OGC® Geospatial Technology Trends

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Geospatial Technology Forecasting Consultation

The Open Geospatial Consortium (OGC) tracks trends in Geospatial Technology. Trends are identified and characterized based on OGC processes that then drive action in consortium programs. Geospatial Tech Trends consultation is available to any organization that could benefit from roadmaps of geospatial technology.

Geospatial Technology Trends

In a survey of global CEOs, technology innovation is anticipated to have the most transformative effect on their business over the next five years (according to PWC Global). Identifying technology trends and developing roadmaps for their development and effect on markets is key to reducing risk and identifying business opportunities. Geospatial technology advances with innovation in the application of location-based information and with general information technology innovations. OGC, as a consortium of over 500 of the most influential geospatial organizations, is the global forum for innovation and standards in geospatial technology. The OGC Technology Trends and roadmaps available to any organization to use in their business planning.

Disruptive Technologies Forecasting and Consultation

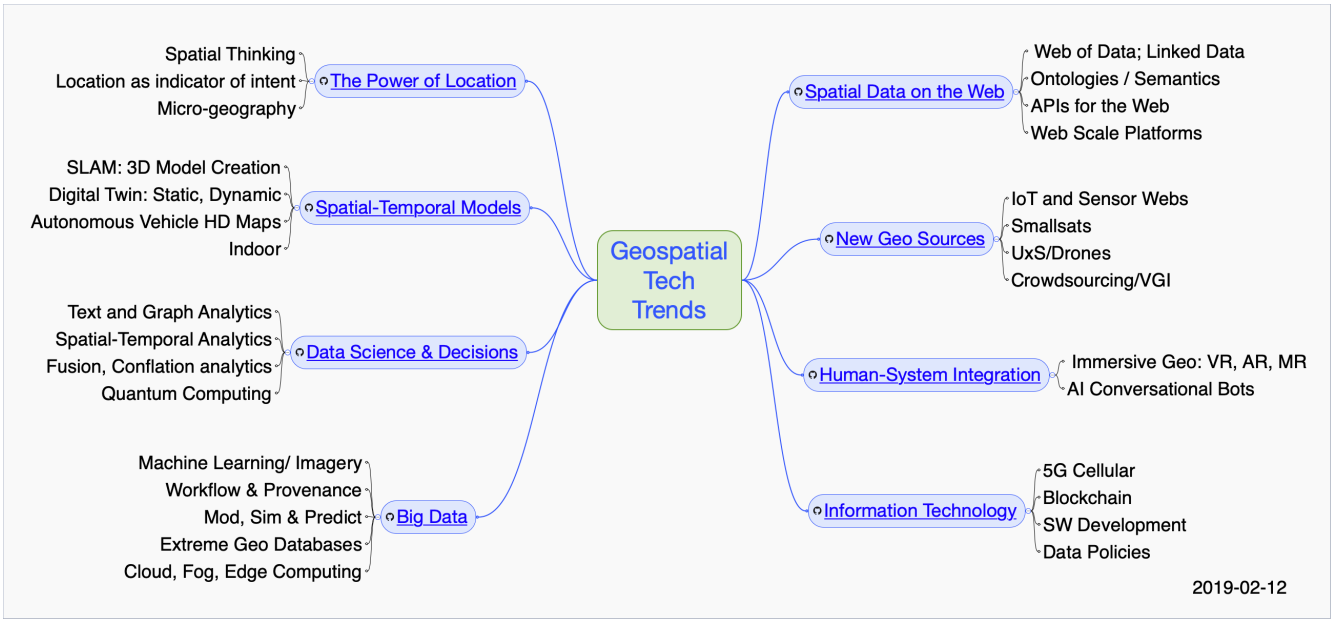
OGC's Geospatial Technology Forecasting Process is based on "best of breed" for persistent forecasting of disruptive technologies (National Academies) and honed by its use across OGC Programs. The identification and characterization steps are performed on a quarterly basis and reviewed by the OGC Architecture Board and OGC Technical Committee. Trends are posted publicly and receive public review and comments.

Action is Taken in the OGC Programs and through Strategic Consultation on an NDA basis providing tailored discussions and forecasts for any organization affected by geospatial and location-based technology innovations.

Chapter 1. OGC-Technology-Trends

Geospatial technology trends as tracked by the Open Geospatial Consortium (OGC) and the OGC Architecture Board (OAB) are listed on this and linked pages. A summary of all tracked Trends is provided in the mindmap. A set of Ripe Trends have been identified as summarized in the Trend Assessment. Also avaiable is an overview of the Technology Trends process.

Each Trend is linked to a GitHub issue - *Comments are welcome and encouraged on the issue linked to the trend*



1.1. Trends grouped into meta-trends:

- The Power of Location
- Spatial and Temporal Models
- Data Science and Decisions
- Big Data
- Spatial Data on the Web
- New Geo Sources
- Human-System Integration
- Information Technology

1.2. Ripe Trends

A subset of the Tech Trends identified as ``Ripe Trends'' are assessed as highest and second priority through an analysis summarized in the graphic below.

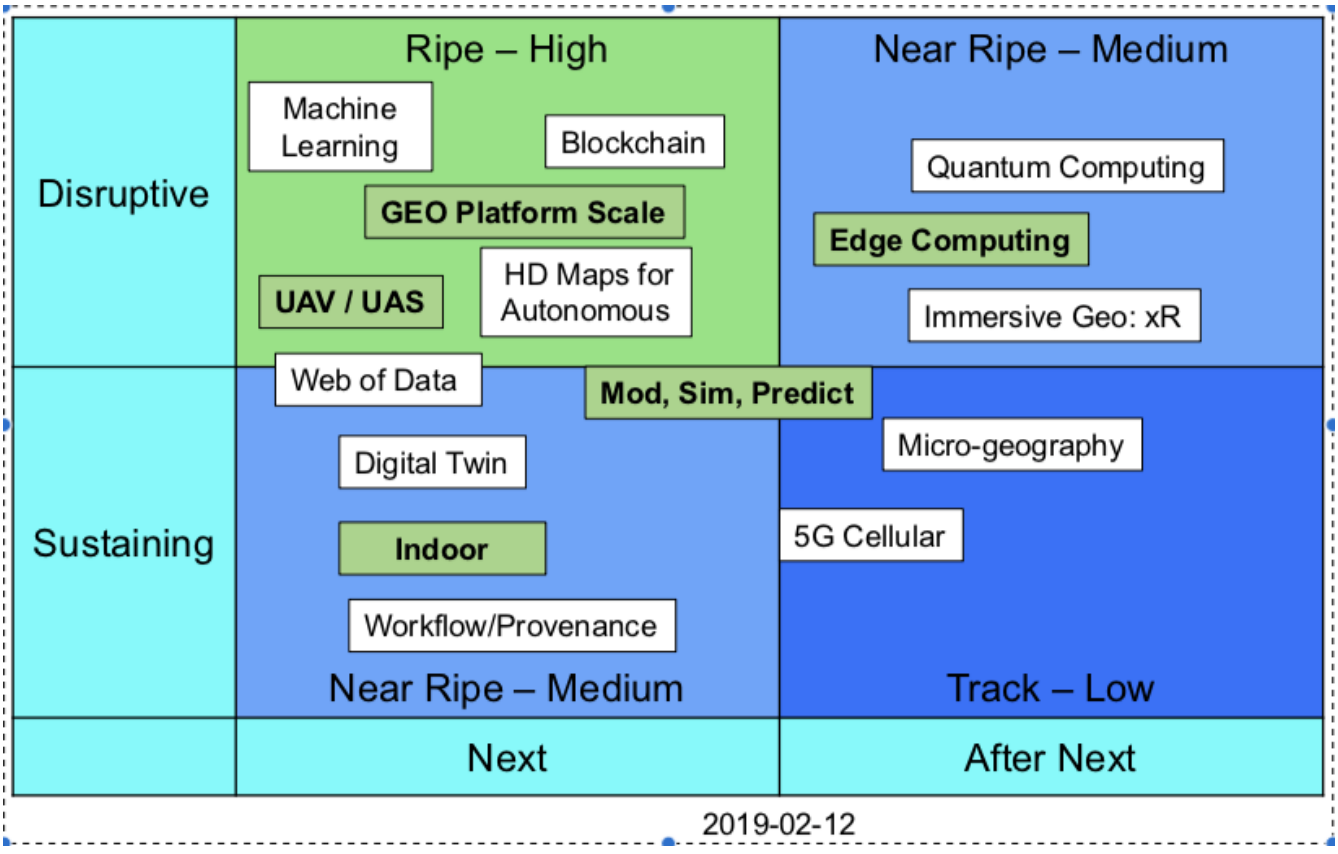
Highest Priority

- Autonomous Vehicle HD Maps
- Blockchain/Distributed Ledger
- GEO at Platform Scale
- Machine Learning/CNNs
- Modeling, Simulation and Prediction
- UAVs and Drones
- Web of Data

Second Priority

- 3D model creation
- 5G Cellular Communications
- Edge and Fog Computing
- Immersive Geo: AR, VR, Mixed Reality
- Indoor: Position, Models and Navigation
- Quantum Computing
- Workflow/Provenance

Ripe Trends are identified based on characterizations of trend Impact (Disruptive or Sustaining) and Horizon (Next or After Next). The trends for highest priority consideration are Trends assessed as Disruptive and Next.



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Chapter 2. The Power of Location (LOC)

Location and place are effectives means to organize, analyze and understand our world and how we live.

Title	Description
SpatialThinking	Trends in spatial thinking includes how GPS affects how we think about our world and navigation. Also the use of place, and how vernacular geography is used to describe it. One must avoid the temptation to think of place only as a location. (DSTL) A place is distinguished by its people, markets, governments, and institutions, as much as it is by its physical landscape and natural resources, transportation systems (including streets and roads), buildings, and boundaries- (US National Academies).
Location as indicator of intent	“Location targeting is holy grail for marketers”- Sir Martin Sorrell, WPP CEO, MWC 2011 By measuring the entropy of each individual’s trajectory, we find a 93% potential predictability in user mobility - Limits of Predictability in Human Mobility, Science 2010 1st law of geography: "Everything is related to everything else, but near things are more related than distant things.” - Waldo Tobler.
Statistics and Geography	As well as geospatial information, Governments and government bodies are increasingly reliant on statistical data to inform policy and decision making. As resources become constrained, it is increasingly important to make sure they are used in the most effective way possible. Geography is often the medium through which statistics are interpreted whether at global, regional, national or sub-national level. As the need for better statistics increases so does the need for greater integration of statistics and geospatial information, resulting in so called spatial statistics - (GGIM).

Title	Description
Human Geography	Well-organized and comprehensive human geography data can be applied to analysis that allows us to better anticipate the behavior of people over space and time and to inform decision-making that supports human security, including crisis mitigation and humanitarian response - (WWHGD_WG).
Micro-Geography	Personal electronic devices now measure much of our activity and context. New methods to capture, quantify and communicate individual human activity at a micro level are now available, e.g., OASIS's Classification of Everyday Living (COEL). Rating services for individual behaviors, e.g., risk rating, will develop similar to credit risk rating services.

Previous Trends

Title	Description
Learn To Think Spatially	Spatial thinking is a collection of cognitive skills. The skills consist of declarative and perceptual forms of knowledge and some cognitive operations that can be used to transform, combine, or otherwise operate on this knowledge. The key to spatial thinking is a constructive amalgam of three elements: concepts of space, tools of representation, and processes of reasoning. (US National Academies) OGC should consider how the innovation it promotes can extend this "learning spatial" to "doing spatial". (This topic has bee made part of SpatialThinking)
Location and Mobile communications	People who communicate digitally also tend to meet in person. 90% of users who have called each other have also shared the same space (cell tower), even if they live far apart.

Title	Description
Location based marketing/consumers	Targeted advertising is at the heart of the largest technology companies today, and is becoming increasingly precise. Simultaneously, users generate more and more personal data that is shared with advertisers as more and more of daily life becomes intertwined with networked technology. The online advertising ecosystem is built upon the ability of advertising networks to know properties about users (e.g., their interests or physical locations) and deliver targeted ads based on those properties - (Paul Vines, Franziska Roesner, and Tadayoshi Kohno).

Chapter 3. Spatial and Temporal Models (MOD)

Creating meaningful spatial representations of the world, the relationships in the world and its entities

Title	Description
3D Geo model creation including Point Clouds	Accurate 3D (Three Dimensional) model construction has been sought for many years as the key to unlocking many other related applications and scientific endeavors. This trend regards all aspects of 3D model construction from research aspects as well as focus on different types of sensing technologies being pursued. Both external and internal models are the topic of this trend. Methods are needed for rapid 3D model construction of urban areas.
Simultaneous Localization and Mapping (SLAM)	SLAM is a computational problem of constructing or updating a map of an unknown environment while simultaneously keeping track of progress within this unknown environment. Examples of approaches are self-driving cars, unmanned aerial vehicles, autonomous underwater vehicles, planetary rovers, newly emerging domestic robots and even inside the human body - (DSTL).
Digital Twins: BIM and GIS	A digital twin is a virtual representation of a physical object, which can be used to simulate how the physical object might behave in the physical world under different situations
Indoor: Position, Models and Navigation	Accurate indoor positioning unlocks a new set of possibilities for mobile services. Consumers will benefit from personalized, contextual information and offers, as well as new services such as indoor navigation. Venue owners will benefit from increased customer satisfaction and enhanced information on customer behavior - (InLocation Alliance).

Title	Description
Dynamic datums	This is now starting to be referred to as an “Earth-fixed” datum but previously was often referred to as a “dynamic datum”. Conceptually, the term “dynamic datum” confuses many people, who assume it to mean that the datum itself is constantly changing. This is obviously not the case – the datum is uniquely defined and fixed in orientation and location. Rather, an “Earth-fixed” datum allows the changes in coordinates of points on the Earth’s “dynamic” surface to be referenced and represented. (ANZLIC). The revision of ISO 19111 anticipates the need for Dynamic Datums.
Dynamic features: 4D models and positioning	The advance of mobile computing and internet-connected sensors (including sensors and GPS transponders in cell phones and notebook computers) brings with it a rapid rise in applications for moving feature data, typically representing vehicles or pedestrians. Many innovative moving feature applications will require the overlay and integration of moving feature data from different sources. Examples can easily be imagined for disaster risk management, traffic information services, security services, navigation for robots, aviation or maritime traffic monitoring, and wildlife tracking and conservation. (Moving Features press release).
Autonomous Vehicle HD Maps	Maps created at centimetre or sub-centimetre precision, typically to support driverless-cars and other autonomous ground vehicles that operate in built-up areas

Trends merged into above or retired

Title	Description
Spatial Temporal Point Cloud	Spatial Temporal Point Cloud. A point cloud refers to a set of data points in some coordinate system. Spatial Temporal components are incorporated (DSTL). Point clouds can be terrestrial, bathymetric, atmospheric. Streaming of point cloud data in real time.
Digital Twins: BIM and GIS integration	It's evident that bringing BIM and GIS together will benefit many application domains such as architecture, urban planning, disaster management, infrastructure engineering, facilities management, decision-making, construction, etc. However, there are many challenges in integrating BIM and GIS. M - (Kalantar in GIM International).
Indoor venue maps	The widespread adoption of smartphones by consumers worldwide has not only led to the advent of new indoor location technologies but also the increasing popularity and use of indoor venue maps. In the last several years, leading mapping technology companies have been competing to bring tens of thousands of high-quality indoor venue maps to smartphone users. There are indoor venue maps for thousands of museums, airports, shopping malls, restaurants and other venues - (Programmable Web).

Title	Description
Time stamps to support analytics	Time-Aware Applications, Computers, and Communication Systems (TAACCS) A new economy built on the massive growth of endpoints on the internet will require precise and verifiable timing in ways that current systems do not support. Applications, computers, and communications systems have been developed with modules and layers that optimize data processing but degrade accurate timing. State-of-the-art systems now use timing only as a performance metric. Correctness of timing as a metric cannot currently be designed into systems independent of hardware and/or software implementations. To enable the massive growth predicted, accurate timing needs cross-disciplinary research to be integrated into these existing systems- (NIST).
Multiscale	features that are represented at multiple scales, automatically (OAB).

Chapter 4. Big Data (BIG)

Big data methods and techniques applied to geospatial data

Title	Description
Big Geospatial Data	Big Data Geospatial builds upon Big Data Analytics and refers to the use of predictive analytics, user behavior analytics, or certain other advanced data analytics methods that extract value from data, and seldom to a particular size of data set - (DSTL). Big data, machine learning, and predictive data analytics allows researchers to extract insights from both scientific instruments and computational simulations (4th Paradigm) - (ACM Comm).
Workflow and provenance	Provenance is information about entities, activities, and people involved in producing a piece of data or thing, which can be used to form assessments about its quality, reliability or trustworthiness - (W3C PROV).
Machine Learning/CNNs on Imagery	Machine learning is the subfield of computer science that gives computers the ability to learn without being explicitly programmed. Deep learning and Convolutional Neural Networks (CNNs) - a sub type of machine learning - consists of multiple hidden layers in an artificial neural network - (Wikipedia).
Modeling, Simulation and prediction	Simulation modeling is the process of creating and analyzing a digital prototype of a physical model to predict its performance in the real world. Models and simulation can be used for analysis and for training.
Extremely Large Geo Databases	An extremely large database (XLDB) is a database that stores and processes enormous amounts of data and associated records and entries. As the largest database form factor, XLDB is created and managed by very few organizations around the world, typically scientific research institutes that have massive data sets at their disposal.

Chapter 5. Data Science and Decisions (DEC)

Data analytics and decision in the context of spatial-temporal data. Human cognition augmentation.

Title	Description
Data Science for Geo	The use of data mining and other functions provided by intelligent systems to facilitate the creation of knowledge.
Text and Graph Analytics	Text Analytics refers to the process of deriving high-quality information from text. Applications of this are Natural Language Processing (NLP) and Social Media harvesting. An example is to scan a set of documents written in a natural language and either model the document set for predictive classification purposes or populate a database or search index with the information extracted - (DSTL).
Spatial-Temporal Analytics	Although real-time spatiotemporal data are now being generated by almost ubiquitously and their applications in research and commerce are widespread and rapidly accelerating, the ability to continuously create and interact in real time with this data is a recent phenomenon. This real-time space–time interactive functionality remains today the underlying process generating the current explosion of fused spatiotemporal data, new geographic research initiatives, and myriad mobile geospatial applications in governments, businesses, and society - (NGAC).
Uncertainty, Veracity	Uncertainty is a situation which involves imperfect and/or unknown information, including aspects of cognition (the process of acquiring knowledge and understanding through thought, experience and senses) and plays a part in understanding Uncertainty Information. How this information is assessed for data quality is important - (DSTL).

Title	Description
Fusion, Conflation analytics	Conflation refers to the act of combining two distinct maps into one new map. It is similar to the practice of image mosaicking. It is usually carried out by registration of an overlapping area. Conflation for digital maps refers to the process of associating real world coordinates to digital ones and it is named Map Matching - (DSTL).
C2/SCADA for GeoIoT	Command and control (C2) a well established ability is the exercise of authority over assigned resources in the accomplishment of a common goal. Supervisory control and data acquisition (SCADA) is a information system architecture for high-level process supervisory management of industrial process plants. Applying C2 and SCADA to IoT environments will reuse existing control system technology in a new communications stack of broader reach.

Roadmap for Data Science Analytics

Chapter 6. Spatial Data on the Web (WEB)

Making geospatial data accessible and usable in the most comprehensive information system ever built.

Title	Description
Web of Data	Data published on the web are made discoverable, accessible and interoperable using WWW best practices for data formats, data access, data identifiers, metadata, licensing and provenance.
Ontologies and Semantics	Ontology is a formal naming and definition of the types, properties, and interrelationships of the entities. Semantics is primarily the linguistic, and also philosophical study of meaning—in language, programming languages, formal logics, and semiotics - (DSTL).
Coverages on the Web	Coverages are geospatial datasets as matrices or tensors that map a spatial-temporal coordinates to a corresponding set of data values, e.g., geophysical parameters. The Web is fundamentally organized as a graph structure with node addresses and relation links. Spatial Data on Web Best Practices are needed to that define Web-native access to Geospatial Coverages.
APIs for the Web	The explosive growth of public APIs for geospatial applications, and the accompanying variability in API practices across the IT industry, as well as in geospatial APIs specifically, has created new opportunities and challenges in supporting geospatial services. The application of standards in APIs to ensure interoperability is an apparent next step - (API CDS Press Release).
Map projections: fit for purpose	Best Practice 8: State how coordinate values are encoded. Provide enough information for users to determine how coordinate values are encoded - (SDWWG Best Practice).
Web Scale Programming	Web scale platforms hosted on large cloud services with web-friendly techniques, enable extreme levels of service delivery as compared to many of their enterprise counterparts.

Title	Description
Linked Data	Linked Data refers to a method of publishing structured data that can be interlinked. It builds upon standard Web technologies such as HTTP, RDF and URIs. It enables data from different sources to be connected and queried - (DSTL).

Chapter 7. New Geo Data Sources (SRC)

New sensor technologies, sensor platforms and new observers

Title	Description
Internet of Things (and sensor webs)	The internet of things (IoT) is the inter-networking of physical devices, vehicles (also referred to as "connected devices" and "smart devices"), buildings and other items—embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data (DSTL).
Smallsats	MicroSatellite is referring to small and compact satellites. They are often the size of two shoe boxes (smaller than 50kg in weight). (DSTL) Planet “will be imaging the entirety of Earth’s earth daily.” (Wired).
UXS and Drones	While large UAVs have been in use for defense, ISR, and remote sensing purposes for many years, the platforms now range in complexity from large, jet-propelled aircraft to palm-sized drones. Similarly, Unmanned Underwater Vehicles (UUVs) also have a long history of operations, becoming increasingly sophisticated in recent years with respect to capabilities and autonomy - (OGC WG Charter).
High-altitude platforms	High-Altitude Platforms (HAPs) are aircraft or airships that operate in the stratosphere at altitudes of up to 22 km, typically to provide communication facilities that can exploit both terrestrial and satellite schemes (IEEE)
Crowdsourcing and VGI	Geo Crowdsourcing includes Social Media and Voluntary Geographic Information (VGI). Crowdsourcing refers to the process of obtaining geo inspired services, ideas, or content by soliciting contributions from a large group of people, especially an online community, rather than from employees or suppliers (DSTL). VGI) is the harnessing of tools to create, assemble, and disseminate geographic data provided voluntarily by individuals (Goodchild, 2007). VGI is a special case of crowdsourcing.

Title	Description
Opportunistic Sensing	An opportunistic sensing approach is proposed, where noise-level data is collected without informing smartphone users.
Open Data	“Open data and content can be freely used, modified, and shared by anyone for any purpose” http://opendefinition.org/.

Chapter 8. Human-System Integration (HSI)

Human Systems Integration (HSI) is the relationship between humans and their environment and how systems are design and used relative to that relationship. The principle goal is to ensure a safe and effective relationship between humans and system. HSI increases the efficiency, usability, and quality of its products because human needs have been considered from the beginning

Title	Description
Location Based Services	Location-based services (LBS) are computer applications (specifically, mobile computing applications) that provide information depending on the location of the device and the user, mostly through mobile portable devices (e.g., smartphones) and mobile networks
Immersive Geo: AR, VR, MR	Virtual reality (VR) refers to computer technologies that use software to generate realistic images, sounds and other sensations that replicate a real environment. Augmented reality (AR) is a live direct or indirect view of a physical, real-world environment whose elements are augmented by computer-generated sensory input such as sound, video, graphics or GPS data.
Automobile as Platform	Maps and Apps for Automotive: The battle around connected cars and autonomous driving will continue this year. Both are impossible without geospatial technology. Hyper-precise and up-to-date maps as well as real-time analytics of sensor data are just two examples. We will see a lot of geo-enabled apps that get integrated into the car (GeoAwesomness).
Ambient services	Ambient intelligence (AmI) refers to electronic environments that are sensitive and responsive to the presence of people. In an ambient intelligence world, devices work in concert to support people in carrying out their everyday life activities, tasks and rituals in an easy, natural way using information and intelligence that is hidden in the network connecting these devices (see Internet of Things). As these devices grow smaller, more connected and more integrated into our environment, the technology disappears into our surroundings until only the user interface remains perceivable by users (Wikipedia).

Title	Description
AI Conversational Bots	Platforms that allow users to interact with software through conversation in natural language (or in nearly natural language).

Chapter 9. Information Technology (IT)

General software development platforms that may affect geospatial technology

Title	Description
GEO at Platform Scale	Today's networked platforms are able to achieve massive success by simply connecting producers and consumers. A platform allows for alignment of incentives of producers and consumers, vastly increasing the products created and then allowing quality control through curation and reputation management. Users of the platform should be able to pull raw information and easily produce their own GEO data and insights, then and contribute those back to the same repository for further analysis.
5G Cellular Communications	The promise of 5G networks is already propelling innovators to design new modes of communication. From remote robotic surgery to ultra-responsive autonomous cars, the 5G network leans into a world of higher reliability and lower latency.
Cloud, Fog, Edge Computing computing continuum	Fog computing is a system-level horizontal architecture that distributes resources and services of computing, storage, control and networking anywhere along the continuum from Cloud to Things (OpenFog Consortium).
Blockchain and distributed ledger	Distributed ledger technology based on cryptographic systems that manage, verify and publicly record transaction data; the basis of "cryptocurrencies" such as bitcoin - (World Economic Forum).
Quantum Computing	Quantum computing capabilities are are growing as the number of Qubits in an array grows. Algorithms based on qubits are being defined. As programming languages for Quantum Computing are developed the applications for geospatial applications are anticipated to emerge.

Title	Description
Software development innovations	Software Programming languages and development methods are rapidly changing. New programming languages drive new capabilities for geospatial information. Software development process improvements including collaborative cross-functional teams, adaptive planning, evolutionary development, and continuous integration.
Informational Self Determination and Privacy	The term informational self-determination was first used in the context of a German constitutional ruling relating to personal information collected during the 1983 census. The German Federal Constitutional Court ruled that: “[…] in the context of modern data processing, the protection of the individual against unlimited collection, storage, use and disclosure of his/her personal data is encompassed by the general personal rights of the German constitution. This basic right warrants in this respect the capacity of the individual to determine in principle the disclosure and use of his/her personal data. Limitations to this informational self-determination are allowed only in case of overriding public interest.”

Trends that have graduated or retired

Title	Description
Event-Driven: Pub-Sub	Publish–Subscribe is a messaging pattern where entities can subscribe to a type of message (defined by a criteria) and receive messages that satisfy that criteria from publishers as and when those messages become available (that is, as and when the events that satisfy that criteria occur).