

# Technical Approach

*Please find attached a very rudimental design in the form of a 3D PDF which is used to help illustrate some concepts.*

## Product Development Methodology

To fully define the technical approach in detail, more information will be required in terms of the user and systems specifications as well as the operating environment. We follow a Lean, Agile product development process, which will involve a close relationship with the sponsor throughout the whole process. We see the sponsor as an integral part of the team. We do have ISO 9001 certification and apply configuration management principles in our product development, which will provide a complete technology package to the sponsor once the development is complete,

## Aerodynamic Design

The chosen aerodynamic design will be a rotorcraft for manoeuvrability and control. To reduce the amount of actuators the rotors will be fixed pitch. The exact configuration will be explored during the project and will be selected based on a few factors like power distribution (electrical and aerodynamic), as well as control algorithms and space requirements.

Therefore no exact sizes of the aircraft are available yet, but will be designed to fit into a 14000cm3 sphere (Radius = 15cm).

## Collision Protection

*The cage described below is not represented in the 3D PDF, the Gimbal concept is attached.*

For collision protection we propose placing the full rotorcraft in a polyhedral cage which will generate an even and safe bounce off, as to avoid loss of control.

The cage will surround a two-axis gimbal set, and using inertial sensors we will keep the inner frame stable. This will allow the cage to roll around the device, while the core remains stable. Thus giving more accurate camera feeds and navigation, as well as allowing the drone to roll on floors, walls and other obstacles.

## Explosion Protection

*The colour references made below are represented in the attached 3D PDF.*

To ensure full explosion protection we have proposed a modular design, using the three most common methods of protection.

Designing intrinsically safe circuits would only be applicable to the control circuitry (Light Grey Box). Since the motor drivers (Orange Box) will be running at much higher powers, we will be encapsulating those circuits. Encapsulation for obvious reasons can’t be applied to moving parts so the motors will need to be contained in their own explosion proof containers (Red Box). The battery (Yellow Box) will be encapsulated and will source power to the other modules through the interlinking connecting shafts (Black Thin Square Tubes).

We have an existing relationship with a South African certification company named, Mining and Surface Certification (MASC). MASC are qualified to certify for both ATEX and IECEx standards. South Africa generally adheres to the IECEx standards which we will adhere to for this project.

## Sensor Packs

To try and locate the higher power consumption areas, encapsulated with the motor drivers are the illumination components (White Hemispheres), Cameras (Blue Hemispheres) as well as some sort of object detection/proximity sensor (Green Hemispheres).

Placing a camera on each quadrant of the device will help the user navigate the device, while one of the cameras will be dedicated for inspection purposes.

In the control box we will include accelerometers and gyroscopes to determine the devices orientation and assist with generating maps of the inspected areas as well as stability.

The working environment needs to be assessed further to develop the appropriate wireless communication protocols, but a possible approach is to place an explosion protected transmitter inside the tank (or other possible environment) to create a signal hub inside, which we can then use as an extension to the outside user.

## Material Selection

The cage will be made from lightweight materials. Potentially carbon fibre for the frames and propellers to ensure light weight designs and that no sparks are generated with a collision. The explosion proof containers will be made from Carbon Fibre or some form of polycarbonate. This will be highly dependent on the specific environment and presence of specific hydro carbon. Corrosion is also of concern and will be an important design criterion; currently a large portion of the petrochemical industry uses Carbon Steels as their building blocks.

## Power consumption and Endurance

To obtain maximum flight time, battery selection becomes pertinent. A high density battery such as lithium ion polymers or a battery pack of a similar chemistry will need to be used. These batteries unfortunately can be unstable so a very careful battery monitoring circuit will need to be introduced. Charging of the battery will be done away from the volatile environment.

Due to the principles of flight, weight will directly affect power consumption, thus the importance of the material selection. From previous experience, flight time can be estimated to sit between 15-30 minutes.

## Disposable Modular Design

When designing for such a hostile and hazardous environment, there is always a risk of device failures. For this reason our approach is to design a modular system with each individual part being a low cost and thus disposable subsystem.

**1.9 Analytical Software**

The required analytical software will be subject to further information about the environment; as well as more specific information from the sponsor about the scanning requirements.

From previous projects we have seen good results by applying a medium strength algorithm on board which flags certain areas. These flags are then sent back to the user where either more intensive off board processing can be done, or the user can visually inspect the images. This approach is a good balance between limiting the required processing power as well as the needed communications. This is useful in a system where both of these factors will be important design considerations.

# Budget

The budget and timing is available for the first three phases and a rough estimate is provided below. Aspects of the later phases are difficult to evaluate at this point in time and can be reassessed with the sponsor further down the line.

Phase 1 – Proof of technical concept

Expected Time: ±3 Months

HR Costs: $100 000

Running Costs: $3 000

Phase 2 – Development and optimisation against the intended application.

Expected Time: ±6 Months

HR Costs: $150 000

Running Costs: $15 000

Phase 3 – Prototype construction and laboratory testing

Expected Time: ±3 Months

HR Costs: $100 000

Running Costs: $10 000

*Current exchange rate used: $1 = R11.75*

*Prices might change pending on the USD and ZAR Exchange rate.*

# Team Experience

The proposed team is a joint collaboration between South Africa’s Council of Scientific and Industrial Research (CSIR) as well as The University of Stellenbosch (US).

## CSIR ([www.csir.co.za](http://www.csir.co.za))

## 3.1.1 Overview

The CSIR in South Africa performs multidisciplinary research and technological innovation with the aim of contributing to industrial development and the quality of life of people of this country -- and increasingly on the wider continent. We employ people who are experts in their fields and passionate about creating a better future through science.

Constituted by an Act of Parliament in 1945, the CSIR is one of the leading science and technology research, development and implementation organisations in Africa. The CSIR’s main site is in Pretoria, while it is represented in other provinces of South Africa through regional offices.

The CSIR transfers the knowledge generated through research activities by means of technology and skilled people. The generation and application of knowledge reside at the core of the CSIR. This takes place in domains such as biosciences; the built environment; defence, peace, safety and security; materials science and manufacturing; and natural resources and the environment, Mechatronic and Robotics.

The CSIR has clients in both the private sector (small, medium and large enterprises; formal and informal), as well as in the public sector (national, provincial and local government). The organisation also deals with public enterprises and institutions, national safety and security establishments, and development structures. Regionally and abroad, the CSIR fosters partnerships and a network of clients and partner organisations as part of a global sphere of influence on matters of technology. The CSIR liaises closely with tertiary education institutions. With a strong emphasis on relevant and developmental work, it also has strong roots in various communities, and collaborates with a wide range of donors and funding agencies.

## 3.1.2 Specific Experience

* [R. Stolper, P. Skinner, J. Hart, T. Naidoo, and D. Joubert, “The development of a multi-spectral sensor and unmanned helicopter for the inspection of electrical power lines,” pp. 1–7. (PLEASE SEE ATTACHEMENT)
* Please refer to some of these URL links to see a small sample of the projects done by the CSIR:
  + http://www.csir.co.za/enews/2013\_mar/16.html
  + http://www.csir.co.za/enews/2013\_mar/19.html
  + http://www.csir.co.za/enews/2009\_feb/gen\_02.html
  + http://www.csir.co.za/enews/2009\_feb/mias\_01.html
  + http://www.csir.co.za/enews/2014\_apr/09.html

## University of Stellenbosch ([www.sun.ac.za](http://www.sun.ac.za))

## 3.2.1 Overview

Stellenbosch University is home to an academic community of some 28 000 students (including more than 3 000 foreign students) as well as just under 3 000 permanent staff members (including 939 academic staff) on five different campuses.

Stellenbosch University (SU) is among South Africa's leading tertiary institutions based on research output, student pass rates and rated scientists, and is recognised internationally as an academic institution of excellence. This is confirmed by two world university rankings after SU was included in the Times Higher Education and QS (Quacquarelli Symonds) world rankings in 2012, for the second consecutive year. In 2011 the University was also listed on the Leiden rankings, and in 2012 SU was named the leading African University by the Webometrics Ranking of World Universities which ranks universities according to their web presence.

SU also boasts the second-highest number of scientists in South Africa who have been ranked by the National Research Foundation (NRF) – 306 in 2012. With 18 research chairs under the NRF South African Research Chairs Initiative (SARChi), the University is regarded as a leader in the fields of biomedical tuberculosis research and management, wine biotechnology, animal sciences and mathematical biosciences. As preferred research partner, SU also participates in various international academic networks

### 3.2.2 Specific Experience

**Electronics Systems laboratory (ESL) (**[**http://www.esl.sun.ac.za/wp/**](http://www.esl.sun.ac.za/wp/)**)**

* A. Maneschijn, T. Jones, and T. von Backstrom, “An operability framework for unmanned aircraft systems,” The aeronautical journal, royal aeronautical society, vol. 115, pp. 361-376, 2011.
* W. H. Steyn and J. Bijker, “Kalman Filter Configurations for a Low-cost Loosely Integrated Inertial Navigation System on an Airship,” *Control engineering practice*, vol. 16, iss. 12, pp. 1509-1518, 2008.
* Iain K. Peddle and Thomas Jones (2011). Acceleration-based 3D Flight Control for UAVs: Strategy and Longitudinal Design, Advances in Flight Control Systems, Dr. Agneta Balint (Ed.), ISBN: 978-953-307-218-0, InTech.

*For a full list of publications please see: http://www.esl.sun.ac.za/wp/index.php/publications/*

## Team Members

*Please find attached the CV’s of the individuals mentioned below.*

### CSIR

John Dickens – Electronic engineer with a background designing products and sensor packs for use in mining environments.

Thegaran Naidoo – Computer engineer with experience in automation, control systems and machine learning. As well as a background in computer vision and image processing.

Danny Naicker – Electronic and software engineer with experience in designing military grade communication systems and other robotic systems.

Angus Steele – Mechatronic engineer with experience in electronic design and robotics. Currently conducting a master’s research project on the development of a, close quarter, explosion protected, aerial robot.

Peter Bosscha – International experience in both electronic engineering and product development. Has a background in Engineering project management as the co-founder and current research group leader of the MMM unit.

### University of Stellenbosch

Johannes Treurnicht – Electronic and control systems engineer with a background in aerospace design. Currently a lecturer in control systems and is doing PhD research in Quadrotor aerodynamics.

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