

MAV State-of-the-Art & Technology Drivers

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- **Introduction**
- **Today's MAV, State-of-the-Art**
- **Technology Drivers**
- **Summary & Outlook**





Unmanned, Unattended
or Unassisted
Air Vehicles



- Introduction
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Development Status:

1. **operational**
 - In use in higher quantities
 - commercial or military use
2. **prototype**
 - functional aircraft
 - technology demonstrator
3. **Under development**
 - not fully functional

Grade of Autonomy:

1. **manually controlled**
 - completely remote-controlled
2. **semi-autonomous**
 - aircraft keeps altitude and track
 - operator commands up-down / left-right
3. **fully autonomous**
 - aircraft follows waypoints
 - no intervention of operator necessary



Today's MAV

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Aerosonde

Manufacturer:	Aerosonde Robotic Aircraft (Australia)
Wingspan:	2.9 m
Mass:	14 kg
Payload:	max. 5 kg (fuel tradeoff)
Endurance:	> 50 hrs
Status:	operational (fully autonomous)



Today's MAV

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MLB Bat

Manufacturer:	MLB (USA)
Wingspan:	152 cm
Mass:	4.5 kg
Payload:	0.5 kg
Endurance:	1 hr
Status:	operational (fully autonomous)



Today's MAV

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Aladin

Manufacturer:	EMT (Germany)
Wingspan:	150 cm
Mass:	3 kg
Payload:	300 g
Endurance:	30 min.
Status:	operational (fully autonomous)



aerospace systems

TU Braunschweig

Today's MAV

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Carolo XL

Manufacturer:	Aerospace Systems, TU Braunschweig (Germany)
Wingspan:	100 cm
Mass:	940 g
Payload:	30 g
Endurance:	30 min.
Status:	prototype (fully autonomous)



aerospace systems

TU Braunschweig



Mikado

Manufacturer:	EMT (Germany)
Wingspan:	?
Mass:	?
Payload:	?
Endurance:	?
Status:	under development



Today's MAV

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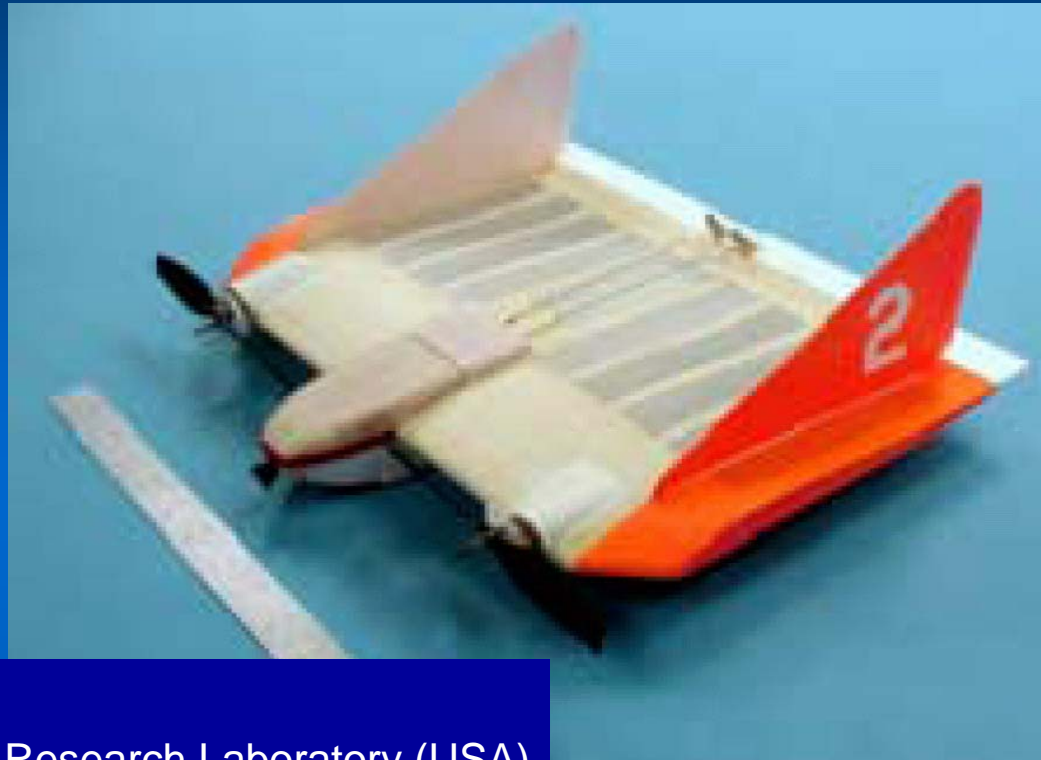
Carolo

Manufacturer:	Aerospace Systems, TU Braunschweig (Germany)
Wingspan:	40 cm
Mass:	380 g
Payload:	20 g
Endurance:	30 min.
Status:	under development (fully autonomous)



aerospace systems

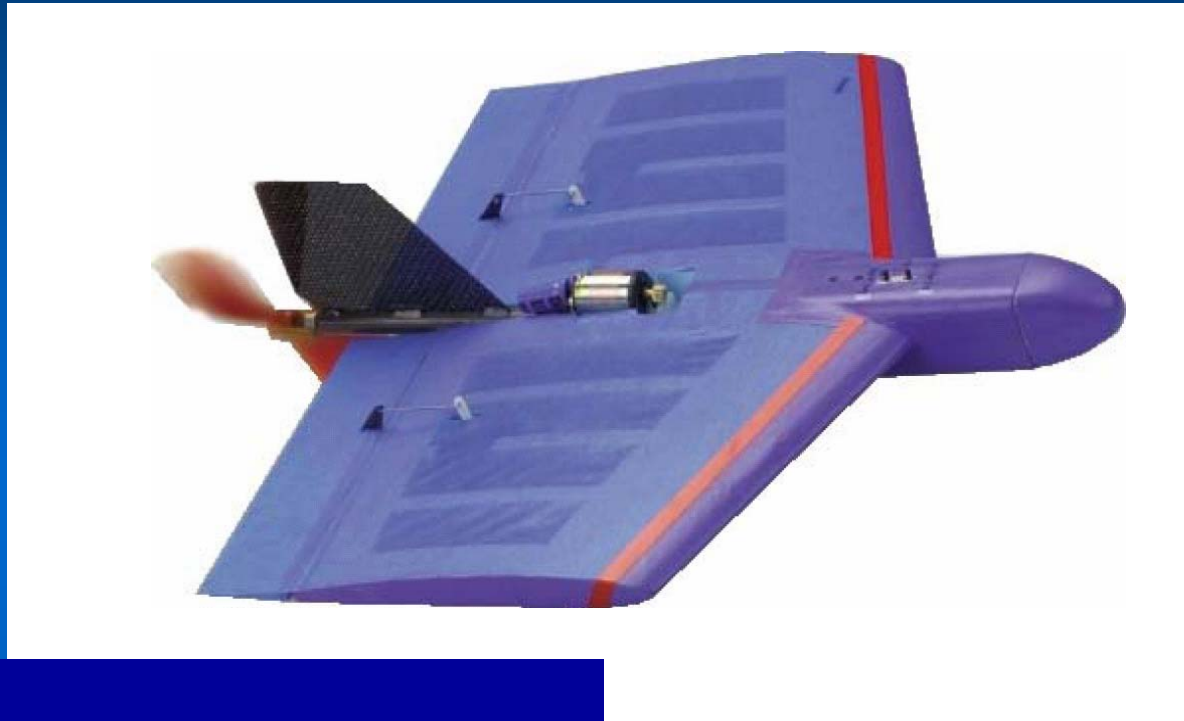
TU Braunschweig



MITE 2

Manufacturer:	Naval Research Laboratory (USA)
Wingspan:	37 cm
Mass:	130 g to 210 g
Payload:	camera
Endurance:	max. 30 min.
Status:	prototype (manually controlled ?)

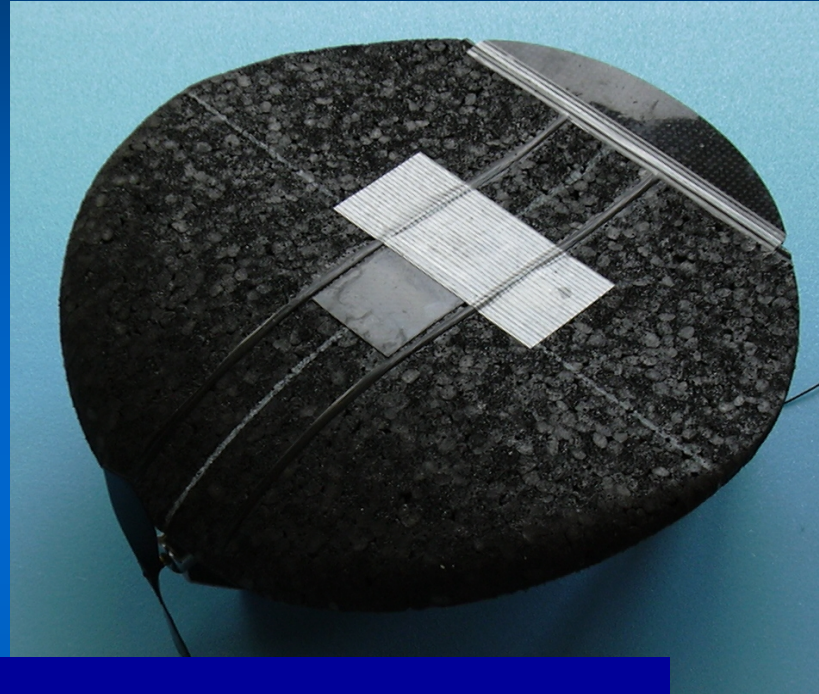




Dornier MAV

Manufacturer:	EADS Dornier (Germany)
Wingspan:	30 cm
Mass:	200 g
Payload:	b/w camera
Endurance:	15 min.
Status:	prototype (semi-autonomous)





RWTH Aachen MAV

Manufacturer:	Chair of Flight Dynamics, RWTH Aachen (Germany)
Wingspan:	20 cm
Mass:	90 g
Payload:	camera
Endurance:	18 min.
Status:	prototype (manually controlled)

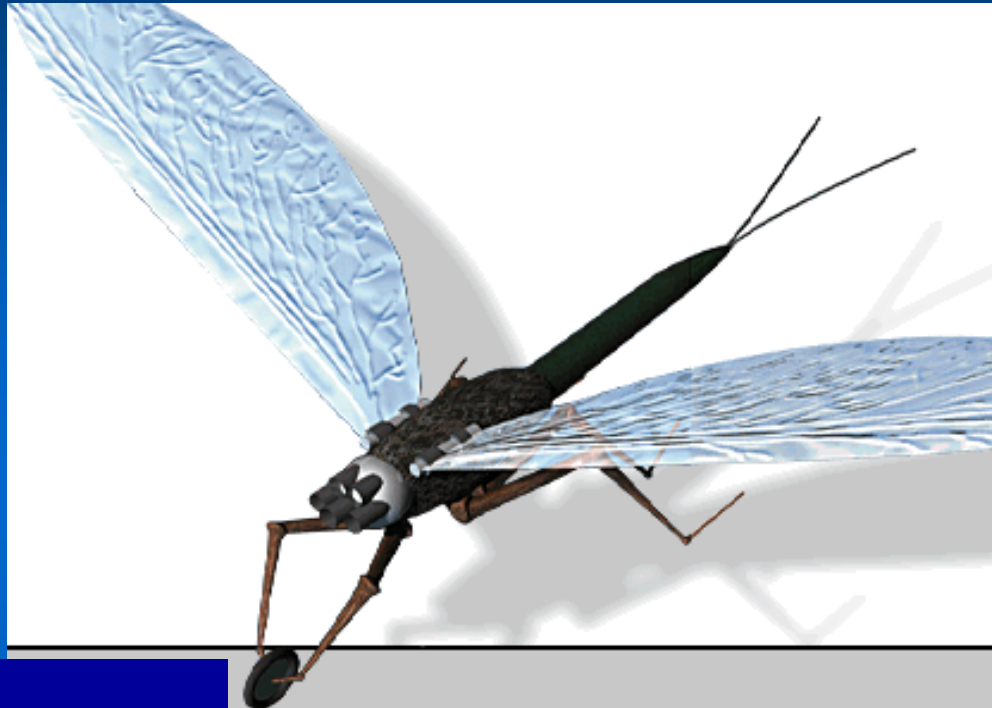




Black Widow

Manufacturer:	AeroVironment (USA)
Wingspan:	15 cm
Mass:	42 g
Payload:	5 g
Endurance:	30 min.
Status:	prototype (semi-autonomous ?)





Entomopter

Manufacturer:	GeorgiaTech (USA)
Wingspan:	?
Mass:	?
Payload:	?
Endurance:	?
Status:	under development

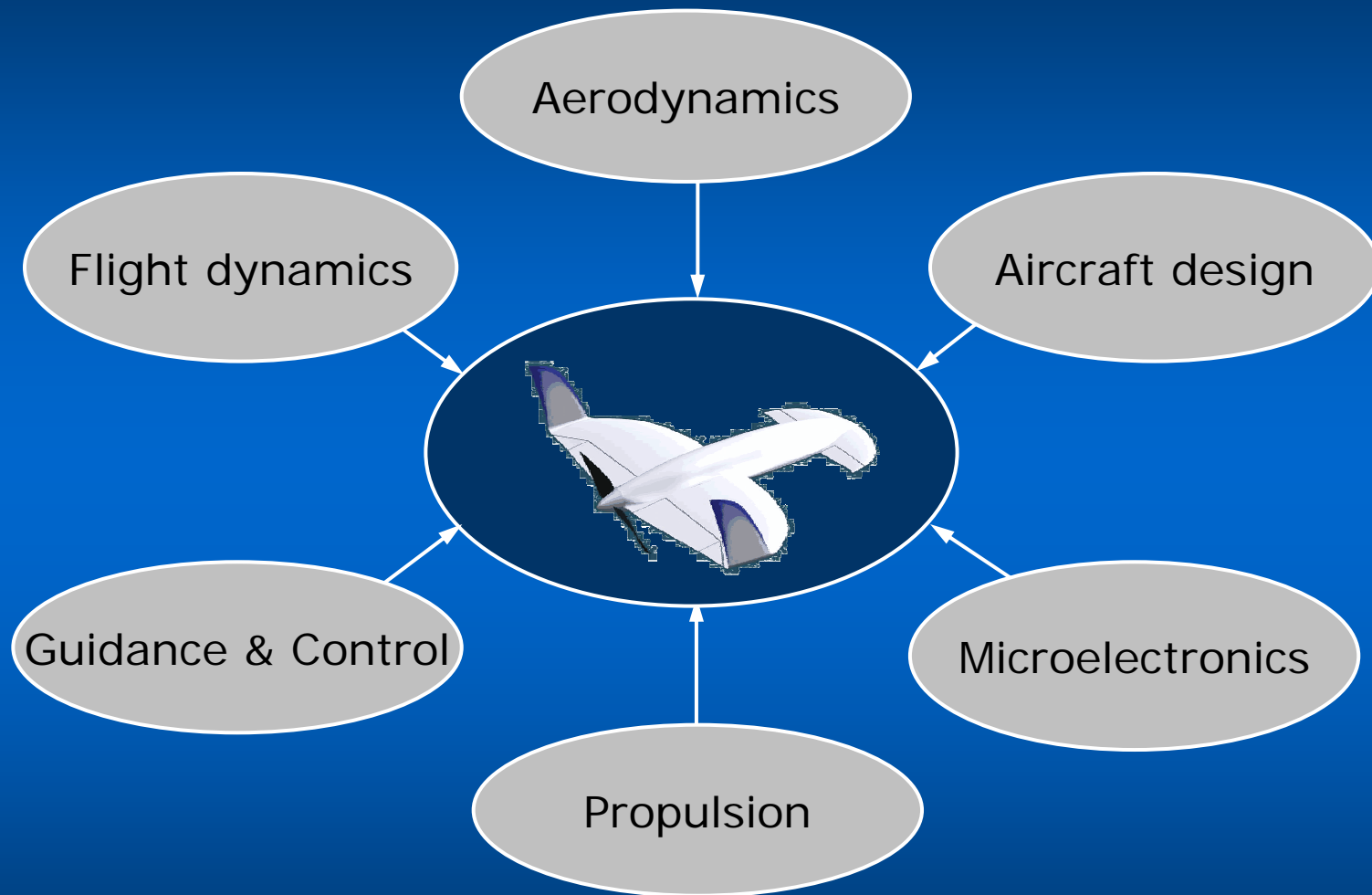


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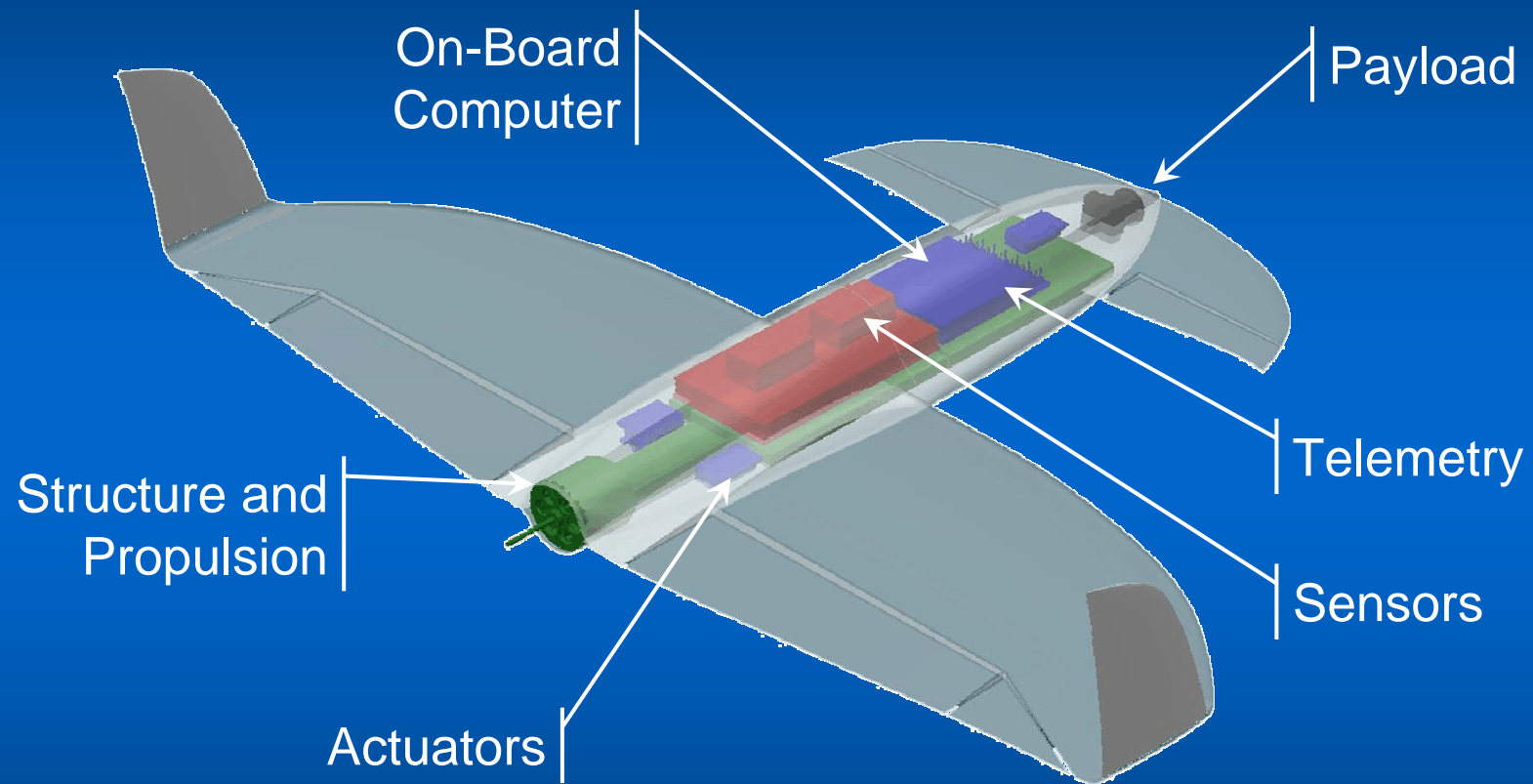
A Multidisciplinary Research Activity

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Transparent view of Carolo

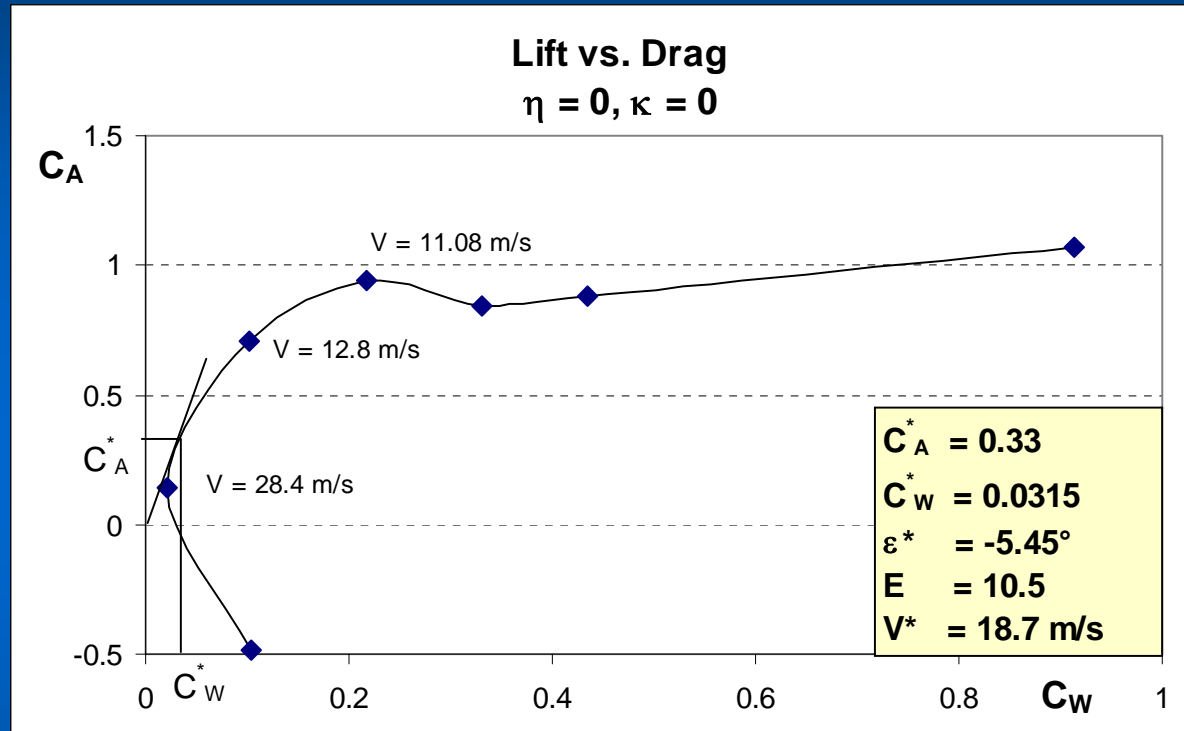
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CAROLO during wind tunnel tests at the Institute of Fluid Dynamics,
Technical University of Braunschweig

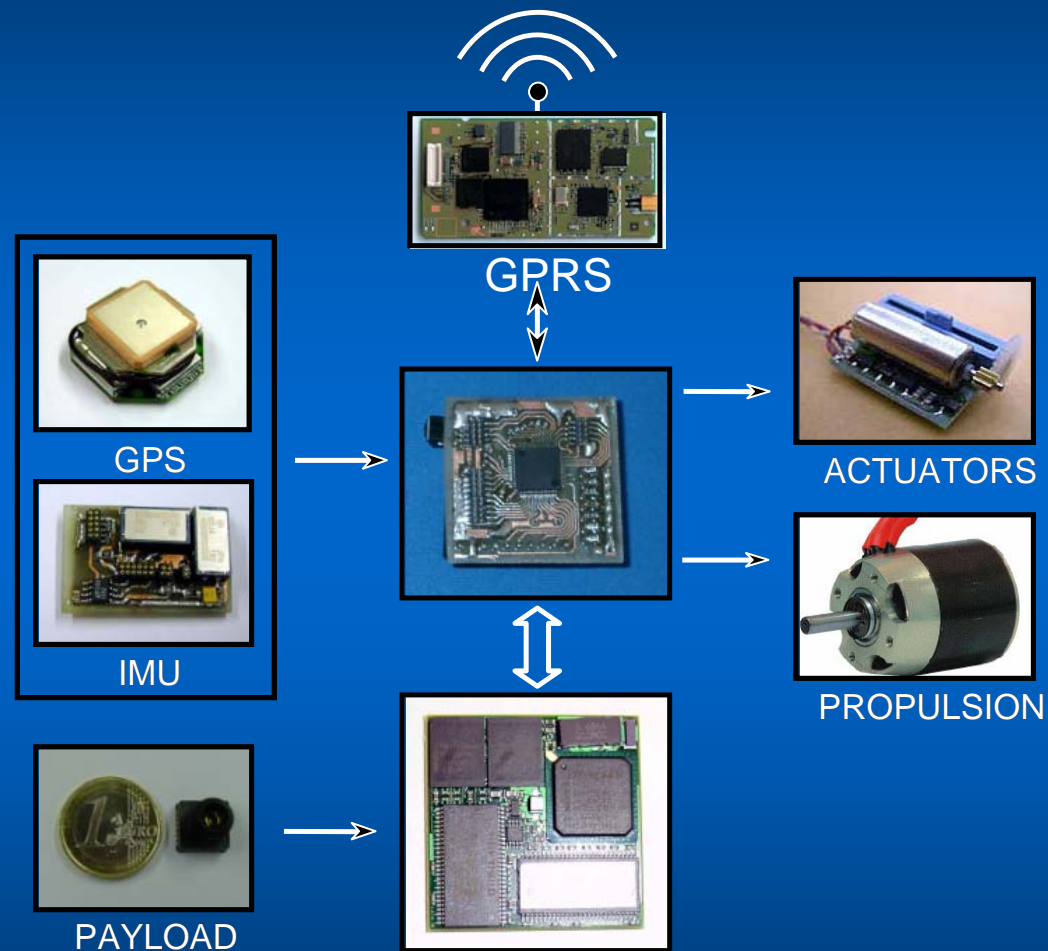


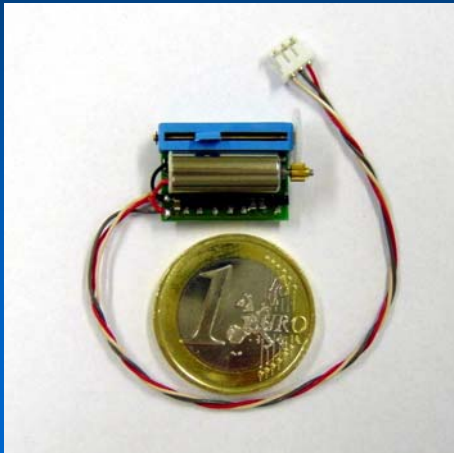


min. glide angle $-5,45^\circ$
optimal speed 18.7 m/s

uncritical stall behavior
flow separation at $\alpha_S = 15^\circ$

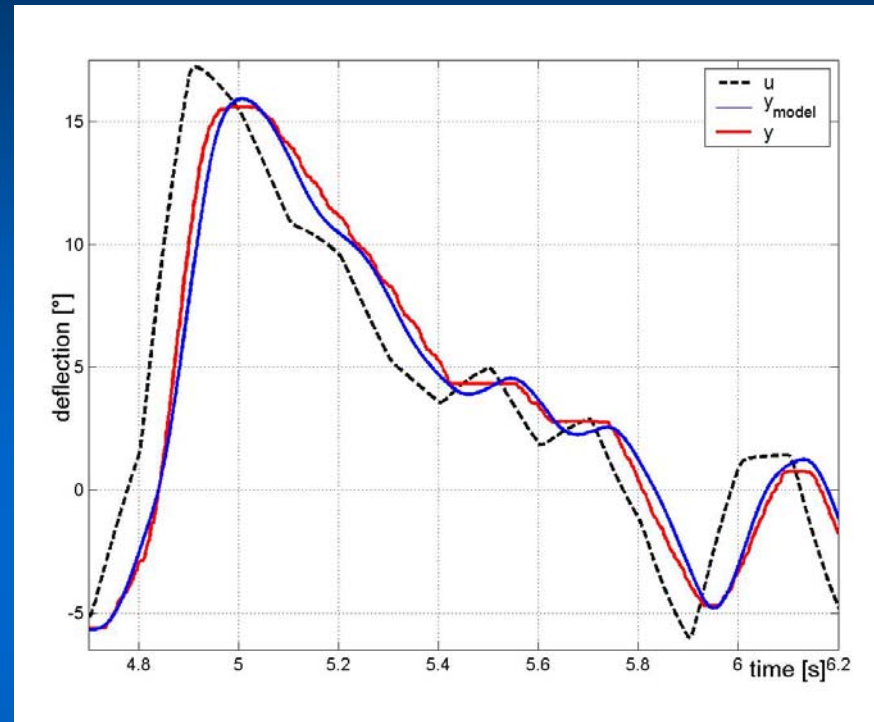






WES-Technik Light Servo 3.0

mass: 3 gram
velocity: 95 mm/s
servo force: 2 N



$$y_s(s) = \frac{K}{Ts + 1} \cdot e^{-j\omega T_t} \cdot u(s)$$

$$T = 0.0165 \text{ s}$$

$$T_t = 0.008 \text{ s}$$

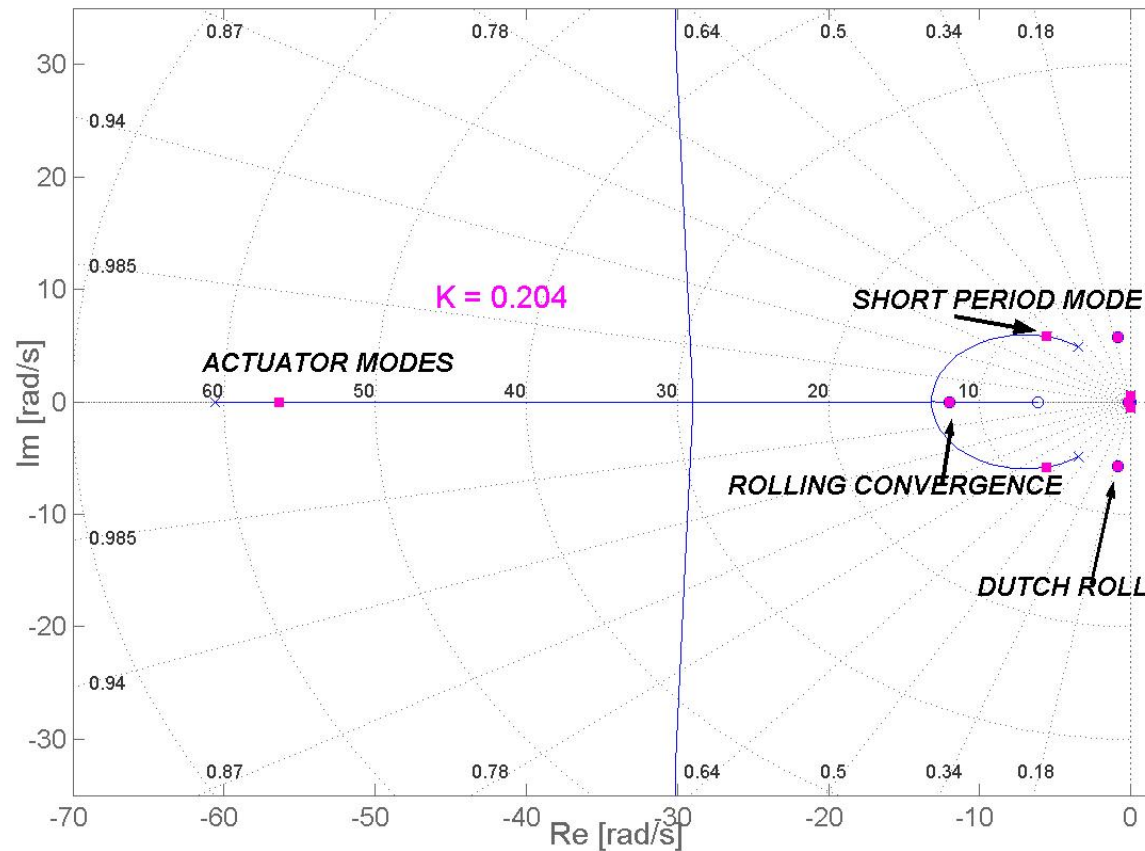




Results – Stability Analysis

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Root Locus with Actuator Dynamics

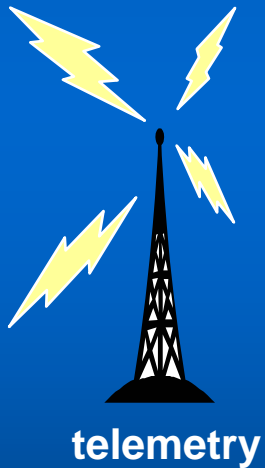
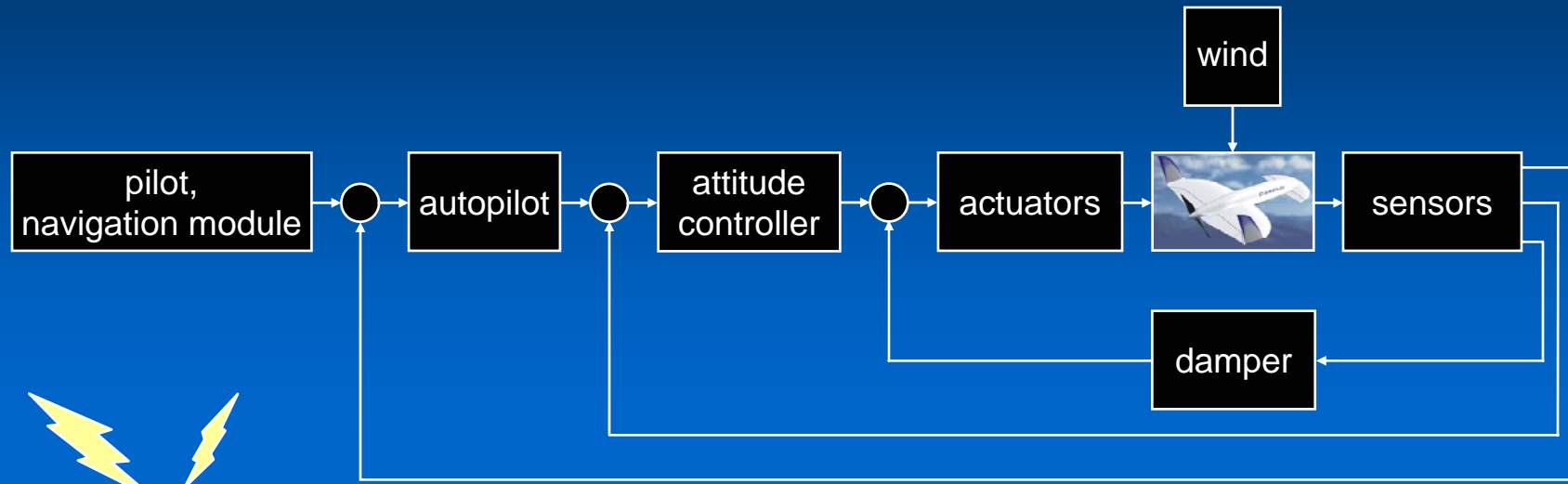


K: Pitch damping
controller gain

-all open loop modes are
stable

-with increasing feedback
gain one real pair of the
SPM combines with the
actuator mode to a new
oscillatory motion



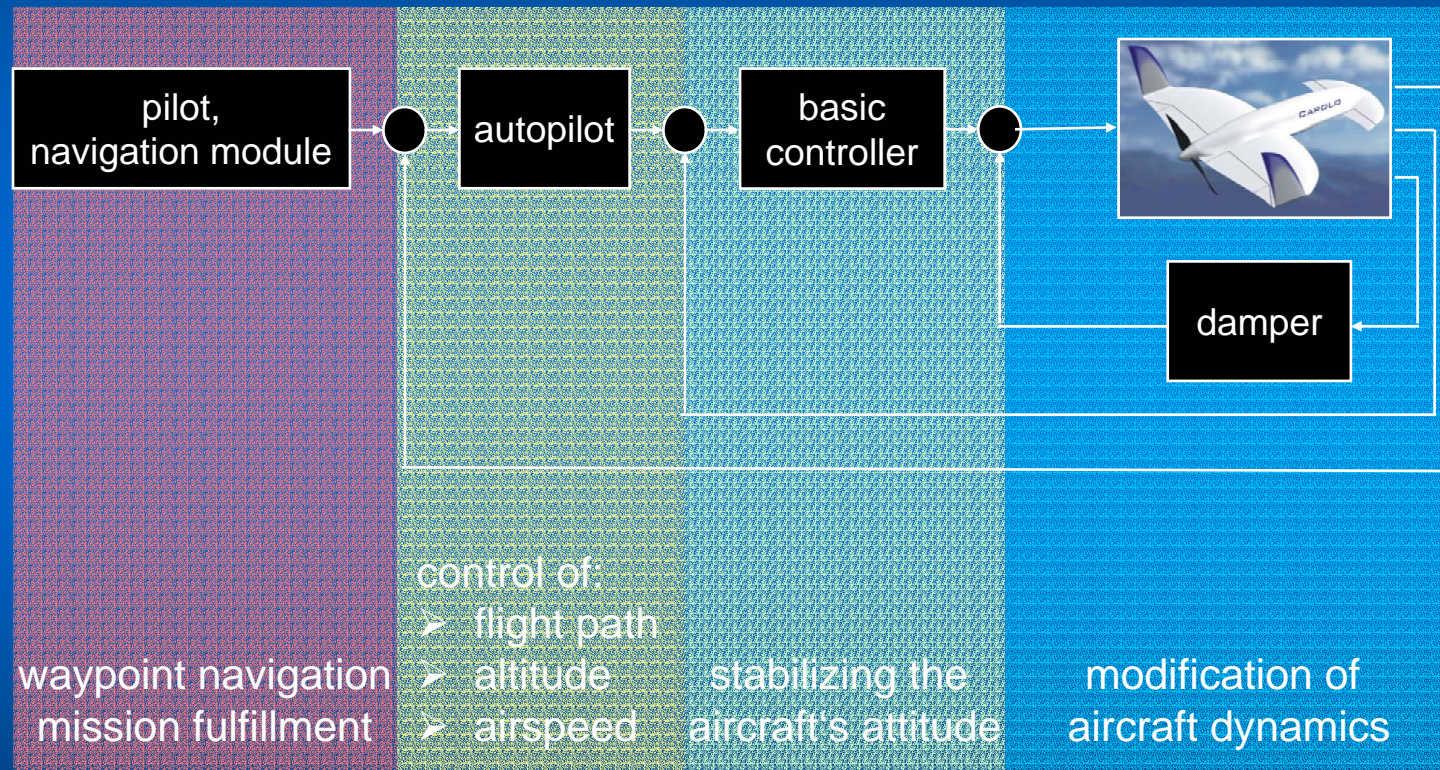


Development of:

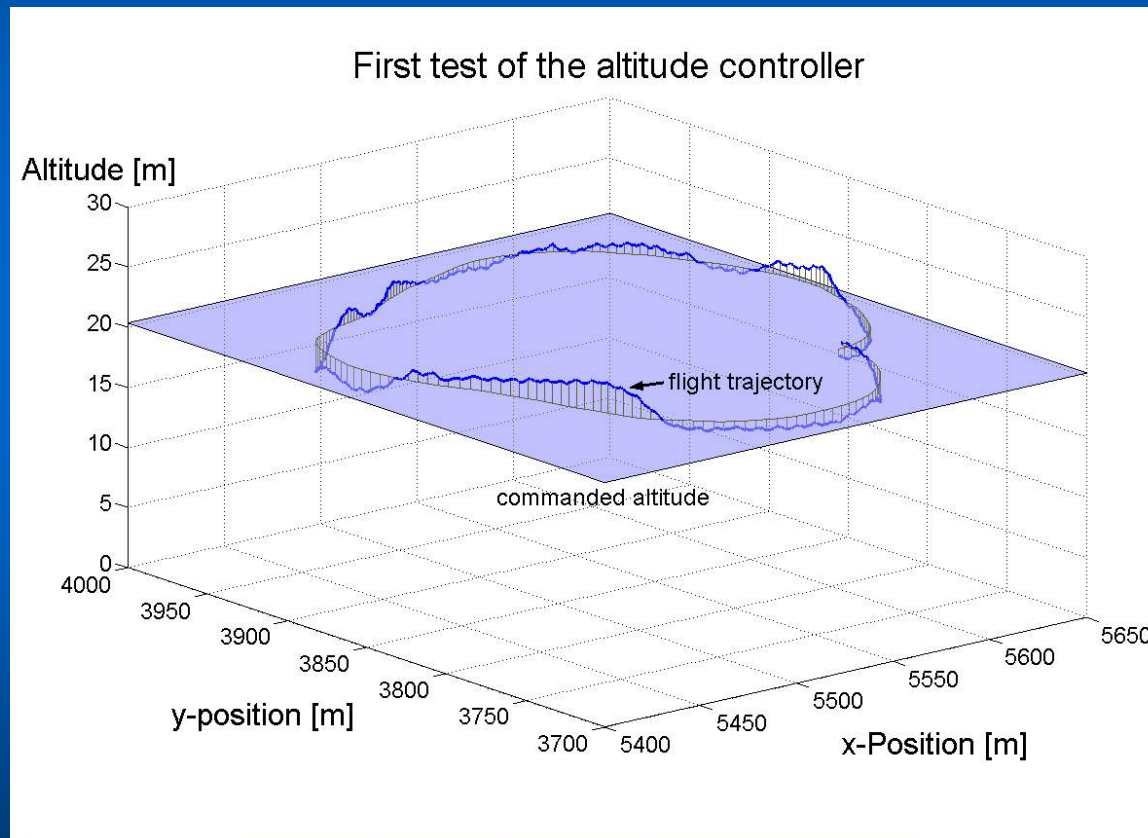
- onboard electronics
- telemetry
- ground control software



cascaded flight controller concept



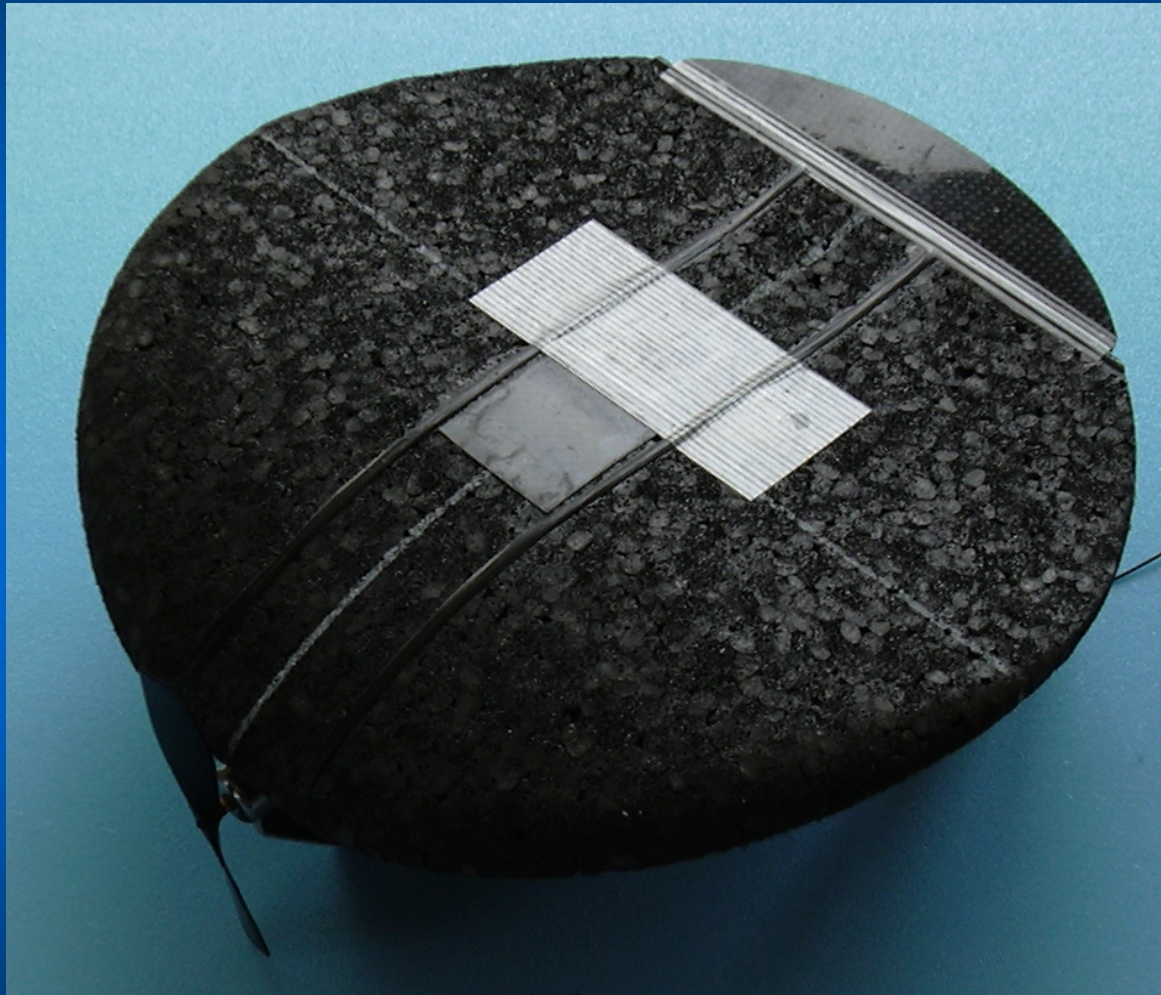
August 2003



- no optimized feedback gains
- circling during strong thermal activity
- $\Delta H < 2\text{m}$





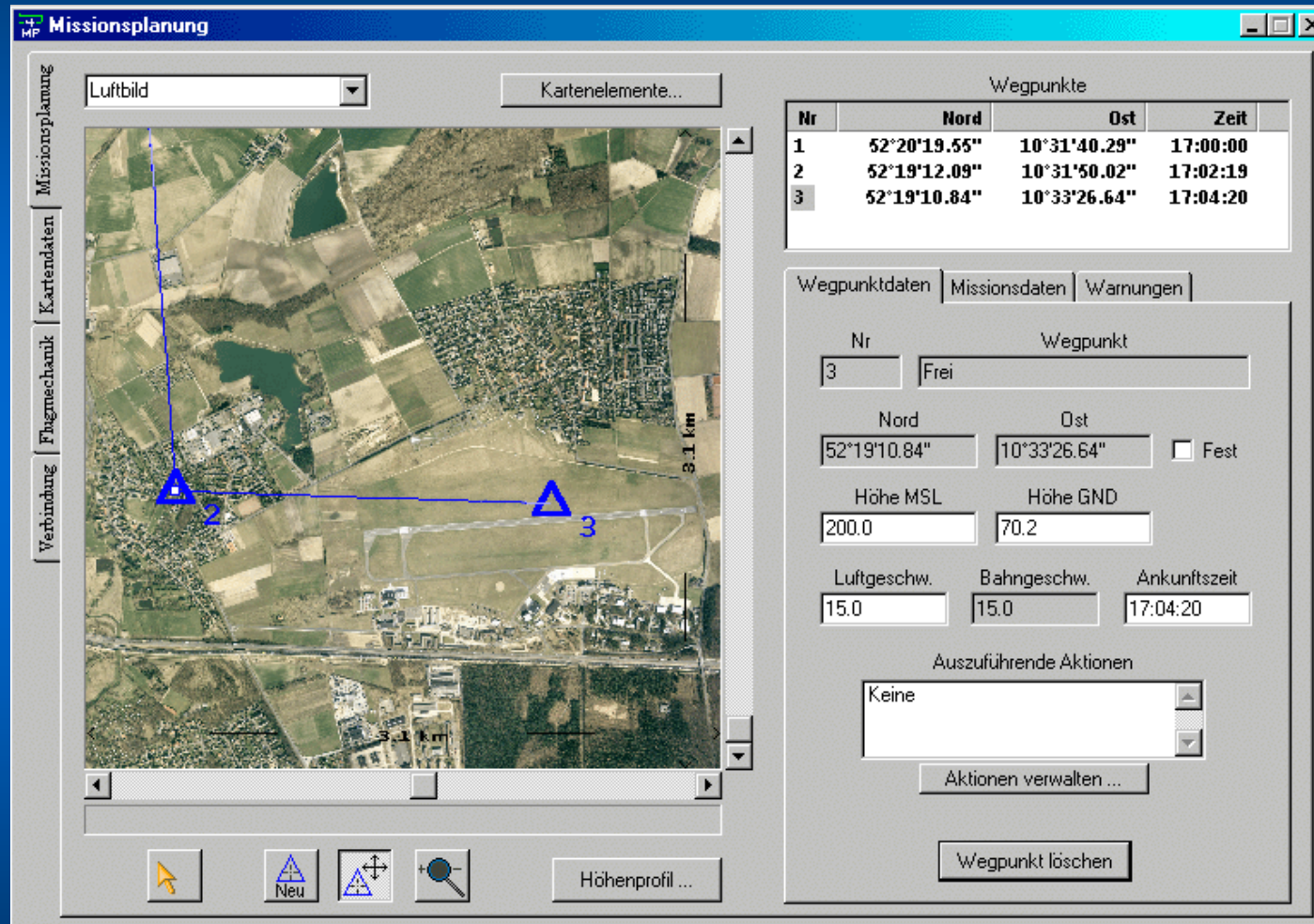


RWTH Aachen MAV



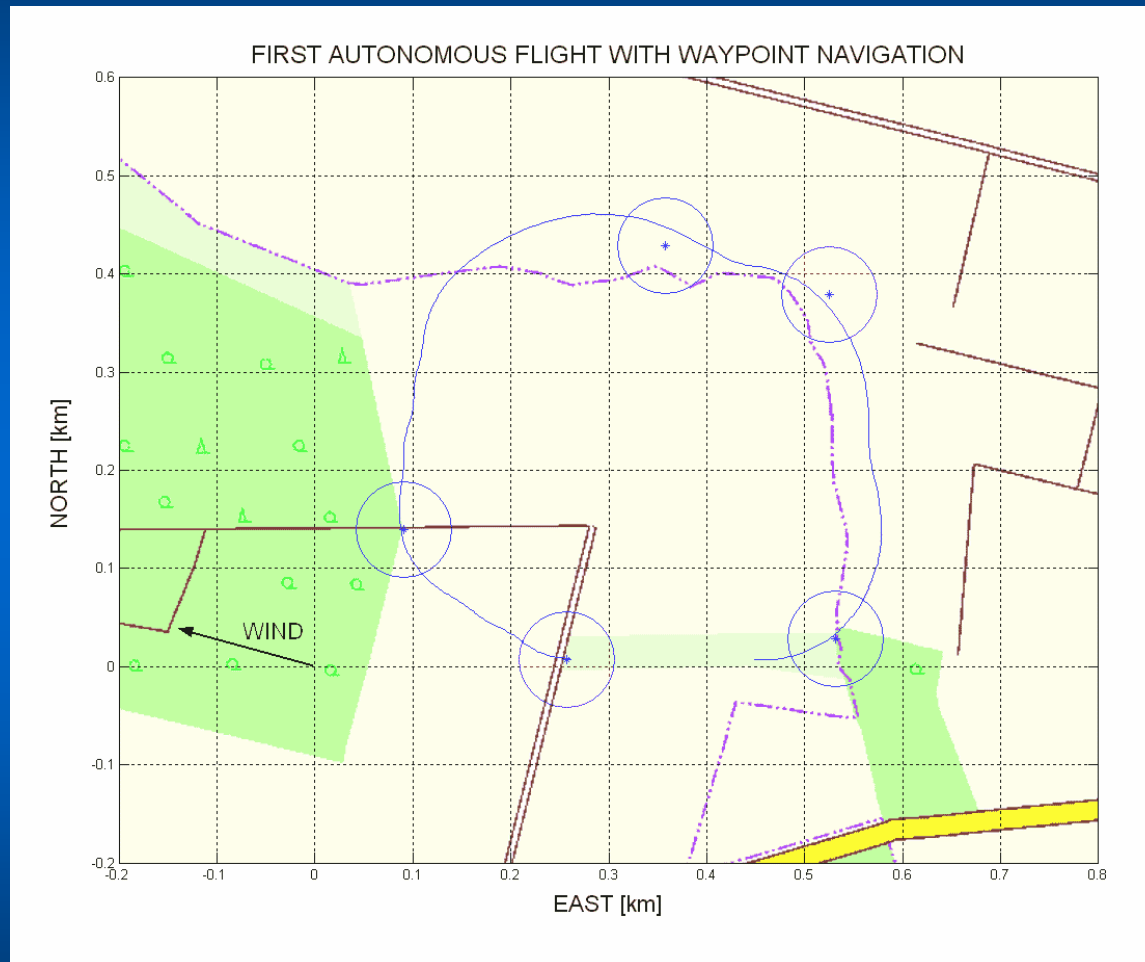
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Autonomous Flight – Waypoint Navigation

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September 2003

Achieved with
Carolo XXL and
Carolo XL



aerospace systems

TU Braunschweig

Carolo's Flug
vom 20.12.2002



First autonomous
Waypoint Navigation
(Sept. 5th 2003)



First European Micro Air Vehicle Conference and Flight Competition

EMAV 2004

Braunschweig, Germany

13 – 14 July 2004



German Institute of Navigation

-Deutsche Gesellschaft für Ortung und Navigation e.V.-

