AUTONOMOUS SYSTEMS CONTROL AIDED BY VIRTUAL TELEPORTATION OF REMOTE OPERATOR

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IAV 2022 - 11th IFAC Symposium on Intelligent Autonomous Vehicles, Prague, 6-8.07.2022

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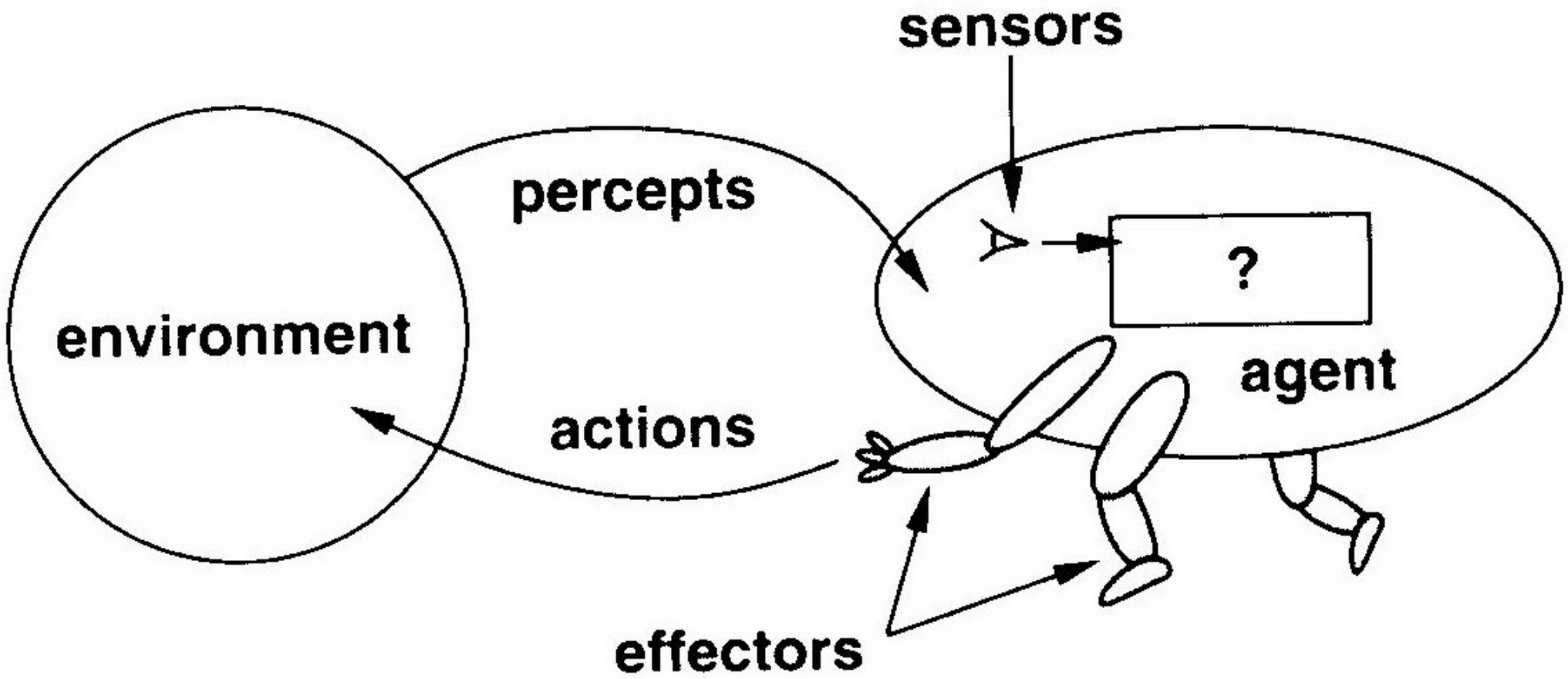
Introduction

Genesis ☺

[John Deere, 2022]

Genesis ☹

An inteligent mobile agent



[Russel & Norvig: Artificial intelligence – A modern approach. Pearson Education, 2016]

Teleportation (H.P.)

(…) you should know what teleportation is. It is the process of disappearing in one place (deportation) and appearing almost immediately in another (apparating). You can learn it at school in the sixth year. It requires concentration and is dangerous.

[https://www.harry-potter.net.pl/Swistoklik-a-teleportacja-i1660.html]

Virtual teleportion

(how we understand and apply it)

What is virtual teleportation (how we understand it)?

VT = Virtual Teleportation is a functionality of innovative user interfaces that allows for full immersion of the user in an environment distant from her/his current location, and thus to create an impression received by the senses of this user, as if she/he was physically present in this environment and could be there personally in a way passive or active to carry out various activities.

In the applications we develop, we use VT on a real time scale!

A bit of history…

2012: Drone Fleet

2013: Adven–ture

2014: TeleRescuer

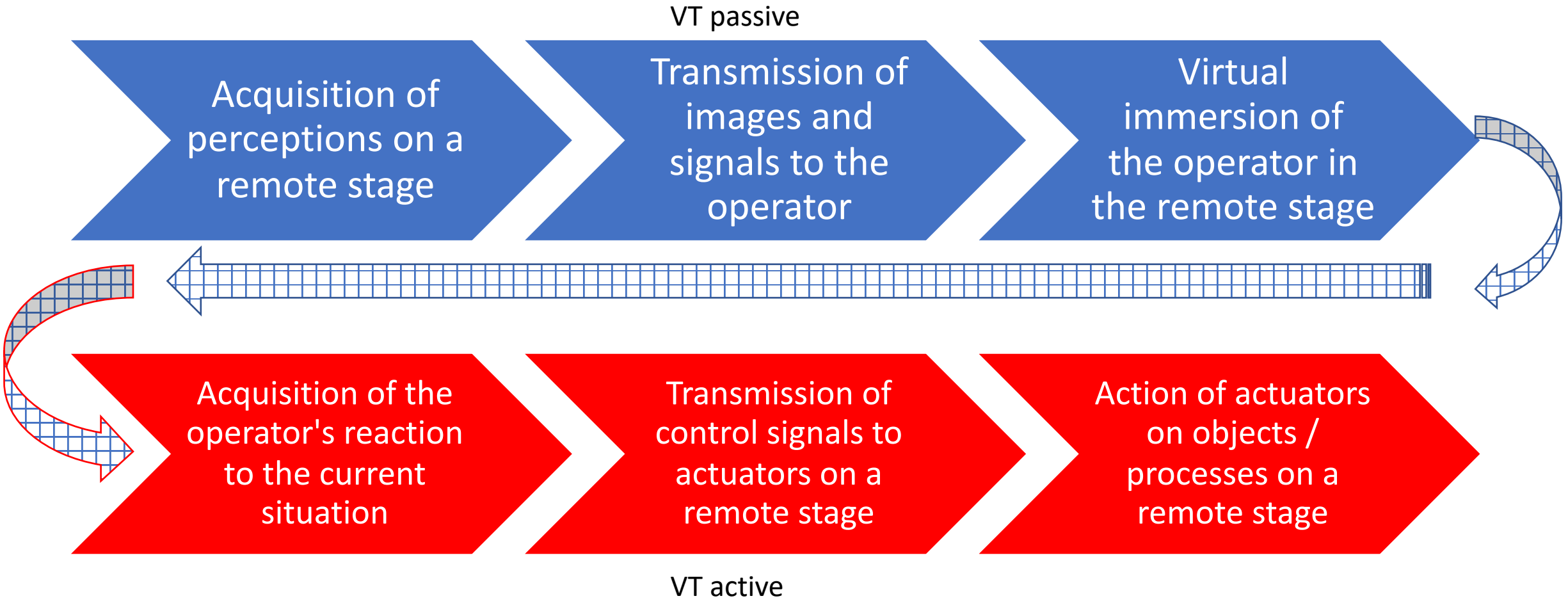
2016: Superior Blimp

2017: ”Railway" patent

2020: Patent RoMoLab

The author of the early conception: dr hab. inż. Krzysztof CYRAN, prof. PŚ
Further development: K. Cyran, W. Moczulski, M. Adamczyk, D. Myszor, M. Paszkuta, T. Rohn, P. Gramała, Ł. Osdarty, …

VT: How to get it?



Acquisition of perceptions on a remote stage

Kind of perception	The form of the data	Acquisition method
Image of the scene and objects	Stereo image	Stereo camera / omnicamera
Sound	Stereo sound	Array of microphones (static / moving)
Fragrances	Components of the vector of fragrances	Fragrances acquisition system
Touch, mechanical resistance	Pressures, forces, ...	Artificial leather, strain gauges
...	...	...

Data transmission (signals / images)

- Wired / wireless transmission
- Wireless transmission range
- Transmission costs
- Delays

Inducing a feeling of immersion in the operator

- Realistic reproduction of signals and images
  - Specialized interface
  - Acceptable delays
  - Teleporting a human to a remote scene requires the use of VR / AR techniques

Acquisition of the operator's reaction to the current situation

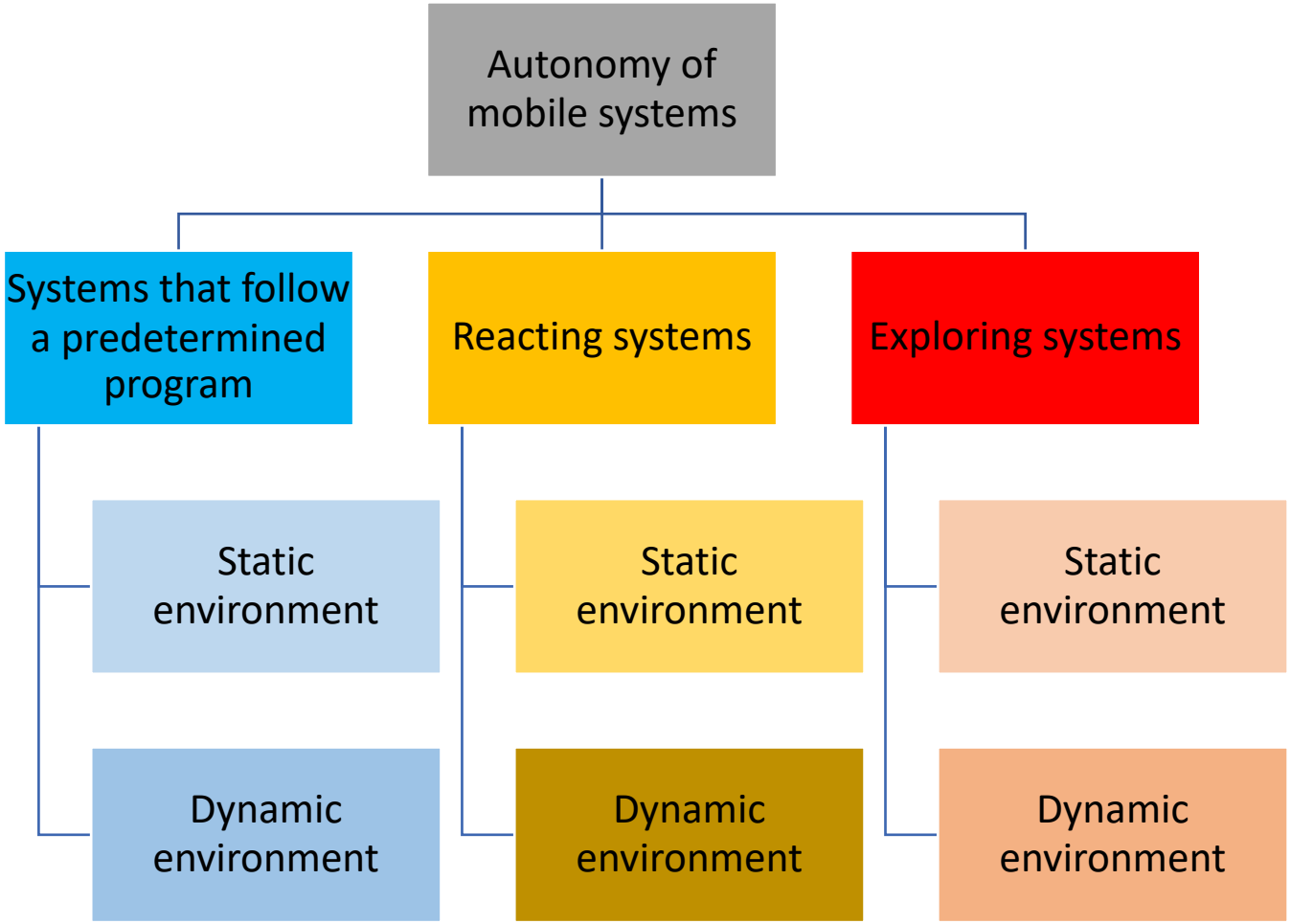
- Use of devices for control
- Use of voice commands and natural language messages
- Use of gestures
- User eye tracking
- Tracking body movements
- Use of facial expressions and other symptoms of the mental state
- …

Autonomy + VT

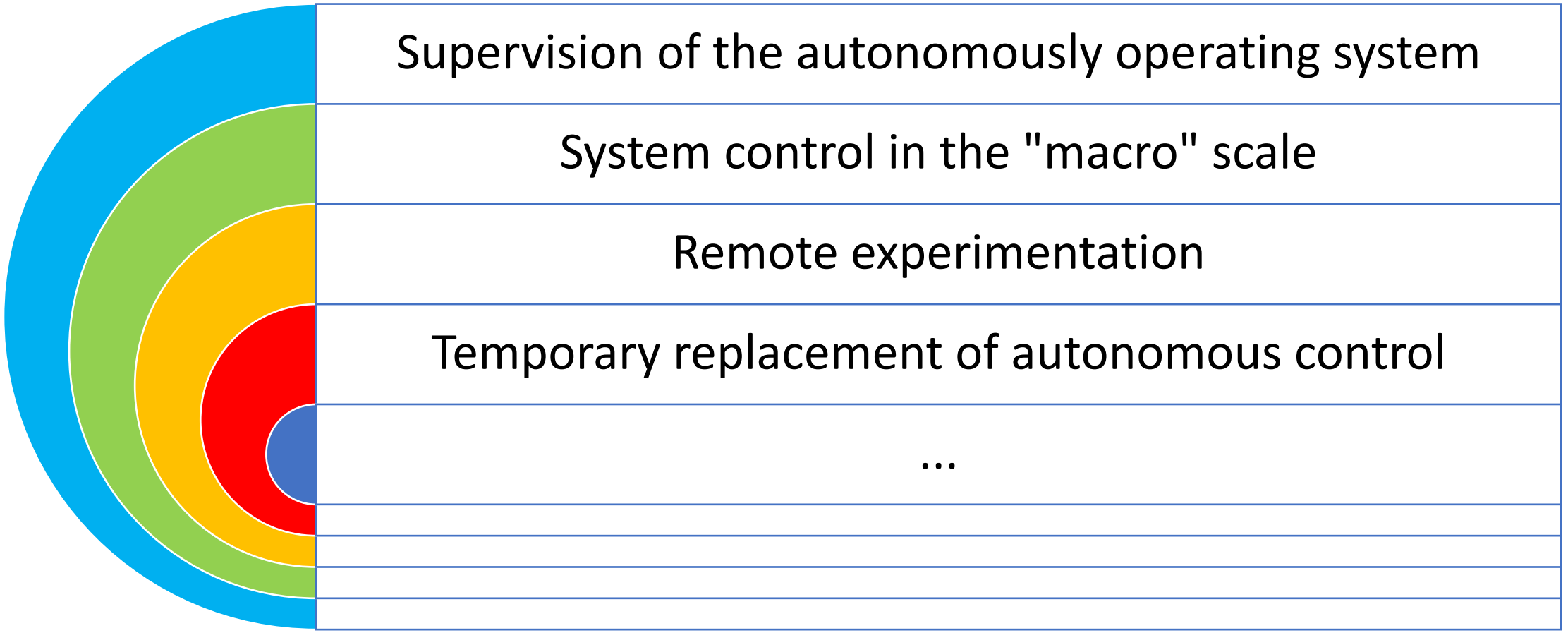
Autonomy – general remarks

- Autonomy applies to each class of automation and robotics systems:
  - Autonomous laboratory system
  - Autonomous agricultural tractor
  - Autonomous UAV
  - Autonomous Mars rover
- In general, autonomy relates to control (extended to decision making)
- In the case of mobile systems, the autonomy takes into account the power supply, the collection of consumption products, etc.

Autonomy of mobile systems

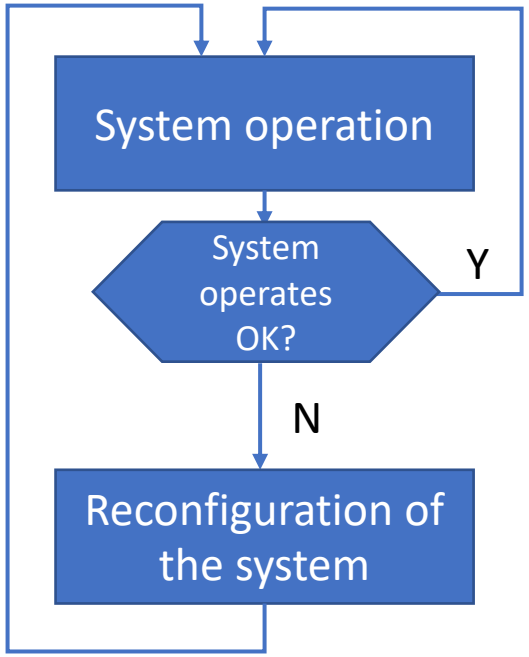


Where is the place for VT?

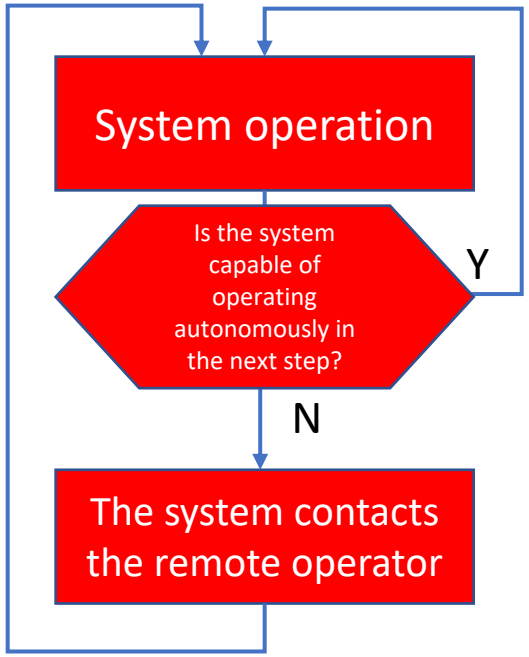


Semi-autonomous vs. Fault-tolerant system

FTS



Autonomous+ VT



Detection of a too difficult situation/problem

General remarks

- A situation / problem that is too difficult to be solved by the autonomous system can be interpreted as a special fault case
- Detection supported by a knowledge base
- Variants:
  - Reactive (the situation I am currently in exceeds the ability of my autonomous control to be solved by its own)
  - Prognostic (the situation I will be in in a moment will exceed the ability of my autonomous control to be solved by its own)

Exemplary solution

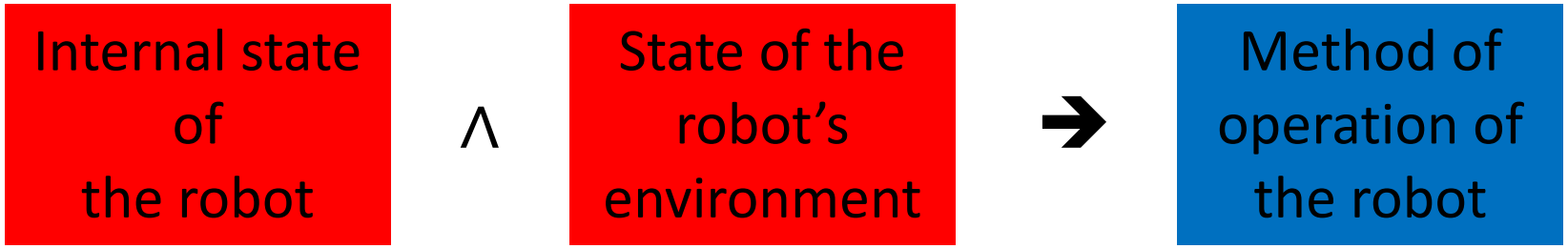
- Expert System with rule-based knowledge base
- Methods:
  - Induction
  - Analogy

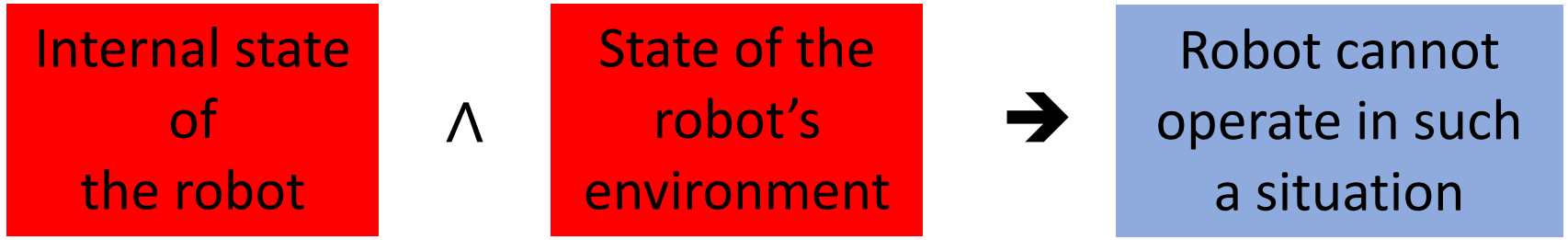
Rules of operation - variant reactive to the internal state

Internal state of the robot → Method of operation of the robot

Internal state of the robot → Robot cannot operate in such a situation

Rules of operation – reactive variant





Rules of operation - prognostic variant

Internal state of the robot ∧ State of the robot's environment ∧ Plan specifies the task to be done → Method of operation of the robot

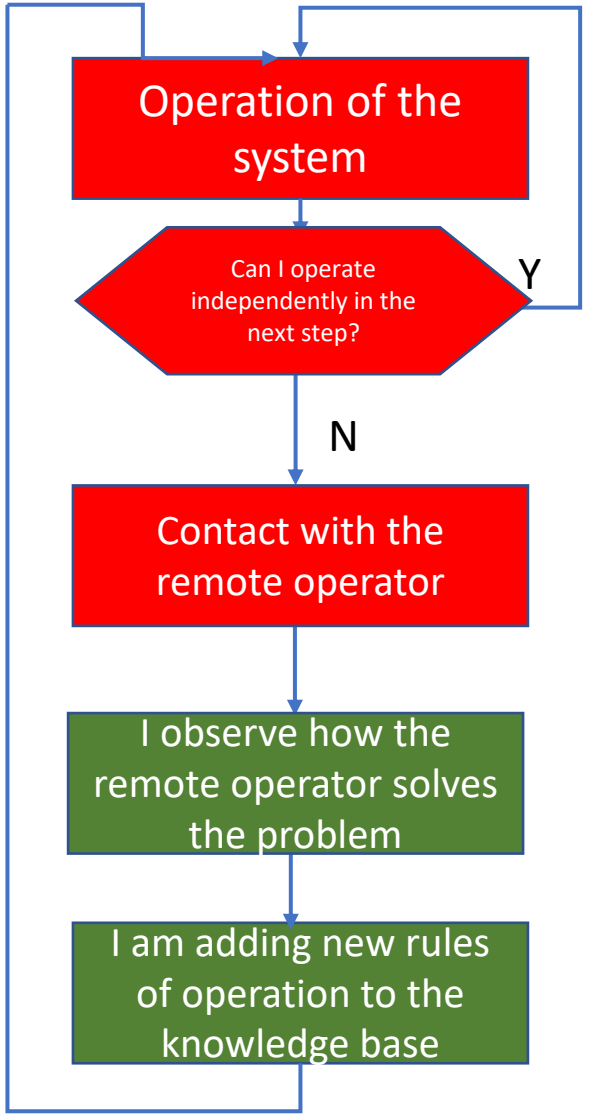
Internal state of the robot ∧ State of the robot's environment ∧ Plan specifies the task to be done → Robot cannot operate in such a situation

General algorithm for detection

```
Data: <CSW=feat. of int. state>, [<CO=feat. of environment>], [<P=plan>]

While(EndOfOperation){
Match=false;
for(RuleID=1,NoOfRules)
if(MATCH(RulePremise[RuleID],CSW,CO,P)) {
       DO_Action(RuleID);          // Action can beCALL_EXT_OPERATOR
       UPDATE(CSW, CO);
       Match=true;
       break;
       }
if( ¬ Match) CALL_EXT_OPERATOR;
}
```

Learning system



Examples of application

Adventure – FP7 (2013)

Advent of virtual teleportation technology – experimental research on system for safe guidance and flight control during critical operations of a fleet of full-scale unmanned aircrafts of the future

Proposal acronym: Adventure

Work programme topics addressed:

ACTIVITY 7.1.6. PIONEERING THE AIR TRANSPORT OF THE FUTURE

AAT.2012.6.3-1. Breakthrough and emerging technologies

Level 0 - CP-FP - Call: FP7-AAT-2012-RTD-L0

TeleRescuer – RFCS (2014-2017)

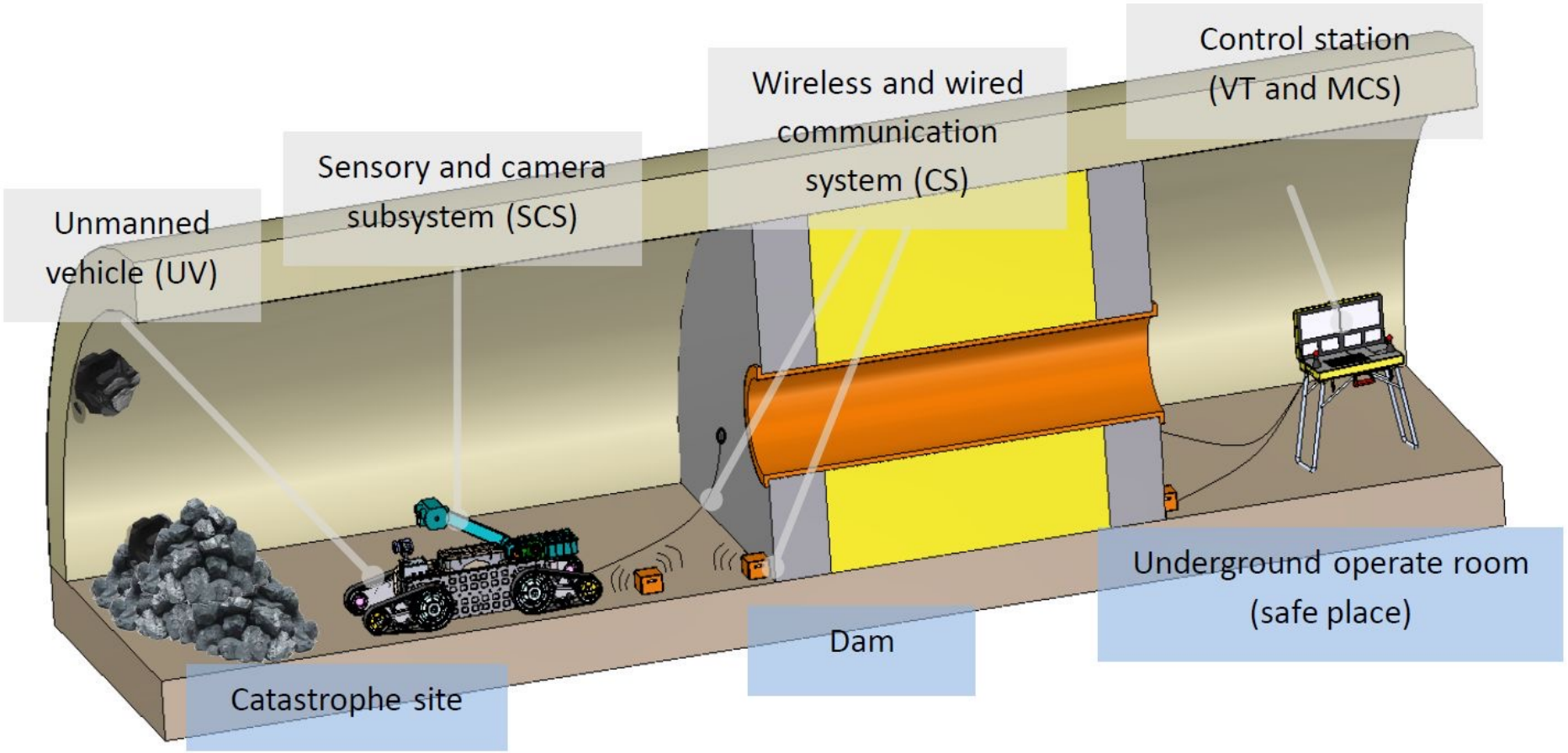
System for virtual TELEportation of RESCUER for inspecting coal mine areas affected by catastrophic events

Proposal acronym: TeleRescuer

Research Programme of the Research Fund for Coal and Steel

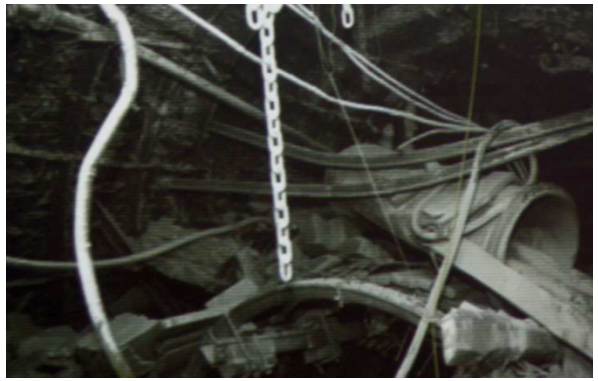
Technical Group: TGC1

TeleRescuer – General idea



TeleRescuer – operational scene for mobile agent

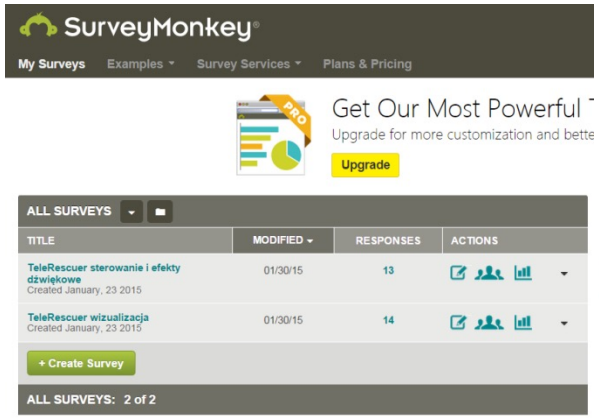
- Inaccessible and dangerous to humans
  - High temperatures
  - Explosive atmosphere
  - Poisson gases
- Obstacles difficult to traverse
- Limited range of wireless communication
- Area closed by a dam



TeleRescuer – Vision system

TeleRescuer – Operator’s station (VT)

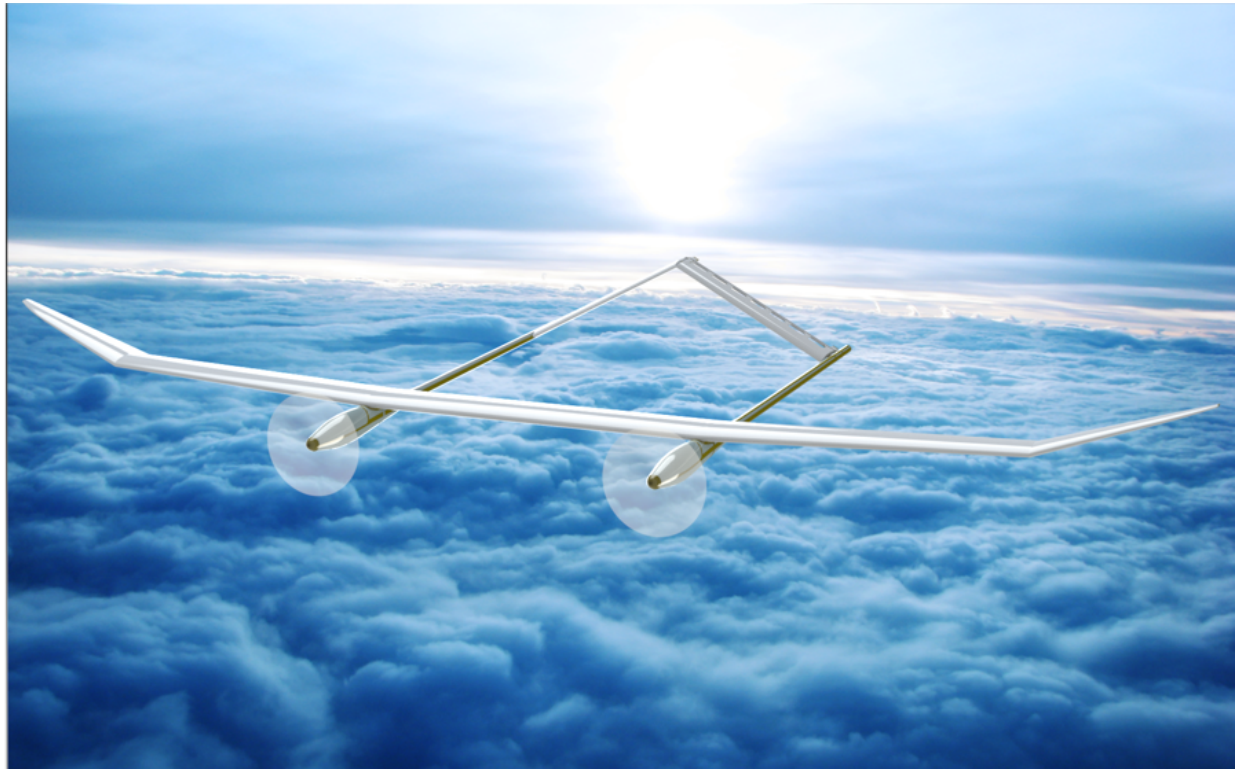
TeleRescuer – Operator's station (VT)



Survey Monkey – tool for creation of survey (left);
Slide taken from one of surveys that were prepared (right)

Example: BSP TwinStratos®

- Implementation of the flight plan in accordance with the optimal mission plan
- Autonomous flight execution with dynamic path planning
- Takeover of UAV control during landing approach
- Problem: very low bandwidth of the communication channel (Iridium - satellite communication)



Detection of difficult cases

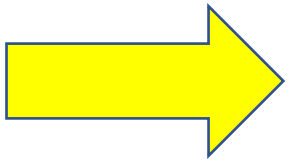
- Rule-based
- Rules of operation:
  if <premise> **then** <operation>
- To speed up finding the right rule (or concluding, that there is no matching rule) – rules are grouped in contexts

Exemplary contexts:

- *TakeOff*
- *FlightToWaypoint*
- *SideWind*
- *SuddenDescending*
- *ScheduledLanding*
- *EmergencyLnading*
- others

Example of swithing to Remote Control

- Context: *EmergencyLanding*
- Wideband duplex communication available
- Before landing the drone inspects the unknown terrain and detects that the terrain is covered by bushes and trees
- At the landing path there is strong sidewind



Conclusion:
call the Remote Operator to take over the control

Concluding remarks

Regarding the idea of VT

- VT is a significant know-how of AuRoVT sp.z o.o (former SkyTech Research sp.z o.o.)
- The idea of VT seems to be (still) futuristic
- The pace of innovation in everyday life reinforces the belief that VT will play an increasingly important role in practical applications

Regarding the implementation of VT systems

- AuRoVT sp.z o.o (former SkyTech Research sp.z o.o.) has significant achievements in research on VT systems
- AuRoVT sp. Z o.o. effectively cooperates with the Silesian University of Technology in the field of implementing ICT systems that use VT
- The development of VT systems requires interdisciplinary research in the field of:
  - Mechatronic systems (sensors, actuators, peripherals)
  - Communication systems
  - Vision systems (stereovision, omnivision, fusion of vision and IR, ...)
  - Artificial intelligence (building knowledge bases)
  - ICT systems

Regarding the construction of autonomous systems supported by VT

- Building a knowledge base enabling autonomous operation in the vast majority of cases
- The "ability" to independently detect a situation, the solution of which "exceeds" the capabilities of the autonomous system
- Ensuring reliable communication
- Resolving the situation when communication with the remote operator is impossible

Research and implementation problems to be solved in the future!

Acknowledgements

This research was partially supported by:

- The Research Fund for Coal and Steel – in the framework of the project RFCR-CT-2014-00002 TeleRescuer „System for virtual TELEportation of RESCUER for inspecting coal mine areas affected by catastrophic events” (SkyTech Research – now AuRoVT)
- The Ministry os Science and Higher Education - Partial financing of the project TeleRescuer – grant 3120/FBWS/2014/2
- The Norwegian Financial Mechanism POLNOR „Applied Research” – in the framework of the project LEADER „Long-endurance UAV for collecting air quality data with high spatial and temporal resolutions” - grant NOR/POLNOR/LEPolUAV/0066/2019-00
- The Silesian University of Technology – in the framework of the own research

THANK YOU FOR YOUR ATTENTION

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