Moving Forward Together: The Emergence of the Interconnected Geospatial Ecosystem

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A New Era for Geospatial Collaboration

Around the world, decisions with far-reaching impact—on climate, infrastructure, finance, and national security—depend on timely, trusted geospatial information. For decades, Spatial Data Infrastructures (SDIs) have played a foundational role in enabling governments and industries to manage, share, and apply this data effectively.

As technologies, demands, and expectations evolve, so too must the systems that support them. What's emerging is a next-generation geospatial ecosystem: a dynamic, scalable, and interconnected environment where people, technologies, and data work together to solve real-world problems. These ecosystems build on the strengths of SDIs but go further—integrating not only stakeholders and systems, but also AI models, analytics, automation, and semantic standards—enabling more adaptive, intelligent, and collaborative approaches to some of the world's most pressing challenges.

In this ecosystem, actors—whether human or machine—can be added, removed, or reconfigured on demand. They form around specific needs, collaborate through shared data spaces, and operate under clear governance frameworks that ensure data sovereignty, trust, and security. The approach is inherently inclusive and flexible, allowing governments, innovators, researchers, and communities to participate meaningfully and responsibly.

Drawing on insights from global projects—including the Saudi Arabian National Geospatial Ecosystem (SANGE)—this paper explores how geospatial ecosystems are reshaping our thinking about digital infrastructure, collaboration, and knowledge exchange. It highlights the foundational role of standards, semantics, and governance in this transformation and why they are critical to unlocking the full value of geospatial data in the digital age.

Introduction

The geospatial landscape has evolved significantly over the past 50 years, driven predominantly by rapid technological innovation and growing market demands for precise and actionable location-based insights. Initially characterized by isolated and incompatible systems, the geospatial data industry has matured through SDIs into robust infrastructures supporting critical services across sectors."

Technological advancements, particularly in artificial intelligence (AI), machine learning (ML), cloud computing, telecommunication networks, and enhanced sensor technologies, have profoundly influenced the geospatial domain. These developments have enabled more efficient data processing, real-time analytics, and predictive modeling, expanding geospatial applications far beyond traditional boundaries such as mapping and surveying into sectors like environmental monitoring, urban planning, agriculture, retail and marketing, health, tourism, finance, insurance, and defense.

Simultaneously, the market dynamics have shifted considerably. The global geospatial market is anticipated to continue growing rapidly, propelled by the increased integration of geospatial data with emerging digital technologies such as digital twins, IoT, the metaverse, and immersive 3D/4D environments. This growth is fueled further by rising demands for geospatial capabilities in many domains, such as smart city initiatives, precision agriculture, climate resilience, defense strategies, or financial risk assessments.

For stakeholders within this evolving landscape—including governments, private sector companies, academia, and civil society organizations—the implications are substantial. Governments remain pivotal as providers of authoritative geospatial data, ensuring integrity, provenance, and trust amid an environment increasingly influenced by AI-generated synthetic data. The need for reliable, authoritative sources that ensure data authenticity and provenance has become paramount.

Summarizing issues with traditional Spatial Data Infrastructures that have been reported by other authors, three main aspects are most prominent (see for example, Coetzee et al 2021, Dissanayake et al 2025, Li et al 2024, Saeter 2024, or Sjoukema et al 2017; and many others). These critiques are not indictments of SDIs, but rather reflections of how the landscape has changed and why SDIs must evolve. First, SDIs have at times struggled with integrating diverse data sources and formats, especially when data quality or semantics are inconsistent—leading to challenges in discovery and reuse. Second, discovery and access mechanisms sometimes emphasized technical implementation over user experience, leaving questions of data ownership, usability, and privacy under-addressed. Third, policy and governance hurdles—ranging from legal frameworks to funding models—have made it difficult for SDIs to adapt quickly to fast-moving societal and technological developments. These observations have informed the emerging vision of geospatial ecosystems, which we explore in this paper.

The concept of geospatial ecosystems itself is shifting towards a scenario-centric model, reflecting how communities and stakeholders increasingly coalesce around specific challenges or scenarios rather than generic spatial data infrastructures. This shift necessitates highly adaptable, responsive systems that can quickly integrate diverse datasets and deliver precise, context-specific insights.

Linked data principles and graph-based systems are emerging as vital components in these ecosystems, facilitating discovery, traceability, and semantic clarity of geospatial information. These principles not only enhance the reliability of data usage but also enable powerful semantic associations, ensuring that each data element is explicitly linked to its meaning and origin.

The growing emphasis on structured data-sharing environments known as data spaces further enriches these ecosystems. Data spaces incorporate data sovereignty, high levels of interoperability, decentralization, and trust, allowing multiple organizations and sectors to collaborate on shared datasets without relinquishing data ownership. This approach enables secure and efficient collaborative environments, reinforcing trust among stakeholders.

In response to these evolving dynamics, geospatial ecosystems must prioritize agility, inclusivity, and continuous innovation. Stakeholders are required to adopt new skills, particularly related to AI, data analytics, cloud computing, and cybersecurity, while maintaining vigilance against potential ethical and privacy concerns. Continuous investment in interoperability, certification, education, and community engagement remains critical to sustain the momentum and ensure widespread adoption of robust standards and technologies.

Overall, the evolution of the geospatial landscape points toward increasingly interconnected, intelligent, and scenario-driven ecosystems, positioning stakeholders across sectors to collaboratively address global and local challenges more effectively. The developments outlined here also have an impact on standardization bodies such as the OGC. The evolving landscape of geospatial ecosystems is heavily influenced by rapid technological innovations, geopolitical developments, and changing stakeholder expectations. The OGC, recognizing these shifts, is proactively adapting its approach to meet the new market requirements and to remain effective.

OGC acknowledges the increasing prominence of open-source ecosystems and agile development practices, which have altered traditional expectations from standards-setting organizations. Stakeholders now demand quicker, iterative development cycles and more agile pathways for transitioning from innovation to standardized solutions. Simultaneously, geopolitical complexities and evolving regional data governance frameworks, including the EU Data Act and China's Cybersecurity Law, necessitate greater agility and adaptability to maintain global interoperability standards.

In response, OGC is undertaking a comprehensive modernization of its governance structures to enhance transparency, inclusivity, accountability, and agility. At the same time, OGC adapts its service offerings to the changing geospatial landscape by providing re-usable building blocks and foundational, pre-competitive solutions to enhance semantic interoperability. These changes are not a departure from the SDI model but a continuation of its core mission—updated to serve a more dynamic, distributed, and AI-integrated world. As with SDIs, aspects such as rapid adaptation to user needs, reusability of proven solutions, and the ability to integrate diverse actors remain paramount.

1) From SDIs to Geospatial Ecosystems with Data Spaces

The evolution from traditional Spatial Data Infrastructure (SDI) to modern geospatial ecosystems highlights a shift from simply providing data to actively using it to generate insights and services. This is crucial as it moves beyond basic accessibility to unlocking practical applications and economic value. The following breakdown categorizes the key shifts.

- ### From SDIs to Geospatial Ecosystems with Data Spaces
    - **Traditional SDI Focus**: Primarily concerned with data availability, metadata, and standardized formats. It was about what data exists.
    - **New Approach:** The focus shifts to how the data is used – creating valuable services and knowledge derived from it. This includes:
        - API-First Design: Data is increasingly accessed and used through Application Programming Interfaces (APIs), allowing developers to build custom applications and services without needing to directly interact with the underlying data. This is about making data actionable.
        - Data as a Service (DaaS): Instead of downloading data, users access pre-processed, analyzed, and integrated data streams.
        - Model as a Service (MaaS): Provides access to pre-trained (analytical) models.
        - Geospatial Analytics Platforms: State-of-the-art platforms and cloud-based solutions are increasingly used to provide ready-to-use geospatial

analytics and insights.
        - Knowledge Graphs: Moving beyond simple metadata, knowledge graphs link geospatial data with other relevant information (e.g., demographics, economic indicators, environmental factors) to create richer contextual understanding.

- ### From Top-Down Government-Driven to Market-Driven & Collaborative
    - **Traditional SDI:** Typically mandated and controlled by government agencies, often with a focus on compliance and standardization.
    - **New Approach:**
        - Decentralization and Federation: We are moving away from a centralized SDI toward federated networks where data providers retain control and autonomy. Though, while this shift fosters innovation and responsiveness to local needs, it remains important to carefully balance public interests, private sector incentives, and community engagement.
        - Private Sector Involvement: Encouraging the private sector to build geospatial services and applications. This leverages market forces and expertise.
        - Community-Based Data Initiatives: Supporting citizen science projects and community-led data initiatives. This expands data coverage and improves data relevance; however, reliability and quality assurance processes need to be addressed carefully.
        - Open Data Principles: Promoting open licenses significantly democratizes access, enhances transparency, and accelerates innovation. For instance, governments making geospatial data freely available have spurred innovation in urban planning and environmental monitoring. On the other side, while openness drives innovation and transparency, robust data governance and equitable access frameworks are essential in many cases, as the data spaces concept clearly shows.

- ### Focus on User Needs & Accessibility
    - **Traditional SDI:** Often designed by experts for experts, resulting in complex interfaces and technical jargon.
    - **New Approach:**
        - User-Centric Design: Designing geospatial services and interfaces with a deep understanding of user needs and workflows. This includes usability testing and iterative development.
        - Simplified Access: Providing easy-to-use search and discovery tools that don't require specialized geospatial knowledge. Think of a "Google" for geospatial data.
        - Data Literacy Initiatives: Investing in programs that improve data literacy and empower users to effectively use geospatial information.
        - Low-Code/No-Code Platforms: These platforms empower non-technical users to develop custom geospatial applications, significantly lowering

the barrier to entry. These platforms will play an increasingly important role in modern geospatial ecosystems, as they enable complex spatial analytics without extensive coding knowledge.

- **Leveraging New Technologies**
  - **Cloud Computing:** Migrating geospatial data and services to the cloud for scalability, cost-effectiveness, and accessibility.
  - **Big Data Analytics:** Utilizing big data technologies to process and analyze massive geospatial datasets.
  - **Machine Learning & AI:** Applying machine learning and AI to automate geospatial tasks, extract insights, and improve data quality. Examples include automated feature extraction from satellite imagery and predictive modeling for urban planning.
  - **Internet of Things (IoT):** Integrating data from IoT devices (e.g., sensors, drones) to create real-time geospatial information.
  - **Blockchain:** Utilizing blockchain technology could enhance data provenance, security, and trustworthiness, vital for robust and secure data sharing, such as verified land registry management systems. Its usage needs to consider sustainability and energy usage aspects.
  - **Security and Privacy:** Addressing cybersecurity risks, data breaches, and privacy-preserving technologies (e.g., differential privacy, homomorphic encryption) is crucial for maintaining trust and integrity in geospatial ecosystems.

Key challenges in the transition are certainly

- Inertia aspects: Overcoming the existing infrastructure and processes of traditional SDIs.
- Data Governance: Establishing clear data governance frameworks for decentralized data networks.
- Sustainability: Developing sustainable funding models for new geospatial services.
- Interoperability: Ensuring that different geospatial data formats and platforms can work together.
- Economic and Business Models: Discussing monetization strategies for geospatial ecosystems, including public-private partnerships, and cost-benefit analysis of transitioning from SDIs is necessary to understand the economic implications.
- Change Management and Capacity Building: Transitioning to ecosystems requires organizational change strategies, training programs for participating organizations, and stakeholder engagement frameworks.
- Environmental Impact: Considering the carbon footprint of cloud computing, AI, and IoT is increasingly important for sustainable digital infrastructure.

As a conclusion, it can be noticed that the transition from SDIs to geospatial ecosystems signifies a major advancement towards more dynamic, inclusive, and innovation-oriented approaches. Addressing highlighted gaps and weaknesses ensures these ecosystems are robust, ethically sound, economically viable, and environmentally sustainable, ultimately enhancing their societal impact and longevity.

2) Understanding Data Spaces

As a relatively new paradigm, Data Spaces represent a significant shift in the methodologies of data sharing and utilization. The following explanation is structured to elucidate the core ideas, key characteristics, and distinctions from traditional approaches.

The core idea is that a Data Space isn't just a repository of data; it's a managed ecosystem designed to enable secure, trusted, and value-generating data collaboration. It's about creating an environment where data owners retain control, users can access and combine data under agreed-upon conditions, and innovation can flourish. Think of it as a digital marketplace for data, but with a strong emphasis on fairness, trust, and sustainability. To be successful, data spaces need to be embedded into the wider geospatial ecosystem, i.e., draw and built from the underlying standards, policies, and best practices, while having the flexibility to agree on specific setups that meet the needs of the addressed business case(s).

- ### Key Characteristics & Components:
  - **Data Sovereignty & Control:** The fundamental principle is that data owners retain ultimate control over their data. They decide who can access it, under what conditions, and for what purposes. This is a departure from scenarios where data is often siloed or subject to restrictive licenses.
  - **Trust & Governance:** Data Spaces rely on robust governance mechanisms to ensure data quality, integrity, and compliance with legal and ethical requirements. This often involves defining clear roles and responsibilities, establishing data usage agreements, and implementing mechanisms for dispute resolution.
  - **Interoperability:** Data Spaces facilitate seamless data exchange between different systems and organizations. This is achieved through standardized data formats, APIs, and communication protocols.
  - **Dynamic Data Usage Agreements (DDUAs):** Unlike traditional licenses, DDUAs are flexible and adaptable. They can specify the specific purposes for which data can be used, the duration of access, and even the fees involved.
  - **Technical Infrastructure:** A Data Space relies on underlying technical infrastructure to enable data discovery, access, and integration. This can include data catalogs, APIs, secure data sharing platforms, and blockchain technologies (though not always).

- **Semantic Interoperability:** Data Spaces strive for more than just technical interoperability. They aim for semantic interoperability, meaning that data is understood and interpreted consistently across different contexts. This often involves using ontologies and controlled vocabularies.
- **Value Creation:** The ultimate goal of a Data Space is to unlock the value hidden within data by enabling new insights, products, and services.

The Saudi Arabian National Geospatial Ecosystem (SANGE) was developed with these key characteristics as guiding principles. In its first year, it succeeded in establishing the necessary foundation in governance, standards, and extensible data models. See further information on https://geoportal.sa.

3) Integrating Essential Technical Components in Geospatial Ecosystems

This section provides essential clarity on how extensible data models, extract-transform-load (ETL) processes, microservices architecture, and data spaces not only support but significantly enhance the operational effectiveness, scalability, and flexibility of geospatial ecosystems, ensuring smooth and cost-efficient transition from legacy Spatial Data Infrastructure (SDI) environments to geospatial ecosystems.

Extensible Data Models

Extensible data models are critical within modern geospatial ecosystems as they address the diverse and evolving requirements of participating organizations while simultaneously ensuring a high level of interoperability. Unlike traditional rigid data structures, extensible data models allow incremental enhancements without disrupting existing operations or data exchanges. They accommodate the specific semantic and functional needs of various stakeholders, enabling them to add custom fields or datasets that comply with standardized frameworks.

For example, extensible data models such as GeoJSON, JSON-FG, or extended OGC API standards enable organizations to include additional contextual information specific to their sector, such as environmental indicators, economic metrics, or infrastructure attributes, without losing the ability to integrate seamlessly within the broader ecosystem. Such flexibility is essential for maintaining the coherence of shared data environments, especially when responding to new challenges or technological advancements.

In practice, these extensible models facilitate easier integration of innovative data types, including IoT sensor data, advanced analytics outputs, or even user-generated content from citizen science initiatives. As a result, geospatial ecosystems utilizing extensible data models can rapidly adapt to new scenarios, preserving the benefits of standardized interoperability while remaining flexible enough to serve varied organizational demands.

In our SANGE use case, all data models are extensible and have been developed following the described modeling approach. They have been socialized with all custodians of the 15 foundation themes to enable solid extension pathways for bi-directional data exchange. That way, evolving requirements from both data producers and consumers can be continuously addressed.

- **Extract-Transform-Load (ETL) Engines**

ETL (Extract-Transform-Load) engines play a pivotal role in transitioning existing geospatial systems into modern ecosystems. Organizations often have extensive legacy data systems and applications, which, while valuable, typically adhere to older or incompatible standards. ETL tools streamline the integration of these disparate data sources, ensuring seamless connectivity and minimal disruption to ongoing operations.

The significance of ETL processes in geospatial ecosystems lies in their ability to translate legacy data formats into standardized, interoperable schemas with minimal changes required in the original systems. By efficiently extracting data from existing systems, transforming it to conform to ecosystem standards, and loading it into integrated platforms, ETL solutions reduce costs, minimize transition risks, and accelerate implementation timelines.

Practical applications include migrating historical geospatial databases to cloud-based data spaces, enabling legacy GIS systems to feed real-time data analytics platforms, and ensuring seamless integration of governmental geospatial data with emerging private sector applications. The cost-effective and efficient nature of ETL processes makes them indispensable for rapidly scaling ecosystem participation, particularly in contexts like national-level initiatives, smart city platforms, and emergency response systems.

- **Microservices Architecture**

The microservices architectural approach significantly enhances the agility, scalability, and resilience of geospatial ecosystems. By decomposing traditional monolithic applications into smaller, independently deployable services, organizations gain flexibility in managing, upgrading, and scaling individual components without disrupting the entire system. Each microservice encapsulates specific functionality, such as data storage, spatial analytics, or metadata management, and interacts with other services through standardized, lightweight APIs.

Within geospatial ecosystems, microservices architecture facilitates rapid innovation and continuous deployment. Stakeholders can introduce or replace specialized services quickly, adapting to evolving user demands and technological developments. For instance, one microservice might handle real-time spatial analytics leveraging AI models, another could manage metadata and semantic annotations, while yet another orchestrates data sovereignty and usage agreements within data spaces.

In practical implementations, microservices enhance resilience by isolating faults within individual services, thus preventing system-wide outages. They also allow for incremental and granular scaling, allocating additional resources only where necessary—for example, during peak periods of data ingestion from IoT sensors during disaster events or seasonal environmental monitoring activities.

In SANGE, we learned that microservice architectures are best suited to meet the demands of the various data custodians. An API pipeline has been developed in consultation with the custodians to be delivered through the microservice architecture. This continuous exchange with data producers and consumers is critical for a sustainable geospatial ecosystem, as it allows for adaptation to changing needs and to exploit state-of-the-art analytical technologies without putting too much burden on existing operational systems.

- **Data Cubes for Performant Analysis at Scale**

Data cubes are critical to achieving high-performance analytics in geospatial ecosystems, particularly when handling extensive and complex spatiotemporal datasets. These multidimensional data structures are specifically designed to efficiently store, retrieve, and analyze data across multiple dimensions, including space, time, and thematic attributes. Data cubes provide a coherent and integrated framework that enables rapid, sophisticated analytical queries and ensures scalability.

In practice, data cubes unify various data streams—such as satellite imagery, sensor observations, and vector datasets—into a single, optimized analytical environment. This approach drastically reduces processing times, improves query performance, and enhances the responsiveness of data-driven applications. For instance, data cubes significantly accelerate tasks like change detection in land use patterns, predictive modeling of environmental phenomena, or real-time monitoring of urban infrastructure.

Within geospatial ecosystems, data cubes serve as a foundational analytical backbone, enabling efficient and scalable interoperability among stakeholders. They simplify the complex process of data integration by providing structured, analytics-ready data, thus facilitating seamless collaboration across diverse domains. Data cubes ensure that ecosystem actors, from government agencies to private enterprises, can leverage consistent, high-quality data for advanced analytical purposes, thereby supporting informed decision-making and rapid response capabilities. Furthermore, their structured nature allows for streamlined integration of GeoAI techniques, fostering continuous innovation and adaptation within geospatial ecosystems.

The role of data cubes will be briefly explained here using the example of the Saudi Arabian National Geospatial Ecosystem (SANGE), driven by the General Authority for Survey and Geospatial Information (GEOSA), which exemplifies how spatial data cubes serve as critical infrastructure within a national-level geospatial initiative. Specifically, the Saudi Spatial Data Cube is envisioned as the analytical backbone of SANGE, enabling efficient storage, retrieval, and analysis of the Kingdom's extensive spatial and temporal datasets. As a central repository, it supports sovereign control and independent management of sensitive geospatial data assets, ensuring national security and reducing dependence on external providers. The cube's strategic value within SANGE arises from its capacity to integrate seamlessly with advanced AI platforms, notably HUMAIN, Saudi Arabia's flagship AI initiative aimed at positioning the Kingdom as a global leader in artificial intelligence.

For SANGE, the spatial data cube functions as more than just a storage system; it actively powers various national priorities, including economic diversification, infrastructure monitoring, and sustainable environmental management. By coupling the data cube infrastructure with AI technologies, Saudi Arabia will enhance its ability to perform sophisticated analyses such as land-use monitoring, urban growth forecasting, infrastructure risk assessment, and environmental conservation efforts. Furthermore, through initiatives like HUMAIN, the data cube's robust and structured data provision accelerates the development of advanced Arabic language AI models and multimodal AI systems. This symbiotic relationship between the data cube, AI, and the broader geospatial ecosystem highlights the cube's transformative potential, embedding deep spatial intelligence into national decision-making processes, policy formulation, and governance strategies, thus significantly advancing Saudi Arabia's Vision 2030 goals.

4) Reimagining Standards & Interoperability

The Open Geospatial Consortium (OGC) has recognized a fundamental change in the requirements for modern standardization and has set the course accordingly. OGC has begun transitioning to a more dynamic and flexible standardization framework. In fact, the OGC is pioneering a novel approach to standardization that fundamentally reshapes how data spaces are constructed and utilized. This new methodology moves beyond traditional methods by integrating community-driven ontologies with online registers and dynamically built knowledge graphs. This approach aims to seamlessly connect all essential components within a data space, ensuring a holistic view of data resources and their associated context. Once fully established, the framework will allow for the linking of data with critical legal information, including licenses and detailed provenance data. This provenance extends from understanding the complete lifecycle of a data product –

from the initial sampling strategy for raw data to comprehensive descriptions of all processing steps, down to the specific vocabularies employed. Crucially, the future system will incorporate dynamic mapping capabilities between different vocabularies, ensuring consistent terminology management across diverse domains. A key strength of this new approach lies in its ability to establish robust identifier regimes, allowing for the unique identification of real-world objects, even when attributed with seemingly disparate datasets originating from different communities. This fosters interoperability and allows for a unified understanding of entities across previously isolated data landscapes.

The OGC's new standardization approach isn't just about defining what data should look like; it's also fundamentally changing how that definition is validated and maintained. Alongside the development of canonical specifications and schemas, OGC is establishing a robust, continuously evolving, and highly automated continuous integration and testing environment. This isn't merely a testing suite; it's envisioned as the very backbone of the future interoperability system. This environment leverages automated build pipelines, comprehensive regression testing, and a collaborative platform for developers and testers alike. The system is designed to continuously evaluate implementations against the specifications, identifying and resolving inconsistencies early in the development process. This includes not only verifying that data conforms to the defined schemas but also ensuring that software adhering to the specifications can seamlessly exchange and process information, regardless of the underlying technologies. The ongoing nature of this testing regime fosters a proactive approach to interoperability, reducing the risk of fragmentation and ensuring the long-term viability of the OGC standards. Furthermore, the public and collaborative nature of the testing environment encourages community involvement, allowing developers and users to contribute to the refinement and validation of the specifications, accelerating the pace of innovation and bolstering the robustness of the interoperability ecosystem.

These technical infrastructures still need to be fully developed and complemented with a robust governance model that allows variety. Every community will be able to operate its own online registers, vocabularies, and other resources, such as processing components and dynamic mappings between semantic resources. At the end, the operational infrastructure will be raised to the same level of importance as the actual development of canonical specifications. Together, both will lead to a new quality of data integration and interoperability.

5) Executive Summary

The geospatial information domain is undergoing a profound transformation, driven by rapid technological innovation, exponential data growth, and increasing societal demands for timely, trustworthy, and actionable insights. This evolution is marked by a shift from traditional, static Spatial Data Infrastructures (SDIs) to dynamic geospatial ecosystems. A geospatial ecosystem is a flexible, scalable, and inclusive system that integrates people, technologies, data, standards, and governance models to enable the dynamic aggregation, analysis, and application of geospatial information. It is characterized by:

- **Interoperability:** Seamless integration of diverse data sources and systems.
- **Data Sovereignty:** Control remains with data owners, supported by trusted data spaces.
- **Semantic Clarity:** Use of linked data and knowledge graphs to ensure consistent meaning and traceability.
- **Scenario-Centric Design:** Focused on solving specific, real-world problems rather than generic data provision.
- **Agility and Scalability:** Ability to rapidly adapt to new technologies, policies, and user needs.
- **Inclusivity:** Engagement of a wide range of stakeholders, including non-experts via low-code/no-code tools.
- **Sustainability:** Consideration of environmental, economic, and social impacts.
- **AI-Readiness:** Enabled for direct consumption by AI agents and models

From a governance perspective, we find data spaces at the heart of this transformation—trusted, interoperable frameworks that enable secure, sovereign data sharing across sectors without relinquishing ownership. These spaces embed principles of decentralization, semantic clarity, and governance, fostering collaboration while ensuring data integrity and compliance.

From a technical perspective, we find linked data principles and semantic annotation moving into focus. These principles enable semantic interoperability and form the basis for integrity, provenance, and trust by embedding various resources, such as data, code, definitions, examples, schemas, libraries, and other elements into graphs. Semantic interoperability is, in turn, an important prerequisite for improved data search and integration and is therefore fundamental to the successful application of artificial intelligence.

Unlike existing spatial data infrastructures, geospatial ecosystems are no longer content with simply paving the way to data. Instead, the focus is increasingly shifting to data analysis. Data cubes, therefore, have a special role to play. These multidimensional data structures organize spatiotemporal data, such as satellite imagery, sensor feeds, and vector data, into unified, queryable formats. Data cubes can serve as the analytical backbone of modern geospatial ecosystems by enabling efficient storage, retrieval, and analysis of large-scale spatiotemporal datasets. This allows minimizing typical weak points in distributed service environments, where data must first be collected for analysis.

Governments remain central as providers of authoritative data, but the ecosystem now includes private sector innovators, academia, civil society, and intelligent systems. This diversity enhances resilience, innovation, and responsiveness, especially in addressing complex challenges like climate change, urbanization, and disaster response.

Standardization bodies like the OGC are adapting by embracing agile, community-driven approaches, enabling faster innovation cycles and more inclusive governance. The OGC supports this new ecosystem paradigm by:

- **Modernizing Standards:** Moving from static specifications to modular, community-driven building blocks that enable reuse and semantic interoperability.
- **Automating Validation:** Establishing a continuous integration and testing environment to ensure real-time compliance and interoperability.
- **Supporting Decentralization:** Enabling communities to operate their own vocabularies, registers, and processing components.
- **Accelerating Innovation:** Embracing agile development practices and open collaboration to reduce time-to-standard.
- **Enhancing Semantic Interoperability:** Linking data with legal, provenance, and contextual metadata to ensure integrity, clarity, and trust.

Ultimately, the geospatial ecosystem of the future is agile, inclusive, and sustainable. It empowers all sectors to participate in data-driven transformation, including governmental entities, private businesses, academia, and civil society. It supports informed policymaking, fosters innovation, and ensures equitable access to the benefits of geospatial intelligence, aligning with national priorities and global development goals.

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