ISTANBUL TECHNICAL UNIVERSITY

TEAM HEZARFEN

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Abstract

UAS of Team Hezarfen from Istanbul Technical University is explained in this paper. Aerial

vehicle is a multicopter(hexacopter) airframe with a custom modified autopilot system and a flight

computer. Autopilot communicates with navigation software on ground via a 901MHz RF

link while flight computer manages the payloads and relays images taken by the DSLR

camera to the ground station via a 2.4GHz WIFI link. There is also a video camera with a

5.8GHz link with a wide angle lens to achieve better peripheral vision during flight. One 2.4GHz

links are used for manual override for safety pilot and gimbal controller for camera.

Battery capacity is 2*8000mAh LiPo battery. Expected flight time is about 35 minutes.

Best Regards

Team HEZARFEN

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1. Mission Overview

Air vehicle has a DJI AND MK flight controller flight computer, connected to other avionics by CAN

Bus, through interface cards designed in our laboratory. Main navigation and waypoint calculations

are done on ground station and transmitted to autopilot via 900 MHz communication link 1.

Imagery system consists of a DSLR camera and a lower resolution video camera with a wide

angle lens. Output from the video camera is directed to a first person view headset worn by

the imagery operator who also uses the gimbal controller on link RC2 to direct the camera.

DSLR camera is controlled by flight computer and the pictures are tagged with position and

time data and streamed to ground station

2. Aerial Vehicle

2.1. Vehicle

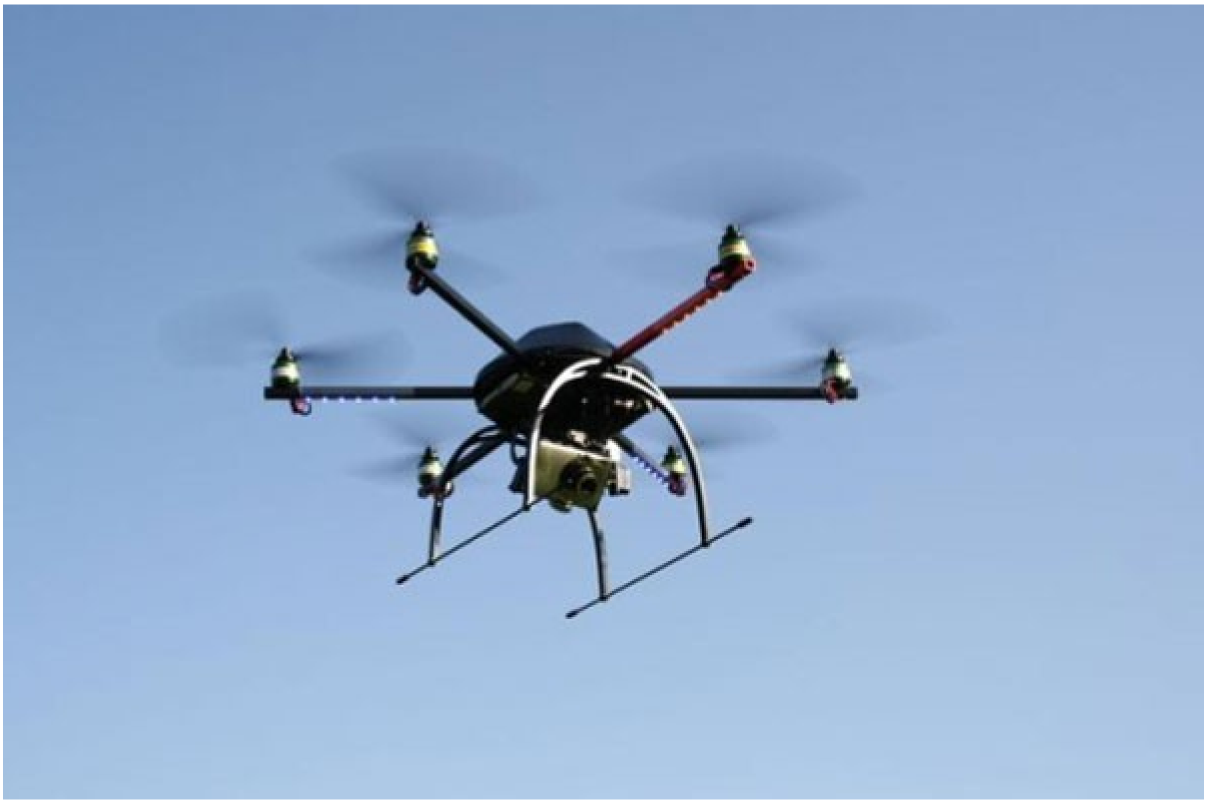


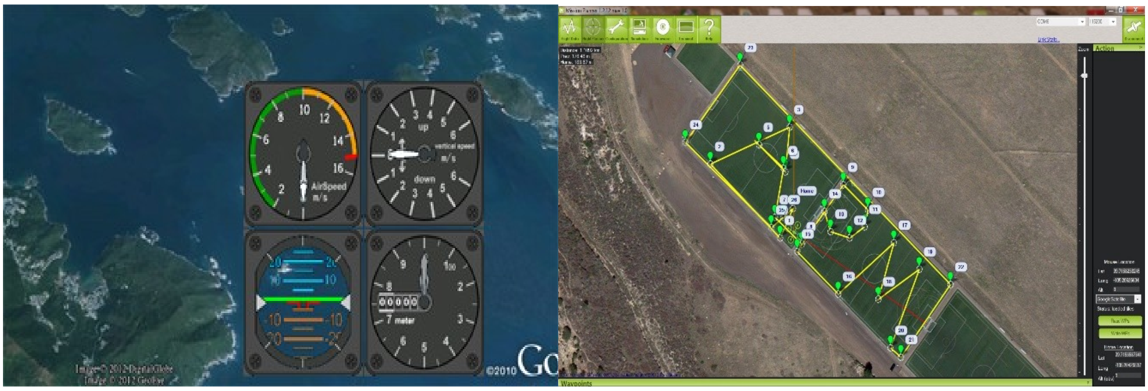
Figure 3: Hezarfen Team Hexacopter

Aircraft	Multicopter
Weight	7kg
Payload	2kg
Diameter	1000mm

Engine	6*500watt
Engine RPM	10000
Gimbal	MK Hisight SLR1
Gimbal sevo	Savox
Propeller	12*6 carbon fiber
Gimbal pan/tilt	+/-90
Servo voltage	5V
Battery weight	1650gr
Battery capacity	2*8000mAh
Battery voltage	14.8V
Esc PWM frequency	440Hz
Battery for avionic	We use 14.8V/8000mAh—(825gr with nonflammable case)

Table 2.1. Aerial Vehicle Components

2.2. Autopilot



We are using a custom modified MK and DJI autopilot. We developed in our laboratory on a

differantielEarthComputer-on-Module. All sensors are connected to interface cards that manage

them andsends data over CAN Bus depending on configurations. Autopilot and flight computer are

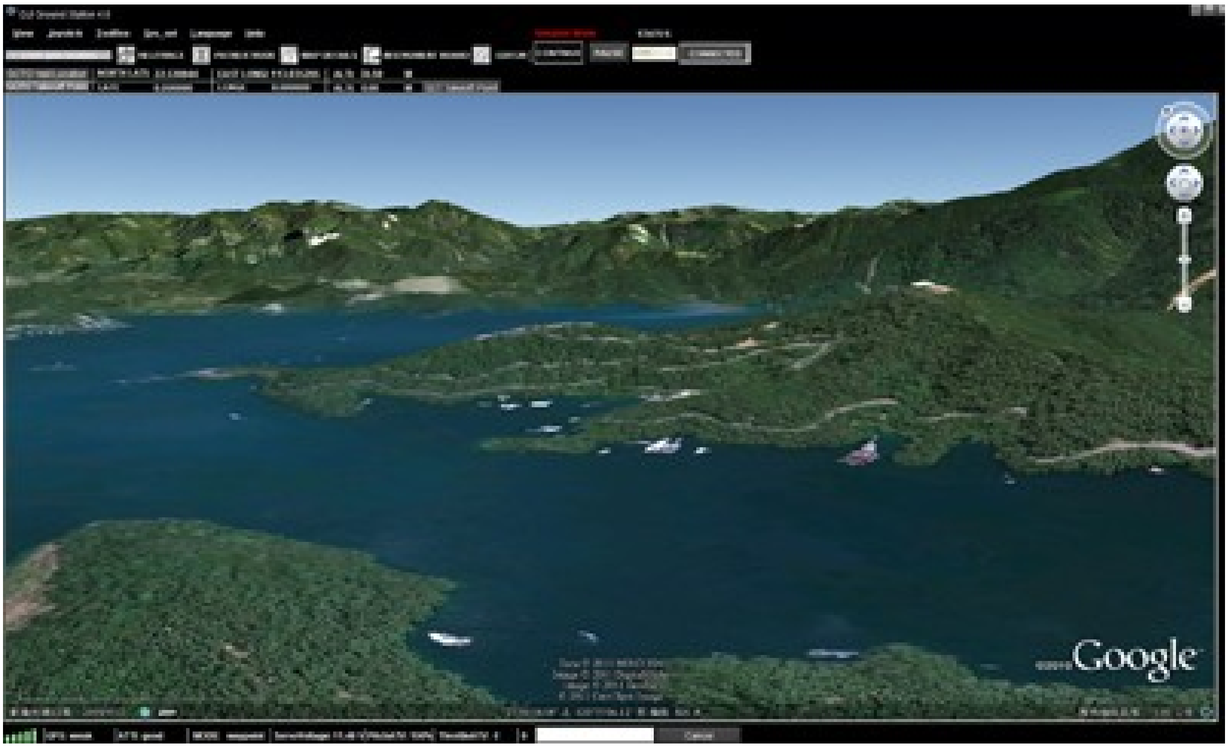
also connected to the same bus. This allows easy integration for new blocks to the

system. For example, to use a different sensor, only the interface card needs to be

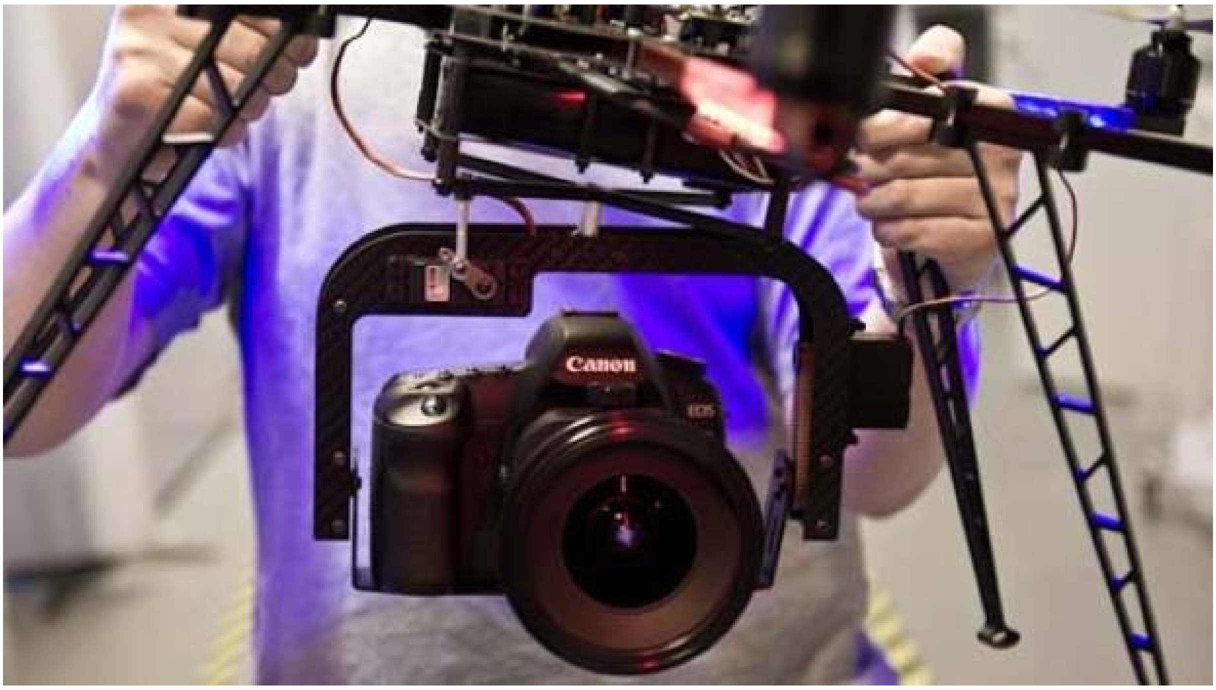
reconfigured for the new part and with switches on the interface card parts of the system

could be changed seamlessly. This gives the freedom to place sensors to optimal

positions on the plane and easy replacements if an error occurs.



2.3. Payload



It is very essential to design payload properly. Aircraft will be affected by payload

directly. Thus, payload shall be designed and implemented within high margin rates. In

this project, UAS payload consists of three main units; an imaging component, a

processing device and a communication unit. The imaging component is a DSLR camera which was chosen as Canon 7D. Also, a second imaging component is planned to be used

for scanning of area. This second camera has a wide angle lens to be got a wide area view for imaging

operator. Moreover, a pan-tilt mechanism is installed to be controlled of

Canon 7D. The processing device points to two main devices. First device is the autopilot

controller card and its peripherals, and second device is the PC which is used to be

handled aerial photography. In similar way, communication unit includes two link

devices. First is functioned for autopilot-ground control communication, and the other is

used for photograph transfer.

2.3.1. Choice of Camera

There are some key points for camera selection. Using of a DSLR camera matches

project expectations within these key points. One of those is lens flexibility. Flight will be

between 100 and 750 feet. Hence, a proper lens for this altitude interval can be selected

easily. In addition to lens flexibility, another key point is focus plus shot time. To be got

shorter focus plus shot time, a camera which has high performance CPU or even more

than one CPU should be selected. Mass of camera has low priority due to the high

margin. Some high performance cameras and other cameras, was used by participant

teams in previous years, within requirement boundaries are examined in details. Final

selection is determined as Canon 7D with 15-85 mm lens. It is seen that test results meets

with project expectations.

2.3.3. Aircraft PC

There are two PC’s on aircraft. One is autopilot PC and its peripherals. Autopilot and

sensor systems are explained under other section. So, it is not needed to be mentioned about those. Other PC is used to be held photography. Camera and router are connected

to this PC. Remote Shooting and Remote Desktop software run on this PC. PC should

have enough high performance, and it shall not be heavy. Its dimensions shall be suitable

interval. This PC includes mainly Mini-ITX motherboard, and rest of the PC is assembled

by us.

2.3.4. Communication Links

Two communication ports are placed on aircraft. One of those is used to transfer

commands & data between autopilot and ground station-monitoring. This product is

LK900 1 Watt Link, and it uses 901 Mhz frequency band.

Other is used to be linked aircraft-imaging PC and ground station-imaging. This link

consists of two main units; router and antenna. The router is Ubiquiti Picostation M-2,

and the Omnidirectional λ/8 Whip Antenna.

2.4. Communication Link

Communication Link 1 is used for communication between GCS and autopilot. The

reason we separated payload link with autopilot link is that payload link has a high

bandwidth requirement since it will be transmitting high resolution images to the ground,

so it might delay some critical data for autopilot. Operating frequencies are also separated

to minimize the interference between autopilot and payload links. We only used standard

frequency bands so if there is failure, replacement would be easier. ISM 900Mhz band is

selected for communication link 1, because of its better propagation characteristics when

compared to 2.4GHz band because communication link 1 carries critical data when

compared to link 2. This comes with an increase in antenna size since the wavelength increases, but in our plane, this is not a problem.

While there were other options 7

that would serve our needs, our main selection criteria for this is ease of obtaining

because of customs problems. We choose equipment we can obtain as fast as possible so

we could start working on them earlier and if there is a need for replacement, we can

replace them easily instead of waiting for week for arrival.

3. Ground Systems

3.1. Grand Control Station

3.1.1. Command & Monitoring Center

It is planned to be used one PC to transfer autopilot data, including set of commands

which are sent to aircraft and set of measurement data which are taken from all sensors.

In runtime, PC shall not malfunction. For stable running, a high performance chipset is

needed. Also, RAM and GPU levels shall be high, and qualified for this type processing.

Monitor of the PC can be clearly seen towards sun. After wide range searching, a PC was

found that matches project expectations. The product is Samsung NP300V5A. Some software are

installed to PC. These are Matlab, Microsoft Visual Studio,

Notepad++ and backup software.

3.1.2. GPS Command & Monitoring Software

This program is written with C# language under Microsoft Visual Studio 2010. The main

purpose of this program is to present incoming flight data to staff and, to send flight

commands to aircraft. Given figures show ground control station interface. Flight paths, no-flight

zones and search areas can be defined, deleted and updated easily.

All data are saved into file. Incoming flight data are received from COM port which is

used by DigiXtend900 1 Watt Link, 901 Mhz. Instant positions of the aircraft are shown

on map. This map is generated by C# extension, named GMAP.

3.2. Ground Control Image Processing Station

Ground control image processing station unit consists of a computer that runs image

processing algorithms and communication network of this computer and air vehicle. Data

processing and target recognition operations and visualization of estimated results are

performed in ground control image processing station. Operations will be performed

continuous during the contest therefore a high performance PC is chosen. Ground control

image processing station has a wireless communication between ground control station

and flying air vehicle. Purpose of this communication is to transfer taken photographs to

ground control station. Ubiquite rocket access point and 14 dB directional antenna are

used for communication.

Taken photographs are transferred to ground control image processing station and all

images saves and holds in a shared folder. Images are used in data processing & target

recognition algorithms are pulled from shared folder. Established target images and

operation logs are also saved in shared folder. Image processing results is written in a text

file that indicates target characteristics and all text files related to main pictures.

Moreover, image processing main steps are shown in the pop-up figures while image

processing algorithms running. It is aim to finished visual user interface for image

processing. User interface will represent real time flight video, processed image and

target characteristic on the screen.

4. Design Description

4.1. Autonomy

Autonomous flight is expected as a competition requirement. Also autonomy is used in

various parts of the system to increase efficiency and performance. Main autonomous

parts of the system are:

- Autopilot: Altitude hold, waypoint navigation, area search and return home functions.

- Gimbal: Gimbal system can autonomously hold camera parallel to the ground. This

helps with stable imagery and easier image processing.

- Ground station: Automatic target detection as well as shape, color, background color

and alphanumeric character, orientation and position properties of the target.

4.2. Mission Planning

Mission planning is directly held by GCS-command center. Aircraft positions and states

are processed and monitored also in this screen. No-flight zone, search area and flight

path can be easily updated, removed, added. This program includes some GPS converting

modes which can be needed to convert any GPS string forms. Figure 10 shows

communication levels roughly.

As the first step, communication link is done. Meanwhile, all telemetry data shall be

received. Take-off will be manual-mode. So, autopilot is activated after take-off. Search

areas, no-flight zones and flight paths are defined in GCS-command center. By clicking

“upload” button, these data are parsed. Parsed data are uploaded part-by-part in order to

not overflow CPU of the autopilot. All instant data are shown on map and monitoring

screen. Landing will be manual-mode. So, if aircraft is close to landing point, manual

overriding will be done. In this time, no command upload will occur.

4.3. Safety

In all aviation projects, the most important thing is safety. Primarily personal safety and

secondly system safety is taken into account in design. Mechanical and electrical systems

are tested, reinforced and integrated for the purpose of safe flight.

Systems safety and reliability explained below;

The launcherisinspected by verifying that:

* Hardware connections are attached in the correct orientation and secured

* Electrical connections are in good condition and secure

* Each ofthe three switchesis operating correctly

* The solenoid powerswitch activates correctly when switches are in the correct positions

* The shuttle canmove freely on the launcher

The aircraftisinspected by verifying that:

* Themotor can spin freely without obstruction and in the correct direction

* Antennas and winglets aremounted securely to the sides ofthe wings

* The launcherinterface isin good condition

* The internal components aremounted securely and properly connected

* The battery straps are tight and batteries are in good physical condition

* RC systemoperates at a range of 50 feet

* Battery voltage is above 12 volts

The autopilotisinspected by verifying that:

* The data link has been established

* Themostrecentflight plan has been upload to the aircraft

4.3.1. Mechanical Design

- Before integration, all parts of the system are tested. Mechanical design consists of

three main parts.

- Weight: All components are selected as light as possible. Total weight system is less

than 55lbs.

- Visibility: Color for vehicle is selected as shiny yellow and batteries are painted to blue for easier identification during if an accident happens.

- Robustness: All part of system are attached by screws or secured with hot glue. Extra

care is given to power cabling and cables are isolated as much as possible to prevent short

circuits even if there is a crash.

4.3.2. Electronic Systems Design

As well as automatic return home and flight termination features during a

communication fail, there is also a switch that bypasses autopilot and get into manual

flight mode with a flip. This switch also detects any autopilot fail early on and hands the

controls to the safety pilot to prevent a dangerous crash.

- Communication Links

There are six different communication links, which are autopilot long range telemetry,

RC safety link, wireless access point, RC Gimbal Link, Video Link Their frequencies are

shown in Table 4.1

Communication links	Frequency
RC Safety Links	2.4GHz
Autopilot Long Range Telemetry	901MHz
Wireless Acces Point	?????
RC Gimbal Link	2.4GHz
Video Link	5.8GHz

Table 4.1: Communication Frequency

- Manual Control Switch

During flight, safety pilot should be able to take over control. Therefore there must be a

system that can hand the control over the safety pilot from autopilot anytime. The switch

circuit shown in the Figure 11, can switch to manual control from autopilot with a single

switch flip on his remote controller. It also listens to a heartbeat signal generated by

autopilot with a 100ms period. If this signal is lost due to an autopilot fail, control is handed to the safety pilot, preventing a possible crash.

4.3.3. Termination

In case of an emergency, or according to termination rules, flight might be needed to

get terminated. The termination process consists of 5 part.

1) Throttle closed

2) Full up elevator

3) Full right rudder

4) Full right aileron

5) Full Flaps down

After these actions, air vehicle will start a spiral descend.

4.3.4. Operation

Before flight, safety pilot tests the aircraft system s' stability. We will use manual

takeoff because of the additional complexity introduced by autonomous takeoff. When

the aircraft is on level flight, autopilot is will take over. Figure 12 shows how aircraft will

react to various events during autonomous flight.

4.4. Data Processing & Target Recognition

Data processing & target recognition are based on some operations on the original and

refined images for the purpose of identification of target properties. All targets have

particular characteristics such as location, orientation, shape, background color,

alphanumeric symbols and alphanumeric color. These characteristics should be recorded.

To record target characteristics, a sequential layer structure is developed in MATLAB.

Image processing toolbox functions and written own MATLAB functions, are used in the

sequential layer structure of data processing & target recognition.

Targets may not appear in all images that are taken from air vehicle or more than one

target may appear in one image. And also unexpected external or internal disturbances may have an negative impact in the image. These negative situations may cause to obtain

incorrect results. Moreover, running of the whole data processing & target recognition

algorithms on all images reduces the speed and accuracy of the performance. Therefore,

before the whole data processing & target recognition operations, necessary preprocessing

operations are performed on the image. First, original image is loaded and transferred to the

MATLAB workspace. Proper size of original image is tuned to have better performance. Then,

morphologic operations are performed to achieve the probable target regions. Original image is

turned into grayscale image. Edge detection algorithm is utilized, thus binary images are obtained via

detecting the differences of the grayscale image contrast. These binary images show edges. After

eliminating outermost regions and tiny edges, more reliable probable target regions are

achieved.

4.5.Test plans and Procedures

The most effective form of risk mitigation is ensuring that everyone at a flight test knows and

follows the plan. Every team member has been trained in specific rolesfor the mission and each is

aware ofthe responsibilities associated with theirroles.

Communication before, during, and after a mission is the most important goal for the team

members operating the system. Before each mission, the team meets to discuss the goals of the

mission, what needsto be tested, and what each team membershould look for. Before launch, the

autopilot operator briefs everyone on the flight plan, how the aircraftshould behave, and conditions

that are acceptable for operation. A communication protocol has been developed for the team

membersto effectively communicate during a flightso that there is no confusion. During a mission, the autopilot operator communicatesthe expected attitude of the aircraft to the safety pilot before

the system performs a maneuver. Upon request from the safety pilot, the autopilot operator will

verbally report the current and desired values for various important flight data such as airspeed,

altitude, attitude, and location. After a flight,the teamperforms an after-action review to determine

what went right during the mission, what went wrong, what should be attempted to improve

performance.

5. Conclusion

Through testing, the AnDrone system has proven to be capable of meeting all the Threshold KPPs

and many of the Objective KPPs specified in the competition rules. From the outset, the team

adopted a systems engineering approach to ensure that the focus remained on the mission rather

than on designing a new airframe or developing custom software. To our knowledge, use of the

Android phone for imaging, on-board processing, GPS and inertialsensing and network capabilities

is novel. This solution was, however, not adopted to be different. It was adopted because our

analysis and testing revealed itto be the bestsolution when considered in the context ofthe overall

system design. The AnDrone system has been developed with a focus on meeting the requirements

of the mission and on the reliability and maintainability of core capabilities. We are confident that