Sensor Networks, Sensor Web: new possibilities, new challenges

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TNO Science and Industry, BU Monitoring Systems

TNO | Knowledge for business

Outline

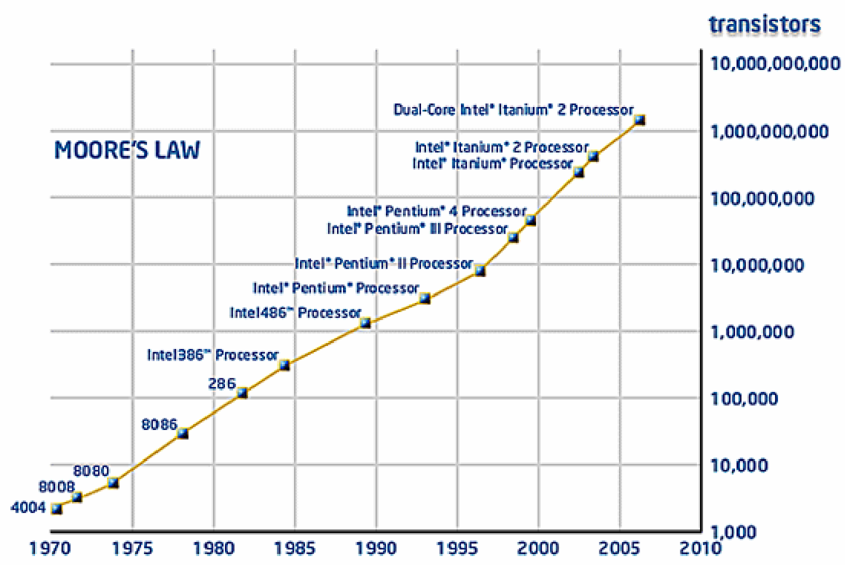
- Changes on the surface
- Are we happy?
- The extended role of models
- New issues to address
- Coping with the challenges
- Conclusions, what next?

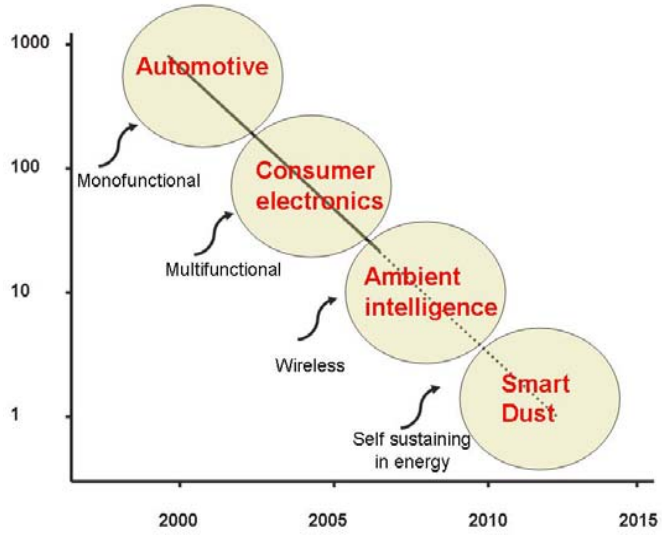
Advancements, trends

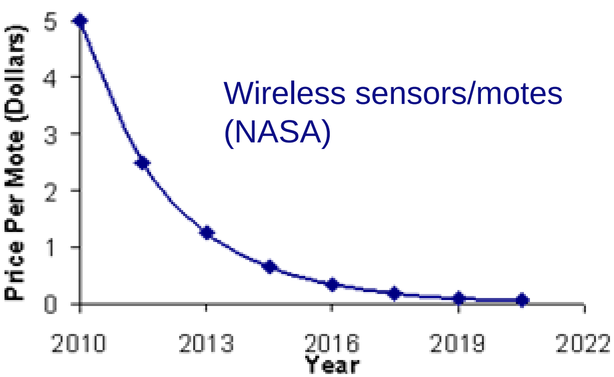
- Cheap/affordable sensing
- Cheap communication: “connected world” → distributed systems
- Cheap computation
- Dramatic increase in performance

→ DATA RICH ENVIRONMENT

Advancement (cont'd)







Issue: Moore's evil twin brother

Limited battery capacity and slow increase

(8% yearly increase Wh/cm3 = doubles every 9 years)

= 150 x

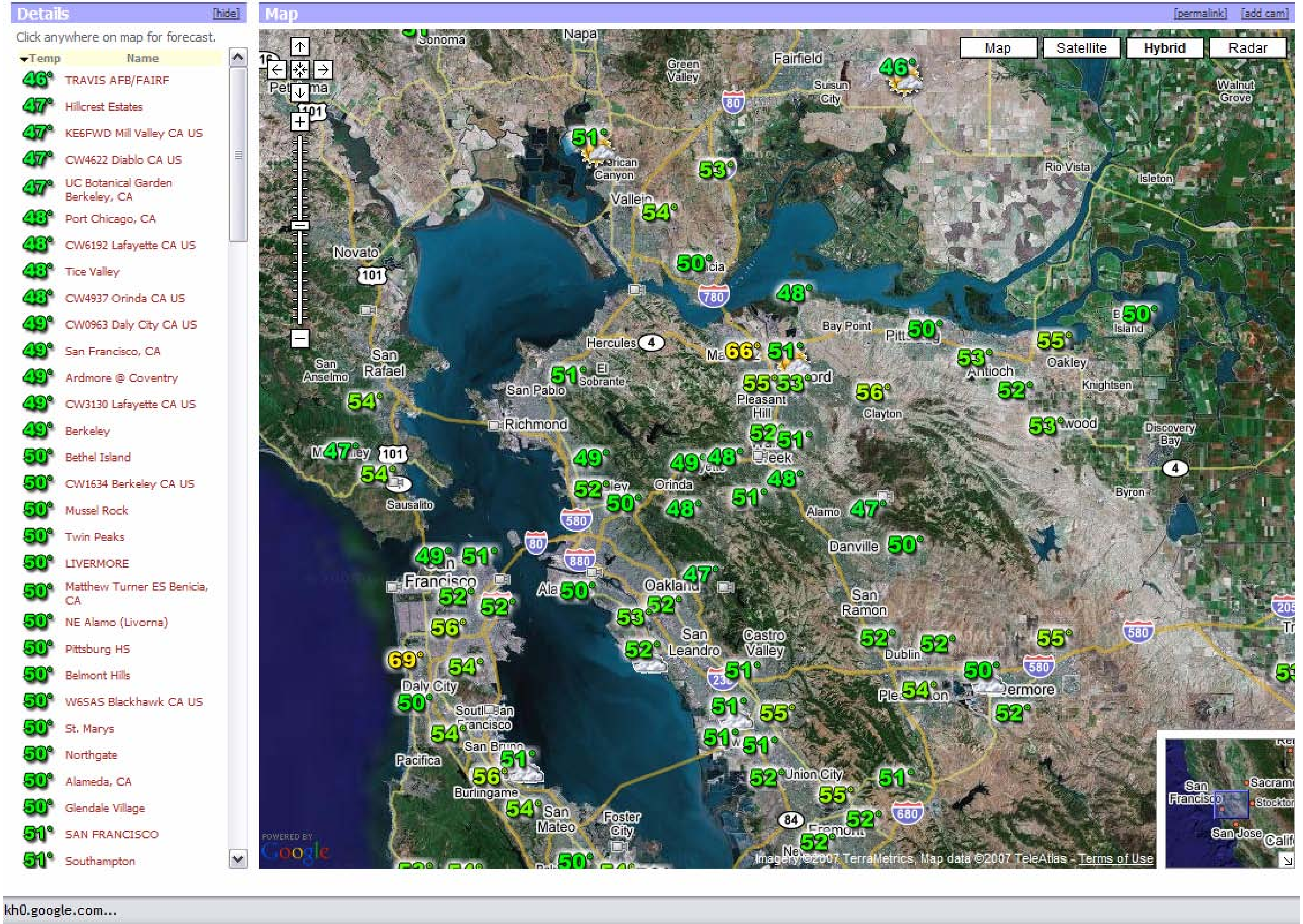
Advancements, trends (cont'd)

An illustration:

- Google Map/Earth: data + visualization
- Google "mashup": API to merge information into the map

Anything new in content? NO!

Impact on how we use content? YES!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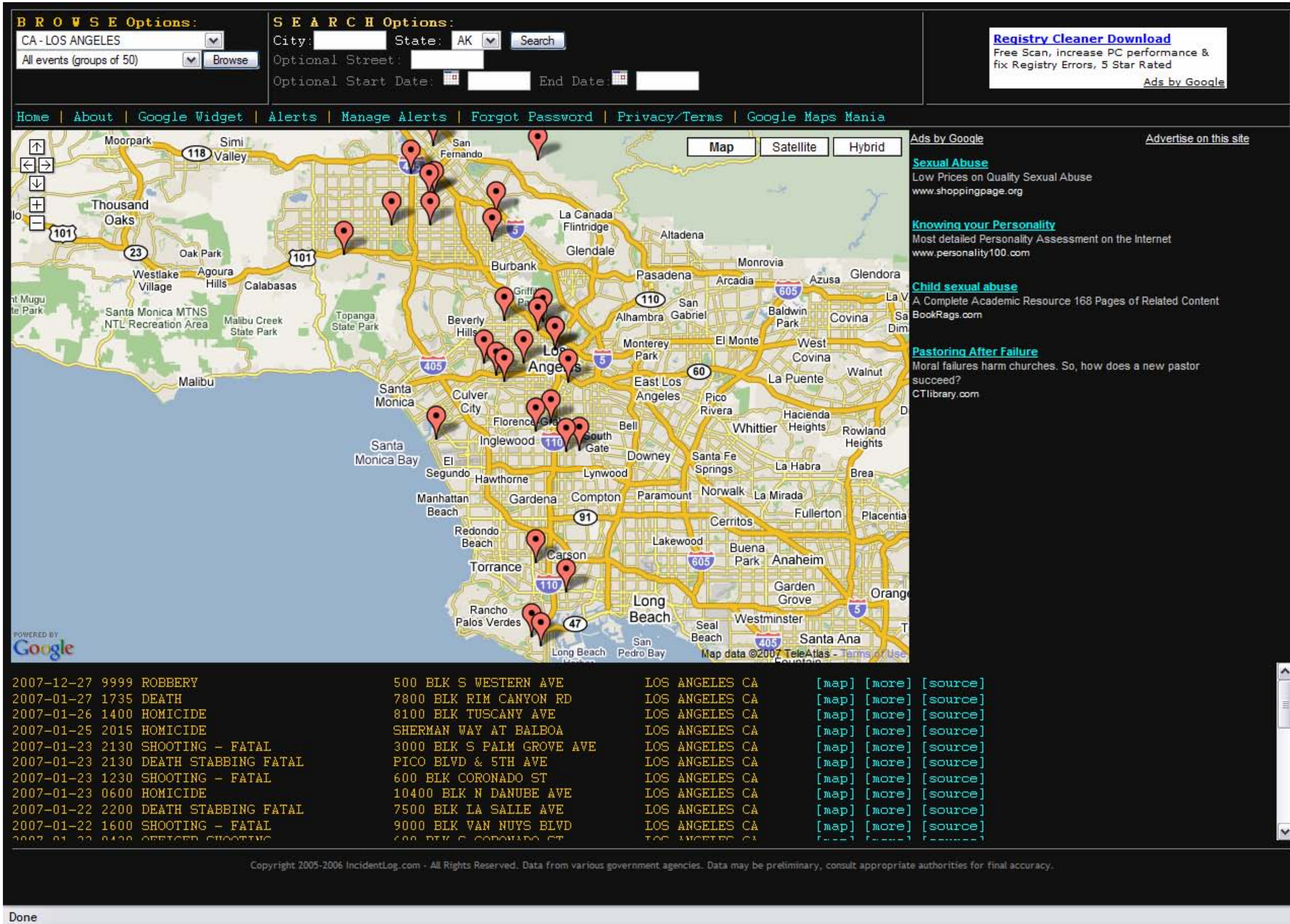
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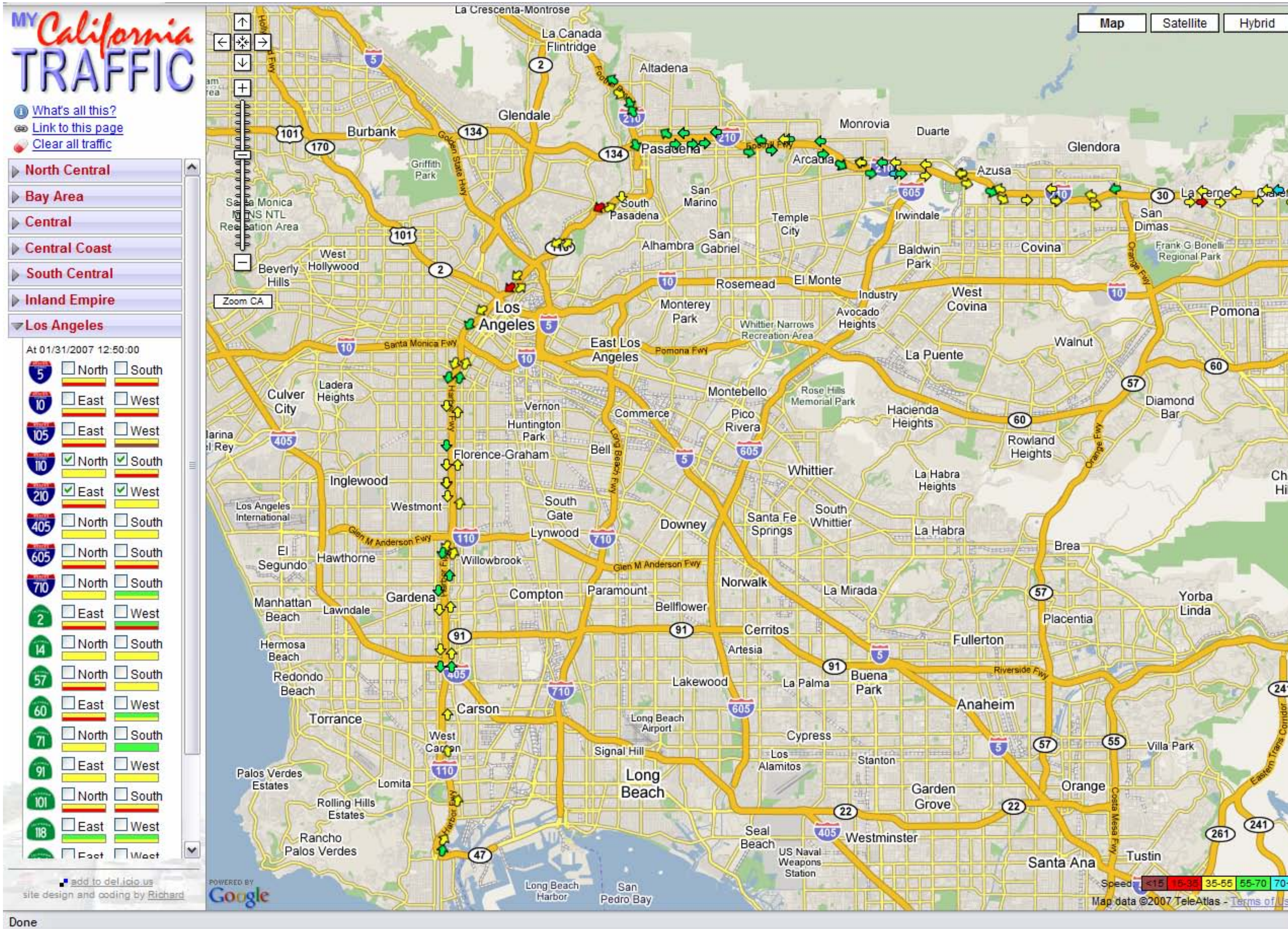
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Downey
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La Habra
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Stanton
Villa Park
Palos Verdes Estates
Lomita
Long Beach
Garden Grove
Orange
Rolling Hills Estates
Rancho Palos Verdes
Seal Beach
Westminster
Santa Ana
Tustin
Long Beach Harbor
San Pedro Bay

Are we happy?

Yes, to an extent…

Worrying observation:

Data is not information.
Information is not knowledge.
Knowledge is not wisdom.

→ long way to go…

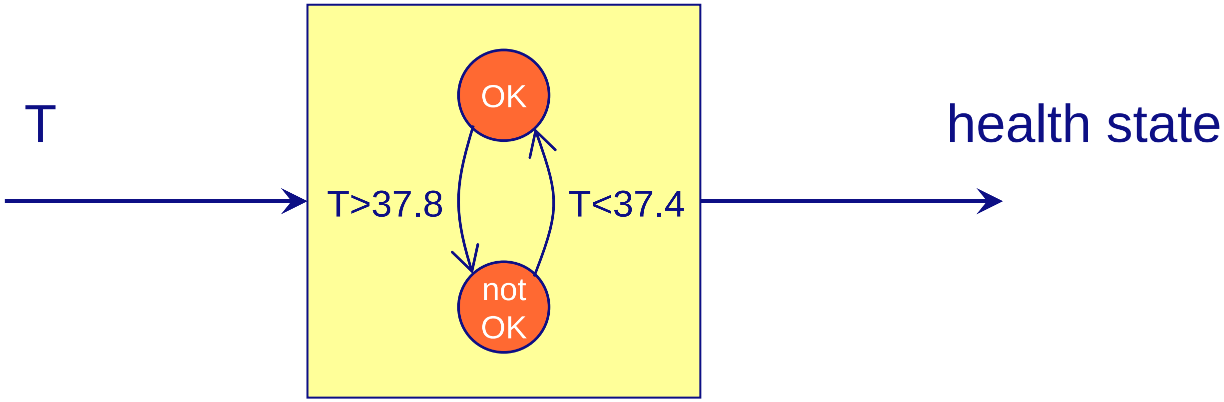
About the roles of models

model ≡ formalized knowledge

Illustration: measuring body temperature

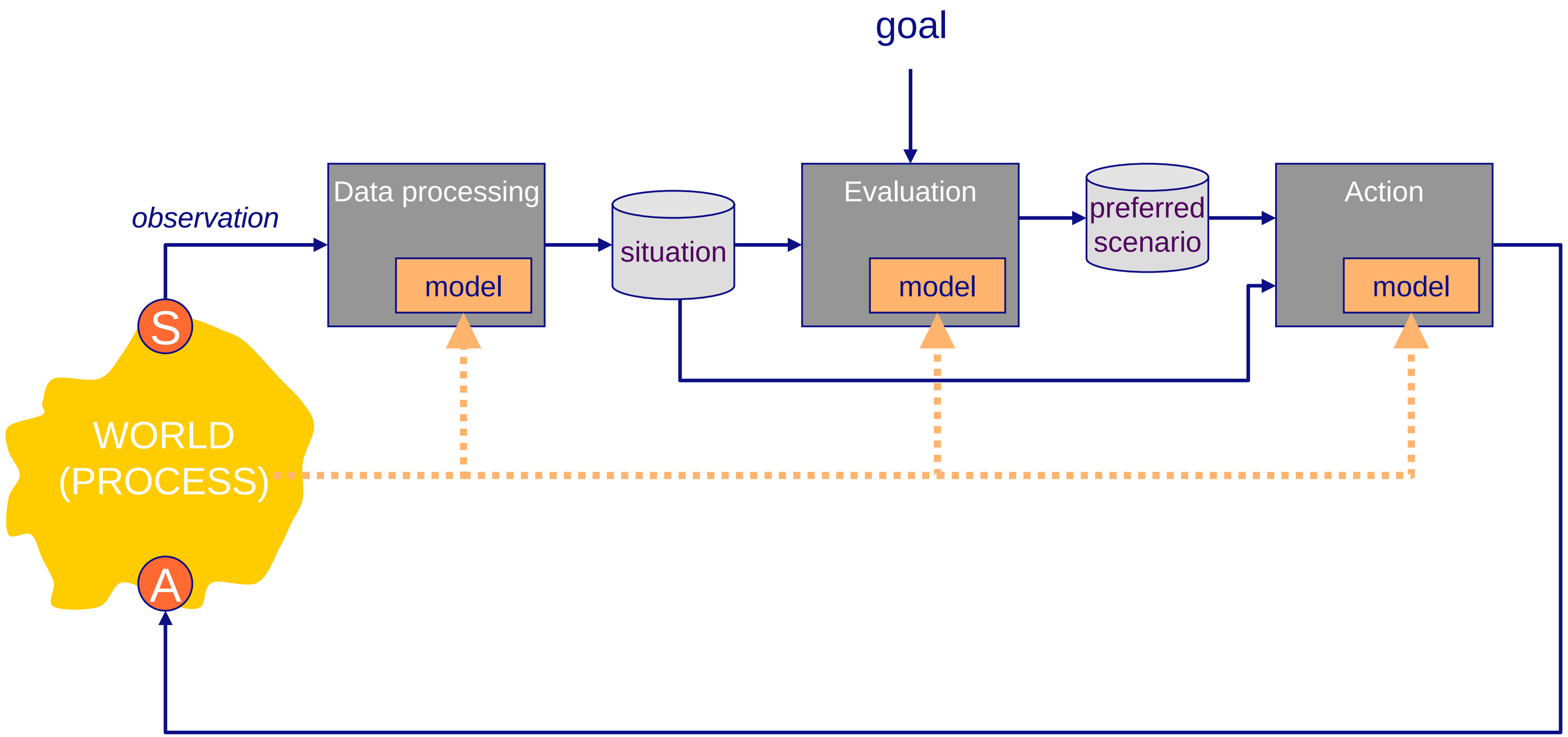
T = 38.3 [ºC]

In itself: no meaning ➔ we use models implicitly!

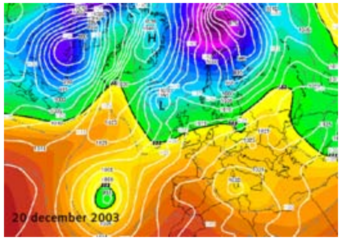


- For laymen: Human = Finite State Machine (+ “dynamics”)
- General Practitioner: hopefully uses a better model…

Models in monitoring and control



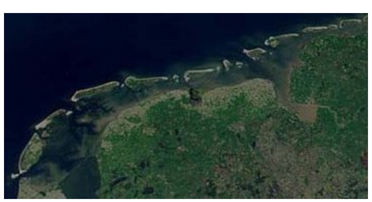
RWS example: determining dike heights



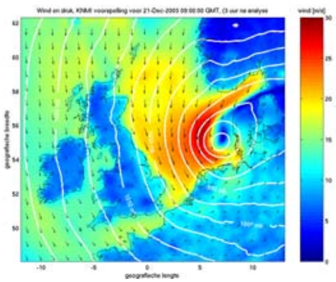
Model validation with limited number of measurement locations

Required safety / acceptable risk

Climate change → Model concerning waves in shallow water → Probability of extreme water levels → Trade-off → Required dike height



RWS example: storm surge warning



Meteo + hydro observations (1/10 min)

ECMWF-model

Long term (10 days) water level prediction

HIRLAM-model

short term (48 hours) wind prediction

DCSM8-model

short term (48 hours) Water level prediction

Statistical relations

short term (9 hours) Water level prediction

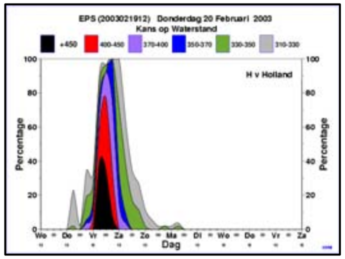
WOMOD-model

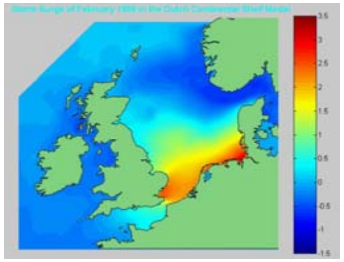
short term (24 hours) Water level prediction

Kalman-filter

short term (48 hours) Water level prediction

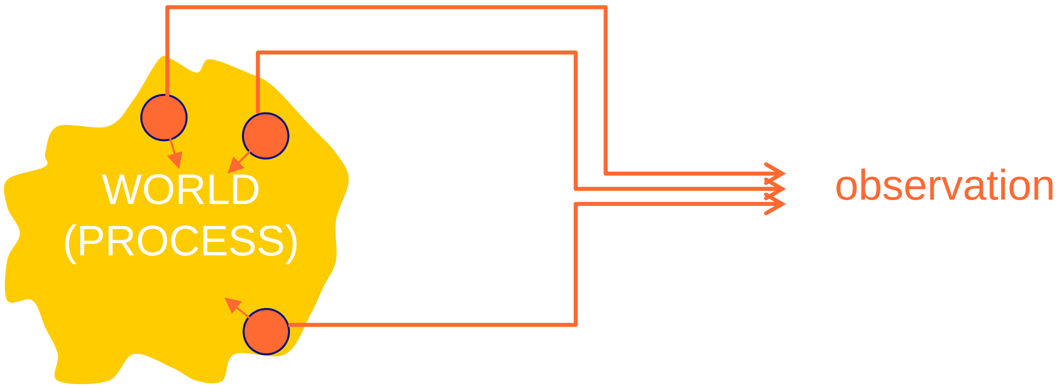
Human interpretation / decision making



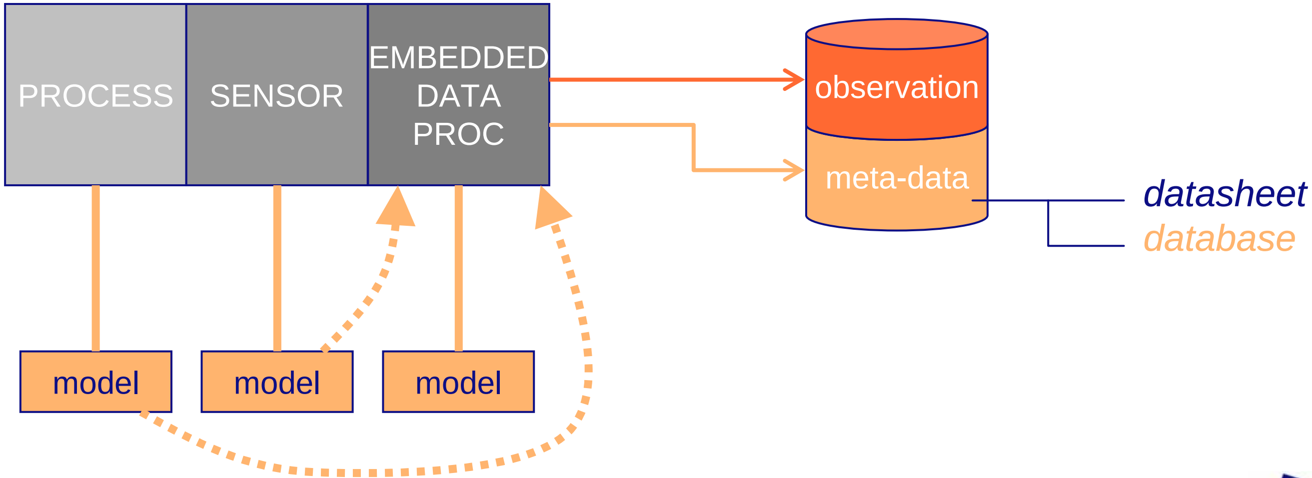


Sensing – a detailed view

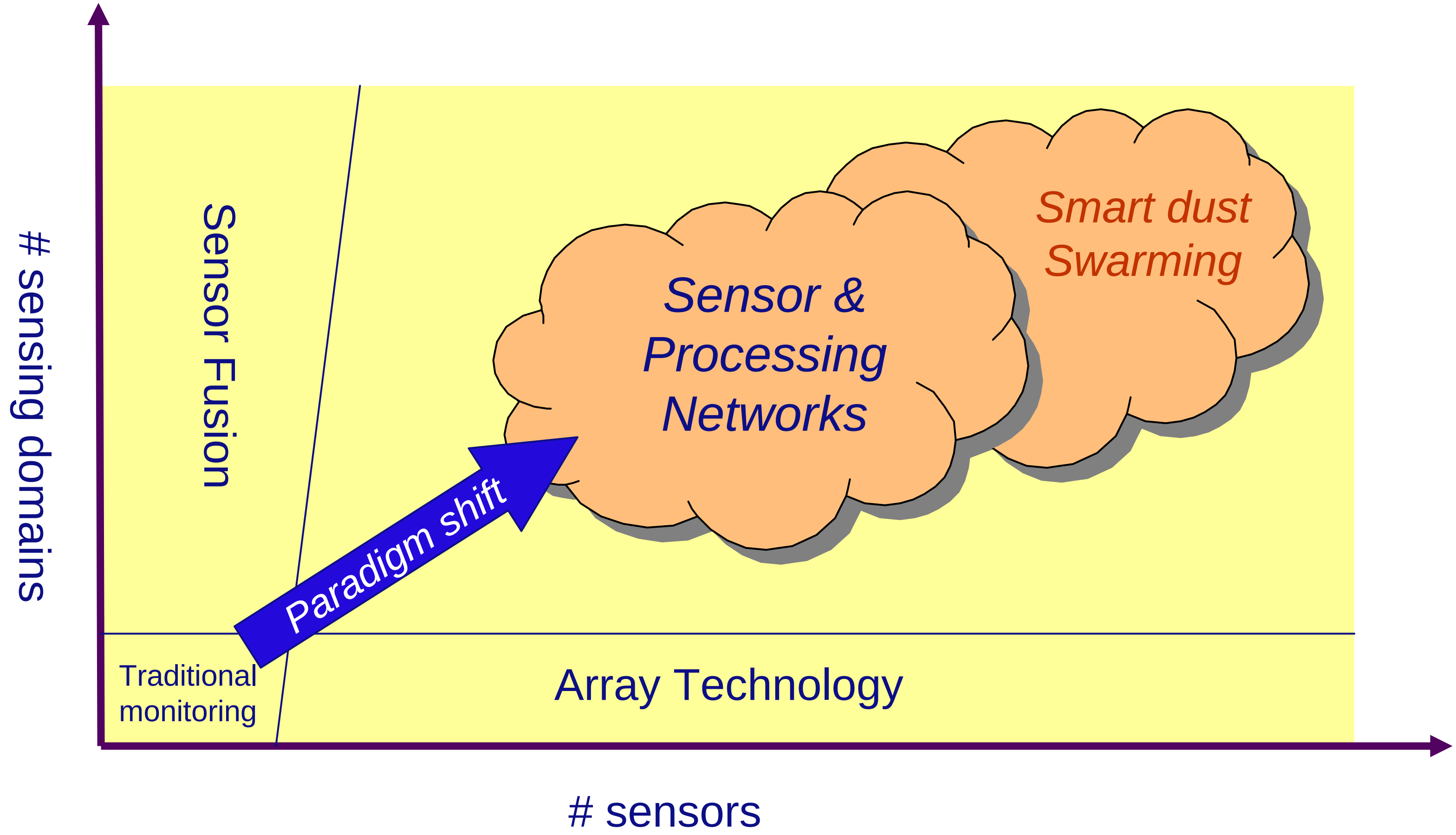
Concept:



Reality:



Networked sensors: new issues to address

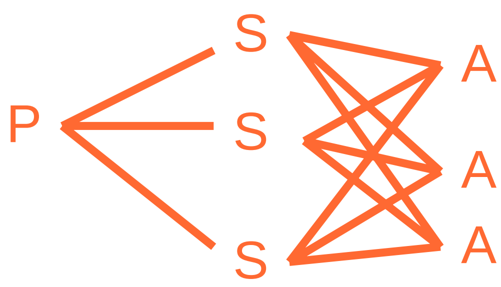


What is different?

1. Amount of data
2. Diversity of data
3. Openness

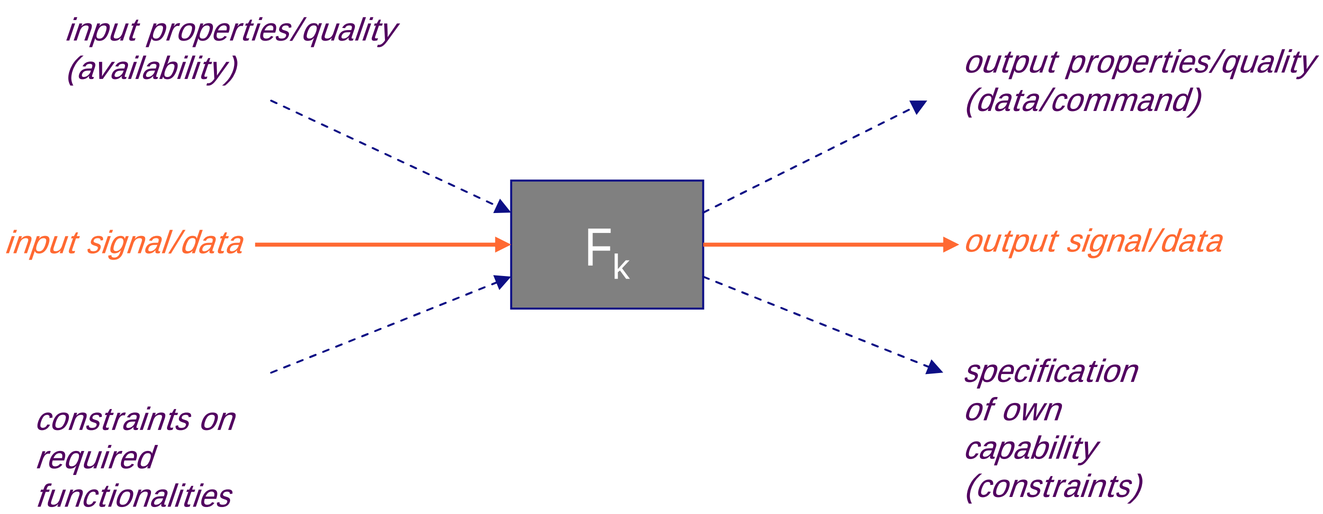
"old school": P —— S —— A

new scheme:



4. Reliability/availability issues
5. Operational issues

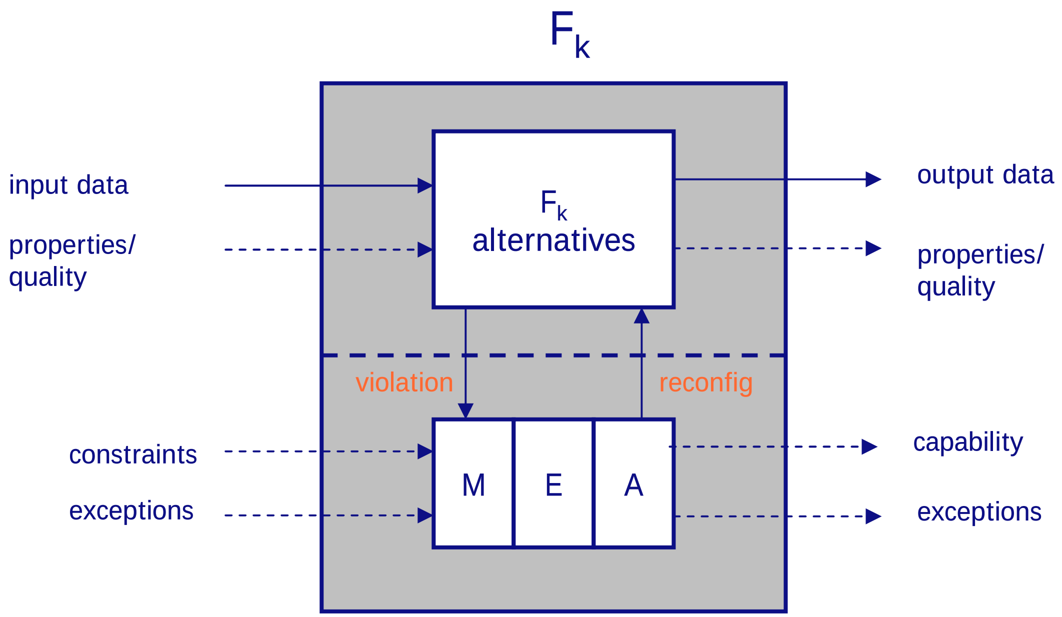
Consequences: openness, reliability



implicit models do not work!

Consequences: openness, reliability (cont'd)

Inside a processing module:

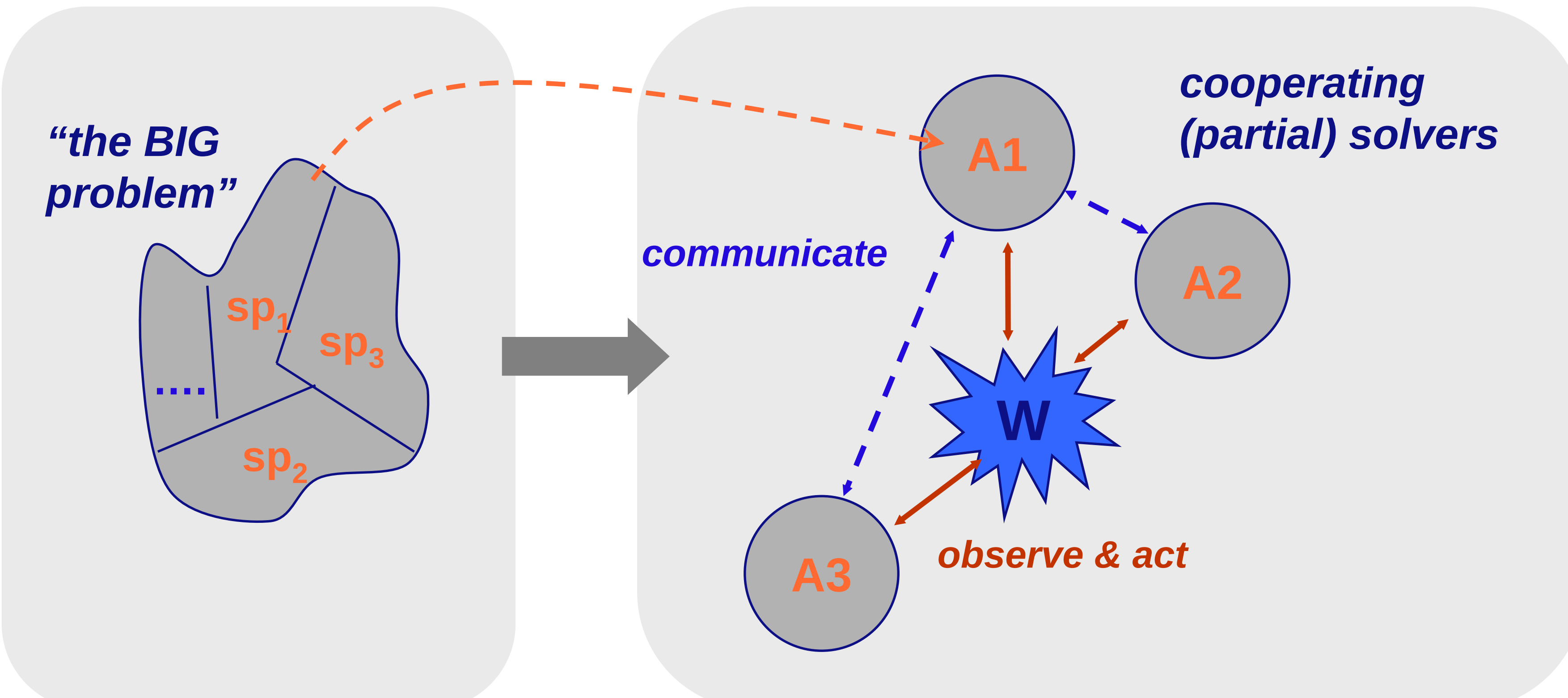


➔ "diversity of data ➔ diversity of models"

Consequences: amount of data

Issue 1: certain models/ algorithms/implementations do not scale…

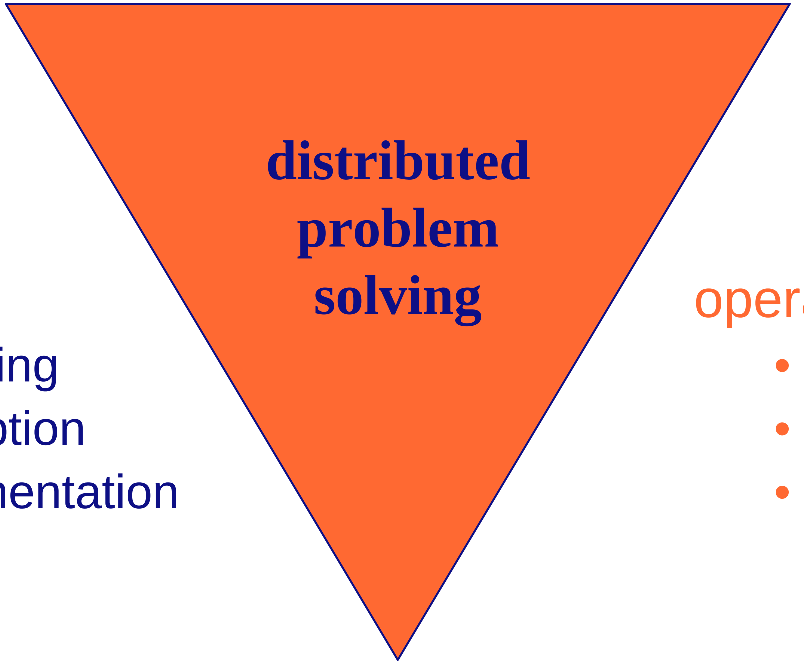
→ distributed solution



Consequences: amount of data, issue 1 (cont'd)

application domain

- decomposition
- algorithms



design

- modelling
- description
- implementation
- test

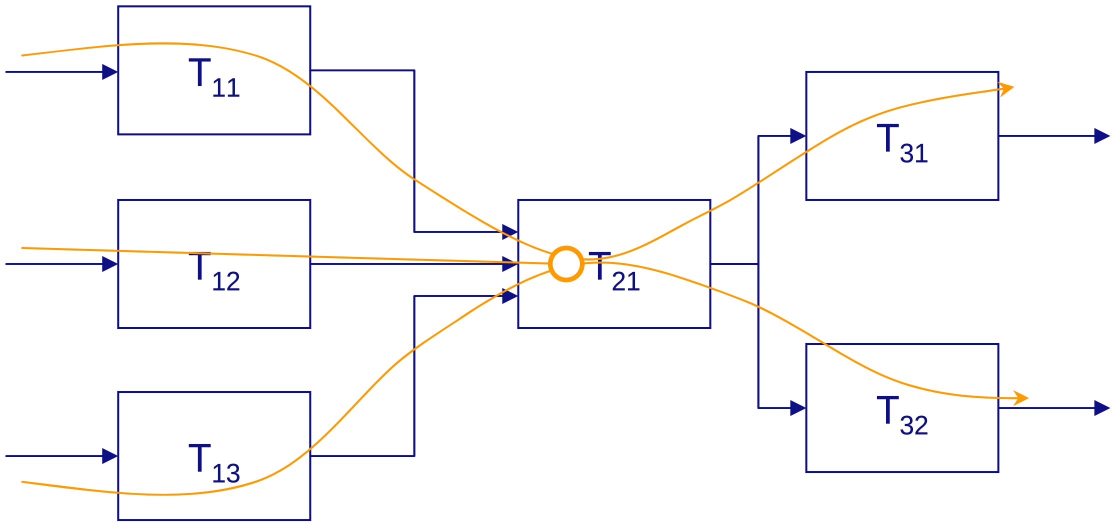
operation

- distributed
- real-time
- reconfigurable

Consequences: amount of data

Issue 2: control of execution

Data-driven control scheme:



Consequences: amount of data, issue 2 (cont'd)

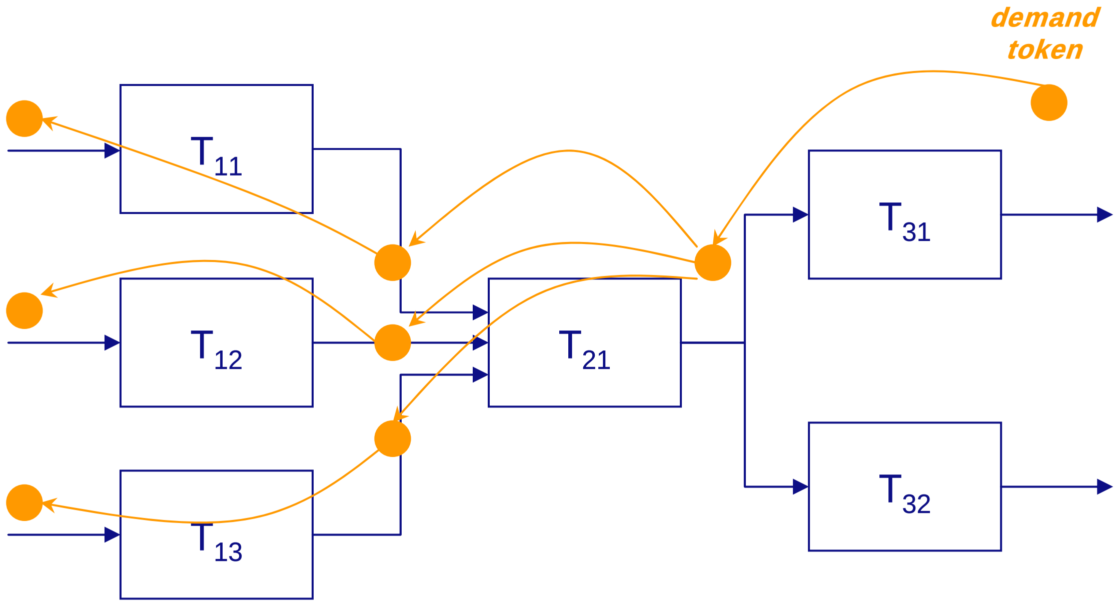
Data-driven control scheme: main features

- *derived data ("information") always readily available*
- *minimal delay/lag*
- *potentially high computing/resource demand*
- *potentially high communication demand*

Consequences: amount of data (cont'd)

Issue 2: control of execution

Demand-driven control scheme:



Consequences: amount of data, issue 2 (cont'd)

Demand-driven control scheme: main features

- *derived data is calculated whenever needed*
- *extra delay/lag*
- *optimized for computing/resource demand*
- *optimized for communication demand*

→ for non-trivial problems:
the *combination* is the answer

Consequences: diversity of observations

Types of diversity

- *syntactic:* what's the format? (e.g., XML)
- *structural:* how is the information structured? (e.g., SWE standards)
- *semantic:* what does it all mean? (e.g., domain ontologies)
- *pragmatic:* what can I use it for? (e.g., aspect ontologies)

Evolution

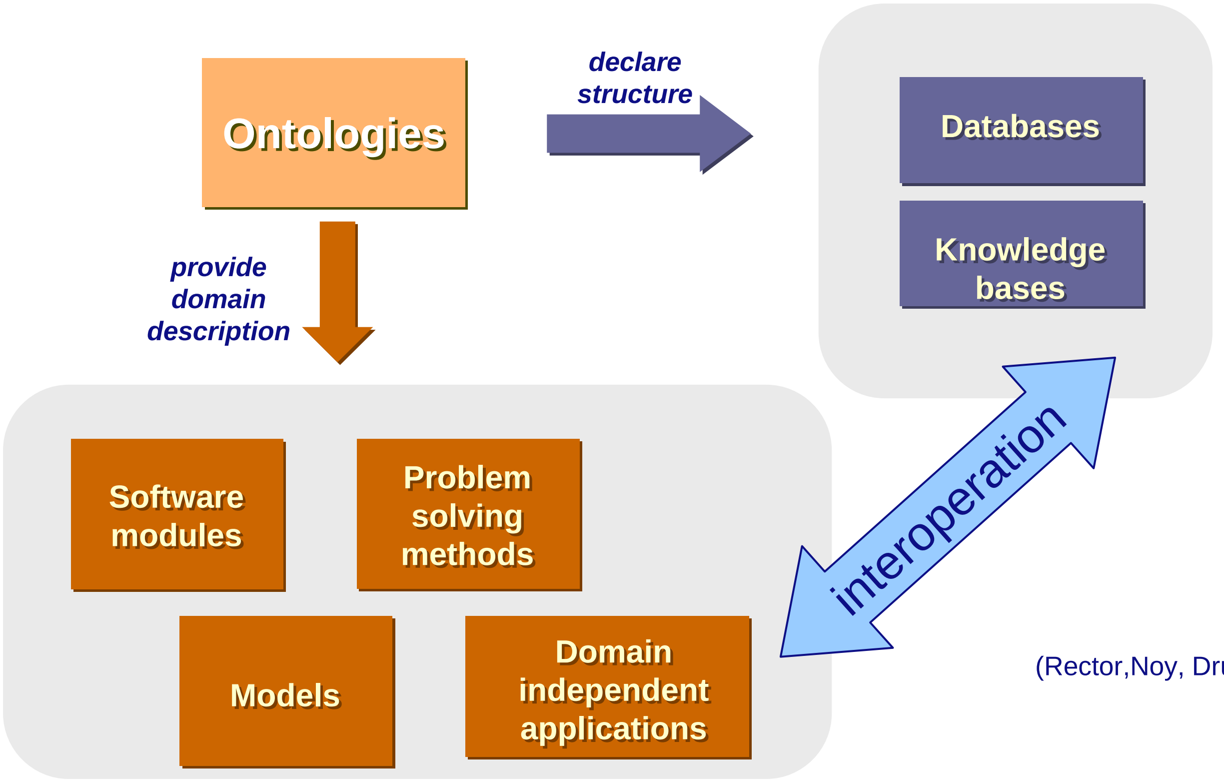
- From "using the same language" to "understanding each other"

→ semantic representation & semantic interoperability become increasingly important

Consequences: diversity of observations (cont'd)

Ontology

- "Explicit description of a conceptualization" (Gruber)
- For us: defines a common vocabulary and shared understanding of a domain or aspect



(Rector,Noy, Drummond, Musen 2005)

Consequences: diversity of observations (cont'd)

In the background: it is all about integration

- *Data integration:* connecting different pieces of (heterogeneous) data into one (virtual) data source
- *Information integration:* exploiting the intended meaning of and the semantic relations between data to obtain an overall picture
- *Information synthesis:* task-/goal-/purpose-specific interpretation of heterogeneous data and information
- *System integration:* connecting distributed hard- en/of software into one tool

Coping with the challenges: Sensor Web Enablement

"Definition": *"Sensor Web Enablement refers to Web-accessible sensor networks that can be discovered and accessed using standard protocols and APIs."* [OGC]

Aspects covered:

- discovery
- sensor capabilities and quality of measurement
- sensor parameters
- retrieval real-time or time series data
- tasking of sensor
- subscription and publishing alerts

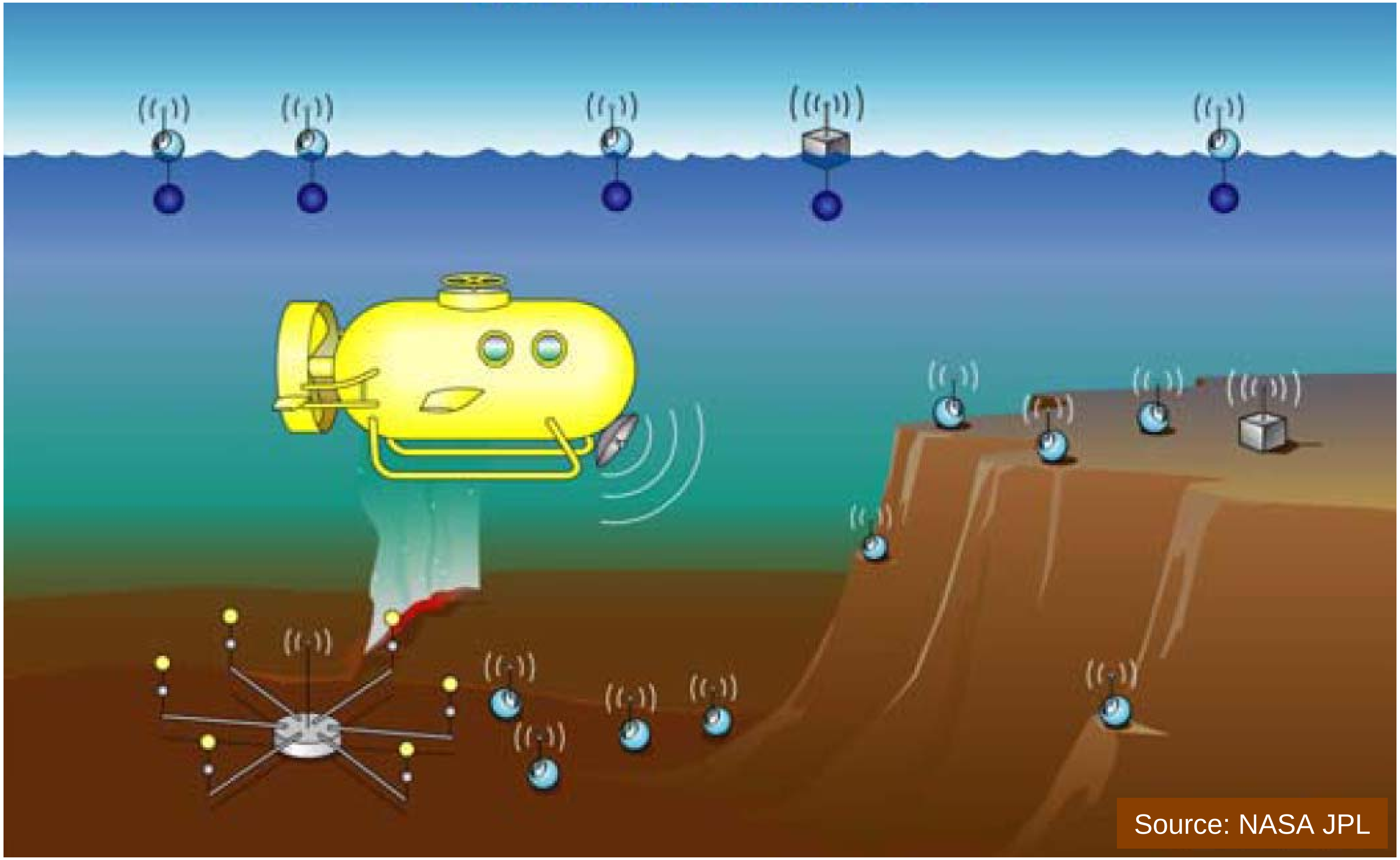
The SWE standards framework

- Observations & Measurement: data formats, data structures
- Sensor Model Language (SensorML): discovery, functional process model
- Transducer Markup Language (TML): abstraction, response/"physical" models (implementation features)
- Sensor Observation Service (SOS): sensor management API
- Sensor Planning Service (SPS): request management
- Sensor Alert Service (SAS): alert management
- Web Notification Service (WNS): message interchange

"Missing link"

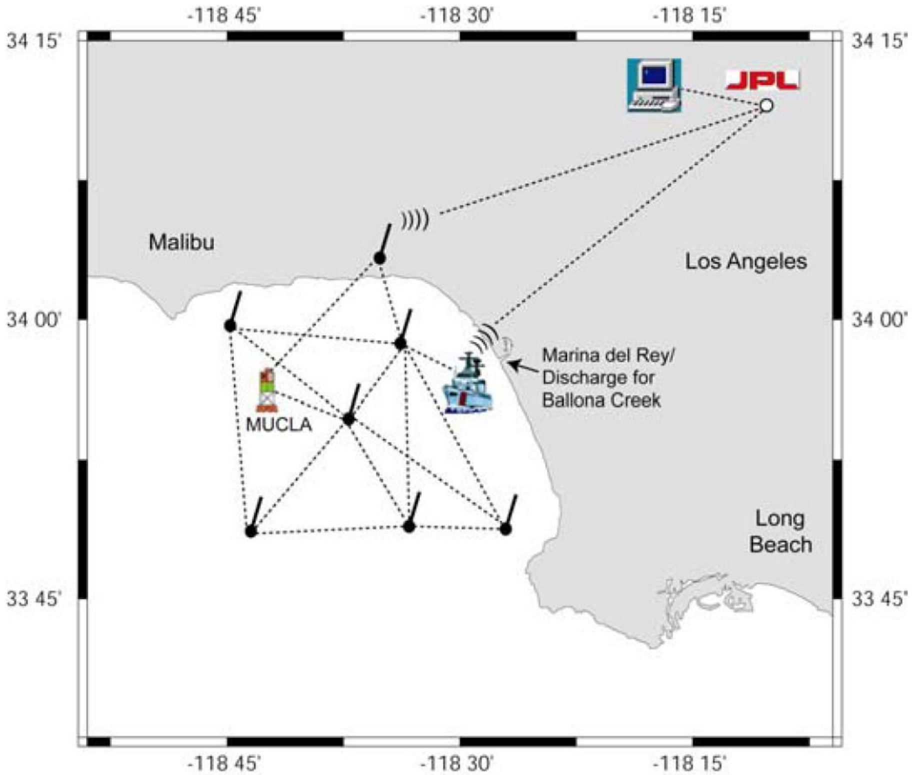
- Field-evolvable sensors: deployment, upgrade management

SWE applications: ocean monitoring



Application example

Problem : characterize the physical and chemical properties of a storm water runoff plume in Santa Monica Bay, California



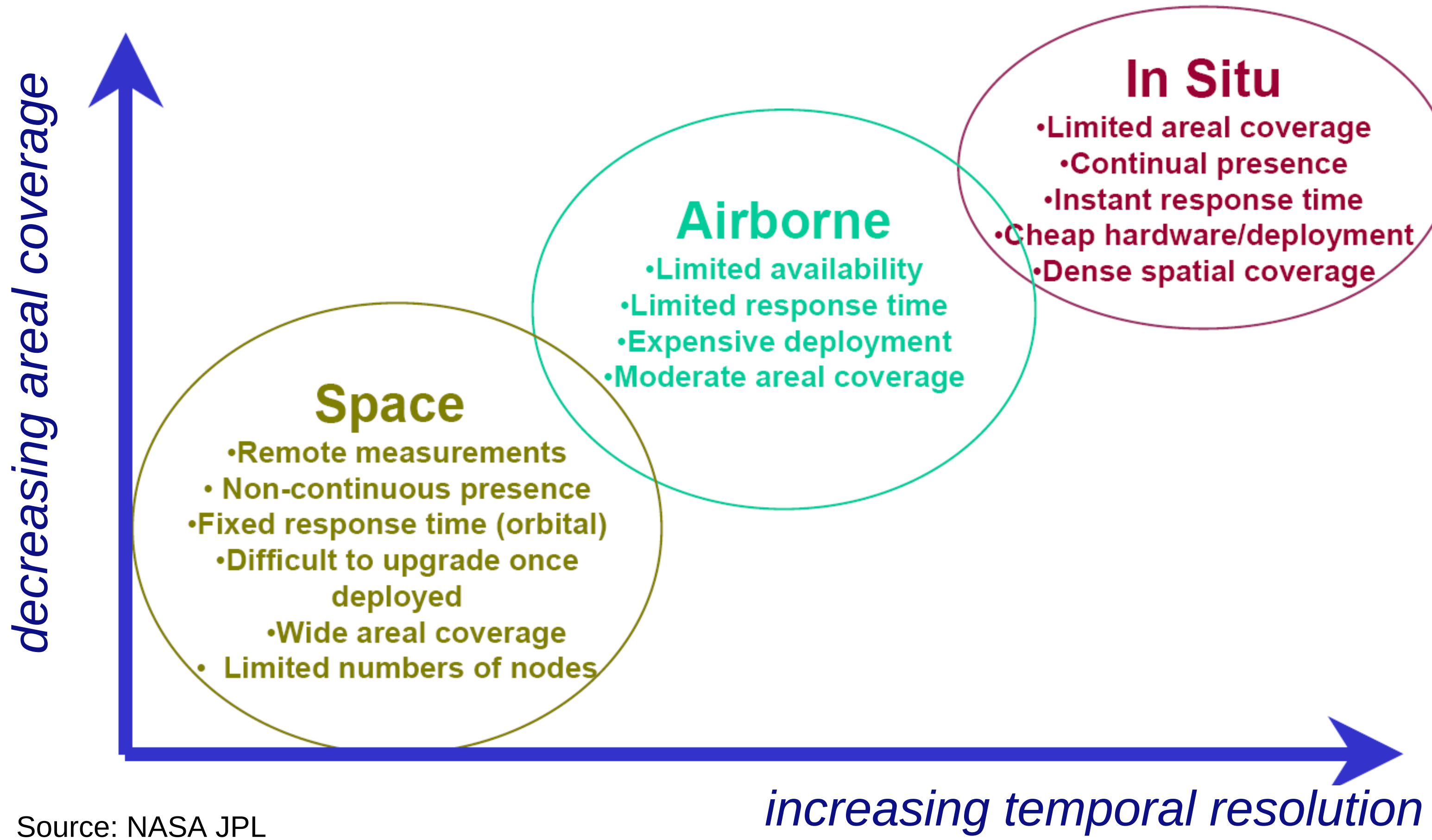
Source: NASA JPL

Features:

- Continual presence captures dynamic and unpredictable events such as run-off (unlike remote).
- High spatio-temporal resolution (unlike single point in situ): as close as 10 m as often as 1 minute.
- Demand driven approach: Sensor Web information augments and directs satellite and UAV acquisitions.

Application example (cont'd)

Why different observation methods?



Source: NASA JPL

Coping with the challenges:
Scientific Workflows (SWf)

“Definition 1”: *SWf is a series of structured activities and computations that arise in scientific problem-solving.*

“Definition 2”: Interoperability at work:

- declarative specification of control and data flow
- semantic transformation and composition
- module integration, heterogeneous execution environments
- automatic execution, exception handling
- grid-ready

→ SWfs make the relation between information need, data sources and processing steps explicit, transparent, and reusable.

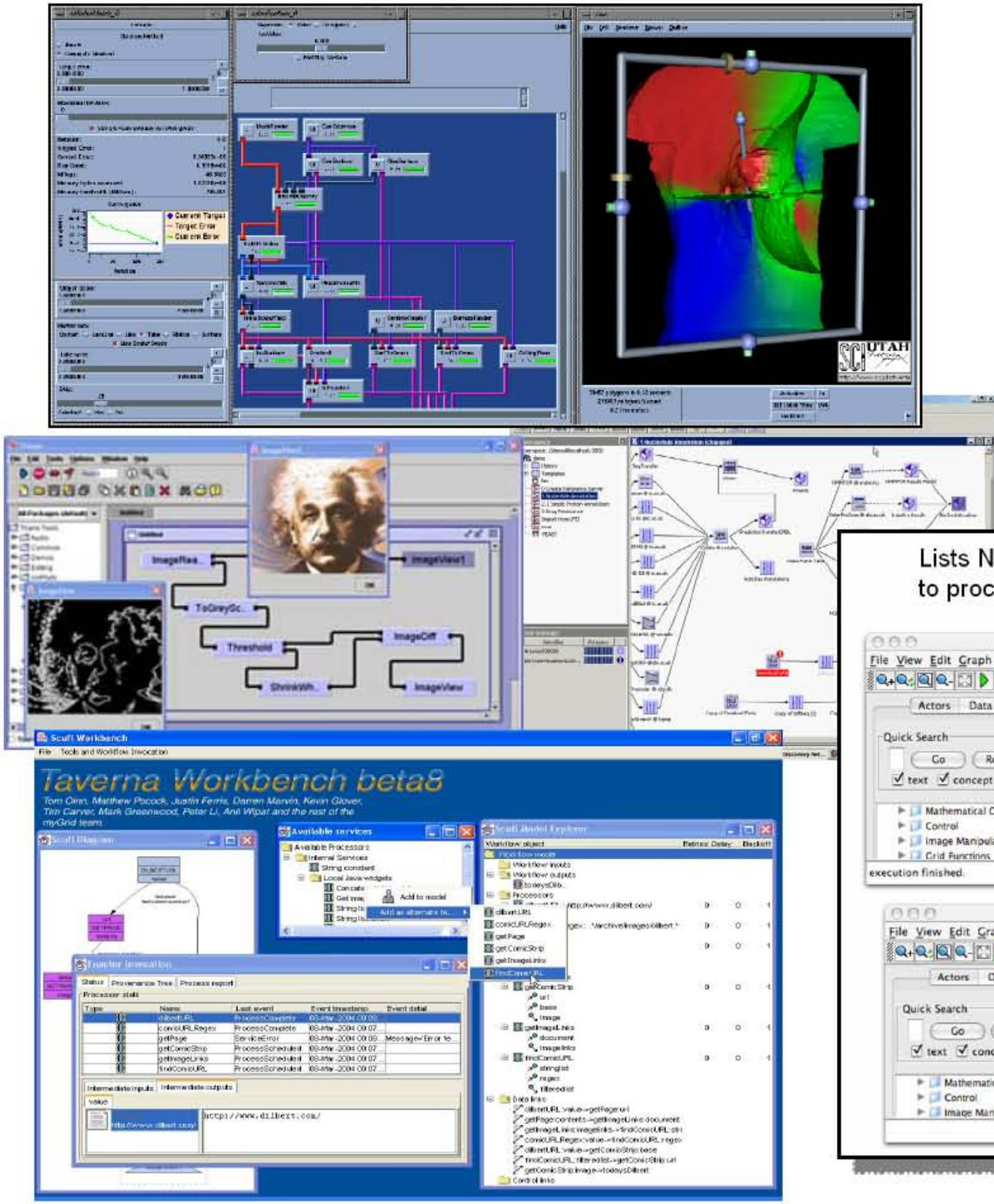
Coping with the challenges: SWf (cont'd)

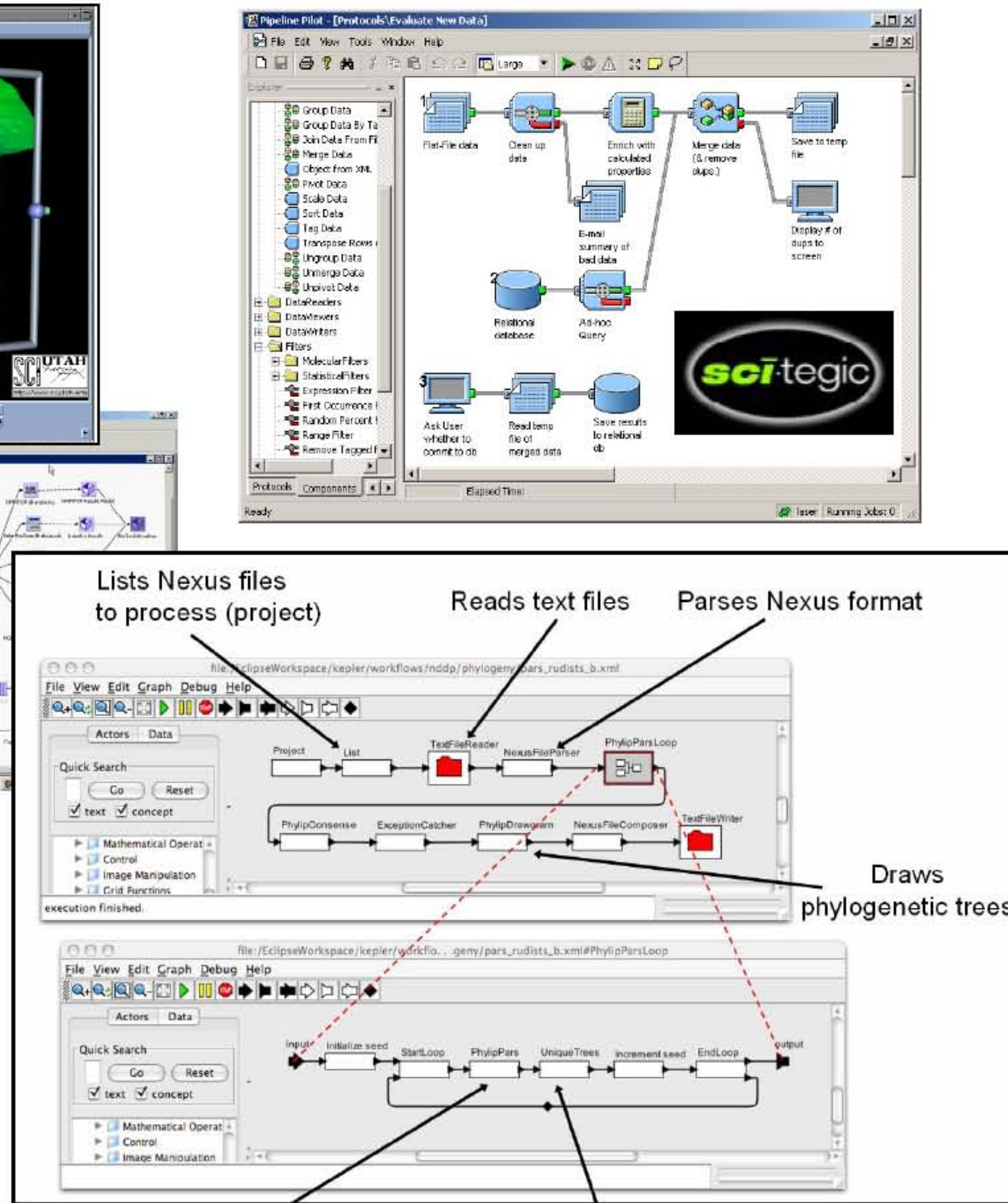
Typical scientific workflow package components:

- workflow modeler
- "process/module" data bases / yellow pages
- workflow validator toolset
- configurator toolset

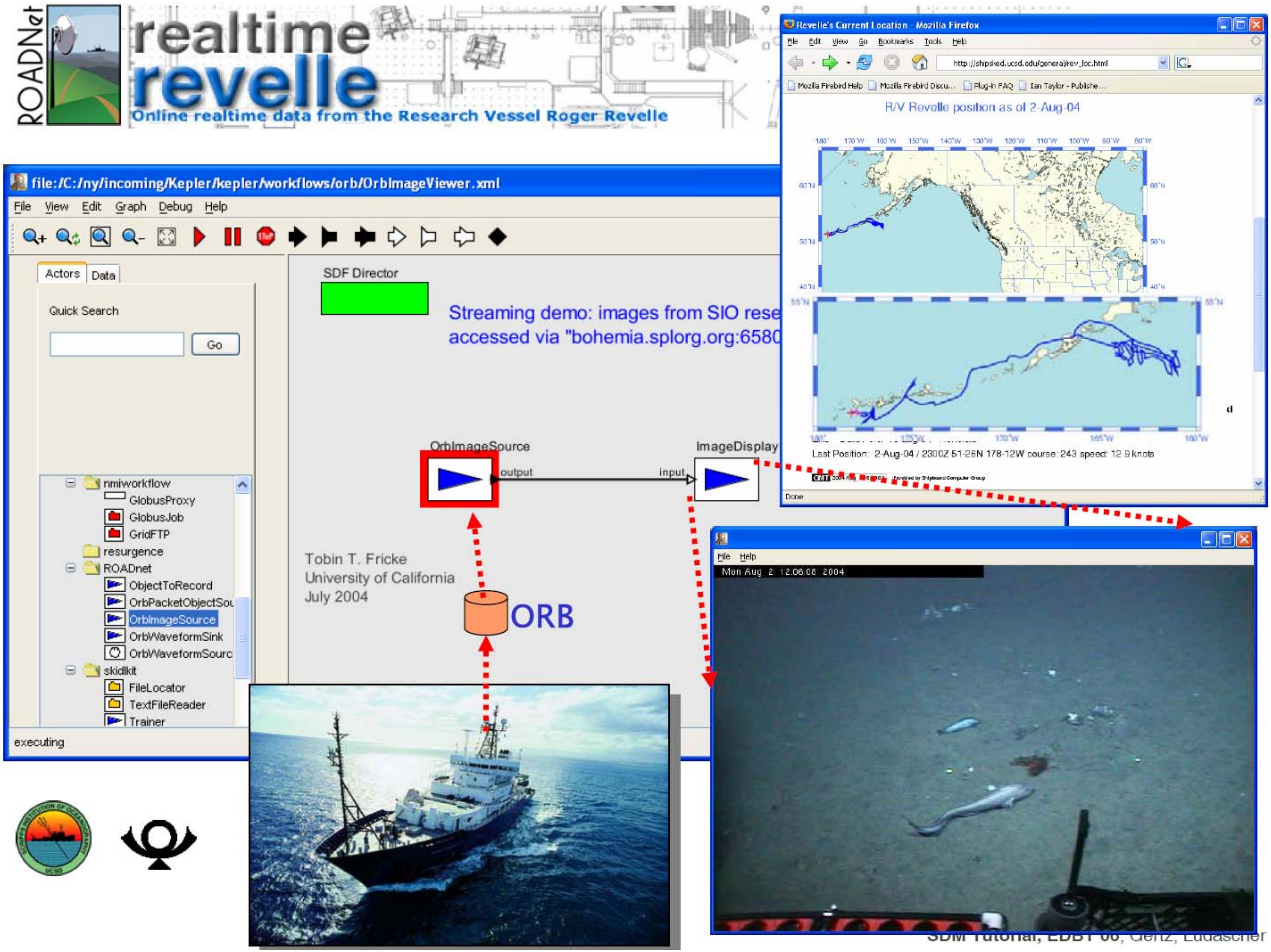
IMPORTANT!

- SWf: "only" glue + robust execution
- the content: the processes/modules/models (→ the experts should provide these in a context aware form)





SDM Tutorial, EDBT'06, Gertz, Ludäscher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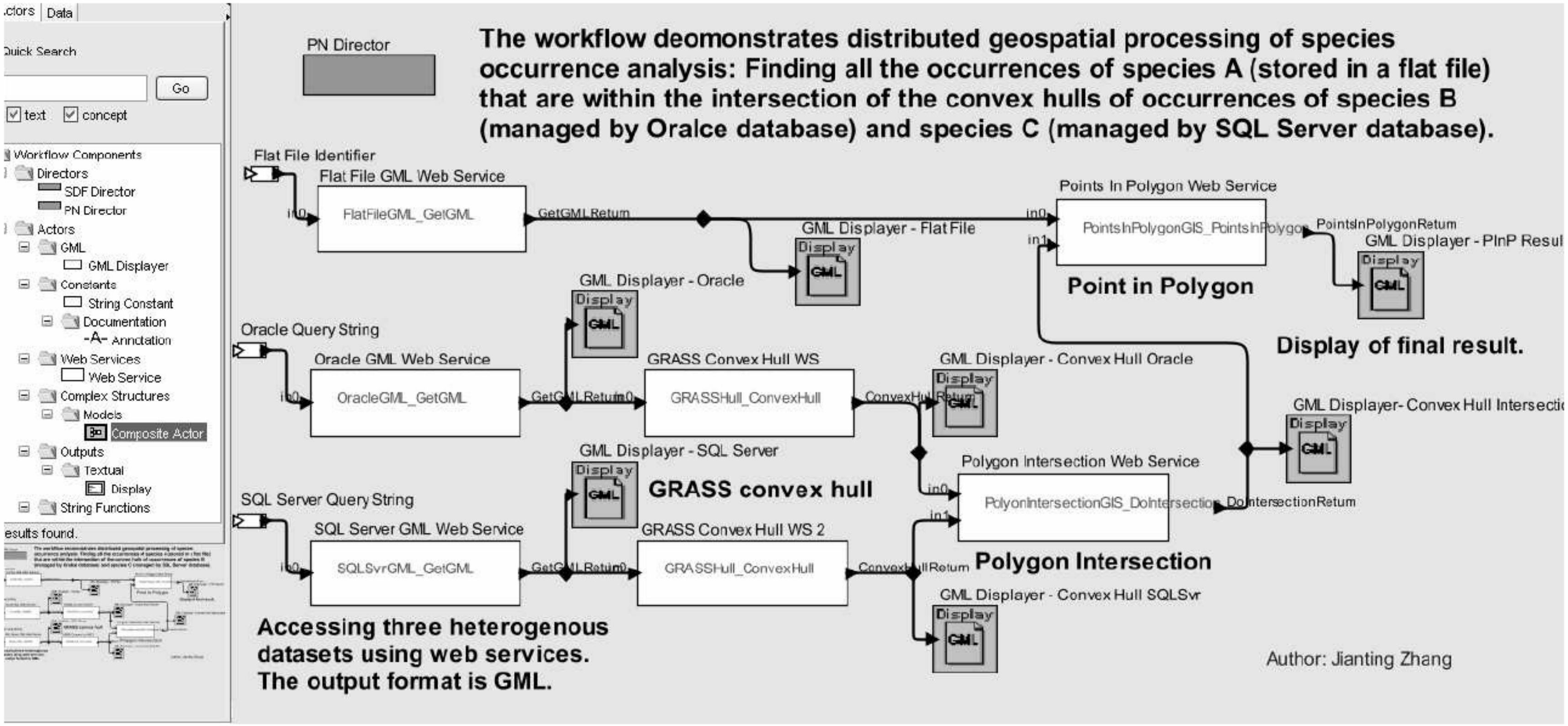
Coping with the challenges: SWf (cont'd)

Illustration



Conclusions, further steps

- Advance in sensor, computer and communication technologies created a data rich environment.
- “Data rich environment” becomes “data tsunami” if not managed and processed adequately.
- The changes induced by “data richness” is not incremental.
- The role and importance of modeling and model based architectures cannot be overestimated; handling “meta-data” is equally important to handling data.
- Distributed architectures become standard – with strong impact on model development and implementation.

Conclusions, further steps (cont'd)

- Sensor Web Enablement related standards and scientific workflows (as an approach) give a solid foundation for further developments.
- Weak point: handling semantics.
- All ingredients are here (or close) to make a big leap into making advantage of combining cheap data and accumulated knowledge.

"Any sufficiently advanced technology is indistinguishable from magic." (Arthur C. Clarke)

The bad news: we are insiders and we know

THERE IS NO MAGIC, ONLY HARD WORK…

Acknowledgements

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