Requirements for aeronautic application

High-Voltage Spinel LNMO Silicon-Graphite Cells and Modules for Automotive and Aeronautic Transport Applications

Horizon Europe | HORIZON-CL5-2021-D2-01-02

Advanced high-performance Generation 3b (high capacity / high-voltage) Li-ion batteries supporting electro mobility and other applications

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PROJECT ABSTRACT

HighSpin aims to develop high-performing, safe and sustainable generation 3b high-voltage spinel LNMO||Si/C material, cells and modules with a short industrialisation pathway and demonstrate their application for automotive and aeronautic transport applications. The project addresses in full the scope of the HORIZON-CL5-2021-D2-01-02 topic, setting its activities in the “highvoltage” line. The project objectives are:

- Further develop the LNMO||Si/C cell chemistry compared to the reference 3beLiEVe baseline, extracting its maximum performance.
- Develop and manufacture LNMO||Si/C cells fit for automotive and aeronautic applications.
- Design and demonstrate battery modules for automotive and aeronautic applications.
- Thoroughly assess the LMNO||Si/C HighSpin technology vs. performance, recyclability, cost and TRL.

The HighSpin cell delivers 390 Wh/kg and 925 Wh/l target energy density, 790 W/kg and 1,850 W/l target power density (at 2C), 2,000 deep cycles, and 90 €/kWh target cost (pack-level). The project activities encompass stabilisation of the active materials via microstructure optimisation, the development of high-voltage electrolyte formulations containing LiPF6 and LIFSI, high-speed laser structuring of the electrodes, and the inclusion of operando sensors in the form of a chip-based Cell Management Unit (CMU).

HighSpin will demonstrate TRL 6 at the battery module level, with a module-to-cell gravimetric energy density ratio of 85-to-90% (depending on the application). Recyclability is demonstrated, targeting 90% recycling efficiency at 99.9% purity. HighSpin aims at approaching the market as a second-step generation 3b LNMO||Si/C in the year 2028 (automotive) and 2030 (aeronautics), delivering above 40 GWh/year and 4 billion/year sales volume in the reference year 2030.

LIST OF ABBREVIATIONS

Acronym / Short Name	Meaning
APU	Auxiliary power unit
BEA	Battery Electric Aircraft, pure electric vehicle without other power source.
BMS	Battery management system
BOL	Beginning of life, when cells are new, and no degradation has occurred yet
C rate	The measurement of current in which a battery is charged and discharged at relative to the battery's capacity.
DoD	Depth of Discharge
EOL	End of life, when either capacity or specific power of a battery cell falls below a set requirement due to ageing.
EOW	Empty Operation Weight
eVTOL	Electric vertical take-off and landing aircraft
HEA	Hybrid Electric Aircraft, combination of two power sources, such as electric and petrol.
KPI	Key performance indicators
LNMO	Lithium Nickel Manganese Oxide
MTOW	Maximum Take-Off Weight
PVS	Pipistrel Vertical Solutions
Si/C	Silicon Carbide
SoC	State of charge
SoH	Sate of Health
TR	Thermal Runaway
TRL	Technology Readiness Level
UAV	Unmanned aerial vehicle
WP	Work package

EXECUTIVE SUMMARY

From the reference/baseline of the predecessor project 3beLiEVe, HighSpin further develops the LNMO||Si/C cell chemistry to maximise its performance. One of the objectives is to address aeronautic requirements with this cell chemistry. This will be realised by designing and demonstrating battery cells and a module for aeronautic applications. HighSpin also aim to include operando sensors that provide cell management capabilities. This report provides the specification for the aeronautic cells and modules.

To establish the end-user requirements for the aeronautic cell and module, PVS contributes to the task 1.2 of WP1. Moreover, PVS contributes to the activities in task 1.3, which is consolidation of automotive and aeronautic performance, safety and sustainable requirements. The specification for the aeronautic cell and module also includes the safety specification.

The end-user requirements are targeted for the upper segment of the general aviation (CS-23 category) and the lower segment of the regional aircraft (CS-25 category). The end-user requirements are derived for both BEA and HEA electric aircraft types, which are foreseeable in future. Therefore, the targeted gravimetric energy density at cell level is 390 Wh/kg and the volumetric energy density is 925 Wh/l. The module-to-cell gravimetric energy density ratio of more than 90% leads to the module level gravimetric energy density of >350 Wh/kg. The nominal gravimetric power density and the peak gravimetric power density is 790 W/kg and 1200 W/kg, respectively. The discharge rate of more than 3C is established to achieve the power requirements, and the 5C charge rate is targeted to increase the capability of fast charging. In addition, 2000 deep cycles are expected until 80% residual capacity. The aeronautic end-user requirements including the safety aspects for the cells and modules are comprehensively provided in the section "Aeronautic cell requirements".

1 INTRODUCTION

The HighSpin project aims to contribute to the ambition of a climate-neutral Europe by 2050 by developing high-performing, safe and sustainable generation 3b high-voltage spinel LNMO||Si/C material, cells and modules with a short industrialisation pathway and by demonstrating their application for automotive and aeronautic transport applications (HighSpin Fact sheet, 2022).

The current generation battery cells can provide up to 350 Wh/kg. However, these cells are not yet available in large quantities. The requirements set in this document will set higher targets for specific energy and reduce industrialisation pathway. Ultimately this will help enable commercial electric and hybrid electric aeroplanes to materialise.

1.1. OBJECTIVES

The objective of this report is to determine the cell and module top-level requirements for aeronautic applications (T1.2). A similar report is created for automotive application (T1.1), and these two reports will be merged into a single document describing the cell requirements regarding performance, safety, and sustainability (T1.3) and will function as input to WP2 and WP5, and for validation/verification in WP6.

1.2. REPORT STRUCTURE

In the chapter ‘Aeronautic cell requirements’, the cell requirements are given in a table, followed by a brief description of each criterion. This is followed by the requirements on module level, in the chapter ‘Module requirements’. Finally, a brief overview is given for three electric aircraft and how these aircraft could utilise this new type of battery.

2 AERONAUTIC CELL REQUIREMENTS

There are basically two distinctive types of aircraft with their own challenges and needs for electrification. The first are fixed-wing fully electric aircraft, with relatively low peak loading on the battery but high specific energy requirement. The other are hybrid electric aircraft and eVTOLs, which both need high peak loads for take-off and landing while specific energy is less of an issue.

Since the maximum specific peak power targeted in this project is too low for eVTOL applications, the requirements will be mainly based for fully electric fixed-wing aircraft, although some fixed-wing hybrid electric applications could be possible too.

Table 1 below summarises the aeronautic high-level battery requirements, followed by a more detailed explanation for each requirement.

Table 1 – List of cell-level requirements for aeronautic application

No.	Name	Value	Unit	Notes
1	Specific energy	390	Wh/kg	Project KPIs either directly stated in the grant agreement or derived from main KPIs.
2	Energy density	925	Wh/L	
3a 3b	Specific power nominal Specific power peak	790 @2C 1200 @3C	W/kg	
4a 4b	Power density nominal Specific power peak	1850 @2C 2775 @3C	W/L	
5a 5b	Fast charging time Fast charging peak load	<15 5	min C	
6	Minimum cell operational temperature	10	°C	Cells will be actively cooled or heated to optimise temperature window.
7	Maximum cell operational temperature	50	°C	Cells will be actively cooled or heated to optimise temperature window.
8	Cell survival temperature	-20 to +60	°C	Nice to have
9	Self-discharge	<5%	-	At 100% SoC (open circuit) at 45 °C per month.
10	Battery cycle life	>2000	-	Deep cycles
11	Cost at pack level	90	€/kWh	As stated in proposal
12	Max discharge	>3	C	As stated in proposal
13	Cell capacity range	10-25	Ah	

14	Cell sensor capabilities	SoC and SoH estimation, load balancing, TR detection and temperature sensor.	
15	Hazard level	UN38.3, AC20-184, and ARP4754	As stated in proposal

2.1. SPECIFIC ENERGY

With the high-voltage spinel cells developed in the HighSpin project, the range will still be the main challenge to overcome for BEA and HEA aircraft. The requirement for specific energy has therefore been set at 390 Wh/kg, which is the maximum target for this project. This will be limiting for lower segment of regional aircraft (CS-25), but it should be sufficient to design a feasible CS-23 commuter aircraft serving short but vital routes in areas where road and rail alternatives are limited.

2.2. ENERGY DENSITY

Volume can be quite limited for both BEA and HEA, especially if the batteries need to be installed in odd-shaped structures like a wing box. High energy density is therefore an important factor for minimising the required space needed to fit all the cells. Hence the maximum requirement for energy density is set at 925 Wh/L for the HighSpin cells.

2.3. SPECIFIC POWER PEAK AND POWER DENSITY PEAK

The peak power requirement for BEA applications is relatively low as these kinds of aircraft will need to fly for long periods of time, reducing the peak load relative to the total capacity of the battery.

However, fixed wing hybrid electric aircraft will need brief bursts of power, from a few minutes up to 15 minutes, resulting in high specific power peak and power density peak. The aim of this project is to achieve 3C discharge, which is on the low side for HEA applications.

With a 3C discharge rate, the specific power peak is 1200 W/kg and the power density peak is 2775 W/L.

2.4. C-RATE FOR FAST CHARGING

To reduce turn-around time at the airport, BEA specifically should be able to charge within 15 minutes. The target is to charge the battery within 15 minutes with a peak charge rate of 5C.

2.5. MINIMUM AND MAXIMUM CELL OPERATIONAL TEMPERATURE

The operational temperature range for the cells has been set from 10 to 50 °C, an active thermal management system will need to be used to ensure the cell temperature is kept within this limit.

2.6. CELL SURVIVAL TEMPERATURE

The cell survival temperature is a nice to have, and not a hard requirement. During normal operation the cells are kept in their optimum operating range using a thermal management system. However, in case this system fails the cells should be able to survive temperatures between -20 and +60 °C.

2.7. SELF-DISCHARGE

Since commuter aircraft are used frequently, up to several times a day, the self-discharge is not expected to be an issue as it is very unlikely that the aircraft will not be used for such long periods of time.

2.8. BATTERY CYCLE LIFE

Changing a part on an aircraft can be quite complex and expensive. The cycle life of the cells should therefore be as high as possible so the batteries will last longer, requiring fewer battery replacements. The HighSpin project aims for a cycle life of 2000 deep cycles, which seems reasonable for aeronautical applications.

2.9. COST AT PACK LEVEL

In the past three decades, battery costs have dropped significantly. In addition to the cost of the cells, the overall cost at pack level must also be decreased, which includes the cell as well as the module costs. As stated in the HighSpin project proposal, the expected battery cost at pack level is 90 €/kWh[1]. The state-of-the-art pack cost is estimated to be 200 €/kWh. To realise the targeted impact of the HighSpin battery technology, it will be necessary to reduce the costs of materials, production, assembly, finishing, and module.

2.10. CELL CAPACITY RANGE

It is essential for aeronautical battery propulsion systems to be capable of containing a thermal runaway within a fire zone. To do so the battery capacity of a single module shouldn't be too high as this increases the potential thermal energy released during the thermal runaway. It was found that cells larger than 25 Ah become significantly harder to contain.

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[1] This requirement comes from the automotive domain.

Too small cells come with their own set of challenges and increasing packaging efficiency to connect several of these cells in parallel.

Ideally the cells have a capacity between 10 to 25 Ah. There are however some mitigations possible, so this is a nice to have and not a hard requirement.

2.11. CELL SENSOR CAPABILITIES

All sensor data about the cell are nice to have and not hard requirements as this data could also be obtained/determined alternatively. However, it is expected that measuring this at cell level is less cumbersome and more accurate.

SoC and SoH are both of high importance for electric flight as an accurate estimation of the available energy is required before flight to make sure the planned flight path can be performed.

During charge and discharge cycles, load balancing is needed to make sure all cells are drained equally to prevent over(dis)charging of cells, which could result in catastrophic events such as a battery fire.

A method to detect a TR event as early as possible is also highly desirable in order to maximise the time available for an emergency landing and evacuation of the plane.

A temperature sensor is the last nice-to-have for the cell sensor capabilities to optimise cooling and could also be used to detect a TR event.

3 MODULE REQUIREMENTS

The module level requirements are given briefly in the table below. In addition, each requirement is explained with the rationale.

Table 2 – List of module level requirements for aeronautic application

No.	Name	Value	Unit	Notes
1	Hazard level	UN38.3, DO311, AC20-184, and ARP4754		As stated in proposal
2	Maximum battery pack voltage, consisting of several modules in series	2000	V	Expected maximum voltage for aviation application
3	Thermal monitoring	Cell level EIS/V/T sensor plus secondary safety features for aeronautics, (over/under voltage, temperature, current, short-circuit detection, vibration, shock		As stated in proposal
4	SoC/SoH monitoring			As stated in proposal
5	On-board EIS			As stated in proposal
6	Module-to-cell Gravimetric energy density ratio	>90	%	As stated in proposal
7	Module is BMS agnostic	Yes		As stated in proposal
8	Specific energy	>350	Wh/kg	As stated in proposal
9	Consistency of materials with eco-design principles (T1.3)	Yes		As stated in proposal

3.1. HAZARD LEVEL

As stated in the HighSpin proposal, the hazard level ought to be compliant with UN38.3, DO311, AC20-184, and ARP4754.

3.2. MODULE SENSOR CAPABILITIES

Depending on the available sensors that can be implemented on cell level (see chapter “Cell sensor capabilities”), the sensors on module level should fill the gaps where the sensors on cell level fall short and guarantee sufficient redundancy.

For example, if load balancing between the cells cannot be done on cell level, a BMS will be needed to prevent cells from under- or overvoltage. The same applies to SoC and SoH estimation, TR detection, and thermal monitoring.

3.3. MODULE-TO CELL GRAVIMETRIC ENERGY DENSITY RATIO

Also known as packaging efficiency, must be at least 90% to minimise additional weight needed to support the cells.

3.4. MODULE IS BMS AGNOSTIC

The module must be capable of supporting a wide range of BMS, including third party and inhouse developed BMS, by means of standard connectors for power and HV isolated data transmission, and should comply with UN-38.3, DO-311, AC20-184, and ARP-4754.

3.5. SPECIFIC ENERGY

The specific energy at pack level must be at least 350 Wh/kg, based on the specific energy on cell level of 390 Wh/kg and a module-to-cell gravimetric energy density ration of >90%.

3.6. CONSISTENCY OF MATERIALS WITH ECO-DESIGN PRINCIPLES

The design of the module must take in account design measures to reduce critical material use, improve manufacturing processes, enhance usability and efficiency but also recyclability and second-life potential to reduce the negative environmental impact of batteries as much as possible. This will be done by focussing on the following three main topics: cycle life improvement, material choice and end-of-life processing.

3.1.1 Cycle life improvement

The battery pack utilises an active temperature management system to reduce cell degradation caused by extreme temperatures. There will also be active cell balancing to ensure the best DoD window for each cell. The DoD window is reduced as well to improve cycle life with a slightly lower maximum voltage while the bottom 30% SoC is rarely used as this is needed for reserve.

3.1.2 Material choice

Aviation in general prefers to use fasteners, such as bolts, over glue, as fasteners are much more predictable for stress analyses and provide a visual check to see whether they are secured correctly. Hence similar fasteners are intended to be used for the battery pack, which should ease disassembly at the end of life to improve reusing/recycling.

The use of high-energy-density batteries will also help to design an eco-friendlier battery pack, as fewer materials are required for the same battery capacity.

Finally, the high utilisation of the aircraft will maximise the usage of the materials embodied in the cells and module.

There are unfortunately also some harmful materials, most notably carbon fibre. Despite its wasteful production process and very poor recyclability, it is unlikely to replace it for a different, less harmful, material. The main advantage of carbon fibre is its strength-to-weight ratio. Replacing the carbon fibre would increase the EOW and, as the MTOW remains the same, reduces the payload.

3.1.3 End-of-life processing

When the maximum capacity of a battery is no longer sufficient for a given flight, the first step in extending its life should be to reuse the battery for shorter-haul flights so less capacity is needed.

If there are no shorter routes available where the battery could be used, the battery could be reused for ground vehicles, as the energy density at EOL for aeronautic application is still significantly higher than at EOL of automotive application.

When the SoH drops below the EOL requirements for ground vehicles, the batteries could be used for grid stabilisation at the airport. Especially when multiple larger aircraft use fast charging to charge the batteries in a 30 to 45 minute turnaround, peak loads on the grid could become a bottleneck.

Optionally, the battery pack could be disassembled so the cells could be reused for ground vehicles/automotive or grid stabilisation while the battery containment can be reused with new cells within the aeronautic application.

4 ELECTRIC AIRCRAFT EXAMPLES

Below are given three aircraft that could utilise the new cells developed in the HighSpin project. For each aircraft, a brief explanation is given of the aircraft itself and how it would benefit from the new cells.

4.1. VELIS ELECTRO

The Velis electro is a two-seater battery electric aircraft and world's first electric-powered airplane to receive a type certificate.

Featuring much lower noise levels, the Velis Electro is considerably quieter than other aeroplanes and produces no combustion gases at all, allowing it to bring flight training much closer to urban areas without adversely affecting communities' quality of life.

The aircraft is equipped with an electric motor (E-811-268MVLC) and two battery packs with a total capacity of 24.8 kWh. A detailed list of the aircraft technical characteristics can be found in Appendix 1 – Specifications Velis Electro.

With the current generation of batteries, the endurance of the aircraft is sufficient for mainly flight school purposes and A-to-A flights, which require only 10 minutes of reserve energy. However, for A-to-B flights – and in some countries even for A-to-A flights – 30 minutes of reserve is required. This severely affects maximum flight time and therefore limits commercial application.

If the cells from the HighSpin project could be used instead, the range would double for A-to-A flights and even triple for A-to-B flights with 30 minutes reserve.

Figure 1 – Pipistrel Velis Electro type certified all electric aircraft

4.2. NUUVA V300

The Nuuva V300 is a long-range, large-capacity autonomous eVTOL UAV for logistics and aerial cargo delivery. With the experience of Pipistrel's capability of designing sophisticated electric aircraft, the Nuuva V300 provides services that are intended to serve the cargo market. The Nuuva V300 is much easier to operate with lower cost and more flexibility for the operators. Using the hybrid-electric powertrain Nuuva V300 can vertically take-off and land using eight independent battery-powered electric motors, which are already type certified. Moreover, Nuuva V300 contains a dependable and proven cruise motor to efficiently reach the destination.

The Nuuva V300 can carry a typical payload of 300 kg while reaching distances up to 300 km. The batteries are primarily used in Nuuva to provide power during the vertical take-off and landing. However, by utilizing HighSpin batteries the weight of the current battery could be significantly reduced, which would increase the range and endurance of the aircraft. The technical characteristics of a Nuuva V300 are given in Appendix 2.

Figure 2 – A concept art of the NUUVA V300 hybrid electric aircraft

4.3. UNIFIER19

The UNIFIER19 is conceptual aircraft developed by Pipistrel Vertical Solutions, Politecnico Di Milano and Technische Universiteit Delft as part of the EU-funded Miniliner project. It is a 19-passenger commuter aircraft powered by a modular liquid hydrogen hybrid-electric powertrain and aims at providing zero emission air mobility.

For the UNIFIER19, high-energy-density batteries with good performance such as the batteries which will be developed during the HighSpin project are essential for success as this will decrease the weight of the powertrain and thus increase payload.

Figure 3 – A concept art of the UNIFIER19 hybrid electric aircraft

4.4. NON-PROPULSIVE BATTERY AND APPLICATION

In this section, the requirements and safety aspects of the non-propulsive application batteries are discussed. Compared to a propulsion battery, the non-propulsive battery is utilized mainly as an auxiliary power unit (APU) in the aeronautic application. APU is a device that provides energy for functions such as starting the main engine, powering the cockpit instruments and other electrical systems, rather than propulsion. The main difference between a propulsive battery and a battery for non-propulsive application is the voltage level. Typical propulsion battery voltage ranges from 400 to 800 volts. However, the non-propulsive battery provides voltage around 28 Volts. Such batteries are subject to compliance with the RTCA DO-247, which provides test guidance and installation considerations for small and medium-sized rechargeable lithium batteries. Some examples of the APU batteries are discussed below.

The Boeing 787 Dreamliner has two batteries that are intended for non-propulsive application. In addition to the main battery, the APU battery provides power to start the APU, which can power a generator to start the main engines if needed. The battery also powers the navigation lights. The APU battery configuration is eight Lithium Cobalt Oxide ($LiCoO_2$) cells in series to provide the nominal voltage of 29,6 Volts DC. These cells have of a metal enclosure, thus falling under the prismatic form factor. With a nominal capacity of 75 Ah and the standard discharge rate of 2C the APU can provide enough power to power up the airplane. The maximum discharge rate of the APU battery cell is 5C. The APU battery cell is capable of providing a standard charge rate of 1C. The gravimetric energy density of the APU battery cell is estimated to be 101 Wh/kg. The estimated volumetric energy density is 212 Wh/L (National Transportation Safety Board, 2013). The operative ambient temperature range of the APU cell is the same as the survival temperature given in Table 1. The Boeing 787 APU battery module is visualized in Figure 4.

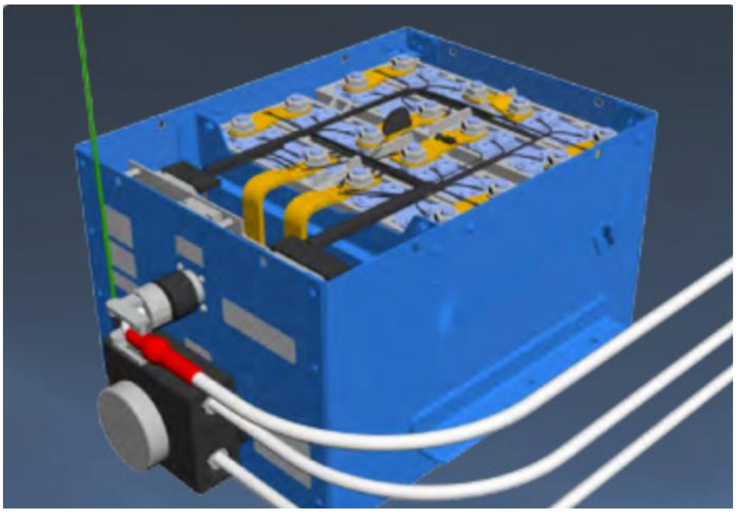

Figure 4 – Illustration of the Boeing 787 APU battery

The non-propulsive battery cells require low weight to avoid reducing the payload of the aircraft. Moreover, the common battery characteristics are high power capability, excellent discharge characteristics, low self-discharge and long cycle life with low cell degradation.

5 CONCLUSION

Electrifying aircraft is a major challenge that needs to be achieved to reduce emissions from aircraft and ultimately go towards zero emission flights. Batteries used for this purpose face challenging requirements. In HighSpin, task 1.2 elaborated the cell and module top-level requirements for aeronautic applications. These requirements, described in this report, can be found in Table 1 and Table 2. Since the maximum specific peak power targeted in this project is too low for eVTOL applications, the requirements focus mainly on fully electric fixed-wing aircraft, with the possibility of some fixed-wing hybrid electric applications as well. The document also briefly described in section 4 the potential benefits for different types of aircraft from using cells with HighSpin target performance.

In next steps within WP1 of this project, the present aeronautic requirements will be consolidated with those for automotive (coming out of T1.1). A gap analysis between the two will be performed, with the aim of obtaining a unified set of requirements that will be used as a basis for development and testing within the project.

6 REFERENCES

HighSpin Fact sheet. (2022, November 11). Retrieved from Cordis: https://cordis.europa.eu/project/id/101069508

National Transportation Safety Board. (2013). *Incident Report - Auxiliary Power Unit Battery Fire Japan Airlines Boeing 787-8, JA829J Boston, Massachusetts.* Washington: NTSB (National Transportation Safety Board).

7 APPENDIX 1 – SPECIFICATIONS VELIS ELECTRO

MODEL	VELIS ELECTRO
ENGINE	Pipistrel E-811 EASA Type-Certified
max power	57.6 kW MTOP
PROPELLER	Pipistrel P-812-164-F3A Certified fixed-pitch composite three-blade, 1.64 m diameter
DIMENSIONS	
wingspan	10.71 m (35.1 ft)
length	6.47 m (21.3 ft)
height	1.90 m (6.23 ft)
wing area	9.51 m2 (102.4 sqft)
aspect ratio	12.04
positive flaps	0° (0), 8° (+1), 19° (+2)
centre of gravity	24% – 32.4% MAC
WEIGHTS	
basic empty weight – with batteries	428 kg (941 lb)
max take-off weight, MTOW	600 kg (1,320 lb)
payload weight	172 kg (378 lb)
PERFORMANCE	
Data published for 600 kg MTOW (1.323 lbs). All speeds in Knots	
stall speed with flaps, V_{S0}	45 KCAS
stall speed without flaps	51 KCAS
cruising speed (at 35 kW)	90 KCAS
maximum horizontal speed at sea level	98 KCAS
never exceed speed, V_{NE}	108 KCAS
max speed with flaps (+2), V_{FE}	65 KIAS
manoeuvring speed	100 KIAS
best climb speed, V_Y	75 KIAS
max climb rate	3.3 m/s (647 ft/min)
best glide ratio speed	64 KIAS
best glide ratio	15:1
Take-off run – grass/asphalt	246/241 m (807/791 ft)
Take-off over 50′ obstacle – grass/asphalt	453/409 m (1,486/1,342 ft)
service ceiling	3,660 m (12,000 ft)
endurance	up to 50 minutes (plus VFR reserve)
max load factor permitted @ (1.875)	+4g -2g
design safety factors & tested	minimum 1.875
Note: Data is for ISA sea-level conditions. Pipistrel reserves the right to revise this data sheet whenever occasioned by product improvement, government/authority regulations or other good cause.	

8 APPENDIX 2 – SPECIFICATIONS NUUVA V300

MODEL	NUUVA V300
HYBRID POWERTRAIN	8 x Pipistrel E-811 EASA certified electric engines 1 x High-efficiency FADEC IC engine
DIMENSIONS	
total length	11.3 m / 33 ft 1 in
fuselage length	9.3 m / 30 ft 6 in
wingspan	13.2 m / 43 ft 4 in
height	3.1 m / 10 ft 0 in
wing area	23 m^2 / 248 ft^2
cargo hold dimensions (L x W x H)	3.65 x 0.85 x 1.00 m / 12.0 x 2.8 x 3.3 ft
cargo hold volume	3 m^3 / 106 ft^3
WEIGHTS	
maximum take-off weight, MTOW	1,700 kg / 3,750 lb
typical mission payload weight	300 kg / 660 lb
maximum payload weight	460 kg / 1,014 lb
typical mission fuel weight	65 kg / 143 lb
maximum fuel capacity	410 l / 108 gal MOGAS, AVGAS or car fuel (min RON 95; EN228 Premium or Premium Plus with max. 10% Ethanol)
PERFORMANCE	
fast cruise speed (at 95 kW and 5,000 m ASL)	220 km/h / 119 kt
economy cruise speed (at 75 kW and sea level)	165 km/h / 89 kt
best climb rate speed, V_Y	144 km/h / 78 kt
max climb rate	3 m/s / 600 ft/min
take-off distance	0 m (standard helipad)
landing distance	0 m (standard helipad)
maximum take-off altitude	2,500 m / 8,200 ft ASL
maximum cruise altitude	6,000 m / 19,700 ft ASL
fuel consumption (at economy cruise)	30 l/h / 8 gal/h
endurance	up to 12 hours
typical mission range (+ 30 min reserve)	300 km / 162 nm
maximum range (+ 30 min reserve)	up to 2,500 km / 1,350 nm
Note: Pipistrel reserves the right to revise this data sheet whenever occasioned by product improvement, government/authority regulations, or other good cause.	