2024 HAI HELI-EXPO
BY HELICOPTER ASSOCIATION INTERNATIONAL

BUILDING TOMORROW

Hot and High Operations

The Role and Importance of OGE max Weight and OGE Ceiling Calculations

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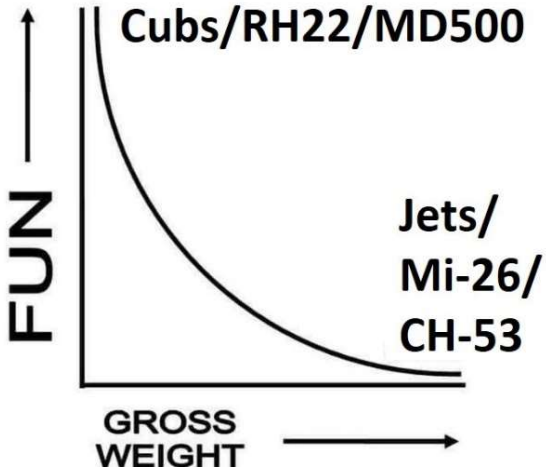
Tuesday February 27th, 2024, 2:15 pm-3:15 pm

www.heliexpo.com

Executive Summary

Less Weight - More Fun



- 'Hot & High'* is relevant to 30% of the planet
- Most operating margins are reduced as performance dwindles
- Temperature, Altitude and Weight – you can't maximize all three
- W&B calculations alone do not keep you safe
- Apps are faster and help communicate the weight trade-off better than the POH
- Density Altitude limitations can not be overcome with superior motorical skills only
- The OGE hover weight (= 'Safe weight') and OGE height limit keeps margins intact
- At the (higher) IGE limits however "it gets emotional quickly" -unless you keep ETL, there is no more margin
- Above OGE weight, watch out for LTE, VRS and use wind and ETL smartly
- Helicopters with a high [Useful load]/[BEW] ratio perform better at H&H

(i.e. RH66 with a 100% useful load/BEW ration only looses 4% useful load at altitude - compared to the average of 23% for comparable other helicopters in its class)

*Hot and high defined as: 95 F/ 35 C, P Alt ~5000", D Alt ~8400" – all other things being equal

Hot and High Operations – Agenda

- Introduction
- ‘Hot & High’ Aspects
- Weight & Balance and Density Altitude
- Calculating Performance and ‘Safe’ Weight
- Mitigating Risks

Glossary

Acronyms and Terms used

- **BEW** – Basic Empty Weight
- **DA** – D Altitude – Density Altitude: Pressure Altitude corrected for Temperature (and sometimes humidity)
- **ETL** – Effective Translational Lift
- **H&H** – 'Hot & High' – here commonly referred to as close or exceeding: ~ 8400" Density Altitude
- **HV diagram** – Height Velocity Diagram
- **IAS** – Indicated Altitude Speed
- **IGE** – In Ground Effect
- **ISA** – International Standard Atmosphere
- **LTE** – Loss of Tail-rotor Effectiveness
- **MAP** – Manifold Pressure
- **MSL** – Mean Sea Level (True Altitude and Elevation are both measured as physical distance from MSL)
- **MTOW** – Maximum Take Off Weight
- **OAT** – Outside Air Temperature
- **OGE** – Out of Ground Effect
- **PA** – P Altitude – Pressure Altitude: Altitude when altimeter set to Standard Pressure (1013mb or 29.92Hg)
- **POH** – Pilot Operating Handbook
- **QNH** – local altimeter setting (pressure) in mb or Hg
- **RPM** – Revolutions Per Minute
- **TAS** – Altitude Speed
- **Useful Load** = MTOW – BEW
- **Vne** – Never Exceed Speed
- **W&B** – Weight and Balance
- **VRS** – Vortex Ring State

* Included for completeness, assuming a target audience with ~1000 hours helicopter experience

Credits

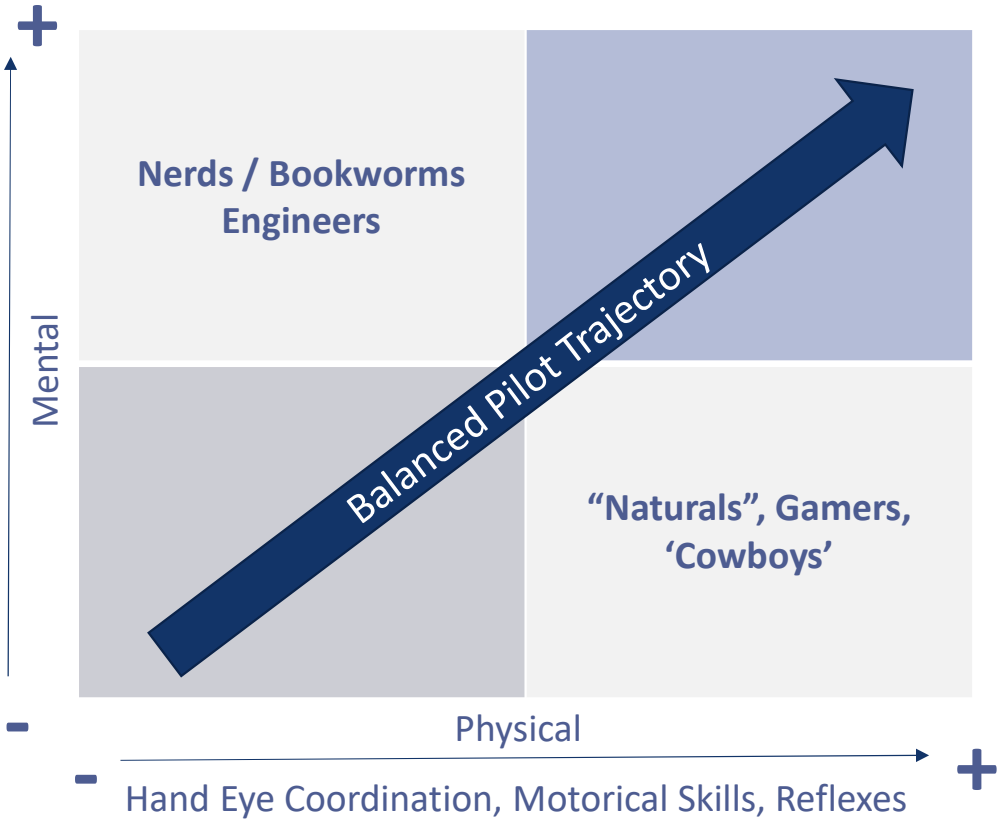
Sources used

- FAA Helicopter Flying Handbook – *FAA-H-8083-21, US Department of Transport*
- Principles of Helicopter Flight – *W.J. Wagtendonk*
- Helicopter Flight Training The Practical Aspects – *K Carter-Watchurst & L Erasmus*
- Aopa Pilot: Proficiency: It's not (just) the heat - *Markus Lavenson, 1 July 2019*
- Aopa Pilot: Proficiency: What is Payload? - *Alton K. Marsh, June 1, 2017*
- Helicopters 101: Hover Charts - by *Maria Langer, November 29, 2013*
- Gyromimo Apps - *Tim Tucker, Claus Richter*
- ibal App - *AirSpayce*
- Manufacturer POHs: RH44,RH66,EN28, EN48, B206, M500, H125, B407
- Isolair Product Specifications
- Wikipedia (for Landmass Elevation Data)

Pilot Types – Target Audience

Pilots have different Learning Styles

- Aeronautical Knowledge
- Decision making
- Intellectual Curiosity
- Judgement



Group at Risk

Hot and High Operations – Agenda

Introduction

‘Hot & High’ Aspects

Weight & Balance and Density Altitude

Calculating Performance and ‘Safe’ Weight

Mitigating Risks

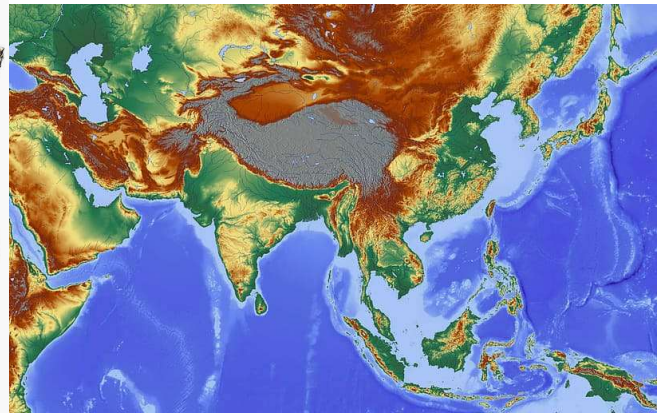
Defining Hot and High

Almost 30% of the Planet is above 5000 Feet Elevation

- Hot: > 35 Celsius / 95 Fahrenheit
- High: > 5000 feet Pressure Altitude
  - ~30% of the South African land mass
  - ~22% of the US land mass (8 mountain states)
  - ~29% of the Earth's landmass is above 5000 feet (about 1524 meters) in elevation

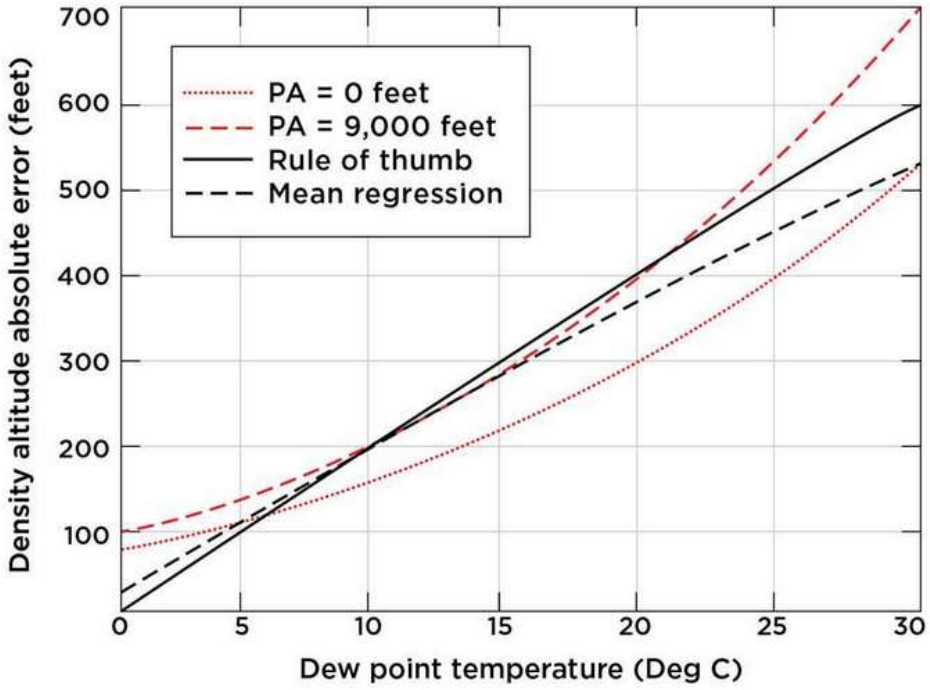
- <u>Density Altitude ~ 8400 feet</u>
- Light and variable wind conditions assumed for most of the scenarios

- 70-80% of all pilots do not learn in Hot & High conditions
- Mountain flying often is an additional (only informal) qualification



Hot, High and Humid

Humidity adds to the Density Altitude (more Water - less Oxygen)



The effects of humidity on density altitude calculations are nonlinear, but double the dew point temperature and add a zero and you've got a pretty good approximation of how much to add to calculations because of water vapor in the air. The rule of thumb is most accurate above dew points of 5 degrees Celsius, although it overestimates the correction at mean sea level for many dew points. *

*Aopa Pilot: Proficiency: It's not (just) the heat - *Markus Lavenson, 1 July 2019*

Graph reproduced from "Quantifying the Effects of Humidity on Density Altitude Calculations for Professional Aviation Education."

Aspects of Hot and High Operations

Helicopter Flying Margins are Impacted by Altitude, Temp, Weight:

Aerodynamics:

- Vne reduces
- Retreating Blade Stall margin reduces
- HV diagram shaded area grows
- Autorotation Vne reduces
- Rotor Stall/Critical RPM increases
- IAS versus TAS increases
- Stability decreases
- Flight control responses are reduced
- LTE, VRS risks increase

Power:

- Power reduces (1” MAP/1000”)
- Temperature versus Torque limits
- First limit indicator, gongs, transient limits
- Overpitching Risk increases/settling/vortex
- IGE/OGE hover weight & ceiling reduces
- MTOW/Useful load reduces

Human Factors:

- Hypoxia, Vertigo, Depth perception
- Dehydration & Fatigue
- Deodorant & Sense of Humor Failures*

*In Short: it gets “emotional” quickly …

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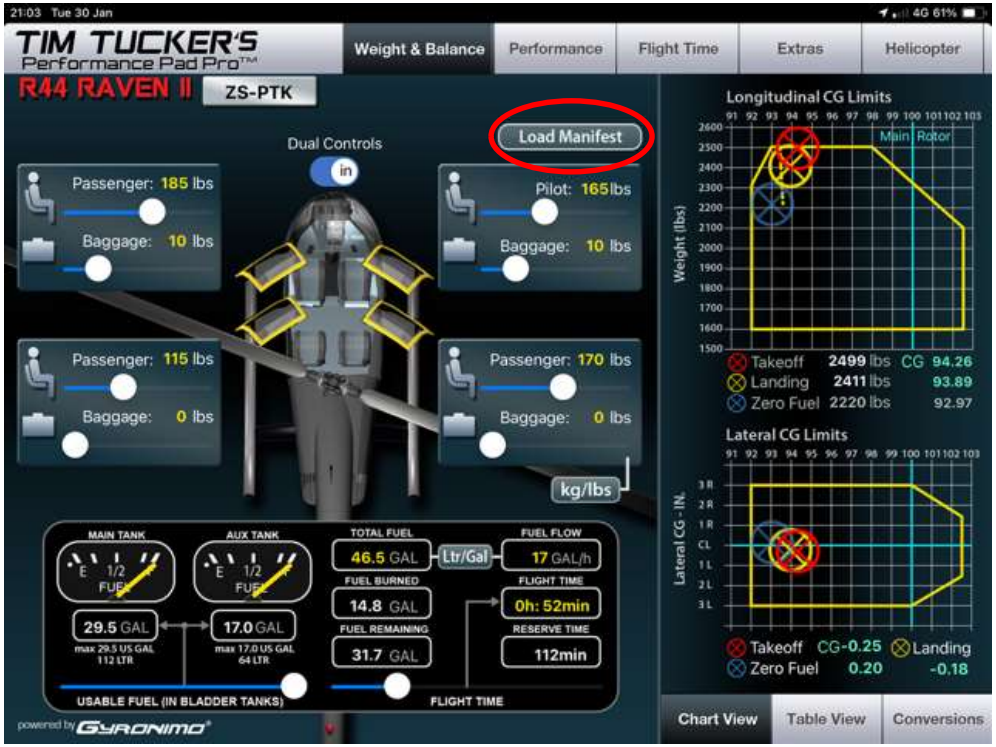
How much Weight is too much?

Weight and Balance Calculation – Necessary but Not Sufficient

Item	Weight (lb)	Location		Moment	
		Long. Arm (in.)	Lat. Arm (in.) + = Right Side	Long. (in.-lb)	Lat. (in.-lb)
Basic empty weight	1510	106.5	0.2	160,815	302
Remove forward right door	−7.5	49.4	24.0	−371	−180
Remove forward left door		49.4	−24.0		
Remove aft right door		75.4	23.0		
Remove aft left door		75.4	−23.0		
Remove cyclic		35.8	−8.0		
Remove collective		47.0	−21.0		
Remove pedals (both)		16.8	−9.5		
Pilot (forward right seat)	170	49.5	12.2	8415	2074
Left forward passenger	170	49.5	−10.4	8415	−1768
Aft right passenger	170	79.5	12.2	13,515	2074
Aft left passenger	170	79.5	−12.2	13,515	−2074
Baggage under forward right seat	10	44.0	11.5	440	115
Baggage under forward left seat	10	44.0	−11.5	440	−115
Baggage under aft right seat		79.5	12.2		
Baggage under aft left seat	10	79.5	−12.2	795	−122
Zero usable fuel weight and CG*	2212.5	93.1	0.1	205,979	306
Usable main fuel at 6 lb/gal.	177	106.0	−13.5	18,762	−2390
Usable aux fuel at 6 lb/gal.	102	102.0	13.0	10,404	1326
Takeoff Gross Weight and CG*	2491.5	94.4	−0.3	235,145	−758

* CG location (arm) for loaded helicopter is determined by dividing total moment by total weight.

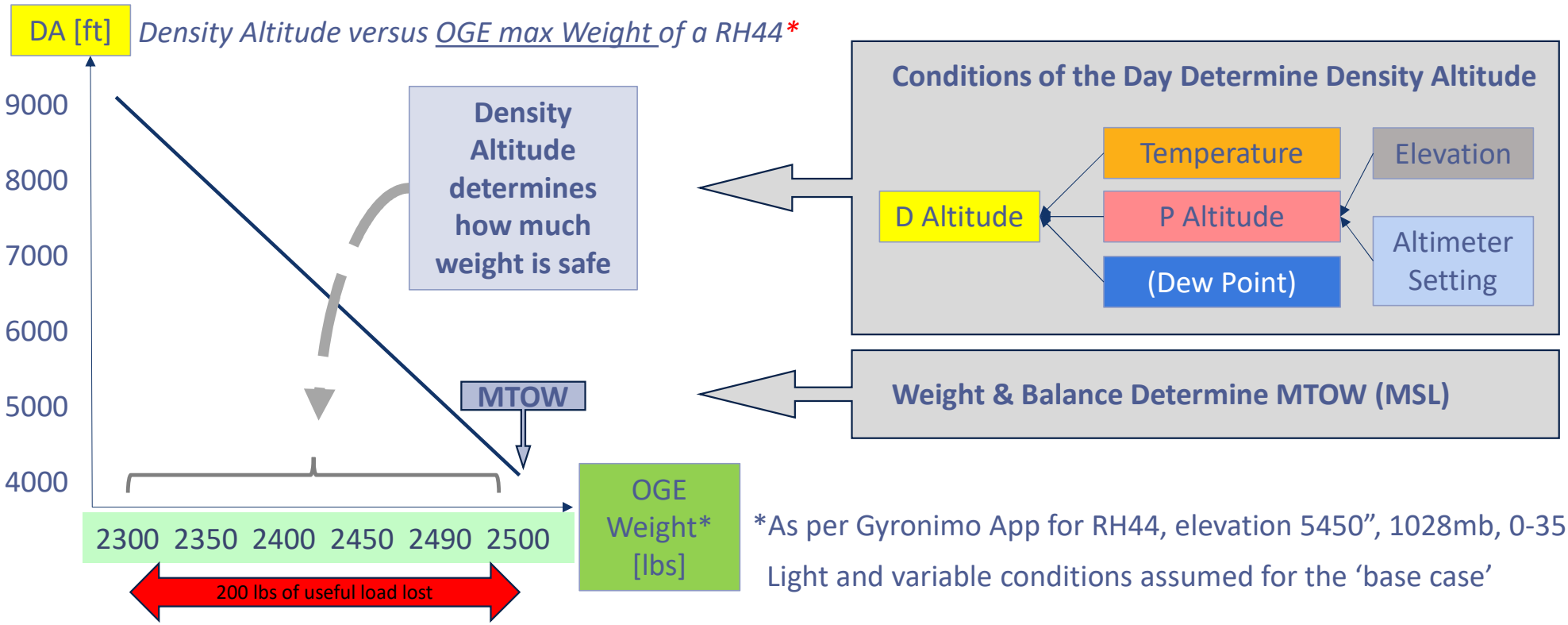
or



Complies with legal load manifest requirements (§ 135.63) but not necessarily conditions on the day

Why the Conditions of the Day?

Density Altitude determines how much you much Weight you can safely lift

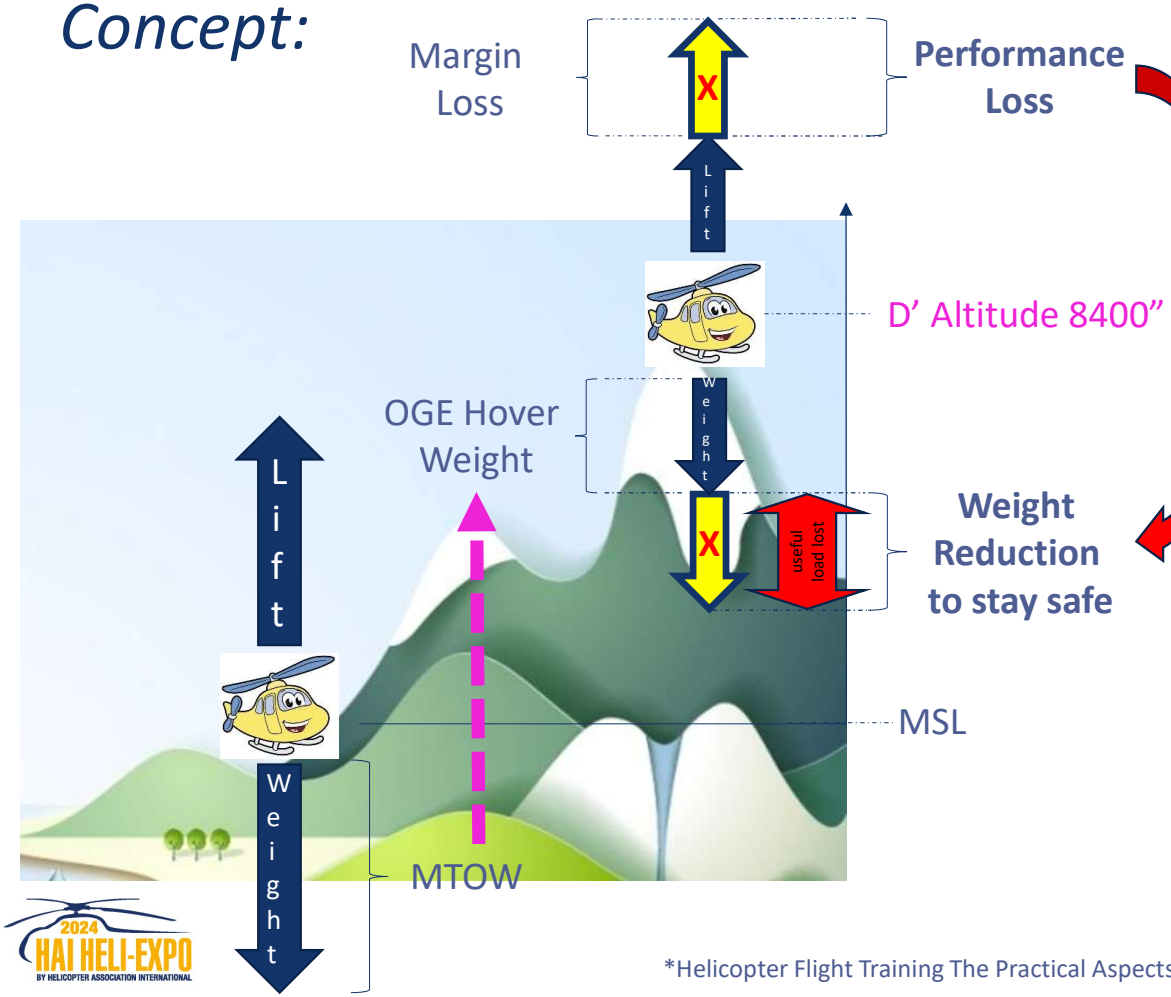


*As per Gyronimo App for RH44, elevation 5450", 1028mb, 0-35 C
Light and variable conditions assumed for the 'base case'

*Not for flight planning purposes – illustrative only – refer to POH

OGE Limits keep you Safe

Concept:



RH44 power/weight figures*:

- 1" MAP lost per 1000" climbed
- 1" MAP required per 35kg/ 77lbs lifted
- 3" MAP required per 100kg/ 220 lifted
- 3" MAP required for vertical take-off/landing margin (OGE ops)

- Weight is literally the only variable we/the operator/pilot fully control!
- Unfortunately weight/useful load is also one of the key profit drivers and pressure points in helicopter operations

Density Altitude limitations can not be overcome with superior motorical skills only

*Helicopter Flight Training The Practical Aspects – *K Carter-Watchurst & L Erasmus*

OGE Weight versus IGE Weight Limits (1)

OGE Weight is less about the Ground Effect or Hover but about the Power Reserve

IGE vs. OGE*

"You might be wondering why I used the OGE chart for a flight that didn't necessarily require hovering. After all, you reason, if you don't have to hover, you don't need a hover chart, right?"

Wrong!

Operating at speeds less than ETL — which is about 25-30 knots in an RH44 — requires about as much power as hovering!

* Helicopters 101: Hover Charts - by *Maria Langer, November 29, 2013*

OGE versus IGE (2)

Aircraft Performance changes drastically between IGE and OGE Weight

- @IGE ceiling and weight limit:
  - skids will barely leave the ground
  - Engine and powertrain will be at their transient limits for take-off
  - Helicopter needs to fly off using limited power technique (with wheels ideally)
  - Confined areas and steep departures/arrivals NOT an option
  - Maneuvering below ETL speed is becomes tricky/dangerously close to settling/vortex
- @OGE ceiling and weight limit:
  - operations have a higher (normal) power margin

Less induced flow, less drag hence less power required and operating ceiling and weight are higher

To overcome the higher induced flow, drag and larger tip vortices, more power is required and hence operating ceiling and weight are lowered to create that extra power margin

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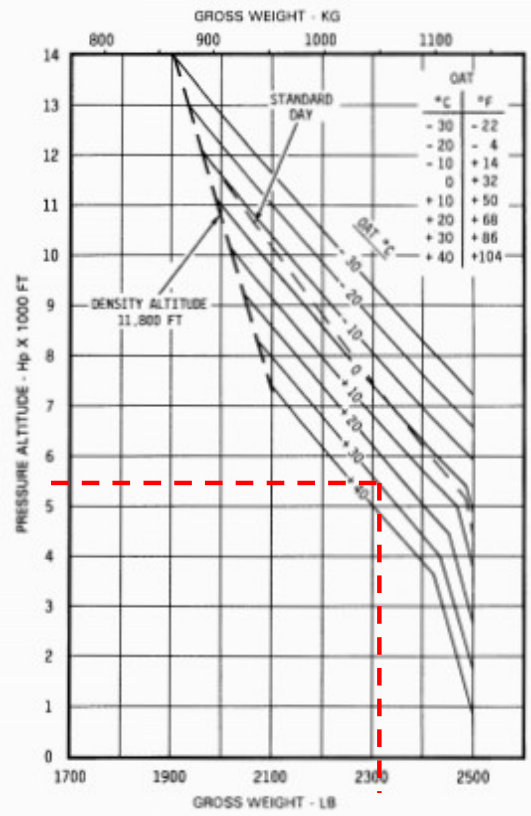
When Did you Last use Any of This?

*OGE and IGE **Weight** limits as a Function of P Altitude and Temperature*



or

Rarely done past PPL (sea) level training, and buried deep in POH

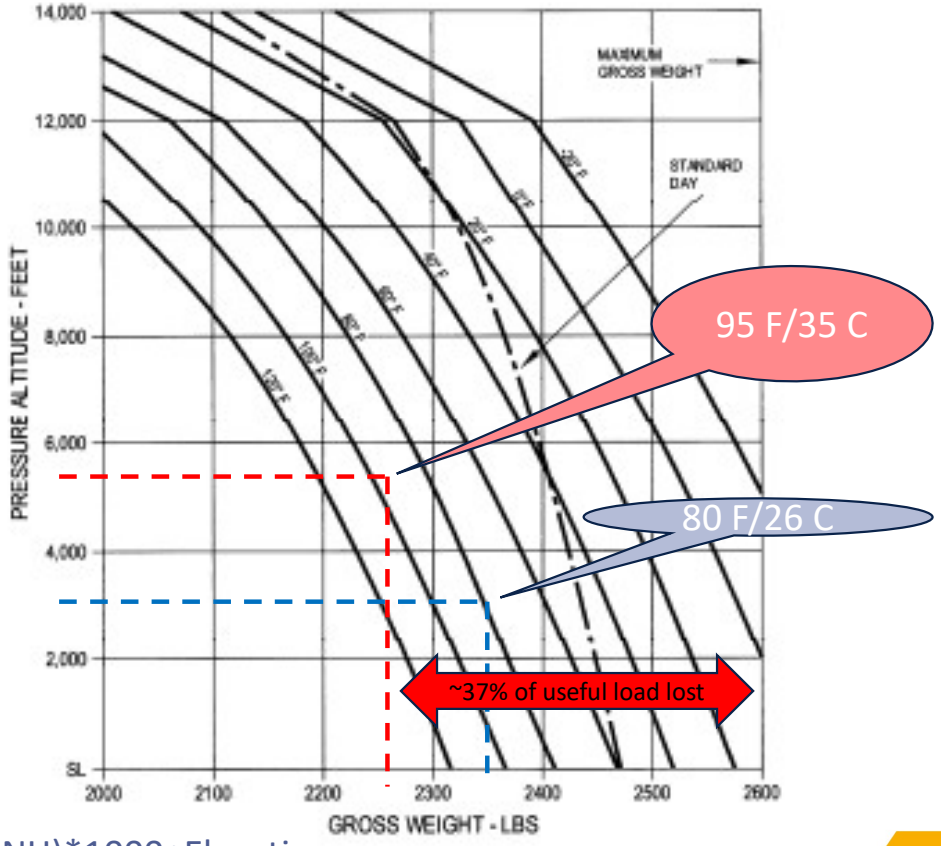
Calculating OGE/IGE (1)

Using POH Graphs – Simple Piston Light Helicopter Example

- Calculate Pressure Altitude*
- Enter graph at the Pressure Altitude
- Move right to Temperature curve
- Drop to the OGE (or IGE Gross Weight)

Or the other way around:

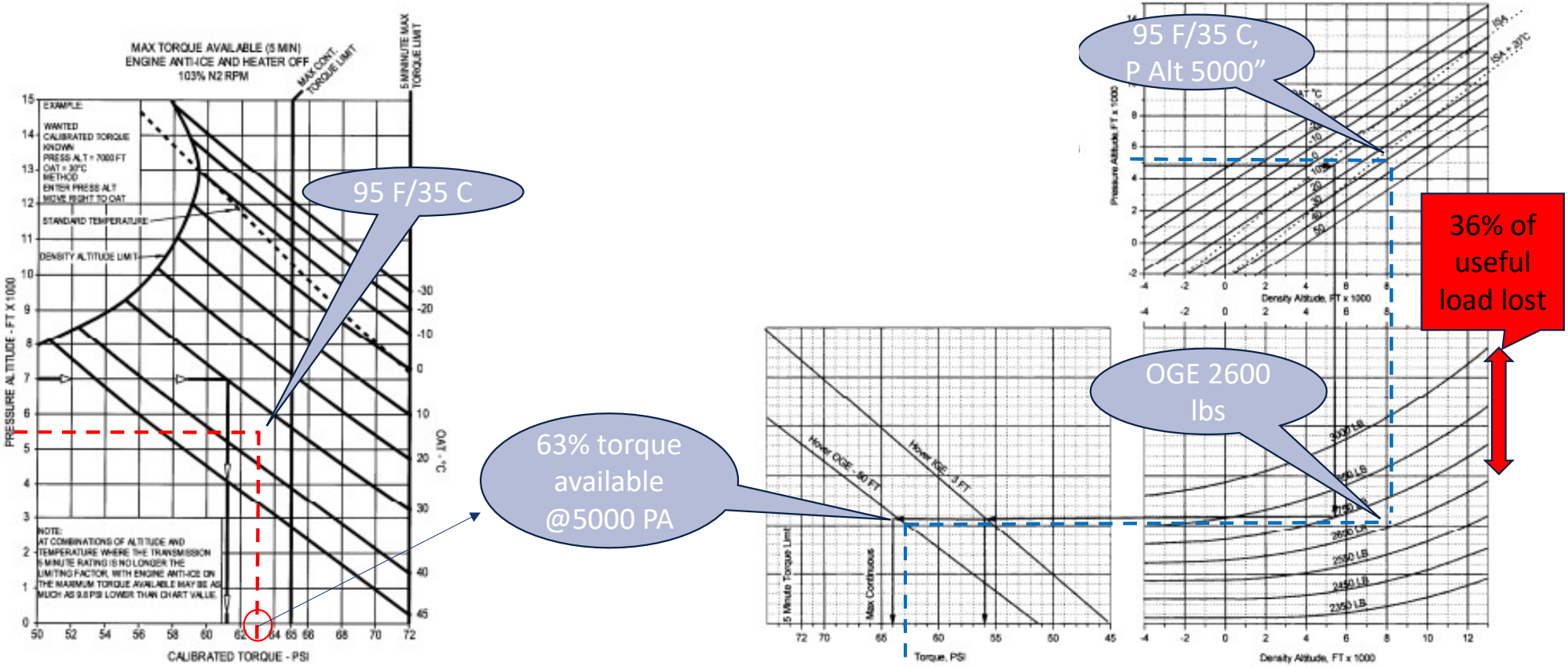
- Enter with your current Gross Weight
- Move up to Temperature
- Reach your OGE or IGE Ceiling (in Pressure Altitude)



* P Alt = (1013-QNH)*27+Elevation in Feet or (29.92-QNH)*1000+Elevation

Calculating OGE/IGE (2)

Using POH Graphs – Complex Light Turbine Helicopter Example



Calculating OGE/IGE (3)

Using Apps

- Start with completing Weight & Balance page
- Enter Elevation and local pressure (works out Pressure Altitude itself)
- Enter Temperature (works out Density Altitude)

Results:

- IGE and IGE ceilings AND weights for the conditions of the day
- Compare to Weight & Balance –> decide on desired margin

App allows to toggle back and forth between W&B and Performance till desired safety margin is achieved

Calculating OGE/IGE – Apps Versus POH (1)

Some Apps Generate Load Manifests that Track Conditions of the Day

<u>App Advantages:</u>

- App is quicker
- Does not require pressure altitude
- Does the piston or turbine performance calculations
- Leaves the pilot with a credibility tool to pushback
- Complies with document requirements (by email)

*Exceeds load manifest requirements 135.63, as it includes conditions of the day

Robinson R44 Raven II — **Load Manifest** *

Registration	Date of Flight	Departure Time
ZS-PTK	01 - 28 - 2024	19:44 Local / 17:44 UTC
Pilot's Name	**Co-Pilot's Name**	
CARLOS THE TERR...	HIS MATE	

	Weight lbs	Longitudinal Arm inches	Longitudinal Moment lbs.inches	Lateral Arm inches	Lateral Moment lbs.inches
BEW	1565.28	105.77	165559.7	-0.2	-313.1
		CG LONG		CG LAT	
Pilot Seat	165	49.5	8167.5	12.2	2013
Seat 2	185	49.5	9157.5	-10.4	-1924.0
Seat 3	115	79.5	9142.5	-12.2	-1403.0
Seat 4	170	79.5	13515.0	12.2	2074.0
Baggage Pilot Seat	4	44.0	176.0	11.5	46.0
Baggage Seat 2	2	44.0	88.0	-11.5	-23.0
Baggage Seat 3	0	79.5	0.0	-12.2	-0.0
Baggage Seat 4	0	79.5	0.0	12.2	0.0
My Item #1	0	0	0.0	0	0.0
My Item #2	0	0	0.0	0	0.0
Doors Front	0.0	49.4	0	0	0
Doors Aft	0.0	75.4	0	0	0
Controls	0.0	33.0	0.0	-13.3	-0.0
		CG LONG		CG LAT	
Zero Fuel Wgt.	2206	93.28	205806.2	0.21	469.9
Fuel Main	177.0	106.0	18762.0	-13.5	-2389.5
Fuel Aux	[illegible]	102.0	10404.0	13.0	1326.0
		CG LONG		CG LAT	
Takeoff Wgt.	2485.3	94.55	234972	0.24	-593.6
		CG LONG			
Landing Wgt.	2396.8	94.19	[illegible]		408.1

OGE Ceiling: 0 ft PA, IGE Ceiling: 6900 ft PA

Pilot's Signature

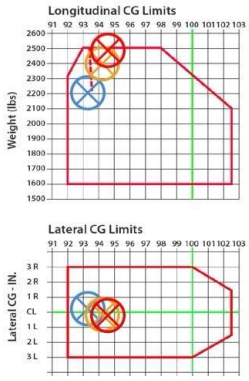
Flight

Departure	Destination
FAGC	FAHS

Routing: ALMOST DIRECT

Remarks:

CG Envelope



Performance Data

Pressure Alt	5010 ft
OAT	35 °C
OGE max Weight	2329 lbs
IGE max Weight	2500 lbs
V_{NE}	101 KIAS
5 min. Max TO Power (23.6 inHg FULL THROTTLE)	
Max. Cont. Power	22.0 inHg

Performance Pad™

Manifest does not flag 156 lbs "over OGE"

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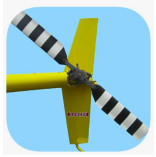
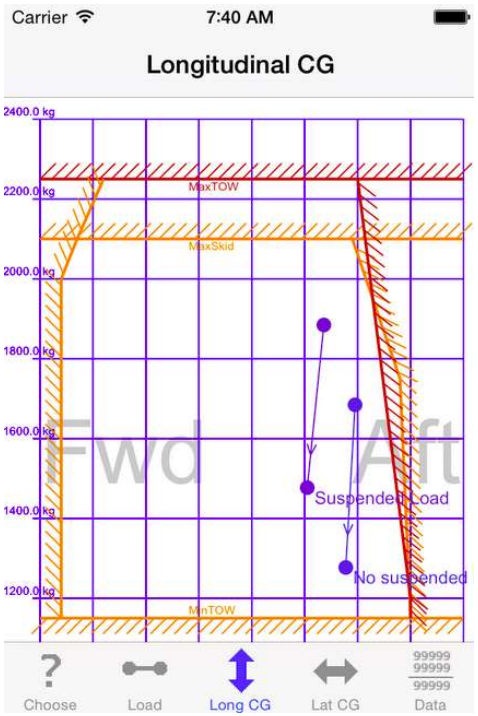
Calculating OGE/IGE – Apps Versus POH (2)

*Some Apps Generate ONLY Load Manifests – No Performance Data**



iBal Rotary



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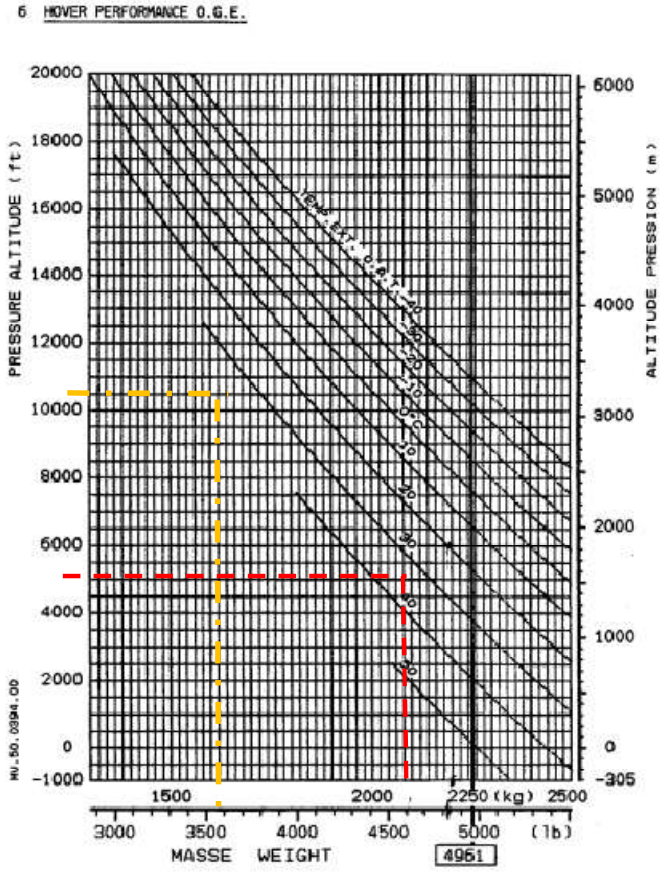

*Manual OGE/IGE computation using POH would be required

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Summary – Mitigating Hot and High Aspects

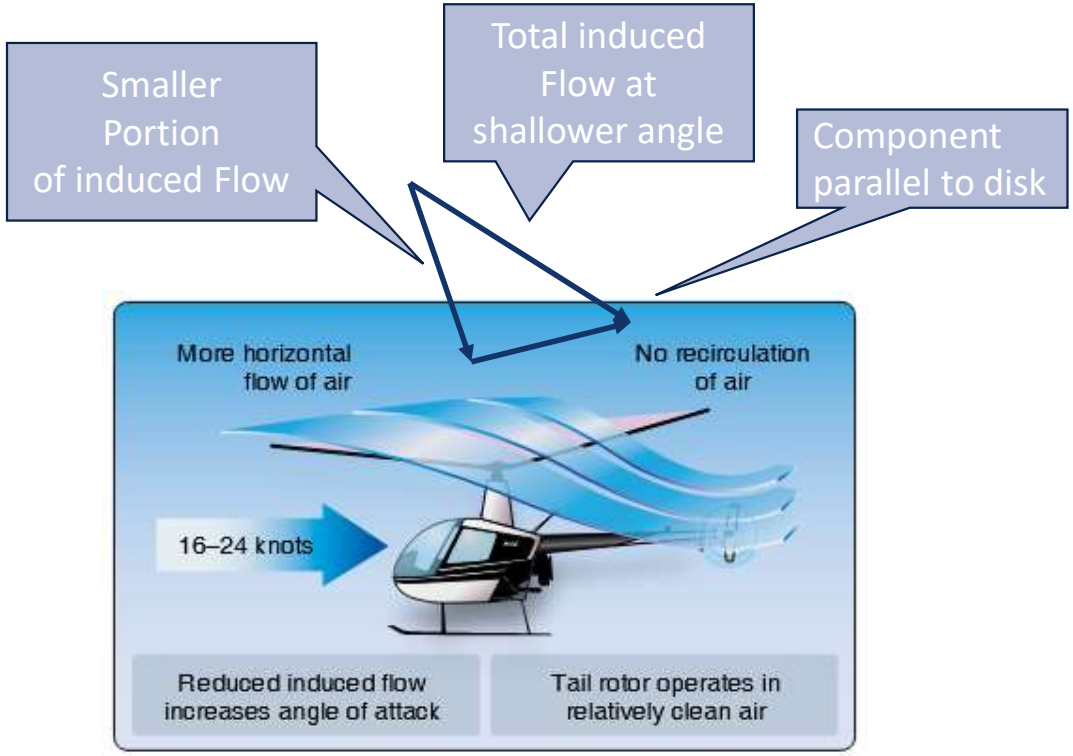
Managing Risks

Issue:	Proposal:
• Client/operator/employer pressures to carry extra loads	• Use Apps (iBal, Gyronimo) – push back on 'non-believers'!
• Time pressure, operational pressure, 'rushing the job'	• Calculate the OGE weight limit for commonly used aircraft/pax/cargo and temperature/ altitude combinations and print for reference ahead of time
• Systemic overloading / disregard (non-compliance) culture	• Force change in documentation requirements • Change operating procedures accordingly (i.e. Refuel Policy)
• Overpitching and transient limit occurrences • Settling/Vortex avoidance and LTE	• Stay within the OGE weight limit as much as possible (the further from IGE limit the better) • Keep ETL till touch down, no vertical ops unless within OGE weight limit • Keep into wind • Change take-off plan (for vertical ops)

The Role of ETL – Power that Comes and Goes

*Effective Translational Lift - Passing 12-24kn**

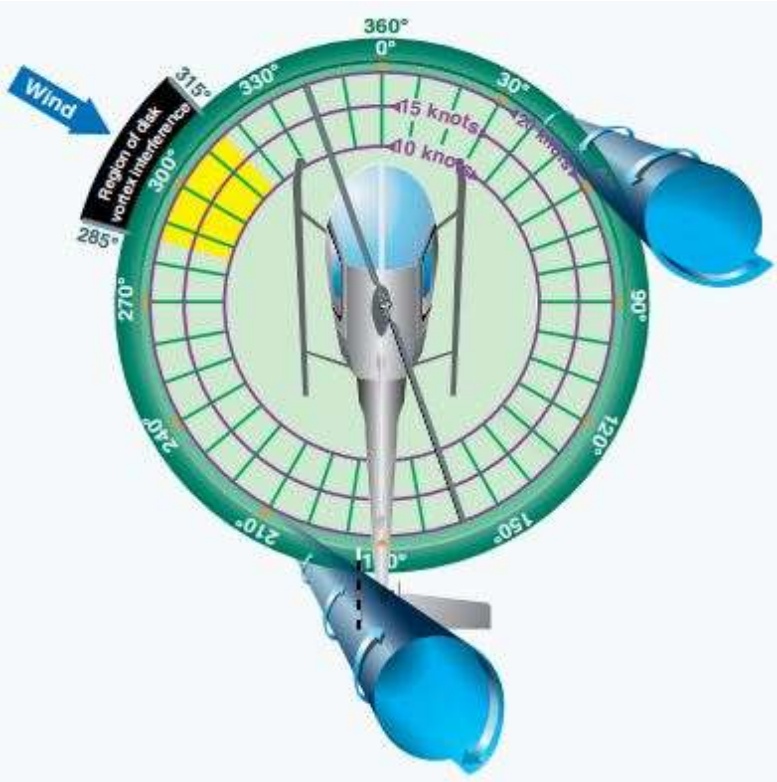
- Occurs passing 12-14kn, or with same amount of prevailing wind
- Rotor and Tail-rotor moves into less disturbed air
- Airflow is more horizontal
- Smaller inflow angles, less induced flow and less drag
- Increased angle of attack and increased lift (gain in height without adding power)
- **RH44 @DA ~8000" the ETL 'produces' about 1"-2" MAP or 70-150 lbs more lift**
- Helps to maximize take-off performance
- Allows for limited power take-offs when combined with hovering in ground effect and using ground cushion
- Caution: same effect is lost decelerating back into the hover from forward flight (note the vibration)



* Depends on helicopter / different ranges cited in different sources. Graphic: FAA Helicopter Flying Handbook

LTE Awareness

As the Helicopter Approaches Maximum Power, the Tail-rotor has to work harder



Loss of Tail Rotor Effectiveness

- Un-anticipated yaw, or un-commanded rapid yaw that does not subside of its own accord, triggered by:
- varying airflow from the main rotor blades (left door wind) - particularly at high power settings (big tip vortices)
- High altitudes and high gross weights
- operating at airspeeds below ETL (effective translational lift)
- Turbulence, mountain waves

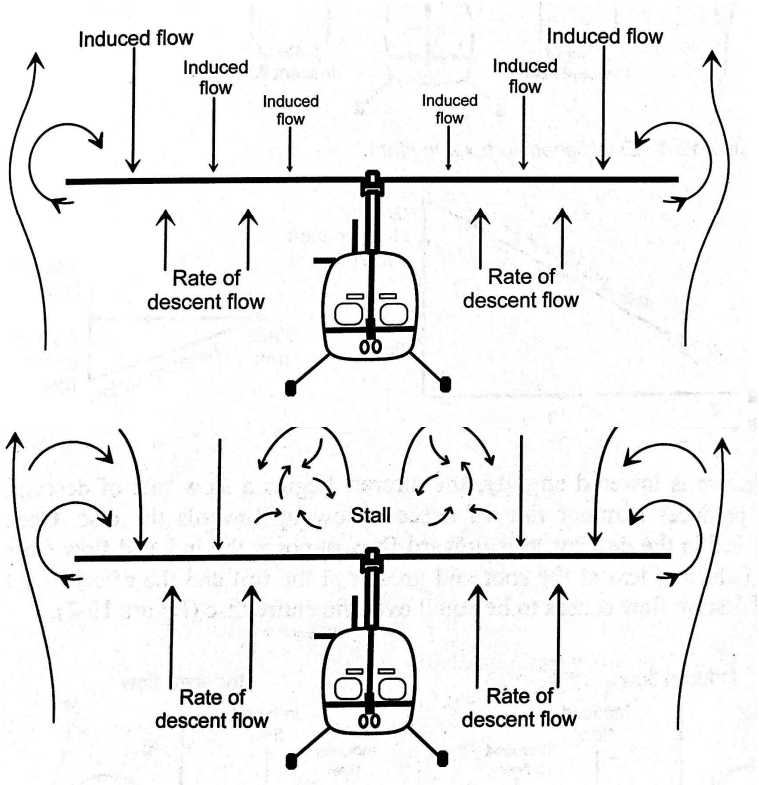
FAA Helicopter Flying Handbook – when BELOW 30 knots:

- Avoid OGE operations and high-power-demand situations!
- Avoid tailwinds or crosswinds!

Italian Airforce Alps LTE: https://www.youtube.com/watch?v=EUDu_oTuoP0

Vortex Awareness (VRS)

In a normal out-of-ground-effect (OGE) hover, the helicopter is able to hold altitude*



Settling with Power

- no adequate performance to maintain height, aircraft descends despite max power
- aircraft will start to settle into the rotor downwash
- When downward settling reaches >300 ft/m descent, induced flow is cancelled out by the upward airflow, angle of attack is exceeded
- The controls shake uncontrollable, helicopter shudders while falling rapidly

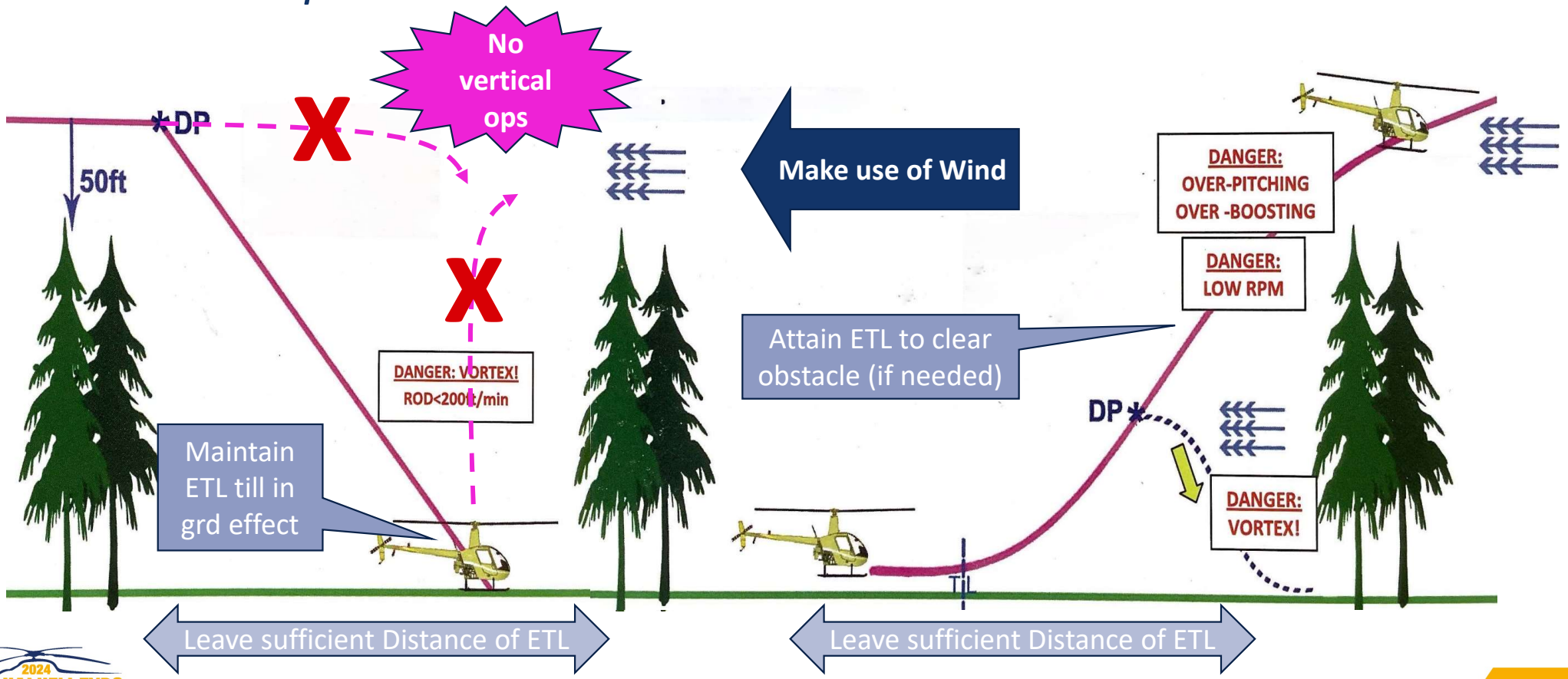
Vortex Ring State (VRS)

- Not when in IGE and not when in ETL
- Always a risk in OGE stationary hover, steep/vertical approaches:
  - 1) Low speed (below ETL),
  - 2) high decent rate,
  - 3) high power
- Recovery by reversing at least one of the 3 conditions

*Operated within OGE Limits

Adopt Profiles Maximizing Margin by using ETL

No vertical Ops unless within OGE limits



Adapted from: Helicopter Flight Training The Practical Aspects – K *Carter-Watchurst & L Erasmus*

Shortcut to Safety Margin – Helicopter Choice

*Sample OGE Performance Calculations by Type**

You can only change the takeoff weight … OR the helicopter

	RH44 II	EN28		RH66	B206	M500E	EN48		H125B2	B407GX
BEW [lbs]	1550	1693		1340	1950	1735	1890		2780	2824
MTOW [lbs]	2500	2600		2700	3200	3000	3000		4960	5000
Useful load Sealevel	950	907		1360	1250	1265	1110		2180	2176
Useful load / BEW ratio	61%	54%		101%	64%	73%	59%		78%	77%
Useful load / MTOW ratio	38%	35%		50%	39%	42%	37%		44%	44%
Max T/O Hot&High (OGE) [lbs]	2329	2260		2650	2910	2681	2600		4565	4653
OGE Height [ft PA]	4900	5040		6000	5000	5000	5050		5000	5000
Useful load Hot&High	779	567		1310	960	946	710		1785	1829
[lbs] loss	-171	-340		-50	-290	-319	-400		-395	-347
"Standard pax" (170lbs) weight loss	-1.0	-2.0		-0.3	-1.7	-1.9	-2.4		-2.3	-2.0
%tage loss of useful load	-18%	-37%		-4%	-23%	-25%	-36%		-18%	-16%

* For Illustration only – Refer to POH, W&B and BEW for the specific helicopter to be flown

* Hot and high defined as: 95 F/ 35 C, P Alt ~5000", D Alt ~8400"

Thank you

Keep the shiny side up!

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