Innovations in Geodata Management, Integration and Analytics

APL Colloquium, 10 February 2017

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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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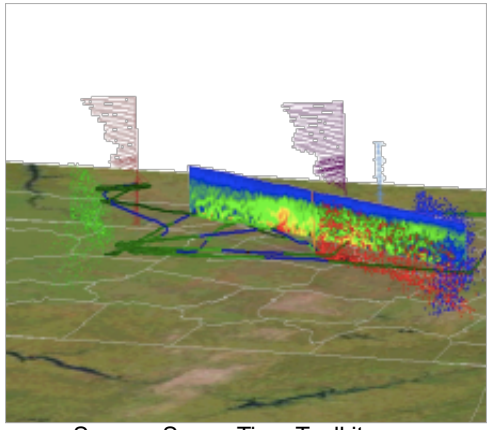
The OGC Mission

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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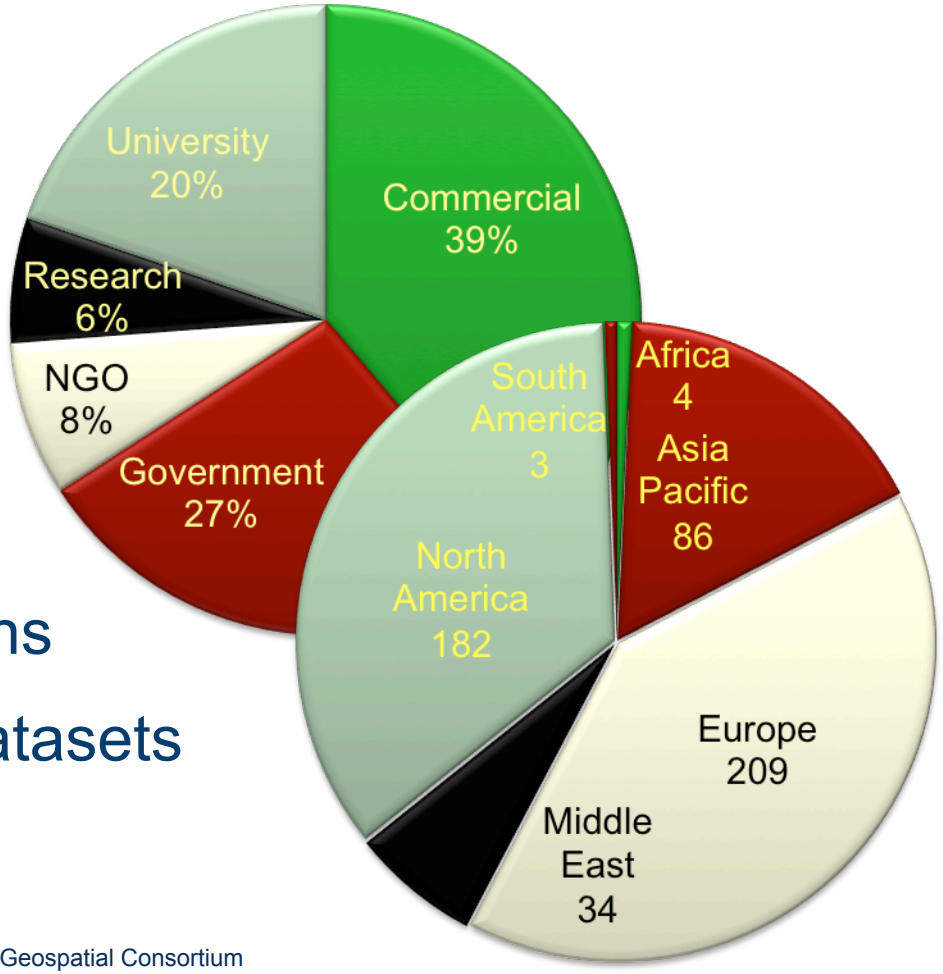
The Open Geospatial Consortium

Not-for-profit, international voluntary consensus standards organization; leading open innovation for geospatial data

- Founded in 1994
- 525+ member organizations
- 90+ innovation initiatives
- 48 Open Standards
- 230 OGC certified products
- Thousands of implementations
- Enabling access to 100K+ datasets



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Innovation in Geodata

Outline of Talk

- Geomatics based on open standards
- What is innovation?
- Innovation in Geomatics

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STANDARDS-BASED GEOMATICS

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Geomatics

Multi-disciplinary science and technology that integrates all means of spatiotemporal data acquisition, information production, and knowledge discovery - as well as location-based services - regarding the physical processes and human activities related to the Earth.

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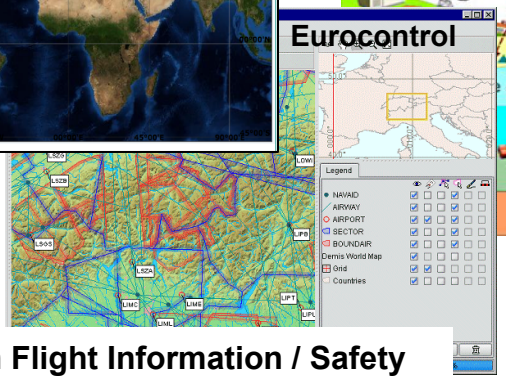
Basic Geospatial Interoperability Challenge Solved

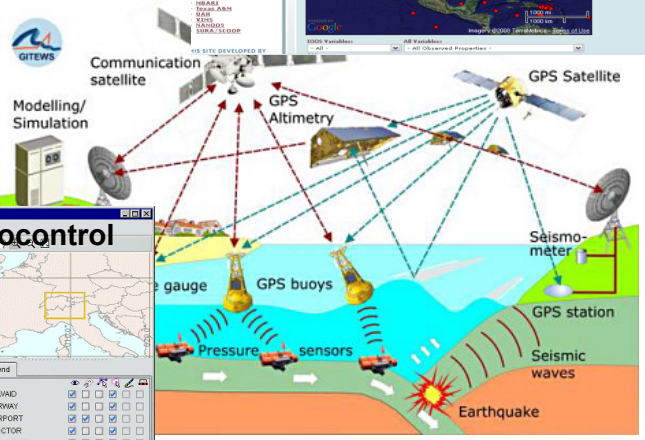
100Ks maps &datasets accessible - 10Ks OGC Web Services

Web Map Servers (WMS)
Web Feature Servers (WFS)
Web Coverage Servers (WCS)

Emergency / Disaster Management



Aviation Flight Information / Safety



Meteorology, Hydrology, Ocean Monitoring

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Why Open Standards?

- Prevents a single, self-interested party from controlling a standard
- Lower systems and life cycle costs
- Encourage market competition
  - Choose based on functionality desired
  - Avoid "lock in" to a proprietary architecture
- Stimulates innovation beyond the standard by companies that seek to differentiate themselves.

"What OGC brings to the table is…everyone has confidence we won't take advantage of the format or change it in a way that will harm anyone"

Michael Weiss-Malik, Google KML product manager

Source: Open Standards, Open Source, and Open Innovation: Harnessing the Benefits of Openness, April 2006. Committee For Economic Development. www.ced.org

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What is an OGC Standard?

- Document; Established by consensus; Approved by OGC membership (balance of interest, all members have vote)
  - Provides, rules, guidelines or characteristics
  - Implementable in software

- Open Standards are not the same as Open Source software
  - See: OGC/OSGeo Paper on Open Source and Open Standards:

- OGC standards are Open Standards
  - Freely and publicly available
  - No license fees
  - Vendor neutral

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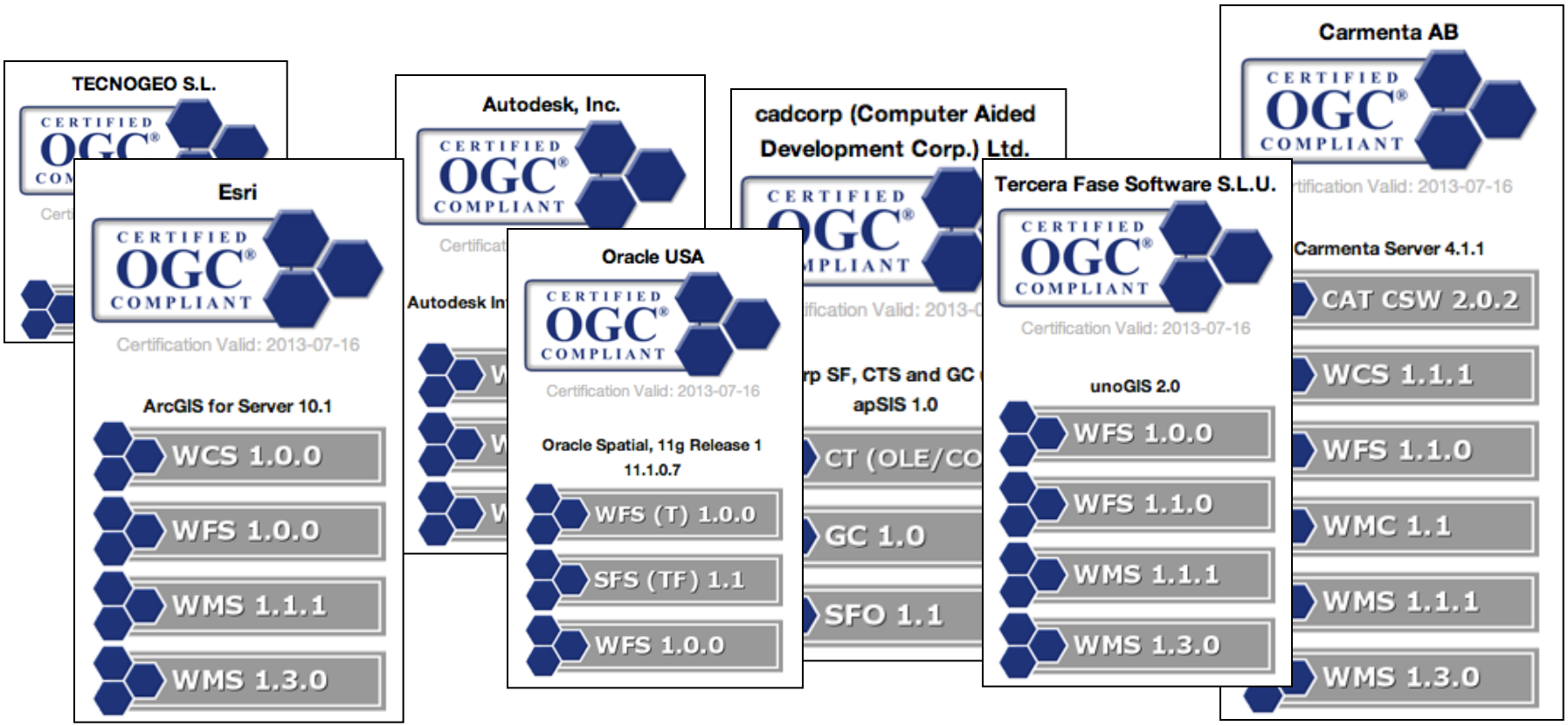
900 implementing products



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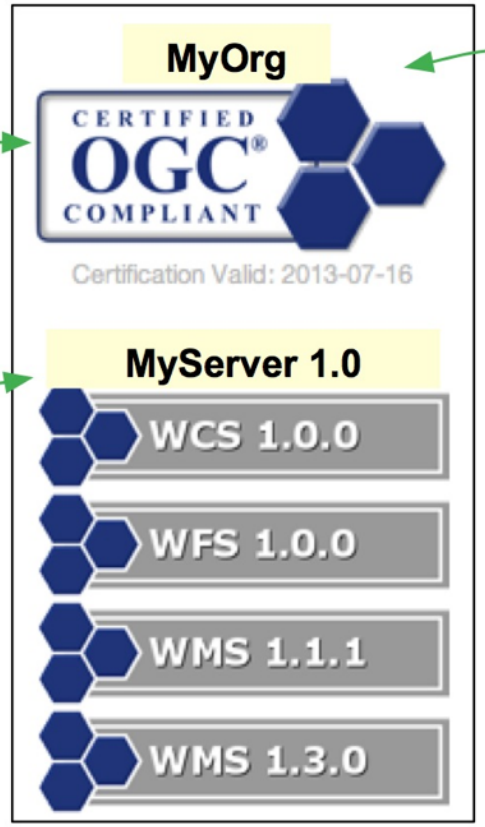
http://www.opengeospatial.org/resource/products/compliant

OGC Certified Implementations



The OGC compliant Mark

Related to a specific product and standard

Granted to an organization as proof of proper implementation of an OGC Standard

Currently
908 implementations
236 compliant products

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OGC Services Architecture

Visualization / Decision Tools and Applications

GeoAPI

OpenLS

Data Models and Encodings

GML | IndoorGML | NetCDF | GMLJP2 | GeoSparql | SLD | KML | WMC

CityGML | WaterML | GeoXACML | FE | SE | OpenGeoSMS | GeoPackage

Other Services
Workflow, Alerts, Security

Processing Services

TJS | WPS | WCPS | OpenMI

Discovery Services

CSW | OpenSearch Geo | ebRIM

Geospatially Enabled Metadata

Access Services

WFS | WMTS | Simple Features Access | WCS | WMS

Sensor Web Enablement

SPS | SensorML | O&M | SOS

Discover | Task | Access

Puck

Sensors

Geospatial Feature Data

Geospatial Browse/Maps

Geospatial Coverage Data

Other Data

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SENSOR WEB ENABLEMENT (SWE)

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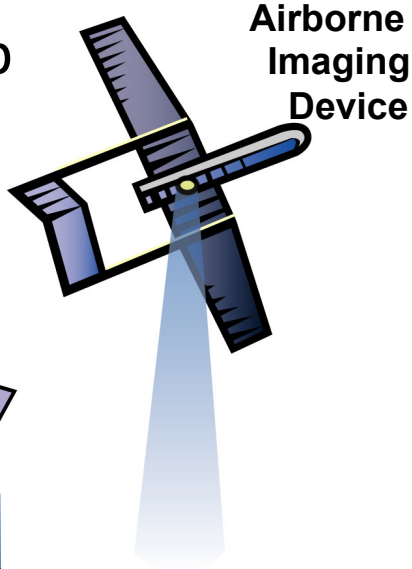
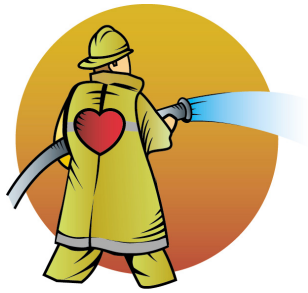
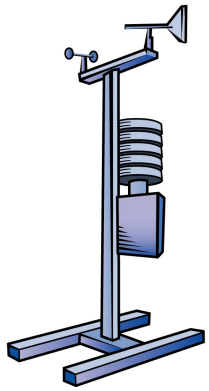
OGC Sensor Web Enablement

- Sensors connected to and discoverable on the Web
- Sensors have position & generate observations
- Sensor descriptions available
- Services to task and access sensors
- Local, regional, national scalability
- Enabling the Enterprise







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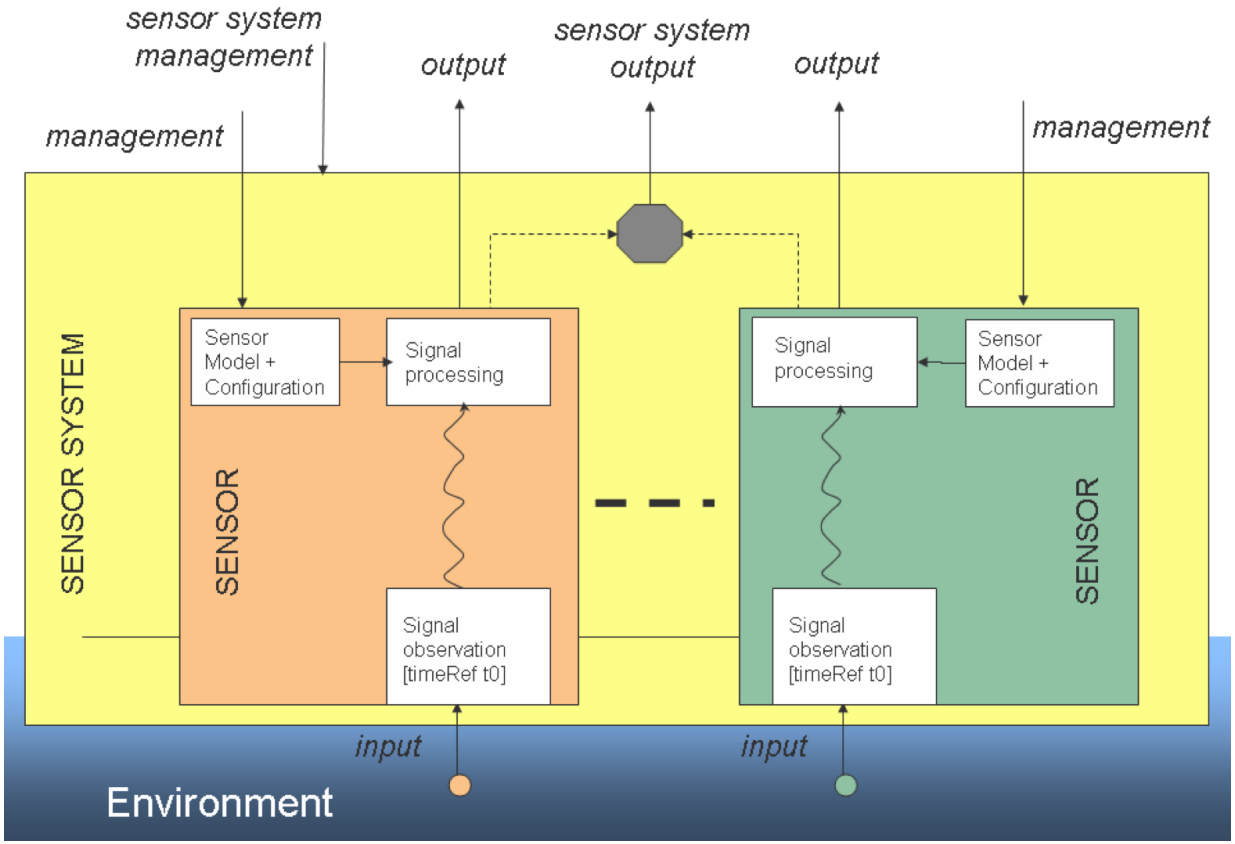
Model of a Sensor System



Sensor Web Enablement Architecture, OGC document 06-021r4
http://portal.opengeospatial.org/files/?artifact_id=29405

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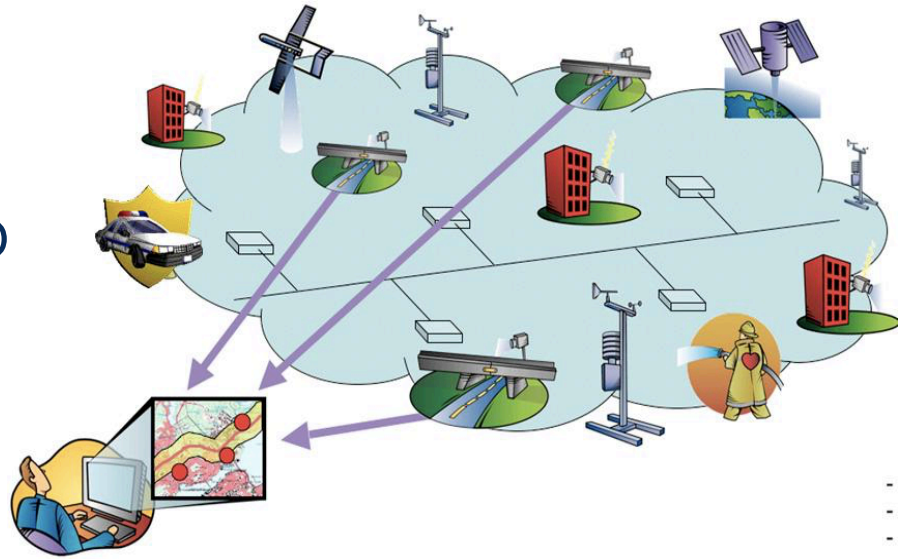
SWE Information Models and Schema

- SWE Information Models and Encodings
  - Sensor Model Language (SensorML)
  - Observations and Measurements (O&M)
  - SWE Common

- SWE Web Services
  - Sensor Observation Service (SO
  - Sensor Planning Service (SPS)
  - Sensor Alert Service (SAS)
  - PUCK



SWE Standards are deployed in operational systems – TRL Level 9

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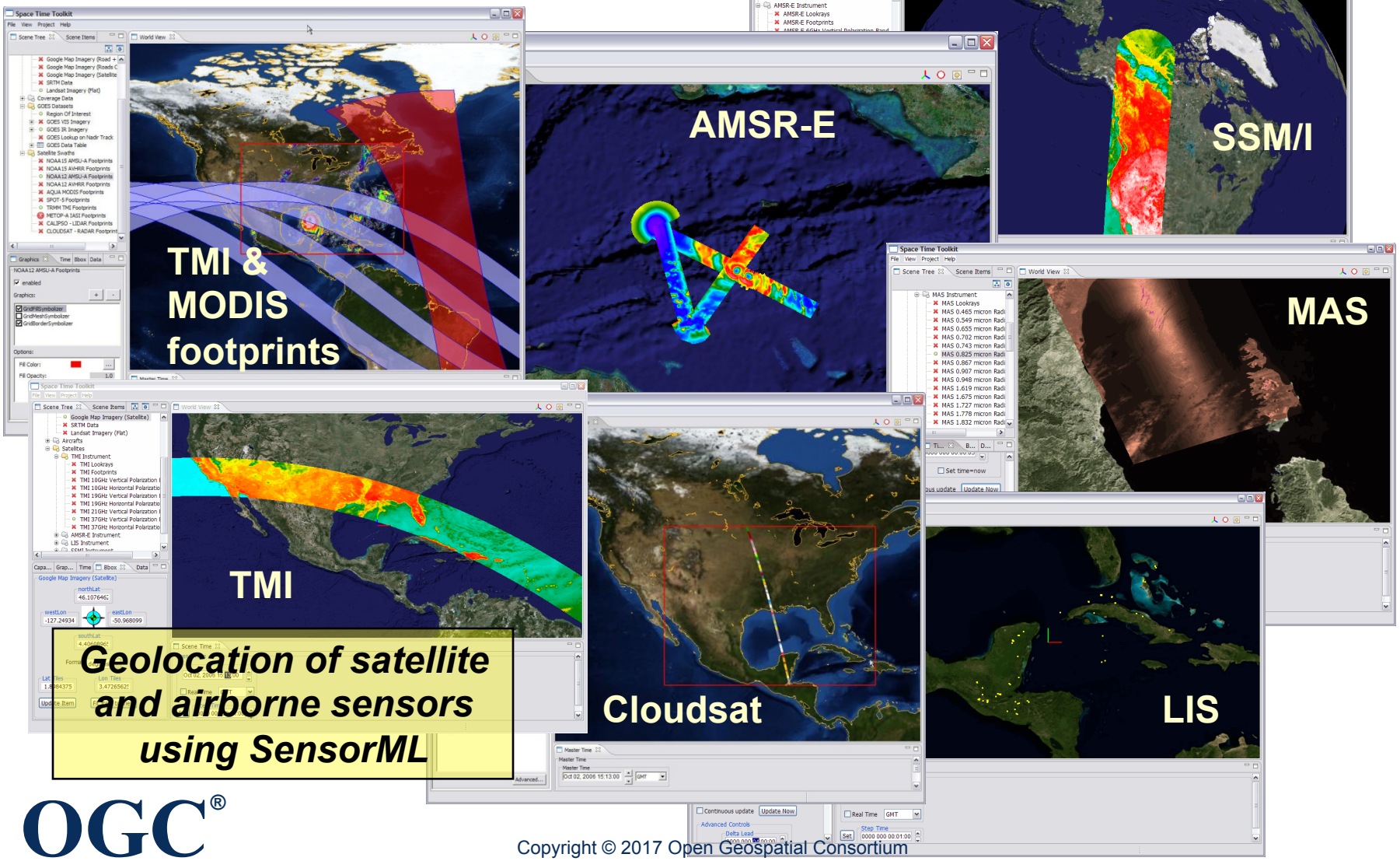
On-demand Geolocation using SensorML



Geolocation of satellite and airborne sensors using SensorML

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Open Geospatial Consortium

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Reference URL for this document: www.opengis.net/def/doc-type/per/OWS9-GPS-SWE

Category: Engineering Report

Editor: Dr. Mike Botts

OWS-9: Engineering Report: Use of SWE Common and SensorML for GPS Messaging

Warning

This document is not an OGC Standard. This document is an OGC Public Engineering Report created as a deliverable in an OGC Interoperability Initiative and is not an official position of the OGC membership. It is distributed for review and comment. It is subject to change without notice and may not be referred to as an OGC Standard. Further, any OGC Engineering Report should not be referenced as required or mandatory technology in procurements.

- https://portal.opengeospatial.org/files/?artifact_id=52162&version=1

Application of SWE to GPS - Results

GPS Raw Data Processing Results

The map below shows GPS navigation solutions obtained using a pseudo-range solver and various ephemeris sources.

- ○ Original Broadcast Ephemeris
- ○ NGA Precise Ephemeris
- ◉ PRED Ephemeris
- ○ Reference Trajectory

Each type of ephemeris data is obtained from a different SOS offering.
All data transits in the SWE Common format.

Click here to run web tool

Click here To watch video

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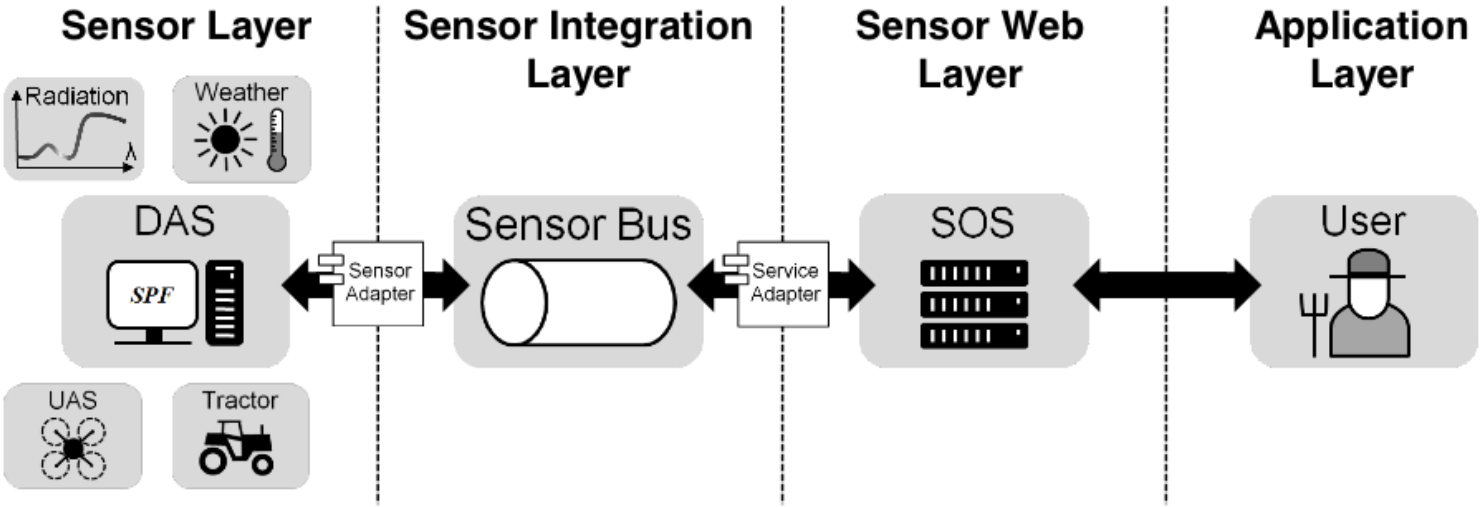
UAS with other sensors using SWE

- SWE-based infrastructure: control, access, transmission and storage of of sensor data for web services
- Field trial proved applicability of the infrastructure.



SWE infrastructure for precision farming (Source: Geipel)

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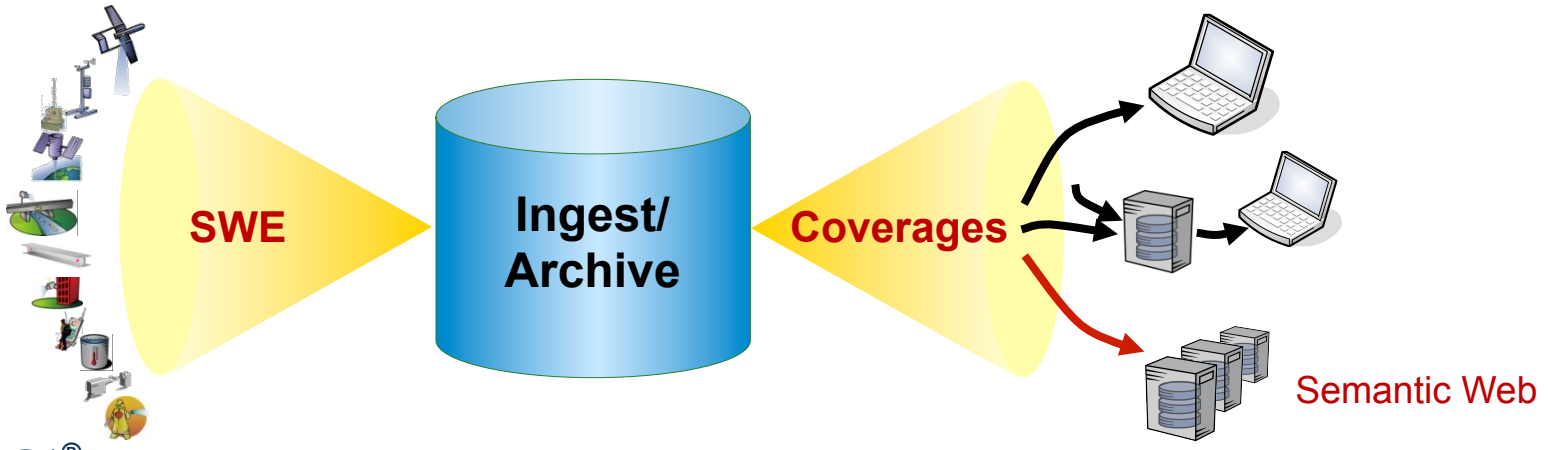
Sensor Webs and Coverages

- SWE:
  high flexibility to accommodate all sensor types
  → upstream integration
- Coverages/WCS
  one generic schema for all coverage types; scalable; versatile processing
  → downstream services



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COVERAGES: WCS, WCPS, ENCODINGS

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Geographic Coverages

"space/time-varying phenomenon"

[ISO 19123, OGC 09-146r2]

«FeatureType»
Abstract Coverage

Grid Coverage

Rectified GridCoverage

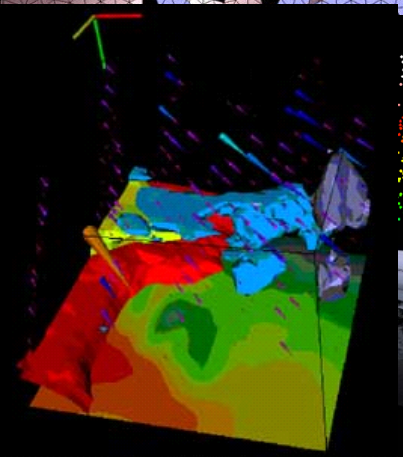
Referenceable GridCoverage

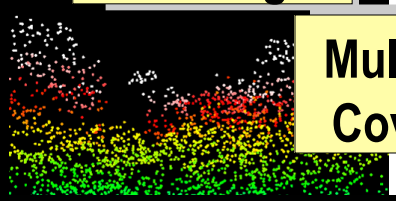
MultiSolid Coverage

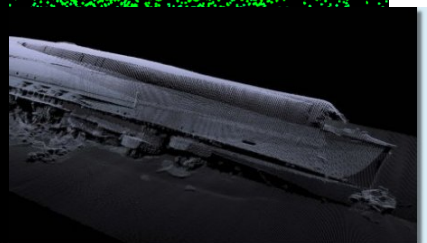
MultiSurface Coverage

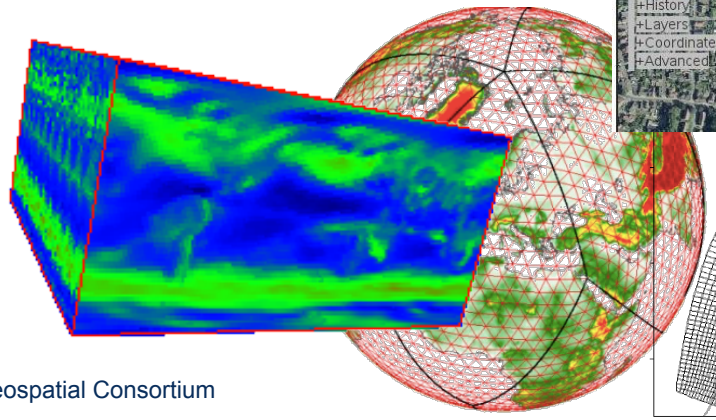
MultiCurve Coverage

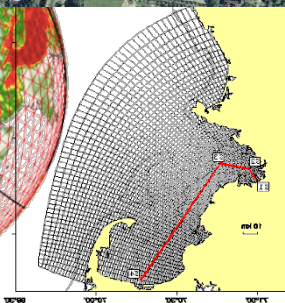
MultiPoint Coverage





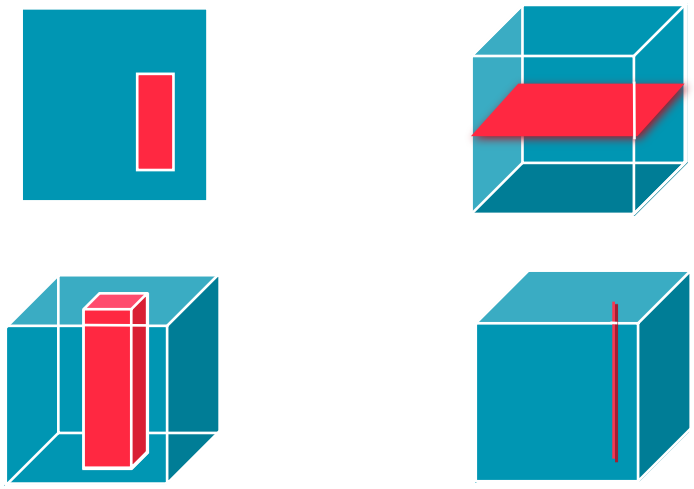






Web Coverage Service (WCS)

- WCS Core: Simple & efficient access to spatio-temporal coverages, in any suitable format
  - subset = trim | slice



- WCS Extensions: additional, optional functionality facets
- WCS Application Profiles: domain-oriented bundling

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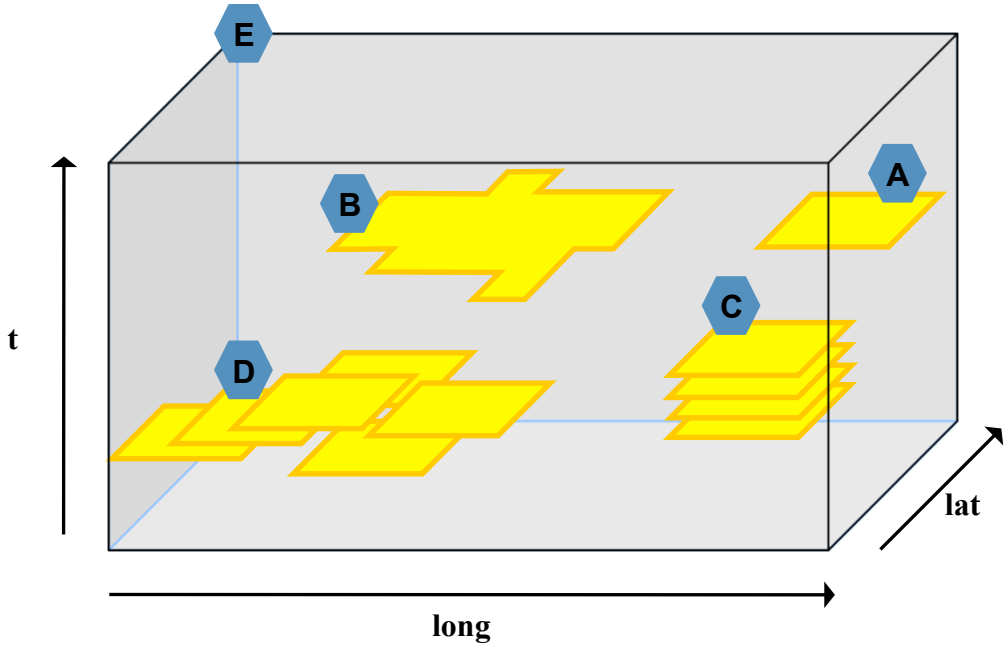
Imagery Collections as WCS Dataset Series



A ….. dataset (e.g. scene)
B ….. dataset (e.g. seamless mosaic)
C ….. datasets of dataset series (e.g. time series)
D ….. datasets of dataset series
E ….. dataset series (e.g. collection)

A dataset may be a member in different Dataset Series

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OGC WCPS - Array Databases

- Web Coverage Processing Service (WCPS)
  = spatio-temporal datacube analytics language

- "From MODIS scenes M1, M2, M3:
  difference between red & nir, as TIFF"
  - …but only those where nir exceeds 127 somewhere

```
for $c in ( M1, M2, M3 )
where some( $c.nir > 127 )
return encode( $c.red - $c.nir, "image/tiff" )
```

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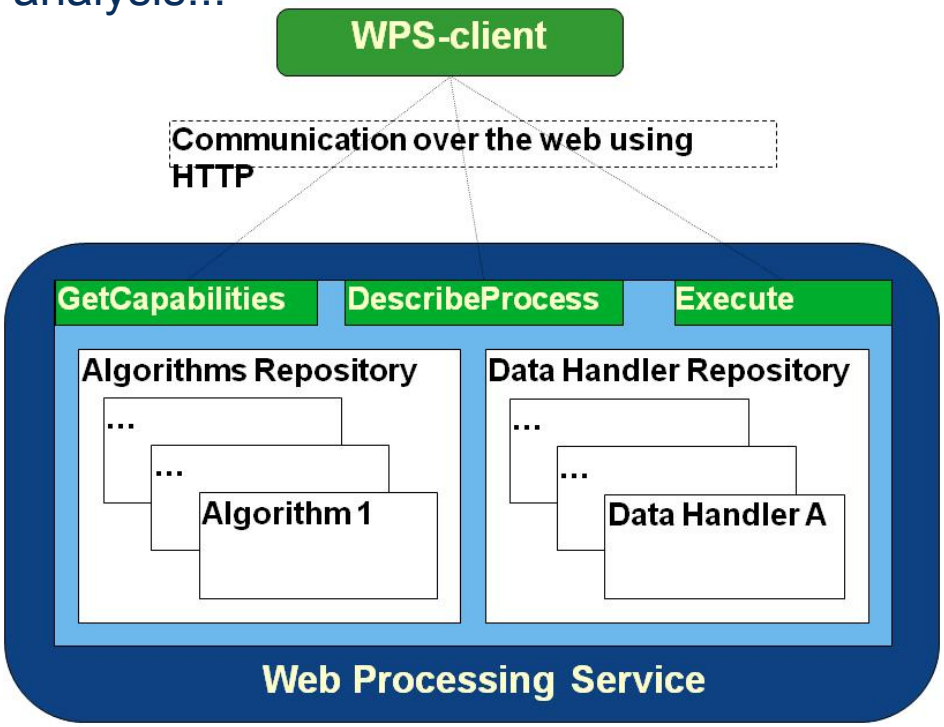
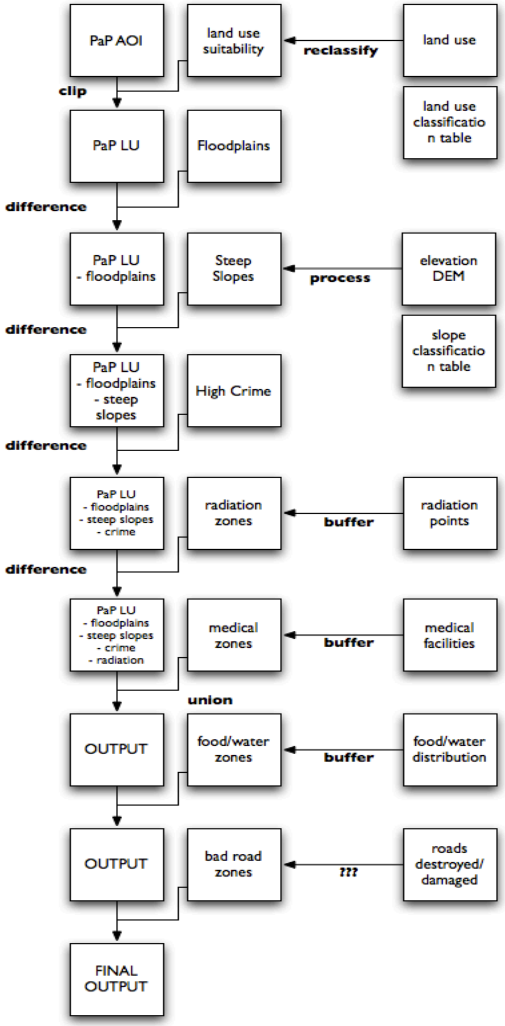
Geospatial Processing, Analysis, Workflow

Web Processing Service – WPS

- OGC Web Service workflow for algorithms
- Change detection, coordinate transformation, predictive models, simulation, geospatial analysis...



Geoprocessing Workflow



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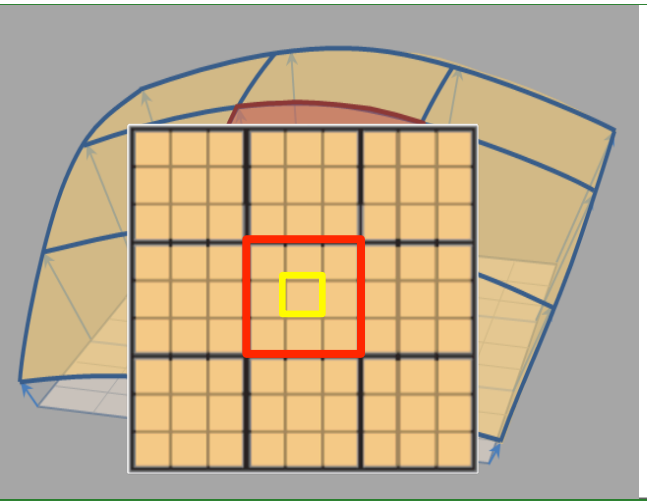
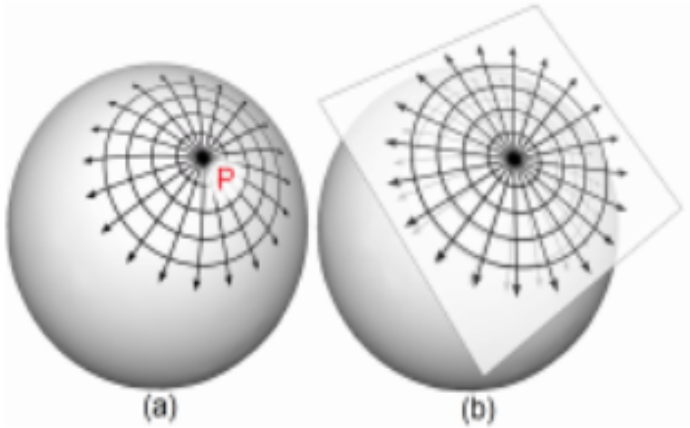
Moving to Global-scale Analysis

- Traditional GIS and image analysis approaches assume flat earth geometries = simpler code… *but data is warped to fit the "flattened" view of the Earth.*
  - OK for local scales *(where approximate Earth surface is relatively flat)*
  - But Fails at larger scales *(where curvature of the Earth becomes significant.)*





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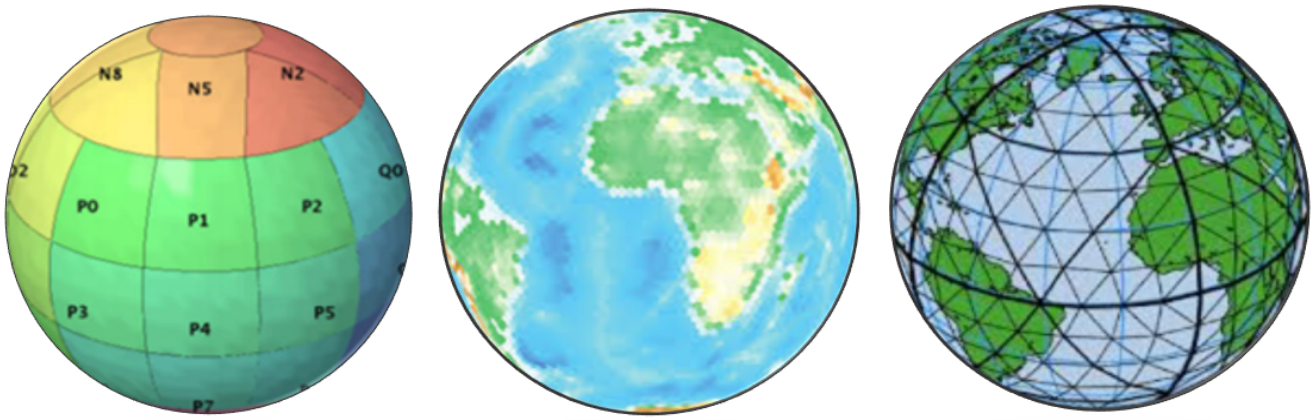
Discrete Global Grid Systems

"…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 Candidate Standard



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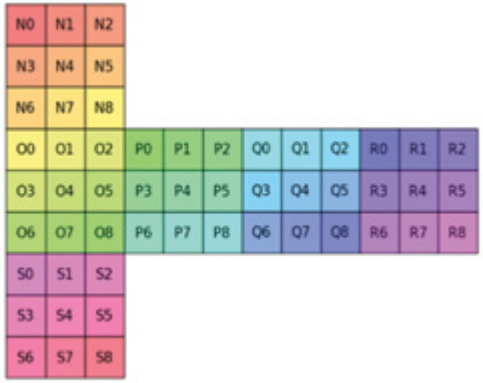
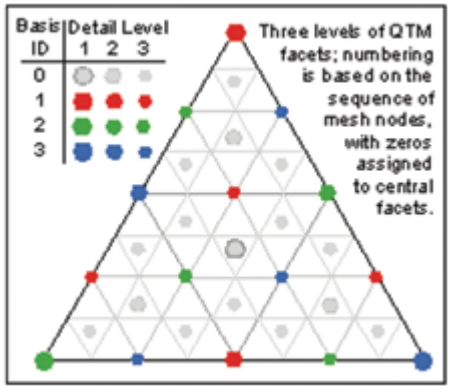
Standardising Discrete Global Grid Systems

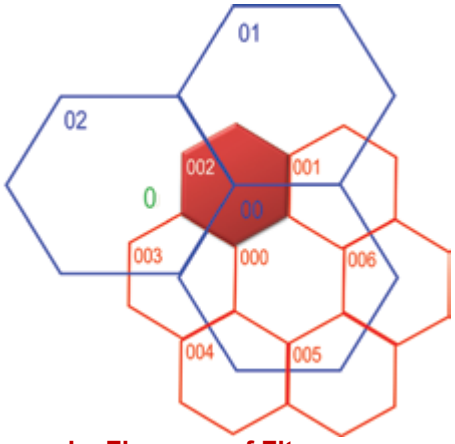
Different Cell Shapes



Square = Familiar



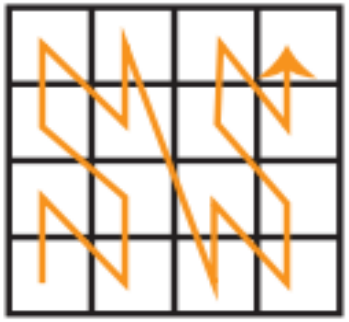
Triangular = Fast



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

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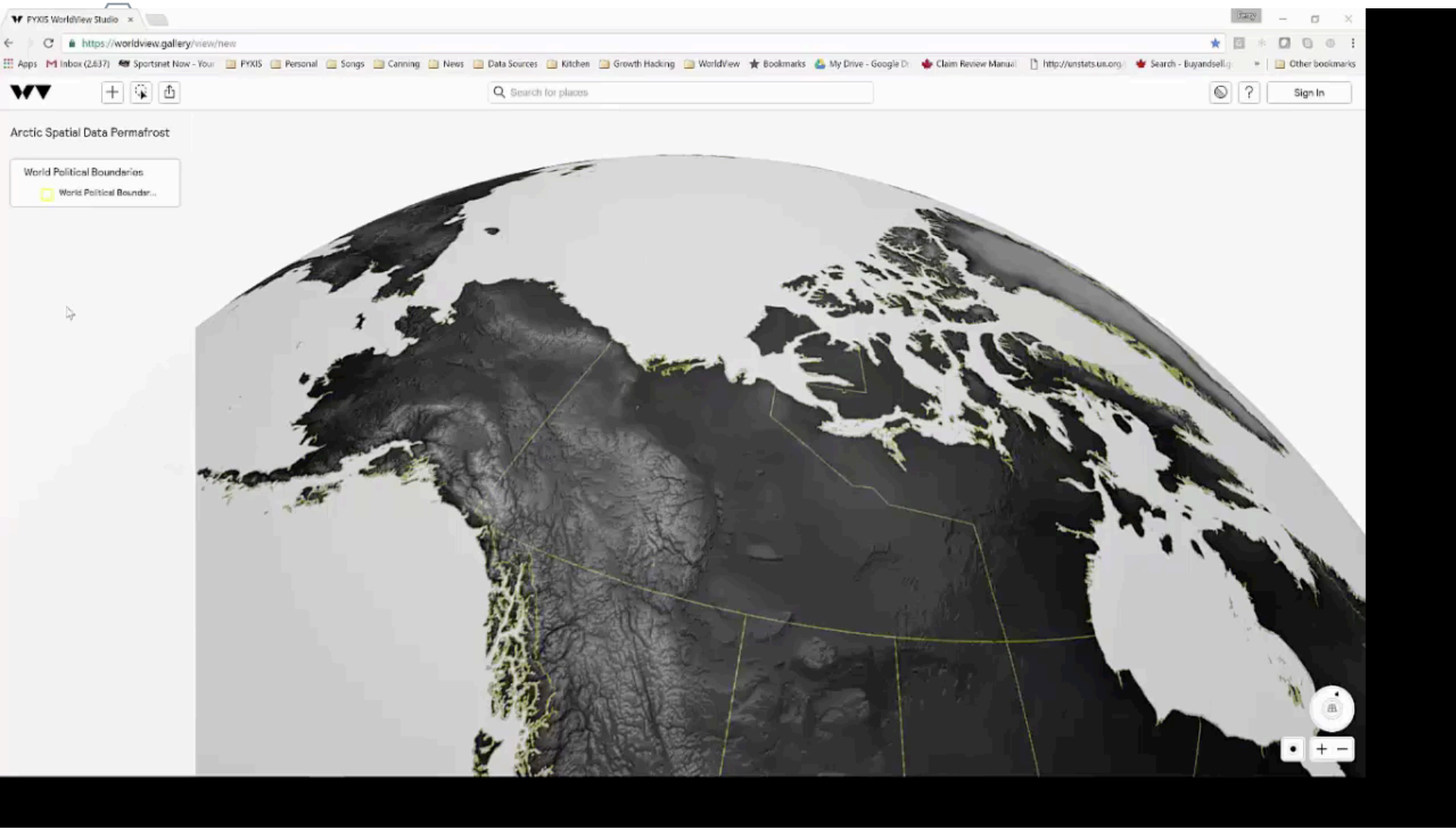
OGC Testbed 12 - Arctic SDI



[See all of OGC Testbed 12 Demonstration]

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WHAT IS INNOVATION?

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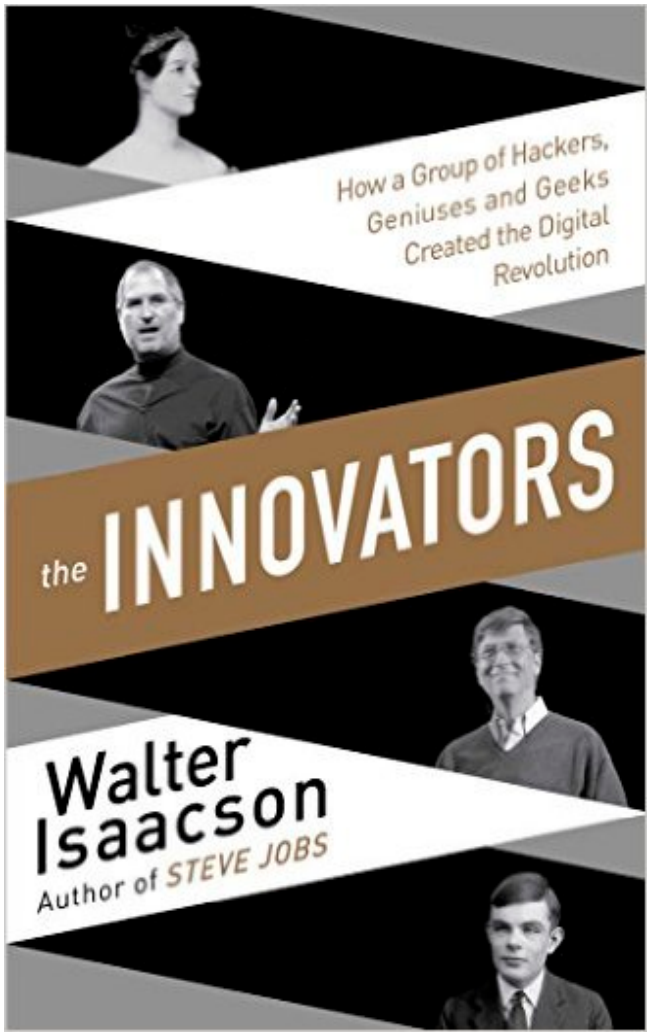
The Innovators of the Digital Revolution



1. Ada, Countess of Lovelace
2. The Computer
3. Programming
4. The transistor
5. The microchip
6. Video games
7. The Internet
8. The personal computer
9. Software
10. Online
11. The Web
12. Ada forever.

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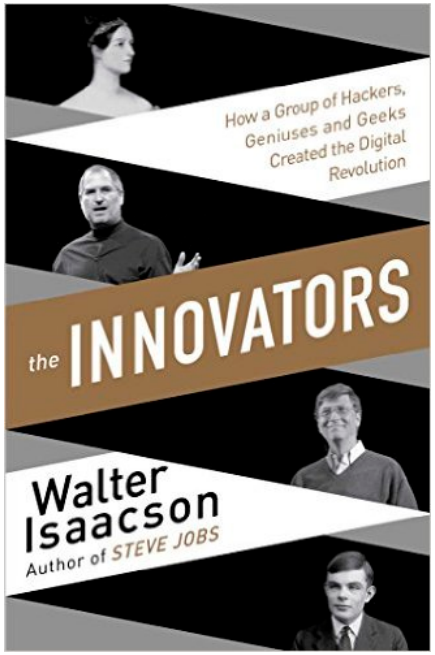
The Innovators of the Digital Revolution



- "Digital age may seem revolutionary, but it was based on expanding ideas handed down from previous generations."
- "Innovation comes from teams more often than from lightbulb moments of lone geniuses"
- "Most of the successful innovators and entrepreneurs in this book had one thing in common: they were product people. They cared about, and deeply understood, the engineering and design."

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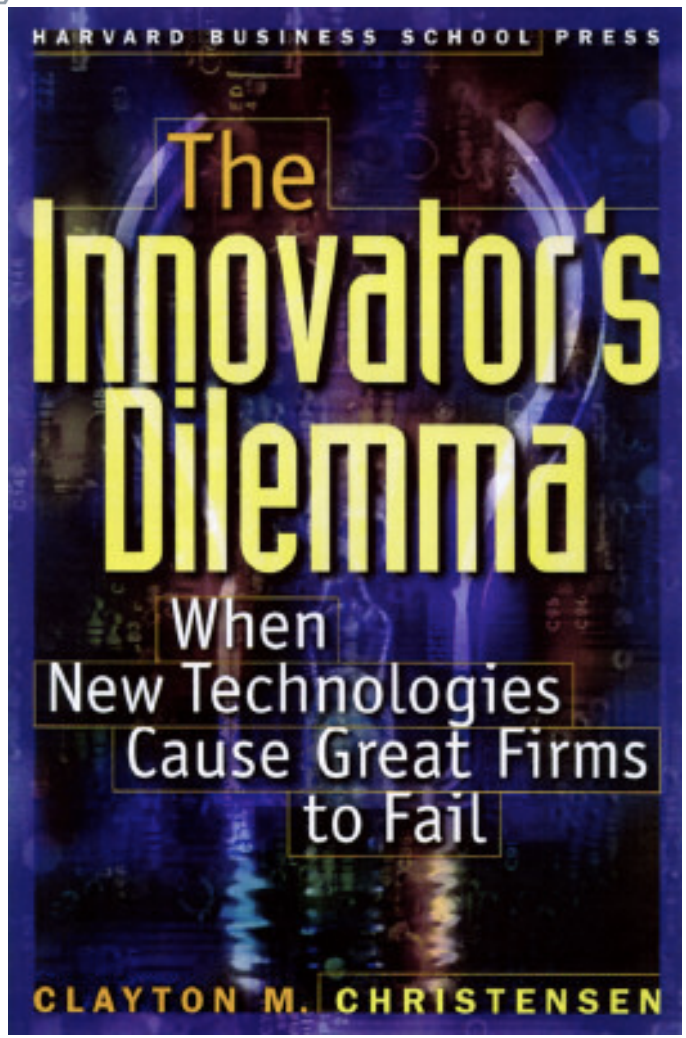
The Innovator's Dilemma



- Tech progress can, and often does, outstrip what markets need
- Disruptive innovations result in worse performance, in near term
  - Cheaper, simpler, smaller, and, frequently, more convenient to use
  - Large companies overlook disruptive technologies until they make a profit
- How to succeed
  - Identify disruptive technologies before they overtake the traditional
  - Discovery-driven planning

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OGC's response to the Innovator's Dilemma

- Must maintain current OGC standards while simultaneously addressing evolution of technology and markets
  - Ensure harmonization in OGC standards

- OGC response to the Innovators Dilemma
  - Extend or adapt the present baseline of standards
  - New standards that overlap with or diverge from existing standards, along with guidance to evaluate among options
  - Harmonization techniques (brokers, facades) for interoperability

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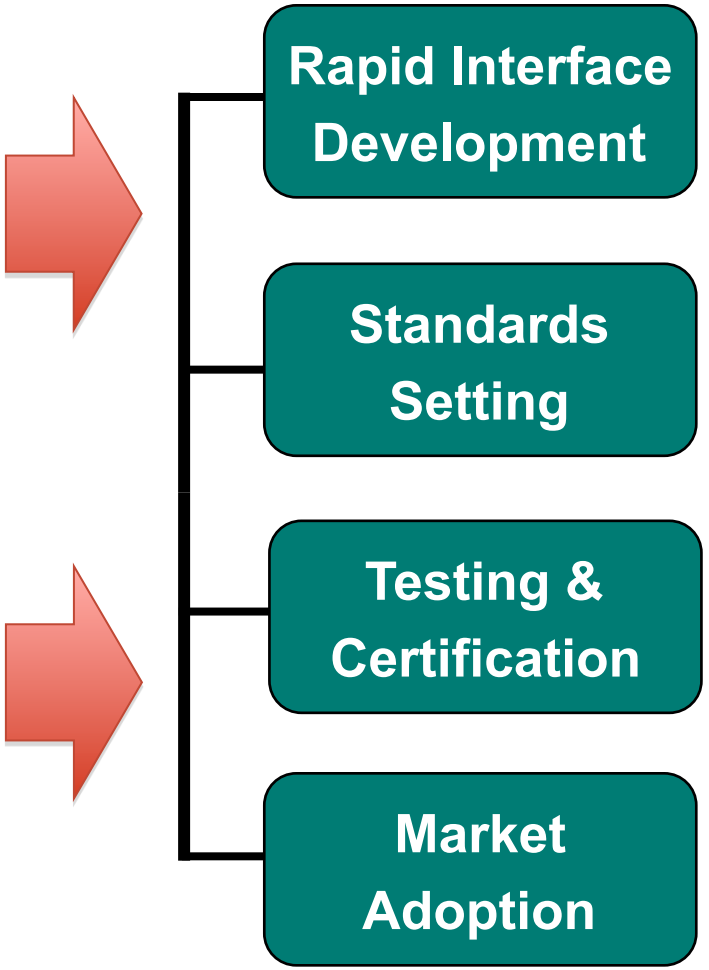
OGC's Approach for Advancing Interoperability

- ***Innovation Program* (IP)** – a global, innovative, hands-on rapid prototyping and testing program designed to unite users and industry in accelerating interface development and validation, and the delivery of interoperability to the market
- ***Standards Program* – Consensus standards process similar to other Industry consortia (World Wide Web Consortium, OMA etc.).**
- ***Compliance Testing and Certification Program* – allows organizations that implement an OGC standard to test their implementations with the mandatory elements of that standard**
- ***Marketing and Communications Program* – education and training, encourage take up of OGC specifications, business development, communications programs**



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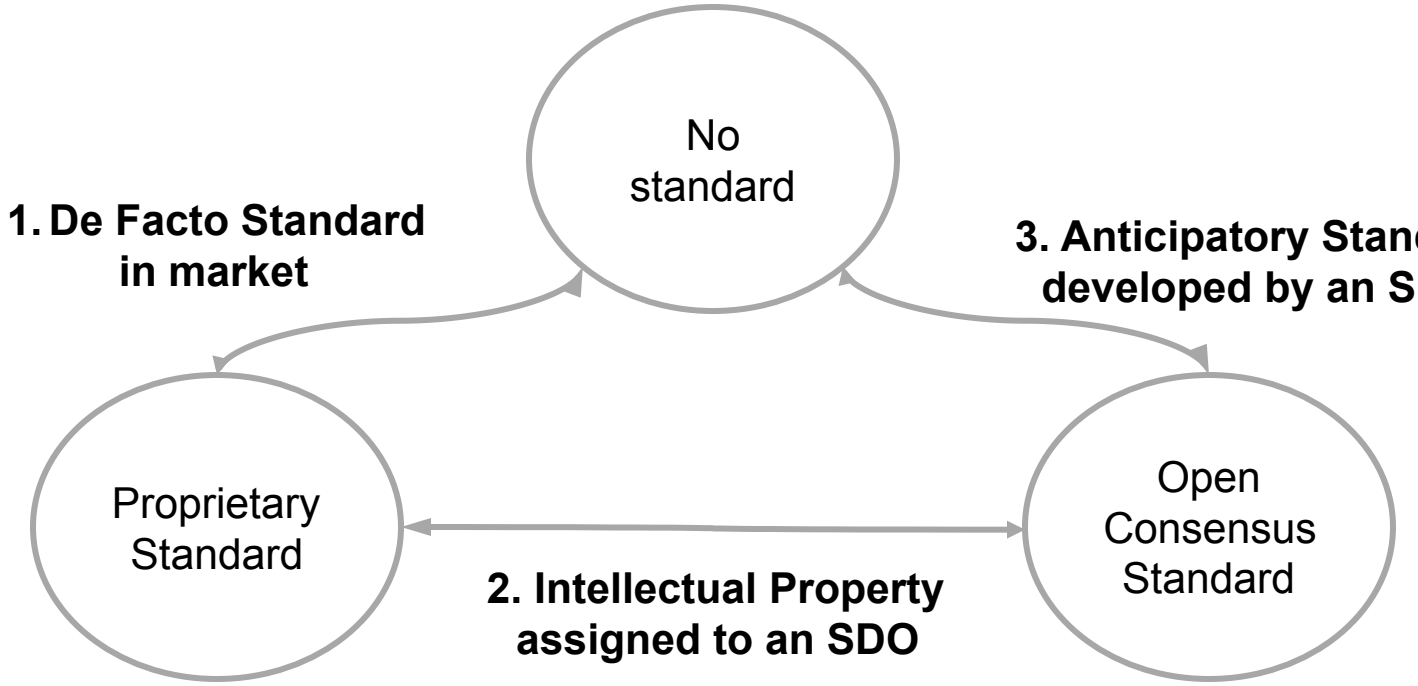
Transition of standards in marketplace



OGC as a Standards Setting Organization (SSO)

2. OGC Community Standards adoption process

3. OGC Innovation Program initiatives

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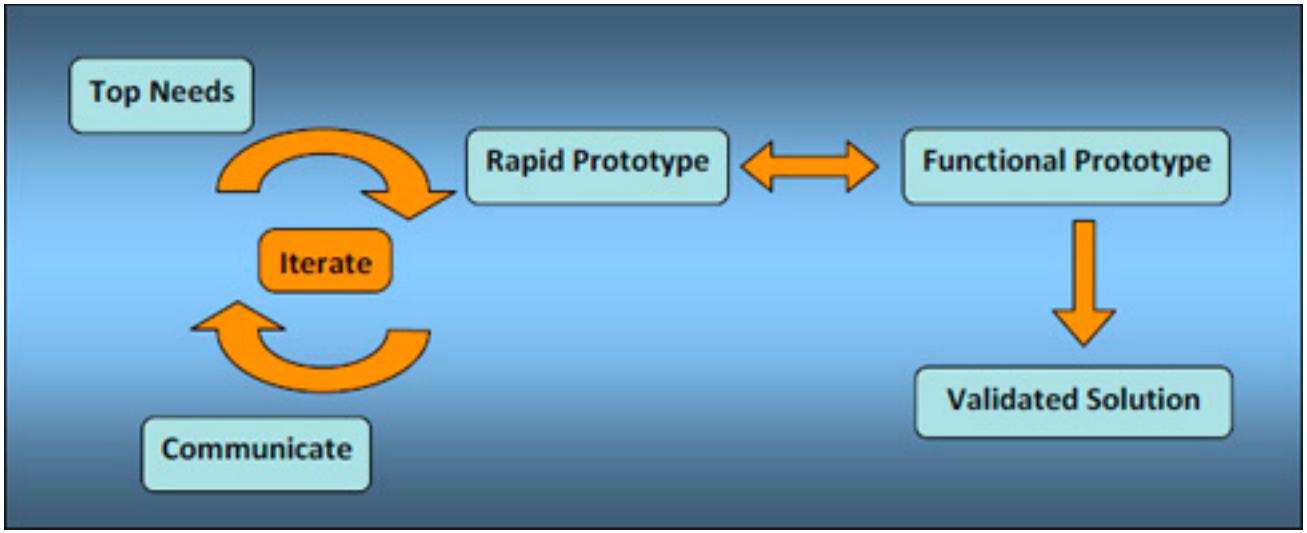
Innovation through prototyping

As a rule, the more prototypes and prototyping cycles per unit of time, the more technically polished the final product.

Serious Play, M. Schrage



Agile, Scrum Iterative, Evolutionary Development

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GEOSPATIAL INNOVATION

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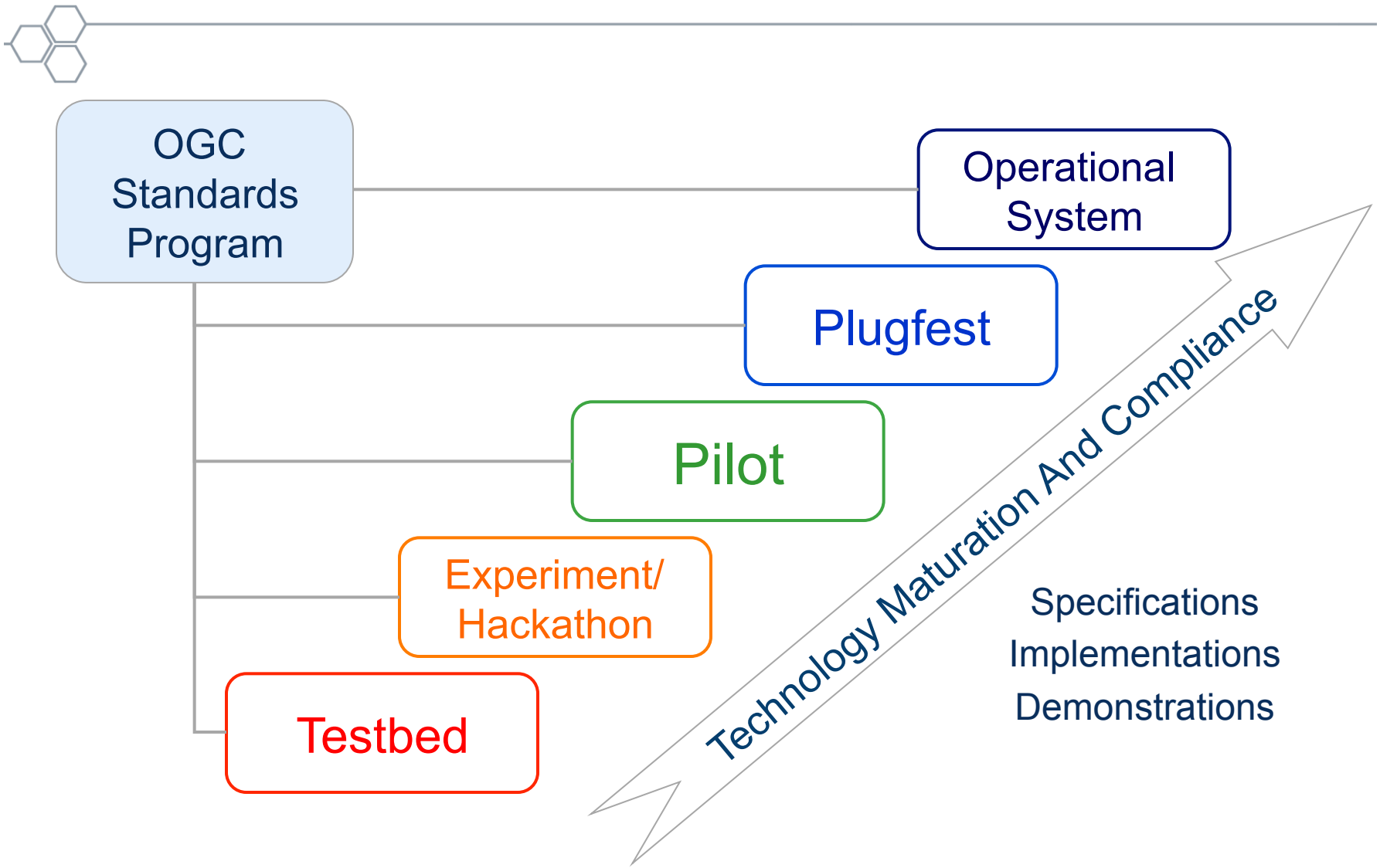
OGC Innovation Program



Types of OGC Innovation Program Initiatives

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OWS Testbeds support of SWE Version 1

OWS-1 Testbed

- Sponsors: EPA, General Dynamics, NASA, NIMA
- Specs: SOS, O&M, SensorML, SPS, WNS
- Demo: Terrorist, Hazardous Spill and Tornado
- Sensors: weather stations, wind profiler, video, UAV, stream gauges

2001/02

OWS-3 Testbed

- Sponsors: NGA, ORNL, LMCO, BAE
- Specs: SOS, O&M, TML, SensorML, SPS
- Demo: Forest Fire in Western US
- Sensors: weather stations, wind profiler, video, UAV, satellite

2005

OWS-4 Testbed

- Sponsors: NGA, NASA, ORNL, LMCO
- Specs: SOS, O&M, SensorML, SPS, TML, SAS
- Demo: Radiation, Emergency Hospital
- Sensors: weather stations, wind profiler, video, UAV, satellite

2006

SWE v1 Standards approved:

SensorML – V1.0.1
TML – V1.0
SOS – V1.0
SPS – V1.0
O&M – V1.0
SAS – V0.0
WNS – Best Practices

2007

Source: M. Botts

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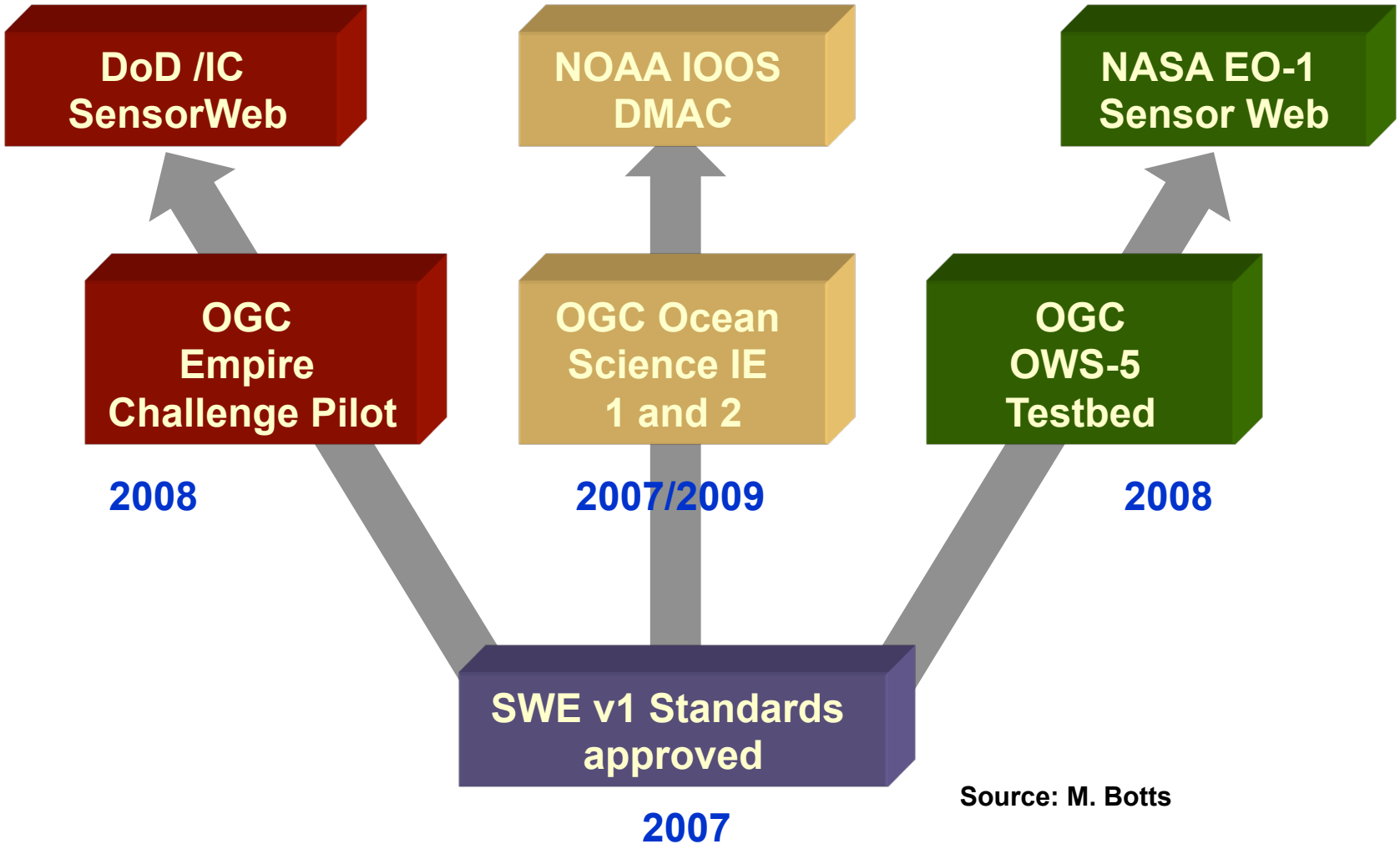
OGC IP influence on SWE deployments



Source: M. Botts

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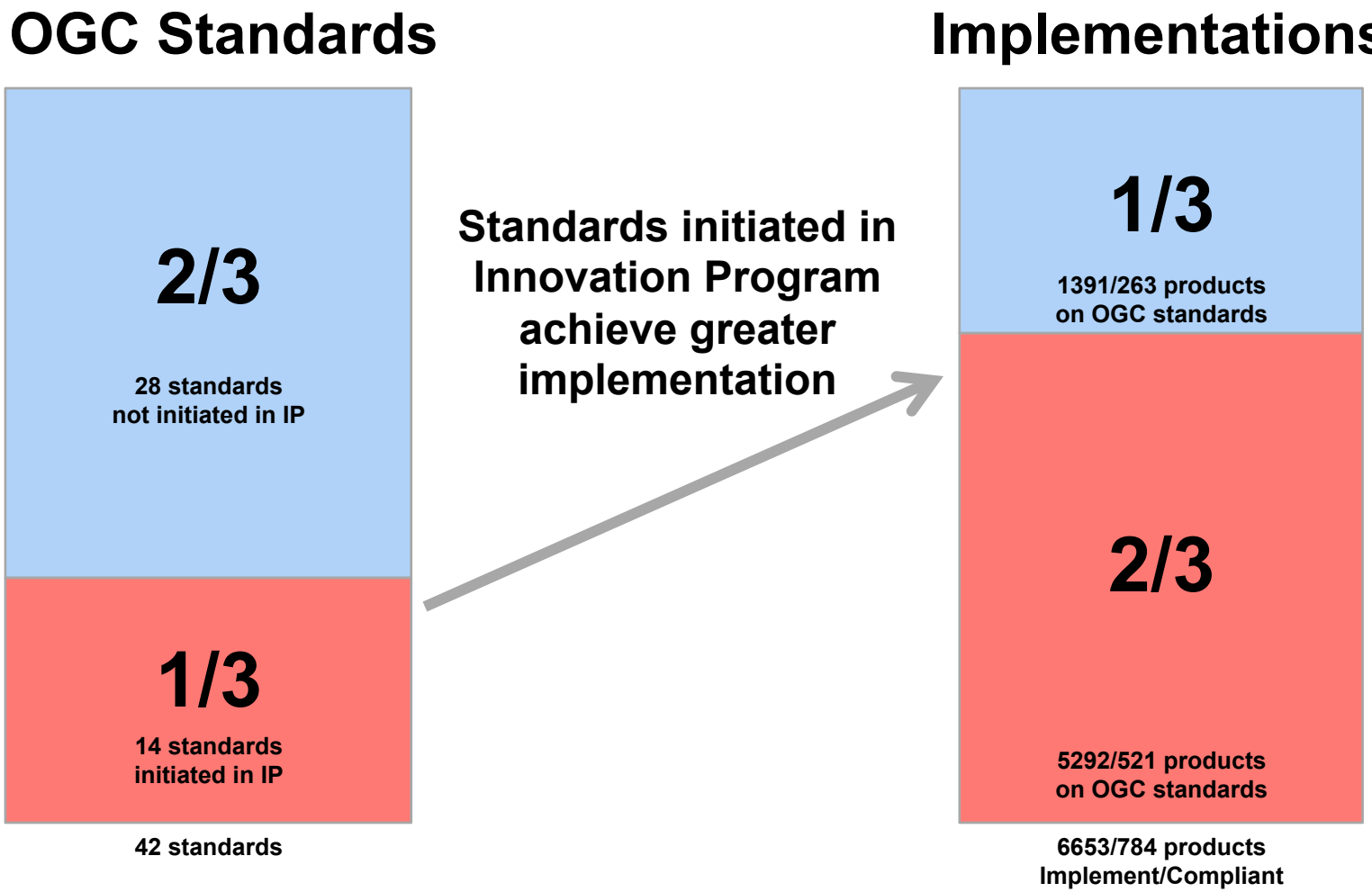
Effectiveness of Prototyping on Standards



Source: "Innovation in OGC: The Interoperability Program," Percivall G.,T. Idol, N. Alameh, J. Harrison; ISPRS Int. J. Geo-Inf. 2015, 4(4), 2362-2378; doi:10.3390/ijgi4042362

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OGC Testbed 12

> 200 individuals	> 37 organizations	47 documents	82 components

$3.6 Million

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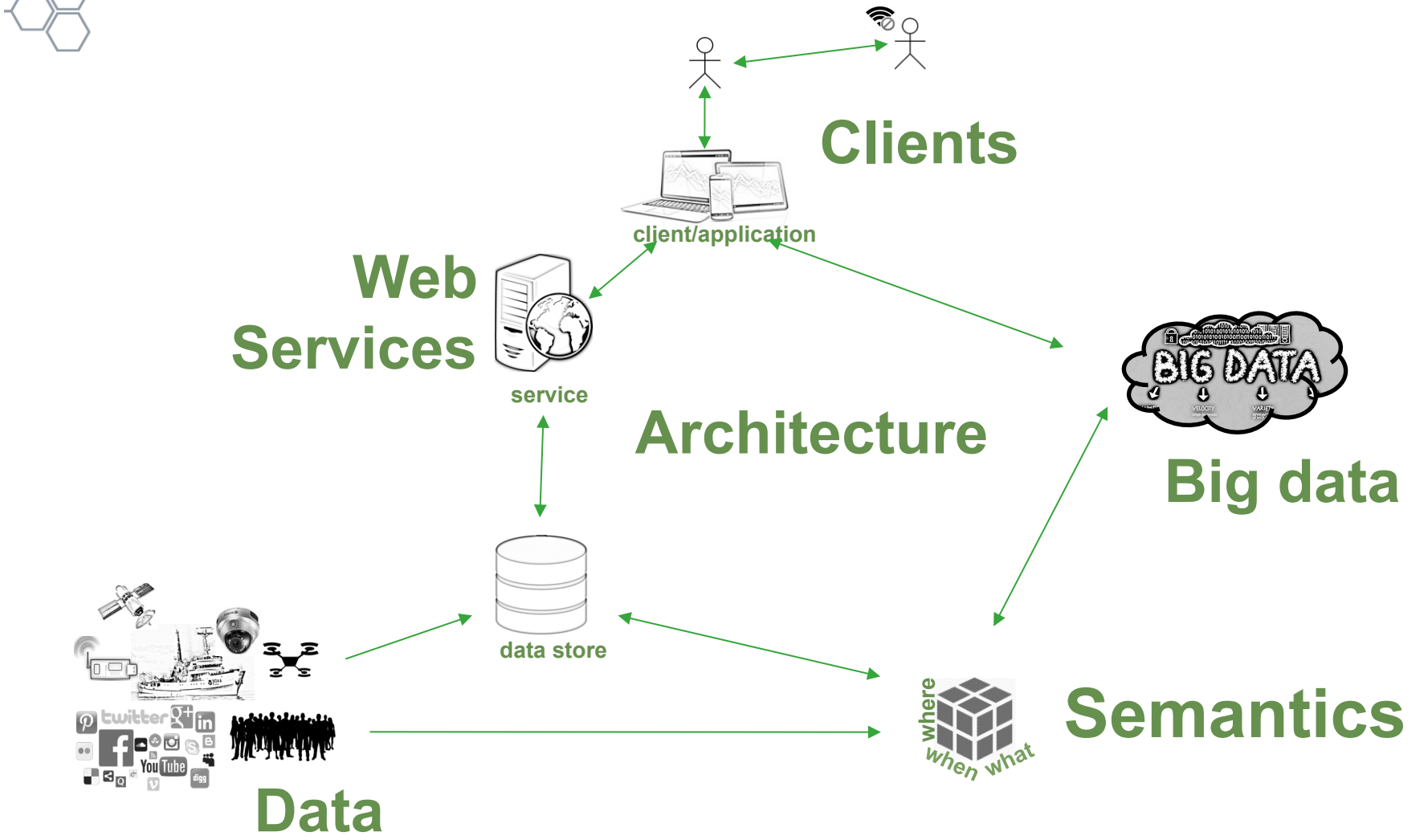
OGC Testbed 12



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OGC Testbed 12

testbed-12
overarching theme
emergency management

2 **OGC web service interfaces**
asynchronous interaction
coverage data access
new services to support geo
and non-geospatial data
new services to define
associations between objects
WFS-temporal extension
data profiles (DGIWG, NSG)
multiple data encodings support

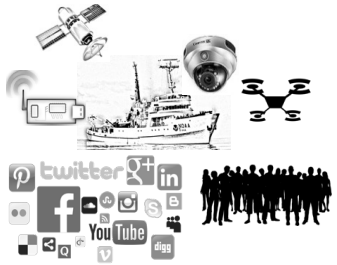
1 **clients**
compression & generalization
low bandwidth support
GeoPackage offline sync

client/application

service

3 **architecture**
multi-catalog integration (DCAT, CSW)
geospatial & non-geospatial data integration
Web service, APIs, REST, SOAP
quality of service
security
messaging, brokering
compliance testing

4 **(dynamic) sources / communities**
quality models
GeoPackage data container
LiDAR streaming
vector tiling
vector data conflation with Hootenanny
imagery quality framework
aviation models & semantics



data store

5 **big data**
Big Data tile stores
Big Data DB model
Big Data metadata models

6 **semantics**
linked data
semantic mediation
semantic portrayal
UML to RDF (NAS)

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Extending OGC Web Services to new datatypes and encodding

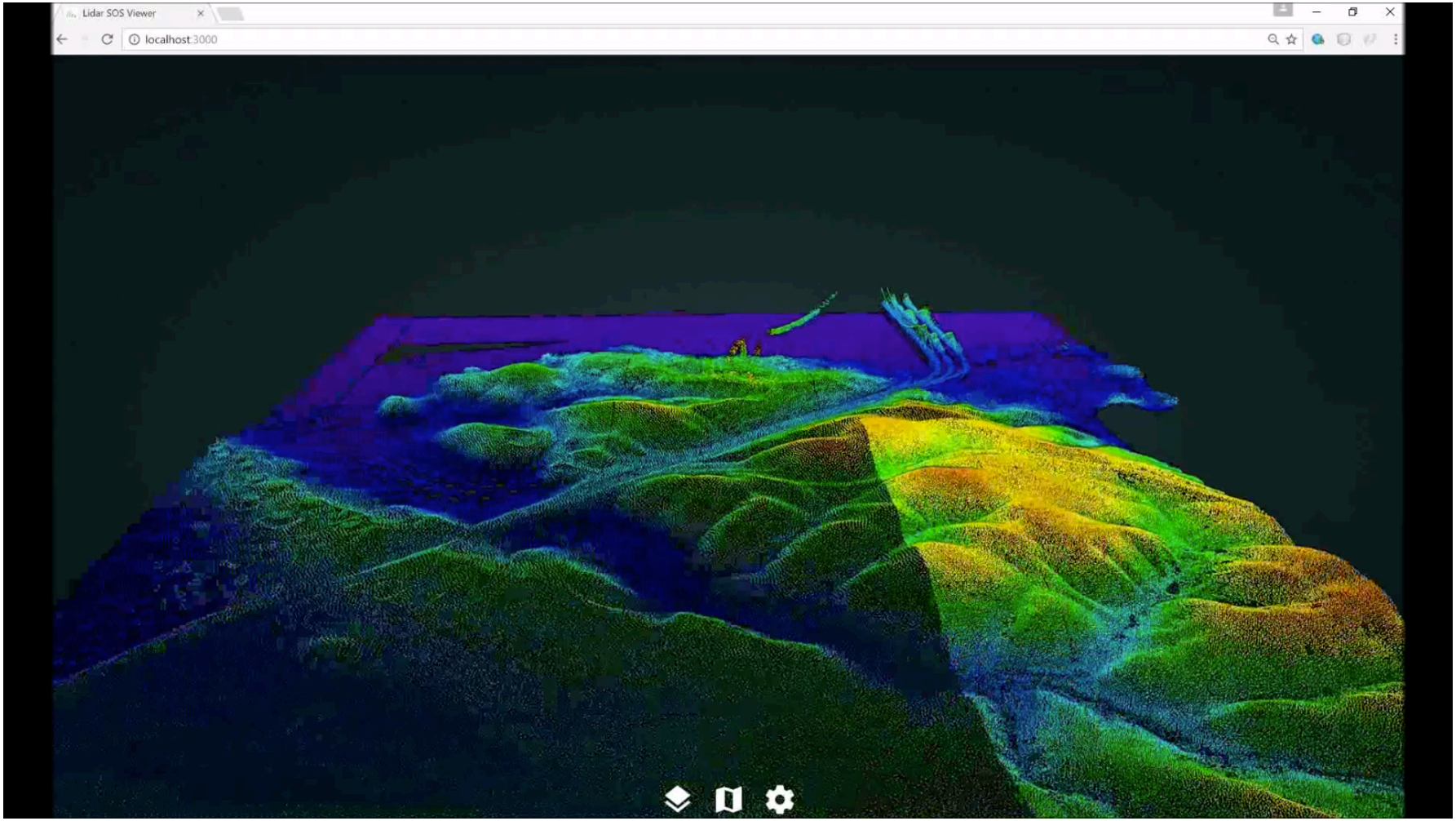
LiDAR

- using ASPRS LAS
- binary 3d point cloud
- compressed: LAZ

SOS-based protocol

- streaming LiDAR data similar to JPIP
- loading LiDAR into SOS
- implementation of Potree
- static hierarchy to compensate for missing cache modelling (state issue)

LiDAR Streaming via SOS in OGC Testbed 12



[See all of OGC Testbed 12 Demonstration]

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Big Geospatial Data

1PB in 1995 required a large building

EROS Data Center, Sioux Falls, SD

1PB in 2015 requires a 1 car garage

CyberGIS at NCSA Univ. of Illinois

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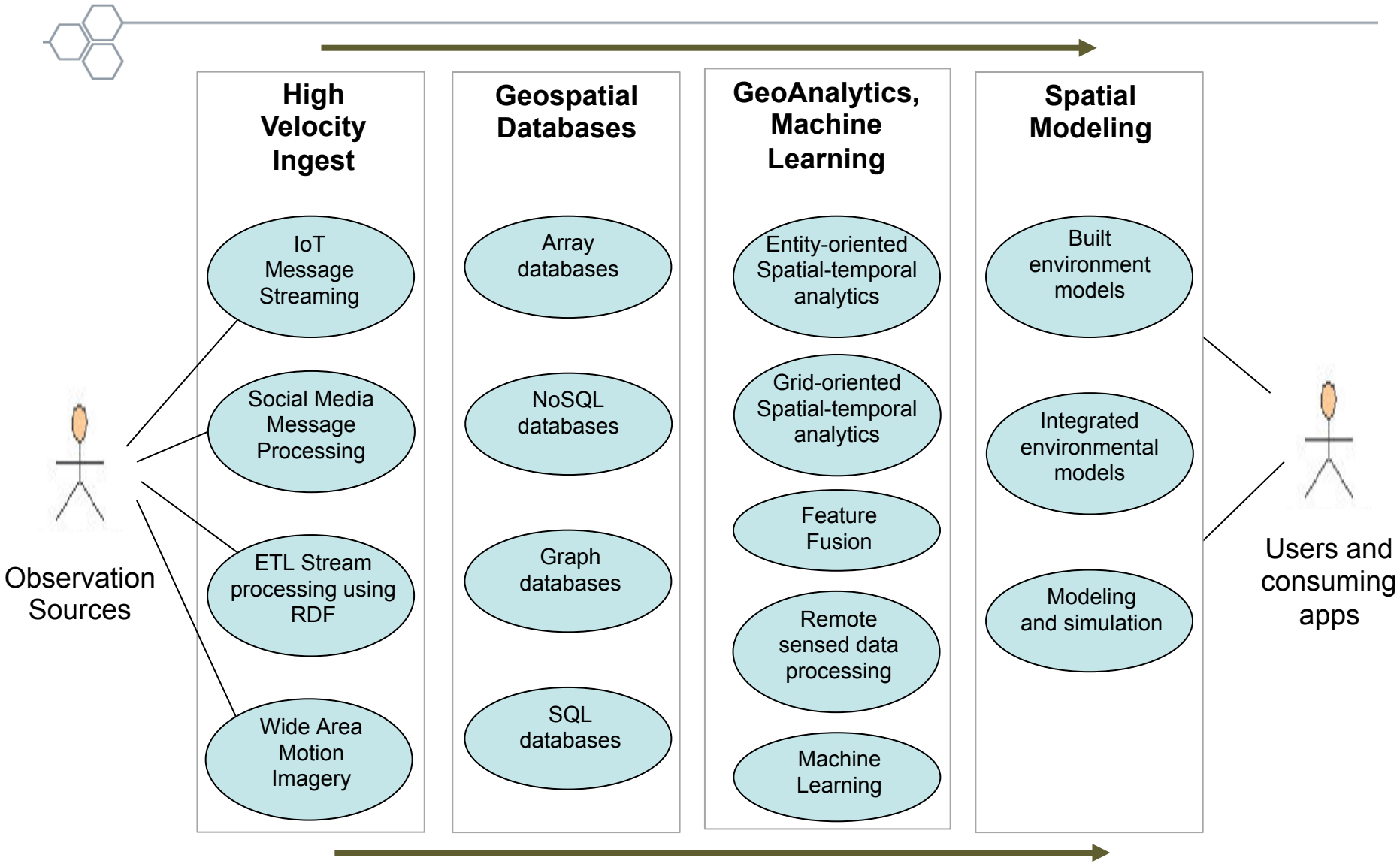
Use Cases for Big Geo Data



http://www.locationpowers.net/

Location Powers: Big Data, 20 Sep 2016

Keynote: Jibo Sanyal, ORNL

Obtaining Big Data

- Geoffrey Fox, Indiana Univ
- Jeff Walter, NASA

Maintain and Access Data:

- Keith Hare, JTC1 SC32 SQL
- Glenn Guempel, USGS
- Rob Emanuele, Azavea

Analyzing Big Data:

- Dan Getman, DigitalGlobe
- Peter Baumann, rasdaman
- Akinori Sahara, Hitachi
- Rose Winterton, Pitney Bowes

Using Big Data: Applications

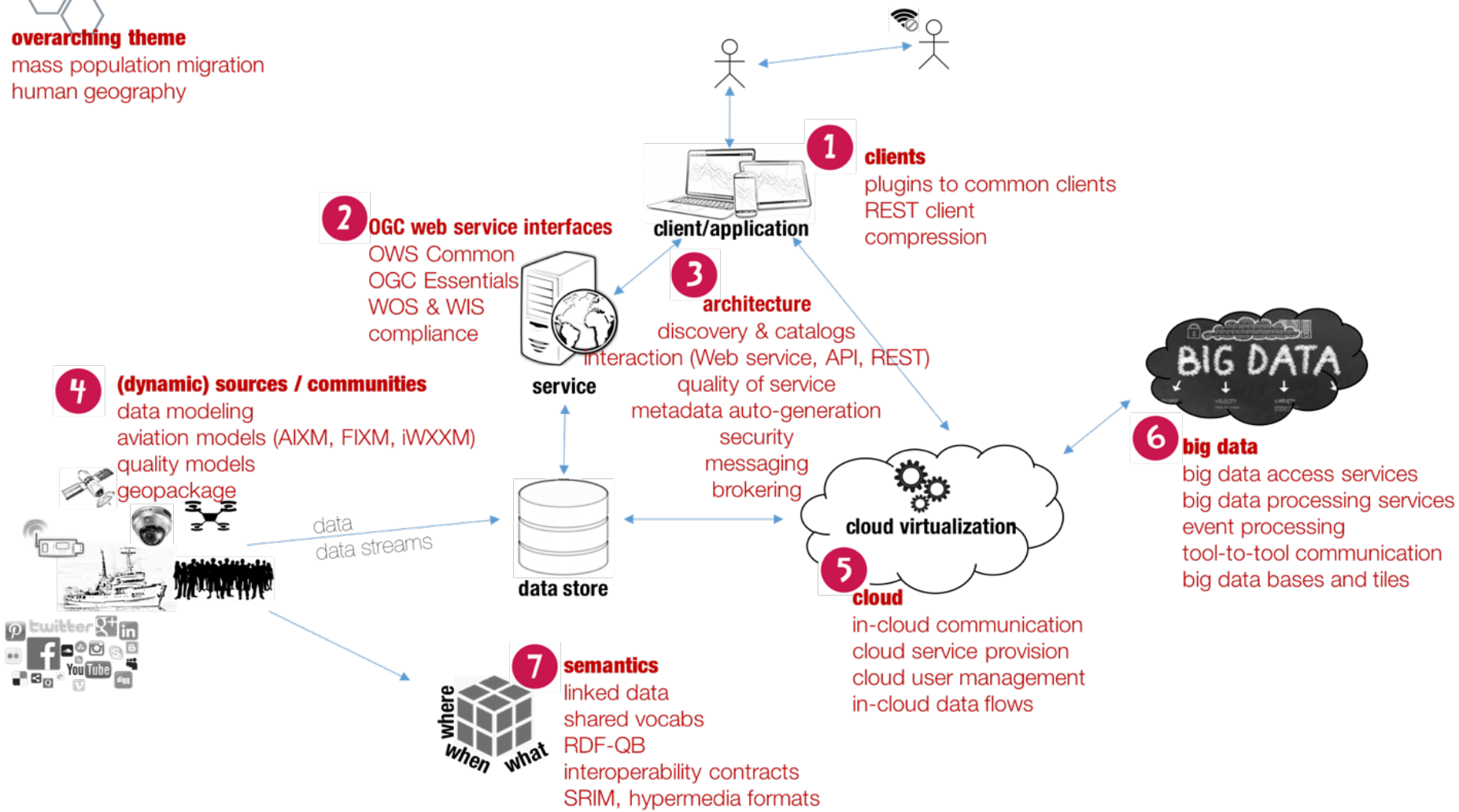
- Shaowen Wang, NCSA/UIUC
- Charlie Greenbacker, In-Q-Tel
- Lea Shanley, South Big Data Hub at RENCI
- Jeff de La Beaujardière, NOAA

Emergent Themes from LPBigData

- Loosely-coupled PB archives for rapid geospatial information product creation at any scale based on open standards
  - Inter-cloud communications; portability across clouds
  - Workflow based on interfaces exposed by containers
- Analysis Ready Data
  - We live in a download mentality. How do we move to answering questions
  - Focus shifting from understanding what happened last week to being able to predict what will happen next week
- Data Models
  - Global Grids, Space Filling Curves, Indices
  - Arrays, Tiles, Point Clouds
- Take advantage of broad developments in Big Data
- Accelerate Big Data innovation in Testbed 13

Testbed 13

overarching theme
mass population migration
human geography



1 clients
plugins to common clients
REST client
compression

2 OGC web service interfaces
OWS Common
OGC Essentials
WOS & WIS
compliance

3 architecture
discovery & catalogs
interaction (Web service, API, REST)
quality of service
metadata auto-generation
security
messaging
brokering

4 (dynamic) sources / communities
data modeling
aviation models (AIXM, FIXM, iWXXM)
quality models
geopackage

5 cloud
in-cloud communication
cloud service provision
cloud user management
in-cloud data flows

6 big data
big data access services
big data processing services
event processing
tool-to-tool communication
big data bases and tiles

7 semantics
linked data
shared vocabs
RDF-QB
interoperability contracts
SRIM, hypermedia formats

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Innovation and Technology Tracking

- Address the innovator's dilemma
  - Maintain current OGC Baseline while developing new standards
  - to support evolving and potentially disruptive technologies, community needs, and market trends

- Active Technology Tracking
  - OGC Architecture Board (OAB) monitors trends to identify technology gaps or issues related to the OGC

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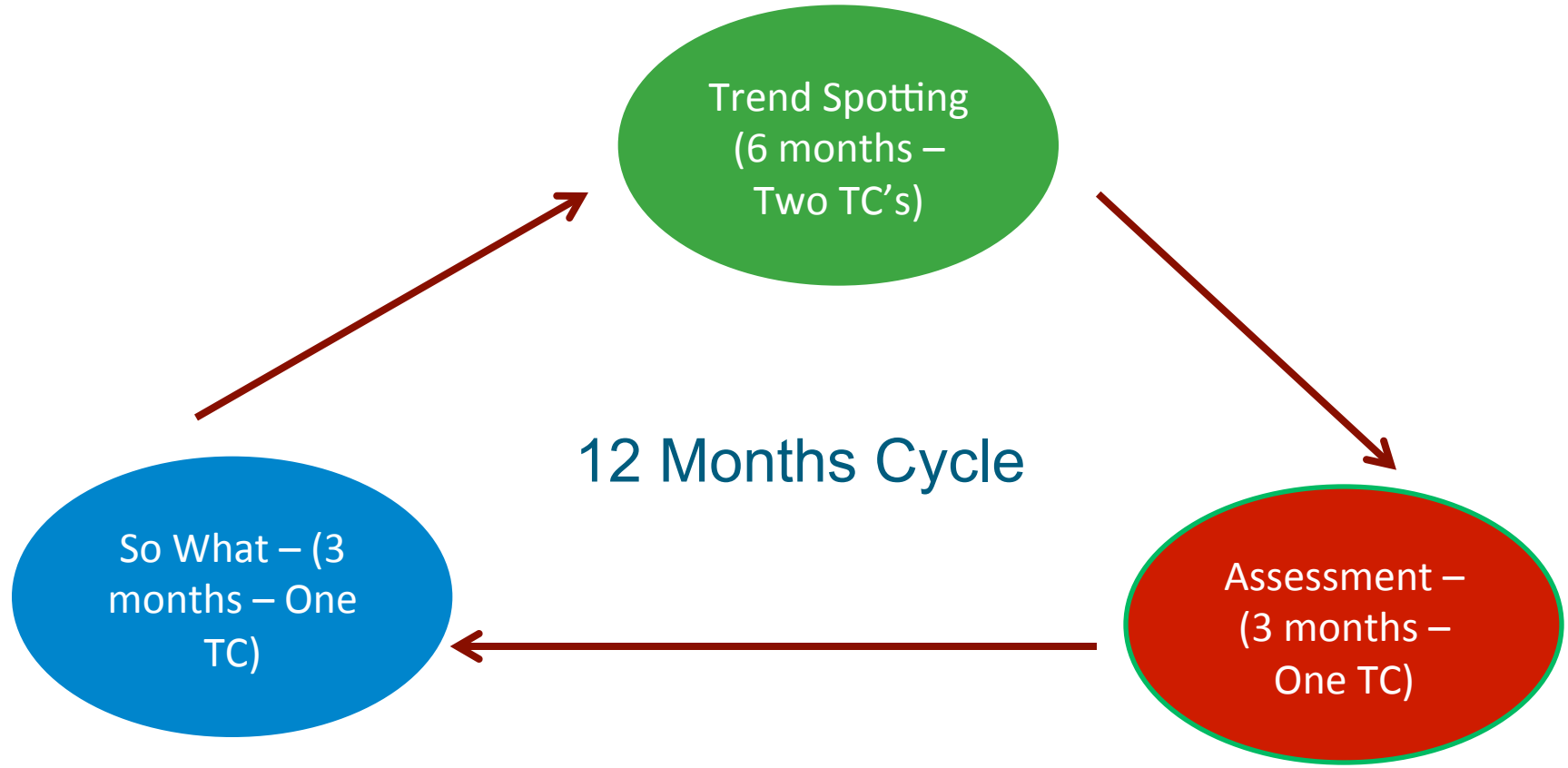
Annual Cycle for Tech Monitoring



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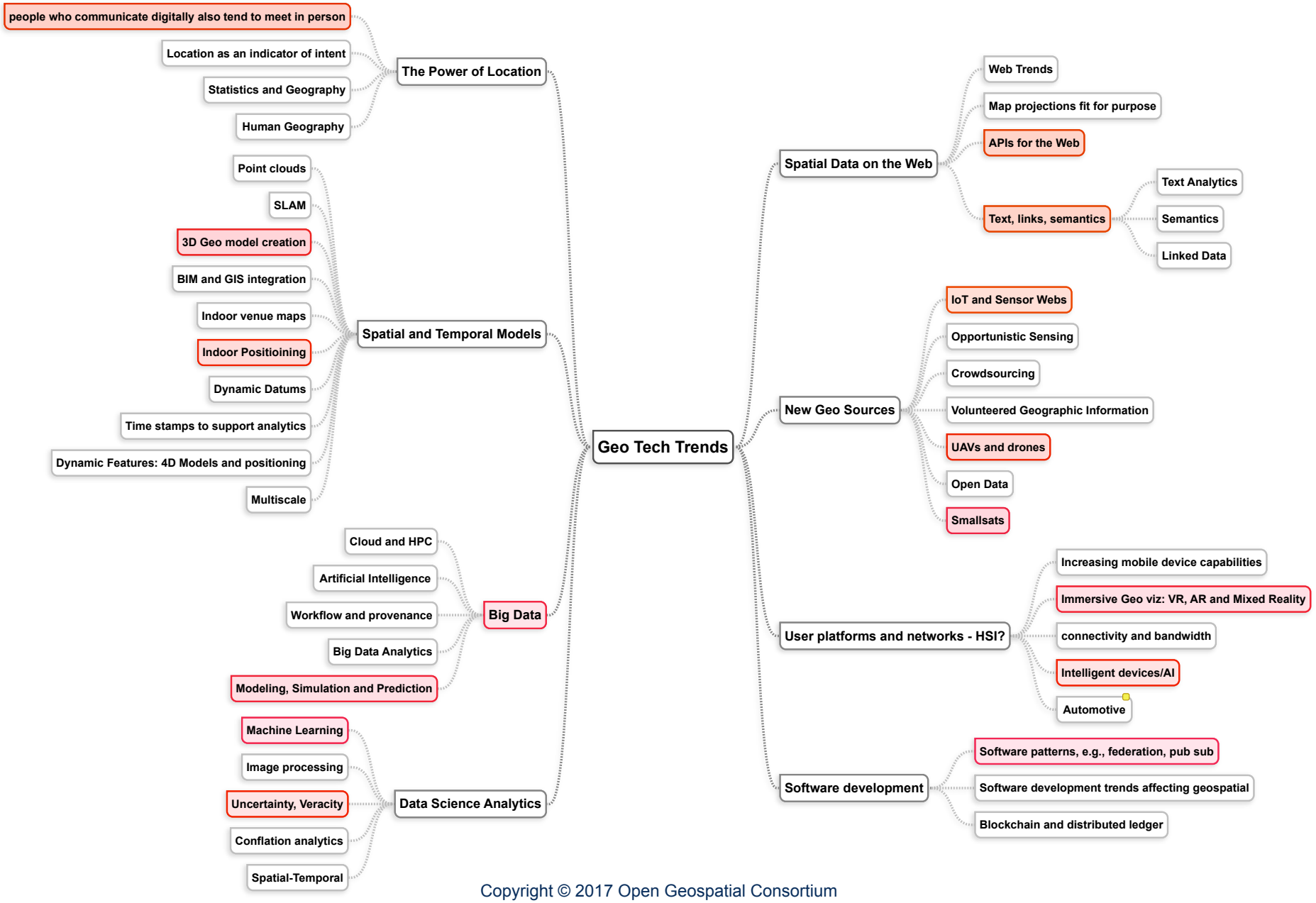
OGC Tech Trends – February 2017



Innovation in Geodata

Outline of Talk

- Geomatics based on open standards
- What is innovation?
- Innovation in Geomatics

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For Details on OGC …

OGC Standards

- Freely available
- www.opengeospatial.org/standards

OGC Innovation Program

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

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