The Golden Age of Geospatial Data Science and Engineering

Geospatial Data Science Distinguished Speaker Series
UIUC Department of Geography & GIS
Wednesday, February 6th, 2019

George Percivall
Chief Engineer and CTO
Open Geospatial Consortium
gpercivall@myogc.org

OGC®
Making location count.

My perspective

- Physics, remote sensing, systems engineering
- NASA weather satellite and information systems
- Standards for science and engineering
- OGC CTO

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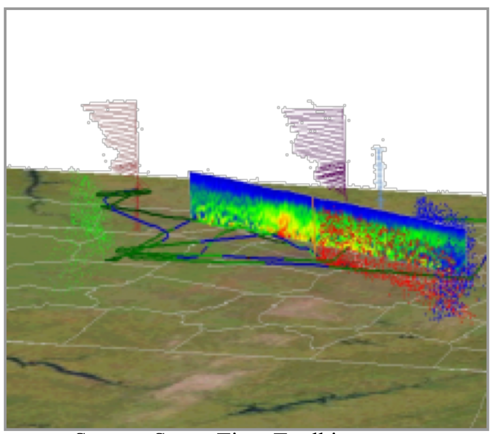
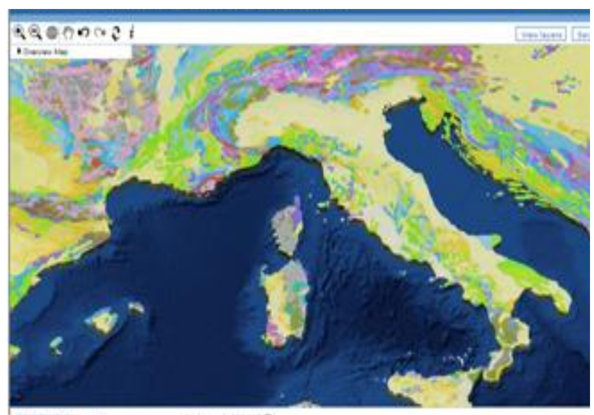
Mission of the Open Geospatial Consortium

Global forum of developers and users of spatial data products and services

Open international standards for geospatial interoperability.


Source: Space Time Toolkit


Source: One Geology


Source: 3d Stadtmodell Berlin

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Basic Geospatial Interoperability Challenge Solved

1000s of Services, 100Ks Datasets Worldwide Implement OGC Standards

Web Map Service (WMS)

Web Feature Service (WFS)

Web Coverage Service (WCS)

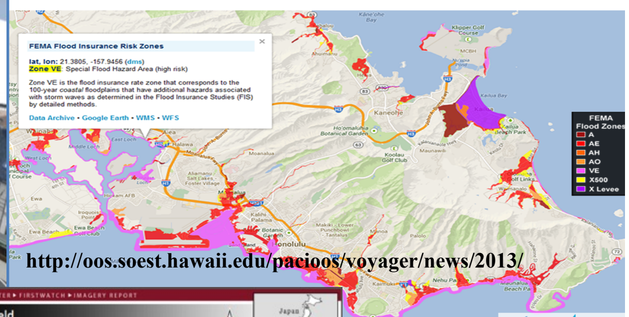
KML, GML, GeoPackage

GeoTIFF, NetCDF, HDF

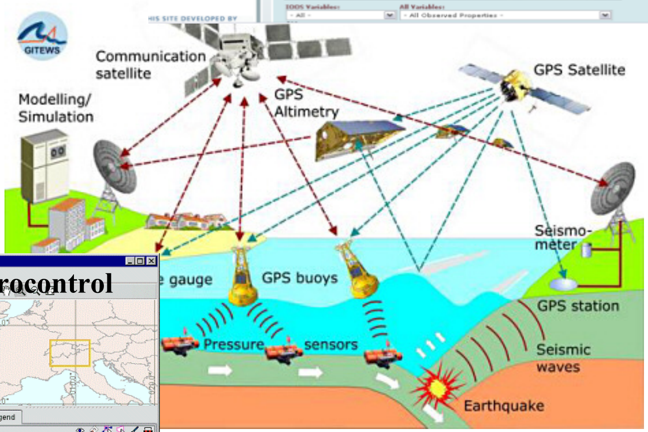
OneGeology.Org

OpenIOOS.Org

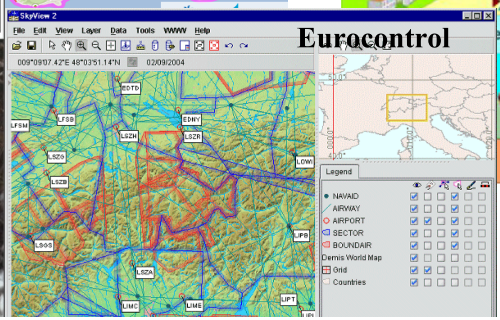
CityGML



http://oos.soest.hawaii.edu/pacioos/voyager/news/2013/



DigitalGlobe



Eurocontrol

Emergency / Disaster Management

Meteorology, Hydrology, Ocean Monitoring

Aviation Flight Information / Safety

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The FOURTH PARADIGM

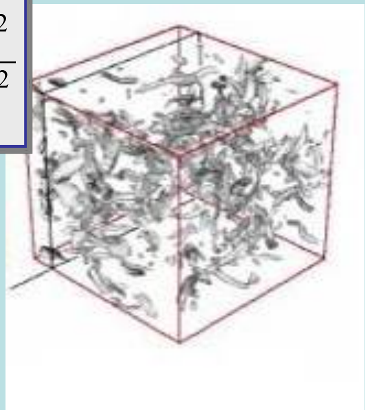
DATA-INTENSIVE SCIENTIFIC DISCOVERY

EDITED BY TONY HEY, STEWART TANSLEY, AND KRISTIN TOLLE

Science Paradigms

- Thousand years ago:
  science was **Empirical**
  describing natural phenomena
- Last few hundred years:
  Theoretical branch
  using models, generalizations
- Last few decades:
  a **Computational** branch
  simulating complex phenomena
- Today:
  Data Exploration
  - Data captured by instruments
    Or generated by simulator
  - Scientist analyzes database / files
    using data management and statistics

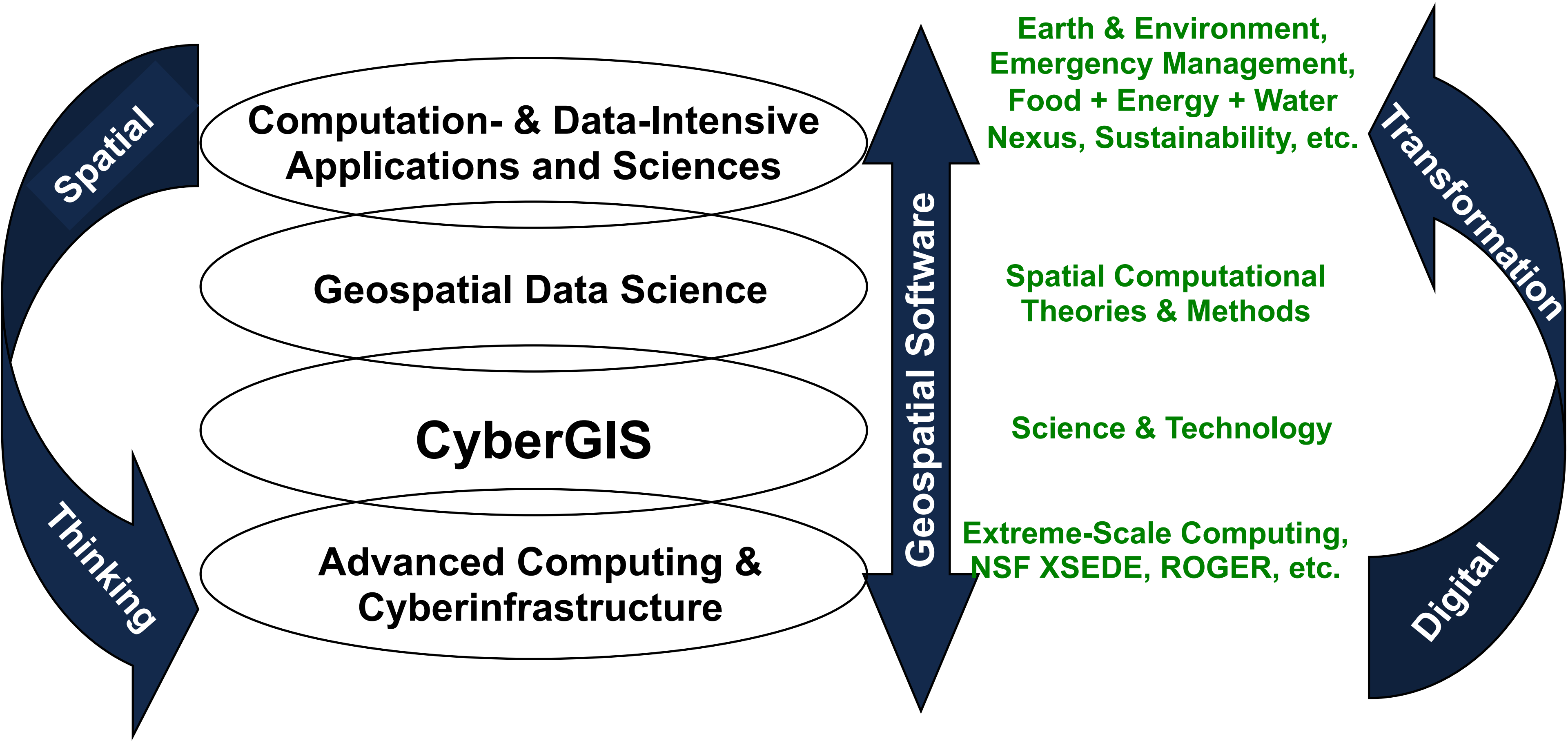
$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{4\pi G\rho}{3} - K\frac{c^2}{a^2}$$



http://research.microsoft.com/en-us/um/people/gray/talks/NRC-CSTB_eScience.ppt.

GSI

Fostering a Sustainable Geospatial Discovery and Innovation Ecosystem



Source: Professor Shaowen Wang, NSF GSI Incubator Workshop, July 2018

Geospatial Data Science

- Increasing data sources and volumes
- Geospatial coverages and analytics
- Semantics and linked data
- Cloud computing
- Machine learning

Progression of Geospatial Information

Region-Centric Geospatial Information

1980s

→

Feature-Centric Geospatial Information

1990s

→

Human-Centric Geospatial Information

2000s

→

Device-Centric Geospatial Information

2010s

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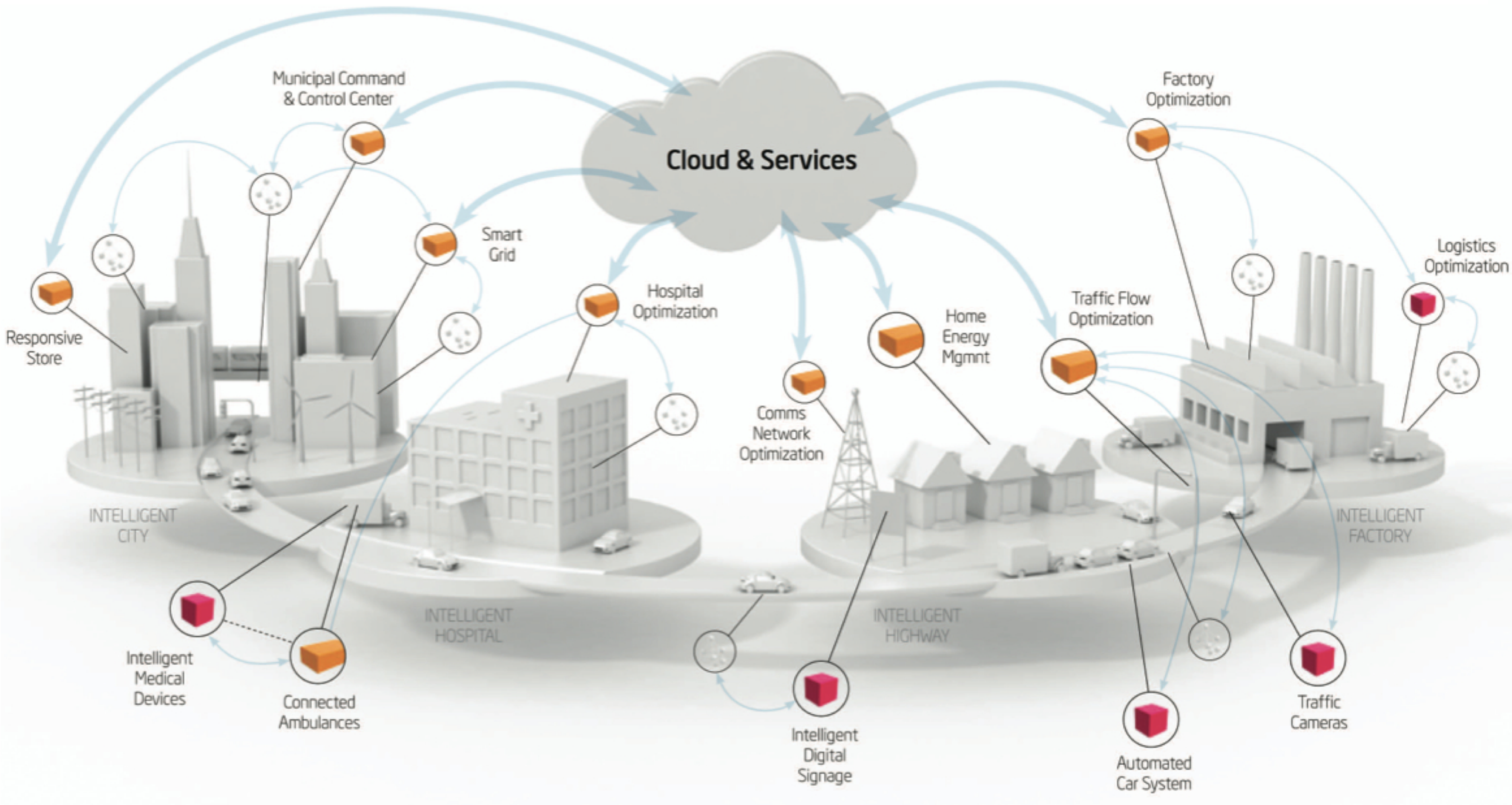
50 billions Internet-connected things by 2020

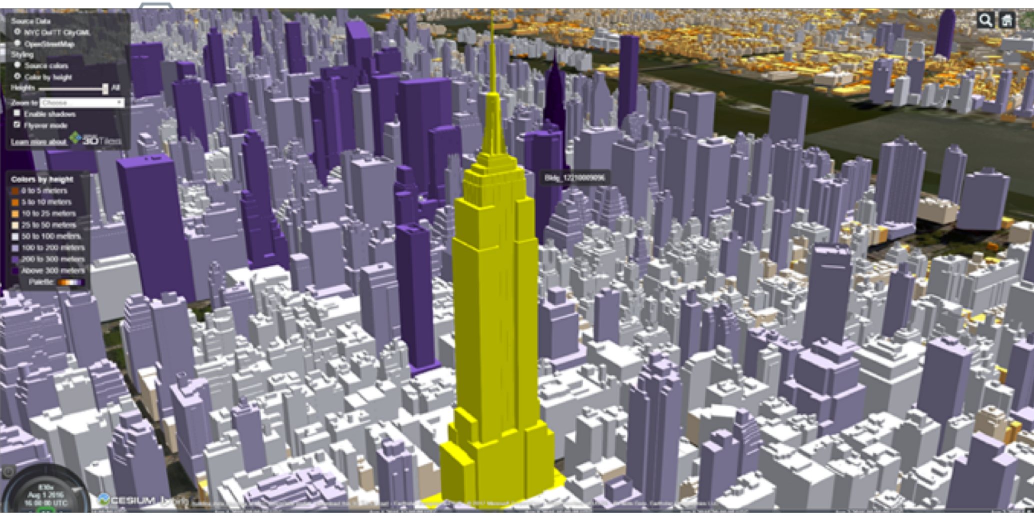
Sensors Everywhere

(Things or Devices)



Slide source: Steve Liang, Univ. Calgary

Urban Models, Sensors, Applications



Source: http://www1.nyc.gov/site/doitt/initiatives/3d-building.page

Source: Singapore Land Authority, and Geospatial Media

CityGML models for 3D visualization and analysis based on semantics

- Urban Planning / Operations
- Emergency Mgt / Response
- Transportation / Logistics
- Indoor navigation
- Retail Site analysis
- Sustainable / Green Communities
- City Services Management
- Noise abatement
- Telecommunications placement
- Many other uses…

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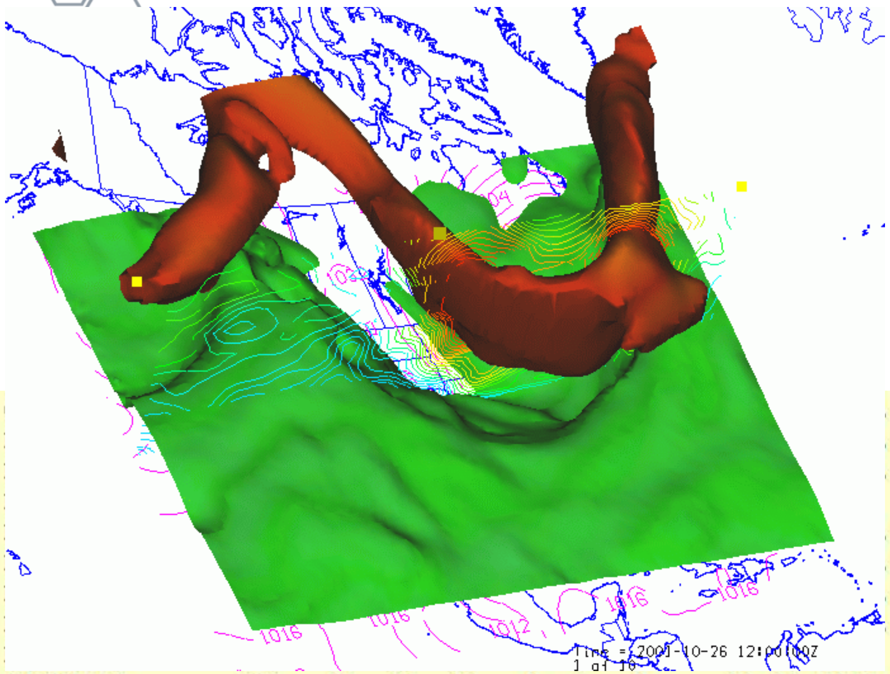
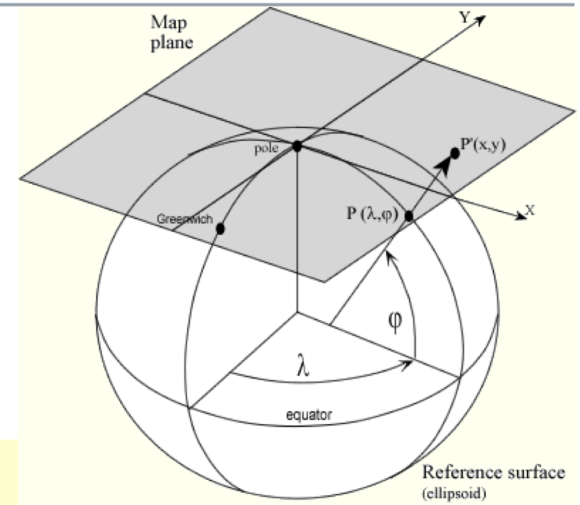
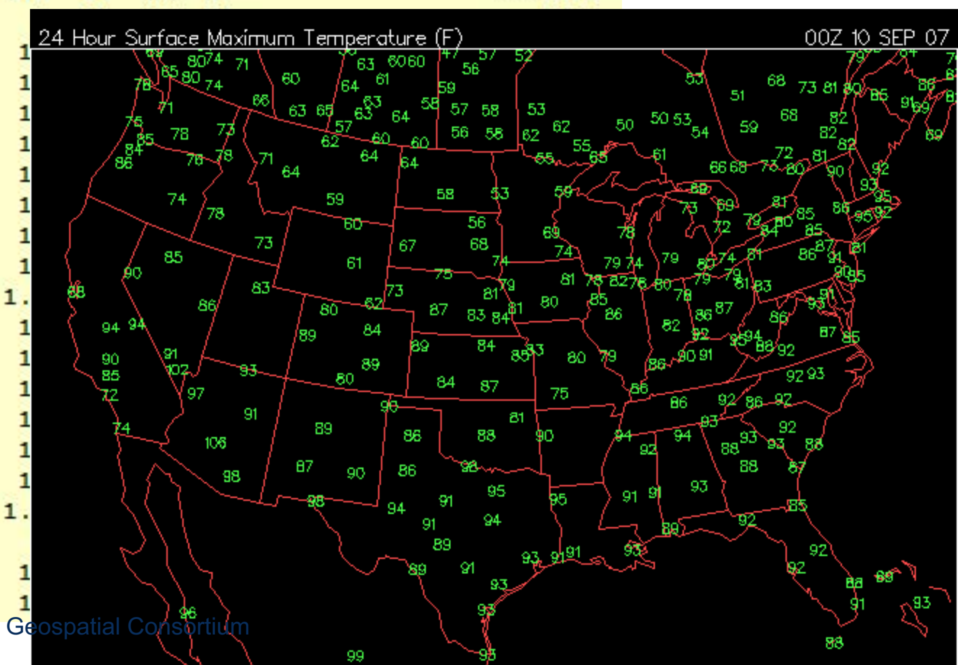
Climate and Weather Observations





6	10		CLR		
0	10		CLR		
2	8	30	OVC		...KDHT
	6	40	OVC	H	...KADS
8	2.0	45	OVC	R-	...KDFW
8					
0	1				
6	1				
	1				

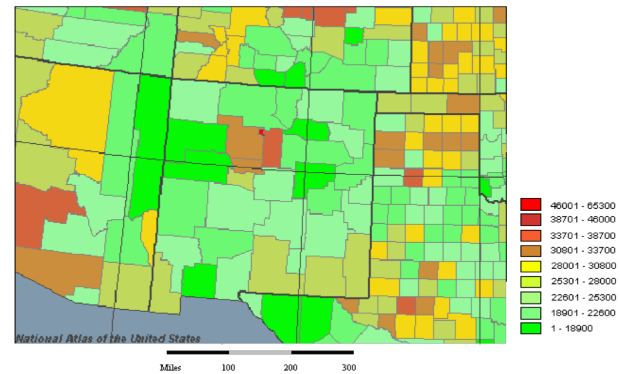
DANVILLE	VA	87	65	48	0	at	0		30.02	1015.5	1
DARLINGTON CNTY	SC	91	66	44	190	at	7		30.06		1
DAVENPORT/QUAD	IA	68	60	76	0	at	0		30.09	1018.8	1
DAYTON	OH	74	62	67	0	at	0		30.09	1018.2	1
DAYTONA BEACH	FL	88	70	55	200	at	5		30.10	1019.1	1
DEADHORSE	AK	45	39	81	230	at	10		29.80	1009.2	1.
DECATUR	IL	80	63	56	0	at	0		30.05	1017.2	1
DEL RIO	TX	84	73	68	170	at	6		30.05	1016.0	1
DEL RIO INTL	TX	84	73	70	130	at	7		30.03	1015.3	1
DEMING	NM	75	59	58	80	at	3		30.20	1016.2	1
DENISON	IA	55	52	88	360	at	7		30.26		1
DENVER/CENTEN	CO	49	44	83	10	at	6		30.42	1028.2	1
DENVER/INTNL	CO	48	46	93	10	at	6		30.43	1027.5	1.
DES MOINES	IA	56	54	93	360	at	6		30.16	1021.3	1
DETROIT CITY	MI	70	59	68	0	at	0		30.09	1018.8	1
DETROIT LAKES	MN	61	41	48	250	at	10	15	30.15		1

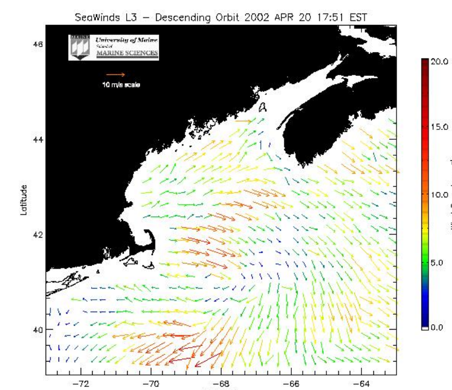


Slide Source: Ben Domenico

Geospatial Coverages

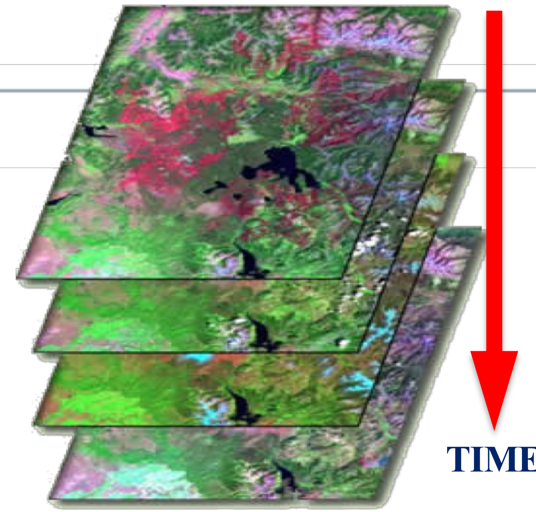
- Coverage Data Structure
  - “spatial function” or “field”
  - Spatial Domain to Values Range
- Continuous Coverage
  - Positions return a value
  - May involve Interpolation
  - *e.g., predictive model outputs*
- Discrete Coverage
  - associate a single value to all positions within a given Geometry Value Object
  - *e.g., imagery, land use*





Geospatial Data Cubes

http://www.datacube.org.au

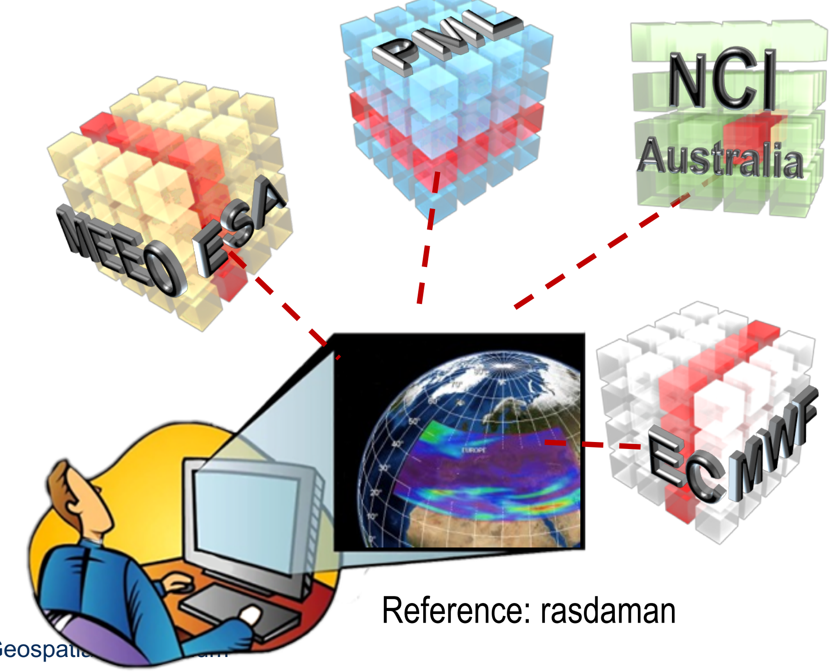


- Data Cube:
  4D space/time Coverages;
  Efficient access and analysis

- Analysis Ready Data:
  Processed products
  with methods to reduce
  burden on users

- Federation based on
  open standards

Geospatial Data Cube Federation



Reference: rasdaman

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Earth Science Data Analytics

- Process of examining, preparing, reducing, and analyzing large amounts of spatial (multi-dimensional), temporal, or spectral data encompassing a variety of data types to uncover patterns, correlations and other information, to better understand our Earth.

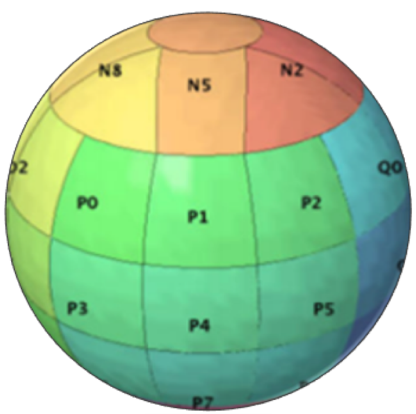
Source: Earth Science Information Partners (ESIP), July 2016

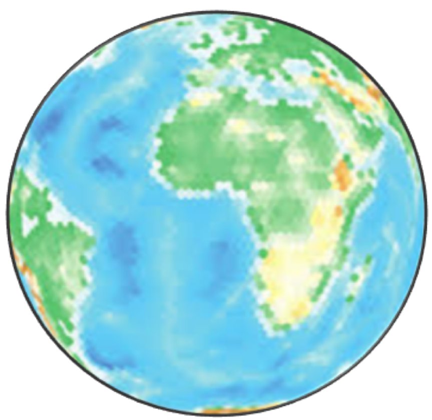
Discrete Global Grid Systems

"…a ***spatial reference system*** *that uses a* ***hierarchical tessellation of cells*** *to partition and* ***address the globe****.*

DGGS are characterized by the properties of their cell structure, geo-encoding, quantization strategy and associated mathematical functions."

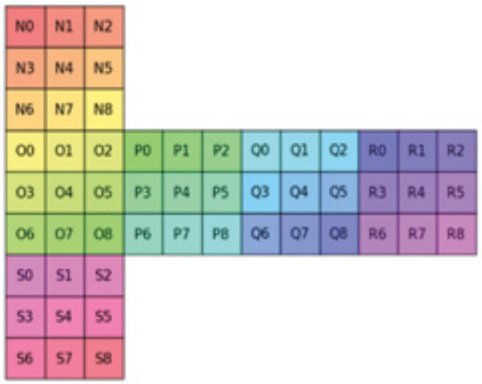
– OGC DGGS Standard



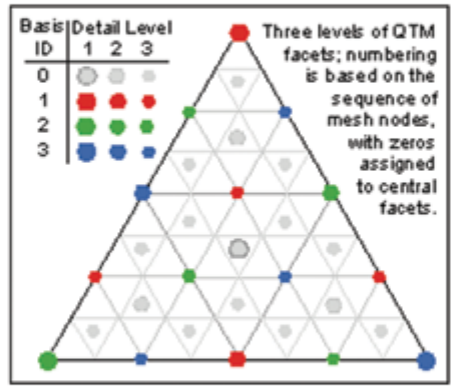


Standardising Discrete Global Grid Systems

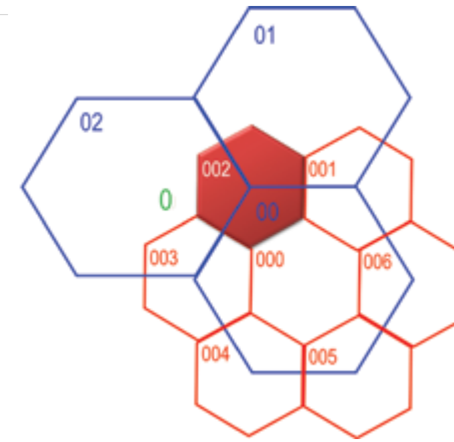
Different Cell Shapes



Square = Familiar



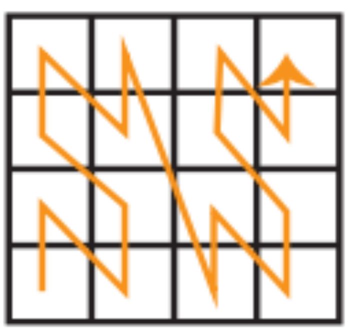
Triangular = Fast



Hexagonal = Fineness of Fit

Unique Cell Indices

- ***Hierarchy-based, Space-filling Curve, Axes-based or Encoded Address***



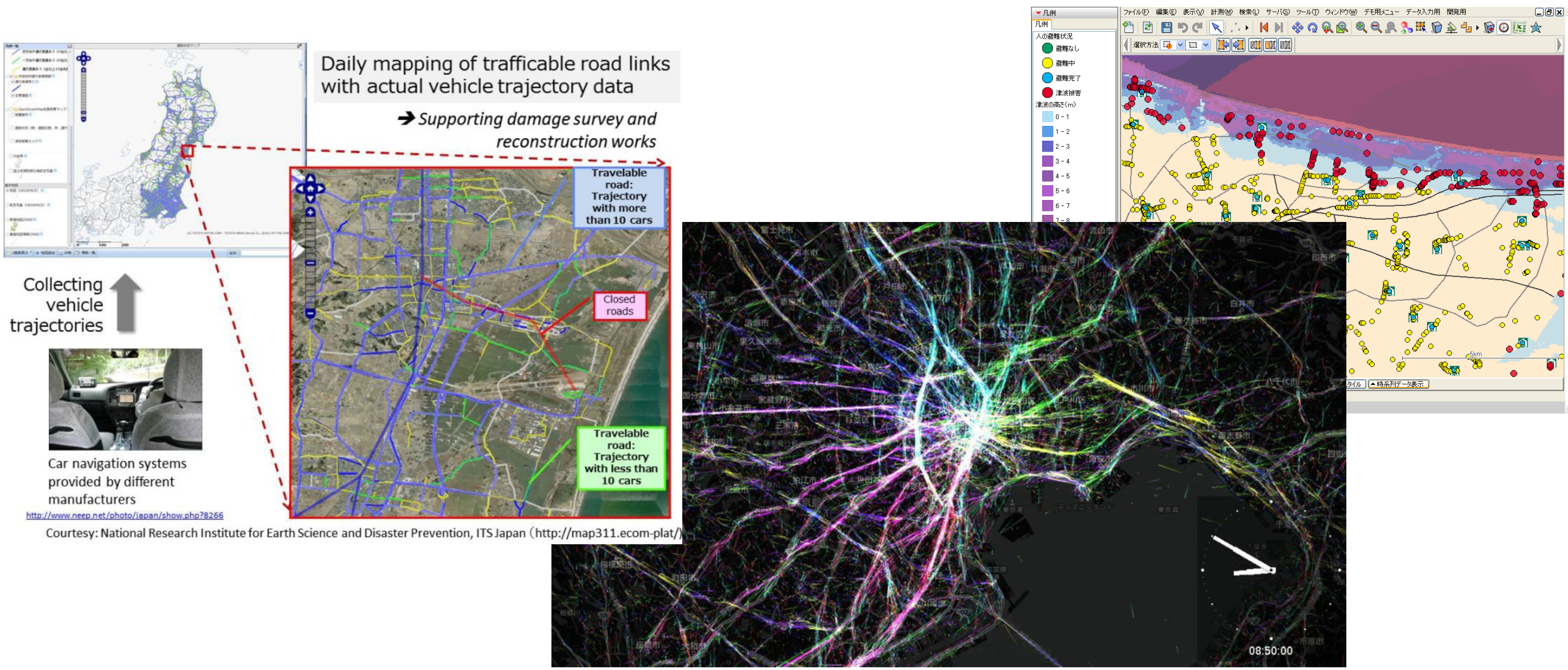
11	13	31	33
10	12	30	32
01	03	21	23
00	02	20	22

nD Spatial Analyses
↓
1D Array Processes

00	01	02	03	10	11	12	13	20	21	22	23	30	31	32	33

OGC Moving Features Standard

"Moving features" data describes such things as vehicles, pedestrians, airplanes and ships.



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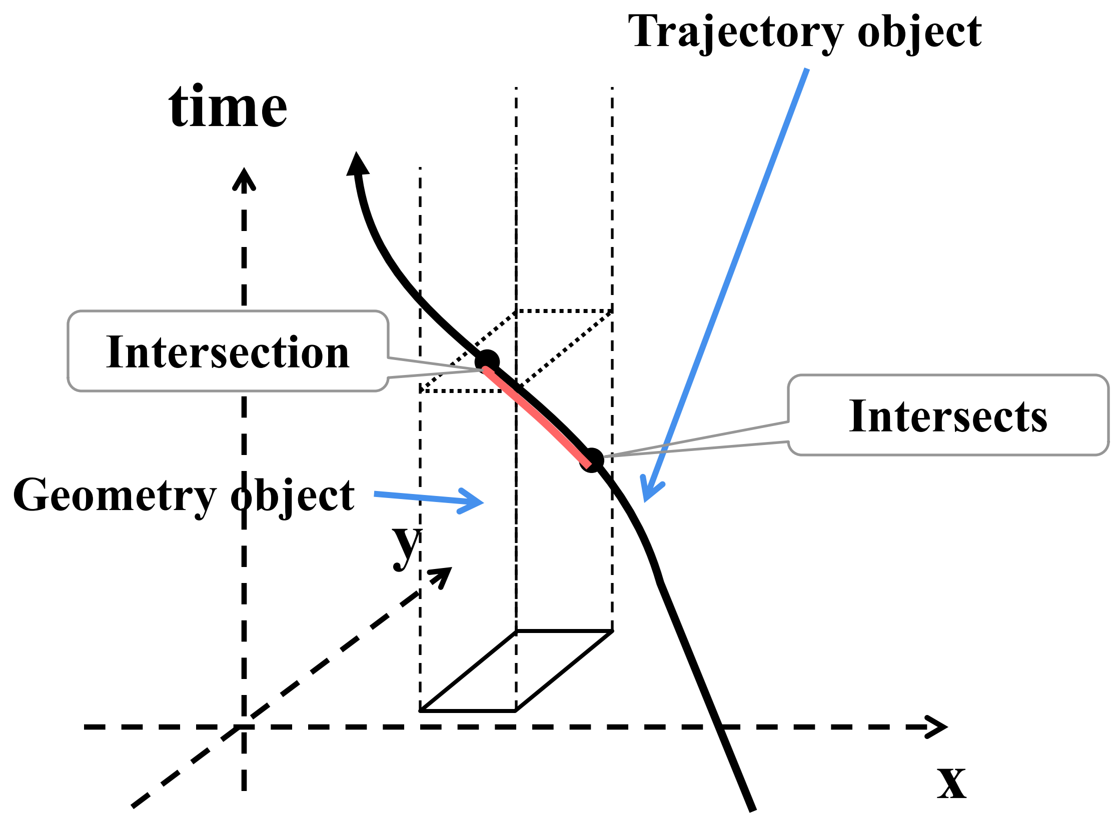
Moving Features: one trajectory, one geometry

Operations between a trajectory object and a **geometry** object of which geometry is stable

Examples:

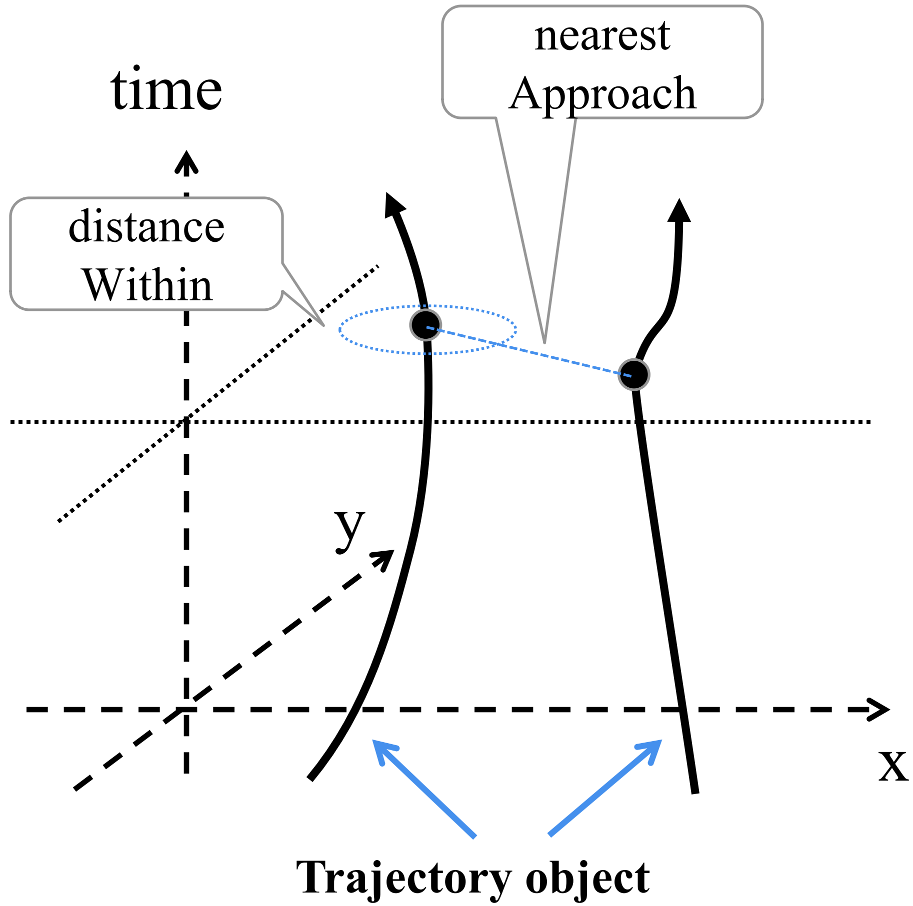
- ***intersects***
- ***distanceWithin***
- ***intersection***



Moving Features: Two trajectories

Operations between two trajectory objects from the spatio-temporal viewpoint

Examples:
- *distanceWithin*
- *intersection*
- *nearestApproach*



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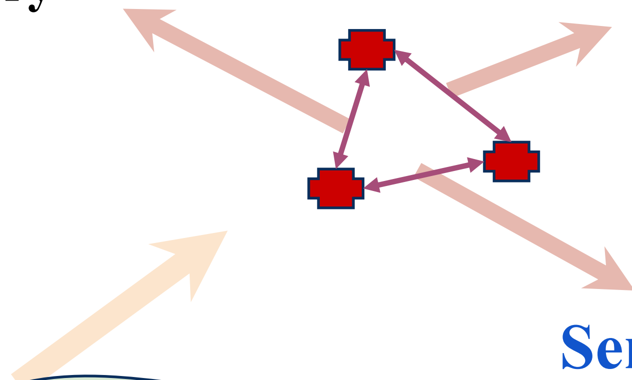
Spatial Semantic Web

Spatial Topological Relations

- hasGeometry
- isPartOf
- overlaps

Knowledge Web Relations

- describes
- owns
- property Of



Semantic Logic Relations (ForAll, ThereExists)

- isA
- IfAndOnlyIf
- functionalProperty

HTML - RDF/JSON - Javascript

HTTP - URI

TCP/IP

Web Foundations

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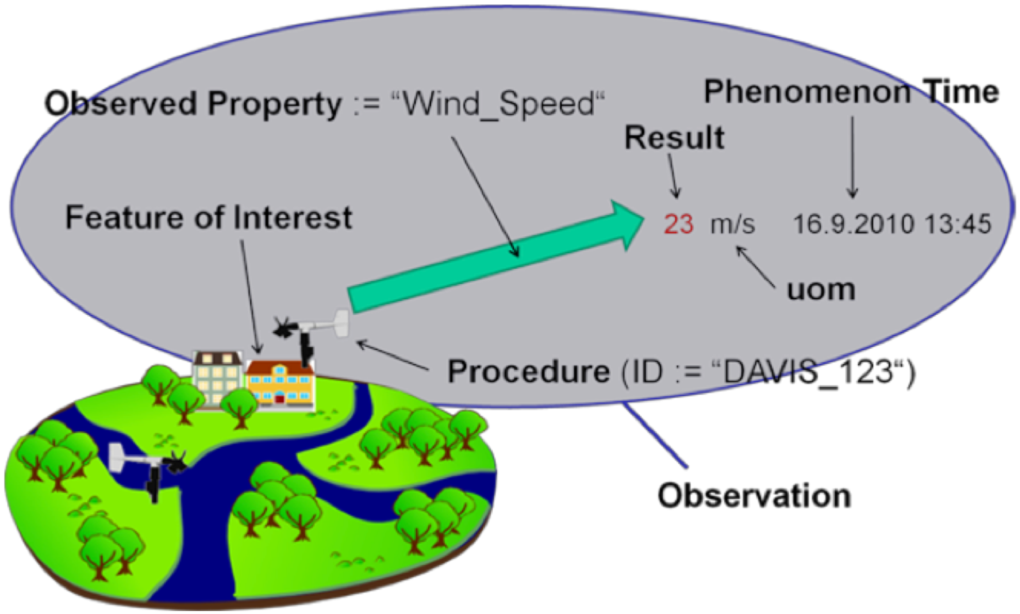
Observations and Measurements

- OGC SWE* defines Observations, relevant entities, and their relationships
- Syntactic interoperability and Semantic interoperability



***OGC Sensor Web Enablement (SWE) Standards deployed in operational implementations for more than a decade**

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Semantic Sensor Network Ontology

- An OWL-2 DL ontology
- Relationships between sensors/ actuators/ sampling and observations/ actuations/samplings
- Modular architecture for judicious use of "just enough" semantics for diverse applications
- Aligned with OGC/ISO Observations and Measurements

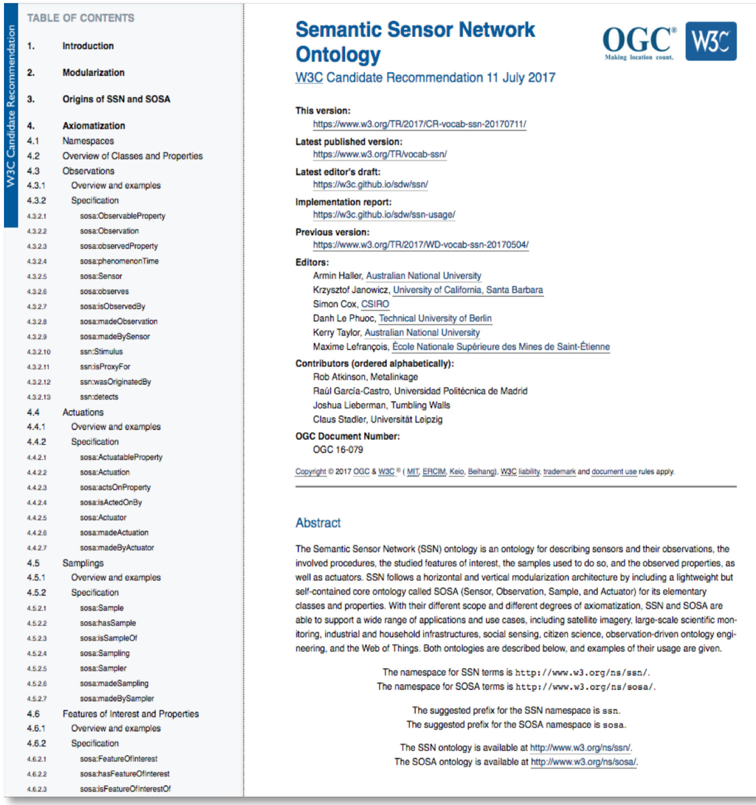
W3C Candidate Recommendation

TABLE OF CONTENTS

Semantic Sensor Network Ontology

W3C Candidate Recommendation 11 July 2017

This version:
https://www.w3.org/TR/2017/CR-vocab-ssn-20170711/

Latest published version:
https://www.w3.org/TR/vocab-ssn/

Latest editor's draft:
https://w3c.github.io/sdw/ssn/

Implementation report:
https://w3c.github.io/sdw/ssn-usage/

Previous version:
https://www.w3.org/TR/2017/WD-vocab-ssn-20170504/

Editors:
Armin Haller, Australian National University
Krzysztof Janowicz, University of California, Santa Barbara
Simon Cox, CSIRO
Danh Le Phuoc, Technical University of Berlin
Kerry Taylor, Australian National University
Maxime Lefrançois, École Nationale Supérieure des Mines de Saint-Étienne

Contributors (ordered alphabetically):
Rob Atkinson, Metalinkage
Raúl García-Castro, Universidad Politécnica de Madrid
Joshua Lieberman, Tumbling Walls
Claus Stadler, Universität Leipzig

OGC Document Number:
OGC 16-079

Abstract

The Semantic Sensor Network (SSN) ontology is an ontology for describing sensors and their observations, the involved procedures, the studied features of interest, the samples used to do so, and the observed properties, as well as actuators. SSN follows a horizontal and vertical modularization architecture by including a lightweight but self-contained core ontology called SOSA (Sensor, Observation, Sample, and Actuator) for its elementary classes and properties. With their different scope and different degrees of axiomatization, SSN and SOSA are able to support a wide range of applications and use cases, including satellite imagery, large-scale scientific monitoring, industrial and household infrastructures, social sensing, citizen science, observation-driven ontology engineering, and the Web of Things. Both ontologies are described below, and examples of their usage are given.

The namespace for SSN terms is `http://www.w3.org/ns/ssn/`.
The namespace for SOSA terms is `http://www.w3.org/ns/sosa/`.

The suggested prefix for the SSN namespace is `ssn`.
The suggested prefix for the SOSA namespace is `sosa`.

The SSN ontology is available at http://www.w3.org/ns/ssn/.
The SOSA ontology is available at http://www.w3.org/ns/sosa/.

https://www.w3.org/TR/vocab-ssn/
https://portal.opengeospatial.org/files/74883

Allen Temporal Interval Algebra

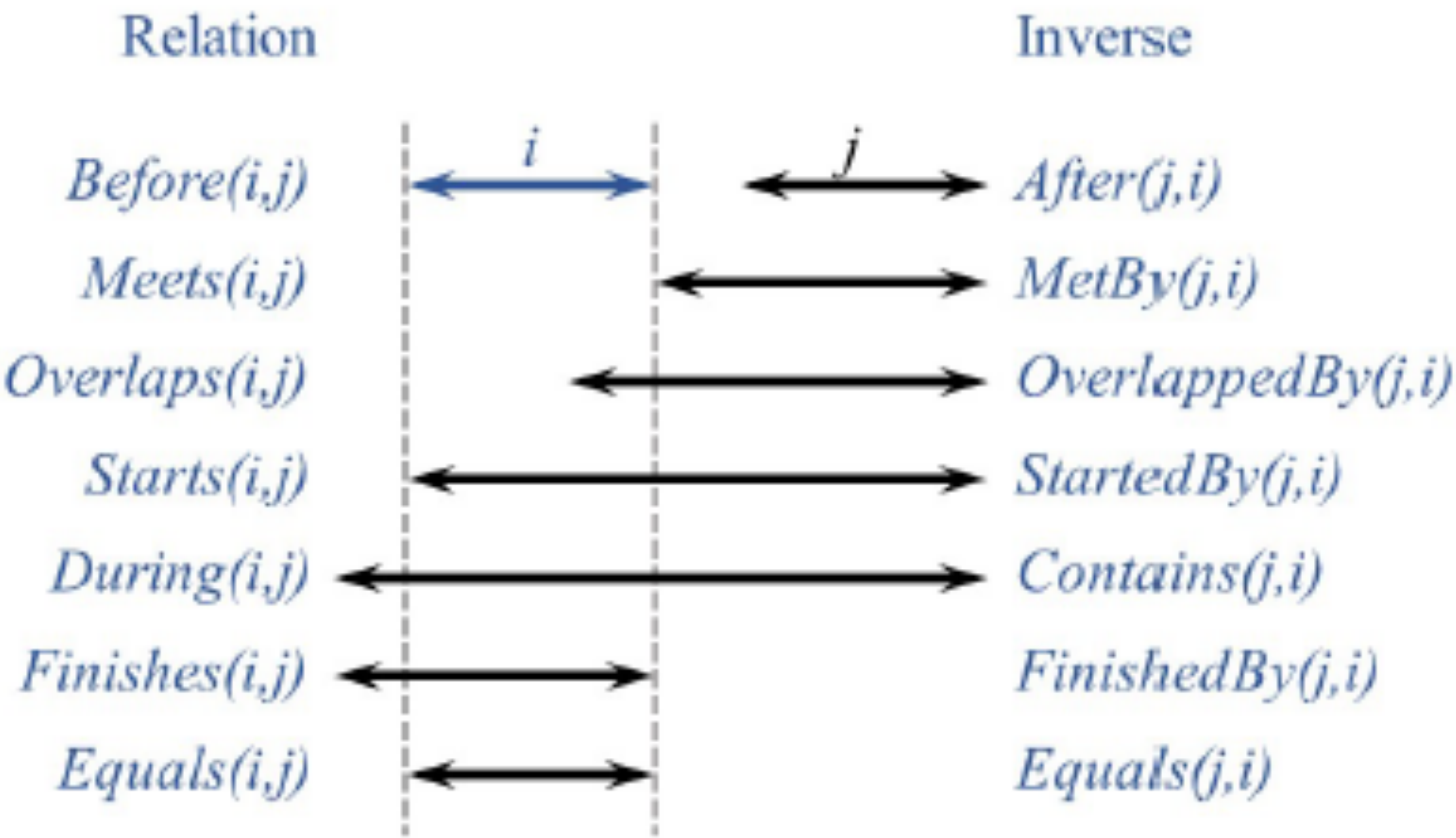

Fig. 2 The possible relations between time periods [AF-97]

Data Science and Cloud

- Methods, processes, algorithms to extract knowledge or insights from data in various forms, either structured or unstructured
  - Unifies statistics, data analysis, machine learning, related methods
  - ”Fourth paradigm" of science:
    empirical, theoretical, predictive models and now data-driven
- Data Science with Cloud Computing
  - Large Datasets stored in clouds
  - Data analysis using cloud capabilities
  - Python and R

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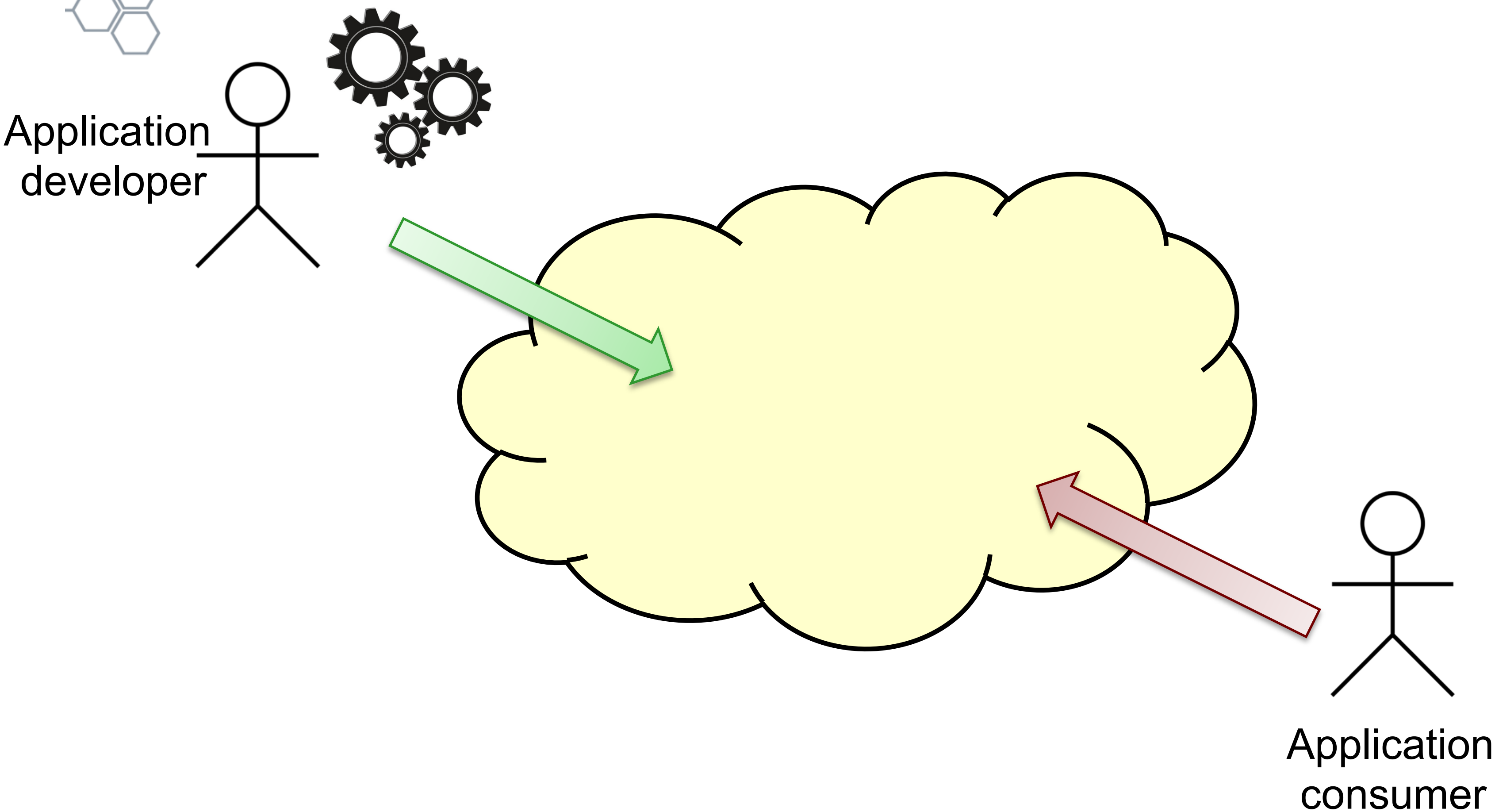
Cloud Computing



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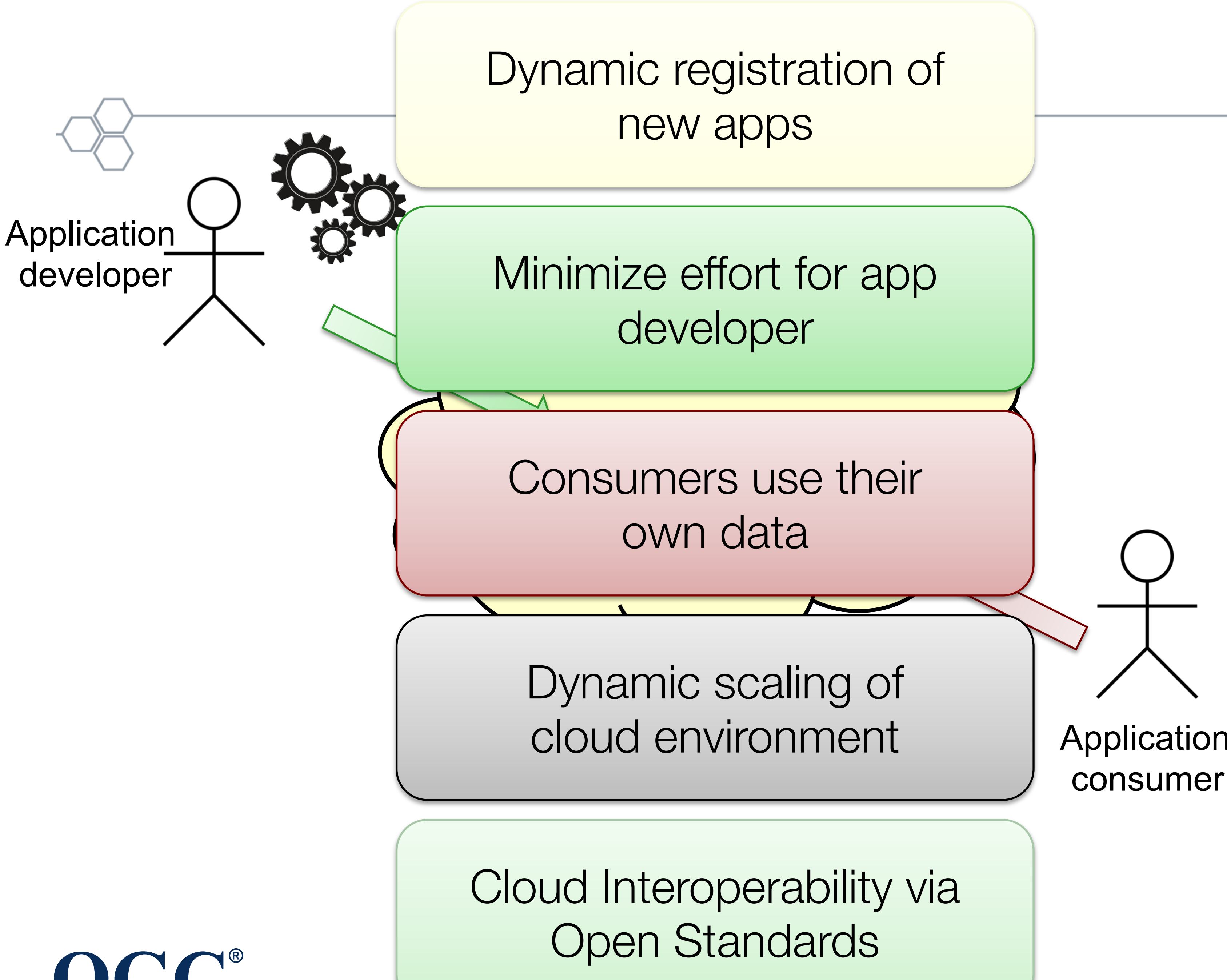
Dynamic registration of new apps
Application developer
Minimize effort for app developer
Consumers use their own data
Dynamic scaling of cloud environment
Application consumer
Cloud Interoperability via Open Standards

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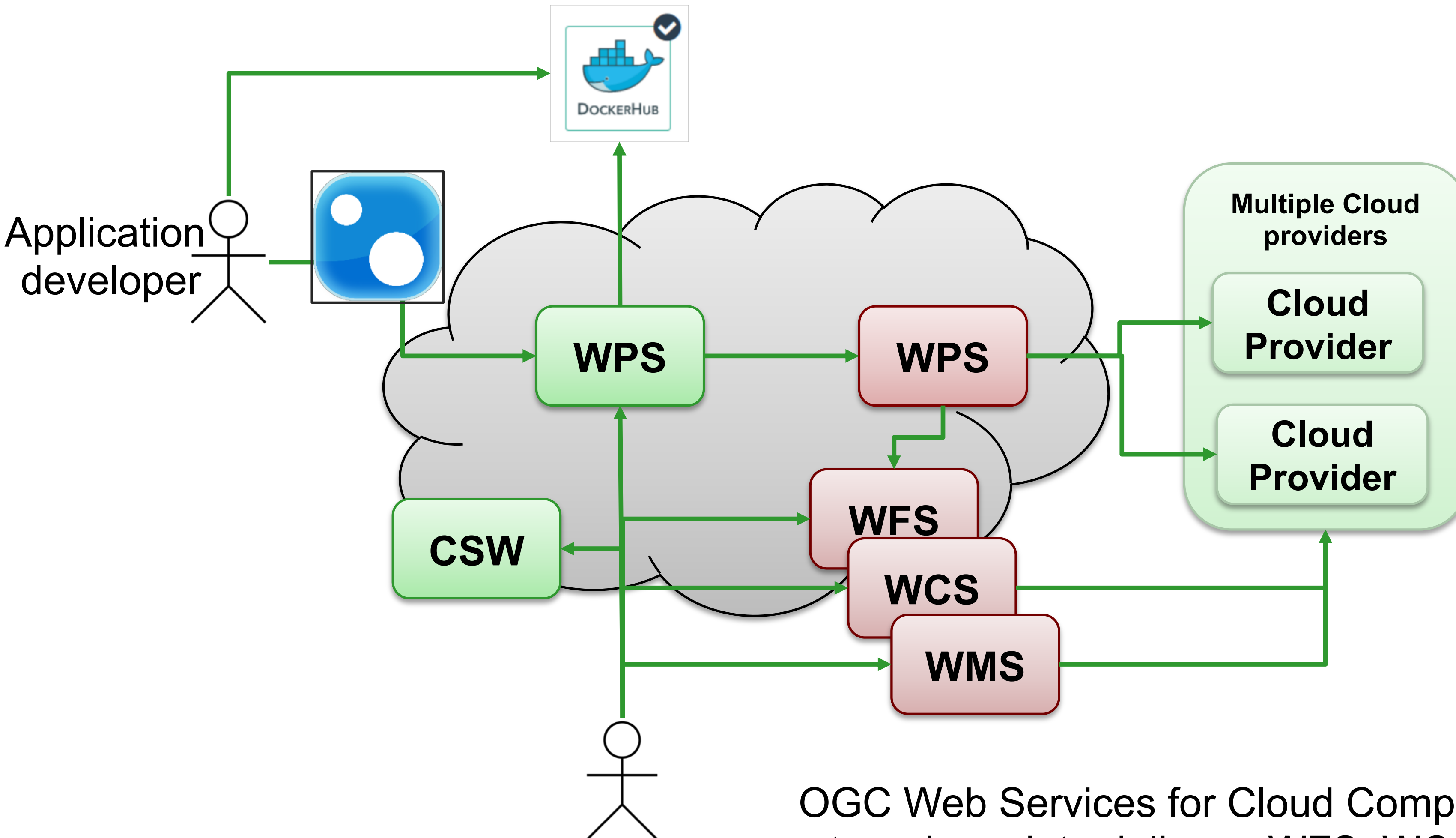
Interoperability and portability between clouds using OGC Web Services



OGC Web Services for Cloud Computing:

- to reduce data delivery: WFS, WCS
- server side portrayal: WMS, WMTS
- server-side processing: WPS, WCPS

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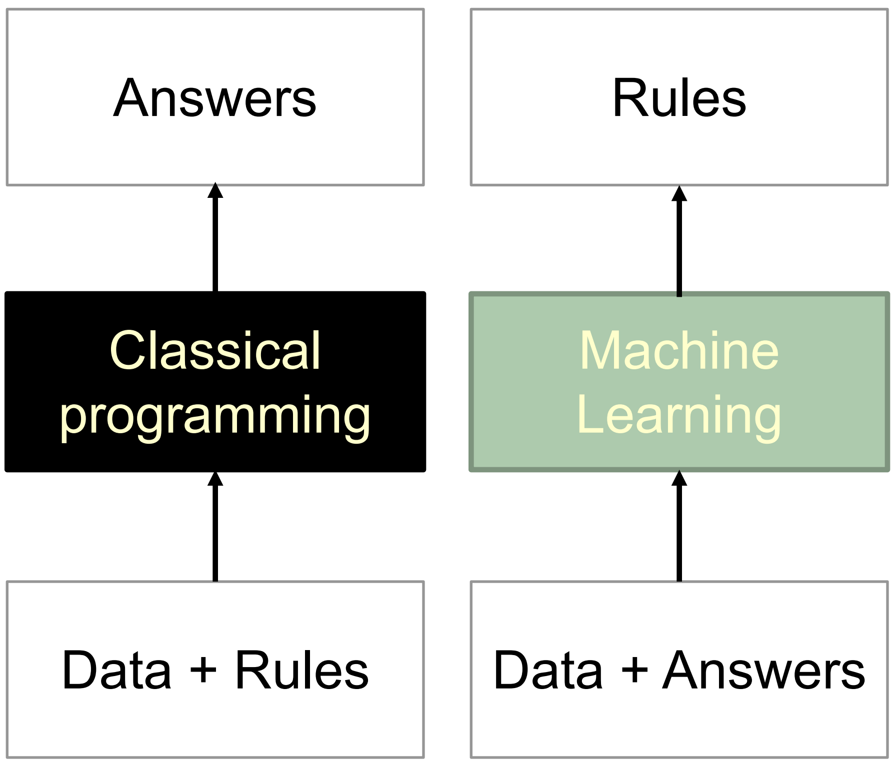
Machine Learning

Programming vs. Machine Learning



ImageNet and CNNs

ImageNet Classification with Deep Convolutional Neural Networks (CNNs)
Source: KSH, NIPS 2012

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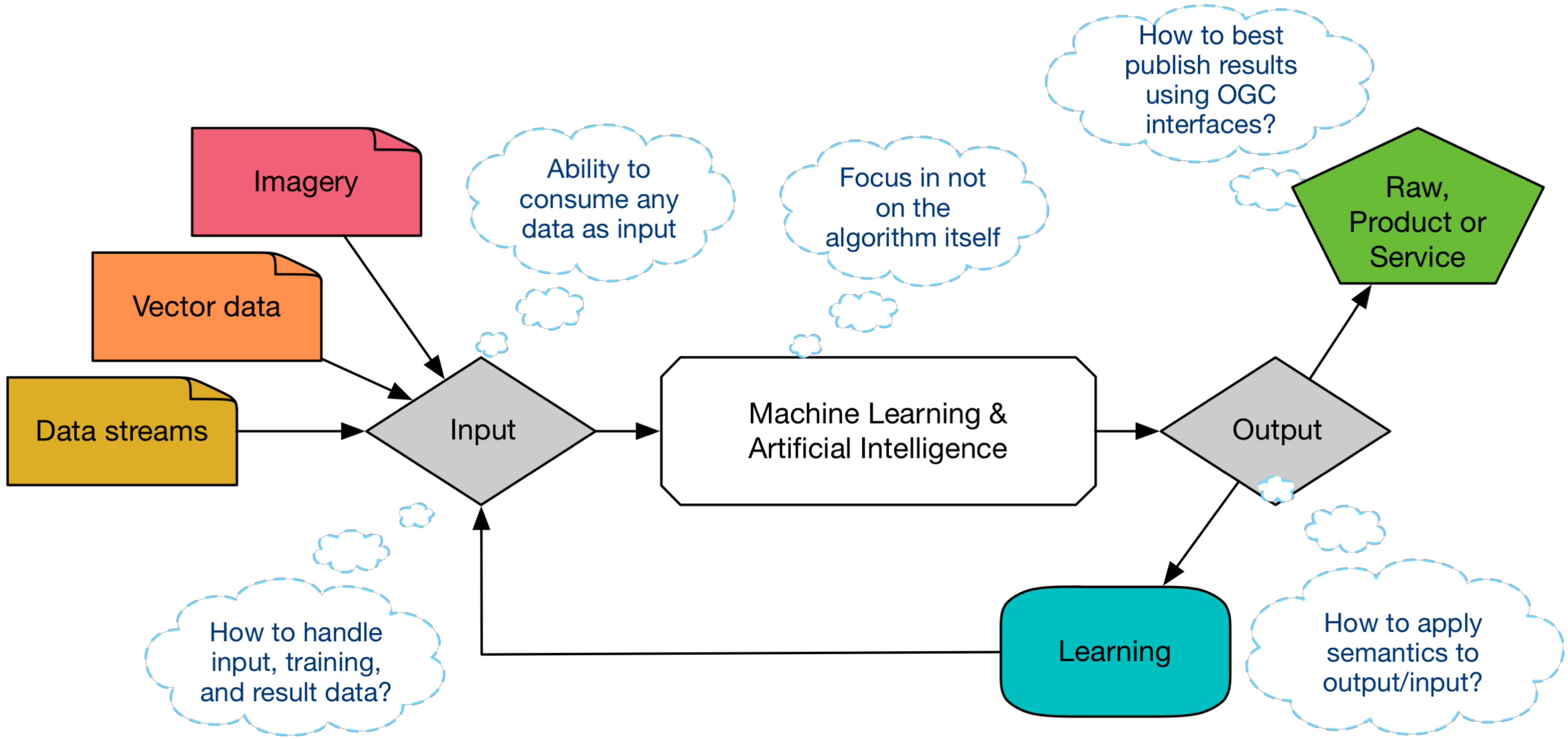
ML&AI applied to Geospatial Data



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Human-Machine Partnership

"An integrated domain where hunches, cut-and-try, intangibles, and the human 'feel for a situation' usefully co-exist with . . . high-powered electronic aids."

– Douglas Engelbart, 1962

"Perhaps no matter how fast computers progress, artificial intelligence may never outstrip the intelligence of the human-machine partnership."

– Walter Isaacson, 2014

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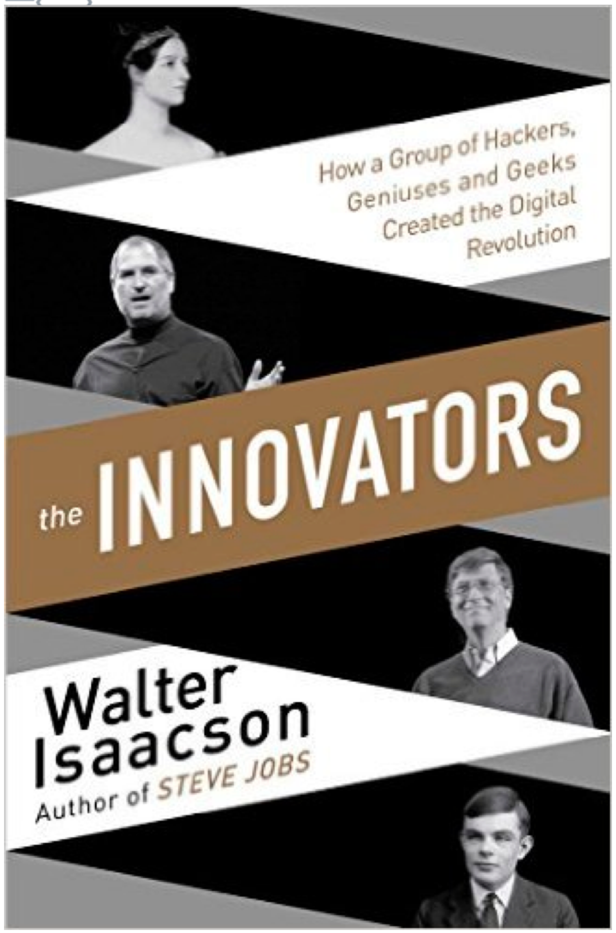
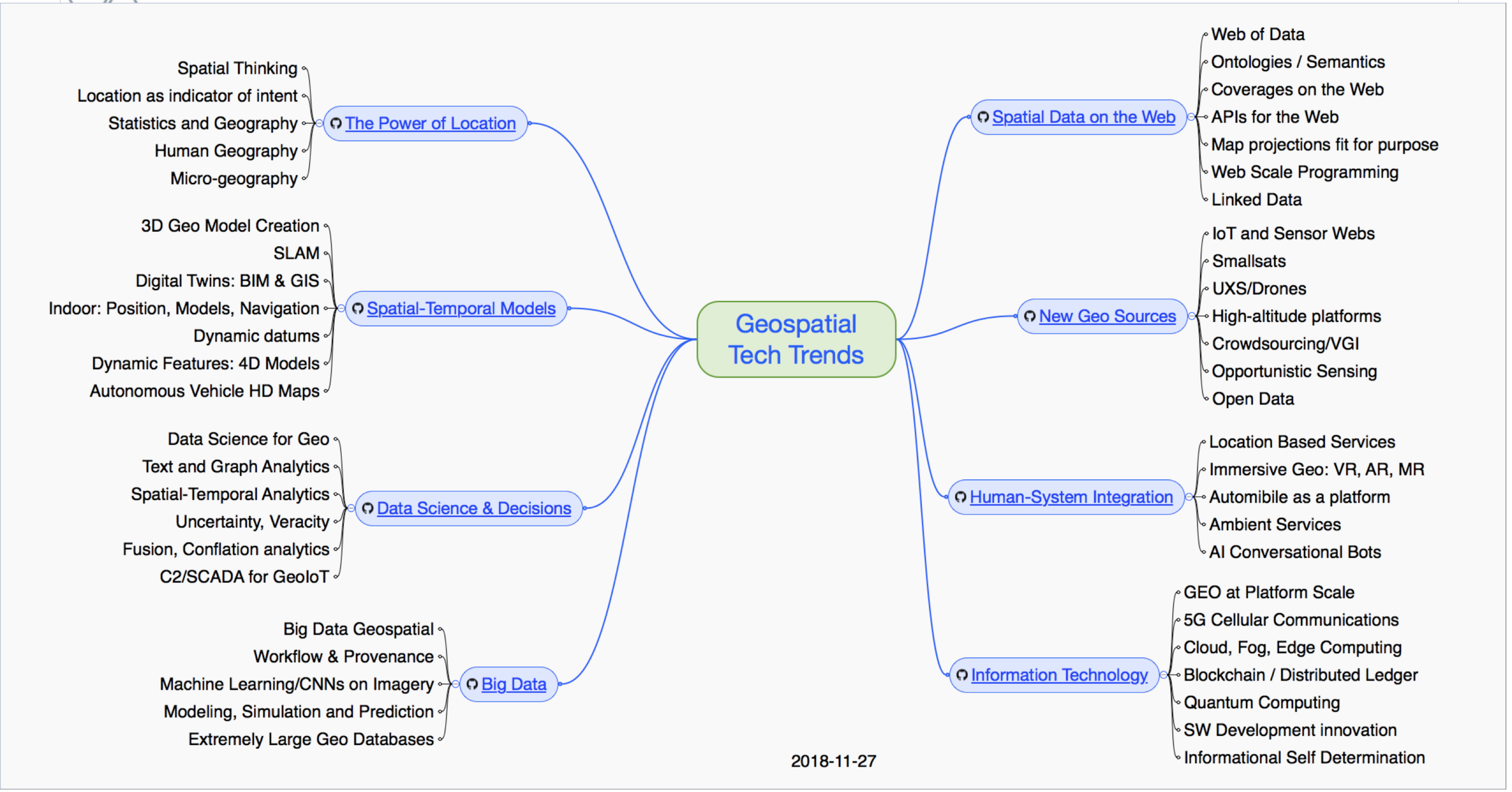
The Innovators of the Digital Revolution



"Most successful innovators had one thing in common: they were "product people". They cared about, and deeply understood, the engineering and design."

"Digital age may seem revolutionary, but it was based on expanding ideas handed down from previous generations."

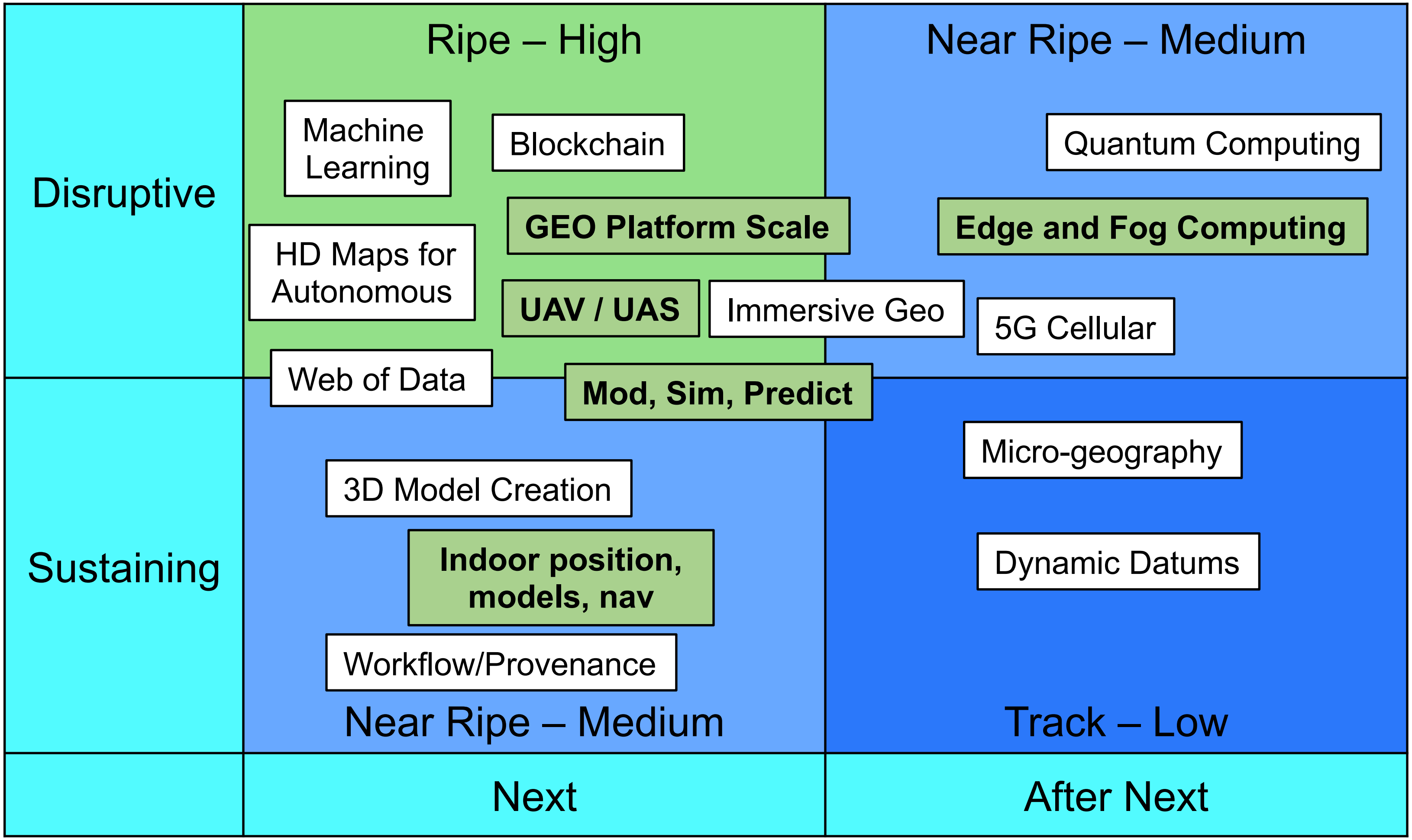
OGC Tech Trends



Publicly Available at: https://github.com/opengeospatial/OGC-Technology-Trends

OGC Geospatial Tech Trends Priorities

Publicly Available at: https://github.com/opengeospatial/OGC-Technology-Trends



2018-09-03

= **Highest Priority**

(MER 2018-11-08)

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George Percivall

gpercivall at opengeospatial.org

@percivall

For Details on OGC …

OGC Standards

- Freely available
- www.opengeospatial.org/standards

OGC Innovation Program

- http://www.opengeospatial.org/ogc/programs/ip