COANDA – A NEW AIRSPACE PLATFORM FOR UAVS

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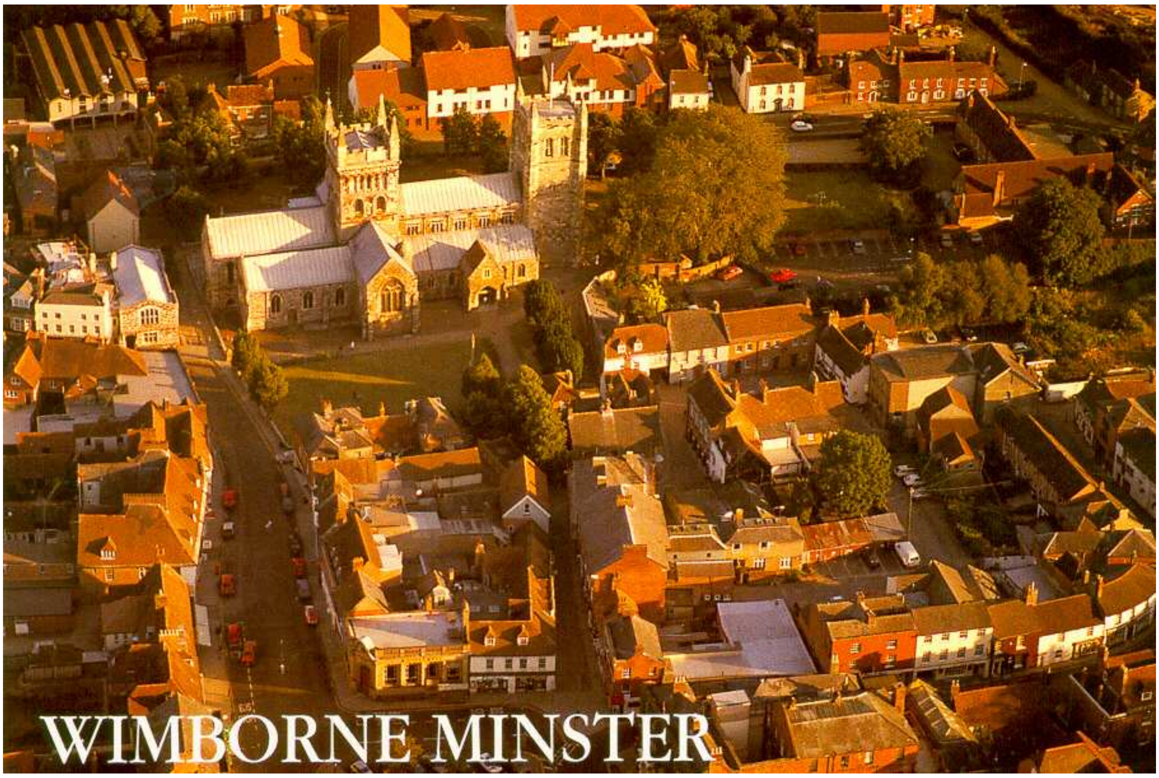
My paper is entitled "Coanda - A new airspace platform for UAVs" and whilst it is confined to UAVs I expect it will become clear that it may have wider applications.

I believe it is true to describe it as a **new** airspace platform because my reading and researches have not so far revealed a similar concept in the public domain or presently under development.

The Coanda concept grew out of a requirement and an interest in possible **civil applications** for UAVs although I assume there are many common factors with military applications. I have deliberately avoided possible military applications and although I have been active in the defence industry for many years I do not feel best placed to comment in this regard.

There is a long way to go before the development of UAVs make them suitable for operation in the civil theatre and so my work should be viewed as largely experimental but never the less aimed at some of the problems that will be encountered along the way toward acceptance by the general public.



My sponsoring organisation has conducted a **requirements analysis** for urban area operation of UAVs and whilst I do not think that the requirements can be satisfied at present, it is never the less an interesting design challenge.

This is a picture of Wimborne Minster in Dorset and is typical of the sort of small town urban area in which Coanda is designed to operate.

You will not be surprised by the fact that UAVs already operate in Winborne Minster. If I look from my office window on a typical day I might find two or three perched on my window sill, fuelled and mission ready. They pose little threat to the population from the point of view of safety and hence they are tolerated. There is no legislation in place to prevent their operation and even if there were they would pay little heed. They operate at negligible cost to the populace, requiring little or no maintenance and with an MTBF of greater than 40,000 hours. The flight phase of a Mission is typically from one or two minutes to about thirty minutes, long enough to survey the whole of Wimborne Minster town if only we could get them to do it.

What came out of the requirements study is that at the present time no known man made UAV stands any chance of matching their performance.

Just to touch on a few of the requirements that came out of our study for urban area application of UAVs:

Public safety is of course a fundamental requirement. I believe that in order for a UAV to be acceptable as a public utility the risk to a member of the public will have to be less than the risk of say being injured by a pigeon falling from the sky, what ever that risk might amount to.

Operational and support costs must be very very low. It will have to be simple to operate which is synonymous with safe and reliable. It should be as cheap as a pigeon (you will pardon pun).

It will be required to operate from **confined places** with **minimal danger of human contact with rapidly moving parts** such as rotor blades or active rudders. Maybe in the way a bird avoids human and any other contact that may risk its safety and fortuitously, avoid danger to us from its flapping wings.

It could not employ chemical propellant thrusters nor exotic or high-energy fuels for similar safety reasons.

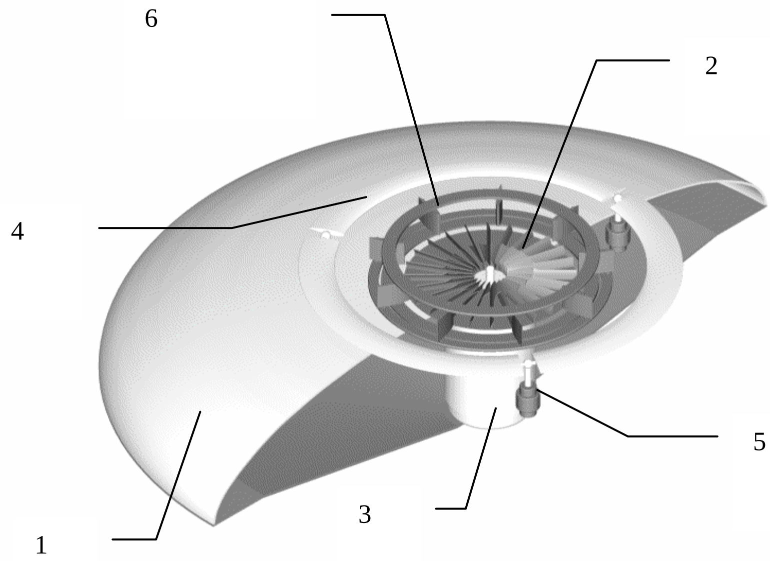
It will be impossible to justify their use if **special facilities such as landing and take off areas or special provisions for fuel handling and storage are necessary**.

It would be useful if they could be **deployed from and recovered to ordinary moving or a parked vehicle** or perhaps **dispensed or dropped from and possibly recovered to other air vehicles**.

There are many more constraints but these few that I mention serve only to illustrate the line of development that I am pursuing, but particularly, Coanda originates as a concept from a **formally defined requirement.** I firmly believe that all the requirements identified for public, urban area operation can be overcome by a systematic approach to development of a UAV.

Clearly the constraints that I have touched on apply to most UAV platforms in one way or another.

The focus of my paper is on several possible configurations of a UAV platform that is designed to overcome at least some of these constraints.



Here is cut away illustration of the **basic** Coanda platform based on the experimental versions now under development.

1. is a specially developed curved upper surface.
2. is a disk fan designed to accelerate air over the upper surface of the UAV.
3. is the motor driving the disk fan.
4. is the lift and horizontal propulsion control mechanism.
5. are control actuators for the lift and horizontal propulsion control mechanism.
6. is the motor torque cancellation and steering mechanism.

Despite impressions that may be forming in your minds, this is an unmanned air vehicle platform and is definitely not extra terrestrial. Although in this embodiment the aircraft is an inverted saucer shape and may resemble a UFO, this is coincidental and no significance should be attached to this.

The most significant aspect of the concept is that it does not depend on conventional fixed or rotating airfoil sections, vectoring jets or thrusters or even flapping wings to effect lift but it does have VTOL capability never the less.

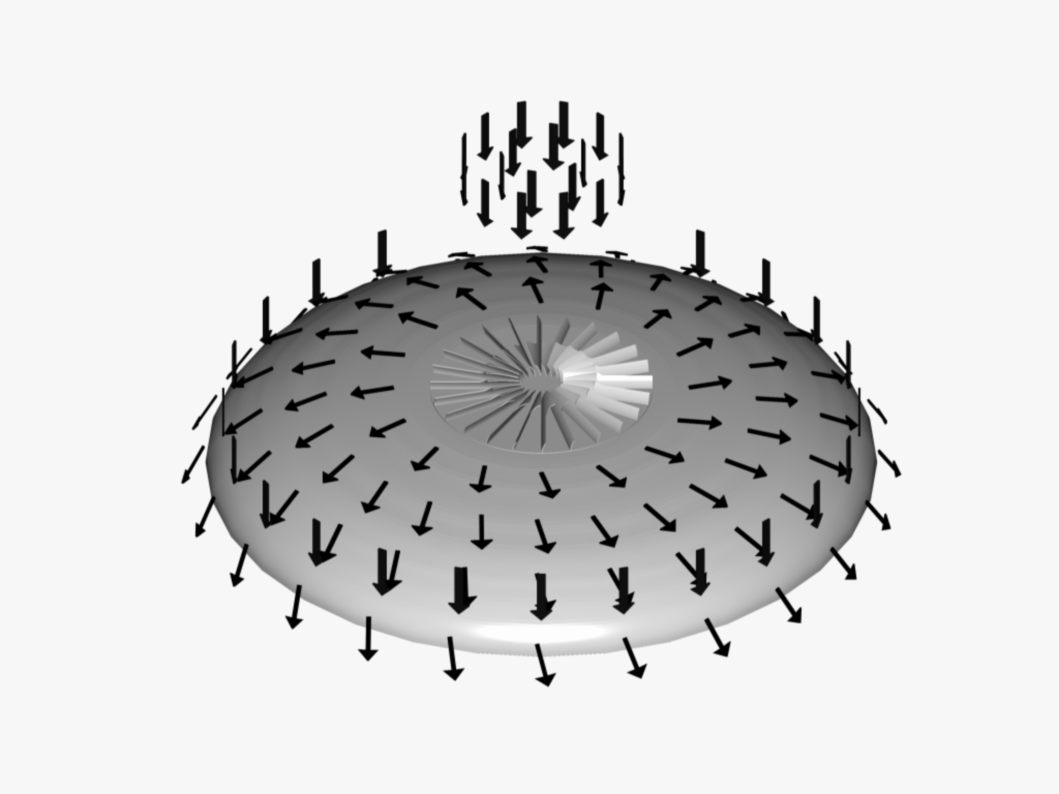
So how does it work?

Lift.

Lift is generated principally by the Coanda effect, hence the name.

As you can see the device is a disk with a radial fan at the centre. I would like you to note that the fan is inboard of the plan area of the disk, which partly comes about as a **safety**

requirement. Consequently, it is not easy to come into accidental contact with a rapidly rotating fan blade, as might be the case with a helicopter for example.



In this simplified illustration I have attempted to explain the lift mechanism. Air is drawn into the disk fan at the centre of the aircraft and a component of lift is developed by this action.

The air is accelerated radially over the upper surface of the body by the action of the disk fan and due to wall attachment or Coanda effect attaches to the upper surface of the aircraft but does not, as you might expect, pass through the body of the aircraft but just over the upper surface.

The air accelerated in this way is deflected downwards by the body curvature toward the lower rim of the body. On reaching the lower rim the air stream readily detaches but by this time, it is moving in a substantially downward direction and thereby imparts further lift to the body as it detaches.

Due to turbulence in the upper regions of the air stream accelerated over the surface, additional air is drawn from above the aircraft and enters the air stream. I call this process induction and it results in a reduction of air pressure above the body as well as contributing to the air mass accelerated over the upper surface of the body, which further contributes to lift.

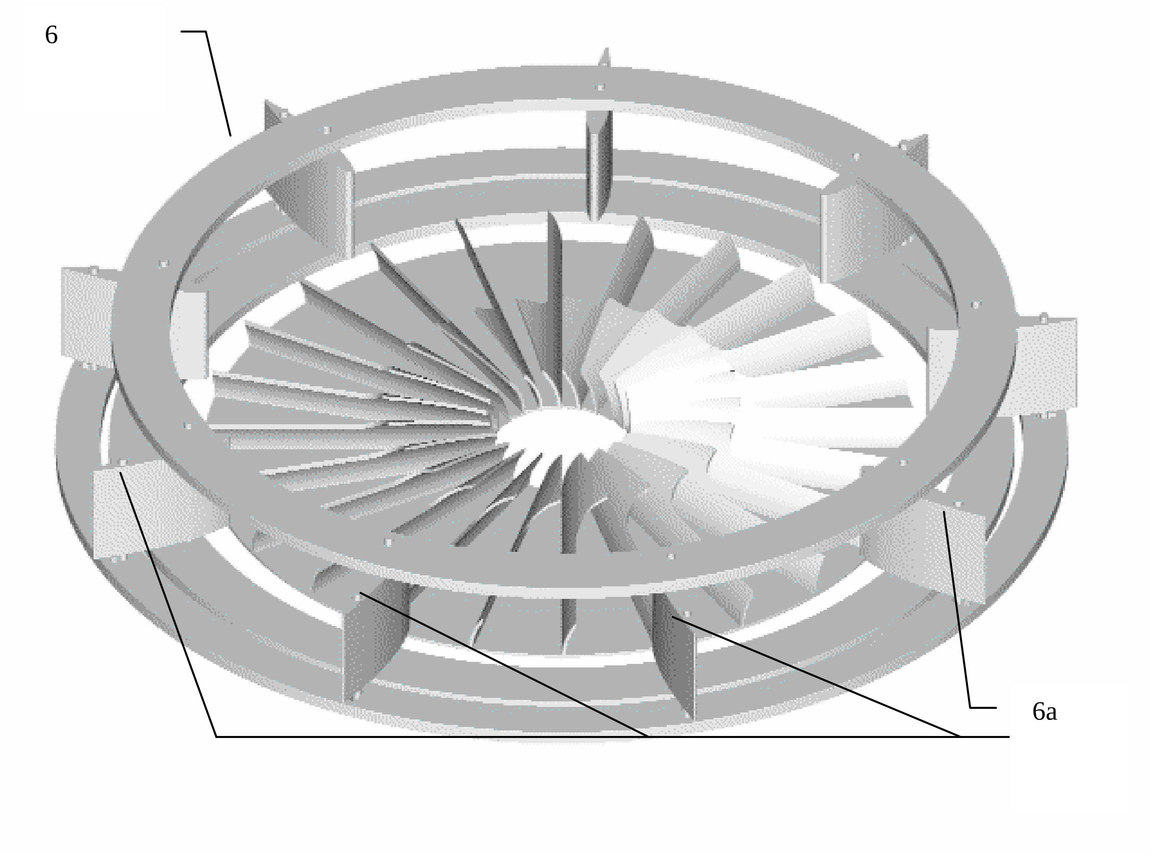
Although the arrows indicating the induced airflow are drawn at the outer edge of the body, induction occurs over the whole plan area of the UAV to some degree and in deed over a greater area than the plan area.

Lift then has three contributing factors, the first of which is the upward reaction to air being drawn into the disk fan. The second factor to the lift force results due to the induction of air into the air stream due to the disk fan and the resulting reduction of air pressure above the UAV. The third factor is that the combined mass of air from the disk fan as well as that induced into the air stream is accelerated downwards by the action of the specially curved upper surface of the aircraft as it detaches and spills from the lower rim of the aircraft.

An interesting feature to note is that the lower surface of the body serves only as a structural member and might be omitted. Coanda has no great need for a lower surface and the underside of the body resembles a parachute profile. One idea being explored is that this feature might be exploited in the event of power failure. The hope being that given satisfactory stability, which might be achieved simply by positioning the centre of gravity, then it might descend in the manner of a parachute and thereby reduce the risk of inflicting injury to persons or damage to property in the event of power failure.

Of course, the rapid rotation of the disk fan and its driving power source results in torque, which tends to rotate the body of the aircraft in the opposite direction to the disk fan. This torque of course has to be countered to avoid this tendency but it is also used to effect attitude control or steering of the aircraft.

Torque cancellation as well as attitude control (steering) is effected by simple passive means. In a single rotor helicopter, for example, torque cancellation and steering is effected by means of active rudders (or vectoring jets or thrusters) which are complicated by the fact that parts in rapid motion have to be controlled. Coanda controls torque and effects attitude control by simple passive means. By this, I mean that there is no need to couple rapidly moving parts such as rotor blades to parts that are not in rapid motion such as a steering column or stick.



Close up detail of the disk fan and motor torque cancellation and steering mechanism

6a are yaw adjustable aerofoils disposed about the disk fan and controlled by rotating the outer ring of the mechanism.

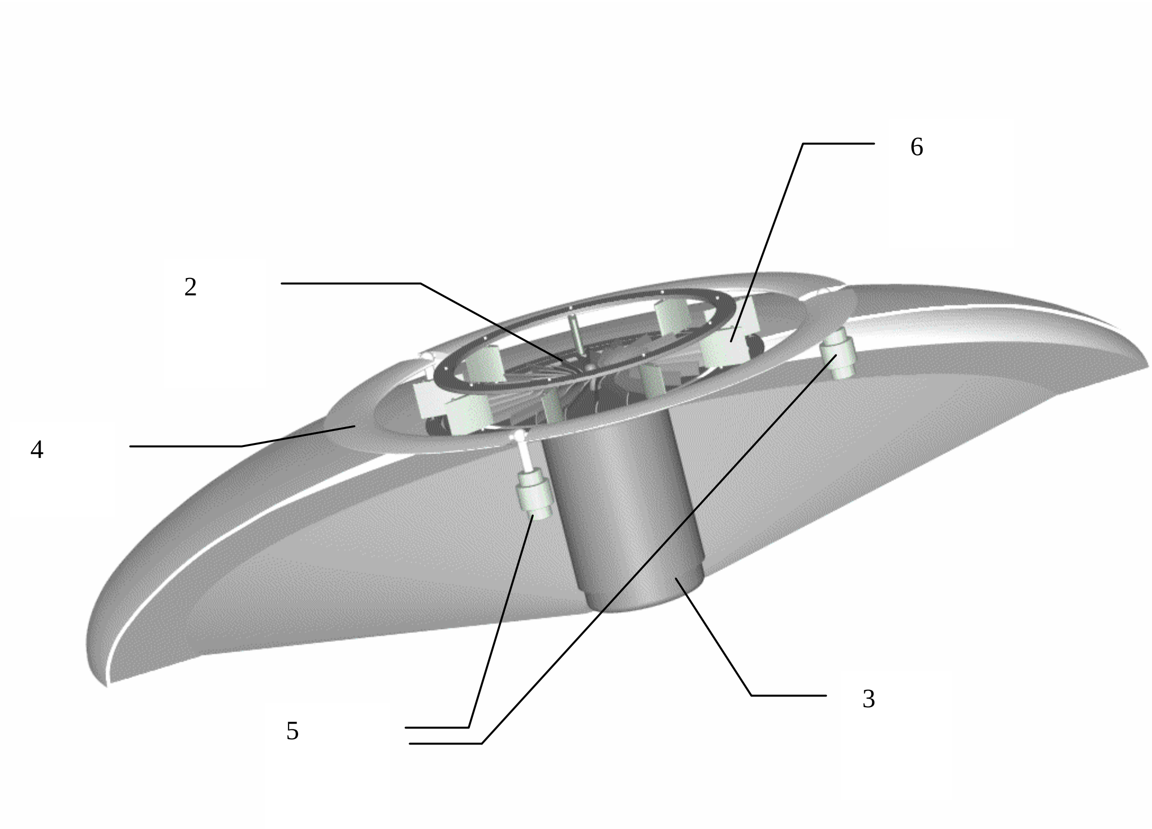
As you see, the disk fan resembles a conventional turbine as might be found as a compressor in a gas turbine engine for example. I believe that as a main provider of lift the turbine or radial fan as I call it is an unusual application but ideally suited to the Coanda.

Motor torque cancellation and steering of the UAV is effected by adjusting the yaw aerfoils by means of the outer ring.

The requirement dictates electric power and thus storage of chemical fuel is avoided plus of course stored solar energy, as a power source is a possibility.

The development model is driven by a 750W DC electric motor and directly drives the disk fan at several thousand RPM. This being the speed predicted for the type of disk fan so far illustrated which is of the order of 100mm radius for an aircraft body radius of 500mm.

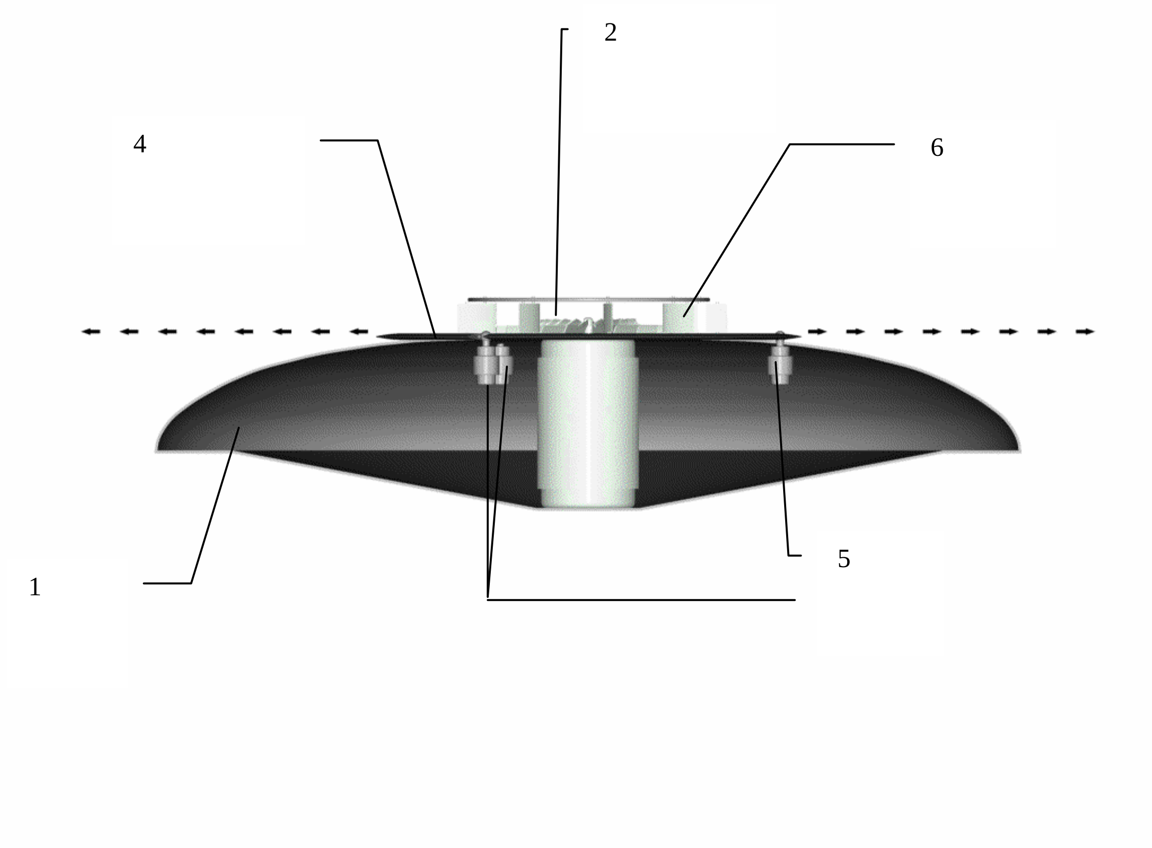
This is just another section view of Coanda which demonstrates the relatively large volume for payload but of course I have conveniently ignored the power storage problem. Never the less I believe that the circular or polygonal plan form will offer payload volume advantages.



As well as just going up and down of course, the vehicle has to be capable of moving horizontally. The transition from the hover to the horizontal mode may be achieved in a number of ways but very simply by a process of local detachment of the boundary layer air stream, which may be effected by simple passive means. I mean by that that there is no requirement for pitch changes to active rudders or the redirection of vectoring jets or thrusters, such as may be employed by a helicopter.

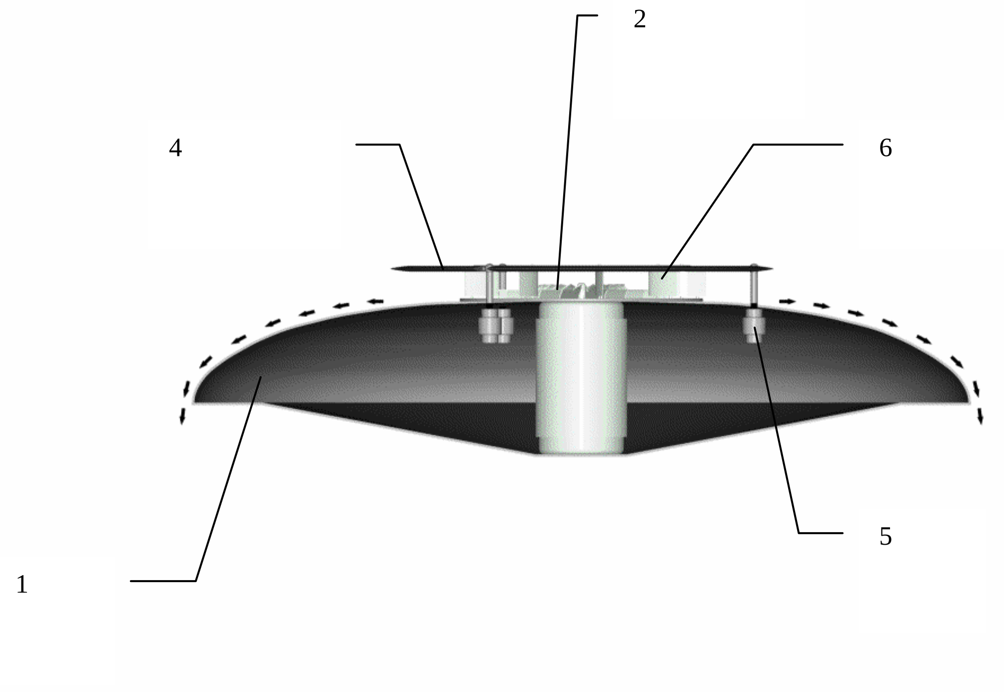
In common with all VTOL aircraft, controlled ascent and descent necessitates the careful dynamic balancing of lift forces to gravitational and other forces. This air platform is no exception. What is significantly new in my view is that dynamic control of the lift force is achieved very simply and in a novel way without the necessity of coupling parts in rapid motion to static control means such as those found in the cyclic control of helicopter aerofoils.

The following illustrations show one of several methods of controlling lift that are under investigation.



The lift and propulsion control mechanism is a circular aerofoil disposed around the motor torque cancellation and steering mechanism controlled by a number of linear actuators such that it can be moved uniformly up and down as illustrate or inclined.

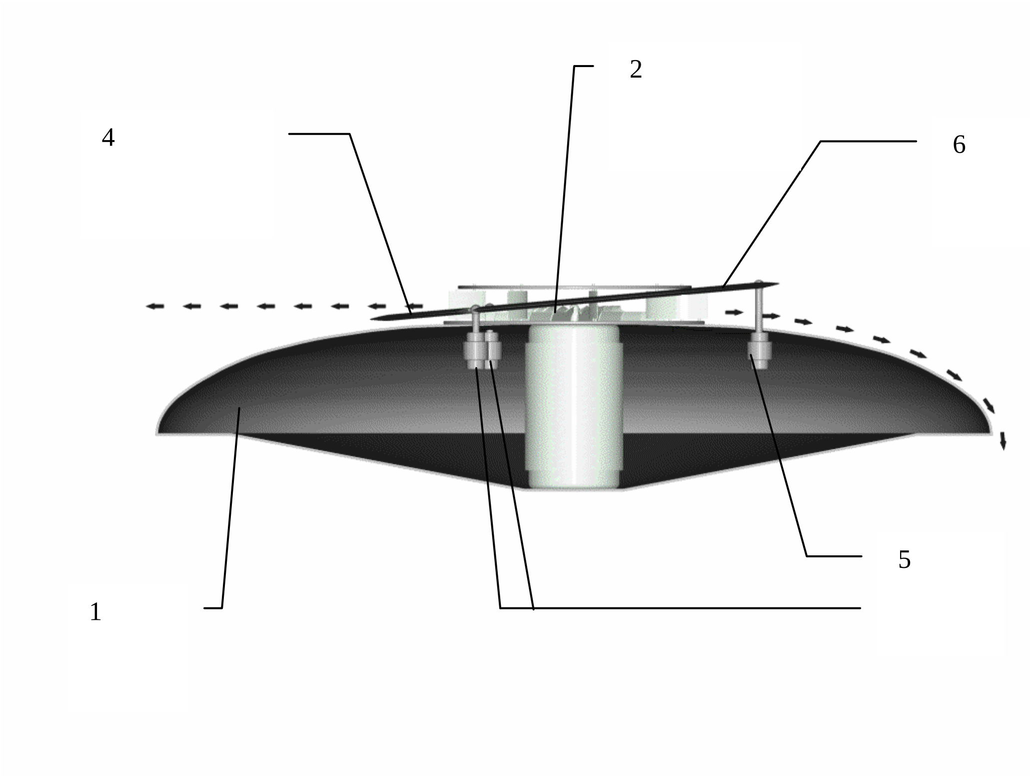
In the first illustration, the lift control mechanism is uniformly lowered such that the air stream from the disk fan is deflected away from the upper surface of the UAV and hence there is no attachment and hence no lift imparted to the aircraft.



In the second illustration, the lift and horizontal propulsion control mechanism is uniformly raised such that the air stream from the disk fan is allowed to attach to the upper surface of the UAV and hence there is maximum lift imparted to the aircraft.

The same mechanism is used to control horizontal motion. In the next illustration the lift and horizontal propulsion control mechanism is tilted by the independent action of the control actuators such that the accelerated air stream from the disk fan passes over the mechanism and hence does not attach to the upper surface of the UAV. Whereas, on the other side it passes under the mechanism and is allowed to attach to the upper surface. As a consequence there is an imbalance in the horizontal forces now acting on the UAV which result in acceleration in the direction of the net force.

This is clearly just one of a number of methods that may be employed to effect horizontal acceleration. I am exploring other method of achieving this end but they do not meet the stringent safety requirements that have been set.



So in effect, lift and hence ascent and descent rate is controlled by the same passive mechanism as horizontal acceleration. I believe that this method of controlling the lift forces combined with directional control is unique to the Coanda design concept.

Another method of controlling ascent and descent rate actively under consideration is Pulse Width Modulation (PWM) of the electrical power to the motor. This is not a new technique and has been employed in model aircraft for many years. However, it is a technique, which lends itself particularly to small UAVs, more so if closed loop feedback control to compensate for varying loading forces is employed.

In this UAV, PWM with closed loop feedback is one of several options which can be employed during all flight phases and is very effective particularly during controlled ascent and descent.

Horizontal flight could be effected by any suitable conventional means such as propellers, jets or thrusters of some sort. However, the method currently under investigation relies on partial detachment of the air stream flowing over the upper surface.

I have chosen to illustrate my paper with just one method of several possible propulsion methods.

Applications

My work in this area is confined to non-military applications.

Perch and peer.

The notion, with no claim to originality, is that a small version of Coanda will perch atop a “flag pole” type structure from which it may be supplied with power, control and communications links. Such a structure might be situated in an urbane area but of course acknowledging that this might not be permitted under present legislation for all manner of reasons. I merely wish to explore the possible engineering solutions.

From its perch, it would periodically lift off and survey (peer) an area and thence return to its perch.

This UAV concept lends particular credence to this notion. Firstly because of the VTOL capability coupled with minimal demands on mission duration. Even one minute in the air would be a useful mission duration requiring minimal pre-take off preparation.

In addition, a significant factor is that the Coanda concept yields a high effective volume ratio. That is to say, that the physical volume of the aircraft is a high proportion of the total airspace volume occupied at any one instant which permits a maximum payload volume.

The relative large upper surface area of the aircraft raises the possibility that this might be occupied by suitable solar panels to extend the power available or even sustain the aircraft in flight.

Aerial display.

Although a rather fanciful idea, but which is never the less one that appeals as an engineering challenge is that of a formation aerial display. A number of UAVs flying in formation display, perhaps within a sports arena would make an interesting and entertaining spectacle. The UAV would of course have to be capable of very versatile flight patterns, something that Coanda holds out some promise.

With these two examples I conclude my paper.

Bob Collins, 28th February 2002