Institute of Flight Systems
Aircraft Dynamics & Flight Guidance

RAID

Responding with AI-planning to Disasters

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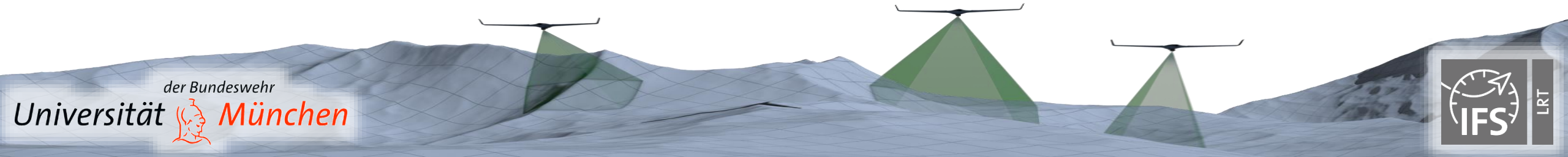


der Bundeswehr
Universität München

Motivations

Background:
- Increasing losses and fatalities due to man-made and climate-related natural disasters

	Today	2100 - no adaptation		
		1.5°C	2°C	3°C
Damage (€ billion/year)	7.8	24	33	48
People exposed (1000/year)	172	252	338	482

Annual flood damage and population exposed to river flooding in Europe by 2100 for different levels of global warming

Annual damage and population exposed to coastal flooding in Europe by 2100 for different emissions scenarios

	Today	High emissions		Moderate mitigation	
		No adapt	Adapt	No adapt	Adapt
Damage (€ billion/year)	1.4	239	23	111	12
People exposed (million/year)	0.1	2.2	0.8	1.4	0.6

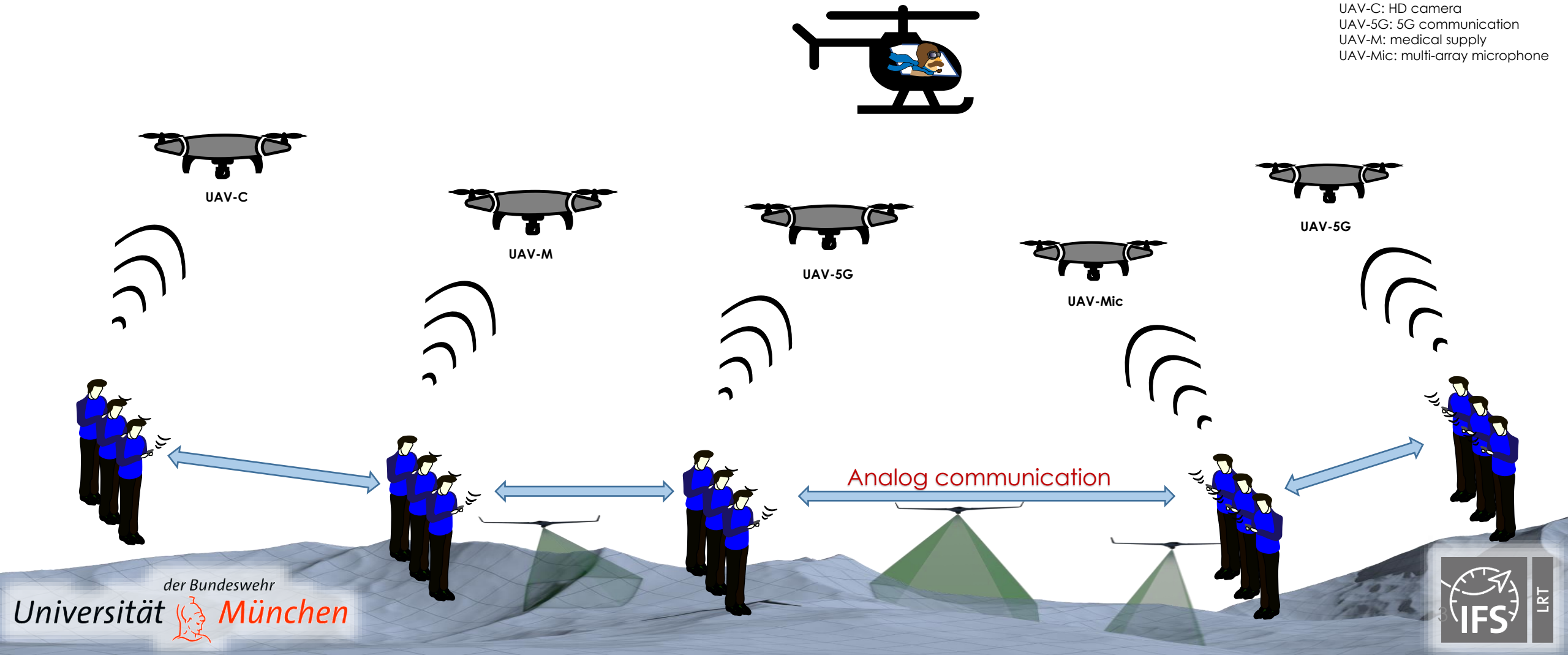
Sources: Feyen L., Ciscar J.C., Gosling S., Ibarreta D., Soria A. (editors) (2020). *Climate change impacts and adaptation in Europe*. JRC PESETA IV final report. EUR 30180EN, Publications Office of the European Union, Luxembourg.

Motivations

Challenges

- SAR in large areas (coastal areas, mountains)
- Rescue operations in inaccessible urban areas

UAV mission payload
UAV-C: HD camera
UAV-5G: 5G communication
UAV-M: medical supply
UAV-Mic: multi-array microphone



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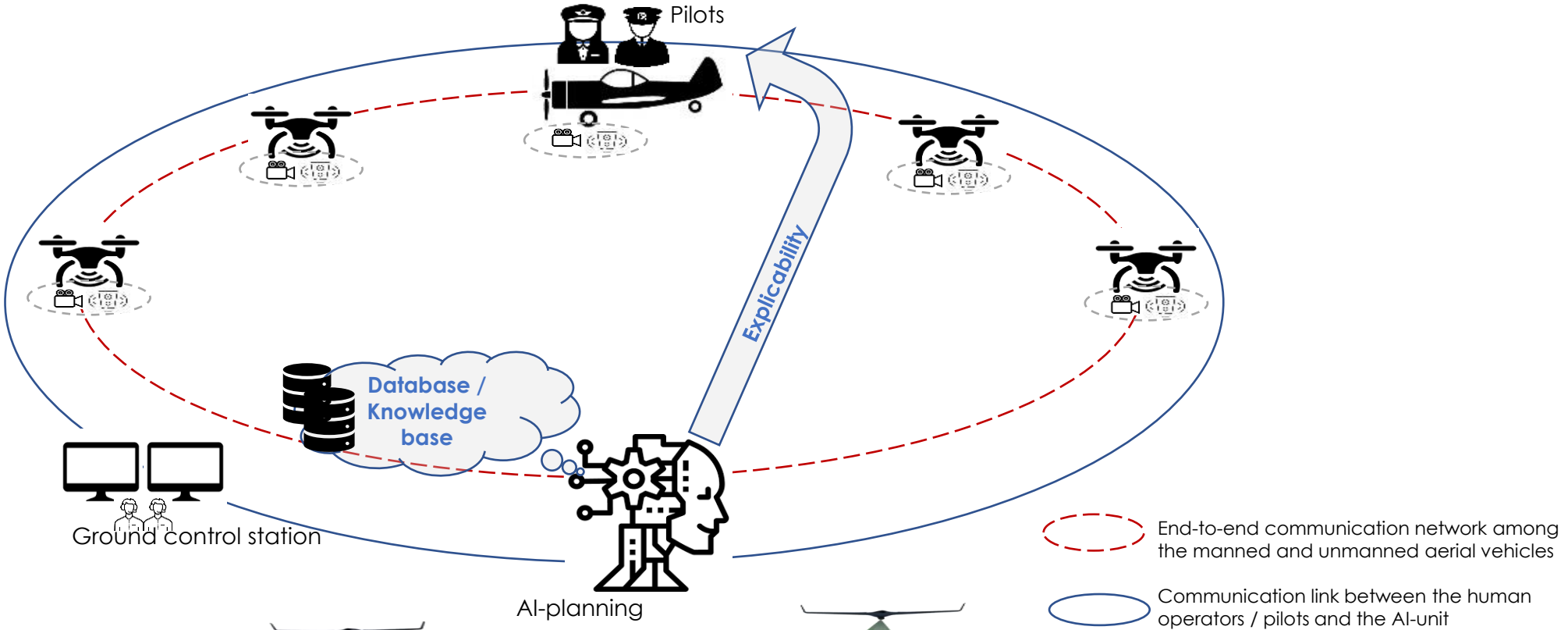

Motivations

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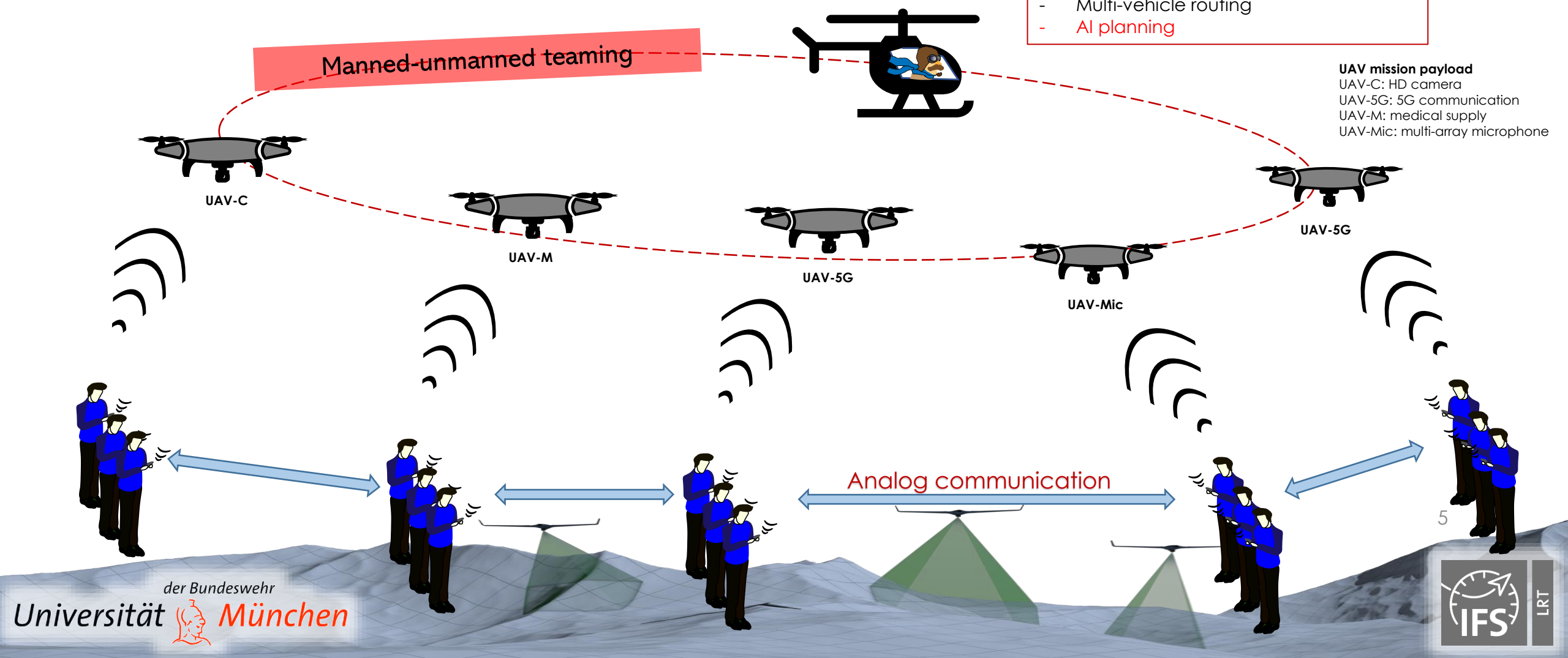
Highly automated decision-making support
- Human-machine interface
- Motion planning
- Multi-vehicle routing
- AI planning



Key problems in planning

Key Problem 1: Time Dependency

- Goals are time-dependent.
- The duration of a task or an action can only be (probabilistically) estimated at planning time.

Key Problem 2: High-Level Task and Motion Planning

- The status quo deals only with very high-level tasks or strategies.
- To automatize the system, the high-level tasks must be decomposed into lower-level ones
- Motion planning for unmanned vehicles is also necessary.
- The executability of the plans depends on the plan refinement.

Key Problem 3: Diverse Forms of Goals and Objectives

- Goals can be a (temporal) state to reach or a task to achieve (within a time window).
- Rewards and costs associated to the tasks / actions are to be considered as objectives to optimize.
- The importance of an objective wrt another can vary and often, the priority is decided by the human operator.

Key Problem 4: Continuous Planning and Plan Monitoring

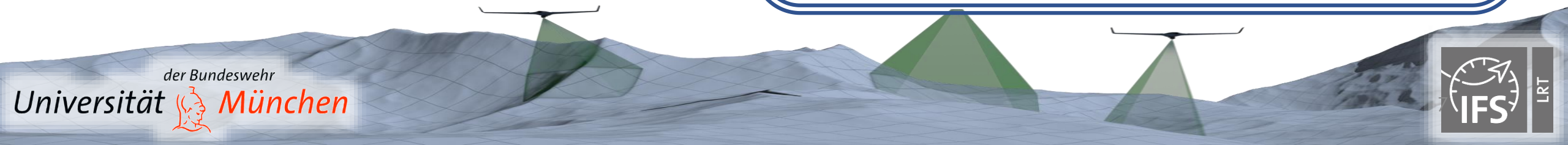
- Computed plans may not be valid given continuous observations obtained during execution in the dynamic environment.
- A local plan repair, instead of a replanning, is preferred, since reorganizing assets of first responders in a disaster area can be problematic.

Key problems in planning: Planning in the Workflow

Standard operating procedure governs the initial plan, which is often articulated using very high level tasks (strategies) by the human operators.

The environment will be observed continuously to refine the very high level tasks (strategies), to validate plans, and to repair plans.

During plan execution, a human operator can always invoke a replanning or intervene with a plan repair.



Impacts: Business Impacts

1. Reduce operating cost and time of first responder
   Target group(s): practitioners
2. Reduce risks and fatalities for citizens
   Target group(s): insurance companies, municipalities
3. Reduce damage on critical infrastructure
   Target group(s): operators of the infrastructure, municipalities / government
4. Digitization of information and automation
   Target groups(s): private sectors, practitioners

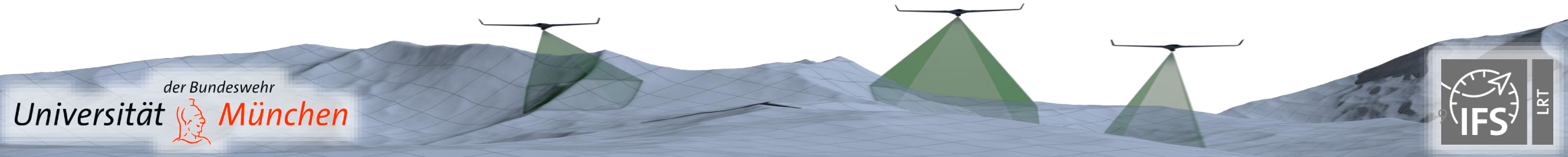
Other Impacts

- **Environmental**
  - Reduce emissions related to disaster response

- **Societal**
  - Protect first responders
  - Protect citizens

} *Even more critical under CBRN-E conditions*

- **Scientific**
  - Make development in AI valuable to European societies
  - Encourage dialogs between practitioners and scientists



Measures of success

- **KPI 1 -** Increase amount of information processed
  measure: consider 10 classes of information
- **KPI 2 –** Reduce response time and fatality in impervious disaster areas
  measure: consider 3 scenarios with the deployment of UAVs using AI planning methods
- **KPI 3 –** Increase explicability for human operators
  measure: conduct survey among first responders to check the benefit of plan validation
- **KPI 4 –** Increase awareness among first responders about AI planning
  measure: participation of first responders and publications / presentations of results, at events targeted at first responders
- **KPI 5 –** Establish a set of standard benchmarking problems for AI planners
  measure: at least 3 benchmarking problems are defined and published

UniBwM: Simulation Environment

NVIDIA

Computer Vision

Path Planning & Obstacle Avoidance

Cameras

Flight Control's Reference trajectory

Informations Gathering

User inputs Vehicle Routing, Actions, …

MAVROS

MAVROS

ROS

Drone Nodes

Exchanges informations between the drones and the users. Constructs a waypoint mission from the ALNS routing and reports back images and the status of the aircrafts.

ALNS Node

Performs the planning, producing the routes for each drone to follow.

GU

I

GAZEBO Unity

Software-in-the-loop simulation

ARDUPILOT PX4 autopilot

MAVLink

External connectivity protocols

Autonomous Flight

Missions, RTL, …

Sensors Hub

GPS, Camera, IMU, Altimeter, RC input

Position Control

Attitude & Rate Control

Position & Attitude Estimator

Extended Kalman Filter: GPS, Optical flow, distance

State Machine

Mode Switching, Arming, Takeoff, Hover, Landing, Circling

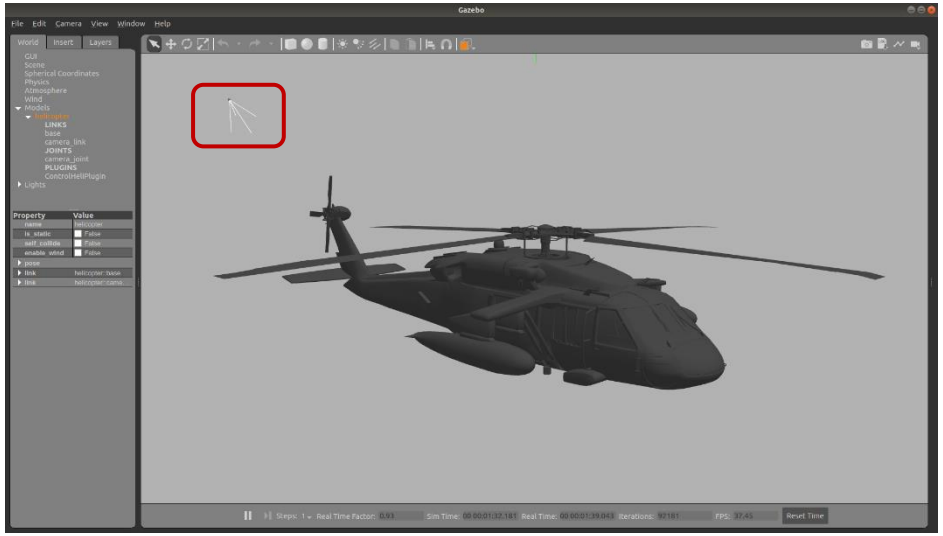
Output Driver

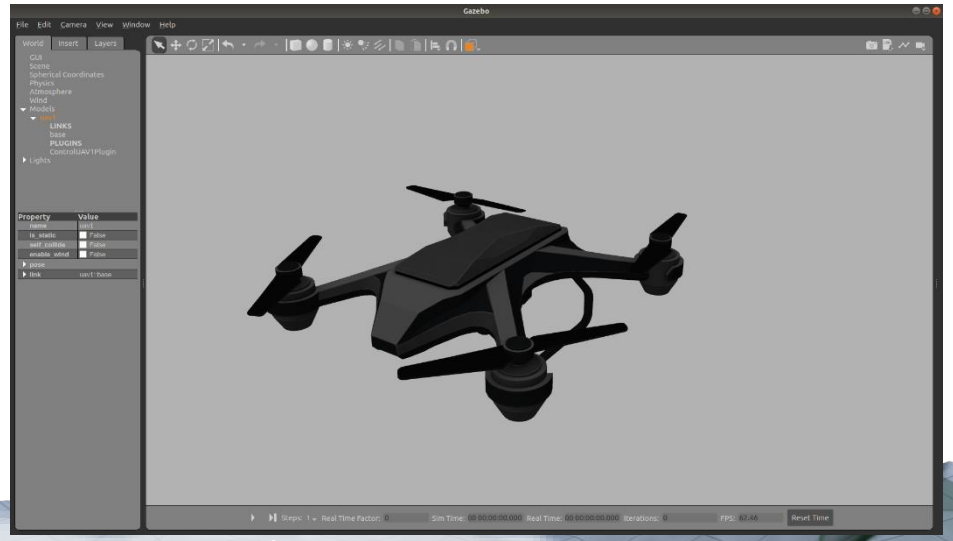
ESC, Servo control, actuation

Universität der Bundeswehr München

IFS LRT

UniBwM: SAR-Simulator with Gazebo-World





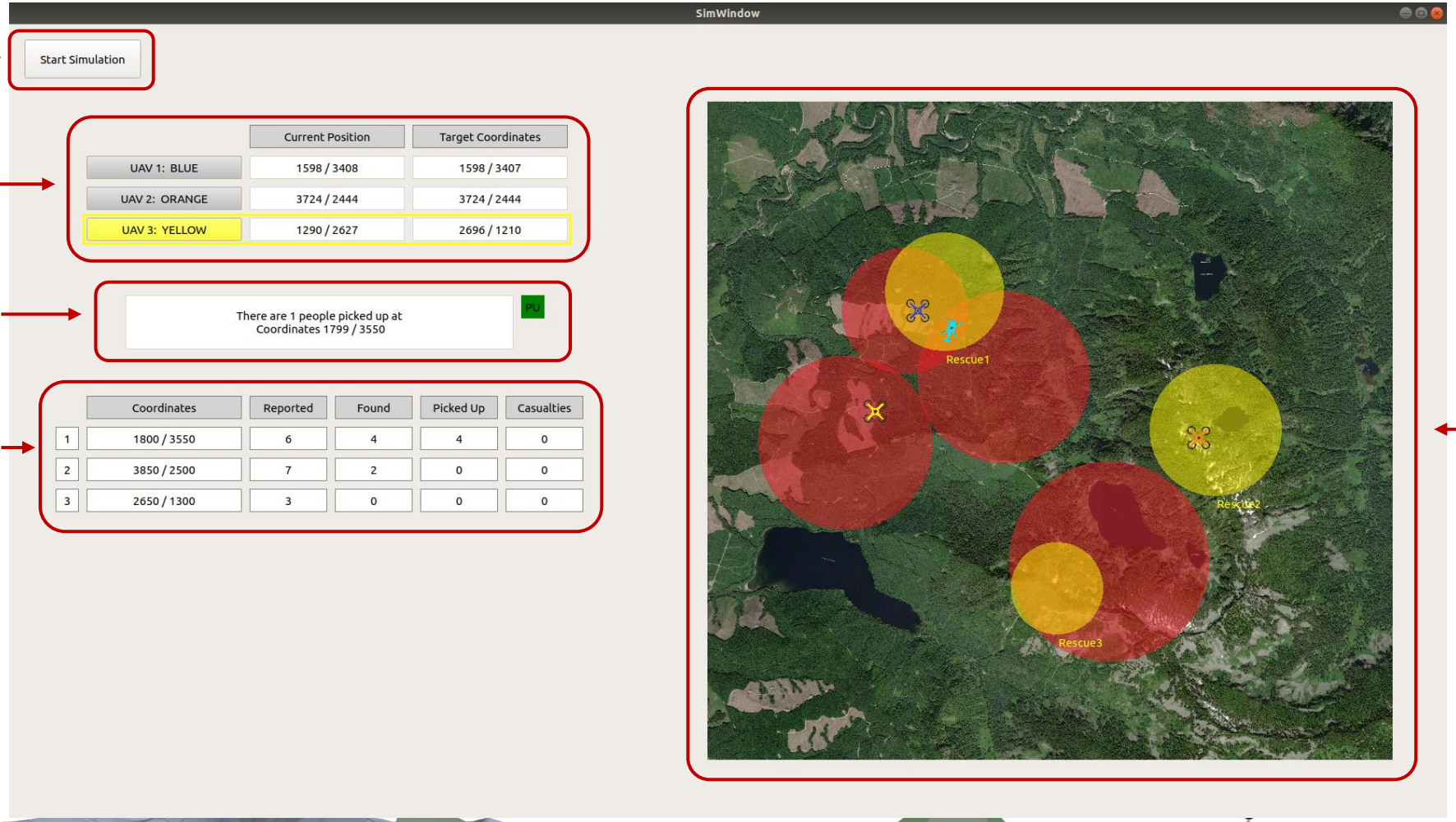
UniBwM: SAR-Simulator with Gazebo-World

Start

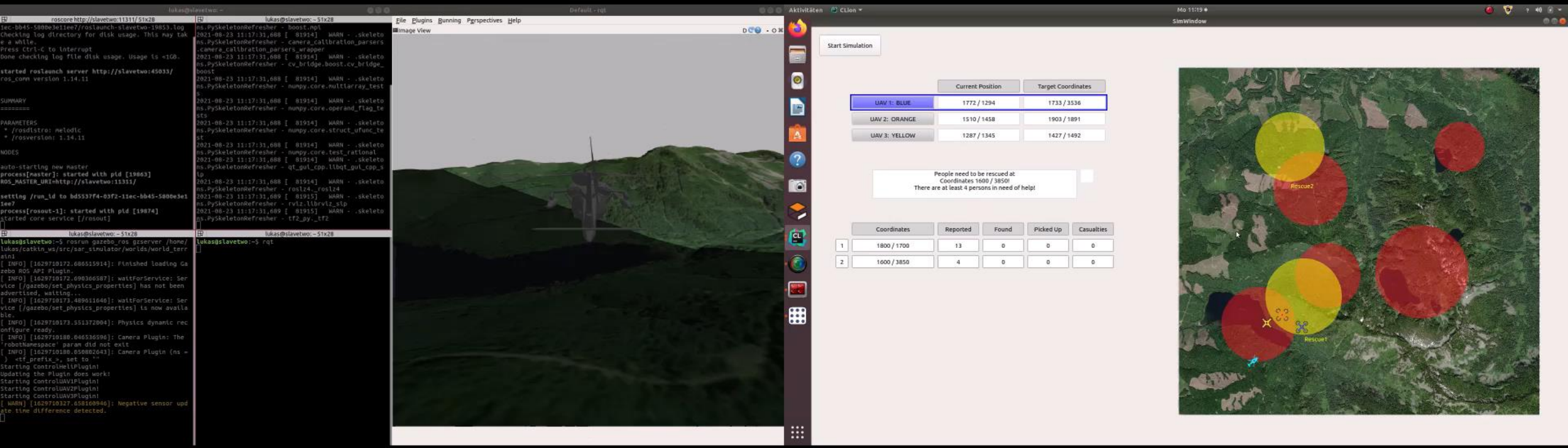
UAV View & Command

Alert

Operation Chart



Dynamic disaster map


roscore http://slavetwo:11311/ 51x28
lukas@slavetwo: ~ 51x28
lukas@slavetwo: ~ 51x28
lukas@slavetwo: ~ 51x28
Default - rqt
File Plugins Running Perspectives Help
Image View
Aktivitäten
CLion
Mo 11:19
SimWindow
Start Simulation
Current Position
Target Coordinates
UAV 1: BLUE
1772 / 1294
1733 / 3536
UAV 2: ORANGE
1510 / 1458
1903 / 1891
UAV 3: YELLOW
1287 / 1345
1427 / 1492
People need to be rescued at
Coordinates 1600 / 3850!
There are at least 4 persons in need of help!
Coordinates
Reported
Found
Picked Up
Casualties
1
1800 / 1700
13
0
0
0
2
1600 / 3850
4
0
0
0
Rescue2
Rescue1

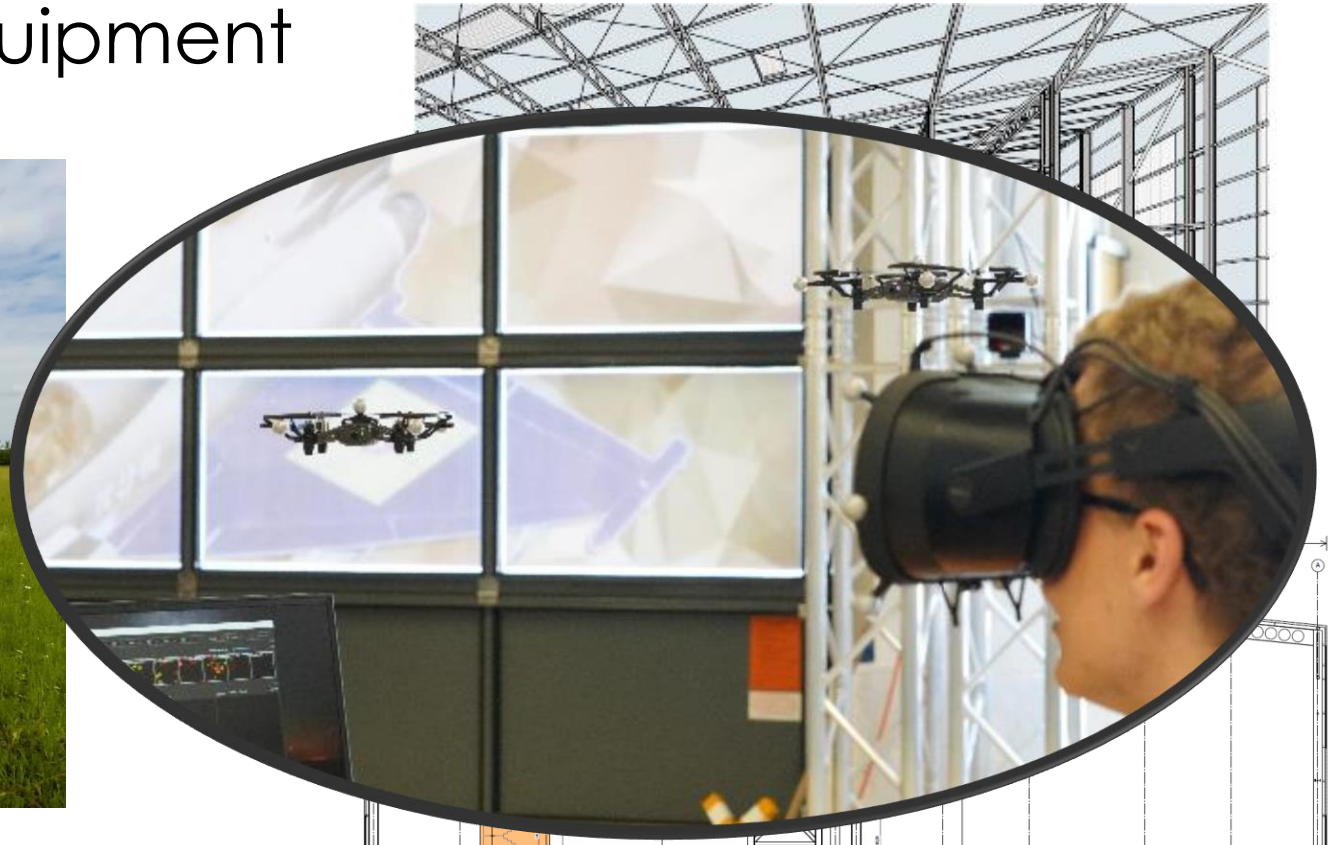
Hardware + Infrastructure

- Holybro
- Raspberry pis
- Px4
- Outdoor flight tests: infrastructure at the UniBwM (Sprinter and test field)

Sources: © Holybro

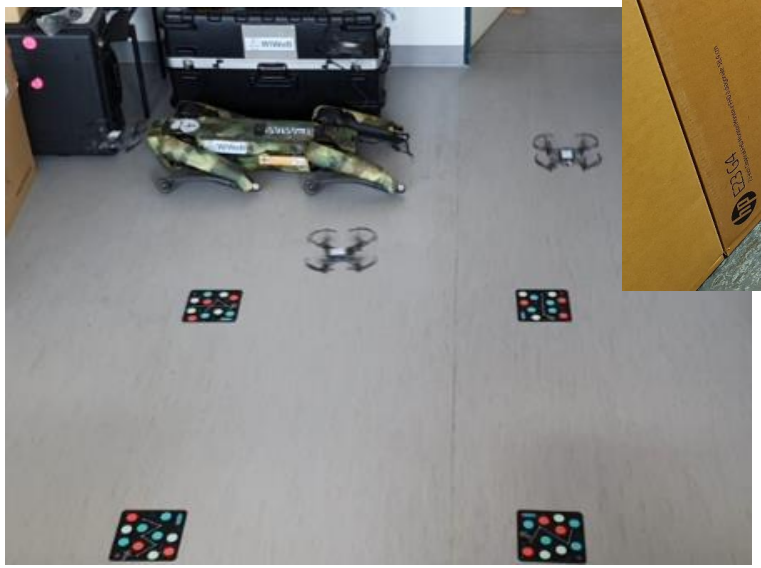
Co-Development with First Responders - WIWeB

- Development of "Soldier as a System"
- Indoor te[illegible]ility and equipment



Co-Development with First Responders - WIWeB

- Development of “Soldier as a System”
- Indoor test facility and equipment



Quelle: https://store.dji.com/de/product/tello-edu?vid=47091

Co-Development with First Responders: Bavarian Red Cross

K9 unit for SAR in flood affected areas

drill for water rescue

evacuation of a patient