

OLM FBW 2006 – Toulouse – 26-28 September 2006



*Presented by*

**Boris Henry**  
Performance Engineer

# Takeoff speed determination at low weights

Reminders on Airbus recommendations



**AIRBUS**

# Introduction

- A few months ago, flight crews in an A321 flight reported that rotation at takeoff occurred without applying side stick input
- This was not the first occurrence
- Trim setting proved correct
- Takeoff data:
  - ▶ CONF1+F
  - ▶ T/O weight: 64 tons
  - ▶ V1/Vr/V2: 149/149/152 kt
- Theoretical study, confirmed by flight tests, confirmed the behavior

# Contents

- 1 Three ways to determine takeoff performance
- 2 Speed correction for low takeoff weights
- 3 Airbus recommendations
- 4 Conclusion



# Contents

- 1 Three ways to determine takeoff performance
- 2 Speed correction for low takeoff weights
- 3 Airbus recommendations
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# Takeoff Charts / Temperature Entry



**IAE 33000lb  
CONF1+F  
TOW 64 t**

A321231 - JAA		IAE V2533-A5 engines		<b>TEST -</b>					
QNH 1013.25 HPA				Elevation 0 FT TORA 3500 M			<b>DRY</b>		
Air cond. Off				Isa temp 15 C TODA 3500 M					
Anti-icing Off				rwy slope 0.00% ASDA 3500 M					
Crosswind UP TO 20KT							0 obstacle		
Dry check									
<b>OAT</b>	<b>CONF 1+F</b>			<b>CONF 2</b>			<b>CONF 3</b>		
<b>C</b>	TAILWIND	WIND	HEADWIND	TAILWIND	WIND	HEADWIND	TAILWIND	WIND	HEADWIND
	-10 KT	0 KT	10 KT	-10 KT	0 KT	10 KT	-10 KT	0 KT	10 KT
-40	100.0 3/7 161/77/81	100.0 3/7 150/78/81	100.0 7/7 149/78/81	98.9 3/6 168/79/80	99.9 2/3 183/91/91	99.9 2/3 181/91/91	93.6 2/3 165/75/78	93.6 2/3 159/76/79	93.6 2/3 157/76/79
54	81.5 3/6 152/59/62	83.2 2/3 162/68/71	83.5 2/3 165/71/73	80.5 3/6 154/60/60	81.4 2/3 164/69/69	81.4 2/3 167/72/72	76.3 2/3 154/58/61	76.3 2/3 150/59/61	76.3 2/3 148/59/61
56	80.1 3/6	81.5 2/3	81.9 2/3	78.9 2/3 154/60/60	79.6 2/3 164/69/69	79.6 2/3 164/70/70	74.5 2/3 151/56/59	74.5 2/3 145/56/59	74.5 2/3 143/56/59
57		<b>80.6 2/3</b>		78.0 2/3 154/60/60	78.6 2/3 164/69/69	78.6 2/3 163/69/69	73.6 2/3 149/55/57	73.6 2/3 143/55/57	73.6 2/3 141/55/57
LABEL FOR DNF	<b>163/68/70</b>			MC	Tref (OAT) = 30 C		Min acc height	495 FT	
DW (1000 KG) D1				ATION	Tmax (OAT) = 55 C		Max acc height	1818 FT	
DVI-DVR-DV2 (K1)							Min QNH alt	495 FT	
(TYMC OAT C) DW (1000 KG) DTFLEX							Max QNH alt	1818 FT	
DVI-DVR-DV2 (KT)									
	1=1st segment 2=2nd segment 3			<b>Correct. V1/VR/V2 = 1.0 KT/1000 KG</b>					
	5=tire speed 6=brake energy 7=								

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# Takeoff Charts / Temperature Entry



IAE 33000lb  
CONF1+F  
TOW 64 t

A321231 - JAA IAE V2533-A5 engines **TEST -**

<b>OAT</b> <b>C</b>	MTOW 80.6 t	Speed Correction	<b>ATOW 64 t</b>
V <sub>1</sub>	163 kt	17 kt	<b>146 kt</b>
V <sub>R</sub>	168 kt	17 kt	<b>151 kt</b>
V <sub>2</sub>	170 kt	17 kt	<b>153 kt</b>

56	80.1 3/6	81.5 2/3	81.9 2/3	78.9 2/3	79.6 2/3	79.6 2/3	74.5 2/3	74.5 2/3	74.5 2/3
				154/60/60	164/69/69	164/70/70	151/56/59	145/56/59	143/56/59
57	80.6 2/3			78.0 2/3	78.6 2/3	78.6 2/3	73.6 2/3	73.6 2/3	73.6 2/3
				154/60/60	164/69/69	163/69/69	149/55/57	143/55/57	141/55/57
LABEL FOR INPI	163/68/70			MC	Tref (OAT) = 30 C	Min acc height 495 FT	Min QNH alt 495 FT		
DW (1000 KG) D1				ATION	Tmax (OAT) = 55 C	Max acc height 1818 FT	Max QNH alt 1818 FT		

(TYMC OAT C) DW (1000 KG) D1/FLEX  
DVI-DVR-DV2 (KT)  
1=1st segment 2=2nd segment 3  
5=tire speed 6=brake energy 7=

Correct. V1/VR/V2 = 1.0 KT/1000 KG

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# Takeoff Charts / Weight Entry



**IAE 33000lb  
CONF1+F  
TOW 64 t**

A321231 - JAA		IAE V2533-A5 engines		<b>TEST -</b>					
QNH 1013.25 HPA Air cond. Off Anti-icing Off Crosswind UP TO 20KT Dry check				Elevation 0 FT TORA 3500 M Isa temp 15 C TODA 3500 M rwy slope 0.00% ASDA 3500 M			0 obstacle		
							<b>DRY</b>		
<b>WEIGHT</b>	<b>CONF 1+F</b>			<b>CONF 2</b>			<b>CONF 3</b>		
1000 KG	TAILWIND -10 KT	WIND 0 KT	HEADWIND 10 KT	TAILWIND -10 KT	WIND 0 KT	HEADWIND 10 KT	TAILWIND -10 KT	WIND 0 KT	HEADWIND 10 KT

66	57 7/9 0.0 112/31/36	57 7/9 0.0 112/31/36	57 7/9 0.0 112/31/36	57 7/9 0.0 112/27/30	57 7/9 0.0 112/27/30	57 7/9 0.0 112/27/30	57 7/9 0.0 111/20/24	57 7/9 0.0 111/20/24	57 7/9 0.0 111/20/24
64	57 7/9 0.0 112/31/36	57 7/9 0.0 112/31/36	57 7/9 0.0 112/31/36	57 7/9 0.0 112/25/28	57 7/9 0.0 112/25/28	57 7/9 0.0 112/25/28	57 7/7 0.0 111/20/24	57 7/7 0.0 111/20/24	57 7/7 0.0 111/20/24
<b>GRAD1/GRAD2 (KG/C)</b>									
	50/430	30/490	30/510	20/490	0/530	***/**			
LABEL FOR INFLUENCE		VMC LIMITATION	Tref (OAT) = 30 C Tmax (OAT) = 55 C		Min acc height 495 FT Max acc height 1818 FT		Min QNH alt 495 FT Max QNH alt 1818 FT		
DW (1000 KG) DTFLEX DVI-DVR-DV2 (KT) (TVMC OAT C) DW (1000 KG) DTFLEX DVI-DVR-DV2 (KT)		LIMITATION CODES: 1=1st segment 2=2nd segment 3=runway length 4=obstacles 5=tire speed 6=brake energy 7=max weight 8=final take-off 9=VMU				Min V1/VR/V2 = 112/20/24 CHECK VMU LIMITATION Correct. V1/VR/V2 = 1.0 KT/1000 KG			

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# Less Paper Cockpit (LPC)



IAE 33000lb  
CONF1+F  
TOW 64 t

Airbus - Less Paper Cockpit V 2.6 - TAKEOFF PERFORMANCE

**AIRCRAFT**

A/C Type : A321-231  
Tail Number : F-321C

Airport/RWY <F2> Heathrow  
Mod LHR EGLL : 27R C

Elev (ft) :79 Slope: 0.00  
RWY Length (m):3492 Clearway (m):0 Stopway (m):0 Obstacles:3  
LineUp (deg): 0 TO Shift (m):0

"Climb on 274 deg. At 1600 turn right to BNN HP."

**CONDITIONS <F3>**

Wind (° / kt) : 0  
OAT (°C) : 25  
QNH (HPa) : 1013  
TOW (kg) : 64000  
CONF : CONF 1+F  
Air Conditioning : Off

**RESULTS**

Perf. Limit Weight (kg): 94514

52	64000	TOW-VMU	112	131	136
53	64000	TOW-VMU	112	131	136
54	64000	TOW-VMU	112	131	136
55	64000	TOW-VMU	112	131	136
56	64000	TOW-VMU	112	131	136

- NORMAL -

QUIT <ESC> [FOUE F12] [R]

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# Takeoff speeds / Summary



IAE 33000lb  
CONF1+F  
TOW 64 t

ATOW 64 t	Chart with Temperature Entry	Chart with Takeoff Weight Entry	Delta Speed
$V_1$	146 kt	112 kt	<b>+ 34 kt</b>
$V_R$	151 kt	131 kt	<b>+ 20 kt</b>
$V_2$	153 kt	136 kt	<b>+ 17 kt</b>



# Three ways to determine takeoff performance



- A340

The A340 are much less concerned by this risk of autorotation at low weights because the four engine aircraft use much lower speed ratios than twin engine aircraft.



# Three ways to determine takeoff performance

- No aircraft performance concern
- No tailstrike concern
- But.... Risk of autorotation

Is the speed correction per ton too low ?

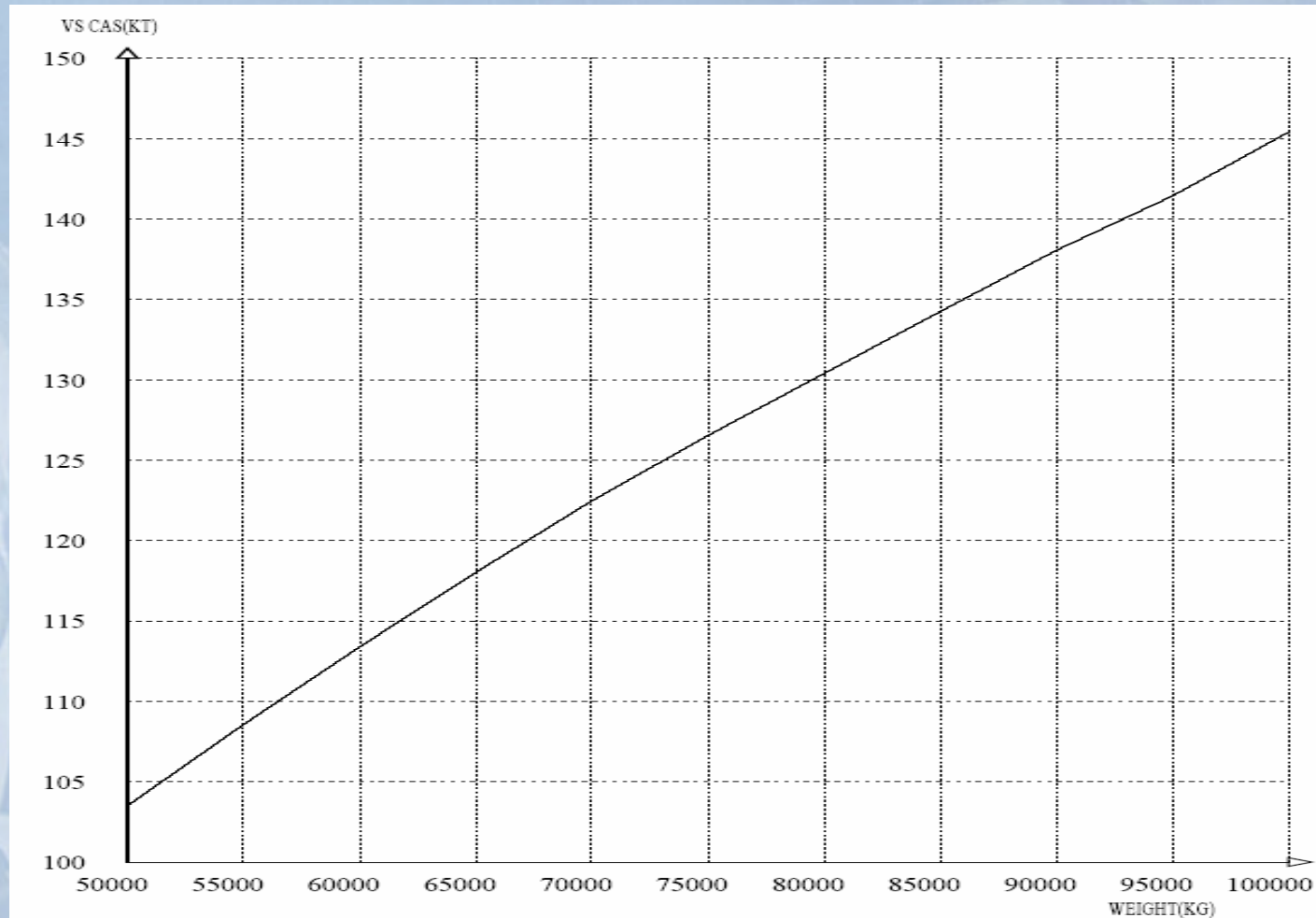
# Contents

- 1 Three ways to determine takeoff performance
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# Speed correction for low takeoff weights

30 C	Min acc height	495 FT	Min QNH alt	495 FT
55 C	Max acc height	1818 FT	Max QNH alt	1818 FT
			Min V1/VR/V2	= 112/20/24
			CHECK VMU LIMITATION	
			Correct V1/VR/V2 = 1.0 KT/1000 KG	

- The speed correction has been determined so as to remain at the same  $V_2/V_s$





# Speed correction for low takeoff weights

30 C	Min acc height	495 FT	Min QNH alt	495 FT
55 C	Max acc height	1818 FT	Max QNH alt	1818 FT
			Min V1/VR/V2	= 112/20/24
			CHECK VMU LIMITATION	
			Correct V1/VR/V2 = 1.0 KT/1000 KG	

- For the A320 family, the speed correction is 1kt per 1000 kg
- For the A330, it is 0.3 kt per 1000 kg.
- Increasing this speed correction would lead to get V2 less than 1.13 Vs in some cases.

It is not possible to provide a higher speed correction

# Contents

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# Airbus Recommendations

- When taking off at low weight on long runway :
  - ▶ Use a direct computation for the actual weight (Less Paper Cockpit (LPC) or equivalent) to obtain the exact speeds for the weight.

Airbus - Less Paper Cockpit V 2.6 - TAKEOFF PERFORMANCE

**AIRCRAFT**

A/C Type : A321-231  
Tail Number : F-321C

**CONDITIONS <F3>**

Wind (° / kt) : 0  
OAT (°C) : 25  
QNH (hPa) : 1013  
TOW (kg) : 64000  
CONF : CONF 1+F  
Air Conditioning : Off  
Anti ice : Off  
Runway Condition : Dry  
Thrust Option : TOGA

**INOP ITEM <F5>**

- NORMAL -

Airport/RWY <F2>      Modify RWY <ALT-F2>

HEATHROW      LHR EGLL : 27R C

Elev (ft) : 79      Slope: 0.00  
RWY Length (m):3492      Clearway (m):0      Stopway (m):0      Obstacles:3  
LineUp (deg): 0      TO Shift (m):0

"Climb on 274 deg. At 1600 turn right to BNN HP."

**RESULTS**



Perf. Limit Weight (kg): 94514

OAT (°C)	Weight (kg)	Code	V1 (kt)	VR (kt)	V2 (kt)	EO acc alt (ft)
25	64000	TOW-VMU	121	128	137	1579

FLEX (°C)	Weight (kg)	Code	V1 (kt)	VR (kt)	V2 (kt)	EO acc alt (ft)
51	64000	TOW-VMU	111	130	136	1579
52	64000	TOW-VMU	112	131	136	1579
53	64000	TOW-VMU	112	131	136	1579
54	64000	TOW-VMU	112	131	136	1579
55	64000	TOW-VMU	112	131	136	1579
56	64000	TOW-VMU	112	131	136	1579

COMPUTATION <F7>      REMINDER <F9>      Detailed Results <F10>

QUIT <ESC>

FOVE F12            

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# Airbus Recommendations

## 2. Use takeoff charts with weight entry:

<b>A321231 - JAA</b>		IAE V2533-A5 engines		<b>TEST -</b>			23.1.1 26-JAN-06 AC231D01 V 9			
QNH 1013.25 HPA Air cond. Off Anti-icing Off Crosswind UP TO 20KT Dry check				Elevation 0 FT TORA 3500 M Isa temp 15 C TODA 3500 M rwy slope 0.00% ASDA 3500 M			0 obstacle			
							<b>DRY</b>			
<b>WEIGHT</b> 1000 KG	<b>CONF 1+F</b>			<b>CONF 2</b>			<b>CONF 3</b>			
	<b>TAILWIND</b> -10 KT	<b>WIND</b> 0 KT	<b>HEADWIND</b> 10 KT	<b>TAILWIND</b> -10 KT	<b>WIND</b> 0 KT	<b>HEADWIND</b> 10 KT	<b>TAILWIND</b> -10 KT	<b>WIND</b> 0 KT	<b>HEADWIND</b> 10 KT	
<b>68</b>	57 7/9	57 7/9	57 7/9	57 7/9	57 7/9	57 7/9	57 7/9	57 7/9	57 7/9	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	114/36/40	114/36/40	114/36/40	112/29/32	112/29/32	112/29/32	110/22/26	110/22/26	110/22/26	
<b>66</b>	57 7/9	57 7/9	57 7/9	57 7/9	57 7/9	57 7/9	57 7/9	57 7/9	57 7/9	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	112/33/38	112/33/38	112/33/38	112/27/30	112/27/30	112/27/30	111/20/24	111/20/24	111/20/24	
<b>64</b>	57 7/9	57 7/9	57 7/9	57 7/9	57 7/9	57 7/9	57 7/7	57 7/7	57 7/7	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	112/31/36	112/31/36	112/31/36	112/25/28	112/25/28	112/25/28	111/20/24	111/20/24	111/20/24	
GRAD1/GRAD2 (KG/C)										
	50/ 410	50/ 460	20/ 480	50/ 430	30/ 490	30/ 510	20/ 490	0/ 530	***/**	
LABEL FOR INFLUENCE	OAT C DW CODES V1min/VR/V2 (kt)		VMC LIMITATION	Tref (OAT) = 30 C Tmax (OAT) = 55 C		Min acc height 495 FT Max acc height 1818 FT		Min QNH alt 495 FT Max QNH alt 1818 FT		
DW (1000 KG) DTFLX DV1-DVR-DV2 (KT) (TVMC OAT C) DW (1000 KG) DTFLX DV1-DVR-DV2 (KT)	LIMITATION CODES: 1=1st segment 2=2nd segment 3=runway length 4=obstacles 5=tire speed 6=brake energy 7=max weight 8=final take-off 9=VMU						Min V1/VR/V2 = 112/20/24 CHECK VMU LIMITATION Correct. V1/VR/V2 = 1.0 KT/1000 KG			

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# Airbus Recommendations

3. Add to takeoff charts with temperature entry one or two lines giving the speeds for low weights:

57	79.3 3/6	80.6 2/3	80.9 2/3	78.0 2/3	78.6 2/3	78.6 2/3	73.6 2/3	73.6 2/3	73.6 2/3
	153/50/62	163/60/70	166/71/73	154/60/60	164/60/60	163/60/60	140/55/57	143/55/57	141/55/57
<b>Standard Takeoff Chart with Temperature Entry</b>									
<small>DN (000 KG) DT/LEX DT1-DT2-DT3 (KT) (TVNO CAT) DN (000 KG) DT/LEX DT1-DT2-DT3 (KT)</small>			<b>LIMITATION CODES:</b> 1=1st segment 2=2nd segment 3=runway length 4=obstacles 5=tire speed 6=brake energy 7=max weight 8=final take-off 9=VMU				Min V1/VR/V2 = 112/20/24 CHECK VMU LIMITATION Correct. V1/VR/V2 = 1.0 KT/1000 KG		

WEIGHT	CONF 1+F			CONF 2			CONF 3		
	TAILWIND	WIND	HEADWIND	TAILWIND	WIND	HEADWIND	TAILWIND	WIND	HEADWIND
1000 KG									
72	118/40/44	118/40/44	118/40/44	112/23/29	112/23/29	112/23/29	149/23/27	149/23/27	140/23/27
64	112/31/36	112/31/36	112/31/36	112/25/28	112/25/28	112/25/28	111/20/24	111/20/24	111/20/24

**Additional Information for low takeoff weights**

# Airbus Recommendations

4. Retain the speeds for tailwind, if lower than for current wind

OAT C	CONF 1+F			CONF 2			CONF 3		
	TAILWIND -10 KT	WIND 0 KT	HEADWIND 10 KT	TAILWIND -10 KT	WIND 0 KT	HEADWIND 10 KT	TAILWIND -10 KT	WIND 0 KT	HEADWIND 10 KT
57	79.3 3/6 153/59/62	80.6 2/3 163/68/70	80.9 2/3 166/71/73	78.0 2/3 154/60/60	78.6 2/3 164/69/69	78.6 2/3 163/69/69	73.6 2/3 149/55/57	73.6 2/3 143/55/57	73.6 2/3 141/55/57

▶ No wind:

80.6 2/3
163/68/70

TOW 64 tons: V1=146

Vr=151

V2=153

Delta V1: 8 kt

Delta Vr: 7 kt

▶ 10 kt tailwind

79.3 3/6
153/59/62

TOW 64 tons: V1=138

Vr=144

V2=147

Delta V2: 6 kt



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# Conclusion

- ✓ When taking off at low weight, and in particular on a routine basis:
  - ✓ Prefer using a direct computation for the current takeoff weight
    - ✓ Less Paper Cockpit (LPC) or equivalent
    - ✓ Takeoff chart with weight entry
    - ✓ Takeoff chart with temperature entry with speed data for low weights
  - ✓ When not available, determine the speeds for the takeoff weight in the tailwind column, if lower
    - ✓ In this case, or if it is not possible, be aware that autorotation may occur.



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