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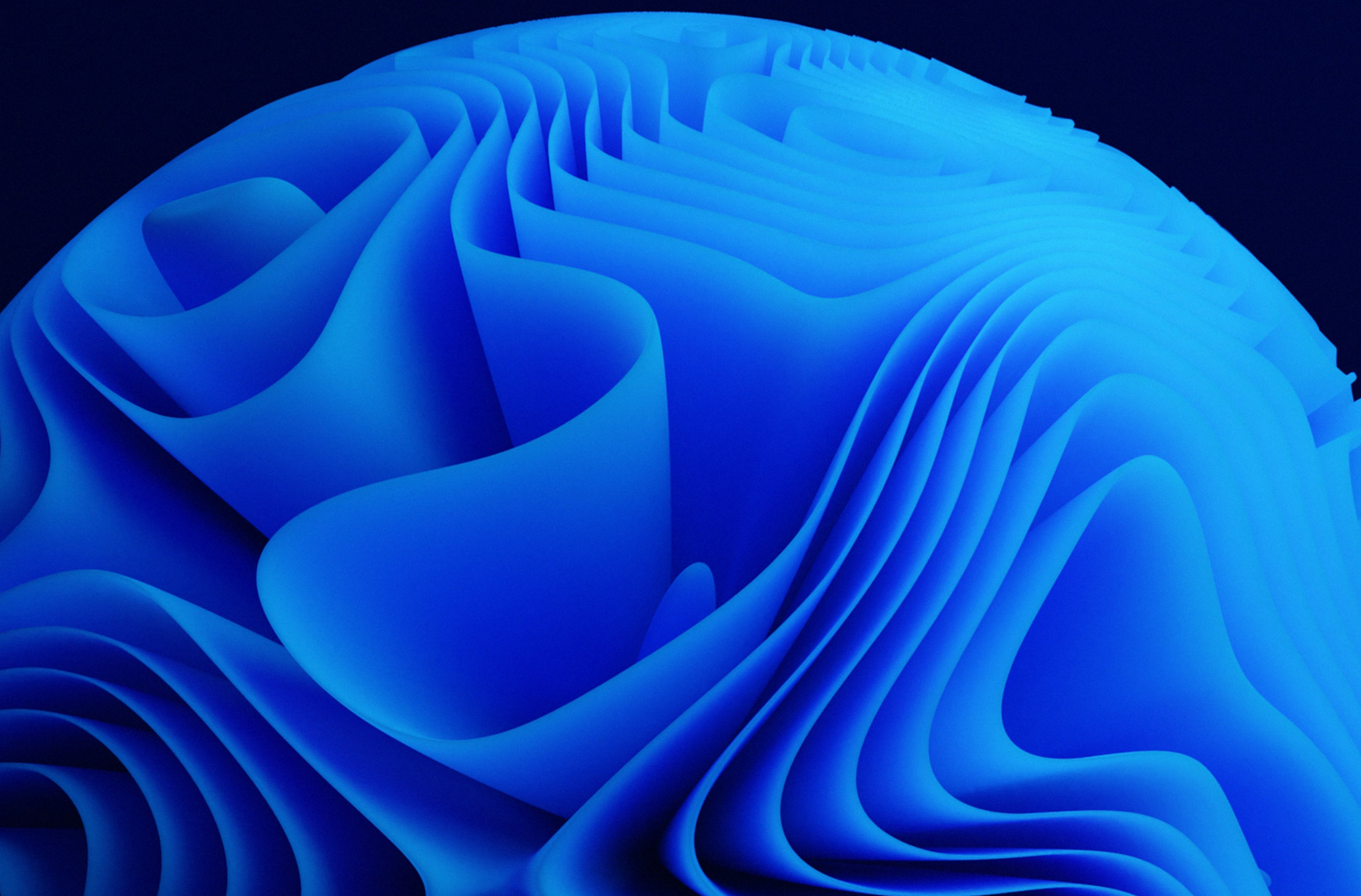
WORLD ECONOMIC FORUM

The Catalytic Potential of Artificial Intelligence for Earth Observation

BRIEFING PAPER

JANUARY 2024



Images: Unsplash, Getty Images

Earth observation data is a vital but underutilized tool

The world is experiencing ecological and climate crises of unprecedented scale. Given the imperative for green transformation across public and private sectors, reliable data and tools that inform decisive action are vital for both climate mitigation and sustainable growth. Earth observation (EO) by satellites, aircraft and ground-based sensors generates a rich stream of data with enormous potential to aid this transformation. With use cases as far-ranging as reforestation, detecting greenhouse gas (GHG) emissions, shaping actuarial analyses and optimizing supply chains, EO data's value proposition is compelling from both climate and business perspectives.

The scale and quality of commercially available EO data has risen exponentially in the past decade, driven largely by new EO satellites. Over 1,170 EO satellites are currently in orbit – 51% of which have been launched since 2019.[1]

On board these satellites, advanced sensors offer dramatic improvements in the resolution and types of measurements that can be made at scale from space. The resulting volume of Earth images is difficult to comprehend – hundreds of terabytes *per day*, and rising. Add to that the data available from Global Positioning System (GPS)-enabled and internet of things (IoT) devices, and the scale of data created vastly outweighs the ability to analyse it.

Earth observation (EO) refers to collecting information about activities and characteristics on Earth, both natural and artificial. EO data is used to monitor and measure the status of, and changes in, the environment and the impact of human activity on the environment.

Practically speaking, the value of EO data (as with any form of information) is not intrinsic. EO data must be used to generate value, and the extent of its value is tied to how, and how widely, it is used.[2] For example, EO data used to identify wildfire hazards becomes valuable when those insights drive actions to mitigate negative impacts. Until recently, the complexity associated with analysing EO data has limited its use to relatively niche applications by government agencies, academia and non-profit organizations. However, the use of artificial intelligence (AI) coupled with low-cost, high-performance computing has shown promise for both public and, increasingly, private sectors. As recent advancements in large language models (LLMs) have done for text-based content, broadening the use of AI for EO will enable significant growth in the value derived from EO data.

The impacts will be profound:

1. **AI tools can answer complex questions with EO data.** AI capabilities allow for more data to be processed quickly and accurately, enabling the transformation of vast reams of raw EO measurements into actionable insights.

2. **AI with intuitive user interfaces will make EO accessible to non-expert users.** In the same way that ChatGPT awakened the world to the power of LLMs, the development of more intuitive user interfaces (UI) will help put AI-enabled EO insights in the hands of business users instead of only data scientists.

3. **AI for EO will drive business model innovation.** As AI makes EO more accessible, scaled application becomes feasible for organizations across nearly all sectors and industries, setting the stage for disruption in commercial and sustainability-focused business models alike.

Trust and transparency from EO data

Collectively, these impacts stand to not only multiply the value derived from EO data, but to also provide additional trust and transparency in the actions being taken to transition to a net-zero economy. The ability to infuse consistent, objective measurements into climate-positive action and environmental disclosures helps to establish a common, verifiable source of truth.

1 AI tools answer complex questions with EO data

Making good use of large, multidimensional and often disparate data sources is nearly impossible with only human analysis. As such, geospatial analysts and data scientists in the EO industry have long relied on AI and machine learning techniques to sift through data and derive value-added information. For example, Google Earth Engine contains 40 years of geospatial data and a catalogue of over 600 datasets. It applies advanced AI analytics to make that data useful. In some cases, AI has even identified unseen patterns in data, unlocking additional use cases and methods of analysis that were previously unknown. The core capabilities that AI brings to EO are illustrated below.

FIGURE 1 **Core capabilities of artificial intelligence for earth observation**

Fusing disparate datasets

EO challenge: EO insights are often derived by combining data from multiple sensors and different sources, which is difficult using traditional computational techniques.

AI capabilities: Machine learning can find patterns across disparate datasets, a capability that increases the value of previously less-studied EO data.

Example: Monitoring of the risk that vegetation poses to utility infrastructure is more robust when using data from multiple types of sensors. Combining hyperspectral, multispectral and LiDAR (light detecting and ranging) data provides a more complete picture of tree species, their health and their growth rates over time.

Creating training data

EO challenge: In many cases, there are not enough tagged images to train AI models effectively, especially for rare objects or under different lighting conditions.

AI capabilities: Generative AI (GenAI) can create pre-tagged synthetic images, reducing time and increasing training data quantity.

Example: Researchers have used synthetic training data to detect offshore wind farms with fewer false positives, a technique easily extended to monitoring other green energy infrastructure.[3]

Detecting objects of interest

EO challenge: Accurately and consistently identifying features of interest requires many hours of labour when done manually or using traditional software-based image processing.

AI capabilities: Once trained, AI models have proven highly effective at detecting and differentiating between specific objects within images.

Example: In supply chain monitoring, AI can be "told" what a fishing boat looks like and can then identify similar boats repeatedly, a use demonstrated through Airbus' Ship Detection Challenge.[4]

Identifying causes

EO challenge: Determining the cause of events spotted with EO is often necessary to plan an intervention, but studying them manually is costly and time-consuming.

AI capabilities: AI can group observations into clusters based on similarities in surrounding features, helping to speed up the identification of root causes.

Example: To reduce methane emissions, AI is being used to quickly differentiate images of gas plumes caused by pipeline leaks, livestock and landfills, which helps to prioritize resources for interventions.

Monitoring changes

EO challenge: Time-series analysis enables normal patterns to be identified; however, manually identifying subtle changes can be subjective and inaccurate.

AI capabilities: AI can take advantage of high-cadence imaging, such as daily revisits of the same location, to identify trends and flag changes that may go unnoticed by human analysts.

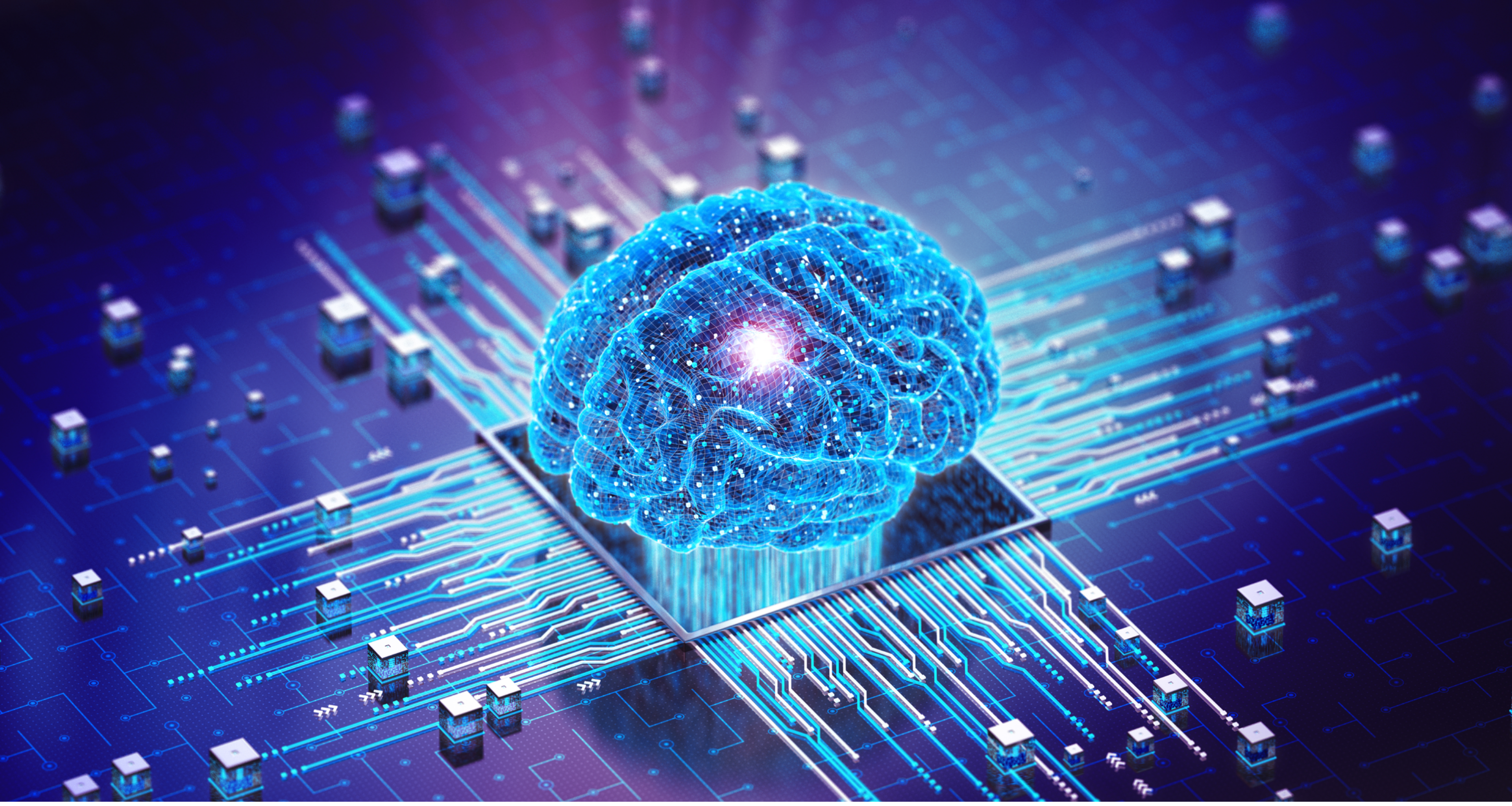
Example: AI can analyse changes to forests at the scale of individual trees to estimate biomass, monitor degradation and provide valuable insight on ecological health over time.[5]

Forecasting future events

EO challenge: EO data can describe a current environment, but predicting future scenarios is complex.

AI capabilities: Not only can AI forecast future trends based on historical data (predictive analytics), but it can also identify optimal courses of action (prescriptive analytics) based on possible future scenarios.

Example: With corresponding EO data and the results of historical flooding events, AI can estimate the environmental impact of varying degrees of flood-prone weather events and inform preparedness strategies before an event has occurred.[6]



But AI alone will not transform the EO industry; rather, the convergence of AI with advanced computing will supercharge the discoverability, usability and usefulness of EO data. For example, the ubiquity of distributed computing and cloud services has enabled the development of promising new foundation models for EO that can accelerate the analysis of large volumes of EO data "on demand." Where, historically, new models would be needed for each use case, foundation models create economies of scale by supporting multiple downstream applications with a single model.

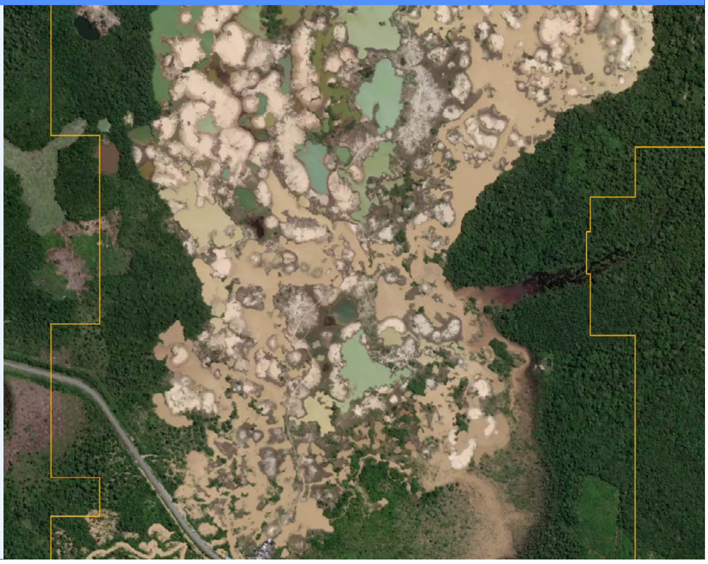
Foundation models are a powerful class of AI models that are trained on broad data and can be used across a variety of downstream tasks.

CASE STUDY 1

AI + EO spots illicit mining

Applications of early-stage foundation models are already emerging, like the recent example of EO helping discover illicit mining activity in the Amazon. Reporters worked with data scientists to leverage a foundation model that revealed a "vast network of illegal mining operations in Venezuela [and Brazil], and their corresponding threats to the environment and Indigenous communities."[7]

A customized, deep-learning model on satellite imagery would have taken months to build and days to yield useful outputs for the journalists, but with the foundation model, the datasets took days to assemble and milliseconds to curate. The resulting stories won the Shining Light Award from the Global Investigative Journalism Network. One jury member noted, "This story is taking us to where journalism is going — and it was a task so immense they used AI to crack the code of a story we would not otherwise have seen."



2 AI with intuitive user interfaces will make EO accessible to non-experts

Even with powerful AI tools and emerging foundation models for EO data, deriving meaningful insights often still requires specialized knowledge and skills. The same was true for working with LLMs before the release of ChatGPT, which has made clear how transformative a user-friendly web-based user interface (UI) can be in democratizing advanced technology.

Industry experts expect a similar expansion in EO models, provided that sufficiently capable AI-enabled tools are presented to users in more accessible UI.[8] Doing so would lower the skill-based barriers to entry, allowing novice users to begin exploring and experimenting with available Earth data. In turn, greater awareness of EO's capabilities and the questions it can answer will empower average users to begin applying EO insights to specific use cases within their industry.

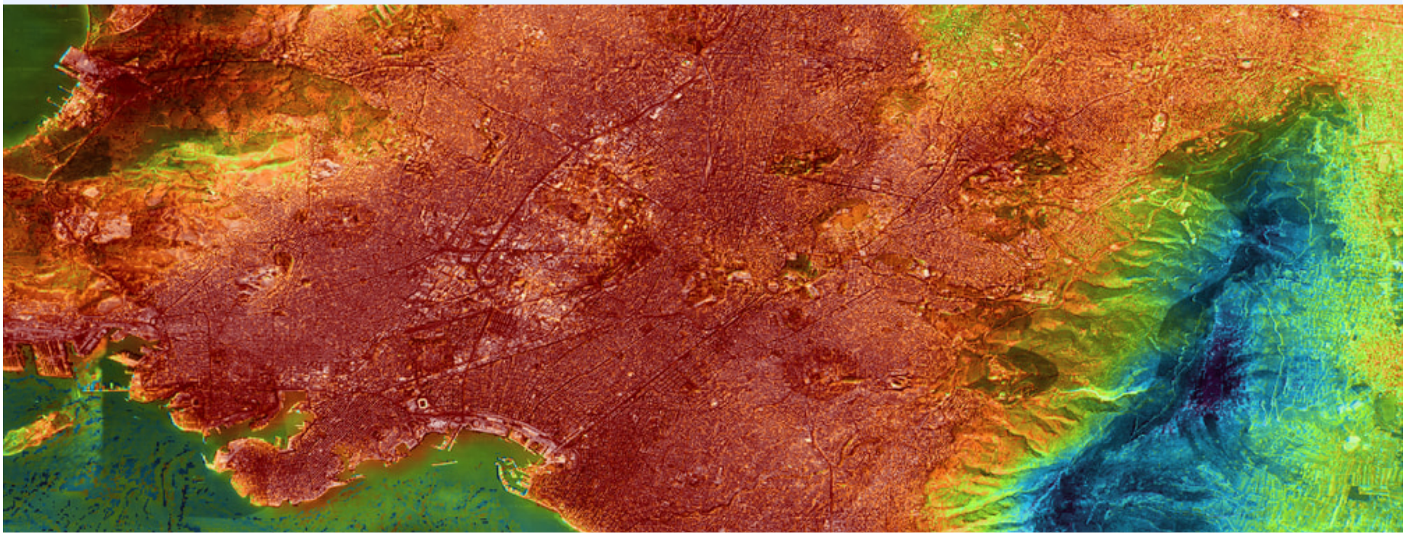
There is still no *generalized* foundation model for EO capable of supporting a broad swath of the many potential use cases for EO. Nor is there a broadly accessible interface for using such a model. However, experts believe a generalized and widely accessible class of foundation models for EO is fast approaching.[9]

CASE STUDY 2

AI + EO at the MIT Media Lab

The MIT Media Lab's initiatives, Earth Mission Control and Climate Pocket, focus on the intersection of user interface/ user experience (UI/UX), AI and EO. These initiatives use AI to analyse complex EO datasets, transforming them into actionable insights and visually engaging representations.

This not only serves to enhance the understanding of systems interactions on Earth, but also provides a valuable tool for informed decision-making across various sectors, from industry to policy. By developing intuitive UI and providing immersive, hyperlocal experiences, these platforms bridge the gap between complex climate data and user-friendly narratives, empowering communities and offering inclusive solutions that address global climate challenges.



3 AI for EO will drive business model innovation

As AI puts the power of data within reach, organizations will be able to adopt it at scale. This trend is already being observed with GenAI and LLMs as they are tailored and woven into the fabric of business models today. Cisco, for example, announced in June 2023 the implementation of a GenAI assistant for their security operations centre, which aims to significantly decrease the time needed for security teams to respond to potential threats.[10]

Within the context of AI for EO, opportunities exist for disruption across a wide range of applications, such as monitoring remote infrastructure, assessing climate risk and adaptively managing supply chains and distribution. Innovative, new business models can emerge by transforming core functions and decision-making processes to make use of differentiated EO insights. In many cases, this will require tailored AI models that use proprietary data.

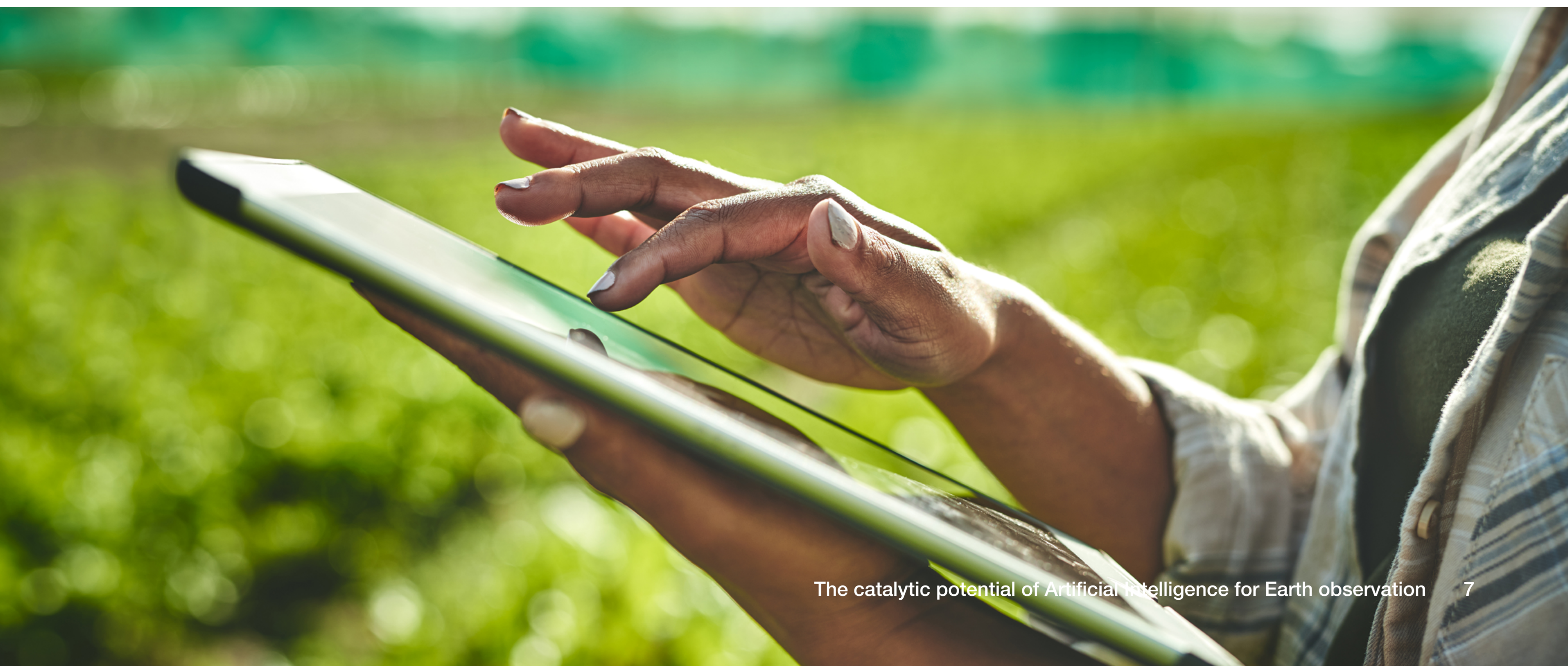
An electricity utility company seeking to monitor its infrastructure could augment satellite imagery of electrical infrastructure with geotagged data about its component parts, such as substations and transmission lines. Then, the utility would need to integrate insights about the status and health of its distributed systems into its workflow. Activated using a whole-of-organization approach, those insights could enable timely and cost-effective decisions to direct preventive maintenance by the organization's workforce.

BOX 1

Ethical considerations

While its potential to do good is evident, AI for EO also presents significant risks and ethical concerns. Without proper governance and safeguards, AI models could create negative impacts. For example, imagery taken of farms without a farmer's knowledge could inform costly regulations, insurance premiums or other actions that negatively impact the same farmers.[11] Additionally, biases in AI models may lead to outcomes that are neither equitable nor inclusive for all regions and populations.

The imperative for trustworthy AI has garnered global attention, with all 193 UNESCO member-states adopting the Recommendation on the Ethics of Artificial Intelligence in 2021.[12] However, innovation is outpacing controls and practical interventions are needed. To start, incorporating humans-in-the-loop is a basic step to help infuse ethical judgment in both research and implementation stages of AI for EO. Decisions should be guided not only by AI models of Earth data, but also by considerations for the economic, cultural and societal consequences of the models' results and recommendations.



4 Benefits and focus areas for key stakeholders

The use of AI to extract actionable business and climate intelligence from data is vital to enhance the value of EO, but key actions are still needed.

The figure below summarizes the value of AI for EO for major stakeholder groups, as well as strategies each should consider.

FIGURE 2 **Value of AI and strategies for progress**

Value	Stakeholders	Strategies

– Helps to prioritize environmental, social and economic challenges, and increases effectiveness of subsequent actions to address them
– Enables emergency planning, response and resilience
– Measures progress towards Paris Agreement and Global Biodiversity Framework objectives
	Government & civil society	– Continue sponsoring programmes and partnerships to stimulate research and development that advance AI models, with special focus on:
		  – Building on publicly available data and producing open-source assets
		  – Creating ethical, trustworthy and equitable practices and models

– Shortens the time from data to insight – Facilitates greater experimentation and exploration of EO data, which lays the foundation for continued innovation in the methods and applications of EO	Academia	– Support research and development of AI models and spatial indexing programmes, enhancing both maturity and accessibility – Drive progress towards technology readiness and the development of geospatial and AI talent through rigorous research and innovation
– Grows demand for EO industry by increasing accessibility and usability of EO – Creates opportunities to increase impact on global Sustainable Development Goals – May provide better returns on capital invested to capture EO data as applications are built upon foundation models	EO Providers & Enablers	– Build intuitive platforms that make EO data discoverable and usable – Continue investment in enabling technologies and infrastructure to accommodate the growing volume of data being collected and used
– Creates value from both a business lens (e.g. savings and product innovation) as well as a cost sustainability lens (e.g. environmental monitoring and sustainable sourcing) – Amplifies the strategic value of Earth data across a wide spectrum of industries and use cases	Broader commercial Industry	– Participate in dialogues around the use of EO, including emerging technologies and potential business models – Take preliminary steps, like indexing relevant datasets with geolocations, to prepare to move quickly as new EO data and models become available

Source: World Economic Forum and Deloitte Analysis

Conclusion

AI is catalysing a dramatic increase in the use of EO data to solve some of the most pressing environmental and commercial challenges. The improvements in speed, cost and precision of information derived from EO, specifically from AI models and advanced computing, promise a new class of applications for a growing and diverse set of new users.

However, while technology gaps are closing, collective action and significantly greater investment are needed to realize the potential benefits, which are critical for achieving climate goals, and the Paris Agreement targets more specifically. A prioritized focus on governance, standards, open-source solutions and business model innovation is paramount for equitable adoption on a global scale. The result will enable a new frontier of value creation across sectors and industries, including a more sustainable future for Earth.

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