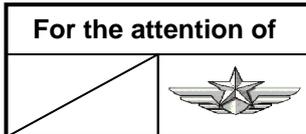


SAFETY INFORMATION NOTICE

SUBJECT: GENERAL

Useful information about the Vortex Ring State (VRS) phenomenon



AIRCRAFT CONCERNED	Version(s)	
	Civil	Military
EC120	B	
AS350	B, BA, BB, B1, B2, B3, D	L1
AS550		A2, C2, C3, U2
AS355	E, F, F1, F2, N, NP	
AS555		AF, AN, SN, UF, UN, AP
EC130	B4, T2	
SA365 / AS365	C1, C2, C3, N, N1, N2, N3	F, Fs, Fi, K, K2
AS565		MA, MB, SA, SB, UB, MBe
SA366		GA
EC155	B, B1	
SA330	J	Ba, L, Jm, S1, Sm
SA341	G	B, C, D, E, F, H
SA342	J	L, L1, M, M1, Ma
ALOUETTE II	313B, 3130, 318B, 318C, 3180	
ALOUETTE III	316B, 316C, 3160, 319B	
LAMA	315B	
EC225	LP	
EC725		AP
AS332	C, C1, L, L1, L2	B, B1, F1, M, M1
AS532		A2, U2, AC, AL, SC, UE, UL
EC175	B	
H160	B	
EC339		KUH/Surion
BO105	C (C23, CB, CB-4, CB-5), D (DB, DBS, DB-4, DBS-4, DBS-5), S (CS, CBS, CBS-4, CBS-5), LS A-3	CBS-5 KLH, E-4
MBB-BK117	A-1, A-3, A-4, B-1, B-2, C-1, C-2, C-2e, D-2, D-2m, D-3, D-3m	D-2m, D-3m
EC135	T1, T2, T2+, T3, P1, P2, P2+, P3, EC635 T1, EC635 T2+, EC635 T3, EC635 P2+, EC635 P3, T3H, P3H, EC635 T3H, EC635 P3H	

No. 3123-S-00

ABSTRACT

- ⇒ The Vortex Ring State is a very dangerous phenomenon that occurs at low airspeeds. It can lead to loss of lift and control of the aircraft with potentially serious consequences when close to the ground.
- ⇒ When in final approach with airspeed below 30 kts, DO NOT ALLOW RATE OF DESCENT GREATER THAN 500 fpm.
- ⇒ When in a degraded visual environment or at night, DO NOT FORGET TO SCAN YOUR INSTRUMENTS (especially airspeed, RoD, power and pitch attitude).
- ⇒ Avoid rapid decelerations below 30 kts, especially while in descent.

INTRODUCTION

The Vortex Ring State (VRS) is a complex aerodynamic phenomenon on the main rotor, which occurs at low airspeeds, usually during the critical segments of final approach and landing. The VRS involves rapid and substantial loss of rotor lift and control power¹. When VRS is not prevented (flight trajectory & power), nor detected (early signs), and in proximity to the ground it can have serious consequences.

The purpose of this document is to inform pilots and operators about means to prevent and avoid VRS, by providing simple explanations about its nature and factors that can bring the helicopter closer to this dangerous condition. If the aircraft does potentially enter into a VRS, some instructions are given in order to detect it quickly and how to attempt to successfully exit it.

SCOPE OF APPLICATION

VRS is independent of the helicopter architecture (tandem rotors, contra-rotating rotors, etc.). In our opinion, OEI descent and landing are particular flight cases, and some of the instructions included here may not apply. Nevertheless, preventing and avoiding entry into VRS should not be neglected during these flight cases either.

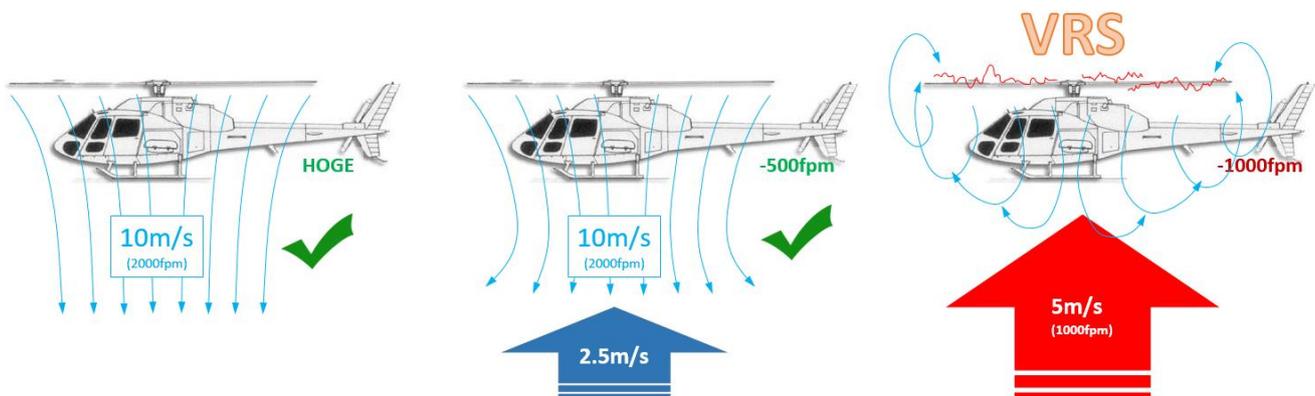
The information provided in this document applies to all Airbus Helicopters models.

¹ Tilting the rotor to the desired direction

SIMPLE EXPLANATION OF THE VORTEX RING STATE

What is the VRS?

The main rotor in hover (HOGE²) produces a strong downward airstream (downwash) as if it was a giant fan. On a standard day (ISA conditions³) the average velocity of this airstream depends on the rotor lift - roughly equal to the helicopter (H/C) weight - and the rotor diameter. For example, a fully loaded H/C at 2250 kg (=5000 lb), with a rotor diameter of 10.7 m (=35 ft), will produce an average downwash of 10 m/s (=2000 fpm). This means that the mass of air displaced by the rotor travels downwards, or effectively descends, at a rate of 2000 fpm. Larger helicopters usually produce a stronger downwash, but its average velocity is not proportional to the H/C weight, as is sometimes perceived. A heavy 11-ton offshore H/C will not produce a downwash that is approximately 5 times (11000÷2250) faster, but roughly one of 15 m/s (=3000 fpm), thus only a 50% faster airflow.



When the H/C is still in the air (HOGE) nothing opposes this airstream from moving continuously away from the rotor disc plane. However, when the H/C descends vertically with a RoD of (say) 500 fpm (=2.5 m/sec), the opposing mass of still air does not allow the downwash to move downwards freely. When the RoD increases to a value of about half the H/C downwash velocity in hover, i.e. 1000 fpm, then the opposing mass of still air will effectively block the rotor downwash. Without any 'escape route' the downwash will 'bend', 'brake', and unavoidably return back to the rotor disc plane, creating a giant violent recirculation. Contrary to normal operation (HOGE or low RoD) this recirculated air is highly turbulent and heavily degrades the lift generated by the blades. Under these conditions, the blades will have difficulty following the inputs (collective/cyclic) from the pilot, and the rotor will become sluggish. Moreover, the giant recirculation of turbulent air will engulf most parts of the H/C fuselage and tail, pushing and pulling it in every direction chaotically. **This causes the overall symptoms of the Vortex Ring State** (not all symptoms may appear simultaneously):

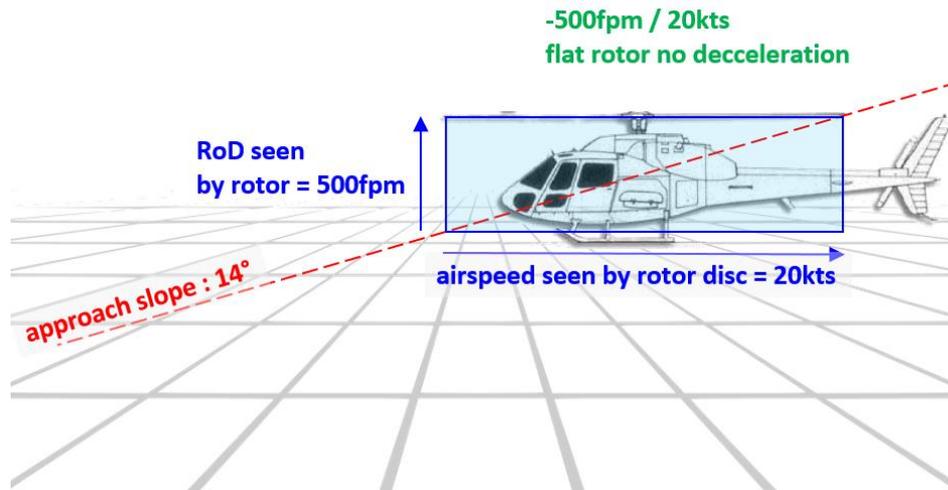
- **Loss of average lift and severe lift fluctuations (similar to flying in heavy turbulence). This is recognised as sudden lightness in the seat (low g sensation)**
- **Reduction of control power (commanding the rotor tilt) and/or sluggish rotor response, wobbly rotor**
- **Erratic fuselage movements**
- **Change in rotor vibrations**

² Hover out of ground effect

³ International Standard Atmosphere (1013 mbar and 15°C (59°F) at sea level)

Vertical VRS versus Low-speed VRS

The Vortex Ring State does not only occur in vertical descent. It can also happen at low speeds, roughly up to 20-25 kts. While in low-speed descending flight (final seconds before landing) the horizontal component of the airspeed (say, 20 kts = 10 m/s) will be combined with the vertical rate of descent. The angle formed by the two speeds (forward and vertical) is the flight path angle, also called the approach slope in the final approach. For example, 20 kts combined with a 500 fpm RoD gives a flight path angle of 14°. Contrary to the 3° approach slope of big airliners, it is not unusual for a H/C to conduct approaches at much steeper angles of 10°, even 15°.



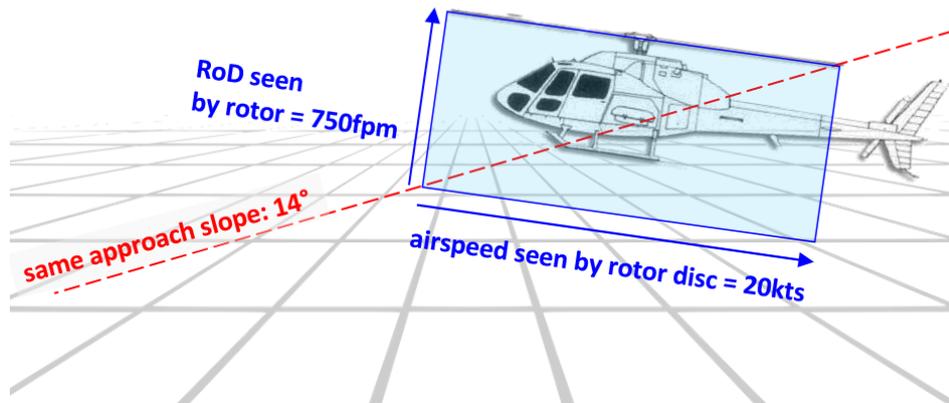
As we have seen with the hover example previously at -1000 fpm we are approaching or entering VRS. The onset of VRS (i.e. -1000 fpm) does not significantly change at low speeds, up to 20 kts. Above 25-30 kts there is almost no chance of VRS. **If we combine a RoD of 1000 fpm with 20 kts we obtain a 26° approach slope**, which is much higher than the usual 5°-10° slope of everyday H/C operations. However, two basic elements that separate low speeds from hover should be taken into account, with regards to VRS:

1. **In final approach, low speed is only a transient phase of a decelerating flight**, from 60-80 kts of steady descent towards the near zero of landing. The deceleration rate is not perfectly monitored by the pilot, and the wind direction and strength are not always known. Therefore flying at 30-40 kts (outside VRS) can be quickly transformed into flying at 10-20 kts in a matter of seconds in terms of airspeed seen by the rotor.
2. **When decelerating the H/C, the rotor maintains a positive tilt angle⁴ of 5°, possibly 10°**. The rotor tilt angle is not to be confused with the H/C pitch attitude. Sometimes, inadvertently, the rotor tilt angle can raise above 15°. A reasonable approximation regarding deceleration is that the rotor must tilt upwards (pitch-up) by 3° for every knot-per-sec of deceleration. For instance, if we decelerate smoothly from 40 to 20 kts in 10 sec, then the deceleration rate is 2 kts/sec, and the rotor tilt is +6°. Now, in the previous example of 20 kts and 500 fpm (=approach slope of 14°), **if we add the 6° of rotor tilt coming from deceleration, we obtain a total angle between rotor disc and approach slope of 20°**. It is as if the rotor was effectively seeing a RoD of 750 fpm, which is much closer to the 1000 fpm VRS threshold in our example. (See graph below)

⁴ The tilt angle is the angle between the rotor disc plane and the horizon. The rotor tilt angle and the H/C pitch attitude can be different by a few degrees due to mast inclination and blade flapping.

No. 3123-S-00

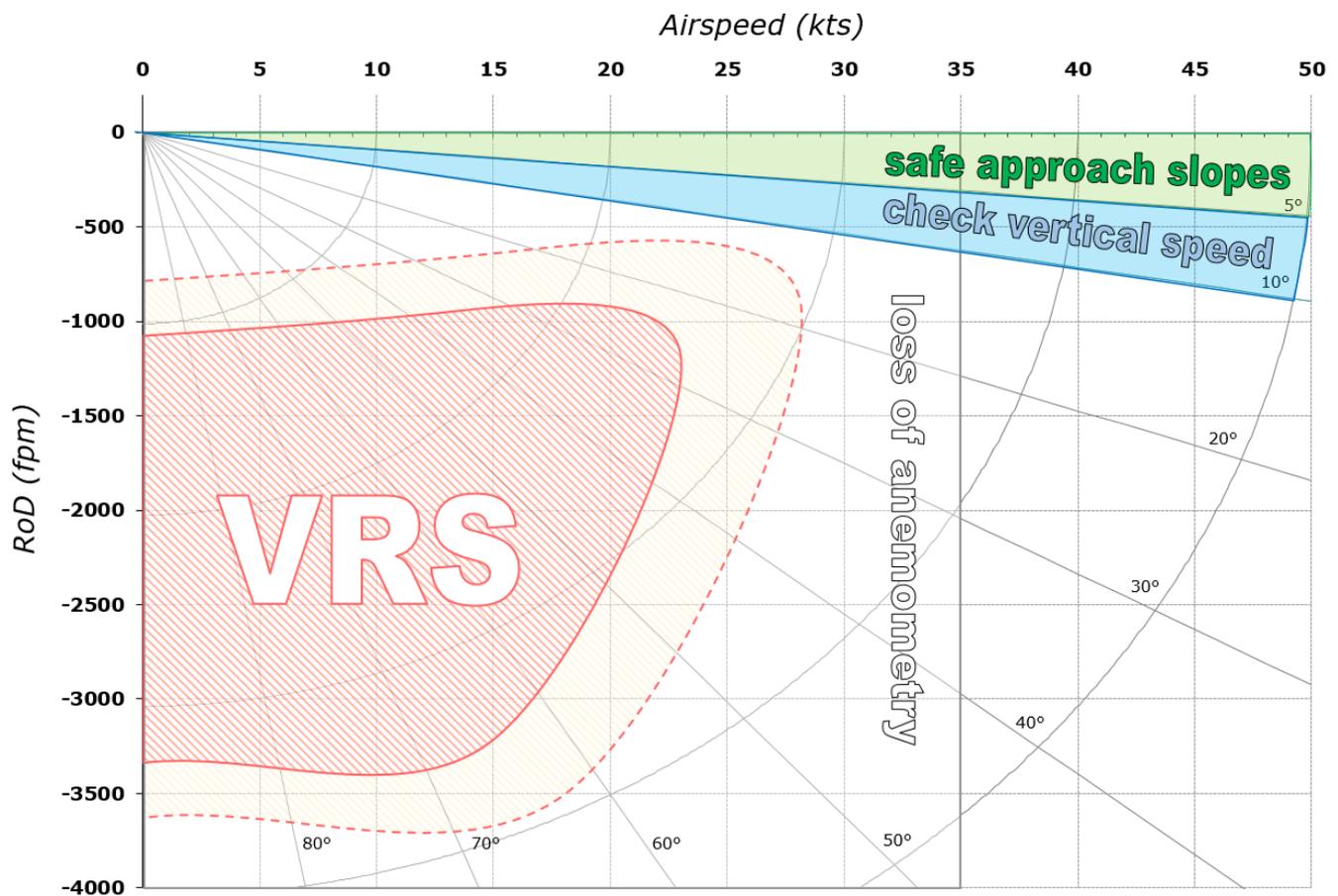
-500fpm / 20kts AND 2kts/sec deceleration



Example of VRS mapping

Many studies have been carried out in the past in order to determine the boundaries of the VRS domain, using both experimental (flight, wind tunnel) and numerical means (simulations). The VRS mappings that can be found in the literature are numerous and differing. **Nevertheless, they all give a very similar message when it comes to the RoD where the H/C can meet VRS conditions at very low speeds (<25-30 kts): the RoD of VRS is about half of the downwash velocity the H/C would have in HOGE.** As a reminder, in our example, the 2250 kg light H/C with 10 m/sec of average downwash velocity in hover (10 m/sec = 2000 fpm) will meet VRS conditions at about 1000 fpm. This should not mean that one can descend safely at (say) 900 fpm just because the limit is 1000 fpm. For various reasons (see next section about aggravating factors) and most importantly **in order to conserve safety margins as a general rule, one should never conduct a final approach below 25-30 kts with a RoD greater than 500 fpm.**

In the VRS mapping graph below, an example (typical of a light helicopter) of the VRS range (red) with associated margins (amber) is plotted as a function of airspeed and rate of descent (RoD). An indicative threshold of the loss of reliable anemometry (IAS) is also given. Based on airspeed and RoD we can also add several approach slopes in order to compare with VRS boundaries. It is observed that for a 5°-10° approach slope the H/C stays away from the VRS range. However (see example in the previous section) the pitch-attitude due to deceleration must be monitored.



NOTE: A steep approach at low airspeed is possible but requires a very specific attention to vertical speed.

AGGRAVATING FACTORS

In this section, we present some conditions or situations where the H/C and the crew can be found even closer to the VRS boundaries, whether intentionally or unintentionally. Thus, besides the general knowledge of VRS provided previously, special attention must be also given to the following information.

1. Flying light

When a H/C flies relatively light the average speed of the downwash is reduced by up to 20%. This means that in our example (2250 kg H/C with 10 m/sec downwash in HOGE) the downwash will be about 8 m/sec or 1600 fpm. As the VRS range is roughly determined as one-half of this downwash speed, **the VRS boundary in this case is not 1000 fpm of the RoD but 800 fpm**. Of course, the required margins must be adjusted accordingly. On the other hand, flying light generally means a greater power margin available to cancel out an excessive RoD.

2. Flying with a tail wind close to the ground

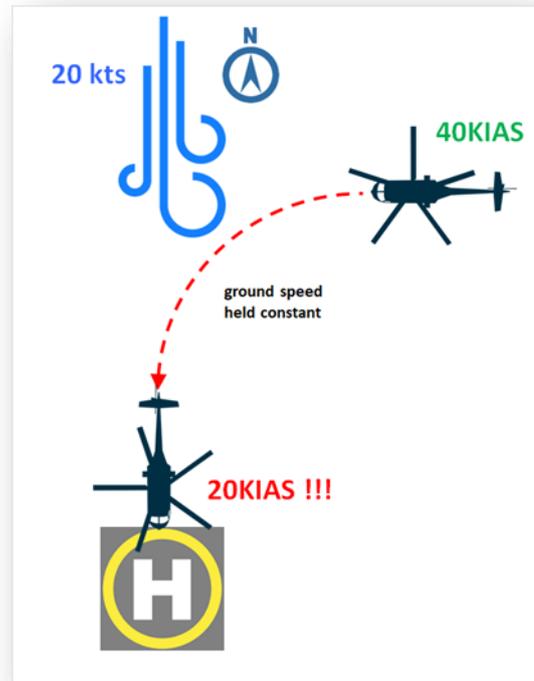
This paragraph is applicable to all evolutions close to the ground, including landing when no head wind option is possible (tail wind landing not recommended).

When flying close to the ground the pilot uses the ground speed to pilot the trajectory (instead of airspeed when higher). In doing so, when turning tail wind, the pilot reduces the airspeed to maintain (or even decrease) ground speed. As a consequence the necessary power for level flight is increased. If the pilot is surprised, a significant RoD appears. This RoD is even more important in the event of a tail wind approach due to the necessity to maintain the approach slope.

When the H/C descends at 40 kts (ground speed) with a tail wind of (say) 20 kts at that moment, then the airspeed becomes 20 kts and we are approaching the VRS danger zone, depending of course on the RoD. In mountainous terrain especially, where the speed direction and strength may vary significantly, additional attention has to be given to the final approach.

No. 3123-S-00

Another not-uncommon case is approaching to land after a turn. Let us suppose a 20 kts wind coming from the north with a H/C approaching at a 270° heading (westbound), again with 40 kts of airspeed. Then, just before landing the H/C performs a 90° left turn (new heading is now 180°). On exiting the turn the H/C will find itself again with a tail wind of 20 kts, and thus its airspeed drops suddenly to 20 kts. In that case the H/C is approaching the VRS danger zone and if power is not adjusted this will result in increased RoD, with the aforementioned consequences.



3. Small power margins

Although small power margins are not directly linked with the VRS range (airspeed, RoD, deceleration) they can become a strong contributing factor when combined with poor management of the sink rate (RoD). When a H/C is heavy and/or in high-density altitude (i.e. hot & high), and reduces its speed in the final approach, then the power required to sustain flight increases rapidly. The pilot has to pay special attention to his/her power management through the collective, because an intended RoD of 300-400 fpm can easily take on higher values in these conditions (above 500 fpm, thus approaching the VRS boundaries).

4. Flying in a degraded visual environment and at night

When visual cues are absent (fog, clouds, dark night) and the crew is in its final approach (descending flight, low speed, deceleration) there are no means to determine the altitude, airspeed, RoD, and pitch attitude, **except by continuously scanning the instruments**. Even the deceleration rate (roughly proportional to the pitch attitude increase) cannot be felt as a longitudinal force (similar to braking inside a car) because of the H/C's specific mechanics. Moreover, under these conditions but with some minimal visual cues (i.e. helipad lights only) sensory illusions (spatial disorientation) can lead to a false understanding of the position and speeds of the aircraft. To make matters worse, **there have been numerous incident & accident reports, where both pilots during final approach, in their intense search for visual references, neglected instrument scanning for a short period of time, only to find themselves with unacceptable RoD and/or pitch attitudes close to or within the VRS boundaries.**

5. Rapid deceleration

As mentioned previously, the deceleration rate during final approach, roughly proportional to the increase of pitch attitude (3° more for every 1 kt/sec), changes the *effective* RoD of the rotor disc. As the rotor tilts backwards (along with the fuselage) more of the horizontal speed of the H/C goes *through* the rotor, similar to the RoD. This is why the *effective* RoD (=not the RoD of the H/C, but the RoD *seen* by the rotor disc) is higher. Sometimes pilots, from fear of overshooting the platform or helipad, decelerate hard in the last seconds before landing, combined with an already established RoD. In this case, the H/C comes closer to the VRS boundaries. Thus, hard decelerations are to be avoided, especially during descent. It should be noted that rapid decelerations (quick stops) might be inadvertently combined with other aggravating factors, such as tail wind (see §2). The combination of two aggravating factors can lead the H/C closer to VRS conditions.

6. Confined environment

Small H/C often operate and land inside city blocks and other confined environments. In this case, pilots usually choose steep approach slopes, which can bring them close to the VRS boundaries. Moreover, wind through big city buildings, and recirculation of the downwash of the H/C itself can make the conditions even more complicated. The RoD must then be carefully monitored and held at less than 500 fpm.

7. Incorrect or insufficient use of AFCS

The knowledge and the correct use of AFCS, when the aircraft is equipped with one, can assist the crew in maintaining the aircraft in the nominal flight envelope, and thus reduce the probabilities of approaching the VRS boundaries.

Particular attention should be given to 3-axis AFCS management that implies a manual management of the vertical axis.

Refer to: **SIN 3558-S-22** about the use of 4-axis digital AFCS

8. Collapsing updrafts at low speed or hovering out of ground effect

Updrafts can either have thermal or dynamic origins. Thermal winds are usually less constant than dynamic ones. Consequently, thermal winds have a stronger tendency to collapse suddenly, which can have a major negative effect on the helicopter in certain operations.

Typical situations where this phenomenon arises are, for example: approaches in the mountains, or near a cliff, or an elevated heliport on buildings or on ships. This phenomenon is generally less present on elevated helidecks where the wind can flow under the platform due to the construction.

The updraft will reduce the power required at low speed or in hover. If this updraft suddenly collapses, the helicopter will fall into a descent due to the missing power. The conditions for developing VRS might therefore be encountered.

Collapsing updrafts may also occur in deserts (particular atmospheric conditions due to excessive heat and winds).

No. 3123-S-00

PILOT INSTRUCTIONS REGARDING VRS

Refer also to: **SIN 3463-S-00**

Vortex Ring State / Airbus Helicopters training recommendations and considerations about the “Vuichard recovery technique”

SITUATION	DESCRIPTION	ACTION
APPROACH - LANDING	When gradually reducing airspeed below 50-60 kts be aware of your RoD. Use collective pitch (power) to control vertical speed. Especially in degraded visual environments, <u>scan your instruments</u> . NEVER ALLOW MORE THAN 500 fpm RoD BELOW 30 kts. AVOID HARD DECELERATIONS WHILE IN DESCENT.	PREVENT/AVOID VRS
APPROACHING VRS	If the airspeed is low (<25-30 kts) and the RoD starts to drop below 500 fpm, you can detect the early signs of VRS: <ul style="list-style-type: none"> ▪ Change in rotor vibrations ▪ Lift fluctuations (similar to flying in turbulence). This is recognised as sudden lightness in the seat (low g sensation) ▪ Sluggish rotor response, wobbly rotor 	DETECT EARLY SIGNS OF VRS AND REACT: <ul style="list-style-type: none"> - Check power and increase collective pitch as required - Apply forward cyclic input in order to accelerate - Monitor vertical speed
INSIDE VRS	If you have entered VRS first accept that you will lose height. Around 100-200 feet are the bare minimum height loss in a recovery maneuver. Additional signs of VRS are: <ul style="list-style-type: none"> ▪ Sudden and strong increase of RoD ▪ Loss of lift and severe lift fluctuations ▪ Significant reduction of control power (tilting the rotor) ▪ Erratic fuselage movements <p>Keep in mind that depending on the available height, this procedure may not be sufficient to prevent a crash landing, but it will be effective enough to significantly reduce the sink rate.</p>	EXIT & RECOVERY: <ul style="list-style-type: none"> - Check power and increase collective pitch as required - Simultaneously, apply decisively forward cyclic input in order to gain airspeed (1-2 sec) - Once sufficient airspeed is achieved (20-30 kts) adjust the pitch attitude to level the H/C