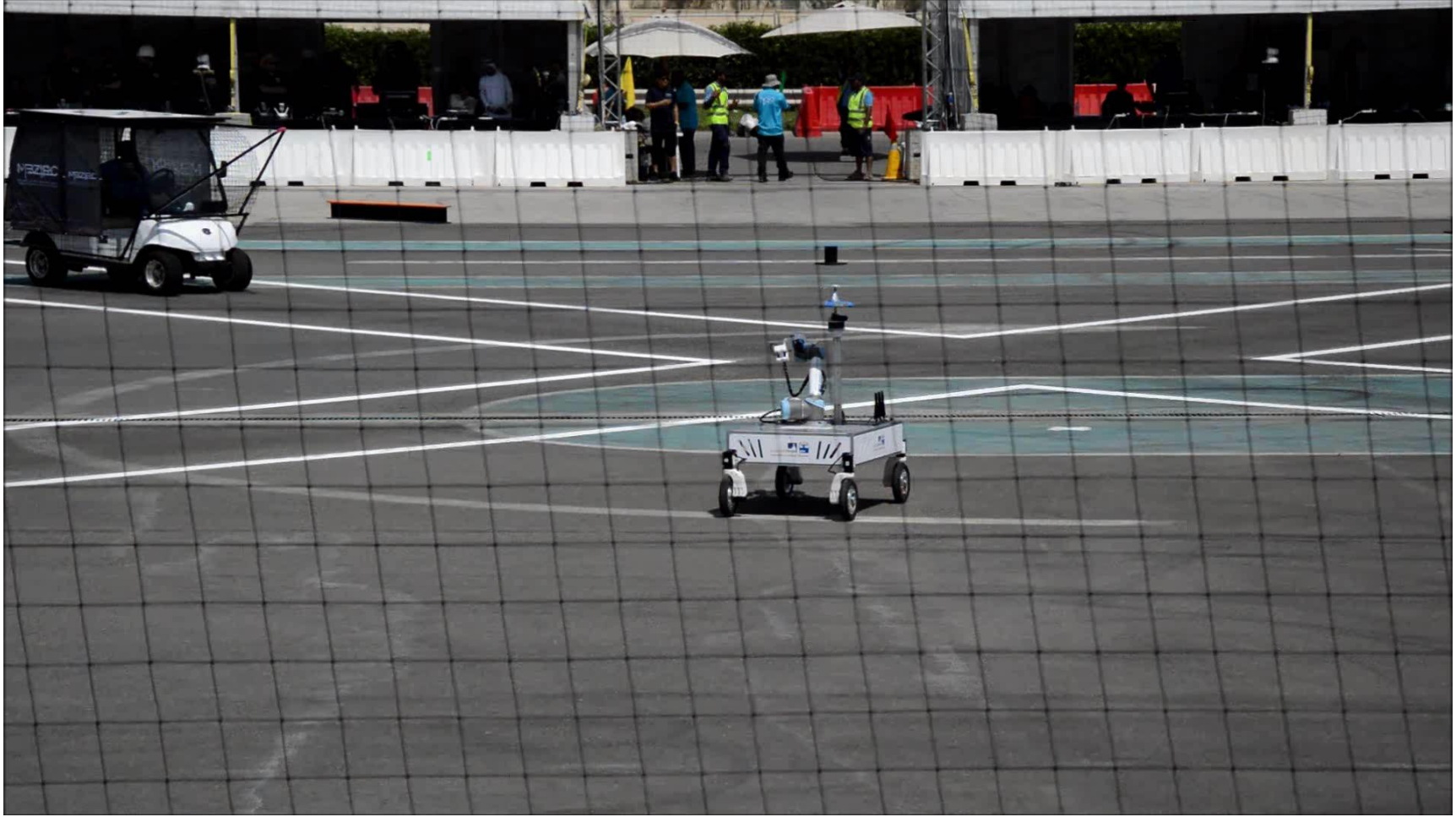
MBZIRC Grand Challenge Winner NimbRo

Sebastian Houben, Marius Beul, Max Schwarz, Matthias Nieuwenhuisen and Sven Behnke

University of Bonn, Germany
Autonomous Intelligent Systems



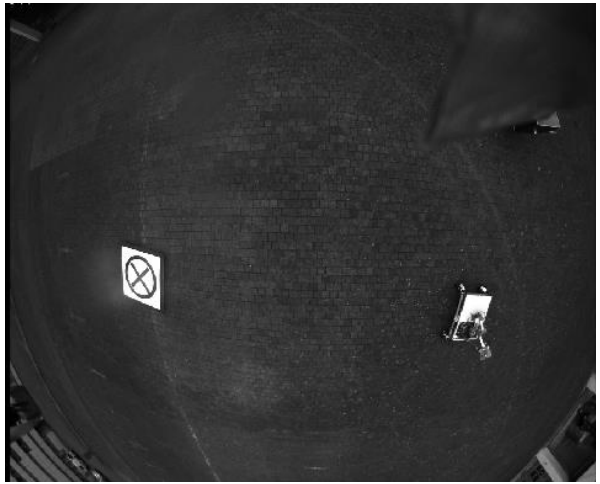
MBZIRC Grand Challenge Winner NimbRo

Landing Copter DJI Matrice 100

- Wide-angle (forward) and fisheye (down) cameras
- Magnetic feet
- Foot contact sensors
- Dual-core PC

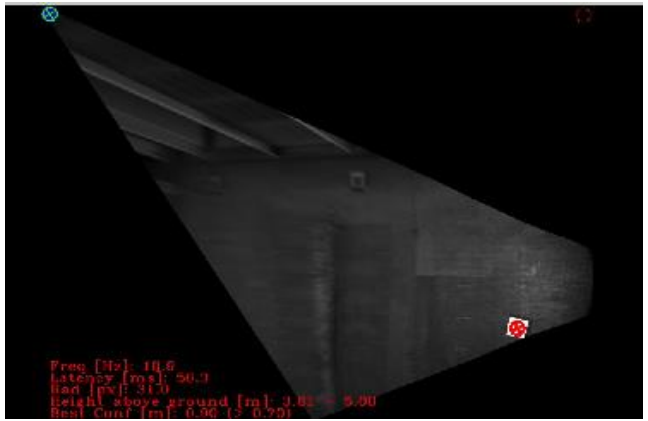
Landing Pattern Detection

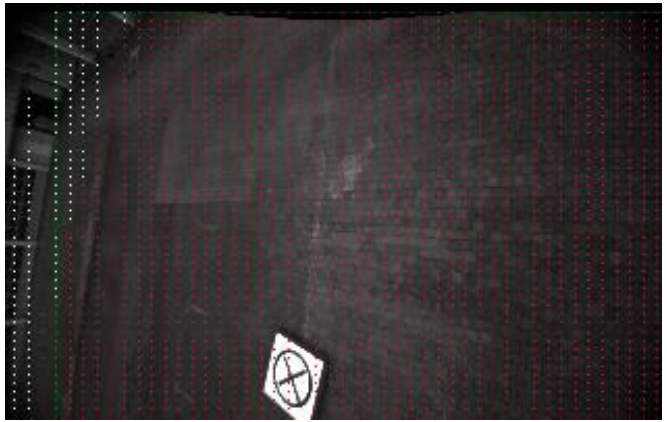
- Far-range tilted camera for search mode
- Fast tracking mode with both cameras (2x 40 Hz)



Landing Pattern Detection: Search Mode

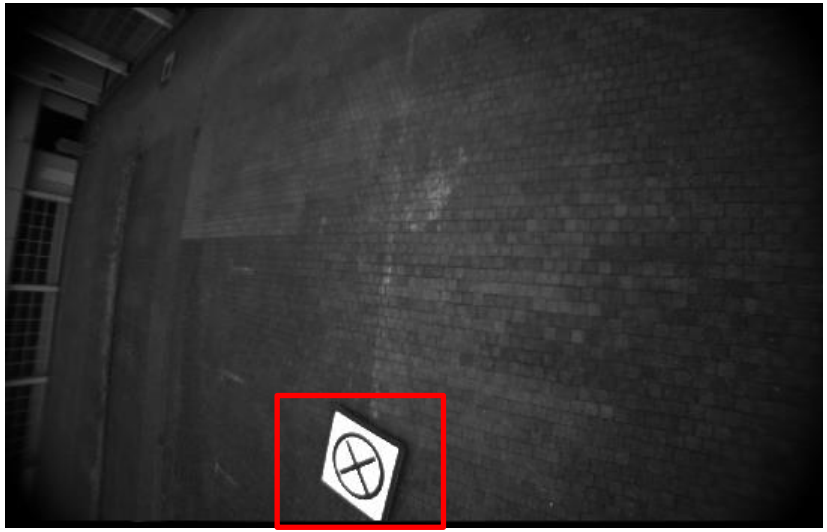
- Uses filtered copter height (barometer) and orientation (IMU)
- Compute regions with sufficient resolution





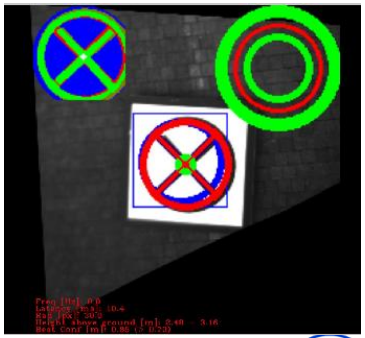
Landing Pattern Detection: Tracking

- Extract a small region around last detection in raw image
- Compensate lens distortion and compute homography only on this region

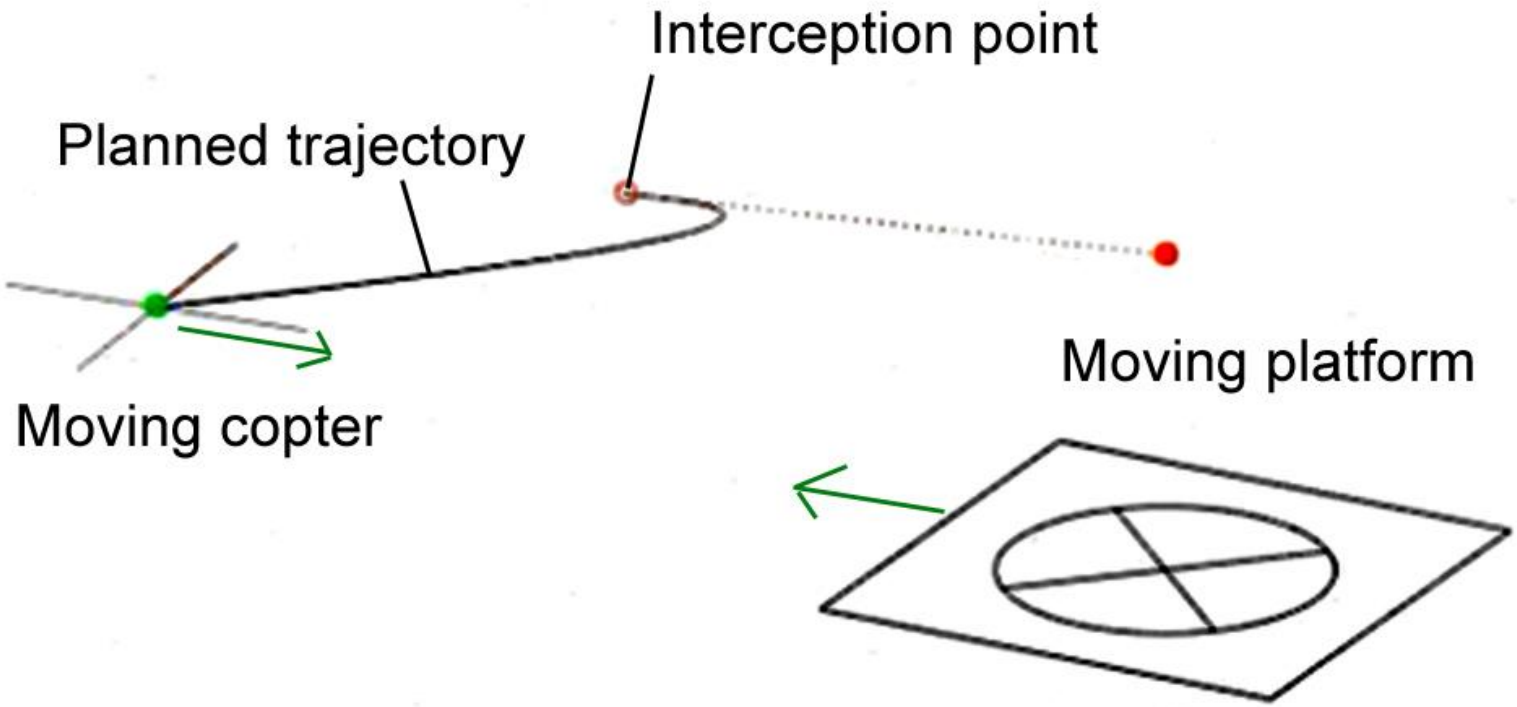


Landing Pattern Detection

- Use measure for symmetry of known size (due to known height) to detect a bright-dark-bright edge
- Detect circles and confirm detection with rectangular lines within
- Compute confidence of detection by overlaying with an artificial pattern and thresholding grayvalue image due to known quantile of dark pixels

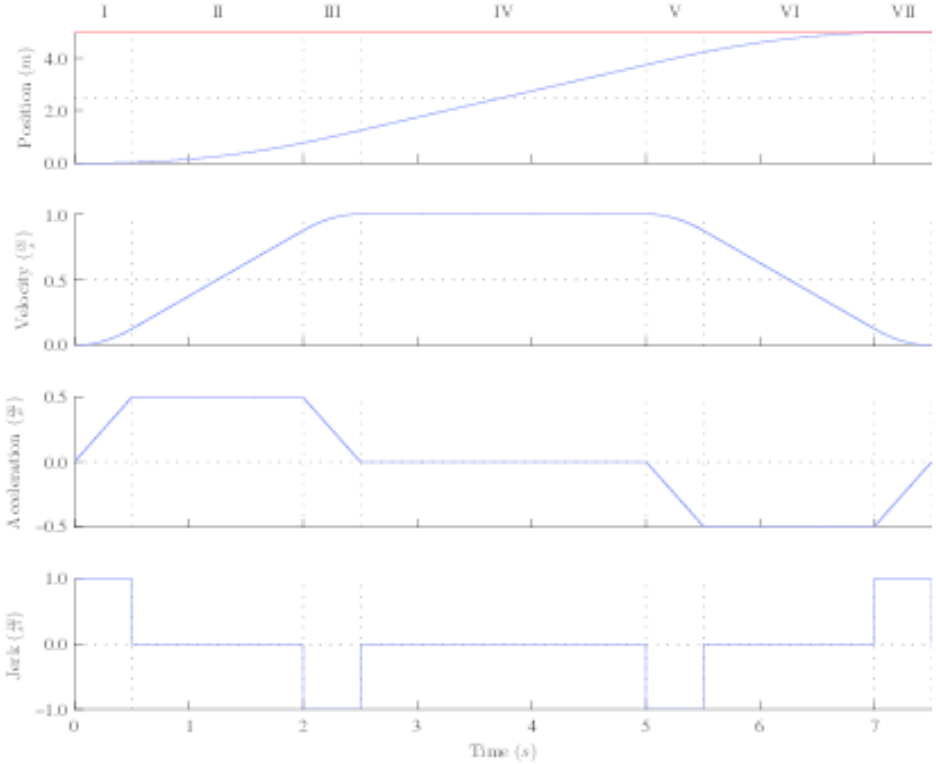


Time-optimal Interception Trajectory

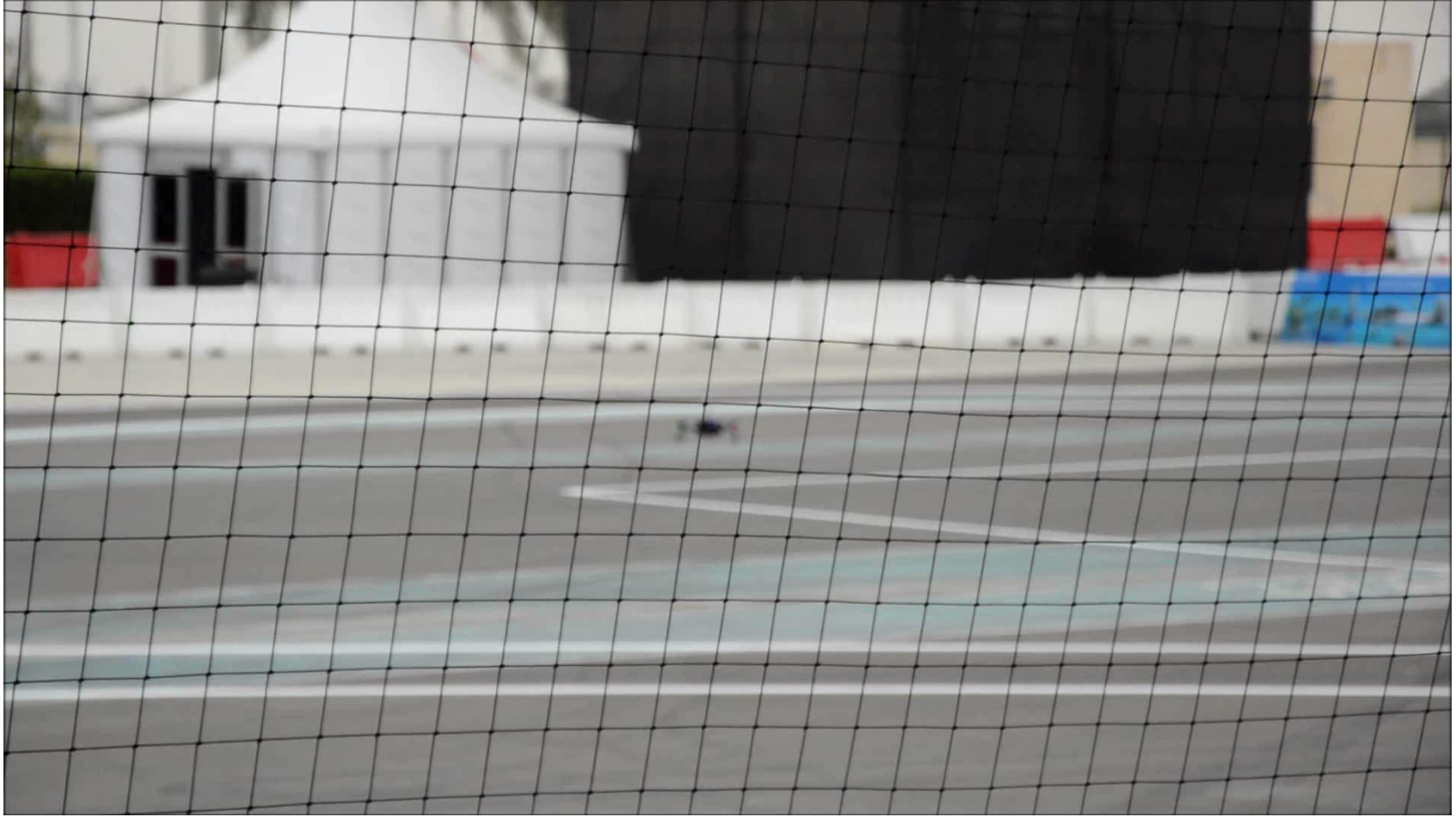


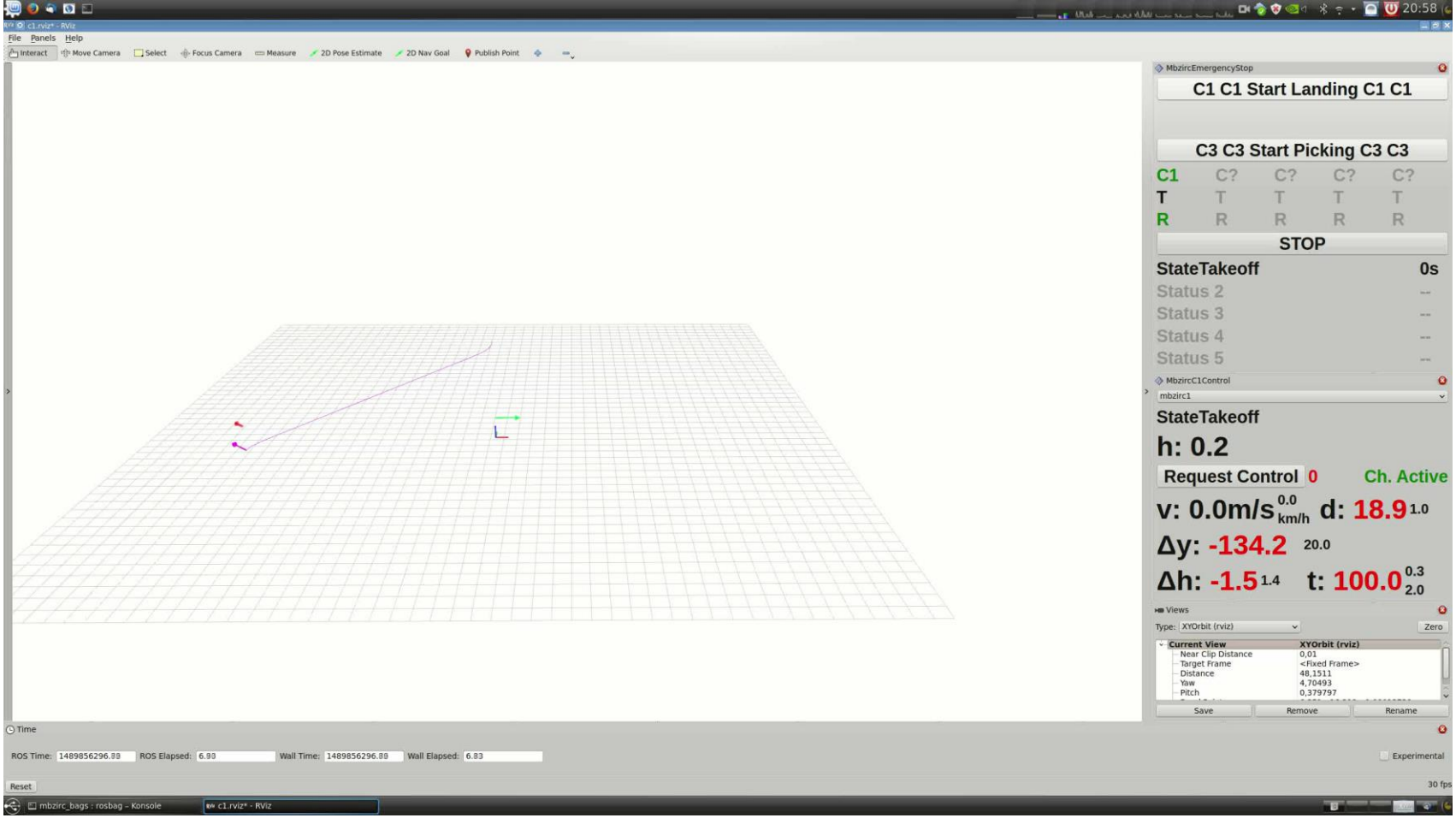
Time-optimal Interception Trajectory

- Analytic solution
- Maximal inputs
- Speed, acceleration, jerk limits
- Seven intervals
- Computation of switching times

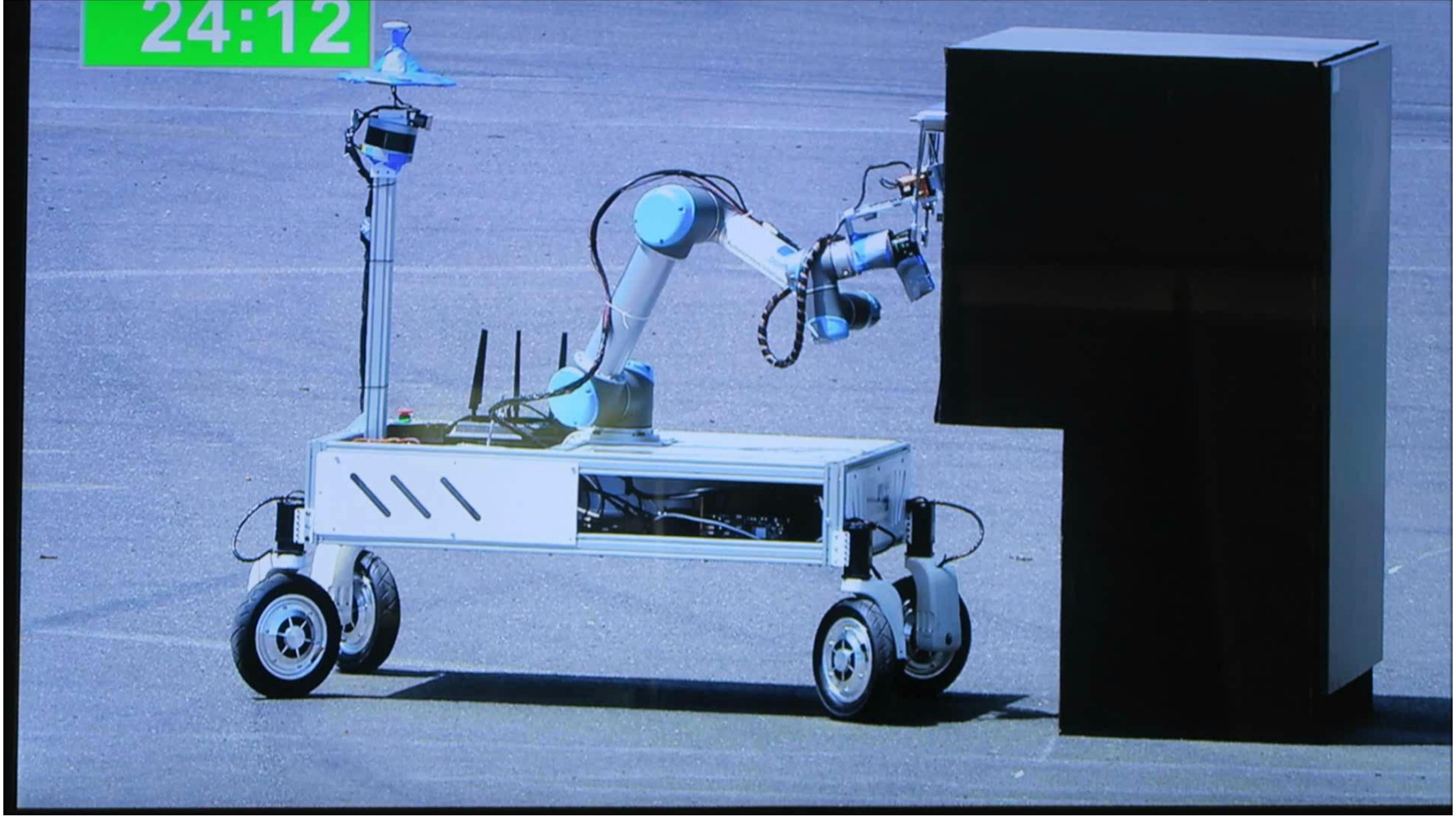


universitätbonn ais



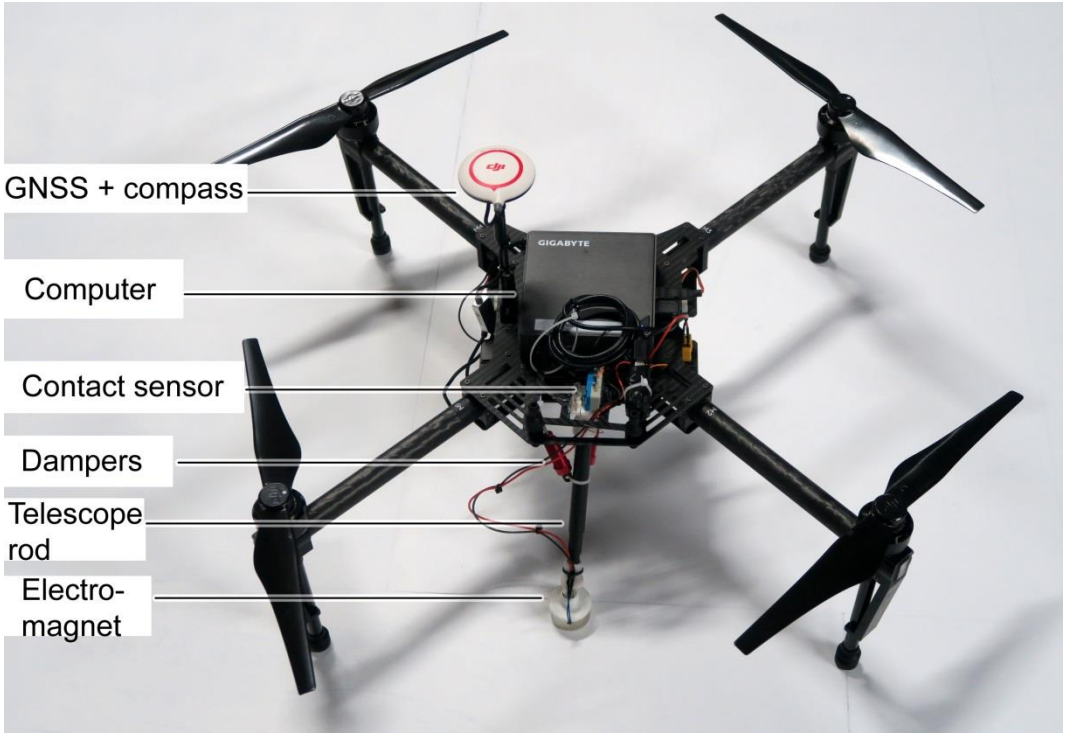


universitätbonn ais


24:12

Picking Copter DJI Matrice 100

- Wide-angle downward looking color camera
- Electromagnetic gripper
- Laser-distance sensor to ground
- Dual-core PC

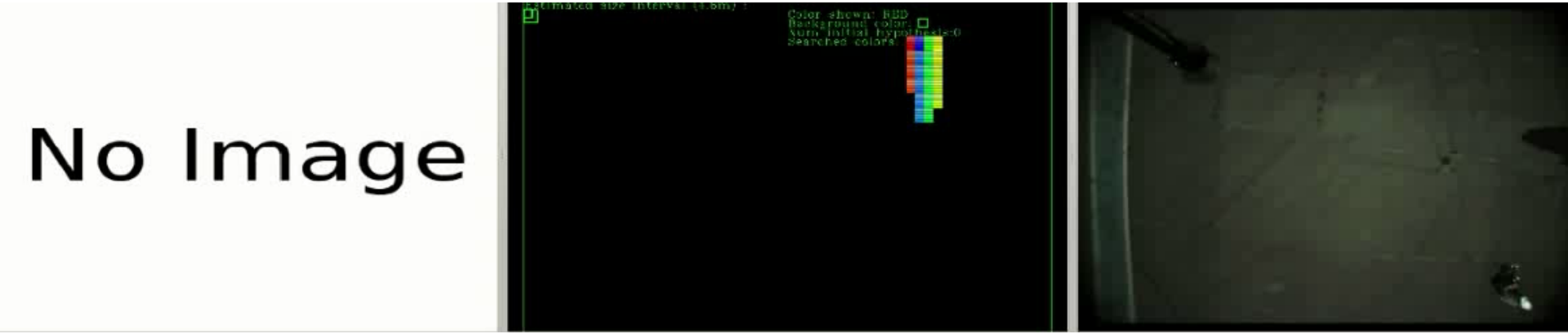


universitätbonn ais

Pickable Object and Drop-box Detection

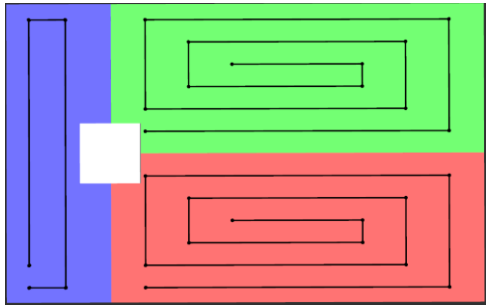
- Probabilistic color segmentation
- RANSAC-like drop-box detection

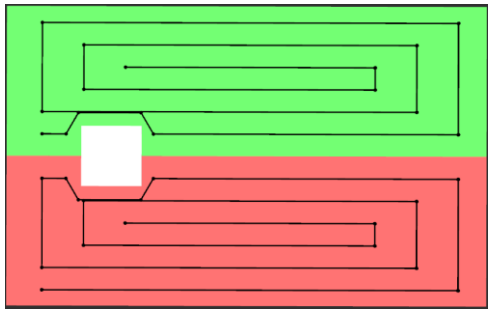
Drop box | Color segmentation | Raw image



Exploration and State Estimation

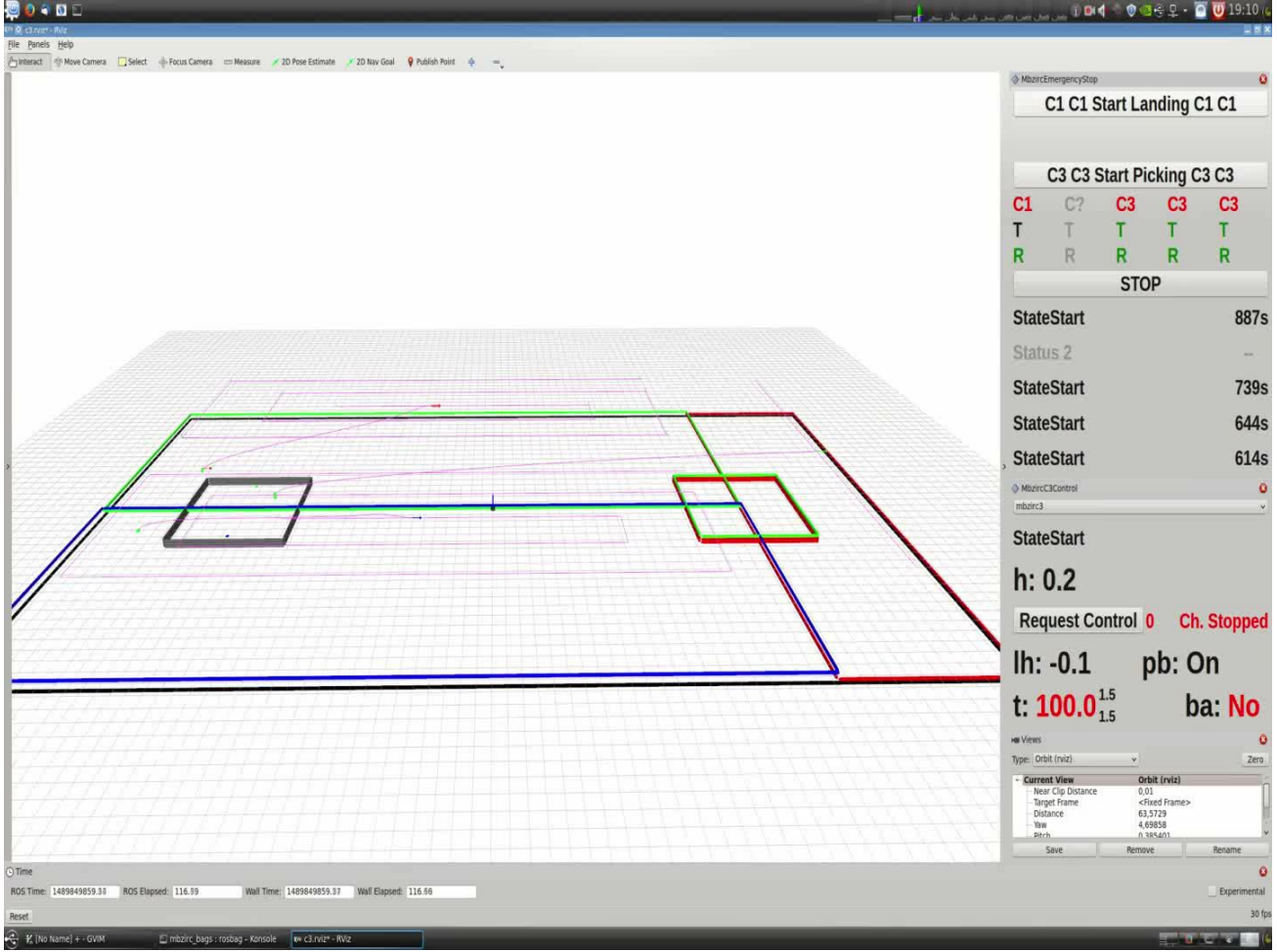
- Separation of exploration patterns and picking zones
- Coordination only necessary at drop zone and at takeoff
- Laser-based barometer offset correction close to the ground
- Optional filtering of dynamic object movements with interception point prediction



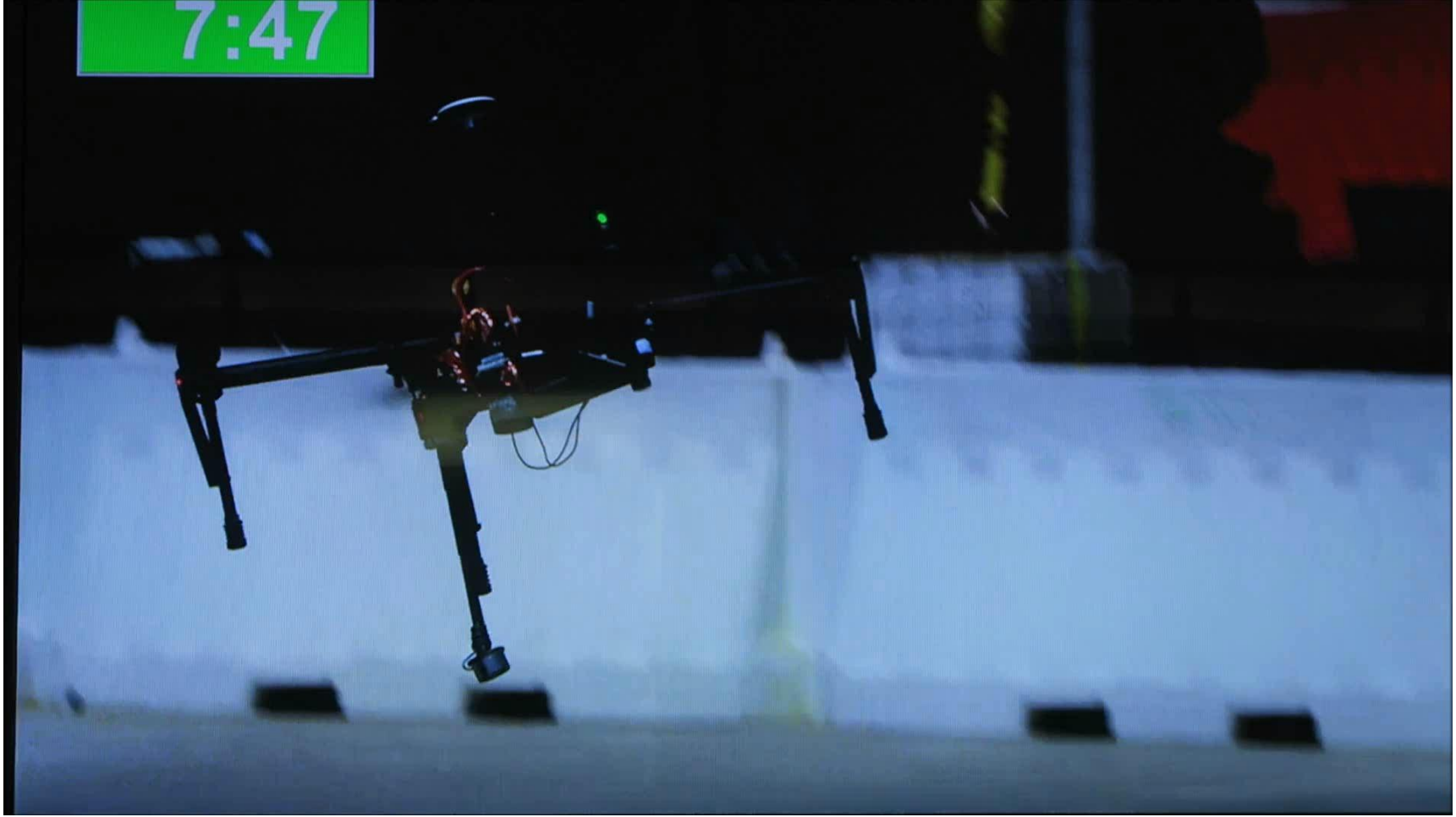


Team Communication

- In C3 coordination is essential for safe operation
- UDP communication unreliable
- No central control authority, every robot fuses information individually
- Fallback strategies, e.g., altitude separation, timeslotting
- Robust against communication failures



universitätbonn ais


7:47

Team NimbRo

MBZIRC Grand Challenge Winner NimbRo

universitätbonn ais