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W3C Semantic Sensor Networks: Ontologies, Applications, and Future Directions

Cory Andrew Henson
Wright State University - Main Campus

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IERC AC4 Semantic Interoperability Workshop

19-20 June 2012, Venice, Italy
co-located with IoTWeek 2012
http://www.probe-it.eu/?page_id=642

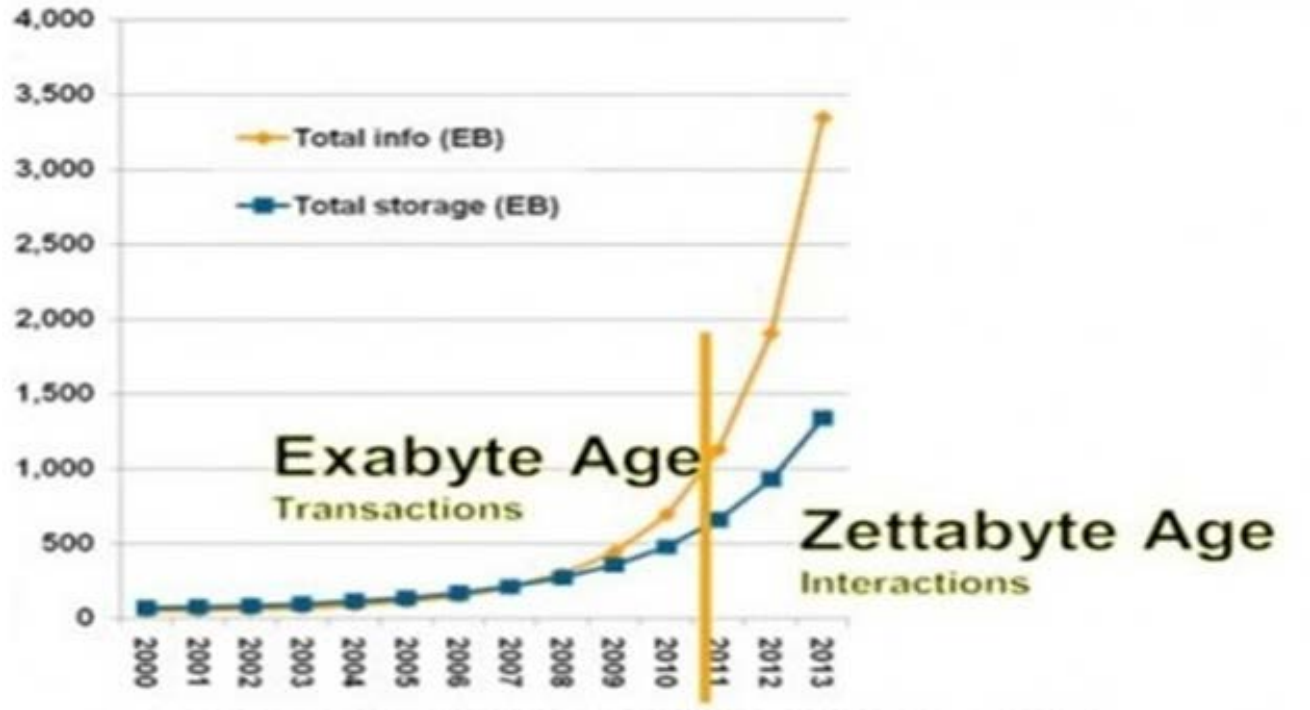
W3C Semantic Sensor Networks

Ontologies, Applications, and Future Directions

Cory Henson

Ohio Center of Excellence in Knowledge-enabled Computing (Kno.e.sis)
Wright State University, Dayton, Ohio, USA


Once upon a time, there was the Web



... and then it grew (ca. 2012)

Who or what is the culprit?

User generated content, new types of media, etc.

A cross-country flight from New York to Los Angeles on a Boeing 737 plane generates a massive 240 terabytes of data

- GigaOmni Media

What happens when all THINGS go online?

(*sensors, devices, and appliances begin to publish data*)

How are machines supposed to make sense
of this noisy, ambiguous, heterogeneous, deluge of data?

Semantic Web

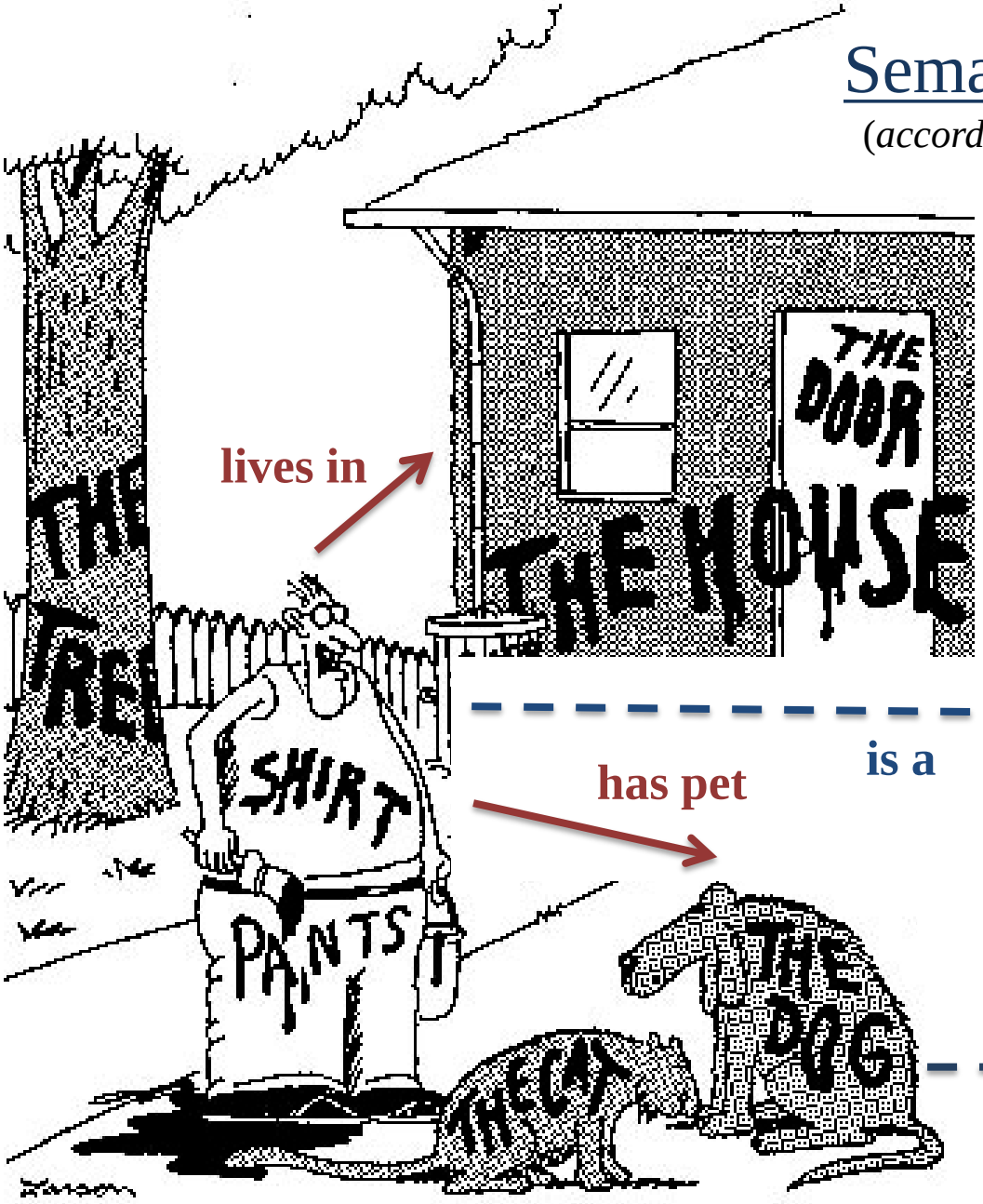
RDF

OWL

kno.e.sis

Semantic Web

(*according to Farside*)

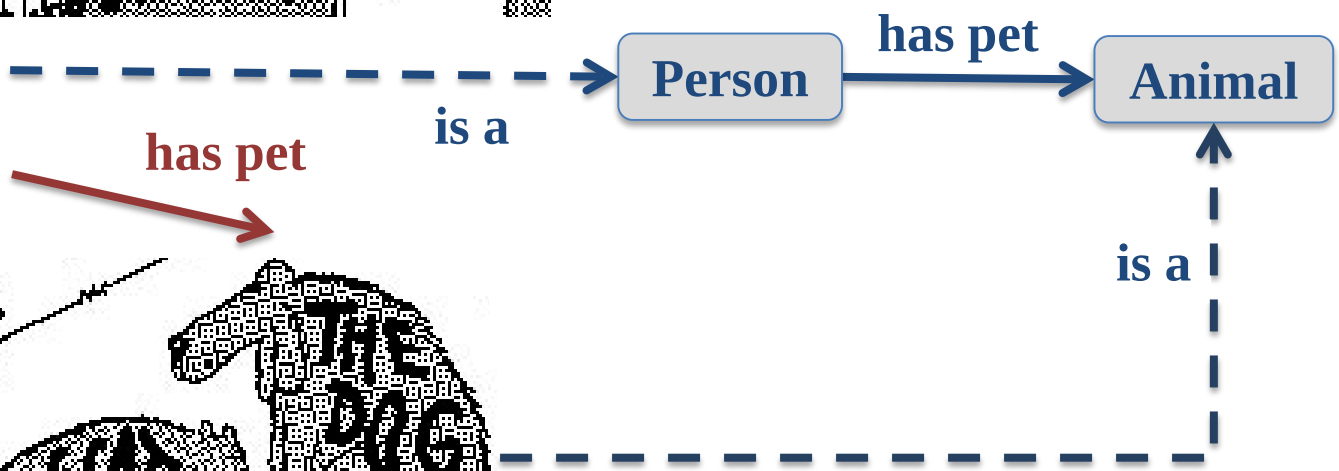


Concrete Facts

Resource Description Framework

General Knowledge

Web Ontology Language

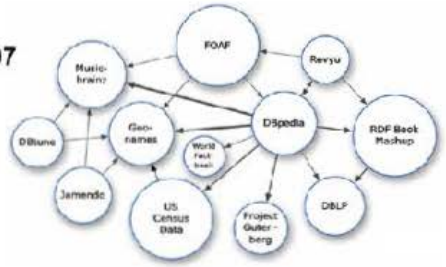


"Now! – *That* should clear up a few things around here!"

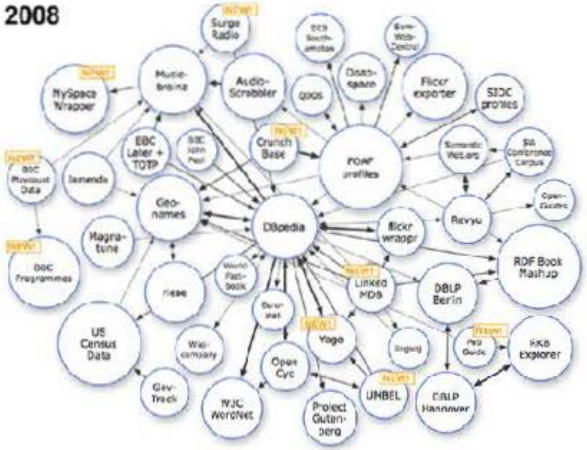
LINKINGOPENDATA
W3C SWEO Community Project

IERC
European Research Cluster on the Internet of Things

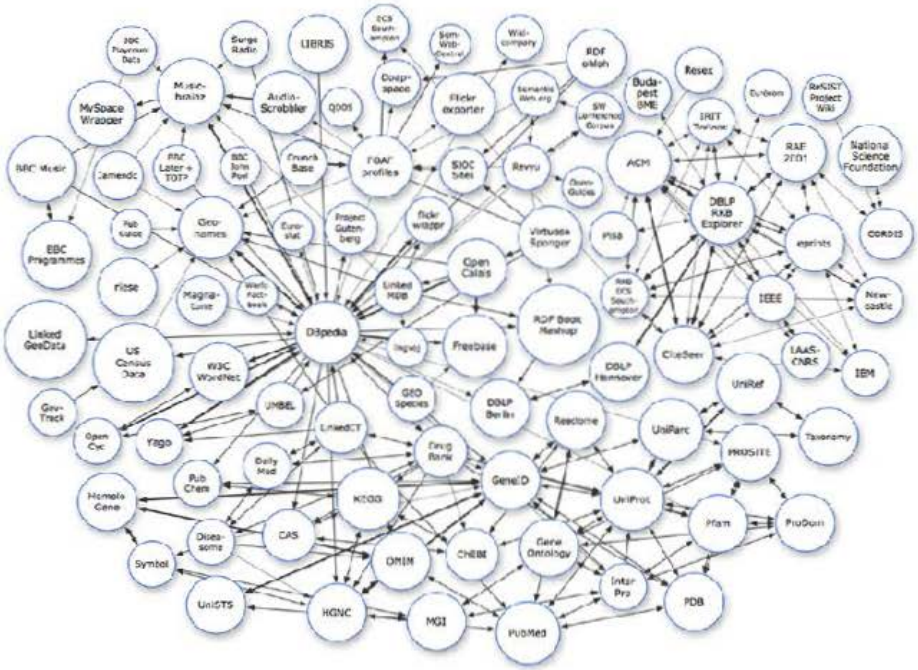
May 2007



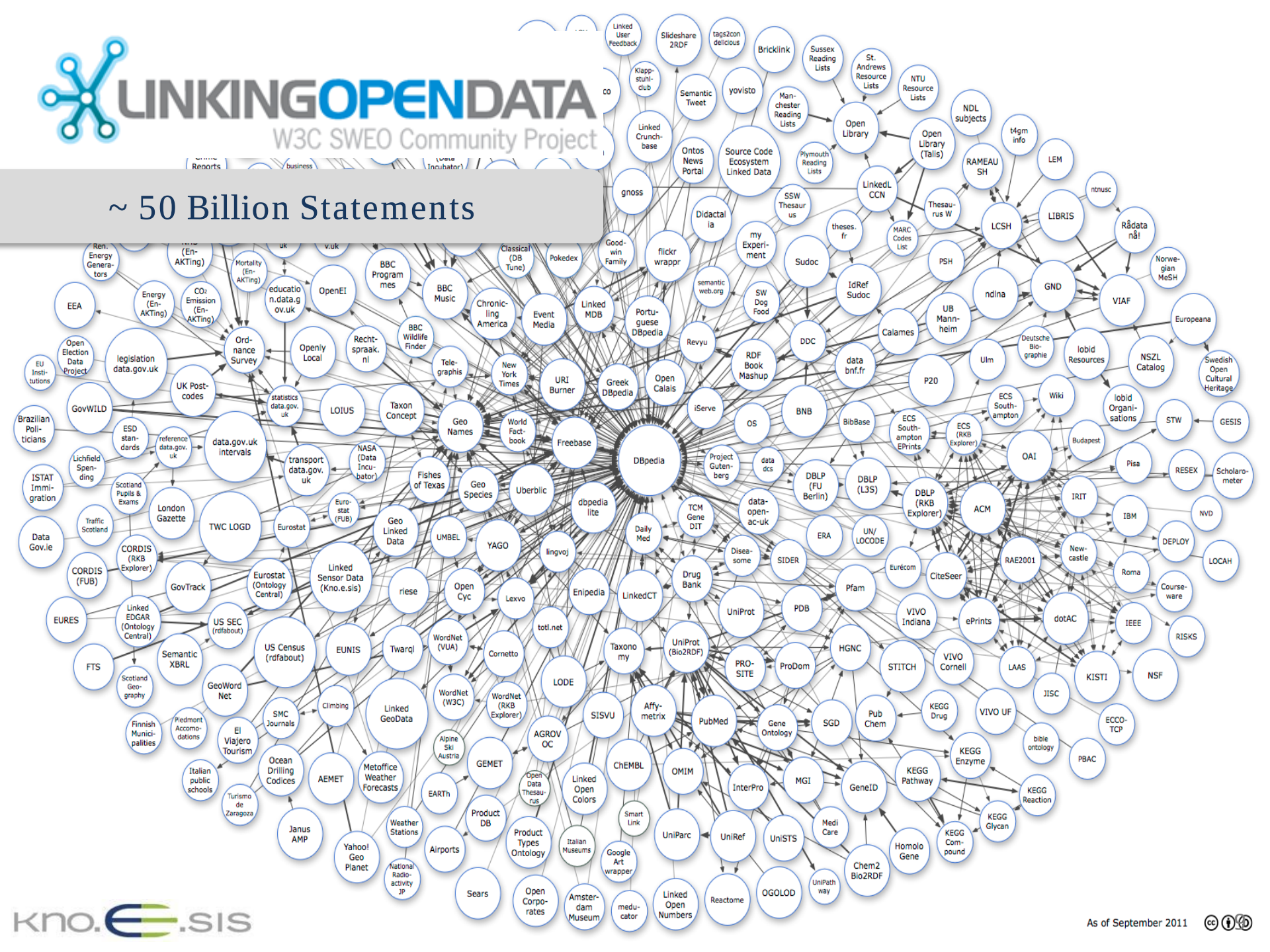
September 2008



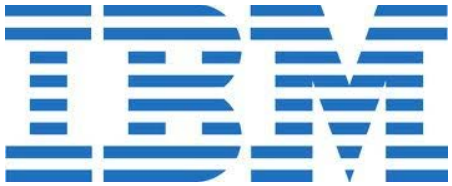
July 2009



kno.e.sis


LINKINGOPENDATA
W3C SWEO Community Project
~ 50 Billion Statements
DBpedia
Freebase
Geo Names
YAGO
UMBEL
Open Cyc
Linked Sensor Data (Kno.e.sis)
Linked GeoData
Linked Open Colors
Linked Open Numbers
Linked MDB
Linked Crunchbase
Linked User Feedback
Slideshare 2RDF
tags2con delicious
Bricklink
Sussex Reading Lists
St. Andrews Resource Lists
NTU Resource Lists
NDL subjects
t4gm info
Open Library
Open Library (Talis)
LinkedL CCN
RAMEAU SH
LCSH
LIBRIS
Råda nå!
GND
VIAF
Europeana
Swedish Open Cultural Heritage
NSZL Catalog
lobid Resources
lobid Organi-sations
Wiki
ndlna
UB Mann-heim
Calames
PSH
IdRef Sudoc
Sudoc
SW Dog Food
RDF Book Mashup
data bnf.fr
P20
Ulm
Deutsche Bio-graphie
BNB
BibBase
ECS South-ampton
ECS South-ampton EPrints
ECS (RKB Explorer)
OAI
Budapest
Pisa
RESEX
Scholaro-meter
STW
GESIS
IRIT
IBM
NVD
DEPLOY
LOCAH
Roma
Course-ware
IEEE
RISKS
NSF
KISTI
JISC
ECCO-TCP
PBAC
bible ontology
VIVO UF
VIVO Cornell
LAAS
VIVO Indiana
ePrints
dotAC
New-castle
RAE2001
CiteSeer
Eurécom
ACM
DBLP (RKB Explorer)
DBLP (L3S)
DBLP (FU Berlin)
UN/ LOCODE
ERA
SIDER
Disea-some
Drug Bank
Pfam
PDB
UniProt
UniProt (Bio2RDF)
HGNC
STITCH
PRO-SITE
ProDom
Taxono my
LinkedCT
Enipedia
totl.net
lingvoj
Daily Med
TCM Gene DIT
data-open-ac-uk
Project Guten-berg
data dcs
Uberblic
dbpedia lite
Fishes of Texas
Geo Species
Geo Linked Data
Taxon Concept
LOIUS
statistics data.gov.uk
transport data.gov.uk
NASA (Data Incu-bator)
Euro-stat (FUB)
Eurostat
Eurostat (Ontology Central)
US Census (rdfabout)
US SEC (rdfabout)
EUNIS
Twarql
WordNet (VUA)
WordNet (W3C)
WordNet (RKB Explorer)
Cornetto
LODE
riese
Lexvo
Affy-metrix
SISVU
AGROV OC
GEMET
ChEMBL
OMIM
InterPro
MGI
GeneID
Gene Ontology
SGD
PubMed
Pub Chem
KEGG Drug
KEGG Enzyme
KEGG Pathway
KEGG Reaction
KEGG Glycan
KEGG Com-pound
Homolo Gene
Chem2 Bio2RDF
UniPath way
OGOLOD
Reactome
Amster-dam Museum
medu-cator
Open Corpo-rates
Sears
Janus AMP
Yahoo! Geo Planet
Weather Stations
National Radio-activity JP
Airports
Product DB
Product Types Ontology
Italian Museums
Google Art wrapper
Smart Link
UniParc
UniRef
UniSTS
Medi Care
Open Data Thesau-rus
EARTh
Alpine Ski Austria
Metoffice Weather Forecasts
AEMET
Climbing
SMC Journals
El Viajero Tourism
Ocean Drilling Codices
Turismo de Zaragoza
Italian public schools
Piedmont Accomo-dations
Finnish Munici-palities
Scotland Geo-graphy
GeoWord Net
Semantic XBRL
FTS
EURES
Linked EDGAR (Ontology Central)
GovTrack
CORDIS (RKB Explorer)
CORDIS (FUB)
Traffic Scotland
TWC LOGD
London Gazette
Scotland Pupils & Exams
ISTAT Immi-gration
Lichfield Spen-ding
ESD stan-dards
reference data.gov.uk
data.gov.uk intervals
Data Gov.ie
Brazilian Poli-ticians
GovWILD
UK Post-codes
legislation data.gov.uk
Open Election Data Project
EU Insti-tutions
Ord-nance Survey
Openly Local
Recht-spraak. nl
BBC Wildlife Finder
BBC Programmes
BBC Music
OpenEI
educatio n.data.g ov.uk
Mortality (En-AKTing)
CO2 Emission (En-AKTing)
Energy (En-AKTing)
EEA
Ren. Energy Genera-tors
(En-AKTing)
Chronic-ling America
Event Media
Tele-graphis
New York Times
URI Burner
Greek DBpedia
Open Calais
iServe
OS
Revyu
Portu-guese DBpedia
Pokedex
Classical (DB Tune)
Good-win Family
flickr wrappr
semantic web.org
Didactal ia
Source Code Ecosystem Linked Data
Ontos News Portal
Semantic Tweet
yovisto
Klapp-stuhl-club
Linked Data
Man-chester Reading Lists
Plymouth Reading Lists
SSW Thesaur us
theses. fr
MARC Codes List
Thesau-rus W
ntnusc
LEM
Norwe-gian MeSH
Kno.e.sis
As of September 2011

SW is now moving from academia into industry



IBM Watson

Apple Siri

In the last few years, we have seen many successes …

Google UK Knowledge Graph

"Strings to Things"

Google venice italy

News for **venice italy**

Tornado tears through parts of **Venice**, **Italy** (VIDEOS)
Washington Post (blog) - 16 hours ago
A rare tornado (or waterspout, when over water) swept over several islands (Lido, Sant'Elena and Sant'Erasmo) off **Venice's** lagoon earlier ...

Italy putting brakes on excitement
London Free Press - 14 hours ago

Italy could be hit by Spanish contagion
Economic Times - 1 day ago

Venice - Wikipedia, the free encyclopedia

en.wikipedia.org/wiki/**Venice**
Venice (**Italian**: Venezia [veˈnɛttsja] (listen), Venetian: Venexia [veˈnɛsja] is a city in northeast Italy sited on a group of 118 small islands separated by canals ...
↳ History of the Republic of Venice - Venice, Los Angeles - Grand Canal

Venice Vacations, Tourism and **Venice**, **Italy** Travel Reviews ...

www.tripadvisor.com/Tourism-g187870-**Venice**_Veneto-Vacations.h...
Venice Vacations: With 130000 reviews of **Venice**, **Italy** travel resources, TripAdvisor is the source for Venice information.

ItalyGuides.it: Virtual tour of **Venice**, **Italy** - travel information and city ...

www.**italy**guides.it/us/**venice_italy**/**venice**_travel.htm
Venice tourism and travel information: transport, attractions, maps, travel advice, pictures, audio guides, airport information, activities, hotels and more in **Venice**, ...

Official website of the Municipality of **Venice** - Comune di **Venezia**

www.comune.**venezia**.it/flex/cm/pages/ServeBLOB.php/L/EN/.../1
Official website of the Municipality of **Venice**, **Italy**. News, information and tools available to citizens and visitors.

Venice

Venice is a city in northeast Italy sited on a group of 118 small islands separated by canals and linked by bridges. It is located in the marshy Venetian Lagoon which stretches along the shoreline between the mouths of the Po and the Piave Rivers. Wikipedia

Area: 159 sq miles (412 km²)

Weather: 72° F, Wind E at 5 mph, 50% Humidity

Local time: 12:13pm Wednesday (CEST)

Points of interest


Grand Canal of Venice


Piazza San Marco

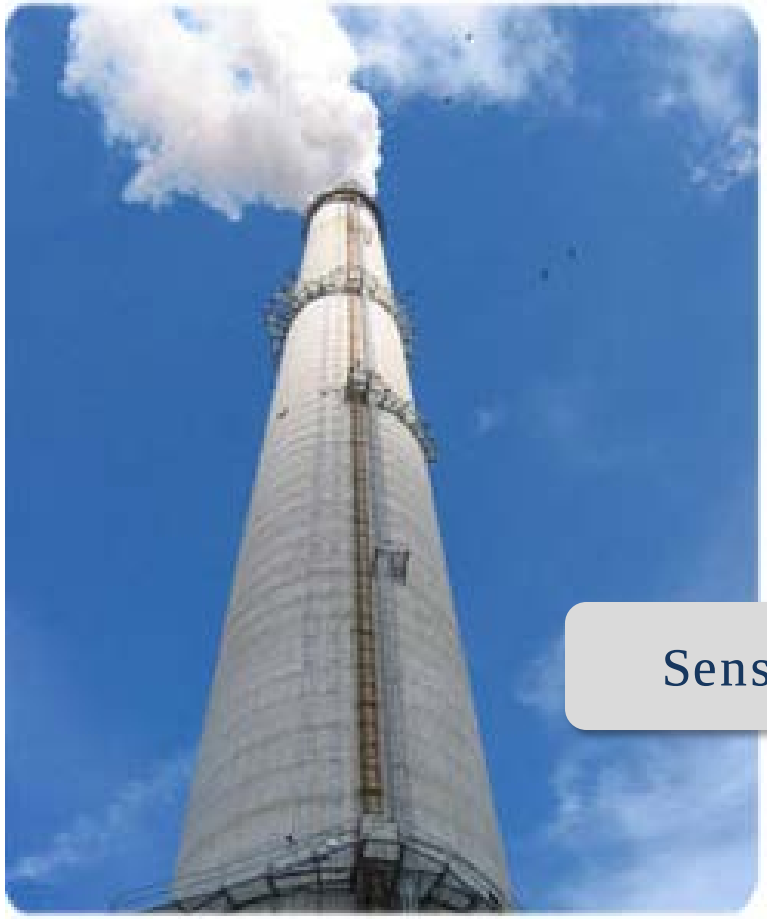

Saint Mark's Basilica


Rialto Bridge


Doge's Palace

Report a problem

Now, what about the Sensor Web?



Sensor systems are too often *stovepiped*

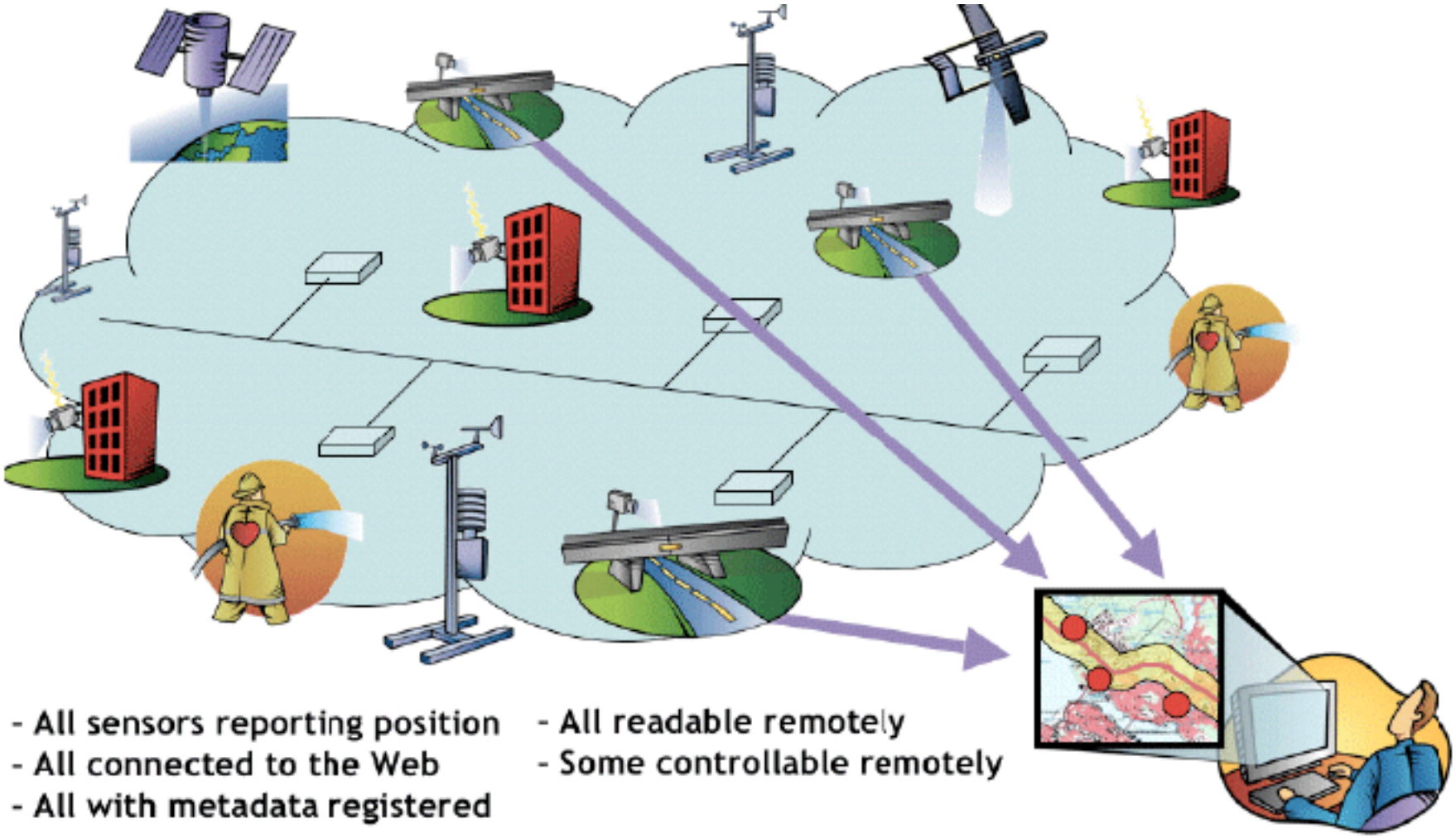
free as a bird.

We want to set this data free

With freedom comes responsibility

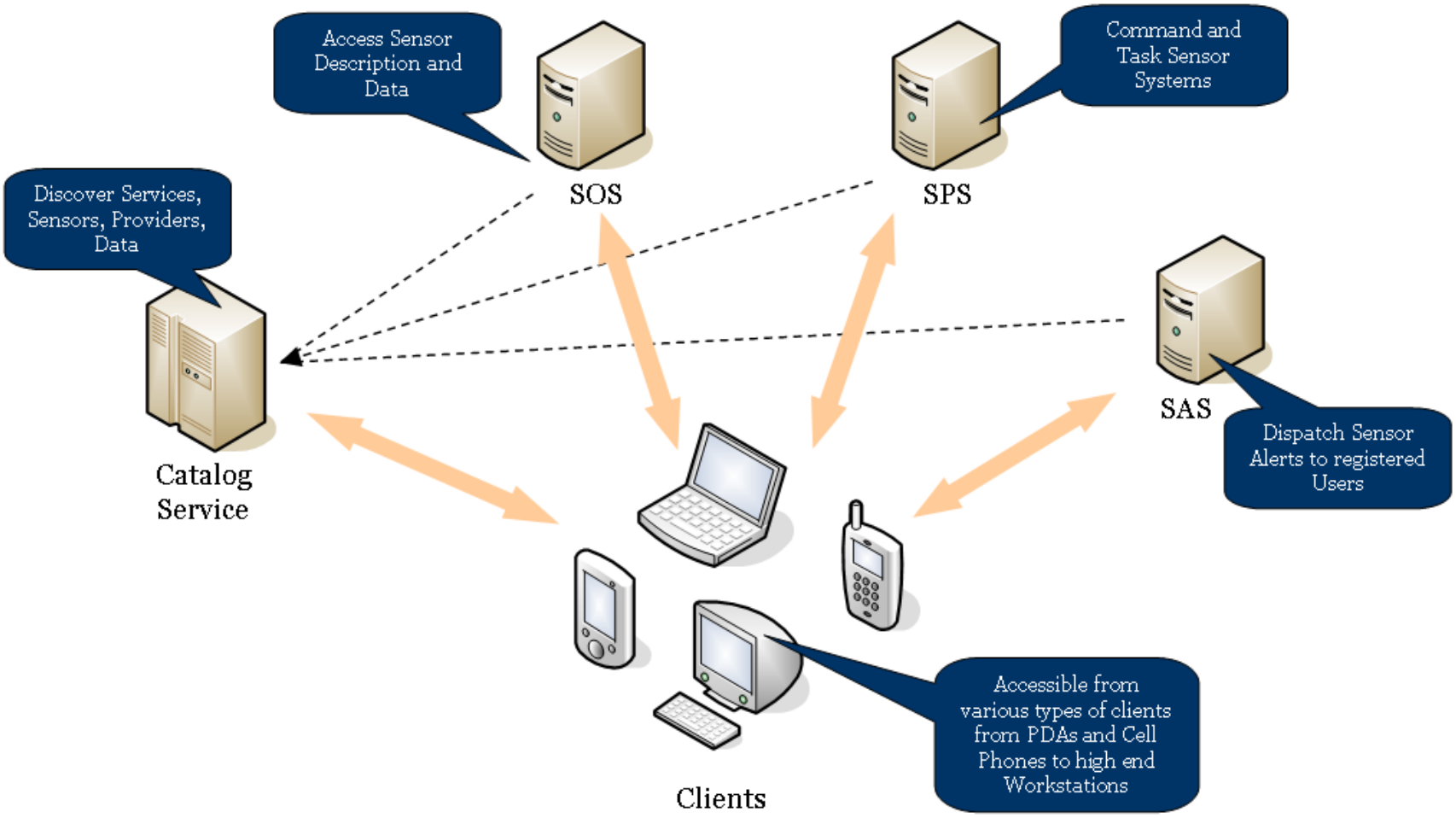
1. discovery, access, and search
2. integration and interpretation

Introducing the Sensor Web Enablement (SWE)



- All sensors reporting position
- All connected to the Web
- All with metadata registered
- All readable remotely
- Some controllable remotely

Introducing the Sensor Web Enablement (SWE)



free as a bird.

We want to set this data free

With freedom comes responsibility

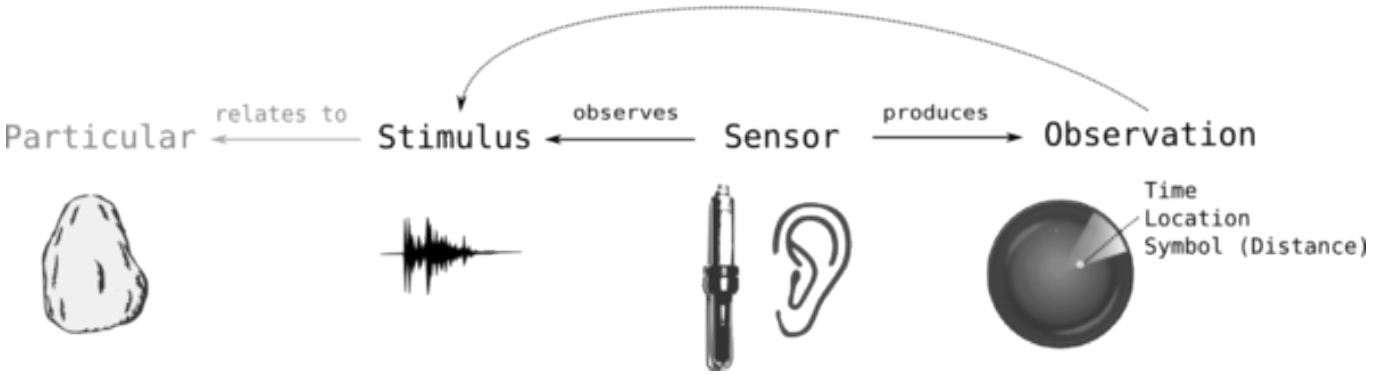
1. ~~discovery, access, and search~~
2. integration and interpretation

So, again …

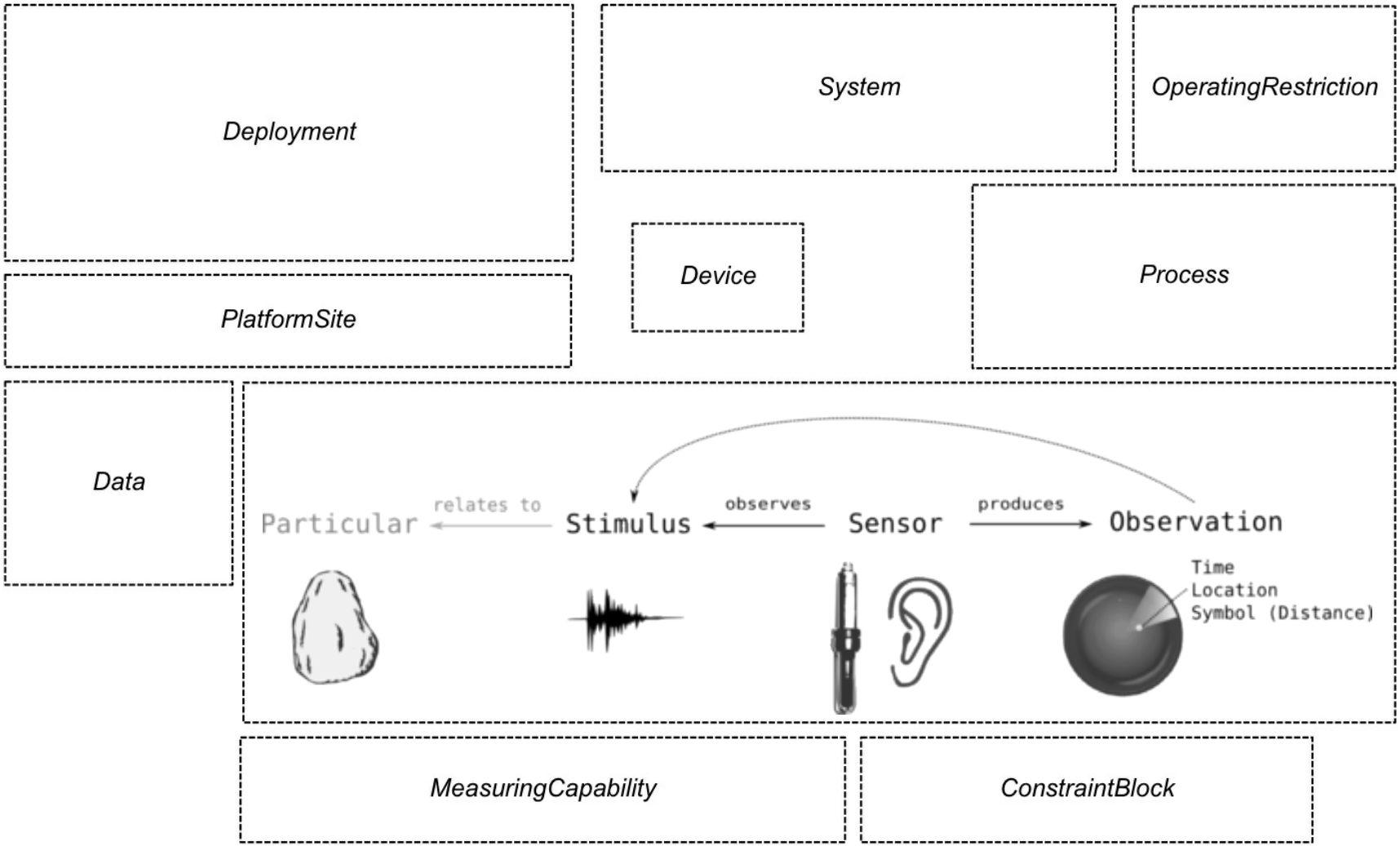
How are machines supposed to make sense of this noisy, ambiguous, heterogeneous, deluge of data?

Semantic Sensor Networks (SSN)

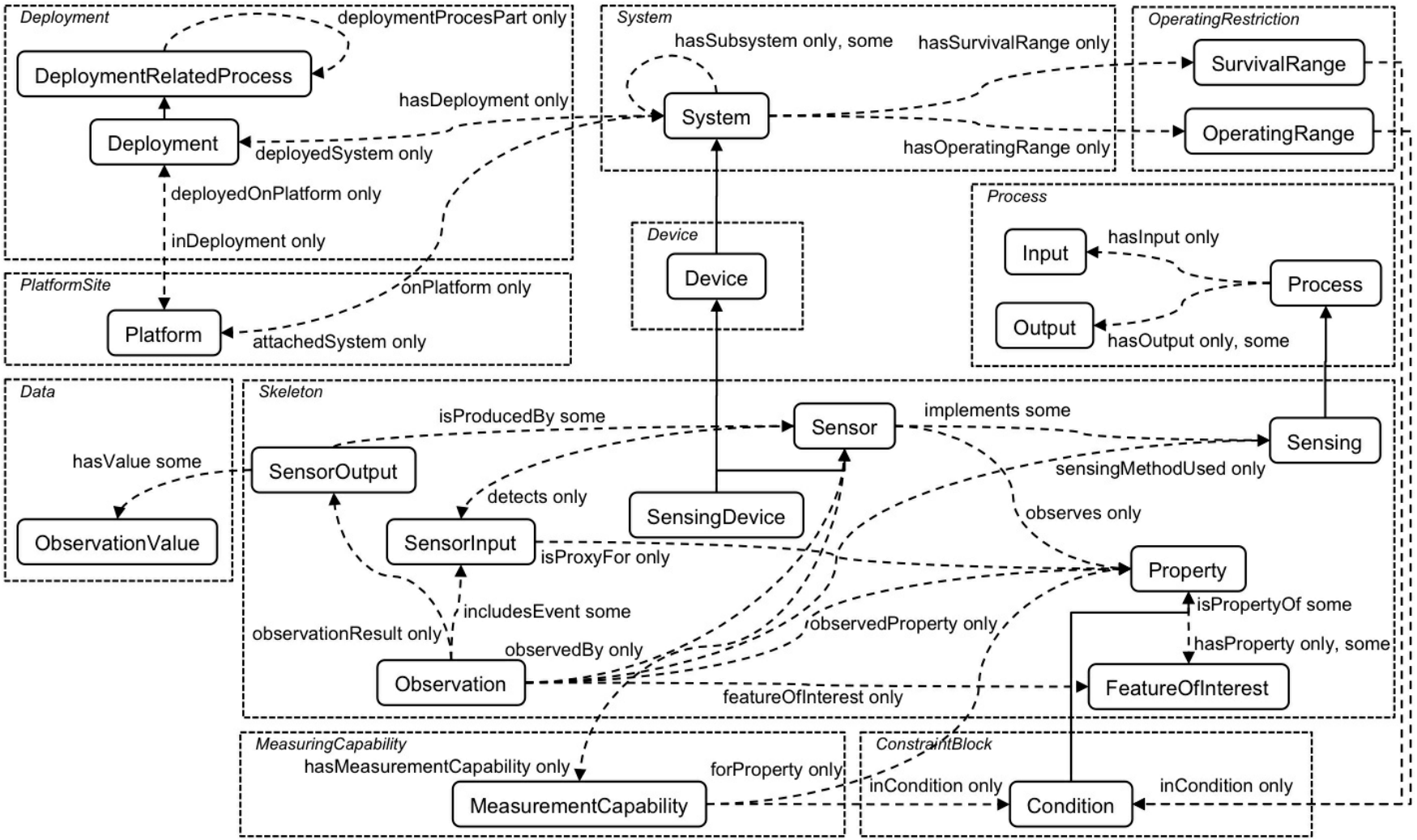
SSN Ontology
(i.e., General Sensor Knowledge)



SSN Ontology
(i.e., General Sensor Knowledge)



SSN Ontology
(i.e., General Sensor Knowledge)



Semantic Annotation of SWE
(backwards compatible)

```
<?xml version="1.0" encoding="UTF-8"?>
<swes:offering xlink:role="http://purl.oclc.org/NET/ssnx/ssn#Observation"
   xlink:arcrole="http://www.loa-cnr.it/ontologies/DUL.owl#hasSetting">
 <sos:ObservationOffering>
   <swes:procedureIdentifier
       xlink:role="http://purl.oclc.org/NET/ssnx/ssn#SensingDevice"
       xlink:href="http://purl.oclc.org/NET/ssnx/ssn-dev#rain gauge sth esk up esk rd bridge"
       xlink:arcrole="http://purl.oclc.org/NET/ssnx/ssn#observedBy">
     http://csiro.au/sw/rain gauge sth esk up esk rd bridge
   </swes:procedureIdentifier>
   <swes:observableProperty
       xlink:href="http://purl.oclc.org/NET/ssnx/cf/cf-property#thickness of rainfall amount"
       xlink:arcrole="http://purl.oclc.org/NET/ssnx/ssn#observedProperty"
       xlink:role="http://purl.oclc.org/NET/ssnx/qu/dim#Distance"/>
   <sos:phenomenonTime
       xlink:role="http://www.w3.org/2006/time-entry#Interval">
       xlink:arcrole="http://purl.oclc.org/NET/ssnx/ssn#observationTime"
     <gml:TimePeriod gml:id="phenomenonTime11">
       <gml:beginPosition
           xlink:role="http://www.w3.org/2006/time-entry#begins"
           xlink:arcrole="http://www.w3.org/2001/XMLSchema#time">
         2001-01-11T16:22:25.00
       </gml:beginPosition>
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         2005-10-18T19:54:13.000Z
       </gml:endPosition>
     </gml:TimePeriod>
   </sos:phenomenonTime>
 </sos:ObservationOffering>
</swes:offering>
```
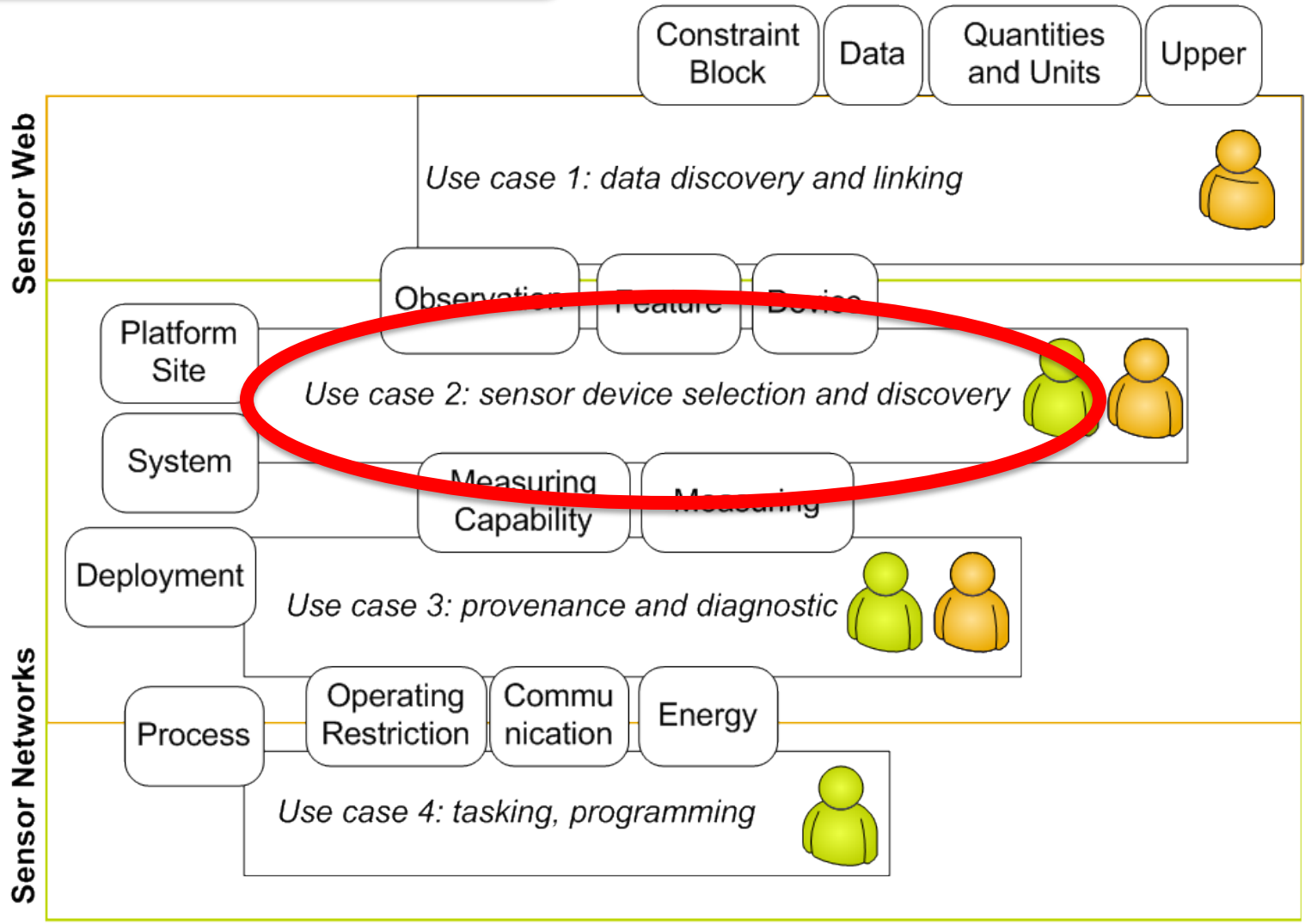
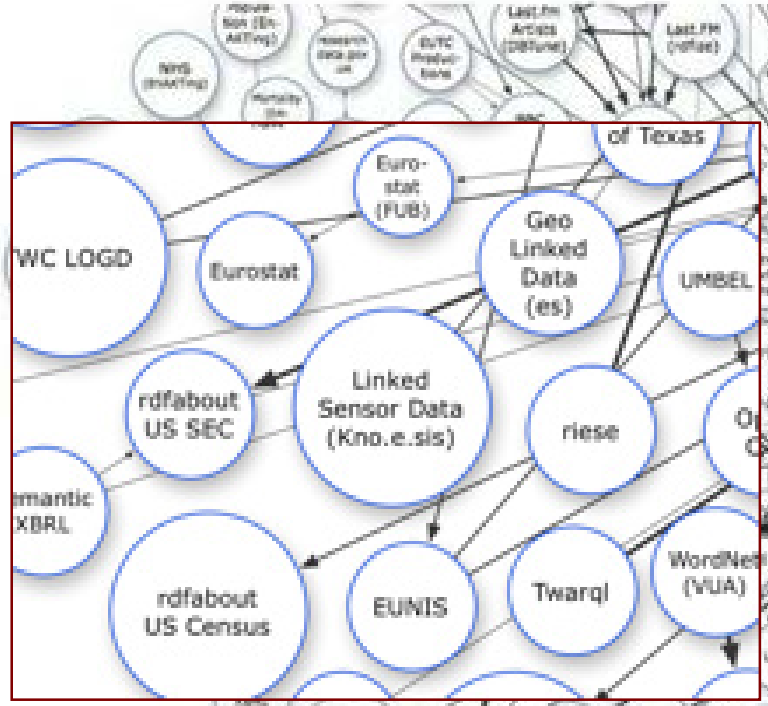

Adoption of SSN

SSN Use Cases

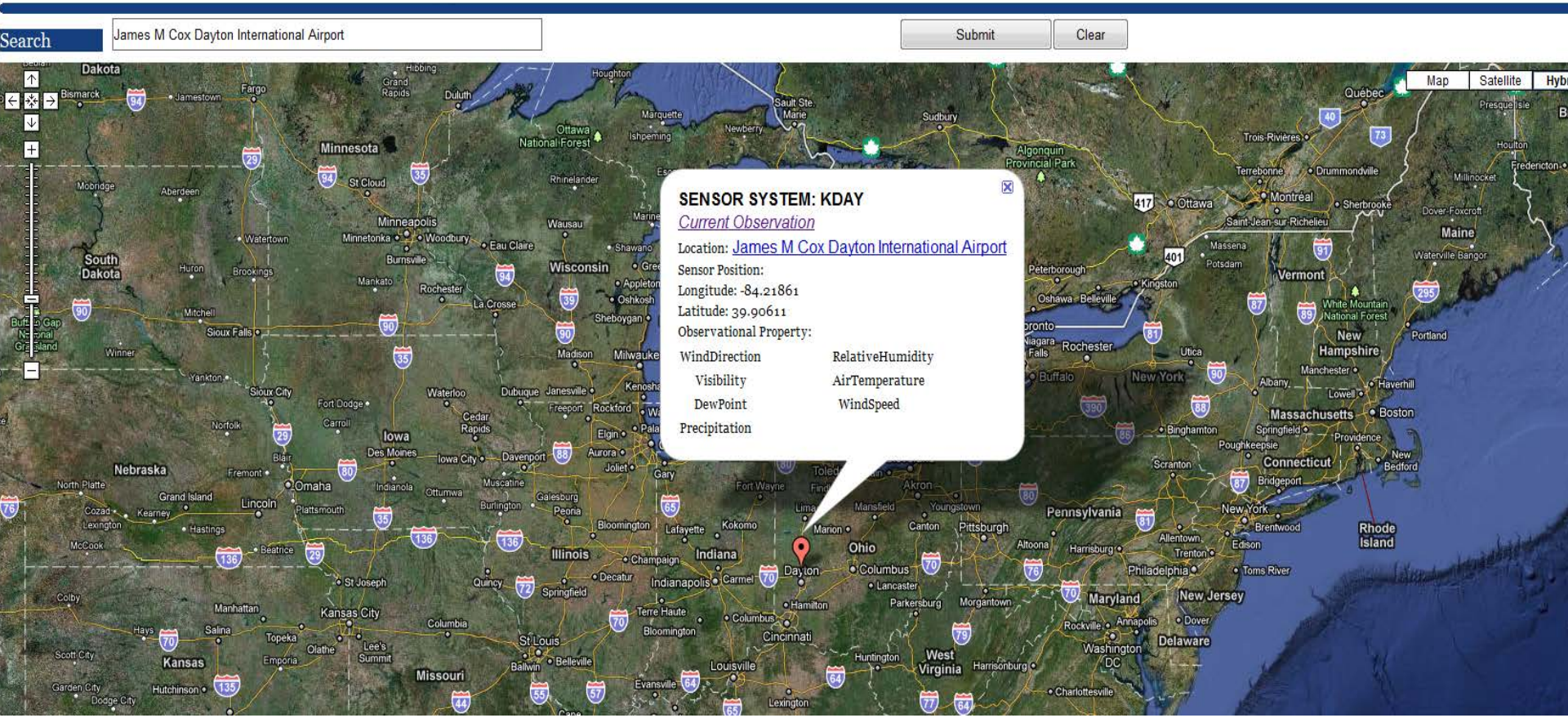


Linked Sensor Data
(~2 Billion Statements)



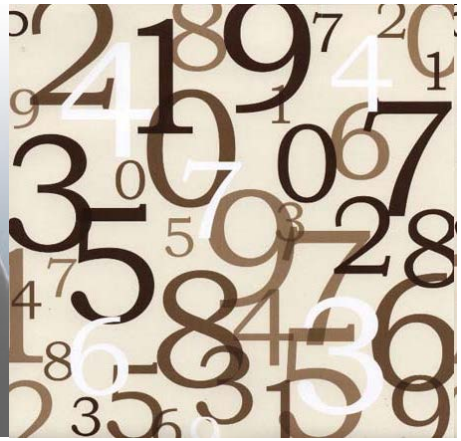
Sensor Discovery Application

Query w/ location name to find nearby sensors



intelleg
"to perceive"

Interpretation (or abstraction/explanation) of sensor data

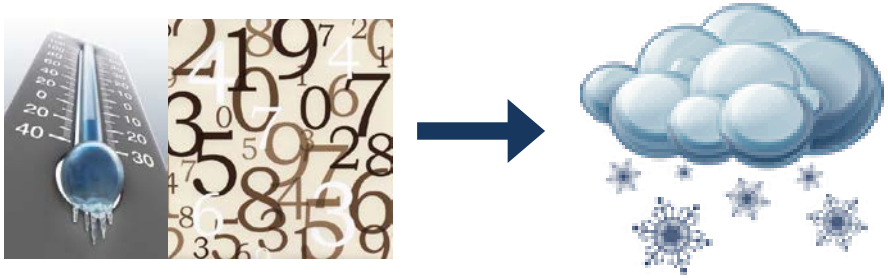
Applications of SSN + intelleg

"to perceive"

Weather

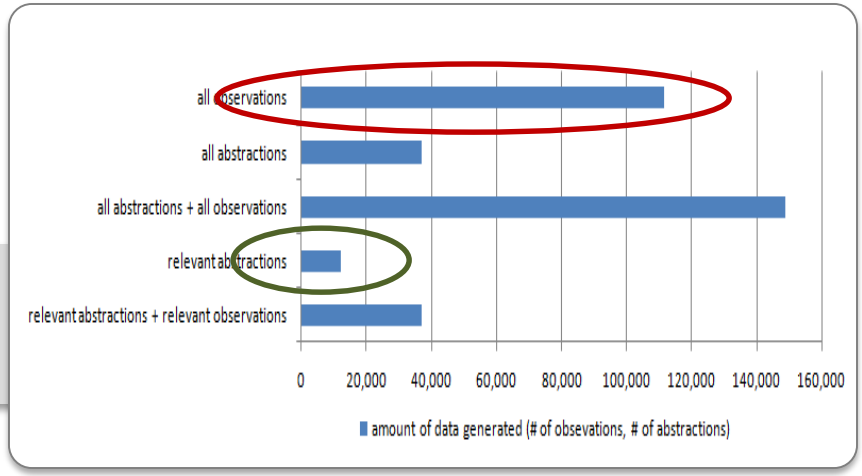
Rescue

Healthcare

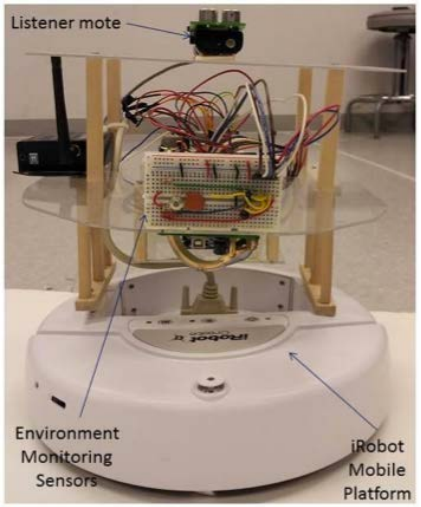


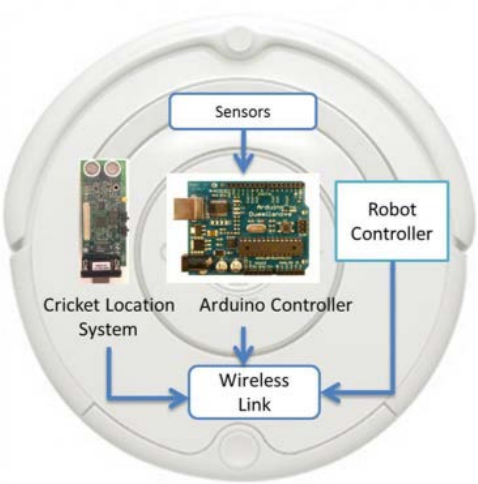
50% savings in sensing resource requirements during the detection of a blizzard

order of magnitude resource savings between storing observations vs. relevant abstractions

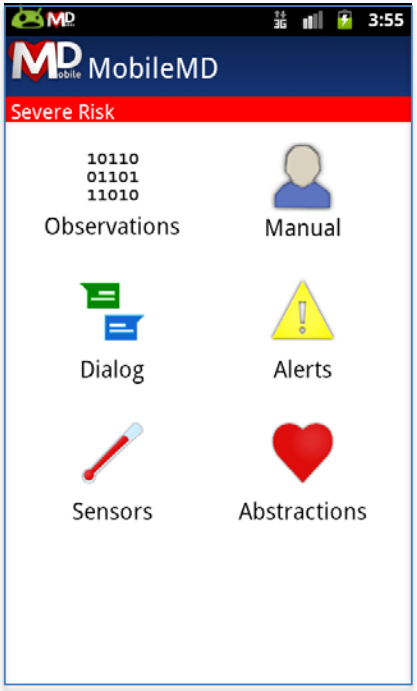


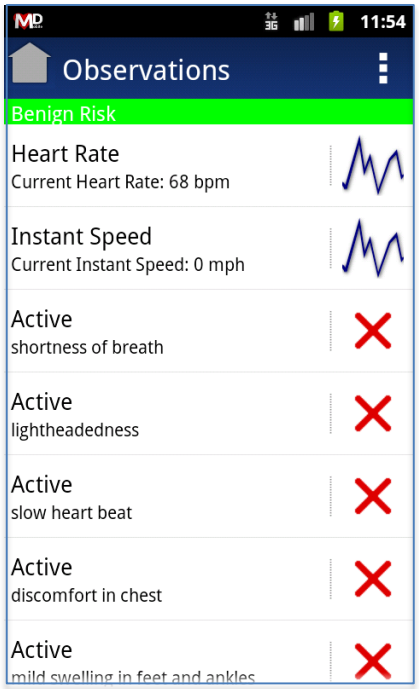
SECURE: Semantics-empowered Rescue Environment
(detect different types of fires)

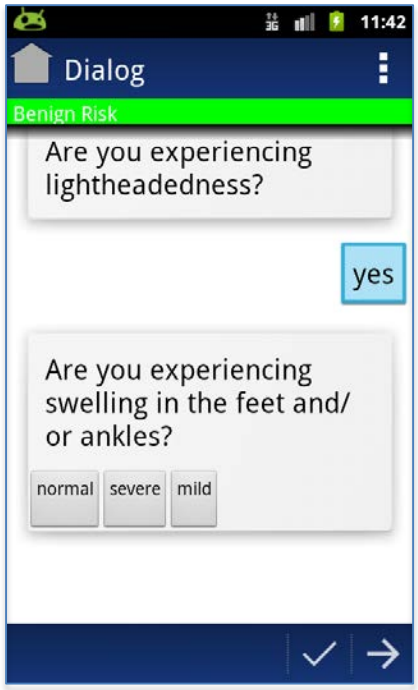


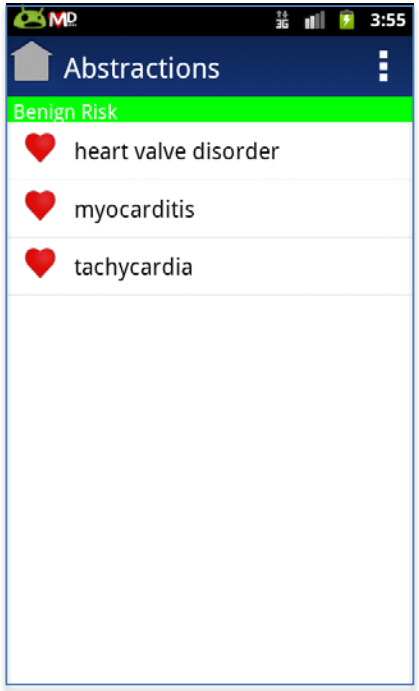


Mobile app to help reduce re-admission of patients with Chronic Heart Failure

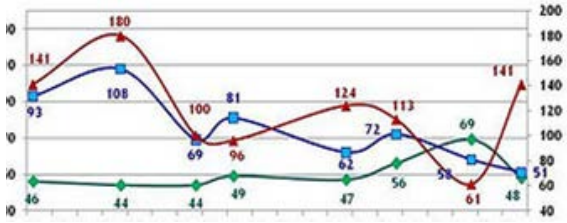








Passive Monitoring Phase



Observed Symptoms

- Abnormal heart rate
- Clammy skin

Possible Explanations

- Panic Disorder
- Hypoglycemia
- Hyperthyroidism
- Heart Attack
- Septic Shock

Electronic Medical Record

- Patient has history of Heart Disease

Health Alert

- Check phone for instructions

Active Monitoring Phase

Are you feeling lightheaded?

yes

Are you have trouble taking deep breaths?

yes

Do you have low blood pressure?

yes

Have you taken your Methimazole medication?

no

Observed Symptoms	Possible Explanations
• Abnormal heart rate • Clammy skin • **Lightheaded** • **Trouble breathing** • **Low blood pressure**	• ~~Panic Disorder~~ • Hypoglycemia • Hyperthyroidism • ~~Heart Attack~~ • ~~Septic Shock~~

Electronic Medical Record

- Patient has history of Hyperthyroidism
- Patient has prescription for Methimazole

Health Alert

1. Take medication: Methimazole
2. See doctor: how about Tues. @ 11am?

IERC European Research Cluster on the Internet of Things

In the next century, planet earth will don an electronic skin. It will use the Internet as a scaffold to support and transmit its sensations. This skin is already being stitched together. It consists of millions of embedded electronic measuring devices.

Neil Gross, The Earth Will Don an Electronic Skin, BusinessWeek, Aug. 1999

Thanks.

W3C Semantic Sensor Networks

Ontologies, Applications, and Future Directions

Cory Henson

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