Mobile catapult system for autonomous aircraft with payload aircraft and flight control station

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RESEARCH UNIVERSITY
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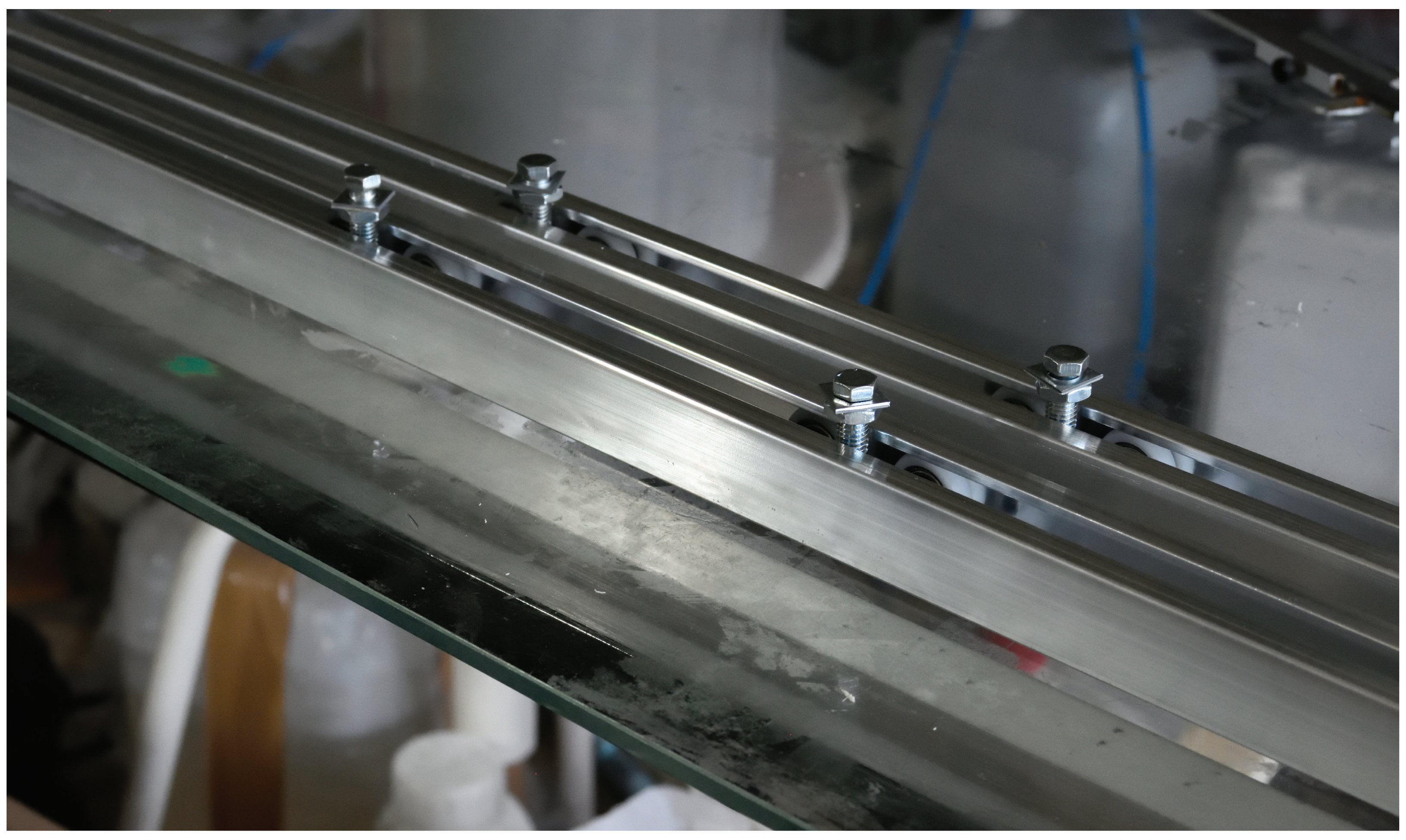
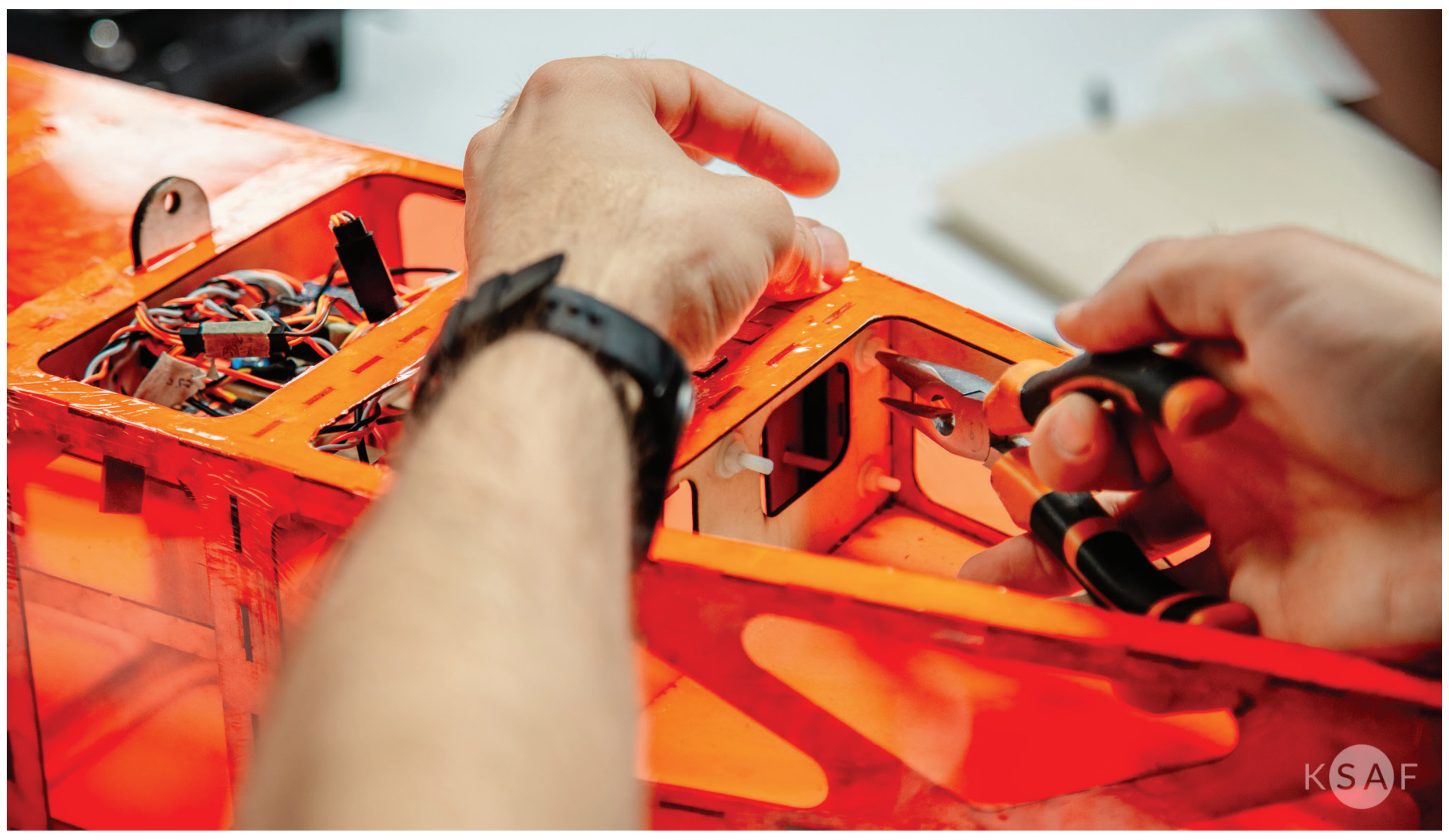
INTRODUCTION:
The project embraces the development of the concept, calculations, building prototypes, and final iteration of the mobile system composed of the unmanned aircraft enabling airdrop of the payload with up to 2 kg weight, the aircraft catapult, which provides safe take-off, and the energetic self-sufficient mobile flight control station, enabling flight operation in a variety of conditions and localisations.



METHODS:
In the initial stage of the project, simulations and calculations necessary in the process were carried out using the Matlab Simulink environment. Physical models of the catapult and aircraft were recreated. The structural designs were made in SolidWorks.The base of the catapult is made of aluminium profiles, on which aluminium guides and carts are placed. The platforms carrying the weight of the aircraft and the mountings for the carts were adapted to specific models. The drive in the catapult is elastic rubber which is pulled by a winch and a set of pulleys so that the force generated by the rubber is maintained along the entire length of the catapult track. The launcher is supported on ground-attached elements that allow height adjustment and selection of the angle of inclination relative to the ground. This configuration allows a 10 kg aircraft to accelerate to a speed that allows for a smooth take-off. Initial iterations of the payload aircraft were made from durable aircraft plywood and composite materials. The structures allow for the transport of payloads of up to 2 kg. The wings and stabilisers were made from extruded polystyrene using a resistance wire plotter to achieve the optimum airfoil. A layer of glass and carbon fibre in epoxy resin was then laminated onto the surface thus shaped, achieving the required strength at low weight. The aircraft's fuselage was made from aircraft plywood. As the aircraft is designed as a payload model, glass and carbon fibre reinforcements were made in critical areas of the structure. Prototypes prepared in this way were presented at the British Model Flying Association 2023 University and Schools Payload Challenges in the United Kingdom. Members of the research group designed and manufactured a portable flight control station, which consists of covered screens, to increase visibility, displaying flight parameters and a meteorological station useful for planning the time and place of take-off. Suitable transmitters using 2.4 GHz and 868 MHz frequencies with a range of up to several tens of kilometres were used to ensure communication with the aircraft. Since the vast majority of flight operations take place at locations far from buildings and without access to the electricity grid, an energy bank with a capacity of at least 720 Wh, which can also be charged using photovoltaic panels, was integrated into the flight control station. The installation of a solar energy collection system allows the operating time of the measurement and control equipment to be extended. A 700 W 'Sinus-pro 1000 W' voltage converter and a 100Ah volt-opti AGM battery was used. The station was equipped with three monitors and a laptop which fulfills its purpose as a base unit. One of the three screens displayed information in the 'Mission Planner', which will be collected by the Pixhawk Orange Cube flight controller and then transmitted to the station via a RFD antenna. The entire unit is housed in a durable, compact enclosure, increasing the station's mobility and robustness.



RESULTS:
The developed system is versatile. It enables the take-off of many different types of aircrafts. Fundamental aspects that were addressed during the design are modularity and lightweight construction. That was the reason for constructing most elements with aluminium, which is characterised by the best ratio of weight and durability. The modularity, easy disassembly into small parts, and fast montage provide simple transport. The largest elements are 1.5 m at maximum. Because of that, they fit even in a car. It is possible to adjust the catapult to different types of aircrafts and the lengths of their take-off run. The shortest configuration is 3.0 m long, including the 1.5 m length of the take-off run. On the other hand, the longest is 6.0 m long with 4.5 m length of the take-off run. After simulating and doing precise calculations in Matlab Simulink, the velocity enabling take-off of 10 kg plane was established for 15 m/s. The first iterations of the payload aircraft were tested during flights at the BMFA 2023 University and Schools Payload Challenges. The constructions proved their ability to carry the loads of the assumed weight. In further iterations, it is possible to install photovoltaic panels on the wings of such prototypes, which will lengthen the autonomous flight. The portable flight control station will improve the mobility of the flight-monitoring devices and lengthen the flight time of the tests off the laboratory. The structure will enable live monitoring of plane parameters, will help implement new technology solutions and shorten the test preparation procedure. Some of those parameters are: localisation check based on GPS data, declension sensors calibration, and unit's communication correctness test. The essential part of the mission is precise and unbroken monitoring of the parameters above. It is possible after creating proprietary software also correlated with the air condition check system, which is not included in standard autopilot equipment. The station will also enable meteorological measurements such as the speed and direction of the wind and other essentials for the safety of the flight weather conditions.

DISCUSSION:
The primary advantages of the remote-controlled catapult are improved operator safety during test flights and autonomous missions and the minimisation of human error that occurs during the manual transmission of the aircraft's initial speed. Instead of using direct muscle power, aircraft take-off is made possible by the remote release of the catapult trigger by the operator, who is at a safe distance from the mechanism. The "Sinus-pro 1000 W" voltage inverter, used in the construction of the mobile flight control station for the unmanned aircraft, was chosen because its main advantage is the generation of a so-called "pure sine" at the output. This significantly increases the versatility of the system by enabling the connection of devices with electric motors of 230 V, including power tools. The inverter used in the project has many functionalities. One of these is to work as a UPS, or uninterruptible power supply system, which can be used to supply power in the event of a power cut from the mains. For example, it will prove useful as an emergency power supply for a computer carrying out long calculations that cannot be interrupted, such as training the neural network models we use in our projects. Other advantages are that it can work as a car charger and has additional safety features to facilitate its use with photovoltaic panels. It was decided to use the AGM technology because it allows the devices to be charged and discharged multiple times, making them more durable than classic car batteries. In addition, devices of this type are significantly cheaper compared to classic gel batteries. Its selection was also guided by a weight of 24 kg, which allows it to be easily carried by one person in accordance. AGM batteries belong to the maintenance-free battery family, so there is no need for servicing in the form of topping up fluids, as is the case with traditional car batteries. "Mission Planner", thanks to its fitted GPS transmitter, also allows the autonomy of the aircraft to be controlled and enables flight planning. It also provides real-time information on the results of the air quality test, which until now had only been stored on an SD card. An HP EliteBook 830 G8 laptop capable of connecting up to four monitors and three ASUS BE24EQSB monitors were purchased for the project. All of these enhancements will help improve flight mobility and allow real-time control, planning and reporting of flight progress. It is an essential element that will improve the operation of the system allowing autonomous aircraft flight and, most importantly, it is an original project by members of the research group. Equipping the resulting structures with photovoltaic panels could make them self-sufficient in energy in the future. This represents the potential for the use of a zero-emission autonomous flight system with applications in air quality research and rescue missions.

CONCLUSION:
The main objective of the project – to create a mobile system that allows maximum autonomous flight minimising direct human involvement – was achieved. The catapult's modifiable design allows it to be adapted to aircraft size and easily transported even in a passenger car. It also ensured the safety of the operator due to the replacement of the previous ejection by muscle power with a mechanism released remotely from a safe distance. The station provided a more streamlined preparation for testing and enabled the desired flight parameters to be monitored in real time, providing a rapid response should problems arise during the test. The first iterations of the payload aircraft performed the mission flight successfully. The constructions will continue to be improved and used for future projects, but their key functionalities have already been implemented.