Emerging Technologies: Use of Unmanned Aerial Systems in the Realisation of Vision 2030 Goals in the Counties

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Abstract

The Unmanned Aerial Systems (UAS) heralds a new convergence of aeronautics, robotics, control and mechatronics. The technology is expected to find numerous unforeseen applications, much in the same way as the mobile phone technology has revolutionised the way people work and socialise in the early 21st century. The main segmentation for applications of UAS are in Energy; Agriculture, forestry and fisheries; Earth Observation and Remote Sensing; Communication and Broadcasting; Fire fighting and others. This paper proposes a roadmap for the integration of Unmanned Aerial Systems into the economy in the realisation of Vision 2030 goals in the counties in Kenya. A background study is carried out followed by structured interviews with key industry players. The direct benefit to adopting UAV technology is found to have an annual value of US$ 24,265,882. This is in addition to the potential for job creation and other downstream economic benefits.

Keywords: Unmanned Aerial Systems, UAV design, Integrated Airspace

1. Introduction

This study makes an investigation and evaluation of unmanned air vehicle technologies and their suitability for use in the counties to realise Vision 2030 goals. Of importance are issues of cost, safety, reliability and operability. The paper presents a roadmap for using Unmanned Aerial Systems (UAS) to tackle the challenges in the counties in a bid to realising the goals of Kenya's Vision 2030.

1.1. Vision 2030 Goals

Kenya Vision 2030 is long-term development blueprint for the country. The aim is to create a "… globally competitive and prosperous country with a high quality of life by 2030." The Vision is anchored on three key pillars: Economic; Social; and Political Governance (GoK, 2007). The key sectors addressed by Vision 2030 are agriculture, education, health, water and environment sectors. The foundations for Socio-economic transformation are identified as Infrastructure and STI (Science, Technology and Innovation). Others are Land Reform, Human Resource Development, Security and Public Sector. Two of the sources of insecurity are identified as Resource Conflicts and Cattle Rustling (GoK, 2007).

1.2. County Government Functions

Kenya enacted a new Constitution in 2010. The new dispensation is expected to enable the country achieve the goals of Vision 2030. Prominent in the new order is devolution of government to the Counties. The devolved units are expected to be more adaptive than the centralised and monolithic government in adoption of new technologies and innovations. Article 185 of the Constitution provides for a distribution of functions between the National and the County governments. These are further elaborated in the Fourth Schedule (GoK, 2010).

1.3. Unmanned Aerial Systems

An Unmanned Aerial System comprises the aircraft carrying the payload (Unmanned Aerial Vehicles, UAV); a control station (CS) which houses the system operators and interfaces between the operators and the rest of the system; the system of communication between the CS and UAV; and the various maintenance and transport equipment. The Unmanned Aerial Vehicle (UAV) is as an aerial vehicle that uses aerodynamic and propulsion forces to sustain its flight along a prescribed path without an on-board pilot. It may carry cameras, sensors, communications equipment or other payloads. This definition of UAVs includes fixed-wing, rotary-wing and airship platform. (Budiyono, 2008). There has been a burst of activity in Unmanned Aerial Systems. UAS constitute the most dynamic section of the aerospace industry. The debut and eventual widespread application of UAVs in Kenya is inevitable. The main segmentation for applications of UAS are in the Energy Sector; Agriculture, forestry and fisheries; Earth Observation and Remote Sensing; Communication and Broadcasting; Fire fighting and various Government Applications (Frost and Sullivan, 2007).

2. Methodology

The paper considers and reviews the existing technologies in Unmanned Aerial Systems and analyses them for applicability in solving various problems and challenges in the counties. Interviews are carried out with personnel in areas where usage is anticipated and the solutions proposed having in mind the existing and evolving technologies. The proposed roadmap is divided into three major sections: UAS Technology Applications gives a review of the current situation and the state of the UAS industry. This is followed by Opportunities and Framework which highlights the opportunities available for use of the technology in the counties. It also considers the legal and regulatory initiatives that need to be put in place. The Implementation Roadmap gives proposals for the way forward.

3. UAS Technology Applications

3.1. Overview of UAS Technology

The first automatically controlled flight of an aircraft took to air in 1916; the era of the modern UAV may however be traced to the early 1970s. The idea of being able to carry out airborne missions behind enemy lines without harm to a pilot has been particularly seductive to military strategists. As a result of significant technological improvements UAVs are now capable of providing near real-time information of the battle space. As a result, the ability for autonomous utilisation in offensive roles including electronic combat and air strikes exists (Lax, et al., 1996). In the military context, the modern day multi-tasked UAV embodies the air power characteristics of Perspective, Penetration, Reach, Technology, Versatility and Concurrent operations (Australian Defence Force, 2002). Recent deployments of Predator, Hunter and other UAVs have demonstrated a significant force multiplier capability.

The UAV looks like a radio controlled aircraft but with the difference that it has the capability of being autonomous during the flight.

UAVs are a game-changing technology, much like the automobile or the computer. They present business with huge opportunities but also pose huge policy, legal and ethical questions. UAS technology is appropriate for dirty, dull and dangerous missions.

More than 70 countries now have some type of UAV although only a few equip them with armaments. In the Eastern African region, Ethiopia has recently unveiled a locally designed drone that can be used for multiple purposes. The drone will reportedly serve a number of missions such as monitoring border security, geophysical surveys, assistance in forest protection and monitoring of forest fires (Sudan Tribune, 2013). Israel has emerged as the UAS super power and Israeli companies were behind 41% of all UAVs exported in 2001 – 2011. Those exports went to 21 countries including the US (iHLS, 2013). The United States has 8,000 UAVs. This figure is expected to sharply increase with the anticipated changes in federal aviation regulations which are supposed to allow UAVs in the National Airspace (NAS) by 2015. According to FAA estimates, more than 30,000 drones could fill the American skies by 2020. As has been famously said, "The drone revolution is coming[1]."

[1] University of Texas assistant professor Todd Humphreys, who has investigated the use of domestic drones, testifying to the US Congress

3.2. Taxonomy of UAVs

UAVs vary in size from several centimetres up to several metres. Current technology allows the making of large pilotless passenger aircraft. The re-usable Soviet space vehicle, *Buran*, was in effect an unmanned aerial/space vehicle. The endurance of UAVs vary from several seconds to hours, and even unlimited time as has been demonstrated by the solar powered Helios. The price of UAVs starts from a low of a few hundred dollars to several millions of dollars depending on the installed equipment and mission. The most common mission aspects are ISTAR (Intelligence, Surveillance, Target Acquisition and Reconnaisance), Combat, Multi-purpose, Vertical Take-off and landing, Radar and communication relay, and Aerial Delivery and Resupply.

UAVs cover a wide range of weights, from micro UAVs which weigh only a several grams, right up to the massive Global Hawk which weighs over 11 tonnes. A useful classification for UAVs is to categorise them by endurance and range. These two parameters are interrelated and the longer a UAV can say airborne the larger its radius of operation is likely to be. Range and endurance determine the type of UAV required depending upon how far the mission objective is from the launch site. It also determines how regularly refuelling is required and consequently how much time can be spent with the UAV performing its task and how much time it needs to spend grounded.

UAVs may be classified based on the maximum operational altitude, or flight ceiling. Some military applications demand high altitude to avoid detection by the enemy. UAVs used for imaging and reconnaissance also require a high altitude so as to capture maximum coverage of terrain.

3.3. UAS Components and Function

The applicability and choice of a UAV is characterised by the flying characteristics and economy. Civilian applications have the added requirement of sensor quality. Developments in science and technology in Micro-Electro-Mechanical systems (MEMS) have led to miniaturisation and reduction in prices. Rapid developments of sensor technology, sensor networking and embedded systems have made UAVs a reality for several different applications.

The UAS Control Station (CS) houses the system operators and the interfaces between the operators and the rest of the system. The Payload is determined by the operational task of the system. This may include video cameras, radar scanner system, various sensors, thermal imaging cameras, etc.

3.4. Successful UAS Applications

Civilian UAS already in active use around the world. UAVs are currently taking on new applications, replacing existing applications and extending a new dimension to existing applications. The main advantages of UAVs for civilian purposes broadly mirror those for the military. These include persistence, cost-effectiveness and the ability to work in an environment which is hazardous to human beings, i.e. the dull, dirty and dangerous missions. UAV systems are cheap to operate, they have little need for space and infrastructure, and they guarantee an unprecedented high level of safety for humans.

UAVs are used for communications and broadcast; ground transportation, monitoring & control. The technology has also been use for air traffic control support and Satellite Augmentation Systems. The technology has become popular in journalism and film making where UAVs are used for television news coverage, sporting events and moviemaking in the place of expensive helicopters. Real estate agents employ them for aerial photos and video. Wildlife researchers and search-and-rescue outfits are using them or studying their potential.

Infrastructure uses include power transmission line monitoring; ground and sea traffic surveillance and pipeline monitoring. UAVs may be used for monitoring freight transport. A possible new application is to develop a network of small UAVs to transport of small packets and packages. This is being fronted by a startup organisation, Matternet. Unmanned aircrafts can assist science where the desired locations of study are either remote or dangerous. UAVs have been used for repeat pass interferometry for surface deformation; cloud and aerosol measurements; stratospheric ozone chemistry; tropospheric pollution and air quality; Water vapour and total water measurements; coastal ocean observations; vegetation structure, composition and canopy chemistry; topographic mapping and topographic change with LIDAR; cloud properties; soil moisture and freeze/thaw states; focussed observations – extreme weather; digital mapping and planning / land management; weather research and aerial imaging/mapping.

In 2005, the American National Oceanic and Atmospheric Administration used a variant of a Predator to conduct a 20 hours survey over the Eastern Pacific; In 2010, NASA used a Global Hawk to collect information on hurricane formation and behaviour. NASA has developed civil applications of UAS for environmental research flights, atmospheric scientific research, and even imaging of Hawaiian coffee crops to help farmers identify optimal harvest days (Pescovitz, 2010).

NASA has conducted research of an active volcano by flying UAVs into the noxious sulphur dioxide plume to acquire data about volcanic ash and gases. The research used three electrically-powered Aeroenvironment RQ-14 Dragon Eye UAVs in a series of ten flights over Costa Rica's Turrialba active volcano in March 2013 (RAeS, 2013). Aerosonde is operated by the Australian meteorological office to sample the atmosphere over wide areas. An atmospheric sampling payload is carried in addition to the usual EO sensor.

UAVs have also successfully been used in the USA to monitor pollution. The NASA sponsored Environmental Research Aircraft and Sensor Technology (ERAST) programme has produced civilian UAVs to monitor pollution and measure ozone levels[2].

Moscow's Forest and Environment Protection Department uses unmanned air vehicles (UAV) systems to patrol the forested areas in the city boundaries and to detect fires in the forested areas around the city. The department uses the small day-night capable ZALA421 – 04M system, which has a wing span of 1.6 meters, weighs 4.8 kg and an endurance 90 minutes. The system uses video camera or photo imagery. The system uses a mobile ground station and two UAVs. Navigation uses Global Positioning System (GPS) technology. The UAVs have a top speed of 65 km/h which is optimal for high image quality. The aircraft use electric motors which are eco-friendly. Indonesia has developed a UAV to assist with Forest Protection. The UAV is named Wulung and was produced by the Office of Technology Assessment and Application (BPPT). The aircraft has an operating range of 70km and speed of 92-146 km/h. Altitude is 3,650 m. Wulung may also be used in forest fire protection. The aircraft uses a two-stroke gasoline internal combustion engine and is made from composite materials.

UAVs are used for Border and coastal patrol and monitoring; Law enforcement; disaster management and operations; Search and rescue; Fire detection and fire fighting management; Search & Rescue; Police surveillance; Large scale public outdoor events surveillance; Counter terrorism operations and VIP and important installations guard.

UAVs have already been used, and proved useful in the aftermath of natural disasters such as the Asian Tsunami and Hurricane Katrina where they were used in damage assessment and in the hunt for survivors (Frost and Sullivan, 2007). In 2008 Soccer World cup, the Swiss police used UAVs to observe suspicious movements and for crowd control; the police was able to determine the direction of the crowd movements in real time and prevent build-ups. In April 2011 an RQ-16 was used to assess the damage to the nuclear reactor in Fukushima, Japan. Manned aircraft could not be used because of the high levels of radiation in the disaster area.

UAVs cost about 100 times less than a helicopter and are significantly cheaper to operate per hour. Helicopters are expensive to fuel and maintain and flying them requires specialized piloting skills. UAVs can revolutionise police work. Montgomery county in the US has purchased a ShadowHawk MK-II for $300,000. Fire-fighters and other government agencies can deploy micro-UAV's to dynamically examine forest fires continuously, while a conventional aircraft such as a Black Hawk can only fly for two hours and eighteen minutes without refuelling. Predators, which can fly at heights of up to 25,000 feet for 20 hours at a time are also used domestically for border surveillance by the DHS's Customs and Border Protection agency in the US at a cost of about $3,000 per hour.

UAVs have been used for Forest fire damage assessment; Forest fire mapping and communications; Forest fire retardant application; Wildlife surveillance, census and animal tracking; Agricultural monitoring including invasive plant assessment, crop yield prediction, vineyard frost protection, coffee harvest optimisation, frost protection, Irrigation and crop management and surveying; Precision agriculture & fisheries; Environmental research & air quality management/control; Land use surveys; Fisheries protection; Mineral exploration; Oil and gas exploration; Digital Mapping and photography & Planning/Land Management and Meteorological observation.

[2] ERAST programme: http://www.erast.com

It is expected that precision agriculture and public safety have the most promising commercial and civil market. These will take about 90% of UAS usage. The supplemental interaction of missions from different areas of utility clearly indicates the integral potential of UAV flight operations as well as direct and indirect benefits of their civil applications. UAVs constitute a rapidly evolving sector. Universities, industry and technology enthusiasts are promoting the development of civilian miniaturised flying technology. The world market over the next decade will be worth $15 billion. Analysts are predicting progressive investment of $3.1 billon to meet the European armed forces demand of 2000 complete UAV systems by 2015. Commercial UAS expected to be approved for use in the US in 2015 are expected to create 100,000 jobs in 10 years and add $13.7 billion to the economy in the first three years of integration cumulating to $82.1 billion between 2015 and 2025 (AUVSI, 2013). The integration of UAV into the NAS will translate into more than $106.6 million in wages annually (Pescovitz, 2010). If US farmers adopt UAS technology at a similar rate to the Japanese, then 90% of the UAV sales will be for agricultural purposes. Some estimates put future civilian UAV market over $400 billion in the US alone.

UAVs have been successfully used in landmine detection and destruction. UAVs have been fitted with radiometry technology that can pick out the tiny electromagnetic reflections emitted by buried objects from as high as 70 m in the air. This technology can be used in landmine detection and with a GPS scan-to-map system. A detailed map may then be created that can be acted upon to eliminate the mines. This method is more effective and less dangerous than the systematic probing of minefields as currently practiced.

Camcopter is an unmanned vertical take-off and landing aerial platform. It has been effectively used for the detection, identification, mapping and marking of landmines. For the purpose of landmine detection, the UAV employs an Inertial Navigation System (INS) coupled with a Differential Global Positioning System (DGPS) for precise positioning, and an Electro-Optical/Infrared Sensor (EO/IR) suite attached to the universal payload mounting base. The UAV is powered by a 15 HP two-stroke engine, allowing about 25 kg of payload. It cruises comfortably at 70 kph with a maximum speed of 90 kph and provides up to two hours of flight time out to 10 km of range. The payload base, located directly below the main rotor vertical shaft, maximizes the payload weight while remaining within center of gravity limits. Typically, the payload station is used for mounting cameras, sensors, dispensing pods, or pendants for inserting and extracting external loads. However, many more applications are possible. The engine powers three generators that produce 300 watts of power for the electronics module and payload power requirements.

UAVs may find use in communications, and Japanese HDTV and 3G phone networks have experimented with Aerovironment's Global Observer HALE UAV prototype. In the remote sensing area applications are expected to include Aerial photography and survey photography using IR, spectral analysis and miniature synthetic aperture radar (SAR), geographical and geological surveying, digital cartography, post-disaster mapping and damage assessment. The monitoring of earthquakes and volcanic events is the subject of research in Italy. The British Antarctic Survey has also used small UAVs to examine the behaviour of the changing climate and its effect on the ice sheets. HALE as well as smaller UAS could be used to monitor desertification and give warning of drought in susceptible areas. Australia has employed a UAV to track the migration behaviour of cetaceans off its coast. This environmental application could also be used to track the migration and population densities of land animals and birds in remote locations. Very High Altitude Long Endurance (VHALE) UAS may provide air quality sampling and pollution monitoring as well as meteorology, tracking cyclones and providing advance warning of floods and extreme weather conditions (Frost and Sullivan, 2007).

3.5. UAS in Agriculture

The application of UAS in agriculture merits special mention due to its great potential to transform the economy, lower food prices and provide new jobs. Farmers have historically walked their land to survey it, looking for areas that need more fertilizer or water. Some farmers use small aircraft to survey their farms from the air, but aircraft rental and fuel costs escalate, and there's a need for a cheaper alternative. UAVs provide farmers with a bird's eye view of their land. They provide an alternative to the use of light aircraft. They weigh less than 50 pounds and are often the size of a child's toy plane. They can drastically reduce the cost of land surveying. The price of a typical fully capable farming drone is around $9,000 which is a one-off purchase that easily pays for itself. Drones allow spraying of crops 2 or 3 feet above the plants. Downwash can be controlled because pesticides are put on the plants and not in the ground where it gets to the groundwater.

Precision agriculture refers to two segments of the farm market: remote sensing and precision application. A variety of remote sensors are used to scan plants for health problems, record growth rates, hydration, and locate disease outbreaks. Such sensors can be attached aerial vehicles. Precision application utilizes effective and efficient spray techniques to more selectively cover plants and fields. This allows farmers to provide only the needed pesticide or nutrient to each plant, reducing the total amount sprayed, and thus saving money and reducing environmental impacts (AUVSI, 2013).

Farm UAVs could also allow for targeted spraying. Aerial application, also called crop dusting, involves the spraying of crops with fertilizers, pesticides and fungicides from an agricultural aircraft. The specific spreading of fertilizer is also known as top dressing. Aerial application accounts for almost 25% of crop protection applications and nearly 100% of forest protection applications. Aerial application is often the safest, fastest, most efficient and most economical way to get the job done. This is especially true for specialty crops that are either too difficult or too dangerous to spray with manned aircraft.

UAS may be used innovatively for agricultural purposes in early detection of disease through aerial imaging of fields for farmers, and for the application of pesticides. Early detection especially of fungal diseases in the field well before crops show sign of infection leads to earlier and more effective treatment. The Yamaha RMAX helicopter is used for surveillance, crop dusting, and other agricultural purposes. It has a payload of about 30 kg, a flight time of about 90 minutes, and range of about 5.5 nm (10 km). Japan introduced the RMAX unmanned helicopter for crop spraying in 1990.

The first utility use unmanned helicopter R-50 was introduced in 1987. The RMAX was introduced in 1998 with improved functionality and operability. Japanese farm hectares sprayed by manned helicopters dropped from 1,328 in 1995 to 57 in 2011 as unmanned helicopter spray rose to 1,000 hectares. UAVs have now established a permanent foothold in the rice paddies since 1990.

3.6. UAS in Kenya

Wildlife Management

A wildlife conservancy in Kenya has pioneered the use of UAV in monitoring its wild animals. Ol Pejeta Conservancy is a 90,000 acre game reserve that is home to endangered black and white rhinos, elephants, leopards, lions and chimpanzees. Poaching, especially of rhinos, has been a menace to the reserve. The reserve has a 190-man security team which cannot effectively patrol the sprawling area. The wildlife conservancy has teamed up with *Unmanned Innovation Inc* to create specialist UAVs to monitor the wildlife. The 'aerial ranger' costs U$ 70,000 and is fitted with a live streaming high-definition camera featuring a powerful zoom for day operations and infrared thermal imaging for night operations. Each UAV covers 50 miles and flies for over one and a half hours. It flies three or four times a day, monitoring the locations of the endangered species and transmitting a live stream to a laptop on the ground. This acts as a deterrent to poachers and also tracks the movement of all tagged animals.

The animals are chipped with RFID tags giving each a unique identification in the database. Sensors on the drone can recognise individual animals and use on-board GPS to store an image tagged with location coordinates. This enables the Conservancy to collect data on animal movements and behaviour.

4. Opportunities and Framework

4.1. UAS Opportunities in the Counties

Agriculture

Agriculture provides potential for the greatest impact of UAVs. Where costs allow, UAVs can be used to reduce the cost of food production and thereby reduce the cost of living throughout the country. UAV have enormous application for the spraying of high-value crops, aerial photography, perimeter control and even fire brigades to assess what's happening around a large building on fire, or getting the heart of a bushfire.

Uasin Gishu, Trans Nzoia and Narok counties are the breadbaskets of the country. These counties are known for their large scale wheat and maize farms. Kakamega county also has large scale farms for sugarcane, whereas Siaya and Busia counties have rice and sugarcane farms.

The biggest potential for UAV is aerial images and data acquisition. A simple UAV may be used to take and repurpose imagery for a farmer's field much more cheaply when compared to using traditional aircraft. The imagery gathered both in standard photos and through thermal imagery assists in identifying areas affected by disease, drought, water logging, pests and treat them more precisely with less inputs which is better for the environment. It also enables seeing parts of the fields that are doing best before the yield map generated at harvest.

Fusarium Head Blight (FHB) is a fungus that infests wheat, barley, maize and other grain cereals. It results in decreased yield, bleached and shrunken kernels and decreased seed quality. The disease also leads to adverse effects on human and animal health. Various methods for its management have been suggested, however early detection can be instrumental in catching disease before they spread to the entire crop. Aerial imaging of fields could also provide high resolution images to farmers on which parts of their fields require tending. Other diseases and conditions may also be managed likewise. CropCam, a Canadian company, is selling a GPS-controlled glider plane equipped with a camera that with snap geo-tagged high resolution images of fields, giving farmers a birds-eye view of which crops are health and which need care.

The Yamaha RMAX is a popular UAV which has been used for several years by farmers in Japan. The UAV operates at 10 % the hourly rate of a manned helicopter. Grower groups can lease a RMAX for about $120,000 over three years with training and maintenance included. Typical operators charge $200 to $300 an hour, which is only a fraction of the cost of running a full-sized helicopter. This is a quarter the capacity of a helicopter, but 1/25 the running cost. RMAX can spray over three quarters of a hectare (two acres) every six minutes. It can operate when the ground is too wet for a tractor to get over. It takes about 2 weeks to learn to fly the UAV. A great innovation in the RMAX is the Yamaha-exclusive flight attitude control system YACS which gives improved ability to hover stationary position. If all input from the pilot is stopped the machine stops dead still and hovers in one spot.

Reduction of Cattle rustling

Two major sources of insecurity identified in Vision 2030 are attributed to resource conflict and cattle rustling. More than 80% of the country is Arid and Semi-Arid and supports over 30% of the population. The livestock sector in these areas provides almost 90% of employment and more than 95% of family income. Cattle rustling has serious socio-economic and humanitarian repercussions. In Kenya between 1996 and 2002, 300,000 cattle worth $37.7 million (KES 3.2 billion) were lost to cattle rustlers; 250 people died between Pokot and Trans Nzoia district; An average raid consisted of up to 1,000 raiders. 189,034 livestock were lost through theft from July 2003 to August 2008 in Karamoja cluster (Ethiopia, Kenya, Uganda borders in a total of 2,283 incidents resulting in 3,674 deaths. 17,358 livestock were lost from July 2003 to August 2008 in the Mandera triangle / Somali cluster in 207 violent incidents resulting in 342 deaths (Miaron, 2013). The cattle rustling belt in Kenya is the North Rift comprising Baringo, Marakwet, West Pokot, Turkana, Samburu, Laikipia and the west part of Isiolo districts. Figure 2 indicates the reported killings in cattle rustling in the period 2008-2009.

Cattle rustling has escalated to levels that undermine security and threaten the stability of the nation. It is now a regional problem. On 10th November 2012 cattle rustlers killed over 40 police officers who were on a mission to recover 450 cattle stolen from Samburu herders. The same group had killed 13 people in another raid on 30th October 2012. The government of Kenya has allocated Shs. 200 million for the electronic tagging of livestock to make it easier to trace and recover. The tracing uses GPS. The electronic chip is inserted through the animal's mouth and contains details such as the name of the animal's owner, district of origin, the animal's breed and country of birth.

UAVs can be usefully integrated in tracking the cattle at short notice and directing security personnel to the location of raiders. Surveillance UAVs can be used to locate the rustlers and the stolen cattle. The security officers who were victims of the Baragoi massacre could have been able to observe the terrain and not fall into an ambush if they had UAS for surveillance and to enable them see over the horizon (over-the-hill surveillance). Tactical UAVs like RQ-14 Dragon Eye, RQ-11 Raven or Spylite mini UAV could have provided crucial reconnaissance and surveillance information for the convoy.

Wildlife Management

Tourism is the major source of Foreign Exchange in Kenya. Wildlife, the main reason for tourist visits, accounts for 15% of GDP. The industry is mainly driven by game found in various game parks.

Almost all counties host game parks and reserves. Counties at the heart of the wildlife industry are Narok, Taita, Transnzoia, Migori and others. Maasai Mara is the main resource for Narok County. Other major parks are Tsavo in Taita County.

Wildlife management in parks involves animal conservation, tracking animals and deterring poachers. This has traditionally been carried out by Kenya Wildlife Services (KWS). Poaching is a major challenge in wildlife conservation. Poaching reduced elephant population in African from an estimated 1.3 million to a mere 400,000 by the 1980s. By late 1980’s Kenyan parks were losing almost a ranger a week to poacher attacks. KWS runs 59 parks and reserves spread over the country. KWS carries out research, handles national park and reserve operations, ensures the security of wildlife and is in charge of the Mt Kenya, Mt Elgon, Abedares Ranges and Chyulu Hills water towers. It is also central to the restoration of the controversial Mau Forests Complex. The KWS has an Airwing to assist it in carrying out its functions by providing air support services in wildlife management.

Kenya Wildlife Service Airwing has a fleet of 12 light aircraft and 3 larger aircraft including a Bell 206 helicopter. In addition to this KWS recently acquired another new 7 seater Bell 407 helicopter. All pilots must be skilled in low-level flying. The Airwing Unit has a total of 12 professional pilots. Airwing roles include park patrols, translocation, veterinary support services, transport (including of rations and ammunition), fire fighting, rescue missions, animal census and security operations. Apart from transportation of personnel, UAS (eco-drones) may be used for all the functions performed by the Airwing, and some performed by ground units. The UAV also have the advantage of low cost. There is unlikely to be abuse of resources in non-official business, unlike in the case of manned aircraft.

Infrastructure Monitoring

Infrastructure surveillance – One of the targets of poverty eradication is to achieve full productive employment and decent work for all. This can only be achieved if the infrastructure is developed and well maintained. One of the major challenges facing Kenya’s small industries is access to reliable electrical energy. This has been exacerbated by vandalism of existing electrical lines through transformer and electric able theft. Copper wire theft is also a major challenge to Kenya Posts and Telecommunications. UAVs can be used in the surveillance of both electricity lines and other infrastructure like pipelines and road conditions.

Powerlines are traditionally inspected for encroaching trees, damage to structure and deterioration of insulators by employees traversing the lines on foot and climbing the pylons. This is time-consuming, arduous and has a considerable amount of risk. In recent times helicopters have been used with personnel using binoculars and thermal imagers to detect the breakdown of insulators. UAS have now been successfully used for this function. The UAS is used in hover flight and carries an electro-optic and thermal imaging payload, the data from which is available in real time to the operator and also recorded. The UAV is automatically guided along the power-line within a limited volume of airspace close to the lines using of range of distance measuring devices. The UAVs should be able to fly close to high-voltage lines without adverse effects from the electromagnetic fields upon control system or payload performance. Compared with manual inspection, the use of UAS offers lower labour cost; more inspections per day; less risk to personnel and easier access. UAS also has advantages over helicopter inspection. This includes less environmental disturbance; lower capital cost; lower labour cost; no risk to aircrew. The utility companies like Kenya Power & Lighting Company (KP&L) and Kenya Electricity Transmission Co. Ltd. (KETRACO) can use UAVs to hunt for downed power lines after a storm.

A UAS with hover capability and electro-optical (EO) and thermal imaging (TI) sensor payload may be used as an inexpensive means of carrying out survey of the land where the an oil pipeline is to be installed. After installation, UAS may be used to look for disruption or leaks by accidents such as landslide or lighting strike and also damage by vehicles or falling trees or sabotage. Kenya Pipeline Co. Ltd. (KPC) may use the technology to monitor oil pipelines and realise great savings from less use of manned helicopters.

Security

The conflicts in the Horn of Africa have exacerbated the security situation in the country. The northern counties have been particularly affected with frequent incidents of grenades and other explosives being detonated in public areas. The area has suffered a systematic deterioration of security. Concomitantly, the expenditure in Security has skyrocketed so as to tackle the emerging threats.

A UAV can fly above an area of interest for a long time and alert its operators on the ground if it discovers suspicious activity. UAV's can be used to patrol national borders instead of ten manned aircrafts or twenty agents on the ground (assuming thirty UAV flight hours) for the same area coverage.

Fishermen at the shores of Lake Victoria and in the Indian Ocean have to contend with escalating cases of piracy. Pirates in the lake take refuge in various uninhabited islands and come out to harass fishermen, snatching their catch and vandalising their boats. UAS can assist security agents in surveillance of the uninhabited islands. Kenya also has a long seafront at the coastal counties which poses enormous security challenges in manning. It is reported that most of the smuggled goods and drugs enter the country in these sections.

Police in Nairobi county and adjoining areas have great challenges in fighting crime and frequently resort to the use of helicopters. Indeed the helicopter at times patrols at night with lights so as to assist the officers in their operations. Unmanned systems are particularly apt for this application especially due to their versatility lower cost of operation compared to helicopters..

The Kenya Police Airwing intends to become a rapid deployment anti-crime unit that can be quickly sent to the air to pursue criminals and cattle rustlers. The unit currently has 8 helicopters (5 unserviceable) and 7 cessna fixed wing (4 unserviceable). The personnel comprises10 helicopter pilots, 13 fixed wing pilots, 18 engineers and technicians and 7 cabin crew. The fleet is expected to increase to 16 aircraft in 4 years and is expected to do 9,850 flights compared to 1,914 flights in 2010. Shs. 16 billion has been set aside to improve the airwing in the next four years (Maganga, 2011). These assets are clearly insignificant given the area of operation of the Police service. A solution which provides for the deployment of UAS will significantly improve the effectiveness of the Police Service at a much less cost than would the procurement of more manned aircraft.

Forest Protection

Forest monitoring, fire fighting, and post-fire damage assessments are all made easier and safer with UAVs. Archived image data allows for automated change detection and post-mission analysis that feed back into better forest management and improved firefighting techniques.

Fighting wildfires effectively requires rapid decisions and a highly efficient management team. Understanding changing conditions, and safely deploying equipment and personnel demand near real time situational awareness. UAVs are versatile alternatives over conventional piloted aircraft in forest fire scenarios. Dense smoke and heat do not inhibit their operation and this eliminates risk to air crew. Optical and infrared sensors provide accurate 24-hour monitoring capabilities, with real-time data downlinks to command centres on site, and to headquarters offices on regional levels. Overlaid with wind and weather information, UAV imagery heightens awareness of what will happen next.

There has been a fast dwindling of Kenya's forest cover due to human activity. Forests have suffered several challenges including illegal excision, destruction by poachers and invasion by land speculators. Others are illegal logging, clearing of forests for plantations and the planting of illegal plants, like bhang, in the forests. Surveillance by UAVs can sharply reduce these encroachments. Forest fires also pose a danger to forests, especially in the dry season. Currently the forest cover is 3,467,000 ha which is 6.09 % of the land mass. The value recommended by the UN is 10%. The annual reduction in forest cover is 12,000 ha per year. Figure 3 indicates trends in reduction of forest cover in Kenya.

The Kenya Forest Service (KFS) has the mandate to conserve, develop and sustainably manage forest resources in Kenya. The KFS is composed of 10 conservancies that are ecologically demarcated, 76 zonal forest offices, 150 forest stations, and 250 divisional forest extension offices located countrywide. The Kenya Forestry Service has procured a Cessna Grand Caravan 14 seater fixed wing Troupe Carrier to enhance forest conservation and management.

The aircraft is part of a long term plan by the Organisation to increase its capacity in managing and protecting forest resources for the economic and social prosperity of the country. KFS also plans to procure a helicopter to further increase this capacity.

UAS is effective in forest patrols and forest fire detection. They may patrol the forest and vulnerable crops like sugar cane and wheat to look for hot-spots when weather conditions are conducive to the outbreak of fire. They may also assist, as an eye in the sky, in directing the application of fire-fighting materials onto any fire. In this case the payload would be an electro-optical and thermal video sensor. Larger UAVs may be used as ‘water bombers’ to replace manned aircraft in this role to eliminate risk to aircrew (Austin, 2010).

Desert Locust Control

The migratory locust (*Locusta migratoria*) ranges from Europe to China. Even small swarms may cover several square miles and weigh thousands of tons. The insects eat the equivalent of their own weight in a day. They fly at night, and may cover 500 km with the wind. The largest known swarm covered 1,036 km^2 and comprised about 40 billion insects. Control methods include spreading poisoned food among the bands and spraying of small concentrated doses of insecticide solutions from aircraft over the insects or the vegetation on which they feed. The insecticide may also be administered by vehicle-mounted sprayers at ultra-low volume (ULV) rates of application. Control is undertaken by government agencies in locust-affected countries or by specialised organisations such as the Desert Locust Control Organisation for East Africa (DLCO-EA). The desert locust is a difficult pest to control. This is further exacerbated by the large and remote areas where they are found. Difficulties are caused by limited resources for locust monitoring and control and political turmoil within and between affected countries.

DLCO-EA has a fleet of 8 operational aircraft including 1 Cessna Caravan, 1 Beech Baron, 1 Islander and 5 Beavers. The organisation employs pilots, aircraft and avionics engineers and support staff. Desert locust control can be effectively managed by UAVs. UAVs currently used as crop dusters like RMAX may also be effectively utilised for this purpose, probably with minor modifications. UAVs may also be used to monitor swarms and get information of the swarm behaviour. DLCO-EA also controls other pests like tse tse fly, army worms and quelea birds.

Fisheries protection

Fisheries protection ensures that illegal fishing is not carried out within protected waters. This function is normally carried out by the Department of Fisheries carrying out patrols. They can be used for monitoring illegal fishing and water resources and for collection of air and water samples. Agriculture and forestry will favour light VTOL or fixed-wing UAVs flying in line of sight, with MALE UAS addressing the fisheries market.

Coastguard and Lifeboat Functions

UAS are also good for coast watch vessels, enabling coast watchers to see what’s happening on islands, up creeks, on the other sides of vessels under observation and to see over the horizon. They may be used for various coastguard activities, and also as the eyes of a lifeboat during search and rescue. Activities include monitoring of traffic in narrow sea-lanes like the Likoni Channel and ensuring that traffic proceeds in allocated lanes and schedules; monitoring of coastline for debris, etc. as the results of shipwreck or the discharge of illegal and polluting substances such as oil; monitoring of coral reefs along the coastline

UAS can be very useful tool against pirating in the Indian ocean; they are not immediately visible to the pirate ships and may be used for surveillance. The Eastern African coastline has suffered an unprecedented attack by pirates, mainly based in Somalia. Several navies, including the Indian navy have attempted to make patrols. Conviction of arrested pirates has not always been possible since the criminals ditch their paraphernalia before being arrested and hence destroying evidence.

If the Patrol Vessel has a UAV system on board it can steer a steady course through the sea and send the UAV to view the vessel. A stealthy UAV with passive sensors can approach closely to the suspected vessel without alerting the crew. It can then obtain evidence in the form of recordable photographic images of the vessel’s perceived activity, with its position and time.. The Patrol Vessel in this case has no need to spend time pursing and extended course to visit each suspect vessel, but only visit those shown by the UAV to be harbouring pirates will full evidence to justify its boarding. This offers greater efficiency in the successful prosecution of pirates and also considerably reduces the distance sailed by the Patrol Vessel to complete its task.

The operation is not only far more effective per ship hour whilst at sea, but also reduces the overall time necessarily spent at sea by the crew.

Communication

UAV's can replace communication satellites in poor weather conditions. Since they fly closer to the ground, their signal distorts less than that of the satellites. In journalism, an MAV can provide a live feed from the scene and at a lower operating cost of a helicopter.

Aerial Photography

Use may be made of a combination of video and high-resolution cameras to obtain pictures of geographic and constructed features.

The technology may also be used in the making of movies, filming of sports events (marathons) and other broadcast and journalism functions. Hover flight is advantageous for positioning, and UAV is cheaper and less intrusive than manned aircraft.

Remote Sensing and Mapping

UAVs may replace manned aircraft on mapping tasks which are generally dull and lengthy. The UAV could carry out a pre-programmed raster flight pattern with arrangement with Air Traffic Control. Use would be made of specialised camera equipment. Kenya is seriously considering nuclear energy. UAVs will be indispensable in monitoring for radiation at both the nuclear plant and at waste disposal sites.

Disaster Management

Small hand-launched UASs equipped with sensors which are able to detect people are especially valuable in disaster situations. UAS may provide real time support for effective decision-making process and disaster management operations. Other uses in disaster management are the monitoring of disaster areas; reconnaissance of disaster regions suffering from floods, earthquakes and other natural disasters; search and rescue and disaster relief operations; delivery of first aid assistance to victims. This includes medicines, food and blankets. UAS may also be used for damage assessment from natural catastrophes and industrial accidents and real time monitoring of the disaster alleviation process.

Situations which can be effectively monitored by UAVs include flood monitoring in areas like Budalang'i, Tana Delta area and the Kano Plains; mudslides in Kakamega and Murang'a; search and rescue in mountain areas and others. The law needs to be harmonised to allow the Disaster Management Unit to use any appropriate technology and tools including the use of UAVs in civilian airspace for limited time under specific conditions. This is because a disaster can occur anywhere and the disaster area could be vast.

Science and Research

Poverty mapping, the spatial representation and analysis of indicators of human wellbeing and poverty, is becoming an increasingly important instrument for investigating and discussing social, economic, and environmental problems (Henninger and Snel 2002).

Oil and Mineral Exploration

UAVs can assist in oil exploration by helping in the building of 3D models of the terrain. This may be matched with data obtained from other sources. This will be especially important in mapping out areas in Turkana county where oil prospecting is going on in earnest, as well as the coastal counties for titanium and other metal ores and the eastern counties for coal prospecting.

UAV versus Satellite

Kenya has launched a Space policy and is working towards having viable satellite programmes. At a very different level, HALE UAS are eventually expected to replace many satellites in communication, broad casting and remote sensing. A UAV can be retrieved, upgraded and re-tasked. It can also be moved to a different location from its automated GPS-generated flight pattern at little cost. The options open to a satellite on the other hand, once launched are relatively few. It can sometimes be moved, but it has a finite fuel reserve, and its hardware cannot be modified; it is doomed to obsolescence once it has left the launch pad.

Job Creation

Introduction and integration of UAVs into the county economies will lead to increase in jobs opportunities for the youth. They will be employed as operators, maintenance technicians and application software developers.

Other Uses

Once a reliable and cost-effective UAS is operating, several other applications will be identified in areas not yet envisaged.

4.2. Summary of UAS Potential Applications

UAS are poised to replace manned aircraft for utility uses due to their relative economy and safety. They also have the advantage of not being misused for non-operational purposes as is often the case with manned aircraft. Most state based agencies operating aircraft suffer misuse of aircraft by personnel and officials in the organisations for non-sanctioned and non-justified flights.

Secondly, aircraft rentals in Kenya are still very expensive. Aviation firms charge from Shs. 40,000 to Shs. 500,000 per hour depending on aircraft type and season. Hiring a helicopter typically costs about Shs. 125,000 per hour (US$ 1,500). Organisations using aircraft also subsidise their costs by leasing them out to third parties, opening up another venue for misuse. Tables 1 and 2 show indicative rates from the more popular service providers in the country.

UAS opportunities in the Counties are twofold:

a) Investment in cooperation with national government
b) Investment purely as county government assets

UAS will applicable both in the solution of National government functions in the counties, like security and also in the solution of county-specific problems. In either case the county will be key in facilitating their application. An analysis of the potential scope for the Kenyan market for air based remote sensing applications showing market size and potential UAV share of the market is indicated below. The most prominent values are expected to be in Security, Mineral exploration, Media resources and Environmental control and monitoring Agriculture

UAVs offer benefits in reduction of operational costs in fulfilment of commercial objectives, increased efficiency of operation and increased work (information acquisition) rate.

The potential benefits of adoption of UAS to the economy is presented in Table 3. The expected immediate annual UAS market from current operations is conservatively expected to be US$ 24,265,882 (KES 2 billion). The average life of a UAS is 11 years.

4.3. UAS Solutions for Counties

UAS operations include installing appropriate payload; transporting UAV to the test site; developing flight plan; pre-flight and post-flight procedures; ground systems to support flight plan development.

UAS costs comprise:

i) Aircraft acquisition (for organisations which have a recurring mission, e.g. security)
ii) UAS operators / personnel – technicians for UAS setup, operation and maintenance; ground operators; payload specialists and users interested in mission results
iii) Vehicle transport – from home base to area of interest. This depends on the UAV and access to the airspace; UAV may be flown or shipped
iv) Payload integration – cost of integrating the payload onto the aircraft; this may require aircraft modifications. It is desirable to implement payload interface standards to support a 'plug and play' concept
v) Support team travel – for cases where the UAV needs to be deployed in a specific area of interest

Counties need to make a commitment to support the nascent technology that will serve a wide range of future programmes with spill down effects in the aerospace supply chain. They should invest in seedcorn projects which will lead to innovations and youth employment.

County utilisation of UAS could be twofold. The first is in solving specific problems encountered and promoting familiarisation with the technology and mainstreaming its applications. The second is to develop capacity for both use and construction of the next generation UAS.

It is proposed that each county purchases UAS and customises them with sensors which answer to its immediate specific needs.

Various possible approaches may be used:

- Purchase
- Purchase services (hire)
- Encourage various innovations and construction of UAS solutions in the country
- Re-engineering

The nascent aerospace industry in the country needs to be supported. There should be long-term investments in various seed concepts. UAS are a generic technology which will give a wide range of future applications and foster a vibrant supply chain as well as directly providing jobs to youth.

4.4. Airspace Integration Policy

Integration of UAVs into non-segregated airspace remains a major challenge. Military and civil UAVs have very much in common as far as the access into non-segregated air space is concerned. Military UAVs however are advantaged since they can operate in restricted airspace which is closed off from civil aviation usage. Most UAV operations are currently carried out in tightly controlled, restricted airspace. There is very limited access to civil airspace for specific times, locations and operations. This is due to the absence of legislation and regulations governing UAV flights in unrestricted airspace and UAVs integration into the existing air traffic management system. (Koldaev, 2007).

UAVs operating in non-segregated airspace should expect to comply with the regulations as they are, and not expect special and favoured regulations applied to them. Some countries like Sweden have made significant progress in the integration of UAVs in civilian airspace (Frost and Sullivan, 2007). In 2006 European Organization for the Safety of Air Navigation (EUROCONTROL) sent recommendations to several European countries[3] in which they made proposed the basis for allowing military UAVs in non-segregated national airspace. The draft specifications follow three basic principles:

a) UAV operations should not increase the risk to other airspace users
b) ATM procedures should mirror those applicable to manned aircraft
c) The provision of ATS to UAVs should be transparent to ATC controllers

An important challenge is to synchronize the highest requirement of controlled and even uncontrolled airspace with existing and future capabilities of UAV systems. The UAV are the biggest threat for air traffic when it is operating in commonly used airspace where (either civil or military) piloted air vehicles operate too. While during military flights the main objective is to execute the task successfully and flight safety is only secondary, in times of peace these aspects change places naturally.

Requirements in both the US and Europe are that UASs not exceed an acceptable level of risk when operating in the airspace used by civilian aircraft. FAA regulations require that all aircraft above civil airspace have a probability of fatal system error less than 10^{-9} per hour of flight. Military aircraft achieve about 10^{-5} whereas data on larger UAVs indicate an even higher failure rate of about 10^{-2} per hour of flight. There are indications that this figure has improved and stabilised for cumulative flight hours of operation of these vehicles.

The requirement that UAS not exceed an acceptable level of risk in the Airspace suggests that UASs should be able to ‘see and avoid’ other aircraft while participating in the air traffic management system for manned aircraft. This has led to the production of collision avoidance sensors with greater detection capabilities than pilots. Work is still continuing on frequency allocation and avoidance algorithms.

[3] EUROCONTROL Specifications for the use of military unmanned aerial vehicles as operational air traffic outside segregated airspace

ADS – B

UAS are expected to operate within the laws governing the airspace as it is, without expecting laws and procedures to be bent for them. Installing the several supporting sensors in UAS to safely operate increases weight and decreases payload. Use of ADS-B will allow UASs to safely participate in the airspace by relaying and receiving the state vector of nearby aircraft. Small UAVs are unlikely to achieve the reliability levels of civil commercial aircraft. Their size and weight limitation does not allow the level of redundancy (usually triple redundancy) implemented in commercial aviation systems. ADS-B has several advantages for this category of aircraft.

Segregated Airspace for UAV tests

Limited types of UAS should be allowed to operate in restricted classes of the Airspace. Limiting small UAS to class G airspace away from flight corridors may provide an initial proving and experimental ground for innovators in the field.

Test centres controlled by research institutions and universities could lay the basis for developing a vibrant UAS industry. Such centres could be used for research in several areas including avoidance technology demonstrations. Efforts should be made to come up with a policy on Airspace Integration. KCAA should lead the way in this.

UAS Policy

The Ministry of Transport should design a UAS policy in conjunction with KCAA and other aviation stakeholders. This should be done in conjunction with KCAA. South Africa already has. This should lead to UAS Regulations under the Civil Aviation Act. It is however advised not to wait for a comprehensive and complete set of laws and regulations concerning UAV safety and environmental certification, radio frequency spectrum, insurance, air traffic management and integration into civil airspace before starting to exploit this technology. It is pragmatic to initiate small non-military UAV applications where possible in restricted airspace in a safe and cost effective manner.

4.5. Technological Implementations

In the UAV sphere size matters, with capabilities directly related to their complexity. The relation between take-off mass as a function of complexity is a parabola, with the minimum saddle in the category of mini-UAVs. This is the area in which civil UAV evolution in the near future will lie. The required technology is already freely available for commercial off-the-shelf. Basic ready-to-fly UAV systems with visual light sensor equipment costs between $1,000 and $2,000 per kilogram. Obviously a UAV cannot be operated outside segregated airspace for such a marginal price. A quadrocopter costs about $300, but has limited capabilities.

Simple UAVs and remote controlled aircraft like the AR Drone sell for US$ 300. This is a very stable quadricopter controllable by iPhone, iPod Touch or iPad via Wi-Fi. It has 2 onboard video cameras (VGA resolution) one forward facing, one downward facing, selectable from a virtual button on the screen. A $5 App called "Flight record" enables recording from the on-board camera and duplicates the control functions of AR FreeFlight. Range is about 150 feet (Wi-Fi range is the limiting factor).

Small and hand-launched fixed wing UAVs are good candidates for various civil and commercial applications. Their small kinetic energy makes them relatively none-dangerous in case of accidents. They fly at low altitudes of 200 – 300 m, and thus do not stray into controlled civil airspace. They are also not expensive.

The greatest need for MAV's and NAV's systems is in dynamic applications. These are applications where the aircrafts have a clear mission and can take action to adjust to a dynamic environment. In such missions, time is the critical factor that can save lives. For example, in a search and rescue mission, MAV's can be deployed much faster than existing alternatives (satellites, tethered aerostat radar, and manned aircrafts) and possess lower cost of operation. Another benefit is the fact that MAV's can be deployed by personnel in the area similar to the Raven in the military. This advantage cuts out the middleman (helicopter pilot, satellite image reconstruction specialist, etc.), and enables continuous and direct flow of information.

5. Implementation Roadmap

5.1. Spurring Innovation

There should be a deliberate move to promote UAS technology for purposes of obtaining a controlling footprint in the technology even as it develops. Large companies are not likely to pioneer, but rather study from the sidelines, since they typically enter a market only when the industry has established a firm demand. UAS have a durable life span of approximately 11 years and are relatively easy to maintain. The manufacture of these products requires technical skills equivalent to a bachelor's degree (AUVSI, 2013). There is need to encourage innovators to adopt the technology and design modifications based on user-defined needs.

5.2. Role of Universities and Professional Organisations

UAV's are currently the fastest growing section of the aerospace industry. Many Universities around the world have their own UAV development programmes. Some examples are University of Sydney, Clark University, Cranfield University, Georgia Tech. University, Berkeley University and Simon Fraser University.

Local universities have hitherto not distinguished themselves in providing a lead in trailblazing useful innovations which drive the economy in engineering based disciplines. This is despite the country being highly rated in innovation. The country is not short of innovators; it is only necessary to identify and direct their energy to ventures which will let their ideas blossom. UAS provide an opportunity for multi-disciplinary research in Aerospace, Control, Electrical, Communication and Materials Engineering as well as in other disciplines like Agriculture and Agronomy, Remote Sensing etc.

University based Research on UAVs

There needs to be a deliberate move to promote the use and application of UAVs in the economy. Universities and polytechnics should be encouraged to develop curricula and research in the various enabling disciplines. Research on UAV's is very useful in various areas such as agriculture, cartography, forest protection, etc. Several universities in the Asia-Pacific region are known to be developing UAVs for various research applications, ranging from flight platform design research, flight controller development, to the use of these flight platforms for sensor development, and flight navigation research.

Monash University is probably a relative newcomer in this as they initiate a collaborative research project with Aerosonde Robotic Aircraft Pty Ltd, to investigate the next generation of flight control systems for the Aerosonde UAV. The Australian National University (ANU) is also involved in UAV research, particularly in the use of insect-inspired vision sensors for flight navigation of mini/micro sized UAVs. The Wackett Centre at RMIT University has been involved in UAV related research for numerous years, with projects in design studies of multi-purpose flight platforms, the ship-borne launch of UAVs, avionic and flight controller developments, and sensor platform developments. The University of Sydney's UAV research and development activities have been most prolific in recent years. Over a period of just over ten years, several UAV flight platforms have been developed and operated, with research in the areas of aerodynamic and structural design, flight performance and control, design concept optimisation, modelling of aircraft characteristics, the use of GPS (Global Positioning System) for platform attitude reference, flight trajectory optimisation, autonomous flight controller design and optimisation, decentralised systems research, and flight mapping and navigation research. The UAV flight platforms that have been developed and operated include: UAV Ariel,36kgAUW (all-up-weight), 10kg research payload when flown remotely; UAV Brumby, 25-45kg AUW, 3-9kg sensor payload when flown autonomously; UAV TWing a tail-sitter VTOL(vertical take-off and landing) concept demonstrator; and UAV Bidule, a mini/micro AV concept demonstrator, less than 0.3 kg AUW.

National Competitions

National competitions will challenge the innovative enthusiasts to embark on various inventions. These can be modelled on competitions organised by the Association for Unmanned Vehicle Systems International (AUVSI). The competition is aimed at stimulating and fostering interest in this innovative technology. Such competitions could be organised by the Institution of Engineers of Kenya (IEK).

5.3. Challenges

Several pre-requisites should be satisfied to render the UAS a viable, cost effective and regulated alternative to existing resources. Major civil and commercial market barriers which have been identified are:

- Lack of airspace regulation that covers all types of UAV systems (encompassing 'sense and avoid', airspace integration and airworthiness issues
- Affordability – price and customisation issues (e.g. commercial off-the-shelf, open modular architecture)
- Liability for civil operation
- Capacity for payload flexibility
- Sensor technology and miniaturisation
- Lack of secure non-military frequency for civil operation
- Perceived reliability (e.g. vehicle attrition rate compared to manned aircraft)
- Operator training issues

Several aspects of one of the primary obstacles to UAV use - cost - are discussed, including the role that safety, reliability, and operability of UAV's has in cost reduction. Also included is a general description and status for each of the capabilities and technologies identified in section 3. Over-the-Horizon communication and 'file and fly' access to the national air space are two capabilities which are seen as critical to expanding the civil use of UAVs. Another area of technology development which is required, particularly for earth science applications, is sensor development in terms of autonomy and size. Finally, a general schedule shows when some of the capabilities and technologies might be available. (Cox, 2004)

Cost

Reliable UAVs remain relatively expensive, despite being significantly cheaper than the manned alternative.

The unit cost varies widely. Whereby micro UAVs like Dragon Eye (US$ 28,500) and Raven are relatively inexpensive, any UAV designed for use in non-segregated airspace will be expensive. The Shadow UAV costs $350,000 while Predator costs $4.5 million (Bone and Bolcom). The primary obstacle to application of UAVs currently is cost and reliability. The lack of 'sense and avoid' capability has hindered acceptance into the national airspace in many countries. The combination of greater flexibility, lower capital and lower operating costs could allow UAS to be a transformative technology in fields as diverse as urban infrastructure management, farming, and oil and gas exploration to name a few. Present-day UAS have longer operational duration and require less maintenance than earlier models. In addition, they can be operated remotely using more fuel efficient technologies. These aircraft can be deployed in a number of different terrains and may be less dependent on prepared runways. Some argue the use of UAS in the future will be a more responsible approach to certain airspace operations from an environmental, ecological and human risk perspective (AUVSI, 2013).

Covering and justifying the cost of UAS is straightforward. In the precision agriculture market, the average price of the UAS is a fraction of the cost of a manned aircraft, such as a helicopter or crop duster, without any of the safety hazards. For public safety, the price of the product is approximately the price of a police squad car equipped with standard gear. It is also operated at a fraction of the cost of a manned aircraft, such as a helicopter, reducing the strain on agency budgets as well as the risk of bodily harm to the users in many difficult and dangerous situations. Therefore, the cost-benefit ratios of using UAS can be easily understood (AUVSI, 2013).

The reasons for the current low levels of commercial activity appear to be associated with the risk of financial investment in as yet unproven systems. In contrast to military users, for which system developments are typically government funded, civilian operators must provide their own investment in aerial systems. There is obviously then a tendency to "buy off-the-shelf" as this provides the perception of a proven product. Potential civilian operators are often hesitant to invest in developmental projects where the level of investment required to realise an operational system is uncertain, and success may not be guaranteed. Unfortunately, the capital costs of off-the-shelf systems will typically still be high on a per unit basis. In addition, there is also a general level of unawareness in the commercial sector, of the level of technological preparedness of the UAV industry and R & D organisations to develop operationally capable systems. The requirements of many organisations will therefore only become evident after operational system demonstrations become widely publicised.

Technical and Technological

Key UAV system technologies are: airframes, structures and aerodynamics; propulsion units; Control systems, i.e. autonomous flight controllers and propulsion control; launch and recovery; navigation and guidance; self-protection; ground control stations; payloads; and data communication, storage, processing, and dissemination (Information Technology). Much of the current research is focussed on these areas.

One of the greatest challenges in the development of UAVs is the adoption of the sense and avoid (S&A) technology. Whereas the technology exists, and is widely used in ordinary aircraft, the challenge remains the successful integration of the components into a workable unit for UAVs. There are concerns regarding the high UAV accident rate. The UAV technology is still evolving, and there is less redundancy built into their operating systems. This has resulted in the high accident rate, currently standing at a rate 100 times more than that of manned aircraft (Jackson, 2004). Figure 4 indicates the improved safety of UAS technology. Uses will also be identified in the military. It is significantly cheaper to buy an advanced UAV than to train an air force pilot (iHLS, 2013).

Safety and Security

Operations of UAS immediately raise questions about privacy. A second concern is about the security of the UAV. Civilian drones can be hacked, or "spoofed," by a counterfeit GPS signal. Unlike military GPS signals, civilian signals are not encrypted. The spoofed drone would allow the hacker to take rudimentary control of the UAV.

Insurance

UAVs are mechanical devices and machines do fail. There needs to be means to prevent injury to persons or animals and damage to property due to failures of UAV; and prevent injury or damage caused by collisions between UAV and other airborne vehicles (i.e. sense and avoid) (Austin, 2010). This calls for a legal framework and drawing up of appropriate regulations.

Safeguards

New technologies are usually susceptible for both benign and evil use. Criminal and terrorist movements may use UAS for non-peaceful reasons.

5.4. Way Forward

This paper has shown that whereas many of the problems tackled could be solved using other technologies, the deliberate introduction and promotion of UAS technology in the counties will result in several advantages like cost savings, technology transfer, employment creation and integration into the global economy. Early introduction and adoption of technology results in many advantages. AUVSI estimates that the amount lost by the US for every year that UAS are not allowed in the National Airspace results in an opportunity loss of US$ 27 million every year (AUVSI, 2013). The emphasis in this paper has been on the opportunities for providing innovative solutions based on the most important and significant emerging technologies. This is the best guarantee for the country to claim its place in the new world economy. Previous experiments like Import Substitution in Manufacturing, Export Processing Zones and the bid for industrialisation by the year 2020 have not provided the required dividends. Focus on the county as the engine for implementation will ensure that implementation does not stall.

UAS have so far benefited from technological spin-offs from other endeavours. There is now a lot of research purely geared into advancing this relatively new technology. Spin-offs from this is likely to find application in other areas of aeronautics, energy and other sectors. The necessary conditions for UAS take-off mirror those in other countries. These are the development of regulations to integrate UAS into the airspace; financing for UAV purchases; high adoption rate of the technology; insurance over liabilities; and availability of sufficient capital to smaller manufacturing companies (AUVSI, 2013).

Further Work

There's need to carry out a study on the adoption rates of the new technology in the country so as to obtain an accurate forecast on the size of the industry. This will influence the required level of investment.

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Figure 1: Reduction of Kenya's forest cover (Trading Economics, 2013)

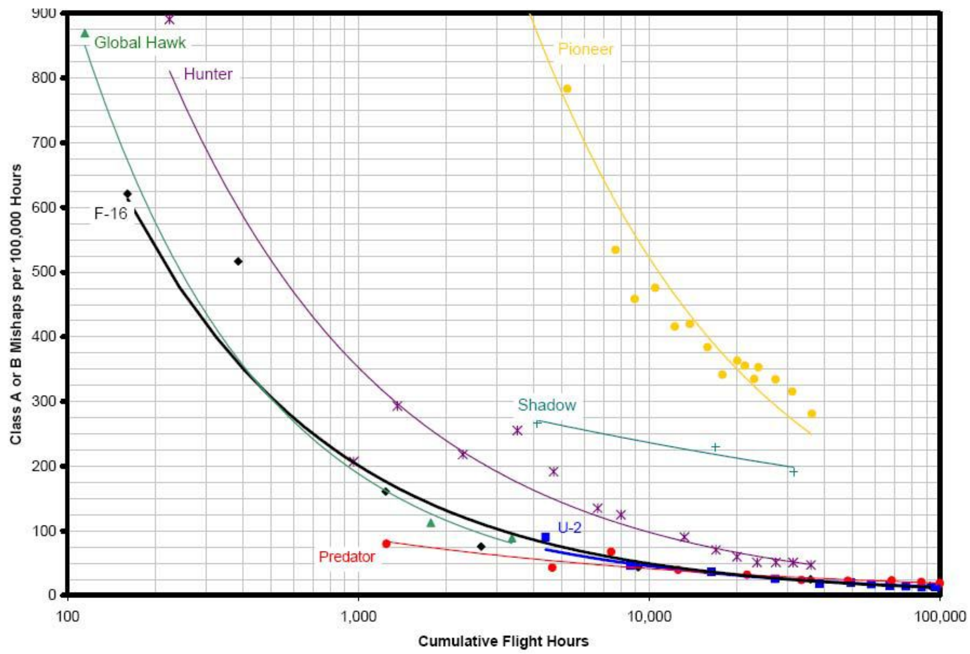

Figure 2: US UAV and Military Aircraft Mishap Rates (DoD, US, 2005)

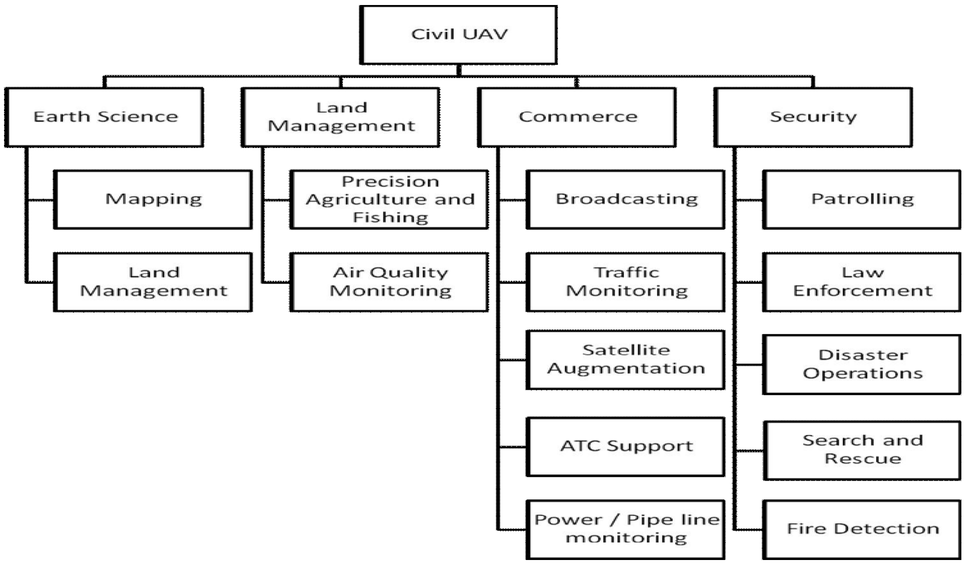

Figure 3: UAV Applications (Cox, Nagy, Skoog, & Somers, 2004)

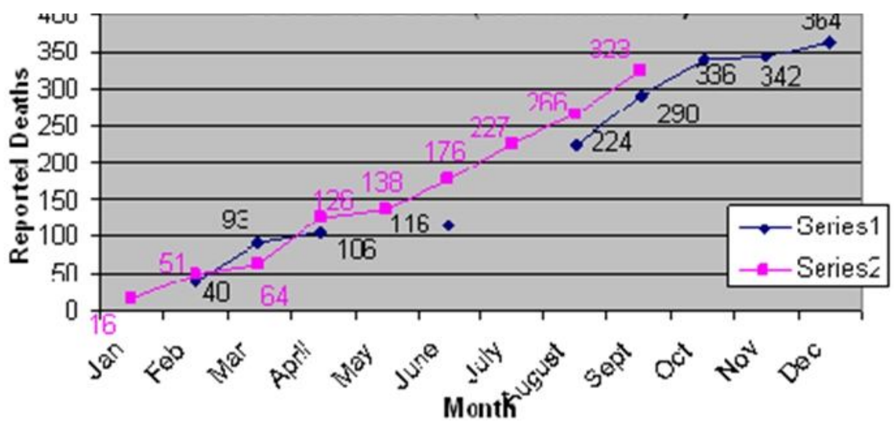

Figure 4: Reported killings in pastoral areas linked to cattle rustling – 2008-2009 cumulative (IRINNEWS, 2009)

Table 1: Indicative Aircraft Hire Rates – Kenya Air Force (GoK, 2013)

Aircraft Type	Characteristics	Hourly Rate (KES)	Hourly Rate (US$)
Y-12 (17 seater)	23,000 ft ceiling	100,000	1,200
Dash 8 (36 seater / 4,500 kg)	2,000 km range	206,425	2,477
Buffalo (34 seater / 8,000 kg)	9,450 m ceiling	385,106	4,621
Puma (20 seater)	580 km range	319,120	3,829

Table 2: Indicative Aircraft Hire Rates - KWS (KWS, 2013)

Aircraft Type	Commercial Activities (per hour)	Discounted Rates (per hour)
Caravan (12 seater)	US$900 + VAT	US$570
Helicopter (5 seater)	US$1500 + VAT	US$840

Table 3: Potential UAV Market in Kenya (Annual Value)

Market	Nationwide KES	Nationwide US$	Potential UAV Share	Potential UAV Value (US$)	Notes
Precision Agriculture and Monitoring	50,000,000	588,235	30%	176,471	Based on acerage that needs to be monitored per annum
Security: Cattle rustling	500,000,000	5,882,353	70%	4,117,647	Based on cattle rustling episodes
Security: Police patrol	700,000,000	8,235,294	60%	4,941,176	Estimated from Police usage estimates of 9,850 flights. Average flight duration is taken as 45 min.
Security: Coastguard and anti-piracy	100,000,000	1,176,471	80%	941,176	Based on required number of hours to be flown annually along the coastline.
Disaster Management	500,000,000	5,882,353	60%	3,529,412	Based on budget for the Department of Disaster Management
Wildlife Management	500,000,000	5,882,353	70%	4,117,647	Based on current estimate for operating aircraft for Wildlife Management
Infrastructure monitoring	100,000,000	1,176,471	80%	941,176	Estimates for potential usage by Kenya Pipeline Company for pipeline monitoring and Kenya Electricity Transmission Company (KETRACCO) for high-voltage power cables
Forest protection	50,000,000	588,235	80%	470,588	Based on current estimate for operating aircraft for Forest Protection
Desert Locust Control	200,000,000	2,352,941	80%	1,882,353	Estimates for usage by the Desert Locust Control
Environmental Control / Weather Research	100,000,000	1,176,471	60%	705,882	Data source from Bureau of Meteorology
Mineral Exploration	100,000,000	1,176,471	30%	352,941	Data source estimates from companies currently providing service
Unexploded Ordnance Location	2,000,000	23,529	30%	7,059	Data source from companies currently providing service. Market is rapidly expanding.
News Broadcasting	10,000,000	117,647	20%	23,529	Based on current-estimate of operating aeroplanes and helicopters for news gathering purposes nationwide.
Remote Sensing of Resources	100,000,000	1,176,471	70%	823,529	Estimates from usage by Remote Sensing Organisation
Aerial photography	10,000,000	117,647	50%	58,824	Estimates for usage by Survey of Kenya
Miscellaneous	100,000,000	1,176,471	100%	1,176,471	Direct civilian UAV applications to be identified by users
TOTAL	**3,122,000,000**	**US$ 36,729,412**		**US $ 24,265,882**	