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Resilience of water infrastructures

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INNOVATIVE SECURE SENSOR NETWORKS AND MODEL-BASED ASSESSMENT TOOLS FOR INCREASED RESILIENCE OF WATER INFRASTRUCTURES



Resilience of water infrastructures

SPONSORED BY THE



Federal Ministry
of Education
and Research



Dr. Olivier Piller & Dr.-ing Jochen Deuerlein
French-German project funded by ANR/BMBF
Critical Infrastructure Protection Call
PICS 2014 – Final meeting
Lyon, the 16th October 2018

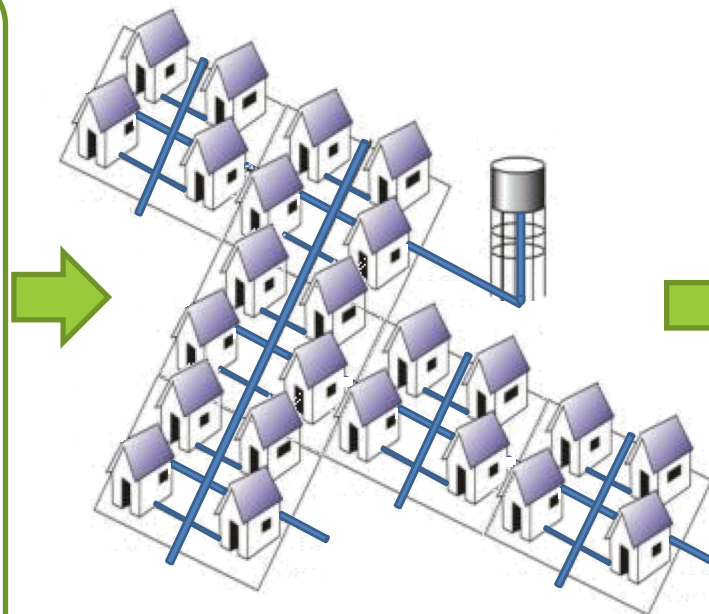


Water Distribution Systems


LARGE INTERCONNECTED CRITICAL INFRASTRUCTURES

potential hazards

- 
- Extreme weather
 - Accidents or technical failures
 - Cyber threats
 - Acts of terrorism
 - Chemical contamination
 - Cascading events
 - others
 - Aging
 - Components degradation



potential consequences or potential impacts

- 
- Pipe break
 - Other infrastructure (damage/failure)
 - Power outage
 - Service disruption (source water treatment, distribution or storage)
 - Loss of pressure/Leaks
 - Change in water quality
 - Environmental impacts
 - Financial impacts (e.g. loss of revenue, repair cost)
 - Social impacts (e.g. Loss of public confidence, reduce workforce)
 - Others

Introduction

CRITICAL INFRASTRUCTURE PROTECTION





Drinking water distribution networks are exposed to natural or human-made disasters

Not only are contaminant warning systems important, but so is water utility preparation, maintenance, training...

The detection of faults and the capacity to return quickly to a normal state after failures and interruption of services are essential for water utilities.



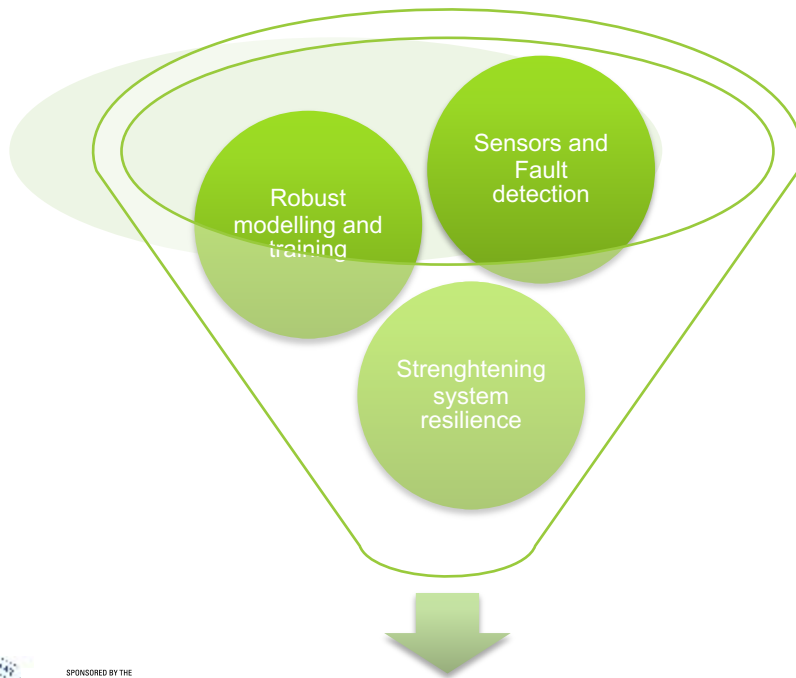
- Prevention ?
- Monitoring ?
- Which responses?

-  Toxicity sensors
-  Hydraulic and water quality sensors
-  Hydraulic stations (tanks, pumps, valves)
-  Terrorist attack

Introduction

OBJECTIVE

Prepare water utilities to crisis management by improving the system resilience with respect to 2 specific case studies: system failure and water quality deterioration.



1. Project consortium & work plan
2. The resilience framework
3. Simulation and resilience training
4. Conclusions and outlook

Better crisis management

Project consortium

PARTNERS (JULY 2015 – JUNE 2018)

End-users

Berliner Wasserbetriebe (BWB, Germany)

Eurométropole de Strasbourg (EMS, France)

Veolia Eau d'Ile-de-France (VEDIF, France)

Engineering Consulting Company

3S Consult GmbH (Germany)

Laboratories and Research Centers

Irstea (France)

Enges GESTE and ICUBE (France)

DVGW-Technologiezentrum Wasser TZW (Germany)

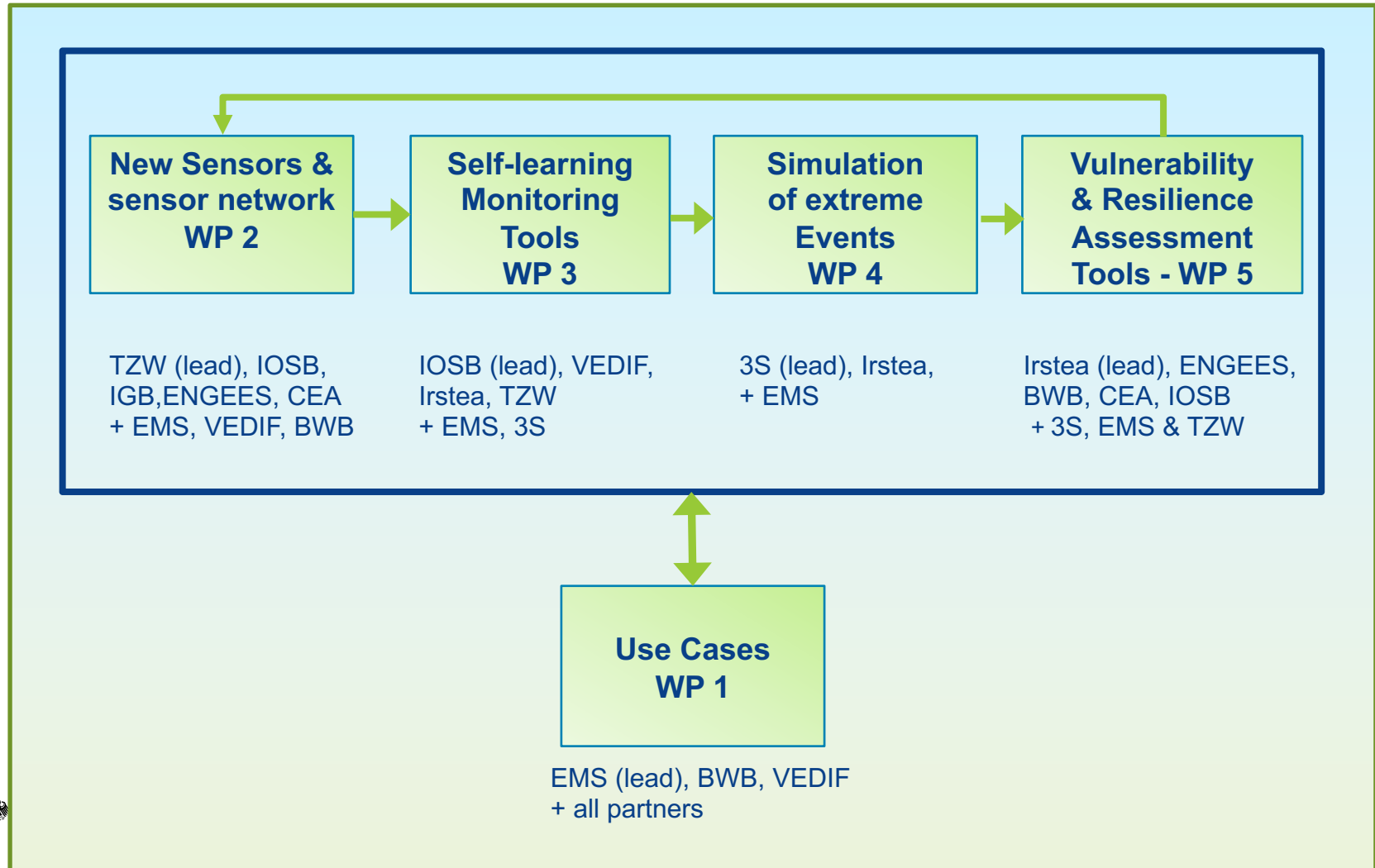
Fraunhofer Institute IOSB (Germany)

Fraunhofer institute IGB (Germany)

CEA DAM (France)

Work plan

SCIENTIFIC AND TECHNICAL PROGRAM



The resilience framework

DEFINITIONS

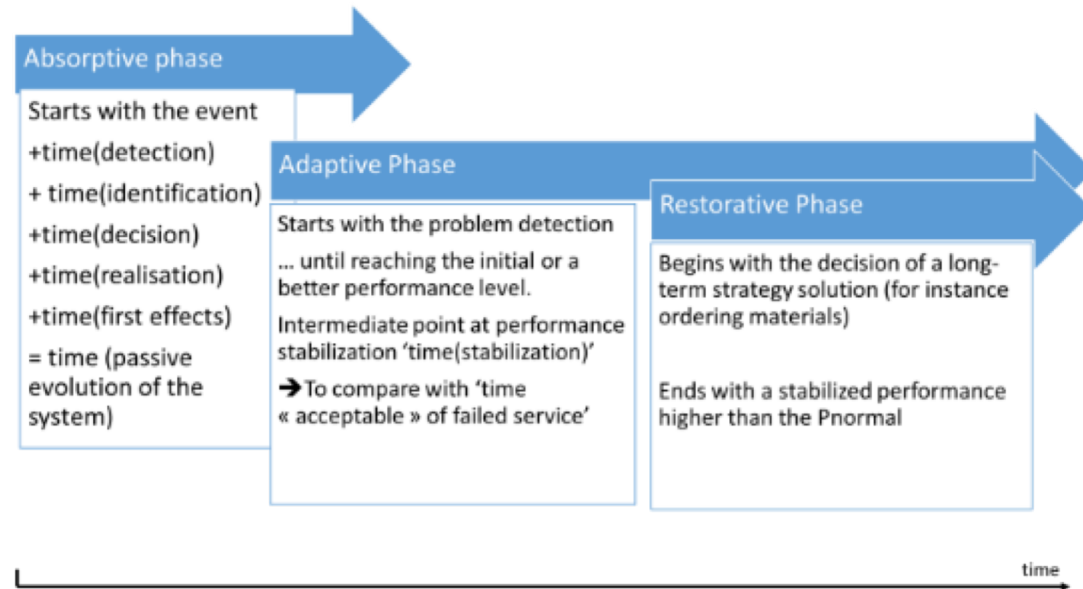
The resilience is the **inverse of a time** for driving back the system into its desirable properties ; the theory of viability is a good mathematical framework that focuses on desired use of a system
More general definitions with technical, social and organisational facets:

- The four R's of resilience and multi-hazard engineering, Bruneau *et al.*, 2003, Redundancy, **Robustness, Rapidity and Resourcefulness**
- Resilience is the ability of the system to **absorb, adapt, and rapidly recover** from a potential disruptive event NIAC, 2009

Simulation and analysis tools can help water utilities explore how their network will respond to expected, and unexpected events

The resilience framework

THE RESIWATER THREE RESILIENCE COMPONENTS



Timeline for the three resilience phases in the ResiWater project

VULNERABILITY and **RESILIENCE** signatures are assessed on a simple three-level scale:



The resilience framework

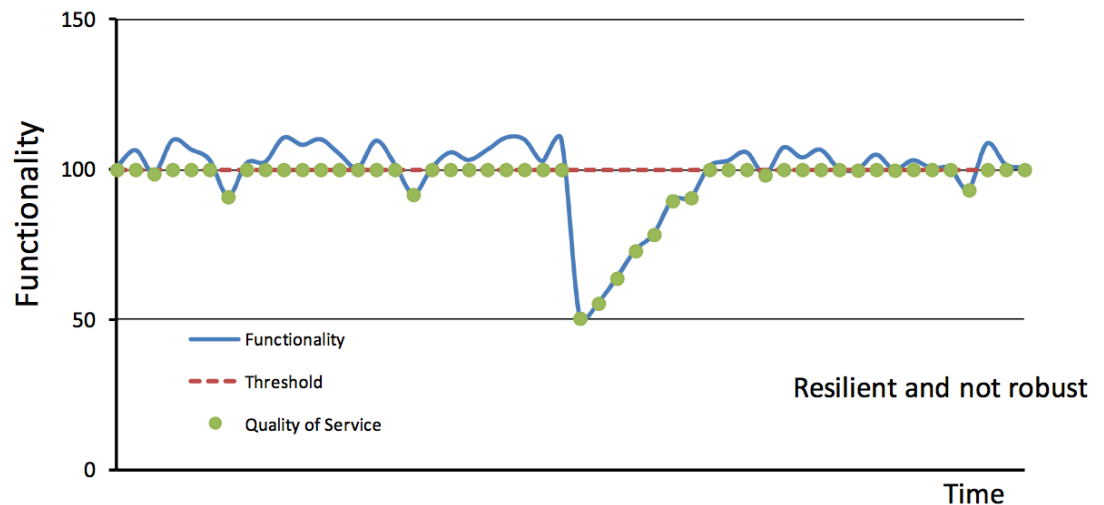
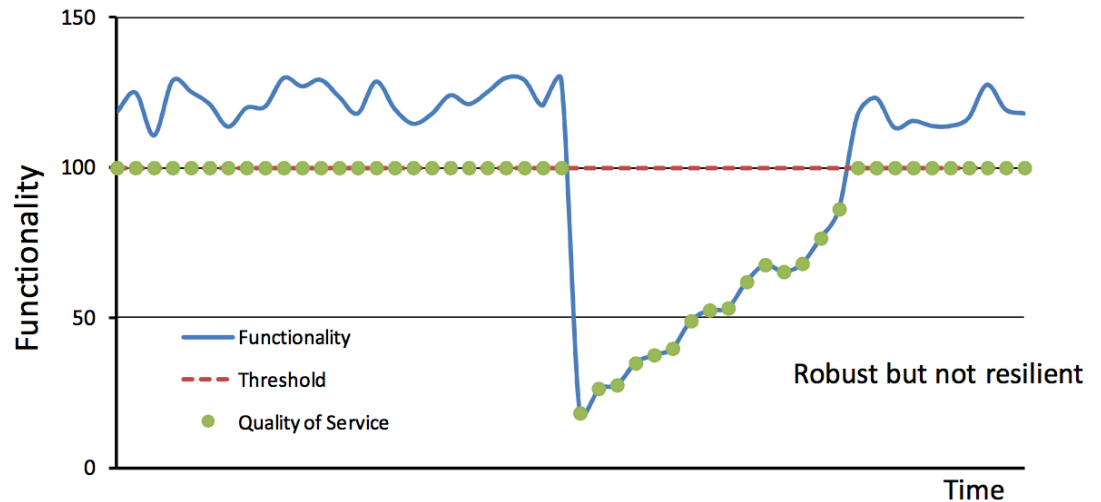
VULNERABILITY, RESILIENCE AND ROBUSTNESS

Kevin Lansey (2013)

Infrastructure resilience is the ability to gracefully degrade and subsequently recover from a potentially catastrophic disturbance that is internal or external in origin

The **robustness** of a system to a given class of disturbances is defined as the ability to maintain its function when it is subject to a set of disturbances of this class

Resourcefulness + rapidity



Simulation and resilience training

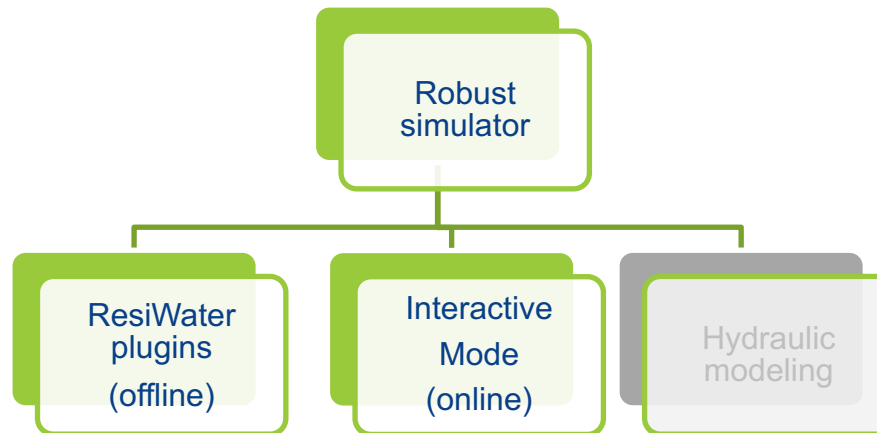
DESIGN

Objective: Managing disruptive events by

- Improved system design
- Improved operations and response

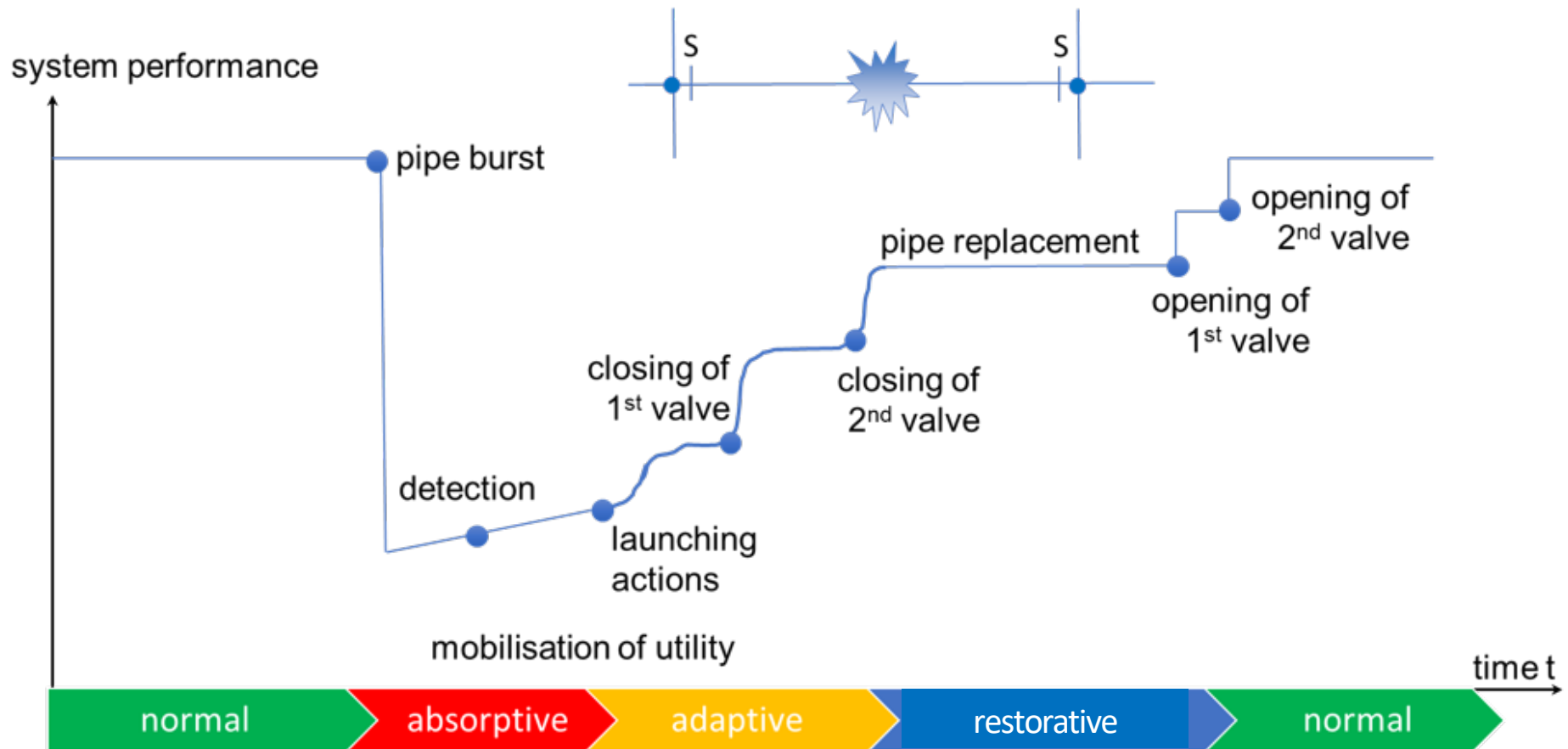
Decision was made to split into two application modes:

- Offline training -> planning and preparedness
- Online training -> network operation and management

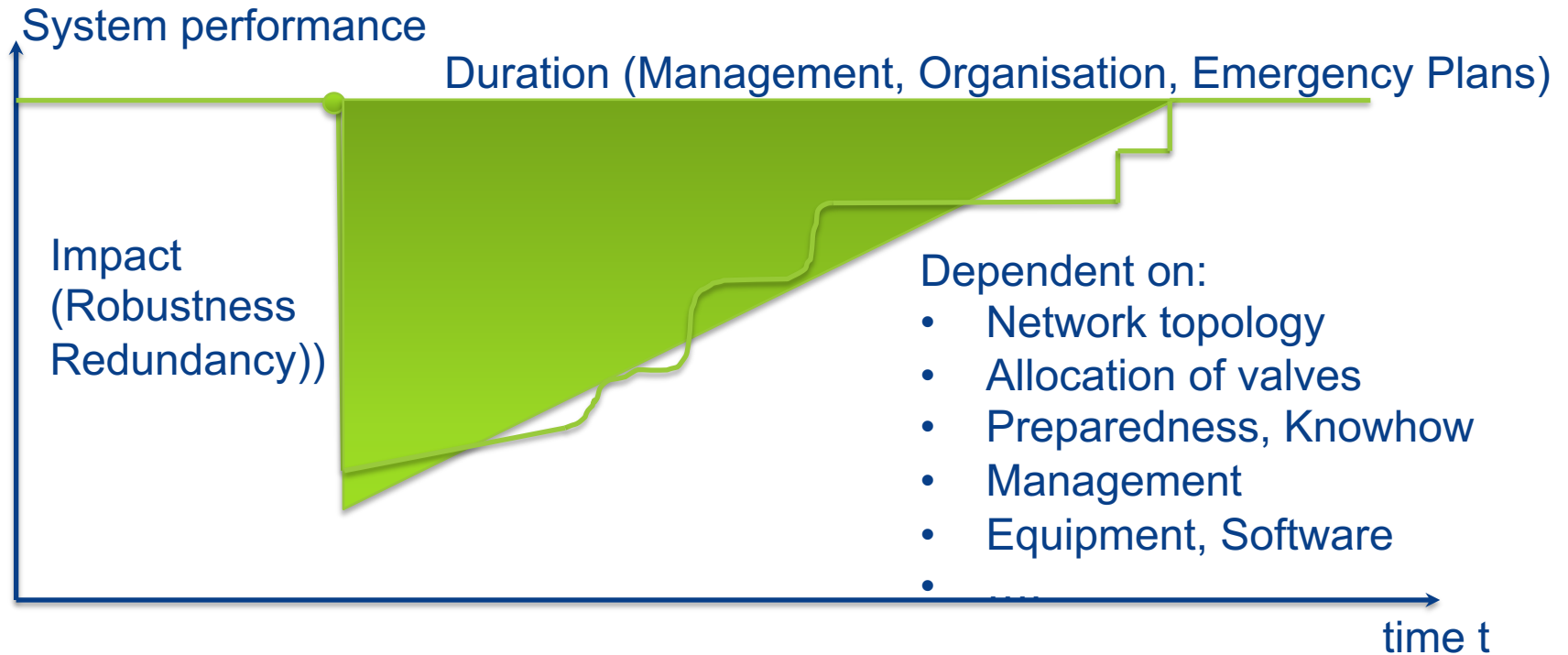


Phases of resilience

SIMPLE EXAMPLE: PIPE BURST



Resilience triangle



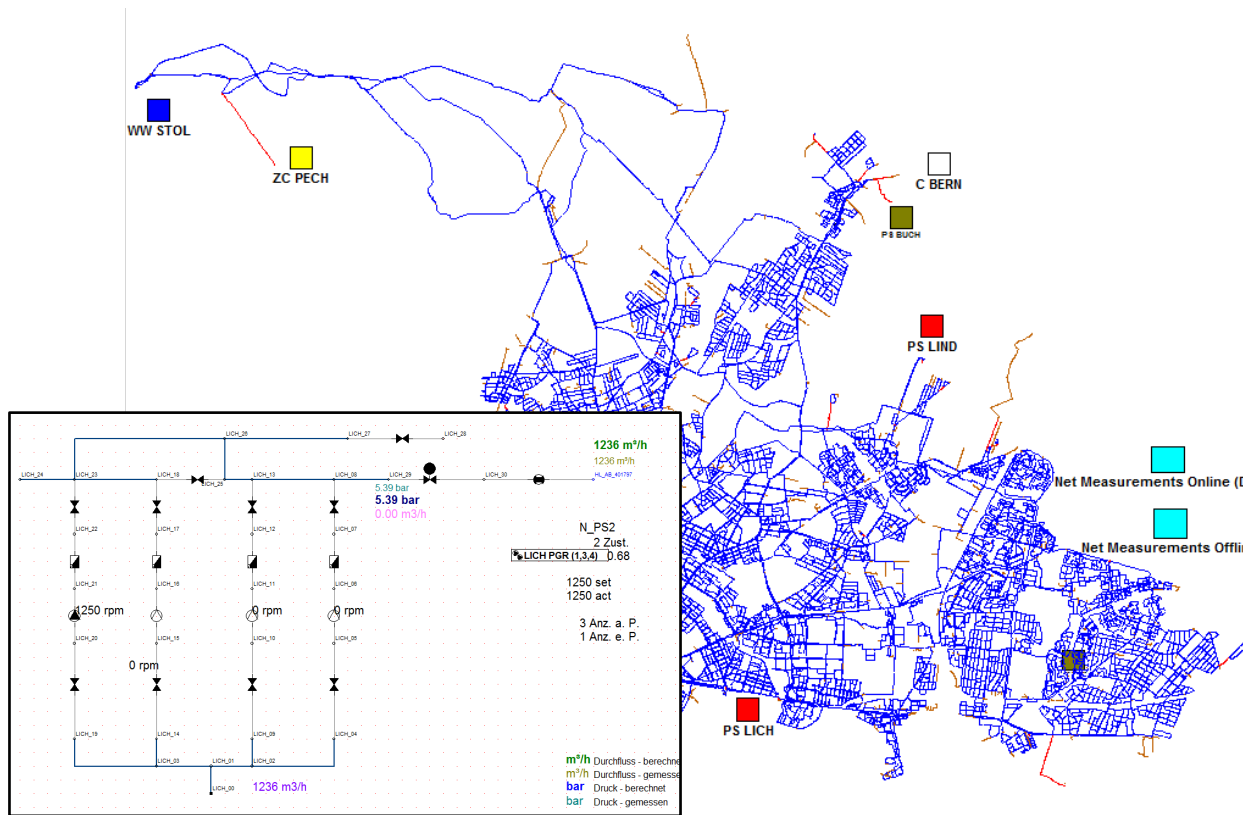
Objective: Area of triangle should be as small as possible.

Decrease area in vertical direction → static Resilience

Decrease area in horizontal direction → dynamic Resilience

Training Simulator

MODEL OF PILOT ZONE



model data:

21.500 nodes

26.300 links

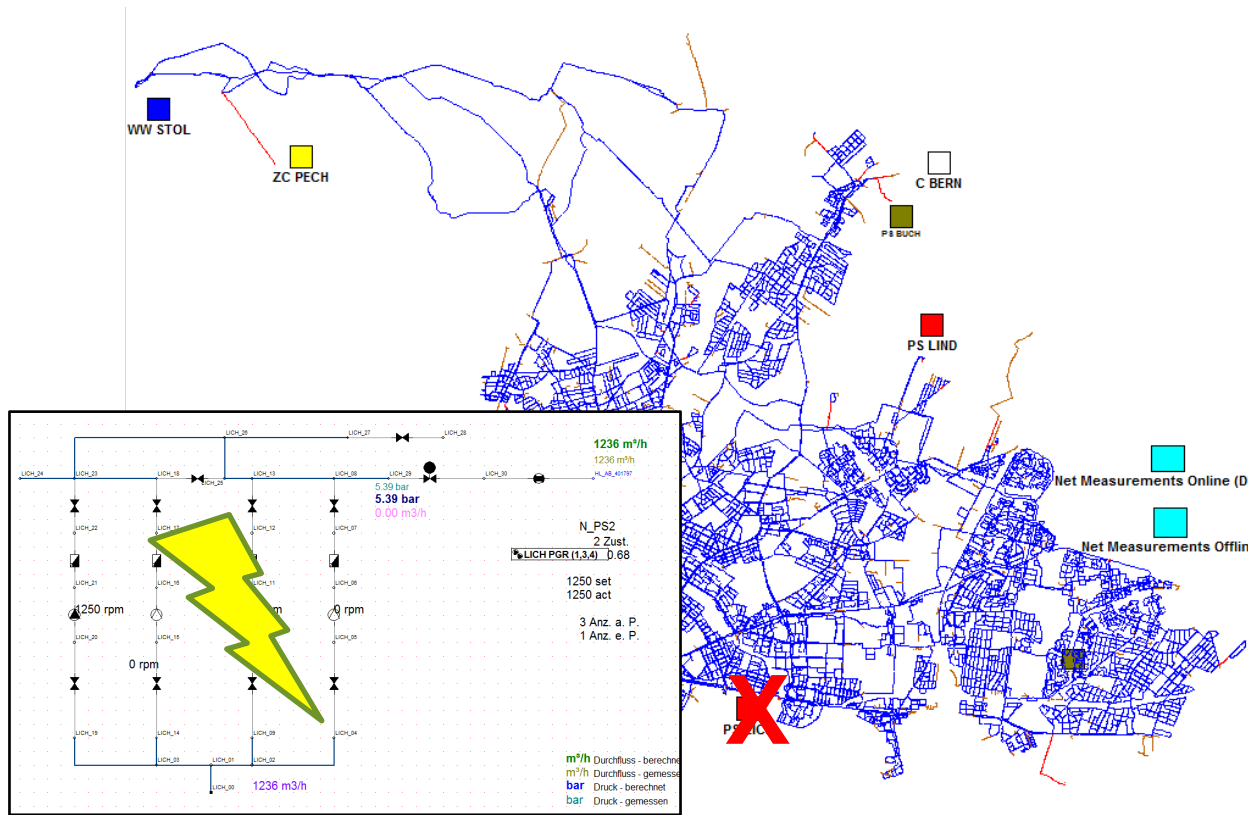
min. supply pressure
for PDM: 3,0 bar

base (average)
demand: 4.500 m³/h

calculation mode:
fast transient solver
(water hammer) with
1 sec time step

Training Simulator

SCENARIO

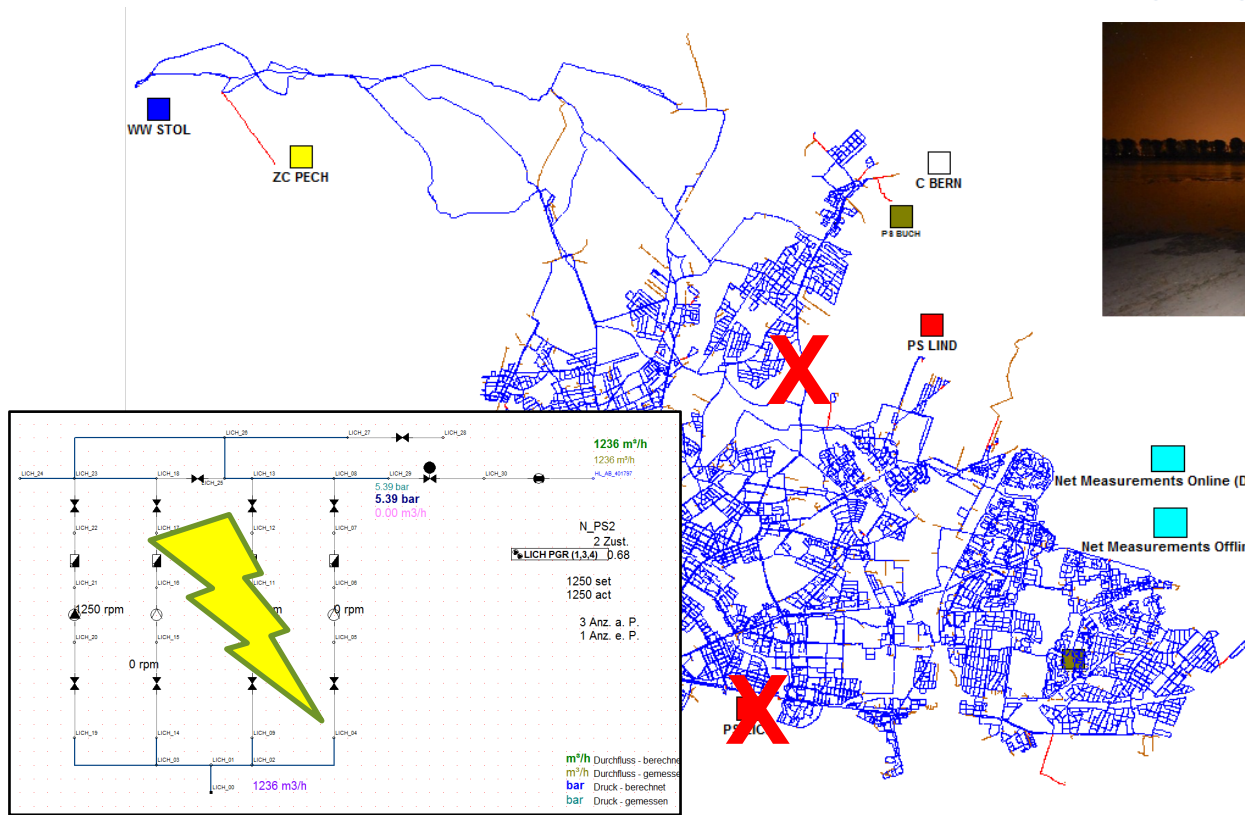


pumping station failure and ...

Training Simulator

SCENARIO

... pipe burst of trunk main at the same time



pumping station failure and ...

Trainees possibilities to control the network

OVERVIEW

The screenshot displays a comprehensive water network control interface. At the top, a menu bar includes 'File', 'Ansicht', 'Kennfeld', 'Einfügen', 'Bearbeiten', 'Berechnen', 'Topologie', 'Abfragen', 'Längsschnitt', and 'Zeit'. Below this is a toolbar with icons for 'Steuerung' (Control), 'Bedienung' (Operation), and 'Navigieren' (Navigation). A red box highlights the 'Steuerung' icons, which include a gear, a valve, a stop sign, and play/pause buttons.

The main interface is divided into several data panels:

- Top Left:** A detailed view of a specific node or valve, showing parameters like '3.30 bar', '0 m³/h act', and '0.67 bar'.
- Top Center:** A 'Customer' panel showing flow and pressure data for 'PS 3', 'PS 1', and 'PS 2'.
- Top Right:** A map of the network with various nodes and connections. A red box highlights a 'Pilot zone'.
- Middle Left:** A 'Leak Isolation Valves' panel with a red box around it. It shows 'Burst #1' with '0 % Crack' and '0 m³/h' flow, and 'Valve North' and 'Valve South' both at '100 % Position'.
- Middle Right:** A 'Total Inflow' panel showing '4186' m³/h, with sub-panels for 'WW' (1906 m³/h) and 'PS 1' (1044 m³/h).
- Bottom Left:** A 'WW' (WaterWork) panel showing '1906 m³/h' and '0.00 m³/h'.
- Bottom Center:** A 'PS 1' (PumpingStation) panel showing '1150.0 set' and '1150.0 act'.
- Bottom Right:** A 'PS 2' (PumpingStation) panel showing '1250.0 set' and '1250.0 act'.

A legend at the bottom right explains the symbols used in the map and data panels:

- WW - WaterWork
- PS - PumpingStation (feeding)
- PS - PumpingStation (internal)
- Customer
- ZC - inter ZoneConnection
- 5 DMPs
- 000 Trainer Settings
- 000 000 000 000 Trainer Only Information - simulated
- 000 000 Trainee Settings
- m³/h flow - simulated
- bar pressure - simulated
- 000 000 000 other - simulated

leak
isolation
valves

Trainees possibilities to control the network

PUMP STATIONS: AUTOMATIC VS. MANUAL CONTROL

Automatic Off

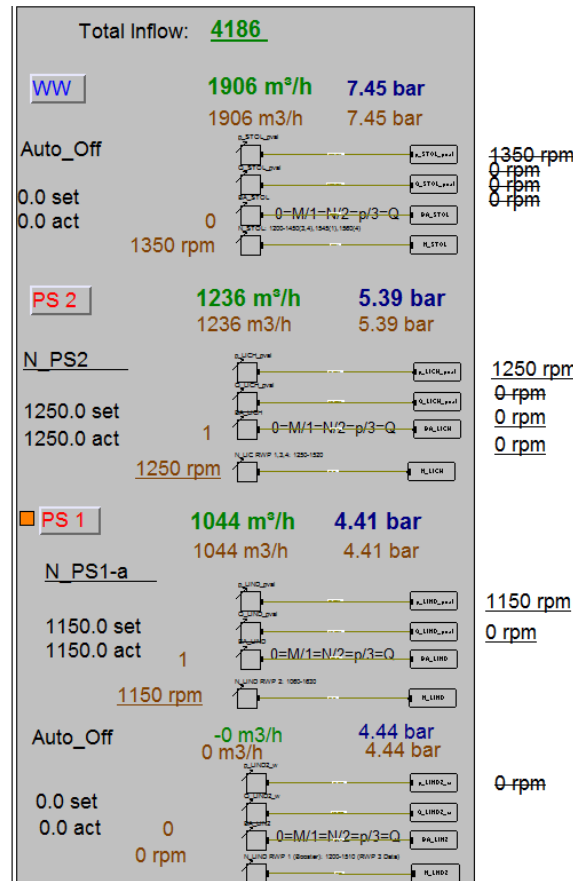
On/N (speed)

On/N (speed)

PS1 pumps 2,3

Automatic Off

PS1 Booster



Automatic On/Off:

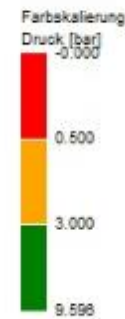
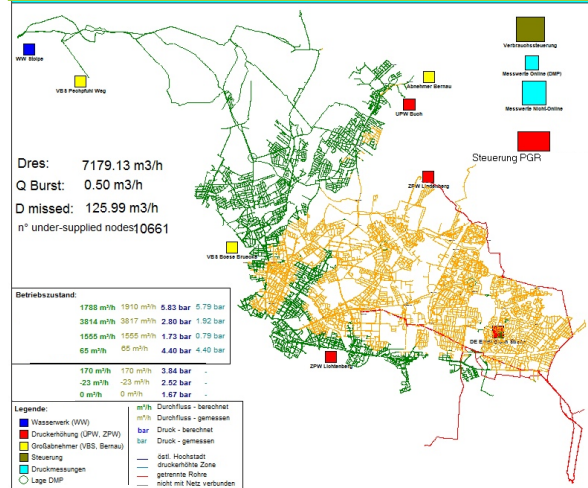
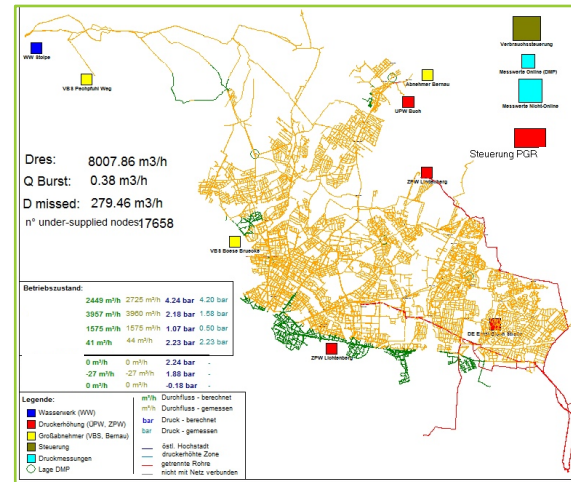
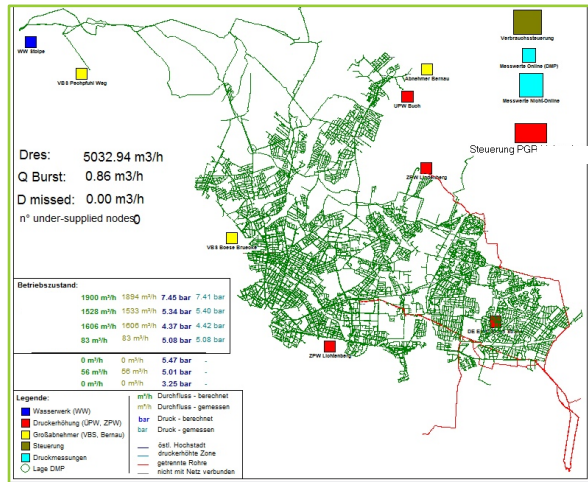
Automatic Off: pump speed has to be set by the Trainee for each single pump

Automatic On: Trainee sets Mode

N (speed), p or Q and setpoint – automatic drives the whole group

Real-time visualization of calculation results

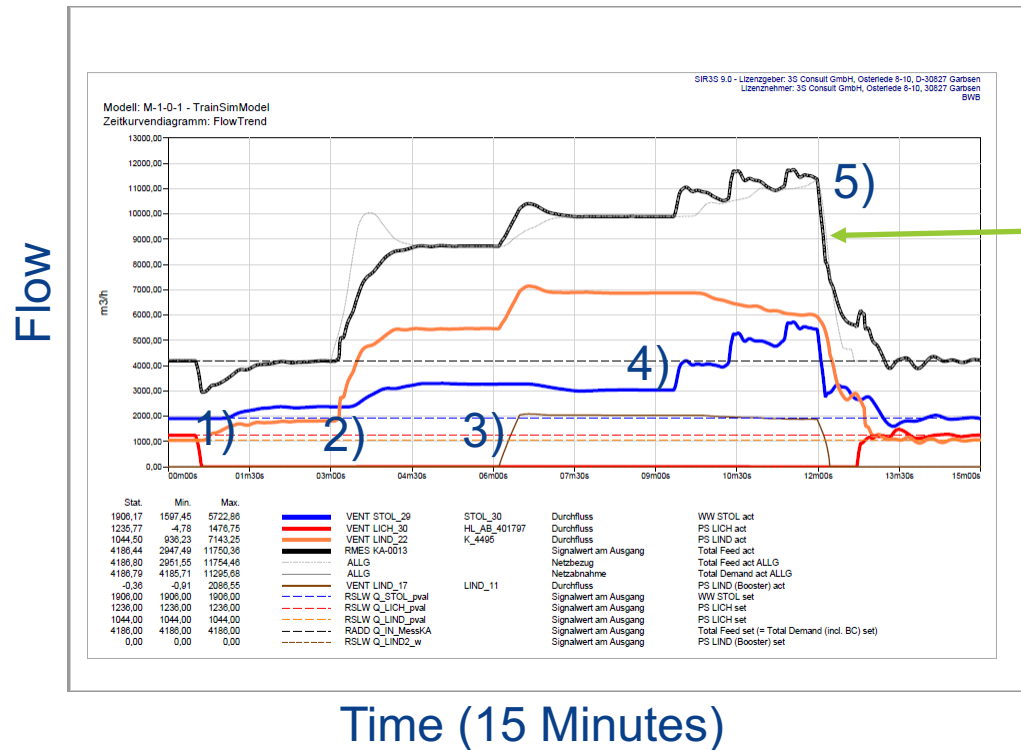
EXAMPLE: SYSTEM PRESSURE



Traffic light colours
(easily and quickly to determine)

Training Scenario - Results

TIME CURVES FOR FLOWS



Demand is constant

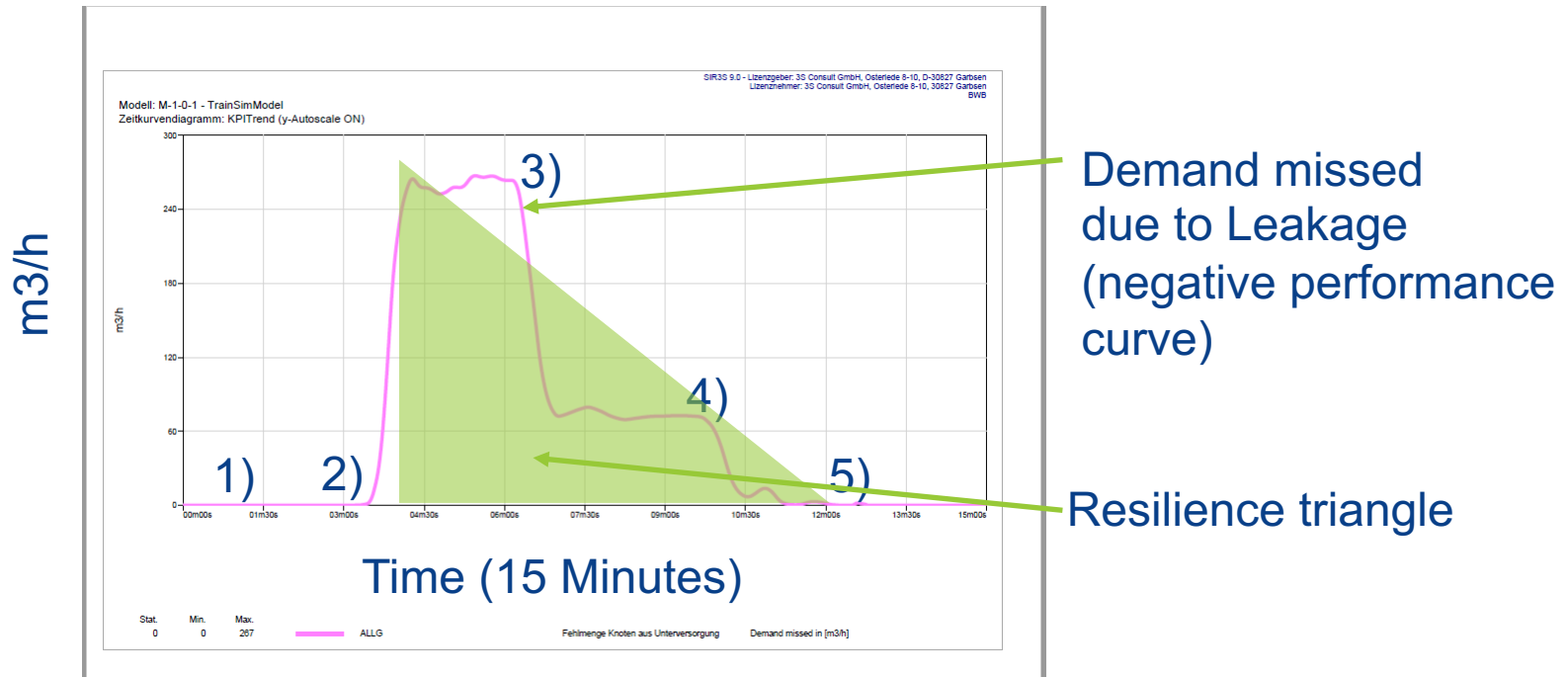
Total inflow
- due to leakage
- and linepack



- 1) PS2 Off!
- 2) Leakage!
- 3) Trainee runs PS1 Booster!
- 4) Trainee runs WW pumps 2>3>4!
- 5) Trainer closes Leakage & Trainee stops PS1 Booster, WW 2,3,4 and starts PS 2 again

Training Scenario - Results

KPI: SUPPLY RATE

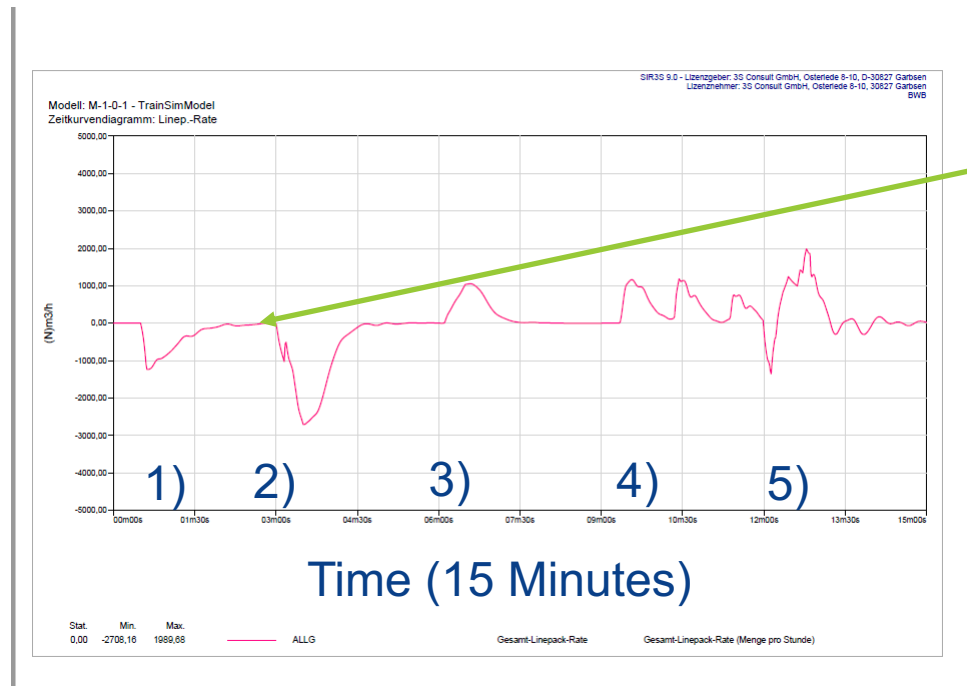


- 1) PS2 Off!
- 2) Leakage!
- 3) Trainee runs PS1 Booster!
- 4) Trainee runs WW pumps 2>3>4!
- 5) Trainer closes Leakage & Trainee stops PS1 Booster, WW 2,3,4 and starts PS 2 again

Training Scenario explained

LINEPACK-RATE

m³/h



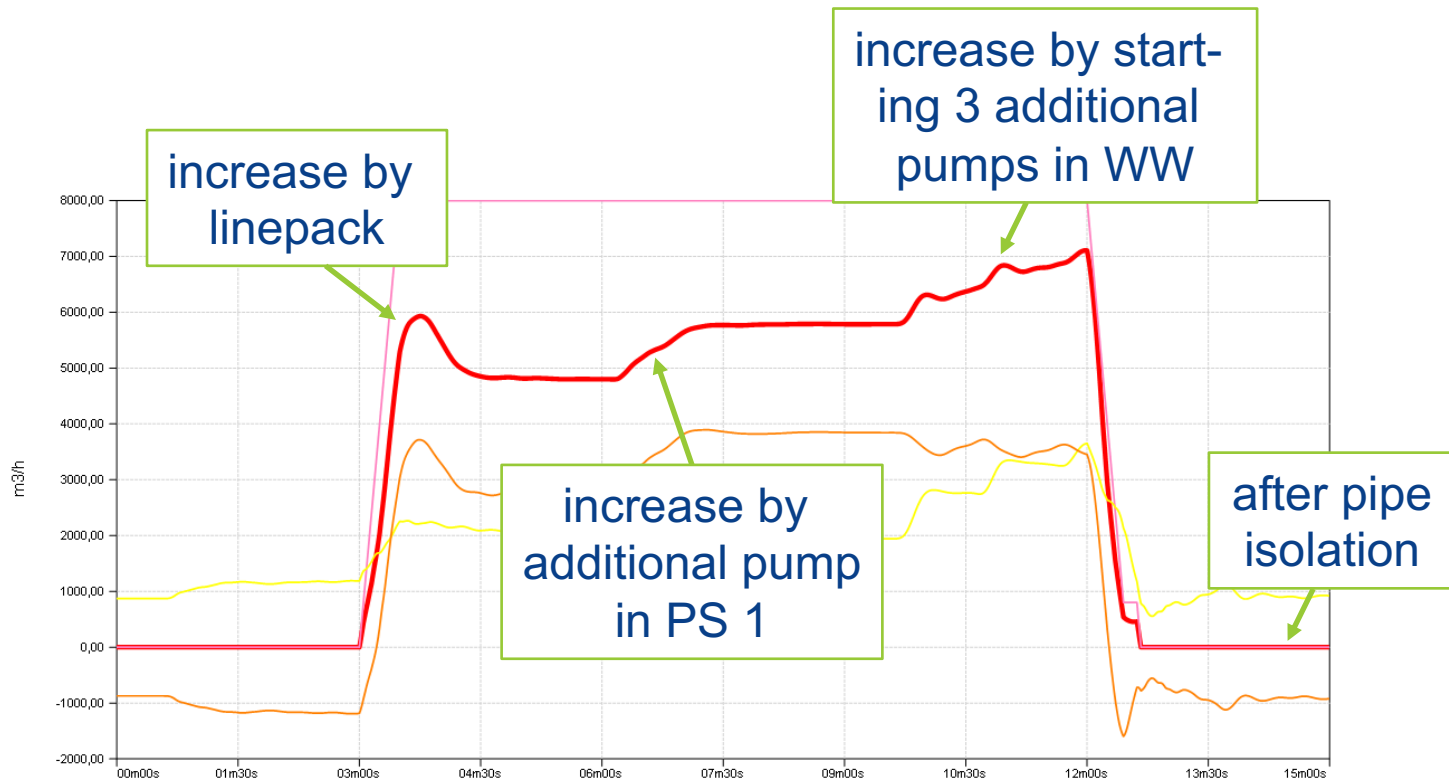
Linepack-rate

understanding Linepack
is key for understanding
dynamic resilience

- 1) PS2 Off!
- 2) Leakage!
- 3) Trainee runs PS1 Booster!
- 4) Trainee runs WW pumps 2>3>4!
- 5) Trainer closes Leakage & Trainee stops PS1 Booster, WW 2,3,4 and starts PS 2 again

Training Scenario - Results

LEAKAGE LOSS



-> Trade-off between system performance and leakage loss

Summary and Conclusion

- ✓ Water supply system is a **critical infrastructure**
- ✓ 3 Resiliences **absorptive, adaptive and restorative**
- ✓ Robust Modelling
- ✓ Sensors, detection and Cost benefit Analysis
- ✓ Simulation and resilience training
- ✓ Event Case studies with end users
 - **Berlin BWB**
 - **Strasbourg CUS**
 - **VEDIF**

Outlooks

- ✓ Resilience by design and adaptive improved control system
- ✓ New technologies or types of critical infrastructures (IoT, robotics, cybersecurity)
- ✓ Holistic and integrated approaches considering interactions between different CIs (communication, cascading effects, etc.)
- ✓ Development of operational metrics and practical approaches to support decision making
- ✓ Model-based decision making (optimisation, sensor and actuator placement)
- ✓ Use of new technologies for the protection of critical infrastructures (big data, artificial intelligence, remote control actuators in the network)
- ✓ Improvement of training on decision-making through proposal of procedures, serious games

Thank you for your attention
Any questions?



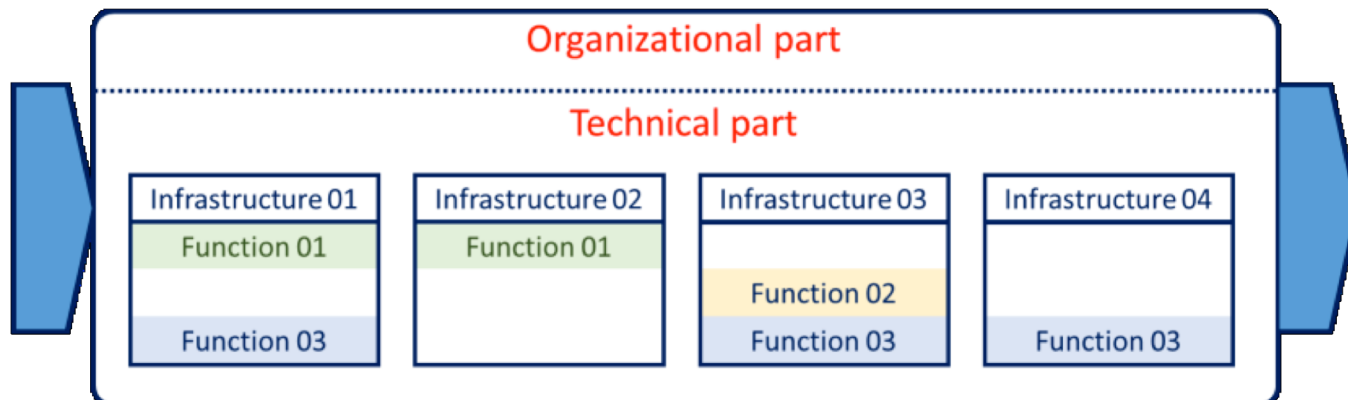
www.resiwater.eu

The resilience framework

VULNERABILITY AND RESILIENCE ASSESSMENT

a WDS is composed of :

- A technical part, described through infrastructures and functions.
- An organizational part (WD utility).

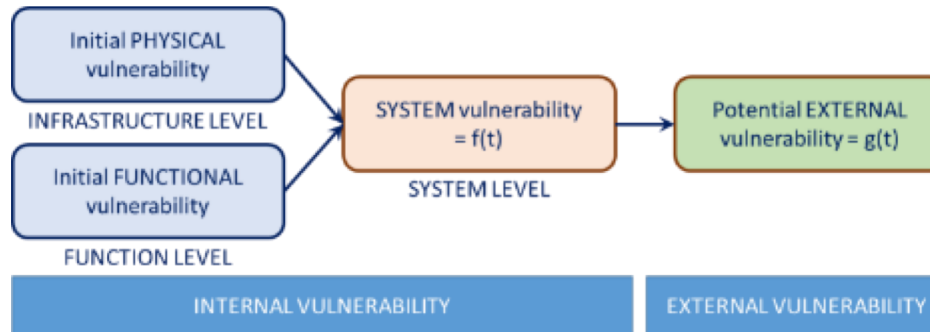


For the present study:

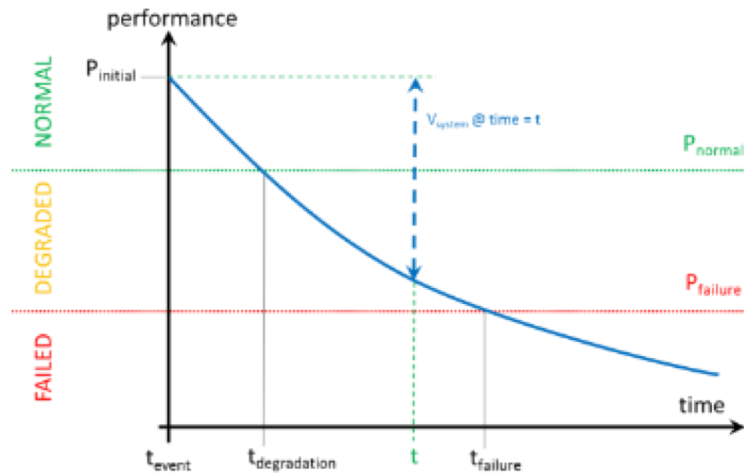
- **VULNERABILITY** concerns the technical part of the system only.
- **RESILIENCE** concerns both the technical and the organizational parts of the system.

The resilience framework

FOUR VULNERABILITY & 3 RESILIENCE COMPONENTS



The 4 vulnerability components in the ResiWater project



Residual performance at time t