The Myth of Losing Tail Rotor Effectiveness

EASA Rotorcraft & VTOL Symposium 2019

HELICOPTERS

A.M Dequin

10-11 December 2019

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A Typical Unanticipated Yaw Accident

- A single rotor helicopter apparently yaws by its own accord, against the will of the pilot
- The pilot suspects that pedal is ineffective and does not succeed to stop the helicopter spinning
- The helicopter is landed with significant yaw rate, usually inducing significant damage
- Investigations show that the helicopter was fully operative
- Unanticipated Yaw is often designated as “Loss of Tail rotor Effectiveness” (LTE)

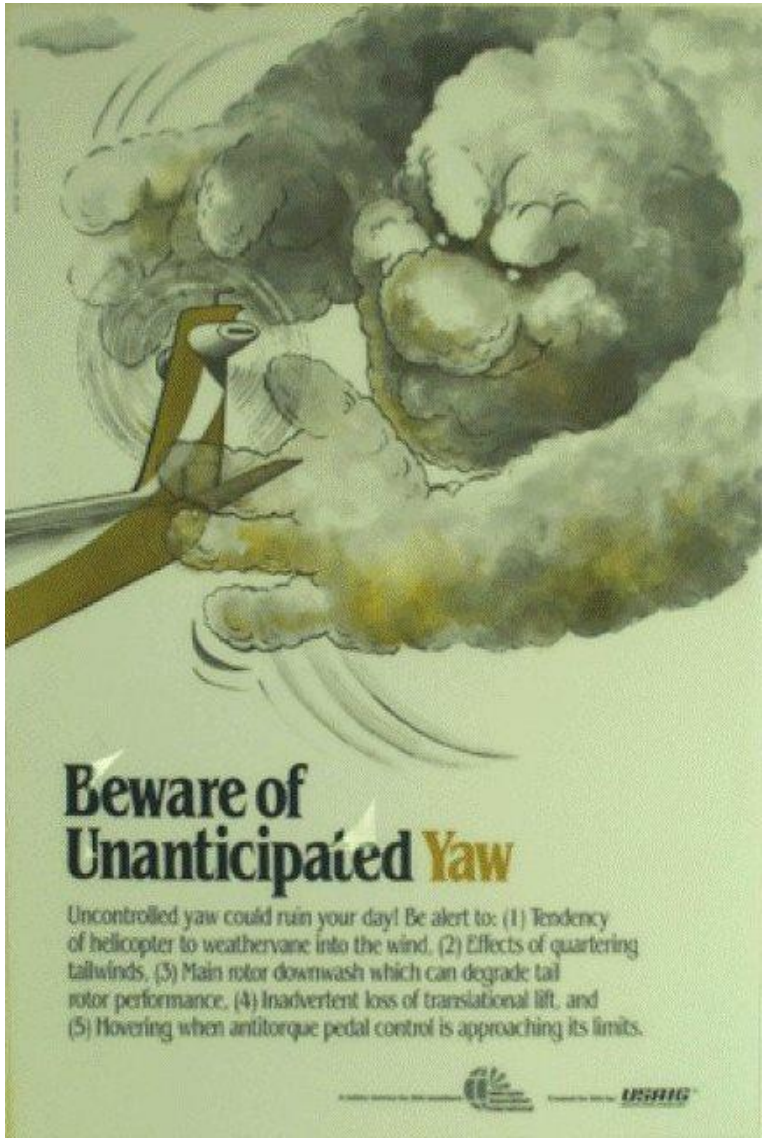
Presentation Outlines

A very short historical view

An analysis of accident investigations reports

An explanation of the phenomenon thanks to the pedal curve

A call to update information given to pilots



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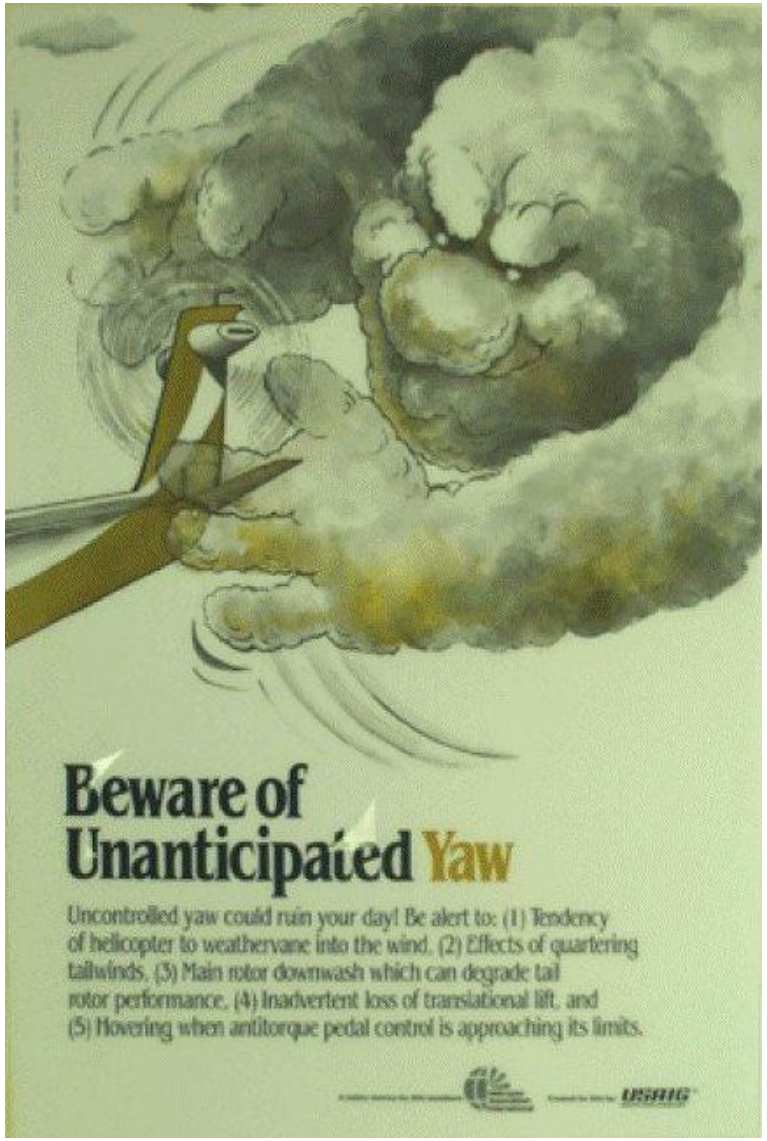

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Unanticipated Yaw Historical View

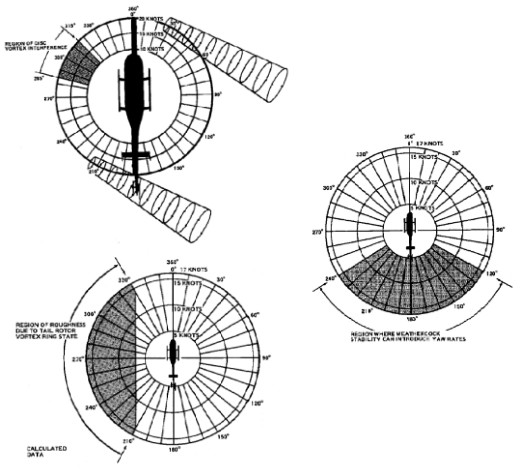

Tail Rotor Stall

This article, previously published by USAAAVS in the DIGEST under the title "How to Crash—By The Book," is being reprinted because of a recent visit by an OH-58 pilot who credits it with possibly saving his life. The pilot had a tail rotor stall, remembered and applied what he had read in the article, and got his helicopter down safely.

NOT TOO MANY years ago—before the advent of the recovery room—the expression "The operation was a success . . . but the patient died," was common, and unfortunately, true.

turn over the objective area. It was one complete 360-degree orbit plus 180 degrees, rolling out on a northerly heading. I traveled several thousand meters north and made a right-hand turn . . . .

- End of the 70s, several similar losses of control in yaw on US Army OH-58 helicopters. Tail rotor stall was thought to be the cause of the problem and, at some time, the recommended procedure included adding first pedal into the yaw
- In 1983 and 1984, following flight and wind tunnel tests, Bell and US Army provide new information
  - the tail rotor stall is exonerated
  - the wind azimuth conditions in which the phenomenon may likely occur are defined
  - tests have shown that it was always possible to stop the yaw rate
  - a recovery associating full opposite pedal and forward cyclic is recommended
- In 1995, following civil accidents, FAA publishes AC-90-95 on Unanticipated Yaw in Helicopters
  - it lists the famous “three wind conditions” and translational lift as being the origin of the problem but does not provide a clear explanation of how it happens.
  - It provides recommendations to avoid entering the LTE
  - It promotes the Bell/US Army recovery technique
- 20 years later, NTSB releases a Safety Alert : The problem is not yet solved



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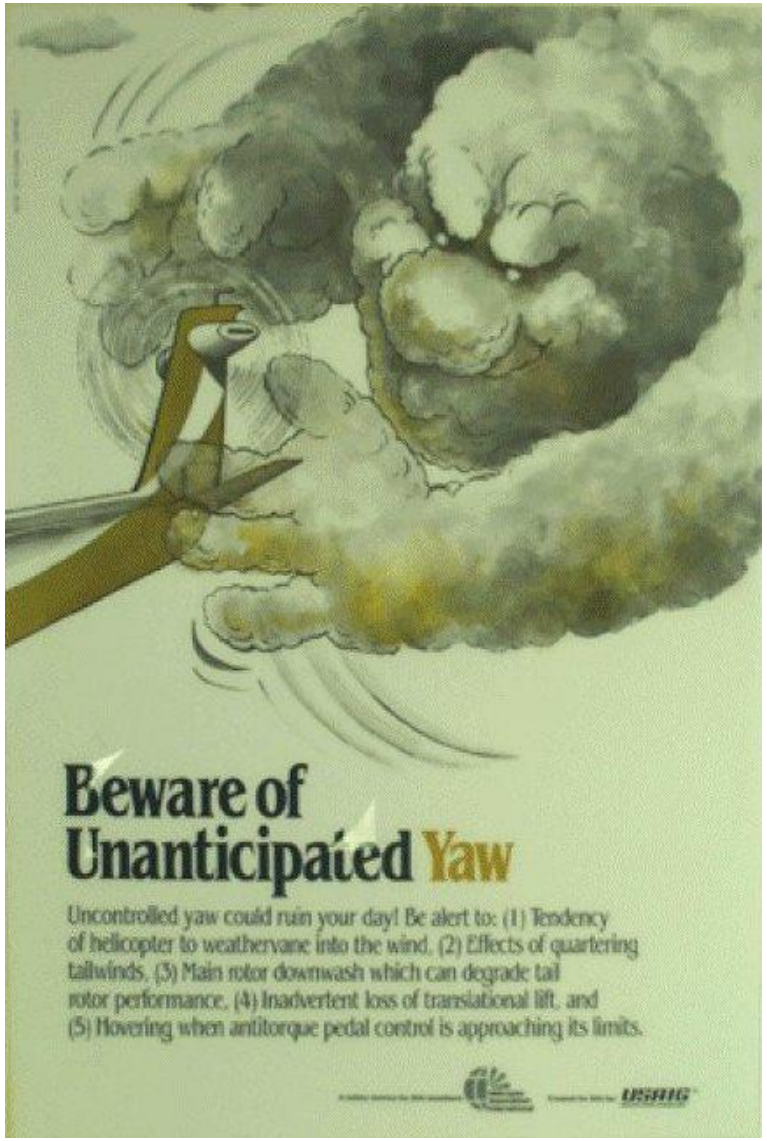

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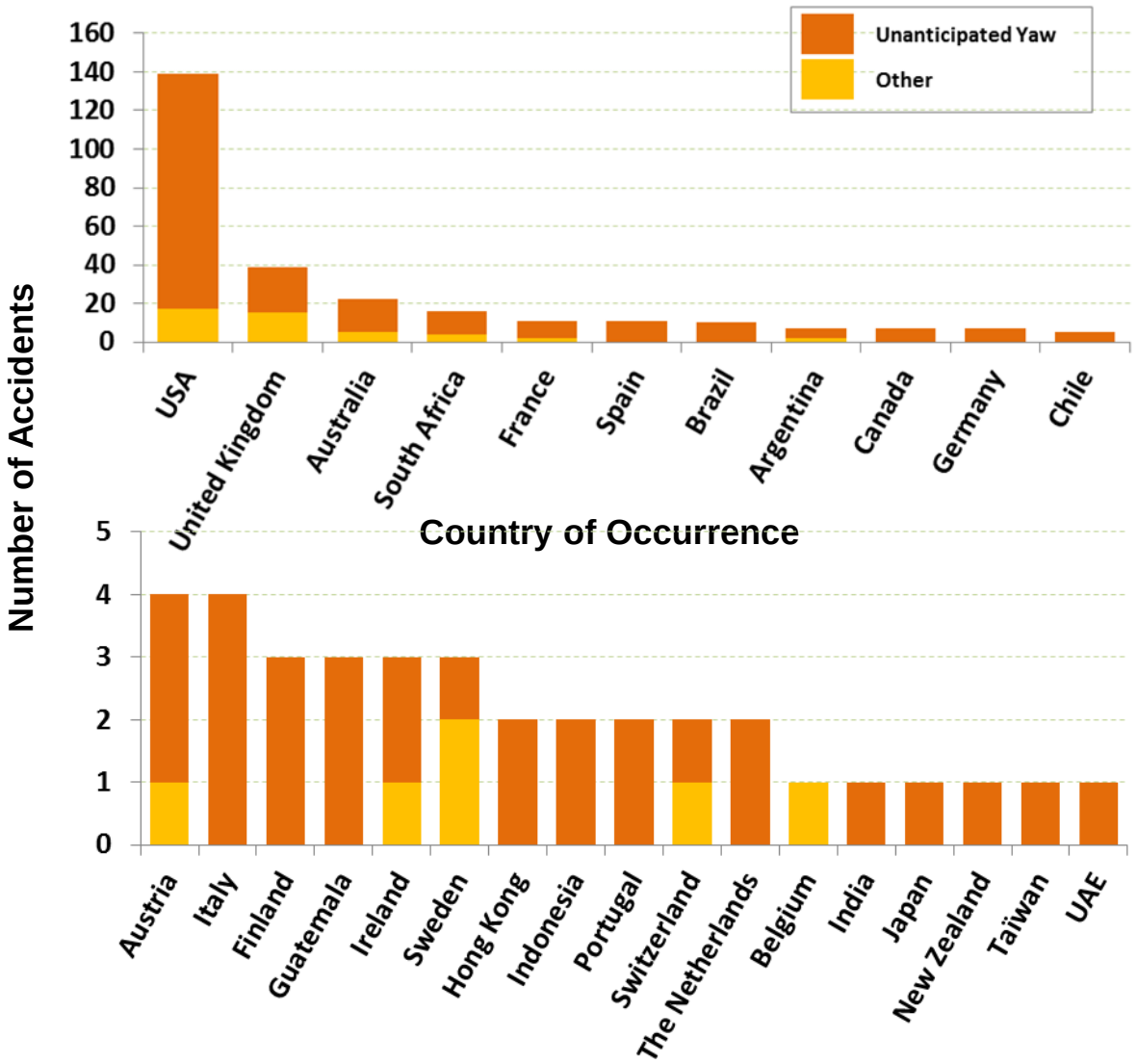
Looking into Accident Investigations Data Bases

From 2000 to 2016 (17 years period)

- 310 accidents reports found
  - starting by a loss of yaw control
  - without previous failure
  - in the civil helicopter world
- All are not unanticipated yaw and about 1 of 6 is untypical (for example yaw started on the ground, before take-off)
- 35 accidents (1 of 9) result in 61 fatalities
- 77 accidents (1 of 4) result in 122 serious injuries
- Most of the time the helicopter is destroyed or at least badly damaged

A huge cost is already paid and still has to be paid if nothing is changed

Lessons learnt from accidents



- Unanticipated yaw accidents occur everywhere…

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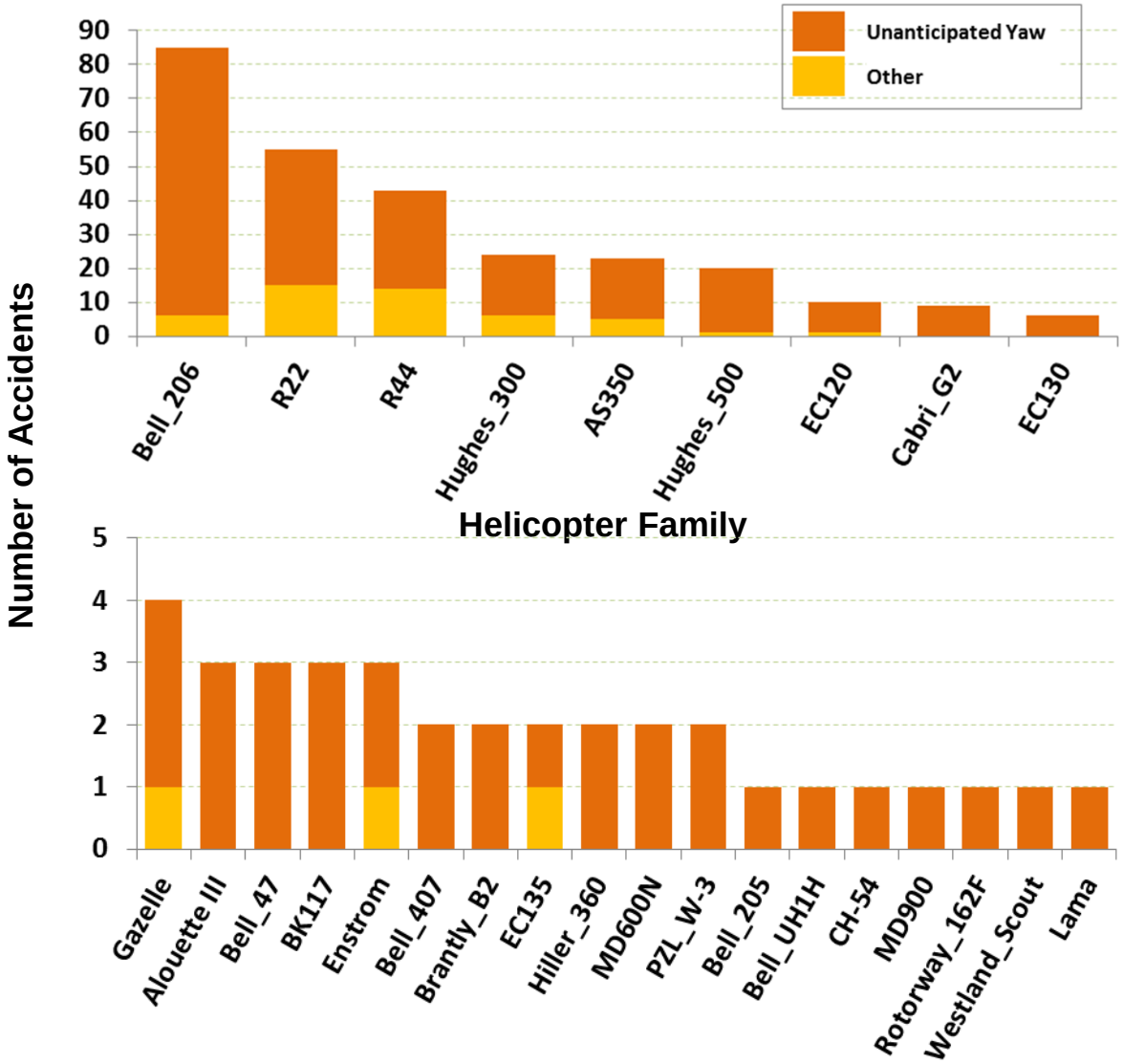
Lessons learnt from accidents



- Unanticipated yaw accidents occur everywhere…
- … on any single rotor helicopter , but light are preferred…

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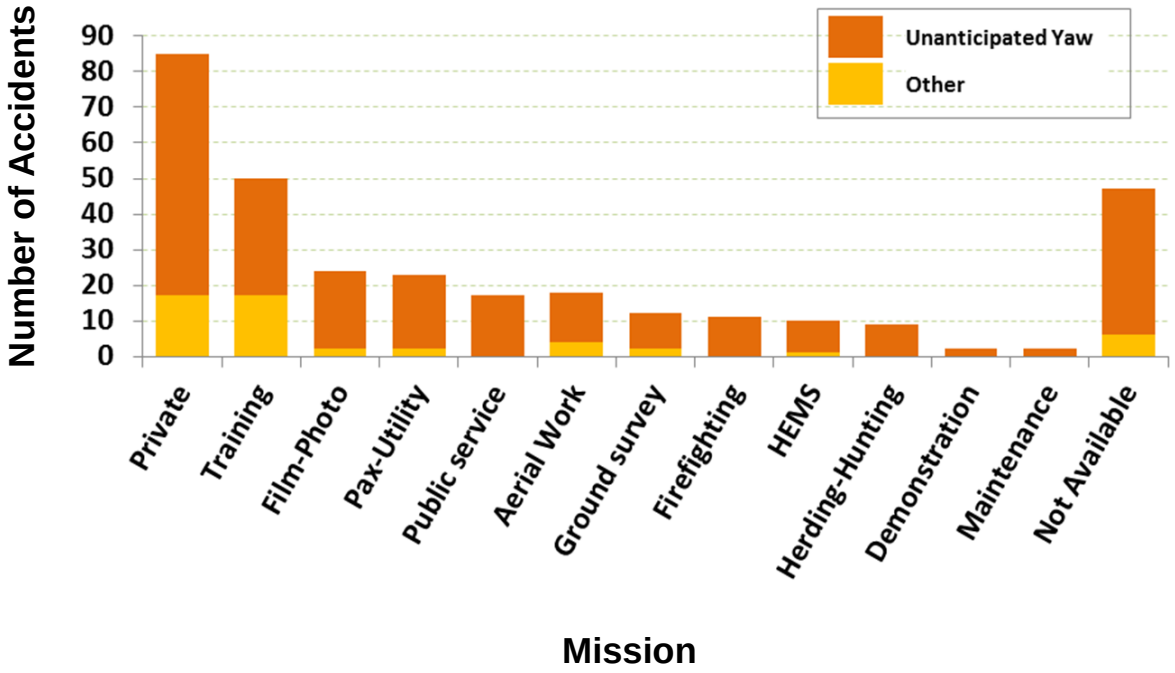
Lessons learnt from accidents



- Unanticipated yaw accidents occur everywhere…
- … on any single rotor helicopter , but light are preferred…
- … especially with private pilots and trainees …

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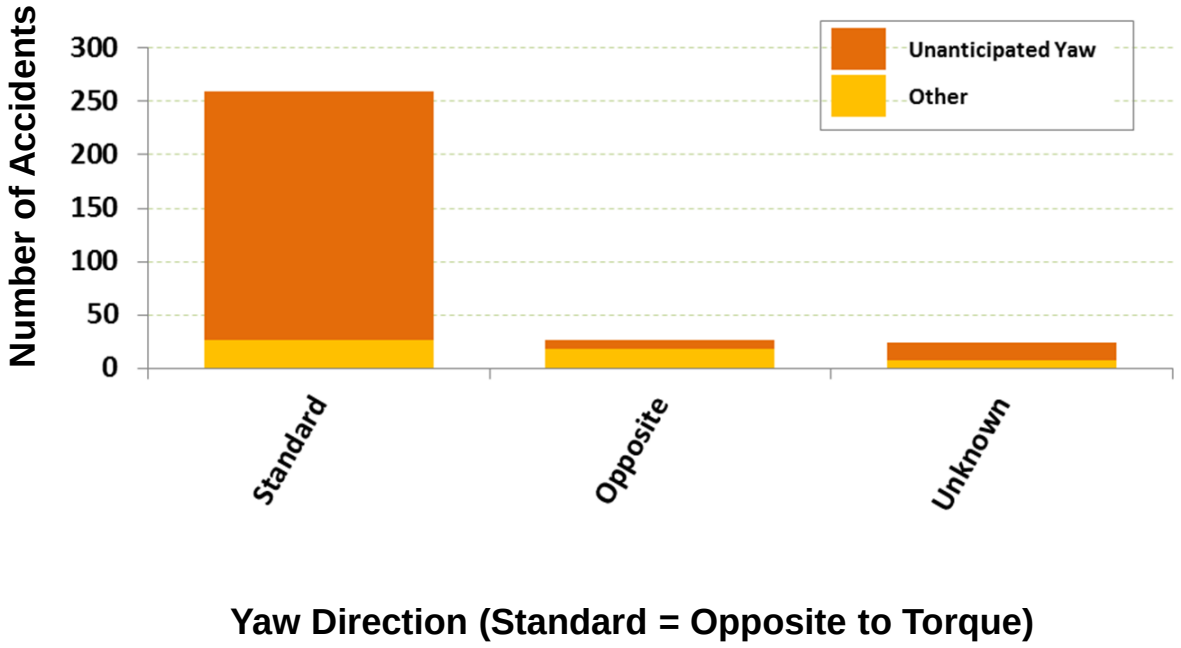
Lessons learnt from accidents



- Unanticipated yaw accidents occur everywhere…
- … on any single rotor helicopter , but light are preferred…
- … especially with private pilots and trainees…
- … mostly in the direction opposite to the torque…

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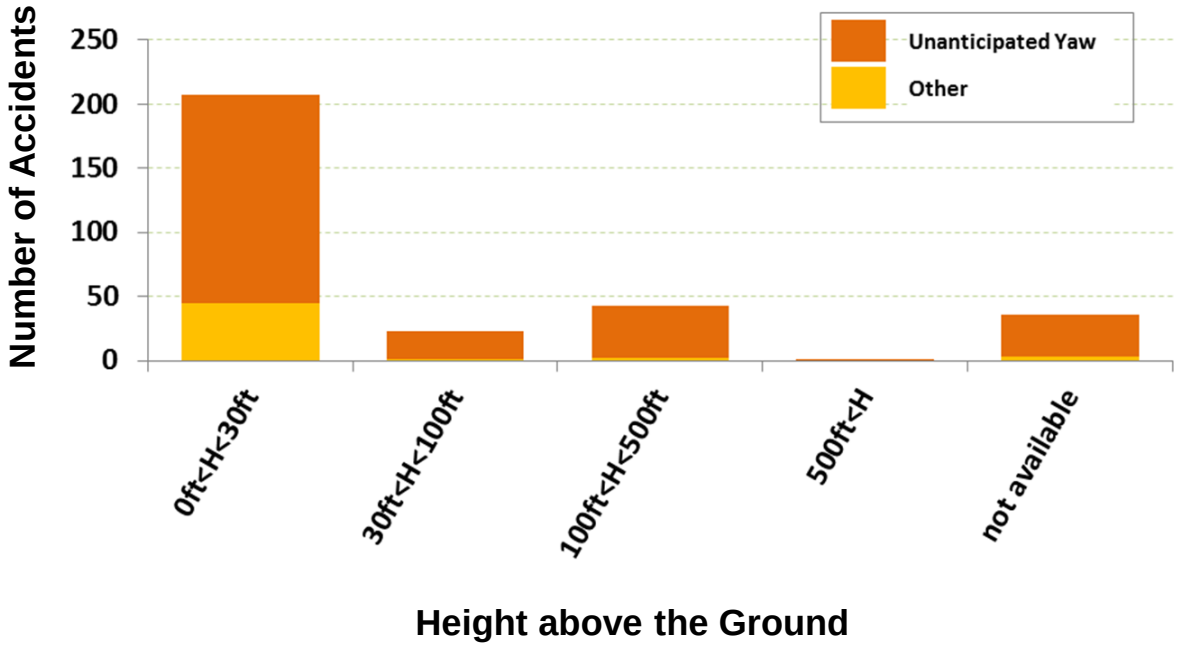
Lessons learnt from accidents



- Unanticipated yaw accidents occur everywhere…
- … on any single rotor helicopter , but light are preferred…
- … especially with private pilots and trainees…
- … mostly in the standard direction (opposite to the torque) …
- … and **close to the ground**

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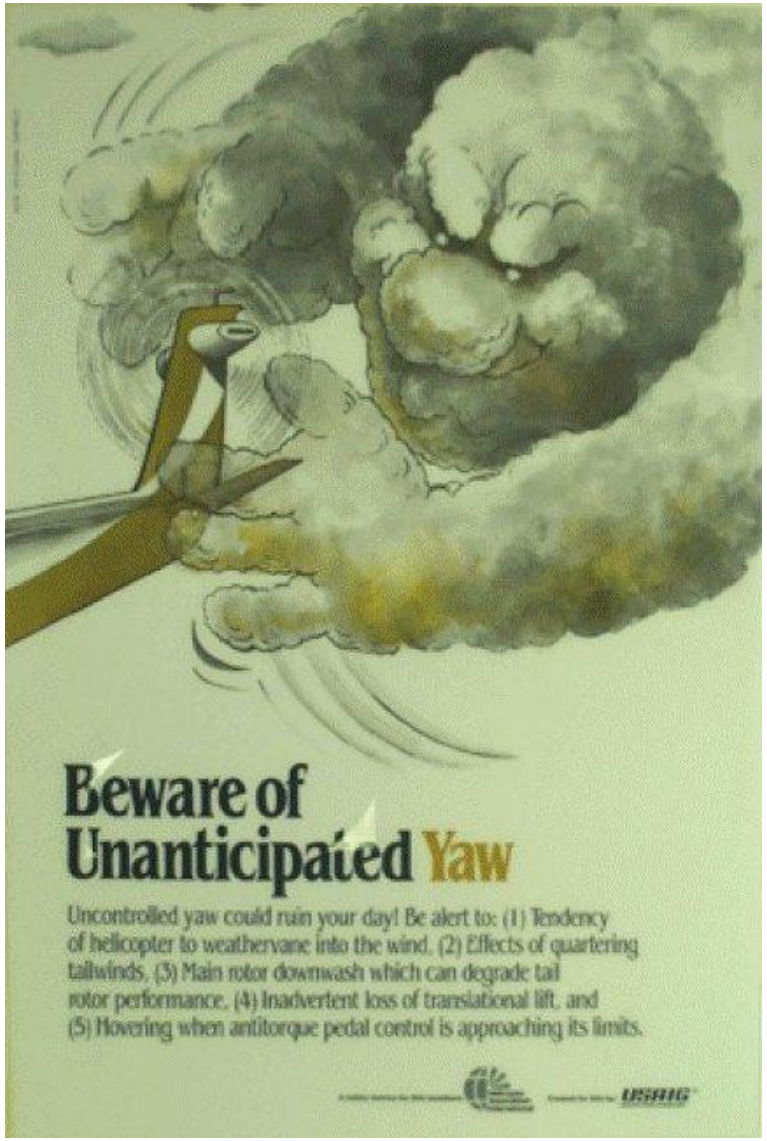


The Pedal Curve

Simple case of hovering with wind

Figures in this presentation are plotted for helicopters which rotor is rotating anti-clockwise as seen from above (US direction)

The helicopter position is defined by its heading with respect to the wind. The pedal curve provides the pedal position at trim as a function of the helicopter heading

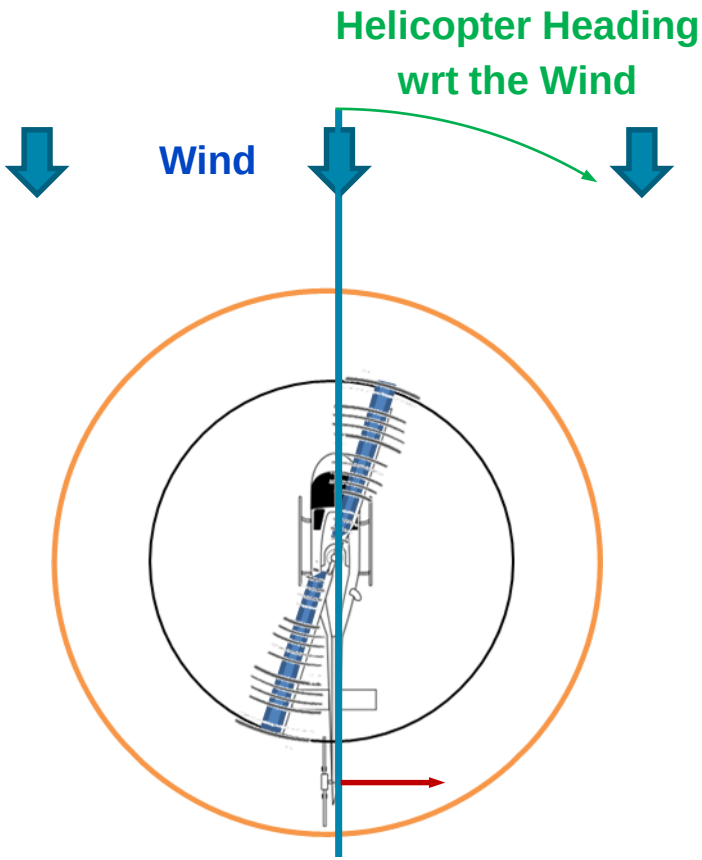
As a first approximation, in low wind conditions, the tail rotor thrust is constant with heading

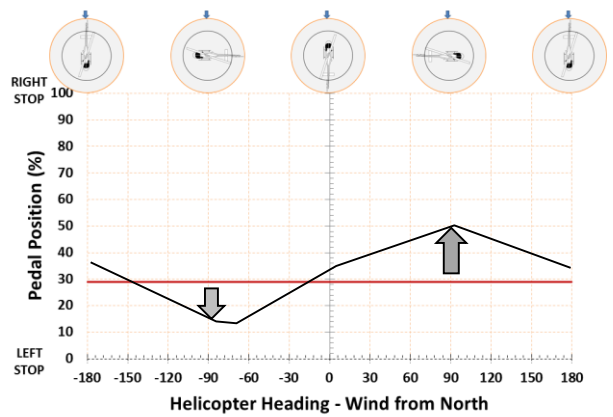
In left wind, the wind adds to the TR thrust and the pilot has thus to move the right pedal forward to stay at trim

In right wind, the wind reduces the TR thrust and the pilot has thus to move the left pedal forward to stay at trim

The pedal curve is a kind of sinusoid

There is one pedal curve for each WAT and wind speed condition.





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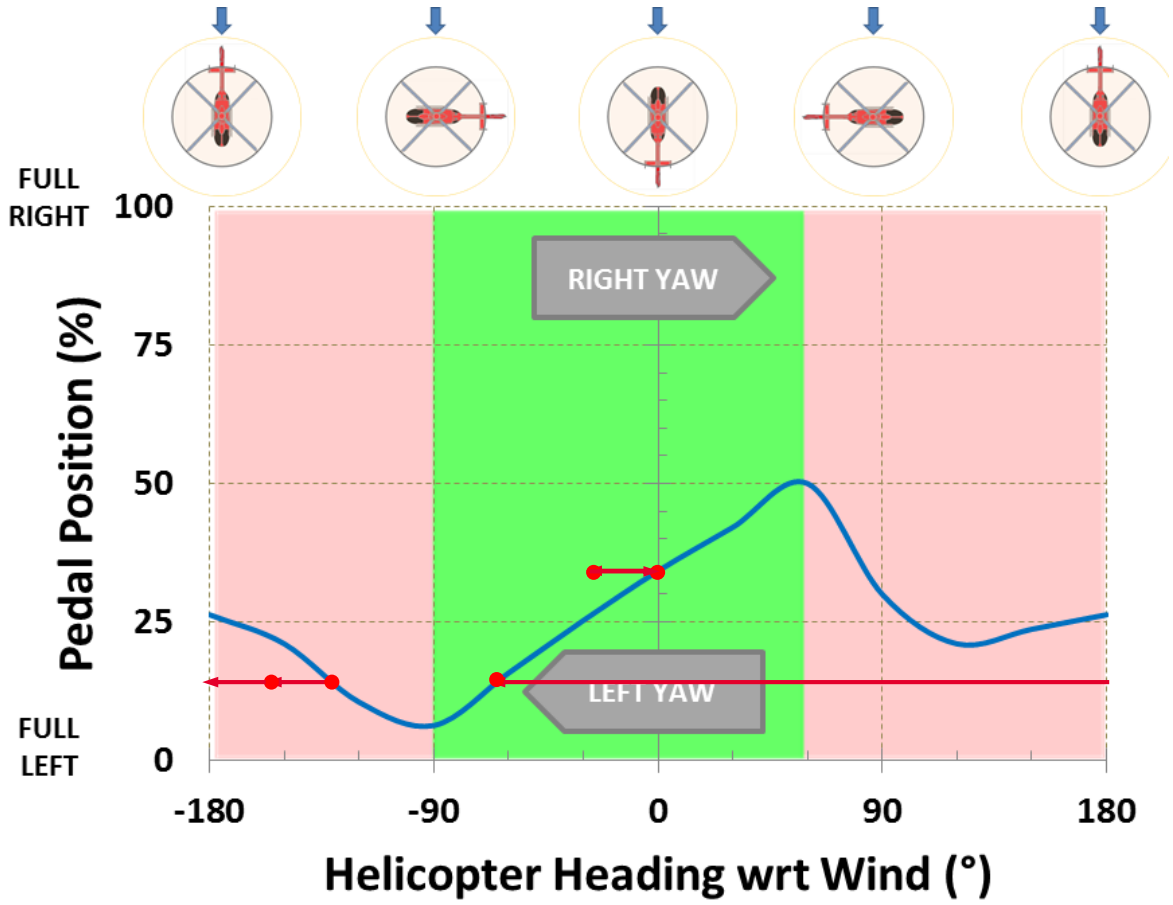
Stable/unstable range



- The green area corresponds to a heading range where the helicopter has a stable behavior. When shifted from the trim, it comes back to the same point.
- The red area corresponds to the unstable range. When shifted from the trim, the helicopter drifts further away.
- Stability is a question of slope: an increasing trim pedal position with heading is stable.
- 180° or -180° heading is the same point : the tailwind instability is the price to pay for headwind stability

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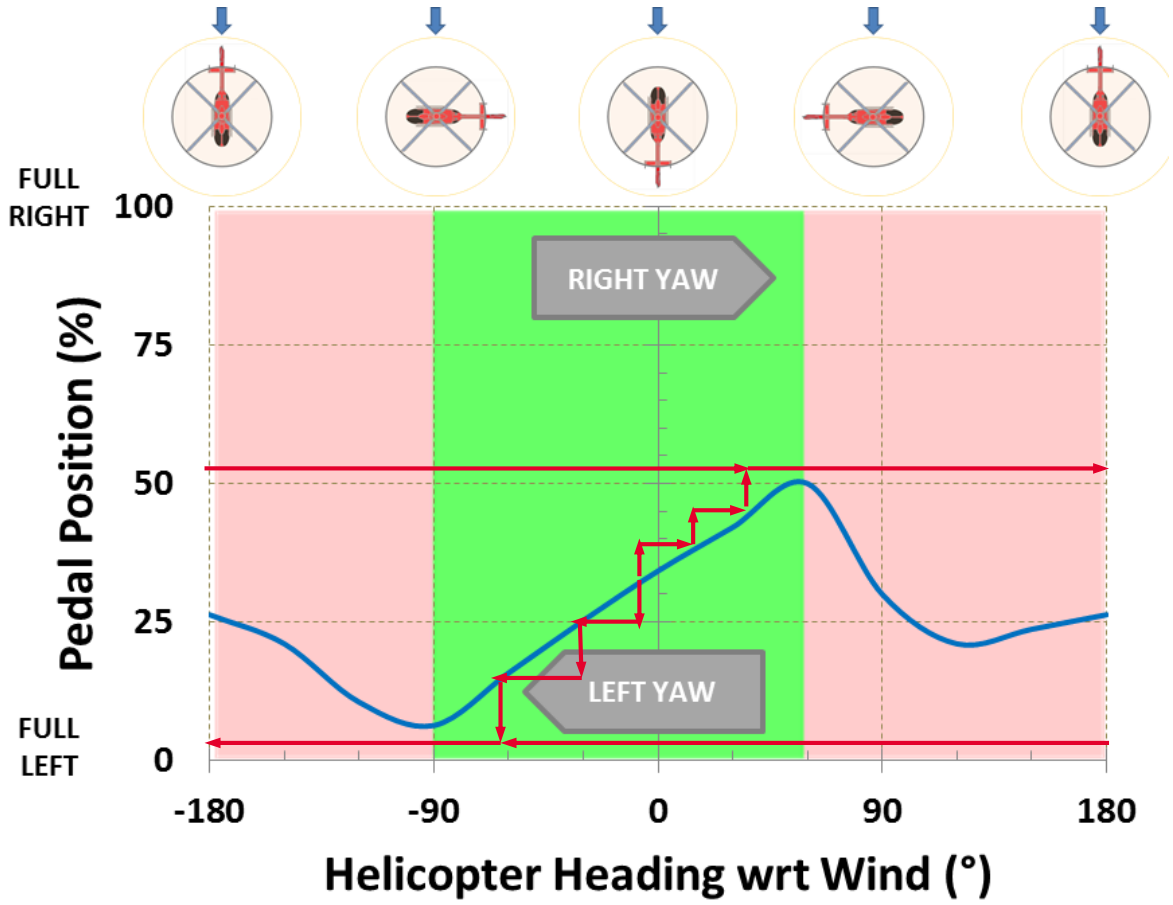
Starting unanticipated yaw



- In the stable range a pedal step mainly produces a heading step
- A second pedal step produces a similar effect
- A third one leads above the maximum of the Pedal Curve and makes the helicopter enter an endless spinning.
- This is the ~~uncommanded~~ rapid yaw rate which does not subside of its own accord described in AC90-95 : this is unanticipated yaw
- The same maneuver may be done on the other side, with the same result, but with an opposite yaw rate.

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Still 2 questions to be answered

To make our unanticipated yaw fit with accidents data

- Why do we have this apparent symmetry whereas the bulk of UY accidents occurs on one specific side ?

The “standard” UY looks like a TR thrust loss (especially when pedal looks to be ineffective), whereas in the opposite direction the TR is obviously working.

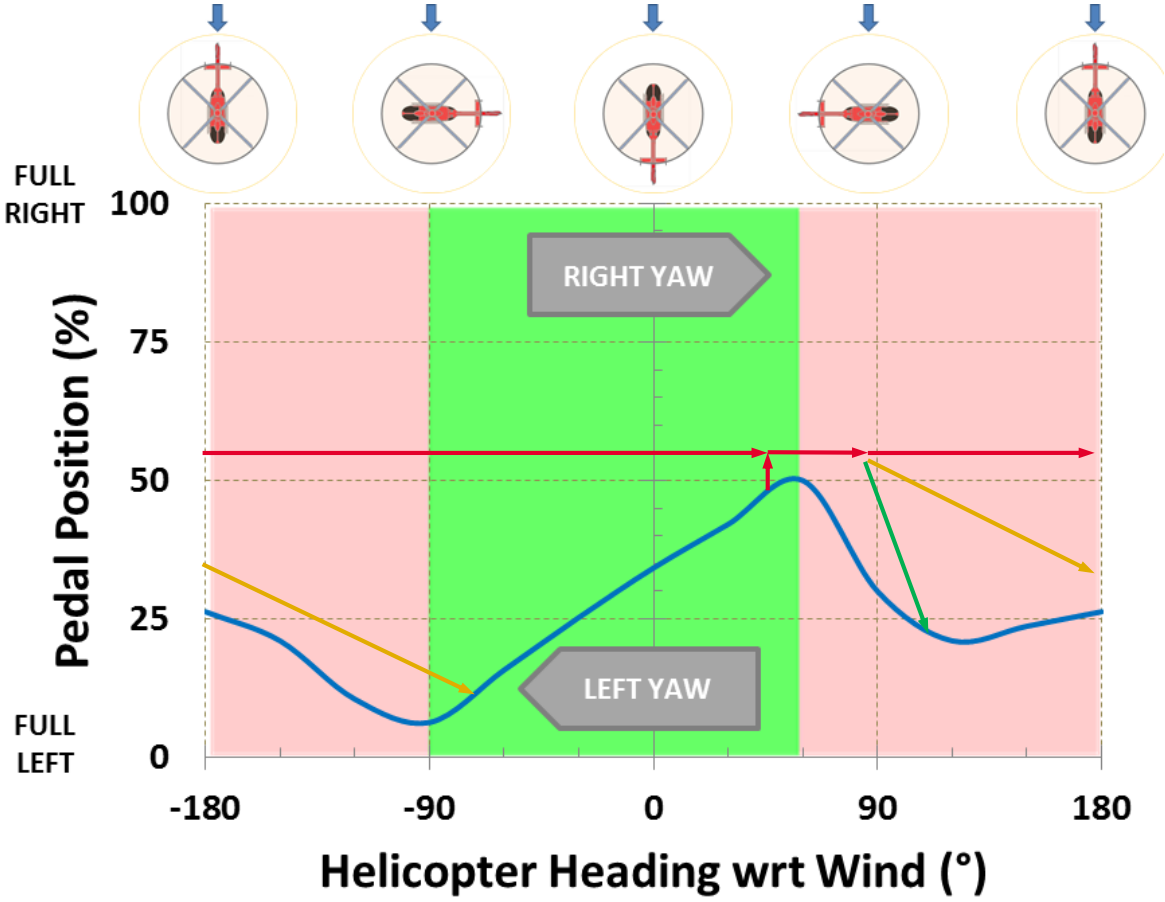
Pilot may be reluctant to have huge TR torque increase (performance or over-torque issue) while there is no similar problem in the opposite direction.

On the unusual side, the pilot is warned by the pedal position.

- Why do pilots fail to stop unanticipated yaw ?

A too small amplitude, too slow and not maintained reaction is most probably the cause.

There is no evidence of a UY accident where pilot unsuccessfully applied full pedal. There are cases where it can be proven that full pedal was not applied.



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A specific case

When performance limited

- Close to performance limitations, the whole available power may already be spent in steady trim conditions
- Increasing the tail rotor pitch makes the tail rotor power increase. This means at best an over-torque and at worse — when the engine cannot provide the additional power — a rpm droop.
- The pilot is trapped :

He needs to increase the main rotor pitch to avoid descending but this would make the rpm further droop
The reduced rpm also means that the TR thrust decreases whereas it is really needed to recover from the unanticipated yaw

- This might be diverging unless some margin is available (height for example)
- When performance limited, it is of prime importance to avoid entering into unanticipated yaw. A close monitoring of the heading is mandatory. Using sideslip to minimize tail rotor power in those conditions, which might seem a safe approach, strongly increases the unanticipated yaw risk.

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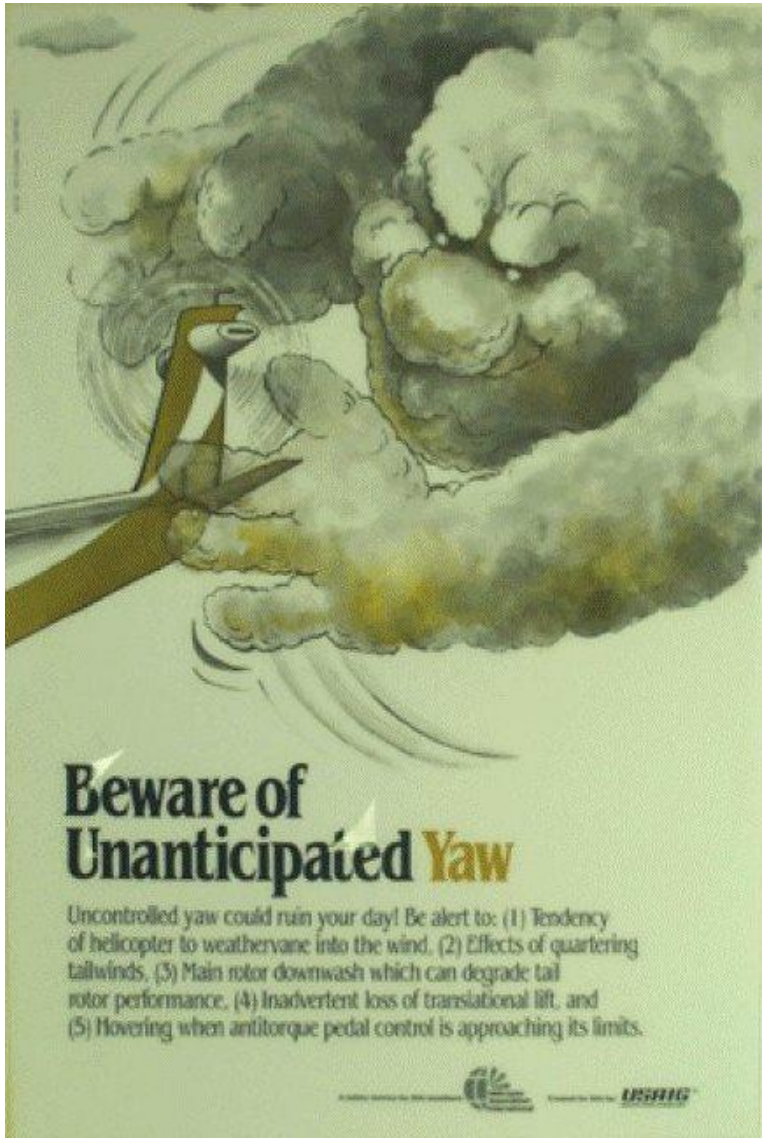

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Inconsistencies and myths spread by existing documents

- The understanding of the “Loss of Tail Rotor Effectiveness” wording changed as time went. Many think now that an “aerodynamic condition” exists where tail rotor loses effectiveness.
- The myth that unanticipated yaw comes from a tail rotor control deficiency is widely propagated by existing documents. Bell clearly stated the opposite in their Information Letters but the weak AC90-95 wording (not necessarily due to…), although not false, opens the door to misinterpretations… Should the certification process allow a control margin deficiency ?
- The myth of unanticipated yaw occurring close to the tail rotor maximum pitch appears in Bell’s Operation Safety Notice and is reproduced in AC90-95.
- The forward cyclic action during recovery is widely advocated, although it is not pracicable in the major part of the accidents. The full opposite pedal even disappeared in the Helicopter Flying Handbook (FAA-H-8083-21A) — it was in FAA-H-8083-21 and is back in FAA-H-8083-21B.
- Training for LTE in the US is mainly theoretical and based on AC90-95 (3 wind conditions, recovery including cyclic) and is of little help when a problem occurs.

Conclusions

- Unanticipated yaw is a lasting, 40 years old, problem
- It was poorly understood : no clear explanation of such events was given, allowing many different interpretations favored by the misleading LTE wording
- For unknown reasons the recommended recovery actions included some forward cyclic input, which is not practical in the huge majority of the accidents and raises doubts about the ability to exit Unanticipated Yaw using only the tail rotor.
- Making the pilots aware of the content of AC90-95 was done, at least in the US. It has not improved the accident rate.
- The explanation of the phenomenon using the pedal curve provides a much better understanding of the problem
  - where it occurs
  - why pedal effectiveness seems to be poor
  - why a limited input may only stop the spinning late
- This must be shared with pilots and the most natural recovery recommended (large amplitude opposite pedal input, up to the stop if necessary)
- Confidence in the tail rotor shall be restored : it represents the better chance for the pilot to recover
- Special care shall be given to operations close to performance limits
- Authorities, Manufacturers and Schools shall provide the same message

Thank you

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Unanticipated yaw is… a Loss of Tail Rotor Effectiveness

A vocabulary issue

> ***"Lack of Tail Rotor EFFECTIVENESS is when it doesn't matter what you do with the pedals, the aircraft is doing its own thing. It is not effective."***

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: **UNANTICIPATED RIGHT YAW IN HELICOPTERS** Date: **12/26/95** Initiated by: **AFS-804** AC No: **90-95** Change:

3. BACKGROUND. Unanticipated right yaw, or loss of tail rotor effectiveness (LTE), has been determined to be a contributing factor in a number of

a. LTE is a critical, low-speed aerodynamic flight characteristic which can result in an uncommanded rapid yaw rate which does not subside

lost control. In most cases, inappropriate or late corrective action may have resulted in the development of uncontrollable yaw. These mishaps have

right turns. This is especially true during flight at low airspeed since the pilot may not be able to stop rotation. The helicopter will attempt to yaw to the right. Correct and timely pilot response to an uncommanded right yaw is critical. The yaw is usually correctable if additional left pedal is applied immediately. If the response is incorrect or slow, the yaw rate may rapidly increase to a point where recovery is not possible.

(1) Apply full left pedal. Simultaneously, move cyclic forward to increase speed. If altitude permits, reduce power.

d. If the rotation cannot be stopped and ground contact is imminent, an autorotation may be the best

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Bell Helicopter Textron Inc.
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Fort Worth Texas 76101
(817) 280-2011

Definition of Unanticipated Right Yaw

Unanticipated right yaw is the occurrence of an uncommanded right yaw rate which does not subside of its own accord and which, if not corrected can result in the loss of aircraft control. The term "loss of tail rotor effectiveness" is misleading. The tail rotor of the OH-58 and 206 series helicopters has exhibited the capability to produce thrust during all approved flight regimes.

- "Unanticipated yaw" is used 7 times in AC 90-95, "Loss of Tail Rotor Effectiveness" 3 times and "LTE" 23 times … No wonder that LTE became the usual wording.
- In AC90-95 LTE is first presented as a synonym of "unanticipated yaw", then as the cause of "uncommanded yaw"
- Out of the AC 90-95 context, it is difficult for people to understand something that is different from the natural meaning of the words.
- The AC 90-95 raises many doubts about the tail rotor efficiency.

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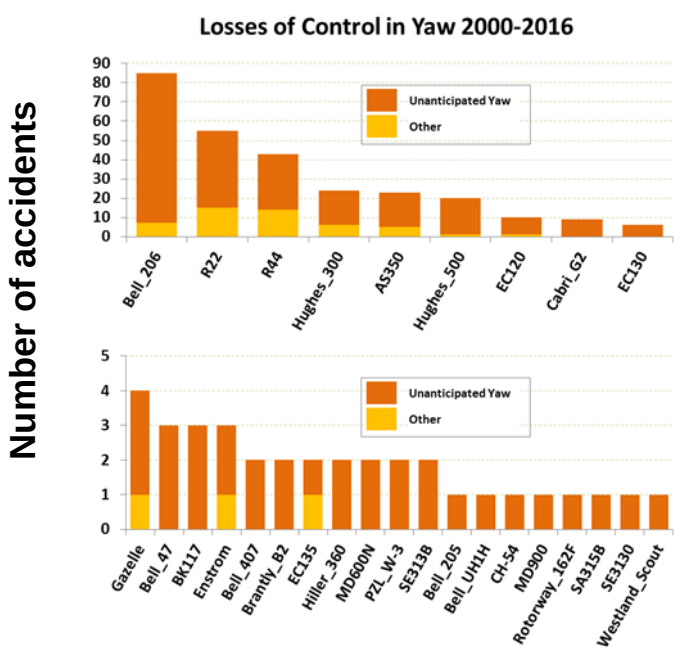
Unanticipated Yaw is…

a problem of all single rotor helicopters

~~the problem of a unique helicopter~~
~~or a problem of tail rotor sizing~~

> ***"…it was some surprise to find that about 95% of all LTE accidents were restricted to one brand name…"***



- Helicopters that are more numerous are more impacted
- Helicopters used for initial training and private use have a higher risk
- Most of the accidents occur in low altitude, standard conditions, far from the tail rotor limits

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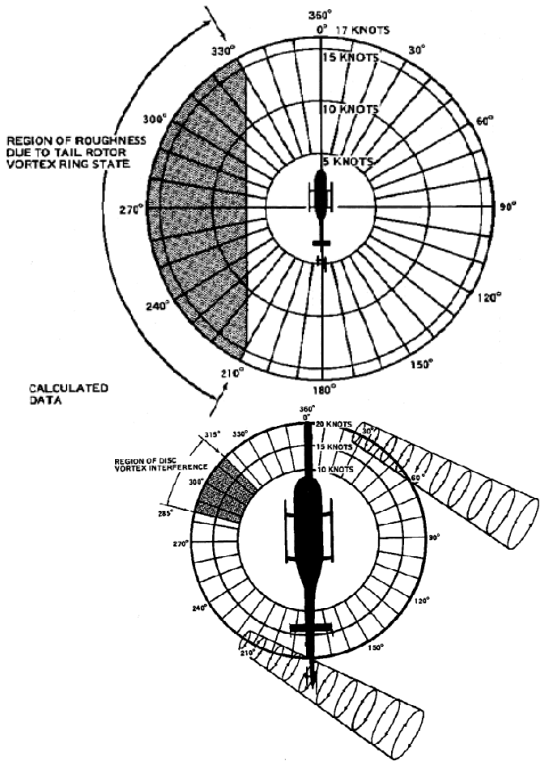
Unanticipated Yaw is …

limit between stability and instability



when the tail rotor enters Vortex Ring State
or when the main rotor vortices are ingested in the TR

- Very local phenomena, indeed occurring where the problem takes place
- They contribute locally to the shape of the Control Curve but disappear as soon as yaw rate builds
- Unanticipated Yaw exists even when those phenomena are not present

NOTAR® TECHNOLOGY DELIVERS:

- **Greater Safety**
  Studies have shown that 21 percent of all crashes ar… strikes or loss of tail rotor effectiveness; NOTAR® systems eliminate these problems.

ERRONEOUS ADVERTISING

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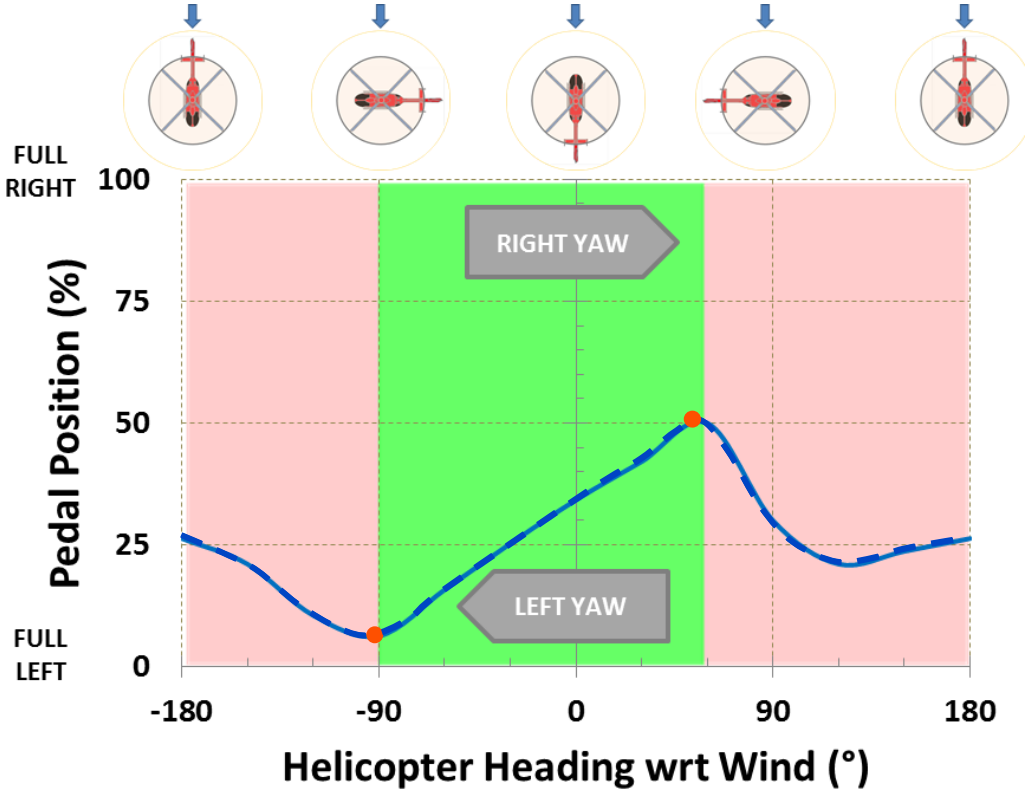
Unanticipated Yaw is…

starting with pedal almost aligned

~~coming out of pedal~~



- Coming out of pedal in hover without wind means not enough anti-torque and building a yaw rate that can only stop when lowering the collective pitch
- This cannot happen on a certified helicopter matching maneuverability requirements : coming close to the pedal stop only happens with maximum wind coming from the critical azimuth
- Close to the pedal stop
  - a collective increase that cannot be fully counteracted with the pedals (coming to the stop)
  - only induces a limited right heading change
- On the other side
  - a collective increase may indeed be fully counteracted on the yaw axis
  - If not the helicopter enters endless spinning

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Close to performance limits

An approach to hover is better

☑ With headwind
- Performance is ensured inside Flight Manual WAT limits, while complying with the helicopter limitations
- Unanticipated Yaw is not an issue

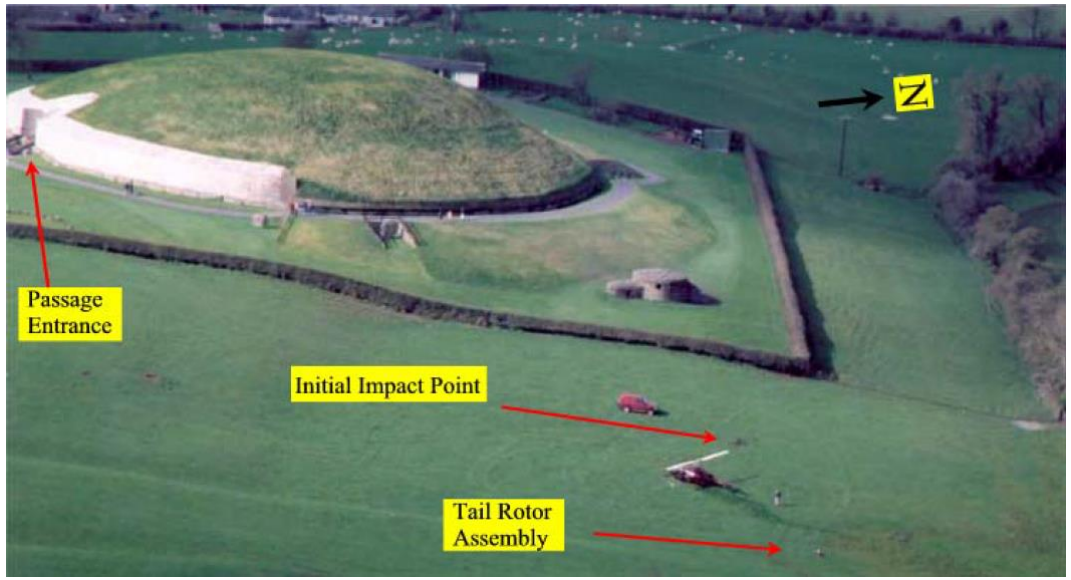
☒ With wind from the right
- Performance inside Flight Manual WAT limits may lead to exceed the helicopter limitations
- Unanticipated Yaw may only happen to the left

☒ With wind from the left
- A few kW are spared on the tail rotor that may be utilized on the main rotor
- Critical Unanticipated Yaw conditions are matched, tens of kW may be necessary to recover

☒ With tailwind
- More time spent in high power conditions, as well when coming to a hover or when interrupting an approach
- Instable hover with a helicopter willing to change heading by 180°

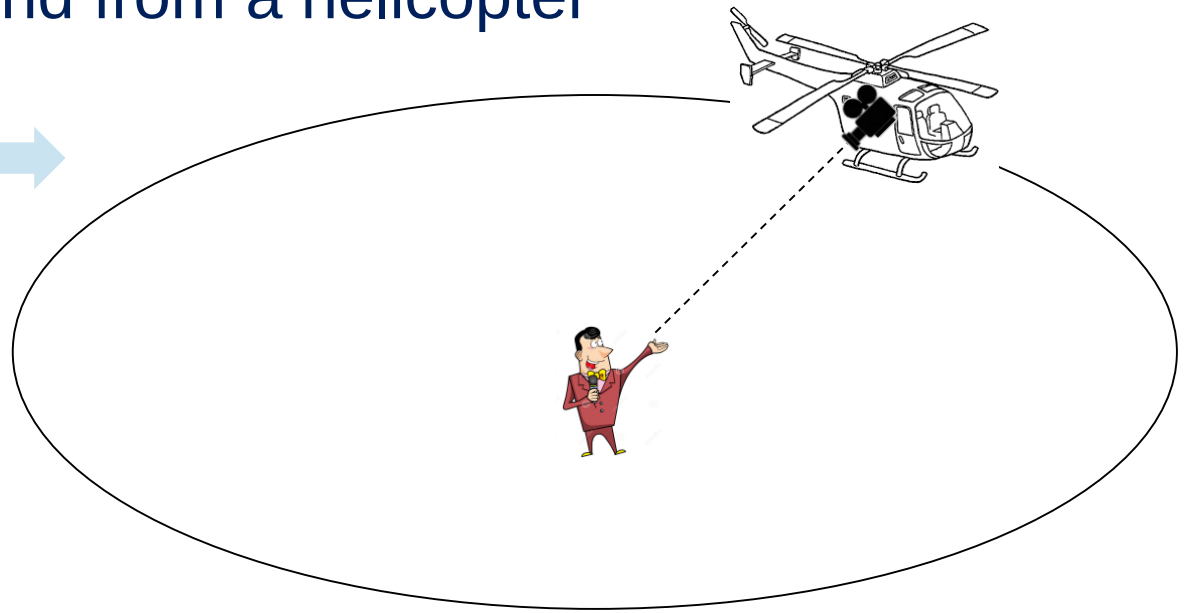
Unanticipated Yaw when filming the ground from a helicopter

A typical accident



AAIU Synoptic Report No: 2004-021
AAIU File No: 2004/0014
Published: 09/12/2004

The helicopter was engaged in aerial filming of the Megalithic Passage Tomb at Newgrange, Co. Meath. During its fourth orbit of the mound, the helicopter was seen to yaw suddenly to the right and spiral out of control. Appropriate corrective action by the Pilot i.e., of opposite left pedal, reduction of collective and pitching the nose down to increase airspeed, proved ineffective as the helicopter continued yawing right in a spiral descent. The helicopter impacted heavily into a field immediately east of the mound, but remained upright. The three persons on board suffered various sudden impact injuries and were transferred to hospital by the emergency services a short time later. There was no fire.



Speaker at the top of the burial mound
The helicopter makes turns around the mound, filming the speaker
15-20kt west wind
During the fourth orbit, when arriving in tailwind, unanticipated right yaw that is not recovered

Assumption : the ground flight path is a circle, flown at a constant ground speed, holding the speaker in the same position with respect to the helicopter

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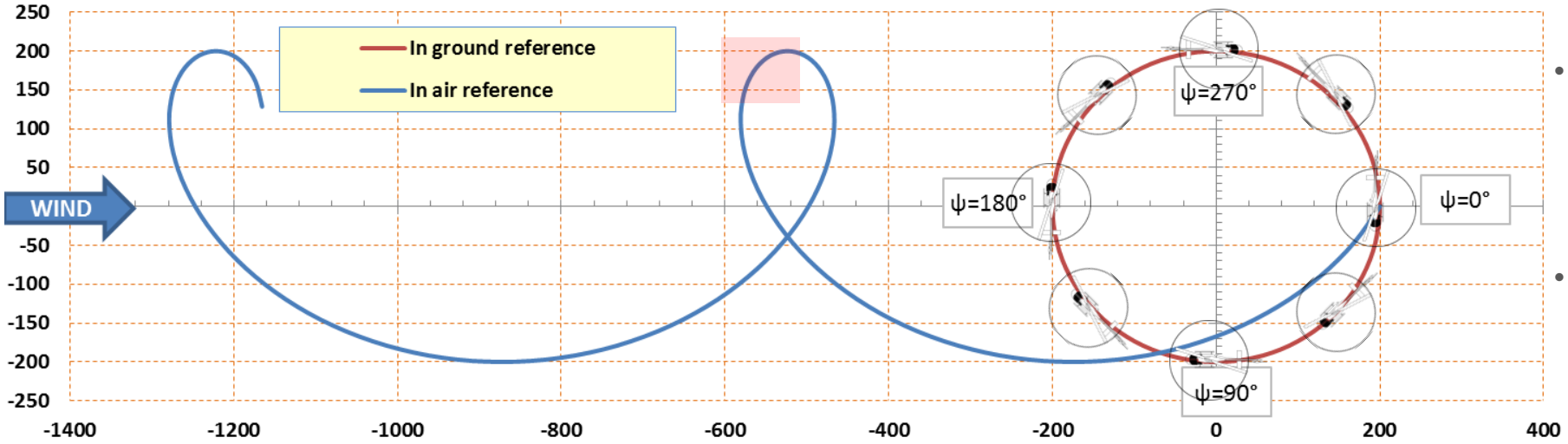
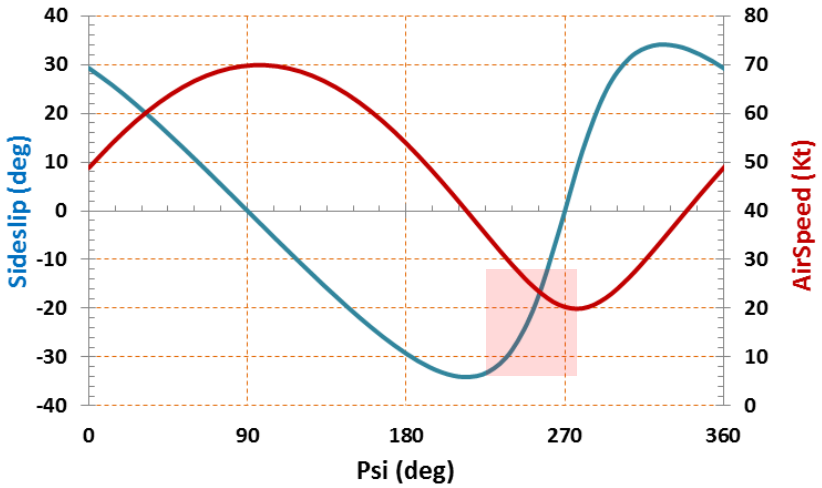
Unanticipated Yaw when filming the ground from a helicopter

Estimating the flight parameters



- In ground reference, constant radius turn flown at a constant speed (Ø200m, 35kt in the shown example)
- In air reference, it is a prolate trochoid flown with variable speed (25kt wind)



- The opposite figure shows how speed and sideslip vary with the azimuth of the helicopter on the circle (moving from the left to the right)
- When coming into tailwind, between 180 et 90° (red area) the negative sideslip is very large whereas the speed is much reduced, asking for collective increase

URY conditions are met

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LTE definition

Bell Information Letter July 1984	Recent testing of the OH-58 series helicopter operated by the U.S. Army has revealed the occurrence of unanticipated yaw under certain low speed conditions. The Army has referred to the right yaw characteristic as loss of tail rotor effectiveness (LTE). … Unanticipated yaw is the occurrence of an uncommanded yaw rate which does not subside of its own accord and which, if not corrected can result in the loss of aircraft control. The term "loss of tail rotor effectiveness" is misleading.
AC 90-95 December 1995	Unanticipated right yaw, or loss of tail rotor effectiveness (LTE) has been determined to be a contributing factor in a number of accidents in various models of U.S. military helicopters. … LTE is a critical, low speed aerodynamic flight characteristic which can result in an uncommanded rapid yaw rate which does not subside of its own accord and, if not corrected, can result in the loss of the aircraft control.
CAA FODCOM 1/2004	LTE can be described as a critical low speed aerodynamic flight condition that can result in an uncommanded rapid yaw rate that does not subside and which can result in the loss of an aircraft if it remains unchecked.
EHEST Training Leaflet October 2010	If tail rotor thrust is insufficient an unanticipated and uncommanded yaw may occur. This phenomenon has been a contributing factor in a number of helicopter accidents and is commonly referred to as LTE. For the purpose of this leaflet, LTE is considered to be an insufficient tail rotor thrust associated with a control margin deficiency.

Tail rotor control margin deficiency?

Bell Information Letter July 1984	The tail rotor of the OH-58 and 206 series helicopters has exhibited the capability to produce thrust during all approved flight regimes.
AC 90-95 December 1995	LTE is not necessarily the result of a control margin deficiency. The anti-torque control margin established during Federal Aviation Administration (FAA) testing is accurate and has been determined to adequately provide for the approved sideward/rearward flight velocities plus counteraction of gusts of reasonable magnitudes
CAA FODCOM 1/2004	LTE is the result of a control margin deficiency
EHEST Training Leaflet October 2010	LTE is considered to be an insufficient tail rotor thrust associated with a control margin deficiency.
Helicopter Flying Handbook FAA-H-8083-21B 2019	LTE is an aerodynamic condition and is the result of a control margin deficiency in the tail rotor. (LTE is addressed in a chapter dedicated to System Malfunctions)

Unanticipated yaw occurring close to tail rotor maximum pitch?

Bell Operations Safety Notice October1983	Be aware that if a considerable amount of left pedal is being maintained, that a sufficient amount of left pedal may not be available to counteract an unanticipated right yaw.
AC 90-95 December 1995	Be aware that if a considerable amount of left pedal is being maintained, a sufficient amount of left pedal may not be available to counteract an unanticipated right yaw.
CAA FODCOM 1/2004	
EHEST Training Leaflet October 2010	LTE is generally encountered at low forward airspeed, normally less than 30kt, where: … ▪ A high power setting requires a yaw pedal position which is close to its full travel
Helicopter Flying Handbook FAA-H-8083-21B 2019	Be aware that if a considerable amount of left pedal is being maintained, a sufficient amount of left pedal may not be available to counteract an unanticipated right yaw

Recovery from unanticipated yaw

Bell Information Letter July 1984	If a sudden unanticipated right yaw occurs, the following recovery technique should be performed : 1. Pedal full left, simultaneously, cyclic-forward to increase speed 2. As recovery is effected, adjust control for normal forward flight 3. If spin cannot be stopped and ground contact is imminent, an autorotation may be the best course of action. Maintain full left pedal until the spin stops, then adjust to maintain heading.
AC 90-95 December 1995	If a sudden unanticipated right yaw occurs, the pilot should perform the following: (1) Apply full left pedal. Simultaneously, move cyclic forward to increase speed. If altitude permits, reduce power. (2) As recovery is effected, adjust controls for normal forward flight.
CAA FODCOM 1/2004	The exact actions to be taken having encountered the phenomenon will vary according to the circumstances, but gaining forward airspeed will remove the problem.
EHEST Training Leaflet October 2010	To exit LTE 1. Apply full opposing pedal to the direction of turn 2. Adopt an accelerative attitude to gain forward airspeed 3. If altitude permits; reduce power
Helicopter Flying Handbook FAA-H-8083-21B 2019	If a sudden unanticipated right yaw occurs, the following recovery technique should be performed. **Apply full left pedal**. Simultaneously, apply forward cyclic control to increase speed. If altitude permits, reduce power. As recovery is affected, adjust controls for normal forward flight. A recovery path must always be planned, especially when terminating to an OGE hover and executed immediately if an uncommanded yaw is evident. Early detection of LTE, followed by the immediate flight control application of corrective action, applying forward cyclic to regain airspeed, applying right pedal not left as necessary to maintain rotor rpm, and reducing the collective (thus reducing the high-power demand on the tail rotor), is the key to a safe recovery