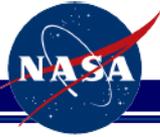




Autonomous Aerial Vehicles for GPS-Denied, Cost-Efficient Inspection and 3D Reconstruction – From Theory to Practice

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Micro Aerial Vehicles as Sensor Carriers

- Automated inspection and reconstruction
- Fast task completion
- Large variety of applications

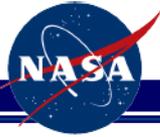


AscTec Falcon (www.asctec.de)



AscTec Firefly (www.asctec.de)





Multicopter Systems for Agile Navigation

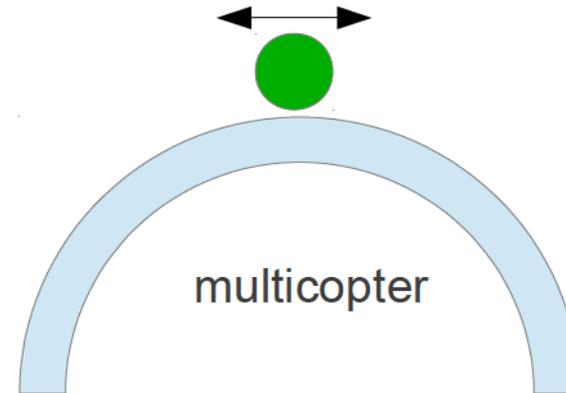
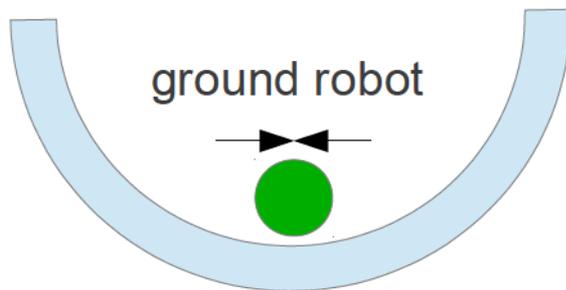
- Agile, fast, and gust tolerant
- Small rotor blades for safer handling
- Inherently unstable
- Tilt in roll/pitch result in acceleration



HeliX coaxial helicopter



AscTec Firefly (www.asctec.de)

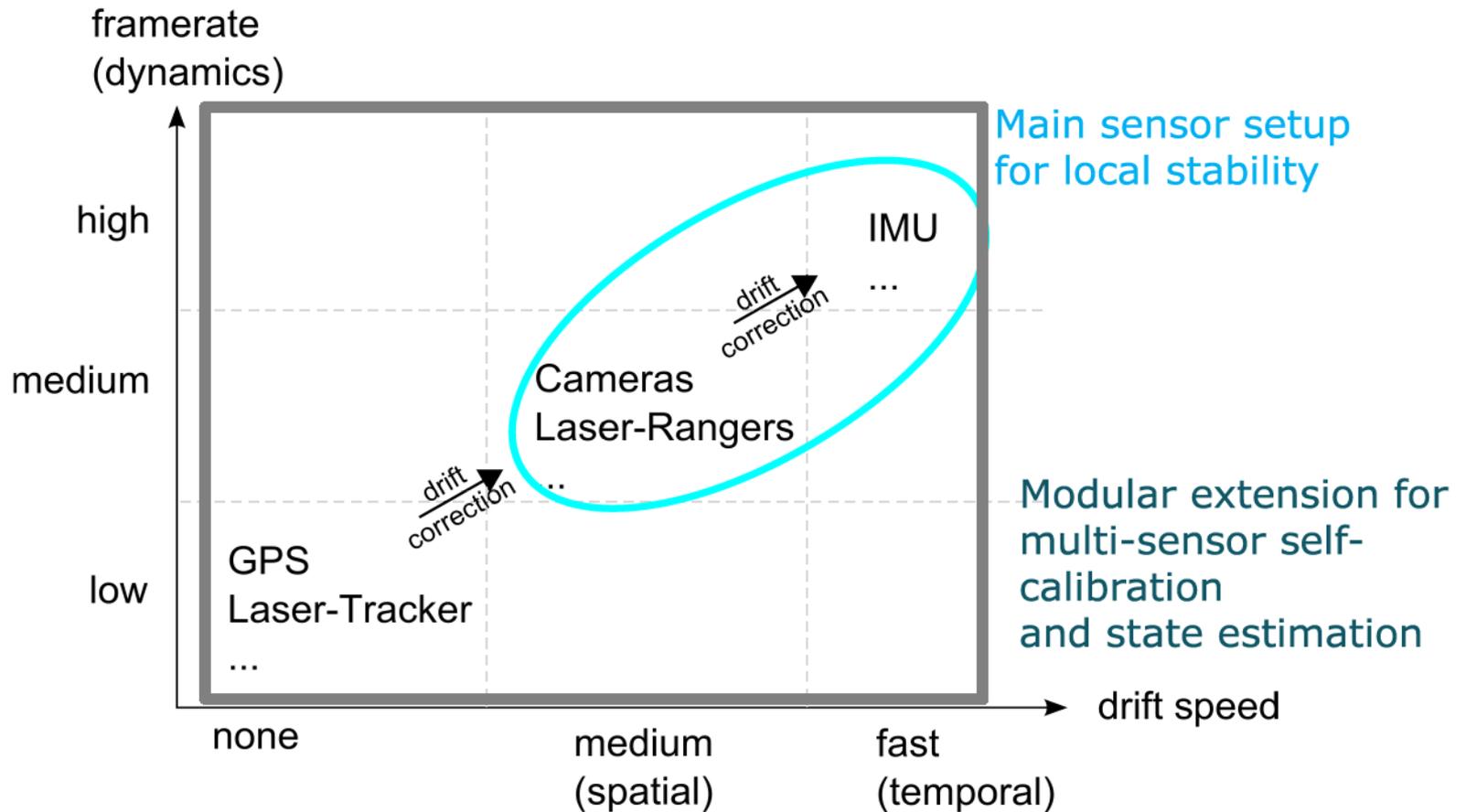




State Estimation for MAV Control

(Weiss PhD, 2012)

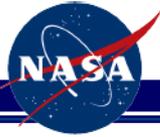
A sensor classification attempt considering frame-rates and drifts





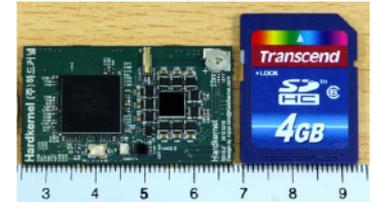
Modular Vision Based MAV Navigation

- Goals:
 - GPS independent navigation
 - Fully on-board, standalone system
 - System self-calibration
 - Drift aware (gravity aligned navigation frame)
 - No pre-mission calibrations (power-on-and-go)
 - Modular: Add/use other sensors
- Main focus: vision based approach
 - One single camera and one IMU



Modular Vision Based MAV Navigation

- Motivation for vision based approach:
 - Only passive sensing, standalone, on-board
 - No link to a ground-station required
 - No environment modification required
 - Lightweight, inexpensive sensors
 - More payload left for inspection sensors
 - Longer battery lifetime and mission times (10g → 1W hovering power)
 - GPS-independent, indoor and outdoor
 - Operation close to and in structures
 - Immune to GPS multi-path issues



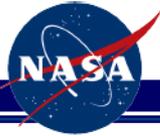
Exynos QuadCore 1.7GHz: <10g



CameraCube: <2g



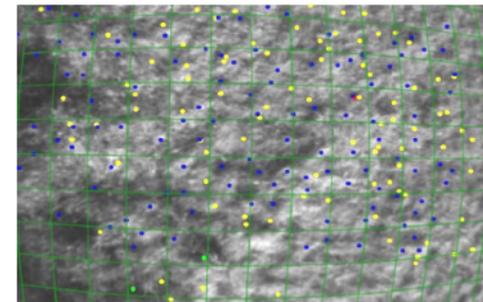
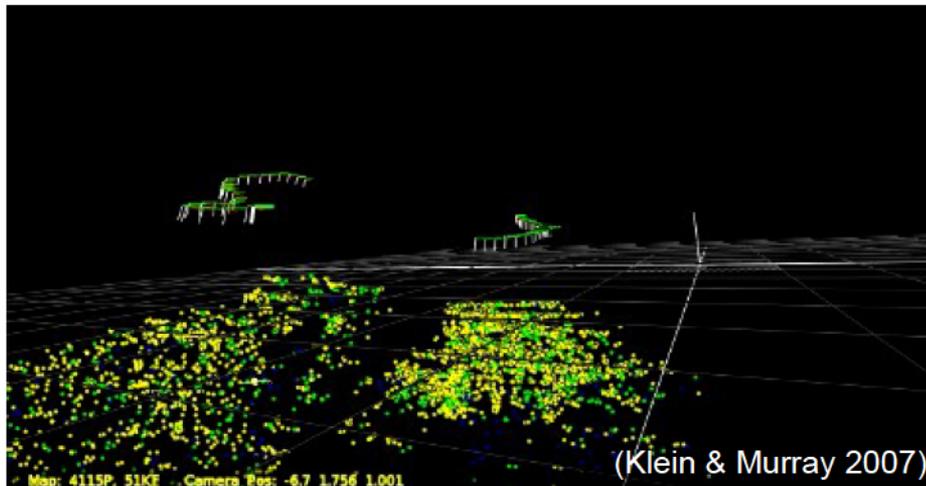
10DoF IMU (acc, gyr, mag, air pressure): <10g



Camera as a 6DoF Pose Sensor

(Weiss PhD, 2012)

- Based on key-frame based visual SLAM
- Improvements for real-time, on-board computation:
 - Constant comp. complexity (visual odometry)
 - 20 Hz on ATOM 1.6GHz
 - Robust in self-similar scenes
- Drifts in all 6DoF

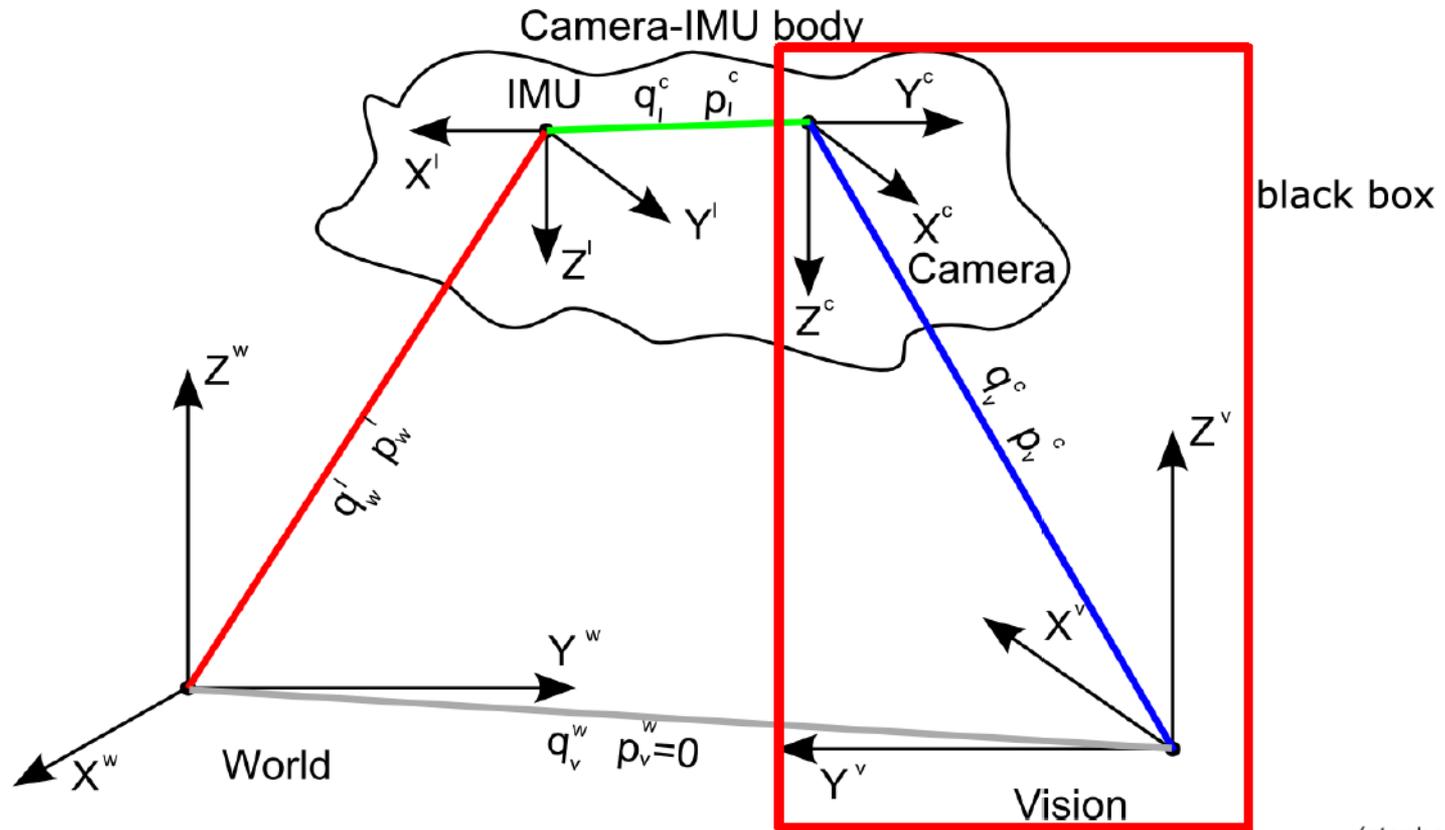


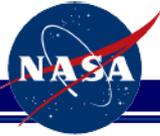
3D features
6D camera pose

Keyframe: typical outdoor scene

Modular Sensor Fusion

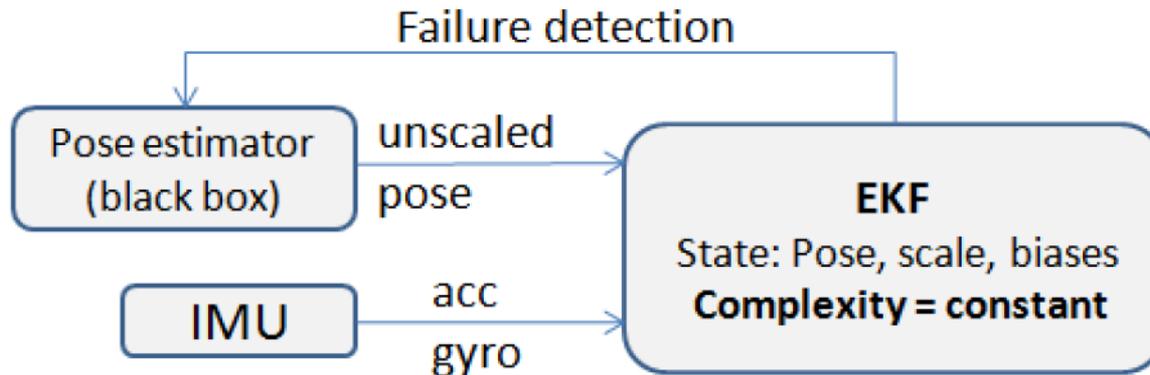
- The idea of decoupling
 - Introduce an independent world navigation frame
 - All sensors measure w.r.t. navigation frame or IMU





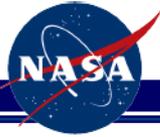
Modular Sensor Fusion

- Modular sensor fusion framework
 - Allows to add different and multiple sensors
 - Always self-calibrating
 - Gravity aligned navigation frame



Autonomous Vision Based MAV Navigation (www.sfly.org)

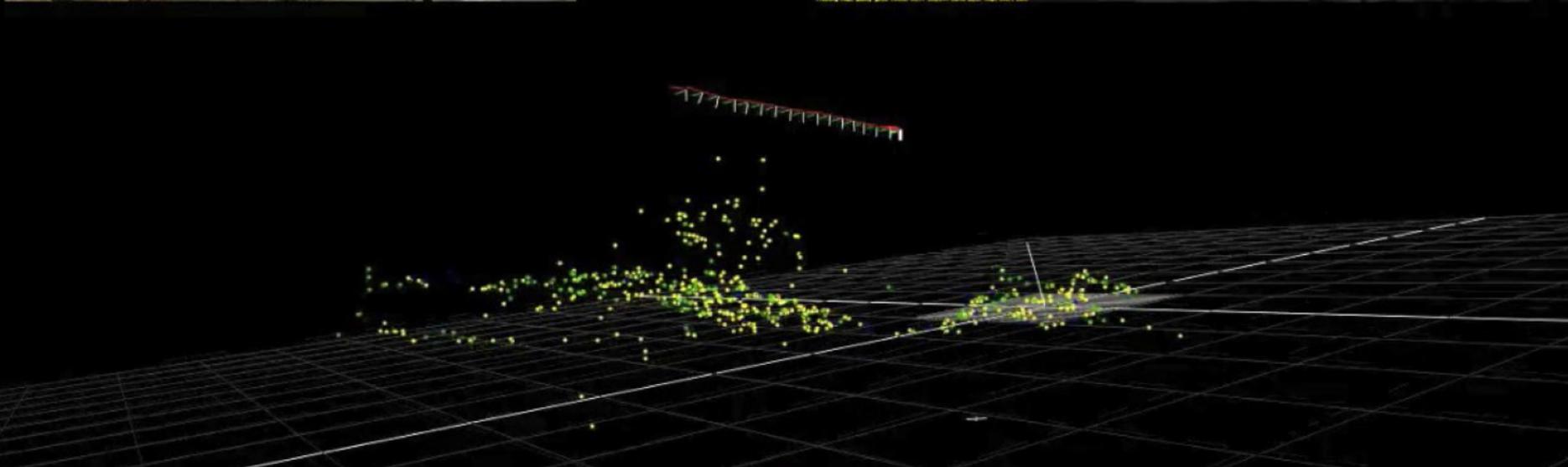
(Weiss PhD, 2012)

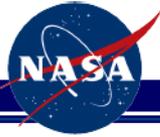


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Tracking Map, quality good, Frame: 0077, 1000x1000, 2012-08-07, 00:00:00





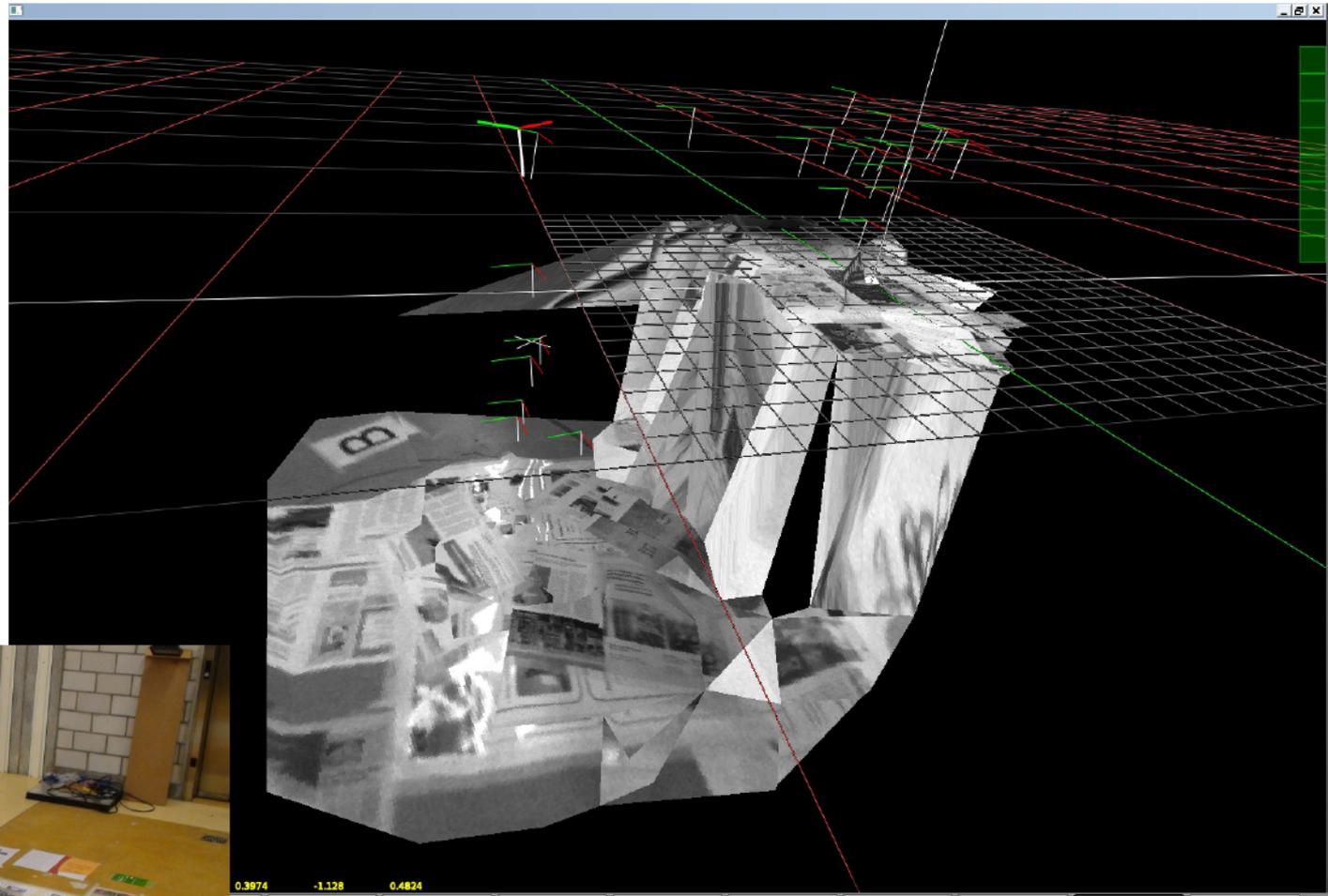
Autonomous Vision Based MAV Navigation

- Robust outdoors on self-similar structure





Environment Reconstruction

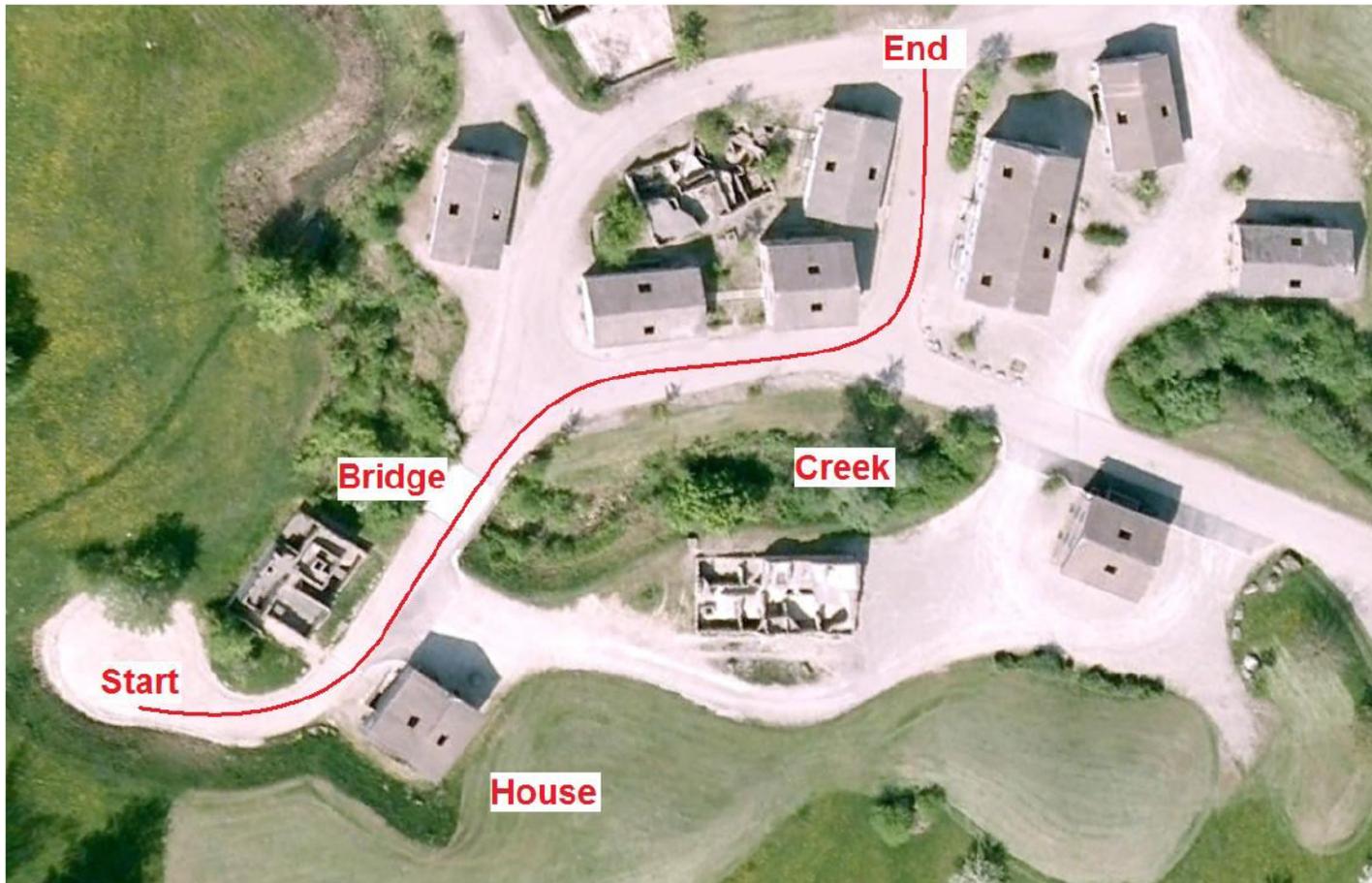


(Weiss et al. JINT11)



Environment Reconstruction

100x100x20m snowy urban environment

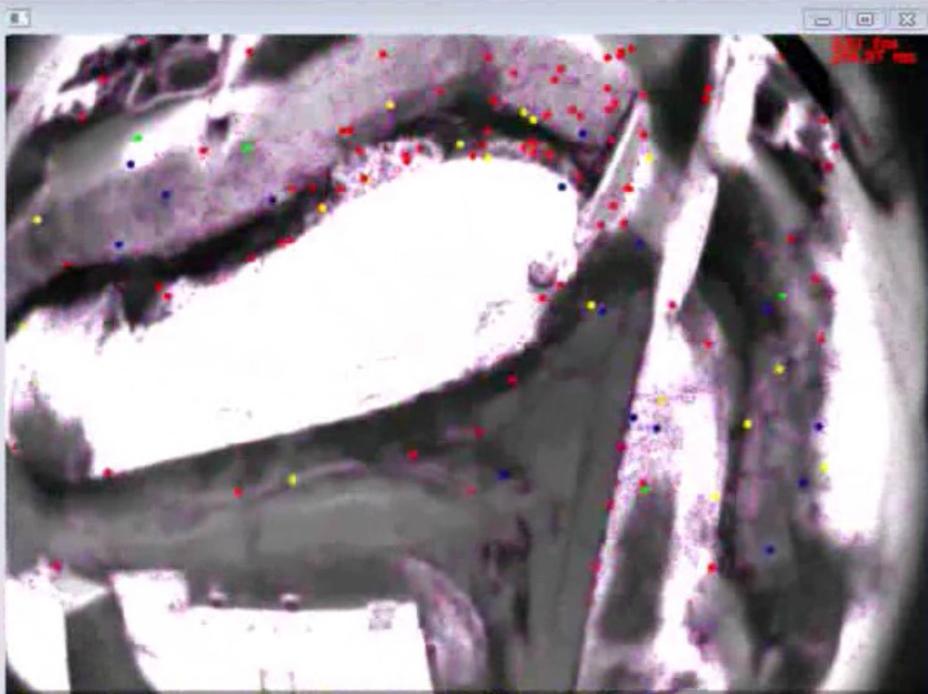


(Weiss et al. JINT11)

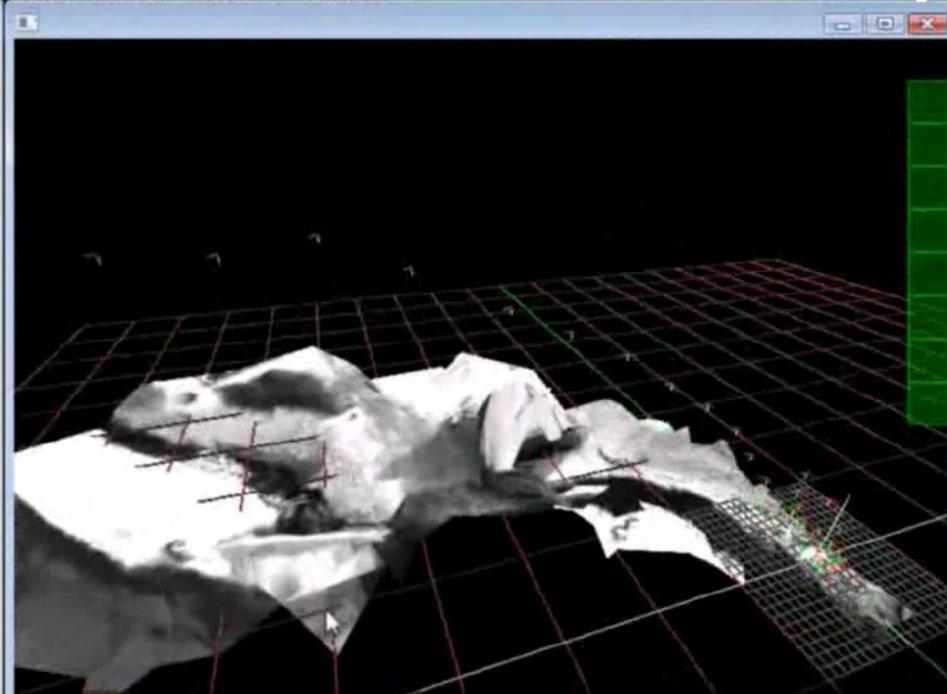


Environment Reconstruction

cam view



3D map



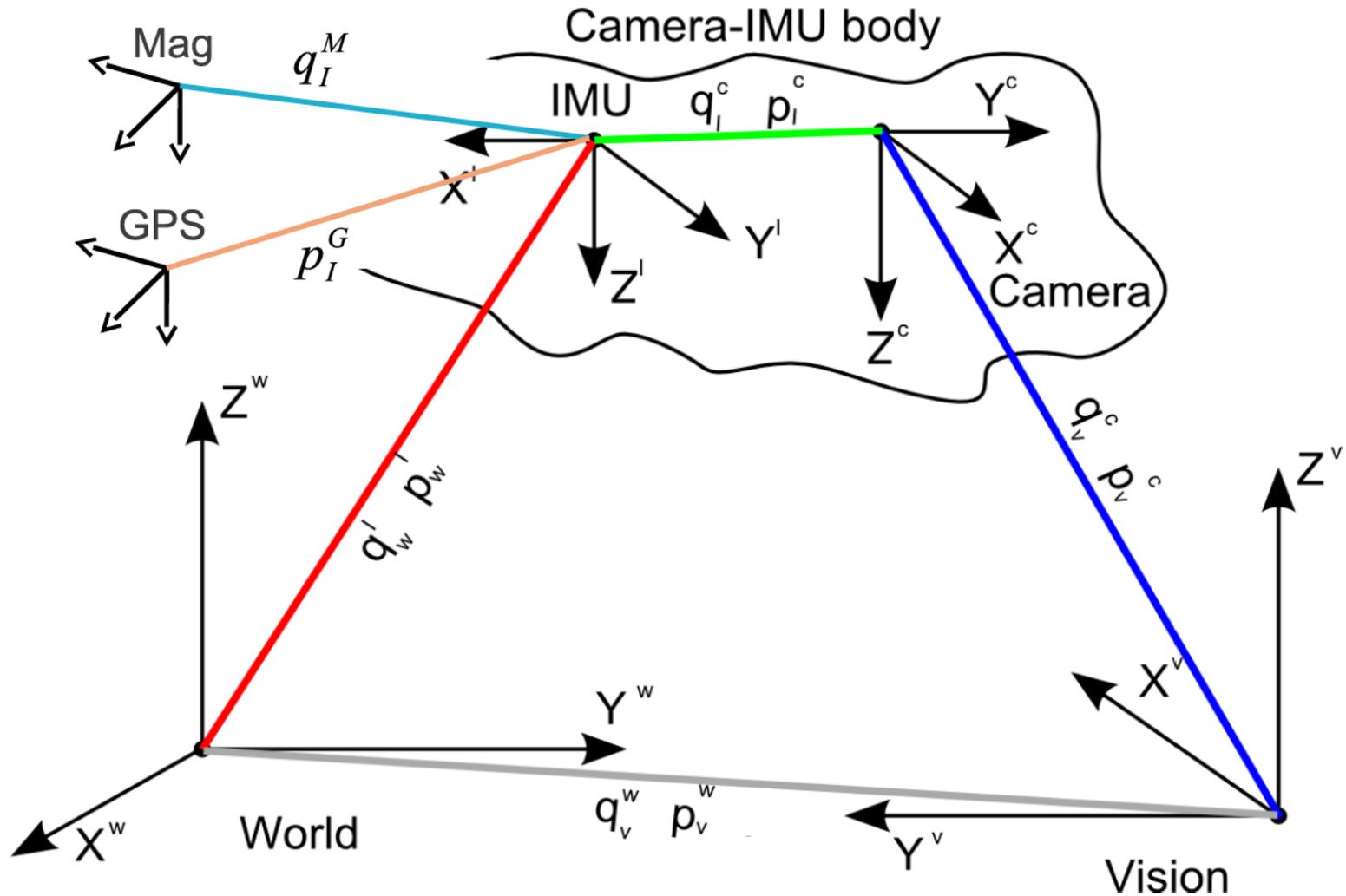
(Weiss et al. JINT11)

Extension to Multiple Sensors

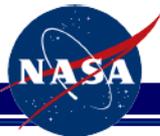
(Weiss PhD, 2012)



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Navigation With 3DoF Total Station (ASL, ETH)



Jet Propulsion Laboratory

- Leica Total Station
 - 7Hz, sub-mm precision, irregular time stamps
 - Range over 1km outdoors
 - Prism mounted on the MAV
 - Independent of environment, link to MAV necessary





Summary and Next Steps

- Current state: vision based navigation tested under real conditions
 - Enables autonomous indoor and outdoor inspection and reconstruction
 - Works in unprepared environments without external sources (GPS, markers)
 - Lightweight sensor suite keeps payload for inspection equipment
 - Self-contained on-board system
 - Modular approach: add other sensors, fail-safe operations
- Next Steps: Efficient and fail-safe user-centered operation
 - Obstacle avoidance
 - Fast navigation close to structure
 - Towards real applications meeting the user's needs



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Q & A

