# autogyros

**An introduction to rotary-winged flight.**
**The history of the autogyro.**
**Autogyro design.**
**Autogyro's contribution to helicopter development.**
**The future of the autogyro.**

**4-11-2014**

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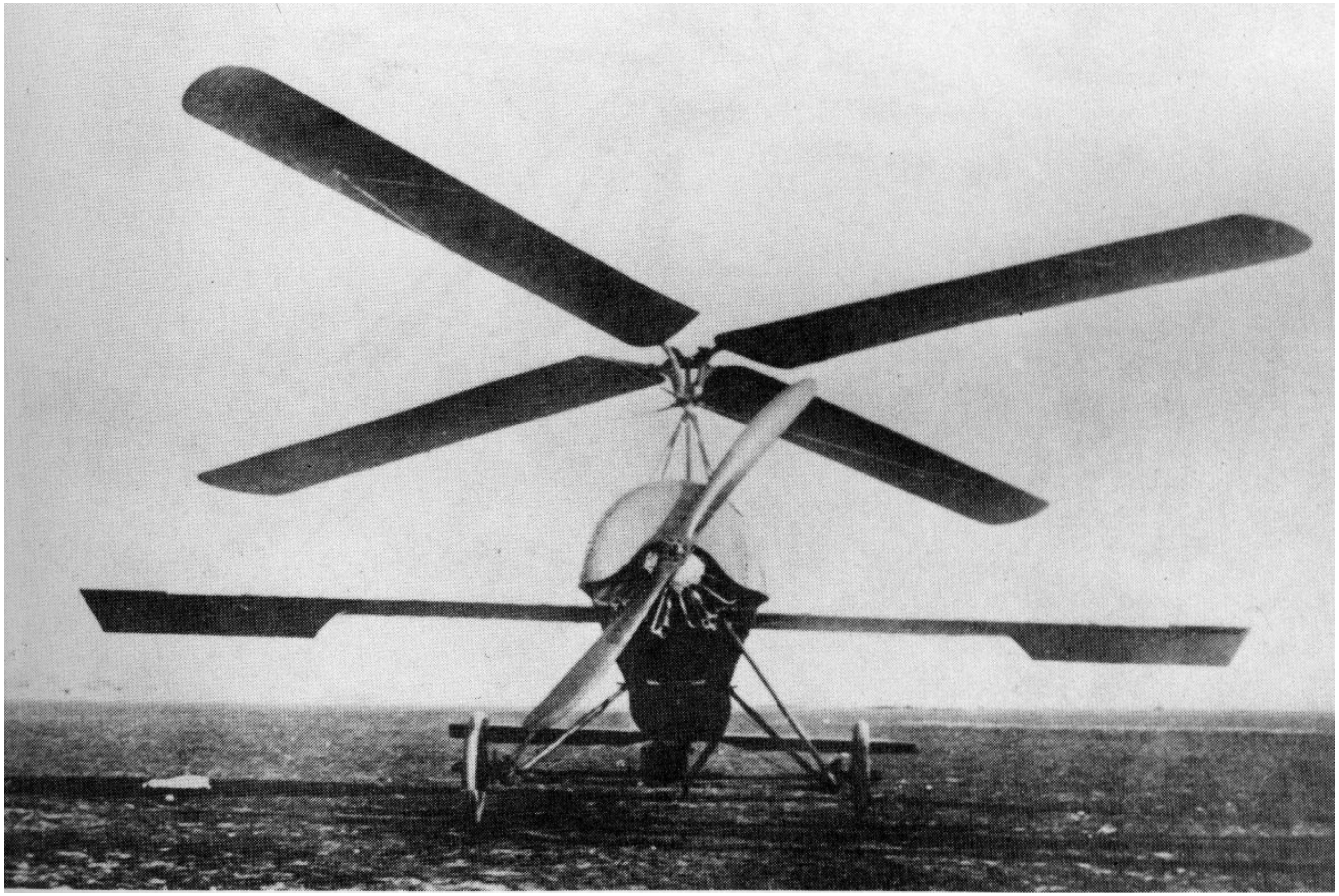
# autogyro
# or
# Autogiro

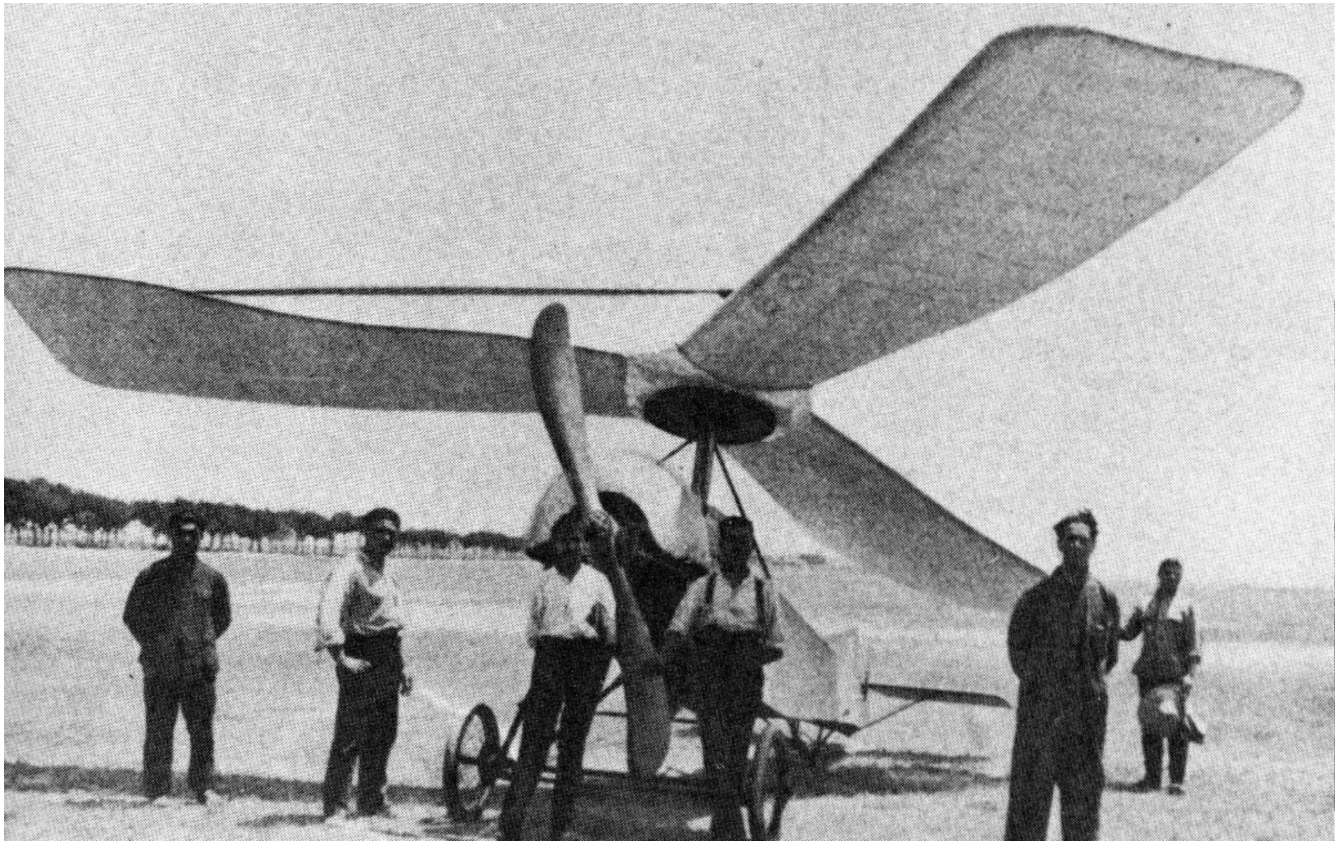
# Autogiro™

The first manned rotary winged aircraft that flew (in the generally accepted sense of this word) was in 1923 and it did not have a powered rotor !



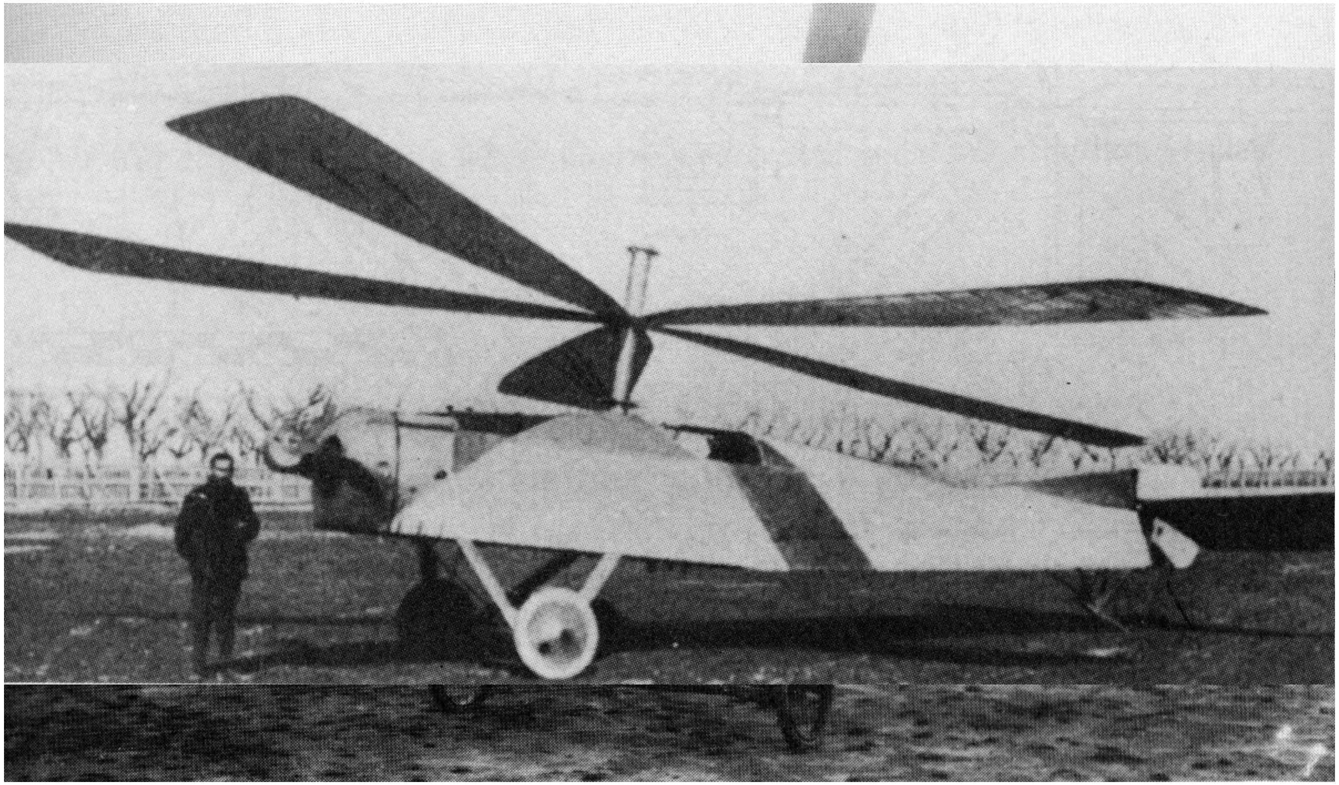
Cierva C4 Autogiro™ (1923)

This aircraft was complete before the Cierva C2 and was therefore the second aircraft to be tested. It had a novel system of “cyclic pitch” through blade warping.



Cierva C3 Autogiro™ (1921)

The Cierva C2 was started before C3 but limited funds and damage delayed eventual successful hops. It had better lateral balance than the C1 and C3.



Cierva C2 Autogiro™ (1922)

The Cierva C1 was Cierva's first attempt at building an autogyro. The idea of two rotors was to cancel the asymmetric lift effects but this was not successful.

Cierva C1 Autogiro™ (1920)

Cierva's Autogiro™ couldn't hover, but that was never his intention.

It did produce a lifting force independent of translational speed – that was!

It didn't stall

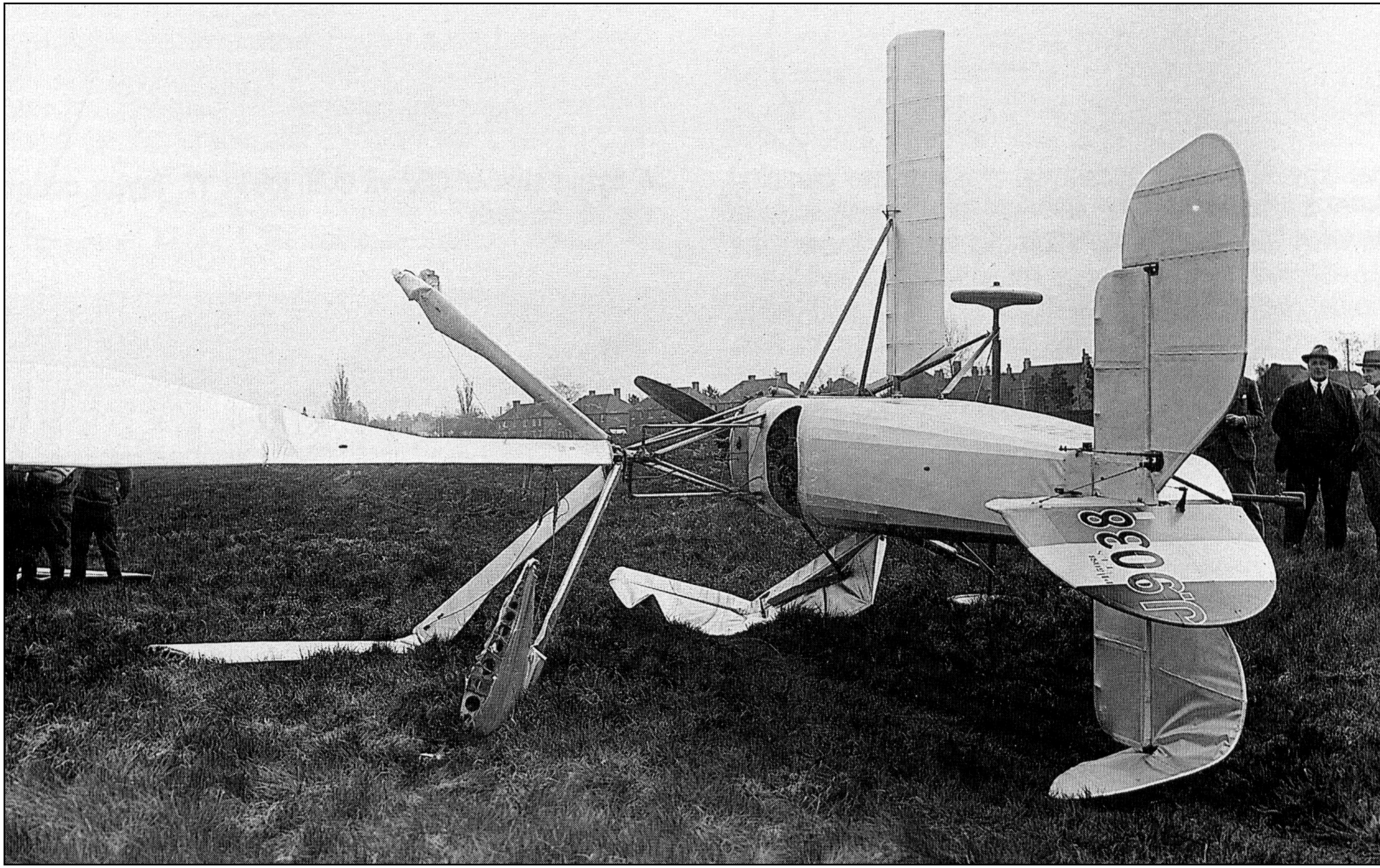
The lifting rotor is a simple device in axial flow (hover and climb).

In edge-wise flight it's anything but simple!

And that is what makes it so interesting

So Cierva was thrown in at the "deep end".

But he survived




….but many of his early aircraft didn't!

…..but the development of the autogyro led to the success of the helicopter !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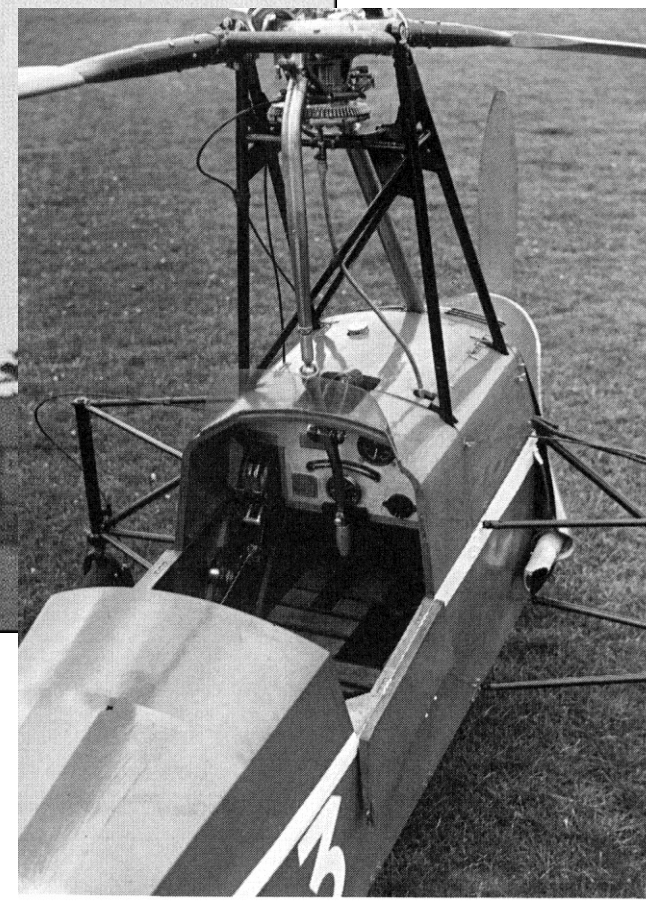

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The helicopter could do everything the autogyro could do but more importantly it could hover - the one thing the autogyro would never be capable of doing !


Cierva C30 MK III making a jump take-off from Hounslow Heath on July 23, 1936

December 9th 1936 Cierva lost his life (aged 41) in a fixed wing aircraft accident. The KLM Airline DC-2 on which he was flying to Amsterdam crashed shortly after take-off from Croydon Airport in thick fog.

**THIS MARKED THE END TO ANY FURTHER SIGNIFICANT AUTOGYRO DEVELOPMENT.**

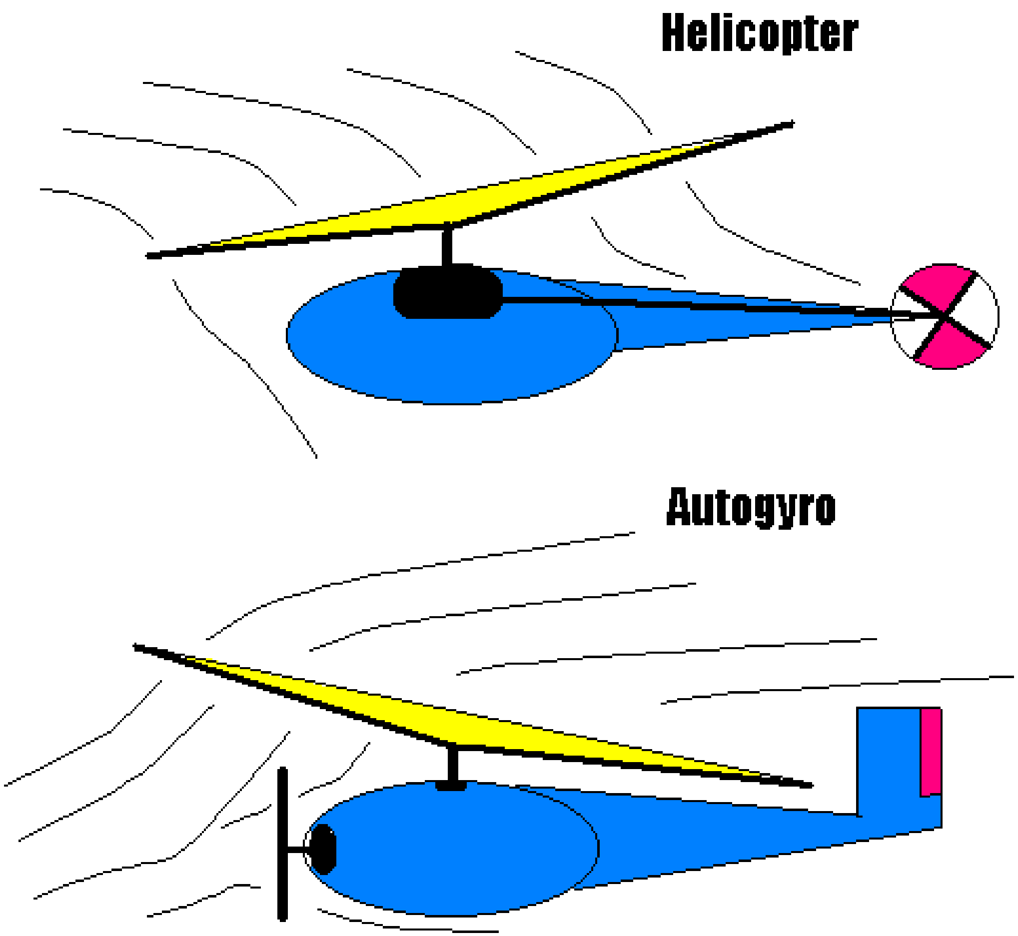

P-5

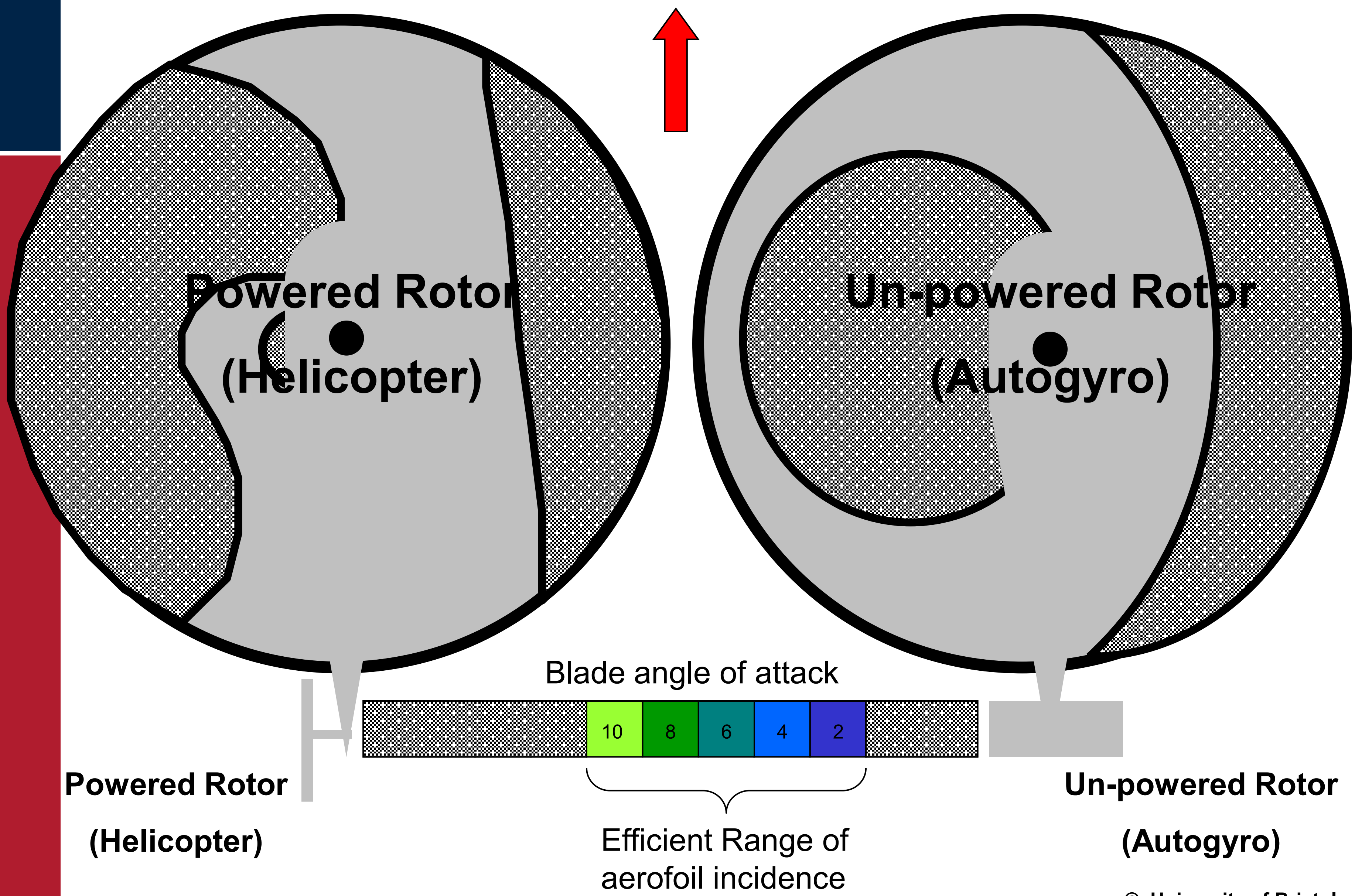
At least until the war years when Raoul Hafner took up the baton

Initially with the Rotachute………..… ….and then the Rotabuggy


Dr Igor Bensen developed the basic design into a form that has been adopted by nearly all sport autogyro designers to date.

# AVDASI 1 – Introduction to Rotary-Wing Aerospace Vehicles






**Powered Rotor**

**(Helicopter)**

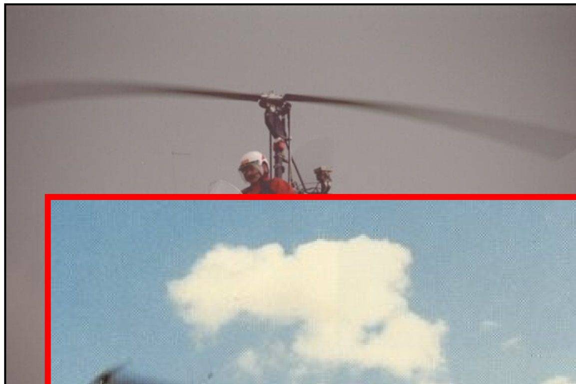
**Un-powered Rotor**

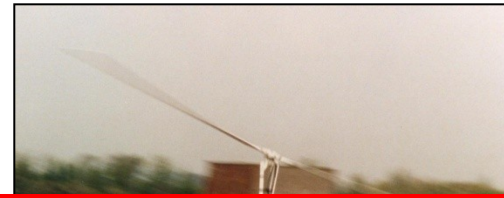
**(Autogyro)**

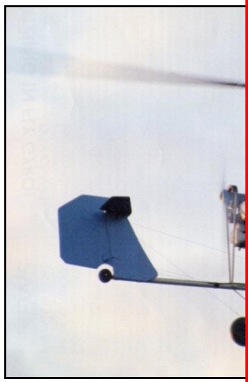
# AVDASI 1 – Introduction to Rotary-Wing Aerospace Vehicles

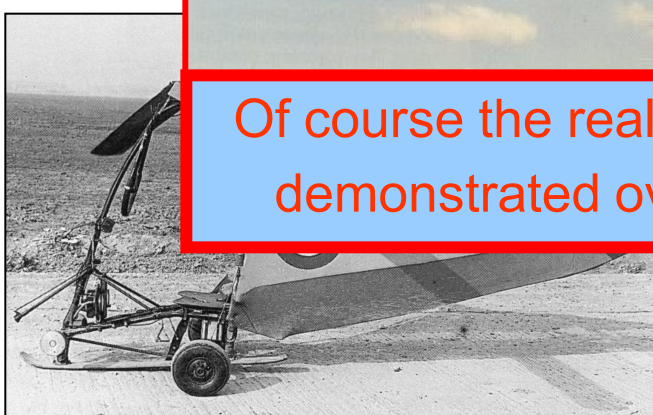
Increasing levels in sophistication of design












Of course the real future for the autogyro was demonstrated over half a century ago!




| | | | |
|---|---|---|---|
| Initial Cost (£ Stirling) | 139,000 | 100,000 | **185,000** |
| Operating Costs (relative) | Medium | **Low** | **High** |
| Payload Fraction (%) | 35 | **50** | 37 |
| Maximum Speed (mph) | **150** | 116 | 118 |
| Minimum Speed (mph) | **57** | 30 | **Zero** |
| Climb rate @ s.l. (ft/min) | 750 | **984** | **980** |
| Take-off Length (ft) | **735** | 262 | **Zero** |
| Landing Length (ft) | **656** | 98 | **Zero** |

# AVDASI 1 – Introduction to Rotary-Wing Aerospace Vehicles




| | Aquila A210 | "Super-Gyro" | Robinson R-22 |
|---|---|---|---|
| Initial Cost (£ Stirling) | 139,000 | 100,000 | **185,000** |
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| **IMAGE / SAFETY** PERCEPTION! | *Nice / Good* | *Ugh! / Scary* | *Cool / Acceptable* |

## Addressing the Autogyro's Image and Safety problem:

### Image - What is it?

- It's rarely (if ever) seen by "Joe Public"
- Ken Wallis* and more recently Barry Jones are excellent ambassadors for the marque but it needs more!
- The profile of the autogyro needs to be raised but, I suggest, not before the ***Scary*** issues are addressed.

### Safety - Is this an unfair perception or are folk justified in such a viewpoint?

- Upon inspection the lay person could be forgiven in thinking it has vital bits missing.
- The better informed may be enticed and will "give it a go".
- The more knowledgeable may be less willing to risk their neck.

Yet, inherently the autogyro is a very safe aircraft

* ***Died, September 2013, from natural causes, aged 97.***

**Consider the safety record**:

The Pioneering Years

January 17$^{th}$ 1923 – First successful flight of an autogyro.

December 19$^{th}$ 1932 – First autogyro fatality

This was a remarkable safety record: - during this pioneering decade… accumulating 35,000 hours and over 2.5 million miles

Cierva lost his life as a passenger in a DC3 out of Croydon.

Pitcairn died from two gun shot wounds to the head.

Hafner lost his life in a sailing accident.

Bensen died of natural causes.

**None of them died from an Autogyro accident**

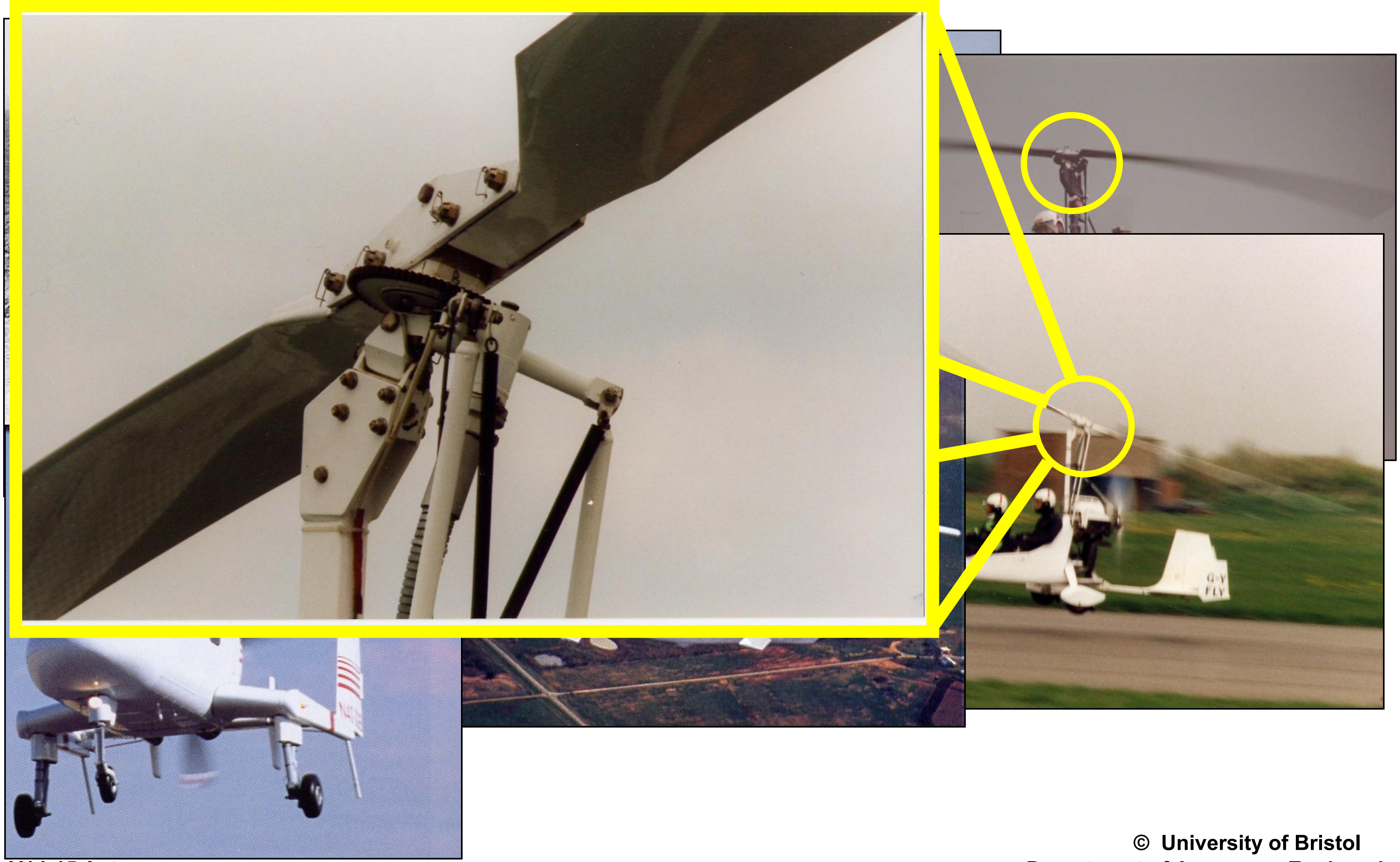
**So why has the accident rate soared, to the extent that the CAA grounded some types of autogyro, notably the Air Command ?**

## The Achilles' Heel:

### The Off-Loaded Rotor and Thrust Dependent Control

## The Achilles' Heel:

The Off-Loaded Rotor and Thrust Dependent Control

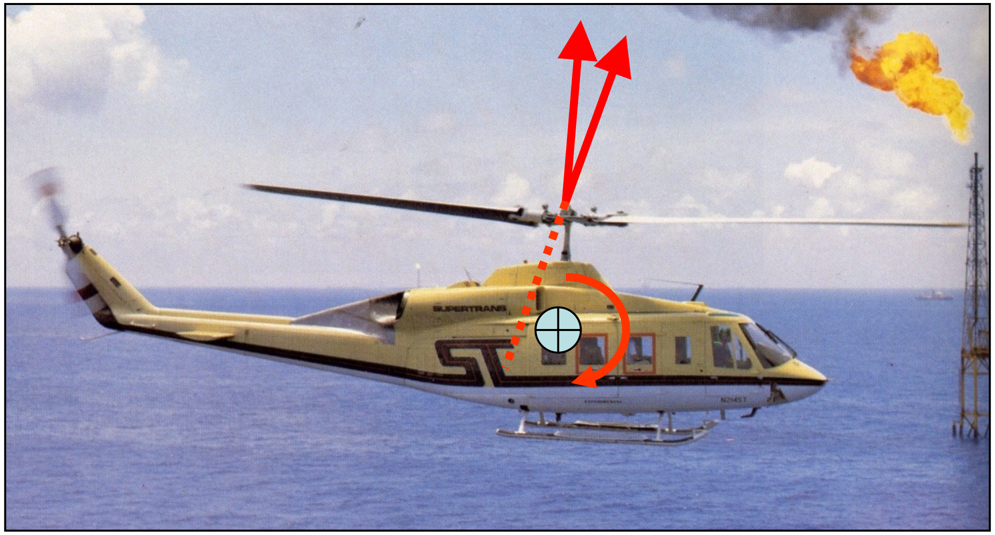


## The Achilles' Heel:

The Two-Bladed Teetering Rotor

Attributes - Cheap
- Simple (particularly conducive to stowage)
- no need for lead~lag dampers
- marginally better than a one-bladed rotor

Drawbacks - Cannot impart a moment into the airframe



Pitch and roll is achieved by orientating the thrust vector relative to the aircraft's centre of gravity.

This form of control is totally dependent upon thrust!

## The Achilles' Heel:

The 2-bladed teetering rotor became the "trade mark" of Bell Helicopters.

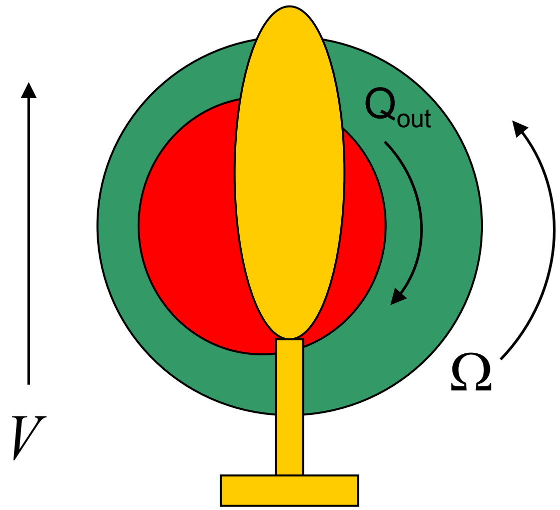
It gave a rough ride and compromised performance.

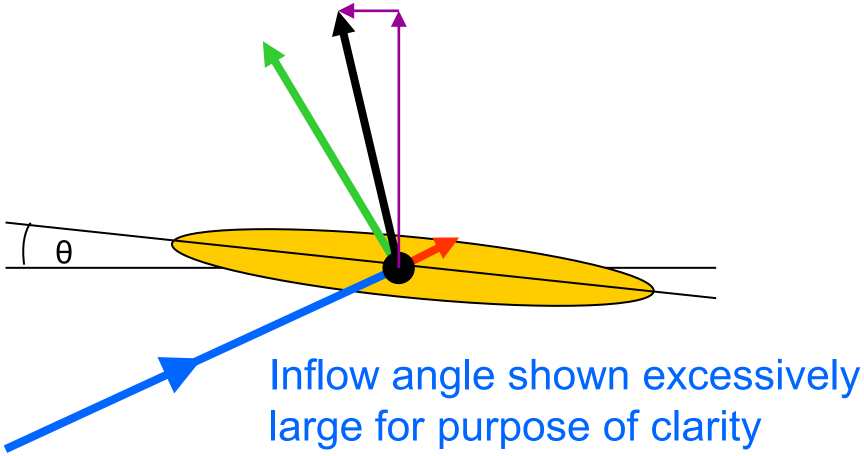
The total reliance on thrust-for-control gave variable handling qualities.

**But at least it had an engine to keep the rotor turning!**

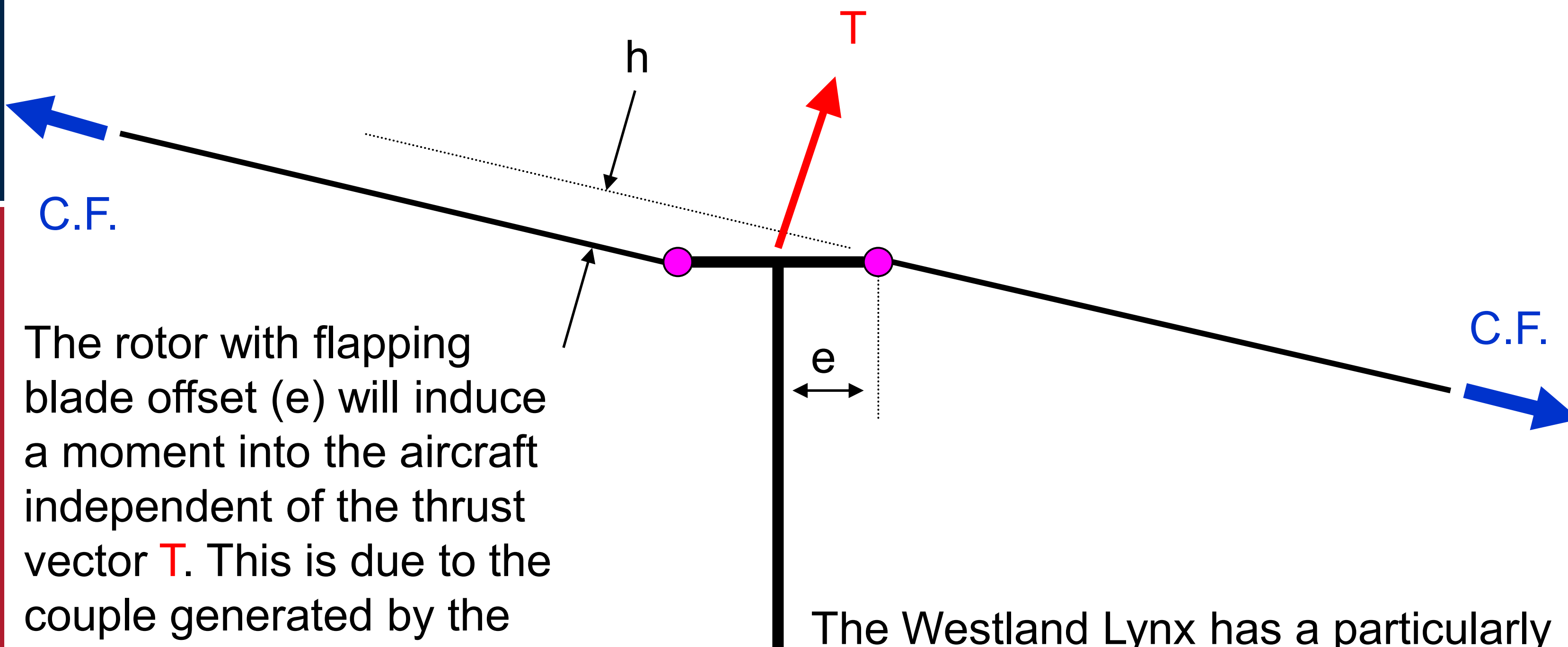
If a "Control-dependent-upon-thrust" characteristic isn't bad enough…..

…for the autogyro, the thrust vector is also required to keep the rotor turning.



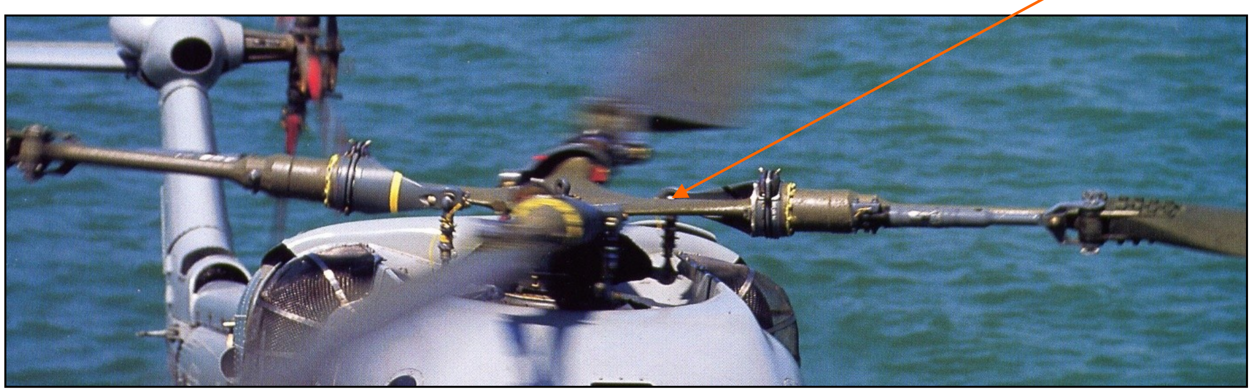



## The Solution: it already exists!

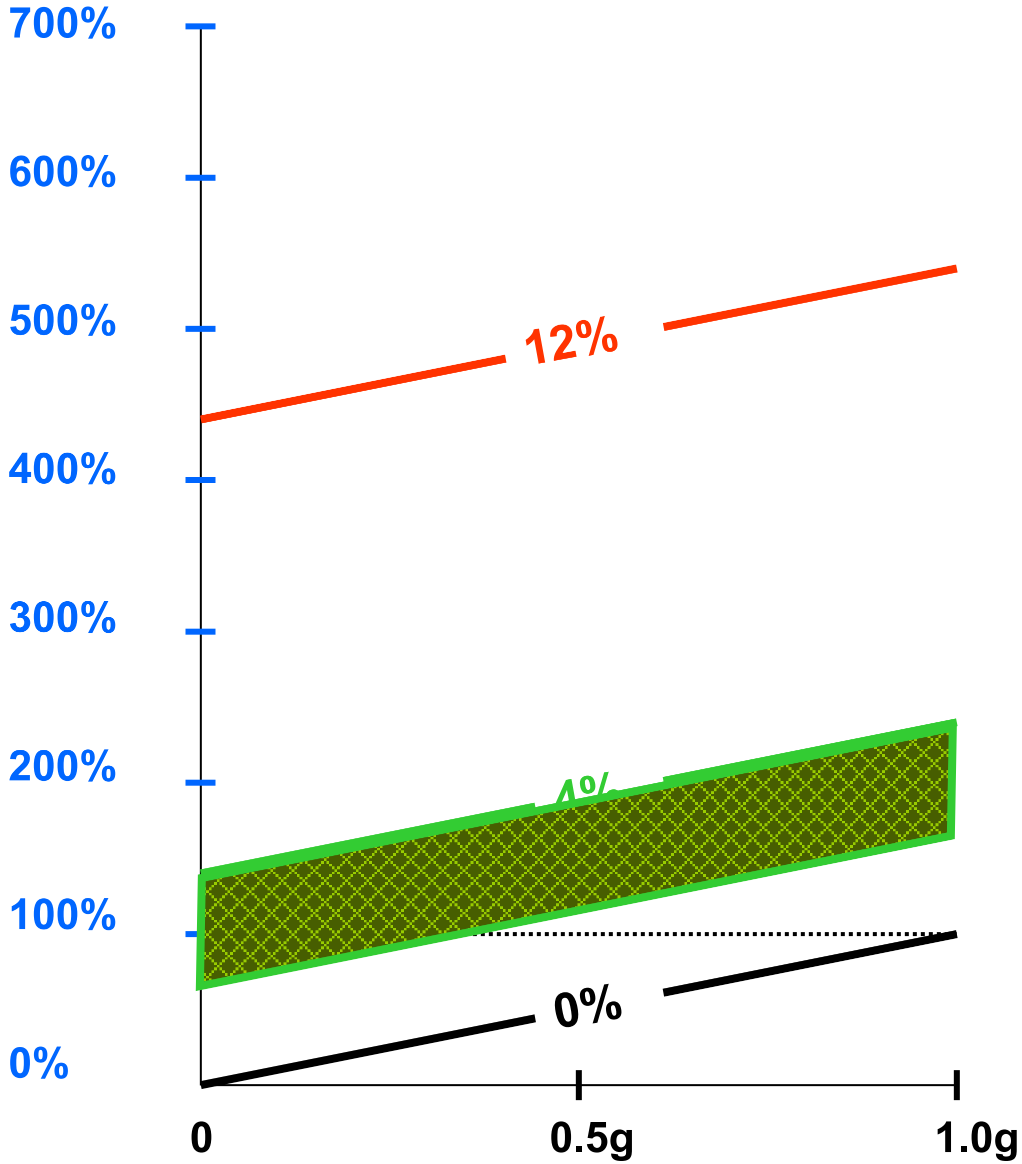



The rotor with flapping blade offset (e) will induce a moment into the aircraft independent of the thrust vector T. This is due to the couple generated by the C.F. and displacement h.

The Westland Lynx has a particularly high "effective offset" flapping hinge of 0.12R



Control power for zero hinge offset, 4% & 12%




It can be seen that the pilot of the Lynx helicopter is unlikely to notice any effect in the aircraft's control power due to change in rotor thrust.

The majority of helicopters have offset hinges between 2% and 4% of the rotor radius.

***Why hasn't such a control-independent-of-thrust rotor been fitted to autogyros, <u>where the need is greater</u>?***

**The "charm" of the autogyro is it's simplicity – move away from that and one run's the risk of reinventing the helicopter !**

**A little restraint is called for - *It's time for a*** *"Super-Gyro"*

Rotary Wing INNOVATIONS LIMITED *


© Barry Jones (Gryojet)

- Enclosed 2-place cabin "tractor" design with excellent visibility
- Hingeless all-composite rotor system *(patent pending)*
- VTOL capability and enhanced handling characteristics

* *Rotary Wing Innovations Ltd is a University of Bristol Spin-out company*

## The Semi-Rigid Rotor is a partial solution, NOT a total solution.

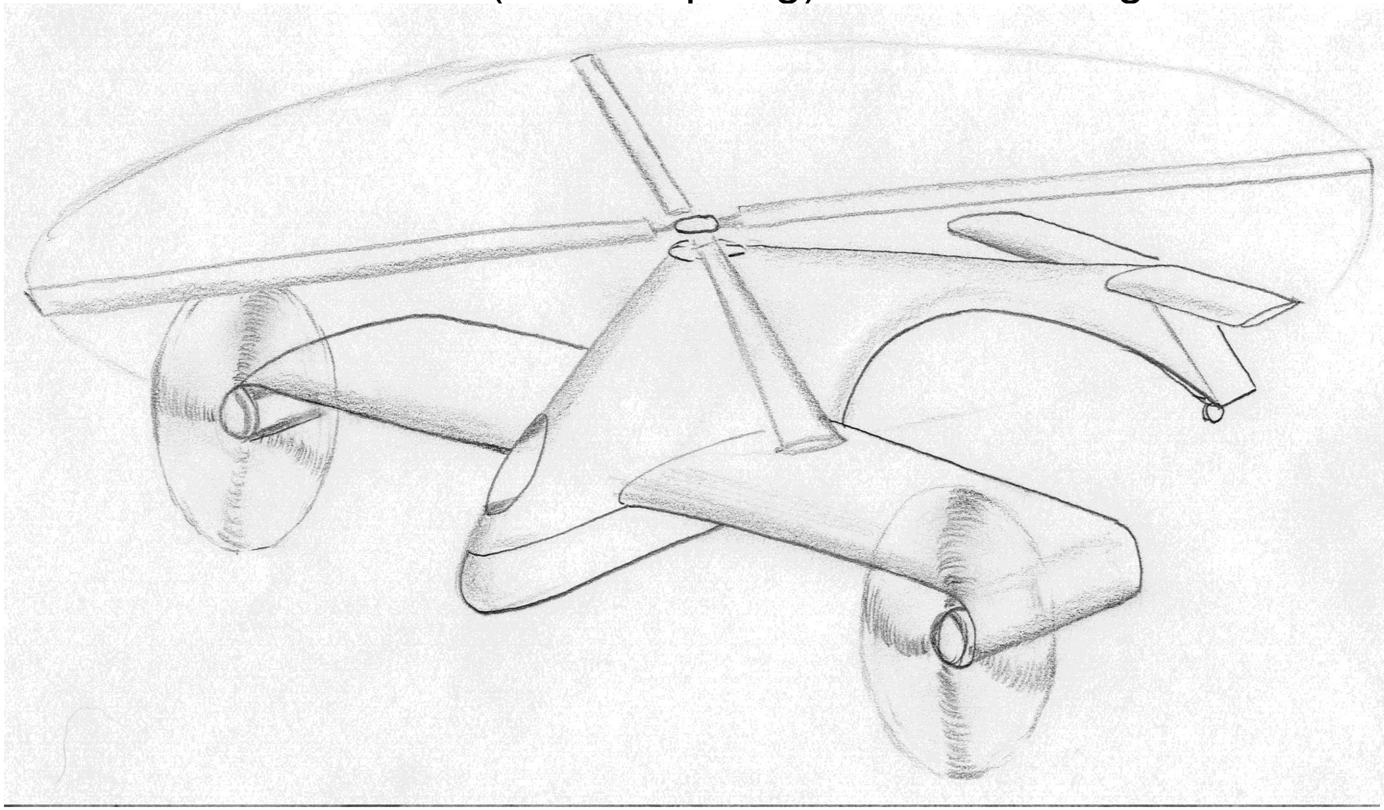
The semi rigid rotor, with high effective hinge offset, will not prevent rotor speed decay during periods of substantial off-loading of the rotor. However, it will provide the pilot with the control authority to re-establish rotor thrust before the rotor speed deficiency has reached a level from which it cannot be recovered.

Attention to propeller thrust lines with respect to the aircraft's centre of gravity, as investigated by Glasgow University will still be an important design consideration.

Whilst the experienced autogyro pilot will always keep the rotor loaded, there is a real need to remove the "never-push-the-stick-forward" rule if the autogyro is to be acceptable to fixed wing pilots – who will invariably revert to their first learnt instinctive reactions in an emergency.

## University Research: A Grand Challenge

In addition to the specific autogyro research the Department of Aerospace Engineering is involved with More Electric Aircraft, Smart Materials (incl. morphing) and UAV's in general.



For all these technologies, a technology demonstrator is required.

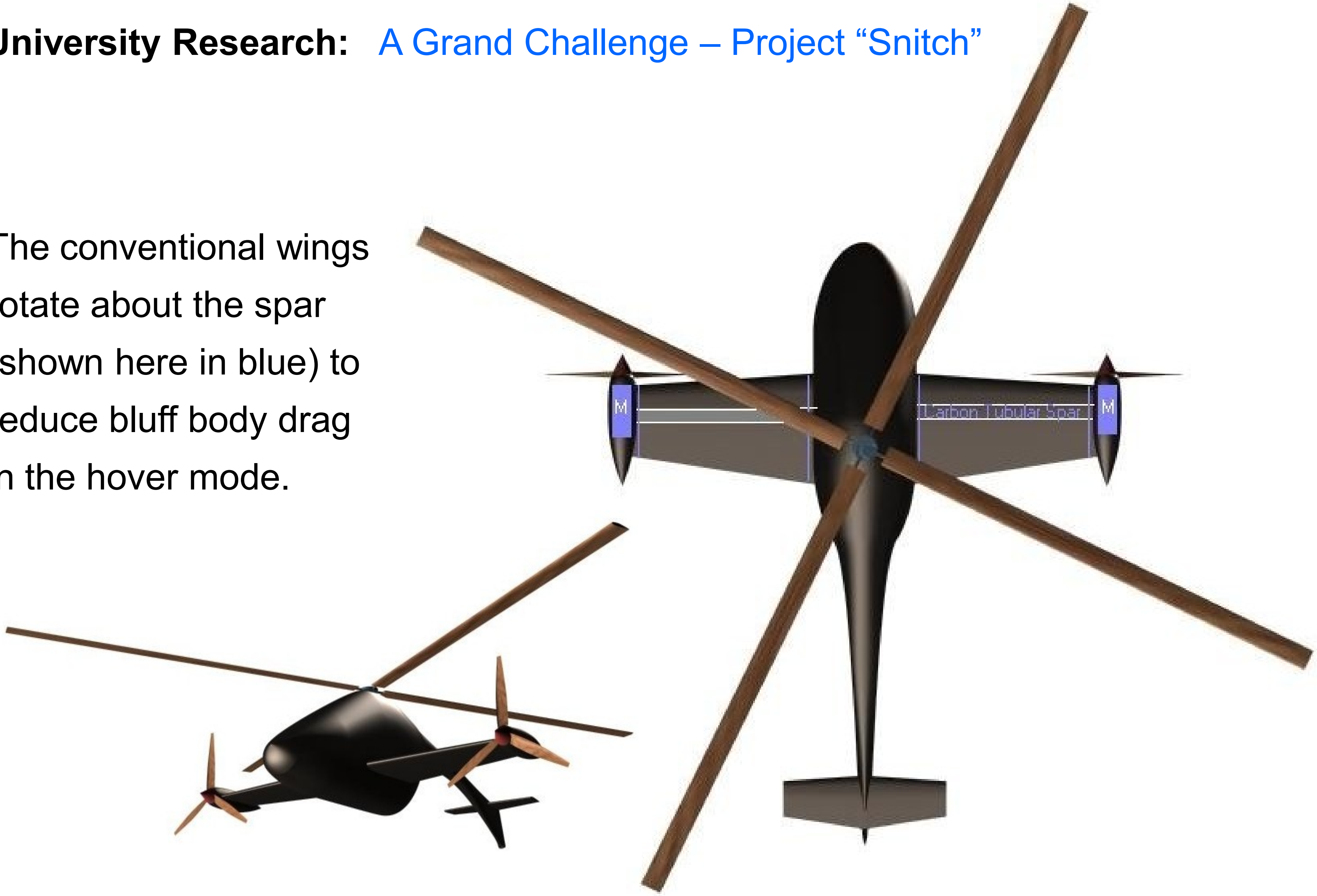
**University Research:** A Grand Challenge – Project “Snitch”


This is essentially an all-electric development of the Rotodyne configuration.

It will primarily function as a technology demonstrator but will also provide an aerial platform that may attract commercial interests. Many of the autogyro related research studies previously mentioned can be developed on this vehicle.

## University Research: A Grand Challenge – Project “Snitch”

The conventional wings rotate about the spar (shown here in blue) to reduce bluff body drag in the hover mode.



**University Research:** A Grand Challenge – Project “Snitch”

## Proposed aircraft Characteristics:

- Maximum take-off weight = 400 lbs (~180 kg)
- Installed power = 107 bhp (80 kW)
- Number of blades = 4
- Rotor diameter = 10 ft (3 m)
- Blade chord = 3.6 ins (91 mm)
- Rotor speed = 1200 rpm (nominal)
- Maximum speed = 180 knots (333 km/hr)
- Payload = 20 kg

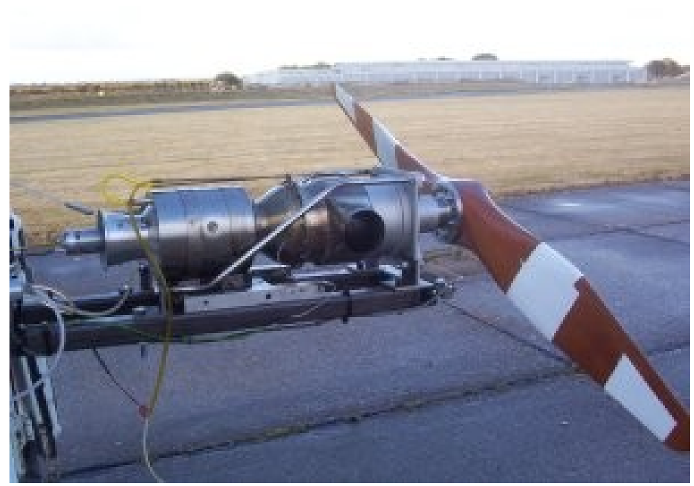
**University Research:** A Grand Challenge – Project "Snitch"

## Primary Power Source:

Gas Turbine (with shaft drive)

Engine illustrated is the HF65KTS from Microjet Engineering.

- 60 shp (continuous)
- 82,500 rpm
- 9.1 kg (without g/b)
- 0.48 m length
- 0.15 m diameter



HF100KTS engine under development:

- 120 shp
- 40,000 rpm
- 15 kg

◄ X 2 …… ? ……X 1►

Yet to be decided !

**University Research:** A Grand Challenge – Project “Snitch”

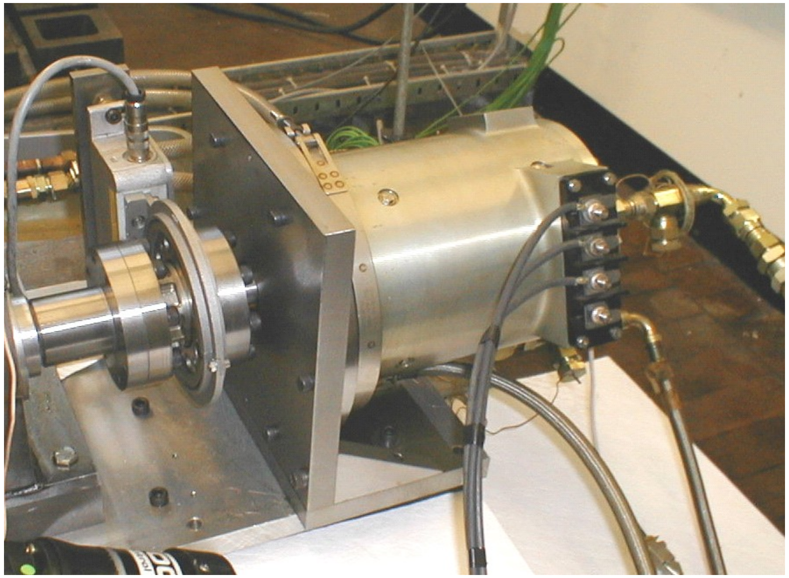
## Electric Drive Technology:

25 kW Motor (low speed)

- 1,000~3,000 rpm
- 92 % efficiency
- 18 kg mass

36 kW Motors (high speed)

- 3,000~5,500 rpm
- 91 % efficiency
- 15 kg mass



75kW Electrical generator

- 50,000 rpm
- 88 % efficiency
- 12 kg mass

**University Research:** A Grand Challenge – Project "Snitch"

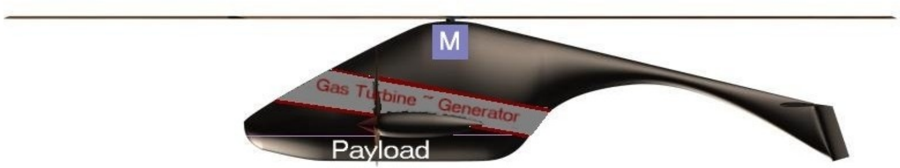
## Drive Configuration:

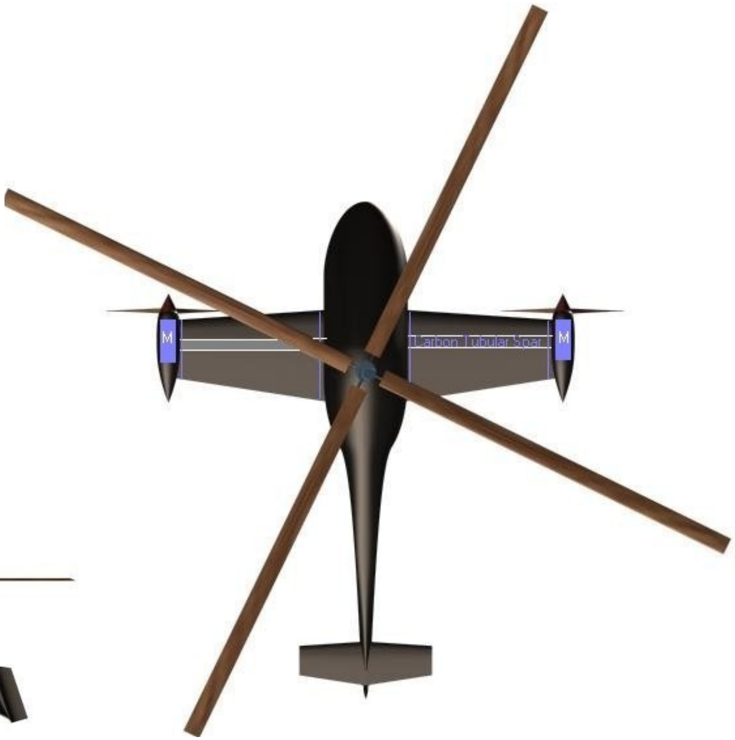
1 x 80 kW turbine engine

1 x 75 kW electric generator

1 x 25 kW (low speed) motor

2 x 36 kW (high speed) motors



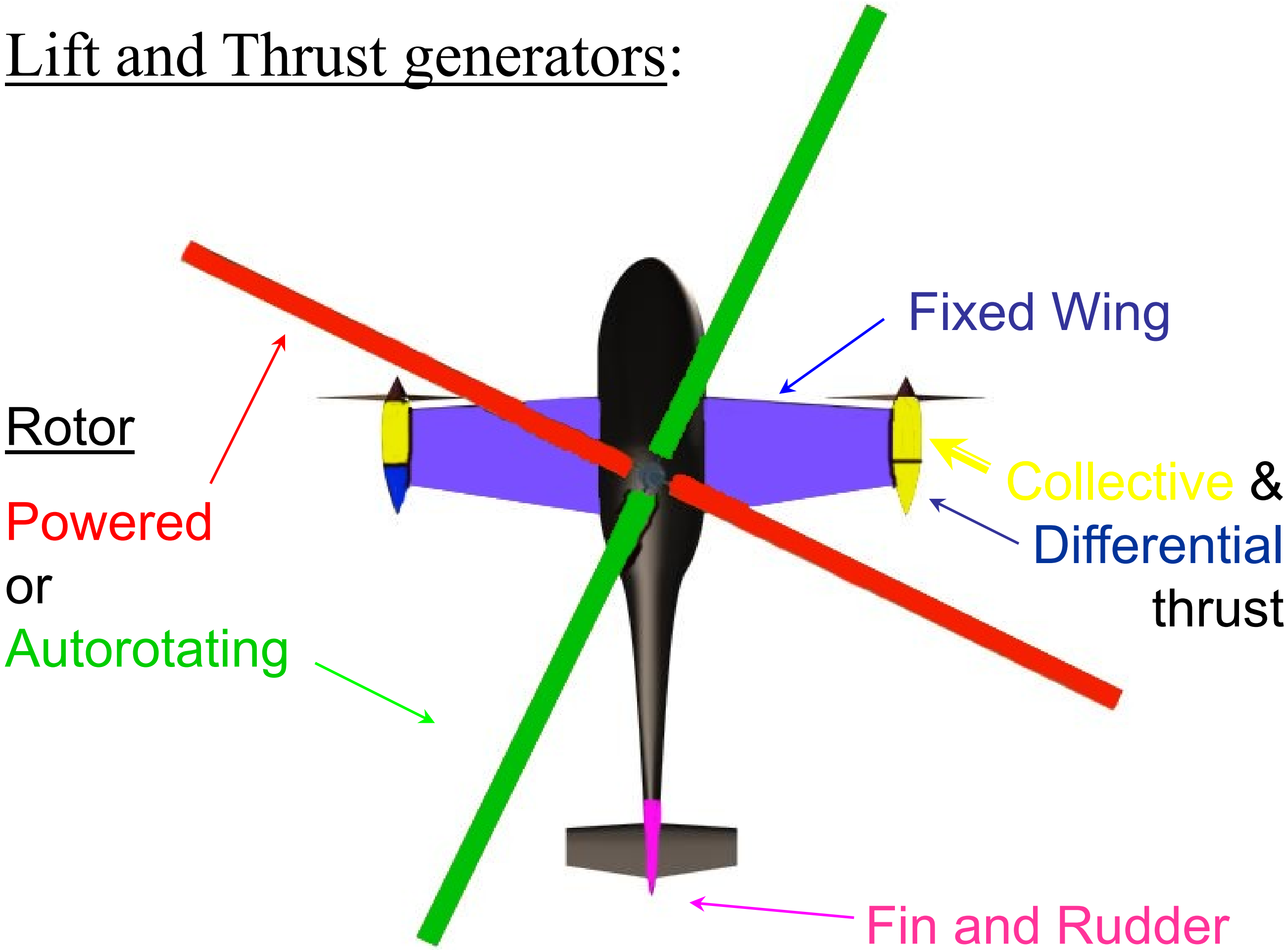




Gas turbine(s) are inclined to avoid exhaust impingement on tail plane

Tubular spar (shown in blue) provides route for electric power cable.

**University Research:** A Grand Challenge – Project "Snitch"

Lift and Thrust generators:



## University Research: A Grand Challenge – Project "Snitch"

| PERMUTATIONS OF TRIMMED FLIGHT | | | | | | |
|---|---|---|---|---|---|---|
| Trim ▶ | Lateral | Longitudinal | | | Yaw | |
| Reacting ▶ | Roll | Weight | | Drag | Torque | |
| VTOL | ++++++++++++ | PR | | ++++++++ | dP | |
| Low Speed | W | PR | | | dP | F |
| | W | AR | | P | ++++++++++ | dP |
| Cruise | PR | W | PR | | dP | F |
| | PR | W | PR | P | dP | F |
| | AR | W | AR | P | ++++++++++ | F |
| High Speed | | W | PR | P | dP | F |
| | | W | AR | P | ++++++++++ | F |
| | | W | PR | P | F | |
| Power-Off | W | AR | | +++++++++ | dP | |

**Key :**

| | | | | | |
|---|---|---|---|---|---|
| PR | Powered Rotor | W | Fixed Wing | AR | Autorotating Rotor |
| P | Propeller Thrust | dP | Differential Propeller Thrust | F | Fin and Rudder |

**University Research:** A Grand Challenge – Project "Snitch"

## Proposed programme of work

Three development aircraft (A, B and C) are planned:

A. Half scale, autorotative flight only. Aluminium construction and conventional power unit (IC). For performance and stability tests.

B. As "A" but with electric drive (tethered by an umbilical power cable et al). For hover performance and stability tests.

C. Full size, hybrid construction (aluminium and composite) with integrated electric drive. For the full range of tests.

*These three aircraft will lead the way to the definitive air vehicle as described in an anticipated (but very funding dependent) five* years.

## University Research: A Grand Challenge – Project "Snitch"