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EPFL

EuroAirport™
BASEL MULHOUSE FREIBURG

DESIGN PROJECT 2021: AUXILIARY POWER UNIT (APU) DETECTION BY THERMOGRAPHY

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Topics

- Introduction
- What is an APU ?
- Methodology
- Data acquisition
- Image processing
- Automation
- Results
- Limitations
- For further APU monitoring

Introduction

The concern is air pollution and greenhouse gas emissions at ground level.

Aircraft doing stopover contribute up to 18% to the total NOx emission, 23% for CO emission.

They are doing so using a device called APU

What is an APU?

It is a gas turbine, used as a back-up motor.

It provides the following services:
main engine starting, heat, air conditioning and electrical power.

It uses kérosène as fuel and function with combustion.

In 2022, the DGAC plans to set new regulations concerning the use of APU.

The EuroAirport wants to examine what monitoring system can be implemented.

This project focuses on the possibility to achieve it by thermography.

Methodology

Data acquisition

Image processing

- Aircraft movement
- APU shutdown
- APU startup

Implementation of automation

Data Acquisition

Material

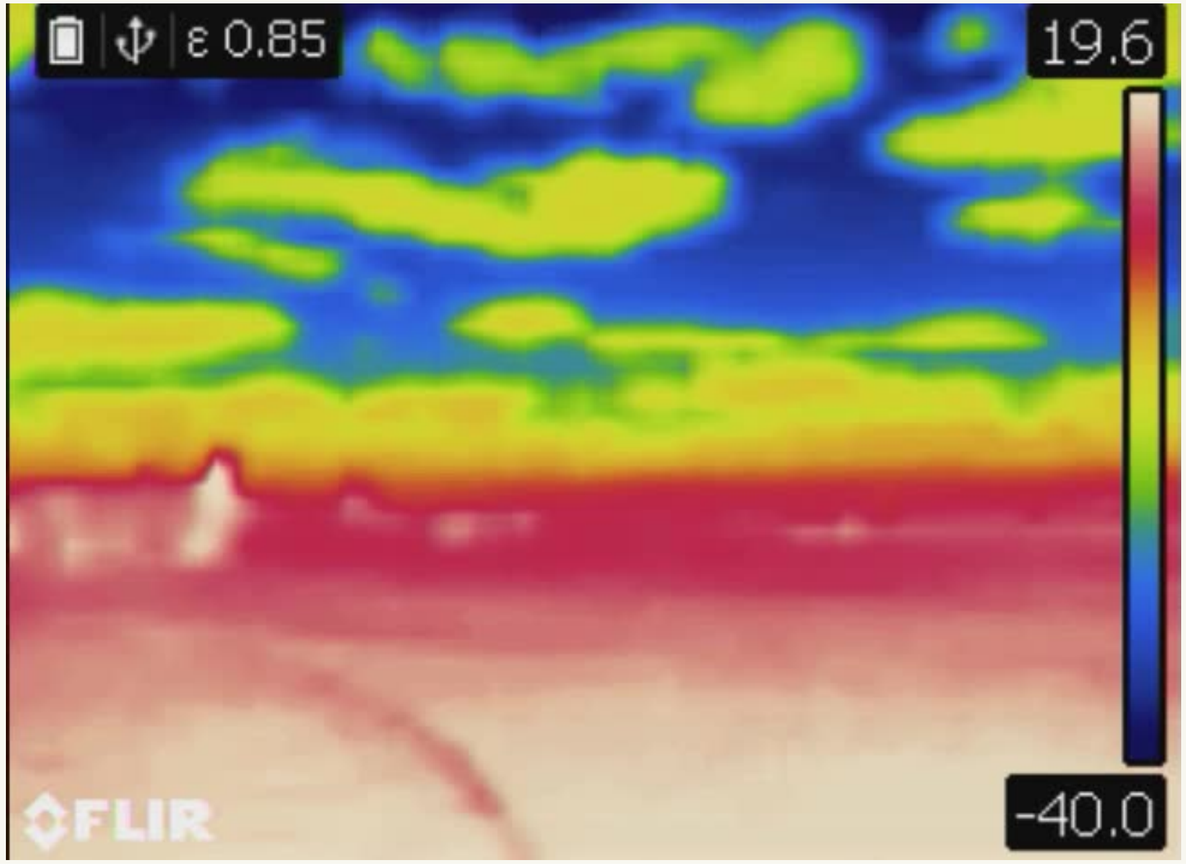
Camera: FLIR C2
Optical resolution (pixels): 160x120
Thermal resolution (pixels): 80X60

Measurements

2 measurement sessions.
6 landings and 6 departures were recorded.
5 APU shutdowns and 4 APU start-ups

Image Processing

Aircraft movement - difference analysis

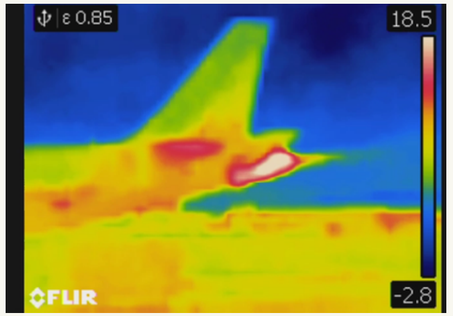


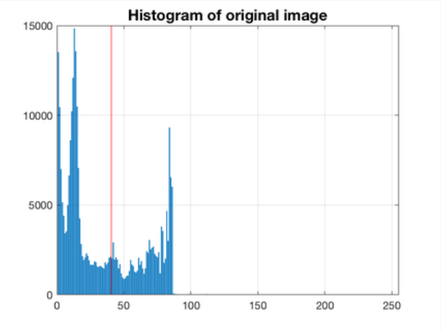
Challenges:
- Aircraft arrival detection.
- Resilience to interfering movements .

Settings:
- The camera is at a distance of 20 meters from the aircraft.
- It is placed so that the vision is perpendicular to the trajectory of the aircraft.
- The camera needs to be in a static position

Image Processing

Aircraft movement





Step 1: Extraction of images every 3 seconds from the video.

Step 2: Removing black borders & transformation in a grey-scaled image

Step 3: Calculation of threshold based on a difference analysis.

Step 4: Creation of binary images.

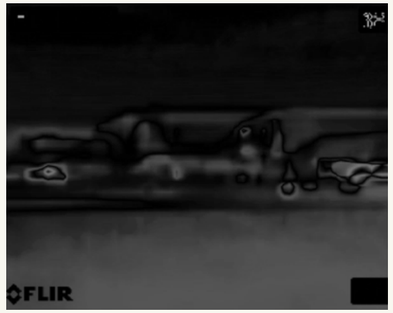
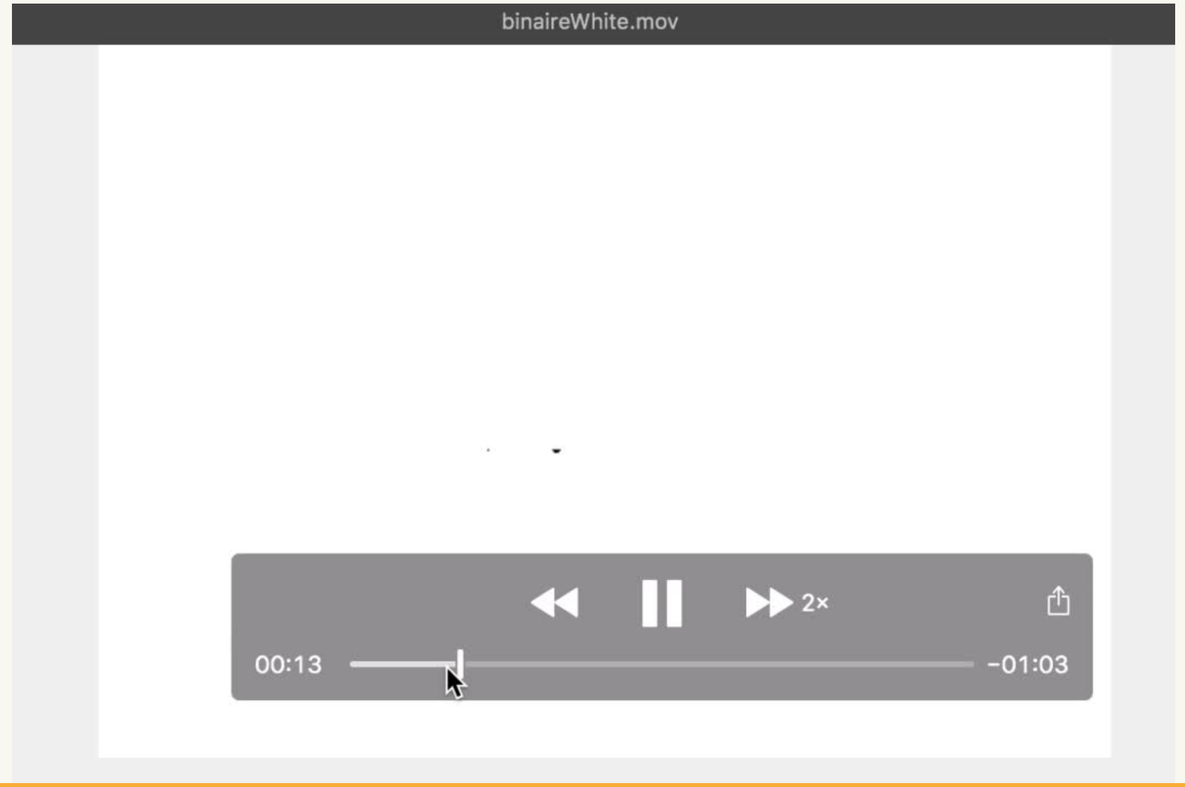


Image Processing

Aircraft movement - Step 5: Difference analysis based on binary images.



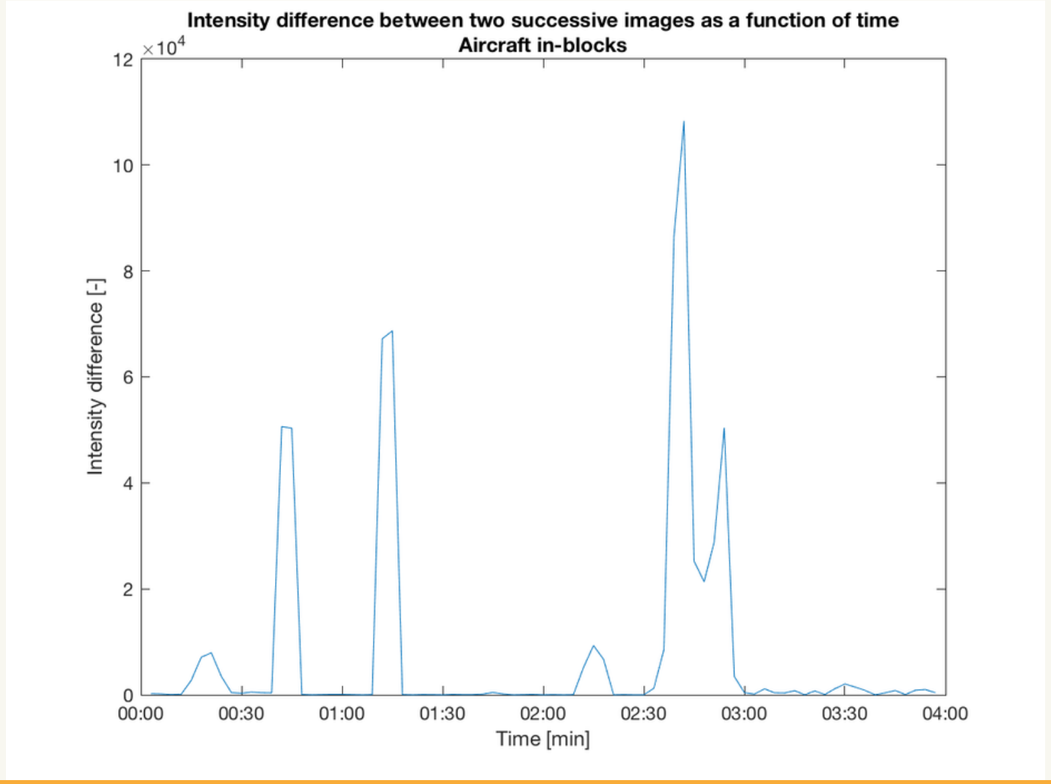
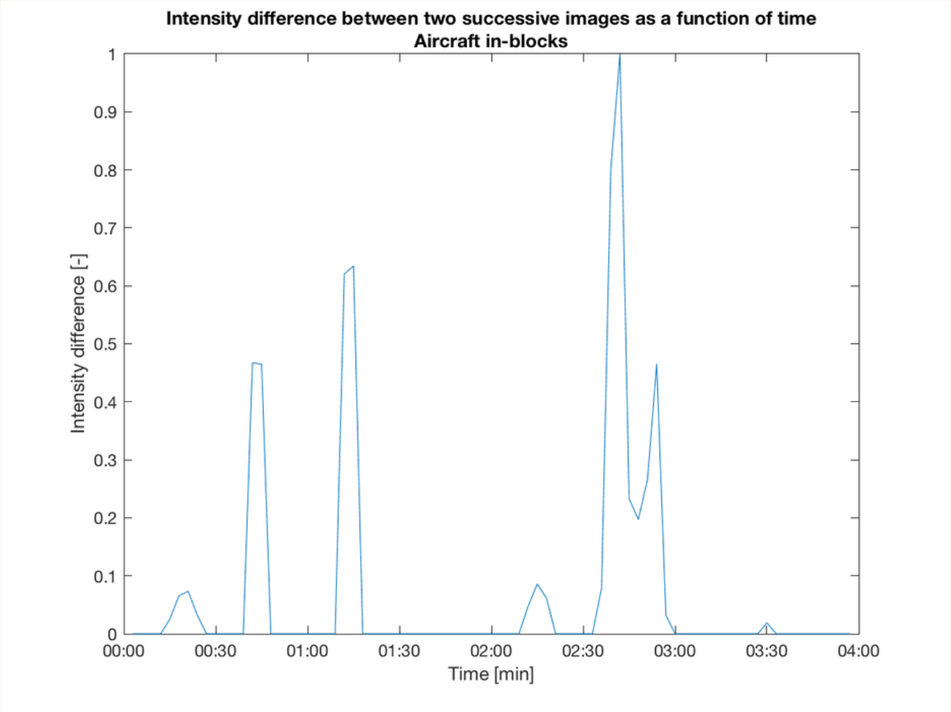


Image Processing

Aircraft movement - parameter analysis

- Peak intensity : 0.2



- Peak duration : 12 secondes

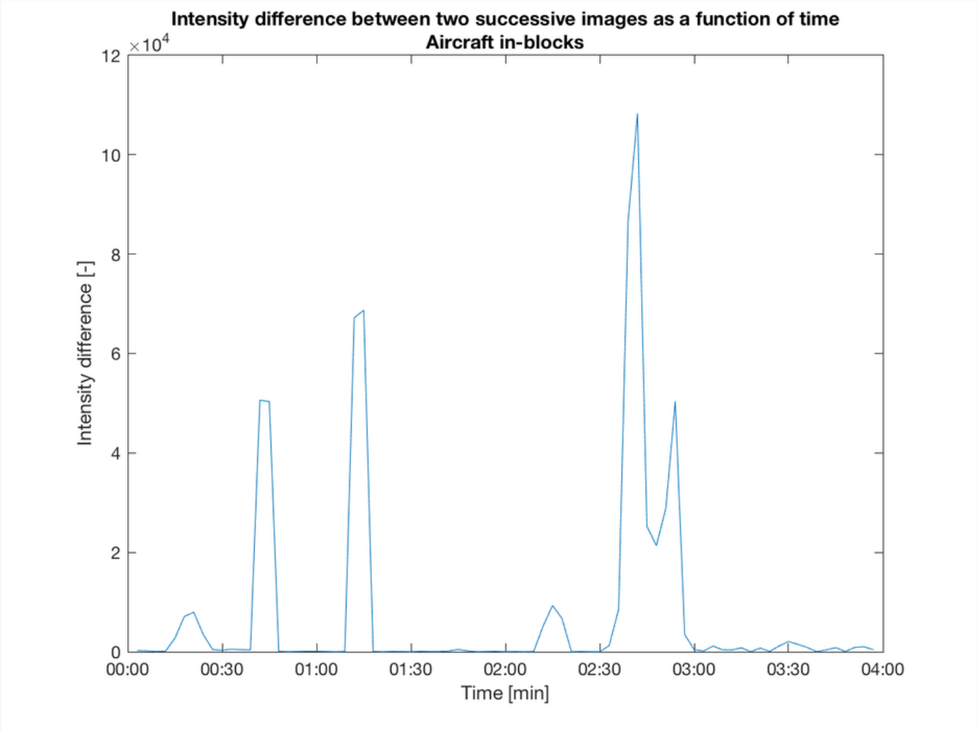
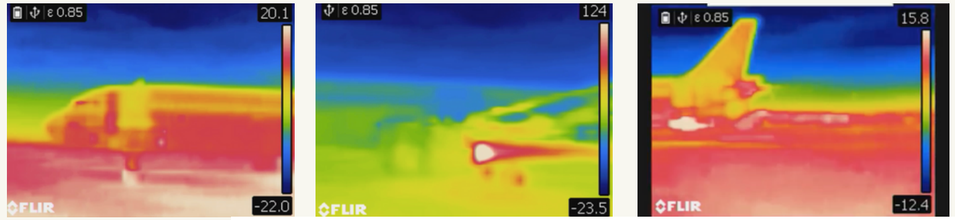
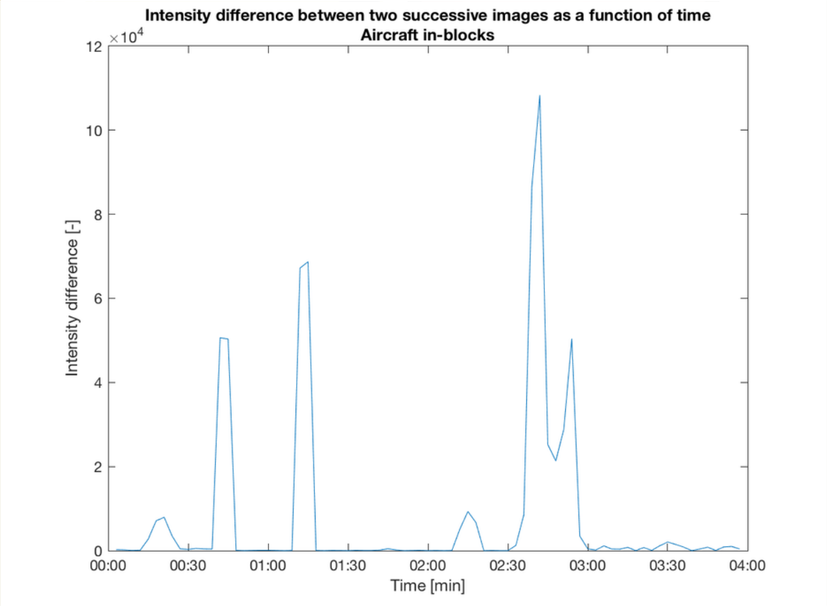


Image Processing

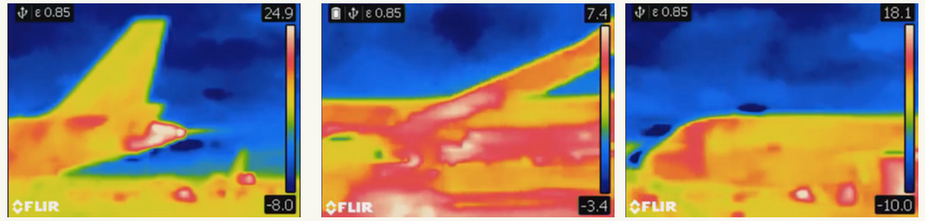
Aircraft movement - parameter analysis

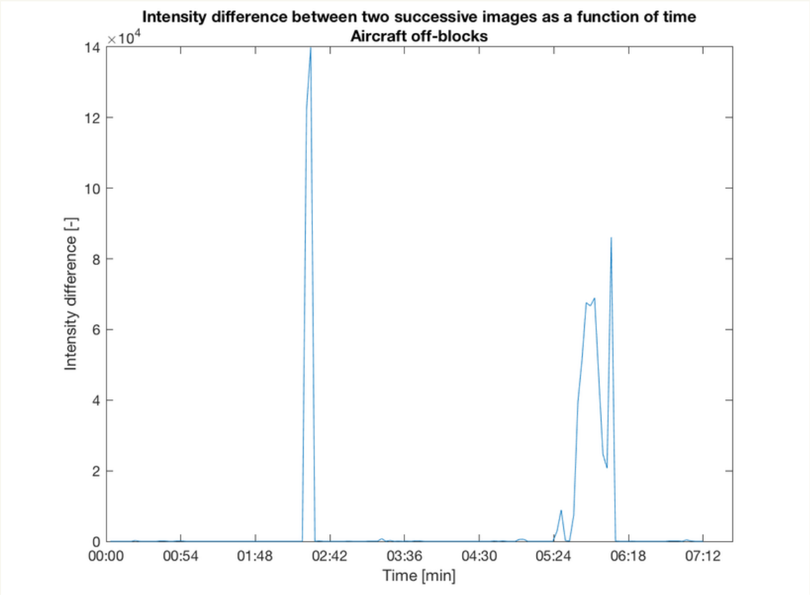
- Diff Peak : 10^5





Arrival
Ia = 13.2 × 10^4





Departure
Id = 7.98 × 10^4

Image Processing

APU shutdown - flow detection

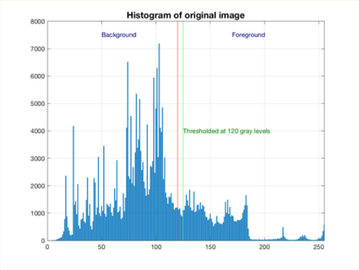
APU shutdown is detected by flow detection.

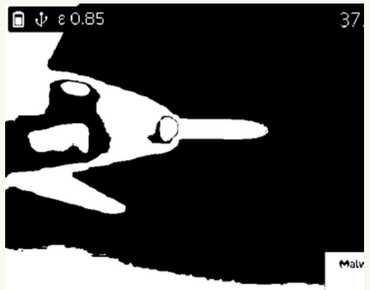
A fully operating APU produces a visible heat flux.

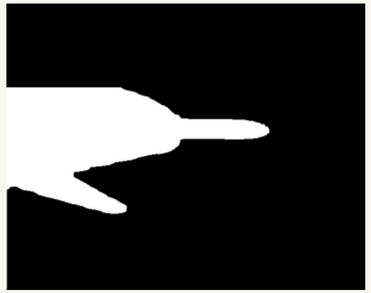
The absence of heat flux is characteristic of an APU shutdown

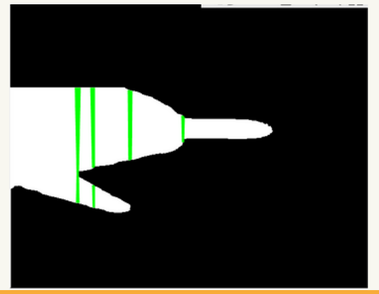
Image Processing

APU shutdown - flow detection









Step 1: Recovery of the grey-scaled images.

Step 2: Setting of appropriate thresholds.

Step 3: Transformation in a binary image.

Step 4: Clean mask by blob selection, smoothing & closing operation to remove noise.

Step 5: Detection of bottleneck with hough lines and turbine location.

Step 6: Separation of area of interest.

Image Processing

APU shutdown - flow detection

Once the horizontal blob is not detected, the engine is displayed.

This is meaning that the APU was shut down.

Image Processing

APU shutdown - limitation

Limitation on rotation

The angle between the camera and the heat flux does not allow to always have an horizontal flux for the analysis.
In this case, the hough lines cannot be correctly implemented.
For now, the method implies someone to input the rotation parameters.

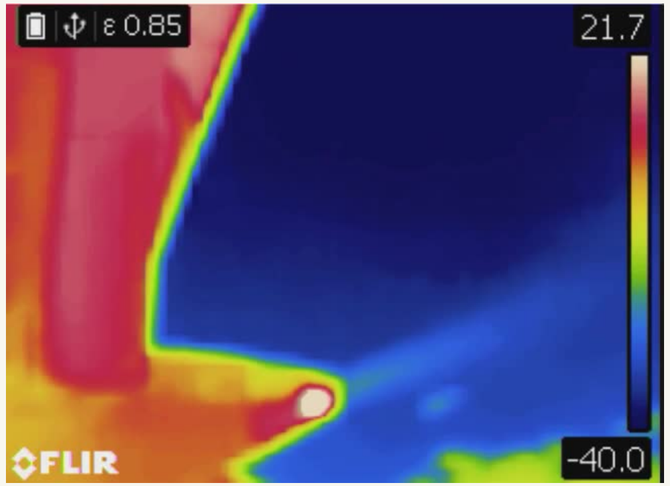
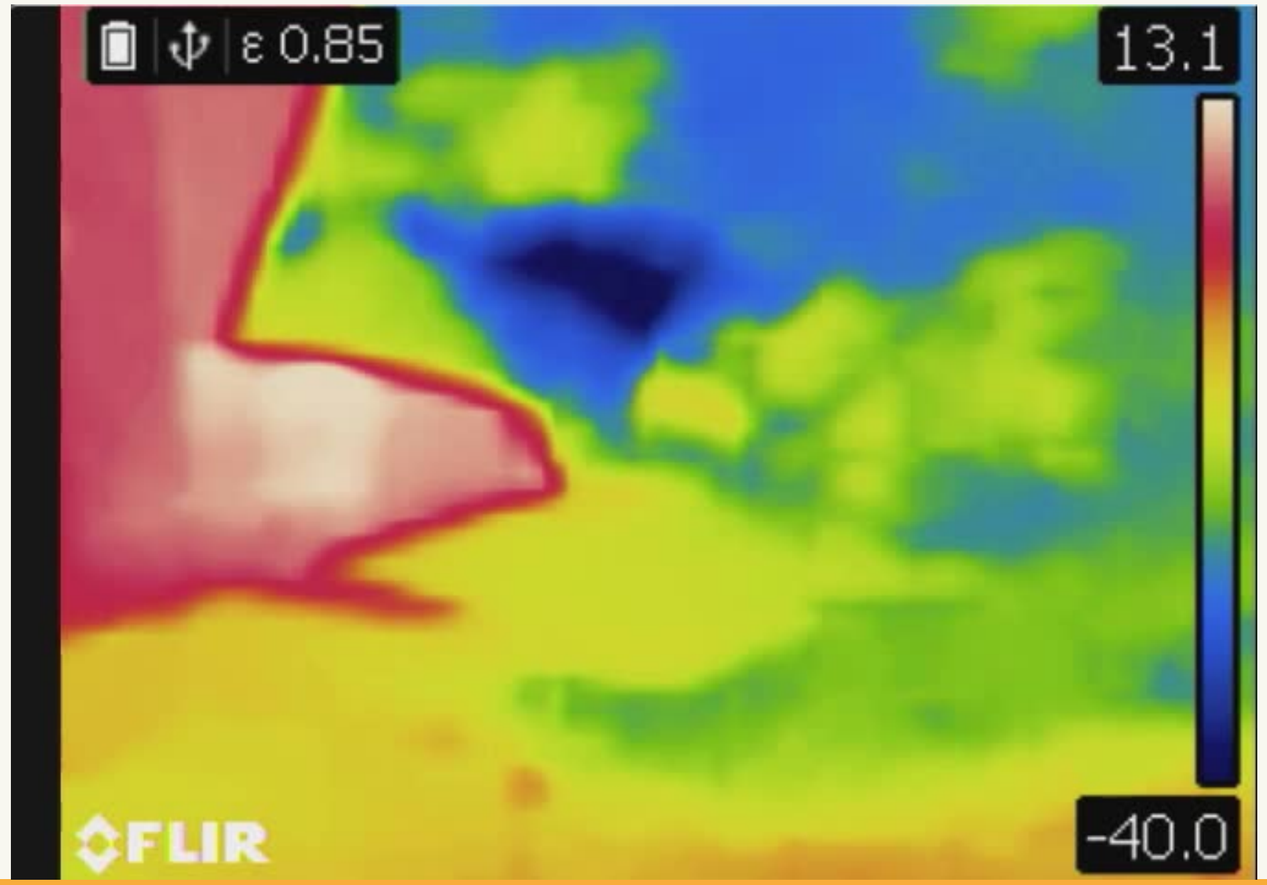


Image Processing

APU startup - turbine detection



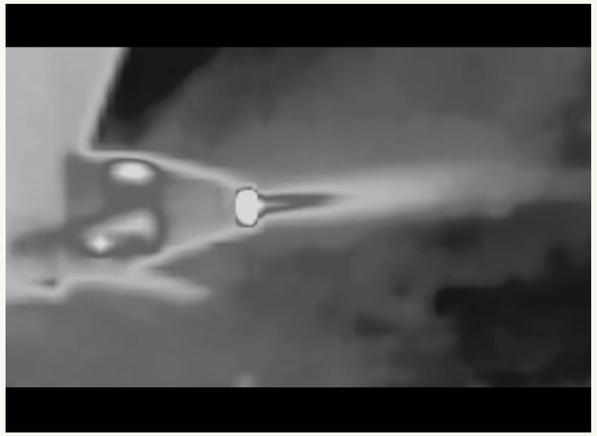
Problem: Flow not constant.

Solution: detection of the turbine, not the flow.

Three white spots representative of a running APU appear on the image.

Image Processing

APU startup - turbine detection



Step 1: Recovery of the grey-scaled images .

Step 2: Smoothing of the image.

Step 3: Transformation in a binary image thanks threshold

Image Processing

APU startup - Step 4: Detection of hotspots.

Detected hotspots can be 2 or 3.

Parameters :
- time
- blob area
- triangular shape

Automation

Three cases have to be considered.

- Arrival - Departure
- APU start-up - Departure
- Arrival - APU shutdown

Arrival and APU start-up detections are considered as starting points.
Departure and APU shutdown detections are considered as ending points.

The running APU duration can be calculated in seconds as the time interval between the detections of a starting and an ending point.

Results

	% of accurate detection	mean of APU-ON duration calculated	mean of APU-ON duration measured on-site
Aircraft Arrival	100%	7min	7min
APU shutdown	100%		
APU startup	75%	7min	11min
Aircraft Departure	100%		

Limitations

Specific:

- Too low camera resolution to record in a single set.
- Method based on specific element.
- Problem with optimal data acquisition setting.
- Not enough observations.

General:

- 2 minutes delay between APU start up and the visible heat flux
- Heterogeneous background impact the heat flux detection.
- Limited site for camera position due to traffic on tarmac.
- Questionable quality of thermography on gaseous flux.

For further APU monitoring

A camera with a thermal resolution of 640X480 pixels

- This would allow to record movement and APU startup/shutdown from a fixed point and in the same video.

A pre-analysis of the field to detect which stands are favorable for APU detection and where to place the camera

- Distance up to 20 meters and observation from the left of the aircraft.
- The height of the camera between 1 and 3 meters from the ground.

A sound-based method to reinforce the accuracy of APU start detection.

- Also necessites a an audio analysis program to filter out interfering noises.

Thank you for your attention!