Federal Aviation Administration

Memorandum

Date:	March 16, 2012
To:	Manager, Small Airplane Directorate, ACE-100
From:	Manager, Project Support Branch, ACE-112
Prepared by:	Jim Rutherford, Aerospace Engineer, Project Support, ACE-112
Subject:	Equivalent Level of Safety (ELOS) Finding to JAR 22.335(f), Change 5, for Schempp-Hirth's Model DuoDiscus-xL, FAA Project # AT00366CE-G
ELOS Memo#:	ACE-11-15
Regulatory Ref:	JAR 22.335(f)

This memorandum requests your office to review and provide concurrence with the proposed finding of an Equivalent Level of Safety (ELOS) for the Design Maximum Speed, V_D, regulation of Joint Airworthiness Requirements (JAR) 22.335(f).

Background

The Schempp-Hirth Model "DuoDiscus" is a two-seat, mid-wing, non-powered sailplane certified in the utility category and used for advanced training and cross-country flying. The sailplane is constructed from carbon and glass fiber reinforced plastic (CFRP/GFRP) and features a T-tail with a fixed horizontal stabilizer and moveable elevator. The sales model variant DuoDiscus-xL incorporates Schempp-Hirth Modification Bulletin Number 396-16, which has the following design features:

- Elongation of the front part of the fuselage (approximately 4 inches).
- Redesign of the cockpit area (elongated control rods, modified water ballast valve actuation and lever location, and some cosmetic changes to coverings).
- Installation of battery mounting in the vertical fin to compensate for the nose heavy moment of the forward fuselage elongation.
- Modification to the Schempp-Hirth airbrakes to improve their efficiency (moved forward approximately 2.4 inches and increased height by approximately 0.3 inches), and
- Increase maximum weight by 110 lbs. (50 kg) to a total 1,654 lbs. (750 kg).

Schempp-Hirth seeks an ELOS finding based on non-compliance to the Design Maximum Speed, $V_{D,}$ regulation found in Joint Airworthiness Requirements (JAR) 22.335(f), Change 5, effective October 28, 1995. Specifically, the ELOS finding is sought for a non-compliance with the term, $C_{d\ min}$, in the V_D equation for Category U sailplanes. Typically, the lowest coefficient of drag, $C_{d\ min}$, is the same as the coefficient that occurs at zero lift, C_{d0}. Schempp-Hirth, however, proposes to use a different C_d to reach a useful V_D. The European Aviation Safety Agency (EASA) has granted an Equivalent Safety Finding to JAR 22.335(f) during its certification. This is documented in the EASA Type Certificate Data Sheet (TCDS) Number A.025.

Applicable regulation

JAR 22.335(f)

Regulation requiring an ELOS finding

The applicable regulation for Design Maximum Speed, $V_{D,}$ is addressed in JAR 22.335(f), Change 5, which states:

(f) Design Maximum Speed V_D. The design maximum speed may be chosen by the applicant but must not be lower than:

$$V_D = 18\sqrt[3]{\left(\frac{W}{S}\right)\left(\frac{1}{C_{d\ min}}\right)} \qquad \text{(km/h) for sailplanes of Category U}$$

$$V_D = 3.5\left(\frac{W}{S}\right) + 200 \qquad \text{(km/h) for sailplanes of Category A}$$

Where:

$\frac{W}{S}$ *= wing loading (daN/m^2) at design maximum weight*

$C_{d\ min}$ *= the lowest possible drag coefficient of the sailplane.*

***P** / For a powered sailplane, V_D must also not be lower than 1.35 V_H.*

Description of Compensating Design Features

Within JAR 22.335, the Design Maximum Speed, V_D (V-Design), is fixed by a formula using the minimum drag coefficient, $C_{d\ min}$. Historically, $C_{d\ min}$ is calculated, where the lift coefficient, C_l = 0. This method of determining the minimum drag coefficient is not ideal, when adapted for modern sailplane design. As justification for this proposed ELOS, Schempp-Hirth proposes to utilize a method derived in the LBA paper, “Concerning the deduction of design maximum speed

V_D in the airworthiness requirements LFS, LFSM, OSTIVAS, and JAR 22" by Mr. Uwe Irmer, LBA, dated September 11, 2001, to make a more reasonable estimate for the Design Maximum Speed, $V_{D,}$ for sailplanes. See Attachment 1.

The LBA paper theorizes that the "use of C_{d0} that occurs at zero lift, does not make much sense, because the speed calculated for this condition can be kept only momentarily. The stabilized speed belonging to this condition, the Terminal Velocity will never be attained by a modern sailplane, because of running out of sufficient height. The $C_{d\,min}$ occurs in the laminar bucket at a C_l higher than that connected to a real dive speed." The paper then proceeds to derive a sink rate speed of -7.8125 m/s that corresponds to a more reasonable value for C_d. This is then used to interpolate a more reasonable V_D for a given sailplane.

Explanation of Compensating Design Features

Based on the performance calculations for the DuoDiscus-xT glider with a maximum mass of 750 kg, the Design Maximum Speed, V_D, of the aircraft was determined at which the sink rate speed equals -7.8125 m/s. Schempp-Hirth determined this value to be 292 km/h. See Attachment 2.

For comparison reasons, the speed polar of the DuoDiscus measured by the idaflieg was converted to a mass of 750 kg. As you can see in Diagram 1 of Attachment 2, the sink rates of the performance calculation for the DuoDiscus-xT with a maximum mass of 750 kg are significantly lower, especially at higher speeds, compared to the converted idaflieg-polar. Thus, the determination of V_D based on the performance calculations can be seen as conservative.

The same Design Maximum Speed, V_D, is assumed for the DuoDiscus-xL, as the DuoDiscus-xL and the DuoDiscus-xT with retracted powerplant are aerodynamically very similar. Both sailplanes have the same wing with the same airfoils and winglets. Also, the vertical and the horizontal stabilizer are the same. The only difference between the DuoDiscus-xT and the DuoDiscus-xL is the elongated fuselage of the DuoDiscus-xL. Between the front and rear seat, the fuselage of the DuoDiscus-xL was elongated by approximately 100 mm (3.94 in) compared to the fuselage of the DuoDiscus-xT. Because of this elongation, the surface of the fuselage has increased slightly and the minimum drag of the DuoDiscus-xL has increased slightly. Therefore, the assumption of the same V_D for the DuoDiscus-xL as for the DuoDiscus-xT can be seen as conservative.

For the above reasons, Schempp-Hirth requests that an ELOS to JAR 22.335(f) be granted for the Model DuoDiscus-xL. The EASA (LBA) accepts the methodology and concurs with the Schempp-Hirth position.

After reviewing the submitted data and analysis, the FAA concurs with the Schempp-Hirth and EASA (LBA) positions on this issue. The basis of this ELOS Memorandum was developed from the Federal Aviation Administration Issue Paper F-3 at Stage 4, which documented the agreement with EASA (LBA) and Schempp-Hirth.

FAA Approval of the ELOS Finding

The Small Airplane Directorate concurs with the requested ELOS for the Schempp-Hirth model DuoDiscus-xL sailplane finding to JAR 22.335(f), Change 5, the Design Maximum Speed, $V_{D,}$ regulation.

James E. Jackson — *3-16-12*

for Manager, Small Airplane Directorate, Aircraft Certification Service — Date

ELOS Originated by: Project Support: ACE-112	Manager, Project Support Branch: William J. Timberlake	Routing Symbol: ACE-112

ATTACHMENT 1

	The Design Speed VD in the Airworthiness Requirements LFS, LFSM, OSTIV and JAR 22	LBA-M531-423/2001 Ausgabe: 2 Jahr: 2001 Seite: 1 von 5

(On the occasion of issuance of the Type Certification of the Sailplane ASW 28)

V_D, the Design Maximum Speed to be used for the design of Category U Sailplanes is given in the Airworthiness Requirements JAR 22 by the formula

$$V_D = 18 \cdot \sqrt[3]{\frac{W}{S} \cdot \frac{1}{C_{d\,min}}} \left[km/h \right]$$

where W/S is the wing loading at maximum design weight in daN/m^2 and
$C_{d\,min}$ the lowest possible drag coefficient of the sailplane.

The formula, as used first in the German Airworthiness Requirement LFS, is an empirical formula that allowed to make a reasonable estimate for the Maximum Design Speed.

The present review , admittedly incomplete, is made to check if it is possible to use another C_d different from $C_{d\,min}$ or the formerly used C_{d0} to reach a usefull V_D.

The use of C_{d0}, the one that occurs at zero lift, does not make much sense, because the speed calculated for this condition can be kept only momentarily. The stabilised speed belonging to this condition, the Terminal Velocity , will never be attained by a modern sailplane because of running out of sufficient height.

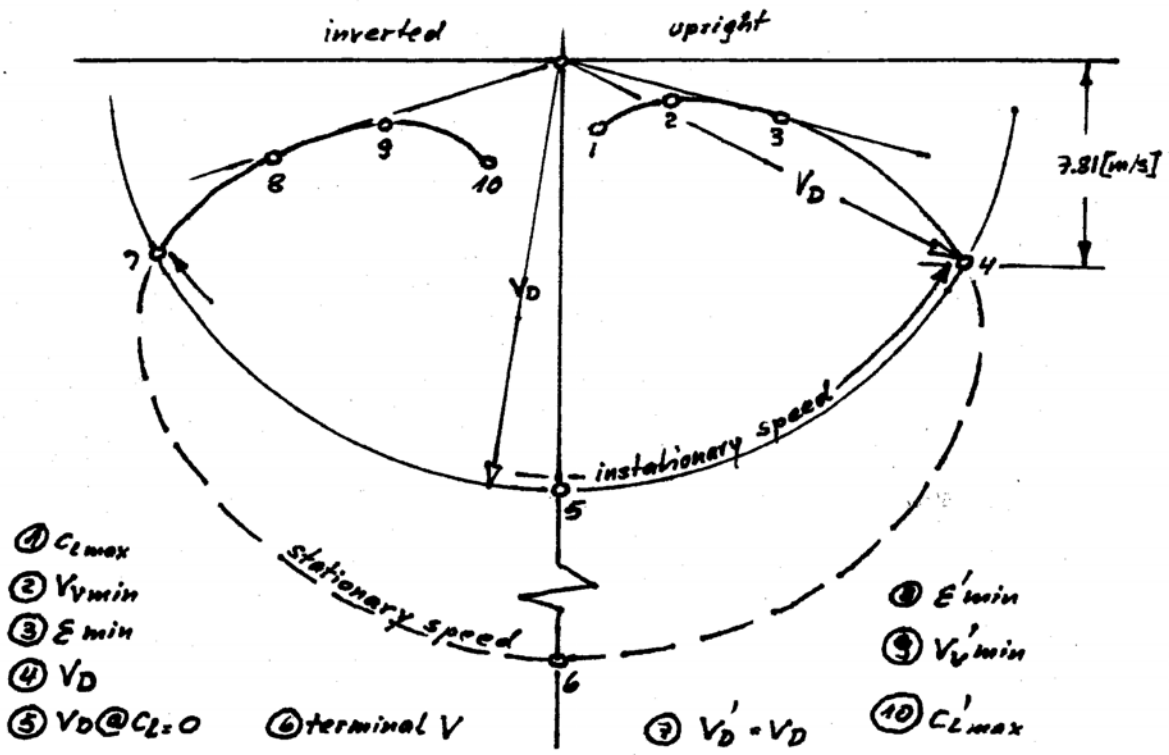
The $C_{D\,min}$ occurs in the laminar bucket at a C_L higher than that connected to a real dive speed.

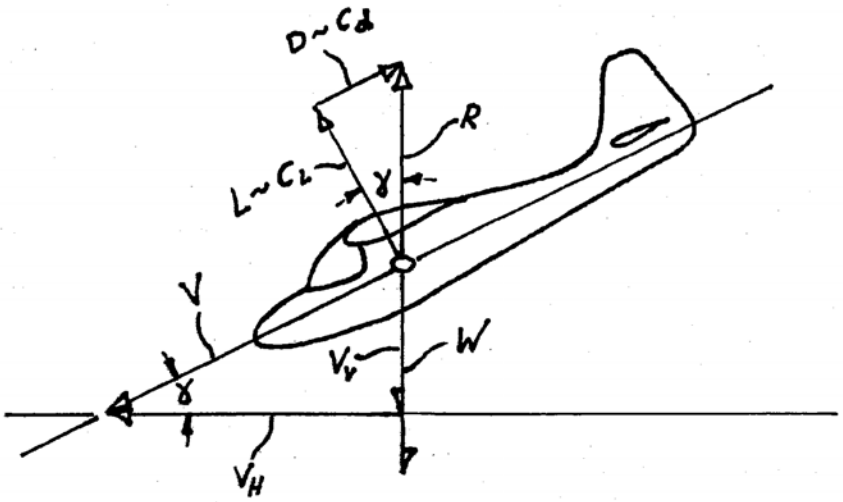
The dive-speed derived using $C_{d\,min}$ may be overconservative, the one derived by using C_{d0} may be unconservative, the correct approach must be somewhere in between.

If the thoughts of the „inventors" of the dive-speed-formula can be back-traced, may be a better interpretation for the dive-speed of the ASW 28 can be made:

Aufgestellt:	Geprüft:	Datum:	Luftfahrt-Bundesamt
Uwe Irmer		11.September 2001	

	The Design-Speed VD in the Airworthiness Requirements LFS, LFSM, OSTIV und JAR 22	LBA-M531-423 /2001 Ausgabe: 2 Jahr: 2001 Seite: 2 von 5





Aufgestellt:	Geprüft:	Datum:	Luftfahrt-Bundesamt
Uwe Irmer		11.Septemb.2001	

$$\sin\gamma = \frac{V_V}{V} \qquad V_V = \sin\gamma \cdot V$$

$$\tan\gamma = \frac{C_d}{C_l} = \frac{D}{L}$$

At $\gamma = 10^0$, an angle that may be expected, the difference between SIN and TAN is about 1,6%, so that SIN = TAN may be assumed with sufficient accuracy.

$$\frac{V_V}{V} = \frac{C_d}{C_l} = \frac{D}{L} \qquad L = C_l \cdot q \cdot A$$

$$C_d = C_l \cdot \frac{D}{L} \qquad \frac{C_l}{L} = \frac{1}{q \cdot A}$$

$$C_d = \frac{D}{q \cdot A} \qquad q = \frac{\rho}{2} \cdot V^2$$

$$C_d = \frac{D \cdot 2}{V^2 \cdot \rho \cdot A} \cdot \frac{V}{V} \qquad R = W$$

$$C_d = \frac{\sin\gamma \cdot W \cdot 2 \cdot V}{V^3 \cdot A \cdot \rho} \qquad D = \sin\gamma \cdot W$$

$$C_d = \frac{V_V \cdot W \cdot 2}{V^3 \cdot A \cdot \rho} \qquad V_V = \sin\gamma \cdot V$$

$$V^3 = \frac{V_V}{C_d} \cdot \frac{W}{A} \cdot \frac{2}{\rho}$$

$$V = \sqrt[3]{\frac{W}{A} \cdot \frac{2}{\rho} \cdot \frac{V_V}{C_d}} \cdot [meter / \sec]$$

The aerodynamic-mechanic relations together with the assumed simplifications lead to the above formula that is valid with acceptable accuracy.

If this formula is compared with the empirical formula that is used in LFS, LFSM, OSTIV an JAR 22 for the determination of V_D the thoughts that led to the V_D-formula become evident.

$$V_D = 5 \cdot \sqrt[3]{\frac{W}{A} \cdot \frac{1}{C_d}} \quad \text{[m/sec]}$$

(A factor of 18 instead of 5 changes the dimension of result to [Km/h])

$V_D = V$

$$5 \cdot \sqrt[3]{\frac{W}{A} \cdot \frac{1}{C_d}} = \sqrt[3]{\frac{W}{A} \cdot \frac{2}{\rho} \cdot \frac{V_V}{C_d}} \qquad \frac{\rho}{2} = \frac{1}{16}\left[\frac{kg \cdot \sec}{m^4}\right]$$

$$5 \cdot \sqrt[3]{1} = \sqrt[3]{\frac{2}{\rho} \cdot V_V}$$

$$5 = \sqrt[3]{16 \cdot V_V}$$

$$125 = 16 \cdot V_V$$

$$V_V = \frac{125}{16} = 7{,}8125 \quad \text{[m/sec]}$$

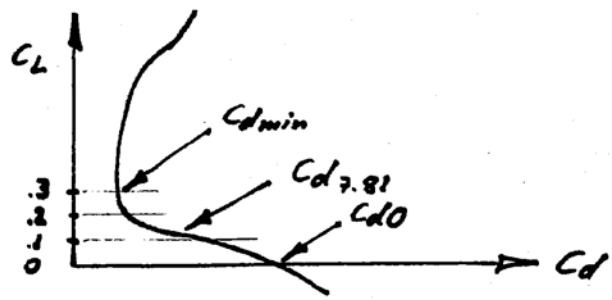
From a conversation with Mr. Heiko Frieß, the retired chief of LBA´s sailplane section, I learned that in the early sixties the late Mr. Walter Stender spent a lot of thoughts on the V_D-determination.
Based on the knowledge of complete polars of sailplanes, that where considered modern at that time, he finally felt able to present a formula.
After a lot of discussion, the formula even passed the Ostiv Sailplane Development Panel, and was entered into the Ostiv Requirements as well as into the German LFS.
The empirical formula

$$V_D = f \cdot \sqrt[3]{w \frac{W}{A} \cdot \frac{1}{C_{d0}}}$$

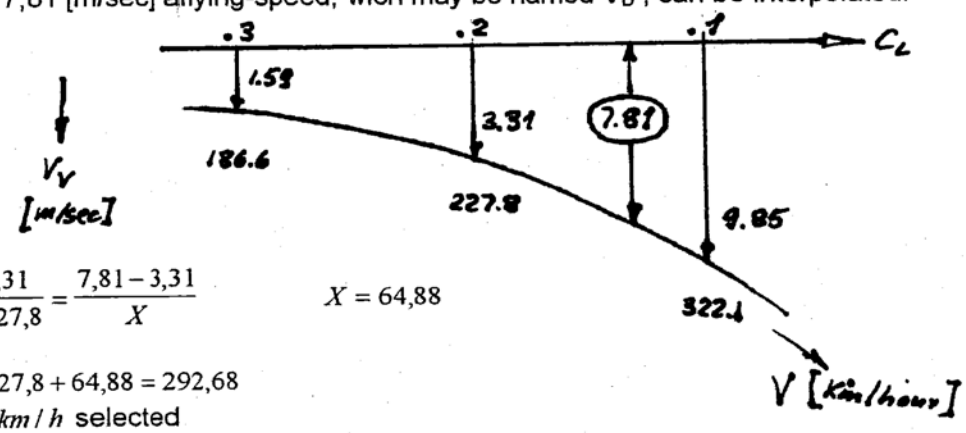
received a „pleasing" form by the use of $f = 5$ for results in [m/sec] and $f = 3{,}6 \cdot 5 = 18$ for results in [km/hour].
The formula is arbitrary for any C_d except the C_d that belongs to the sinking-speed V_V = 7,8125 [m/sec], where C_L, C_d, V_v and $V = V_d$ belong together.

The sinking-speed of V_V =7,8125 [m/sec] had been found by the Ostiv Sailplane Developement Panel, at that time, as sufficient or typical for the leaving of clouds or cloud-streets.

The original LFS-formula made use of C_{d0}, that is the drag coefficient at C_L= 0, the vertical dive case.



Modern sailpanes usually have C_{d0} that are outside the lamiar bucket of the polar. The accompanying high value of the C_d may therefore result in an unconservatively low V_D.
On the other hand gave the introduction of $C_{d\,min}$ into the LFS in the year 1967 also no undisputable facts.
The $C_{d\,min}$ of the ASW 28 occures at an C_L~0.3 and therefore the V_D derived from that $C_{d\,min}$ does not match the C_L.
Based on the ASW 28´s speed-polar, that is very precisely calculated, for a sinking-speed of 7,81 [m/sec] aflying-speed, wich may be named V_D , can be interpolated.



$$\frac{9{,}85-3{,}31}{322{,}1-227{,}8}=\frac{7{,}81-3{,}31}{X} \qquad X=64{,}88$$

$V_{D\,min} = 227{,}8 + 64{,}88 = 292{,}68$
$V_D = 300 km/h$ selected

The LBA accepted a <u>V_D = 300 km/hour</u> as suitable for the sailplane ASW 28.

ATTACHMENT 2

Schempp-Hirth Flugzeugbau GmbH Krebenstr. 25 D-73230 Kirchheim/T	EINZELNACHWEISE Änderungsblatt 890-6, 750 kg				Blatt
	Muster:	DuoDiscus xT	Geräte Nr.:	890	0. 3. 22-750
JAR 22.335	C – Festigkeit LASTANNAHMEN				

JAR 22.335 Bemessungs-Fluggeschwindigkeiten

Die berechneten Geschwindigkeiten sind alle äquivalente Geschwindigkeiten (EAS)

(a) Bemessungsmanövergeschwindigkeit V_A

Die maximalen und minimalen Auftriebsbeiwerte des verwendeten Flügelprofils HX 83 Nase 3 werden aus dem Bericht „Polarenmessungen am Profil HX 83 Nase 3" des Instituts für Aero- und Gasdynamik der Universität Stuttgart ermittelt:

$C_{A\,max}$	$C_{A\,min}$		
	gemessen	gewählt	Blatt
1,32	-0,64	-0.70	1.3-750

Das angesetzten $C_{a\,min}$ wurde auf der sicheren Seite liegend gewählt. Das tatsächliche $C_{a\,min}$ wurden den Vermessungen Messung bestimmt und liegt mit -0.64 positiver.
Unabhängig von der verwendeten Flügelgeometrie und den Einfluß des Rumpfes auf die Auftriebsverteilung wird zur Berechnung der Überziehgeschwindigkeit der maximale Auftriebsbeiwert des Profils herangezogen.

Daraus ergibt sich bei Maximalmasse und eingefahrenen Bremsklappen folgende rechnerische Überziehgeschwindigkeit:

V_{S1} = 84,9 km/h Bl. 1.3.750

Mit dem Lastvielfachen im Punkt A des v-n-Diagramms errechnet sich somit folgende Bemessungs-Manövergeschwindigkeiten:

V_A = 195,4 km/h Bl. 1.3-750

(b) Bemessungsgeschwindigkeit für ausgefahrene Flügelklappen V_F:

Entfällt, da Starrprofil

(c) Bemessungsgeschwindigkeit für starke Böen V_B:

Die Bemessungsgeschwindigkeit für starke Böen V_B wird der Bemessungs-manövergeschwindigkeit V_A gleichgesetzt:

$V_B = V_A$ = 195,4 km/h Bl. 1.3-750

Bearbeiter:	Musterprüfer:
Datum: 23.02.2011	Datum:

Schempp-Hirth Flugzeugbau GmbH Krebenstr. 25 D-73230 Kirchheim/T	EINZELNACHWEISE Änderungsblatt 890-6, 750 kg				Blatt
	Muster:	DuoDiscus xT	Geräte Nr.:	890	0. 3. 23-750
JAR 22.335	C – Festigkeit LASTANNAHMEN				

(d) Bemessungsgeschwindigkeit für Flugzeugschlepp V_T:

V_T wird gewählt und ist nicht kleiner als 125 km/h.

V_T = 180,0 km/h Bl. 1.3-750

(e) Bemessungsgeschwindigkeit für Windenstart V_W

V_W wird gewählt und ist nicht kleiner als 110 km/h.

V_W = 150,0 km/h Bl. 1.3-750

(f) Design Maximum Speed V_D:

The design maximum speed was set to:

V_D = 292,0 km/h *Bl. 1.3-750*

Equal level of safety

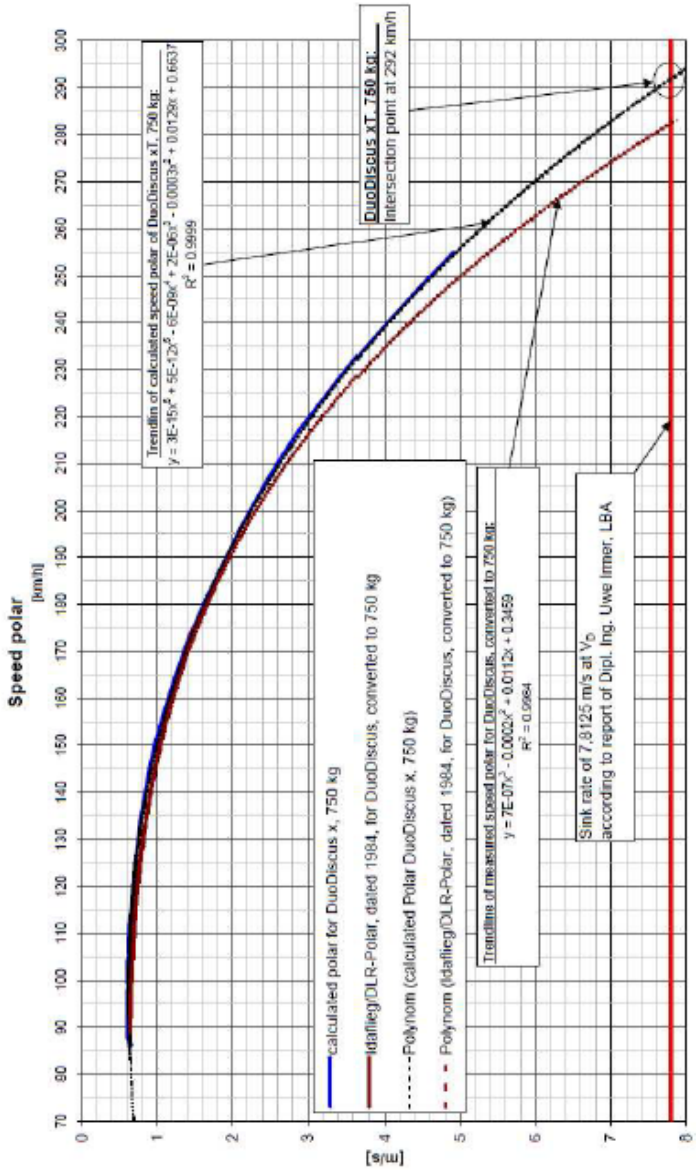
*For the determination of the design maximum speed V_D the report „**Concerning the deduction of design maximum speed V_D in the airworthiness requirements LFS, LFSM, OSTIVAS and JAR 22**" (Dipl. Ing. Uwe Irmer, LBA Braunschweig, dated 11th september 2001) was taken into account.*

Based on the extensive performance calculation for the DuoDiscus xT with a maximum mass of 750 kg, the speed of the airplane was determined, at which the sink rat equals -7,8125 m/s.

For comparison reasons the speed polar of the DuoDiscus, measured by the idaflieg, was converted to a mass of 750 kg.
As you can see on the diagram on the next page, the sink rates of the performance calculation for the DuoDiscus xT with a maximum mass of 750 kg are significant lower, especially at higher speeds, compared to the converted idaflieg-polar.

Thus the determination of design maximum speed V_D based on the performance calculations can be seen as conservative.

Schempp-Hirth Flugzeugbau GmbH Krebenstr. 25 D-73230 Kirchheim/T	**EINZELNACHWEISE Änderungsblatt 890-6, 750 kg**				Blatt
	Muster:	DuoDiscus xT	Geräte Nr.:	890	0. 3. 24-750
JAR 22.335	C – Festigkeit LASTANNAHMEN				



Bearbeiter:	Musterprüfer:
Datum: 23.02.2011	Datum:

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Diagram 1

LASTANNAHMEN

2.) V_{DM} für ausgefahrenes Triebwerk:

$C_{wmin} = 0{,}035$ Bl. 2.10.2.1 DDT

Damit ergibt sich:

$V_{DM} \geq 195{,}4$ km/h

Die Horizontalfluggeschwindigkeit wird vom DuoDiscus T übernommen. Wegen der Zunahme der maximalen Masse liegt man mit dieser Abschätzung auf der sicheren Seite:

$V_H = 115$ km/h Bl. 0.2.22 DDT

$V_{DM} \geq 1{,}35 * V_H = 1{,}35 * 115$ km/h $= 155{,}25$ km/h

Es wird gewählt: **V_{DM} = 195,4 km/h**