Robust Precision Landing for Autonomous Drones Combining Vision-based and Infrared Sensors

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Outline

- Motivation & Contribution
- Autopilot Structure & Precision Landing
- Robustness approach
- Evaluation
- Conclusions

Drones

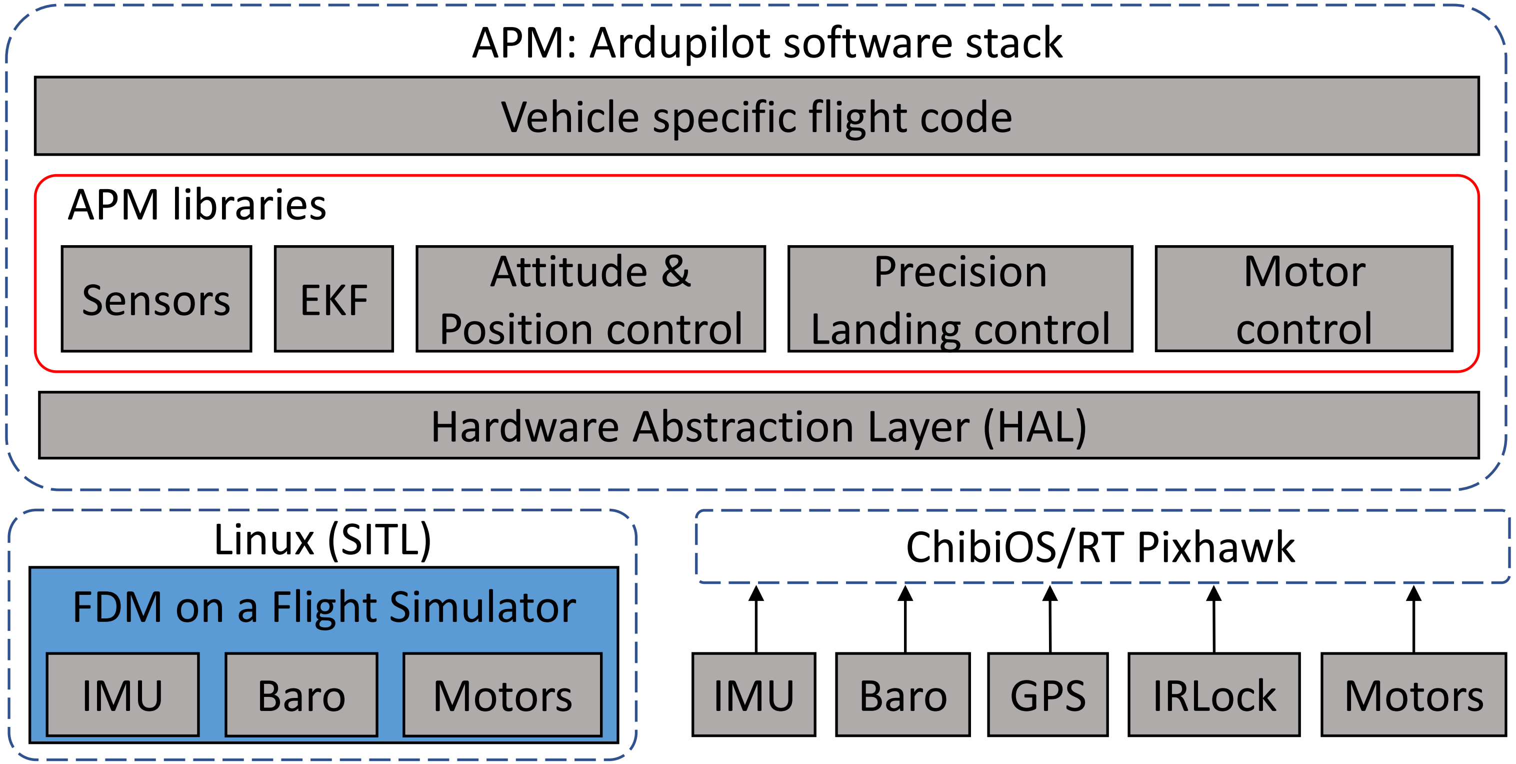
Need for precision landing

- Drones may need to land with high precision
  - on a pad to recharge their battery
  - within a hangar to be protected from weather conditions and harsh environments
- GPS receivers not sufficient, large errors
- Most common precision landing sensors
  - infrared sensors
  - RGB camera sensors
- Most works use only one
  - Single point of failure

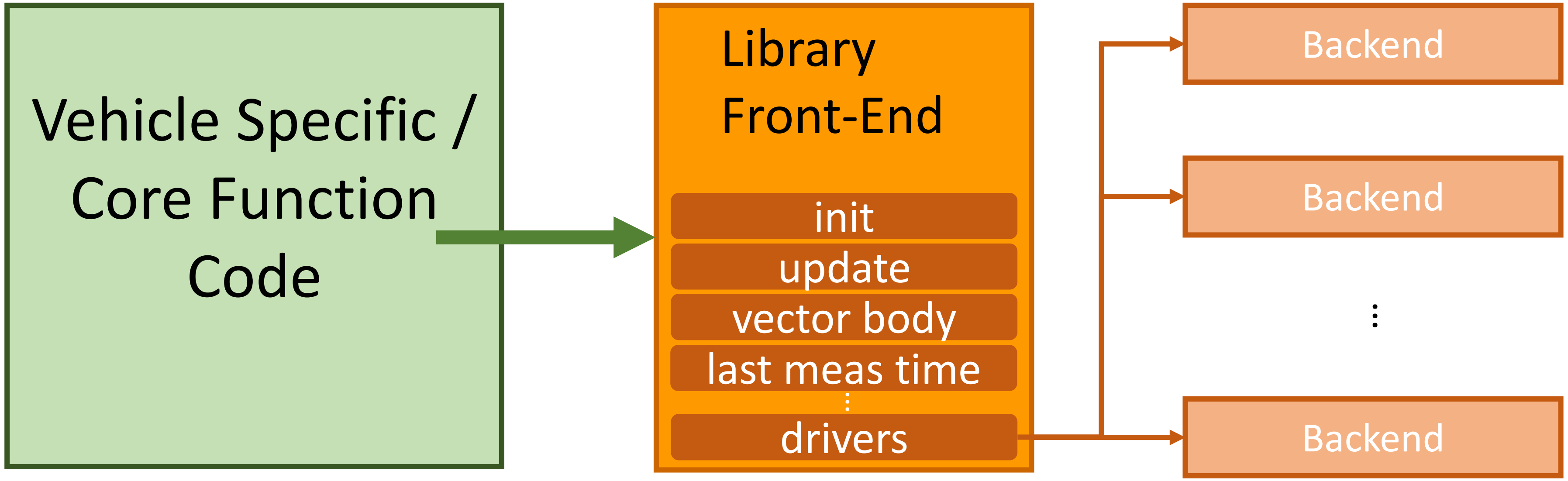
Contribution

- Increase precision landing robustness by combining
  - a mature infrared sensor system, IRLock
  - a marker sensor (RGB-camera based) system
- Tolerate failures of any single sensor sub-system
- Introduce a new cautious landing in case of a failed target detection
- Functionalities smoothly integrated into the ARDUPILOT

ArduPilot framework



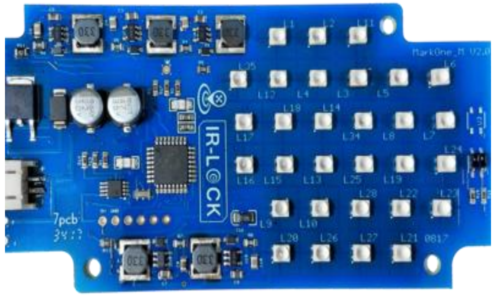
Sensor access



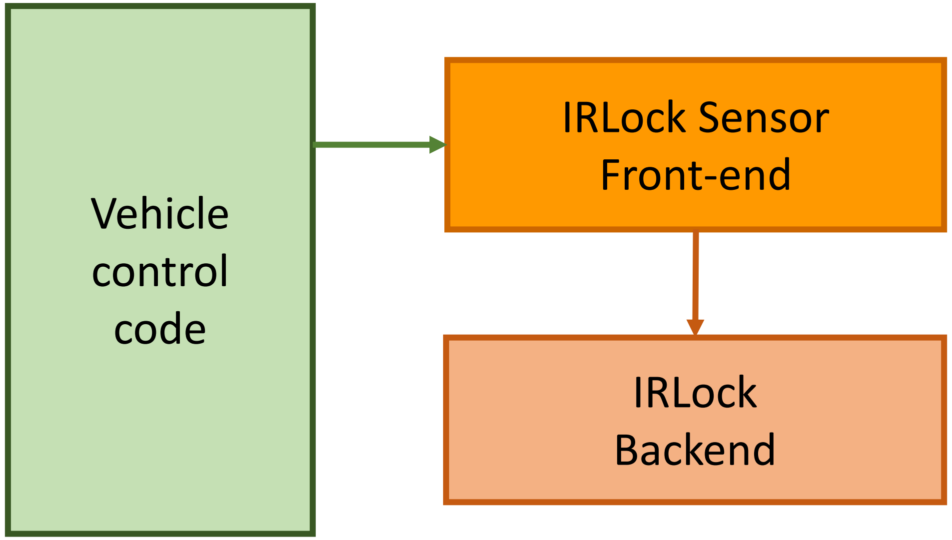
IRLock sensor subsystem

- Based on Pixy vision sensor
- With a specialized firmware and an IR-LOCK filter
- Tracks & detects pixel position of LEDs in a frame
- I2C protocol
- Position updated every 20ms (50Hz)
- Combined with MarkOne beacon to overcome lighting difficulties
- Detection range up to 12-15 meters

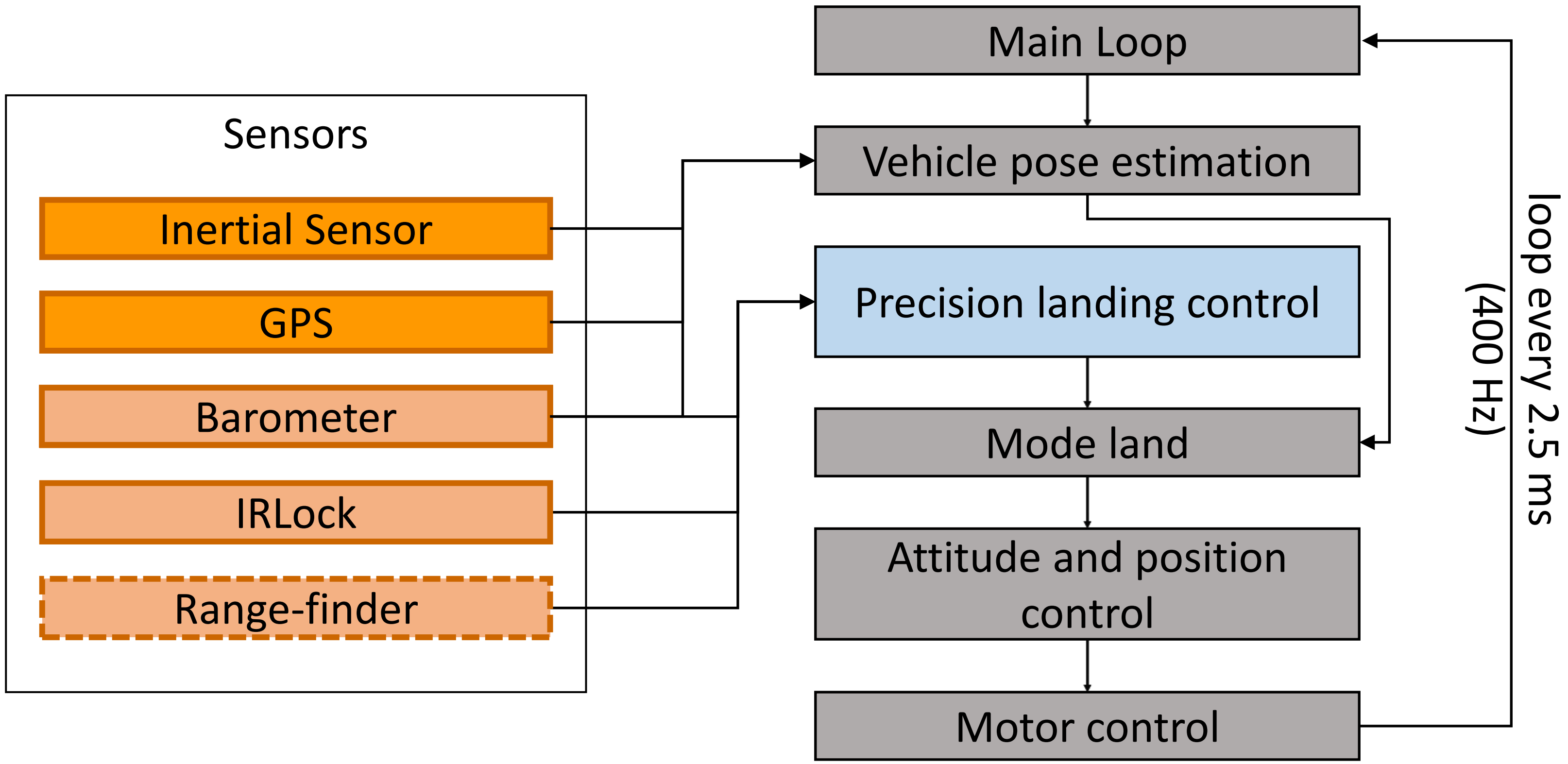
IRLock sensor



MarkOne beacon



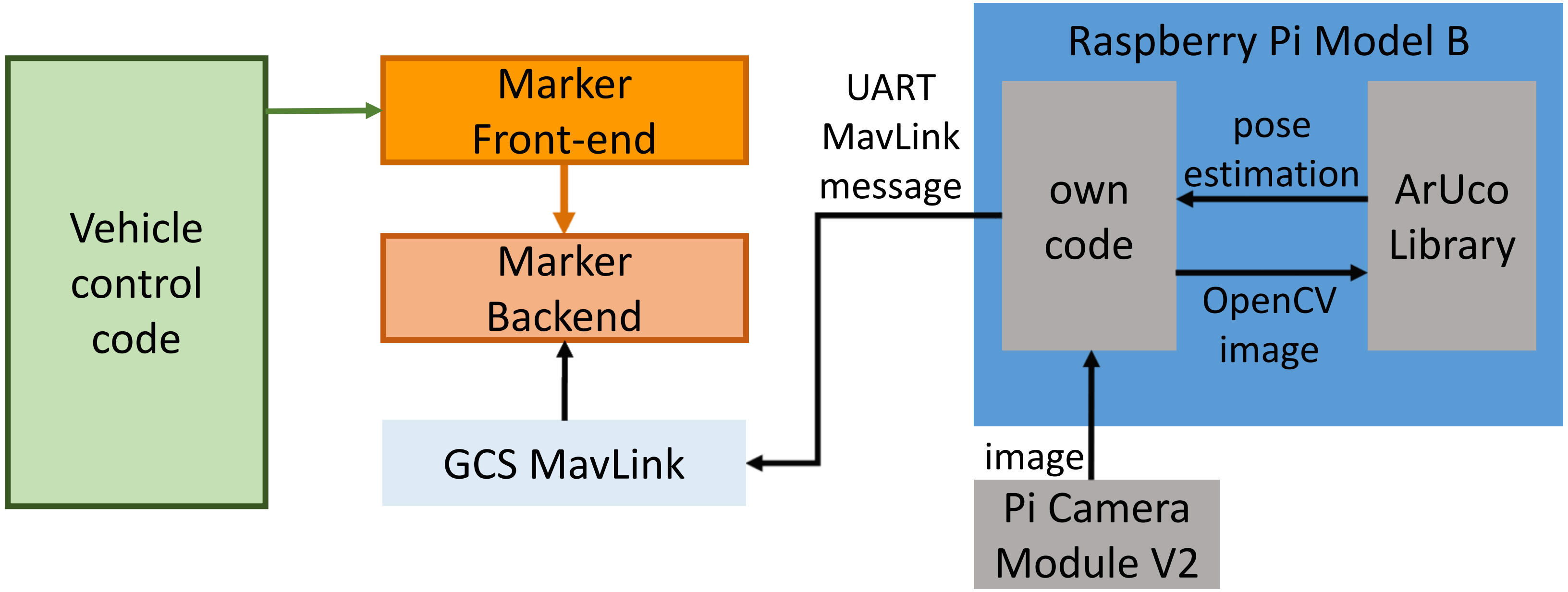
Control flow with precision landing

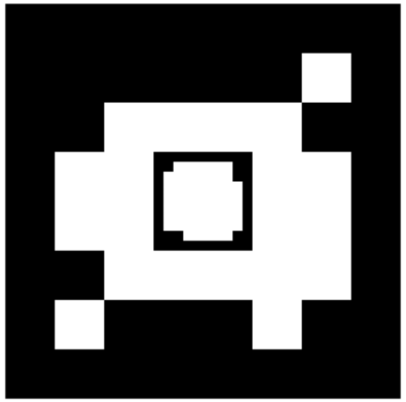


Marker sensor subsystem

- Pi camera configured at 640x480, 30fps
- Pose estimation every ~50ms (20 Hz)
- Updates sent via MavLink over UART

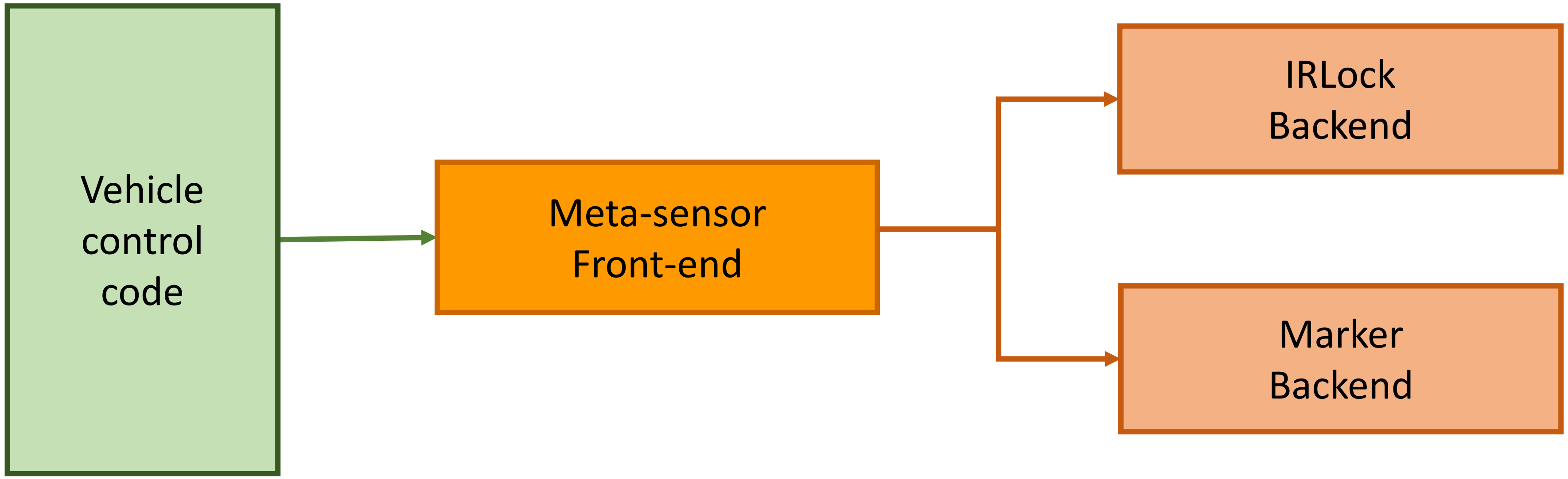
- ArUco custom fractal marker
- Enables detection from different heights



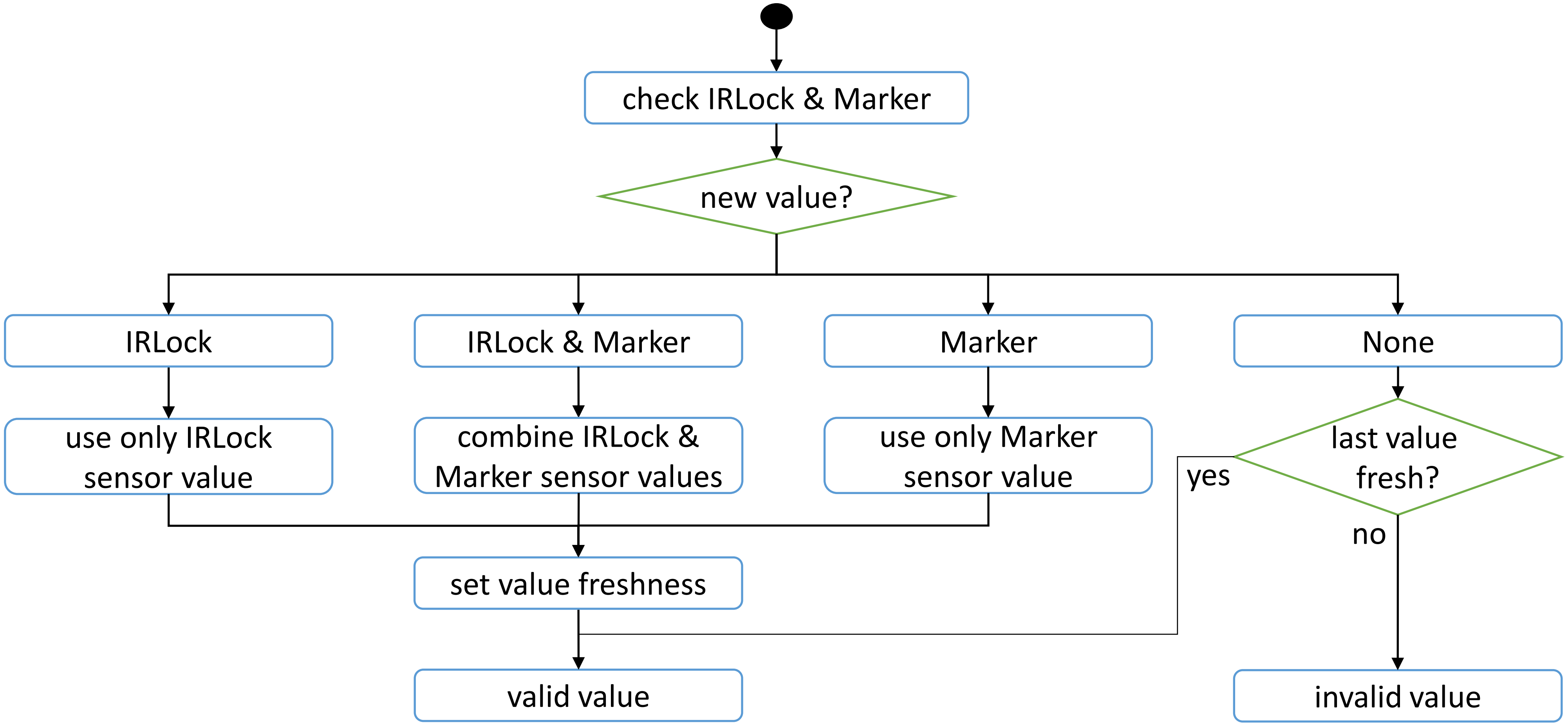


Meta-sensor aggregation

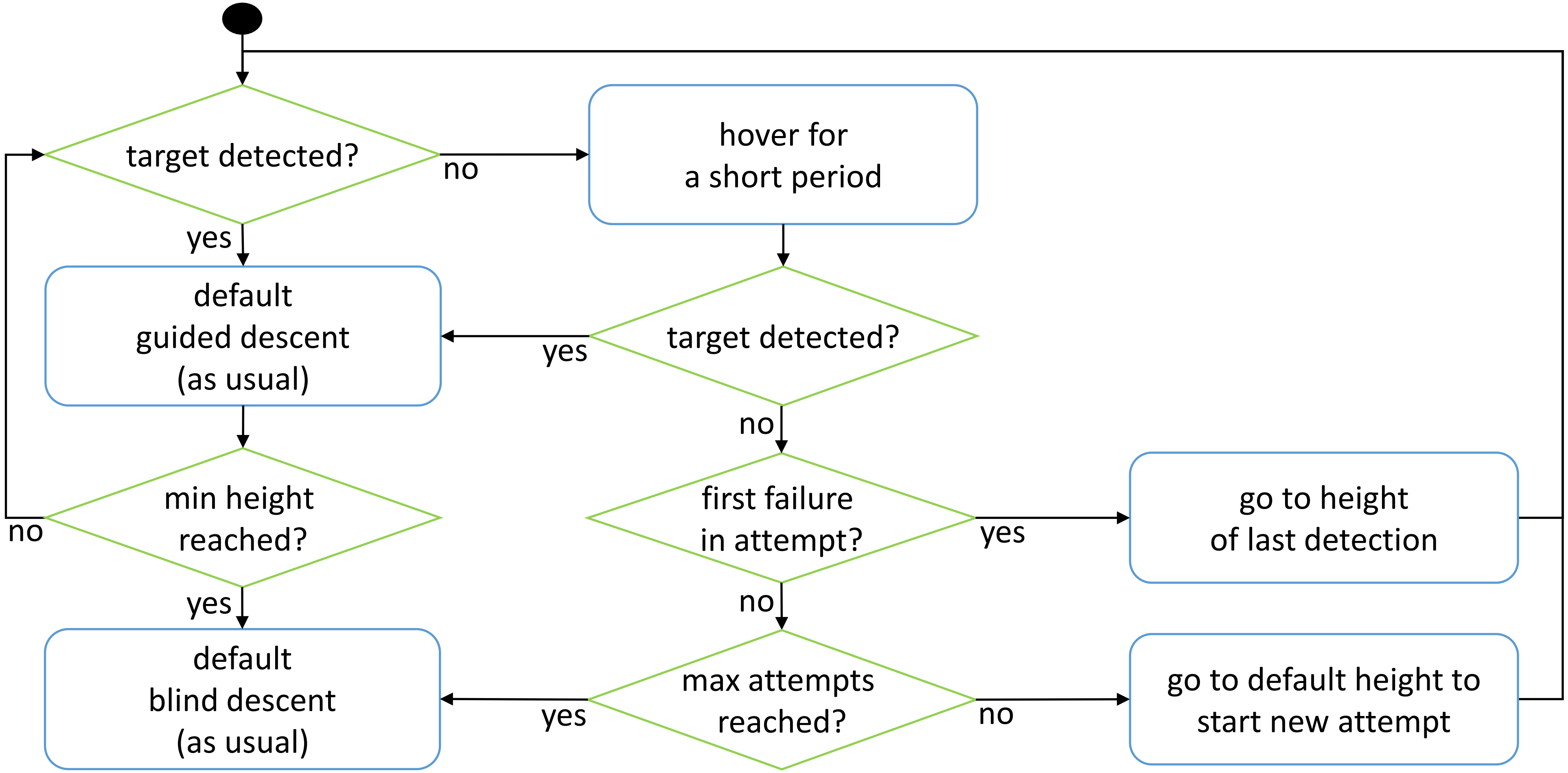
- Front-end component that hides all the back-end details
- Front-end does not have its own back-end
  - instead connects to the back-ends of the IRLock and marker sensors



Aggregation logic



Cautious land mode



Artificial failures

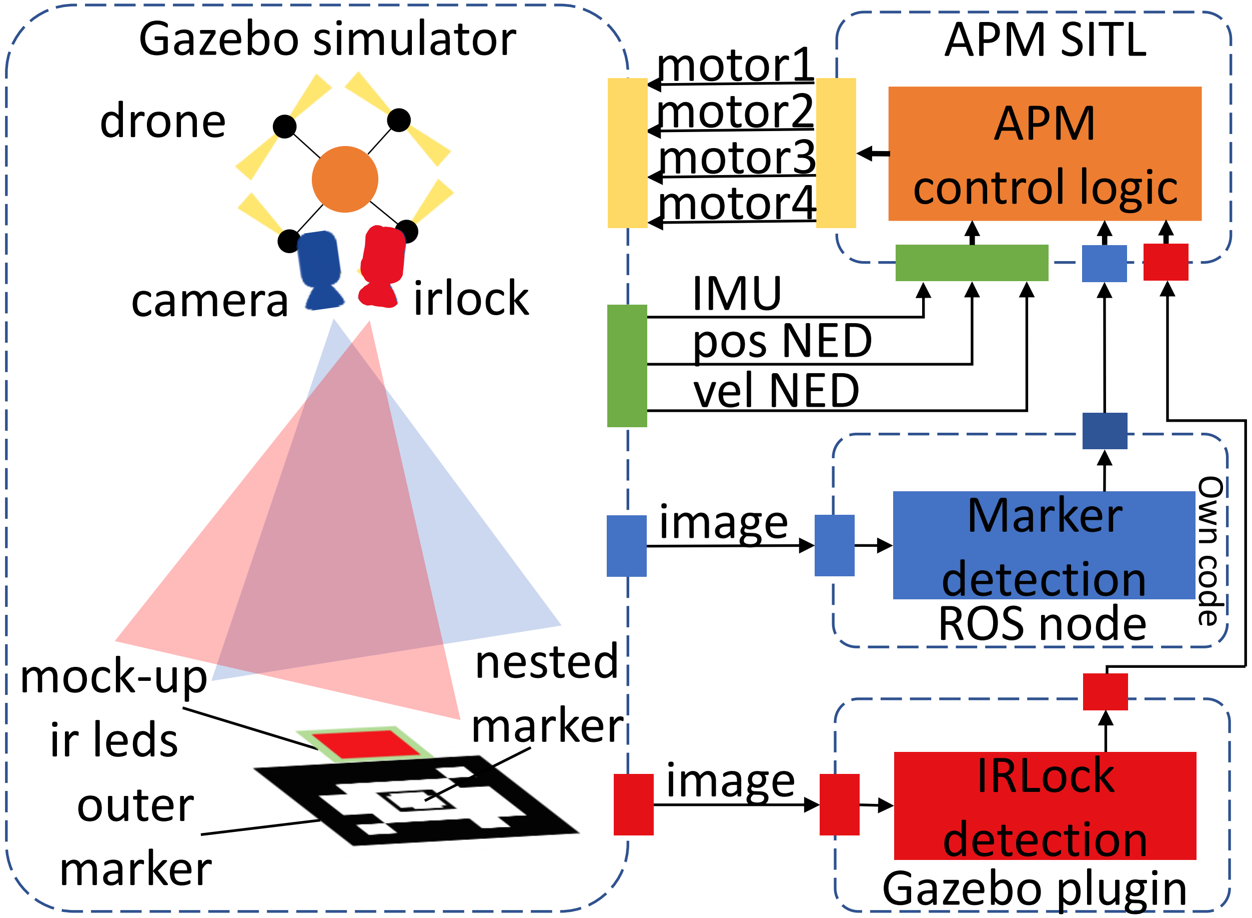
- Failure modes
  - random drop
  - systematic drop
- Modified the front-ends of the respective precision landing sensor subsystems
- Drop the values produced by the respective back-ends
- Set at runtime via a MavLink message

Field	Type	Description
target	uint8_t	Target sensor subsystem (IRLock: 1, Marker: 2, both: 3)
r_drop	float	Probability for dropping a new sensor value
s_keep	uint16_t	Number of consecutive new sensor values to keep
s_drop	uint16_t	Number of consecutive new sensor values to drop

MavLink message

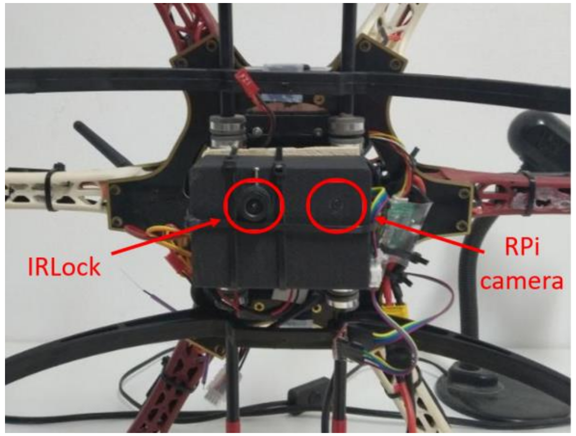
SITL via Gazebo

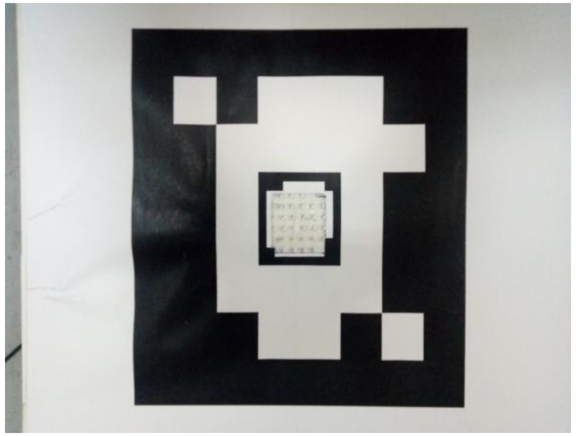
- Gazebo acts as a flight-dynamics simulation engine for the APM autopilot
  - SITL platform configuration derived from the same code base that targets real controllers
- Supports IRLock mockup detection
- Extended the simulation to enable marker detection



Hardware setup

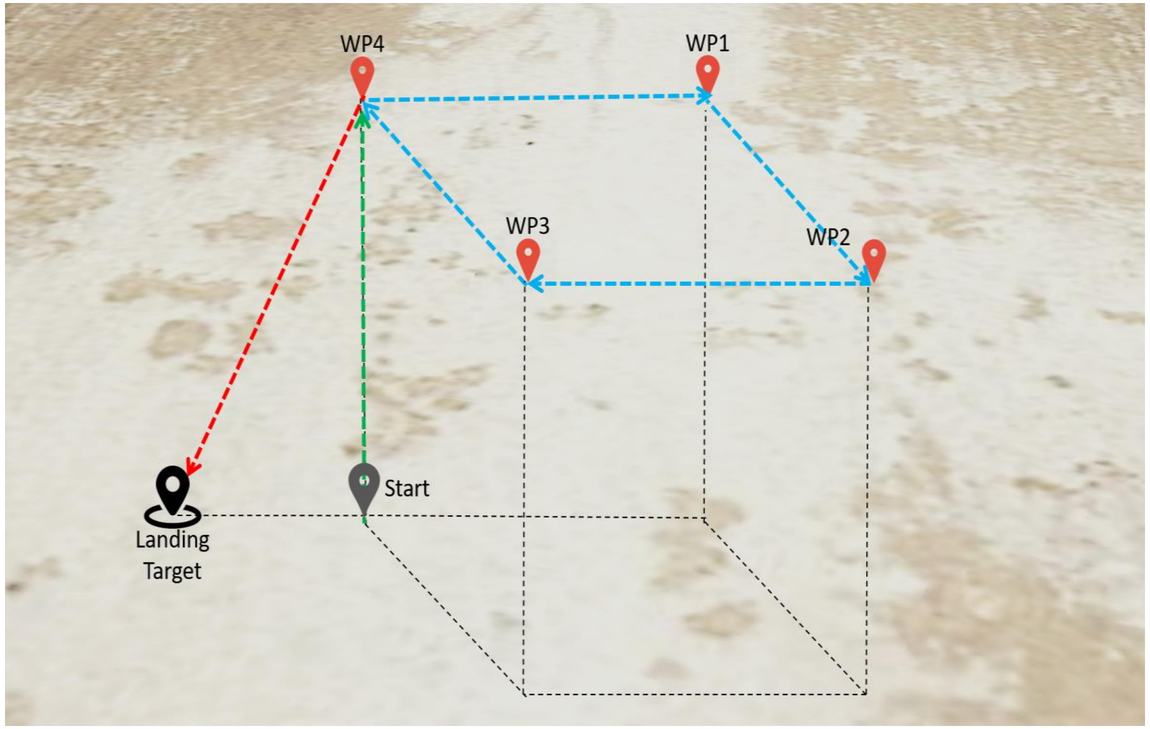
- Autopilot CUAV Nano v5
  - ICM20689 accel/gyro
  - ICM20602 accel/gyro
  - BMI055 accel/gyro
  - IST8310 magnetometer
  - MS5611 barometer
- Neo v2 GPS/Compass
- Raspberry Pi model b & camera
- IRLock target tracking system
- Landing pad



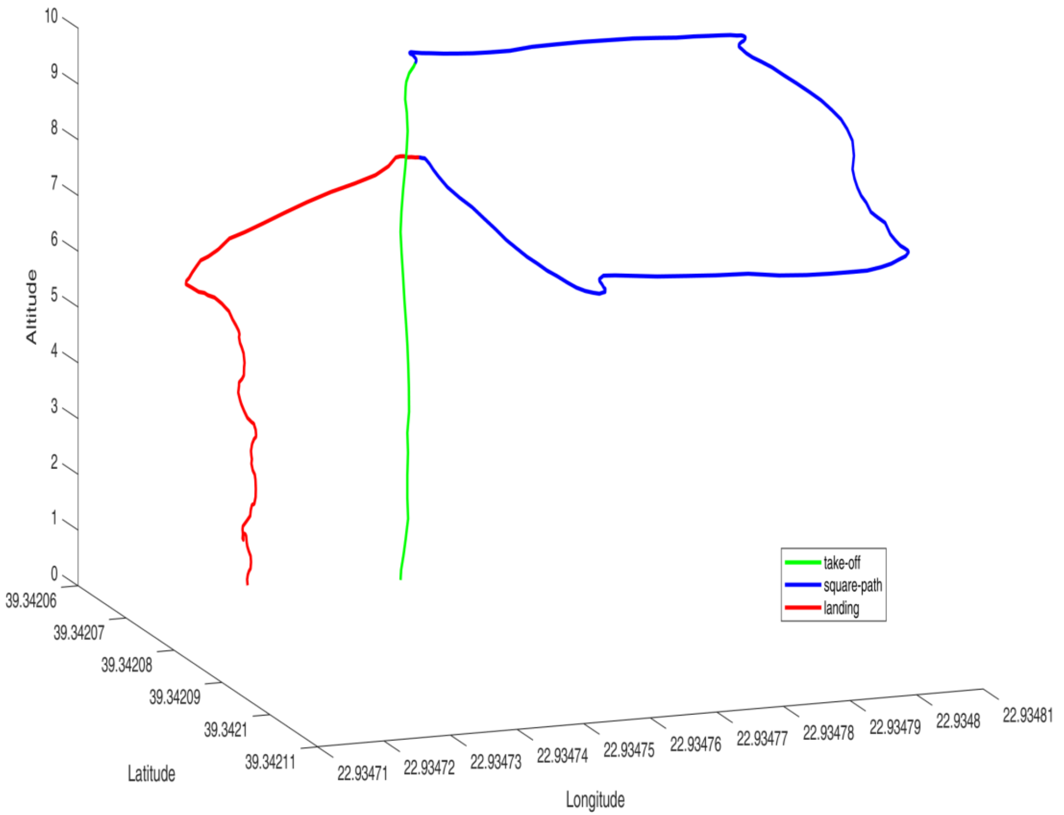


Test mission

Mission plan



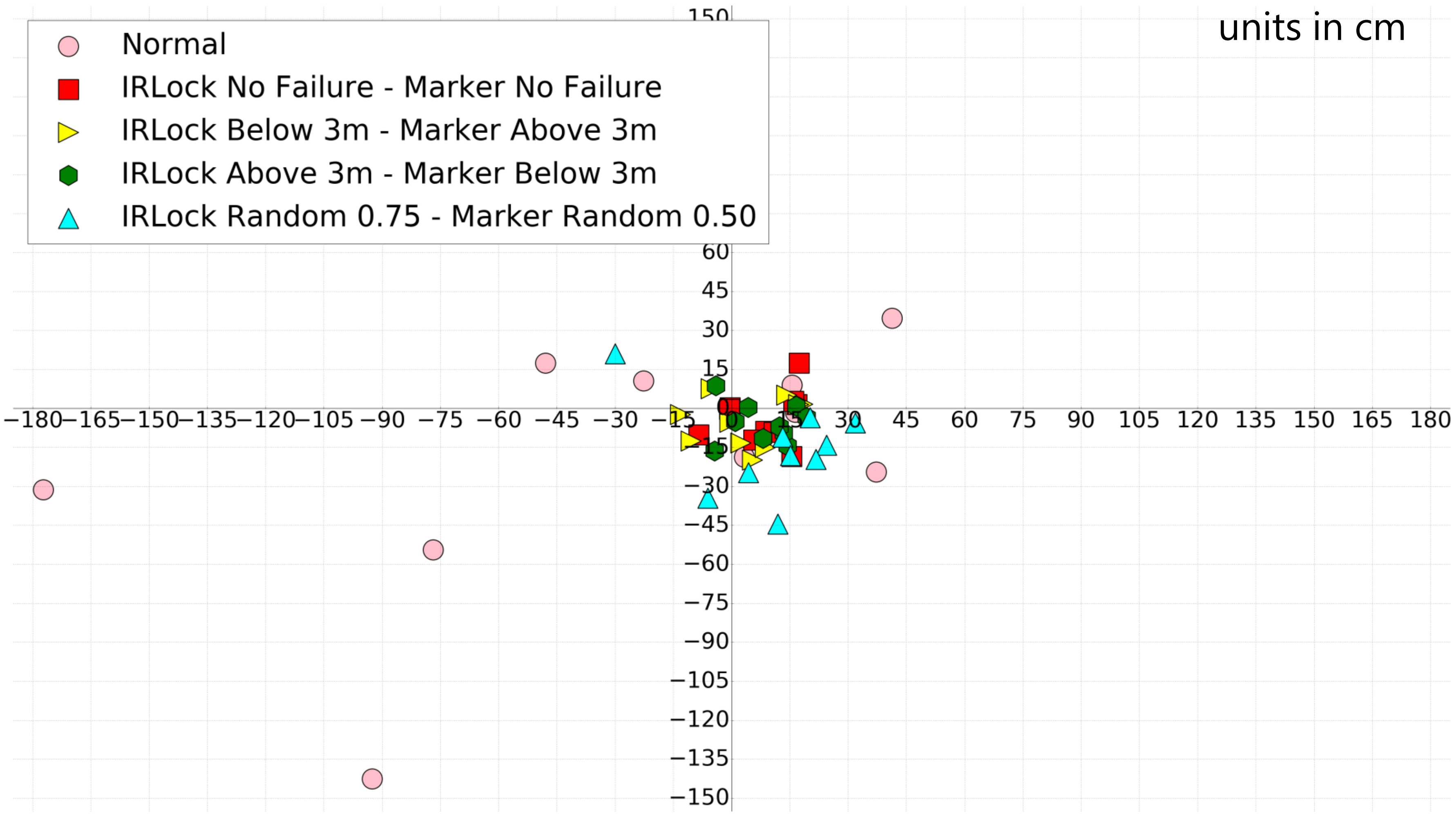
Indicative real trajectory



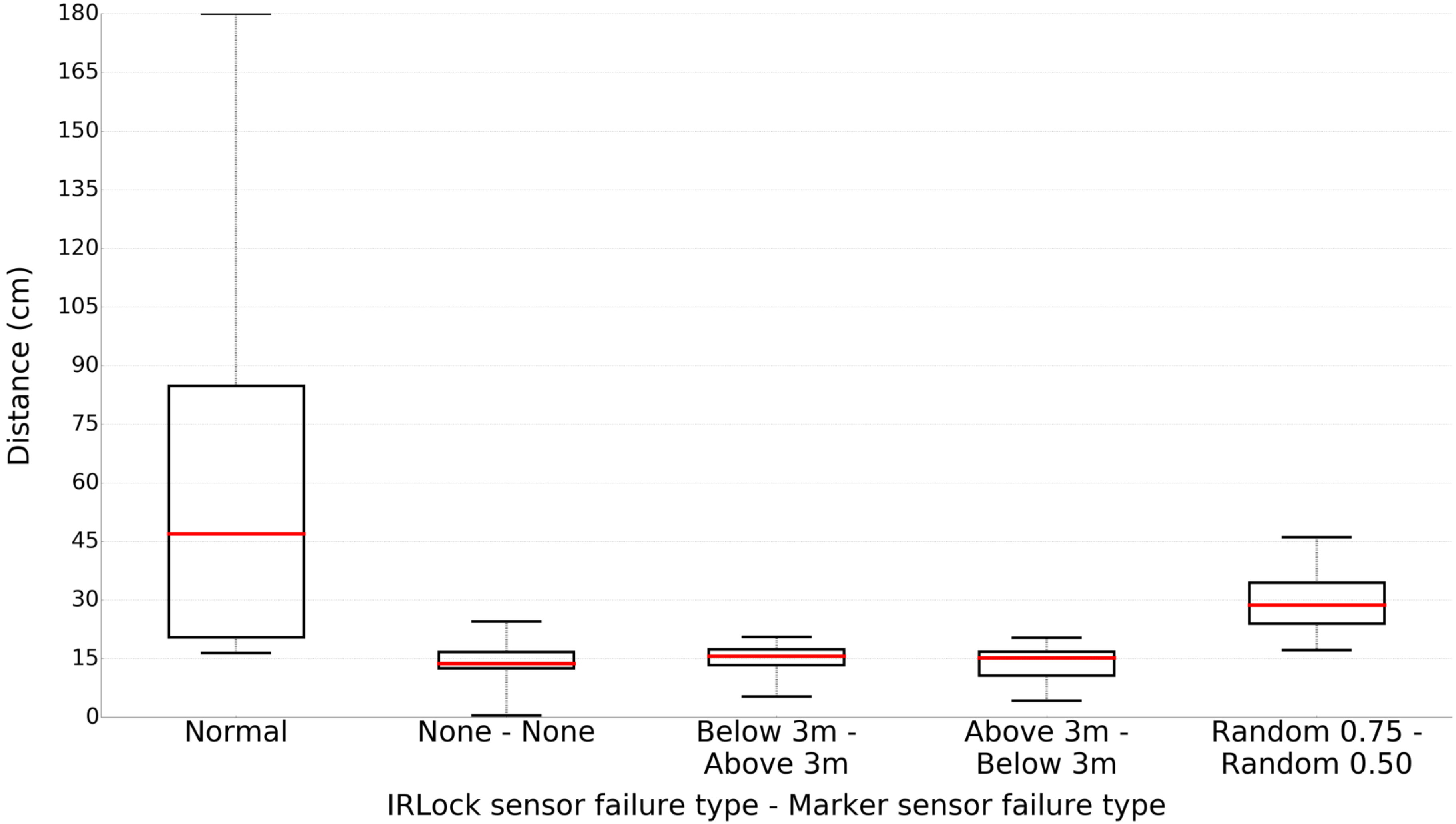
Configuration options

Landing Sensor	Sensor Failure
IRLock Marker	No Failure (no drops)
	Random X (drop with probability *X*)
	Below X (drop only if <= *X* meters above target)
	Above X (drop only if >= *X* meters above target)

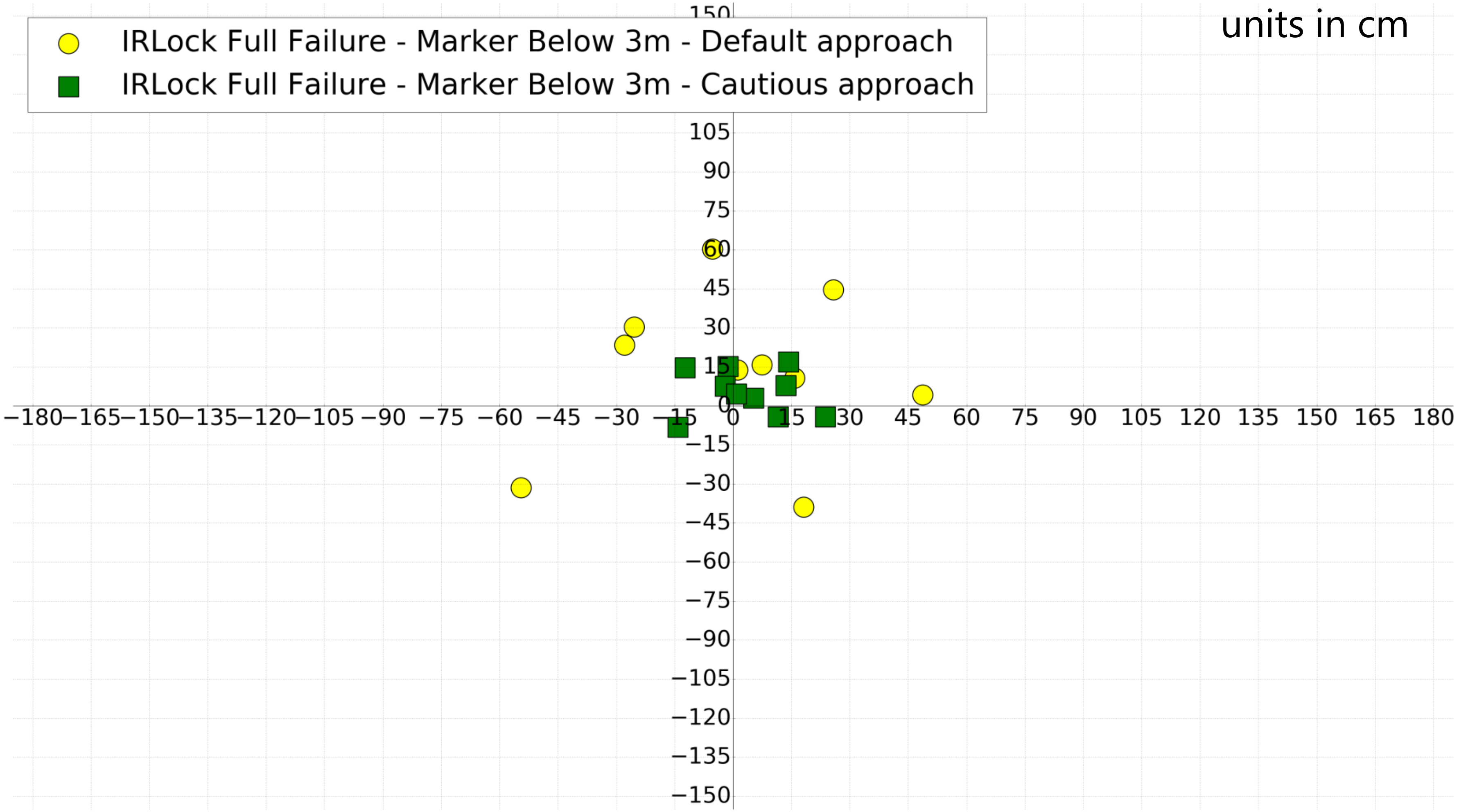
Meta-sensor aggregation results (1/2)



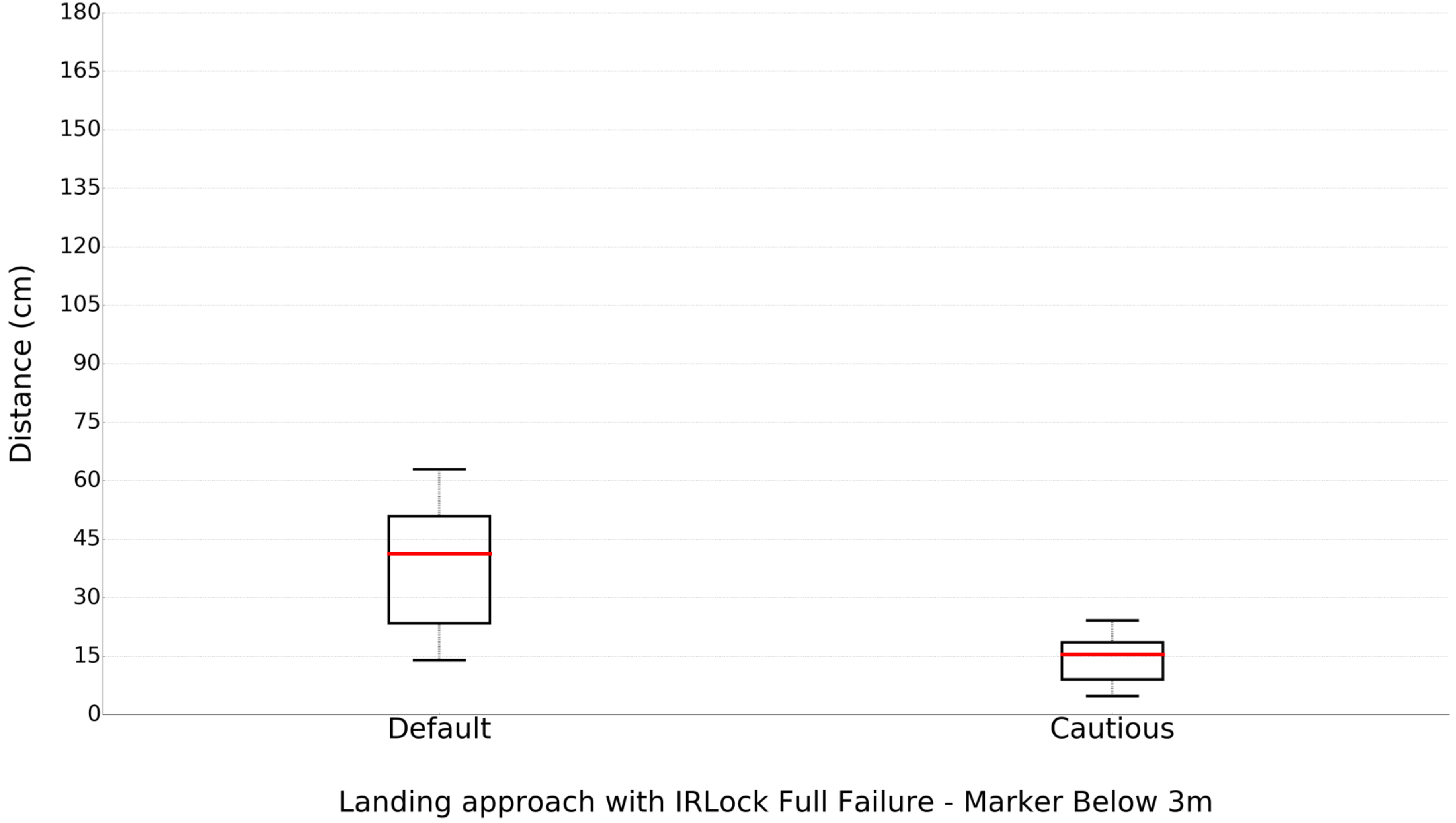
Meta-sensor aggregation results (2/2)



Cautious land mode results (1/2)



Cautious land mode results (2/2)



Concluding remarks

- Extended the precision landing capability of ArduPilot
  - new marker-based sensor subsystem
  - new meta-sensor which aggregates data of IRLock & marker subsystems
  - new cautious precision landing
- Robust precision landing mechanism
  - tolerate failures of any single precision landing sensor
  - repeat landing procedure in case of a failed detection
- Future Work
  - integration of additional precision landing sensor mechanisms
  - such as ultra-sound signals, magnetic materials

Acknowledgments

Auto-Scout

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Thank you!

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https://csl.e-ce.uth.gr/projects/pv-auto-scout

Feel free to contact us