity, decreased growth in plants and neurological affects in vertebrates (d). The disposal and recycling of imaging components in older technologies can pose serious environmental challenges. Due to this reason, technological advancements in the imaging field have been sped up which has led to the development of VISIR2 technology. This technology is based on Ge-On-Si based photodiodes and is free from lead and therefore can be disposed of easily."

"The manufacturing processes and materials involved with the manufacturing of any product is an important factor to consider carefully. Many materials are either inherently harmful to people or the environment. For other materials, their mining, purifying, or manufacturing process is harmful or produces harmful byproducts. Additionally, some materials take large amounts of energy or water to produce which has its own harmful effect on the environment. A good example of a harmful material to use is lead which is a heavy metal that can be extremely toxic to both animals and plant (Sandru, 2020). Lead has been shown to be harmful to animals in the environment since the 1800s although this was generally in reference to lead shot as the form of environmental exposure ("Lead contamination in wildlife," no date). The harm posed by lead is an important factor to consider when producing a product that contains lead as it increases the risk or lead finding its way into the environment as well as increasing the need for mining and processing lead. Some sensor technologies used for infrared imaging systems use lead as a component of the sensing chemical. Two examples of this are InSb and PbS2 sensors. HgCdTe based sensors are also a technology that one must consider using carefully as, while they do not contain lead, they do contain cadmium which is a chemical that the WHO stated is a major public health concern (Satarug et al., 2020). These health concerns highlight the importance of technology such as VISIR2 that can replace existing technology in a higher performance and yet more environmentally friendly manner. In summary, it is important to consider the

chemicals used in the products that are engineered as some chemicals are harmful to the environment for humans and wildlife. Using these chemicals can have many harmful side effects that one may not immediately consider. For example, the mining or refining process may leave behind toxic waste."

Wildfire Detection

"One of the critical technological aspects discussed in the case is the use of VISIR2 technology for early wildfire detection. This technology is directly influenced by the need for improved wildfire management and prevention. Large-scale and more severe wildfires have become a growing concern worldwide, impacting human lives, property, and the environment. VISIR2's differential imaging capabilities, coupled with the ability to eliminate sunlight interference, provide a technological solution to detect wildfires promptly. This aligns with the global shift towards using advanced technologies to address environmental and safety challenges."

"The other area that VISIR2 can have positive contribution is in early wildfire detection system. Several advanced techniques were proposed over the years to help official authorities and first responders in identifying wildfires at their early stages and allocate the right resources to extinguish them. In this field, one of the most popular advanced technologies is utilising an Unmanned Aerial Vehicles (UAV) to collect visual data from the inspected region complemented with image processing technique (Bouguettaya, 2021). What is lacking with UAV based system is that the system is not designed for continuous 24/7 monitoring. Meanwhile, the VISIR2 can be installed in various potential locations that will warn the authorities if there is an indication of wildfire at any time. The shortwave infrared detector of VISIR2 can detect the flame and its visible light detector can be used to eliminate false alarm in real time. In early wildfire detection system, it can reliably detect flame earlier than UAV based system due to its 24-hour-monitoring capability."

"Wildfires, in 2021, accounted for 1.76 billion tonnes of carbon. This is more than Germany's annual CO2 emissions (Abnett, 2021). Thus, as all countries strive towards carbon neutrality, natural phenomena such as wildfires cannot be directly controlled, and as the effects of climate change increase nearly year-on-year, these wildfires are turbocharged by the drier and hotter and are only more likely to further spiral out of control. The challenge with wildfires is the sheer size of the area on fire, and the amount of fuel (forests, trees, dried-out vegetation) on fire. Purely to contain the fires, and not even speaking about extinguishing, is a massive task due to the logistics of how much water is needed for these massive infernos. These wildfires are only detected when they spiral out of control as they happen in rural aread´s. Thus, the use of VISIR2 infrared imaging can help in early detection of these widlfires, especially in the early stages when it is much easier to extinguish the fire. Thus, the carbon emissions caused by wildfires can be drastically reduced by using VISIR2 to monitor forests, for example on drones that do scheduled flyovers in high-risk areas."

"Wildfire detection would require the imager to be installed at a height where it would be able to record a large area in a

high-risk region, which would expose it to the effects of the wildfire itself. Considering this, three environmental considerations could be temperature fluctuations, chemical exposure and vibration & mechanical shock. Wildfires generate heat and toxic fumes, exposing the imager to both temperature fluctuations and chemical exposure. If installed on a drone for example, the imager might be required to operate at high humidity and colder temperatures."

"Wildfires contribute significantly to climate change. They cause up to 20% of annual global greenhouse gas emissions (Navin Singh Khadka, 2018). The VISIR2 imagers can detect wildfires by combining information from visible and infrared light images. A network of cost-effective VISIR2 sensors could be deployed in high-risk regions to detect wild fires early, when they are much easier to put out."

"As this technology can help with a huge problem that is wildfires, it would already be beneficial to the environment, as wildfire smoke releases numerous pollutants such as nitrogen dioxide, ozone, aromatic hydrocarbons, and large amount of greenhouse gases into the atmosphere. (WHO 2023.) These pollutants and gases are dangerous and cause a lot of damage for the environment. This technology can make a real difference in protecting people and the environment. It is crucial because smoke can spread over a wide area, impacting people's health and air quality. VISIR2 can help pinpoint the location of the smoke plumes and track their movement, assisting authorities in alerting the public and making necessary evacuation decisions."

"Wildfires pose significant environmental challenges, contributing to soil degradation, water scarcity, loss of biodiversity, and greenhouse gas emissions. VISIR2's early detection capabilities can help minimize the environmental consequences of wildfires by enabling faster response times and more effective firefighting. This highlights how technology can play a pivotal role in addressing environmental challenges, offering innovative solutions to mitigate the ecological impact of wildfires (ATTRACT, 2021)."

Legal Dimensions & Considerations

Copyright, Patent Law, and Export Control

"Patents are very crucial for protecting the innovations and technologies developed by someone. One of the most important legal considerations in the VISIR2 project is the protection of intellectual property rights. The technology involved in the VISIR2, especially the use of dual-imaging and AI integration, may be subjected to intellectual property protection. The development of the project and its commercialization can be severely affected by the ownership of these rights. To prevent others from using one's product unlawfully, patents provide legal cover. By protecting the rights of the person who has invented the technology, this can foster positive feelings among the innovators that their rights are protected and any future innovation that they do will be safeguarded. This incentive provided by patents fosters innovation and has also contributed to the development of the VISIR2 technology."

"With the development of a novel imaging system, intellectual property rights such as patents become a key legal consideration. Proper patent filing would protect the technology from unauthorized replication and usage, giving the project a competitive edge in the market. However, this also brings the responsibility of ensuring that VISIR2 does not infringe upon existing patents, to avoid legal disputes that could derail the project."

"While designed for civilian applications such as waste sorting and environmental monitoring, the technology's night vision and IR capabilities have obvious benefits for defense and military industries. This overlap introduces legal complexities related to export controls, especially given international treaties on arms regulation. Both the VISIR2 project and policymakers must consider how to govern the technology's dual use to prevent it from falling into the wrong hands or being used in conflict zones in violation of international laws."

"As the VISIR2 technology is innovative, legal considerations regarding intellectual property rights come into play. Protecting the intellectual property, including patents, trademarks, and copyrights, is essential to secure ownership and prevent unauthorized use or replication of the technology. Legal mechanisms and agreements, such as patents, can safeguard the project's innovations, ensuring that the consortium and its partners have exclusive rights to their developments."

Democratization of Night Vision and IR Imaging

"The democratization of night vision and IR imaging capabilities, made possible by the affordability of VISIR2, has immense implications for personal privacy. As the technology becomes increasingly accessible to the public, it raises concerns about unauthorized surveillance and invasion of privacy. Legal frameworks

would need to be established to regulate the use of such technologies, particularly in public spaces, to prevent misuse and safeguard individual rights."

Evolving Automotive Legislation and Regulations

"The introduction of VISIR2 technology will affect the legislative and regulatory processes. When market-disruptive products are launched, they often have drastic effects on legislations and regulation. Consider the introduction of rentable e-scooters to Finland. On launch, there were no restrictions, but as time has passed there are now restrictions such as driving at night or under the influence of alcohol (Pohjanen, 2021). Furthermore, some cities have restricted the use of these e-scooters by physical location, for example allowing parking in only certain areas determined by local government (Voi Technology, no date). Thus, if we consider the case of VISIR2 being used in self-driving cars as a main camera capable of high-quality video input to the car, and at night through its "night-vision" ability, it may be the case that this will push the relevant authorities to set regulation that this is required hardware on self-driving cars. Vibro-Meter was a Swiss company founded in 1952 that made vibration sensors for aero engines. They launched their staple product, which had huge demand, but also pushed regulators to require new aero engines to have vibration sensors as safety devices fitted. This is yet another example of innovation driving legislation."

"Self-driving cars have been designed for a long time but there has been a lot of challenges with the detection systems. Now, only various "assistants" are used but complete self-control has not been achieved. It is possible to achieve a certain level of self-driving, but the manufacturer does not want to take the risk of an accident due to the detection program. Product liability refers to the legal responsibility of manufacturers and suppliers for injuries caused by their products. When it comes to self-driving cars, the traditional concept of product liability becomes more intricate due to the evolving nature of these vehicles. Self-driving cars have been illegal on the road for a long time, and only recently has the EU begun to consider legislative changes to allow automated vehicles. The lack of legislation has slowed down the adoption of the technology (European parliament 2019)."

"Implementation of this technology in vehicular industry may be impacted negatively by export restrictions rule regulated by International Traffic in Arms Regulation (ITAR) which states "Thermal imaging cameras described in ECCN 6A003.b.4.b that have a frame rate greater than 60 Hz or that incorporate a focal plane array with more than 111,000 elements or that are being exported or reexported to be embedded in a civil product continue to be subject to NS column 2, RS column 1, AT column 1 and UN reasons for control. These cameras generally will continue to require license based on CCL license requirements for all destinations other than Canada" (eCFR, 2023)."

"One example of a way in which VISIR2 technology could affect laws and regulations is their impact on vehicle safety system regulations. Due to technology integrating SWIR and VIS light detection capabilities being superior to a single band system regulations could be adapted to

require a combination of these technologies or similarly performing systems. For example, regulators could require that systems monitoring driver focus work if the driver is wearing dark sunglasses. As SWIR technology can "see" through sunglasses, integration of this wavelength band may be mandatory. As soon as this technology has been proven and is not restricted to highly expensive laboratory equipment, it could force regulators to adopt it as a mandatory safety feature. This is especially true because, as stated in the case brief, driver fatigue is a major cause of accidents. Additionally, the ability of these systems to work in poor weather conditions may contribute to the pressure on regulators to make the technology mandatory for self-driving and driver safety systems. This could be similar to seatbelts where the safety benefits they offer forced regulators to make them compulsory."

Impact of New or Changing Legislation

"There was a change to The National Fire Protection Association (NFPA) NFPA 70B, that is a set of guidelines for creating an effective electrical preventive maintenance (EPM) program commonly used in industrial plants, commercial buildings, and large residential complexes. The big change for thermography, is that NFPA 70B 2023 has recognized that thermography is now mandatory and mission-critical to an effective EPM (Flir, 2023). The new regulation will potentially increase the demand of utilisation of infrared imaging device and create opportunity for VISIR2 to be implemented in industrial maintenance program."

"Restriction set by the FDA on the utilization of industrial infrared imaging device in the medical field, for example human body screening, will negatively impact the potential of VISIR2 implementation in this application (FDA, 2021). The restriction was established in the pandemic era where plenty of industrial thermal camera being used to evaluate people's health condition related to COVID-19. It was found that industrial camera could not be used to accurately measure human's body temperature due to several factors which includes porous skin surface, environment temperature, and its typical accuracy of ±2 °C or 2% (whichever greater)."

Privacy

"Finally, there is a concern for privacy laws concerning this case. This allows for powerful video recording in extremely low-light scenes, which allows the abuse of this technology to film people in private settings or without their consent. This raises concern for the legislative branch of government that are the laws regarding privacy and filming up to scratch, as this new technology unravels a new domain of filming."

"An imager, being able to record and analyse detailed imagery, could store data about consumers and people going about their business. This data must not be used for purposes other than the development of the imager's intended usage to respect the privacy of consumers and other people that might be captured in the imager's recordings."

"Privacy is a large concern for many consumers especially when it comes to

electronics that are capable of visual scanning. The VISIR2 is under consideration to use for drivers monitoring. Face scanning with both SWIR and visible spectrum allows better data on how capable the person driving currently is. SWIR allows for example eye-tracking through sunglasses. The problem with scanning people with equipment that can penetrate material has been a topic before. A cell phone camera was able to scan people through clothes using infrared imaging (Moncton, 2020). This led to huge backlash as well as misuse of the feature. Pointing VISIR2 type sensors to people leaves the connected systems under threat to say the least."

"With the advent of technologies like VISIR2, which enable eye tracking through sunglasses and other devices, a host of privacy concerns emerge. The use of dual-band sensors among other new technologies raises questions about the extent to which this technology can or should be used for surveillance purposes. As eye tracking technology becomes more, it becomes increasingly important to consider the potential legal implications. Specifically, issues related to user consent and the boundaries of surveillance need to be addressed. Regulations must strike a balance between enabling innovation and protecting individuals privacy rights."

"Data integrity is also crucial when large amounts of data is collected. Data privacy regulations must be followed correctly to ensure data integrity. Cybersecurity is also very important in these kinds of cutting-edge solutions. Trust between users and stakeholders is important and it enforces its legal and ethical foundations in the evolving digital landscape."

"There are many data privacy and security concerns regarding the use of AI in various products. Because, different machine learning models used for predictions require data on which they are trained. The data that is obtained for training the machine learning model must not breach the privacy and security of people. For training the models in various applications like automotive safety and surveillance data is collected which is then later fed into a machine learning model for making predictions. This process must adhere to the various international as well as local legal privacy considerations and regulations. The VISIR2 technology development is greatly affected by this aspect of protecting privacy and various data privacy regulations like the European General Data Protection laws influence how the VISIR2 technology collects, processes, and stores data, to ensure that the privacy rights of individuals are not violated. So, in short, the data privacy and security legislations and concerns also influence the innovation of new products, processes and technologies."

"While new imaging technology may affect regulations in the realm of automotive safety systems, it will most likely be affected greatly by privacy and surveillance laws. As the prevalence of camera technology such as VISIR2 based systems becomes more common and perhaps even mandatory on vehicles, the regulations on the privacy and imaging of the public and users of the technology becomes more relevant. In the United States, the National Highway Traffic Safety Administration has already began discussing privacy concerns and regulations with a variety of stakeholders to ensure consumers rights are protected ("Vehicle Data Privacy," no date). This is an important factor to consider as manufacturers of camera

systems must prove to regulators and consumers that the data collected is secure and will not be used to violate the rights or privacy of the public. This issue becomes especially complicated as every country has its own unique regulations. So, the exact specifics of the measures taken may need to depend on the country in which the system is manufactured or sold."

Regulating Harmful or Dangerous Materials

"As there are SWIR sensors based on lead today, it is possible that the developers of SWIR have experimented with lead in the concept phase. However, due to a combination of technical factors such as the slow processing speed of lead-based sensing and legal factors surrounding lead use the developers have tried and succeeded in finding other materials to use. This is a positive impact by legislation."

"The negative effects of lead-based products have led to complex legal and regulatory challenges (World Health Organization 2023). Governments around the world have implemented strict regulations to limit the use of lead-based products, particularly in consumer goods. Compliance with these regulations can be costly and challenging."

"Lead-based materials in the existing products do not ensure compliance with regulations and certifications. VISIR2 has no lead-based materials so it ensures compliance and has better acceptance in the market. VISIR2 can be considered as a safe and sustainable technology."

"Environmental regulations are another important consideration that can greatly vary from country to country or region to region. The regulations on heavy metals are relevant examples of this. Due to the dangers discussed in the environmental concerns section of this report, heavy metals such as lead are regulated in many countries. In fact, the EU has implemented many regulations on the use of hazardous materials such as lead and cadmium in electrical products, such as the RoHS Directive which restricts the use of these chemicals in some cases ("RoHS directive," no date). As outlined in the RoHS Directive page, the directive also promotes recycling of these materials which is, as previously stated, an important environmental consideration. Regulations such as this mean that the fact that VISIR2 technology does not use these hazardous materials is an ever-important distinction. Regulations that restrict hazardous materials such as the RoHS Directive make space for new technology that is more environmentally friendly to take hold."

Responsibility and Liability

"As present wildfires are a reoccurring problem. It is predicted that the number of wildfires is only going to increase and by the year 2050 it will be a third more than now. (Kshitij & Saheel 2023.) That is why utilizing technology that could help to predict or notice the beginning of a wildfire straightaway is more than important. However, when using technology like VISIR2 for early forest fire detection, questions about who's responsible come up. If VISIR2 doesn't detect a fire or causes harm, there could be legal issues. So, it's important for the VISIR2 project and its partners to clarify

who is responsible and consider getting insurance to protect themselves from any legal claims."

"The case mentions VISIR2's potential application in the automotive industry, specifically in enhancing nighttime driving and fatigue detection. Legal considerations in the automotive sector are critical. Manufacturers must ensure that technologies comply with liability laws and safety standards. Legal frameworks often govern liability in the event of accidents or failures, and technology must meet specific safety standards to be deployed in vehicles. Complying with such legal requirements is essential to minimize legal risks and ensure consumer safety".

Safety During Use

"In Europe to be able to enter the market, the product must fill all the EN standards linked to it. Infrared light is invisible light and therefore it doesn't trigger human defence mechanisms especially in our eyes. Direct, strong enough exposure of human eye to SWIR spectrum may lead to permanent blindness. Therefore, all products labelled under the laser category, must fill the requirements set by EN 60825 standard. SWIR technology falls under laser class 1 in the standard, which means that the allowed power for the laser is 1 mW in the shorter wavelength end and 10 mW in the longer. (EN 60825.) There is work to be done to fulfil these requirements and no clear line is set how the legislation goes for sensors with dual purposes. Before VISIR2 can be sold commercially, these problems must be addressed."

"At first, cars didn't have seatbelts. Then seatbelts were introduced in certain models. Now seatbelts and their use are mandated by law. Seatbelts are just one example of a sequence of events where a technology first becomes ubiquitous and is later mandated by law. This could happen to VISIR2 powered driver fatigue/ drowsiness detection systems if they become common place and are found to reduce accidents on the road. A similar case, as described above, could be made for mandating night vision systems for passenger cars. One could argue that this is a positive development that will improve everyone's safety, but we must always be careful not to unnecessarily infringe on anyone's rights when making new legislation."

"If VISIR2 will be applied in the automotive industry, it is crucial to acknowledge the legal factors. For example, in Portugal or Switzerland it is completely illegal to use a dash cam (Cobra 2023). Therefore, usage of VISIR2 will need an approval of the government. Many countries also have limitations about camera and monitor placements and therefore it can't be placed anywhere where it can harm driver's visibility (Viatech, 2020)."

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