WATERfly

UAE DRONES FOR GOOD TECHNICAL SUBMISSION

DECEMBER 01 2014

CONTENTS

TEAM

MIT
SENSEABLE CITY LAB

Situated at the intersection of architecture, urban design, engineering, human-computer interaction and the social sciences, the MIT Senseable City Lab addresses the relationship between cities, new technologies and people.

The Digital Revolution is changing the way we live today as radically as the Industrial Revolution did almost two centuries ago. Pervasive digital sensing is transforming the way we describe and understand cities, as well as the tools we use to design them. The Lab aims to investigate and anticipate these changes and their implications at the city scale.

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UNIVERSITY OF TORONTO INSTITUTE FOR AEROSPACE STUDIES
DYNAMIC SYSTEMS LAB

The Dynamic Systems Lab headed by Prof. Angela Schoellig envisions a new generation of robots that have the ability to sense their environment and intelligently interpret information about it in order to improve their performance. Learning algorithms that can process large amounts of previously collected experience data will allow these robots to operate robustly and reliably in changing and challenging environments.

By conducting research at the interface of robotics, controls and learning, Prof. Schoellig's ultimate research goal is to extend the performance and autonomy of robots and dynamic systems.

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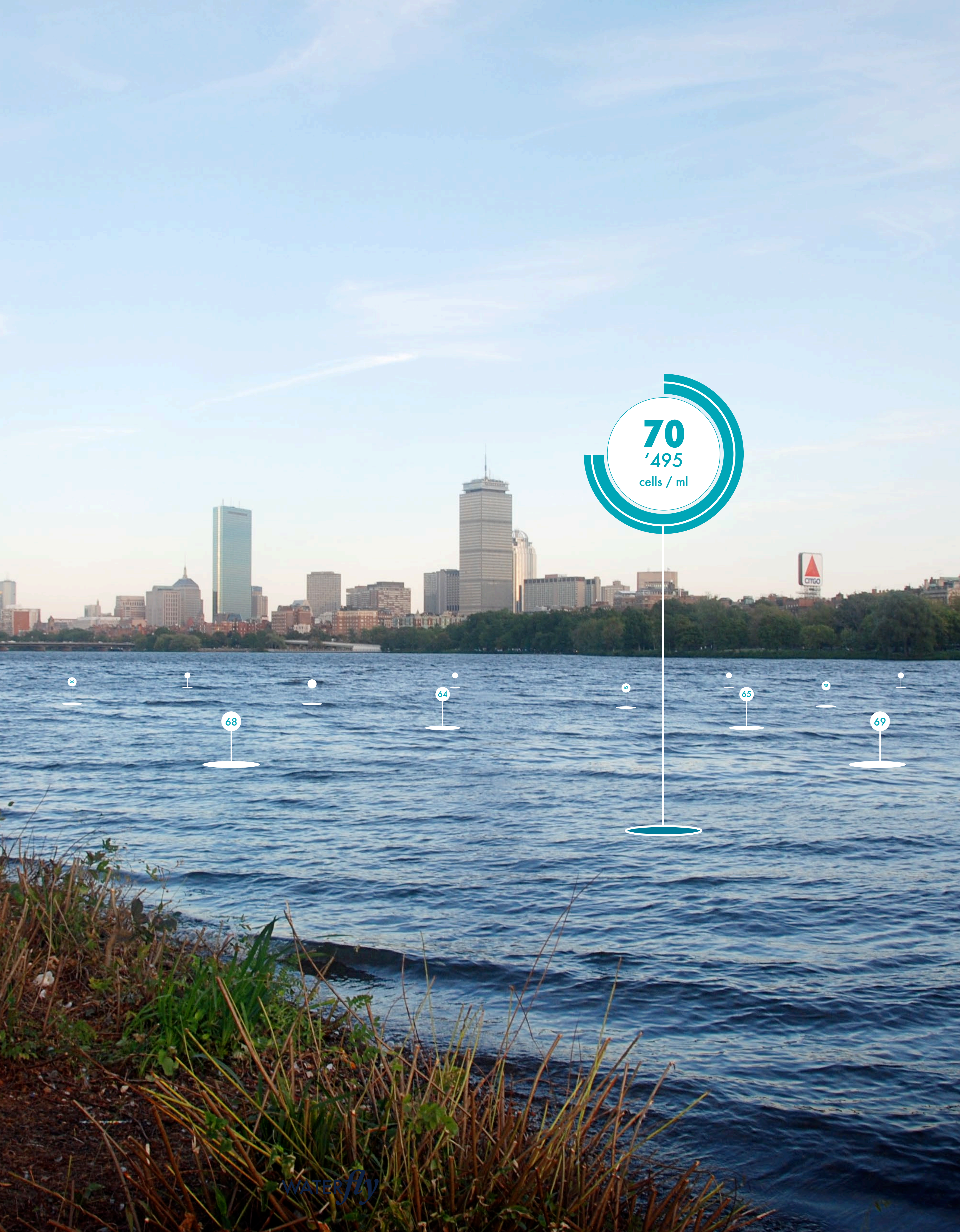
DRONE DEPLOY

BCB



SERVICE DESCRIPTION

Waterfly is a new environmental sensing platform that rethinks the way in which we monitor, research and protect water quality across the globe. Combining the latest in aquatic sensing techniques with UAV technology, autonomous flight controls and real-time data acquisition, the Waterfly system is a drone platform designed to scan and probe lakes and rivers for emerging pollutants and environmental problems.

EMERGING ENVIRONMENTAL THREATS

The monitoring of water quality presents one of the greatest challenges we face today. The health of aquatic ecosystems hangs finely in the balance of numerous environmental inputs; however, we are increasingly seeing case studies around the world where large imbalances in environmental ecosystems are leading to serious water quality issues. From toxic cyanobacteria blooms to chemical pollutants, these threats present ongoing problems to drinking supplies, wildlife habitats, and public health. Furthermore, the root causes of these problems lie not only in changeable natural conditions, but in the human actions of our increasingly urbanised world. For example, in summer 2014 the toxic algae blooms in Lake Erie - some of the most dangerous in recent history - were believed to come as a result of increased runoff from agricultural activities.

By identifying and mapping water quality issues with high precision, we can begin to identify not only problematic areas, but root causes.

DATA COLLECTION PLATFORM

The Waterfly system is being developed to tackle issues of water quality monitoring that could not be addressed with existing sensing techniques. Although many different sensors exist today and are being used by scientists to monitor bodies of water, the Waterfly system brings together a combination of techniques under one platform, to generate unprecedentedly high-resolution, geolocated, spatiotemporal datasets. This 'big environmental data' will enable a new paradigm in the high-quality modeling and analysis of water quality.

Using agile quadrotor vehicles, dynamically deployable across vast areas, each one carries onboard sensors enabling them to gather environmental data. The system is able to gather information at both macro and micro scales by utilising both aerial imaging and water probing techniques. Working as a swarm, the vehicles share these sensing tasks, enabling the system to map vast areas, and gather multi-layered data on the health of aquatic ecologies.

Flying in formation, the lead vehicle performs high-resolution imaging tasks to procedurally generate maps of the water, analysed in realtime to detect and geolocate problem areas, such as high concentrations of algae or thermal profiles. Supporting UAVs carry probing equipment, and use the geolocated

>> SERVICE DESCRIPTION

Waterfly development - Hyperspectral Imaging UAV

data from the lead UAV to investigate pinpointed locations and collect spot-readings from the water itself.

HYBRID SENSING INFRASTRUCTURE

Waterfly is conceived as a cyberphysical system - a physical network of aerial vehicles, deployed as dynamic digital sensors. As an infrastructure for environmental sensing, the system comprises of two key aspects - autonomous quadrotors performing sensing tasks, and a digital backbone for communication and data collection. The key components of this hybrid infrastructure can be described as follows:

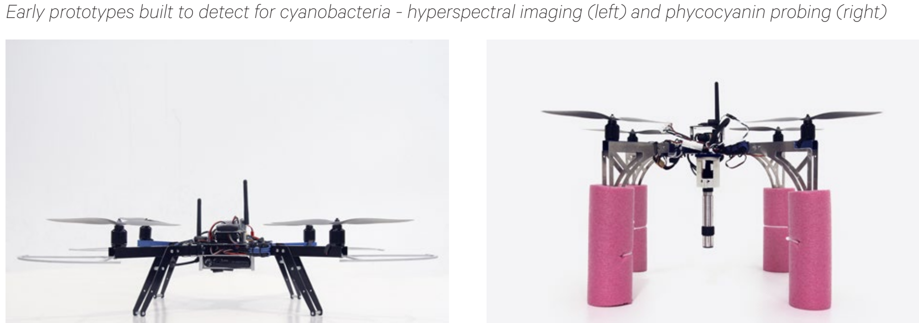
1) High-performance quadrotors capable of carrying different onboard water-monitoring sensors, with autonomous flight controls designed for variable weather conditions.

2) Swarm-sensing between multiple vehicles, with scalable strategies to share numerous sensing tasks between quadrotors over vast areas.

3) A robust, user-friendly web-based opeartor interface, enabling users to easily deploy the system.

4) An accessible web user interface that receives and visualises data in realtime, and is easy to use by a wide audience.

Early prototypes built to detect for cyanobacteria - hyperspectral imaging (left) and phycocyanin probing (right)



HIGH-PERFORMANCE UAV DESIGN

Waterfly utilises the agile aerial performance of the quadrotor to create a dynamically-deployable airborne sensor. Through the development of high-performance autonomous aerial controls, the UAVs are designed to fly along optimised flight paths created for aerial imaging, water surface and sub-surface probing. The small, lightweight design enables the vehicles to be easily deployable and allows for longer flight times and larger survey areas. The carbon fibre frame also creates a robust layer of protection from propellers, ensuring the vehicles are safe and easy to handle. A completely waterproof design makes them suitable for operation across lakes and rivers.

SWARM SENSING

The system proposes a novel approach to combining different sensing techniques into one multi-UAV platform, using realtime image processing and analysis techniques to coordinate and share sensing tasks across multiple quadrotors. Working together as a swarm, the autonomous UAVs are able to cover vast areas, and undertake multiple sensing activities during one flight.

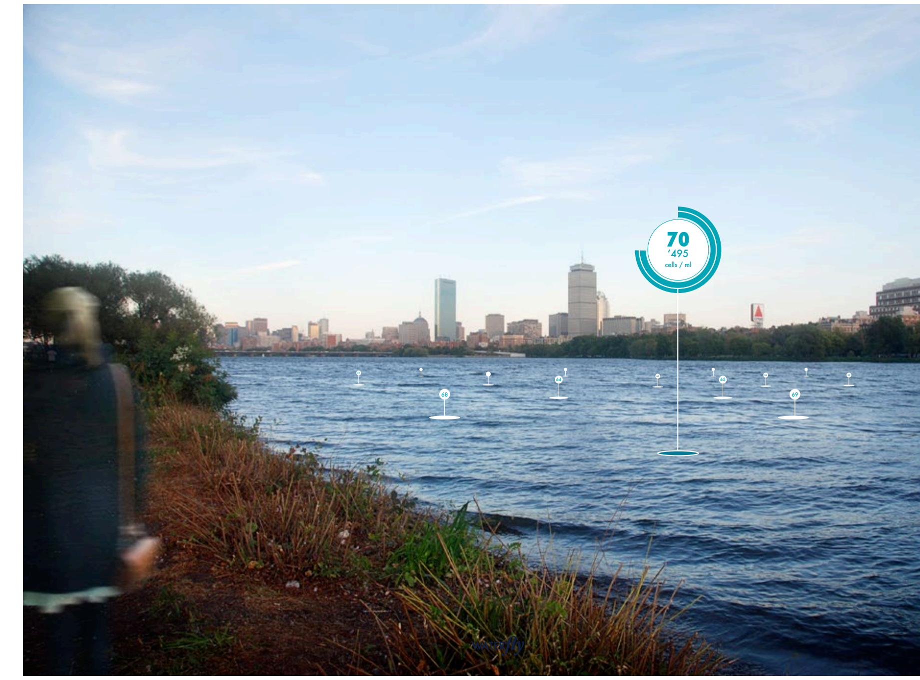
WEB-BASED DATA VISUALISATION

Using realtime data collection across cellular networks, a web-based platform has been developed that receives data directly from the UAVs out in the field, centralising the data in the cloud, and making the data easily and instantenously available to both researchers and the wider public through an easy-to-use UI. As data is collected over time, a rich repository of spatiotemporal data will be generated. Promoting both existing sensing techniques and future intermodal systems, the platform will also be able to receive data from separate sensor networks, creating a multi-layered archive of environmental data which can be easily combined, cross-correlated, visualised, and exported. This data will be made available with the intention of developing new spatiotemporal models for determining water quality, with the eventual goal of informing actionable change, through both data-driven policy-making and public awareness and engagement.

CASE STUDY : CYANOBACTERIA-SENSING

As a first case study, the Waterfly system was prototyped to deal with the growing problem of cyanobacterial blooms. This blue-green algae is an environmental hazard both locally to the Charles River in Cambridge and Boston, and globally as an emerging threat to many other water bodies particularly located around areas of urban growth. Working with local stakeholders including the Environmental Protection Agency and the Charles River Watershed Association, a strategy was devised to design a UAV system tailored to detect cyanobacteria.

In collaboration with University of Toronto Institute for Aerospace Studies and MIT Interactive Robotics Group a first prototype was developed using two vehicles to perform aerial imaging and probing tasks respectively. Hyperspectral imaging was used to detect photosynthetic activity on the water - a cue to the presence of cyanobacteria. Phycocyanin probes were then used to determine the presence and concentration of phycocyanin, a pigment-protein complex found in cyanobacteria, and hence a direct indicator the the algae's presence. A proof-of-concept flight, performed within an indoor motion capture system, successfully demonstrated the coordination of two vehicles to detect cyanobacteria, through the use of hyperspectral imaging to map the simulated 'bloom,' and water probing to identify the phycocyanin concentration levels in parts-per-billion.



The Waterfly system gathers spatiotemporal data on the health of aquatic ecosystems, and makes the data available to both citizens and researchers through an online visualisation platform.

SCALABLE, RAPIDLY-DEPLOYABLE INFRASTRUCTURE

With the system operating on cellular network communications, Waterfly can be rapidly deployed globally. Working with local stakeholders in environmental health, the system can be easily tailored to identify threats specific to a given area. Designed for scalability, the system is conceived as a flexible sensing platform that, through ongoing development, is able to scan and detect for numerous toxins, pathogens, and chemical contaminents.

DATA-DRIVEN CHANGE

Waterfly opens up new opportunities for engaging a wider audience with water quality issues, and looks to address actionable change through the processing and visualisation of collected data. The data platform will create a public portal for environmental monitoring - visualising complex sensor data to communicate clear messages about environmental monitoring to a public audience, and engage them in a new platform for citizen science.

The data platform will also connect key stakeholders in environmental research with high-quality datasets, significantly advancing our capabilities to achieve the following aims:

1) Detect waterborne threats,

2) Predict future problem areas through spatiotemporal analysis and machine learning

3) Mitigate threats through the deeper analysis and understanding of root causes.

As a cyberphysical infrastructure operating between the manmade and natural worlds, it will enable a closed feedback system to facilitate data-driven action, and the increasingly effective mitigation of aquatic ecological threats.

TECHNICAL DETAILS

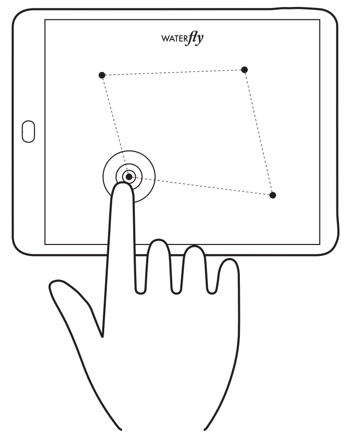
The folowing pages detail :

- Plans & Schematics
- Flight time, Speed & Range
- Components
- Communications
- Operating System
- Power Source
- Payload Sensors
- Take-off and Landing
- Flight-Planning Algorithms
- Tracking / Management System
- Safety, Security & Regularity Issues
- Limitations & Solutions
- Estimated Cost

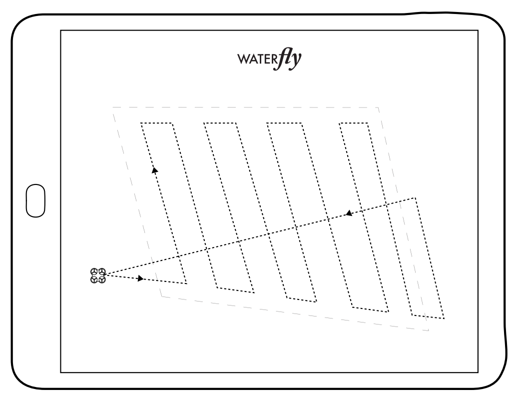
SCENARIO OVERVIEW

A typical flight operation follows the steps outlined below:

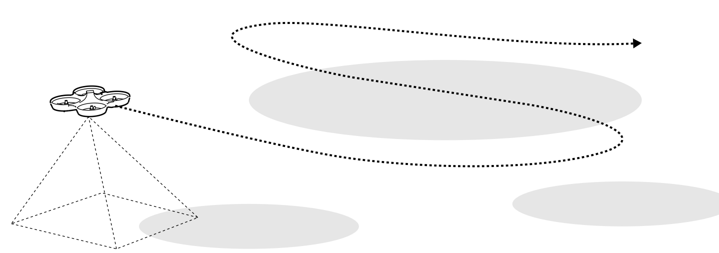
1) The operator uses a simple web-based user-interface on a laptop or tablet device to launch the vehicles. The user begins by selecting an area of water to survey, identifying the outer boundary points of the area of interest.

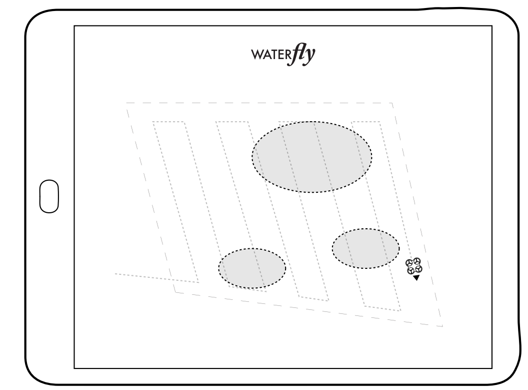


2) Using this area information, the system calculates the optimum flight path for the leading vehicle to fly in order to gather high-quality images of the water.

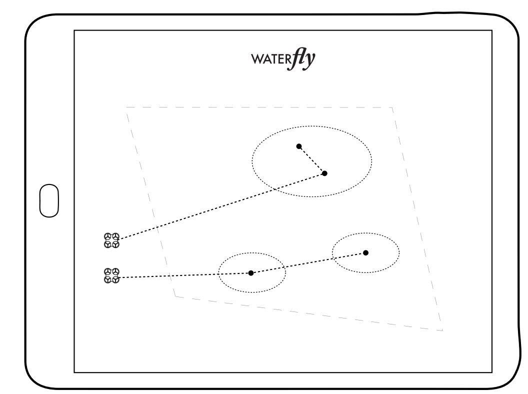


3) Upon pressing launch from the user interface, the first UAV takes off from its starting position next to the body of water, and follows the set waypath. It begins to take images and relay them to the cloud via an onboard 4G connection.

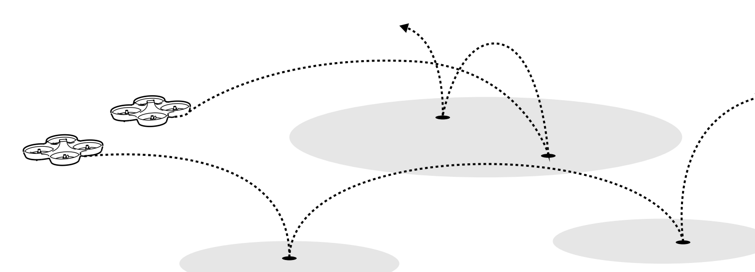




4) The images are stitched together in realtime during the flight, and appear on the user interface map. The images are processed on the fly to detect problem areas - for example, detecting high levels of *chlorophyll a* from hyperspectral images. The result is a new map of 'hotspots' displayed on the user interface- geolocated regions of interest marked by their outer boundaries.



5) The system uses these geolocated boundaries to calculate new waypaths for the supporting probing UAVs to investigate and take readings from the water. The boundary areas are subdivided into a number of spot locations, that are then translated into waypoints for the probing UAVs to follow.



6) The new waypoints are distributed as waypaths for the supporting probing UAVs. As the system is able to support multiple vehicles flying as a swarm, the probing tasks can be shared amongst a number of vehicles. The waypoints are optimally distributed between the vehicles, enabling the system to probe many different areas simultaneously. At each point, the probing UAV lands on the water, takes a reading, and relays the information back to the cloud - and to the user interface - via the 4G connection.

OVERVIEW

A typical flight operation comprises of the following components:

OPERATOR

Using a laptop or tablet device, an operator is able to deploy and control the waterfly system. By connecting to the user interface on the web, the operator is able to send and receive commands to and from the UAVs.

CLOUD SERVER

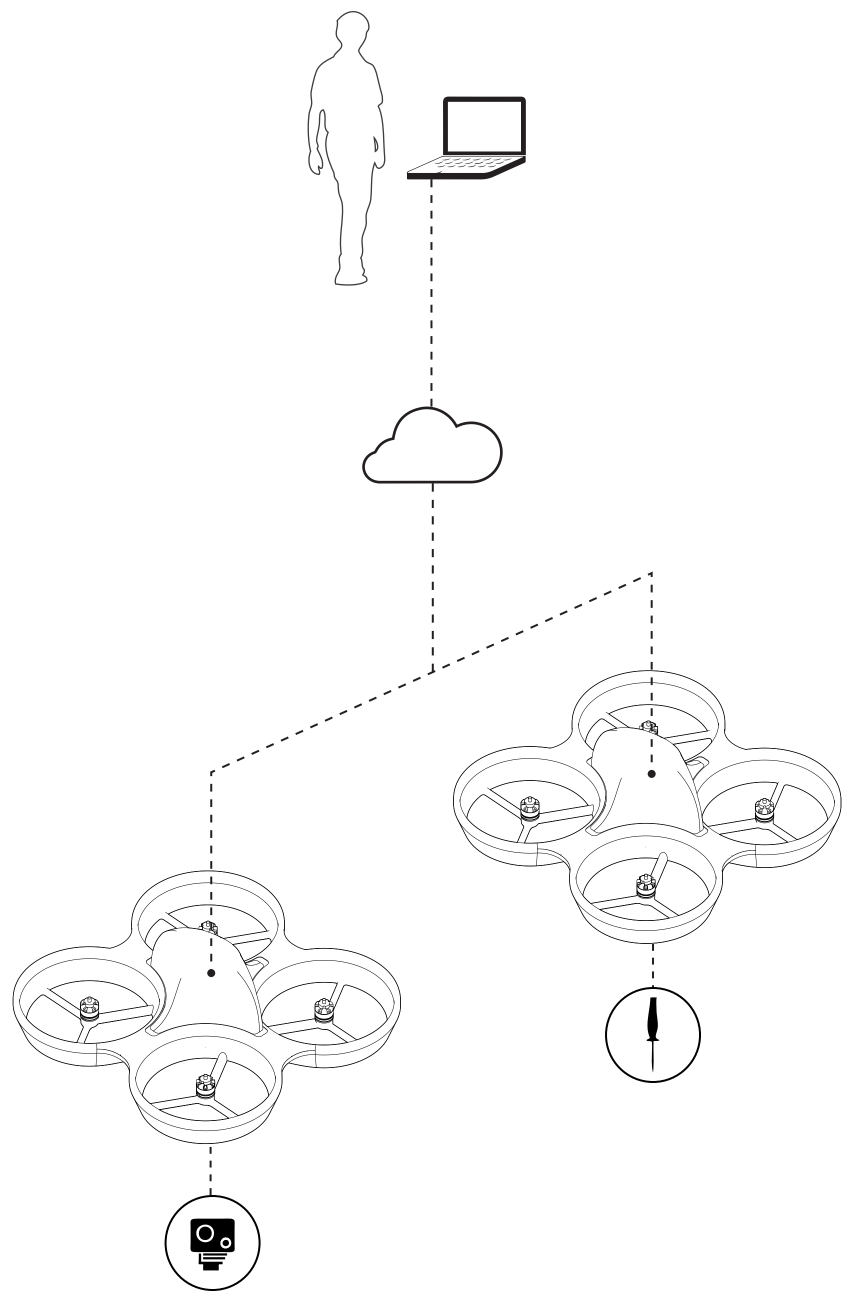
All communications are passed via the cloud, enabling the system to be deployed over vast areas in areas of good LTE coverage.

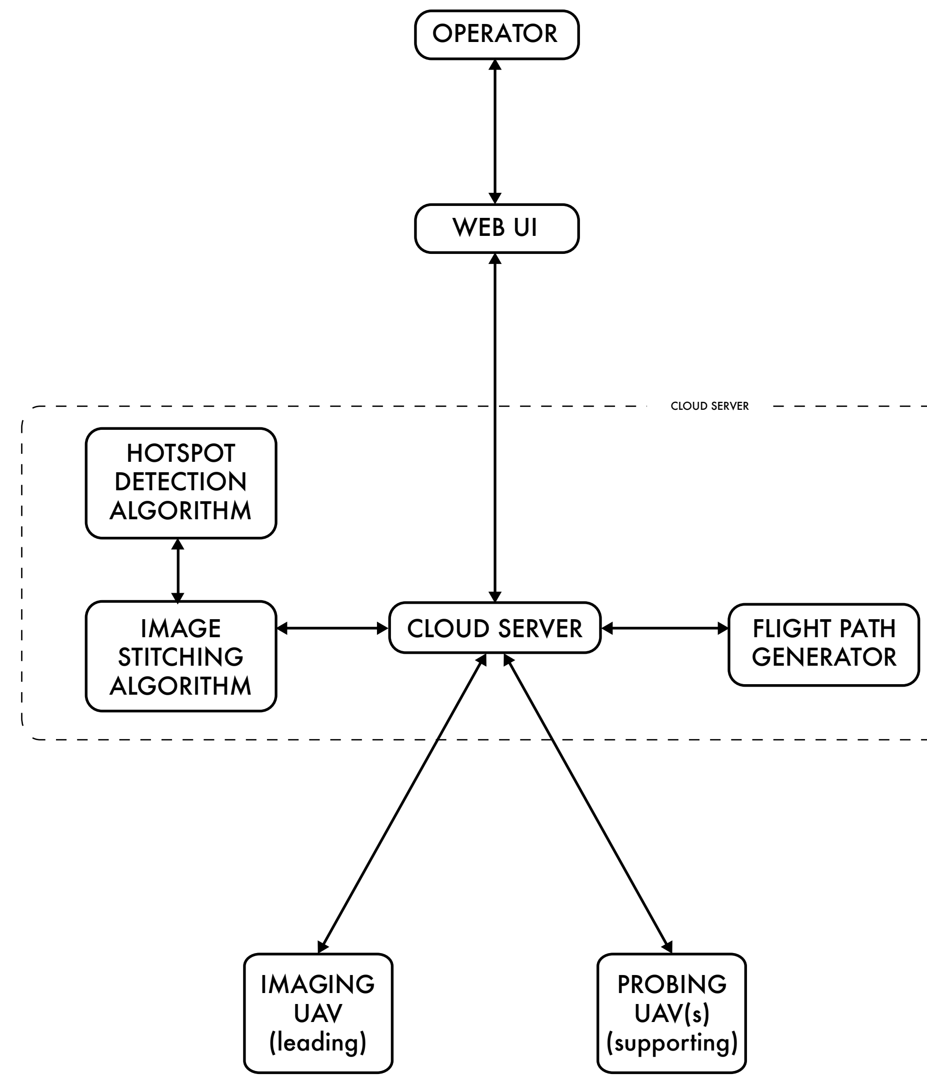
PROBING UAVS

The probing UAVs carry onboard probes, used to take readings from the water when the vehicle lands at spot locations.

IMAGING UAV

The Imaging UAV leads the swarm of vehicles and relays images of the water back to the user interface in realtime.





SYSTEM OVERVIEW

The system is comprised of the following components: web user interface (Web UI), web server, flight path generator (FPG), Cloud server, image stitching algorithm (ISA), hotspot detection algorithm (HDA) and the UAVs.

An operator starts by selecting an area of interest in the web UI. The FPG generates an aerial flight mission for the aerial UAV that then flies above this area to capture multiple overlapping images of the area. These images are transmitted via a LTE network to the cloud server.

An image stitching algorithm stitches these images together to produce the aerial map of the area and display the map on the Web UI. Another classification vision algorithm (hotspot detection) is also used to detect area of interest in the image - for example, algae blooms. These detected areas are dispalyed on the Web UI.

Using the area information from this hotspot detection, the FPG generates a water probing flight path. Once the probing flight path is generated, The probing vehicles then fly to these areas, land at each point, and take an optical reading. These readings are transmitted back to the cloud in real time, which are displayed on the Web UI.

UAV SPECIFICATION

FLIGHT TIME

15 minutes

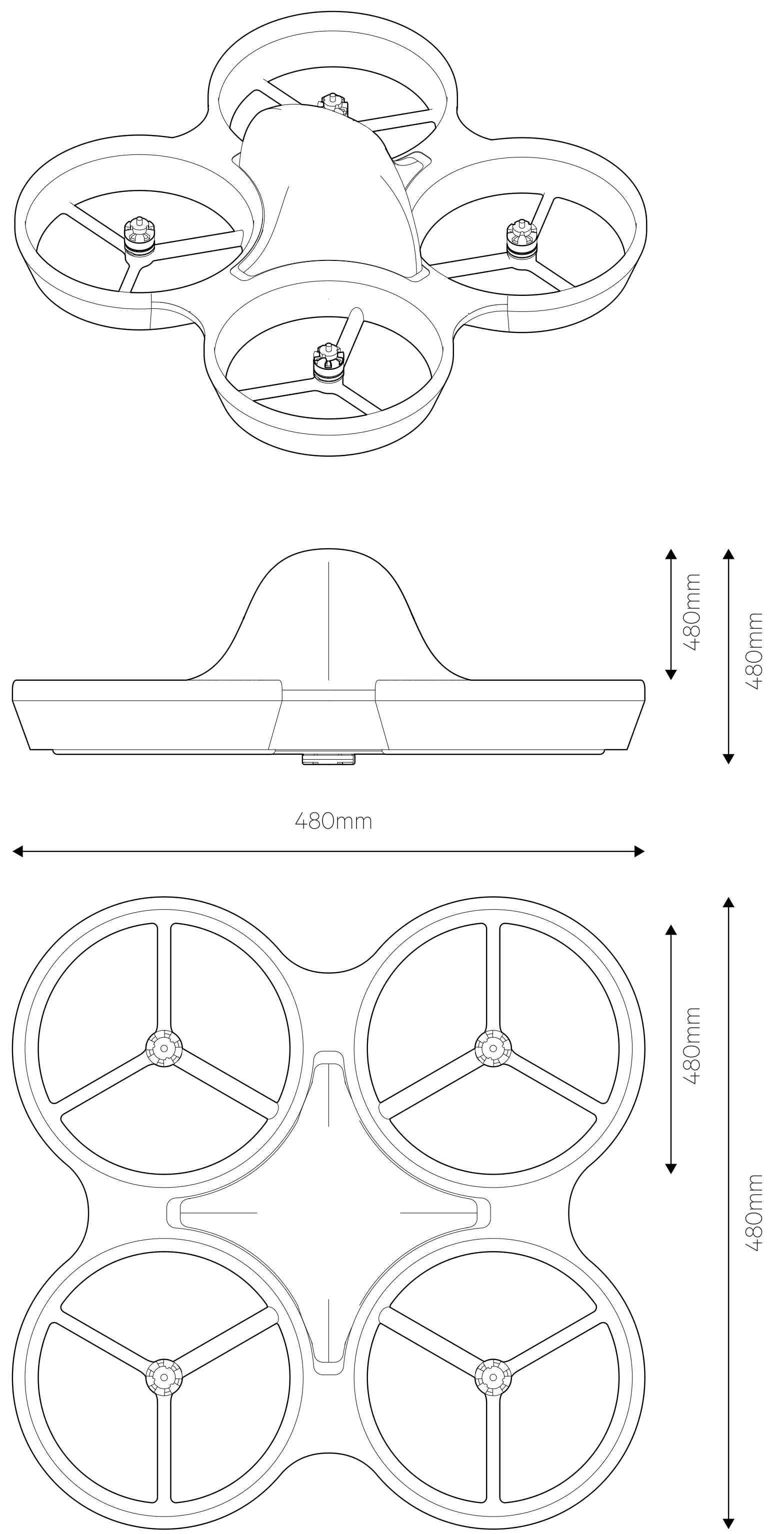
SPEED

5 metres / second

RANGE

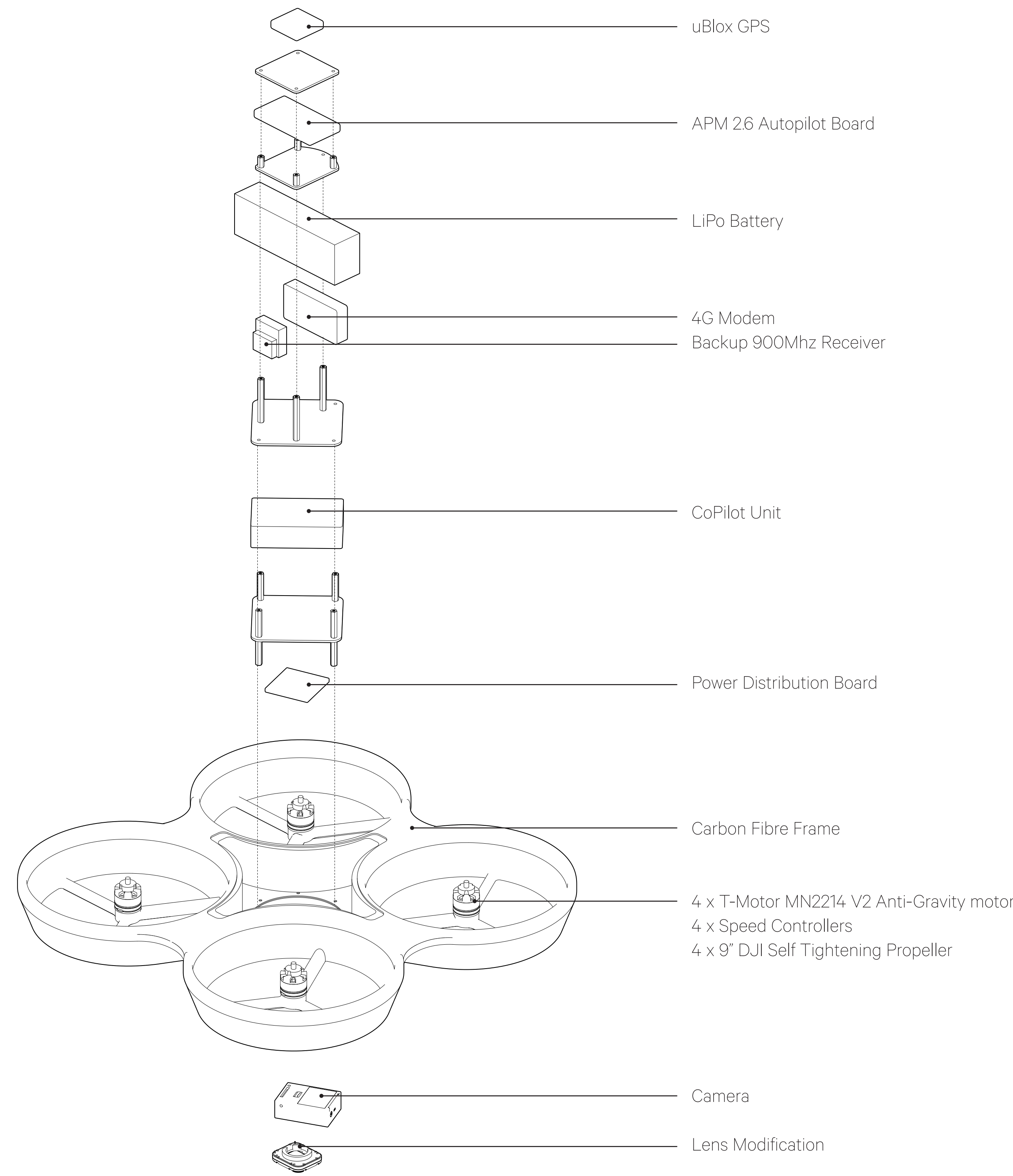
No maximum range from ground station (communications to UAV via onboard cellular connection).

2 kilometres - based on battery life and a return flight to home location.



COMPONENTS

UAV COMPONENTS



COMMUNICATIONS

4G CELLULAR COMMUNICATION

Waterfly utilises a communication system that operates on any 4G cellular network - enabling the autonomous operation of multiple UAVs globally, with no maximum range from the operator, provided there is cellular coverage in the area. Supported by DroneDeploy, the system works as follows:

DroneDeploy Copilot: a cellular telemetry radio that directly connects to a telemetry port on the APM board which enables bidirectional communication between vehicles and the cloud. (Figure: Waterfly system overview)

DroneDeploy Cloud: The cloud system provides several functions including controlling built-in air traffic to avoid collisions, processing live photo and videos, allowing multiple drones deployment and enhancing operating ranges to where cellular network is available. (Figure: Waterfly system overview)

Web-based Operator UI: The interface enables the intuitive interaction between operator and the Waterfly system. Via this interface, the operator can monitor UAVs, modify UAV firmware parameters, launch missions and plan different flight missions.

MANUAL CONTROL

RC transmission: Each vehicle includes a telemetry receiver that allows operators to manually control the vehicle via RC controller, for testing purposes or for manual water sampling. The receiver connects to several APM input ports. The transmitter has 7 channels and pre-program functions.

OPERATING SYSTEM

APM 2.6

Onboard software and operating system: Arducopter on APM Linux board 2.6 . The onboard control supports several flight modes: stabilize (manual), altitude hold, loiter, return to launch (RTL), auto and land. The operators can tune different PID parameters for stabilization, altitude and position controllers.

Flight navigation using on-board sensors:

- accelerometer
- gyroscope
- magnetometer
- pressure sensor
- connection to GPS module

POWER SOURCE

BATTERY SOURCE

Turnigy nano-tech 6000mah 4S 25~50C
Lipo Pack
Capacity: 6000mAh
Voltage: 4S1P / 4 Cell / 14.8V
Discharge: 25C Constant / 50C Burst
Weight: 623g (including wire, plug & case)
Dimensions: 175x49x38mm
Balance Plug: JST-XH
Discharge Plug: HXT4mm

SENSORS

IMAGING

The aerial imaging quadcopter carries carries a downward-facing camera, able to detect for indicators to water quality threats. Depending on the indicator being scanned for, different camera and lens configurations may be used, for example:

1) Hyperspectral Imaging - for detecting indicators photosynthesis and algae blooms

2) Thermal Imaging - to detect various water pollutants

This page documents the specification used for **hyperspectral imaging**, used for monitoring cyanobacterial blooms:

The imaging quadcopter carries a downward-facing Gopro Hero3 camera. The camera captures 5-megapixel images, and transmits the images wirelessly to the onboard CoPilot device.

The camera is modified with an infrablue lens. The NDVI BLU22 lens reads infrared as the red channel and a lighter blue for the visible channel. These can be used to measure photosynthetic activity. The lens has a mix of red and blue in them and turns the camera into an infrared/visible compositing multispectral camera.

Above : GoPro camera with infrablue lens fitted
Below : example of infrared images returned by camera

Above : Turner Designs Cyclops 7 probe

PROBES

The water-probing quadcopter carries onboard probes designed to optically measure a number of different criteria pertaining to water quality.

1) For initial experiments, a Turner Designs Cyclops 7 fluorometer probe was used to measure Phycocyanin, in determining the presence of cyanobacteria in the water. At 14.5 cm long, 2.3 cm wide and 142 grams, it is small, lightweight, and well suited to the quadcopter platform.

When the vehicle lands on the water, the probe is submerged below the surface of the water. The probe emits light at the excitation wavelength of phycocyanin, and monitors the resulting fluorescence given off by any phycocyanin in the water.

The probe connects directly to the vehicle autopilot board, providing a voltage reading that, through pre-calibration of the sensor, is translated via the server into a phycocyanin reading in ppb (parts per billion).

2) For future water monitoring, a more diverse range of probes can be used to sense both indirectly for cyanobacterial blooms, and directly for other water quality issues, including:

- Phycoerythrin (marine)
- Chlorophyll in vivo
- Turbidity
- Wastewater Monitoring
- Temperature
- Dissolved Oxygen
- pH

TAKE-OFF & LANDING

BEFORE TAKING-OFF

- Check that batteries are charged.

- Attach propellers, check propellers, motors and nuts are tightened.

- Run APM tests on each vehicle.

- Connect batteries of all vehicles.

On the DroneDeploy interface, for each vehicle, an operator choose a flight name, aircraft id, a camera if carried by the vehicle and the flight location. The operator then clicks on the map to define vertices of a polygon to be explored by the aerial vehicle and clicks finish button when done.
The flight path will be displayed and overlayed on top of the polygon and the operator can alternate the flight path by changing parameters in the advanced tab depending on the camera specs, desired image resolutions, flight attitude, etc.
After the desired flight path is chosen, the operator can click "prepare flight" button and a pre-flight check window will be displayed and safety tests are performed on the vehicle. If all checks passed, the operator can launch the vehicle to perform the autonomous mission. The GPS flight mission is written to the vehicle before taking off.

TAKE-OFF PROCEDURE

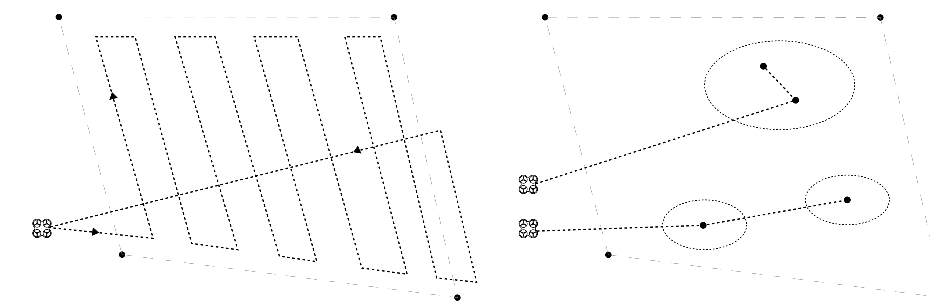
The procedure is part of the autopilot functions which uses the APM sensors. For the take-off procedure, when the throttle is increased, the vehicle uses navigation controllers to guide the vehicle to get to a target position. The vehicle can take off vertically from a flat ground or water with specified taking-off speed

LANDING PROCEDURES

The procedure is part of the autopilot functions which uses the APM sensors. When the vehicle flies right above the landing position, if the vehicle has GPS lock, to land, the vehicle slowly reduces throttle to drop altitudes while maintaining the horizontal positions. The operator can adjust the target horizontal position just as in Loiter mode. The vehicle can land on the ground or on the water with specified landing speed .
The landing algorithm recognizes that the vehicle has landed if the motors are at minimum but it's climb rate remains between -20cm/s and +20cm/s for one second. It does not use the altitude to decide whether to shut off the motors except that the vehicle must also be below 10m above the home altitude.

Upon reaching the ground the copter will automatically shut-down the motors and disarm the copter if the pilot's throttle is at minimum. In emergency cases, the pilot can send manual landing command or disarm the vehicle. To keep the continuous flight during whole mission, the throttle stick should be kept at around center position.
If the copter appears to bounce or balloon back up a couple of times before settling down and turning the props off, the operator should lower the LAND_SPEED parameter
If the vehicle does not have GPS lock the horizontal control will be as in stabilize mode so the operator can control the roll and pitch lean angle of the copter.

FLIGHT-PLANNING ALGORITHMS : PATH GENERATOR



FLIGHT PATH GENERATOR (FPG)

The team has developed a Flight Path Generator that automatically determines the desired GPS waypoints and speeds for both the aerial imaging and probing vehicles, based on certain input criteria. The FPG closely interacts with GPS-based position controller onboard the autopilot; this position controller takes a desired GPS position and speed as an input, and generates the necessary motor commands to guide the vehicle to the given position at the desired speed..

AERIAL IMAGING VEHICLE

Through the web interface the user selects an area of interest to gather aerial images. The FPG is also provided with camera resolution and other parameters including field of view.. From this information, the FPG algorithm generates an optimal 'zig-zag' flight path that guarantees full coverage of the selected area. The flight altitude is calculated in relation to the required image resolution, the flight velocity is related to the shutter speed, and the distance between its zigzagging paths is based on the camera's field of view.

PROBING VEHICLE

The input to the FPG for the sampling vehicles is derived from the Hotspot Detection Algorithm, described in the following page. The 'hotspot' areas are downsampled based on a user-defined sampling density. For example, for a hotspot area of 10 meters by 10 meters and a user-defined density of one measurement per 25 square meters, the FPG algorithm calculates four equally distributed sampling points. The FPG plans the shortest path between those points and issues landing and take-off commands for each probing destination.

FLIGHT-PLANNING ALGORITHMS : IMAGE ANALYSIS

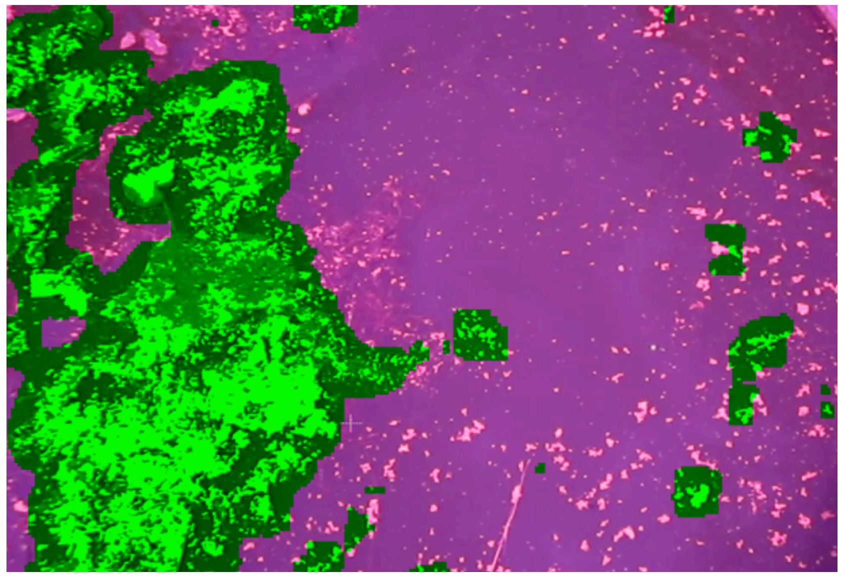


IMAGE CORRECTION & PROJECTION

To detect the points of interest on the water that we want to analyze, we are using aerial imaging and image processing techniques. We have a GoPro Camera fixed on the imaging drone, taking pictures at a fixed time interval. From the pictures taken, we want to detect coloured elements in the images such as algae, and compute their GPS coordinate to send a drone to analyze this point.

1) Lens Correction : Since we are using a GoPro Camera and we want to know the exact direction of every pixels seen on the image, we have to correct the lens distorsion to have a perfect pin-hole type image.
To correct the images, we are using Adobe's LPC model to be able to directly use the coefficient calibrated in Adobe Labs for a wide selection of cameras.

2) Image Projection and localization : After correcting the lens distorsion, we will project the camera image on the floor using the data given buy the drone IMU (altitude, roll, pitch and yaw) and the GPS position to projet the image on the map

IMAGE ANALYSIS

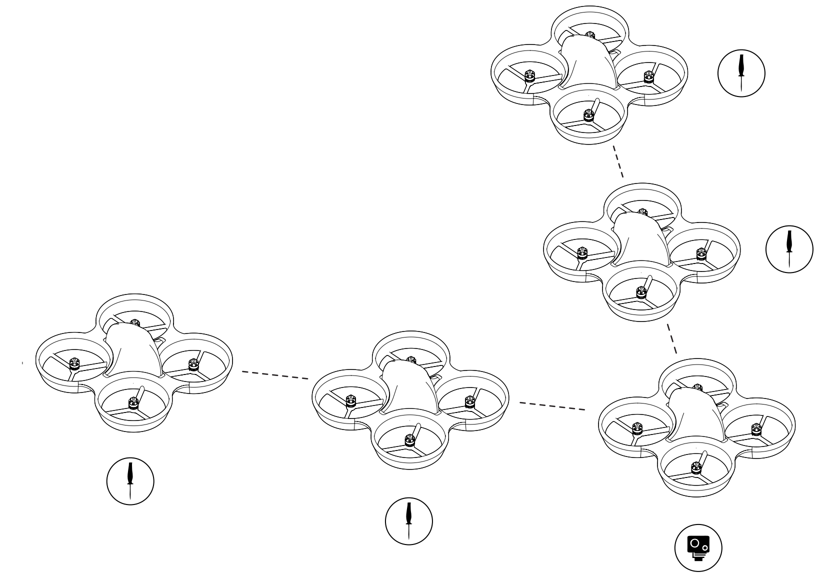
At this point we use different algorithm depending on what we want to detect.
For example, for algae detection, we use infrared imaging to monitor the level of photosynthesis activity - we use a threshold on the infrared level at a given point.
Given the limit of precision of our localization system (GPS) we also want a certain amount of algae on a significative area. To be sure of that, we convolve a round kernel to the entire image of the size of this minimum area, then we can apply a threshold depending of the minimum percentage of algae we want in the area or keep the float value to be able to select the most dense area in the next steps.

PROBING PATH CREATION

1) Probing Spot Distribution : We have a limit in the density of probing points given by the precision of localization. To select the best point, we take the maximum value of the object detection, then we take the second maximum if it's further than the minimum distance to all the probing points and we continue while the value stays greater than the threshold of minimum object density

2) Waypoints Ordering : This is basically the travelling salesman problem, if we want the best solution we just have to compare all possibilities. This stay feasible for a low number of points but if we have more than 10 points. We will then use an approximation of the solution using algorithm that only consider closest points.

FLIGHT-PLANNING ALGORITHMS : MULTIPLE VEHICLES



FORMATION FLIGHT

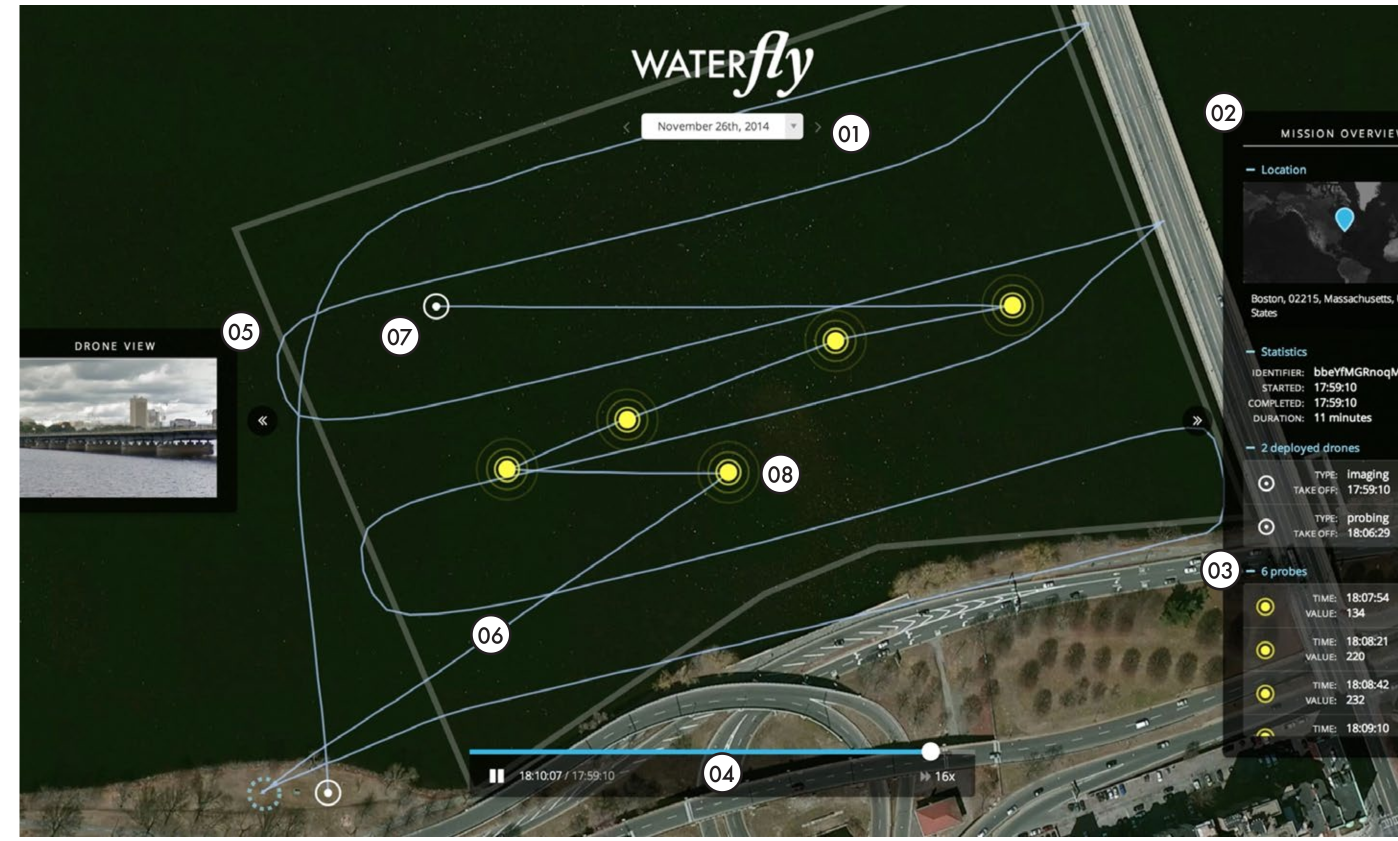
We distinguish two types of formation operation: (a) when vehicles share the same airspace, and (b) when each vehicle operates in different, dedicated airspace. In mode (a), we plan path segments for each vehicle that at no time intersect and always keep a safe distance, and compensates for any unexpected delay of one of the vehicles. When each vehicle has reached their final waypoint, a new non-colliding path segment is assigned to each vehicle. In mode (b), safety of the vehicles is guaranteed by giving each of them their own space to operate in. Instead of 'synchronizing' their motions as done in (a), each vehicle is completely separately controlled.

MULTI-VEHICLE SAMPLING

A swarm of vehicles is dispatched to complete the monitoring task quickly. We use mode (a) at the beginning (and end) of a multi-vehicle operation. In real time as algae hotspots are detected by the imaging vehicle, sampling vehicles are assigned to it. Here, we use mode (b). The imaging vehicle is separated by altitude from the sampling vehicles. The sampling vehicles are each assigned a separate area and are responsible to probe any hotspot detected in their area. As a result, vehicles simultaneously and asychronously perform waterprobing at assigned locations.

COLLISION AVOIDANCE

Nominally, mode (a) and (b) guarantee a collision-free operation. However, a simple collision avoidance strategy is implemented for any unexpected situation. All vehicles continuously report their position and velocity to the cloud. If two vehicles are detected that are close to each other and flying towards each other, hover commands are sent to all vehicles to hover at their current locations. The MFPG then sequentially re-routes each vehicle to a safe position to continue the mission.



FLIGHT OPERATION PLATFORM

For flight operation, Waterfly utilises a front-end user interface supplied by the DroneDeploy communication system.

The interface allows the operator to select the desired vehicles for the flight, perform all necessary safety checks pre-flight, and implement any necessary changes to onboard firmware parameters. During flight, the interface enables the operator to monitor the progress of the flight, tracking the vehicles' locations, waypaths, health status, and sensor data being transmitted.

The DroneDeploy API as enabled to realtime integration of inflight procedures image stitching, image processing and analysis, and automated waypath generation for probing UAVs based on image analysis.

01 Vehicle speed & altitude
02 Battery indicator & LTE signal strength
03 Vehicle name & link to data collected
04 Vehicle firmware parameters
05 Safety checklist, including number of GPS satellites available.
06 Planned flightpath
07 Current vehicle location
08 Actual vehicle flightpath

01 History of flights
02 Current flight overview
03 Data collection overview
04 Flight replay
05 Flight image data
06 Vehicle flightpath
07 Vehicle current location
08 Probing locations and readings

DATA VISUALISATION PLATFORM

Data from every flight is stored in the cloud, and made available for viewing via the Waterfly data visualisation platform. This web-based tool enables any user to explore a repository of past flights, and the sensor data collected on each flight - a spatiotemporal archive of environmental data.

Using the easy-to-use interface, the user is able to select regions of interest, browse through past flights, and replay individual flights using the replay function. For each flight, the image and probe data is visualised on the map. Analytics tools will enable the user to explore data migration over time, visualise spatial patterns in the data, and easily export the data for further anaylsis by environmental researchers.

SAFETY, SECURITY & REGULATION

COLLISION POSSIBILITY

- The ground control station (GCS) will send hover commands to all vehicles in the collision zone and let them hover at its current positions. The GCS then sequentially re-routes each vehicle if necessary to finish its mission.

GUSTY CONDITIONS

- The UAVs will perform automatic landing.

MOTOR FAILURE

- During flight, the failed vehicle will perform automatic landing.
- Before flight, check each vehicle soldered connections between motor, electronic speed controller, and power distribution board for all four motors.
- Use of properly balanced, undamaged, and unchipped propellers
- Full range throttle check prior to each flight
- Fully charged battery prior to each flight
- Positively restrained connectors from the ESC to the power distribution board and from the power distribution board to the APM flight controller (autopilot)
- ESC is mounted with heat sink contact to the aircraft frame for heat dissipation
- Motor bearings, stator coils, rotor magnets, propeller drive shaft, and motor mount are checked and replaced if the vehicle cannot perform a simple 10cm altitude hold flight.

RC LINK FAILURE

- An additional diversity receiver is connected to the main receiver onboard the vehicle to enhance signal reception
- Spread Bandwidth Frequency Hopping is utilized to prevent interference
- In the event of the RC link failing, the failsafe commands the aircraft to land

APM FLIGHT CONTROLLER MALFUNCTION

- APM is mounted in a hard case with rubber dampening grommets. The case is mounted to aircraft frame with an anti-vibration pad
- All control and sensor connectors are positively restrained to prevent these from disconnecting

- Run the pre-checks on DroneDeploy interface before launching a mission.

BAD MAGNETOMETER HEALTH

- Magnetometer is mounted away from strong magnetic sources (motors), on a standoff platform well above the failed vehicle frame
- Magnetometer is checked prior to each flight.

GPS FAILURE

- For each vehicle, GPS is mounted on a standoff platform well above the vehicle frame, where its antenna has a clear view of the sky
- In the event of a GPS failure, the pilot commands the failed vehicle to perform a vertical landing.

GROUND CONTROL STATION CONNECTION FAILURE

- In the event of internet connection failure for 10 seconds, the cloud commands the failed vehicle to Return-To-Launch
- The ground station is constantly checking whether any vehicle drifts too far off the survey area. If this is the case, the GCS will command the corresponding vehicle to return to launch.

DESIGN SAFETY

- The vehicles are designed in such a way that they are small, lightweight, and minimise the danger of impact in the unlikely event of falling. Future design revisions will include emergency mechanisms such as a parachute or airbag.
- The carbon fibre frame keeps the propellers from being exposed, increasing safety when handling the vehicles or coming in close contact with the vehicles during flight.

REGULATORY OPERATION

- The nature of UAV regulation currently differs from country to country. However, as a guideline example of the regulatory use of UAVs, refer to Transport Canada and the article below, explaining a new framework for the governing of UAV operations:

http://robohub.org/transport-canada-releases-new-framework-for-governing-uav-operations

LIMITATIONS & SOLUTIONS

FLIGHT TIME LIMIT

- Reduce payload of the vehicles, choose lightest sensors possible.
- Use batteries that have longer life and minimum weight.

PAYLOAD LIMIT - THE VEHICLE CAN'T CARRY MORE WEIGHT

- Use higher-torque motors.

FLIGHT AREAS WITHOUT GOOD GPS OR CELLULAR SIGNALS

- Navigation using computer vision-based solutions instead of - or in addition to - GPS.
- Amplification of cellular signal.

GUSTY WEATHER

- Further testing and develop of increasingly robust flight controllers.
- More powerful motors.
- Schedule flights for times of low expected wind.

COLLISION AVOIDANCE IN ANY WEATHER

- Implement a system such as FLARM in a small and lightweight fashion: http://en.wikipedia.org/wiki/FLARM
- Develop additional, autonomous collision avoidance strategies implemented on board.

ESTIMATED COST

IMAGING UAV

APM+GPS	300
CoPilot	300
Chassis & Motors	1000
Batteries x2	100
Camera	300
Total	$2000

PROBING UAV

Probing vehicle costs will vary depending on the type of probe specified.

APM+GPS	300
CoPilot	300
Chassis & Motors	1000
Batteries x 2	100
Probe	100 - 2000
Total	$1800 - 3800

DATA CHARGES

Data charges will vary depending on the location, but are projected to be very low, in the region of a few cents per MB of data.

WHOLE SYSTEM

For a swarm of 5 vehicles,

1 x Imaging UAV	$ 2 000
4 x Probing UAV	$ 10 000
+ Spare Parts	$ 3 000
TOTAL	**$ 15 000**

VIDEO

To access the explanatory Waterfly video, follow the link below:

HTTPS://VIMEO.COM/113311604

WATER*fly*