

Technical Description Paper for Maverix eVTOL

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ABSTRACT

Maverix is an unmanned eVTOL developed at RWTH Aachen University's Institute of Flight System Dynamics as a research aircraft. The tilt-wing configuration enables vertical take-off and landing capabilities, while retaining the efficiency of a fixed-wing aircraft during cruise. The structure of the aircraft's fuselage and wing is made out of wood and carbon fiber reinforced plastic, with the wing using a rib design and plastic covering. Maverix is capable of automated beyond-visual-line-of-sight operations, enabled by its guidance, navigation and control (GNC) systems. All of Maverix's GNC software has been developed at RWTH Aachen's Institute of Flight System Dynamics and runs on custom-made printed circuit boards and Maverix has been used in multiple publications. These include, among others, investigations on control algorithms for tilt-wing aircraft [1], wind tunnel experiments focused on the aerodynamic characteristics of tilt-wing aircraft [2, 3] and radar-based landing support systems [4].

1 INTRODUCTION

The eVTOL Maverix is a tilt-wing UAS that can tilt its wing from 0° - 88° referenced from the main centre line, depending on the desired airspeed. This enables the aircraft to take-off and land vertically while operating very efficiently in fixed-wing flight. The main propellers are mounted on the main wing and are permanently active. Differential thrust on the main propellers is used either for roll control in hover mode or yaw control in cruising mode. In hover configuration, the tail motor is only used for pitch control while in cruise mode, an elevator is employed and tail motor deactivated. The ailerons are used for yaw control in hover mode and for roll control in cruise mode. Power is supplied by a three cell LiPo battery. Figure 1 shows Maverix during hover flight, Figure 2 and Table 1 show the dimensions most relevant to flight mechanics.

2 STRUCTURE, CENTER OF GRAVITY AND LOAD LIMITS OF THE AIRCRAFT

The UAV load bearing frame is made out of plywood and reinforced by carbon fiber tubes. The wings are covered with



Figure 1: Maverix during hover flight

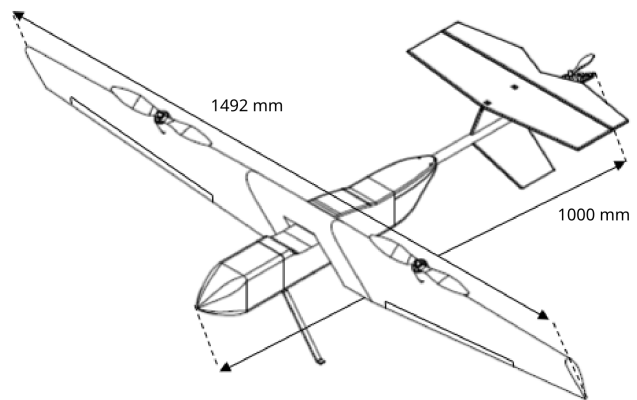


Figure 2: Maverix's Size and wingspan

shrink foil, while the nose and coverings are made out of 3D printed materials. When designing the wing, fuselage and tail unit, the loads occurring in the relevant flight envelope have always been taken into account. Hours of flight tests have proven that the airframe can withstand loads that are within the operational envelope. As can be seen in Figure 3, the design center of gravity is located 370 mm behind the nose. A safe operation can be assured with the center of gravity in the range of 330 mm to 410 mm behind the Nose. Tilting the main wing does not significantly shift the center of gravity due to a balanced chord wise wing design.

3 FLIGHT PERFORMANCE

Due to the tilting of the wing and the very different inflow conditions in the entire flight envelope, the magnitude and direction of effect of the individual control surfaces changes. As a result, different flight performances are achieved in the different flight conditions from hovering to fast forward flight. In Table 2, the key performance statistics for hover-

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Characteristics	
Length	1000 mm
Wing Span	1492 mm
Wing Area	0.275 m ²
MAC	0.21 m
∅ Main Propeller	12"
MTOW	3.0 kg
Battery Voltage	11.1 V (3 S)
Capacity	5000 mAh

Table 1: Maverix key characteristics

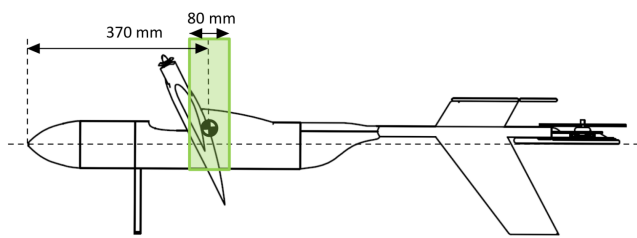


Figure 3: Center of gravity

ing and fixed wing flight are displayed. The maximum flight times were performed without payload (OEW). A standard flight operation as a combination of hover and fixed wing flight allows a flight time of approx. 15 minutes. The actual range depends on the flight speeds and wind conditions specified in the mission profile. The speeds are given as "calibrated airspeed" (CAS) relative to air. The resulting ground speed is dependent on the current wind speed in the environment. Maximum hover airspeed is only limited in the tailward direction due to the mechanical tilt limit of the wing.

Since the tilt angle of the wing is automatically adjusted by the flight controller according to the airspeed, there is no stall speed to consider. The attitude of the aircraft is stabilized throughout the entire flight envelope by the flight controller, using appropriate control variables. In addition to the technical maximum flight altitude specified here, the locally appli-

	Hover	Fixed wing flight
Flight time	up to 5 min.	up to 30 min.
Range	n.a.	45 km
Max. climb -/sink rate	± 1 m/s	± 2 m/s
Max. bank angle	± 35°	± 35°
Max. turn rate	± 20°/s	± 15°/s
Cruise speed	n.a.	+15 m/s
Max. speed	2 m/s	25 m/s
Stall speed	n.a.	n.a
Max. flight altitude	2000 MSL	2000 MSL

Table 2: Maverix flight performance

cable regulations must always be observed during operation.

4 OPERATIONAL CHARACTERISTICS

The hybrid wing UAV is designed and equipped for fully automated flight operation. Taking into account the availability of the necessary services and the legal requirements, BVLOS operation is possible. For safe operation it is necessary to follow the checklists and procedures for maintenance and flight operation.

Table 3 shows the requirements for the flight environment to ensure safe operation: During take-off and landing, the air-

Env. conditions	
Max. constant wind	10 m/s
Max. Gustiness	15 m/s
Operating temperature	-3°C up to +30°C
Humidity	avoid heavy rain, hail, snow, ash, dust and smog
Ice conditions	No flight in icing conditions
Visibility	BVLOS possible

Table 3: Flight environment requirements

craft should be oriented in the direction of the wind, therefore no distinction is made between headwind and crosswind. The electronics of the aircraft are designed for an operating temperature of -5°C to +40°C. and mechanically protected against spray water.

As there is no ice detection installed on the aircraft and neither the wings nor the pitot tube have "de-icing" or "anti-icing" mechanisms, flight operation in "icing conditions" is not intended. The aircraft is equipped with sensors that allow a completely safe flight beyond visual line of sight (BVLOS), of course exclusively under consideration of any legal restrictions. Therefore, there are initially no restrictions regarding the minimum visibility.

5 MISSION AND FLIGHT CONTROL SYSTEM

The core of the flight hardware is the "Mission and Flight Control System" (MFCS). The MFCS was developed in-house with integration of OEM components (e.g. computer module, GNSS, etc.) and external professional production of the electronic assemblies.

5.1 Avionics

The MFCS features a so called FluCoV4 flight computer with three chips from the STM32 family which run the control, navigation and communication software. These chips are placed on the FluCo board together with the IMU, magnetic field and static pressure sensor as well as other components. The FluCo is the central part of hardware inside of the MFCS, as it features the three most important processing units and communicates with the various sensors, actuators and auxiliary avionics devices via CAN and UART in-

interfaces. Additionally Maverix uses a High-Level Board V4 (HL-Board) for additional processing power and datalink options. The HL-Board features a Thundercomm C5165 chip, FLARM and ADS-B receivers as well as 5G-modules, an LTE-M/NB-IoT module as well as an NB-IoT module and Iridium 9603N module for as a communication fallback option. Both the HL-Board and FluCo are developed in-house.

5.2 Navigation

The MFCS features a standalone navigation processing unit on the FluCo's board. The navigation unit is tasked with fusing all incoming sensor data and calculating a highly accurate navigation solution. The following sensors are included in Maverix's basic configuration:

- IMU (accelerometer, gyroscope): TDK MPU-6000, measurement of three-dimensional acceleration and rotation rates
- Magnetic field sensor: Memsic MMC5983, measurement of the earth's magnetic field and thus the UAV's heading
- Static pressure and temperature sensor: TE Connectivity MS5611, measurement of static pressure and thus barometric altitude
- Differential pressure sensor: Honeywell HSC-Series, Measurement of dynamic pressure and thus aerodynamic speed
- Dual GNSS receiver: NovAtel OEM-7720, measurement of position and velocity as well as course angle via dual receiver setup. Real-time kinematic position accuracy is ensured by using a ground-based augmentation system (GBAS INT accuracy). To increase availability, all GNSS constellations (GPS, GLONASS, Galileo and BeiDou) are used if available.

The navigation unit updates an Error-State-Extended-Kalman-Filter (ES-EKF) with a frequency of 1 kHz with the IMU measurements as well as other measurements, as soon as they are available. When processing GNSS measurements during the estimation step of the ES-EKF a loosely coupled algorithm is used. This means the position of the aircraft is estimated instead of the distance to individual satellites. The navigation unit delivers a navigation solution for position, velocity, acceleration, attitude, and turning rates (all in 3-DoF) which is available at a frequency of 1 kHz. The quality of the GNSS position determination is continuously monitored so that a GNSS fix loss (due to jamming or shadowing) or a complete failure of the GNSS system can be detected immediately. For this purpose, the accuracy and validity data of the corresponding GNSS module are evaluated. Furthermore, the time since the last GNSS data packet is monitored to detect the complete failure. In the case of a GNSS error, the

altitude is determined via the barometric pressure sensor. The horizontal position is still determined by integrating the inertial measurement data, but with rapidly degrading accuracy, so following predefined procedures an emergency landing is initiated by the remote pilot.

5.3 Flight Control System

The autopilot of the "Mission Flight Control System" is also completely developed in-house and provides the real-time environment on which the flight control runs. The goal of the control system is to keep the system in a stationary, stable operating point, meaning that no forces or moments act on the aircraft.

If for example a higher airspeed is commanded, the control system needs to bring the aircraft to the next stationary operating point, and thus flight state, with a higher air speed. From a control theory perspective, tilt-wing aircraft have unique characteristics in the sense that its actuators have constantly changing effectiveness depending on the system state, leading to over-actuation, as well as heavy cross-coupling effects.

This means that the aircraft has multiple ways to affect the same system state (e.g. pitch angle affected by both tail rotor as well as elevator) during transition. Here, each stationary operating point can be mapped to a set of solutions, instead of a unique solution.

Table 4 shows the available control surfaces and motors and which forces and moments they are able to generate depending on the tilt angle σ of the wing (which itself is controlled by the control system) and the resulting air speed.

The indices of the forces and moments are denoted in the

Actuator	$\sigma = 0^\circ$	$\sigma = 88^\circ$
Wing Propellers	F_z, M_x	F_x, M_z
Tail Propeller	F_z, M_y	F_z, M_y
Aileron	-	M_x
Elevator	-	M_y

Table 4: Maverix actuator effectiveness depending on σ

body-fixed coordinate system. The table shows only the highest and lowest sigma, but during the transitional phase the effectiveness of the actuators constantly change as the wing is tilted forward with increasing air speeds, leading to an over-actuated system during transition. For example, at transitional airspeeds up to 12 m/s, the pitch angle can be controlled by both the elevator and the tail motor, with nonlinear effectiveness depending on the airspeed. Any commanded forces and moments thus cannot be directly mapped onto actuator states. Instead multiple input, multiple output algorithms which allocate actuator commands have to be used. Additionally during the transition to cruise speed highly nonlinear and difficult to predict forces and moments might occur as the flow attaches to the wing and lift is first generated. Similar considerations must also be made for the transition back

to hover speed during which nonlinear stall effects occur. The transition from hover to cruise flight (and the reverse transition) is not a scripted sequence, instead all air speeds of the flight envelope can be held as stationary operating points. The control systems authority ranges from the base attitude control stabilizing the aircraft up to the path controller ensuring the planned flight path is followed. The control system has a cascaded structure with position, velocity, acceleration, rates, attitude and height control. Among the control strategies used are:

- Incremental Nonlinear Dynamic Inversion (INDI) for attitude control (see Sieberling et al.'s work [5]).
- Model-based, operating-point-based, feed-forward control for translatory acceleration control.
- Linear-quadratic regulator feedback controller for rates control.
- PID or PI feedback controllers for position and velocity control.

A higher-level path controller ensures low horizontal and vertical deviation from a specified flight path.

5.4 Automated Flight Sequence

During automated flight, the autopilot fully controls the aircraft, unless the safety pilot intervenes by terminating automatic flight. The standard automated operation of the tilt-wing UAS starts with a vertical take-off procedure that results in a hovering condition. An advantage of the tilt-wing design is its ability to adjust the tilt angle of the wing depending on the wind speed already during take-off, and thus neutralizing the wind forces without changing the pitch or roll angle. This enables the aircraft to take-off even during high wind speeds. After take-off the aircraft transitions into its cruise configuration by tilting its wings forward. During the transitional phase the wings are tilted inside of the entire range, from 0° to 88°. At the end of the operation, the aircraft hovers over the landing site and performs a vertical landing. During take-off and especially during landing, the aircraft must maintain its position very precisely. Between take-off and landing, the aircraft flies fully automated along a predefined path.

5.5 Manual Control

For initial flight operation and possible system testing, a qualified Safety Pilot can operate the aircraft manually. During manual operation the base attitude control is still active to stabilize the aircraft, while the pilot can command accelerations. Optionally take-off and landing can also be carried out manually. The manual mode is also a fallback option in case of failures. The remote Safety Pilot has full control over the UAV if necessary (also see Section 7.9).

6 MISSION PROCEDURES

A typical automated mission performed by Maverix consists out of an automated start, automated flight and mission specific tasks and an automatic landing. Specific procedures for missions have been established and are presented here.

6.1 Take-off

A major advantage of the tilt-wing configuration is the ability to prevent getting blown away directly after take-off despite higher wind speeds. For this, the aircraft is aligned in the main wind direction as part of the pre-flight procedures. Before the aircraft is cleared for take-off, various systems and conditions are checked. These include:

- Std.-Dev. GNSS Solution Position
- Std.-Dev. GNSS Solution Heading
- RC-Link quality
- IAS set
- Wind speed setup
- Mission set
- Safety pilot has correct RC settings
- Large attitude angles on the ground

When all values are in the adequate range, the Remote Pilot from the ground station can command the launch. After automated take-off, a vertical climb at a constant rate to the safety altitude is initiated while the position controller maintains the position above the take-off site.

6.2 Flight and mission

During flight the flight control system has the task of keeping the aircraft in a stationary straight flight and stabilizing the aircraft at the same time. In addition, the flight state controller ensures the highest possible control reserves throughout the entire flight envelope.

The flight mechanical characteristics of a tilt-wing aircraft change throughout the flight envelope as the wing tilts and the inflow conditions vary greatly. An important task of the flight state controller is therefore to mask the changes in the behavior of the closed-loop system due to different inflow conditions in such a way that the UAV shows an almost identical response for the higher-level controllers in all flight states. Overall, the flight state controller allows the UAV to be kept within the defined limits (in terms of flight envelope, structural limits, and performance) and to be safely stabilized within them.

6.3 Landing

The landing procedure starts once the designated landing site has been reached. The aircraft is in a hovering state relative to ground, facing into the wind. A vertical descent at a constant rate is initiated, while the position controller maintains the position above the landing site. During the descent, the quality of the navigation solution is continuously monitored, so that the aircraft can immediately climb back to safety altitude or approach an alternate landing site. After touchdown, the motors are shut down automatically.

7 SAFETY FUNCTIONS

The various automated safety functions of the flight control system are presented below. These safety functions are partly triggered automatically and partly by the Remote Pilot in the ground station. The operator's emergency procedures (Contingency and Emergency Procedures) in the event of a special or abnormal situation can be found in additional documents regarding procedures and checklists.

7.1 Health Monitoring

The Remote Pilot receives all critical information in the ground station. The current attitude, altitude and position, critical power consumption, critical battery charge and avionics system failures on board can be monitored throughout the entire flight. At present, any anomalies that may occur do not trigger any automatic responses, but are displayed to the specially qualified Remote Pilot in the ground station. Based on defined procedures, appropriate measures are then taken. The Remote Pilot can intervene during any flight phase to ensure a safe landing.

7.2 Static obstacles

The flight path is calculated before start of the UAV considering all static obstacles, geofences, and flight geography. If a recalculation of the flight path is necessary in order to avoid conflicts during the flight, the waypoints are manually shifted, respecting static obstacles, geofences and flight geography and then sent to the UAV.

7.3 Battery management

Under normal conditions, the batteries are not discharged below 10.2V. This makes sure that there is always enough energy left for a safe landing. The prescribed procedures during operation and charging of the flight batteries ensure the safety/lifetime of the batteries. The current state of charge of the batteries is continuously monitored throughout the entire flight. This is done by evaluating both the real-time voltage of the flight batteries and the total electrical charge consumed. Based on this information, the remaining flight time is calculated and displayed to the Remote Pilot in the ground station.

7.4 Geofencing

The described UAV has a geofencing system installed which prevents the aircraft from leaving the desired airspace. During the planning phase of a mission, geofence positions

can be defined which result in a polygon around the desired airspace. In case of an unlikely geofence crossing, the software limiter is opened, the motors are shut down and a steady decent is initiated.

7.5 Hover and POS

When this function is activated, the current mission is terminated and the aircraft decelerates along the current trajectory. This mode is automatically activated at GNSS-loss but can also be manually activated.

- No GNSS: When hovering without GNSS, a heading and airspeed required to maintain the current position over ground is commanded based on last wind estimation and is controlled using the backup magnetometer. The current height is controlled using the backup barometer. If the GNSS does not recover after a certain time a slow descent rate is commanded at this (unknown) position.
- GNSS functional: When hovering, the Remote Pilot can command minor displacements (e.g. 2 m west or 5 m south) to shift the aircraft to a more suitable landing spot. Additionally, the Remote Pilot can command a predefined slow descent rate for landing at this location.

7.6 Return to Home

When this function is activated, the current mission is terminated and the trajectory planner calculates a safe trajectory back to the take-off location, taking into account known static obstacles and limitations of the flight area. The aircraft then follows the newly calculated trajectory and lands safely at the initial starting point.

7.7 Land at current location

Once the Hover and POS-Control has been initiated and the UAV is stationary, landing can be initiated at the current location. In this mode, the aircraft will descent with a constant speed until the ground has been reached. Once the UAV has touched down, the motors will be deactivated.

7.8 Emergency-Off

When this function is activated, all engines are switched off to minimize the effects of ground impact (spinning blades) and to stop adding energy to an uncontrolled situation. This mode can be used as a last resort for geofence violations, and/or to minimize ground risk.

7.9 Remote control (for the Safety Pilot)

The UAV can also be controlled by a trained Safety Pilot in visual range. For this purpose, a 2.4 GHz remote control is used. A planned flight and take-off command in the GCS are always necessary.

- Auto mode Pos. 2 (Full automatic): When this mode is selected, the system performs a fully automated flight, from take-off to landing.

- Auto mode Pos. 1 (Manual mode): When this function is activated, the safety pilot can control the aircraft by controlling roll, pitch, yaw, wing tilt angle and thrust.
- Auto mode Pos. 0 (E-Parachute): When this function is activated, the safety pilot can control the aircraft by controlling roll pitch, yaw and thrust. The wing tilt angle will be fixed to 90°. Full wing tilt control can be handed over to the safety pilot if the wing tilt command on the remote control is turned to 90°.
- Limiter (Motor on/off): This option can be used by the safety pilot for example to stop a faulty take-off if he notices that not all motors are running or as a last resort for a control loss, to minimize the effects of ground impact or the risk of the spinning blades.

8 DATALINK AND GROUND CONTROL STATION

The MFCS has multiple communication options for secure data transmission of telemetry, telecommand and user data. The availability of LTE mobile data allows for out-of-sight operation. There is an integrated SSD for storing payload data. During a mission the aircraft is operated exclusively in fully automatic mode. For safety purposes, the aircraft is equipped with an RC receiver of a commercially available 2.4 GHz system in addition to the C2 link. Communication between the ground station and the aircraft (C2-Link) takes place by one of the following methods:

- Line of sight radio communication in one of the following frequency bands: 2.4 GHz, 868 MHz, 433 MHz, 2.4 GHz WiFi
- 5G
- LTE-M/NB-IoT with NB-IoT over satellite support
- Iridium Short Burst Data as a satellite-based fallback option

8.1 Datalink Protocol

The primary data link of the flight system is realized through a cellular network modem via a UDP connection to a static server. Over this bidirectional link, the flight system continuously sends telemetry data and can receive different control commands. The server processes this telemetry data and makes it available to the end user(s) via a separate TCP interface. The server and the aircraft also exchange heartbeat packets with each other in a clocked manner. In this way, the aircraft can independently determine whether the connection to the server has been lost and, if necessary, use an alternative communication path, e.g. via satellite. The latency of the entire data link

- regarding commands of the Remote Pilot in the ground station until the successful delivery to the control system of the aircraft and

- regarding telemetry data from the aircraft to be displayed in the ground station

is smaller than 0.5 seconds based on long range tests in different flight environments.

8.2 Datalink Degradation

The main communication link of the aircraft is realized by two redundant cellular network modules. All telemetry data is always sent in parallel over both channels. The antennas are arranged in the fuselage in such a way that simultaneous shadowing by the aircraft itself is very unlikely. The signal quality of the modules is available in the ground control station and is displayed to the Remote Pilot. The SIM cards used can register with any network operator. When switching on, the mobile network with the highest signal quality is used in each case. If the mobile network currently in use is no longer available, the cellular network module dials into any other available cellular network. For the communication between aircraft and server, a UDP protocol is used to prevent unsent packets blocking the most recent data. This ensures that the server always receives the critical live information, which can then be passed on to the Remote Pilot's ground station.

8.3 FSD Ground Control Station

The ground control station (GCS) used in the research projects of the Institute of Flight System Dynamics is also developed in-house. The ground control station enables mission planning and surveillance, as well as the live streaming and logging of aircraft data via internet connection. The graphical user interface of the mission planning plugin of the FSD GCS is shown in Figure 4.

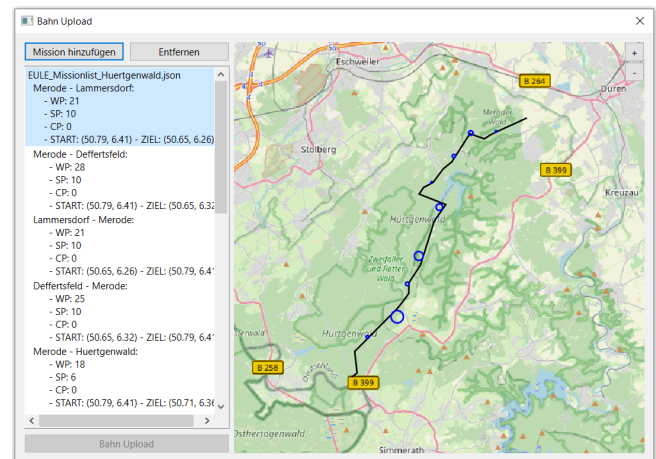


Figure 4: FSD GCS

9 IMAV 2025 TASKS

During IMAV 2025 Maverix will be used only in the outdoor competition. As an eVTOL and transition aircraft Maverix is well suited to mapping and endurance tasks during

cruise flight. However, Maverix's potential payload weight is comparatively small limiting its capabilities in transportation tasks. Additionally, so far integrated flight operations with multiple Maverix UAVs have not been implemented and tested, meaning that any tasks requiring cooperation between multiple UAVs can not be completed. Hence, Maverix will be used for the outdoor missions one and two, as well as for the outdoor surveillance challenge, as described in the IMAV 2025 rulebook.

9.1 Mission 1: Mapping of a disaster area

Mission one requires the mapping of an area defined by GPS points. Here, according to the rulebook it is possible to be dropped by another UAV at a height of 30 m and transition into cruise flight during the fall. Since Maverix is designed as a VTOL aircraft with no capability to stabilize after being dropped from a larger UAV, it will not use that possibility and instead take-off from the take-off zone on the ground. Both take-off and landing can be performed autonomously. For the mapping mission Maverix is equipped with a camera pod under its fuselage as a payload. The payload currently used for mapping tasks uses a Raspberry Pi Camera Module 3 on a 2-axis 3-D printed servo gimbal. All required image processing algorithms as well as the control of the gimbal are performed by a Raspberry Pi Zero 2 microcontroller. The 3D-printed pod as well as the gimbal and camera of the payload are shown in Figure 7. In the future, an Arducam OV9281 and an NVIDIA Jetson for higher resolution images as well as processing power will be integrated. Additionally, a 2D ball-bearing swashplate gimbal with passive damping is being developed to simplify the design, improve tracking capabilities and reduce noise.

To generate the map a stitching Oriented FAST and Rotated BRIEF (ORB) algorithm is run in real-time on the NVIDIA Jetson. FAST (Features from Accelerated Segment Test) is a feature detection algorithm using corner detection. BRIEF (Binary Robust Independent Elementary Features) is a feature description algorithm, calculating a corresponding "fingerprint" to each feature, making it possible to differentiate between features. ORB fuses these to algorithms, resulting in an efficient, real-time capable algorithm. Whenever a new image is taken by the camera, the ORB tracks and recognizes features, the features are then matched from image to image, rotated and translated, and then finally merged, creating a new, larger map. The flowchart of the Mapping algorithm is depicted in Figure 5.

The additional computing capabilities of the Jetson processor and the datalink options provided by the HL-Board will enable Maverix to run the mapping and stitching algorithms online while live streaming the feed to the ground control station. Figure 6 shows the in-progress mapping of an area.

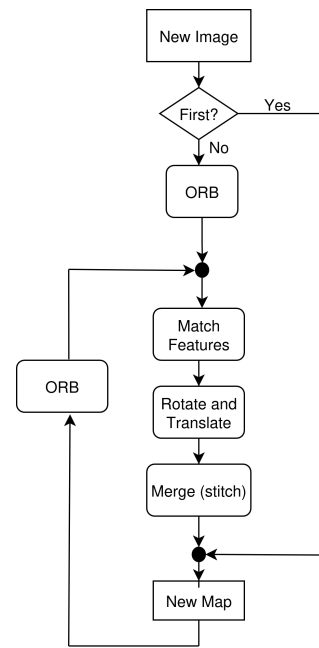


Figure 5: Mapping flow diagram

9.2 Mission 2: Finding a person

Mission two requires identifying a person in a target area within a 20 m radius surrounding a given GPS coordinate. Out of multiple persons in the target area the correct person has to be identified with a previously given textual description. The MAV then needs to autonomously land within a radius of 2 m of the identified person without landing on the person.

This task will be solved with the same camera pod and processing hardware used in the first mission. The UAV will fly over the target area while scanning it with its camera. While the area is being scanned by the MAV a YOLO image recognition algorithm runs on the NVIDIA Jetson processing unit, detecting any person in the area in real-time. YOLO (You Only Look Once) algorithms are a family of object detection algorithms based on convolutional neural networks. YOLO algorithms only require limited computational power, enabling on-device, real-time object detection. The YOLO algorithm places a bounding box around the person it detected and calculates the corresponding coordinates of the box. Then, the content inside the box is interpreted by an image description model also running on the NVIDIA Jetson unit in real-time, delivering a description of the person. A large language model subsequently decides if the person matches the given description. Should that be the case, a landing point is placed on the closest point on a 1.5 m radius around the coordinates of the person. This landing point is then used to perform the autonomous landing.

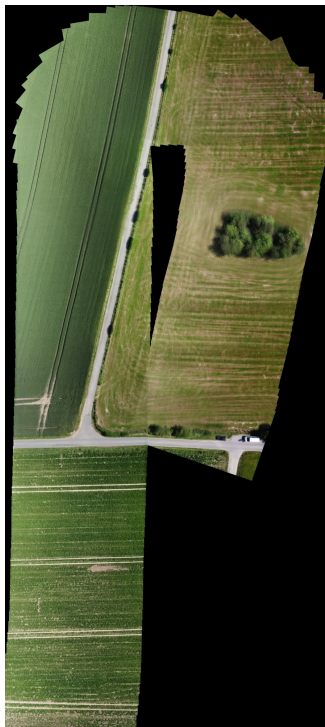


Figure 6: Mapping in progress



Figure 7: Maverix camera pod

9.3 Outdoor surveillance challenge

The outdoor surveillance challenge is an endurance challenge, for which the UAV has to fly surveillance laps over an area for as long as possible. For this task, the trajectory planning algorithm and battery monitoring algorithms need to be adapted. As long as there is enough battery charge (additional to a safety margin allowing for a safe landing), the trajectory planner needs to add new waypoints so the UAV flies as many laps as possible. Since Maverix is a tilt-wing aircraft, it can transition from hover flight to a much more energy-efficient cruise flight, increasing its maximum flight time.

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