





#### SOFTWARE IN THE LOOP SIMULATION FOR SMALL AUTONOMOUS VTOL UAV WITH **TEAMING CAPABILITY**

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# **Motivation**





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# Outline



#### Introduction

#### VTOL UAV Platform AirQuad

- Sensors and navigation
- Waypoint navigation
- Communication modules

#### Software-in-the-Loop (SiL)

- Environment model
- Algorithm testing

#### Teaming

- Communication protocol
- Formation flight
- Waypoint synchronization

## **Results & Conclusion**



# Introduction



#### UAV tasks

surveillance and reconnaissancecivil, security, and military applications

photogrammetric data collecting
 anti terror / homeland security
 support of rescue forces
 reduced risk for human operator





#### **Technical aims**

- platform for versatile sensors
  - **CBRN Sensors**

(Chemical, Biological, Radiological, and Nuclear)

- → autonomous flights
- dynamic mission planning
- teaming of multiple platforms

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# **VTOL-UAV** Platform



#### **Technical data**

- 4 brushless motors
- fixed pitch rotors
- maximum diameter 92 cm
- take off weight 1000g
- payload 200g
- battery powered
- operating time 25 min
- altitude < 500 m</li>
- operating range > 5 km
- max velocity 50 km/h
- MEMS based GPS/INS



## **Payload** options

- camera still photography, video
- dawn and IR camera
- air sample collector

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# **Waypoint Navigation**



#### Waypoint setup

planning with geo-referenced maps or GIS (geographic information system)

- - position (lon, lat, and height)
  - velocity
  - time
  - payload control e.g. camera
  - point of interest
  - emergency reaction

flight telefesoftradioalypoiheffawgation:

- of Cangutagest bed
   completerations
- storeveral about alter alt points of interest
  - visualized in GIS system





## **Communication Links**

### Transceiver "TinyOne Pro"

- ISM band 868 MHz
- 21 x 38 x 4 mm, 4 grams
- Transmitting power: 500 mW
- Digital up- and downlink with up to 38.4 kbps
- Range: up to 4 km LOS
- Mesh networking







#### Video Transmitter

- ISM band 2.4 GHz
- 27 x 29 x 10 mm, 6 grams
- Transmitting power: 200 mW
- downlink of video data (analog PAL)
- Range: up to 1 km LOS

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# Software-in-the-Loop (SiL)



- realistic simulation tool is
  - essential for algorithm development and testing
- easy comparison of different algorithms with ideal reference
- impact of disturbances like wind easily possible
- no special hardware required
- test of operational C-code





## **Motor Rotor Identification**





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## **Communication Protocol**



#### Message oriented



### **Formation Flight**





lever arm definitions:  $\vec{l_i}$ 

- constant with respect to absolute coordinate system (navigation-frame)
- constant with respect to relative coordinate system (body-frame)

#### navigation of the slaves:

 $\vec{x}_{master}^{n} = \mathbf{C}_{e}^{n} \cdot \vec{x}_{master}^{e}$   $\vec{x}_{set_{slave_{i}}}^{n} = \vec{x}_{master}^{n} + \vec{l}_{i}$   $\vec{x}_{set_{slave_{i}}}^{n} = \vec{x}_{master}^{n} + \mathbf{C}_{\Psi} \cdot \vec{l}_{i}$ 

smooth trajectories by using the master velocity:



## **Waypoint Synchronization**



difficulties with synchronization during autonomous waypoint flights

- wind disturbances
- minor differences in sensor information (GPS)

#### decoupling would occur !



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solution:

implemented synchronize protocol

- + synchronization with a hand shake method
- + synchronization from formations is possible







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## **Simulation Result Teaming**





# Conclusion



#### Conclusion



Software-in-the-Loop simulation tool

- + realistic representation
- + analyzing and compare of algorithms with ideal reference
- Teaming strategies for more complex missions
  - + synchronization
  - + formation flight



#### **Future Work**

- decentralized teaming strategies
- collision avoidance
- other team members stationary observers mobile ground vehicles

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## **Communication Rang Test**



#### Transceiver "TinyOne Pro"



- Car based test drive
- Urban environment
- Range > 1000m NLOS



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## **Bluetechnix CM-BF561**



#### **Technical Data**

- Dual-Core DSP
- 600 MHz clock frequency , 2 x superscalar
- 2 x 64 kB SRAM
- 64 MB SDRAM
- 8 MB Flash
- Weight 5 g
- Current consumption: 470 mA
- Dimensions: 36 x 31 x 3 mm





## Laser Range Finder





Module	URG-04LX
Producer	Hokuyo
Range	0.01 – 4.00 m
Beam width	240°
Angle resolution	0.36°
Weight	160 g
Update rate	10 Hz

 $-120^{\circ}$ 

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#### Master Ueberschrift bearbeiten

### Master Ueberschrift



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