IAB230 2021 Semester 1

# IAB230: Bushfire Management System for National Parks

Satellite and Drone IOT Solution

Declan Barrett – N10219358

# Contents

# Task 1: Project Idea and Solution

## 1.1

The problem domain is detecting and managing when a bushfire has started in remote parts of the Queensland national parks and providing accurate information about it. It is very difficult for Queensland Fire and Emergency Services (QFES) to be able to monitor for fires due to Queensland Parks and Wildlife Services (QPWS) managing 130,000km$^2$ of land and possibly having fire spread to the parks from the 1,800,000 km$^2$ of land that makes up the rest of Queensland (Department of Environment and Science, 2021). "Every 10-minute delay in detecting a fire can see it grow up to 1500m$^2$" meaning the reaction to fires is paramount (The Minderoo Foundation, 2021).

## 1.2

The proposed solution is to install an array of Low-Earth Orbit (LEO) and Geostationary Orbit (GEO) satellites that monitor the national parks for fires, with an accompanying fleet of automated drones. The satellites would provide non-stop coverage of Queensland using cameras and LIDAR. The aggregation and analysis of this information would predict the spread of the fire and the best way of combatting it (ABC, 2021). The drones would be deployed on detection of a blaze as both a real-time monitoring system, gathering more information on conditions, and a fire prevention effort being able to carry water drops to put out small fires. Upon fire detection QFES and QPWS would be notified and then provided updating information surrounding the location, terrain, and conditions of the blaze.

This solution is better than current fire management options since the majority of fire detection comes from people reporting fires by 000 (Dickerson, 2021). 000 calls only catch fires that are immediately affecting people which is too late since the blaze has normally spread beyond a manageable level. Lookout towers with cameras are inadequate since they require lots of large structures in remote areas, have limited site lines and have difficulty detecting fires until there is a lot of smoke (Matthews et al., 2021).

The value of the satellite and drone solution is that it will drastically reduce the response time to fires, put out some fires automatically, saving QPWS time and money from response and repair. It will also enable the prioritization of emergency service manpower, provide strategic fire information, and improve safety for QFES (Fireball, 2021). As rapidly spreading fires cause major damage to local infrastructure and damage valued habitat for local wildlife, the solution will be invaluable for QPWS.

## Task 2: PACT Analysis

| PEOPLE | ACTIVITIES |
|---|---|
| **QPWS Staff:**<br>▪ Psychological:<br>    o Willingness to adopt technological systems.<br>    o Differences in computational skills<br>▪ Social:<br>    o Rural and other cultures<br>    o Attachment to national park<br>▪ Physical:<br>    o Strong and Fit<br>▪ **Managers & Park Rangers**<br>▪ **Volunteers**<br>**QFES Firefighters (Professional and Volunteer):**<br>▪ Physical:<br>    o Fit<br>▪ Psychological:<br>    o Dealing with extremely stressful situations<br>    o Lack of knowledge of park environment<br>▪ Social:<br>    o QPWS culture different to QFES<br>**General Public:**<br>▪ **Locals**<br>    o Attachment to national parks<br>▪ **Tourists**<br>    o Worldwide cultures<br>    o Languages<br>**Drone Maintenance Staff** | Using satellites with cameras, send fire location, size, and fire predictions to drones, QFES, QPWS and public<br>▪ Constant 24/7 monitoring which triggers frequent updates.<br>▪ Quite complex continuous action to analyse images to detect fire location and size, and cloud to predict fire behaviour.<br>▪ Communication between sensors on satellites, drones, and ground services<br>▪ Safety for camera feed in terms of privacy. False alarms wasting resources. Response time matters to limit damage.<br>▪ Large amount of data that is changing slightly but constantly.<br>Use drone to put out fires threatening parks and then monitor them.<br>▪ Activated by fire location, more active during fire season.<br>▪ Simple fly to point, drop and measure.<br>▪ Response time to fire is important, interrupted by new updates from satellites and the sensors on the drone.<br>▪ Cooperation between satellite data, its own data and QFES fighting the fire.<br>▪ Drone crash leading to damage.<br>▪ Large amount of data that changes constantly. |
| **CONTEXTS** | **TECHNOLOGIES** |
| **Physical Environment:**<br>▪ GEO for large lidar<br>▪ LEO for smaller cameras<br>▪ Drones in hubs and flying over national parks.<br>▪ QFES and QPWS in rural locations<br>▪ Ground stations in raised areas to receive satellite data.<br>**Social Context:**<br>▪ Support for languages, cultures, non-tech savvy and stressed individuals for information provided.<br>**Organizational Context:** | **Input:**<br>Image data (Infrared, Reflected-Laser)<br>Wind<br>Humidity<br>Keyboard, Mouse, Touchscreen for QPWS access<br><br>**Output:**<br>Drone Video Feed<br>Application Screen with Fire Information and Predictions<br>Fire Retardant Drop<br><br>**Communication:**<br>Wired Connections |

| | |
|---|---|
| ▪ Large initial investment for satellites and drones<br>▪ Running and maintenance costs for drones and satellites requiring personnel<br>▪ Drone landing areas infrastructure | S-Band and X-Band Radiowaves<br>Ethernet for ground to hub/fog<br>4G and Satcom for cloud and service communications<br><br>**Content:**<br>Images and Video of Fires<br>Humidity and Weather Information<br>3D environment maps |

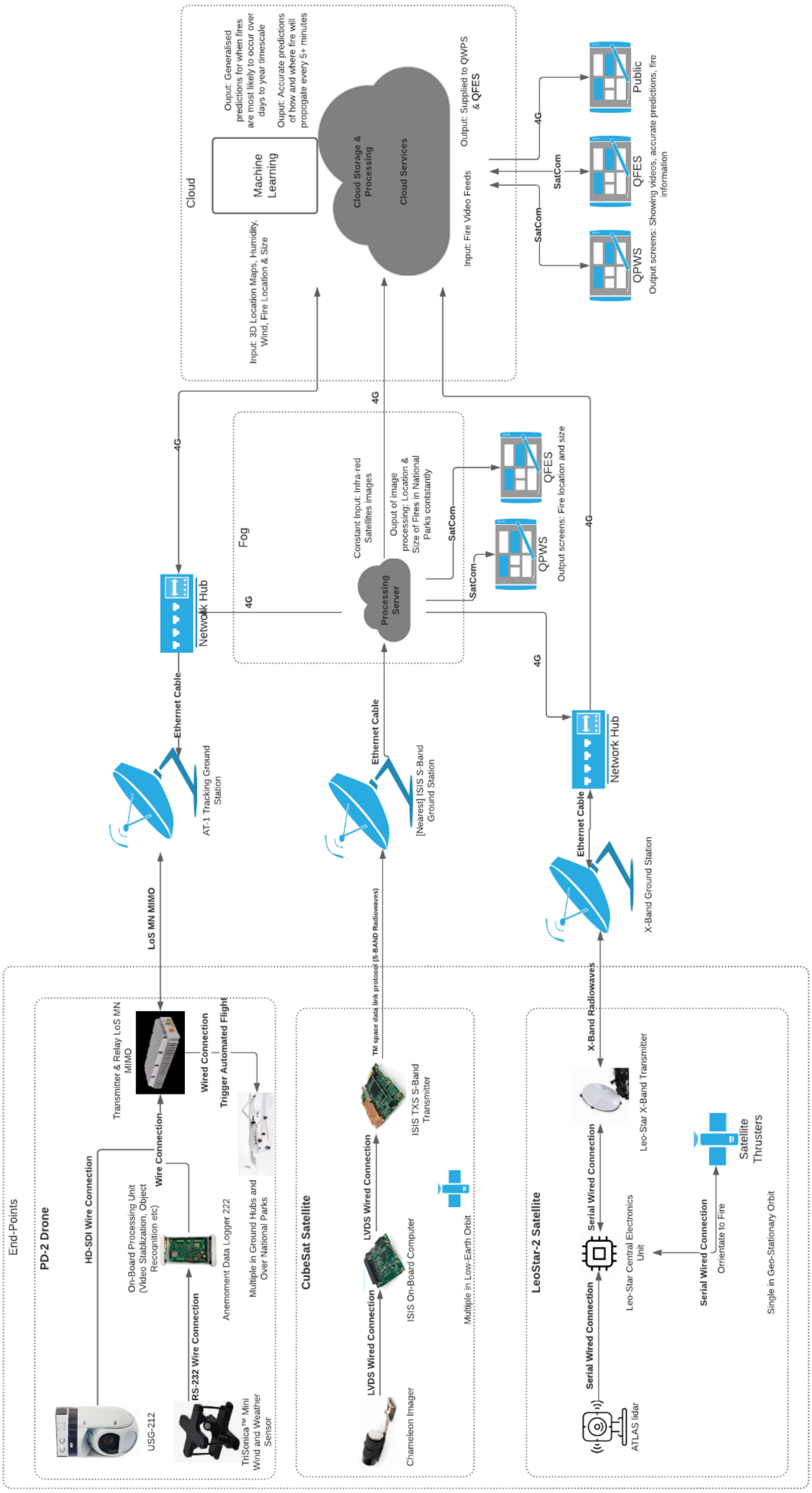
## Task 3: IOT Devices

| Sensors | Characteristics | Components | Input | Output |
|---|---|---|---|---|
| Chameleon Imager (Dragonfly Aerospace, 2021) | - Designed for small 3U CubeSats, enabling easy satellite construction<br>-Spatial Resolution at 500km: 6m for Inferred PanChromatic (2.4m @ 200km)<br>- Relatively affordable and configurable line scan imager compared to others ($258K)<br>- Power consumption less than 3.5W, which is under what a single cubesat solar panel produces<br>- Can convert image data from RAW to JPEG to reduce size<br>-Is temperature tested, radiation proof and vacuum sealed for space<br>- Penetrates Cloud and Smoke (Space Advisory Company & SCS, 2021) | - Linescan Imager – with modes: Hyperspectral, MultiSpectral, PanChromatic<br>-LVDS, SPI, I2C CAN, RS422 data interfaces (1-480mbps)<br>- Integrated mass storage 128GB<br>- 5VDC Power Interface | - 770nm Inferred wavelengths emitted from fires in Queensland | - 8-10bit raw image output, or JPEG2000 of inferred images of Queensland |
| Orbital Sciences Corporation Advanced Topographic Laser Altimeter System (ATLAS) (ESA, 2021) | -Large LIDAR sensor<br>-Spatial Resolution at 600km: 10cm<br>-Extremely expensive, $125 million for satellite and sensor launch (NASA, 2021b)<br>- Able to penetrate through Cloud and Smoke<br>- Able to scan the trees, low ground cover and floor all at once<br>- Uses 1374 Watts requiring huge solar panels | -Fibertek Laser split 9 ways, 10kHz<br>-704gb mass storage<br>- MIL-STD-1553 data bus and RS-422 serial interfaces<br>- Photon-sensitive Photomultiplier Tube (PMT) detector arrays<br>-Mounted on Leo-Star Satellite with GPS and Laser Ranging<br>-LRS (Laser Reference System) | -Lasers bounced off of Earth | -precise 3D terrain and tree maps of fire areas<br>-40m wide scans |
| USG-212 EO/IR gimbal (UKR SPEC SYSTEMS, 2021) | -Regular and Infrared combined camera used for surveillance<br>-Compatible with PD-2 UAV<br>-Full 360 rotation enabling constant tracking of the fires<br>-Camera provides 30x Optical Zoom @ 30Fps | - HD-SDI (BNC 75 Ohm)<br>- AV/CVBS (BNC 75 Ohm)<br>-Sony Block Full HD Camera | -Images of fires around national parks | - 60fps Video feed of fires<br>-30fps Infrared feed |

| | | | | |
|---|---|---|---|---|
| | - Built in stabilization and target tracking<br>- USG and PD-2 Platform does not state costs until the solution is commissioned, but is stated to be competitively priced by external sites<br>- Runs on electricity produced by the PD-2 UAV which runs on gasoline which is cheap but not environmentally friendly | - Thermal Camera Flir Tau 2<br>-Digital Processing Module (stabilises video and identifies objects) | | - Encrypted Video Feed |
| TriSonica™ Mini Wind and Weather Sensor (Anemoment, 2021) | -No moving parts<br>- Very Small, less than 10cm * 10cm and weighs 50g, so will not affect PD-2 Drop Weight<br>- Can be custom inserted onto the PD-2 using ½ DN15 Schedule 10 Pipe<br>-Low power consumption, meaning it can draw from the PD-2 (36 VDC @ 30mA)<br>-Provides a range of sensors all in one | - RS-232 Serial Output<br>- Wind Speed & Direction Sensor<br>- Humidity Sensor<br>- Temperature Sensor<br>- Pressure Sensor<br>- 3D Accelerometer<br>- Magnetometer | - Wind, Humidity, Pressure and Temperate surrounding UAV | - Strength and direction of wind in knots<br>- Humidity 0-100% RH |

# **Task 4**: Connectivity Diagram

## 4.1



## 4.2

The Chameleon Imager sensor has a LVDS output which can be wired to an onboard computer which will transfer via LVDS the data to an S-Band Transmitter. This transmitter will be using the TM space data link protocol with S-Band radio waves and the data will be received by a ground station, connected via ethernet cable to ground based fog computing (CSSDS, 2021). The data collected from the Chameleon Imager is gathered constantly when it is over Queensland (Scott, 2021). The Chameleon Imager will output 15 fps of panchromatic infrared images in JPEG format with the ISIS transmitting them at up to 4.3Mbit/s (ISISSpace, 2021). The Cubesat platform is not large enough to facilitate fog computing, thus it needs to be done on the ground at the station. The infrared images will then be analysed by the fog, in real time, for indicators of fires, and outputting fire locations and size.

The ATLAS sensor uses a wired serial connection to a CEU, which uses a wired connection to the Leo-Star Transmitter, using X-Band Radio waves to communicate with a ground station. This is connected via ethernet to a network hub, using 4G to transfer to the cloud. The previous fire locations are transmitted to the network hub by 4G, and then to the satellite via X-Band, upon fire discovery, so it can orientate to scan the environment around the fire. Each ATLAS scan takes several minutes, producing up to 4GB of 3D information about the forest environment and its density (NASA, 2021a). The X-Band transmitter can transmit this data at 220Mbit/s, which is then transferred via network hub and 4GB to the cloud.

The USG-212 records stabilised video and transfers it via HD-SDI wire connection. The TriSonica Mini has a RS-232 Wired Connection, which is logged by a data logger. The video feed and weather information is passed through a LoS MN MIMO transmitter, which is picked up by a tracking ground station, connected to a network hub that uses 4G to connect to the cloud. The previous fire locations are transmitted to the drone, to tell the drone where to fly to. The USG-212, once near the fire, constantly produces video of the fire, both inferred and not, in HD, the data being well under the 100mb/s offered by the LOS MN-Mimo (Silvus Technologies, 2021). The TriSonica also produces constant humidity and wind information upon reaching the fire, being in the kb/s data range.

The 3D Forest, Wind Speed and Humidity, fog generated fire location and size are all aggregated in the cloud and analysed every five minutes with machine learning, to produce accurate predictions of the propagation of the fire. QPWS and QFES are notified directly from the fog via satcom (since LTE isn’t available in remote locations) of new fires, location and sizes. The cloud also acts as a platform for an application that provides video feeds and fire spread predictions to QPWS and QFES. Fire predictions are also given to the public.

# Task 5: Conclusion and Limitations

In conclusion, the satellites and drones provide a very capable and valuable solution, decreasing response times, reducing damages caused by fires, and making it safer for QFES and QPWS to do their jobs. However, there are quite a few limitations to the solution. The largest limitation is the initial cost of setup. Launching multiple satellites is incredibly expensive, with each CubeSat running around $260,000 including sensor loadout and launch, with at least twelve needed due to low-earth orbit and its limited swath (Crow, 2021). The ATLAS on a Leo-Star is also incredibly expensive, and the PD-2 drones with sensors are not priced till contracted. At least four drone hubs need to be built across Queensland, with each needing personnel, refuelling with both petrol and water. These running costs, with Fog and Cloud costs, on top of the CubeSats in LEO having a limited lifespan before they fall out of orbit, make the solution a continual charge. Weather conditions can also affect drone usage since extreme winds can make the PD-2 unstable to fly. There is also a delay between detection and the drone arriving on the scene, allowing the fire to spread. Overall, the reduced fire-damage costs outweigh the negatives.

## References:

ABC. (2021). The bold plan to detect bushfires within one minute. Retrieved 13 April 2021, from https://www.abc.net.au/news/science/2021-03-14/bushfires-detecting-them-from-space-fireball-satellite-launch/13203470

Anemoment. (2021). TriSonica™ Mini Wind and Weather Sensor. Retrieved 13 April 2021, from https://anemoment.com/features/#trisonica-mini

Crow, T. (2021). Australia's Small Satellite Revolution. Retrieved 18 April 2021, from https://particle.scitech.org.au/space/australias-small-satellite-revolution/

CSSDS. (2021). TM SPACE DATA LINK PROTOCOL. Retrieved 18 April 2021, from https://public.ccsds.org/Pubs/132x0b2.pdf

Department of Environment and Science. (2021). Fire management. Retrieved 13 April 2021, from https://parks.des.qld.gov.au/management/programs/fire-management

Dickerson, M. (2021). Looking to the stars for answers to detect bushfires within minutes of them forming. Retrieved 13 April 2021, from https://www.youngwitness.com.au/story/7182812/looking-to-the-stars-for-answers-to-stop-bushfires/

Dragonfly Aerospace. (2021). Chameleon Imager - Dragonfly Aerospace. Retrieved 12 April 2021, from https://dragonflyaerospace.com/chameleon/

ESA. (2021). ICESat-2 Satellite Missions. Retrieved 13 April 2021, from https://earth.esa.int/web/eoportal/satellite-missions/i/icesat-2

Fireball. (2021). Detecting & Notifying Authorities About Bushfires. Retrieved 20 April 2021, from https://www.fireball.international/

ISISSpace. (2021). High Data Rate S-Band Transmitter - ISIS - Innovative Solutions In Space. Retrieved 18 April 2021, from https://www.isispace.nl/product/isis-txs-s-band-transmitter/

Matthews, S., Sullivan, A., Gould, J., Hurley, R., Ellis, P., & Larmour, J. (2021). Field evaluation of two image-based wildland fire detection systems [Ebook]. Retrieved from https://publications.csiro.au/rpr/download?pid=csiro:EP112825&dsid=DS1

NASA. (2021a). Algorithm Theoretical Basis Document. Retrieved 18 April 2021, from https://icesat-2.gsfc.nasa.gov/sites/default/files/files/ATL03_05June2018.pdf

NASA. (2021b). NASA Selects Launch Services for ICESat-2 Mission. Retrieved 18 April 2021, from https://www.nasa.gov/home/hqnews/2013/feb/HQ_C13-011_ICESat-2_Launch.html

Scott, T. (2021). Australia's Bushfire-Hunting Satellites. Retrieved 18 April 2021, from https://www.youtube.com/watch?v=99_Abbuf3cQ

Silvus Technologies. (2021). Retrieved 18 April 2021, from https://silvustechnologies.com/applications/airborne-isr/

Space Advisory Company, & SCS. (2021). Chameleon Imager. Retrieved 20 April 2021, from https://www.cubesatshop.com/wp-content/uploads/2018/04/Chameleon-Brochure-2019-07-10.pdf

The Minderoo Foundation. (2021). Automated Bushfire Detection. Retrieved 13 April 2021, from https://www.minderoo.org/fire-and-flood-resilience/fire-shield/detect/automated-bushfire-detection/

UKR SPEC SYSTEMS. (2021). USG-212. Retrieved 13 April 2021, from https://ukrspecsystems.com/drone-gimbals/usg-212