



Exploring the Unknown

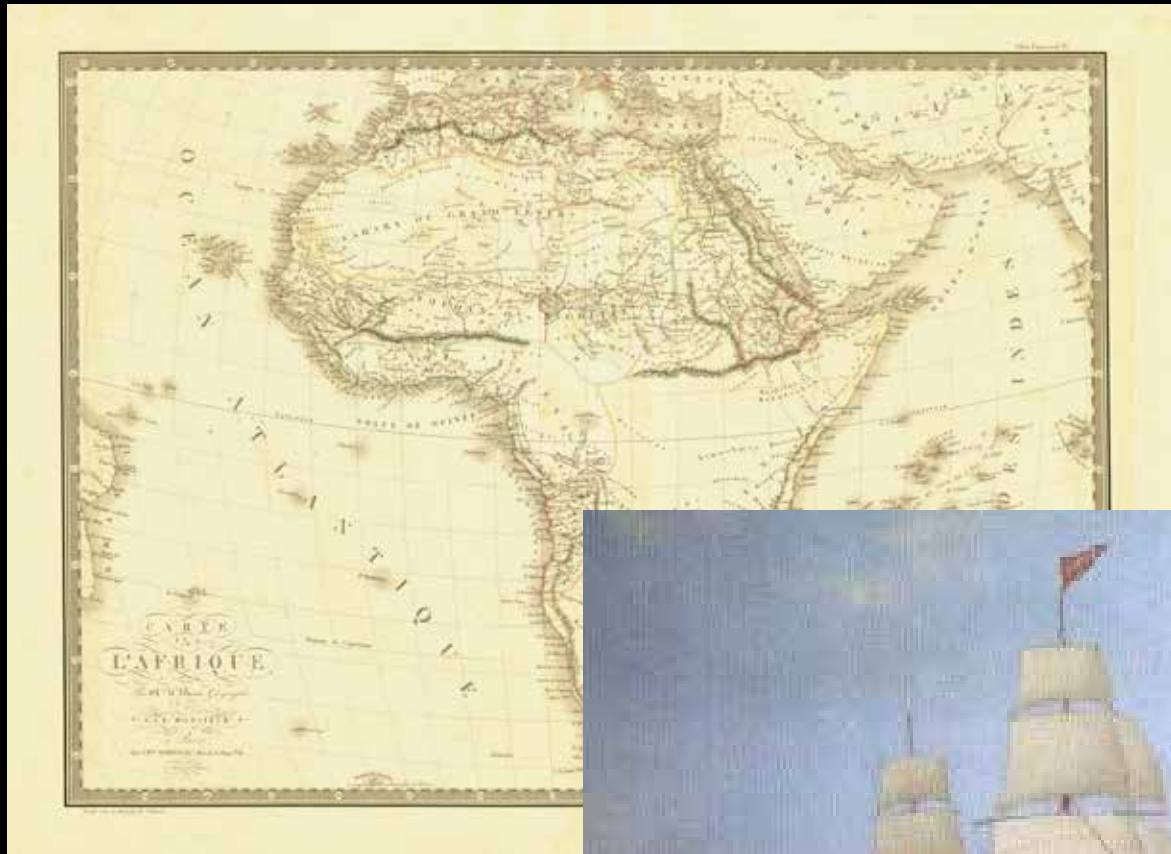
CWT/e Research Retreat 2019

Peter Baltus, 20191009

The Problem

Exploration

is old

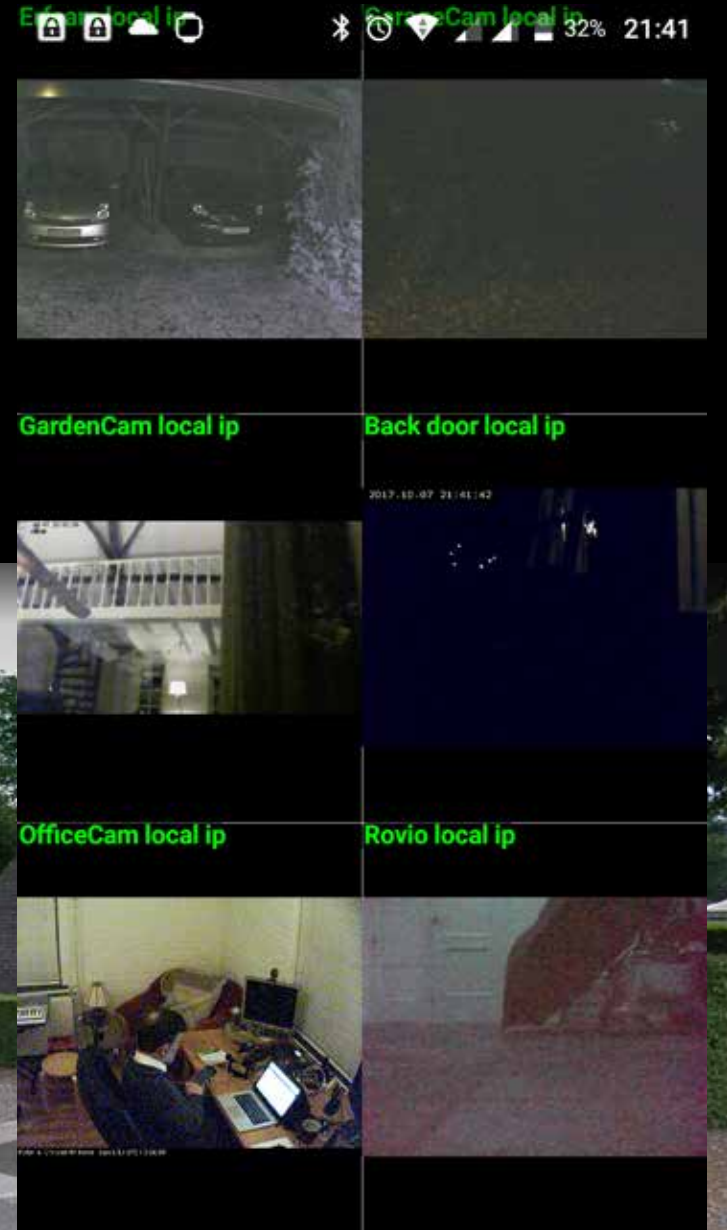


Exploration

is old

The era of adventures

is over



Or is it?

...

What about
“Unknown
environments?”



Is it possible to explore
“Unknown
Environments?”



Existing Solutions:

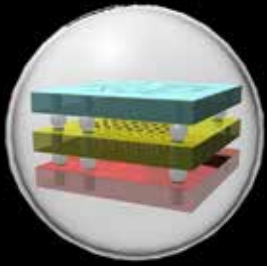
- Modeling
- Imaging (US/THz/X-ray/Optical/...)
- Spectroscopy
- Endoscopy
- Sensors/Sensor Swarms

Sensor Solution:

If Brute Force not Acceptable:

Use Sensor for Exploration

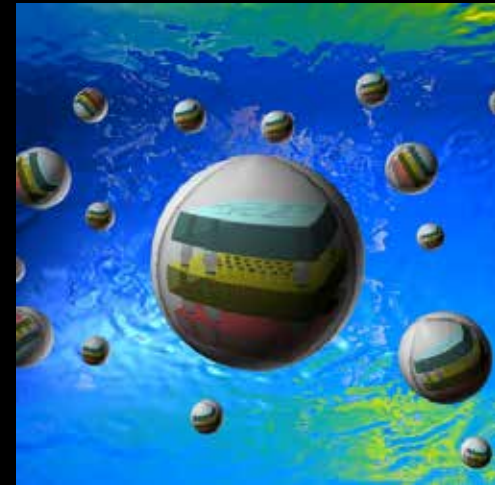
Sensor Design Choices



How often?

How big?

How many?



How expensive?

How heavy?

How accurate?

Which parameters?

How long?

Sensor Problem: Impossible to design Optimum sensor for truly Unknown Environments



The Solution

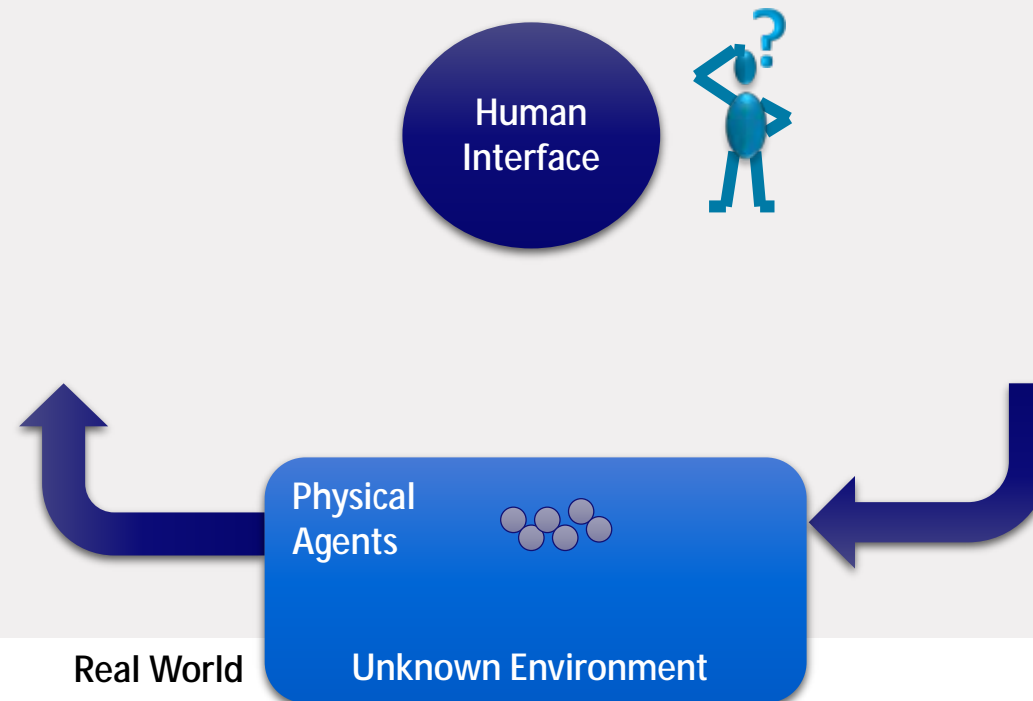


Phoenix Systems Overview

Pose question (top-down)

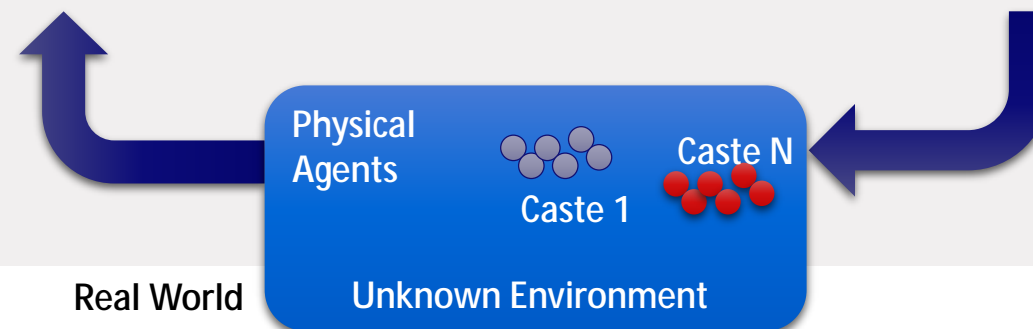
Observe unknown environment (bottom-up)

- Inject agents
- Agents have limited programmability: "instincts"
- Recover subset of agents



Phoenix Systems Overview

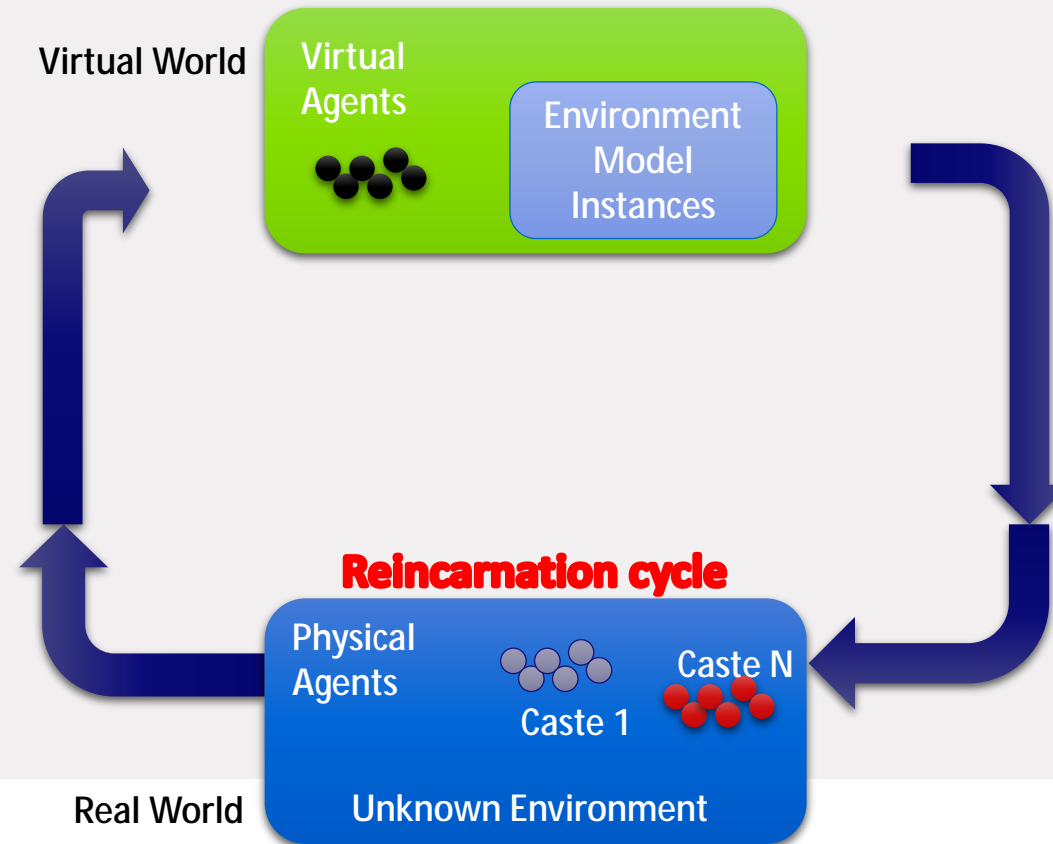
Agents can have different roles: "Caste"



Phoenix Systems Overview

Use virtual world to iteratively:

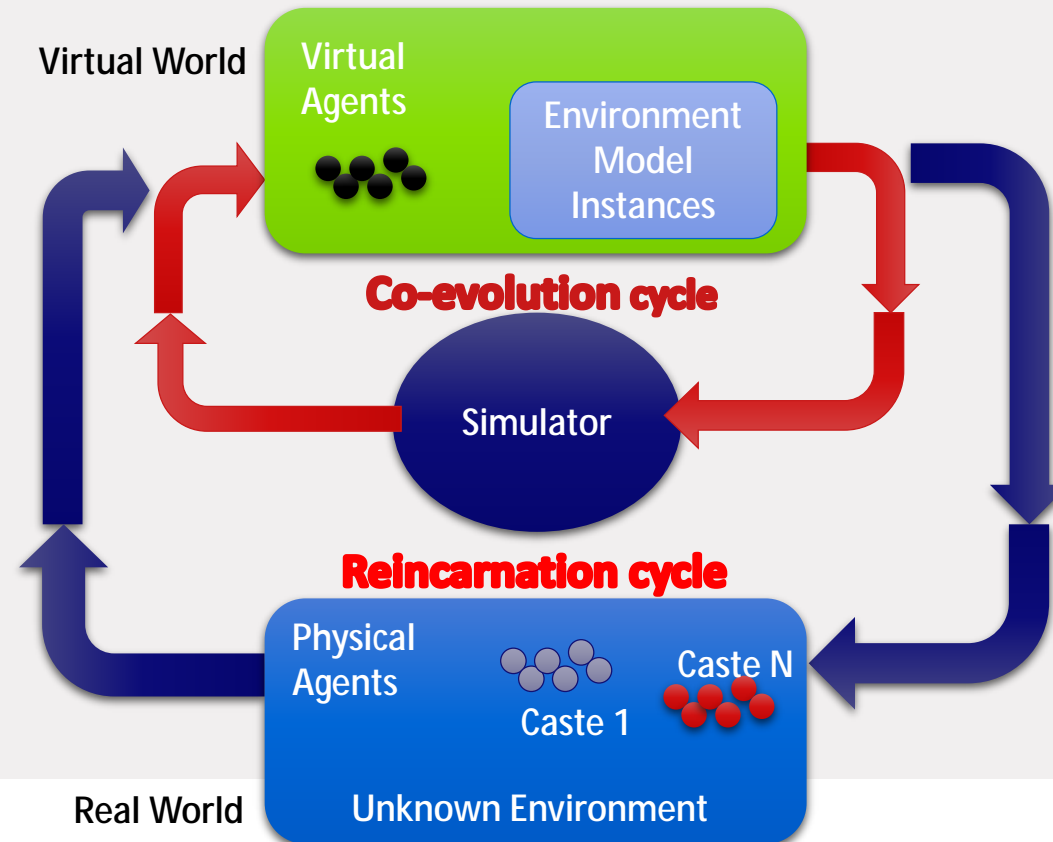
- build & test model
- Optimize (instincts of) agents (“reincarnation”)



Phoenix Systems Overview

Automate model & agent improvement:

- Interleaved Knowledge-driven Co-evolution
- Many Co-evolution cycles interleave with each Reincarnation cycle



Phoenix Systems Overview

Application expert interface to Co-evolution:

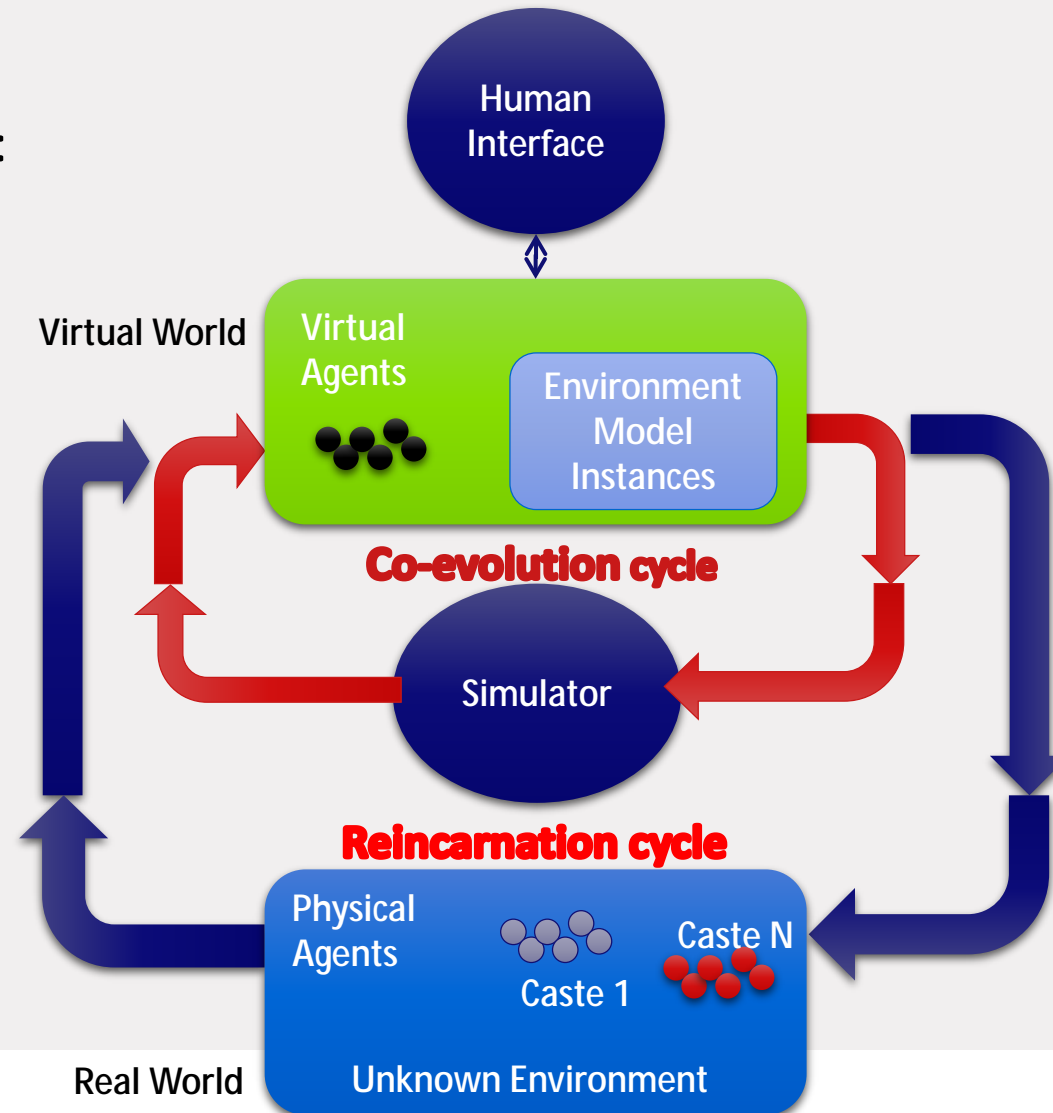
- Questions & answers
- Provide knowledge



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Technology expert interface to Co-evolution:

- Steer evolution
- Define convergence
- Provide knowledge



Research: The Team



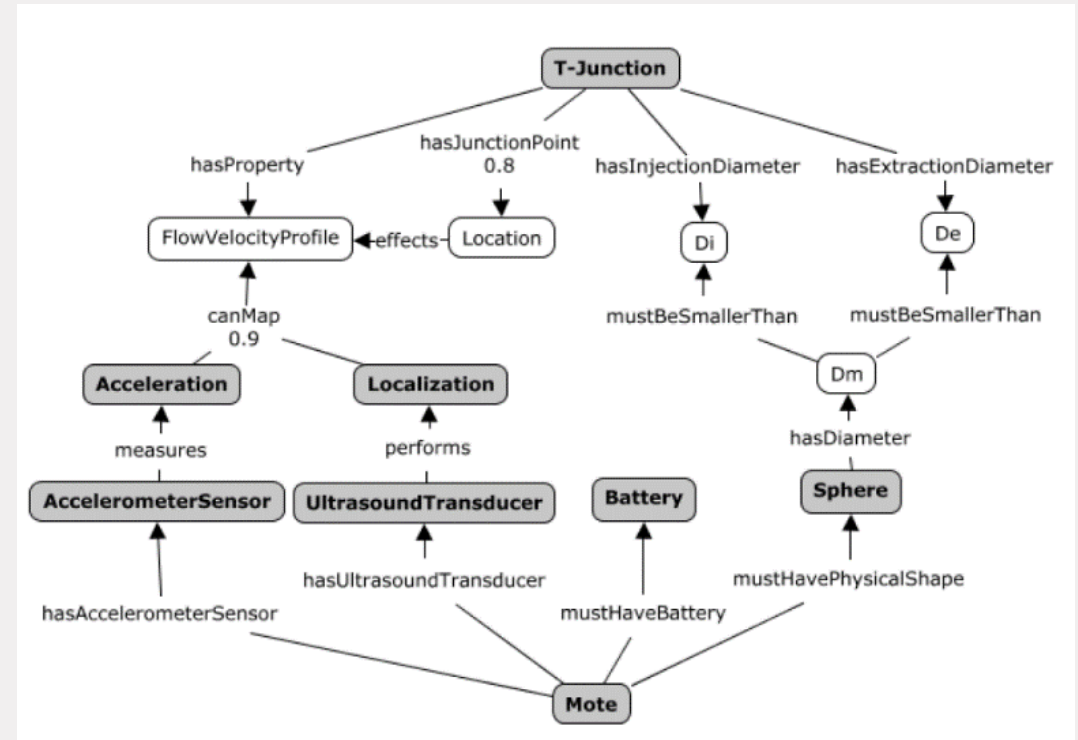
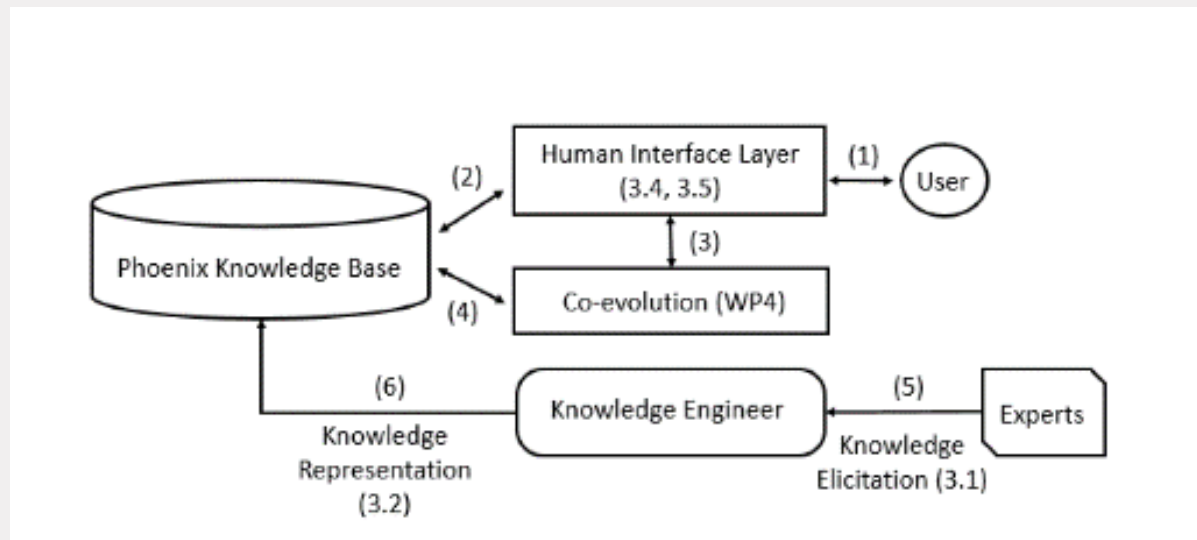
Results: Human Interface



Results: Knowledge Base

Inaccessible & Unknown Environments: à Uncertain knowledge

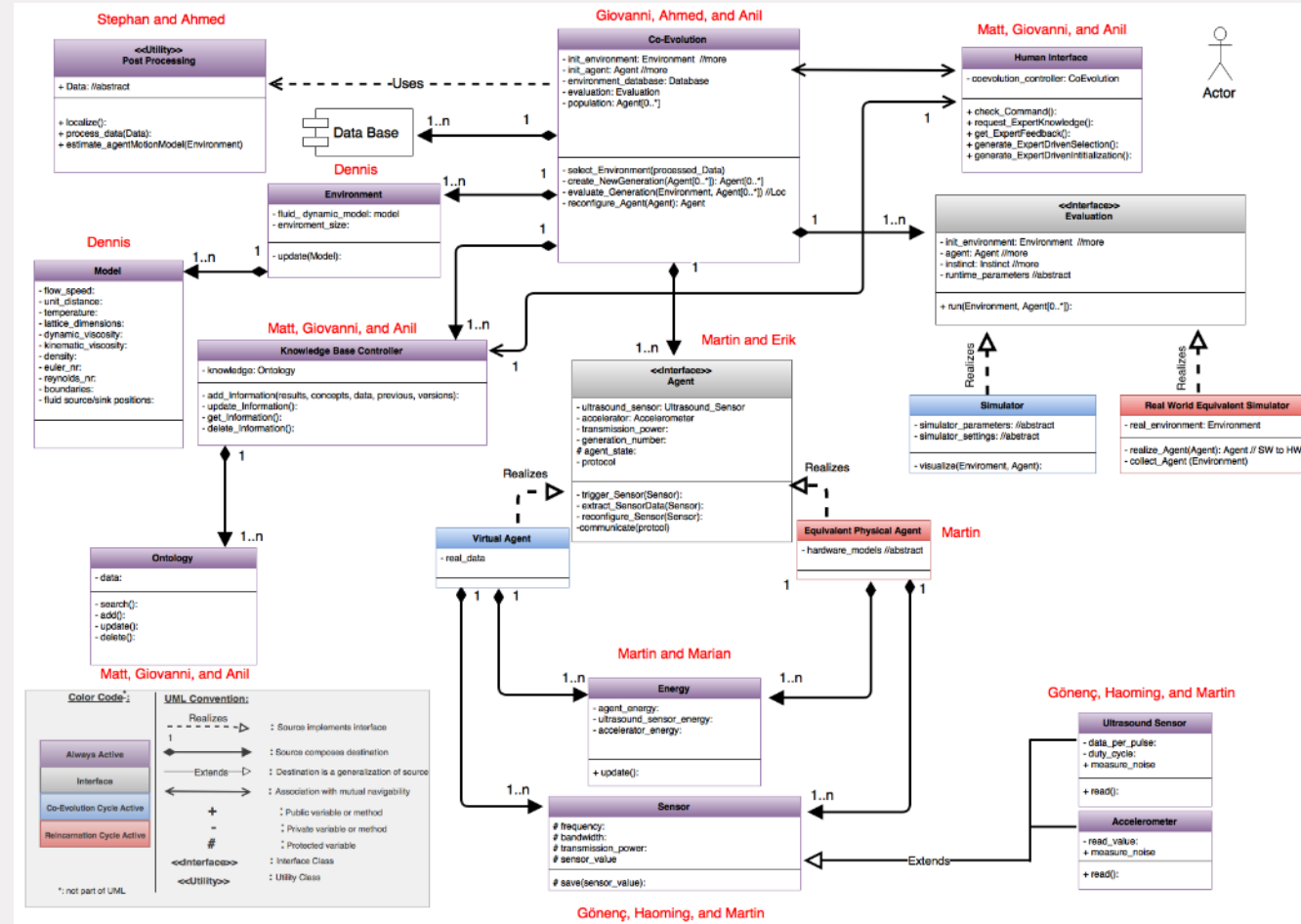
Results:
Methods & software for storing, retrieving
And processing of uncertain knowledge



Results: Co-Evolution

Results: Co-evolution Environment Model & Virtual Motes

Exploration of Library- based Environment simulation



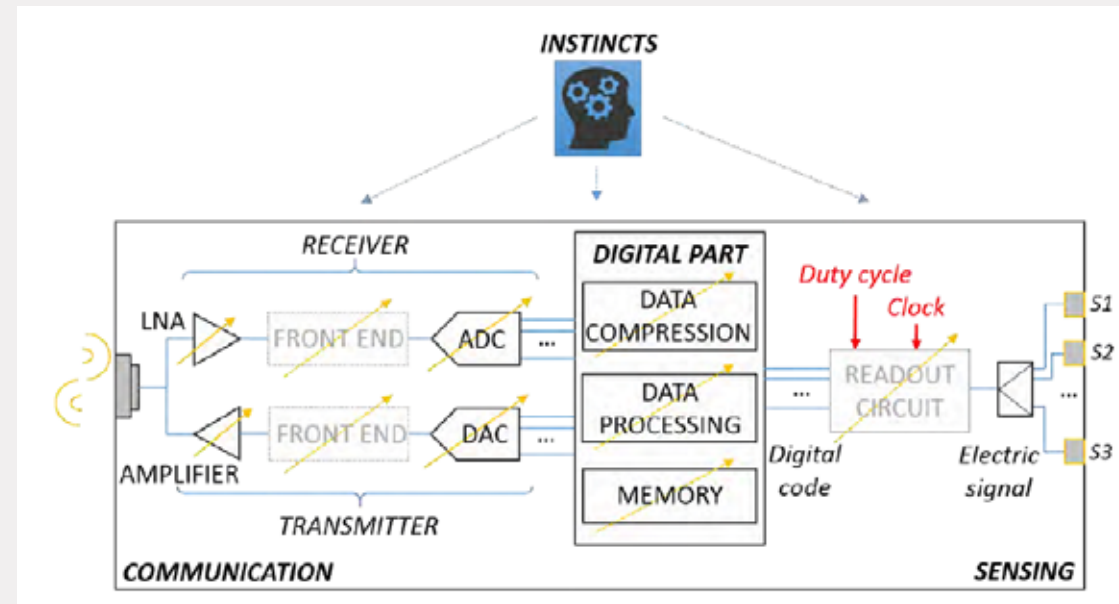
Results: Instincts

Results:

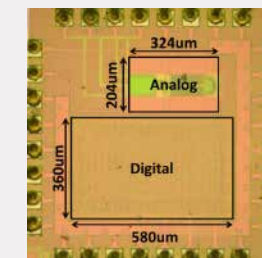
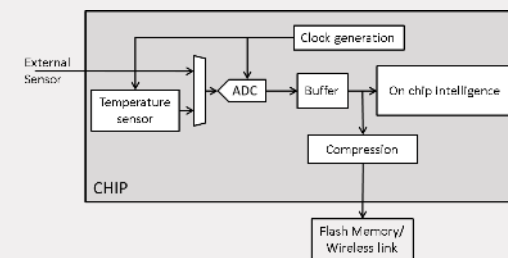
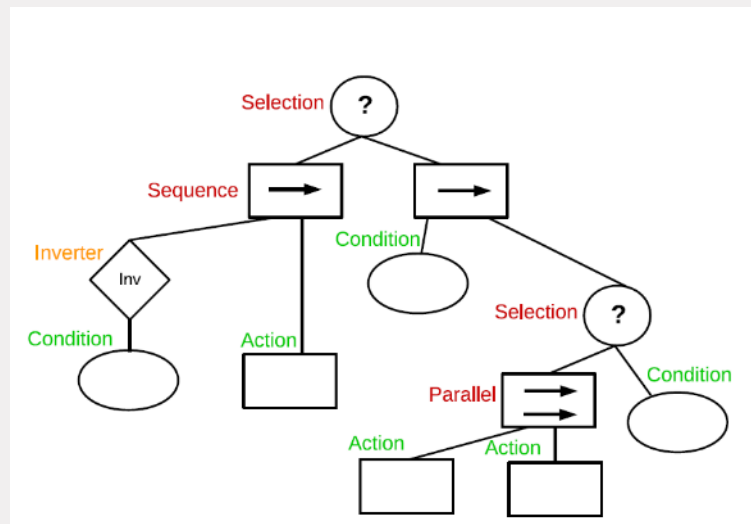
Flexible low-power processing core

Instincts using BT/BN

Low-power robust & evolvable behavior



Digital processing core



Sense and compress, instincts

Results: Sensors

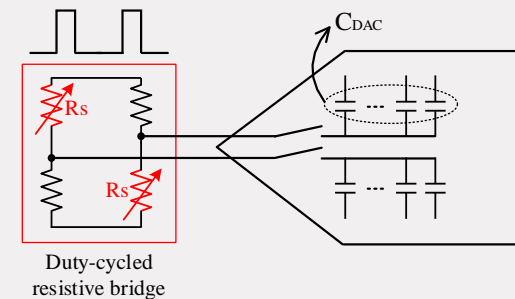
Results:

Extremely low-power flexible sensor interface

Fully integrated

Capacitive & resistive sensors

> 1000x power reduction over existing ICs



Resistive, capacitive, impedance sensors

Results: Motes

Research results:

Many castes: different sensors/memory/etc.

Both motes & critical components for micro



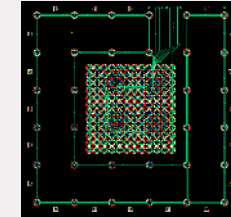
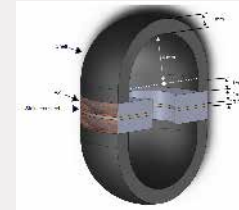
Results: Localization

Results:

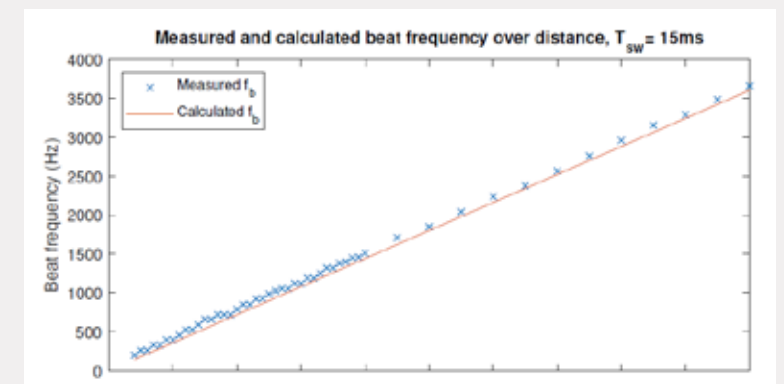
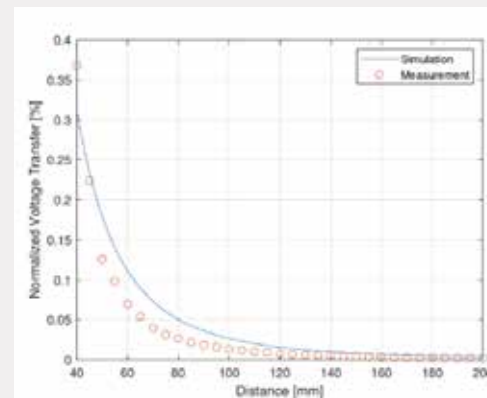
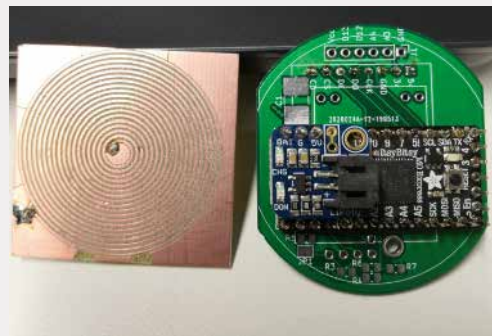
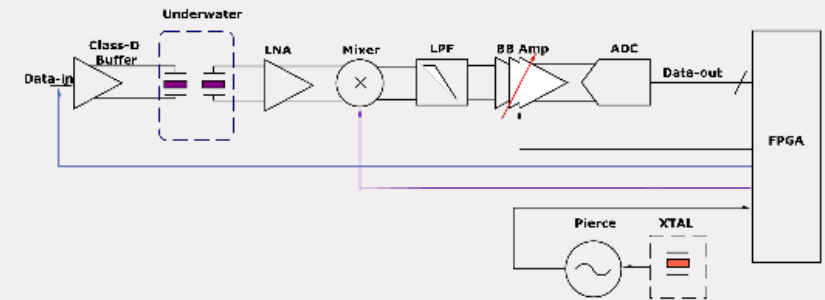
FMCW ultrasound communication/localization technology

Break-through high accuracy inertial navigation

Accurate & low-power NFM communication/localization technology



Ultrasound transducer & transceiver



Results: Evaluation

Result:

Straight line with T-junction test

Set-up (now stored) + data

Simple start

Single, short runs (< 10 s)

Single variable (T-junction)

Constant pressure from buffer

Outside, summer only

Environment gets wet

Scientists/students get wet

Off-the-shelf components: DIY



Results: Evaluation

Results:

Pipeline test

Set-up + data

“Infinite” runs

Random paths

Atmospheric pressure

Speed up to 30cm/sec

Controlled insert/extract

Modular, many variables

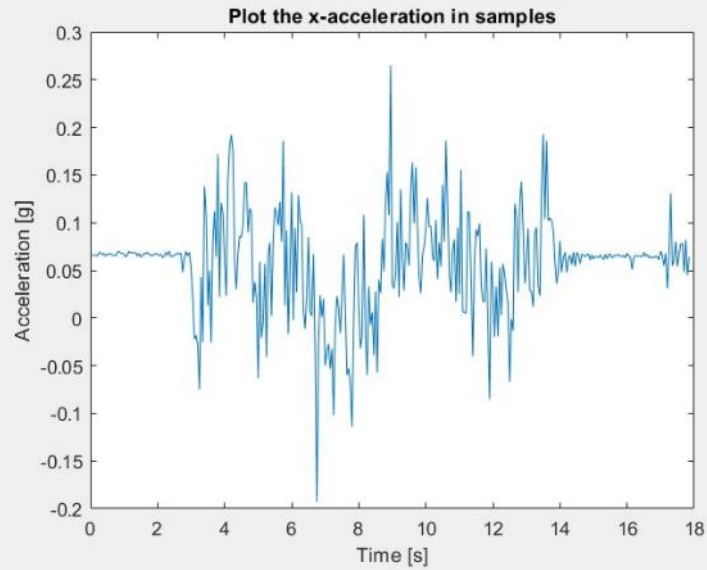
Transparent for ground truth

Off-the-shelf parts: DIY

Scientist & environment
remain dry (mostly)

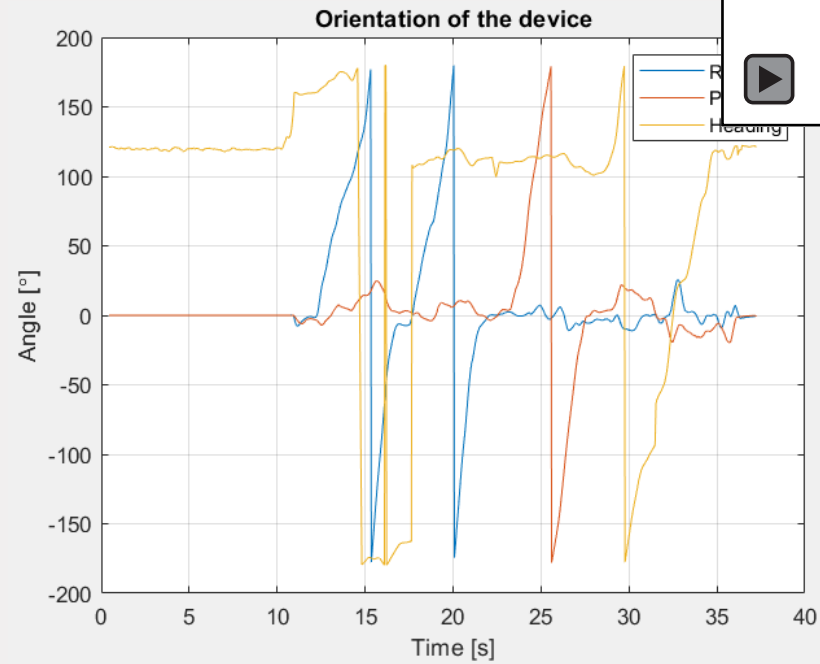


Results: Data



Results:

- Raw data
- Processing
- Analysis



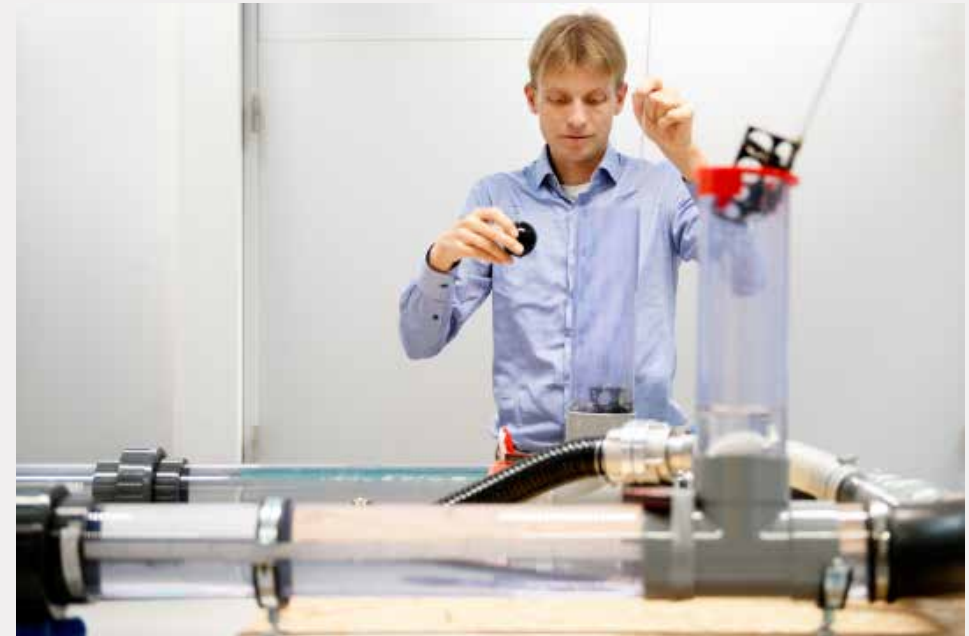
Results: Concept Verification

Demonstrated repeatable performance increase through co-evolution:

- Reconstruct pipe layout pipeloop from inertial navigation sensors
- Accuracy Improvement from ~ 80% to > 90% in 1 loop
- Energy consumption reduction ~ 20% in 1 loop

Through adjustment of instincts for:

- Sensor configuration:
 - Sample rate
 - Resolution
- Data compression



Results: Documentation

Publications

Presentations/workshops

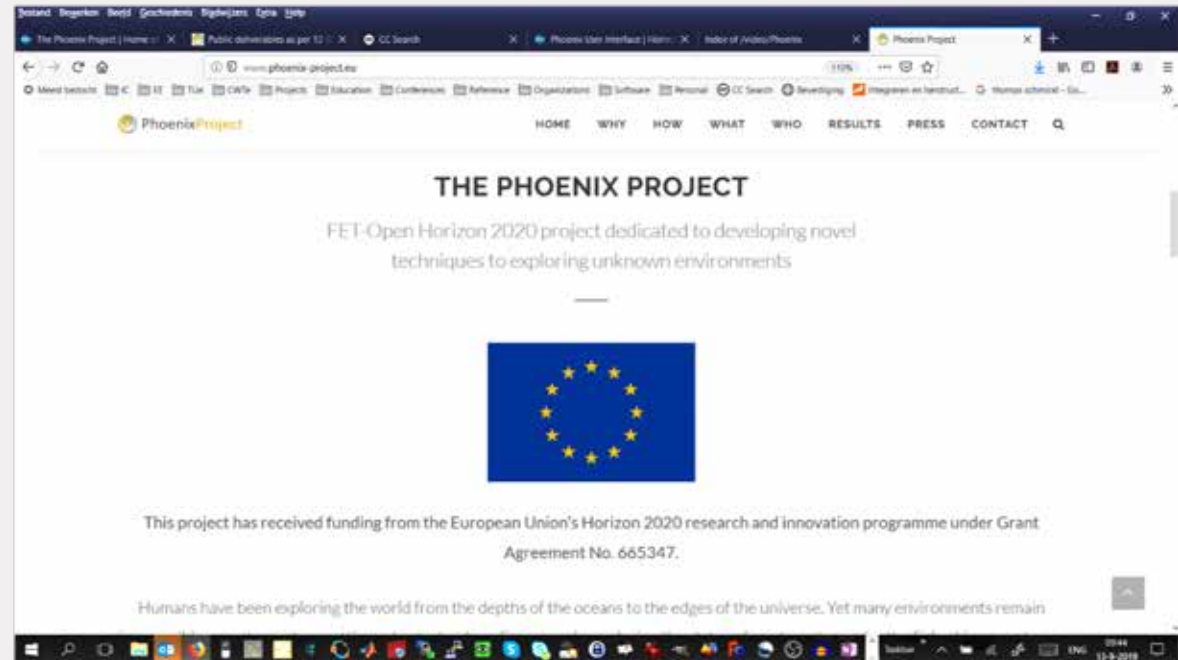
Movies, pictures, data

Designs

Software

All available at website:

<https://www.phoenix-project.eu>



The Applications

Applications

Pipelines



Healthcare



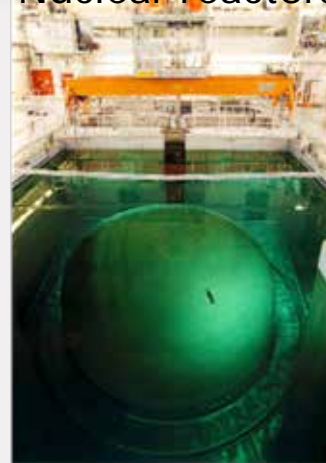
Underground rivers



Mixing reactors

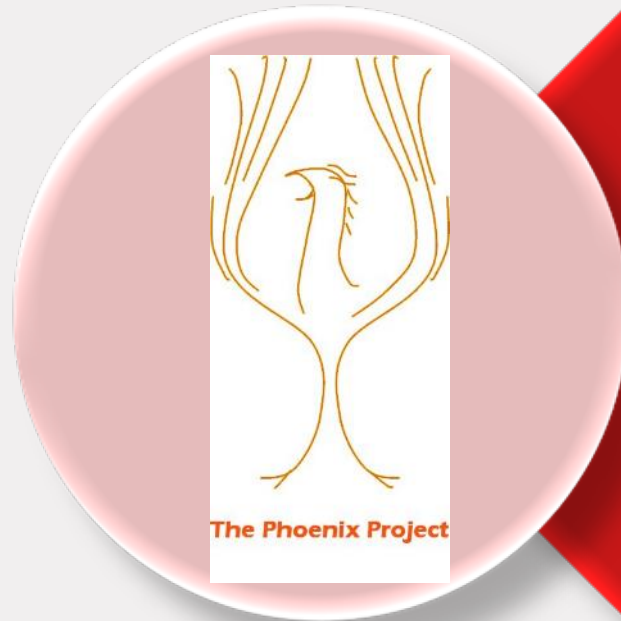


Nuclear reactors



Societal Relevance:

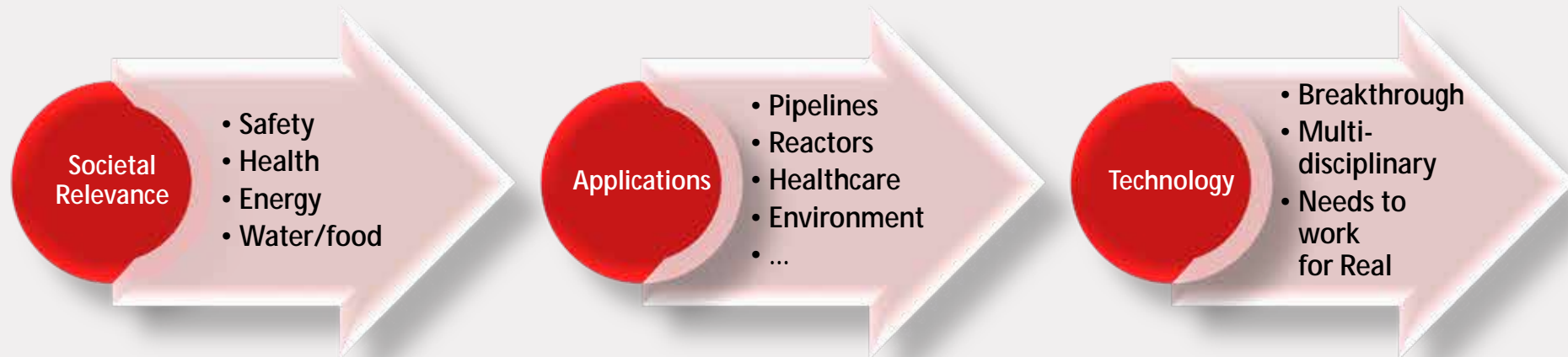
Why these applications?



Addressing primary human needs:

- Safety
- Health
- Energy
- Water/Food

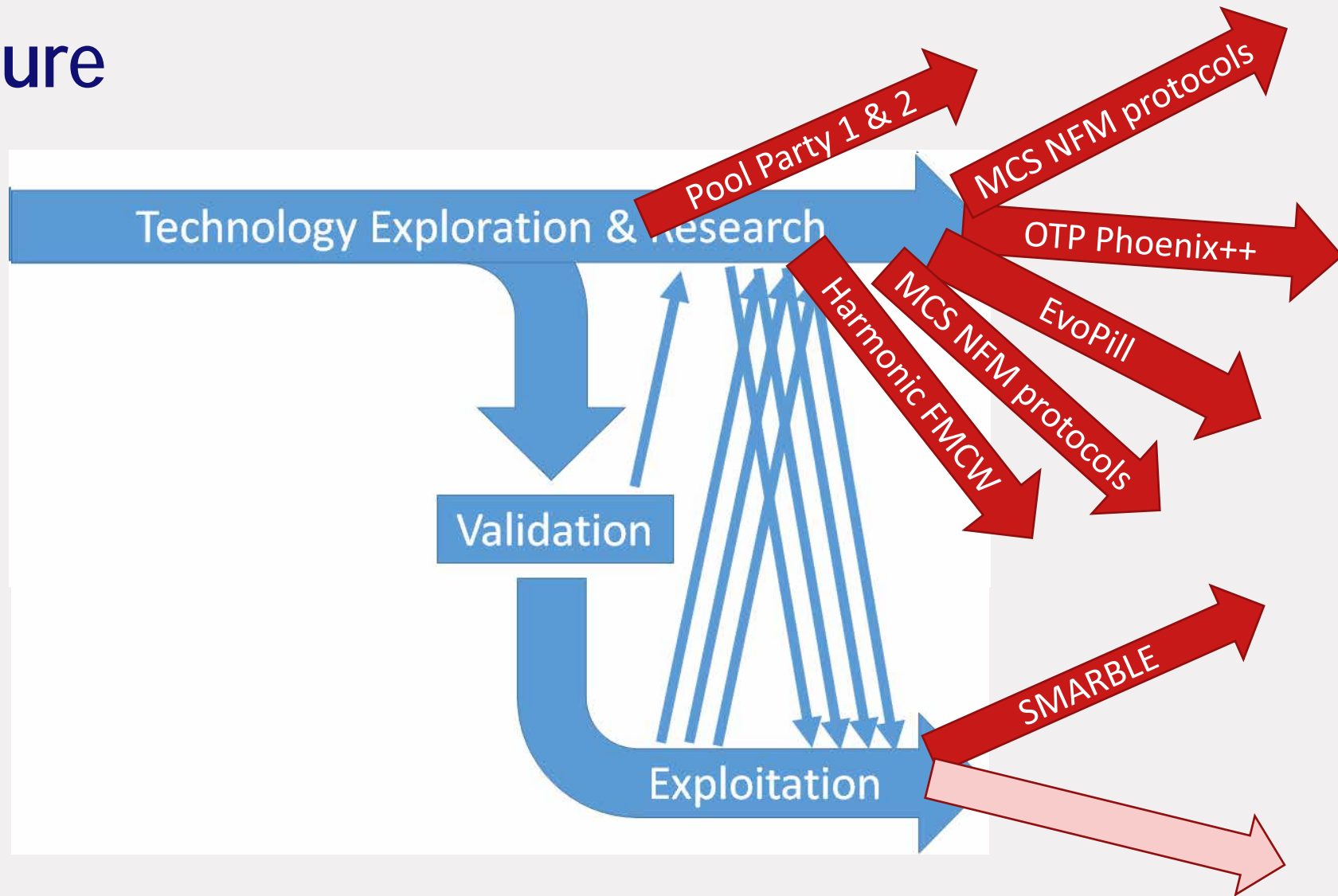
Societal Relevance: Consequence



Needs to work for Real!

The Future

The Future



The Future: Next Steps

Phoenix End-of-Project Outreach:

CWT/e research retreat, Workshop etc.

Background story:

<https://www.tue.nl/nieuws/features/go-with-the-flow-speuren-naar-het-onbekende-met-een-zwerm-slimme-knikkers/>

Finalizing & Releasing Complete Documentation

Research Continuation:

Advanced applications: further miniaturization

Advanced applications: swarms of actuators

Industrialization:

Real-world tests with application partners

Look for “SMARBLE”: <https://www.smarbleproject.eu/>

Bonus: Build your Own Swarm

Software design à Open source

COTS Hardware designs à Open source

Firmware designs à Open source

Mechanical design à Open source

Data à Open source

Released over next month at <https://www.phoenix-project.eu>

Limitations:

- Some commercial libraries, tools used
- IC design library NDAs do not allow making full design database open source



Acknowledgements

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Hilde de Laat

And many, many
others!

The End

Thanks for your attention!

Are there any questions?

Open Invitation:

If you have interesting
applications/problems,

PLEASE CONTACT US!



References & sources

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https://upload.wikimedia.org/wikipedia/commons/9/98/Oil_well_scheme.svg

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