HIP

Please read "HIP" prior to reviewing this PDF (DAMS doc)

PDF copy of "HIP" is in the MIT Library https://dspace.mit.edu/handle/1721.1/123984

Tim the Beaver is the official mascot of MIT.

Beaver, the **"nature's engineer"** was adopted as the mascot at the annual dinner of the Technology Club of New York on January 17, 1914 by a group of MIT alumni.

Building DAMS

Out-of-the-box suggestions by Shoumen Datta, MIT

DAMS

Digital Architecture and Mapping Sensors

Search & Discovery is the Central Concept

for

Data

Query

Response

Design and Purpose of the Software Architecture

How to respond to query from non-expert users

Response to query from non-expert users

Starts with dissecting the query to understand **which sources** of data (***discovery*** of sources and connecting to sources) and **what type** of data (***discovery*** of data, selection of data and data interoperability) from the sources are relevant to respond to the query. Aggregating the data, data fusion and *synthesis* of the data to **inform** the user are the next steps.

Purpose of Software Architecture: Data-Informed Optimization of Key Performance Indicators

Ad hoc data ***discovery*** must be relevant to the ***search*** from users

Experts create sensors and deploy sensor networks to harvest data and extract actionable information.

Users ask questions to improve their practice and use the information from sensor networks to adjust/adapt their performance to maximize benefit/value/profit.

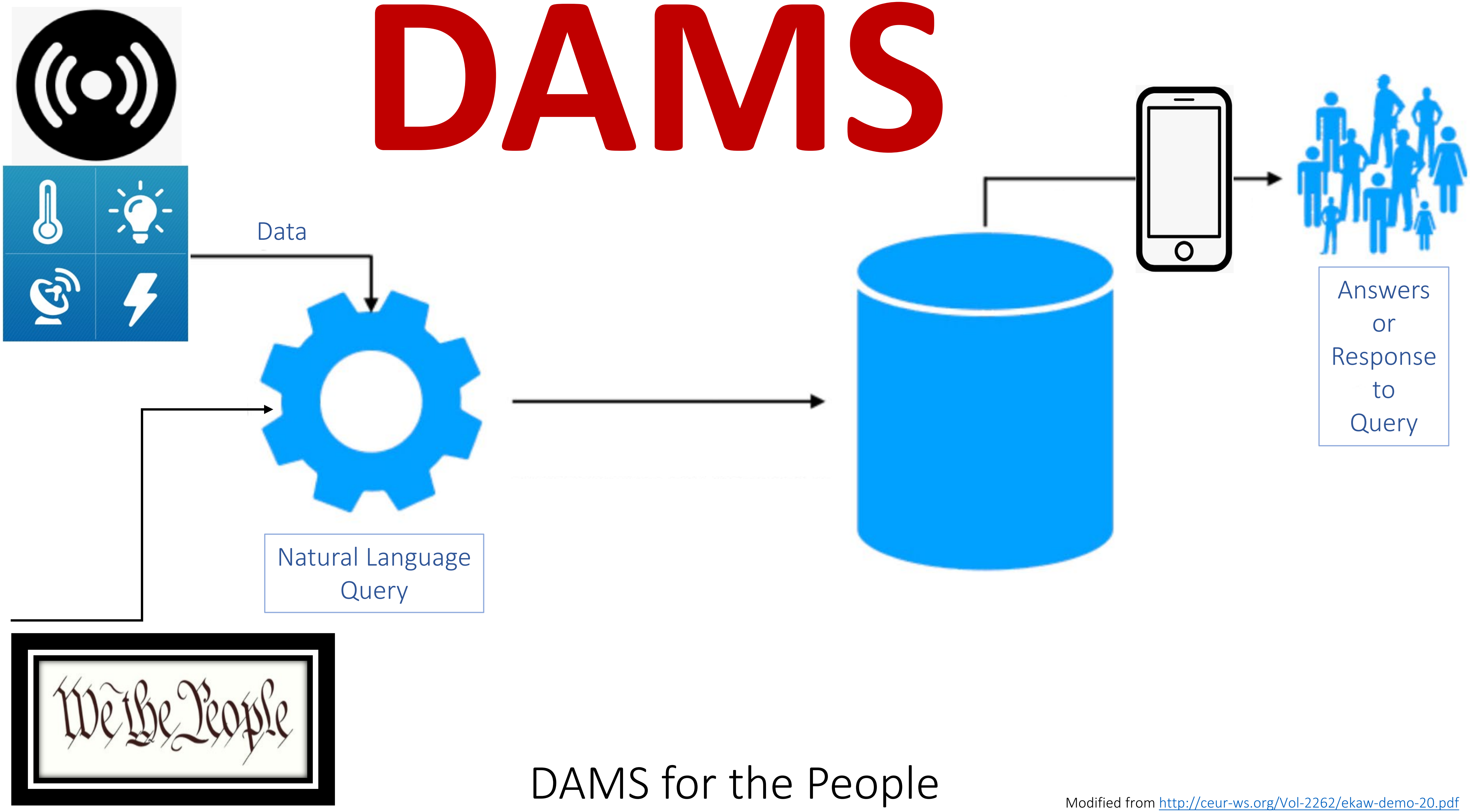
Building DAMS

Digital Architecture and Mapping Sensors

must enable

Search and Discovery

DAMS



DAMS for the People

Modified from http://ceur-ws.org/Vol-2262/ekaw-demo-20.pdf

Data from Signal

↓

Feature Extraction

↓

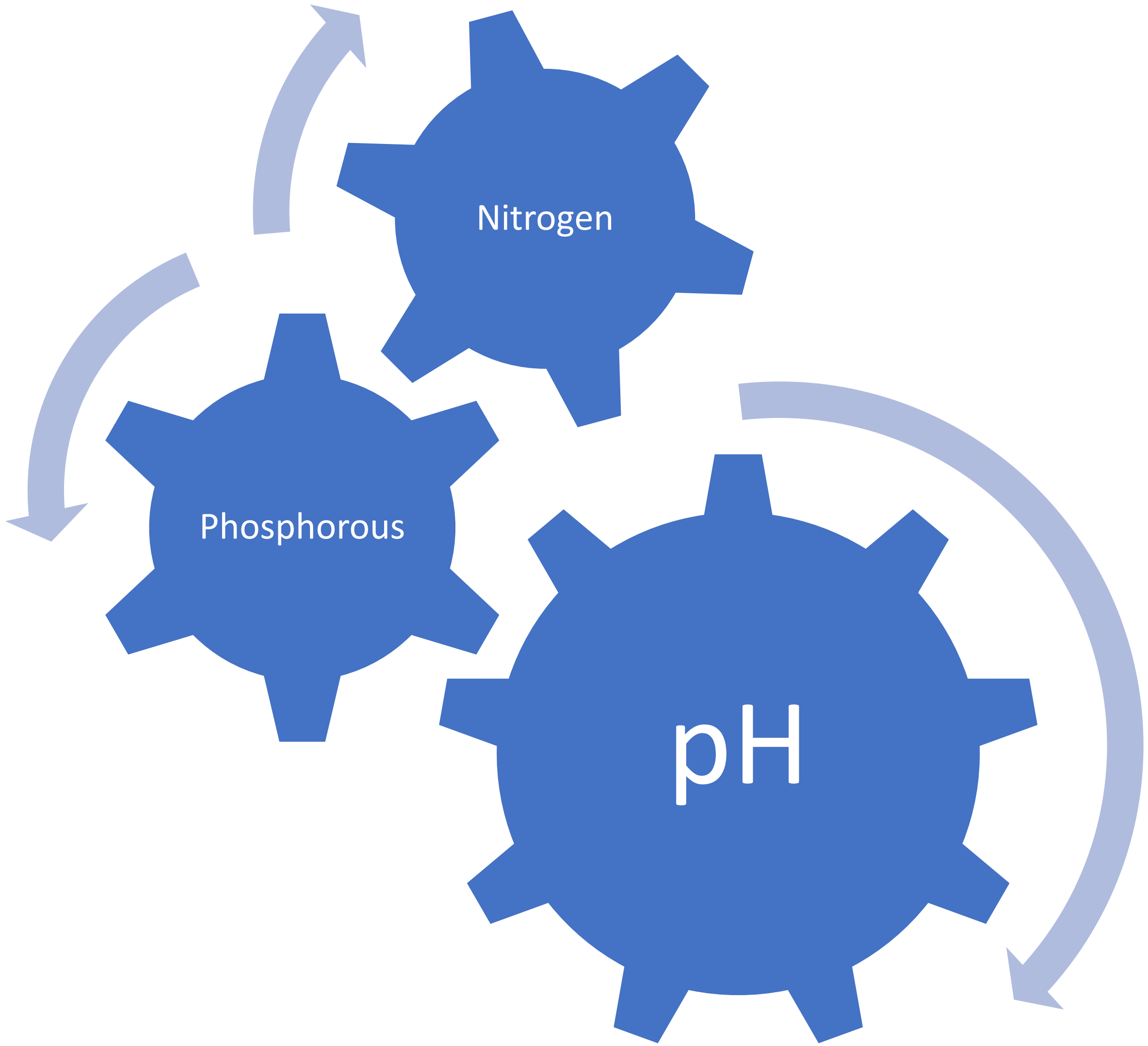
Feature Vector

Parameters which are connected to data sources (scalability). Data sources may be sensors in soil, above ground, mobile sensor on vehicles or drones, *ad hoc* deployment of sensor (establish com, transmit data).

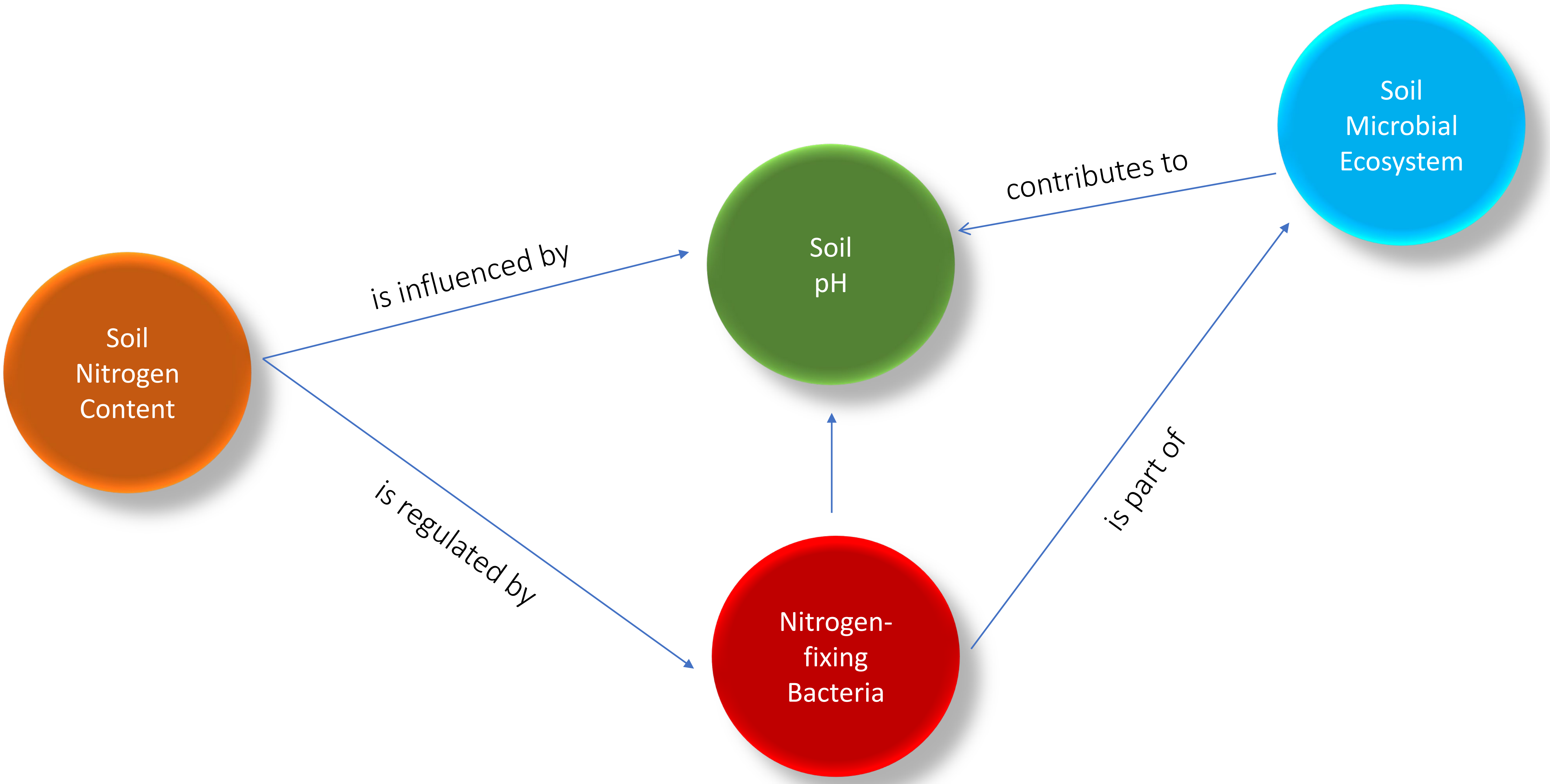
Relationship between Independent Variables (Feature Selection)

SENSORS	Moisture	Temperature	Nitrogen	Phosphorous	pH	Bacteria	Enzymes	Pesticides	Arsenic	Mercury	Other
Moisture		↑ Temp ↓ Moisture									
Temperature											
Nitrogen					↑ Nitrates ↓ pH						
Phosphorous											
pH							↑ pH ↓ Enzyme				
Bacteria											
Enzymes											
Pesticides						↑ Pesticides ↓ Bacteria					
Arsenic											
Mercury									↑ Arsenic ↓ Mercury		
Other											

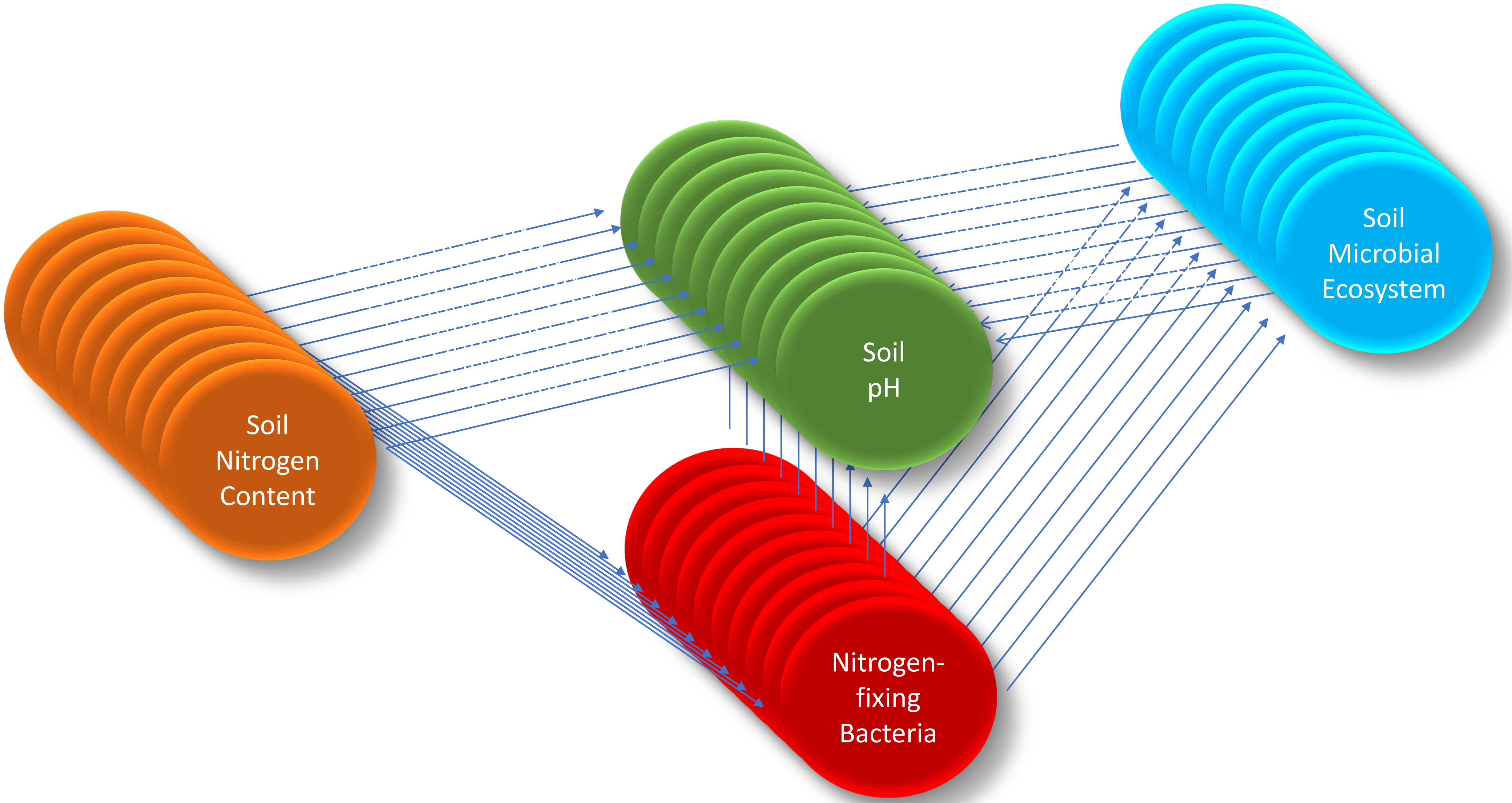
Relationship between Independent Variables (Feature Vector)



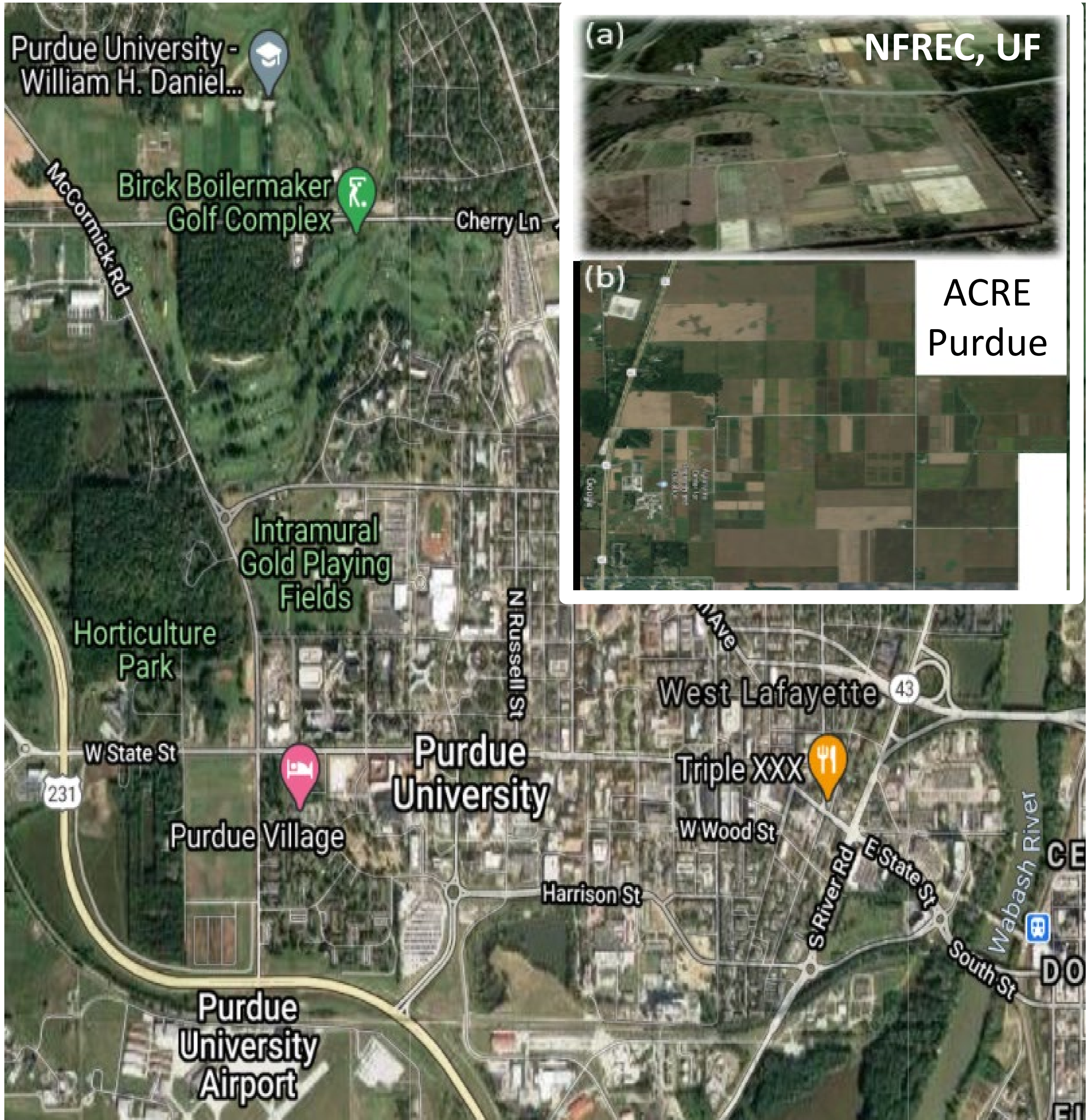
Relationship between Independent Variables (Knowledge Graph)



Relationship between Independent Variables (Time Series Data)

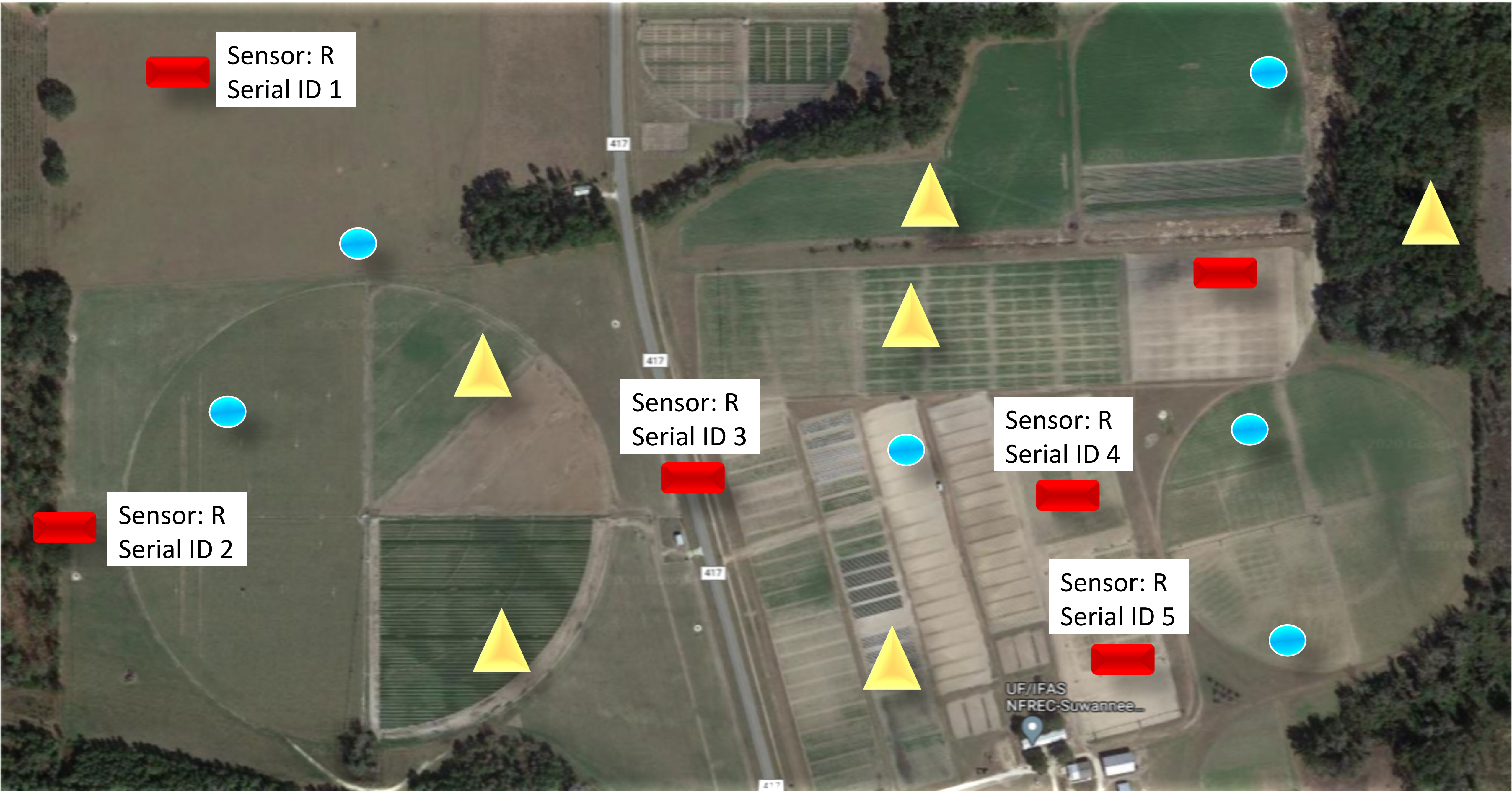


GIS Sensor App – drill down to each sensor (search by location)

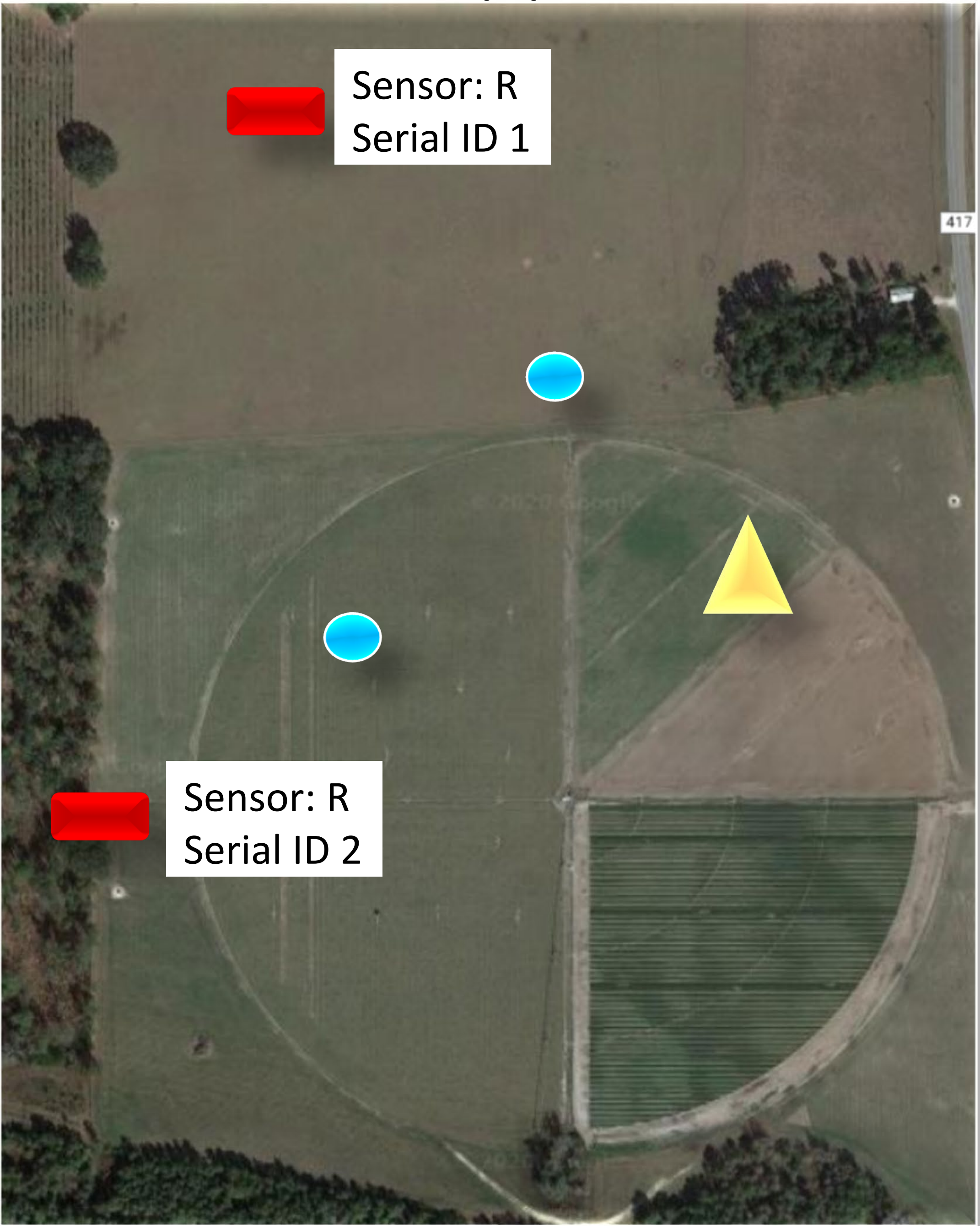


https://www.intelligentriver.org/data

GIS Sensor App – drill down to sensor type, serial ID, GPS match



GIS Sensor App - drill down to sensor type & SENSOR FEATURES



A	B	C	D	E	F	G	H
Device number	MW [Da]	Category	Target	Recognition-transduction scheme	Platform	Range (LOD)	Range (max tested)
1	201	heavy metal	mercury (Hg2+)	AuNP		1.00E-08	NR
2	201	heavy metal	mercury (Hg2+)	MIP??	Sol gel	5.00E-06	NR
3	201	heavy metal	mercury (Hg2+)	Rhodamine		1.00E-07	NR
4	201	heavy metal	mercury (Hg2+)			5.00E-07	NR
5	201	heavy metal	mercury (Hg2+)	foldamer	micelle	5.00E-07	NR
6	201	heavy metal	mercury (Hg2+)	corroloe derivative	PVC	5.60E-06	NR
7	201	heavy metal	mercury (Hg2+)	tetraarylborate		3.00E-07	NR
8	201	heavy metal	mercury (Hg2+)			1.00E-07	NR
9	201	heavy metal	mercury (Hg2+)	polythiophene		3.00E-05	NR
10	201	heavy metal	mercury (Hg2+)	thiosemicarbazone		5.00E-06	NR
11	201	heavy metal	mercury (Hg2+)	dansylcarboxamide		1.00E-05	5.00E-04
12	201	heavy metal	mercury (Hg2+)	quenching		3.00E-06	5.50E-05
13	201	heavy metal	mercury (Hg2+)	DNAzyme		2.40E-09	NR
14	201	heavy metal	mercury (Hg2+)	chromo-ionophore assembly	PVC	3.40E-08	NR
15	201	heavy metal	mercury (Hg2+)	AuNP		5.00E-09	1.00E-05
16	201	heavy metal	mercury (Hg2+)			1.00E-08	2.00E-04
17	201	heavy metal	mercury (Hg2+)	Rhodamine 6G	AuNP	6.00E-11	3.60E-08
18	201	heavy metal	mercury (Hg2+)	Cholic acid		5.00E-08	NR
19	201	heavy metal	mercury (Hg2+)	thiacalixarene		2.00E-06	8.50E-06
20	201	heavy metal	mercury (Hg2+)			7.00E-07	NR
21	201	heavy metal	mercury (Hg2+)	anthraquinone/urea		5.0E-05	2.0E-04
22	201	heavy metal	mercury (Hg2+)	anthracene/ionophore hybrid	PET	1.0E-06	
23	201	heavy metal	mercury (Hg2+)	oligonucleotide	AuNP	1.0E-07	1.0E-06
24	201	heavy metal	mercury (Hg2+)	oligonucleotide		4.2E-08	6.7E-07
25	201	heavy metal	mercury (Hg2+)			5.0E-08	
26	201	heavy metal	mercury (Hg2+)	phosphorescent iridium(III) complex		2.0E-05	
27	201	heavy metal	mercury (Hg2+)	MerR protein		1.0E-08	
28	201	heavy metal	mercury (Hg2+)			1.0E-06	

Q: Located sensor R serial ID1 at GPS (DD) 41.881832, -87.623177 and R-10 at 41.881832, 87.623177. Is there any difference in the limit of detection (LoD) between sensor type R serial ID 1 vs R serial ID 10?

Quintessential task for DAMS (Software Architecture)

Respond to this user query

Q: Located sensor R serial ID1 at GPS (DD) 41.881832, -87.623177 and R-10 at 41.881832, 87.623177. Is there any difference in the limit of detection (LoD) between sensor type R serial ID 1 vs R serial ID 10?

To answer question – discover and connect to SENSOR FEATURES

Device number	MW [Da]	Category	Target	Recognition-transduction scheme	Platform	Range (LOD)	Range (max tested)
1	201	heavy metal	mercury (Hg2+)	AuNP		1.00E-08	NR
2	201	heavy metal	mercury (Hg2+)	MIP??	Sol gel	5.00E-06	NR
3	201	heavy metal	mercury (Hg2+)	Rhodamine		1.00E-07	NR
4	201	heavy metal	mercury (Hg2+)			5.00E-07	NR
5	201	heavy metal	mercury (Hg2+)	foldamer	micelle	5.00E-07	NR
6	201	heavy metal	mercury (Hg2+)	corroloe derivative	PVC	5.60E-06	NR
7	201	heavy metal	mercury (Hg2+)	tetraarylborate		3.00E-07	NR
8	201	heavy metal	mercury (Hg2+)			1.00E-07	NR
9	201	heavy metal	mercury (Hg2+)	polythiophene		3.00E-05	NR
10	201	heavy metal	mercury (Hg2+)	thiosemicarbazone		5.00E-06	NR
11	201	heavy metal	mercury (Hg2+)	dansylcarboxamide		1.00E-05	5.00E-04
12	201	heavy metal	mercury (Hg2+)	quenching		3.00E-06	5.50E-05
13	201	heavy metal	mercury (Hg2+)	DNAzyme		2.40E-09	NR
14	201	heavy metal	mercury (Hg2+)	chromo-ionophore assembly	PVC	3.40E-08	NR
15	201	heavy metal	mercury (Hg2+)	AuNP		5.00E-09	1.00E-05
16	201	heavy metal	mercury (Hg2+)			1.00E-08	2.00E-04
17	201	heavy metal	mercury (Hg2+)	Rhodamine 6G	AuNP	6.00E-11	3.60E-08
18	201	heavy metal	mercury (Hg2+)	Cholic acid		5.00E-08	NR
19	201	heavy metal	mercury (Hg2+)	thiacalixarene		2.00E-06	8.50E-06
20	201	heavy metal	mercury (Hg2+)			7.00E-07	NR
21	201	heavy metal	mercury (Hg2+)	anthraquinone/urea		5.0E-05	2.0E-04
22	201	heavy metal	mercury (Hg2+)	anthracene/ionophore hybrid	PET	1.0E-06	
23	201	heavy metal	mercury (Hg2+)	oligonucleotide	AuNP	1.0E-07	1.0E-06
24	201	heavy metal	mercury (Hg2+)	oligonucleotide		4.2E-08	6.7E-07
25	201	heavy metal	mercury (Hg2+)			5.0E-08	
26	201	heavy metal	mercury (Hg2+)	phosphorescent iridium(III) complex		2.0E-05	
27	201	heavy metal	mercury (Hg2+)	MerR protein		1.0E-08	
28	201	heavy metal	mercury (Hg2+)			1.0E-06	

Located sensor type R serial ID1 at GPS (DD) 41.881832, -87.623177 and R-10 at 41.881832, 87.623177. Is there any difference in the limit of detection (LoD) between sensor type R serial ID 1 vs R serial ID 10?

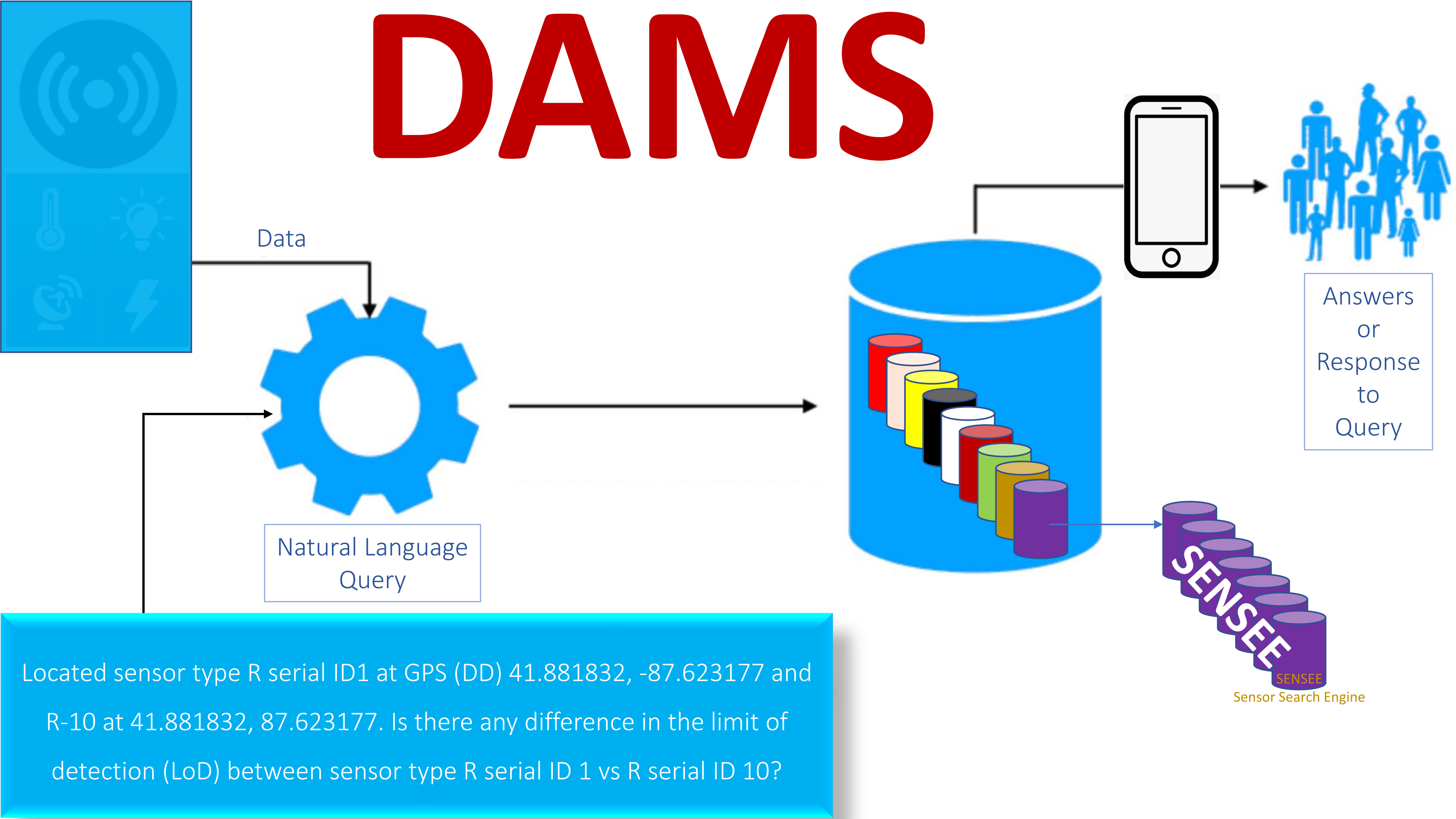
SENSEE – DB with Sensor Characteristics (SENSOR FEATURES DB)

MW [Da]	Category	Target	Recognition-transduction scheme	Platform	Range (LOD) [M]	Range (max tested)	Selectivity (interferent species tested)	Response time [sec]	Durability	Shelf Life	Hysteresis	USE CATEGORY
1	small molecule	H+	H+ ionophore (liquid)	glass capillary	1.0E-13	1.0E-04	excellent (K+, Na+, Ca2+, Mg2+)	2	medium	low (one day)	med	hydroponics
1	small molecule	H+	anthocyanin/nanocellulose	paper filter	1.0E-15	1.0E-02	excellent	2	high	medium (one week)	high	irrigation water
18	small molecule	Ammonium	NH4+ ionophore (liquid)	glass capillary	5.0E-09	1.0E-01	excellent	5	medium	low (one day)	med	wastewater
18	small molecule	Ammonium	NH4+ ionophore (solid)	LSG	2.8E-05	5.0E-01	excellent	2	medium	high (one month)	high	wastewater
30	small molecule	N/O radicals	nanoplatinum/nanoceria	Pt electrode	1.0E-08	3.0E-06	medium	1	medium	excellent (one year)	med	ocean water
32	small molecule	DO	Pt porphyrin-nTiO2	fiber optic	1.0E-06	5.0E-06	excellent, temp sens	1	High	excellent (one year)	low	hydroponic media
32	small molecule	DO	Pt porphyrin	96 well	1.0E-06	5.0E-06	excellent, temp sens	45	low	excellent (one year)	low	hydroponic media
32	small molecule	DO	Pt porphyrin	glass vial	1.0E-06	5.0E-06	excellent, temp sens	45	low	excellent (one year)	low	hydroponic media
34	small molecule	H2O2	fractal nPt	Pt electrode	5.0E-09	5.0E-05	excellent	1	high	excellent (one year)	low	ocean water
39	small molecule	K+	K+ ionophore (liquid)	glass capillary	1.0E-06	2.5E-01	excellent	2	low	low (one day)	low	wastewater
41	small molecule	Ca2+	Ca2+ ionophore (liquid)	glass capillary	1.0E-06	5.0E-01	excellent	1	low	low (one day)	low	Hoaglands media
58	small molecule	acetone	chemosensory proteins-nPt	Pt electrode	5.0E-06	1.0E-05	high	10	low	medium (one week)	med	buffer
62	small molecule	Nitrate	NO3- ionophore (liquid)	glass capillary	1.0E-06	2.0E-01	excellent	2	medium	low (one day)	low	wastewater
62	small molecule	Nitrate	NO3- ionophore (solid)	LSG	2.0E-05	1.5E-01	excellent	2	medium	high (one month)	low	wastewater
108	small molecule	Ag+	Ag+ ionophore (liquid)	glass capillary	1.0E-06	5.0E-02	excellent	2	high	low (one day)	low	wound dressing
111	small molecule	histamine	diamine oxidase-nCu	LSG	6.3E-05	1.0E-03	excellent	2	medium	medium (one week)	med	fermented fish
147	small molecule	Glutamate	CNT/nPt/GlOx	Pt electrode	1.0E-06	1.0E-03	excellent	2	low	low (one day)	med	INS1 tissue culture
147	small molecule	Glutamate	CNT/nPt/GlOx	Si biochip	1.0E-06	5.0E-01	excellent	2	low	low (one day)	med	INS1 tissue culture
154	small molecule	catecholamines	nPt	LSG	5.0E-07	3.0E-03	excellent	2	high	excellent (one year)	low	ocean water
154	small molecule	catecholamines	graphene anchored nCuO	LSG	3.0E-07	3.0E-03	high	2	medium	high (one month)	low	buffer
176	small molecule	indole acetic acid	fractal nPt	Pt/Ir microwire	1.0E-06	1.0E-03	high	1	high	excellent (one year)	low	root growth media
181	small molecule	Glucose	nPt/GOx	graphene paper	8.0E-08	1.0E-03	excellent	2	medium	medium (one week)	med	buffer
181	small molecule	Glucose	nPt/GOx	Pt/Ir microwire	1.0E-07	5.0E-06	excellent	1	medium	medium (one week)	med	blood
181	small molecule	Glucose	nPt/nCe/GOx	Pt electrode	1.0E-07	3.0E-06	excellent	1	medium	medium (one week)	med	buffer
201	small molecule	ionic mercury	graphene anchored nCuO	LSG	9.9E-08	1.3E-05	excellent	180	medium	high (one month)	high	buffer
256	small molecule	imidacloprid	rGO-nPt	Pt electrode	5.6 e-6	2.0E-04	medium	3	medium	excellent (one year)	low	buffer
507	small molecule	ATP	RGO-nPt-hydrogel	Pt electrode	2.0E-06	1.0E-05	excellent	2	low	low (one day)	low	plant growth media
17000	small protein	MBF1	TBP-nPt	Pt electrode			excellent	300	low	low (one day)	hysteric	buffer
17146	small protein	interferon gamma	aptamer-nPt-rGO	Au IDE	2.2E-11	1.1E-10		2100	low	medium (one week)	hysteric	buffer
NA	bacteria	E. coli (generic)	IgG + PNIPAAM	Pt electrode	4 CFU/mL	10^4 CFU/mL	excellent.	1000	medium	medium (one week)	hysteric	buffer
NA	bacteria	E. coli (generic)	lectin + PNIPAAM	Pt electrode	4 CFU/mL	10^4 CFU/mL	medium	1000	medium	medium (one week)	hysteric	buffer
NA	bacteria	E. coli (generic)	aptamer-nPt	LSG/nanocopper	5 CFU/mL	10^7 CFU/mL	excellent.	1000	medium	medium (one week)	hysteric	buffer
NA	bacteria	E. coli O157:H7	aptamer-nPt	graphene paper	9 CFU/mL	10^4 CFU/mL	excellent	1000	medium	medium (one week)	hysteric	buffer
NA	bacteria	Salmonella	aptamer-nAu	Au electrode	89 CFU/mL	10^3 CFU/mL	excellent	1000	medium	medium (one week)	hysteric	buffer
NA	bacteria	Campylobacter	aptamer-nAu	Au electode	10 CFU/mL	10^2 CFU/mL	medium	1500	medium	medium (one week)	hysteric	buffer
NA	bacteria	Listeria	aptamer + CHI	Pt electrode	5 CFU/mL	10^4 CFU/mL	excellent	720	medium	medium (one week)	hysteric	buffer
NA	bacteria	Listeria	IgG + CHI	Pt electrode	5 CFU/mL	10^4 CFU/mL	excellent	720	medium	medium (one week)	hysteric	buffer
NA	bacteria	E. coli O157:H7	aptamer-Au	gold-cotaed paramagnetic microdisc	10 CFU/100mL	10000 CFU/100mL	excellent (E coli K12)	21600	high	high (one month)	hysteric	vegetable broth
NA	bacteria	E. coli	Con A + nPT/rGO-CHI	Pt electrode	4 CFU/mL	10000 CFU/100mL		21600	high	medium (one week)	hysteric	pond water
NA	bacteria	E. coli	aptamer + nPT/rGO-CHI	Pt electrode	4 CFU/mL	10000 CFU/100mL		21600	high	medium (one week)	hysteric	vegetable broth
NA	bacteria	Listeria	aptamer	Pt IDE (Si)	7 CFU/mL	10000 CFU/100mL	high (Listeria innocua, Salmonella)	21600	high	medium (one week)	hysteric	vegetable broth
503	small molecule	mesosulfuron (Orthello)	sulfonyl urea Ab	RP C18 cartridge prefilter	2.5E-09	2.5E-08	medium	1200	low	low (one day)	med	drinking water

SENSEE - DB with Sensor Characteristics (SENSOR FEATURES DB)

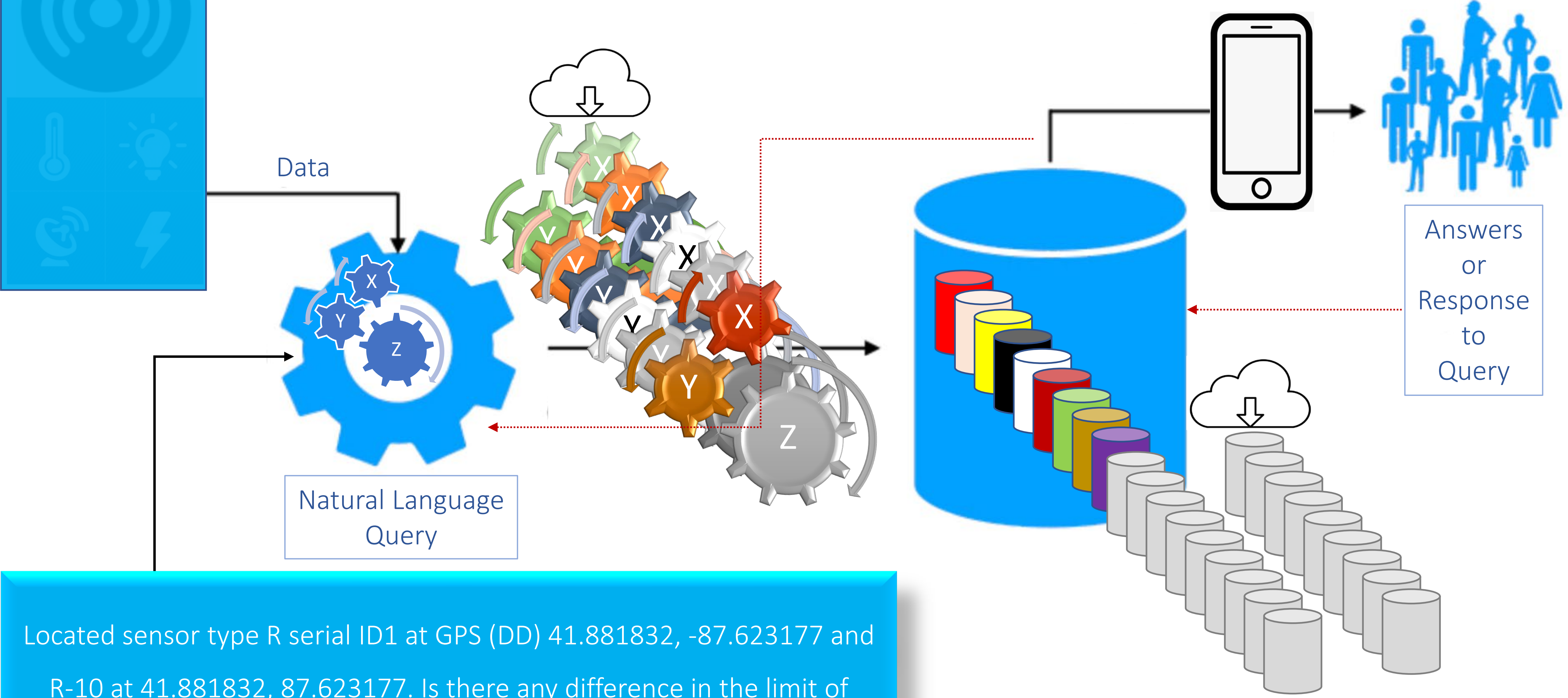
What is SENSEE?

One or more databases (**does not store sensor data**) which stores descriptions and numeric values which relates to SENSOR PRODUCT ENGINEERING CHARATERISTICS AND FEATURES related to sensor material, sensor properties, sensor specificity, sensor limits of detection, sensor response time, sensor reusability (hysteresis).



DAMS
Data
Natural Language Query
Answers or Response to Query
SENSEE
SENSEE
Sensor Search Engine
Located sensor type R serial ID1 at GPS (DD) 41.881832, -87.623177 and R-10 at 41.881832, 87.623177. Is there any difference in the limit of detection (LoD) between sensor type R serial ID 1 vs R serial ID 10?

DAMS is an "umbrella" architecture which connects to multiple sources and serves as a platform for data interoperability and aggregation (query-specific data fusion). Multiple user-specific and application-specific logic and learning modules will consume data from diverse sources (via open APIs). Various processing tools (analytical engines, algorithms, machine learning) will use input data and stored data to respond to user queries.



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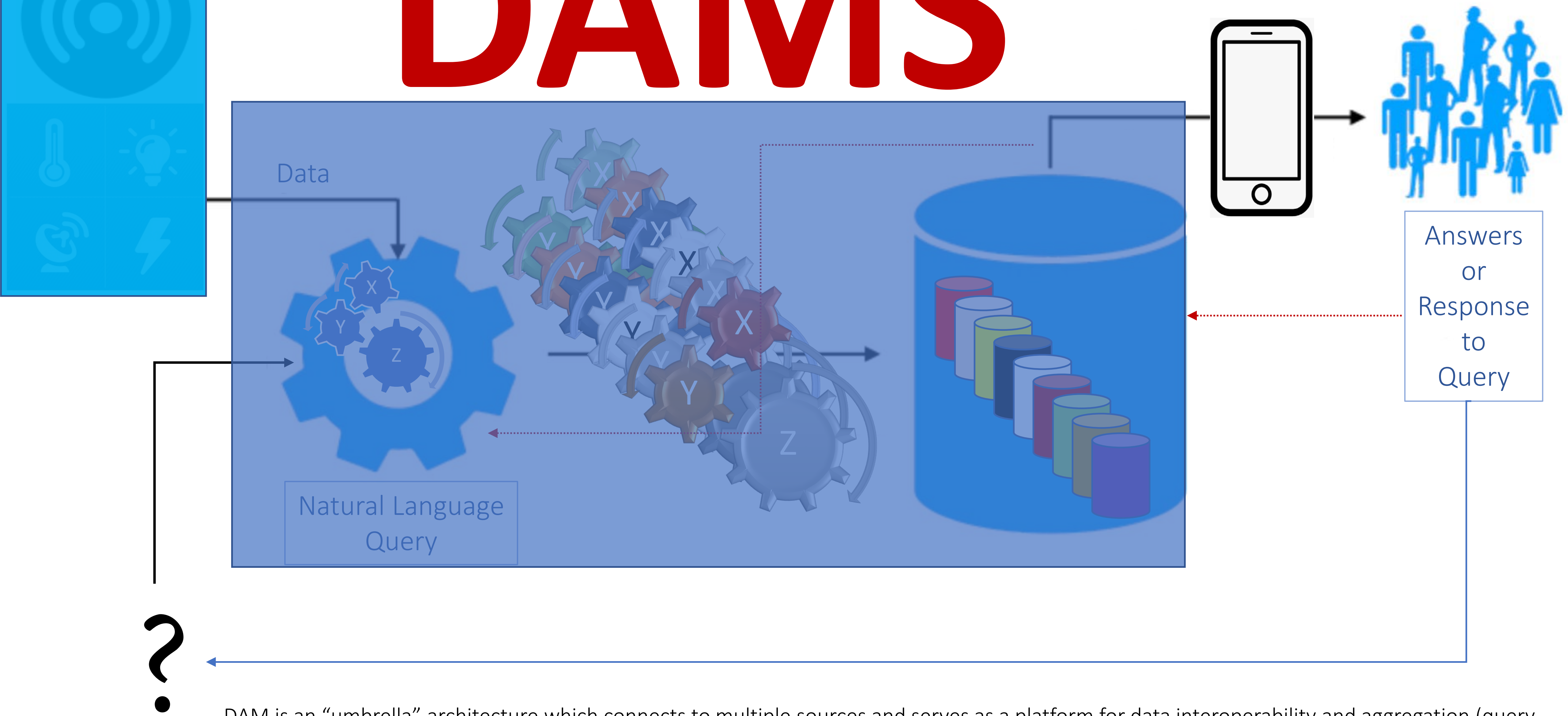
DAMS



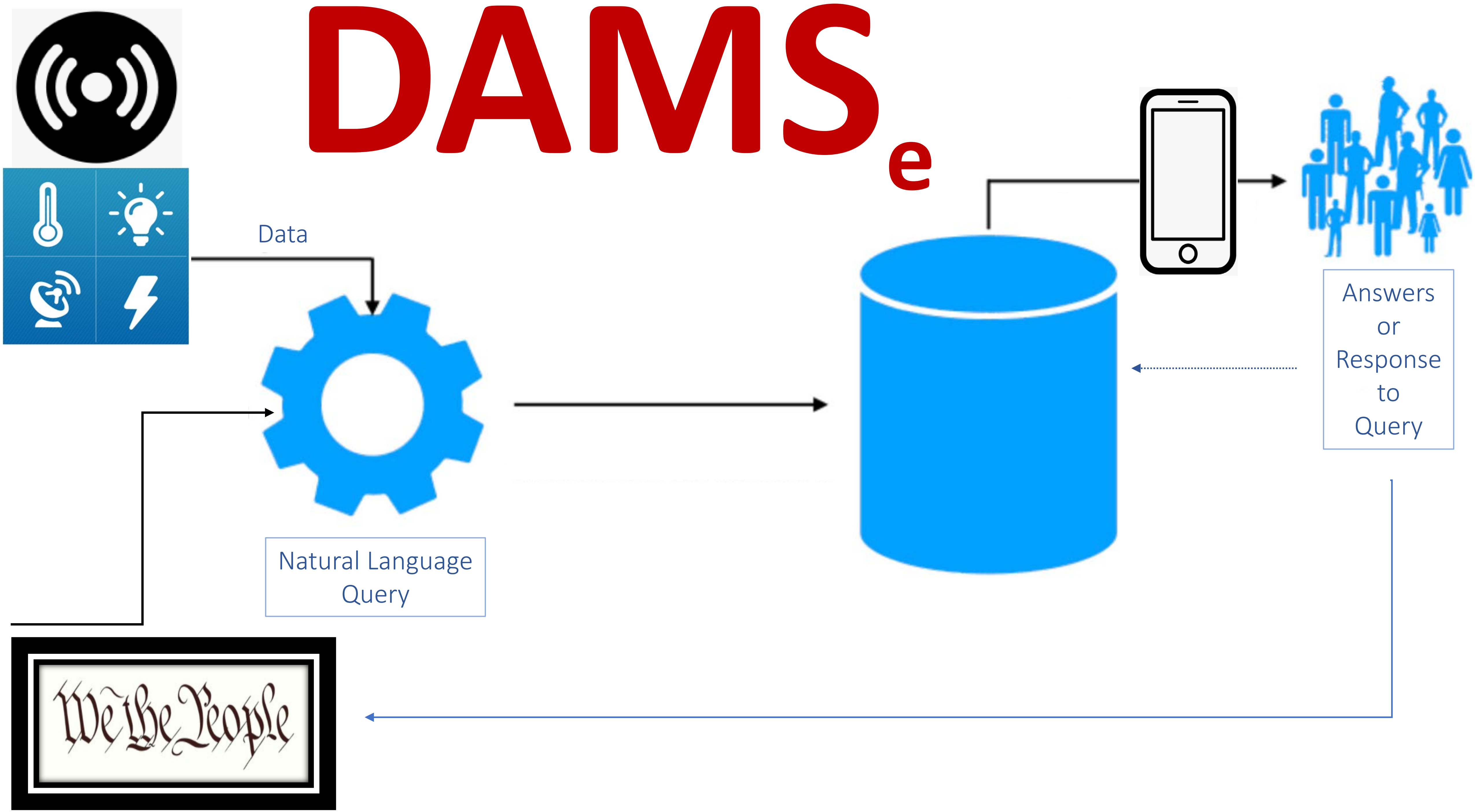
DAM is an "umbrella" architecture which connects to multiple sources and serves as a platform for data interoperability and aggregation (query-specific data fusion). Multiple user-specific and application-specific logic and learning modules will consume data from diverse sources (via open APIs). Various processing tools (analytical engines, algorithms, machine learning) will use input data and stored data to respond to user queries.

DAMS

VERSIONS / INSTANCES / VIEWS

Public User-specific, Private User-specific, Application-specific, Security-specific,

Data-specific, Cloud-specific, Country-specific, Domain-specific, Vertical-specific


DAMSe
Data
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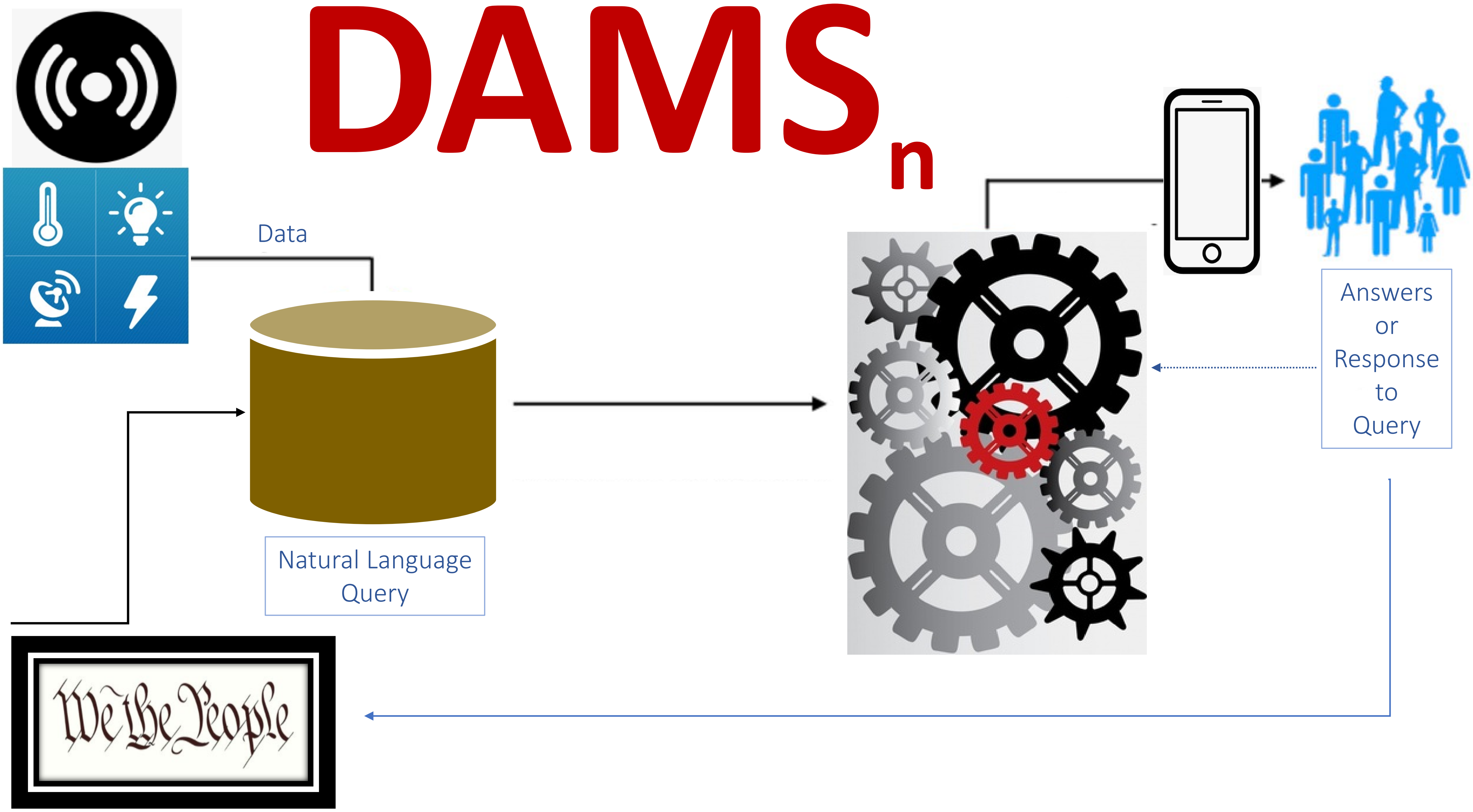
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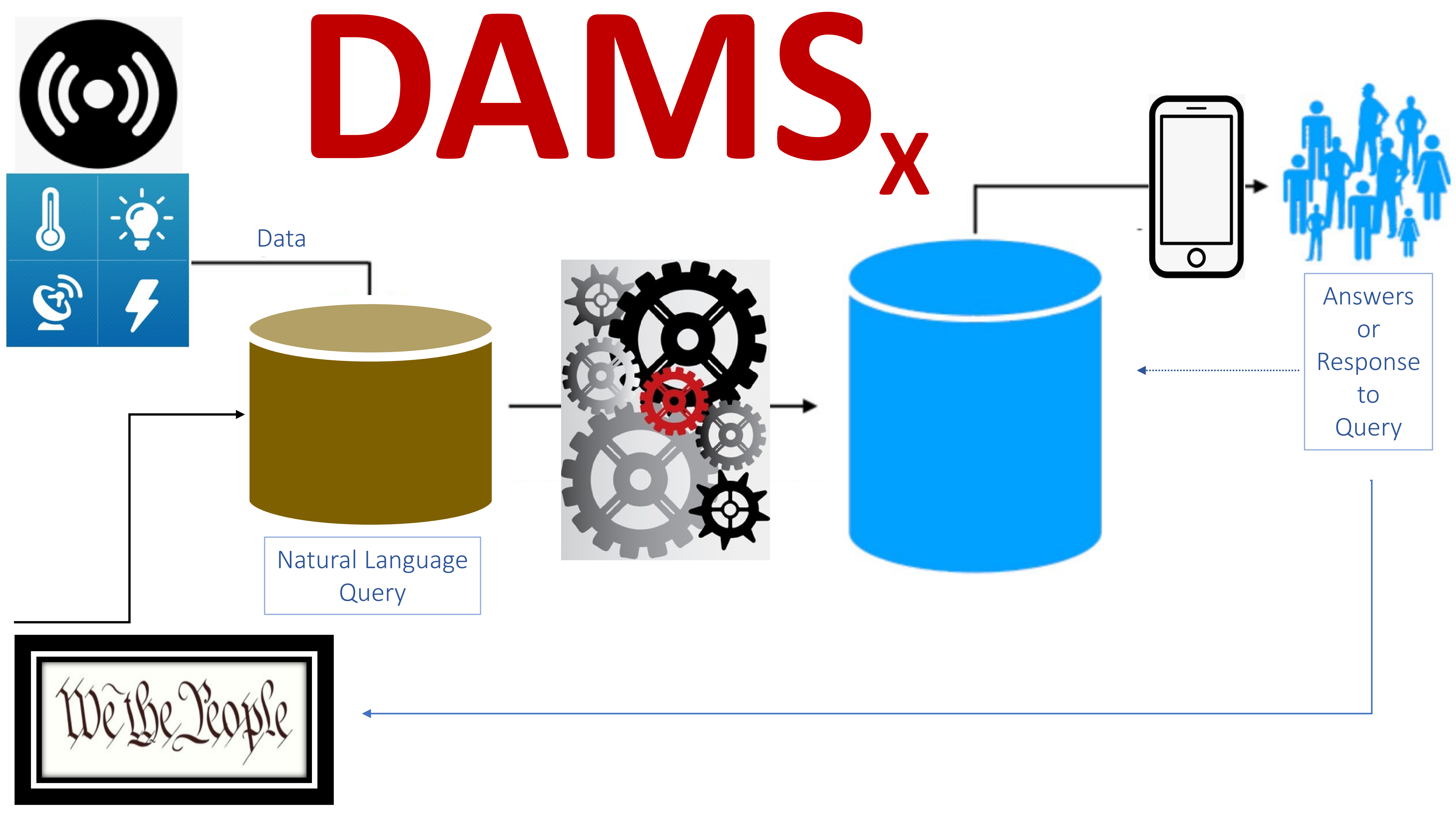
DAMS$_x$
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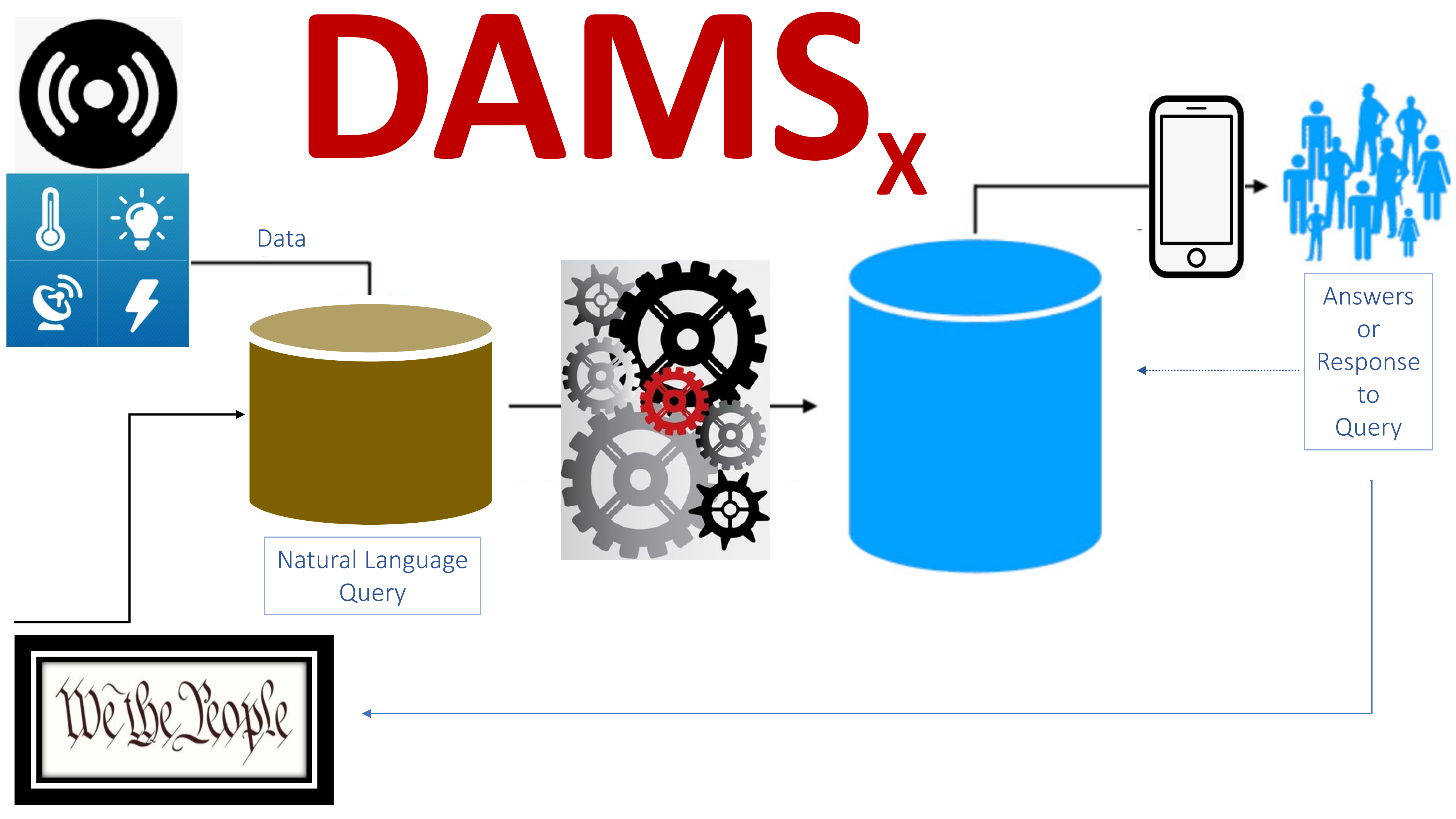

DAMSX
Data
Natural Language Query
Answers or Response to Query
We the People

How experts may view

DAMS

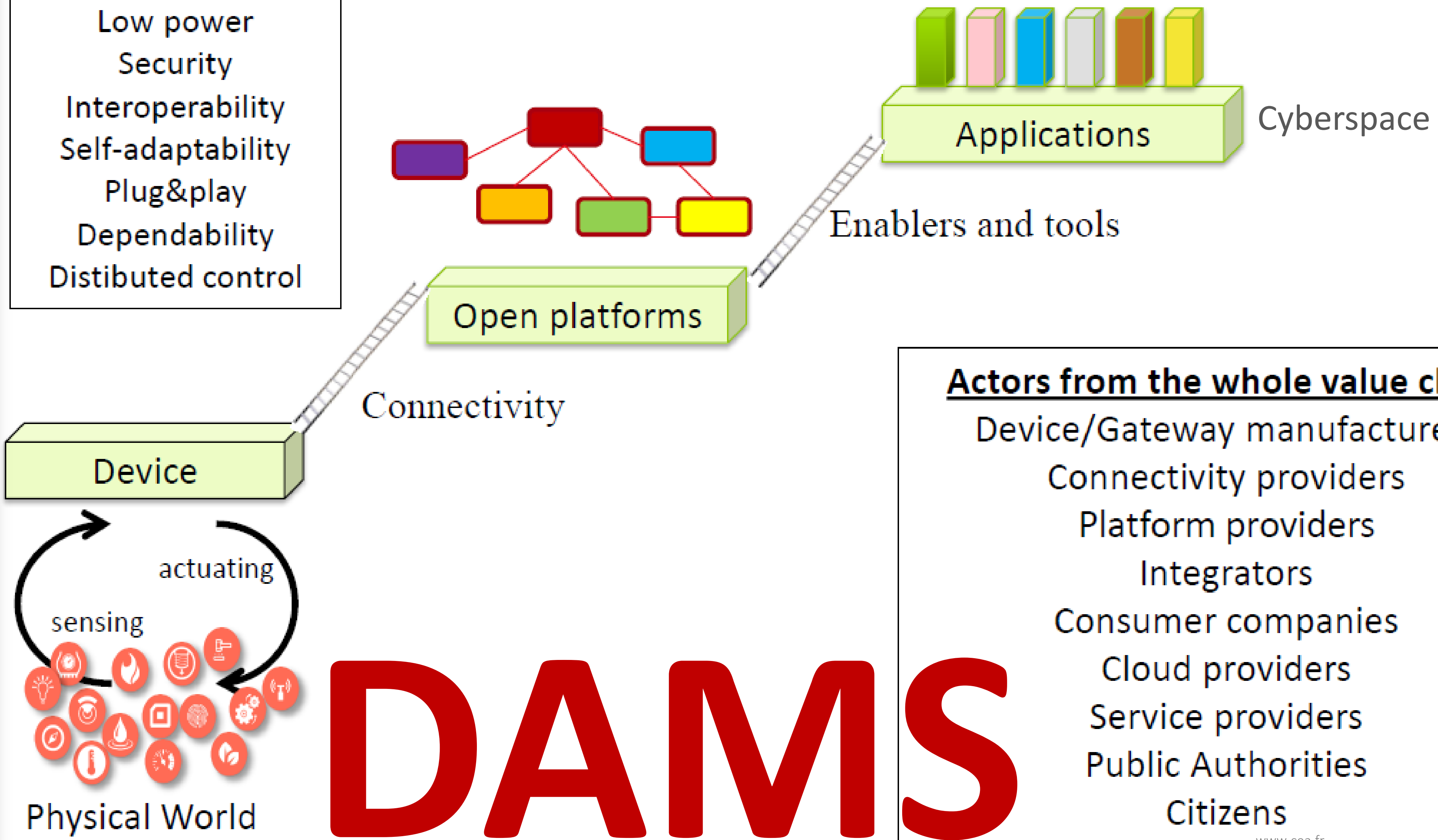
CPS

A B S T R A C T I O N

Technical challenges

Heterogeneity
Integration
Low power
Security
Interoperability
Self-adaptability
Plug&play
Dependability
Distibuted control

NIST - Framework for Cyber-Physical Systems
Vol 1 - https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1500-201.pdf
Vol 2 - https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1500-202.pdf



DAMS

Actors from the whole value chain

Device/Gateway manufacturers
Connectivity providers
Platform providers
Integrators
Consumer companies
Cloud providers
Service providers
Public Authorities
Citizens

DAMS is an architectural **CPS ECOSYSTEM** which connects multiple sources & is a platform for data **interoperability**, fusion and aggregation (**TASK**-specific data **DISCOVERY**). Multiple user-specific and application-specific logic, rules, reasoning tools (LRRT) & learning/ML modules will consume data from diverse sources. Analytical engines, ML techniques & LRRT will use input data, stored data & reference data to **synthesize information**.

UX – example – explore wastewater

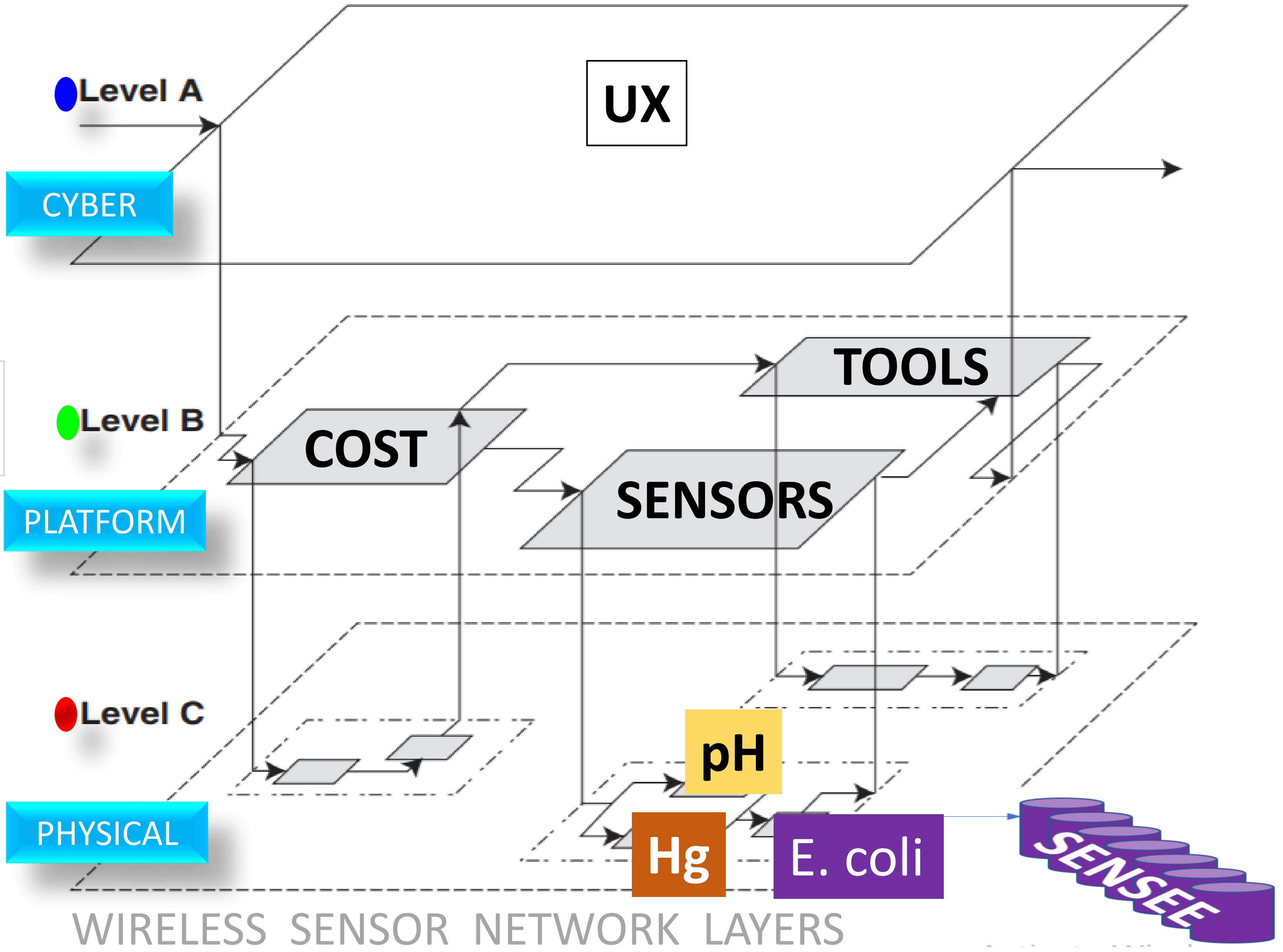
Data Discovery - Network of Factors (subnet/dependencies of each factor)

- Sensors (water quality data from)

  - Heavy metal pollution (Mercury)

  - Microbial contaminants (E. coli)

  - Chemical characteristics (pH)



SOFTWARE ARCHITECTURE DESIGN CONSIDERATIONS FOR FUTURE-PROOFING DAMS SCALABILITY

Initially, the architecture may be limited to sketches (https://c4model.com/) with components (tool, software, connection) explained. DAMS will be dynamic, configurable and "composable" design tool (**watch MPEG** http://oxygen.csail.mit.edu/videosketching.html) with "drag and drop" features for sensor engineers to "click-in & click-out" sensors or devices or locations on the DAMS screen (**watch** http://bit.ly/META-TOOL-SUITE). DAMS will be used as multi-purpose demonstration and teaching tool (http://web.mit.edu/jsterman/www/SDG/beergame.html) when downloaded from URL (buildDAMS.net) on a mobile device (smartphone, tablet, laptop). It will offer an option to upload "library" of components displayed in a "menu" similar to spare parts for automobiles or made-to-order laptop on Dell.com (other examples are Lego MindStorm or IKEA room-kitchen planner). DAMS simulation to mimic https://play.vidyard.com/5FLitPENqKJbruBhsZUksB from www.ansys.com/products/3d-design but may be less sophisticated (example HGTV www.roomsketcher.com/features/live-3d-floor-plans/). Investigators may reconfigure to acquire data (asynchronous mode, parallel) from different wireless sensor networks (WSN) and change parameters (wastewater, ammonia gas in air, soil nitrates). Inserting new/different crop (entity model: orange, tomatoes) or animal (entity model: beef, poultry) changes entity models in DAMS with respect to knowledge graphs (DB, search algorithms) embedded in LRRT modules. This function requires CS and ML experts who can work with industry experts (IAB) and DAMS user groups (DUG) to create knowledge-GRID modules (multi-***layer*** composite of knowledge **G**raphs, **R**elationships and **I**nteractions between knowledge nodes, sub-nodes and **D**ependencies such as rate/flow, IFTTT, direct/inverse proportionalities, activation/inhibition). K-GRID libraries contributed by experts and users must be developed in ***containers compatible*** with DAMS interfaces, algorithms and ***discovery/search*** engines to optimize ***interoperability*** (https://www.dds-foundation.org/). Architects must embed potential meta-models, tools and 'hooks' for future development (www.isis.vanderbilt.edu/sites/default/files/OpenMETA%20-%20Sztipanovits.pdf). When inserting new sensors (new entity), the CHARACTERISTIC of the sensor must be connected to DAMS in order to respond to user queries about *that* new sensor. The latter will be accomplished by uploading DB of sensor characteristics in SENSEE. If a sensor-specific query is presented then DAMS will discover and source necessary data from SENSEE DB. The ***data*** collected by sensors are ***not*** in SENSEE (which contains only descriptions and numeric values related to *sensor characteristics/features*). The data collected by the "newly inserted" sensor will be uploaded to the **sensor data DB** and DAMS 1.0 will provide the framework to indicate how that data will connect with the correct sensor data store (likely to be a time series DB). Insertion of digital entities using "drag & drop" will explode in scope and complexity (K-GRIDS) when *data and information may be combined with policy and regulatory mandates*. Data interoperability ***with DAMS data flow*** and information arbitrage engines must be maintained to extract information from data and to inform users (smartphone app).

DAMS

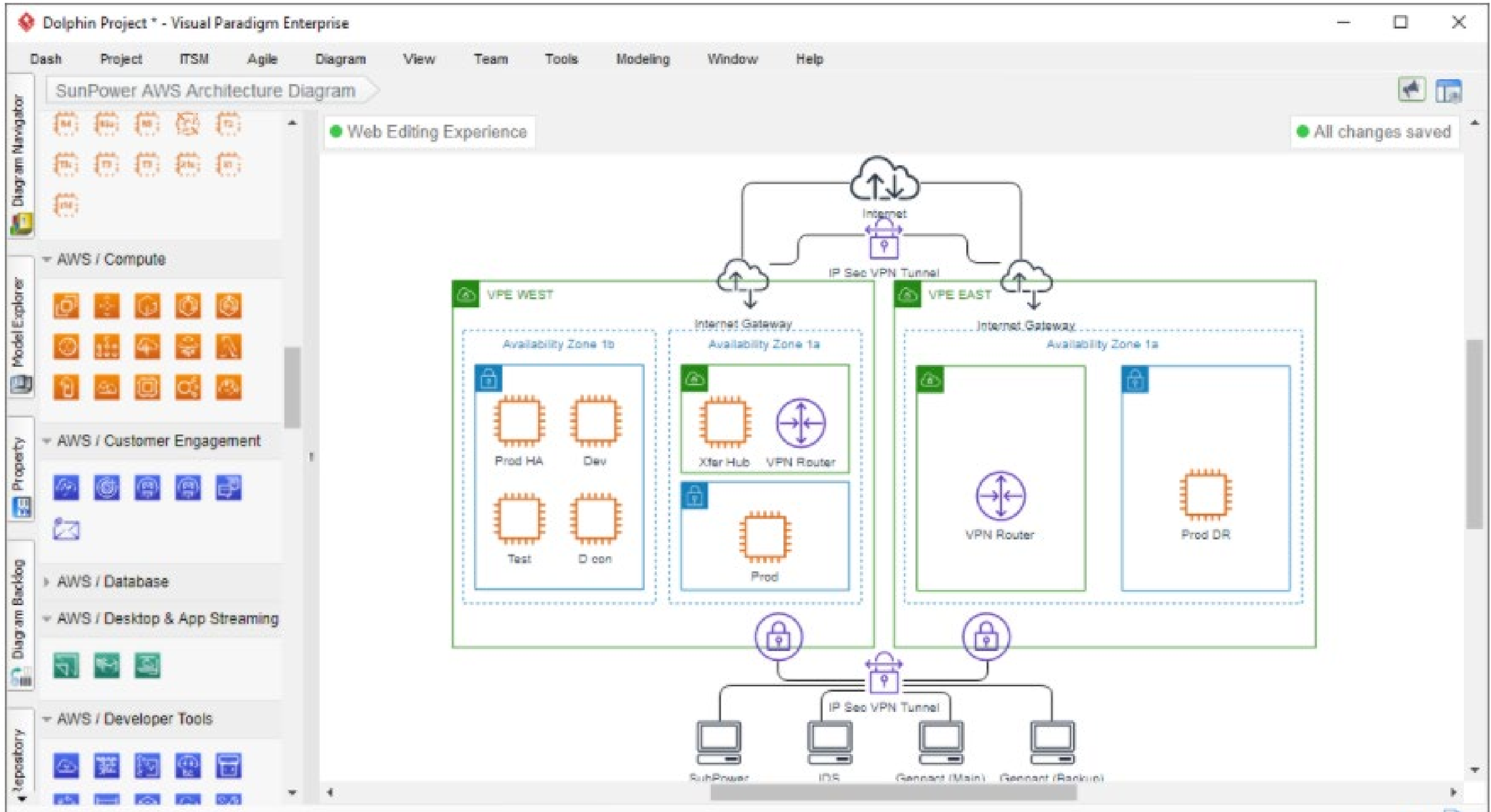
DASHBOARD

MOBILE APP

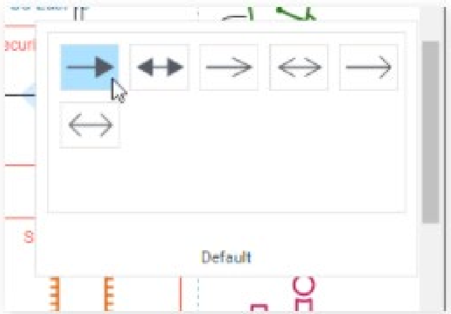
https://dspace.mit.edu/handle/1721.1/111021

?

shoumen@mit.edu

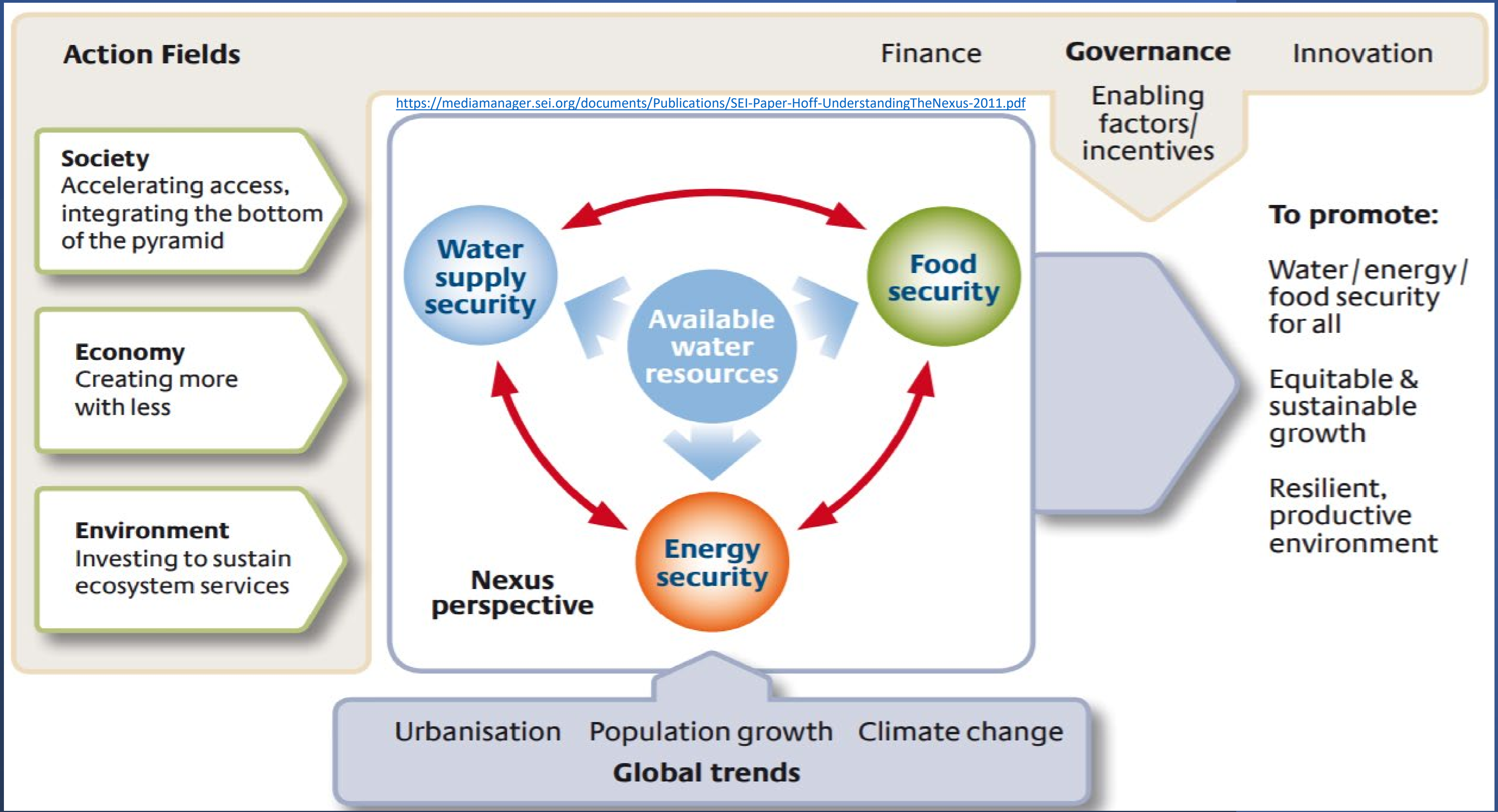


https://www.visual-paradigm.com/features/aws-architecture-diagram-tool/



Drag-and-drop editing

DAMS is a Context Awareness Tool (CAT)



The nexus of multiple domains and sub-domains each with its own CAT. Data from CATS may be a measure of performance.

RELATED ESSAY

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Datta, Shoumen Palit Austin, Tausifa Jan Saleem, Molood Barati, María Victoria López López, Marie-Laure Furgala, Diana C. Vanegas, Gérald Santucci, Pramod P. Khargonekar and Eric S. McLamore (2020) *Data, Analytics and Interoperability between Systems (IoT) is Incongruous with the Economics of Technology: Evolution of Porous Pareto Partition (P3)*. Chapter 2 (in press, Wiley). Download pre-print of “P3” from the MIT Library https://dspace.mit.edu/handle/1721.1/123984