National Aeronautics and Space Administration

FY23 Topic Areas Research and Technology Development (TRTD)

Long-range Navigation for Mars Helicopters

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Strategic Focus Area: Autonomous GNC, planning, scheduling, and execution

Project Objective:

Extend and demonstrate previously developed autonomous navigation capabilities for a future Mars Science Helicopter (MSH) to enable fully autonomous multi-kilometer, long-range flights at altitudes of up to 100m, and safe landing at previously unknown locations.

- State estimation that includes absolute localization using orbital image maps (e.g. HiRISE) for global localization, including improvements for challenging conditions such as lighting change or low textured terrain
- Landing hazard avoidance for altitudes of up to 100m
- Fully autonomous flight demonstration

FY23 Results:

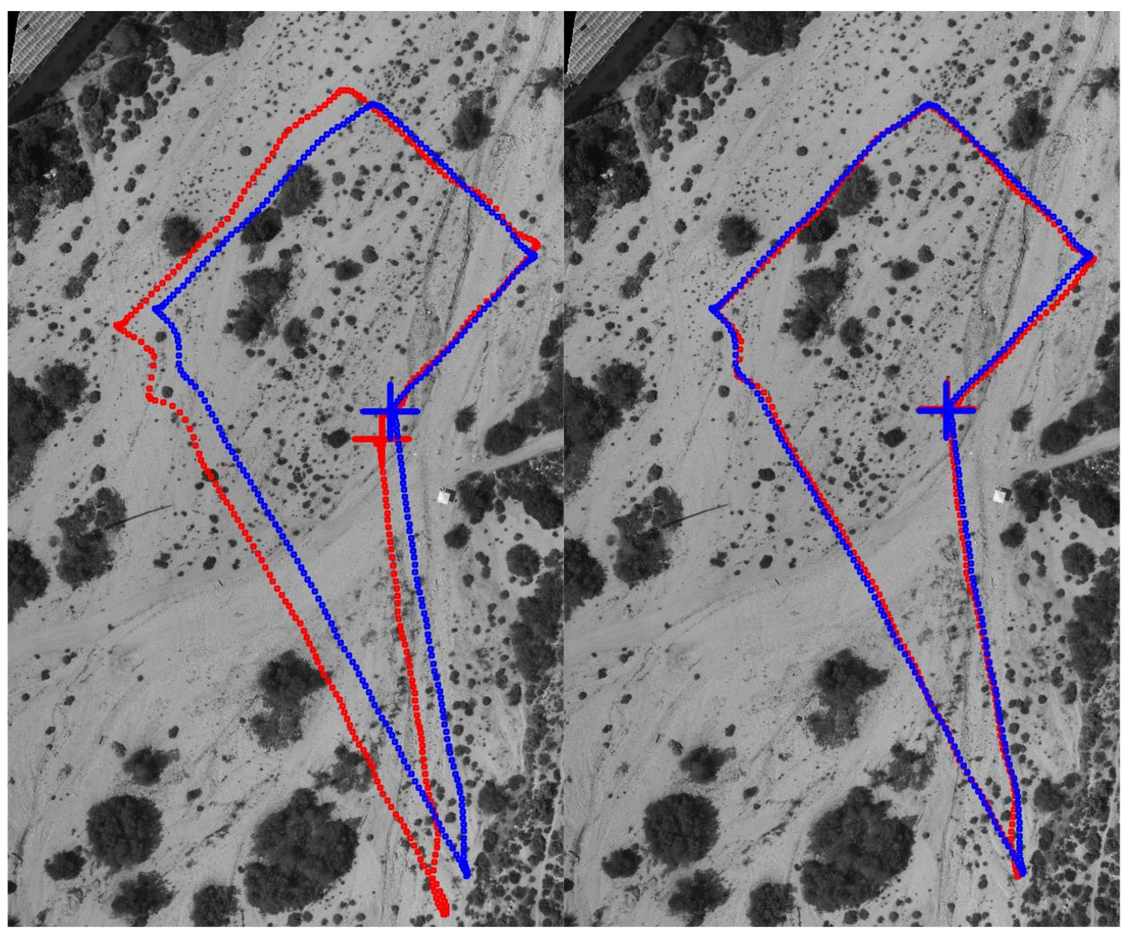
- Integrated and demonstrated map-based localization in simulation and on Earth demonstrator UAS
- Developed and demonstrates new autonomy framework for fully autonomous mission execution
- Study to use learning-based matching approach for map matching with significant lighting changes

Significance to NASA/JPL:

A highly capable Mars Science Helicopter (MSH) could have major impacts on future Mars exploration by enabling high priority investigations addressing all four of the top-level themes of Mars science (Life, Climate, Geology, and Prepare for Human Exploration).

All such missions require significantly more capable autonomous navigation than exists on Ingenuity.

Absolute (map-based) localization



State estimation with map-based localization (MBL) using a keypoint-based matching approach (SIFT). Left: Earth demonstrator UAS flight with VIO only. Right: Flight with MBL. Red: on-board state estimate, Blue: GPS flight path. Flight altitude: 100m. VIO max error: 17.7m. MBL max error: 4.2m

SITL testing in Gazebo Simulation environment

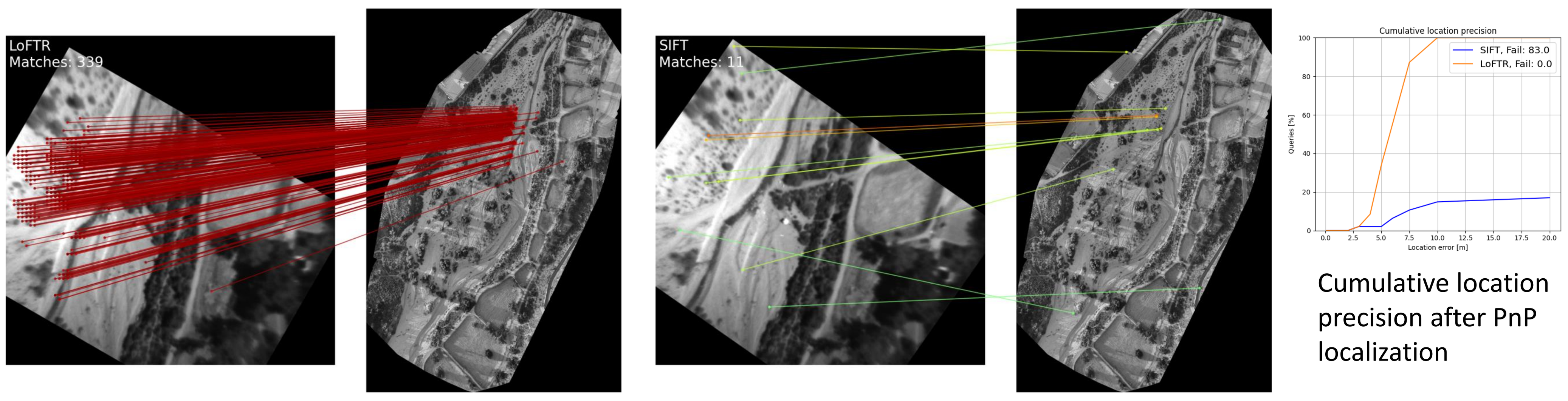
Digital twins of Earth demonstrator UAS (ModalAI Sentinel with Voxl2) in Arroyo Seco environment

Autonomy Framework

Fully autonomous mission execution demonstration on Earth demonstrator UAS. Left: Mission plan; Middle: Earth demonstrator UAS executing the mission; Right: Flight track (using onboard GPS)

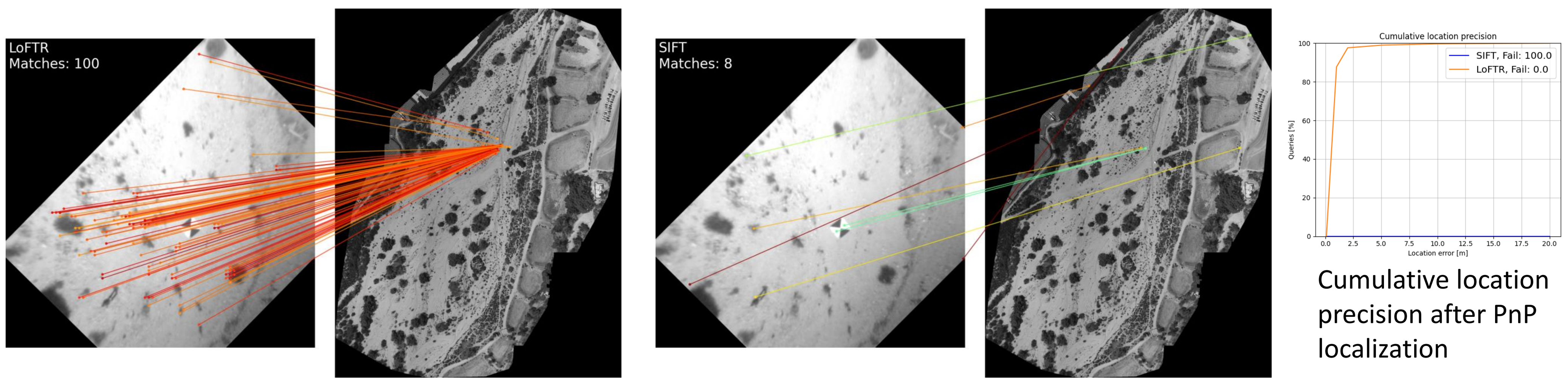
Map matching in challenging conditions

Comparison of keypoint-based (SIFT) matching with a learning-based matcher (LoFTR)



Cumulative location precision after PnP localization

Significant lighting change: Flight at 100m altitude, map created in evening (5:30pm) with HiRISE resolution (25cm/pix), flight in the morning.



Cumulative location precision after PnP localization

Significant scale change: Flight at 12m altitude, map with HiRISE resolution (25cm/pix)

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