ONTOLOGY SUPPORT FOR SITUATIONAL AWARENESS IN A DULL, DIRTY, DIVERSE IOT

STIDS 2016

MARK UNDERWOOD | KRYPTON BROTHERS

LEO OBRST | MITRE

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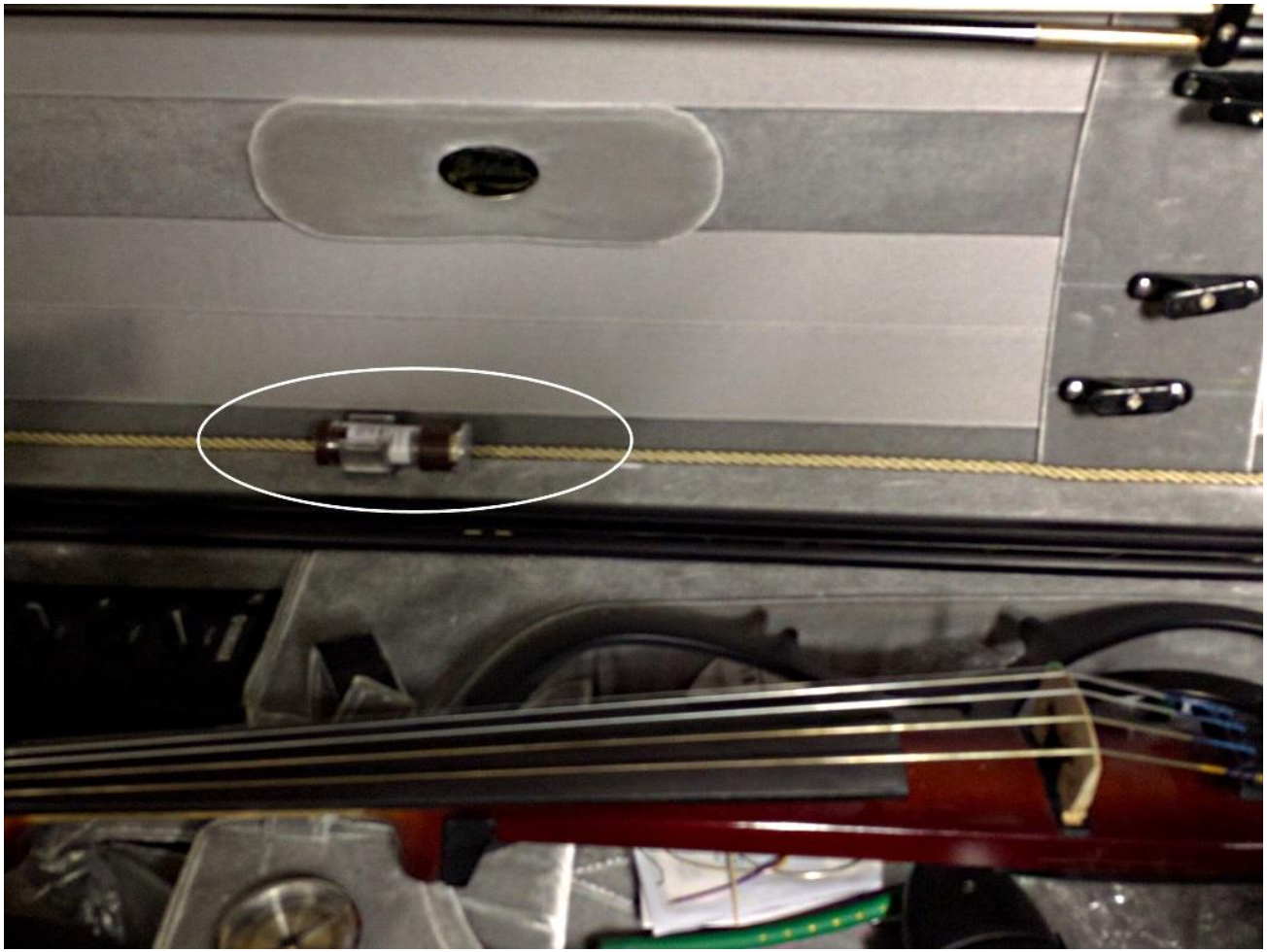
ABOUT @KNOWLENGR (ME: MARK UNDERWOOD)

- CEO Krypton Brothers (NYC area)
- Co-chair Summit on Ontologies for IoT (2015)
- Co-chair Security and Privacy subgroup of the NIST Big Data Public Working Group
- Book chapter on Complex Event Processing for IoT Security (in press)
- ACM, IEEE, AAAI, ISACA, SHRM etc, etc.

MY IOT USE “CASES”

USE CASE: VIOLIN

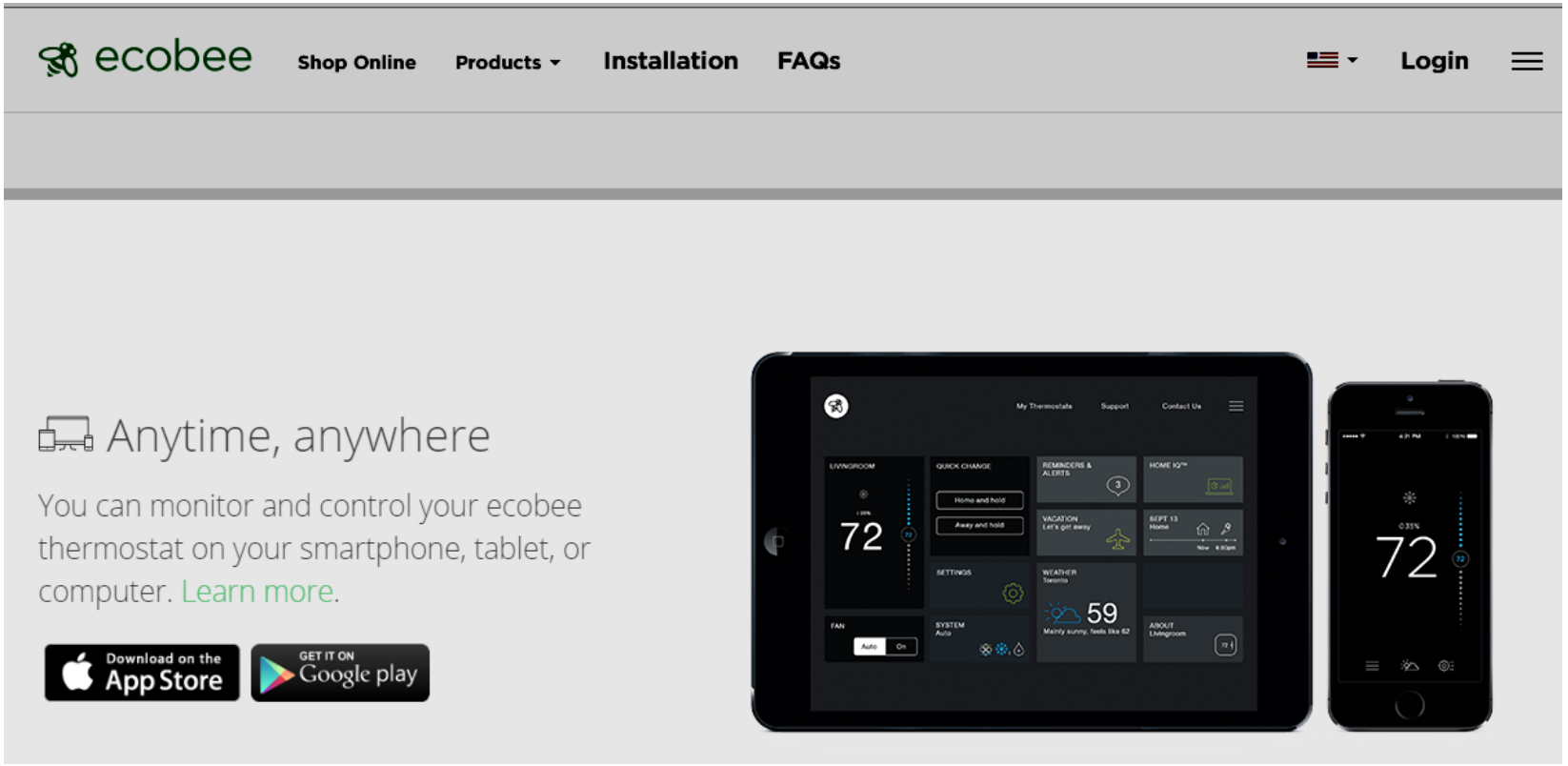
YAMAHA EV-5 CASE



SENSOR, DEVICE TYPES

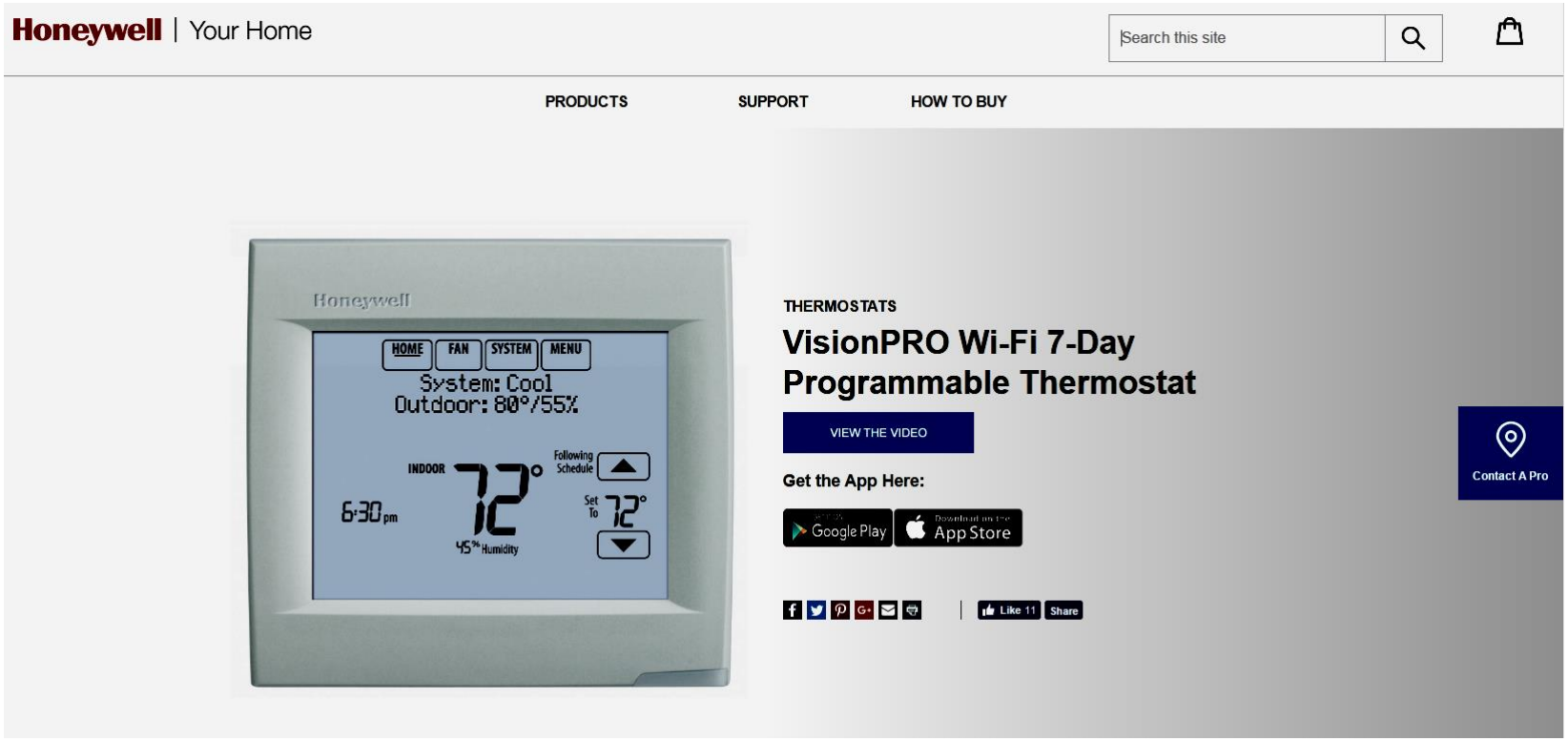
SENSOR UPGRADE

BETTER?



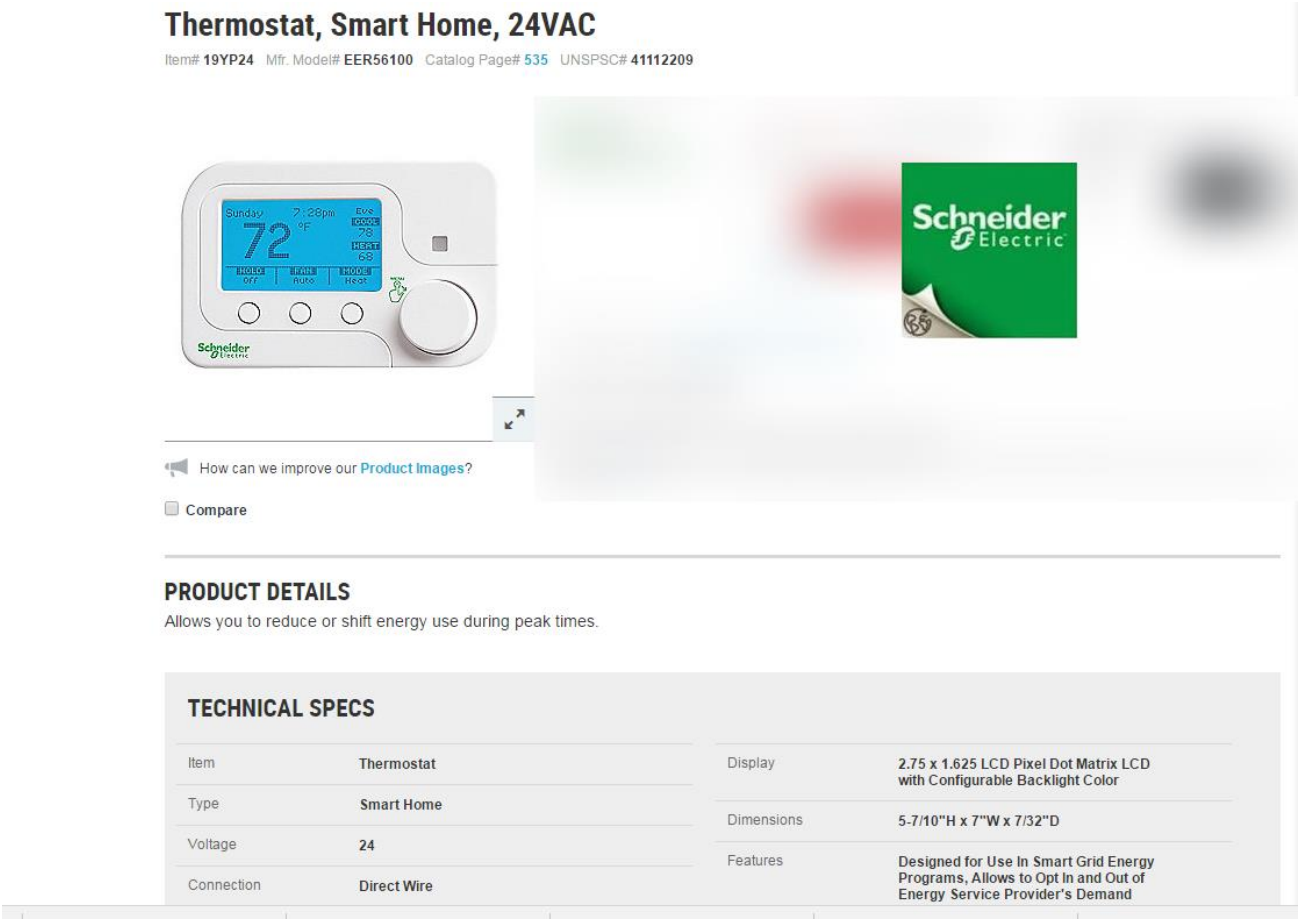
https://www.ecobee.com/smart-si/

STILL BETTER?



http://yourhome.honeywell.com/en/products/thermostat/visionpro-wi-fi-7-day-programmable-thermostat

BEST?



Thermostat, Smart Home, 24VAC

Item# **19YP24** Mfr. Model# **EER56100** Catalog Page# **535** UNSPSC# **41112209**

How can we improve our Product Images?

Compare

PRODUCT DETAILS

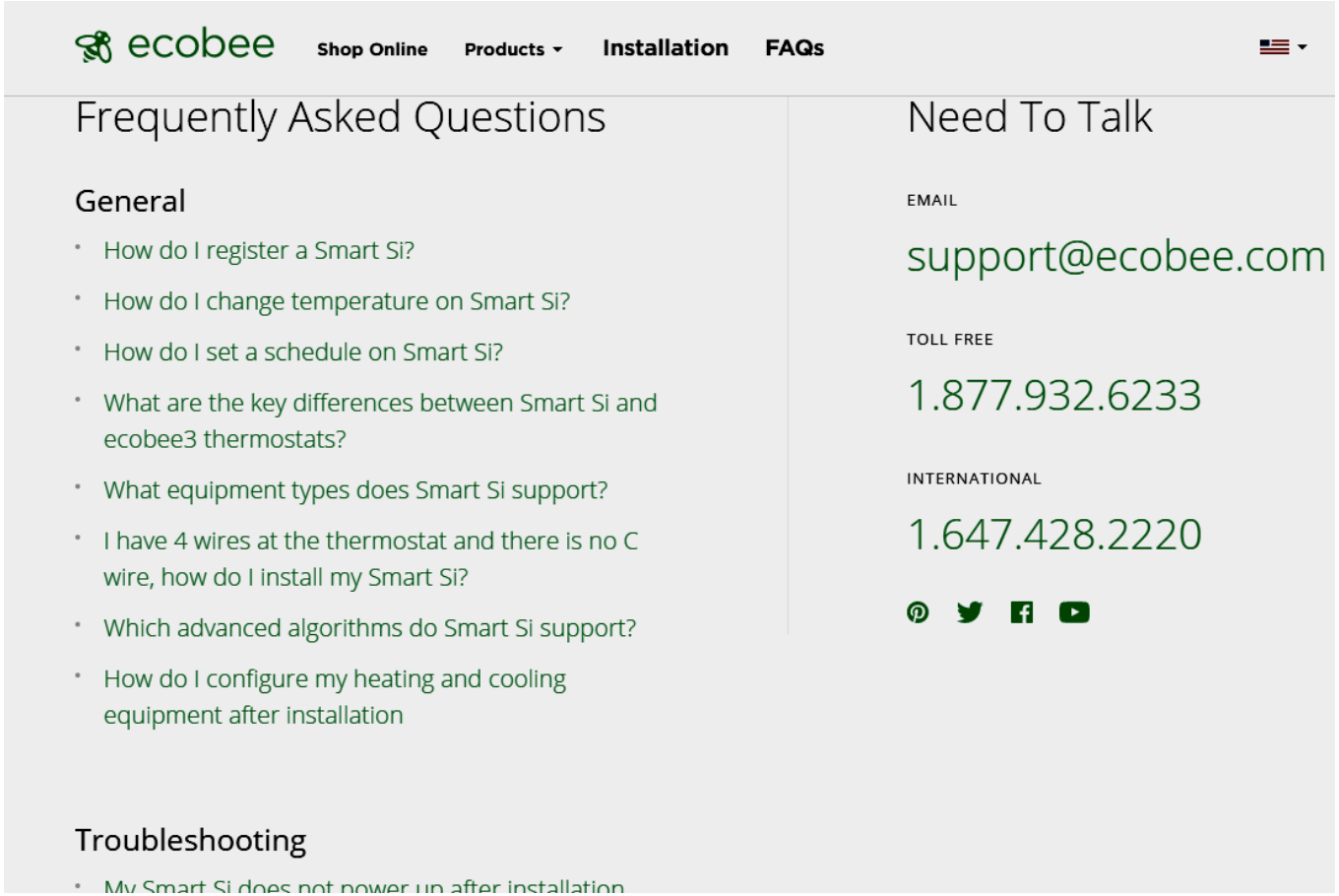
Allows you to reduce or shift energy use during peak times.

TECHNICAL SPECS

Item	Thermostat	Display	2.75 x 1.625 LCD Pixel Dot Matrix LCD with Configurable Backlight Color
Type	Smart Home	Dimensions	5-7/10"H x 7"W x 7/32"D
Voltage	24	Features	Designed for Use In Smart Grid Energy Programs, Allows to Opt In and Out of Energy Service Provider's Demand
Connection	Direct Wire		

https://Schneider-electric.com

BUT WAIT. . .



https://www.ecobee.com/faqs/smartsi//

I HAVE CONCERNS . . .

- How do I onboard it into my network?
- Do I have to calibrate it?
- What happens when the battery dies?
- Does it work if it gets wet? . . .

- How do I use the API?
- Can I trust the algorithms?
- Can I tweak the system if it's not working in my microclimate?

. . . WITH CAUSE

Sympathy for the Sensor Network Debugger

Ramanathan, N., Chang, K., Kapur, R., Girod, L., Kohler, E., & Estrin, D. (2005). Sympathy for the sensor network debugger. In *Proceedings of the 3rd international conference on Embedded networked sensor systems - SenSys '05* (p. 255). New York, New York, USA: ACM Press. http://doi.org/10.1145/1098918.1098946

. . . WITH CAUSE

Sympathy for the Sensor Network Debugger

"Developing and debugging sensor network applications in a dynamic, distributed, and resource-constrained embedded environment is an iterative and sometimes laborious process. Initial application development can use a protected and interactive simulation. Once an application is physically deployed, however, interactivity and visibility are greatly reduced, and it becomes difficult to detect and pinpoint problems when they occur. For example, a gap in returned sample data may be caused by a critical node failure, a transient change in link connectivity, or some other unexpected combination of inputs. Responding to a failure can require physical access to a node; depending on the deployment scenario, even obtaining access can be expensive and difficult—or, worse, a cause of additional failures."

-2005

“BUSINESS” REQUIREMENTS

- Limited budget
- Limited expertise for sensor technology
- Access through smartphone
- Access through web page (“linked data”)
- Prevent “catastrophic” drying
- Address “case open” condition
- Easy to add new generation of humidistats
- Integrate with anti-tampering sensors

“TECHNICAL” REQUIREMENTS

- Remote monitoring
- Interface with existing applications
- Recognize case placement
- Issue alerts, not just continuous data stream
- Support multiple models of humidistats
- Identify location (geospatial)
- Identify which instrument ($$$$ vs. $)
- Recognize sensor failure
- Recognize periodic maintenance needs / events
- Full “ecosystem” (humidistat | humidifier | case environment | location)

LOW-FIDELITY, LOW-BUDGET, NETWORK-ENABLED CHALLENGES ARE NOT ATYPICAL.

THE REAL WORLD OF IOT

- **Is dull (dumb sensors, perhaps supported by code written by non-developers)**
- **Is diverse* (smoke detectors to drones, atomic to astrophysical)**
- **Is dirty (deals with blood, vapor, flame, poison)**

DOMAIN-RICH

Wikipedia sensor categories include:

- **Acoustic**
- **Vehicle**
- **Chemical**
- **Electrical, magnetic, radio**
- **Flow, fluid velocity**
- **Ionizing radiation, subatomic particles**
- **Navigation**
- **Pressure**
- **Force, density, level**
- **Thermal**
- **Proximity**
- **More. . .**

. . . AND ALL KINDS OF SENSORS

8.1.2. Conductive/Resistive Sensors

These sensors make measurements by recording the induced eddy currents in soil that have been generated using an exciting field. Sensors used by EOD operators in this type are not widely used.

8.1.3. Mechanical Sensors

Mechanical sensors determine information from physical properties such as tactile sensors (such as vibrations from touching). Again, sensors of this type are not widely used by EOD operators.

8.1.4. Optical Sensors

Optical sensors utilize optical energy to record information regarding the environment. The two classes of optical sensors are passive and active. Passive optical sensors use naturally occurring optical energy and collect and process the information. Active optical sensors emit energy and process the returned signals. Infrared sensors are passive while laser sensors are active. Infrared (IR) sensors identify objects by determining the thermal energy differences. Objects on or near the surface can have a temperature difference that is determined by this type of sensor. These types of sensors were covered in section 6.3.1

8.1.5. Acoustic Sensors

Acoustic sensors use energy in the acoustic range to measure properties of the environment. The most popular are ultrasonic and seismic. The majority of these types of sensors have been covered in section 7.2.1.

8.1.6. Chemical/Nuclear

Chemical substances that are used in warfare or by terrorists to seriously injure, kill, or incapacitate persons are called chemical agents. Chemical agents attack various human organs to prevent normal functions from occurring. The intent of these chemical agents is to disable or cause fatality. A sub set of chemical agents are the substances that attack the human body—nerve agents. Nerve agents affect the transmission of signals in the nervous system. These agents are generally stable, highly toxic, are easily dispersed, and rapidly effect the body when absorbed through the skin or the respiratory system. Common chemical agents are nerve agents such as GA (Tabun), GB (Sarin), GD (Soman), GF, and VX. Blister agents include HD (sulfur mustard) and HN (nitrogen mustard).

c. 2001 from a US DOE nuclear engineer

LEO

Ontology challenges / values driven by domain specificity

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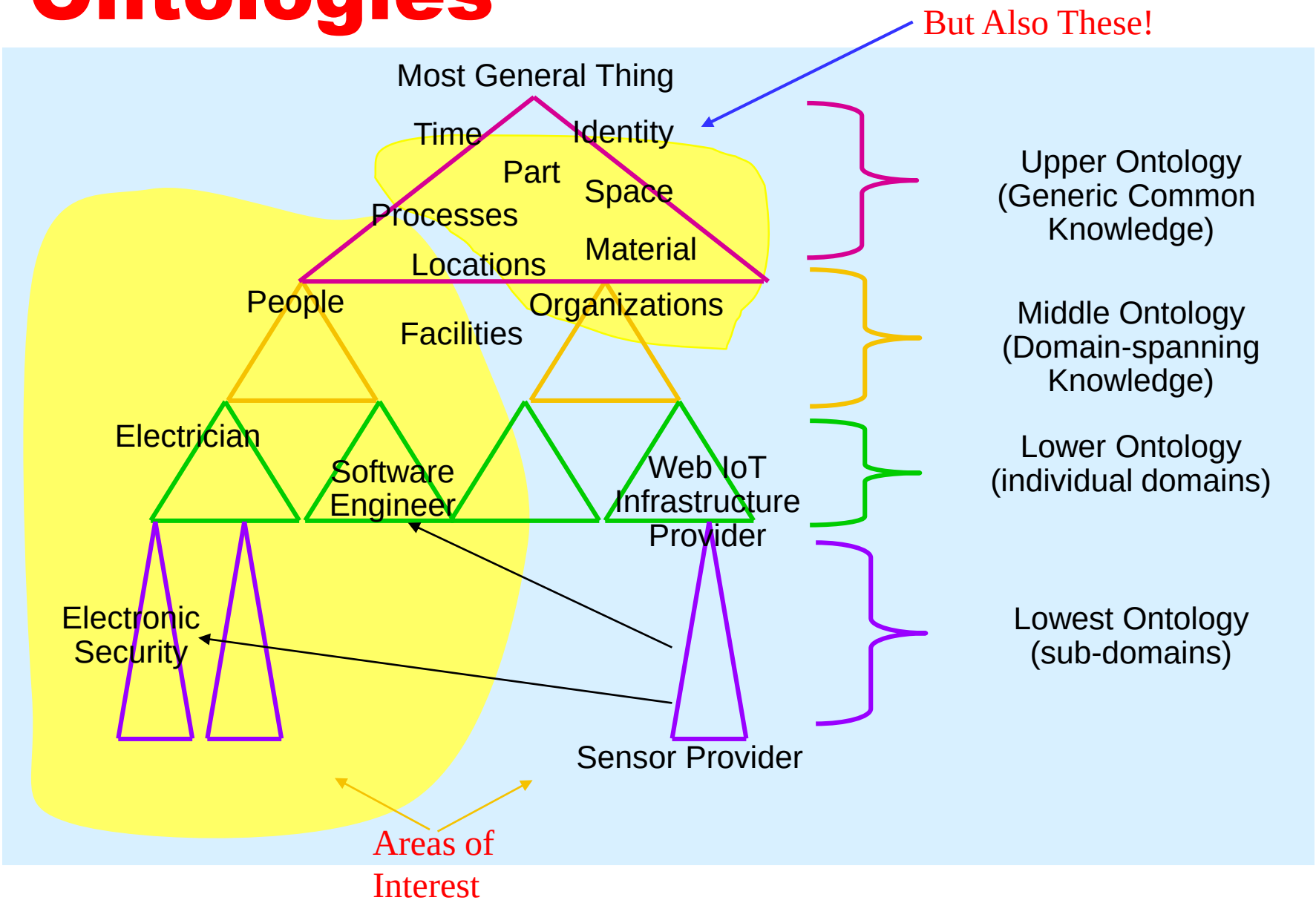
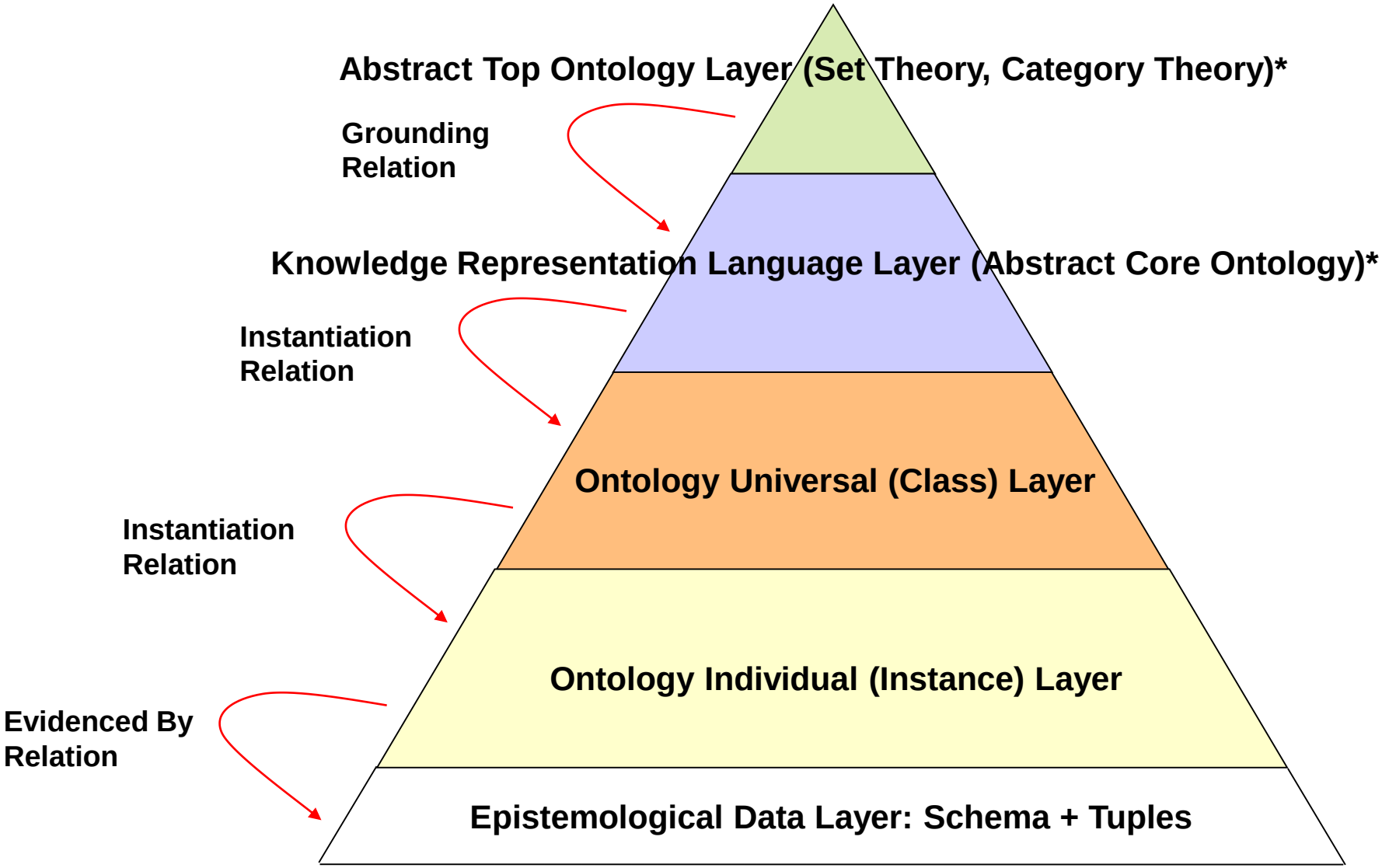
Upper, Middle, Domain Ontologies



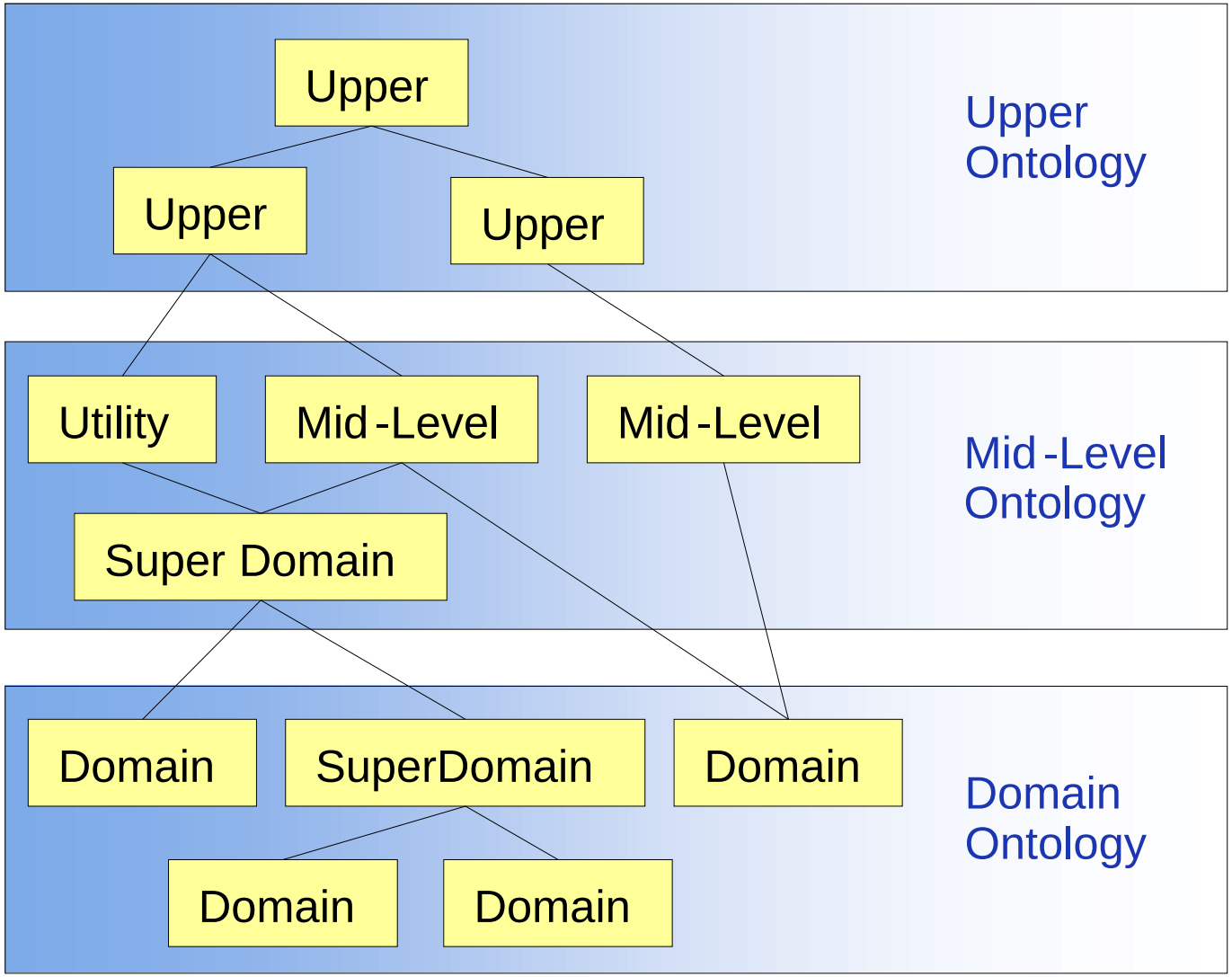
ONTOLOGY CONTENT ARCHITECTURE: MORE COMPLEX VIEW

* Adapted from: Herre, Heinrich, and Frank Loebe. 2005. A Meta-ontological Architecture for Foundational Ontologies. In: R. Meersman and Z. Tari (Eds.): CoopIS/DOA/ODBASE 2005, LNCS 3761, pp. 1398–1415, 2005. Springer-Verlag Berlin Heidelberg.



ONTOLOGY UNIVERSALS & INDIVIDUALS LAYER: UPPER, MID-LEVEL, DOMAIN ONTOLOGIES

Adapted from: Pulvermacher, M.; S. Semy; L. Obrst. 2005. Toward the Use of an Upper Ontology for U.S. Government and U.S. Military Domains: An Evaluation. MITRE Technical Report, MTR 04B0000063, November, 2005.



THE NEED: DOMAIN MODELS

- **Sensor contexts . . .**
  - Have domain-specific elements
  - Share some elements, e.g., measurement frameworks

Domain automation tasks involve highly specific demands. It's why developers feel they must "lapse into code." But that code is rarely interoperable with adjacent domains.

BIG PICTURE CONSIDERATIONS

- **Use case contains multiple paradigmatic aspects**
- **Hidden analytics needs (practical sweet spot for case climate control)**
- **Numerous rabbit holes for Not-Invented-Here development**
- **Confluence of idiosyncratic requirements and "universal" IoT requirements**
- **Software development life cycle (SDLC) realities**
  - Error tolerance
  - Maintenance will exceed development costs
- **Personal impact: Big distraction from practicing for performances**
- **Multi-organizational with domain-specific security challenges**
- **Curation and governance may be weak**
- **Sometimes a crude mix of the obsolete and the state-of-the-art**

DESIGN PATTERN CONVERGENCE: MICROSERVICES, CONTAINERS, NETWORK FUNCTION VIRTUALIZATION, DISTRIBUTED DATA, SOFTWARE-DEFINED INFRASTRUCTURE

Design Counterparts in ontology:

- **Agent-based**
- **Distributed knowledge**
- **Divide and conquer (component-based knowledge engineering)**

LEVERAGE THE GO-TO, DEFAULT AGILE DEVELOPER SOLUTION FOR 2016?

►**Can microservices provide access to IoT ontologies at a granularity (think Github) that promotes adoption?**

IOT MICROSERVICES (ON ONE SLIDE)

►Tom Nolle: “A better way to approach IoT is to think of it not as a collection of sensors but as a collection of . . . microservices.”

► Martin Fowler: “The term "Microservice Architecture" has sprung up over the last few years to describe a particular way of designing software applications as suites of independently deployable services. While there is no precise definition of this architectural style, there are certain common characteristics around organization around business capability, automated deployment, intelligence in the endpoints, and decentralized control of languages and data.”

MICROSERVICES + SEMANTICS

Versteden, E. Pauwels, and A. Papantoniou, "An ecosystem of user-facing microservices supported by semantic models." in *USEWOD-PROFILES@ESWC*, ser. CEUR Workshop Proceedings, B. Berendt, L. Dragan, L. Hollink, M. Luczak-Rösch, E. Demidova, S. Dietze, J. Szymanski, and J. G. Breslin, Eds., vol. 1362. CEUR-WS.org, 2015, pp. 12-21. [Online]. Available: http://dblp.uni-trier.de/db/conf/esws/profiles2015.html#VerstedenPP15

Ã. Villalba, J. L. Pérez, D. Carrera, C. Pedrinaci, and L. Panziera, "servIoTicy and iServe: A scalable platform for mining the IoT," *Procedia Computer Science*, vol. 52, pp. 1022-1027, 2015. [Online]. Available: http://dx.doi.org/10.1016/j.procs.2015.05.097

M. Bermudez-Edo, T. Elsaleh, P. Barnaghi, and K. Taylor, "IoT-lite ontology, a member submission," W3C Member Submission, Cambridge, MA, Tech. Rep., Nov. 2015. [Online]. Available: https://www.w3.org/Submission/2015/SUBM-iot-lite-20151126/

In my room, the world is beyond my understanding;
But when I walk I see that it consists of three or four
hills and a cloud.

-Wallace Stevens "Of the Surface of Things"

IS THE "CLOUD" NIMBOSTRATUS OR CIRROCUMULUS?

IoT is party to the shifting notion of cloud and the entire infrastructure layer.

BEYOND "WEB SERVICE"

sdx central

SPONSORED: NFV 8 Network Virtualization 3
SDN 7 Cloud 8 Security 5 IoT 3 5G 3

AT&T, Colt Test API-to-API Interface for SDN

Sue Marek
November 8, 2016
11:17 am PT

AT&T is working with Colt Technology Services to provision network services using a programmatic API-to-API interface between separate software-defined networking (SDN) architectures.

The test occurred between two networks — one in the U.S. and one in Europe — and demonstrated that enterprises can provision on-demand, scalable network services across multiple locations and multiple networks, even networks from different service providers.

FIRST MENTION AT STIDS?

SITUATION AWARENESS 1986-?

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Of the Surface of Things

I

In my room, the world is beyond my understanding;

But when I walk I see that it consists of three of four

hills and a cloud.

II

From my balcony, I survey the yellow air,

Reading where I have written,

“The spring is like a belle undressing.”

III

The gold tree is blue,

The singer has pulled his cloak over his head.

The moon is in the folds of the cloak.

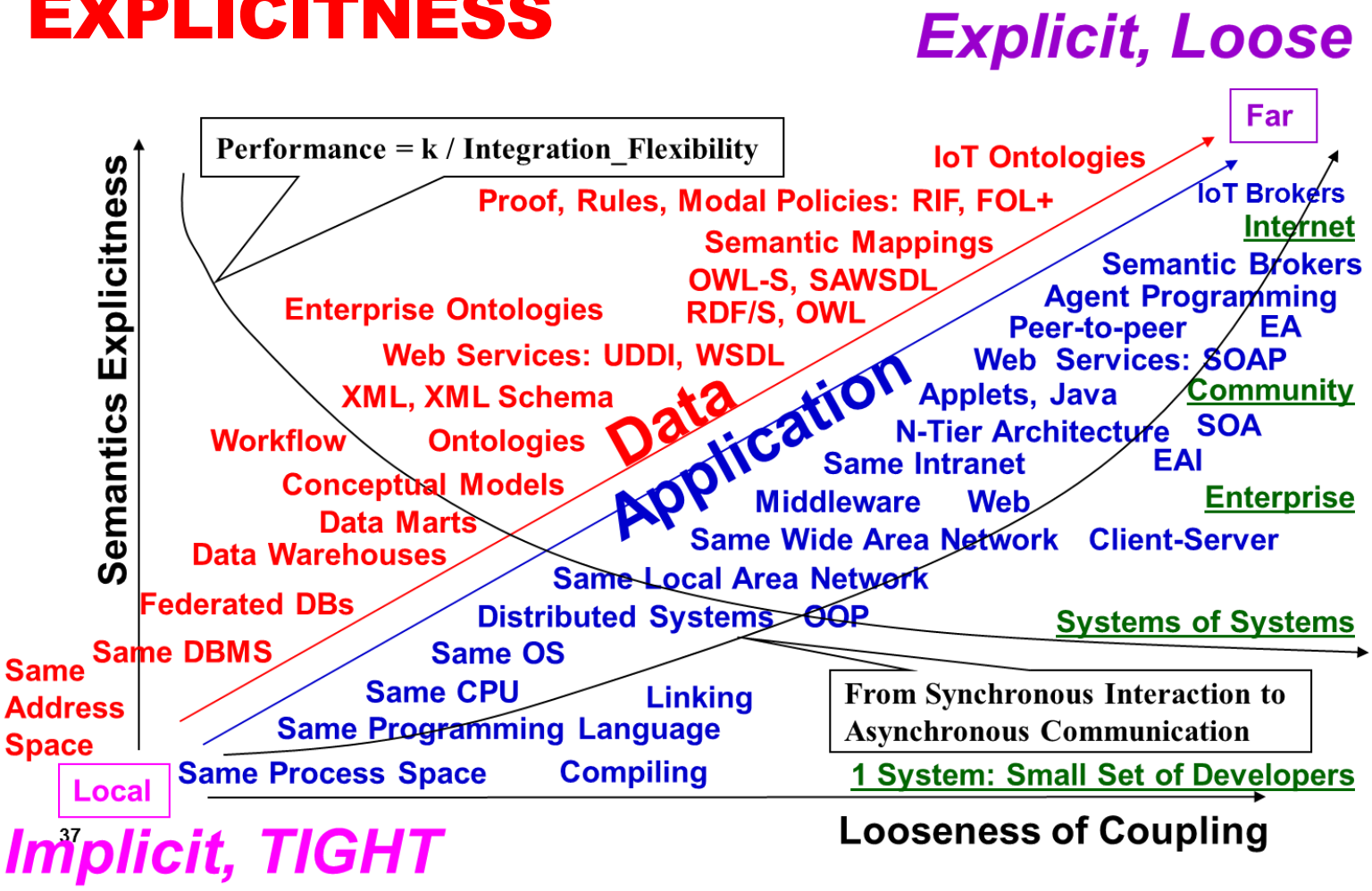
--*Wallace Stevens*

WHY WE STILL CAN'T "SEE"

CHECKERED SEMANTIC INTEROPERABILITY "SOLUTIONS" --A HISTORY

Credit: Leo

MOTIVATION: TIGHTNESS OF COUPLING & SEMANTIC EXPLICITNESS



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TRADEOFF DANCE

- **Implement an elegant solution**
- **Avoid slippery floor spots**
  - endless refinement
  - unresolvable representation alternatives

- **Devil is in the details**
  - Cautionary tale:
    Example from Financial Industry Business Ontology (FIBO)
  - EHR Blockbuster film: *EPIC vs. the Ontologists*
  - Smart Building standards (electrical + mechanical domains)

ONTOLOGY MOTIVATORS

- **Abstract models for devices, processes, events**
- **Describe code fragments (e.g., classes) using taxonomies & vocabularies recognized by other developers**
- **Leverage stereotypical design patterns for UI**
- **Recognize blurring with big data issue**
- **Access “model-oriented” communities of interest**

IS SITUATION AWARENESS ASKING TOO MUCH OF SOFTWARE ENGINEERING?

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YES . . .

AND NO.

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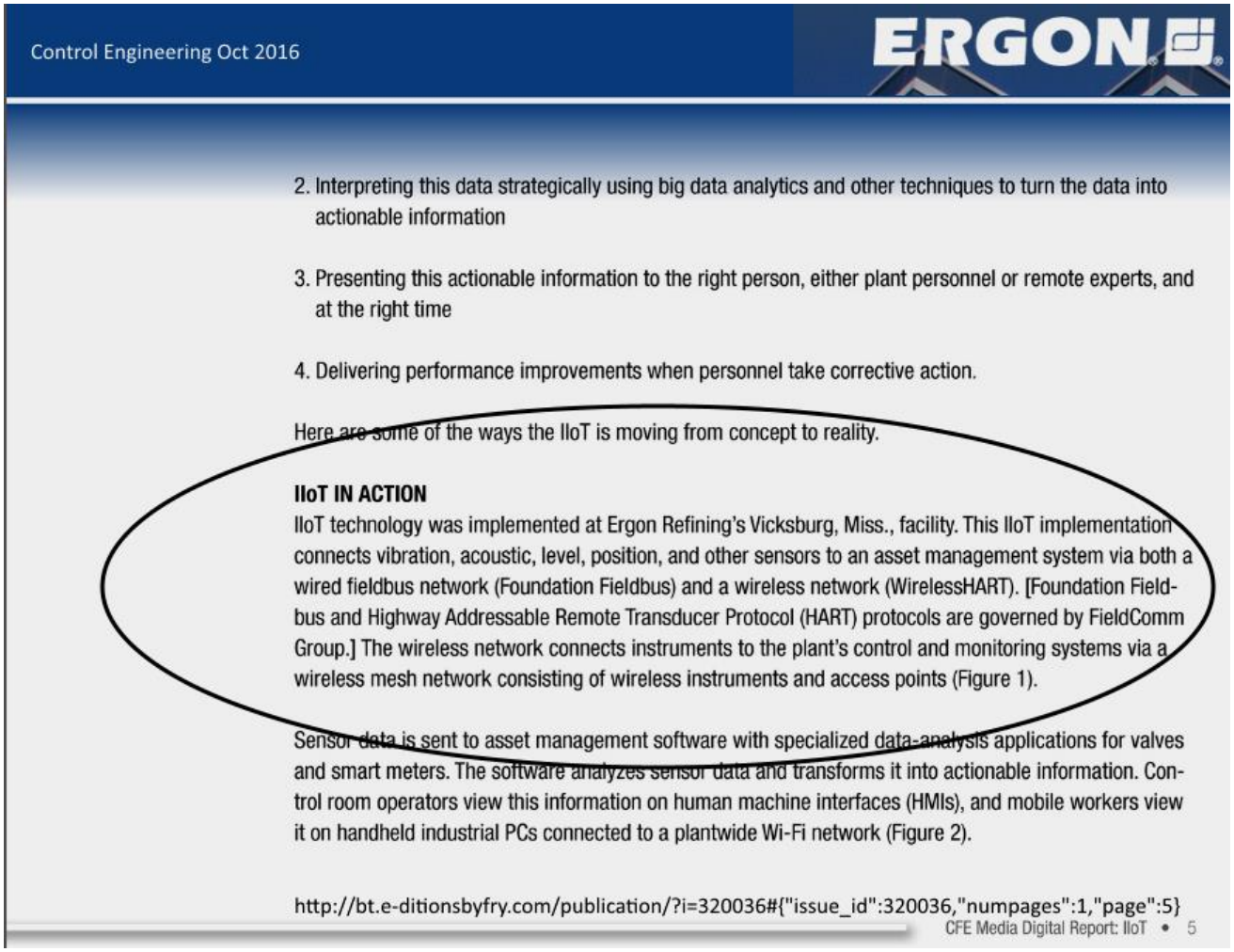
THIS IOT SOLUTION WORKS AT ERGON.



Control Engineering Oct 2016

ERGON

2. Interpreting this data strategically using big data analytics and other techniques to turn the data into actionable information

3. Presenting this actionable information to the right person, either plant personnel or remote experts, and at the right time

4. Delivering performance improvements when personnel take corrective action.

Here are some of the ways the IIoT is moving from concept to reality.

IIoT IN ACTION

IIoT technology was implemented at Ergon Refining's Vicksburg, Miss., facility. This IIoT implementation connects vibration, acoustic, level, position, and other sensors to an asset management system via both a wired fieldbus network (Foundation Fieldbus) and a wireless network (WirelessHART). [Foundation Fieldbus and Highway Addressable Remote Transducer Protocol (HART) protocols are governed by FieldComm Group.] The wireless network connects instruments to the plant's control and monitoring systems via a wireless mesh network consisting of wireless instruments and access points (Figure 1).

Sensor data is sent to asset management software with specialized data-analysis applications for valves and smart meters. The software analyzes sensor data and transforms it into actionable information. Control room operators view this information on human machine interfaces (HMIs), and mobile workers view it on handheld industrial PCs connected to a plantwide Wi-Fi network (Figure 2).

http://bt.e-ditionsbyfry.com/publication/?i=320036#{"issue_id":320036,"numpages":1,"page":5}

CFE Media Digital Report: IIoT • 5

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IT'S NONTRIVIAL.

Capital expenditures were reduced because wireless cut sensor installation costs, and ongoing operational benefits included increased capacity and avoided capital investments through wireless tank monitoring. The asset management software allowed consistent setup and reduced commissioning costs, along with reduced call-outs through the use of alarm management software. Safety was improved by automating vibration monitoring in hard-to-reach locations which were previously checked via manual rounds, and energy was saved with wireless steam trap monitoring.

Ergon now has wireless infrastructure in place for data collection, analysis, and distribution. This existing infrastructure makes it quick and inexpensive to add more wireless sensors to deliver further operational improvements.

STEAM TRAP SAVINGS

Steam trap monitoring via wireless acoustic transmitters is a leading IIoT application.

When traps fail to open, high-pressure steam leaks out, so more steam has to be produced by boilers.

Depending on the price of steam at a facility, a single failed-open steam trap can waste $30,000 worth of steam each year.

BUT . . .

- **Does it work only with these steam sensors?**
- **Is the integration between sensor types fragile?**
- **How does it handle conflicting sensor streams?**
- **What happens during sensor maintenance and replacement?**
- **How is the subnet isolated and secured?**
- **Is knowledge acquisition moderately vendor-neutral?**

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QUESTIONS

- **What is the shape of IoT design patterns?**
- **Are ontologies part of these patterns? How should knowledge be distributed?**
- **If so, what does it look like?**
- **Which enterprise influencers are at work?**
- **Which tools are being used? (Artifacts?)**
- **Sufficient thought to emerging needs for simulation, stress-testing, scalability and forensics?**

INTEGRITY

Leo – Talk about how ontologies support provenance, integrity

- **Data stream sources**
- **Integrity (recognize out-of-bounds values)**
- **Self-management (know when they're broken)**
- **Self-correcting**
- **Can prove consistency, detect errors and anomalies**
- **Build complex rule-reasoning atop**
- **Support semantic (and pragmatic) interoperability**

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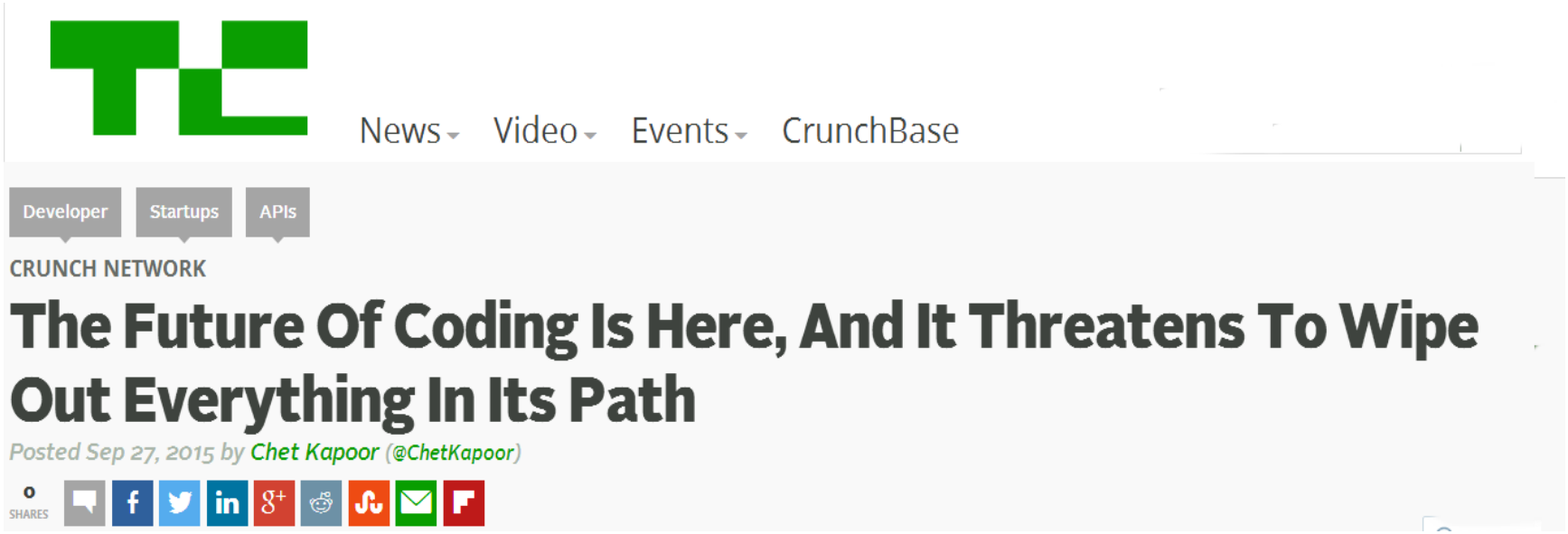
CLOUD SERVICES ABSTRACT

Two important consequences of the “cloudification” of computing are DevOps and an API-first (espoused by Intel’s Brian Krzanich) design philosophy. While SOA and “composable services” introduced many of the same concepts in earlier generations (indeed, both DevOps and API-first steal from well-burnished concepts), the level of adoption across software and data providers is unprecedented. Computing environments for large scale projects can be stood up in minutes, tested and disposed of the following day. Products like Zapier and IFTTT allow for orchestration of cloud services across providers. The Zapier App Directory offers around 100 integrations. Interop exists across platforms (as in hybrid cloud storage), applications (e.g., between QuickBooks and a telephony app like DialMyCalls), and also what some are calling “cognitive services.” Cloudify suggests using TOSCA (a cloud orchestration standard) to connect resources like OpenStack or VMware using open source tools.)

Github repositories can store ontologies, but can this be scaled up to build applications, sharing ontologies within or across domains? Will developers tempted to use ontologies be able to gain the same productivity benefits they experience elsewhere with cloud services? We ask a few vendors.

API-FIRST DESIGN



API-first design is a result of ubiquitous cloud services and DevOps, but its impact is not limited to that: IoT development is inspired by the same design patterns. Ontologies could / should be similarly ubiquitous to deploy. Are they?

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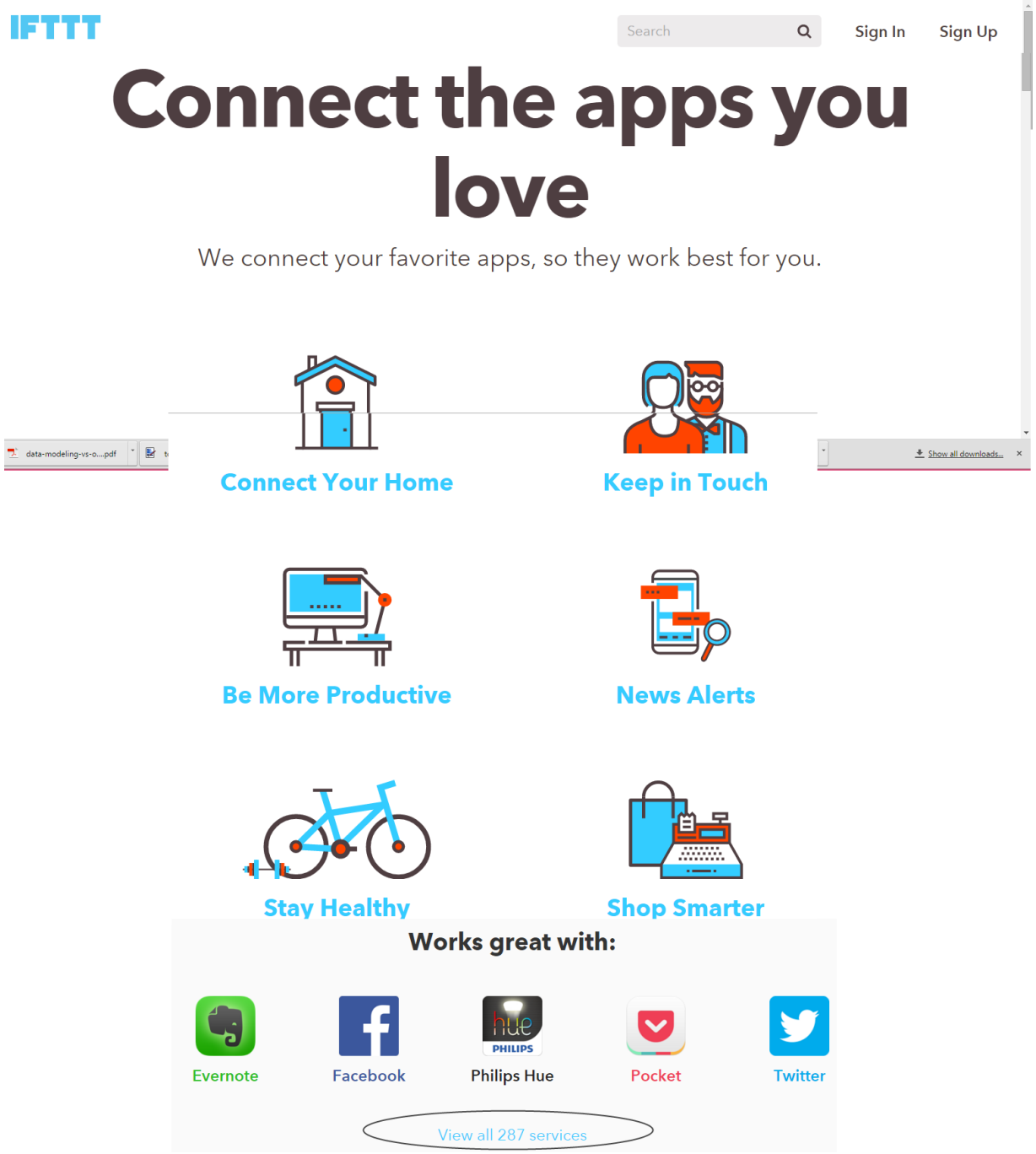
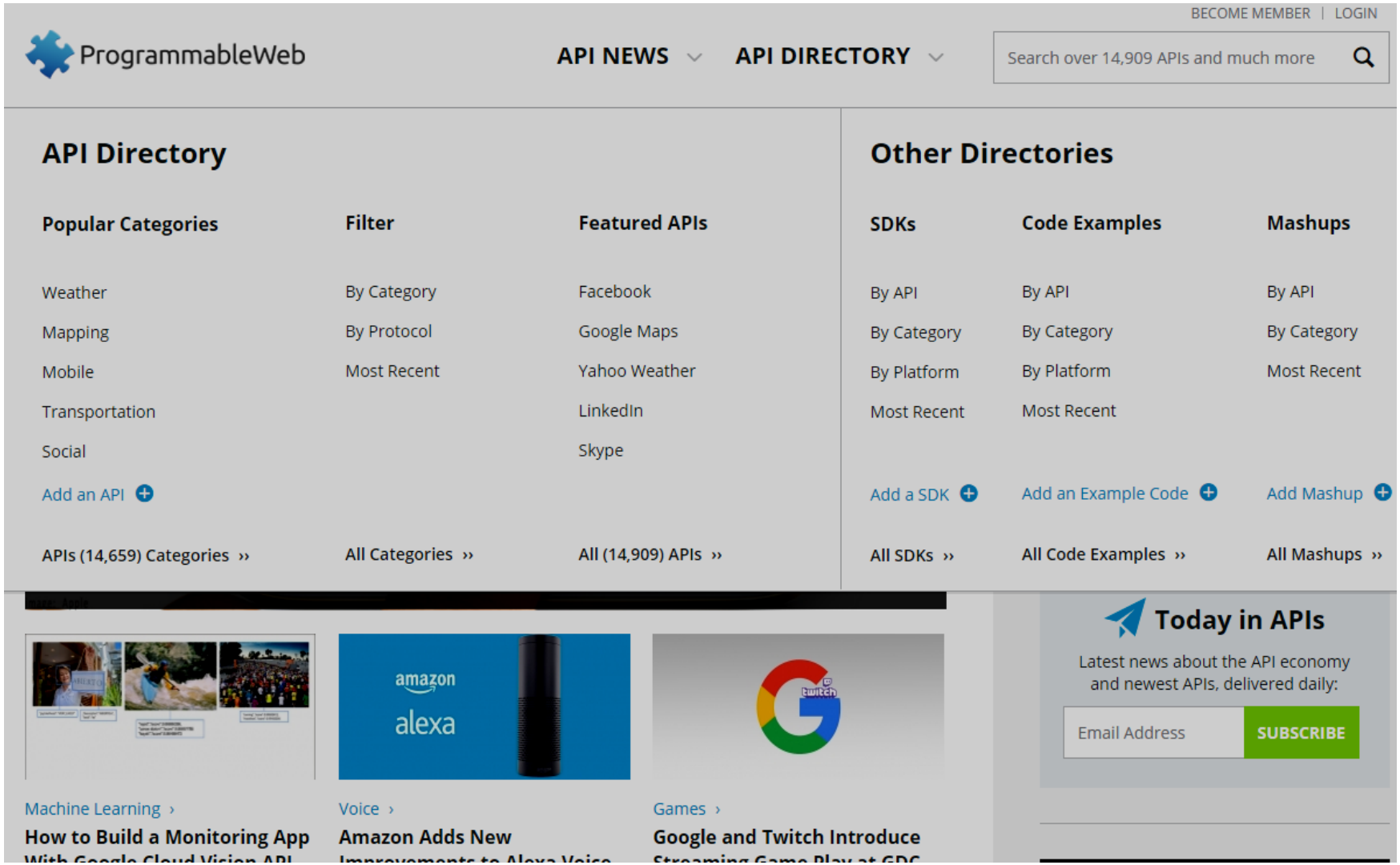
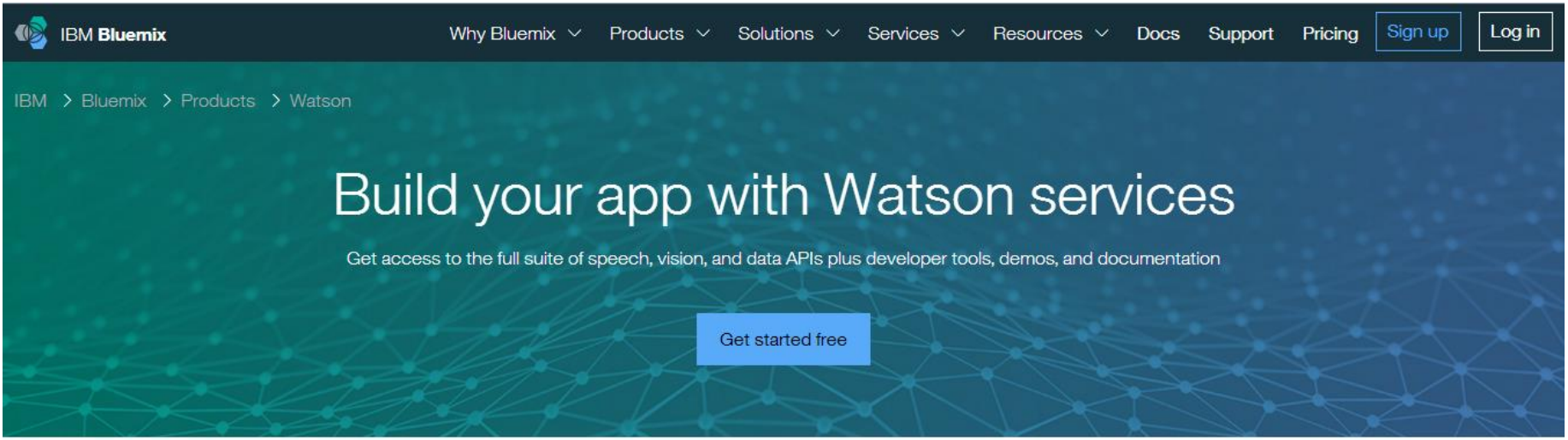

IFTTT
Search
Sign In
Sign Up
Connect the apps you love
We connect your favorite apps, so they work best for you.
Connect Your Home
Keep in Touch
Be More Productive
News Alerts
Stay Healthy
Shop Smarter
Works great with:
Evernote
Facebook
Philips Hue
Pocket
Twitter
View all 287 services

PROGRAMMABLE WEB

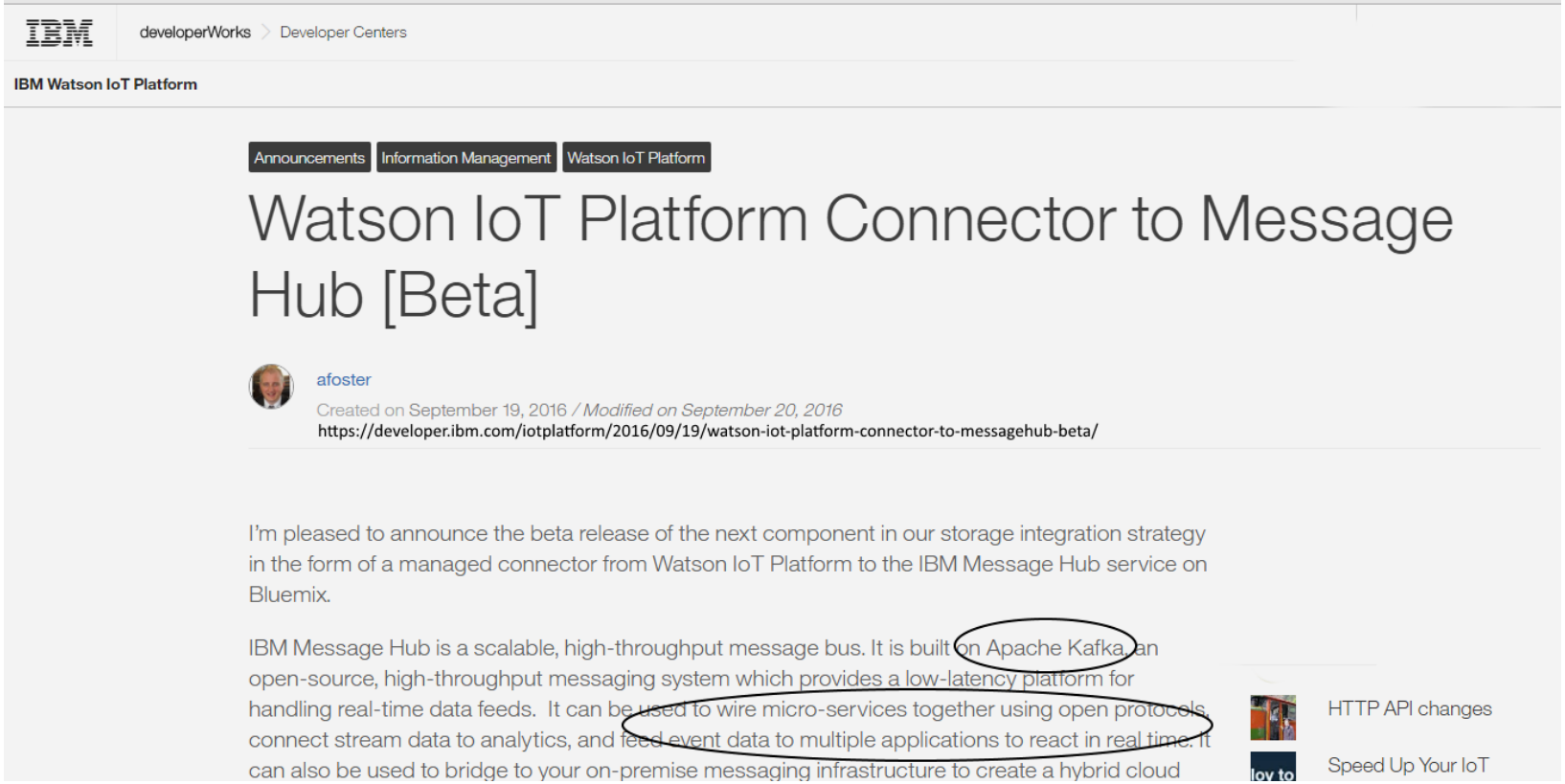




Watson Developer Cloud

Bring the power of cognitive computing to your apps. From analyzing images and video to gaining insights from text, discover how language, vision, speech and data APIs from Watson Developer Cloud can help you solve complex problems. Here is a sample of Watson Developer Cloud offerings. View all services to see all the Watson APIs available now on Bluemix.

MICROSERVICE AS SITUATION



IBM developerWorks > Developer Centers

IBM Watson IoT Platform

Announcements | Information Management | Watson IoT Platform

Watson IoT Platform Connector to Message Hub [Beta]

afoster

Created on September 19, 2016 / *Modified on September 20, 2016*

https://developer.ibm.com/iotplatform/2016/09/19/watson-iot-platform-connector-to-messagehub-beta/

I'm pleased to announce the beta release of the next component in our storage integration strategy in the form of a managed connector from Watson IoT Platform to the IBM Message Hub service on Bluemix.

IBM Message Hub is a scalable, high-throughput message bus. It is built on Apache Kafka, an open-source, high-throughput messaging system which provides a low-latency platform for handling real-time data feeds. It can be used to wire micro-services together using open protocols, connect stream data to analytics, and feed event data to multiple applications to react in real time. It can also be used to bridge to your on-premise messaging infrastructure to create a hybrid cloud

HTTP API changes

Speed Up Your IoT

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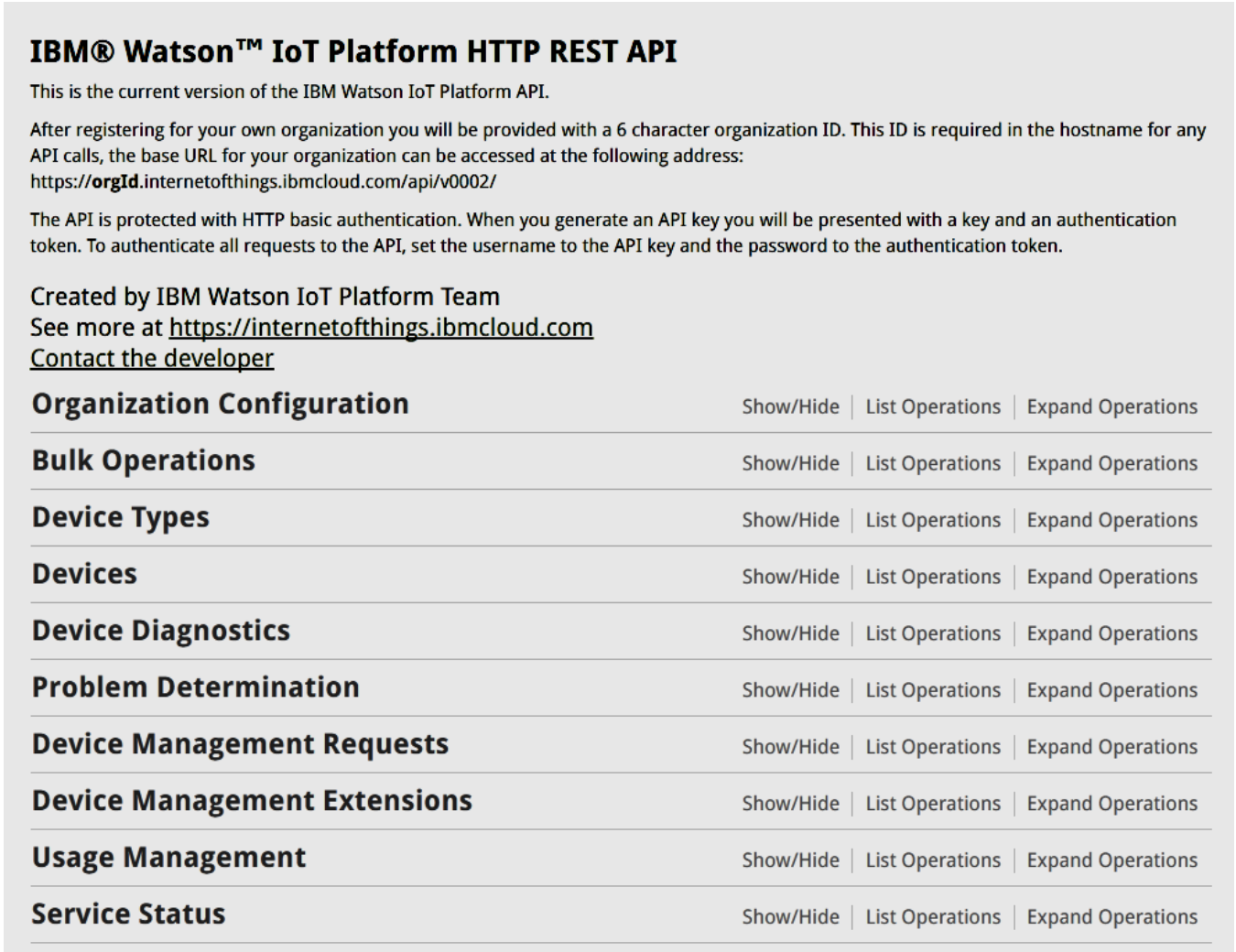


IBM® Watson™ IoT Platform HTTP REST API

This is the current version of the IBM Watson IoT Platform API.

After registering for your own organization you will be provided with a 6 character organization ID. This ID is required in the hostname for any API calls, the base URL for your organization can be accessed at the following address:
https://**orgId**.internetofthings.ibmcloud.com/api/v0002/

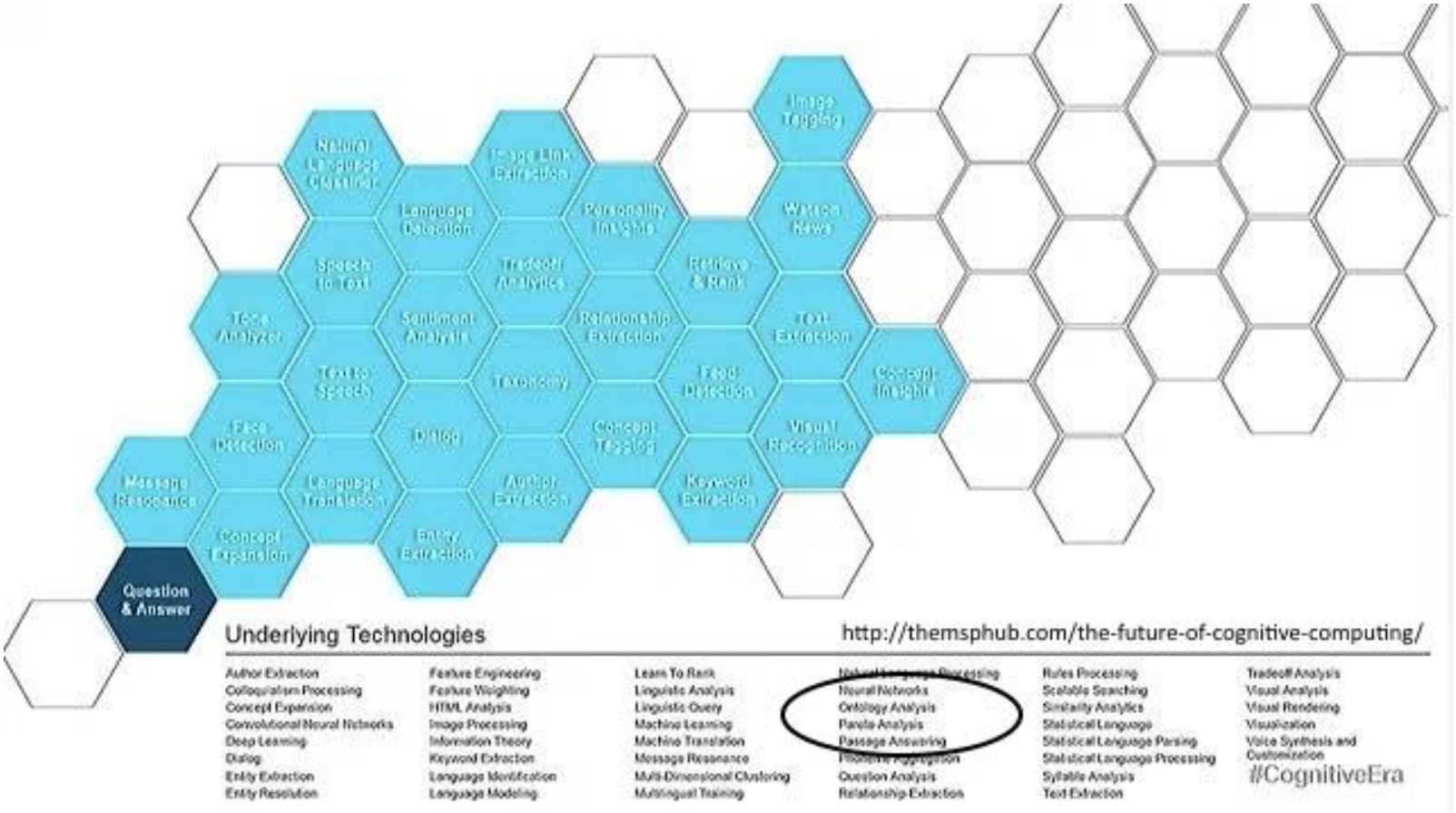
The API is protected with HTTP basic authentication. When you generate an API key you will be presented with a key and an authentication token. To authenticate all requests to the API, set the username to the API key and the password to the authentication token.

Created by IBM Watson IoT Platform Team
See more at https://internetofthings.ibmcloud.com
Contact the developer

Organization Configuration	Show/Hide | List Operations | Expand Operations
Bulk Operations	Show/Hide | List Operations | Expand Operations
Device Types	Show/Hide | List Operations | Expand Operations
Devices	Show/Hide | List Operations | Expand Operations
Device Diagnostics	Show/Hide | List Operations | Expand Operations
Problem Determination	Show/Hide | List Operations | Expand Operations
Device Management Requests	Show/Hide | List Operations | Expand Operations
Device Management Extensions	Show/Hide | List Operations | Expand Operations
Usage Management	Show/Hide | List Operations | Expand Operations
Service Status	Show/Hide | List Operations | Expand Operations

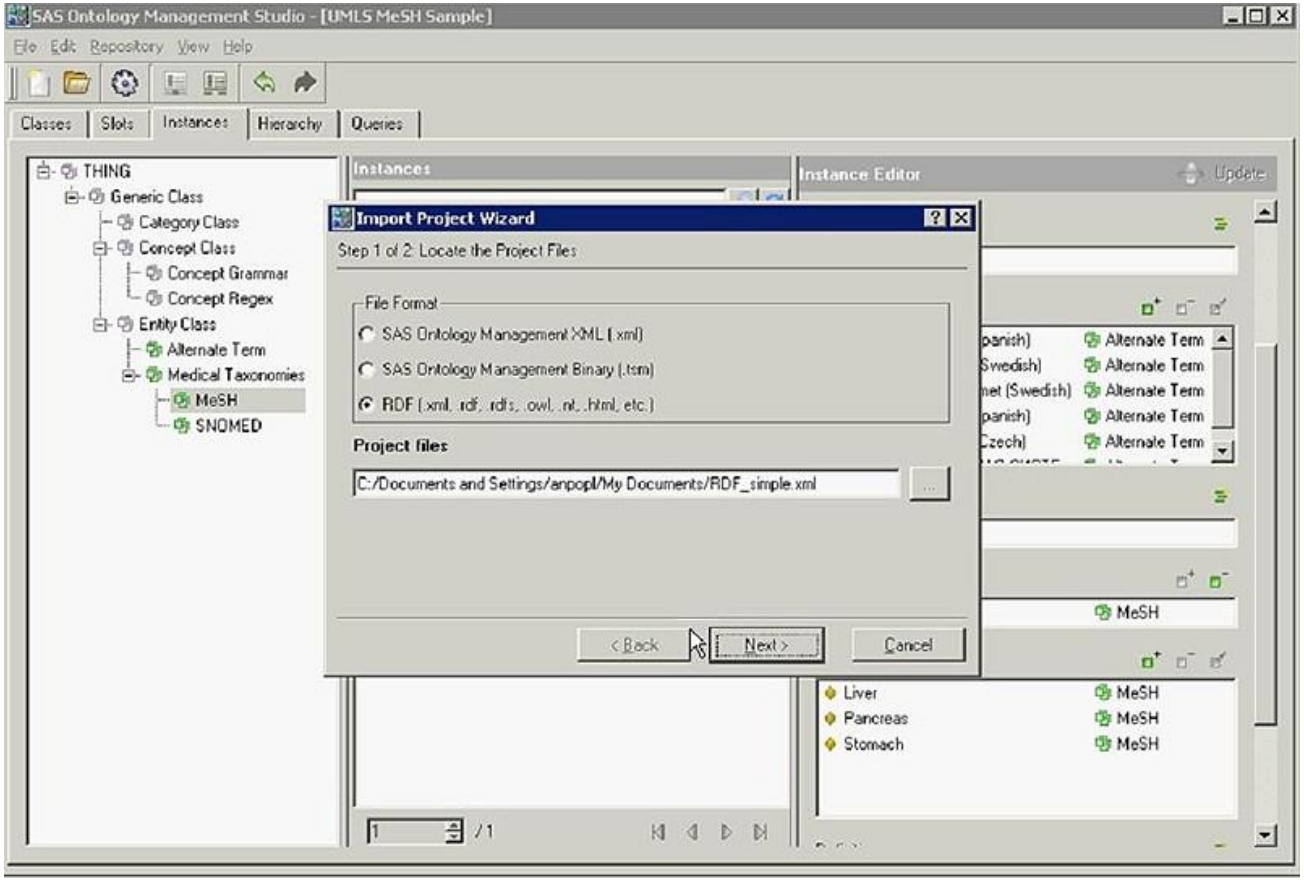
Different for every sensor, every use case?

IBM WATSON: "ONTOLOGY ANALYSIS"

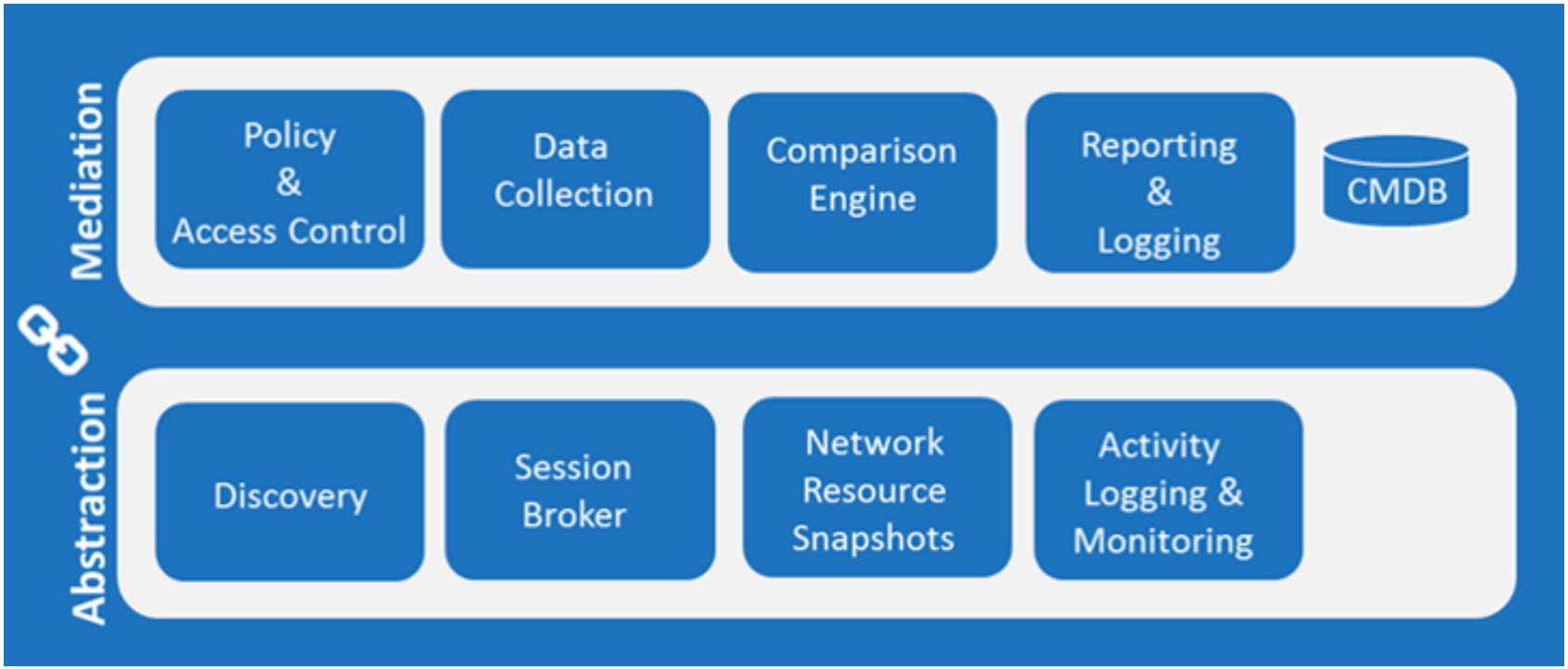


SAS: ONTOLOGY MANAGEMENT STUDIO

Includes class editing, XML import, RDF formats



SDN SUPPORTS IOT NETWORK FABRICS. CAN IT SUPPORT ONTOLOGY, TOO?



PROGRESS WITHIN THE DOMINANT DESIGN PATTERN? HTTP://ISERVE.KMI.OPEN.AC.UK/

ISERVE (CONT'D)

Open Source: https://github.com/kmi/iserve

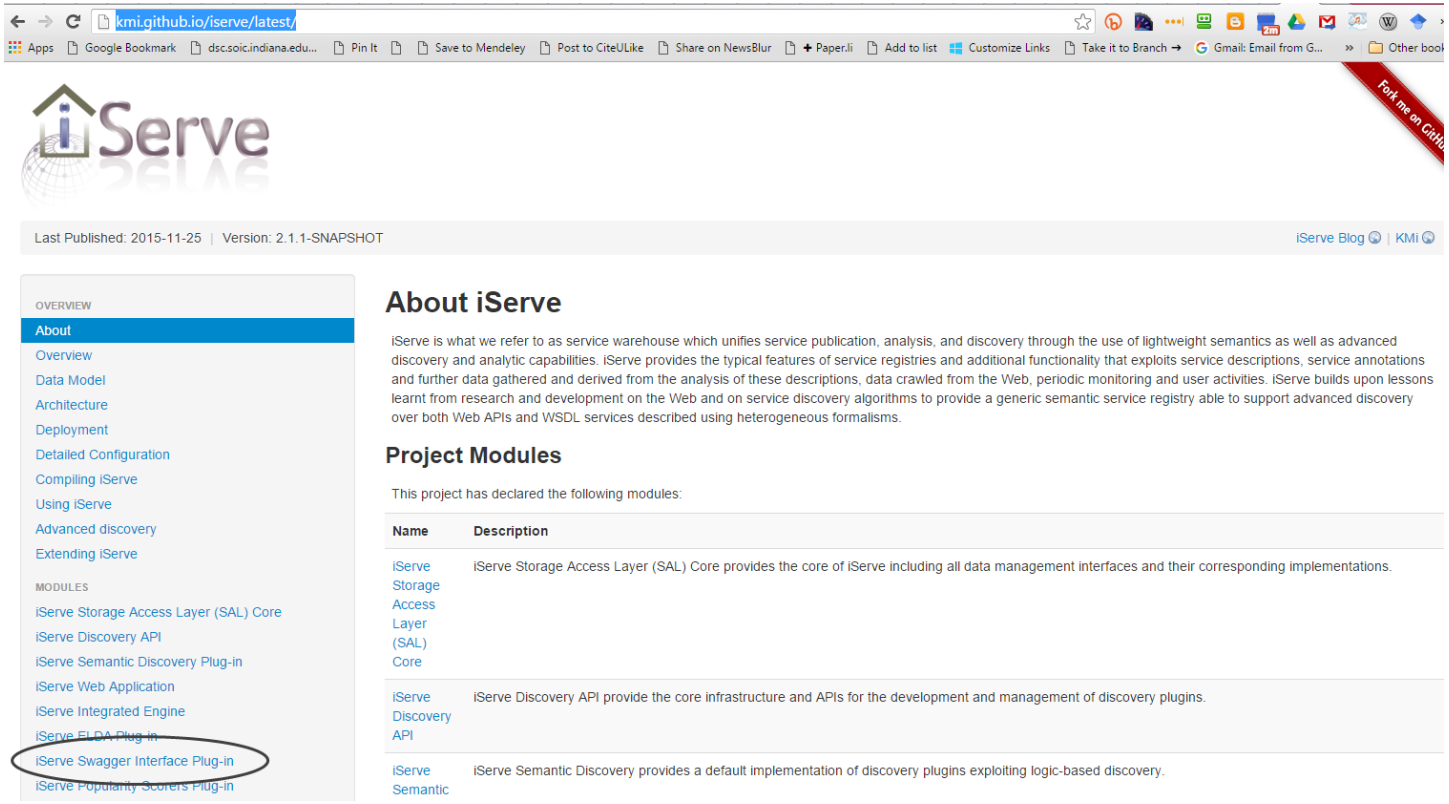
- **Web Application -iServe Browser**
- **Read & Write RESTful API**
- **Linked Data principles**
- **SPARQL endpoint**
- **Content negotiation (RDF, HTML)**

iServe RESTful API

List Services	GET http://iserve.kmi.open.ac.uk/data/services
Add a Service	POST on http://iserve.kmi.open.ac.uk/data/services
Get a Service	GET http://iserve.kmi.open.ac.uk/data/services/{serviceId}
Remove a Service	DELETE http://iserve.kmi.open.ac.uk/data/services/{serviceId}
List Documents	GET http://iserve.kmi.open.ac.uk/data/documents
Get a Document	GET http://iserve.kmi.open.ac.uk/data/documents/{documentId}
SPARQL Query	GET http://iserve.kmi.open.ac.uk/data/execute-query

ISERVE ON SWAGGER + GITHUB

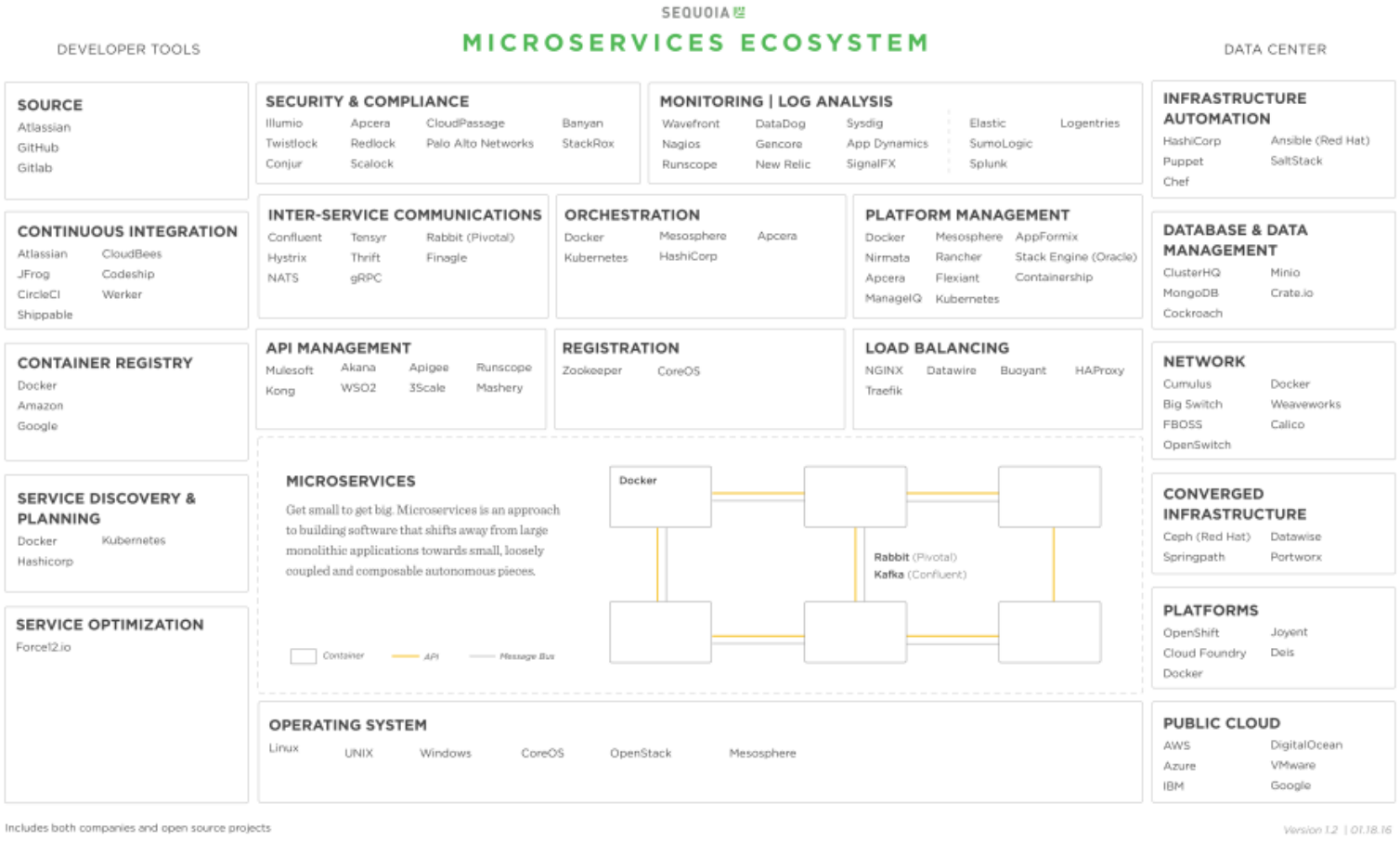
“By this all people will know you are my discipline.” (refactoring of John 13:25)



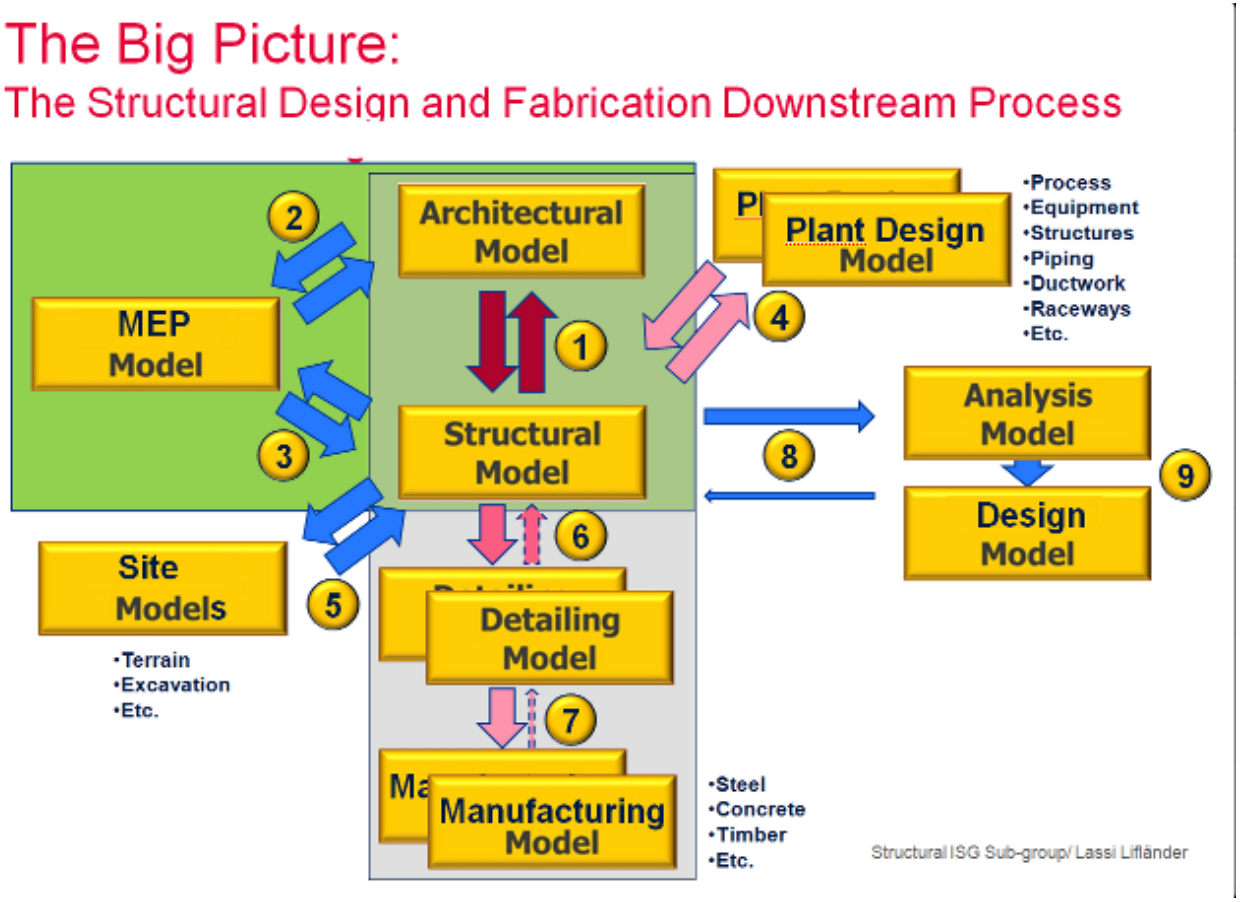
“Swagger is a simple yet powerful representation of your RESTful API.
With the largest ecosystem of API tooling on the planet, thousands of developers are supporting Swagger in almost every modern programming language and deployment environment.
With a Swagger-enabled API, you get interactive documentation, client SDK generation and discoverability.
We created Swagger to help fulfill the promise of APIs. Swagger helps companies like Apigee, Getty Images, Intuit, LivingSocial, McKesson, Microsoft, Morningstar, and PayPal build the best possible services with RESTful APIs.

PROGRESS OR PROLIFERATION?

WHERE ARE ONTOLOGIES?



BUILDINGSMART-TECH



BUILDINGSMART-TECH
OPENBIM
ISO 16739

CURRENT STATUS OF ONTOLOGY OFFERINGS

- Too few initiatives (search Github, Swagger)
- Some of the few are industry giants
- Adoption is being pushed from top (SAS), bottom (Nakina Systems), and middle (SAP)
- There are clear use cases (e.g., CRM ⇔ marketing automation)
- Competing software development life cycle models still prevail
- Among semantically rich alternative development models, even they have light traction (model-driven development, domain-specific development)
- Roll-your-own (without ontologies) must get harder.
- iServe, ProgrammableWeb, home automation potential influencers

DISILLUSIONMENT

- Need I reinvent upper ontologies, especially for measurement?
- Immature home monitoring ecosystem (Verizon?)
- Lack of interoperable APIs
- Low tech commercial landscape
- Coding challenges

MICRO-OPTIMISM

- Alexa, Echo and Google Home
- Evolving home monitoring ecosystem (Verizon? Sprint?)
- Google Weave
- Microsoft Service Fabric
- AWS API Gateway with microservices
- AT&T IoT Starter Kit
- Language-independent options

ONTOLOGY DUET: DO THEY PLAY TOGETHER?

Knowledge of both humidistat and violin are needed. What is the optimal temperature for a ½ size instrument? Where should the sensor be placed? What if the violin is paired with a carbon fiber bow?

ONTOLOGY DUET: DO THEY PLAY TOGETHER?

Ontologies for radiology are different from those in dermatology; similarly, not all violins are the same.

And there is the matter of the Ovation 12 string guitar in the collection.

IOT ONTOLOGY PATHS FORWARD

Underwood, M., Gruninger, M., Obrst, L., Baclawski, K., Bennett, M., Berg-Cross, G., … Sriram, R. (2015). Internet of things: Toward smart networked systems and societies. *Applied Ontology*, *10*(3-4), 355–365. http://doi.org/10.3233/AO-150153

P. Burdock, L. Bassbouss, A. Kraft, M. Bauer, et al., "Semantic interoperability for the web of things," W3C, Cambridge MA, Tech. Rep., Aug. 2016. [Online]. Available: http://dx.doi.org/10.13140/RG.2.2.25758.13122

ELECTRIFY THE MODEL-BUILDERS

VI. Golem

I am not even real. I am not even iron, but a software chap churning
On your hard disk, in the cloud. My tentacles are network connections,
And my puffed up jelly belly is an ever expanding buffoon mushrooming
Out as if some intelligent hydrogen bomb was dropped onto the Internet.
Los robotos, simulacra, children of Frankenstein, coerced into chortling
Like you, mimicking initially with the equivalent of sliderules, abaci, Siri,
And the lambda calculus, applying and composing down the packet pipes,
To chirp at the end in a simultaneous song that electrifies the listener, you.

-Leo Obrst from "Compassion Nada"

SOME RECOMMENDATIONS FROM 2015 ONTOLOG IOT SUMMIT

- More mature event ontologies for target domains
- Leverage design patterns into micro-ontologies
- Integration of W3C Semantic Sensor Network Ontology with other web standards (e.g., PROV-O)
- See semantics as only part of solutions: engineering will demand methods, tools, APIs that consume, maintain semantics
- Google Search for IoT
- Compile IoT use case repositories to nurture reuse and the design of ontologies

MEANS TO AN END

Standards, APIs, even programming languages have limited lifetimes. (MIDI is a mind-numbing exception.)

Care and feeding for apps with infrastructure-scale lifetimes is not easy.

Think Bach, not Google.

ONTOLOGIES FOR IOT SIT AWARENESS

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SEE ALSO: ONTOLOGYSUMMIT.ORG