Introduction

Wecorp Industries Ltd is currently developing a UAS for urban warfare and is proposing an adapted version of the system it has developed up to this stage. The company has identified that minor modifications to the original development plan and project would be necessary, without endangering the Technology Readiness Level (TRL) 6 status of the currently developed system. These modifications in majority revolve around craft and payload safety measures and base specifications of presently achieved functions and capabilities. The demonstration of feasibility of the proposal shall be conducted through the following sections.

The current features and capabilities of the system are detailed in Section 1 including evidence that the system has achieved TRL 6. To demonstrate the feasibility of the proposal, the existing capabilities are mapped to a set of newly defined product requirements. These may be found in the attached document WE- INHIBITOR Product Requirements.

Section 2 and the attached WE-INHIBITOR V&V Plan contain the verification and validation strategy and testing timeline proposed to meet the Product Requirements and bring the product to market.

Section 3 explores the innovation and risk aspects of the project by providing a technical risk matrix and a comparison of the developed solution to alternative solutions.

Section 4 provides evidence of the team's expertise and experience capability to successfully bring the project to its conclusion.

Wecorp Industries has defined new Project Requirements for its INHIBITOR craft to conform with the requirements of the competition proposed by DASA. Following the tender application, the company shall immediately implement the proposed plan into its R&D activities. All remaining verification timelines are to be defined in Phase 0 (by 31st December 2020) to develop the detailed project plan required to successfully fulfil the Product Requirements.

For the sake of clarity, in this document the "Craft" and "Platform" refer to the craft principal system, an Unmanned Air System for operation in an urban environment. The "Payload" and "Module" system refer to the lethal capability payload integrated with the craft during its operation.

1. Description of Developed System

1.1 Introduction

In this section a brief overall description of the system is provided. The platform capabilities are listed and described and are then mapped to the Lot 3 requirements of the competition to show relevance with and feasibility of the project. In the following section the main challenges encountered during the development of the project are explained with emphasis on the scientific, technical and practical choices made to overcome the challenges and increase the likelihood of successful delivery of the project.

1.2 System Description

The INHIBITOR Platform consists of an Unmanned Aerial System (UAS), remotely controlled by an operator via a Radio Transmitter. For the sake of clarity, the block diagram in Figure – Feasibility_1 shows the conceptual high-level architecture of the main components and sub-systems and their interaction.

The WE-02 (internal identifier for the version 2 of the INHIBITOR product line) has 6 rotors (hexacopter) disposed into a rectangular arrangement as shown from the top view in Figure – Feasibility_2. It has a width of 700mm and it is 980mm long and an all up weight of 10kg.

The body consists of an enclosed composite shell made of carbon fibre and fibreglass. This can be segmented into three main components: a core/main monocoque body with structural function as well as housing for electronics, an outer structure with the role of protection from external impacts and housing of some sensors (cameras and GPS) and a removable module shell, hosted as an extension below the main body, with the double function of protecting the payload and enclosing it by making it an “independent/modular” unit.

Figure – Feasibility_3 and Figure – Feasibility_4 show respectively the side and front view of the full platform.

The core body also hosts at its centre a battery which is inserted vertically from the top; 4 visible latches lock the battery in place and provide the release mechanism to the user.

The outer structure hosts the navigation, thermal and depth cameras as well as visible and IR lights and ventilation openings in the front pod, the stereo Visual Inertial Odometry Cameras in the left, right and rear pods; the rear pod also hosts a downwards facing 1D Lidar (range finder) and visible/IR lights. Figure – Feasibility_5 offers a view of the bottom of the platform.

Hidden in the rear pod is also the GPS antenna visible as a “fin” in Figure – Feasibility_6.

4 landing legs extend from the main body to protect it from landings and/or vertical impact and to distance the payload from the ground.

The 57-Module is a 1.4kg payload which was developed to be fitted on the INHIBITOR drone platform using its universal mechanical and electrical/data interfaces. The module comprises of a semi-automatic weapon system chambered for use with FN 5.7x28mm ammunition, a 5-round magazine, a recoil compensation system, a LIDAR and all required electronics and mechanical components to ensure safe, reliable and effective use of the system. The use of the FN 5.7x28mm round guarantees high penetration while the bespoke recoil compensation system and the introduction of a LIDAR whose data can be communicated to the INHIBITOR platform, enables accurate targeting and shooting from the craft.

Figure – Feasibility_7 to Figure – Feasibility_12 show details of the arrangement of the sensors mentioned above as well as the internal components (Power Distribution Board, Companion Computer, Flight Controller and payload). Figure – Feasibility_13 shows the interaction via data signal and power among the electrical components and sensors.

For further reference to the reader, following a model-based system engineering approach, Figure – Feasibility_14 shows the Context Diagram of the WE-02. It is well known that the system model is a living and interactive tool, hence in this proposal snapshots of the main systems are presented and referenced as follows:

- WE-02 Level 1: Figure – Feasibility_15
- Power Supply: Figure – Feasibility_16
- Flight Control: Figure - Feasibility_17
- Sensors: Figure - Feasibility_18
- RF Receivers: Figure - Feasibility_19
- Propulsion: Figure - Feasibility_20
- System Control Data Flow: Figure - Feasibility_21

1.3 Capabilities Analysis

In this section the current capabilities of the system are listed and described. These are split in Functional Capabilities, i.e. what the product does or can do, and Non-Functional ones, i.e. product's properties.

Functional Capabilities:

- **Altitude hold**: The craft is able to control its altitude (z) at constant height between 0m and 3000m, indoor (30cm accuracy), outdoor (10cm accuracy) in GPS denied environment and outdoor with GPS.
- **Position hold**: The craft is able to control its position (x,y) in a fixed point in space, indoor (30cm accuracy), outdoor (10cm accuracy) in GPS denied environment and outdoor with GPS.
- **Position control**: The user is able to control the position of the craft (x,y,z) directly from stick inputs, indoor, outdoor in GPS denied environment and outdoor with GPS.
- **Wind resistance**: The craft autonomously reacts to wind disturbance to maintain constant position or desired setpoint for wind up to 10m/s, outdoor in GPS denied environment and outdoor with GPS.
- **Low light - outdoor**: the craft is able to control its position (x,y,z) in low light environment (0 lux), outdoor with GPS
- **Low light – indoor 1:** the craft is able to control its position (x,y,z) in low light environment, as low as to 15 lux without the aid of controllable visual light and with the aid of controllable visual light for lower illuminance, indoor.
- **Low light – indoor 2:** the user is able to navigate with FPV visibility in low light environment with the aid of controllable visual light, indoor, outdoor in GPS denied environment and outdoor with GPS.
- **Indoor-outdoor transition**: the craft is able to navigate stable in the transition between GPS and GPS denied environment (e.g. indoor)
- **Impact protection**: the craft is able to navigate against and around obstacles with flight speed of max 1.5m/s, indoor, outdoor in GPS denied environment and outdoor with GPS.
- **Shooting**: the user is able to activate the payload to shoot a 5.7cal rifle bullet, indoor, outdoor in GPS denied environment and outdoor with GPS,
- **Lethality**: the payload is able to penetrate a IIIA body armour at a maximum range of 100m, indoor, outdoor in GPS denied environment and outdoor with GPS.
- **Reloading:** the payload is able to automatically reload the round into the chamber after having fired the previous.
- **Shot survivability**: the craft is able to handle the recoil of the shot via a system of rails, springs and oleo dampers as well as a muzzle break

- **Round capacity**: the payload is able to host a magazine with a maximum of 5 standard 5.7mm rounds
- **Manual aim**: the user is able to point the platform and payload at a potential target within the FPV field of view, with a precision of ± 0.7° in outdoor or open indoor environment or a precision of ± 1.4° in indoor environment (residential room).
- **AI assisted aim**: the craft is able to autonomously aim at a selected human target within 2 seconds from the target selection, with a precision of ± 0.7° in outdoor or open indoor environment or a precision of ± 1.4° in indoor environment (residential room).
- **Autonomous tracking**: the craft is able to autonomously keep the aim at a selected (by the user) human target
- **Target re-acquisition**: the craft is able to autonomously re-detect a previously selected target in the scenario in which the target temporarily moved outside of the FPV field of view.
- **Moving target**: the craft is able to correct the aim to a target moving at walking speed.
- **Flight time**: The craft is able to continuously hover on a single battery cycle for 18mins
- **Cross ID**: the craft is able to distinguish and maintain the aim at the selected target if it crosses with other potential targets.
- **Semi-autonomous take-off and landing**: the user is able to semi-autonomously take-off and land using a single input from on-screen button, indoor, outdoor in GPS denied environment and outdoor with GPS.
- **Autonomous landing**: the craft is able to land autonomously upon activation of safety procedure (e.g. loss of communication with controller), indoor, outdoor in GPS denied environment and outdoor with GPS.
- **GPS waypoints**: the craft is able to navigate autonomously following user-selected GPS waypoints, outdoor with GPS.
- **Internal cooling**: The craft actively cools battery and internal electronics, between 0°C and 30°C
- **Payload interface**: the craft is able to accommodate different modular payloads via standard mechanical and electrical interfaces, with a quick release mechanism.
- **Thermal feed**: the craft is able to provide thermal camera feed via FPV to the user, upon selection of the user from the controller
- **FPV (First Person View)**: the craft provides analogic visible light video feed via FPV by default to the user.
- **Health checks 1**: the craft autonomously checks the status of the main flight parameters and sensors upon power-up, before being ready to take-off within 60 - 100 seconds.
- **Heath checks 2**: the craft is able to autonomously check the status of the payload every 0.0025sec: loss of communication, logical state and mechanical state (arm, disarm and safety).
- **Flight speed**: the craft is able to fly in any direction at a maximum velocity of 60 km/h

<u>Non-Functional Capabilities:</u>

Here the non-functional properties of the system are listed (i.e. what the system has):

- Dimensions: 980x700x210 mm
- All up Weight: 10.6kg
- Payload capacity: 1.5kg max

- Sensors redundancy
- Structural protection from external impact (operations and transportation)
- Ingress protection from dust and rain
- Modular battery design to allow air transport of battery pack (874Wh)
- Smart battery to monitor current usage
- Power button
- Designed with product integrity and design for manufacturing criteria
- Designed according to DOSG standard criteria
- Designed with ease of maintenance criteria
- Encrypted digital controller
- Manual firing button
- Manual payload arming button
- Manual offboard-mode button
- Recoil compensation
- Fail-safe procedures
- Designed according to company’s ethical guidelines
- Graphical User interface (GUI)
- System range (open air) > 500m

1.4 Capabilities- Requirements Mapping

The capabilities of the developed system are mapped to the newly defined Product Requirements in Section 3.3 of WE-INHIBITOR Product Requirements. The existing capabilities will be further developed in order to meet the Product Requirements and hence they are mapped against these requirements. The identified major technical risks related to the development and modification of existing capabilities are detailed in Section 3.2 of this document.

1.5 Design Choices

This section shows some of the main challenges faced during the design of the system and the respective solutions.

One of the first choices made for the design of the INHIBITOR product line was about the design philosophies adopted to avoid failures of components or minimise the effect on the entire system of any possible components’ failure. In this context it is possible to refer to the attached document “WE-01-MaintenanceStrategy-01”, which was originally produced as an internal report to highlight the maintenance and inspection strategy of different components in different domains.

An example of the application of these philosophies is the choice of a **monocoque** body as the core structural component and an outer structure connected to the core body but not as a continuous structural element.

The benefits of such approach lie in the fact that a structural shell (monocoque) has a distributed load pattern; the reduction of the load density compared to a concentrated loads structure leads to a lower rate of damage nucleation as well as to a slower propagation rate. This obeys to the well-known damage tolerant approach, which, by assuming the presence of invisible damages already present in the structure, allows to estimate the growth of the damage, plan the inspections and design more efficiently by reducing the safety factors required, hence reducing the weight of the structure which is a critical parameter for weight sensitive structures like aircrafts.

The conceptual disconnection between the core body and the outer protective structure has two more benefits. First, it allows to isolate the design criteria of the two components: the core body needs resist to the nominal and more standard load patterns of the flight, i.e. thrust and vibrations coming from the motors, while the outer structure needs to be designed to absorb the loads resulting from impacts with the external environment. Second, the presence of a physical interface between the two elements (core and outer) allows that in presence of any damage nucleating in the outer structure (as a result of a hard impact), the same is not able to propagate across the interface and affect the core body; in other words, the physical interruption itself acts as a crack stopper.

As a direct consequence of this strategy, bespoke **propeller guards** were designed, with the requirement to absorb the kinetic energy resulting from the entire craft impacting a hard wall on a single prop guard, by dissipating the energy in deformation and eventually energy released in the nucleation of fracture surfaces. This research project has been conducted at Wecorp, in collaboration with Ecole Centrale Nantes, during the development of a Master thesis project.

An analytical formulation has been developed based on the coupling between normal and bending actions in circular beams that generally causes an early buckling instability compared to the traditional Euler beam. This was then used to create a Finite Element Model that allowed to span across different geometrical parameters. Experimental tests have finally confirmed the design as well as the choice of materials and composite layup orientation.

Regarding the implementation of a lethal payload onto a UAS, one of the early and biggest challenges that Wecorp has faced was the elimination or absorption of the **recoil force** generated by any projectile leaving the muzzle.

An early design incorporated in the first version of the INHIBITOR drone (WE-01) was to have an active system of recoil compensation consisting into a convergent-divergent nozzle that simultaneously to the firing from the front barrel (12-gauge shotgun) would fire a blank cartridge with the scope to expand the gases at nearly Mach 3 and neglect the backwards recoil of the weapon.

Even though the scientific and technical principles of such a system work, the practical drawback consists in the need to design and manufacture the cartridges bespoke for the system and perfectly balanced in terms of amount of powder. This also slows down the approval from DOSG since the system did not use standard ammunitions.

In order then to bypass the aforementioned drawbacks and at the same time have the opportunity to refine the requirements of the system by achieving penetration against body armour, another payload has been developed at the same time of the design of the second version of the system (WE-02): 5.7x28mm rifle.

The benefits of this design choice can be summarised as follows: 1) the recoil force generated by this kind of weapon is smaller, without compromising on the lethality; 2) the use of standard ammunition offer an immediate reduction in technical risk about the sourcing of the ammunitions for the users; 3) by using existing standard NATO rounds, additional compliance processes are not needed to bring the system to service.

It is worth noting that the lethality is guaranteed by the muzzle velocity of 750m/s achieved on the Wecorp's system as shown by the attached internal report "WE-AS-AS-006 F1P1 Effect Delivery Testing.pdf".

The recoil compensation is then achieved via: 1) the use of a muzzle break; 2) the use of a system of rails, springs and oleo dampers.

The attached internal report "WE-AS-AS-007 F1P2 Recoil Compensation Testing.pdf" shows the experimental tests results and the analysis used to design and validate the recoil compensation.

The ultimate tests conducted at Wecorp to ensure the feasibility of the implementation of the 5.7x28mm payload on the WE-02 craft is a full system test into an environment relevant to the operational field, i.e. indoor firing range. The report of this tests can be found in the attachment "WE-AS-AS-012 INHIBITOR V1 In-Flight Shot Testing.pdf". The main results of the test were:

- Confirmation about stability of the craft during and after the shot
- Confirmation of accuracy during in flight shot
- Confirmation of post-shot behaviour and survivability of the system.

1.6 Technology Readiness Level

The INHIBITOR Programme started in 2019 with the development of the WE-01 – the first prototype of a weaponized drone by Wecorp Industries. This prototype was developed for the Urban Environment warfare and therefore shares many features with those stated in this competition.

This system was fully assessed by the Type Airworthiness Authority (TAA) and tested by 700X Naval Air Squadron and found to be advanced to TRL8 as stated in the attached file (20200110-TAA_Airworthiness_Audit_Report_WeCorp_Revisit_Final-OSC).

However, the WE-01 is also missing several key capabilities such as the modular and standard interface, the minimum rounds munition capacity and the return to the launch position ability. These requirements led to the redesign of the weapon system as the 57-Module payload and the introduction of a GPS. While the 2nd iteration of the INHIBITOR, the WE-02 project, aims to introduce the missing capabilities identified above, it does share a large amount of technology and development with the WE-01 and therefore the features verified on the WE-01 can safely be assumed to be of sufficient technology readiness for this current application.

The key new features introduced in 2nd iteration have also been successfully tested and verified to TRL6 and above. Report WE-AS-AS-006 F1P1 Effect Delivery Testing shows the successful development of a new weapon system for the 57-Module payload for the INHIBITOR able to deliver lethal force. Report WE-AS-AS-007 Recoil Compensation Testing shows the ability to compensate the recoil from said weapon system as part of the 57-Module. Report WE-AS-AS-0012 INHIBITOR V1 In-Flight-Shot proves the integration of the 57-Module on the first version of the WE-02. This test clearly proves the capability of providing lethal force from the flying craft without destruction of the platform and hence carry-out post-engagement assessment. Finally, the GPS Flight Report 11-08-20 summarizes the positive testing of the GPS integration on the INHIBITOR craft.

By combining the proven, existing technology of the WE-01 and the extensive development and tests of these new features TRL6 and above, Wecorp Industries feels confident that its application meets TRL6 requirement and hence applies for Lot 3 of the competition.

2. Validation & Verification

The testing regime defined to Verify and Validate the newly defined Product Requirements of the INHIBITOR craft may be found in WE-INHIBITOR V&V Plan.The document builds upon the V&V activities conducted on the Wecorp Industries prototypes up to now.

Sections 4.0 and 5.0 of the V&V plan detail the philosophy behind the V&V process employed and the Certification and Acceptance plan. The Verification Matrix defined in Appendix A describes the timeline and strategy for high-level verification testing of the system features and requirements.

The Validation Matrix defined in Appendix B describes the validation activities planned on being undertaken to ensure stakeholder requirements are met. The method by which the different requirements shall be validated may be found in the Validation Product column of the Product Requirements. All undefined timelines and criteria are planned to be defined by the end of Phase A (31st March 2021).

3. Innovation and Risk

3.1 Competitor Analysis

The INHIBITOR craft is a robust, weaponised UAS optimised for deployment in urban combat environments. For military platoons to successfully deploy the drone in its intended environment and application, it was designed, assembled and supported with state-of-the-art hardware and software technologies by a world-class team of engineers - in terms of components and development personnel, no expenses have been spared. The result is a product which has overcome a multitude of technical challenges and provide unparalleled value to end-users through its ability to perform as an alternative option to provide real-time support to soldiers in urban combat environments.
Its state-of the art sensors, edge computing and propulsion components were further enhanced by purpose-build bespoke PCBs for power distribution across the craft, battery management, payload modularity and weapon safety. All components are encased in a lightweight structure specifically designed to enhance the performance of this drone in military applications. While this approach does lead to increased costs for developing the drone, it aligns the product with the end-user's pain points and ensures optimal performance while being competitive in the Defence landscape.
The INHIBITOR's modular payload, and the fact that the craft can accommodate any payload (be it advanced sensors or weapons) with a maximum weight of up to 1.5kg, it offers users a range of applications for multi-mission use. Realistically, the product is expected to have service time ranging from 1-3 years (depending on the types of missions deployed in), spreading the costs for the buyer across that same timeframe. The modular hardware concept opens cost effective and fast options to procure a wider spectrum of capabilities, meaning that more capabilities can be quickly added to the system without sacrificing the

superior performance of the main platform. The result would be that the costs of the main platform will be further spread over a wide spectrum of capabilities.
The cost-effectiveness of our product is boosted even further with the software-enhanced hardware strategy. This strategy already allows for enhanced autonomy, reconnaissance, and data collection capabilities to be unlocked with software updates, without needed to upgrade the platform or its sensors. The best example is the current array of cameras that is already technically capable to 3D- map the surroundings of the platform but has not been unlocked by our software team due to time constraints and prioritisation. This is a feature that will become available to the user with the release of a software update package.
The INHIBITOR drone was not designed to solve a single tactical problem. It was designed to be the Unmanned Air platform of Choice for Military Operators within the NATO on the platoon level. Allowing end-users to procure a single drone and add a wide spectrum of capabilities within its product ecosystem. This allows for the money spend by the buyer to be re-invested in the R&D of the platform – ultimately ensuring that the NATO/ specifically the UK will remain world-leading within this strategy relevant capability need.
Most competing capabilities aim to solve a subset of the challenges the INHIBITOR is addressing. While this might come at a lower price tag it comes at a massive loss in future capability and even worse in some cases at a lack of ethical consideration. Examples for the ladder are non-stabilized (and consequently riskier) weaponised drones, small explosive drones or small drones that drop explosives that have been pointed out as one of the most ethically devastating concepts tech companies can come up with. “Slaughter-bots” is just one powerful example that addresses this massive public concern.
As for the lack of future capability – if there isn’t a business model that supports the sustainable flow of multi-millions of GBP being re-invested in the development of such a drone system or its ecosystem, it will not be able to compete mid-long term with what state-funded R&D from Russia and China is creating. This means that a drone from different suppliers for each of the challenges that exists on the platoon level will not solve the mid-long-term problem. Only a short pain relief without solving the underlying structural problem. The US calls it a “Big Bets” and has already taken two with Palantir and Anduril – the UK needs a Big Bet for this capability – and Wecorp Industries is in a leading position to take on the challenge.

3.2 Technical Risk Matrix

The technical risks identified with the implementation of newly defined Product Requirements may be found in the attached INHIBITOR Project Technical Risk Matrix. The risk level of the identified requirements is taken into account in the verification planning to mitigate the higher level risks in priority.

4. Team Expertise and Capabilities

To overcome the technical challenges associated with delivering a product that could add value to the end-user in the complex environment of urban warfare, innovation across different disciplines of science and engineering was required. Therefore, It was crucial for the company to assemble a talented team of innovators that were, one the one hand knowledgeable about the current technological trends, and on the other structured enough to comply with the demanding quality and compliance standards associated with the Defence and Security Sectors.
Wecorp Industries’ solution was to attract graduates across different disciplines from world-leading universities that could lead the innovation efforts, and compliment them with accomplished professionals with industry experience to guide their efforts with the correct methodology and approach to make a viable product. The team has a strong scientific

educational background with graduates having obtained their degrees from top tier scientific institutions such as Imperial College London, University College London, and ETH Zurich (see TEAM EXPERTISE_Table1). Obtaining what most would consider a 'top-tier education', these graduates are knowledgeable about the current technological trends, while at the same time they bring high work ethic with an enthusiasm to innovate and think outside of the box to the table. This is invaluable for Wecorp Industries' effort to revolutionise the industry, since there is no existing solution to improve, and it is necessary to develop a product by reasoning from first scientific principles. Also, to tackle the plethora of technical challenges, a balanced multidisciplinary team was assembled (see TEAM EXPERTISE_Table2), to bring a diverse set of skills and perspectives to the table, which would aid the team-effort in overcoming these challenges.

To mitigate the risk of inexperience, the talented core of graduates is complimented with experienced professionals in team-lead and managerial positions (see TEAM EXPERTISE_Table3). Their knowledge of industry standards, structured approach to managing large and complex projects from concept to delivery, would provide the necessary structure and methodology to meet all the deliverables.

The company's project portfolio in its 2.5-year lifetime only attests to the team's ability to deliver a viable product that would add value to end-users (see TEAM EXPERTISE_Table3). Starting from 2018, the team has successfully innovated across a variety of fields including weapon design (*Rocket-compensated drone-mountable shotgun*), drone design (1.5kg payload drone to mount recoilless shotgun), integrated UAV systems (*Development of a Reconnaissance Drone Concept*) and AI (*Drone Concept Demonstrator: AI Face identification drone stream to base station*). This was made possible by adopting a rapid prototyping approach to design, where the team would initially attempt to solve a simple problem on a sub-system level under a tight deadline, before moving on to the next one. At the same time, the team would actively participate in challenges (*Hackathon: Antiterror AI Competition*) where they had the opportunity to not only demonstrate, but compare their solutions in order to understand what the next step would be to improve the product.

By late 2019, the team had successfully developed the WE-01 UAS (*Tactical Remote Effects Delivery NATO Challenge*), which was the first iteration of our current solution. The WE-01 has achieved huge success as it attracted interest from military bodies (jHub) and received critical acclaim and eventually reaching TRL-8 accreditation by TAA.