ELECTRICALLY DRIVEN AND CONTROLLED LANDING GEAR FOR UAV UP TO 100KG OF TAKE OFF MASS

Zbigniew SKORUPKA, Wojciech KOWALSKI and Rafał KAJKA
Institute of Aviation
02-256 Warsaw, Poland
E-mail: zbigniew.skorupka@ilot.edu.pl
rafal.kajka@ilot.edu.pl
wojciech.kowalski@ilot.edu.pl

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ABSTRACT

UAV - Unmanned Aerial Vehicle is very rapidly growing area of flying objects. Various tasks and possible areas of UAVs use are generating increasing demand for various types and designs. Thanks to simpler certification requirements UAV market could be used as a test field for various new technologies like wide use of modern electric systems. One of the area where electric systems could be implemented is a landing gears with its steering, braking or retraction / extension systems.

1. WHAT IS UAV?

An Unmanned Aerial Vehicle is an aircraft without any human crew. It is controlled remotely from stationary or mobile command center. UAV control is performed by radio (directly from ground or via satellites for wider ranges of operation) or autonomously (by on board computers). Autonomous control of the UAV is based on pre-programmed flight plans using complex automation systems.

Figure 1. UAV monitoring and control at CBP (photo: Wikipedia)

UAV main use is military. It can perform attack or reconnaissance missions.
For reconnaissance missions UAV's are often equipped with variety of cameras (from normal video cameras to high resolution infrared ones) and sensors ex. for sensing nuclear or chemical weapons.

Figure 2. A Rheinmetall KZO of the German Army, used for target acquisition and reconnaissance (photo: Wikipedia)

For attack missions UAVs can carry full range of aerial weapons such as missiles, bombs etc. It can be also equipped with systems enabling targeting for artillery and missile attacks (such as laser targetters).
Non military usage of UAVs is jet not so wide but this type of air vessel is in interest of fire fighting brigades (for spotting fires or even to carry extinguishers to areas where extreme danger is present), police operations, media (filming from distance), security work (ex. surveillance of pipelines), rescue missions. In other words UAVs are preferred for missions that are too dull, dirty, or dangerous for manned aircraft.
UAVs come in shapes of regular airplanes or helicopters. Most used propulsion system in aircraft-like UAVs is propeller system. Jet propulsion system is used in systems operating on higher flight levels mainly for wide area reconnaissance.
Size of the UAV depends on what mission it is designed for. UAV take off mass can be as less as 50[kg] and as large as few tons depending of type.
All of UAVs are equipped in features as normal aircrafts. Steering system, landing gear and shape of vessel itself is similar to normal aircrafts.

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Figure 3. RQ-4 Global Hawk, a high-altitude reconnaissance UAV capable of 36 hours continuous flight time. (photo: Wikipedia)

2. LANDING GEARS.

Dissipation of the energy during landing process can be achieved in different ways:
- spring L/G (in aeronautics L/G is an abbreviation for landing gear) made as a spring beam (fig. 4)
- flexible elements the most often rubber or different elastomers built-up in the L/G structure.
- steel disc springs
- oleo-pneumatic shock absorbers (fig. 5)

Figure 4. Spring beam L/G for Cessna 195 airplane (photo: Wikipedia)

The first three solutions are preferred in light airplanes because of their low cost in connection with high efficiency rates and low weight. Yet use of the oleo-pneumatic shock absorber is the most effective solution during landing.
Because of the largest efficiency in energy dissipation use of oleo-pneumatic shock absorbers is general in military and commercial airplanes where cost of the construction is not the most important criteria.
Oleo-pneumatic shock absorber absorbs energy by "pushing" a volume of hydraulic fluid against volume of gas (usually nitrogen but can be dry air.)
Oleo-pneumatic shock absorbers carry out two functions:
- a spring or stiffness function, which provides the elastic suspension by the compression of a gas volume.
- a damping function, which dissipates energy by forcing hydraulic fluid through one or more small orifices.

UAV landing gear is constructed same way as landing gear for normal aircraft. Landing loads absorption has to be even more effecitve because of delicate sensors onboard UAV.
In small UAVs fixed spring landing gear is most often used. For special applications miniature (but as effective as full sized) retractable landing gear is used. Institutes' of Aviation Landing Gear Departments' small UAV landing gear is a fully operable landing gear with shock absorber which can absorb energy of permissible vertical landing speed up to 3.05 m/s

Figure 5. M-28 „Skytruck" main L/G with oleo-pneumatic shock absorber (design Institute of Aviation L/G Department, photo: IA archive)

3. CONTROL SYSTEMS OF THE UAV'S LANDING GEAR.

In UAVs the same variety of control systems (electric, pneumatic or hydraulic) can be used as in normal air vessels. In big constructions with adequate thrust power and enough space, hydraulic system for steering and landing gear controlling is used.
In smaller constructions fitting hydraulics is a problem of space and mass. Also having enough electric power for sensors, computers and cameras doesn't explain putting other control systems than electric in such UAV.
The main problem of the electric control systems is that they are not as compatible with mechanics as everybody think. Main problem is that electric power can be easily transferred into mechanical movement for rotation. Best example is ordinary electrical motor. In airplane control systems almost always linear movement is needed. Of course there is a variety of electrical linear motors but they are expensive and not light enough. Best way is to make rotary movement into linear. This can be achieved by putting some mechanical gears but this also has it's downback in lowering power and torque with every gear level used. Of course special linear actuator can be built but there are two main problems: price and availability. Price of custom made linear actuator can be much higher than UAV itself. Availability of such actuator is also a problem during operation, there can be situation

in which UAV is grounded for weeks because of time for actuator manufacturing time.

Figure 6. Nose Landing Gear on test stand in Laboratory (photo: IA archive)

These aspects were taken into account during landing gear planning phase in Landing Gear Department. First of all low (100kg) take off mass and plenty of electric power onboard made not reasonable of taking into the account hydraulic control systems.
Second cost of landing gear system had to be acceptable and active parts of the landing gear had to be easily available.
Also there was no restriction of using aviation grade parts because these regulations only apply when air vessel is carrying humans. For non-human aircrafts there is only need of using parts which are reliable enough.

Figure 7. Main Landing Gear on test stand in Laboratory (photo: IA archive)

When all restrictions were taken into the account, Landing Gear Department engineers decided to use common use servos for modelers. Servos had to be durable enough to meet safety requirements and loads generated in the landing gear system. Because of these loads, servos with titanium gears were used.
Exemplary specification of servo that can be used in small UAV's landing gear.

Table 1. Exemplary Specifications of Possible Landing Gear Servo

Control System:	Pulse Width Control 1500usec Neutral
Required Pulse:	3.3-7.4 Volt Peak to Peak Square Wave
Operating Voltage Range:	4.8-7.4 Volts
Operating Temperature Range:	-20 to +60 Degree C (-68F to +140F)
Operating Speed (6.0V):	0.15 sec/60° at no load
Operating Speed (7.4V):	0.12sec/60° at no load
Stall Torque (6.0V):	333.29 oz-in. (24kg.cm)
Stall Torque (7.4V):	416.61 oz-in. (30kg.cm)
Standing Torque (6.0V):	433.27 oz-in. (31.2kg.cm) 5 degree deflection
Standing Torque (7.4V):	541.59 oz-in. (39kg.cm) 5 degree deflection
Operating Angle:	60 Deg. one side pulse traveling 450usec
Direction:	Clockwise/Pulse Traveling 1500 to 1950usec
Idle Current Drain (6.0V):	3mA at stop
Idle Current Drain (7.4V):	3mA at stop
Current Drain (6.0V):	300mA/idle and 4.2 amps at lock/stall
Current Drain (7.4V):	380mA/idle and 5.2 amps at lock/stall
Dead Band Width:	2usec
Motor Type:	Coreless Metal Brush
Potentiometer Drive:	6 Slider Indirect Drive
Bearing Type:	Dual Ball Bearing MR106
Gear Type:	4 Titanium Gears
Connector Wire Length:	11.81" (300mm)
Dimensions:	1.57" x 0.78"x 1.45" (40 x 20 x 37mm)
Weight:	2.18oz (62g)

Figure 8. Example of Servo (photo: HITEC RCD)

Retraction system is a simple system with servo as actuating part and few gears for multiply lifting power of the servo itself. Notification of the open/close state is via computer signal based on position signal from the servo. Closed position is maintained by gas spring and

by computer signal to servo in case of unwanted retraction. All landing gears have also gas spring used as mechanical help during retraction/extension of the landing gear. In retraction system servos were used without any reconfigurations.
Main landing gear is equipped with electrically actuated disc brakes. Brakes themselves are mechanical disc brakes working on the same principle as any disc brakes (ex. car disc brakes). Actuating device is the same servo as one used in retracting and steering systems. Braking is performed by brake lever by servo what is transposed to linear movement of brake pads. Braking force is maintained by spring between actuator and brake mechanism.

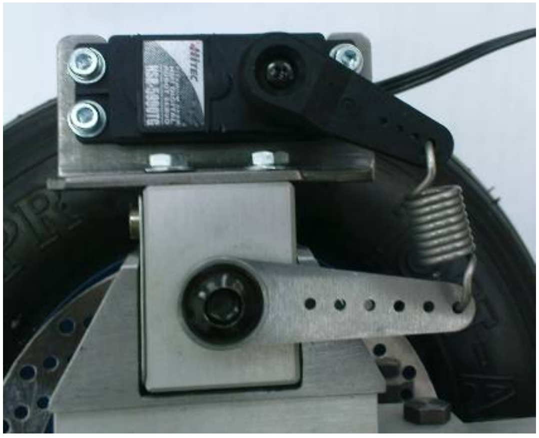

Figure 9. UAV's Main Landing Gear mechanism (photo: IA archive)

Nose landing gear has steering system for ground movement (taxiing). This system is also actuated by the same servo as retraction system. Main difference is that there is a need of knowing current position of the landing gear during whole time of taxiing so the potentiometer form the servo is mounted to front landing gear axis of revolution. During closing of the landing gear front landing gear is rotated onto central position by signal from commanding computer. All landing gears control is purely electric and for operation needs only electrical power source and steering computer. This landing gear can be used in any UAV which take off mass is no more than 100kg. Only need is to plug it to the computer and proper power source.

4. MAIN CHARACTERISTICS OF IA'S UAV LANDING GEARS.

Table 2. Nose Landing Gear Components

Structural parts	Aluminum Alloy.
Wheel	200x50.
Steering system servo	HSR 5990TG.
Steering system potentiometer	EXTERNAL
Retraction / Extension system servo	HSR 5990TG.
Retraction / extension potentiometer	EXTERNAL
Shock absorber	Oleo / pneumatic
Retraction / extension support	Gas spring
Total mass of one nose landing gear	4,8 kg.

Table 3. Main Landing Gear Components

Structural parts	aluminum alloy.
Wheel	200x50 and disc brake size 100 mm
Braking system servo	HSR 5990TG.
Brake pads	Accent FREEZER
Brake spring	Helical
Retraction / Extension system servo	HSR 5990TG.
Retraction / extension potentiometer	EXTERNAL
Shock absorber	Oleo / pneumatic
Retraction / extension support	Gas spring
Total mass of one main landing gear	4,1 kg.

5. SUMMARY

UAVs are most likely to have only electrical control systems in landing gears.
Due to the lower certification requirements and lower development costs, electrically controlled landing gears on UAV are easier and cheaper way for future implementation for bigger, passenger aircrafts. All new electrical technology could be quickly tested on less demanding unmanned vehicles.
The knowledge acquired during the development of presented project, results in better understanding of problems and design principles of electrical loading systems, especially for aviation applications where landing gears systems are special and very challenging system responsible for the most dangerous phase of the flight process.
Described landing gear is currently mounted in research UAV for NACRE project which is a part of UE 6^{th} Framework Programme. All landing gear systems were verified during laboratory tests as well as UAV final flight tests.

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AUTHOR BIOGRAPHIES

ZBIGNIEW KONRAD SKORUPKA, born in 1977 in Warsaw, Poland. Finished Warsaw Academy of Technology, where he studied Shaping Machines Design and Steering. He received his M.Sc. in 2004. Currently he is working at Landing Gear Department of Warsaw Institute of Aviation. His current professional area are: use of smart materials in landing gear, general design and testing of landing gear, brakes and test stands.
E-mail: `zbigniew.skorupka@ilot.edu.pl`

WOJCIECH KOWALSKI, born in Warsaw, Poland and went to the Warsaw Academy of Technology, received his M.Sc. in Engineering in 1970, Faculty of Power and Aeronautical Engineering in Applied Mechanics and 2000 PhD from Warsaw University of Technology, Faculty of Automotive and Construction Machinery Engineering. Now he is working at Warsaw Institute of Aviation. His current professional area are: load and stress analysis, construction dynamics, test parameters determination, results analysis and interpretation of tests and calculations
E-mail: `wojciech.kowalski@ilot.edu.pl`

RAFAŁ KAJKA born in 1977, received his M.Sc. in Engineering (2000) from Warsaw University of Technology, (Poland). Directly after graduation he started his doctoral studies and in 2005 he received PhD from Warsaw University of Technology, Faculty of Automotive and Construction Machinery Engineering. Since 2001 he is working at Institute of Aviation, Warsaw initially as a strength engineer and from 2007 as a Manager of Landing Gear Department, Institute of Aviation, Warsaw, Poland.
E-mail: `rafal.kajka@ilot.edu.pl`