Remote Sensing Applications: Society and Environment 24 (2021) 100641

Contents lists available at ScienceDirect

Remote Sensing Applications: Society and Environment

journal homepage: www.elsevier.com/locate/rsase

FERN.Lab: Bridging the gap between remote sensing academic research and society

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ARTICLE INFO

Keywords:
Education
Remote sensing
Technology transfer
Academic intermediary

ABSTRACT

Technology transfer (TT) between academia and industry is an important source of innovation and economic development and is becoming increasingly relevant across a diversity of research fields. Successful TT depends on effective communication between academic and external partners. This is best facilitated by an academic intermediary who can provide meaningful interactions. An academic intermediary can ensure expertise and knowledge are communicated using a common language and that goals and expectations are clear between partners. In the field of remote sensing where complex technologies, datasets and analyses are required to develop user friendly products, intermediaries play a particularly essential role. The rapid expansion of the remote sensing sector over the last decade, including sensor technologies and the volume of freely available data, has created a bottleneck between available data and technology and ready to use products. In an effort to address this bottleneck and establish a long-term innovation platform and thematic TT infrastructure, FERN.Lab, Remote Sensing for Sustainable Use of Resources Helmholtz Innovation Lab was founded at the Geodesy Department of the German Centre for Geosciences (GFZ) in January 2020. FERN.Lab is funded by the Helmholtz Association, the largest scientific organization in Germany. The goal of FERN.Lab is to facilitate TT and deliver remote sensing products to commercial and non-commercial partners by acting as an expert intermediary platform. FERN.Lab will improve the TT activities of GFZ from two distinct approaches. The first is a "pull" approach where tailor-made technologies are developed for and funded by external third parties. The second is a "push" approach where existing departmental technologies with high market potential are promoted. The pull and push of technologies to external partners is accomplished by a set of competencies and services delivered by the core FERN.Lab team. Competencies include business development, scientific development, software development, and public relations which directly address institutional, financial and skills gap that can cause the TT process to fail. By implementing a robust TT framework for remote sensing products, the impact of research has the potential to be much broader and farther reaching. Additionally, these efforts can improve the acceptance of remote sensing outside of academia improving and modernizing methods used in diverse sectors which in turn can benefit not only individual partners but also politics, society, and the environment. As application-oriented innovation platform, with a close interaction with partners and customers, FERN.Lab will be a crucial part of modern TT at GFZ.

1. Introduction

1.1. Knowledge and technology transfer

Knowledge and technology transfer (hereafter referred to as KTT) between academia and society has long been recognized as a key driver of innovation and economic development (Bercovitz and Feldman, 2006; Mowery and Shane, 2002). Knowledge transfer (KT) is defined by Bloedon and Stokes (1994) "as the process by which knowledge concerning the making or doing of useful things contained within one organized setting is brought into use within another organizational context". Similarly, technology transfer (TT) can be defined as the movement of a specific technology from one place to another (Bessant and Rush, 1995).

KTT in academia has greatly diversified over time to include fields

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https://doi.org/10.1016/j.rsase.2021.100641
Received 3 May 2021; Received in revised form 31 August 2021; Accepted 27 September 2021
Available online 30 September 2021

Acronyms

ARD	analysis ready data
BD	Business Development
DaaS	Data as a Service
DIAS	Data and Information Access Services
FAIR	Findable, Accessible, Interoperable and Reusable
FERN.Lab	Remote Sensing for Sustainable Use of Resources Helmholtz Innovation Lab
EO	Earth Observation
ESA	European Space Agency
GFZ	German Centre for Geosciences
HaSa	Habitat Sampler
HIL	Helmholtz Innovation Lab
IP	Intellectual Property
IT	Information Technology
KTO	Knowledge and Technology Transfer Office
KTT	Knowledge and Technology Transfer
MiSa.C:	Minimal Sampler Classifier
NASA	National Aeronautics and Space Administration
LST	land surface temperature
NGO	Non-Governmental Organization
PPP	Public-private partnerships
R&D	Research and Development
PR	Public Relations
RS	Remote Sensing
SaaS	Software as a Service
SciD	Scientific Development
SD	Software Development
SME	Small Medium Enterprise
TT	Technology Transfer
UAV	Unmanned Aerial Vehicle

not traditionally associated with industry or private sector partnerships and in some cases has become a standalone research field (Good et al., 2019; Jofre, 2017). The past decades have seen a push to implement KTT into long-term academic infrastructure in order to overcome what is colloquially known in the innovation process as the Valley of Death (Grimaldi et al., 2011; Muscio, 2010). The Valley of Death refers to when "a technology … fails to reach the market because of an inability to advance the technologies demonstration phase through commercialization phase" (Frank et al., 1996, Fig. 1). The reasons for this are due to institutional, financial and skills gap which create a missing link in the transition of an emerging or existing technology to a market-driven business (Barr et al., 2014). Another way the Valley of Death can be understood is through Technical Readiness Level (TRL), a universal scale used to characterize the maturity level of a technology from discovery and feasibility through development and testing and finally to integration into the user's world.

The vast majority of research in academic institutions is geared towards discovery and feasibility which can include both fundamental and applied research. Entrepreneurship is often not relevant in the case of fundamental research or not seriously considered in the case of applied research reducing opportunities to develop scientific research and technology into commercial ventures (Barr et al., 2014; Kirzner, 1997). However, in the case of applied research this is changing. In the past 10 years there has been a push across publicly funded research institutes in Germany. For example, the 60-million-Euro Helmholtz Validation Fund of the Helmholtz Centres was established in 2011 (Helmholtz Association, 2020)[1] and in 2019 the European Investment Fund and Fraunhofer Institutes established the 60-million-Euro Technology Transfer Fund (European Commission, 2019). Both funds aim to commercialize applied research from large research institutes in Germany and Europe.

From a practical perspective, limitations to successful KTT of applied research between academia to other sectors can generally be explained by two specific barriers of cognitive differences and different goals (de Wit-de Vries et al., 2019). These barriers can be more generally understood as first, a lack of expertise and knowledge by the non-academic partner and second, poor communication between the two parties leading to different expectations, goals and desired outcomes. Research shows that these barriers can be adequately addressed with the use of an intermediary who provides direct and meaningful interactions between academic and non-academic partners (de Wit-de Vries et al., 2019). In other words, communication can be improved, and confusion reduced when a common language is established between all parties. In fields where complex technologies, datasets, and analyses are central to research, such as remote sensing (RS; defined here as information about the Earth's litho-, atmo-, hydro-, and biosphere gathered by spaceborne, airborne and ground-based remote sensing systems), intermediaries who have sector-specific knowledge play an essential role in effective KTT.

1.2. Technology transfer for remote sensing

The availability of RS data and technology has increased dramatically in the last decade driven by a diversification of industry players as well as new initiatives by traditional providers, namely national governments and public institutions (Denis et al., 2017). This increase in availability has been driven by rapid advancements in sensor technologies across all spatial scales but particularly Unmanned Aerial Vehicles (UAVs) and small, low-cost satellite constellations such as CubeSat. In addition to the technological advances, there has been an explosion of freely available and commercial satellite imagery, concurrent with improved quality and resolution (Fig. 2).

These advancements have been accompanied by investments from large multinational technology companies bringing rapid change to the RS landscape. In concert with recent technological advances, cloud services, data handling, and server capacity have increased exponentially with the entrance of the commercial providers Google and Amazon into the market as well as the establishment of European initiatives such as the Copernicus Data and Information Access Services (DIAS). Much of the RS research in the European Union relies heavily on publicly funded research clusters and public-private partnerships (PPP) to drive innovation. These research clusters in turn foster the development of small companies, spin-offs, and start-ups who bring RS products and applications to the market further driving the commercial potential of RS which is estimated to be worth 21.6 billion USD by 2022 (Denis et al. (2017); www.marketandmarket.com).

The rapid expansion and innovation of the remote sensing sector has created a bottleneck between available data and technology and "ready-to-use", scalable products. This is particularly true for applications outside of academia. Regional and municipal government agencies, small-medium enterprises (SMEs), and Non-Governmental Organizations (NGOs) who would greatly benefit from remote sensing data often lack expertise and capacity to produce or access high quality products and technologies (Onoda and Young, 2017). Additionally, large private sector companies with expertise in internal Research and Development (R&D) departments who operate on profit-driven strategies may limit investment in new untested RS solutions. Academic institutions are well positioned to act as intermediaries and address this bottleneck through the implementation of robust KTT strategies to help meet regional, national and international demand for high quality RS data and

[1] https://www.helmholtz.de/en/transfer/technology-transfer/innovation-and-funding-programms/helmholtz-validation-funds/.

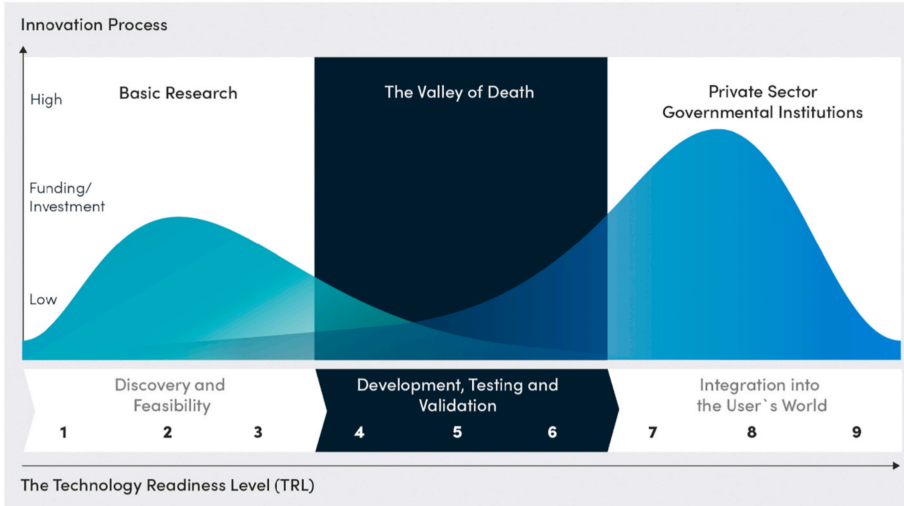

Fig. 1. The gap in funding and skills colloquially known as the "Valley of Death" refers to when technology fails to make it to market due to a lack of funding. Credit: GOA (Persons, 2014).

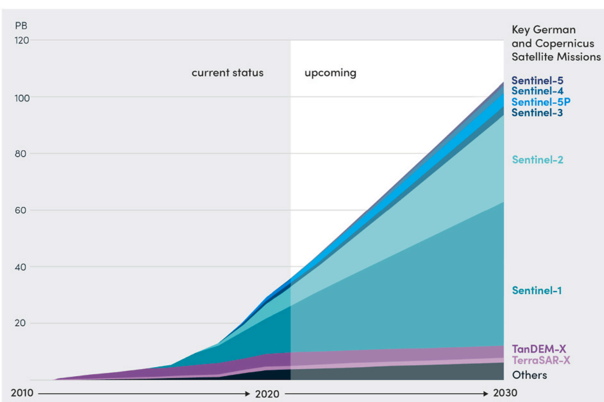

Fig. 2. The amount of available satellite data in petabytes (PB) from the last decade and the upcoming increase in the next decade of select German and European satellites. Source: Earth Observation Centre, DLR.

technology.

1.3. Overview of KTT activities in remote sensing

There has been a recent acknowledgement by large space agencies and private companies that KTT of scientific developments to real world applications is lacking. Key stakeholders are addressing this topic in different ways. For example, in the US NASA has established a Technology Transfer Program which aims to license developments for external use. This can be done for patents, issued patents or software by spin-offs or publicity. NASA's KTT program follows a clear scheme of 1. Find, 2. Apply, 3. Set Terms, 4. Sign, 5. License Use. Currently, software from NASA's KTT program covers 832 programs.[2] In comparison to the license driven approach of NASA, the European Space Agency (ESA) approaches Technology Transfer as a business incubator to support business ideas based on RS method developments. ESA's KTT program covers different sub-programmes including the Business Applications program which supports the development of sustainable services that use space assets. The Business Application program offers expert support to entrepreneurs and three funding opportunities: 1. Kick start, 2. Feasibility studies and 3. Demonstration projects. In 2003, ESA established regional Business Incubation Centres to inspire and work with entrepreneurs to turn space-connected business ideas into commercial start-ups companies. Over 700 start-ups have been founded since 2003. These initiatives are supported by ESA technology brokers who support business development basics such as market studies and product development services as well as the commercialization of space and RS technologies. An additional European initiative is the Copernicus Masters, a global innovation competition at the forefront of Earth observation (EO) data utilization. It awards funding to innovators fostering new solutions and concepts that showcase the benefits of the European Copernicus services to everyday life.[3]

In addition to continental space agencies, large national research institutes in Germany such as Fraunhofer, Helmholtz and Leibnitz have recently focused on the importance of KTT and its increasing relevance in publicly funded research. Each of the major German research centres have established KTT units to encourage and support this process. KTT units mainly work at the interface between science and economy, research and application and science and administration. The spectrum of support ranges from Intellectual Property (IP) consulting and licensing to spin-off support and is often embedded at the institutional level.

Examples of highly successful EO/remote sensing spin-offs from public institutions in Germany:

- *Drift&Noise* from the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research. A company assisting diverse stakeholders operating in polar waters by providing ice conditions and forecasting from models and satellites.[4]
- *Earth Observation Services Jena* from the University of Jena. EOS Jena is a pioneer in the operational use of active microwave remote sensing data for mapping biomass and other forest related parameters, important for a sustainable forest resource management.[5]
- *EOMAP*, from the German Space Agency (DLR) in Oberpfaffenhofen. EOMAP is now a world leader in EO hydrology and aquatic applications.[6]

[2] https://software.nasa.gov/.

[3] https://copernicus-masters.com/.

[4] https://driftnoise.com/.

[5] https://www.eos-jena.com.

[6] https://www.eomap.com/.

- *HelioPAS AI Analytics* from the Karlsruhe Institute of Technology. HelioPAS developed an app called Waterfox which helps farmers and agricultural suppliers deal with drought and irrigation.[7]

In parallel to research institute-driven efforts, private companies such as Airbus DS, OH, VISTA, Remote Sensing Solutions or EFTAS are also filling the gap between scientific development and application by acting as RS service providers and/or offering consulting, training or testing of hardware.

The KTT initiatives outlined above appear to cover a broad range of KTT work but upon closer examination, all of these initiatives focus on profit-based operation predominantly by licensing developments and products or the creation of spin-offs. The authors of this paper regard these efforts as not comprehensive enough, as the following aspects are not considered:

1. Missing benefit for scientists. Current KTT frameworks are often viewed as mutually exclusive or as direct competition for resources and reputation with scientific work. This results in lost opportunities for further operational development of innovative ideas being developed in research settings.
2. Undervaluation of the social impact of KTT. KTT is mainly seen as a profit-driven initiative and more weight and value should be put on the social, political and environmental impact of KTT activities to broaden the reach and participation.
3. Combining open science with commercial use. KTT can and should focus on the simultaneous development of open-source community and commercial versions with advanced functionalities to maintain the principles of open science which are central to current good scientific practice.
4. KTT should not only be viewed as an exit strategy for scientists to leave academia. KTT should be imbedded in institutional frameworks to encourage and inspire scientific developments from scientists pursuing academic careers.

The following sections focus on a new strategy that connect KTT efforts for RS more closely to researchers' goals by establishing an Innovation Lab directly at a department level of a research institute, and thus close to the scientist's basis.

2. The Helmholtz Innovation Lab – FERN.Lab

The Helmholtz Association, a union of 18 autonomous German research institutes specializing in a wide range of fields, has recently emphasized, and actively promoted TT through multiple initiatives to support the Helmholtz Centres transfer activities including the creation of the Helmholtz Innovation Labs (HILs) funding program in 2015. The goal of HILs is to act as a core instrument within academic departments to match scientific expertise with the needs of industry. HILs and the resulting TT are embedded in the long-term strategy of Helmholtz Centres. In 2019, the second cohort of HILs were funded after a competitive, two-stage selection process. FERN.Lab, Remote Sensing for Sustainable Use of Resources, hosted in the Geodesy Department at the German Centre for Geosciences (GFZ) was one of the successfully funded HILs.

The primary objective of FERN. Lab is to act as an intermediary to effectively and efficiently facilitate TT of RS products by harnessing the extensive expertise of institutional researchers and matching this with identified needs of external partners. FERN.Lab will accomplish this by providing:

1) An interface between the Geodesy Department of the GFZ and other entities such as industry, non-governmental organizations, public authorities and research institutes
2) An opportunity for researchers and external partners to collaborate on equal footing
3) Internal support and promotion of scientific output and research sustainability
4) Externally deliver methods and research developments to market via third party digital, online platforms

The overarching concept of FERN.Lab is to facilitate the delivery of technology to commercial and non-commercial markets by acting as an expert intermediary within an innovation platform in the field of remote sensing technologies. FERN.Lab will facilitate the TT process using two distinct "pull" and "push" approaches. The pull approach involves creating tailor-made technologies for and funded by external partners, and second, the push approach promotes commercialization of existing departmental technologies with high market potential. Both approaches are supported by a combination of FERN.Lab competencies and services. Competencies can be defined as FERN.Lab expertise and skills, whereas services are the mechanisms by which FERN.Lab develops and delivers technologies to market. Combined, these competencies and services provide the necessary intermediary functions for effective TT and address the financial and skills gap that cause the Valley of Death in the innovation-manufacturing process (Fig. 3).

2.1. Competencies and services

FERN.Lab competencies can be broken down into two categories of departmental competencies and FERN.Lab core team competencies. Departmental competencies encompass diverse active and passive RS technologies and other Earth Observation (EO) expertise. Across all departmental competencies, Big Data oriented technologies and analyses are also available. The core team competencies include business, scientific, and software development, as well as public relations and serve as the foundation for the intermediary role of FERN.Lab. Within each core team competency, FERN.Lab offers a set of internal and external services that provide the mechanisms for TT.

2.1.1. Business development

The Business Development (BD) competency encompasses all market-related matters such as business modelling, market analyses, and benchmarks, as well as process-related matters such as partner contact, negotiations, and administration. This competency is provided together with the GFZ KTO team and is novel within an academic setting and provides necessary services to ensure FERN. Lab pursues TT in a successful and marketable manner. At the formation of FERN.Lab, an initial department-wide technology screening was conducted together with the KTO to gain a broad overview of available technologies and their corresponding technology readiness level (TRL). From this broad screening, a shortlist of the most promising technologies (high TRL) was compiled, and a value-added market analysis was conducted. The value-added market analysis uses a scoring system to evaluate six TT relevant categories of scalability, maturity levels, synergy effects, level of innovation, competitiveness, and strategic relevance which are standard criteria for assessing the commercial potential of a technology. This screening serves as the baseline for identifying the most promising technologies to push as well as providing a clear picture of the maturity and marketability of available technologies, facilitating timely and strategic responses to pull requests. Additionally, screening is an important basis for the established GFZ KTO tools, such as funding of internal innovation projects and Intellectual Property (IP) strategies. Internally, BD services include proactively seeking and approaching potential partners in the market or matching external partners and their needs to suitable researchers at the GFZ. In addition, all contract and legal negotiations are handled by the legal department with the BD team acting as a liaison to

[7] https://heliopas.ai/).

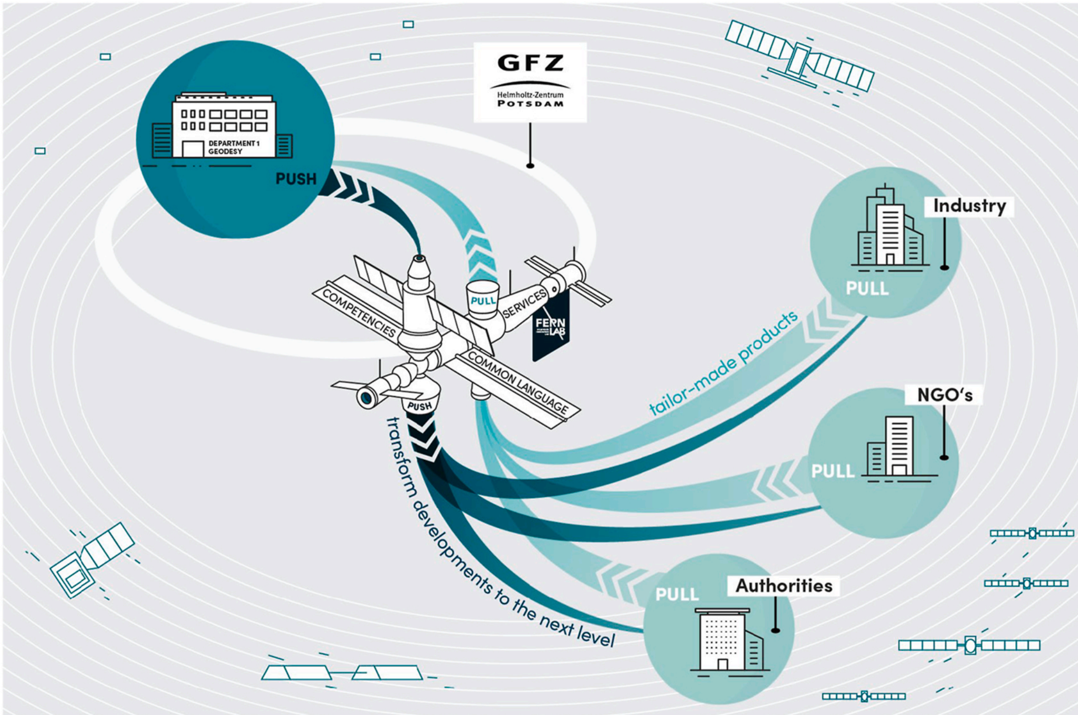

Fig. 3. FERN.Lab concept schematic illustrating the intermediary role of FERN.Lab in the push and pull TT processes. FERN.Lab uses the core team competencies and a common language to provide the support and infrastructure necessary to facilitate effective TT.

ensure fair and mutually beneficial partnerships.

2.1.2. Scientific development

When pursuing TT from both the pull and push approach, the desired departmental competency is integrated into FERN.Lab facilitated by the scientific development (SciD) team in close collaboration with contributing researchers. The SciD team acts as an expert scientific intermediary to ensure clear communication of the scientific concept, method and goals between researchers and external third parties or market demand. This approach provides equal access and support to researchers who are interested in pursuing TT. It also enables a flexibility and depth of available scientific competencies increasing the ability and speed with which FERN.Lab can respond to TT pull requests. The services provided by the SciD team are designed to support and promote researchers throughout the entire TT process. These include preliminary services such as initiating a dialogue with researchers responsible for identified push technologies together with the BD team to discuss further development, as well as assisting in securing funds by supporting preparation of relevant scientific proposals. Additional services include liaising between researchers, the BD team, and external partners to ensure continuous and comprehensive communication, as well as technical scientific support throughout the development process. The SciD team also promotes research and technologies at external events such as conferences and conventions, as well as within the scientific community by supporting the preparation of peer-reviewed publications.

2.1.3. Software development

Software development (SD) is a crucial FERN.Lab core team competency which supports key internal and external TT processes. The SD team is responsible for the development of stable and high-quality technologies as well as FERN.Lab information technology (IT) services that are the mechanisms by which technologies are delivered to market. Having SD as a dedicated core team competency ensures that FERN.Lab can support and respond to TT activities efficiently and effectively. Internal services related to supporting researchers and technology development include sustainable software development, consisting of systematic testing, version control, and maintenance and where necessary, software licensing. Software developments are generally incorporated into an open-source community version designed for long-term research and to encourage community developments. FERN. Lab also aims to create a commercial product or minimum viable product (MVP) with extended functionality and fine-tuned to market needs from the community version.

The SD is also responsible for facilitating access and delivery of technologies to external partners and the market. This is accomplished by exploiting an existing rich ecosystem of RS and EO platforms. There are several high-quality platforms that provide the necessary infrastructure which can be exploited by the SD team to efficiently make technologies available. Platforms include international initiatives such as the European Commission's NextGEOSS,[8] and the Euro Data Cube,[9] as well as national initiatives like CODE-DE (Storch et al., 2018) and commercial platforms like UP42, a subsidiary of Airbus[10]. These platforms provide a wide variety of cloud-based services such as catalogues of raw and analysis ready data (ARD), interactive tools for data analyses and visualization, as well as coding and developer interfaces to integrate programs like QGIS and Jupyter Notebooks for individualized applications. As part of FERN.Lab TT activities we will tailor delivery of technologies based on project needs by choosing existing platforms that best fit the technologies and partners involved. Developing the digital infrastructure required to support a streamlined, cloud-based platform to access data and applications is a complex undertaking that has garnered a lot of attention and investment in recent years. By using external platforms, FERN.Lab can focus efforts and resources on the development of high-quality technologies.

2.1.4. Public relations

Given the intermediary role of FERN.Lab, the public relations (PR)

[8] www.nextgeoss.eu.
[9] www.eurodatacube.com.
[10] https://up42.com.

services must appeal to a diverse audience and go beyond dissemination and communication of scientific research. Scientific publications will remain a key PR strategy of FERN.Lab, however additional passive and active business-oriented approaches will be undertaken including a professional website[11] listing expertise and services as well as easy-to-use, interactive online services to provide external partners access to data and technologies. The PR team will play a key role in building and maintaining a network with customers and external partners. Additional approaches to promote FERN.Lab and reach external partners will include passive approaches like a social media presence as well as active approaches like a quarterly newsletter, direct calling and attending conventions and conferences.

3. Use cases

In the following section we provide exemplary use cases that put the core team competencies and services of FERN.Lab into action. Firstly, the pull approach use cases demonstrate how FERN.Lab develops tailor-made solutions for different external partners. Secondly, a use case for the push approach shows how FERN. Lab develops and promotes an existing departmental technology with high market potential. For all use cases, the role of each FERN. Lab competency and resulting services in the development and transfer of a technology are outlined, to demonstrate the support opportunities an Innovation Lab like FERN.Lab can provide.

3.1. Pull approach

The pull approach examples can be divided in collaborations with external partners that are funded directly by those partners (contract research) or collaboration that are third-party funded in form of joint projects.

3.1.1. Contract research

The contract research pull approach use case involves contracting departmental competencies in the form of high precision drone flights and accompanying biomass and vegetation volume analyses to improve an ecosystem management strategy in an area of conservation importance. Building from an existing scientific collaboration between a researcher and the requesting NGO Heinz Sielmann Stiftung (www.sielmann-stiftung.de), the TT process was initiated by the BD team through contract negotiations for the cost of piloting drone flights, the data acquired, and the resulting data analyses for continues habitat monitoring. The BD services provide the legal and financial framework for the partnership. Once the partnership was established, the SciD team supported the compilation of data and analyses into a scientific manuscript to be submitted for peer review. The support of the SciD team ensures internal scientific benefits of the TT process for researchers and FERN. Lab. To ensure sustainability of the scientific method, the code used to analyse the high precision drone data was developed with the SD team to create a licensable biomass and vegetation volume estimation software to be licensed long-term to the NGO. A final service from the PR department was to create a promotional video from the drone footage about the conservation efforts of the NGO in this ecosystem. This unique service provides a science and conservation communication tool and promotional content for all parties involved.

3.1.2. Third-party funded KTT projects

The third-party funded projects build on existing FERN. Lab competencies that are adapted and further developed to tailor-made services.. Building on the FERN. Lab competency of processing large amounts of heterogeneous satellite remote sensing data towards ARD products, three projects have evolved at the starting phase of FERN. Lab: CropClass, FINDR, and MIPSTR.

The aim of the CropClass project[12] is an operational web service using optical and radar satellite time series data for highly accurate classification of crop types as early as possible, important, e.g., for agricultural management and yield predictions. The SciD team develops operational processing pipelines producing ARD as input for machine learning algorithms for crop type classification, which are developed by the project partner dida Datenschmiede GmbH (dida). The SD team is responsible to build the frontend of the web service and jointly with dida the BD team develops a pricing model for the final tailor-made solutions.

The FINDR and MIPSTR projects are collaborations with the German start-up ConstellR.[13] Further project partners of FINDR are also the Frauenhofer EMI, eLEAF (ELE) from the Netherlands as well as ACK Cyfronet AGH from Poland. The goal of FINDR[14] is to build up an Information and Communication Technology (ICT) platform that provides access to analysis ready EO data from all major EO missions while including freely available but also commercial data on request. A key feature of the platform is to offer a comprehensive overview of available data as well as to provide data availability forecasts to fasten and simplify decisions. This allows the user to easily benefit from inter-comparable multi-sensor, multi-temporal satellite data. MIPSTR aims at offering a service that provides time series of satellite-derived land surface temperature (LST) data that may, e.g., be used in the context of precision agriculture applications. The product will incorporate thermal data from existing satellite missions in a first phase and will later be improved in its coverage and spatial resolution by adding data acquired by new cubeSat sensors that will be first launched in 2023. In both projects, the SciD team develops operational harmonization workflows that unify the underlying satellite data geometrically and spectrally (if applicable) and allow to process the data in an automatic and scalable processing architecture. The SD team provides a Web-API that allows to call the harmonization workflow via a frontend which is developed along with data search and retrieve engine by ConstellR. The BD team is responsible for defining the business including pricing, license terms and related contracts.

3.2. Push approach

The push approach use case involves the further development of Habitat Sampler (HaSa), a tool originally designed to autonomously generate representative reference samples for predictive modelling of terrestrial vegetation type probabilities using optical remote sensing (Neumann, 2020). HaSa is an innovative classification tool for remote sensing image data that allows a classification of complex surfaces over space and time by considering only a minimal amount of training samples as reference input data. By incorporating machine learning with expert user knowledge the tool uses the small sample of training data as a reference to automatically create an enlarged set of unbiased and comprehensive training data, which is used as foundation for the classification of the image pixels into predefined classes.

This technology was identified by the BD value-added market analysis as having the most promise as a marketable technology scoring well in all six categories. To ensure successful growth of this tool, the BD team organized a product development workshop with an external coach to guide the core team through the creative process of developing a highly marketable product. As a result, the decision was made to focus development efforts on the change of HaSa from a command line tool, only useable for experts with programming skills, to an easy-to-acccess Software as a Service (SaaS) solution (Fig. 4). Key player for this transition was the SD team, which had also participated at the product development workshop to gain a thorough understanding of the tool. In

[11] https://fernlab.gfz-potsdam.de/eng-pages/homeeng.html.

[12] https://dida.do/de/projekte/klassifizierung-der-kulturpflanzenart.

[13] www.constellr.space.

[14] www.eofindr.space.

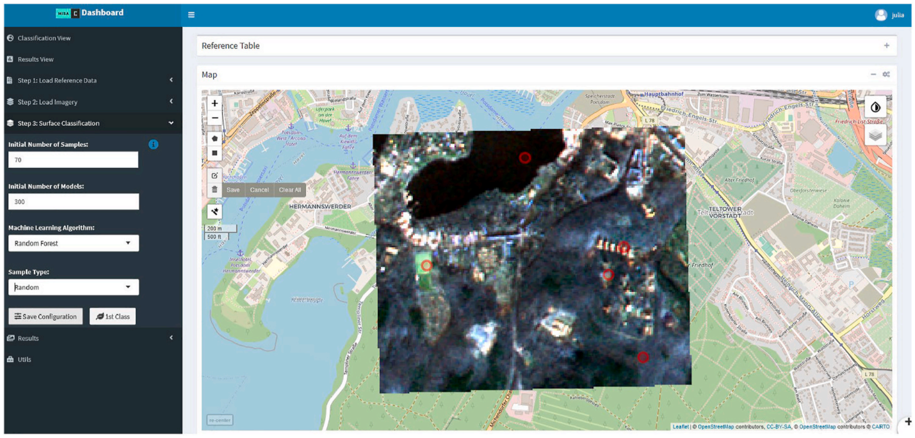

Fig. 4. MiSa.C SaaS MVP interface showing the dashboard on the left, and an input Sentinel-2 data stack with 5 reference points (red circles) for the classification of 5 different classes. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

the following, SD activities focused on combining the backend functionalities of HaSa and the functionalities of the GFZ in-house Sentinel-2 data processing chain GTS2 with a user-friendly web portal based front end solution. The accompanying dashboard, whose design process was closely supported by the PR team, enables users to perform any type of complex classification problems by only providing on single reference information for each target class. Furthermore, multiple remote sensing image types can be added, reaching from UAV to satellite platforms. For easy data access, the implementation of Copernicus Sentinel-2 data timeseries is also included.

All these developments led to a rebranding of the commercial tool variant to MiSa.C – Minimal Sample Classifier, which will be accessible in the future via a pay-per-use-scheme online platform, linked on the FERN. Lab website (Fig. 5). Currently MiSa.C is in an MVP status, where the product is evaluated by selected external test users. After the launch of the market product, envisaged for spring 2022, FERN. Lab aims to broaden the scope of this technology by marketing MiSa.C in a more generic way, moving away from the focus on terrestrial vegetated surfaces that it was originally developed for.

4. Challenges and expected impacts of FERN.Lab

4.1. Challenges and solutions

The implementation of a TT framework by FERN. Lab comes with a set of challenges that fall broadly into challenges of perception, legal framework, and data accessibility. Though there are clear benefits of TT within public institutions, acceptance and recognition can take time. The lack of acceptance and recognition often stems from a common misconception is that commercialization is the only goal of TT (Huang-Saad et al., 2017). Researchers are often unaware of the breadth of internal services available to them that accompany external partnerships making them less open to participate in TT activities. While commercialization will be the goal of some partnerships, scientific, societal, environmental and political impact are also a central motivator. This refers to the goal of FERN. Lab TT activities as well as the GFZ and the Helmholtz Association (System Erde, 2021). To clarify the entire TT process and the benefits to researchers, comprehensive outreach efforts facilitated by the FERN. Lab PR team will be undertaken.

Challenges related to the legal framework of TT including contractual obligations, Intellectual Property (IP), and warranty must also be considered. When drawing up contracts between FERN. Lab and external partners, precise language and clear communication on contractual obligations, i.e., best efforts or reasonable efforts must be specified. The differences, though subtle, are important because it dictates the provisions of the contract ranging from the most onerous (required to do everything in one's power to accomplish the goal) to the least onerous (required to do one's due diligence to accomplish the goal). Academia adopts a best-efforts approach but when one approach does not result in the intended goal, researchers change their approach or their goal. This flexibility may not be possible when working with external partners and must be taken into consideration. The same consideration must also be paid to warranties and indemnities (security against financial loss). In general, German public institutions cannot issue warranties or indemnities which must be clearly communicated to external partners during contract negotiations. All legal details of

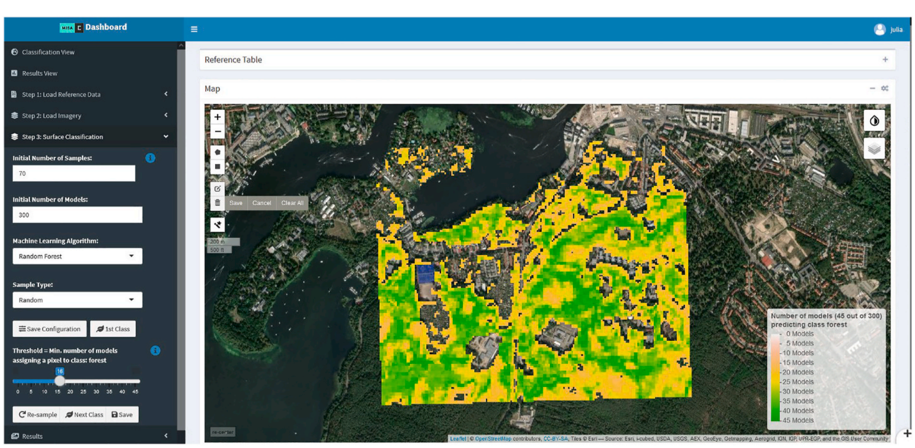

Fig. 5. MiSa.C interactive classification of machine-learning generated results by evaluating probability maps with expert knowledge.

contractual obligations, IP, and warranty will be thoroughly examined by the in-house legal department and the KTO at the GFZ.

An additional challenge is ensuring that the Findable, Accessible, Interoperable and Reusable (FAIR) principles and open source are not neglected during the commercialization process of software. For TT activities that involve commercialization of software, providing an open-source option raises some challenges that require careful decisions around licensing and proprietary functionality. The current FERN. Lab business model encourages sustainable development of open-source software to promote community involvement, thus creating value to the scientific community. To create a commercial product, FERN. Lab extends the core-software with proprietary features and develops either SaaS or Data as a Service (DaaS). In some cases, due to licensing or shared Intellectual Property (IP), an "as a Service" product is not always possible but will strived for in as many cases as possible.

4.2. Impacts and benefits

The expected impacts of implementing a robust TT framework for remote sensing products through initiatives like FERN. Lab have the potential to be far reaching. Internally, the TT process encourages researchers to think differently and more broadly about their research. By encouraging and facilitating cooperation with external partners, academic research can have a broader impact and reach improving the standing of individual researchers and the GFZ as a whole. Externally, by providing access to the most current and cutting-edge research, TT activities can increase the overall acceptance of remote sensing products and technologies outside of academia. This in turn can improve and modernize current methods used by partners in diverse sectors while simultaneously improving understanding of user requirements and resulting research goals and applicability within academic institutions. TT activities also give public institutions a better understanding of the needs of a diverse set of sectors which can facilitate putting the wealth of knowledge and research available into practice. With external partners ranging from diverse industry players, to public authorities, to NGOs, not only will there be beneficial impacts to individual partners but also broadly for society, the environment, and politics. The reach of FERN. Lab TT activities has the potential to be international by building off existing collaborations and the cooperative spirit present in scientific research, particularly in remote sensing research which relies heavily on international cooperation (Lautenbacher, 2006). FERN. Lab represents an innovative framework for the implementation of a TT-oriented long-term structure built by competent experts from an innovative research field together with industry and other network partners. This complements the existing TT channels and exploitation paths of GFZ such as patents, licensing and spin-offs with an application-oriented innovation platform for close integration with partners and customers. FERN. Lab capitalizes on the fast-growing RS sector while simultaneously promoting innovative Geodesy technologies increasing the sustainability and visibility of GFZ and its research.

Author contributions

AB conceptualized the idea for this paper and wrote the original draft. LA, RB, RG, JK, AL, JN, DR, DSch, MT, and DS all contributed to the methodology, reviewing and editing of the manuscript. MT created visualizations for this paper. DS and JN supervise the group.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

FERN.Lab was funded through the Helmholtz Innovation Labs innovation program (HIL-A15 FERN. Lab). FERN. Lab would like to thank all partners who provided Memorandum of Understanding and Letters of Support in the proposal process as well as our current partners for their trust and collaboration in our TT activities. FERN. Lab is also indebted to the many GFZ scientists who supported the HIL proposal and continue to support the work we do. We would also like to thank the Technology Transfer Office of the GFZ for their continued support and guidance. We would like to thank Jörn Krupa from the GFZ Technology Transfer Office for his insights and guidance on technology transfer within public institutions.

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