Milestone I Presentation

FPGA-Based Machine Learning on a Drone

Capstone Team 109

Peter Deutsch *me@peterdeutsch.ca*
Muchen He *i@muchen.ca*
Arthur Hsueh *ah11962@outlook.com*
Meng Wang *wzfftxwd@gmail.com*
Ardell Wilson *ardellw96@gmail.com*

https://capstone-skynet.github.io

Presentation Overview

Context and Purpose

Requirements

Constraints

Viability of the Project

Risks

Risk Mitigation

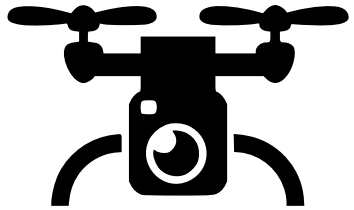
Solution Path

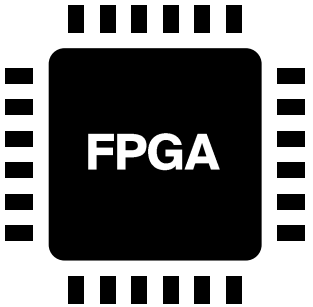
Why?

Context & Purpose

Increasing ***machine learning*** and ***drone*** applications

No existing combination of FPGA + ML + drone on the market





Context & Purpose

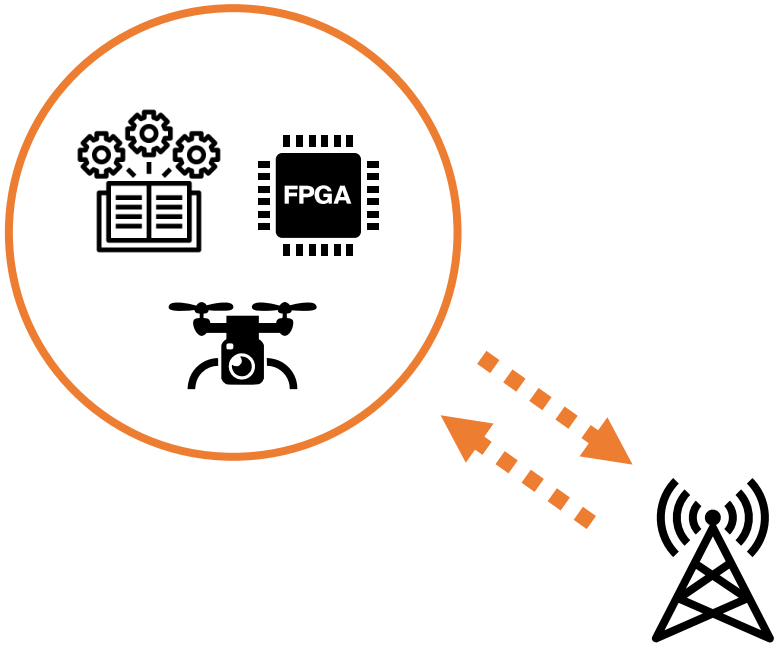
Want to combine all of them → ***computing platform***

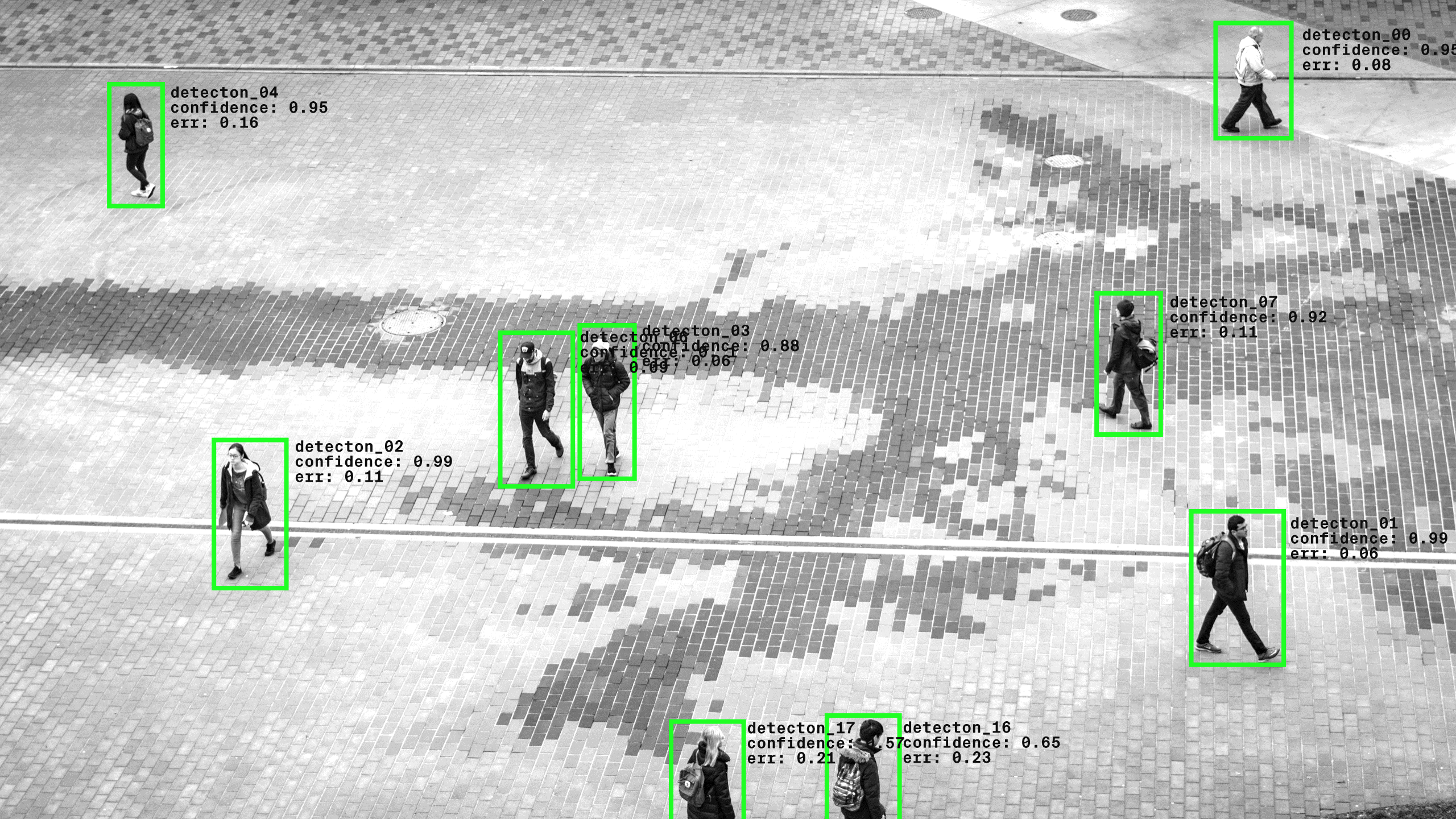
- Accelerate ML using FPGA
- FPGA on deployed on the drone

For client's **ML research**

Communicate with ground station

Detect pedestrians from above




detecton_00
confidence: 0.95
err: 0.08
detecton_04
confidence: 0.95
err: 0.16
detecton_07
confidence: 0.92
err: 0.11
detecton_03
confidence: 0.88
err: 0.06
detecton_02
confidence: 0.99
err: 0.11
detecton_01
confidence: 0.99
err: 0.06
detecton_17
err: 0.21
detecton_16
confidence: 0.65
err: 0.23

Requirements & Constraints

Requirements

Integrated Drone Requirements

- Capable of flying with the computing platform
- Flight duration at least 10 minutes
- Remote controlled by the pilot

Requirements

Drone Legal Requirements

- Operation is compliant with *Transport Canada*
- Tests inside YVR controlled airspace is permitted

Government of Canada / Gouvernement du Canada

Requirements

Data Transmission Requirements

- Data processed on the drone transmitted to ground station
- Ground station receives and display data to the operator
- Transmission via WiFi (2.4GHz or 5.2GHz)

Machine Learning Requirements

- Machine learning model fits on FPGA
- Model detects pedestrians and outputs bounding boxes

Requirements

Data Transmission Requirements

- Data processed on the drone transmitted to ground station
- Ground station receives and display data to the operator
- Transmission via WiFi (2.4GHz or 5.2GHz)

Machine Learning Requirements

- Machine learning model fits on FPGA
- Model detects pedestrians and outputs bounding boxes

Constraints

Time & Budget

Limited to C$1,000

Limited time to perform 2 sub-projects

Coordination and leadership is challenging

Future-Proofing

FPGA chip area big enough for future ML models

Power & Weight

Battery power is limited

Weight and power draw affects flight duration

Portability

Data Transmission

Limited bandwidth for data

Limited power emission

Limited range

Viable?

Viability

Assess system feasibility on 3 objectives:

1

Integration of FPGA with a Drone

2

Air-to-Ground Data Transmission

3

ML Implementation on FPGA

Viability

All three objectives individually has existing solutions

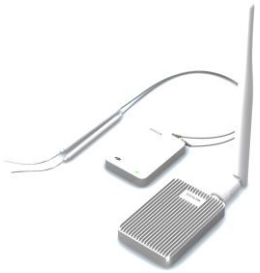
1

Integration of FPGA with a Drone

Aerotenna FPGA flight controller

2

Air-to-Ground Data Transmission



DJI DATALINK

3

ML Implementation on FPGA

SymbioticEDA MARLANN

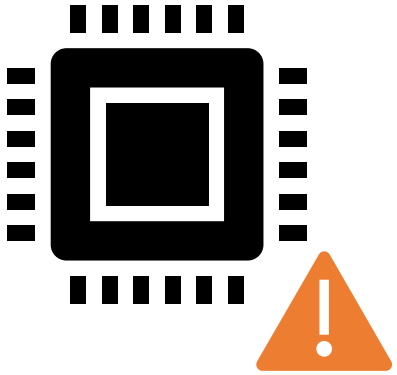
Viability

Combination of the three will further this field of research

This project is a **proof-of-concept**

Risks?

Risks



Hardware

Flight crashes

Loss of FPGA

Loss of drone

Management

Insufficient commitment

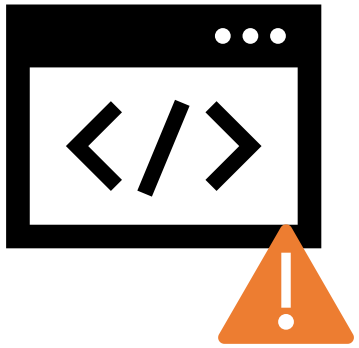
Poor task management

Poor decision making

Legacy

Low repairability / maintainability

Client doesn’t know how to operate



Software

Tech. debt

Inadequate documentation

Risk Management

We keep track of an updated copy of the ***risk profile***

Active mitigation on risks with index ≥ 0.4

- Triage tasks to mitigate risk
- Weekly update on risk status

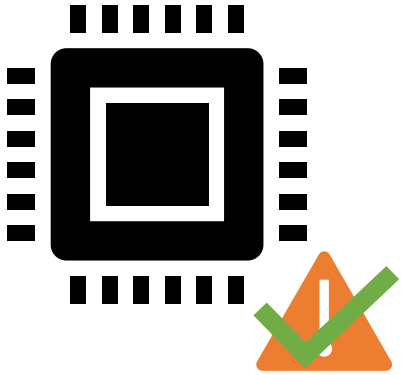
Passively monitoring on risks with index < 0.4

Table 2: Risk Profile

Risk description	Likelihood	Impact	Risk (I_j)
Drone flight hardware (flight controllers, radio, motors) cannot function due to crashes and/or damage.	0.9	1.0	0.90
Payload is too heavy which significantly increases drone motor requirements and significant reduction in flight duration.	0.8	0.8	0.64
Accidents that damage the drone and computation equipment that require extra budget that we may not have.	0.6	0.9	0.54
Total loss of drone hardware and payload during flight.	0.5	1.0	0.50
Not enough time commitment from team members.	0.7	0.7	0.49
Access to tools and shops for modifying and repairing drone hardware is inadequate or non-existent.	0.6	0.8	0.48
Underestimation of project scope or work required, leading to insufficient time management and burn outs.	0.5	0.9	0.45
Payload is too heavy which exceeds total take off weight.	0.4	1.0	0.40
Legacy documents for the project are insufficient, resulting in poor maintainability/extensibility for the client.	0.7	0.5	0.35
Financial inefficiencies leading to budget overruns or lack of capital.	0.4	0.8	0.32
Constrained to purchase lower-quality components due to budget, resulting in lower performance.	0.6	0.5	0.30
Team is indecisive or cannot make a timely decision — resulting in delay.	0.4	0.6	0.30
Development and management technique/methodology is not effective, leading to productivity losses.	0.4	0.7	0.28
Not enough time to work on documentation.	0.7	0.4	0.28
Not enough machine learning training data.	0.5	0.5	0.25
Not enough FPGA logic elements to implement a desired ML model.	0.5	0.5	0.25
Failure to acquire regulatory compliance resulting in inability fly drone legally.	0.3	0.7	0.21
The software, tools or development environment for the project is inadequate.	0.4	0.5	0.20
Knowledge and skill regarding ML is insufficient.	0.5	0.4	0.20
Technical debt paydown impacts project timeline.	0.4	0.5	0.20
Deliverables fail to meet client's expectations.	0.2	0.9	0.18
Client demands modification to the scope and requirements of the project that leads to delays or feature cuts.	0.3	0.6	0.18

Continued on next page

Risk Management



Hardware

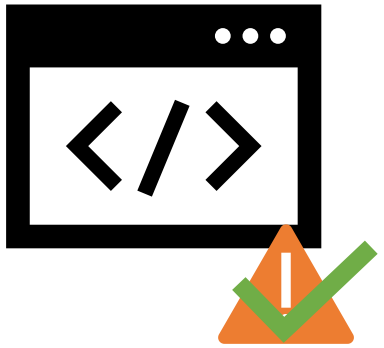
- Follow safety protocol
- Only power on when absolute ready

Management

- Weekly updates and status report on assigned tasks
- Timeline closely tracked

Legacy

- Actively updating all documents alongside changes

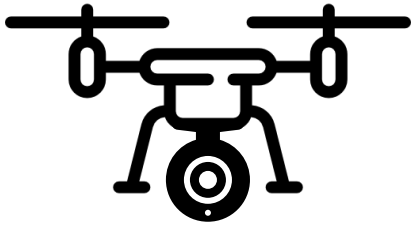


Software

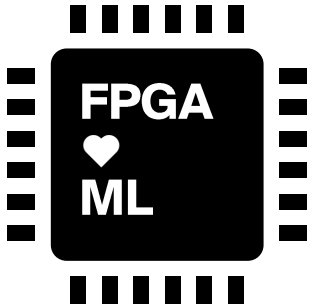
- Version tracking
- Code review

Solution?

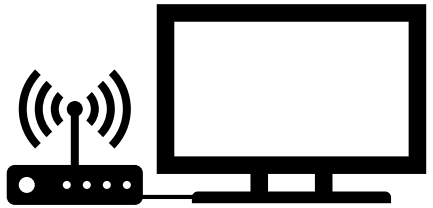
Deliverables



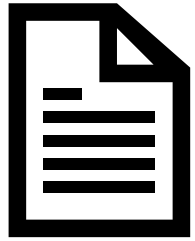
1x



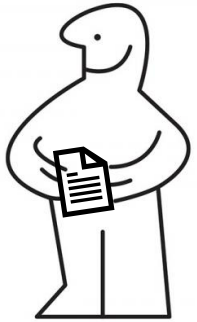
1x



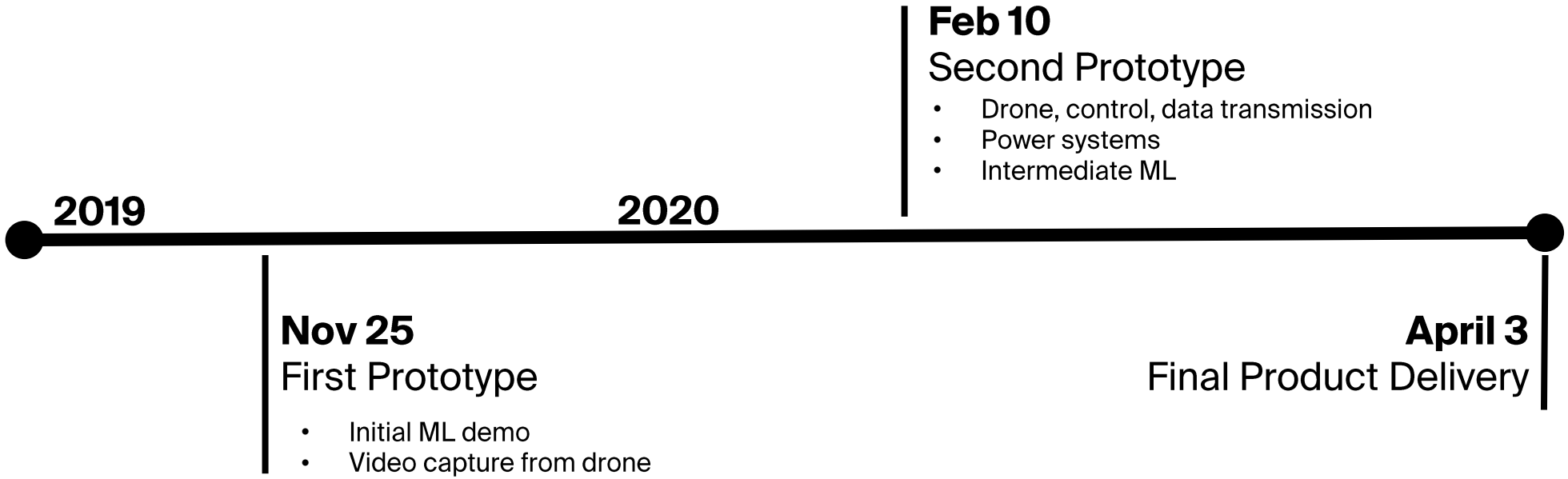
1x



5x



Deliverable Dates



Immediate Steps

Start **Small**

- Function over scale
- Integrate existing model

Start **Quickly**

- Create purchasing plans
- Tool setup takes time

Start **Legally**

- Drone registration
- Pilot and radio certifications

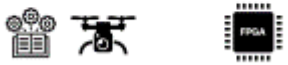
Q?

Q?

Context & Purpose

Increasing ***machine learning*** and ***drone*** applications

No existing combination of FPGA + ML + drone on the market



Context & Purpose

Want to combine all of them → ***computing platform***

- Accelerate ML using FPGA
- FPGA on deployed on the drone

For client's **ML research**

Communicate with ground station

Detect pedestrians from above

Requirements

Integrated Drone Requirements

- Capable of flying with the computing platform
- Flight duration at least 10 minutes
- Remote controlled by the pilot

Requirements

Drone Legal Requirements

- Operation is compliant with *Transport Canada*
- Tests inside YVR controlled airspace is permitted

Requirements

Data Transmission Requirements

- Data processed on the drone transmitted to ground station
- Ground station receives and display data to the operator
- Transmission via WiFi (2.4GHz or 5.2GHz)

Machine Learning Requirements

- Machine learning model fits on FPGA
- Model detects pedestrians and outputs bounding boxes

Requirements

Machine Learning Requirements

- Machine learning model fits on FPGA
- Model detects pedestrians and outputs bounding boxes

Constraints

Time & Budget

Limited to C$1,000

Limited time to perform 2 solo-projects

Coordination and leadership is challenging

Future-Proofing

FPGA chip area big enough for future ML models

Power & Weight

Battery power is limited

Weight and power draw affects flight duration

Portability

Data Transmission

Limited bandwidth for data

Limited power emission

Limited range

Viability

Assess system feasibility on 3 objectives:

1 Integration of FPGA with a Drone

2 Air-to-Ground Data Transmission

3 ML Implementation on FPGA

Viability

All three objectives individually has existing solutions

1 Integration of FPGA with a Drone

Aerotenna FPGA flight controller

2 Air-to-Ground Data Transmission

DJI DATALINK

3 ML Implementation on FPGA

SynticsticsEDA MAPLAMPI

Viability

Combination of the three will further this field of research

This project is a **proof-of-concept**

Risks

Hardware

Flight crashes

Loss of FPGA

Loss of drone

Management

Insufficient commitment

Poor task management

Poor decision making

Legacy

Low repairability / maintainability

Client doesn't know how to operate

Software

Tech. debt

Inadequate documentation

Risk Management

We keep track of an updated copy of the ***risk profile***

Active mitigation on risks with index ≥ 0.4

- Triage tasks to mitigate risk
- Weekly update on risk status

Passively monitoring on risks with index < 0.4

Risk Management

Hardware

- Follow safety protocol
- Only power on when absolute ready

Management

- Weekly updates and status report on assigned tasks
- Timeline closely tracked

Legacy

- Actively updating all documents alongside changes

Software

- Version tracking
- Code review

Deliverables

1x

1x

1x

5x

Deliverable Dates

Immediate Steps

Start **Small**

- Function over scale
- Integrate existing model

Start **Quickly**

- Create purchasing plans
- Tool setup takes time

Start **Legally**

- Drone registration
- Pilot and radio certifications

Milestone I Presentation

FPGA-Based Machine Learning on a Drone

Capstone Team 109

Peter Deutsch	*me@peterdeutsch.ca*
Muchen He	*i@muchen.ca*
Arthur Hsueh	*ah11962@outlook.com*
Meng Wang	*wzfftxwd@gmail.com*
Ardell Wilson	*ardellw96@gmail.com*

https://capstone-skynet.github.io