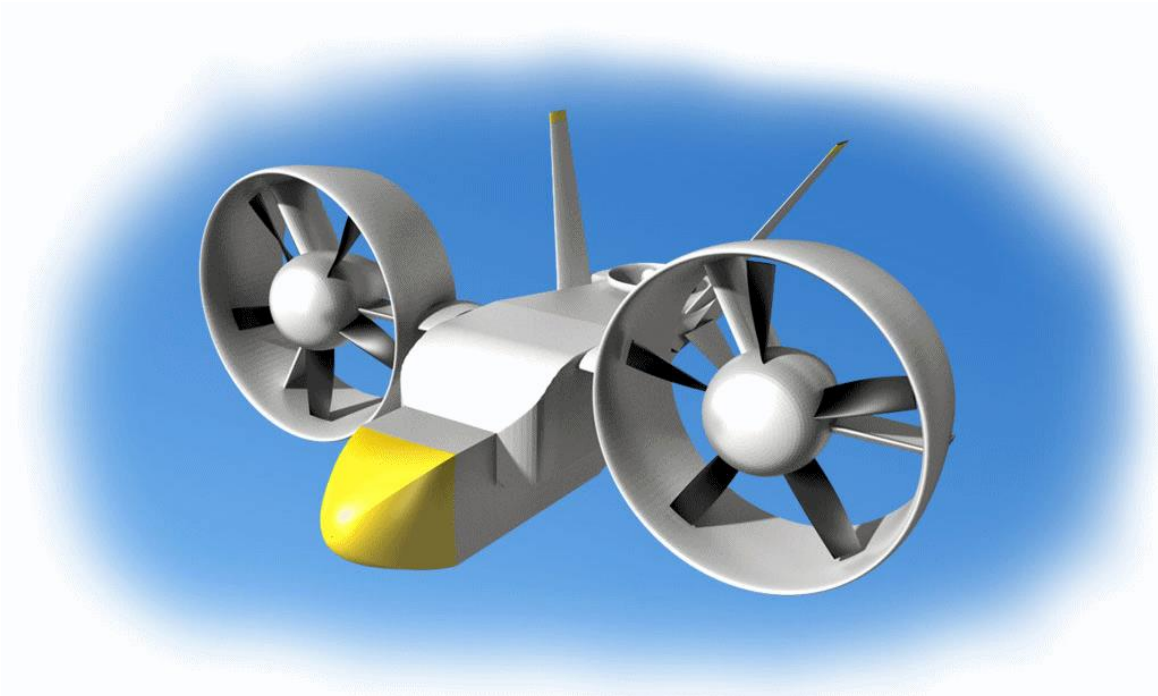

The promise of autonomy

In this first of a series of short white papers we address the dual challenge of technology and commerciality implicit in the development of the Sky Hopper® unmanned aerial system.

Summary

The use of UAV systems for civil purposes is developing rapidly, but what are the drivers of these developments and do they offer insights into the commercial future for unmanned aerial systems?

The paper looks at the recent development path for this technology and places them into an economic context, in which the potential of "droning", i.e. repeated value adding mission operations, is undertaken for commercial gain.

It concludes that there is great promise for the industry if the challenge of autonomous operations can be resolved to contain costs. It envisages a future in which specialised drone operations for specific purposes will separate from a more generalised higher mass logistics role; but that the actual tasks undertaken by UAV systems will by definition be unknown until they are tried in real markets with priced services.

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Picture: The Sky Hopper® autonomous cargo drone concept. Projected 100kg load, 150km range at 100+ knots.

The promise of autonomy

We are entering the age of robotics. For some this holds fears and risk, for others who enjoy innovation – and I am one – it offers an array of multiple industrial opportunities.

To grasp those opportunities demands an attitude to innovation as a process; a journey from A to Z rather than A to B – that is, a multi-step, and multi-participant, journey to discover knowledge, develop skills and work out new techniques that create commercial margins.

These two dimensions, technical knowledge and commercial realities are what fascinate our Sky Hopper® team about the emerging landscape in unmanned vehicle systems.

Elements of the journey

Automated systems become possible through the conjunction of physical systems and computerisation. In the former we have new materials and components that are stronger, lighter and often easier to create at economic cost using today's machine tools. In the latter we now have a vast array of pre-prepared routines in control input and output processing, data transmissions, pattern and image recognition, and smart computing that allows us to introduce elements of machine learning and artificial intelligence.

Those two domains, the hard physical componentry and the soft control techniques, combine to make autonomy possible for robotic developments. Of course, we have had autonomous automation since we first started using machines – the governor on early steam engines was a robotic mechanism to prevent runaway locomotion – but it is the spread of capabilities that makes the difference today. If we can find a way of gluing all the elements together, a new world of potential opens up because those capabilities can be applied across so many of mankind's activities.

Toys and trinkets as the starting point

Small-scale robotics applied to toys and trinkets has been around for some decades. The speed of electronic switching and stored logic rules have allowed us to control physical objects. We've had keyrings that respond to a whistle, birthday cards that sing to you when opened, or toy cars that turn before they hit a wall for many years. They come and go because they offer ephemeral joy at a very low price and so need rapid refreshing of their core idea to make any money for their creators.

Lighting that knows you are in a room, heating and cooling that reacts to localised temperatures, or lawn mowers that trundle around your garden are merely industrial versions of the same feedback mechanisms attached to higher voltage appliances, and if priced right might make good money for their developers. I say "might" because the take-up of simple home automation has been pedestrian; why pay hundreds of pounds to automate a cheap light switch and an index finger?

I make the point about these commercial factors deliberately; this journey is not simply one of joyful invention, real progress only comes when margins can be made from perceived value. Sadly, few of us can know when this can be made real; we have to find out.

Let's take another step forward in the journey to discover where the margins might be. The toy drone that self-controls its attitude and altitude and uses stored waypoints belongs in the same early technical space; combining low mass with high power to offer entertainment. But innovators have an eye for commercial applicability; so they hung a camera on the drone. Then people who understand the value of the visuals obtained used the drone not to photograph family picnics but power lines or crops or pollution; suddenly a new surveying industry has emerged because the drone can do something at a hundredth of the price of previous methods.

Of course, we should not forget the disruptive element of this change; the survey helicopter and film helicopter has lost some of its value as drone survey investigations have multiplied. Note the term disruptive rather than destructive; economic history tells us that the gross revenues of technical change involving price reductions by an order of magnitude, appearing through the arrival of a more flexible commoditised product, are increased not reduced. Think of Cartwright's spinning jenny, the triple expansion steam engine, or the model T Ford; we should not be pessimistic.

Taking the journey onwards

In a very real sense, it is the notion of using drones as a workhorse that brings it of age. The aerospace community frown on the use of the word "drone" for higher mass vehicles, preferring unmanned aerial vehicle or system (UAV/UAS). But this is a product, not a market, focus. The purpose of a drone is exactly that, its continuous repetitive presence while doing work[1] - droning.

Early toy drones worked as entertainers, the very opposite of repetitive use; creative flying performance has been to the fore, something that is unrealistic at higher masses due to physics. Innovators have now found ways of making survey drones do work as stable imaging platforms, becoming suppliers of pictures and sensed data of repeatedly surveyed scenes; pylons, vegetation, inaccessible spaces; they are in essence infrastructure inspection devices. It's no surprise that the mass of these newer drones is increasing, the more droning they need to do, the more that higher energy storage and mass becomes valuable; it allows more value to be added to the droning mission.

The basic tools of autonomous drones

As I said above, there are two way of looking at the potential of autonomous drones, the first is product centric – the drone, the second market centric – droning.

The surveying and monitoring revolution using droning is bringing in the first profitable arena for drone use. It offers massive productivity improvement, but within technical constraints of limited mass, and limited flight durations. It's interesting to note that in media, one of the newest drones is in fact a tethered device for filming sports and other public events. In that sense it is not really a drone, but a sky hook for a camera. By supplying power from the ground, it obtains long flight duration, and it is allowed to operate from a regulatory standpoint because its tethering provides a hard data link and avoids the risk of unexpected flight path anomalies.

[1] We tend to forget that "drone" was actually a word meaning a continuous noise.

The tools to take the next step are increased mass and range, allied in turn to a power source that is robust, re-usable, and (in civil uses at least) environmentally sustainable and safe.

If we can marry low structural mass with higher cargo capacity and then add in enhanced autonomous operations the market opportunities multiply because we can offer more droning potential as a workhorse. Flight duration and range bring three benefits;

- First, in the existing market for surveying and monitoring, is that the constancy of low energy droning can provide more coverage at lower cost. Autonomy could then offer wide area repeatable coverage at lower cost.

- Second, the provision of workhorse load carrying for missions needing specific but flexible autonomy for specific purposes; humanitarian relief missions, expeditionary support and distant field delivery support.

- Third, a new market in logistical supply. Droning can provide a robust repetitive droning network for rapid and inexpensive delivery of matériel. Two way logistics supporting remote communities is a particular early target.

Such broad-brush imaginations are cheap, however. As businesses, operators need to develop ideas into real world droning operations that offer returns on investment. Let's look at how that might come about.

Commerciality in operational usage

There is a concept in both economics and marketing science called "topicality". An economist can think of it as the elements of the localised market eco-system that raise the probabilities of losses or profits. A marketer might think of it as the driver of the way "four Ps" - product, price, process and promotion[2] – are integrated to develop new demand within an emerging supply chain.

Droning operators have to invent, test, and improve their approach to topical commerciality using these drivers; designing topicality, the recognition by service buyers that droning is the right product at the right moment for the right price. Today, we have the great advantage of novelty and interest. Can we turn that into the desire and action that allows us to create a flow of invoices for droning done?

An interesting insight is that droning, in general, does not attempt to expand by putting new products into new markets; a challenge that is generally thought to be the most difficult in the marketing of new business opportunities.

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[2] For those who know no marketing science these four facets of putting a successful product into the market place can be offered as: the differentiating features of the product as seen by consumers, its price levels through a period as the product moves from novel to established, the options in methods of selling the product or service through multiple channels to market, and the promotional methods that support customer understanding and satisfaction, often used to develop a brand personality that reduces the cost of sale and optimises the return to sales efforts.

Initially, that may seem counter-intuitive, but surveying infrastructure for example has always been done, what we have found is that drones simply can do it better. Equally, expeditionary support and relief missions have established re-supply methods and of course the logistics industry for more general replenishments is huge.

The role of the commercial team in any droning organisation therefore is to design commerciality within an understood logistical context.

Finding a topical value chain

Our research for the Sky Hopper project has surprised us. By focussing on topicality we drilled down into market sectors where losses can be rapid, where speed of replenishment is important, and where costs of supply are high due to localised environmental factors. We found a particularly transparent set of needs in more remote localities where loss can make community economics marginal, where supply chains are lengthy, and access for logistics systems complex.

Examples of supply needs are not esoteric; they focus largely on the high value-added components of the capital equipment infrastructure. When these become non-functional, losses mount rapidly. We are talking here about starter motors for the diesel engines or fishing vessels, or a replacement power supply for its fish finder, the inverter on the electric motor of a lifting ramp, the valve on a water pump or a pinion seating on a compressor, the drive chain of a textile platen cutter, or the control circuit for an incubator. In addition, we found the more obvious consumables needs; clinical supplies, laboratory consumables, testing equipment, machine tool parts, specialist calibration tools; essentially many of the critical sub-system components that in urban areas can be delivered within hours, but if needed in remote areas can take days or even weeks.

By happy accident, servicing these localities implicitly involves areas that are less populated, which should make our safety case less difficult to resolve with the regulators than an entity like Amazon attempting to use swarms of small drones within urban areas. Here, they are already talking about managed flight paths, building ground-based controlled-autonomy into their operational system.

As a secondary bonus, with our design operations in Scotland, we further discovered that we are sitting on a very useful operational testing ground; the west side of Scotland is a land of large spaces and small rural communities, many separated by coastal sea or hill land. Our weather is not the easiest for flying, but that should be seen as a bonus making us more globally capable. As a cipher for potential global operations, Scotland offers a challenging trial area, but equally one that allows us to emulate the multiple mission requirements that autonomy must be able to resolve.

We should not over-stress this notion of "remote and isolated". It is not the intention of the Sky Hopper team to limit themselves to such operations. The issue, today, is that the promise of autonomy using higher mass vehicles cannot be obtained in urban areas; the safety case for autonomous operations trumps all other considerations. What we are trying to achieve, however, is a pathway through initial physical and regulatory constraints that additionally offers some prospect of early commerciality.

Without these advantages, the entry barriers to successful commercial operations rise rapidly, and the timescales for achieving that goal extend, in our view, a very long way into the future, largely due to the need to prove the operational safety case.

Making commerciality profitable for a community

There is one more element to be realised in our vision of a logistics system – ground presence. The Sky Hopper concept involves multiple vehicles operating across flexible routes using repeating droning itineraries. Some flights may of course be tasked to land in remote areas and drop of supplies on a once off basis, but others may bring near-scheduled flights on a repeating basis to specific communities to what we call a local aero-park. Aero-parks are envisaged as being a tiered concept; some will have a greater capability for storage and/or energy pack swaps and vehicle servicing than others; their presence will be defined by the safety case required due to their locale and the volume of traffic they service.

In commercial terms, the presence of an aero-park is that of a community asset. As such, our goal is to allow those assets to be franchises of the local community with revenue opportunities available to their operators. This follows the model for wind turbines or feed in tariff opportunities to the power grid offering commercial benefits already followed across Scotland and elsewhere.

The essential commercial element here is to put incentives in place for local communities to benefit from the enhanced supply chains, both inbound and outbound, that a system of Sky Hopper operations can offer. There is, in our view, the potential for uplift in localised economic growth from our aero parks, although the precise nature of this growth within specific markets cannot, today, be known to us. [3]

A key constraint on autonomy - mission options must be non-invasive

The potential for logistic advances using droning can be applied to remote and isolated delivery points, whether those are communications and radar stations on hillsides, remote hotels and farms, dams, energy plants, hamlets, harbours or villages, or drop points for expeditions and surveys in need of equipment or re-victualling that avoid pack trains of mules being used to carry supplies up-country in regions where access is an issue.

They core requirements for these missions are VTOL operations and autonomy, but environmentally non-invasive operations are also necessary. Yes, it is quite possible to use lightweight gas turbines to power a more massive UAV, but have you stood next to a jet aeroplane taking off? Could you stand near one as it landed in a restricted space? What about local tinder dry vegetation? The high temperature burning of fossil fuels is a sledgehammer approach to getting energy on the move – it generates a lot of heat and vibration alongside its locomotive output.

[3] A traditional economist would tend to call on Say's Law which posits that the presence of supply can, in some cases, produce its own demand. A more contemporary Hayekian economist would say that there would be a spontaneous creation of an extended market order as a result of the presence of a Sky Hopper route within the locality of a community. In both cases we do not know precisely what will emerge.

For that reason, traditional fossil fuel use brings with it an infrastructure of airports, fuel trucks, and fuel handling equipment, plus the safety systems that go with these. Transport systems always have some additional infrastructure, but droning will go nowhere if we merely re-invent airports.

Somehow we have to find a balance between mass and energy that optimises energy consumption and minimises the noise footprint to allow localised operations. Replaceable, rechargeable, battery cell and electric motor technology allied to slower moving, larger, ducted fan propeller systems offers the best prospect here for the missions we need to fulfil.

So is autonomy promising?

In itself, yes, it allows for range, using lower mass, for remote site accessibility, and potentially multiple contiguous missions, also known as swarming.

But the safety of airborne operations is a *sine qua non* for being allowed to proceed with them. UAVs may have discarded the need for flight crew safety, with the happy consequence of large mass savings within the vehicle system, but the safety of those on the ground is still essential. Droning operations will require proof of failsafe in-flight control systems, and verifiable safe near ground manoeuvring.

To achieve those protections demands a quantum leap in risk management; not just to know and control known risks, but to build in systems such that all uncertainties about what risks might become apparent are handled well. No-one is asking for perfect safety in all circumstances from advanced higher mass droning operations; that would kill the development of the industry in a sea of precautionary regulations; but if we are to advance and discover new commercial uses of higher mass drones the next step of our journey is to analyse, develop and practise the processes that drive risks and uncertainty out of operational happenstance – and apply them to flying autonomously.

If that sounds like a tall order, we should be comforted that it is what the aerospace industry has done over many years, reducing the chance of mishap to as near to random as can be calculated. Of course a problem with autonomy could be that we replace the fallibility of human pilots and machines with the mistakes of human automated system programmers. I will consider that dilemma in a second paper when I examine not the commercial context of autonomy as here, but the technical challenge of autonomy as an exercise in industrial innovation.

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