Weper-Göttingen

TOW-TEST-DRONE OR/ODER SCHLEPPDROHNE

Eine Idee von Bodo Rengshausen-Fischbach und Georg E. Koppenwallner / plotter

Im DLR durch die SKA-Messung und die Erfahrung mit den Antrieben gereift.

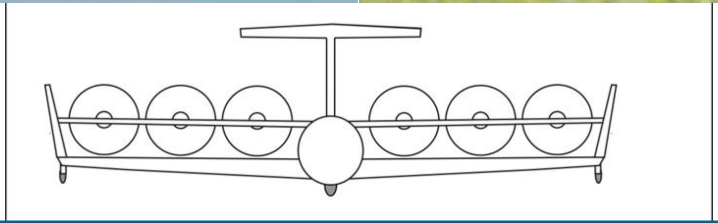
(basiert auf einem Vortrag 2022 bei STAB gehalten)

TOW-TEST-DRONE

LOW   ENERGY AERO TOW

looking for
cooperation partners
for development and marketing
of OTW=over the wing UAVs

TOW-Planes Large and strong or small and UL



Typical tow planes: Let- Z -37A, Remoqueur, Morane, Bristell-23, Rans S7 (example of the lecture) below as a drawing:
Topic of the lecture: Sketch of a tow drone

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Schubklappe retractable wing impeller (like airbrakes)

OTW – DE 10 2016 010 216 A1 Impeller-Schubklappe-ISK

Idea: **Re/Extraction** of Impeller – groups instead of airbrakes – my first view impression of early Lilium jet

Fig. 11

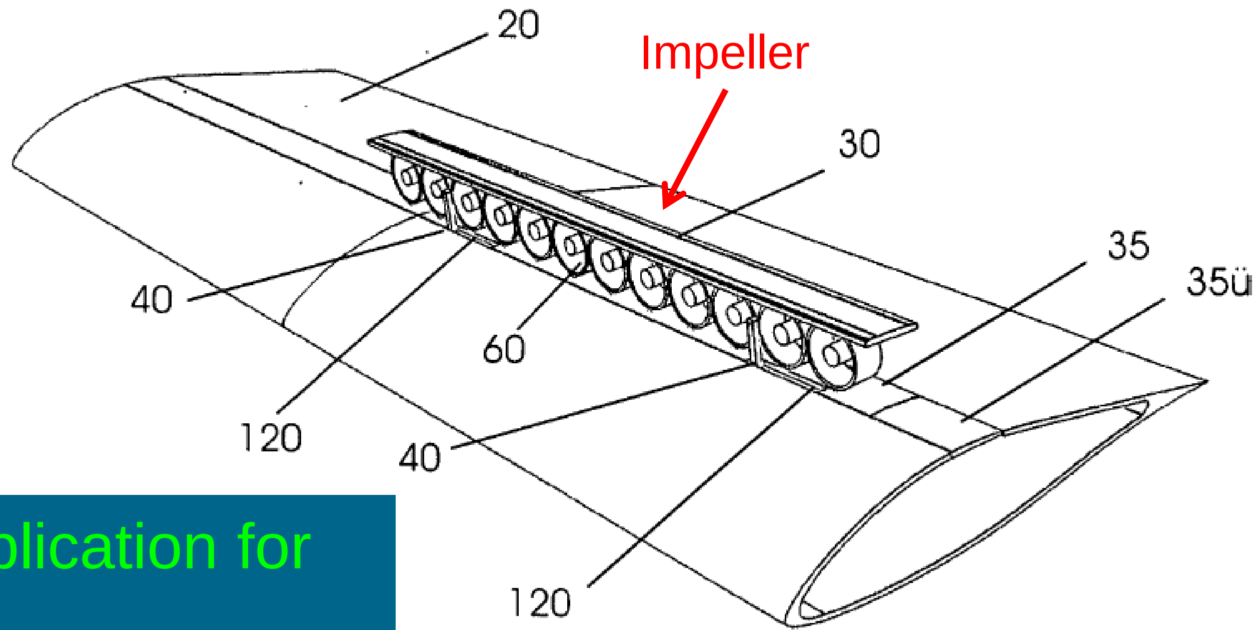


Fig. 7

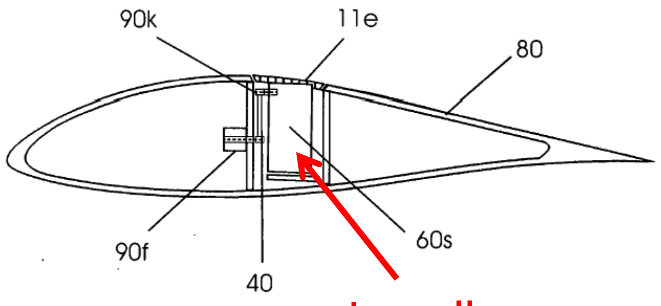
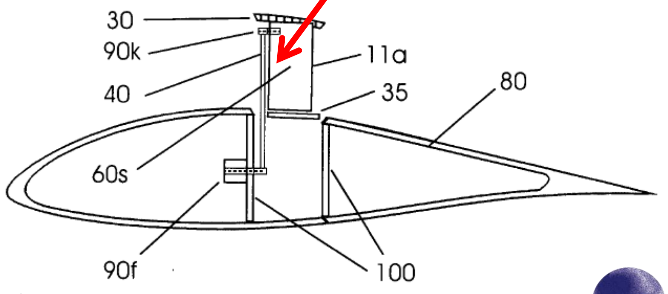


Fig. 8



Application for blown elevator

PLOTTERLAND INVENTION

Schubklappe   retractable wing props (like airbrakes)

OTW-Schubklappe DE-10 2018 007 160 (patent granted 2024)

Starting point of the measurements for the tow drone retractable *OTW = over-the wing propeller*

DE-10 2018 007 160

Fig. 2

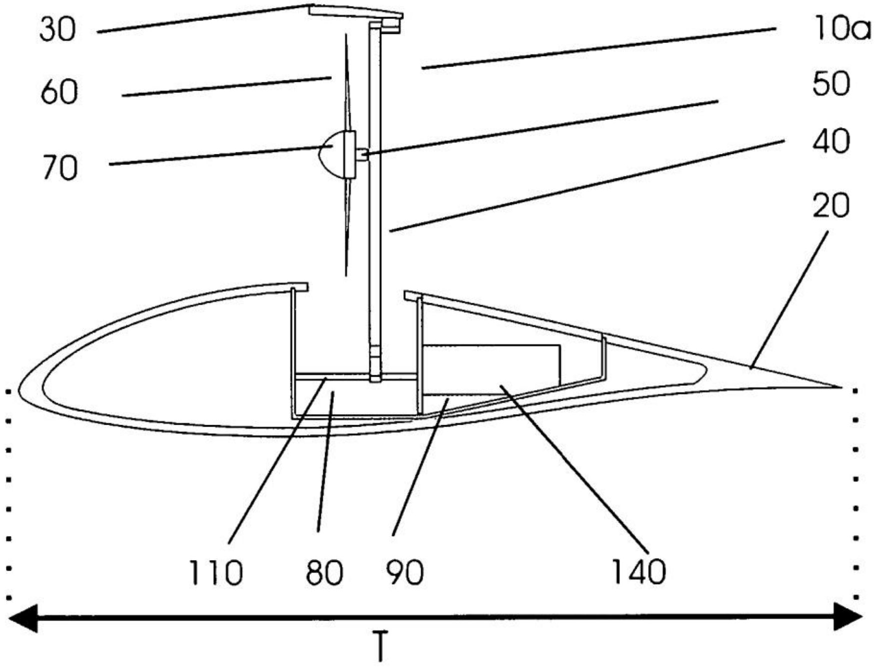
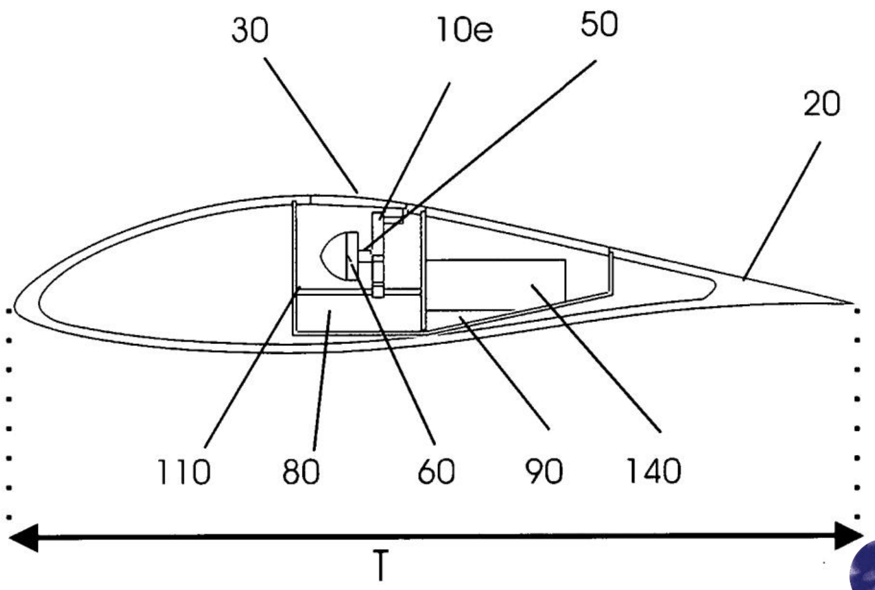


Fig. 3

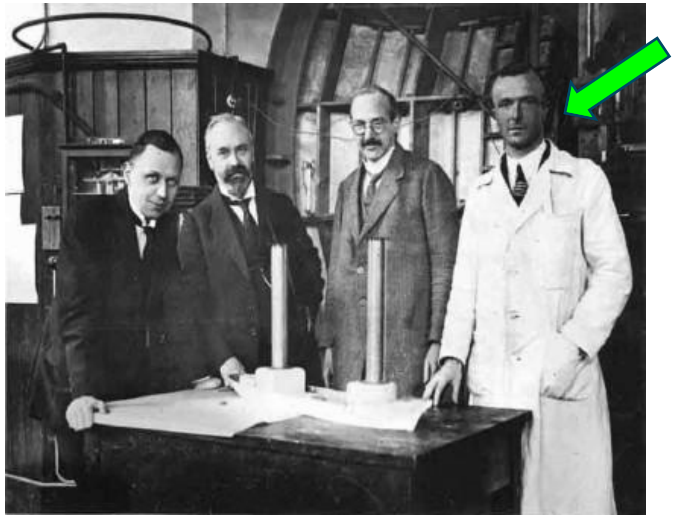


PLOTTERLAND INVENTION

The beginnings   propeller position OTW props

OTW-Prop. 1926
Reinold Seiferth,

Göttingen



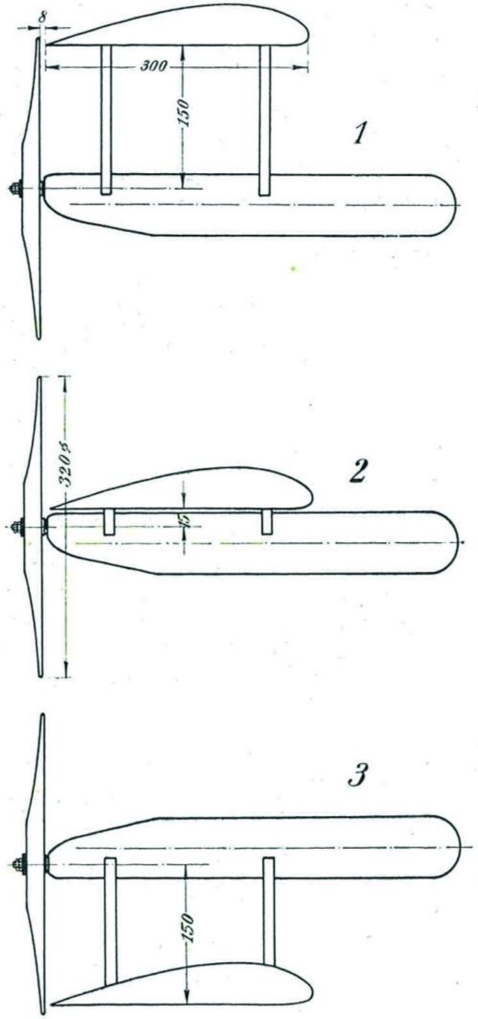


Abb. 1.

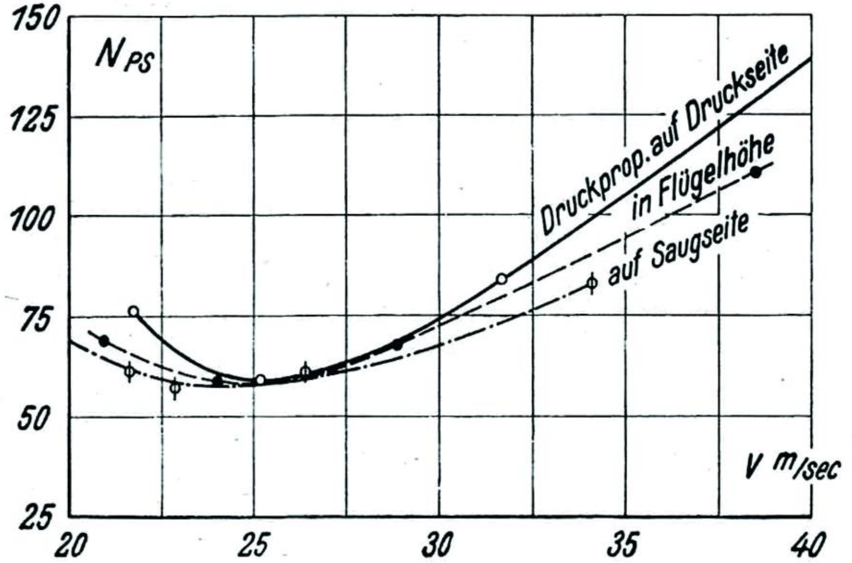


Abb. 8.

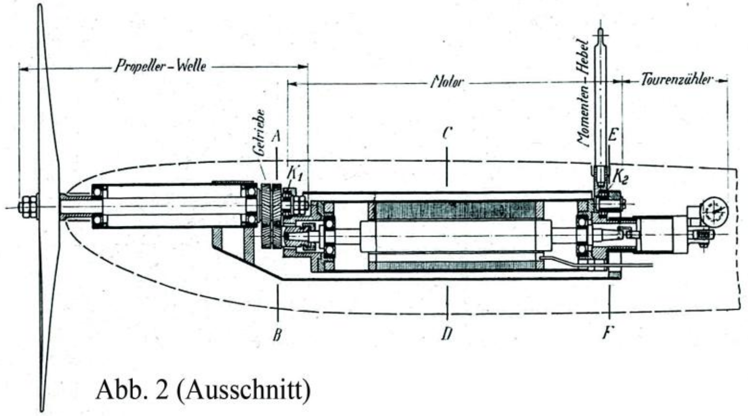
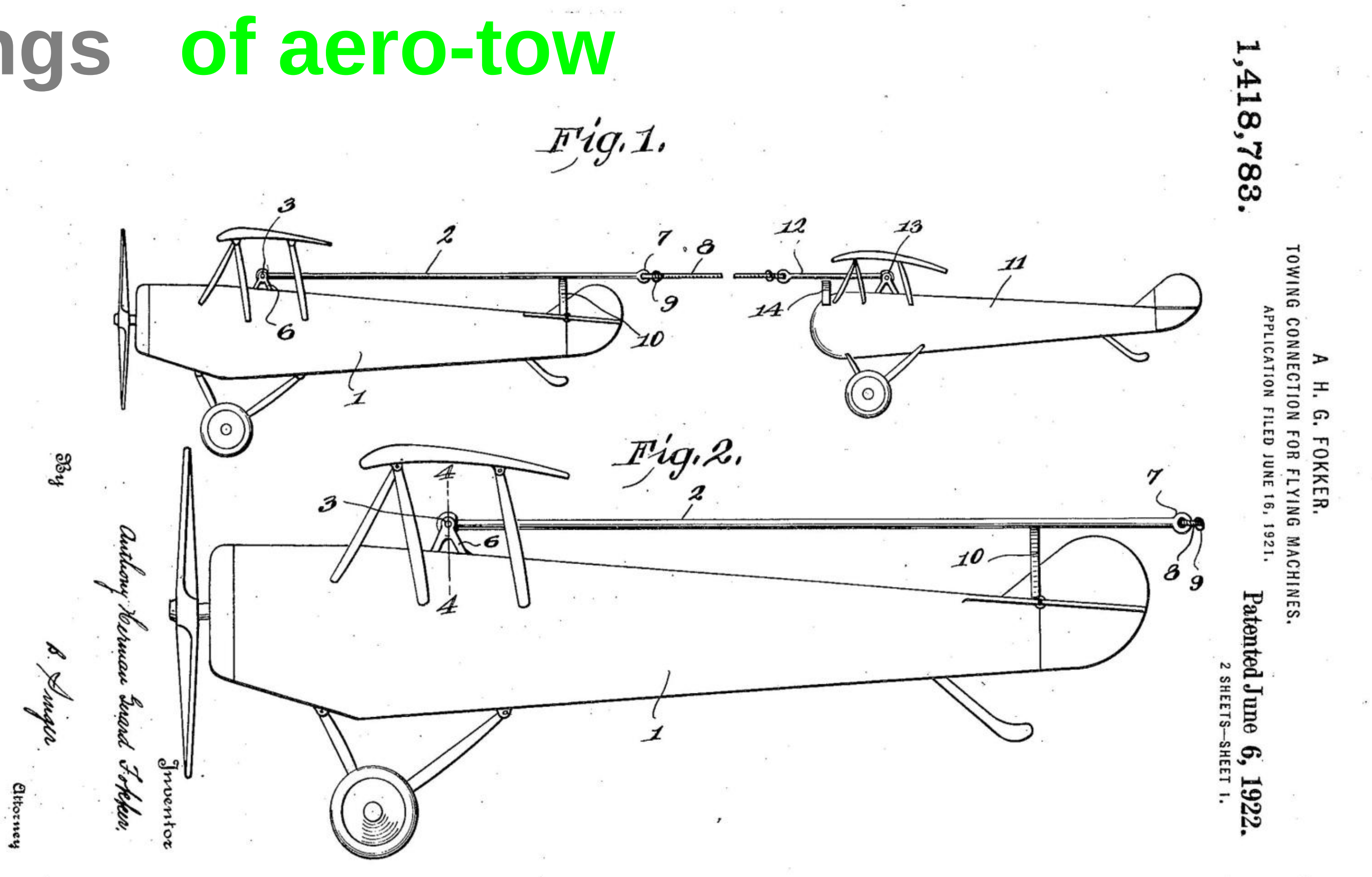


Abb. 2 (Ausschnitt)

The beginnings of aero-tow



Development of the Aero-tow by Antony Fokker (NL), Glenn Curtiss (USA); Antonius Raab and Kurt Katzenstein around 1927 in Kassel Waldau

The normal practice of aero-tow in 1941

Aerotow 1941 Weper near Göttingen –Towplane Heinkel -72
(since end of 1930s a standard take-off procedure).

https://de.wikipedia.org/wiki/Flugzeugschlepp#Entwicklung_und_Etablierung_in_den_1930er_Jahren

Thanks to Hans Ulrich Renner, Halle, fotoarchive of his father)

High wing loading, tailwind and short runway – risky aerotow 2024

Comparision

Rans S7 aerotow of double seaters

SF-34

14,8 m² wing area

ASK-21

17,8 m² wing area

tow planes unchanged principle since 1920

	Gewicht	Spann-weite	Flügel-fläche	Flächen-belast.	Leistung	v_{Max}	v_{Min}	$v_{(EMax)}$	E_{Max}	Stand-schub	Jahr	Streck-ung
	Mass MTOW	Span	wing area	wing loading	power	v_{Max}	v_{Min}	$v_{(EMax)}$	E_{Max}	static thrust	year	aspect ratio
	kg	m	m²	kg/m²	PS	km/h	km/h	km/h		N		
Heinkel-72	820	9	20,7	39,61	168	194	77	-	-	-	1933	3,9
Morane	770	9,75	12,3	62,60	150	250	73	-	-	-	1959	7,7
DR 400 - Remorqueur	1000	8,72	14,2	70,42	180	260	87	145	9,3	-	1972	5,4
Rans-S7	559	8,92	13,67	40,89	100	190	66	**102**	**8,4**	**1800**	1985	5,8
SF-25 (Rotax)	485	16,6	17,5	27,71	100	180	60	85	20	-	1999	15,7
Bristell B23 - 915	750	9,27	11,75	63,83	140	260	80	-	8,5	-	2020	7,3
Schleppdrohne towdrone	150	5,5	3	50,00	60	-	-	**100**	**8,4**	**1650**	-	10,1

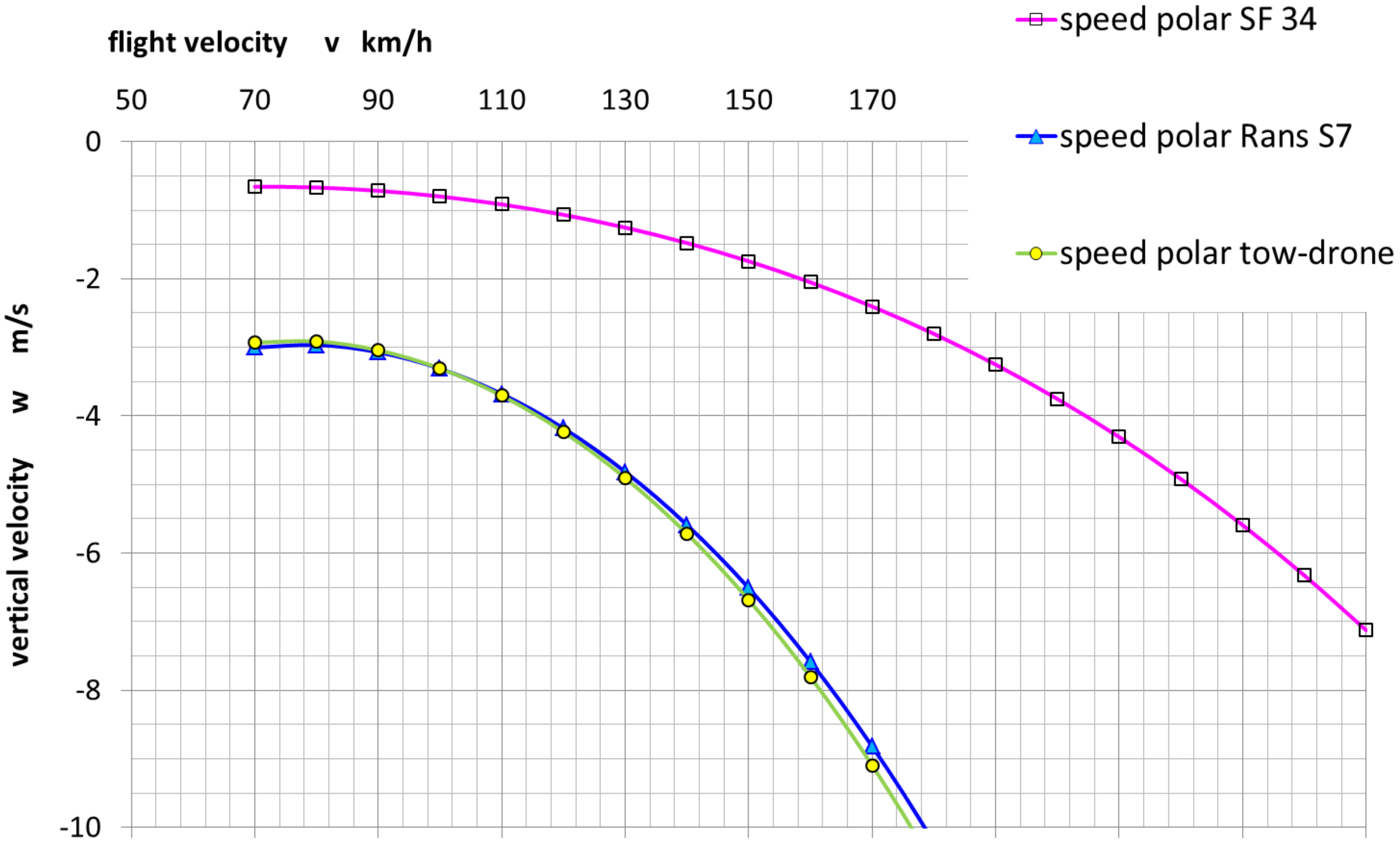
Approximation of speed polars

Reichmann (1976) und Wandinger (2011) Assumption *cos(γ) ≈ 1*

$$w = a_1 \cdot \frac{1}{v} + b_1 \cdot v^3$$

$$b_1 = \frac{1}{2 \cdot v_{E_{opt}}^2 \cdot E_{opt}}$$

$$a_1 = \frac{v_{E_{opt}}^2}{2 \cdot E_{opt}^2}$$



Assumptions for the estimation of climb rate

drag towtrain =

drag towplane + drag glider

drag coefficient in horizontal flight and in tow equal

V (best glide) and E (best glide) define the speed polars

Formula for the climb rate of aerotow

$P_{climb} = P_{thrust} - P_{hover}$ **try to achive: low mass and high thrust**

$$P_{climb} = m \cdot g \cdot w$$

$$P_{thrust} = F \cdot v \;, \quad P_{hover} = W \cdot v \Rightarrow F_{hover} \cdot v = W \cdot v$$

W = Drag (Widerstand)

$$\Rightarrow P_{climb} = P_{thrust} - W_{tot} \cdot v = m \cdot g \cdot w$$

$$= P_{thrust} - \left(W_{towplane} + W_{glider}\right) \cdot v = m \cdot g \cdot w$$

$$W_{tot.} =: W_{towplane} + W_{glider}$$

$$\Rightarrow \boxed{w = \frac{(F - W_{tot}) \cdot v}{(m_{towplane} + m_{glider}) \cdot g}}$$

Approach:

Power for Climbing = P_{climb}

$= P_{thrust} - P_{hover}$

= Thrust power – power for sustaining (hovering) flight

Assumption thrust as function of flight velocity

$$F_{towplane}(v) = F_0 - \frac{(F_0 - k \cdot F_0)}{v_{E_{opt}}} \cdot v \quad , \quad k =: \frac{F_{E_{opt}}}{F_0}$$

$$F_{Eopt} = k \cdot F_0$$

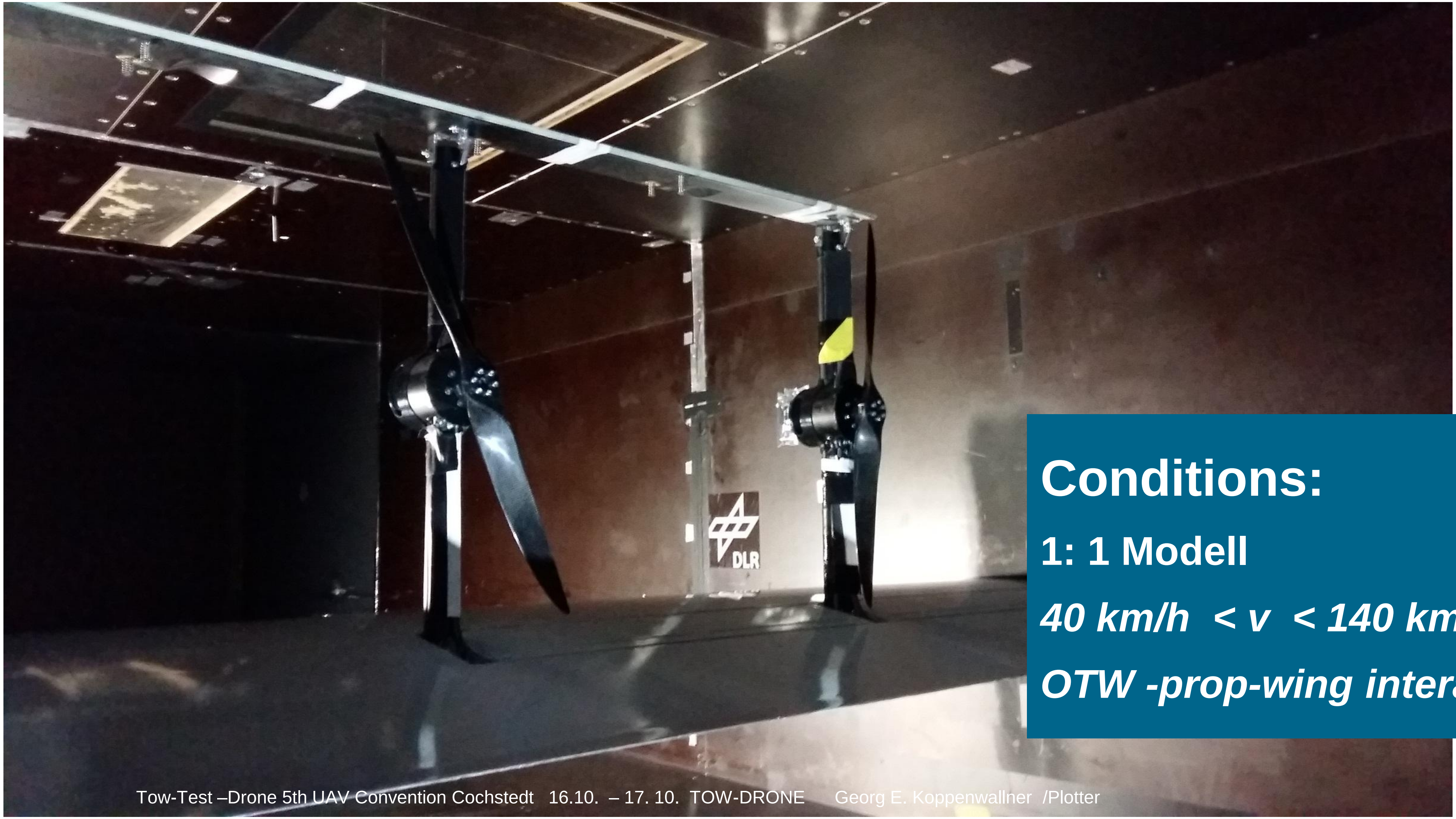
$$k_{tow-drone} =: 0.55, \quad k_{towplane} =: 0.6$$

Approach:

Thrust decreases linearly with flight-velocity.

At $v(E_{opt})$ the thrust is about half the static thrust F_0

Testing facility Göttingen SWG Seitenwind Versuchsanlage



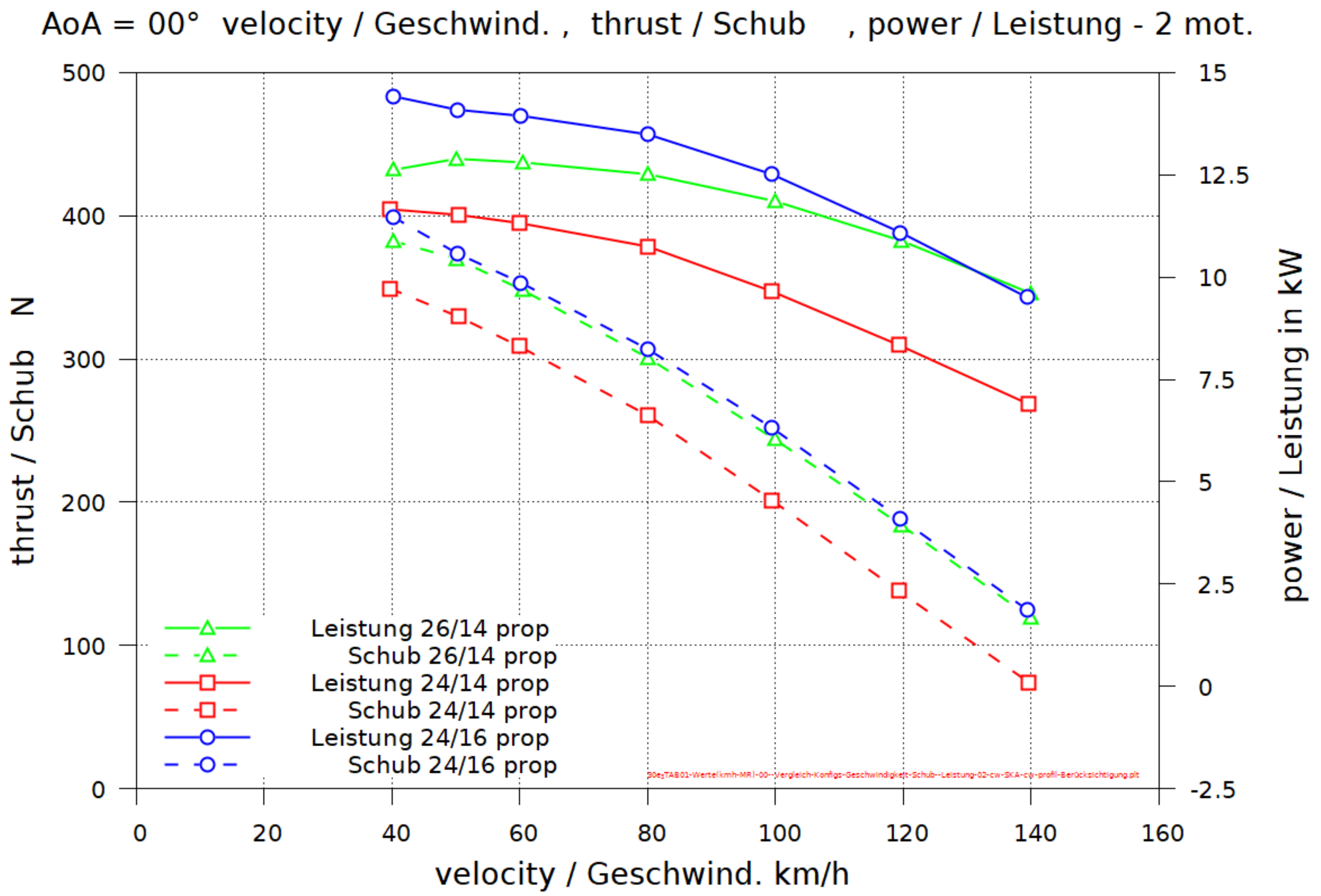
Conditions:

1: 1 Modell

40 km/h < v < 140 km/h

OTW -prop-wing interaction

SKA Project measurements 13kW/500 N = 0,026 kW/N



Measurements OTW:

Power and thrust as function of (v) flight velocity

6000 rot/min 26 ´´

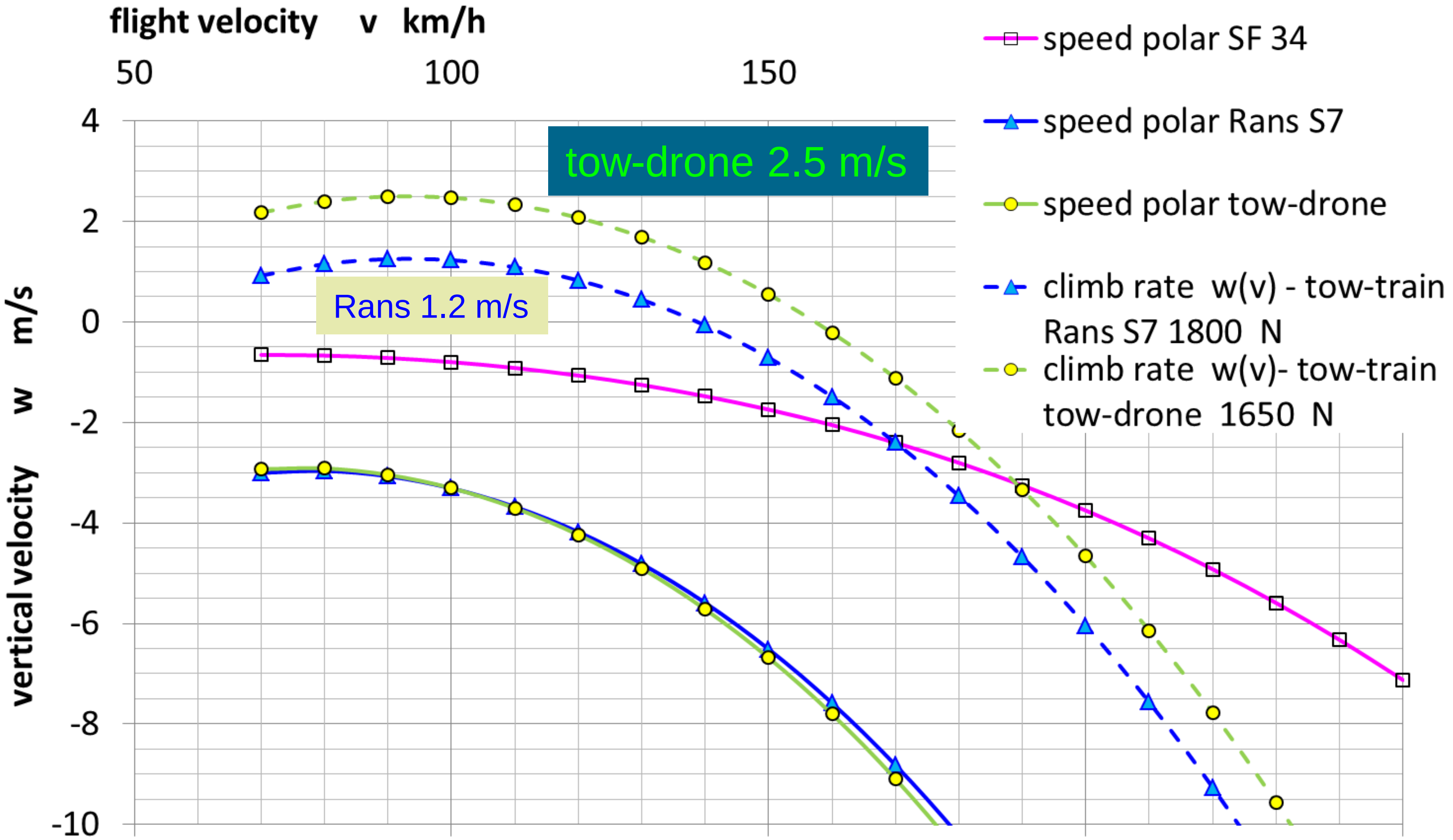
6500 rot/min 24 ´´

Full power

13 kW with 2 props

26 kW with 4 props

„Aero tow polars“ and speed polars = Rans / Schleppdrohne and SF 34



Comparison :

Towplane
Rans S7
1800 N, 450 kg,

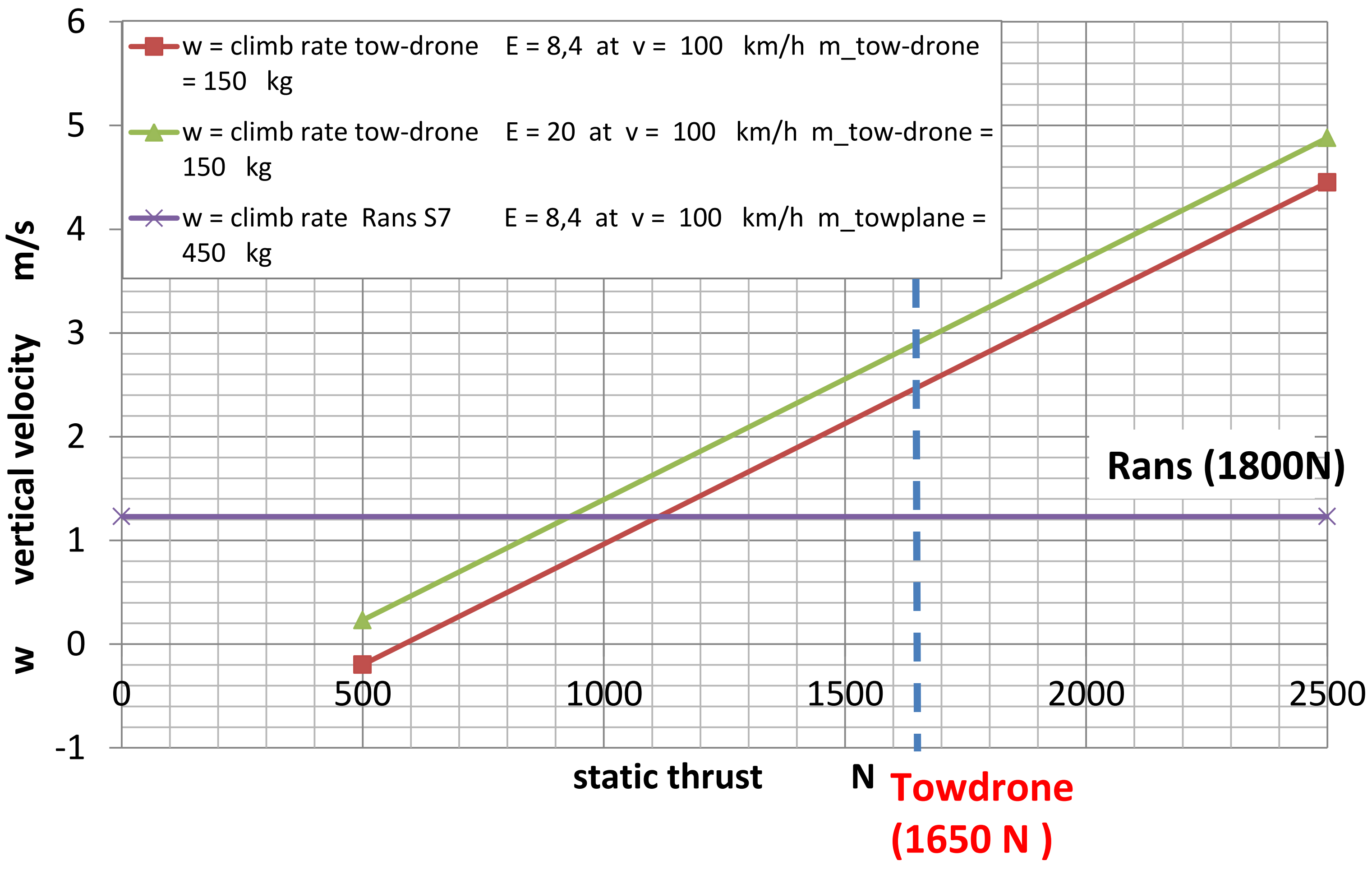
Tow-drone
1650 N, 150 kg,

SF-34, 520 kg

and

speed-polars

Influence of thrust and glide ratio E on climb rate at (v = 100 km/h)

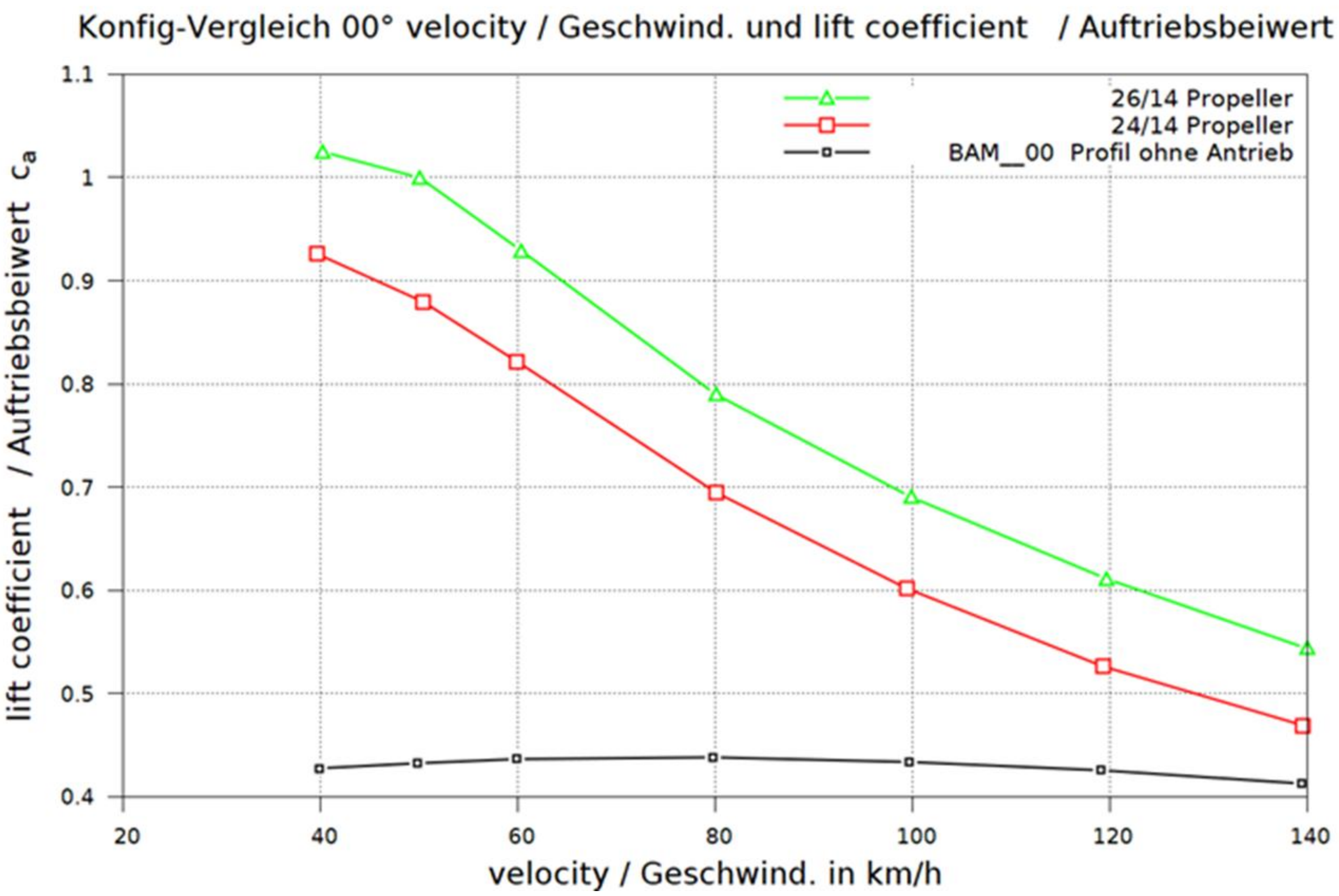


Comparision at:
100 km/h
Aerotow SF 34

Thrust of towdrone varies from
500 N – 2500 N
m = 150 kg,

towdrone
E_{opt} = 20 and 8,4

Blown wing effect – SKA propulsion unit with profile HQ 51



OTW - measurements

Blown wing effect

6000 rot/min 26 ´´

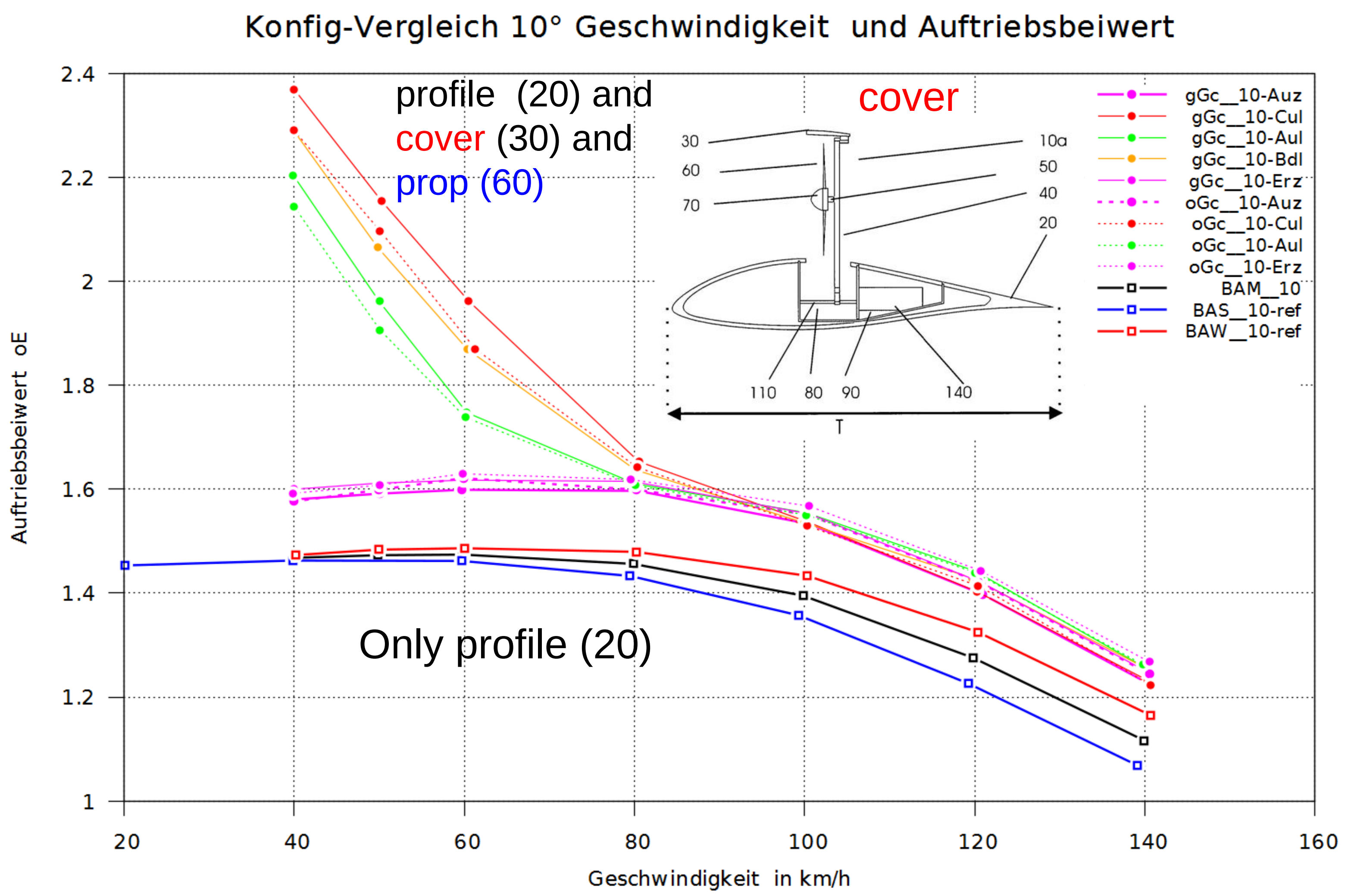
6500 rot/min 24 ´´

und herzlichen Dank

an

Uwe Fey für die Messung

Blown wing effect – SKA propulsion unit with profile HQ 51



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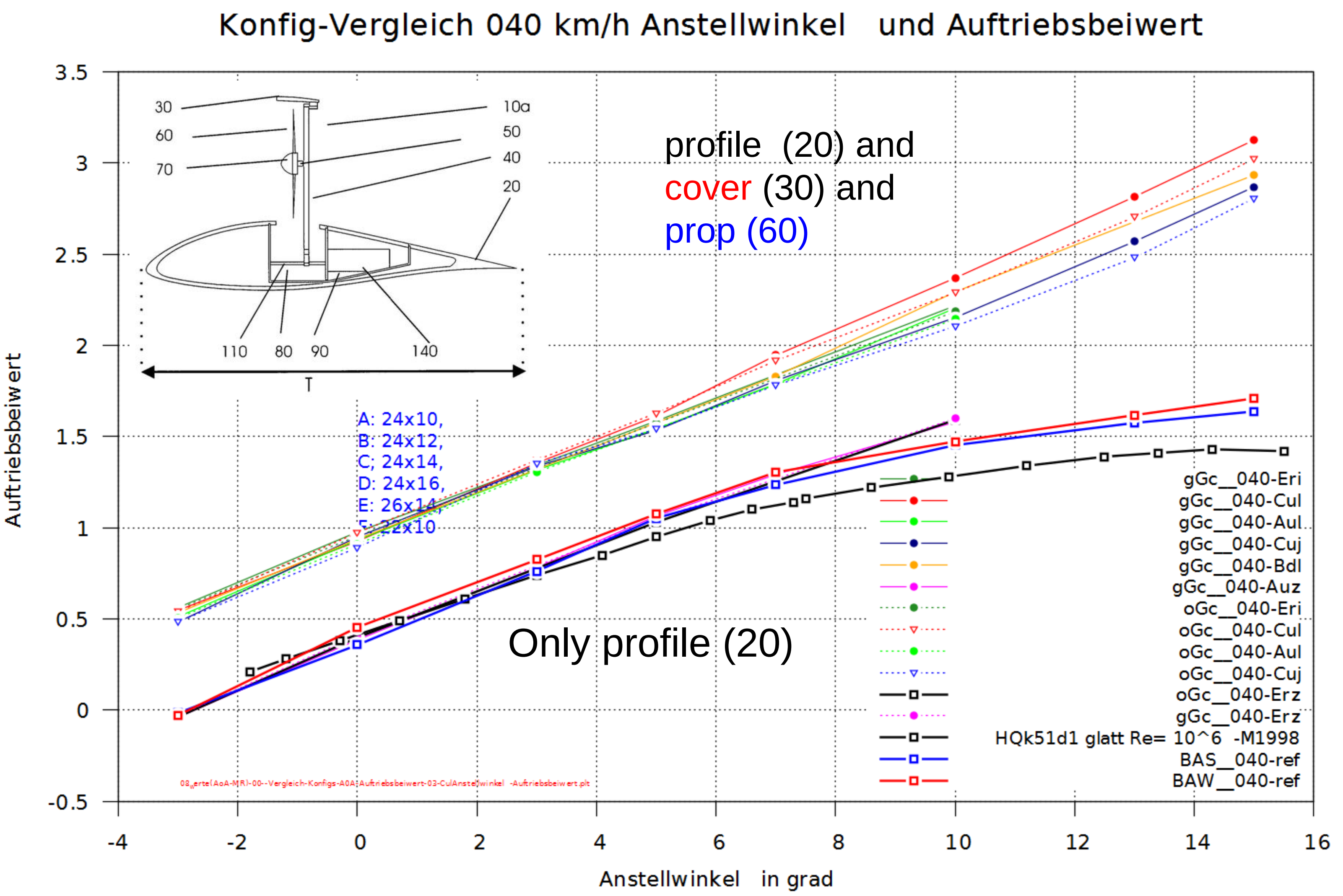


OTW - measurements

Blown wing effect

6000 rot/min 26 ´´

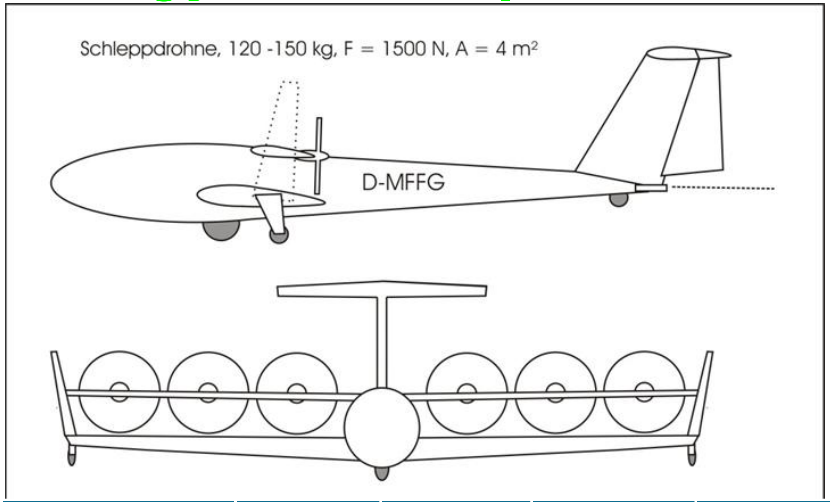
6500 rot/min 24 ´´

und herzlichen Dank

an

Uwe Fey für die Messung

Energy consumption and Power $1650\ N \cdot 0{,}026\ kW/N = P_{tow} = 42{,}9\ kW$



	E_{max}	v_{Emax}	mass	w_{climb}	t_{climb}	t_{tow}	F_{stat}	P_{climb}	E	Fuel
unit; remarks		km/h	kg	m/s	s ; 500 m	min	N	kW	kWh	Liter; mogas
SF - 34	35	95	520	-	-		-	-	-	-
Tow-drone SD-1	8,4	100	150	2,5	200,0	7	1650	42,9	5,01	-
Rans S-7	8,4	102	450	1,2	416,7	11	1800	75	13,75	4

$$t_{tow} \cdot P_{tow} = 7/60\ h \cdot 42{,}9\ kW = 5{,}01\ kWh$$

Towdrone SF-34

(rigid OTW-props)

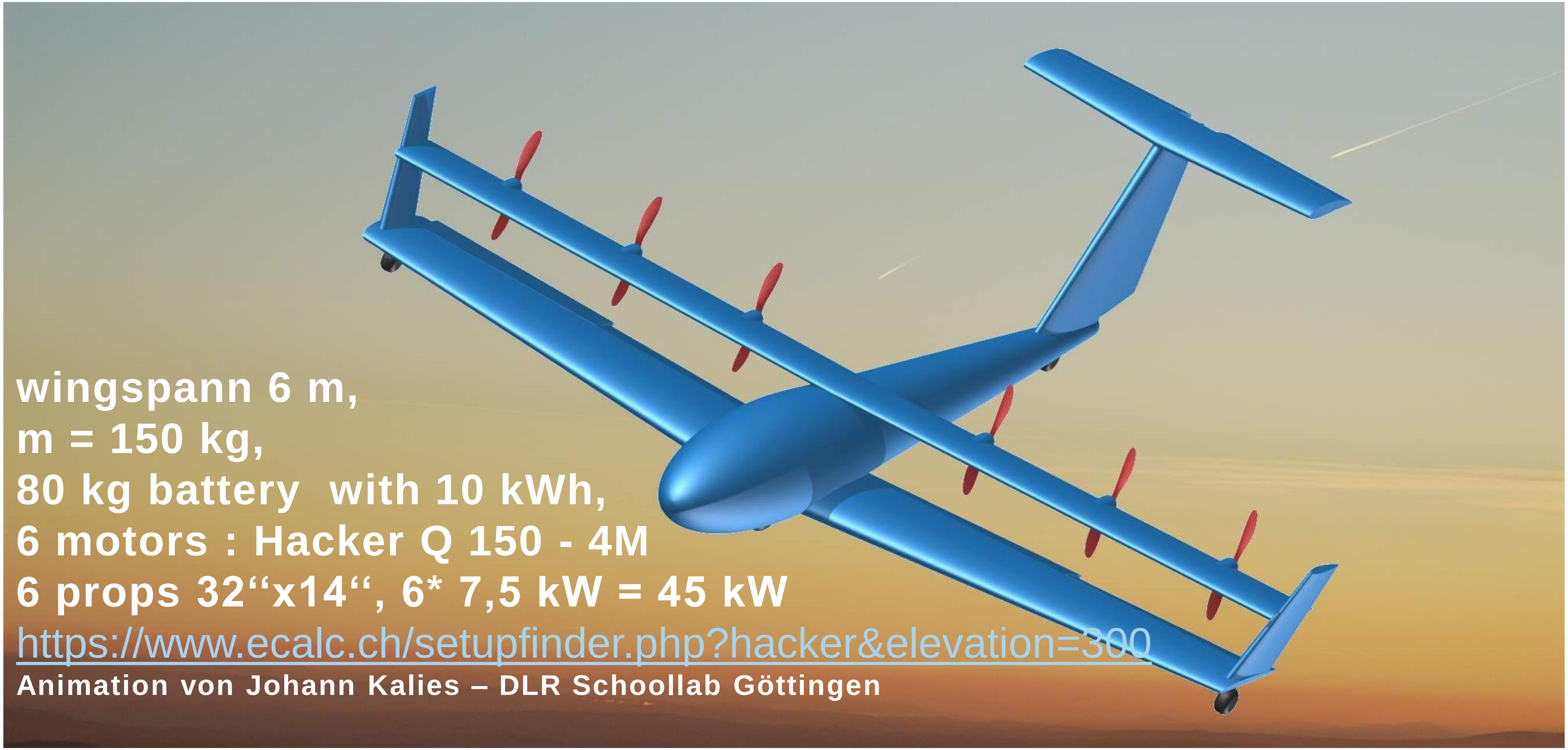
5,1 kWh energy per tow

Instead of

4 l petrol i.e.
4*8,5 kWh = 38 kWh

Aero-tow:
Rans S-7 SF-34

Schleppdrohne – towdrone SD - 1



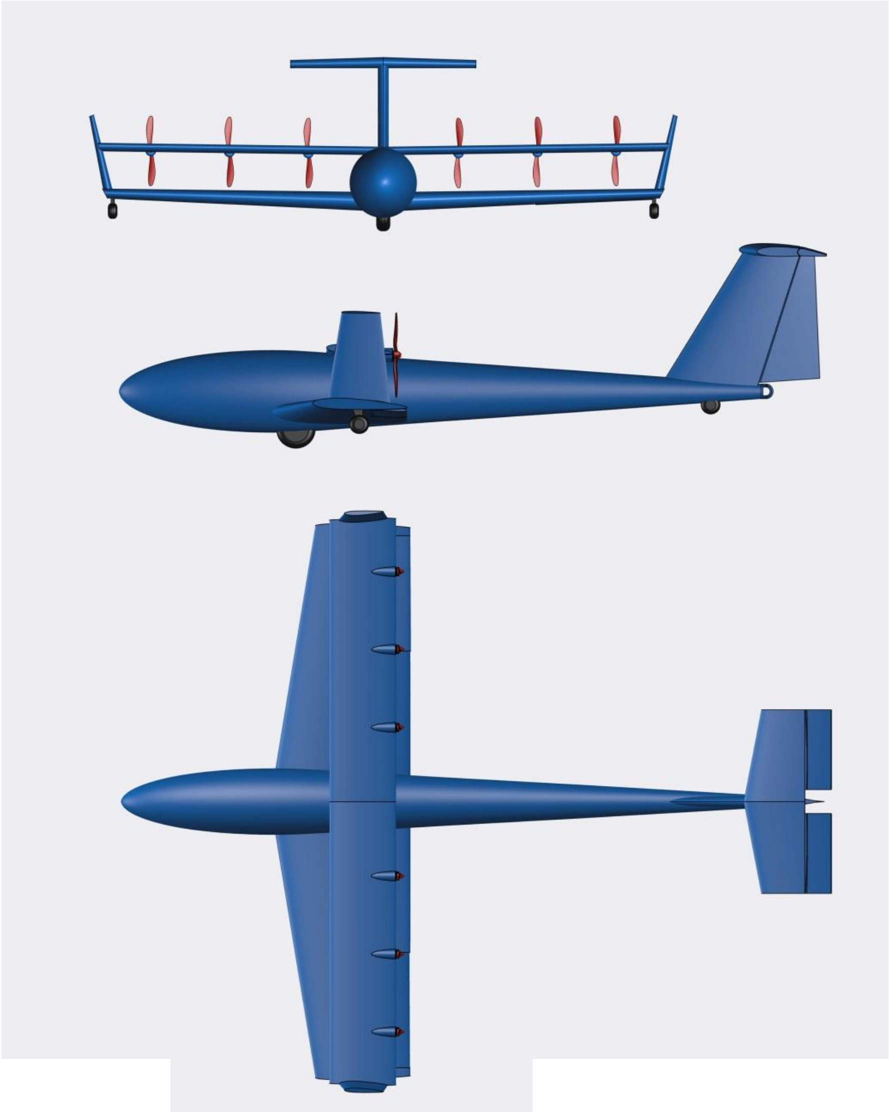
wingspann 6 m,
m = 150 kg,
80 kg battery with 10 kWh,
6 motors : Hacker Q 150 - 4M
6 props 32“x14“, 6* 7,5 kW = 45 kW
https://www.ecalc.ch/setupfinder.php?hacker&elevation=300
Animation von Johann Kalies – DLR Schoollab Göttingen

Schleppdrohne – towdrone SD - 1

Distributed e-drives
Over-the-wing-configuration
Low landing gear

Extremly good ratio
1650 N Schub/ thrust
150 kg Masse/mass

Geringe Risikoklasse/
low risc class
SORA (Specific Operations Risk Assessment)

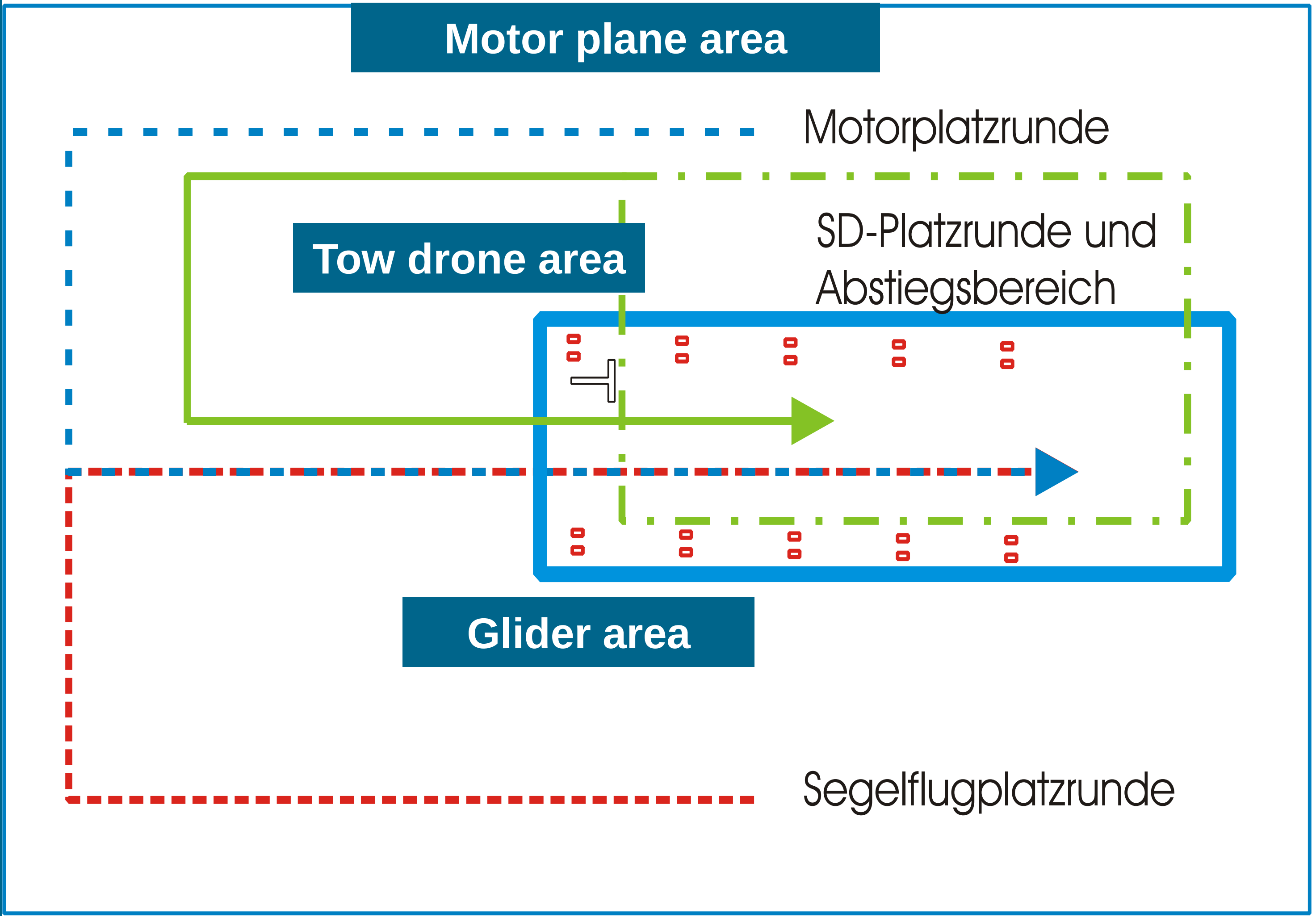


Traffic-pattern and procedure – towdrone SD – 1

Towing drone should behave like a towing aircraft

Operating procedure with SD circuit
(Platzrunde)
and SD descent area

comparable to the “taboo area” of over the airfield with winch launch



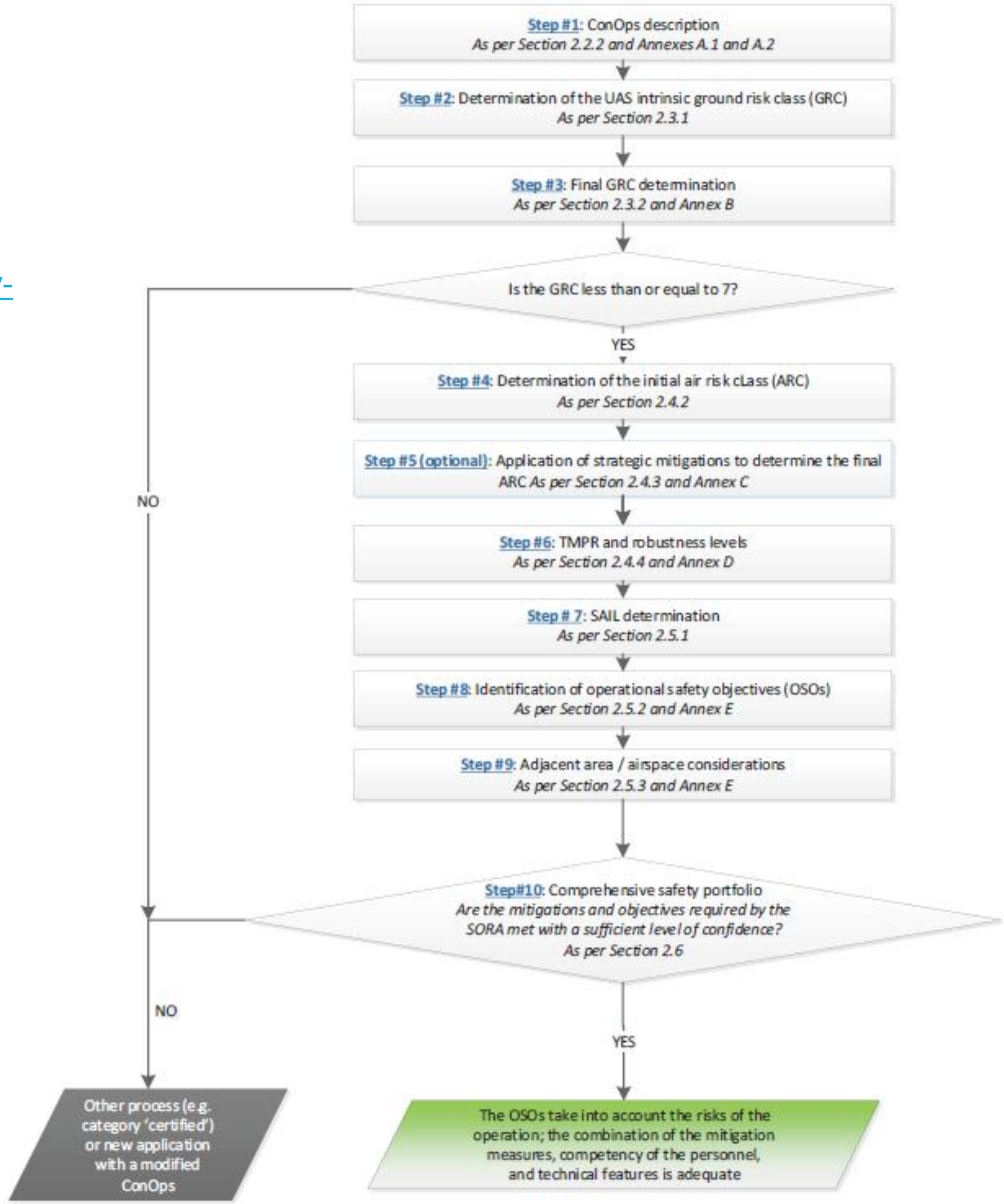
SORA for Tow-Drone

https://www.easa.europa.eu/en/document-library/easy-access-rules/easy-access-rules-unmanned-aircraft-systems-regulations-eu - S- 49

SORA
(Specific Operations Risk Assessment)
Spezifische Betriebsrisikobewertung
GRC - Ground Risk Class
ARC - Air Risk Class

SAIL
(Specific Assurance and Integrity level)
Spezifisches Sicherheits- und Integritäts -Niveau
OSO (Operational safety objective)
Betriebssicherheitsziel

Betriebsverfahren festlegen



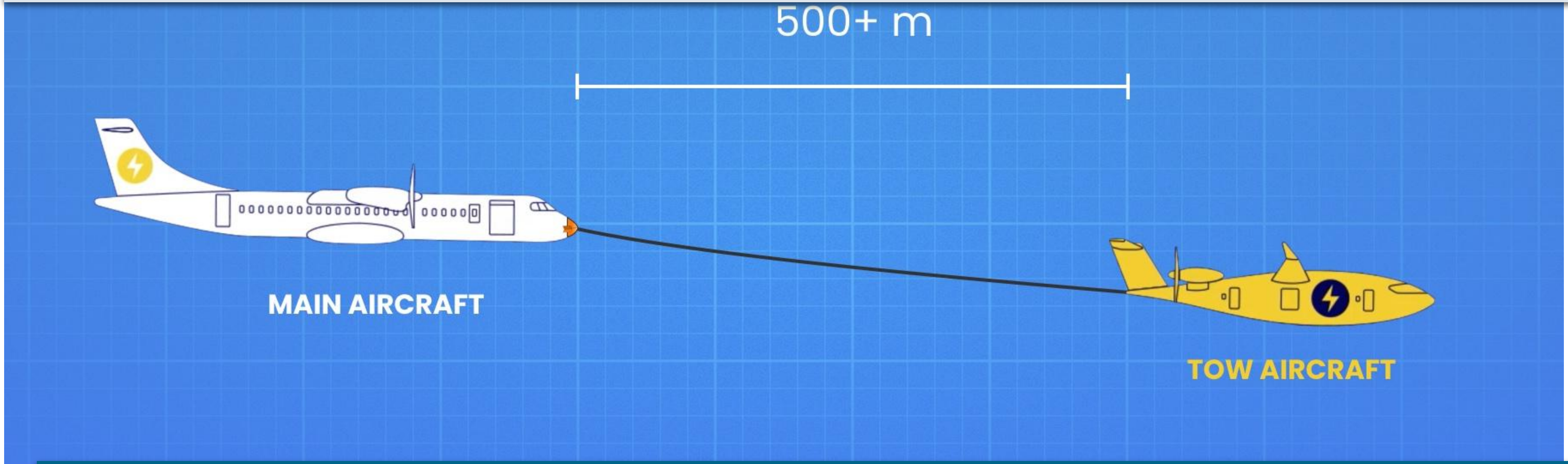
Tow drone not only for gliders - ME 231

Me 231 „Gigant“ towed by He 111 Z
(Z = Zwilling = twin)

Towplane in the imagination of - Magpie Aviation

Problem of long distance aerotow: two similar planes means:

double mass, double drag, double energy consumption



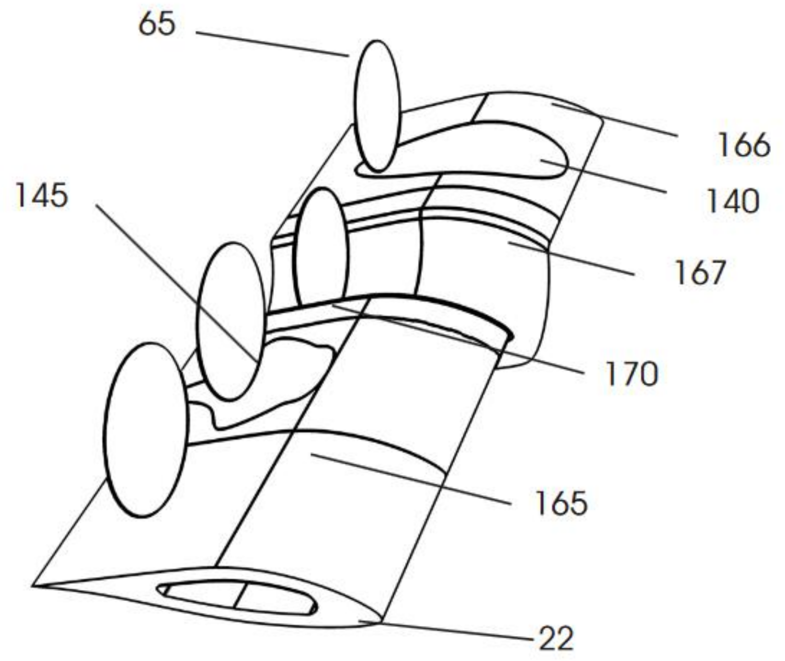
https://www.magpieaviation.com/aerotowing/how-it-works
https://www.magpieaviation.com/aerotowing/flight-tests

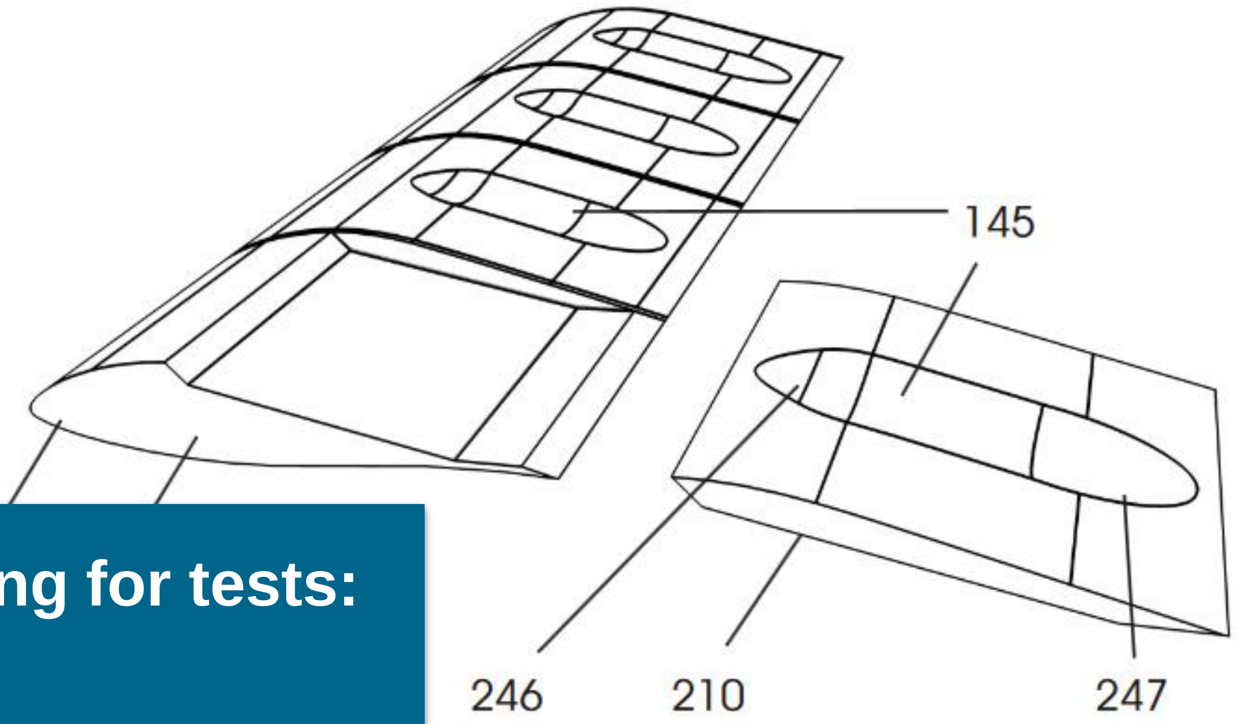
Tow -drone for take-off assisting E-regional planes

Tecnam P Volt, el. 9-seater,
Project with Widerøe
2023 Cancelled for battery problems

Tow – drone test – drone for (Custer wing modification)

DE 10 2024 001 505.1





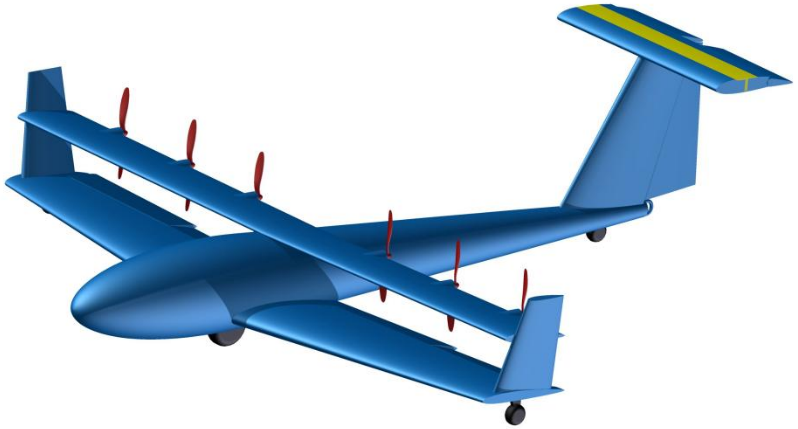
Test drone with rectangular wing for tests:
prop – wing-contur interaction

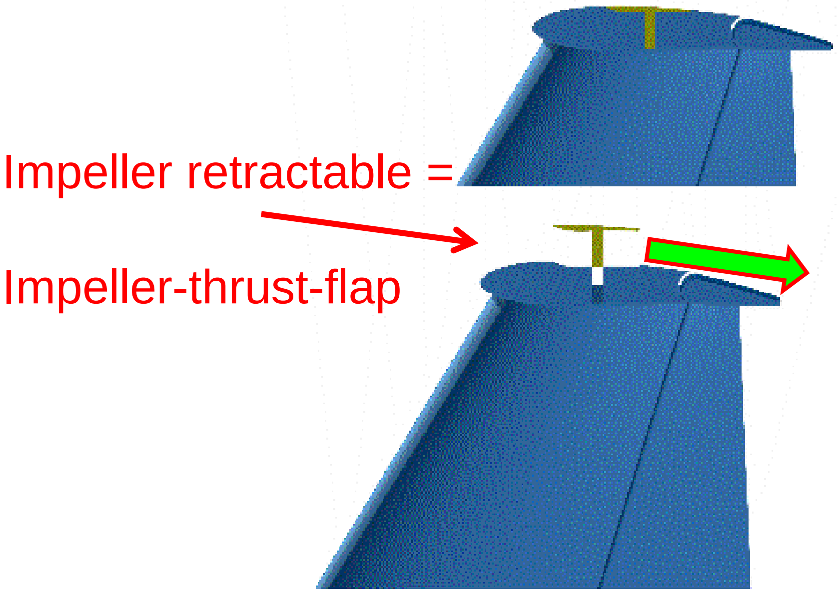
contour - spanwise formvariation
profile - streamwise formvariation

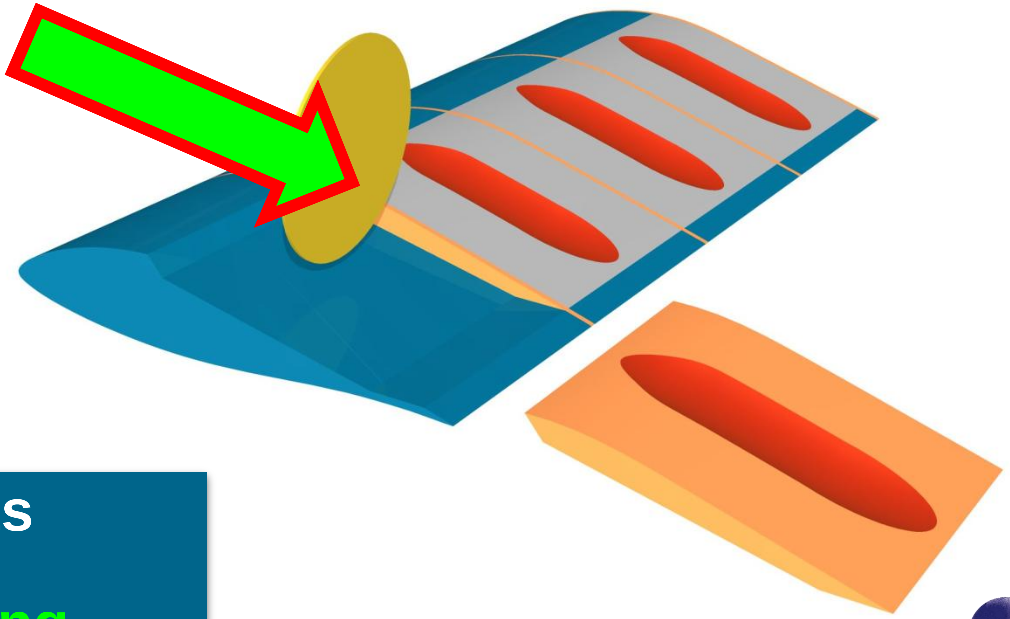
PLOTTERLAND INVENTION

blown surfaces of wing and elevator

Test drone with blown Elevator with ISK for low speed STOL → VSTOL







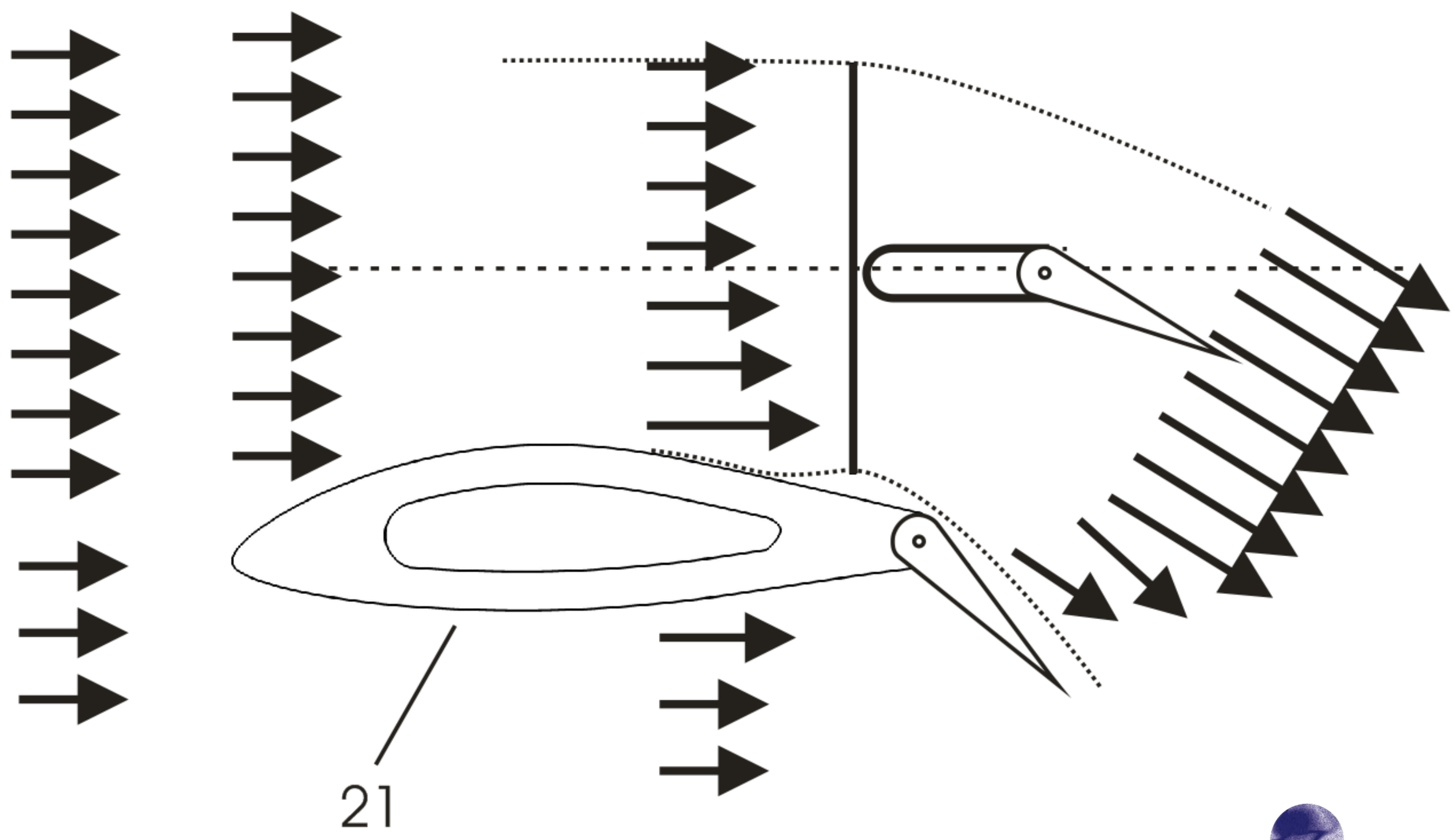
Test drone with modular surface Elements
- **Contouring in spanwise direction**
- **= Konturierung in Spannweiten-Richtung**

Improvement of Custer wing

Test drone with high lift devices

- Double flap configuration

Economical and practial substitution of many applications of multicopter air-taxis



Summary: Tow-Test-Drone

- low mass, low need for ressources
- low energy consumption
- high climb rate = secure take off
- secure props – over the wing
- distributed propulsion – blown wing effect
- small – small space requirement

- Independence for gliders (autonomous towdrone)

- test-drone - explorationt of wing prop interaction
  - subscale testing of new principles
- Development toward low energy e-flight and V/STOL with OTW = over-the- wing configuration

Thank you for your patience and attention

PLOTTERLAND INVENTION

looking for
cooperation partners
for development and marketing
of OTW = over-the-wing UAVs

www.coandajet.de

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