Can the Graveyard Spiral be Tamed?

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What is it anyway?

Imagine driving on an *Autobahn*

Now imagine letting the wheel go

You will get into trouble quite fast

(Faster than in a typical light aircraft)

An aircraft operates in three dimensions

- it gets even more lost

Graveyard Spiral / High-Speed Spiral Dive

It’s one of the dangers of flying

Pilots all know about it

We learn to avoid it

Wikipedia has an article, with links

Can anything be done about it?

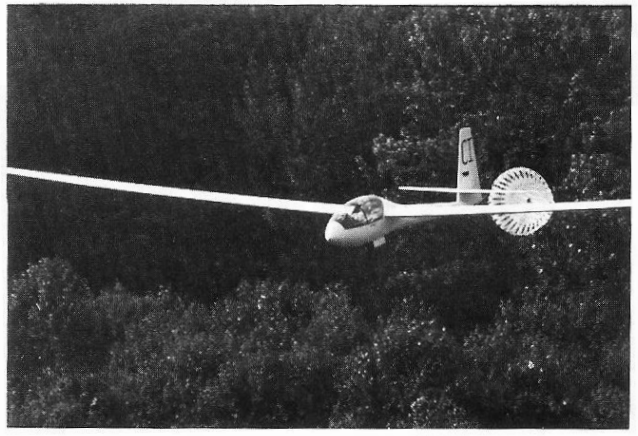
Well, I think so

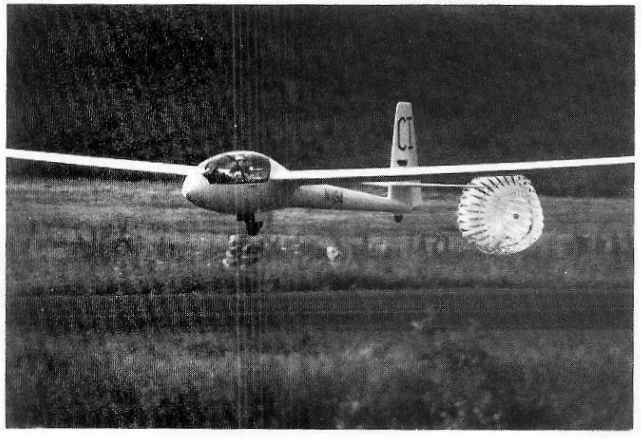
Light Aircraft (Cessna 182) and its Cockpit

Grob 109

Schweizer 1-34

Another technique (Wolters,1971)



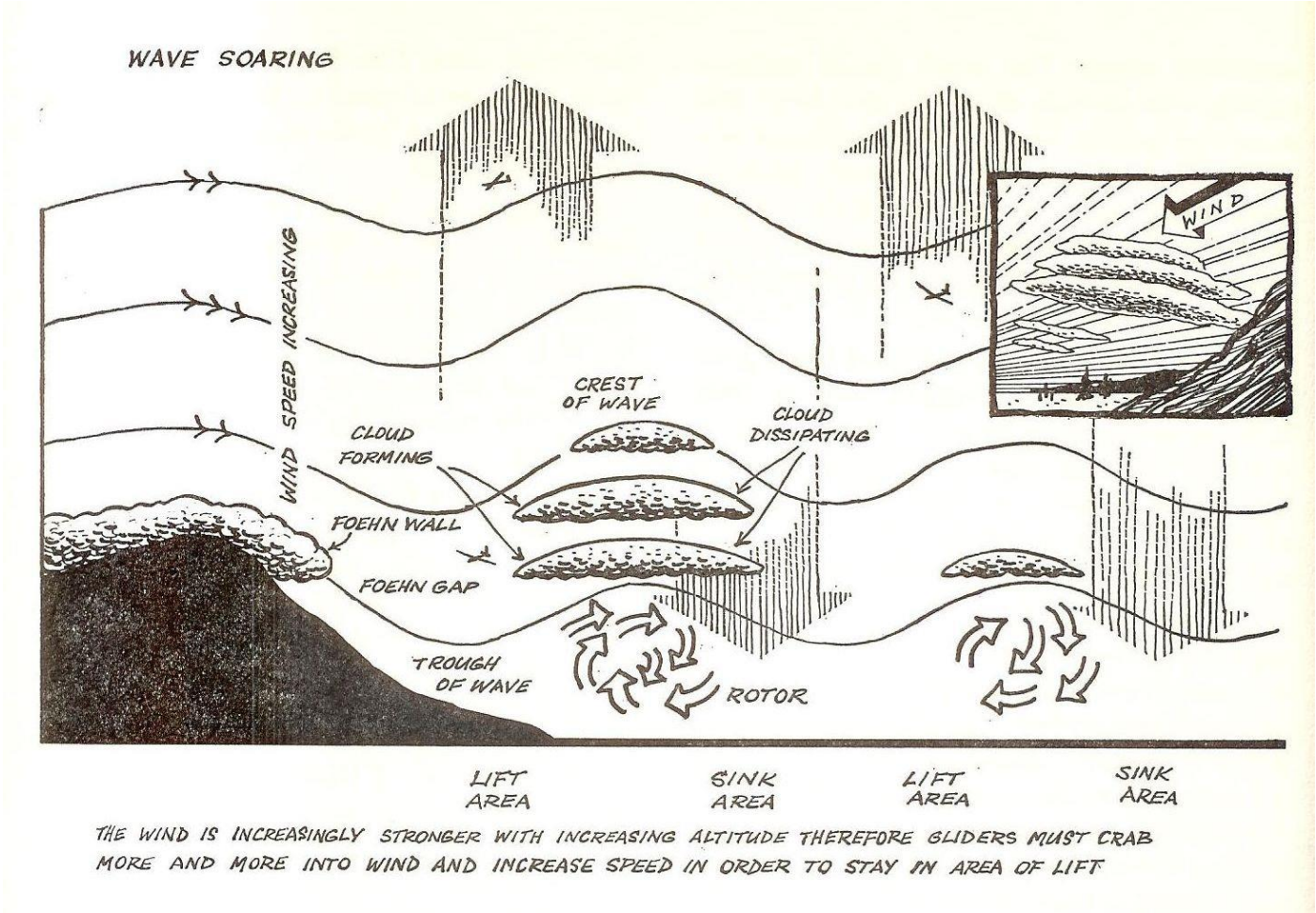


Chute landings are spectacular: because of their much greater landing speeds, high-performance open-class sailplanes use these drogue chutes to facilitate landing in short fields

How do gliders stay up?

- There are several ways
- Mostly in thermals: Sun heats the ground, air rises *organised*; a really big one is a thunderstorm
- Wind blows against high ground
- Two air flows can interact
- Waves of various kinds

A Mountain Lee Wave



From Joy of Soaring, Carle Conway / Gil Parcell, 1969

A little "hangar flying"

11.03.1974; Schweizer 1-34 (BASA Club); in SW wave over SFO Bay

There was partial cloud, I was in clear air, 3 km

More cloud approached: go home, i.e. go down

Full brakes (like an airliner), trim full back, 40°-50° spiral

Suddenly realised I was doing nothing

The 1-34 was flying itself – quite comfortably – at least with my weight, and full back trim

I intended to look into this, and never got round to it

Then I saw a reader's letter in *Soaring* for September 2018

What's going on? How can a plane pilot itself?

Let's try a few things

Just drop a cardboard sheet

-- it descends stably

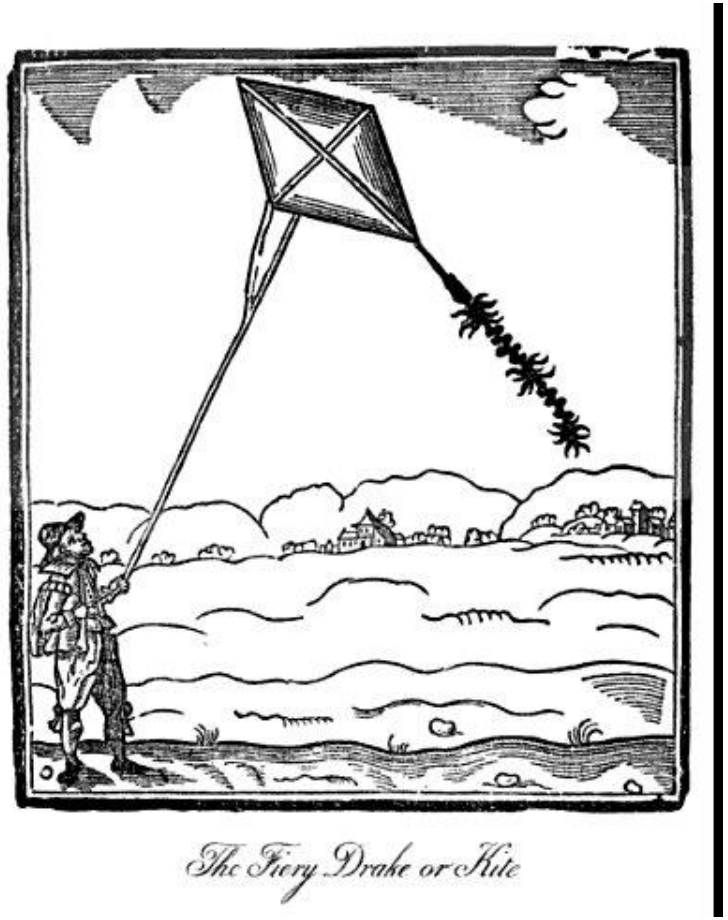
We can even use the Drag Equation to work out how fast it falls:

$$D = \tfrac{1}{2} C_D \rho A V^2$$

Here D is the drag force, C_D the drag coefficient (the tricky one), ρ the air density, A the area, and V the velocity

Simplest Possible “Flying” Device

Kites

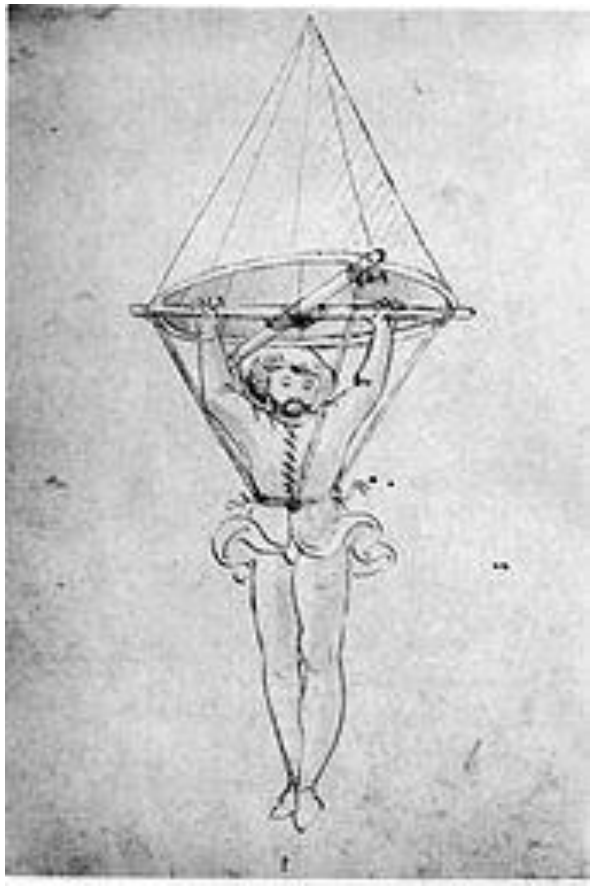


From Wikipedia: Woodcut print of a kite from John Bate's 1635 book *The Mysteries of Nature and Art in which the kite is titled How to make fire Drakes*

Kites go back to 9000 BCE – older than the wheel

Some kites need tails for stability; some don’t

Parachutes



From Wikipedia: The oldest known depiction of a parachute, by an anonymous author (Italy, 1470s)

Emergency (round) parachute will descend stably to the ground

Bear this in mind for what follows

Huge Dive Brakes?

Aircraft have a “never exceed” speed V_{ne}: not a legal limit; the structure can fail.

There is an argument that dive brakes should be so large that, when they are fully open, the glider cannot fly faster than V_{ne}, even in a very steep dive: “terminal velocity limiting dive brakes”. This is like a WW2 dive-bomber.

You can imagine the glider pointed vertically down, “flying” with no pilot input; but stably.

In effect, it’s flying itself.

What we have so far

Several devices that are stable in an airflow

They are perhaps not flying as in a dictionary

They are piloting themselves, so to speak

But we still don’t understand how it works

Centre of Gravity

In cardboard, the CoG is in the plane of the sheet; stability comes from aerodynamics

In a parachute, the CoG is well below the "Centre of Drag”

In a flapped aircraft, the flaps are at the trailing edge of the wing, well behind the CoG

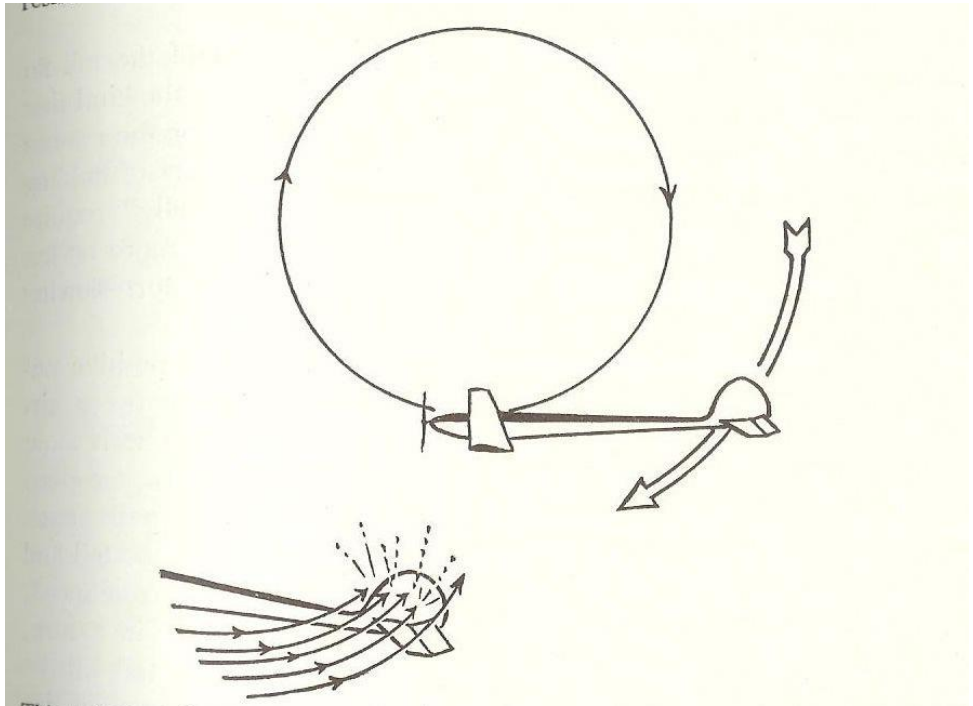
In addition, the brakes will behave a bit like a single plate

Drag comes mostly from brakes/flaps; but some will come from the "wetted surface" of fuselage tail, well behind the CoG

"The Joy of Soaring“, Carle Conway, 1969
Five undesired side-effects of a turn:

1. Adverse yaw -- https://en.wikipedia.org/wiki/Adverse_yaw
2. Diving tendency
3. Overbanking tendency -- https://en.wikipedia.org/wiki/Graveyard_spiral
4. Yaw against the turn -- this helps, especially with brakes/flaps
5. Increased stalling speed

Wolfgang Langewiesche, “Stick & Rudder”, 1944



This caricature, for grown-ups only, shows why some airplanes need a bit of “inside” rudder after all during a turn. If an airplane’s tail is long enough and its speed slow enough, so that its turning radius is short, its vertical tail fin meets a Relative Wind somewhat as sketched in the lower left corner. The tail then cannot swing around as quickly as would be required for a slipless turn, and must be helped around by a little “inside” rudder.

Over the last few years, I & others tried several very different aircraft

Schweizer 1-34 (1974)
Cessna 172
Two-seat Spitfire
Piper Warrior
Grob 109
Spitfire simulator -- but how realistic is this?
Super Decathlon: no flaps or brakes; cross-controls only
Piper Super Cub Float-plane
Arcus M self-launching sailplane (stick-fixed)
Mudry CAP-10
Tecnam P 2008 JC
Doubtful cases so far: a B-737 simulator (realistic?); two rotorcraft: R44 helicopter; J-RO gyroplane

Cessna N4660G, Palo Alto, 29.04.19

Grob 109, Schupfart, 10.12.2019

At start, motor is off, brakes are in, pilot does nothing

Spiral starts

Half-brakes: glider stabilises

This aircraft spirals right only

Super Decathlon: neither brakes nor flaps

I'll spend a bit of time on this, because it's interesting that a plane can be stabilised in this way with crossed controls only

I went looking for an aircraft stressed for aerobatics

-- and a pilot unstressed by aerobatics

Wound up at Wrong Brothers in Pensacola, FL, (since closed by Hurricane Sally in 2020)

Super Decathlon, Pensacola, 07 Feb 2020

Super Decathlon, Pensacola, 07 Feb 2020

25% left stick, 25% right rudder

Power at idle

800-1500 fpm descent

Gentle turn to right

Stable

Super Decathlon, Pensacola, 07 Feb 2020

50% left stick, 50% right rudder

Power at idle

1000 -1300 fpm descent

Gentle turn to right

Stable

Super Decathlon, Pensacola, 07 Feb 2020

75% left stick, 75% right rudder

Power at idle

Turn to left

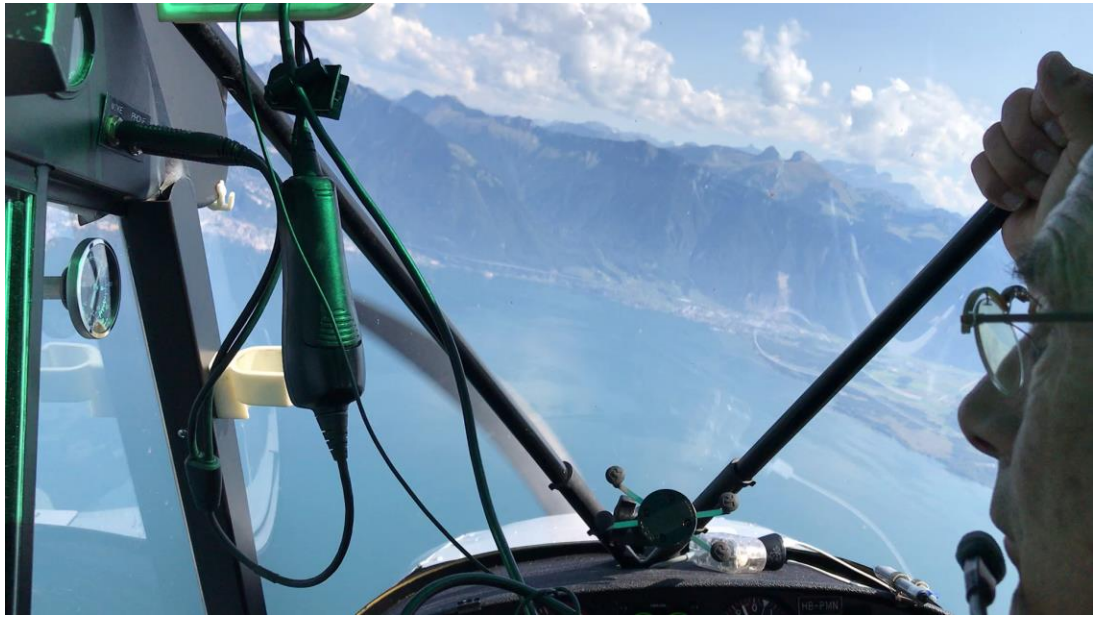
Unstable

Piper Float-plane HB-PMN, Bex, 14.09.2020

Piper Float-plane HB-PMN, Bex, 14.09.2020

- Idle power
- No flaps
- Stable R circle

Piper Float-plane HB-PMN, Bex, 14.09.2020



- Power idle
- No flaps
- Unstable L circle
- Stable R circle

Some Comments

In the Decathlon, turns at 25% and 50% were quite gentle

They were also opposite to that at 75%

This suggests there may be a setting with no turning

-- does this mean stable, straight flight?

In the Piper, right turns were already stable without flaps; left turns were not. Floats are «draggy». With flaps, turns were stable both ways.

In the Pipeline or in Prospect

Antonov An-2: 5 tons, 12 seats

Spitfire Simulator again

VariEzE / Long-EZ / Speed Canard; I expect it to fail here, because the airbrakes are so far forward

Something with a drag chute

Anything else I can get my hands on

But I could use some help: «smart ballast»

In the Pipeline or in Prospect

What I’d like to do now

I’d like to encourage any pilot to try this – at least in braked/flapped AC

What I usually do is open the brakes / flaps fully, power off (if you have any), trim (I think) for cruise, and turn it loose

It should stabilise at a fairly steep bank; if necessary I normally stop at about 60°, where aerobatic flight starts

Be aware that this is not in the Pilot’s Operating Handbook

In effect you’re test flying; this is a Work in Progress; Alpha version

You might like to let me know how you get on: john.crawford@psi.ch

Others Should Try It

I've shown three ways: flaps, brakes, crossed controls

Flaps / brakes: piece of cake

Crossed-controls: take a bit more care

The Decathlon went on its ear a few times as we played

Why is This Interesting?

I want to get this into everyone's bag of tricks, in soaring and General Aviation – not just some people

I'm trying to build up as large a database of types as I can

Are there any bugs?

I want to generate publicity for it

If it's useful, it's very wrong that only some pilots know it

Old MIT Soaring Association used to teach it

It might even have saved the unfortunate JFK Junior and his passengers in 1999

Ballistic Recovery Systems, St Paul, MN

- Solid-fuel rocket extracts a parachute, which lowers the aircraft to the ground
- 35,000 installations
- 423 survivors to date
- Several deployments on YouTube