An IT infrastructure for smart levee monitoring and flood decision support

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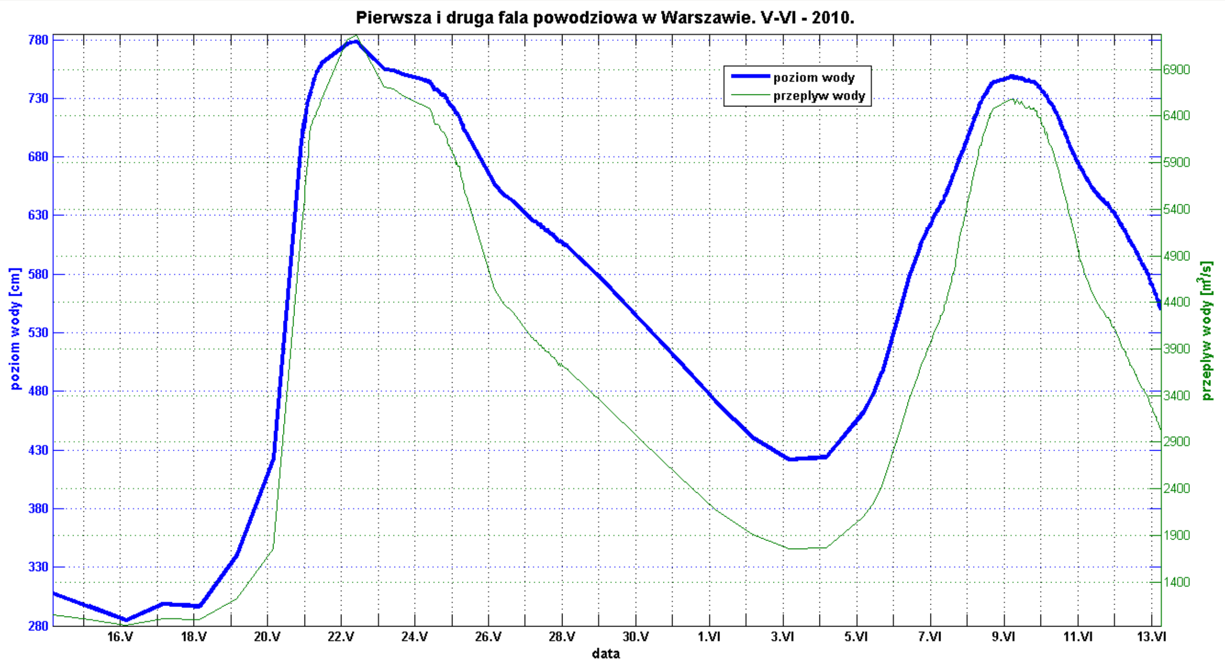
Agenda

- Motivation, ISMOP IT infrastructure
- Data processing and resource management
- Data management
- User interfaces (live demo)
- Holistic approach to system optimization

Motivating scenario

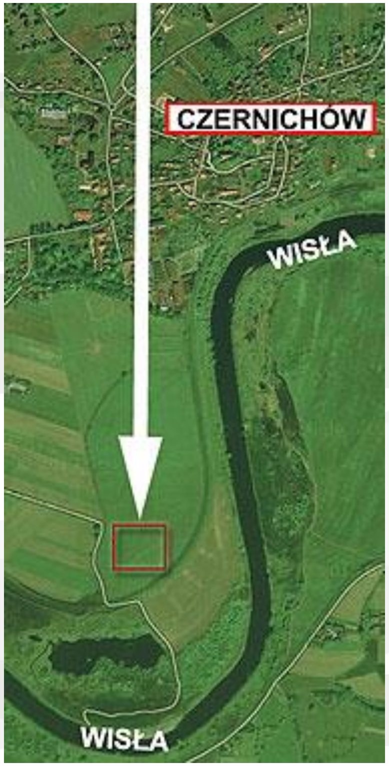
- Flood threat due to a passing water wave
- High water levels lasting up to several weeks
- Increased probability of levee failure



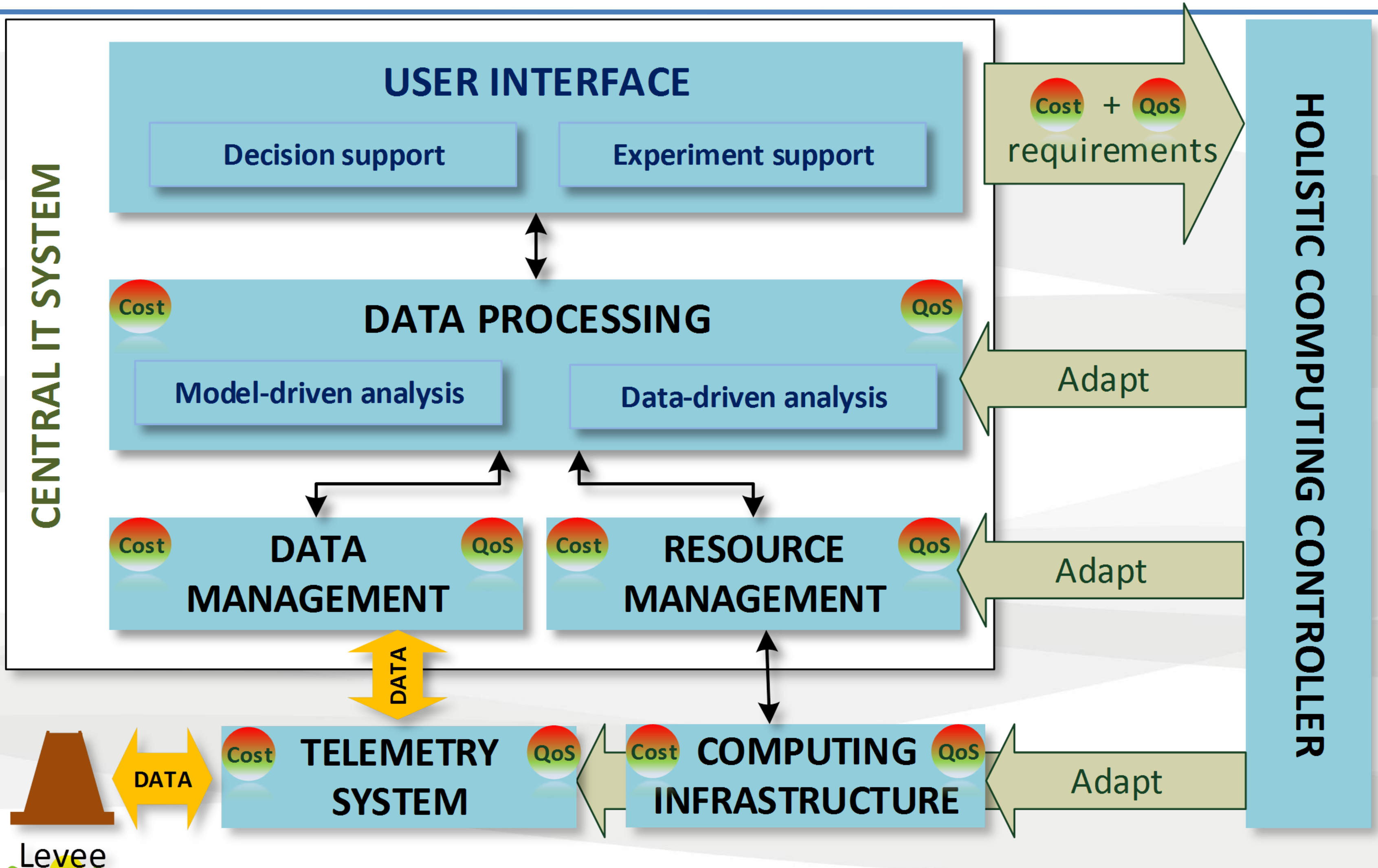
ISMOP project overview

ISMOP: a smart levee monitoring and flood decision support system

- Construction of an experimental levee
- Design of wireless sensors
- Innovative data transmission system
- Model- and data-driven modeling of levee behavior
- **Monitoring and decision support system**



The ISMOP IT infrastructure



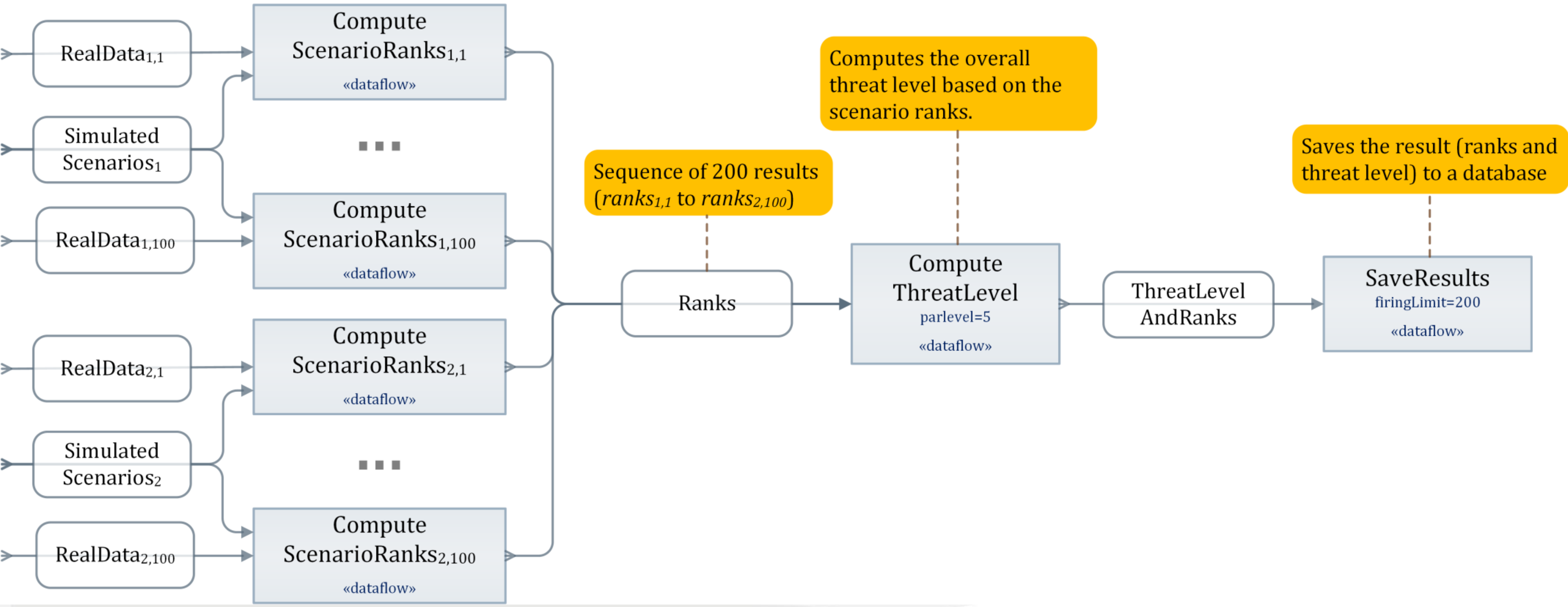
DATA PROCESSING AND RESOURCE MANAGEMENT

Challenge: urgent computing support

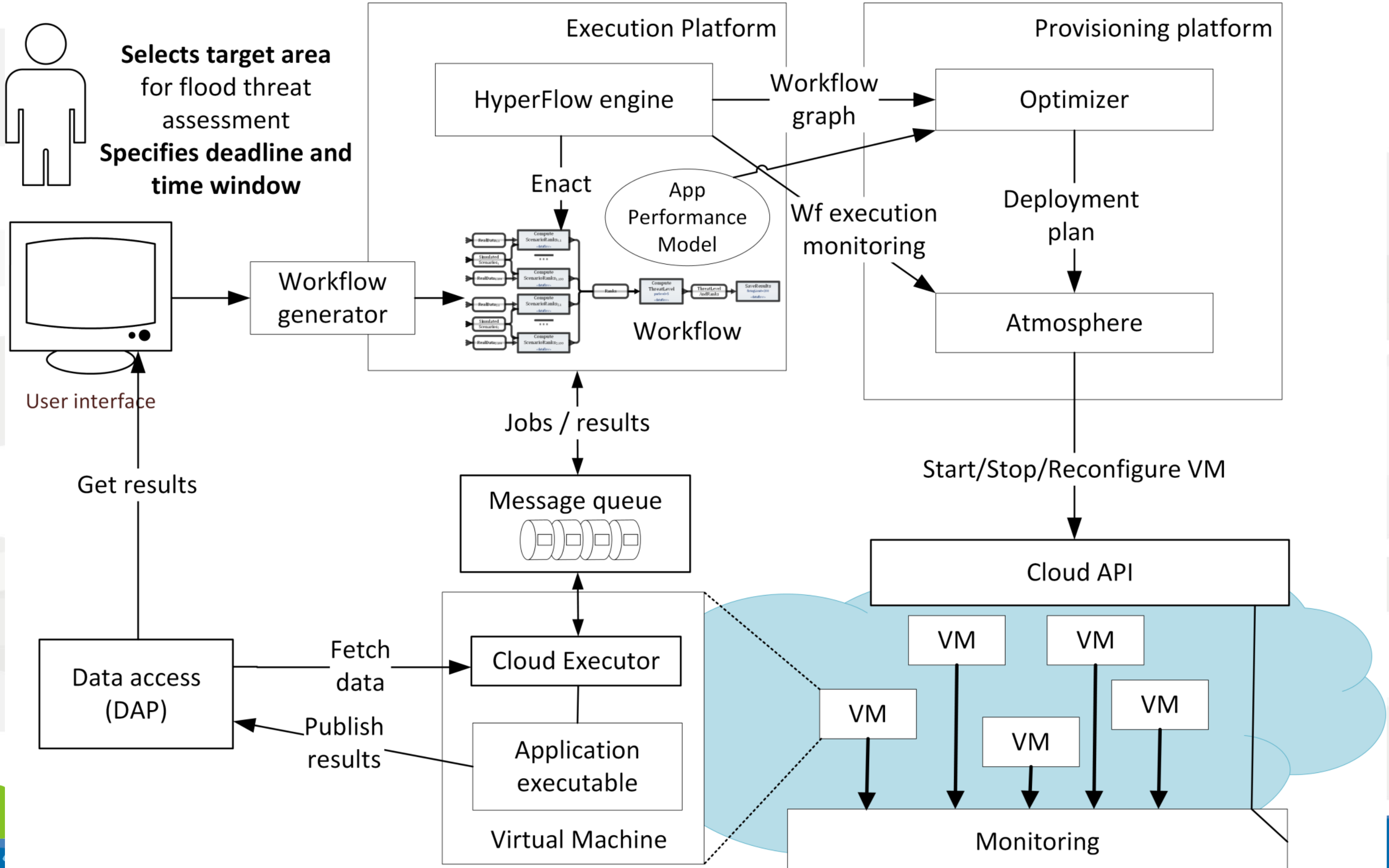
- Assess flood threat risk for large area (50+ km) of levees
- Compute results by a specified deadline

Objective: dynamic provisioning of cloud resources to meet the deadline

Levee breach threat assessment workflow for many levee sections

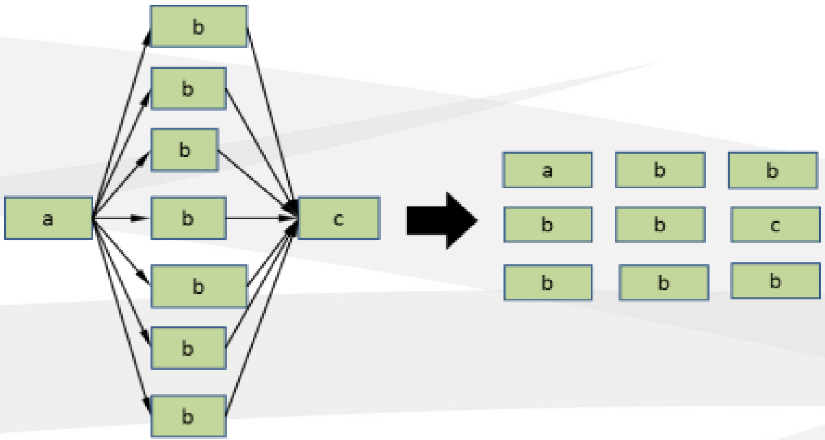


Urgent computing implementation



Resource provisioning model

- Bag-of-tasks model
  - Selection of dominating tasks
  - Uniform task runtimes



- Performance model: $T = f\,(v, d, s, \ldots)$
  - T – *total computing time*
  - v – number of VMs
  - d – time window in days
  - s – number of tasks (sections)

Resource provisioning model

$$\boldsymbol{T} = a * \frac{\boldsymbol{s} * \boldsymbol{d}}{\boldsymbol{v}} + b * \boldsymbol{v} + c \qquad (1)$$

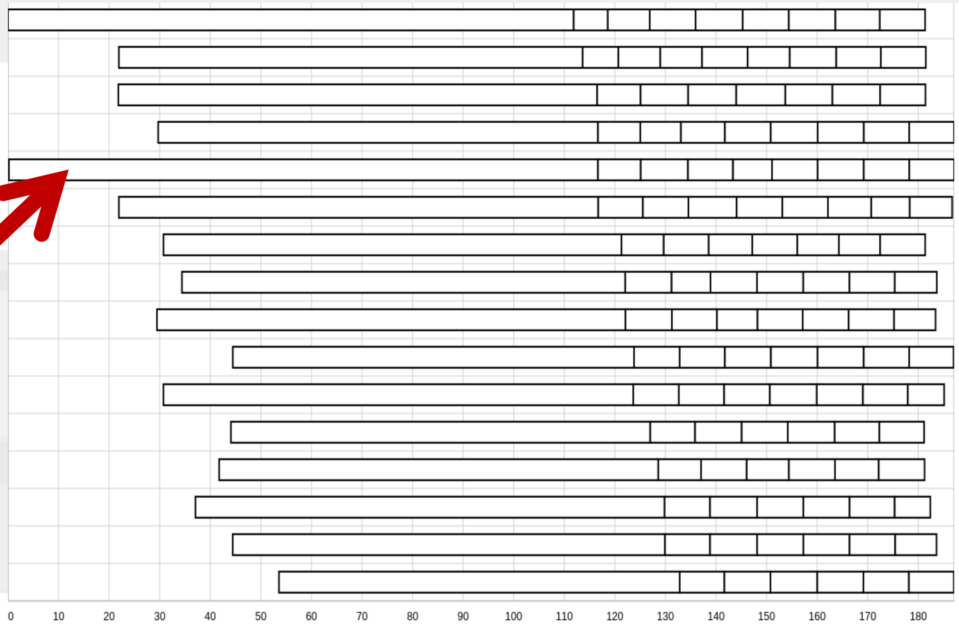
$\boldsymbol{T}$ – *total computing time*
$\boldsymbol{v}$ – number of VMs
$\boldsymbol{d}$ – time window in days
$\boldsymbol{s}$ – number of tasks (sections)

Parameters a, b, c to be determined experimentally

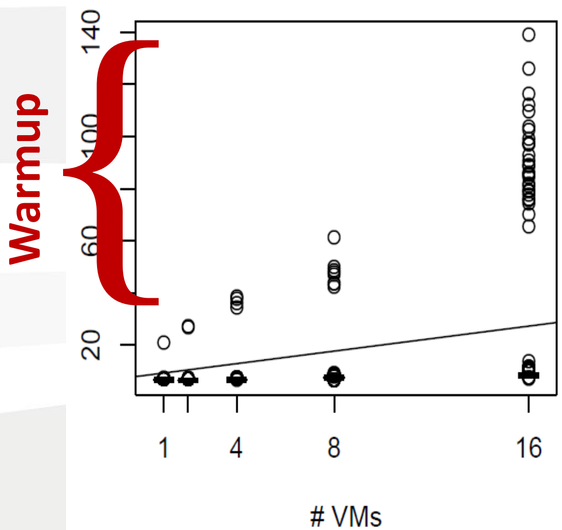
Solve eq. (1) to compute $\boldsymbol{v}$ (# of VMs) given $\boldsymbol{T}$ (deadline)

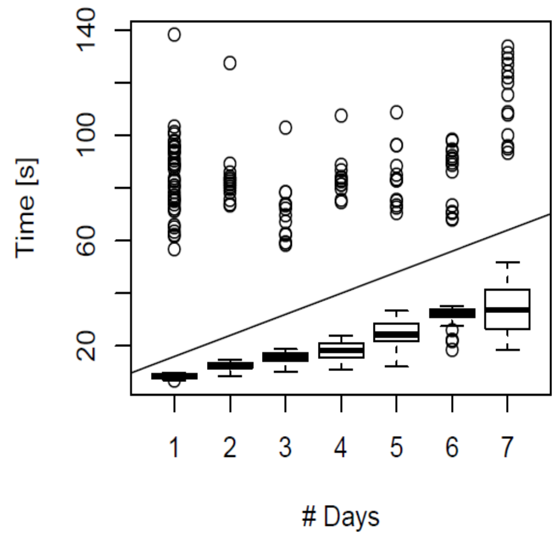
Experiments

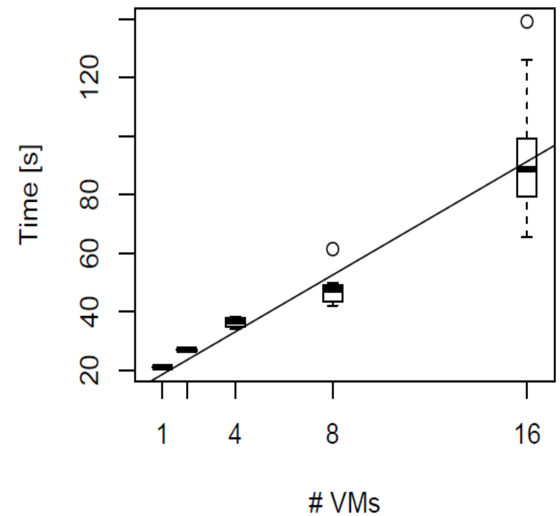
- Setup: private cloud infrastructure
  - a node with 8 cores (Xeon E5-2650)
  - virtual machines (1VCPU, 512MB RAM)
  - data for simulated scenarios (244MB total) on local disks
- Test runs:
  - 1-1024 sections
  - 1-16 VMs
  - 1-7 days time window
- Warmup tasks:



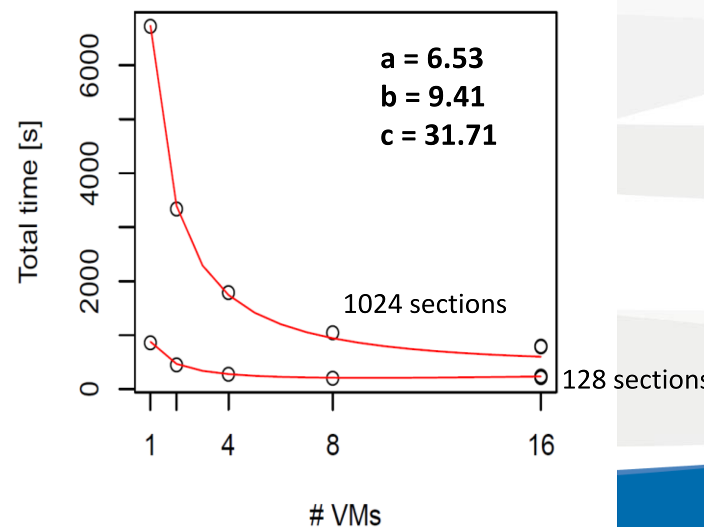
Analysis of results







- Warmup tasks clearly separated as outliers
- Linear functions
- Parameters a, b, c determined using non-linear fit
- The model fits well to the data

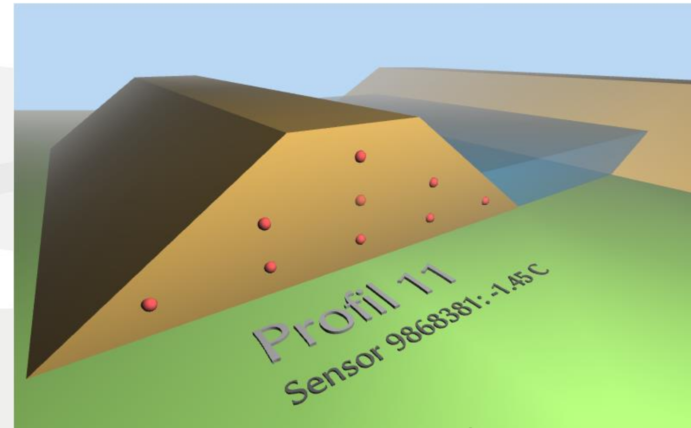


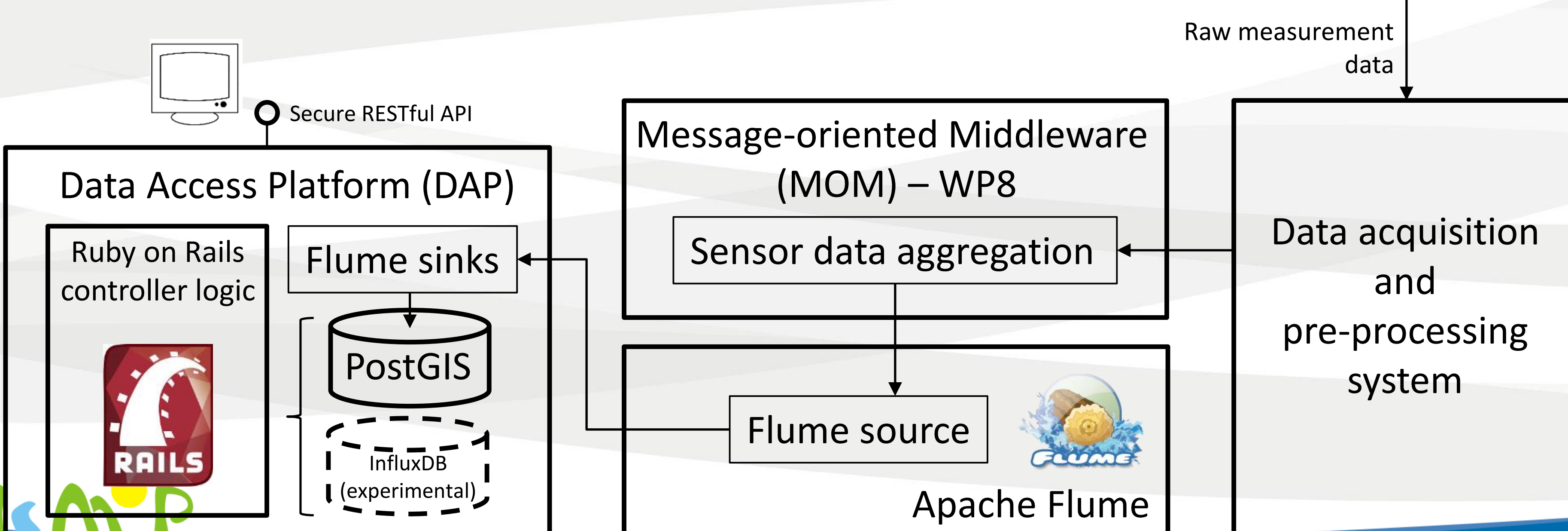
DATA MANAGEMENT

Reliable data storage

Data Access Platform (DAP):

- Ensures fault-tolerant collection of sensor data
- Provides redundant, heterogeneous backend data storage
- Implements real-time query capabilities for ISMOP UIs and simulations





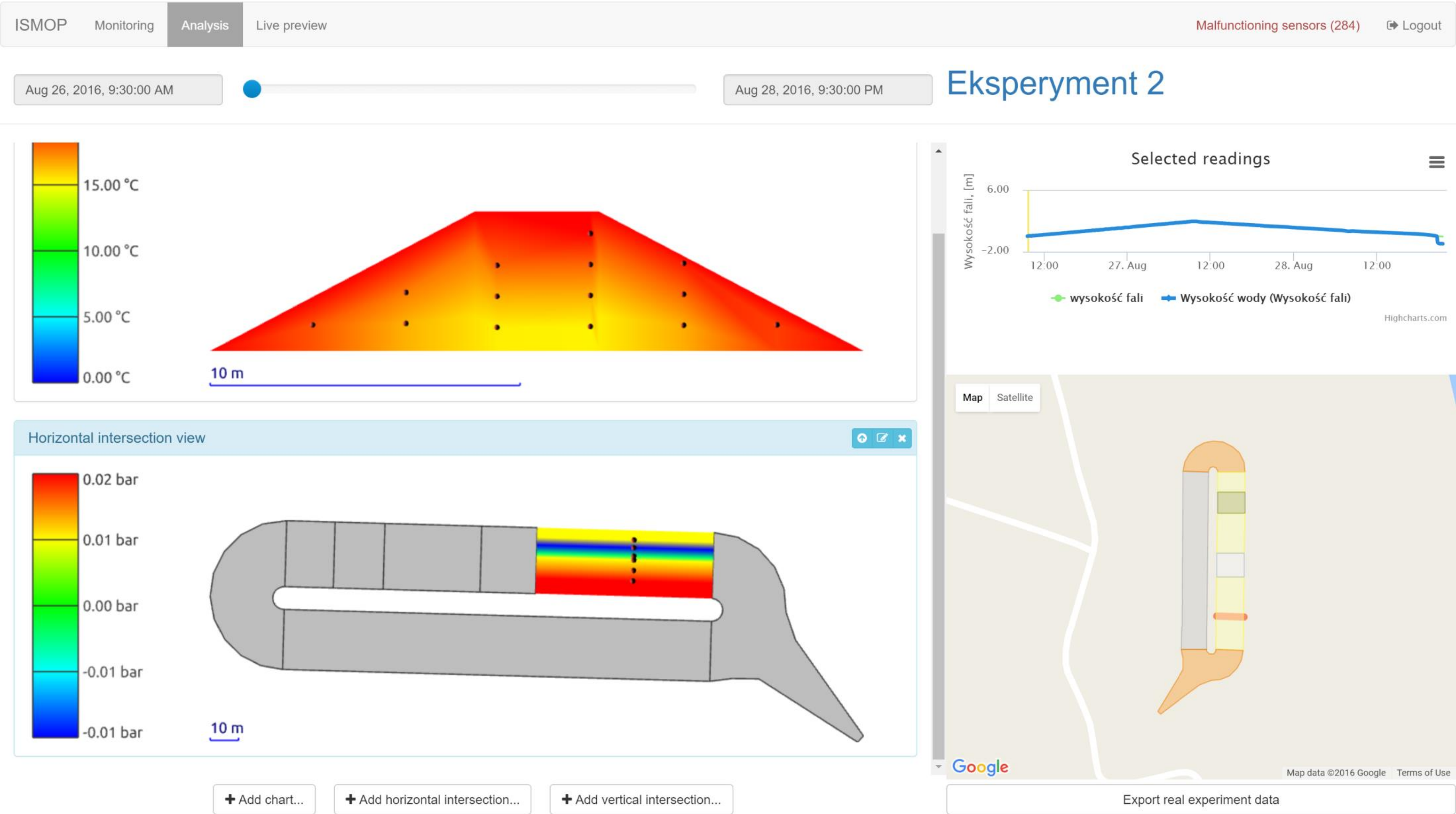
Health monitoring and data quality

- Monitoring of sensor health and reactions outages/malfunctions: more practical to implement at the data management layer
  - End-to-end principle
  - Availability of metadata
  - Access to historic data
- Data quality
  - Sanity checks: are sensor readings correct?
  - Quality metrics (accuracy, validity, completeness, consistency)
  - E.g.: Do we have all readings? Do values fall within expected range?

USER INTERFACE

User interface functions

- Experiment monitoring
- Data visualization and retrieval
- Decision support
  - Data analysis results
  - Model-based prediction of levee behavior


ISMOP
Monitoring
Analysis
Live preview
Malfunctioning sensors (284)
Logout
Aug 26, 2016, 9:30:00 AM
Aug 28, 2016, 9:30:00 PM
Eksperyment 2
15.00 °C
10.00 °C
5.00 °C
0.00 °C
10 m
Selected readings
Wysokość fali, [m]
6.00
-2.00
12:00
27. Aug
12:00
28. Aug
12:00
wysokość fali
Wysokość wody (Wysokość fali)
Highcharts.com
Horizontal intersection view
0.02 bar
0.01 bar
0.00 bar
-0.01 bar
-0.01 bar
10 m
Map
Satellite
Google
Map data ©2016 Google
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+ Add chart...
+ Add horizontal intersection...
+ Add vertical intersection...
Export real experiment data

HOLISTIC APPROACH TO SYSTEM OPTIMIZATION

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Problem formulation

- **Goal**: optimize the IT infrastructure in terms of
  - **QoS parameters** (measurement interval, performance, timeliness, etc.)
  - **Cost of operation**
  - **Energy consumption**
- **Problem**:
  - These objectives are contradictory
  - Their priorities depend on the mode of operation (e.g. cost important in the normal mode, perfomance and timeliness in the urgent mode)

Optimization of IT infrastructure

Multi objective optimization problem:

- **Objective functions**: non functional properties of the system
- **Decision variables**: configurations of all subsystems of the IT infrastructure

Isolated approach: each subsystem is optimized separately

Holistic appoach: the entire system (all subsystems) is optimized

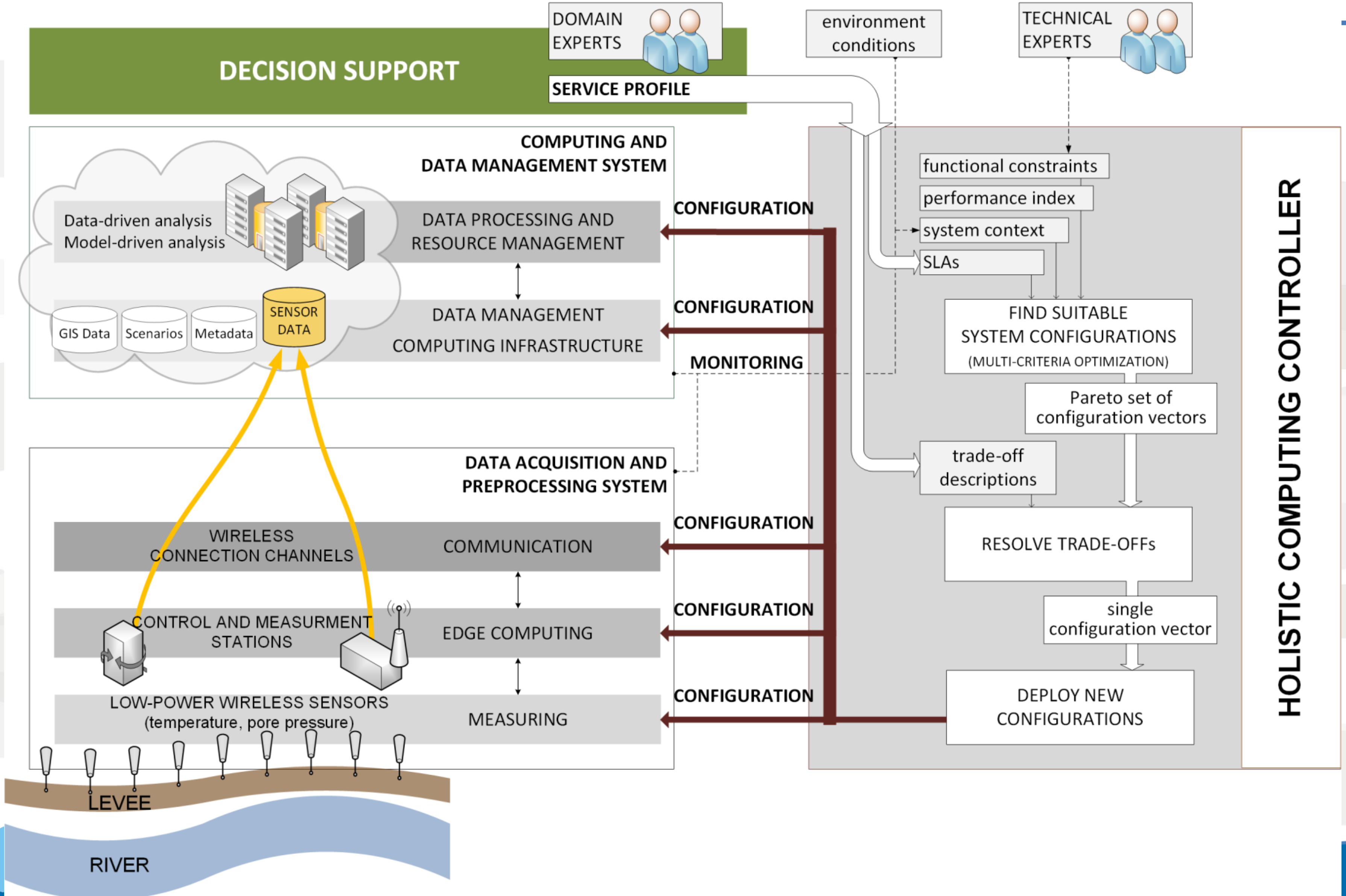
Objective functions (examples)

- **Operating cost** (OPC): expenses required to maintain operation of the system
- **Energy Efficiency** (EE): a function indicating how energy efficient the system is
- **Data measurement interval** (DMI): time interval at which sensor parameters are captured
- **Data processing interval** (DPI): time interval at which data analyses are performed
- **Data processing time** (DPT): maximum time to complete a single data analysis

Example configurable properties

Subsystem	Configurable properties
Data processing and resource orchestration	***Processing interval***: 5,15,60,720,1440 min ***Scheduling algorithm***: time-optimized, cost-optimized
Computing infrastructure	***VM allocation policy***: aggressive, conservative
Communication	***Transmission protocol order***: (Xbee-SMS-GPRS), (GPRS-SMS-Xbee)
Edge computing	***Encryption***: on, off ***Data aggregation***: off, low, high
Measurement	***Measurement interval***: 1, 5, 15, 60, 720, 1440 min ***Accuracy***: high, low

Holistic computing controller



Conclusion

- A modern IT infrastructure for environmental monitoring and decision support needs to address non-trivial technical requirements and provide demanding quality of service
- ISMOP proposed IT infrastructure is build on the IoT-Cloud technology stack
- Provides urgent computing capabilities
- Holistic approach to system management optimizes configuration of the entire IT infrastructure towards various optimization objectives

http://www.ismop.edu.pl

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