ALGORITHM FOR DETECTING AIRBORNE OBJECTS WITH A THERMAL INFRARED CAMERA TO ENSURE A SAFE OPERATION OF LASER-OPTICAL GROUND STATIONS

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DLR

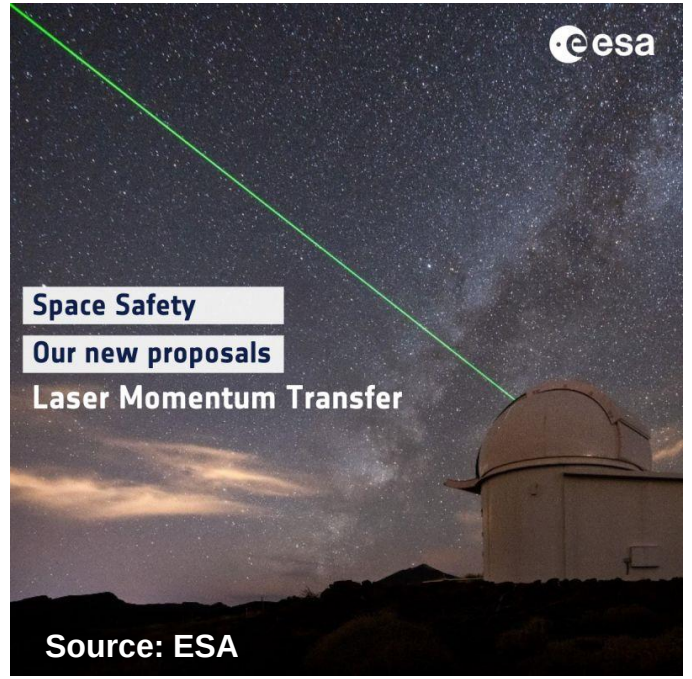
ALGORITHM FOR DETECTING AIRBORNE OBJECTS WITH A THERMAL INFRARED CAMERA TO ENSURE A SAFE OPERATION OF LASER-OPTICAL GROUND STATIONS

DLR / Paul Wagner

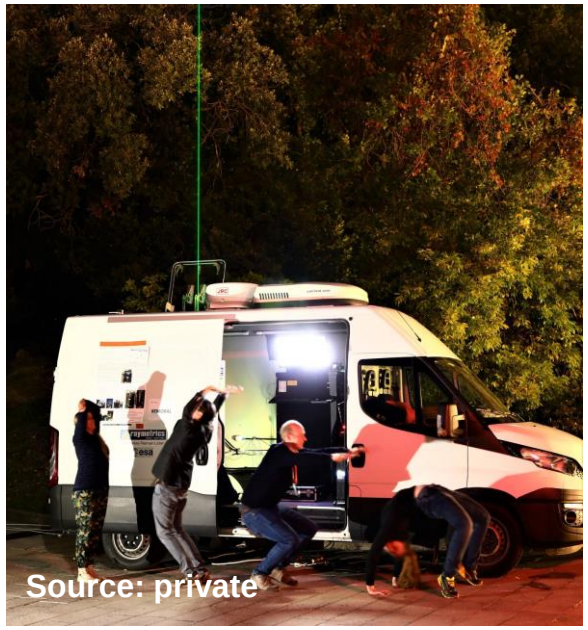
Lasers in public airspace

Satellite/space debris laser ranging

Laser communication



Laser momentum transfer

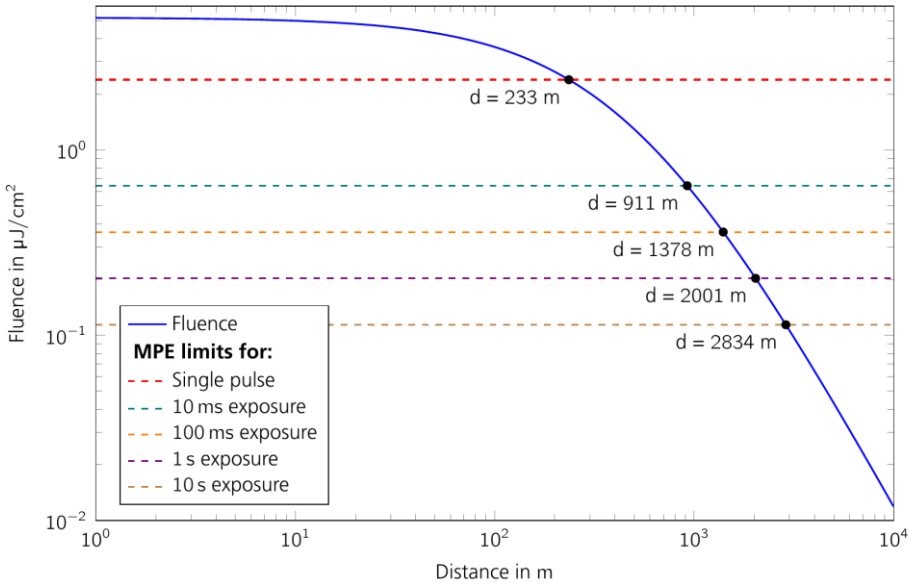


(Atmospheric) LIDAR

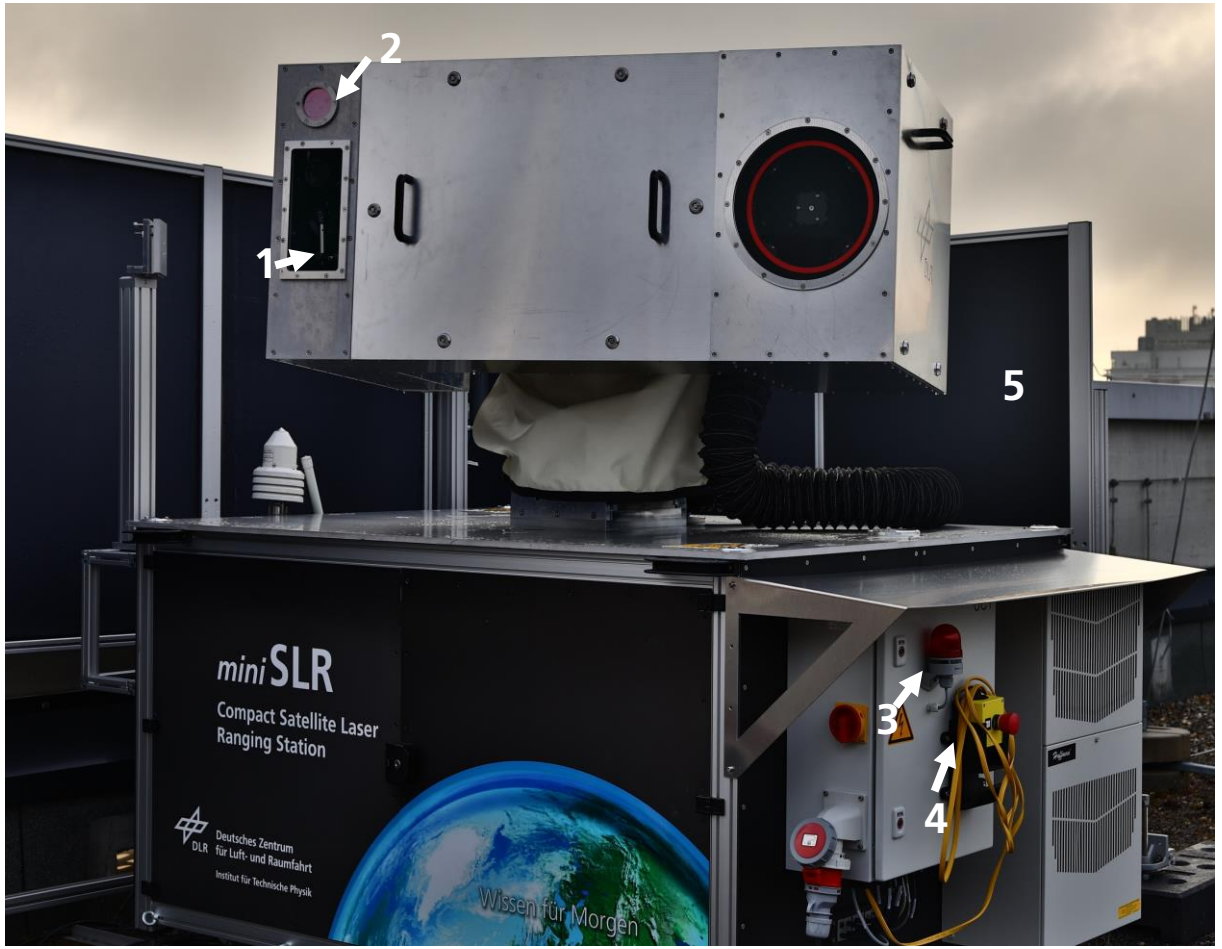
For fun/advertisement…

Laser safety at miniSLR®

Laser parameters miniSLR®	
Wavelength	1064 nm
Pulse energy	85 µJ
Pulse duration	500 ps
Pulse repetition rate	50 kHz
Beam divergence	50 µrad
Beam diameter (transmitter exit)	5 cm



→ Laser safety system needed

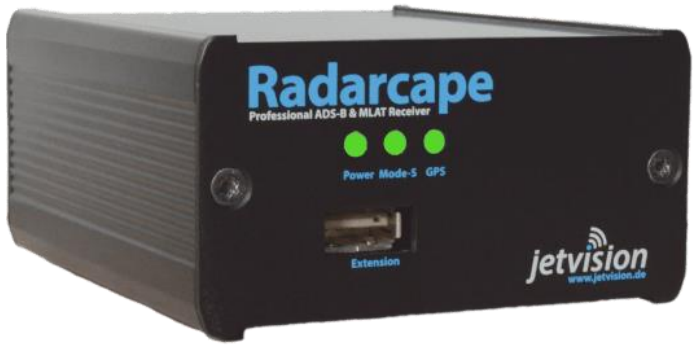


1 = laser transmitter window, 2 = Germanium window of the thermal infrared camera, 3 = laser warning lamp, 4 = emergency stop button (4), and physical laser safety barriers (5).

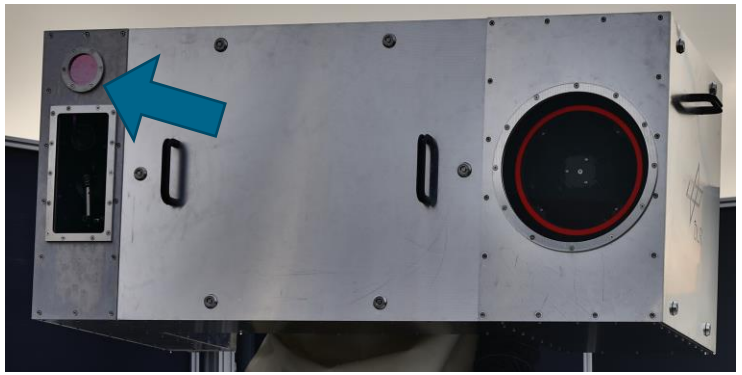
Laser safety at miniSLR®

Radar (as data stream from air traffic control)	ADS-B receiver	Thermal infrared camera

Quelle: https://www.dfs.de/homepage/de/flugsicherung/betrieb/ortung/



Quelle: https://radarcape.com/de/ads-b-empfaenger-mlat-radarcape/

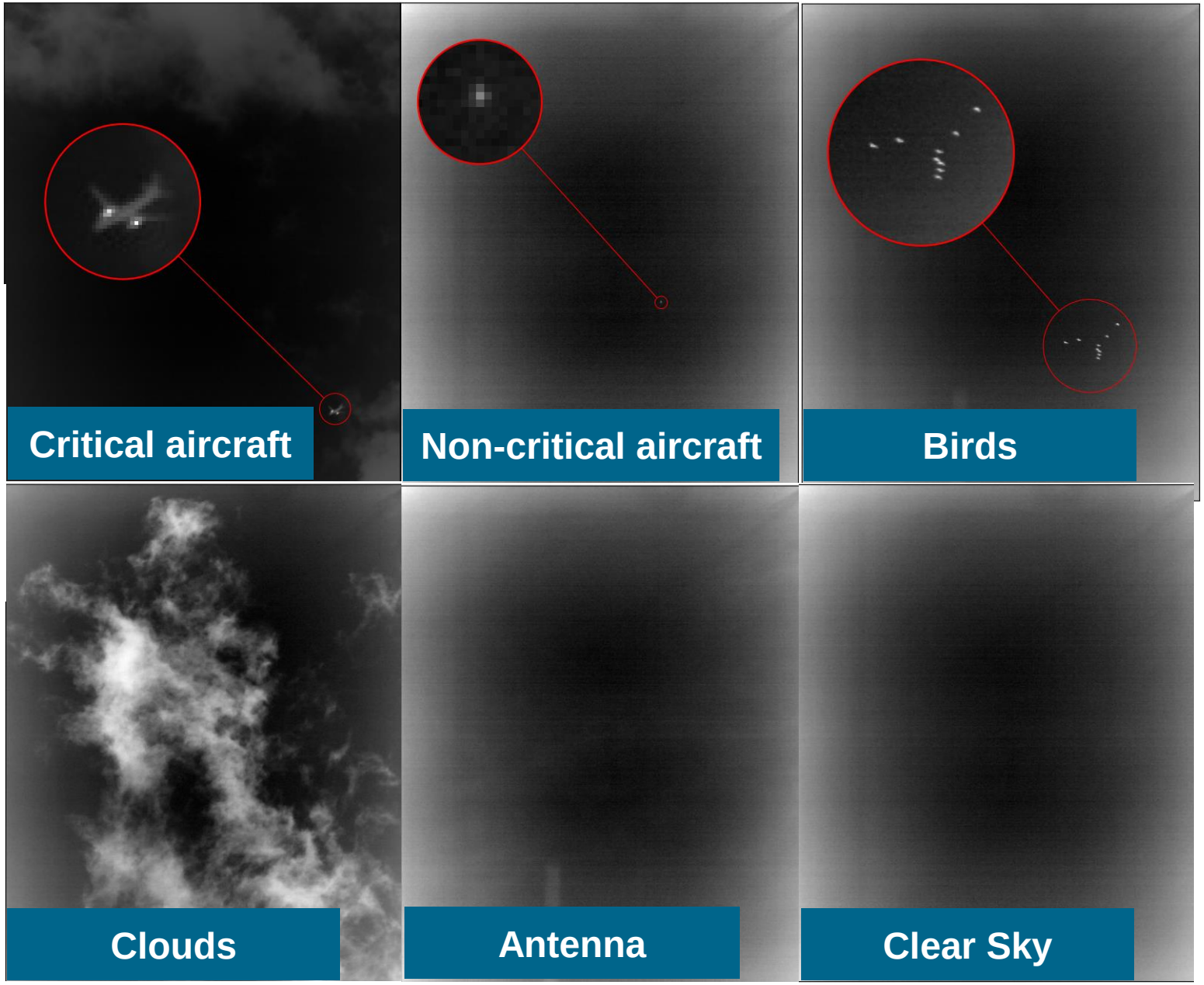


Key task: Reliable detection of aircraft from thermal infrared images.

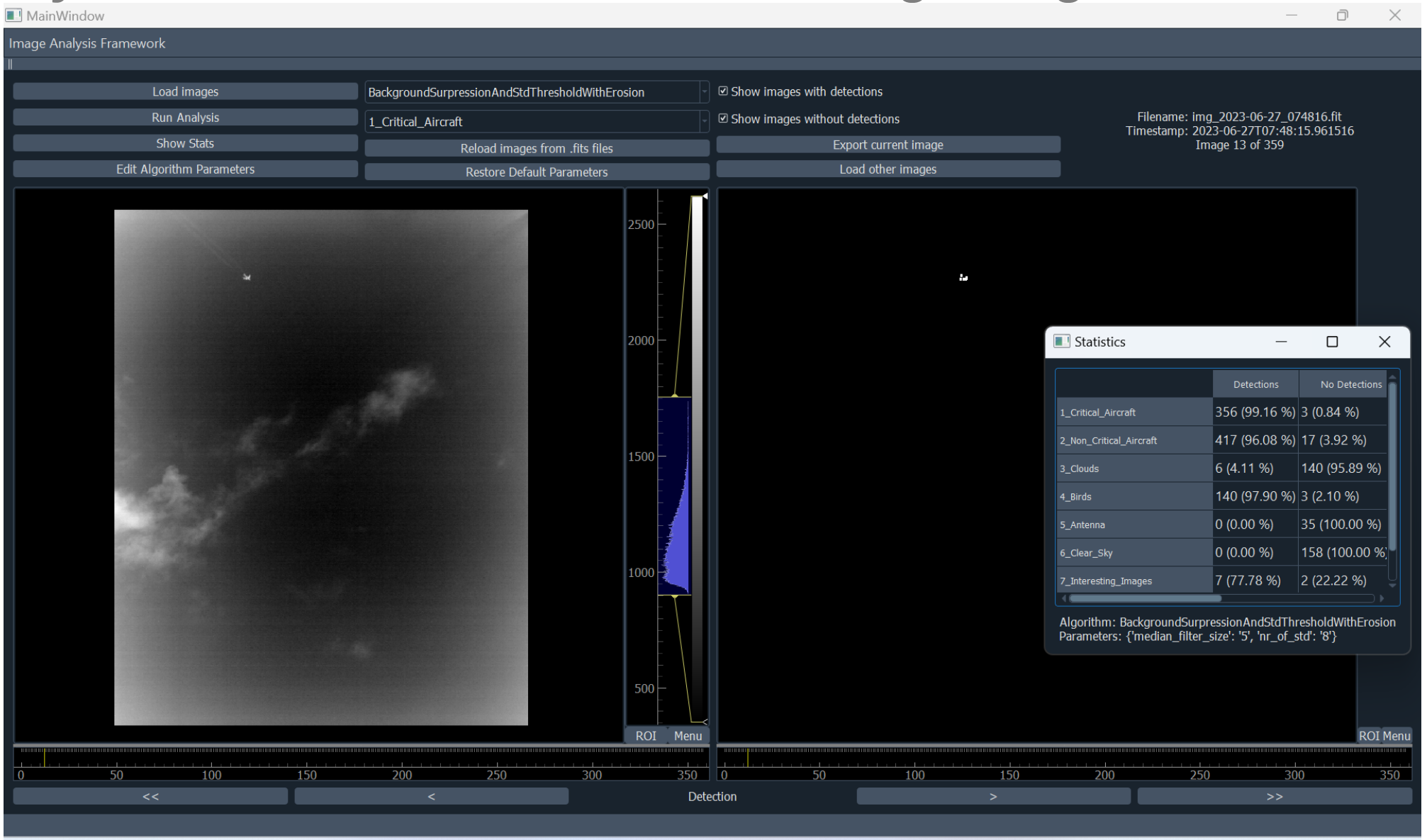
Dataset

Table 3. Number of Images and Targeted Classification of Different Categories in the Generated Dataset

Category	Number of Images	Target Classification
Critical aircraft	359	Unsafe
Non-critical aircraft	434	Unsafe
Clouds	146	Safe
Birds	143	Unsafe
Antenna	35	Safe
Clear sky	158	Safe
Interesting images	9	Unsafe
Total	1284	–



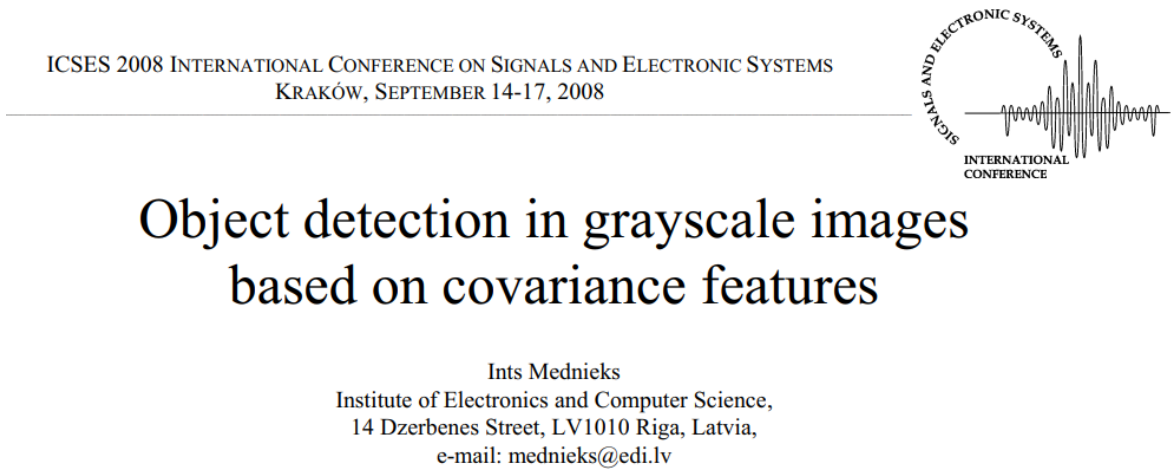
Python software with GUI for testing of algorithms



Simple comparison of different algorithms and parameters…

Results

- Different algorithms tested:
  - Laplacian filter with edge detection
  - Canny edge detection
  - Background subtraction with median filtered image (→ best algorithm)



ICSES 2008 INTERNATIONAL CONFERENCE ON SIGNALS AND ELECTRONIC SYSTEMS
KRAKÓW, SEPTEMBER 14-17, 2008

SIGNALS AND ELECTRONIC SYSTEMS INTERNATIONAL CONFERENCE

Object detection in grayscale images based on covariance features

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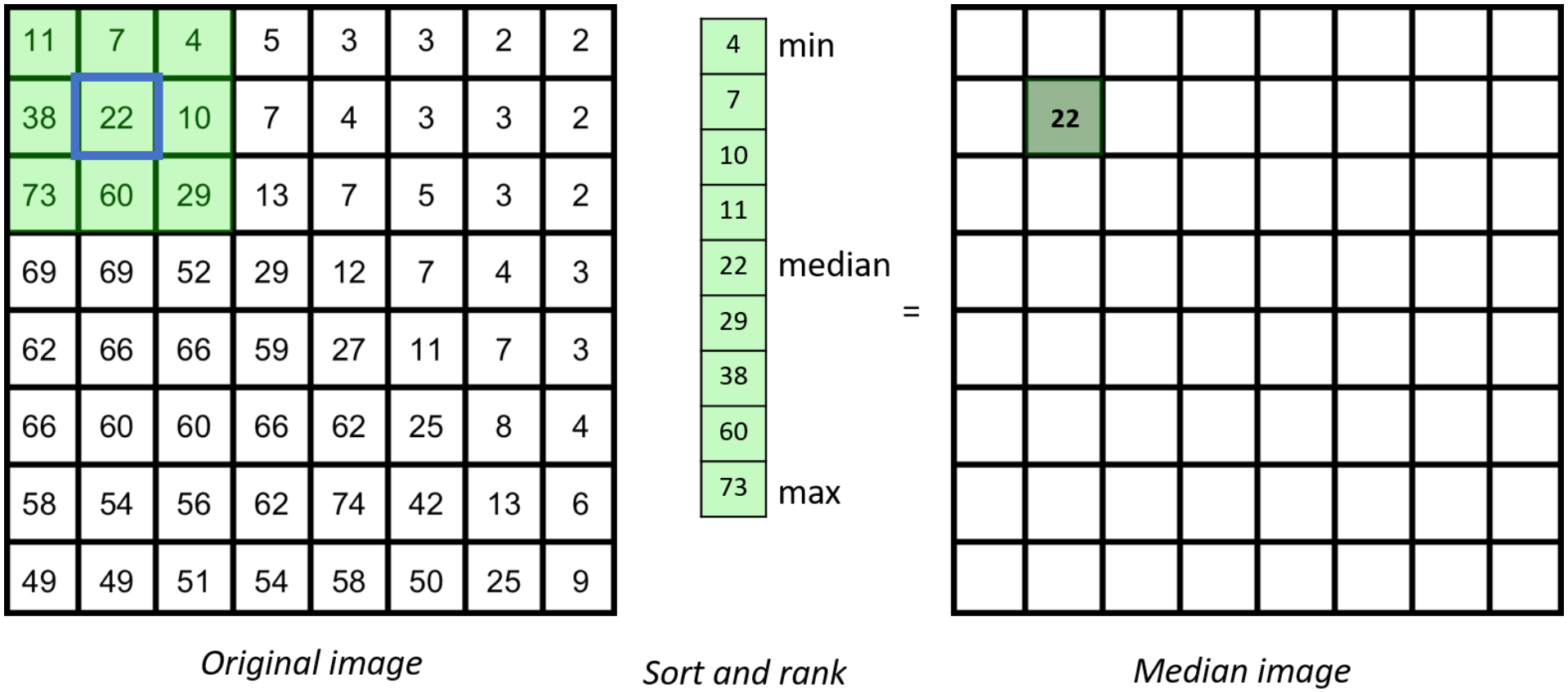
Idea came from an article dealing with the detection of artificial objects in processed food via X-ray imaging.

Quelle: https://doi.org/10.1109/ICSES.2008.4673393

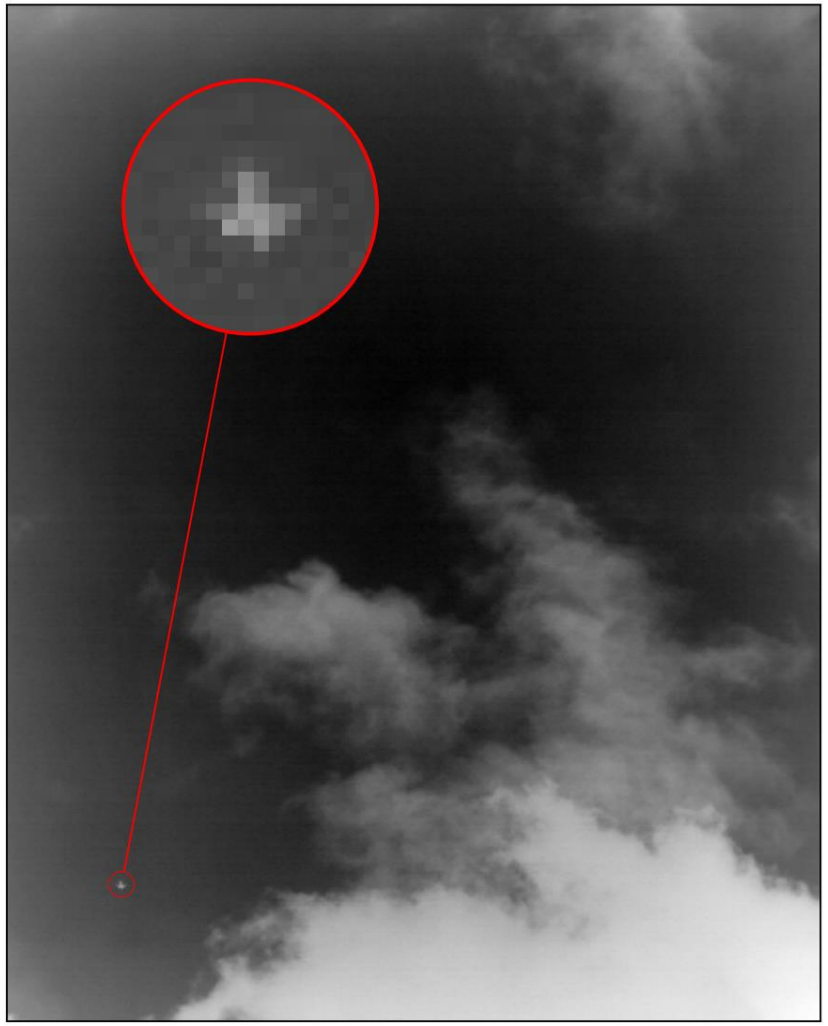
What is a median filter?



Quelle: https://neubias.github.io/training-resources/median_filter/index.html

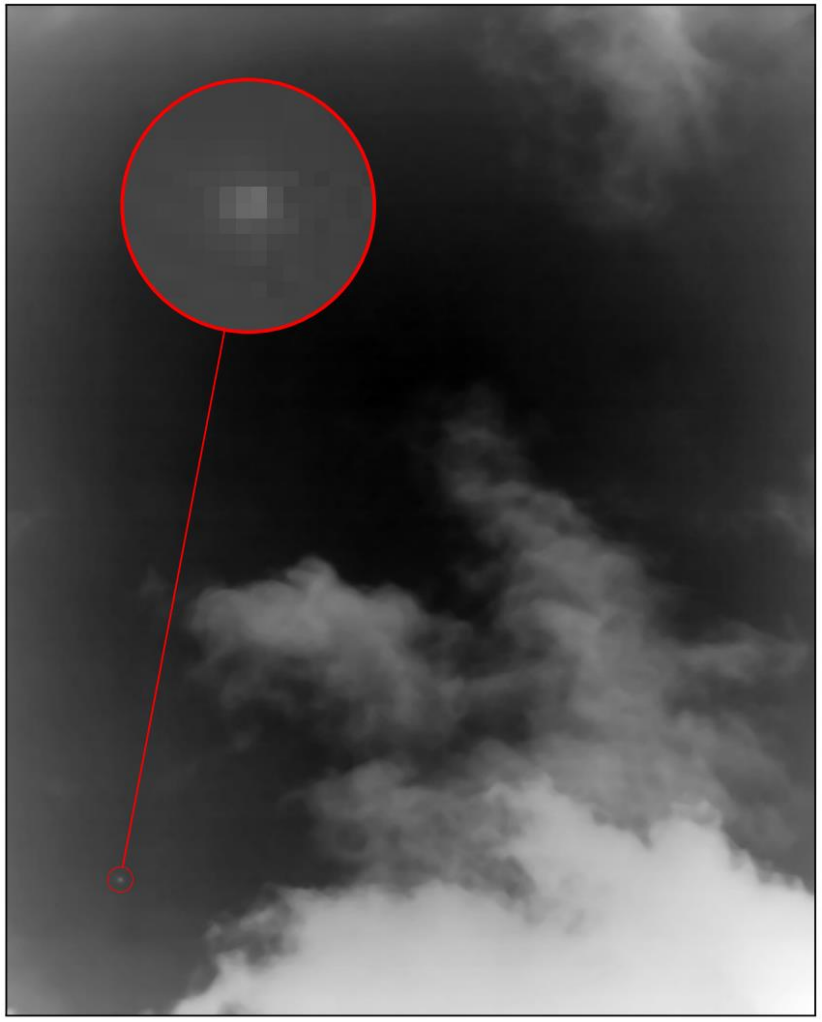
Median filter for noise reduction

Original image



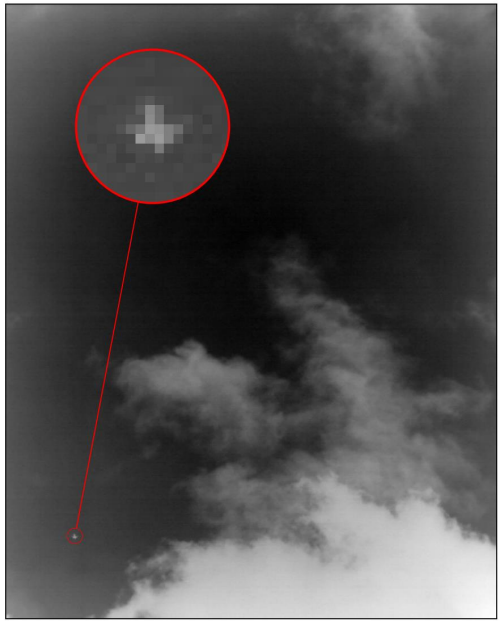
Median-Filter

Image after 5x5 median filtering

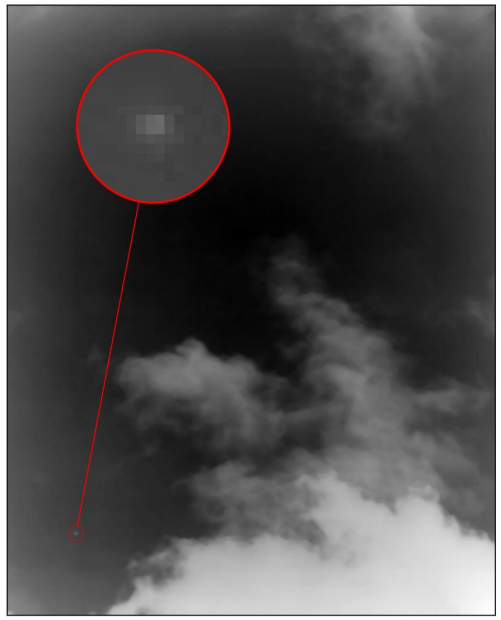


Median filter for background subtraction

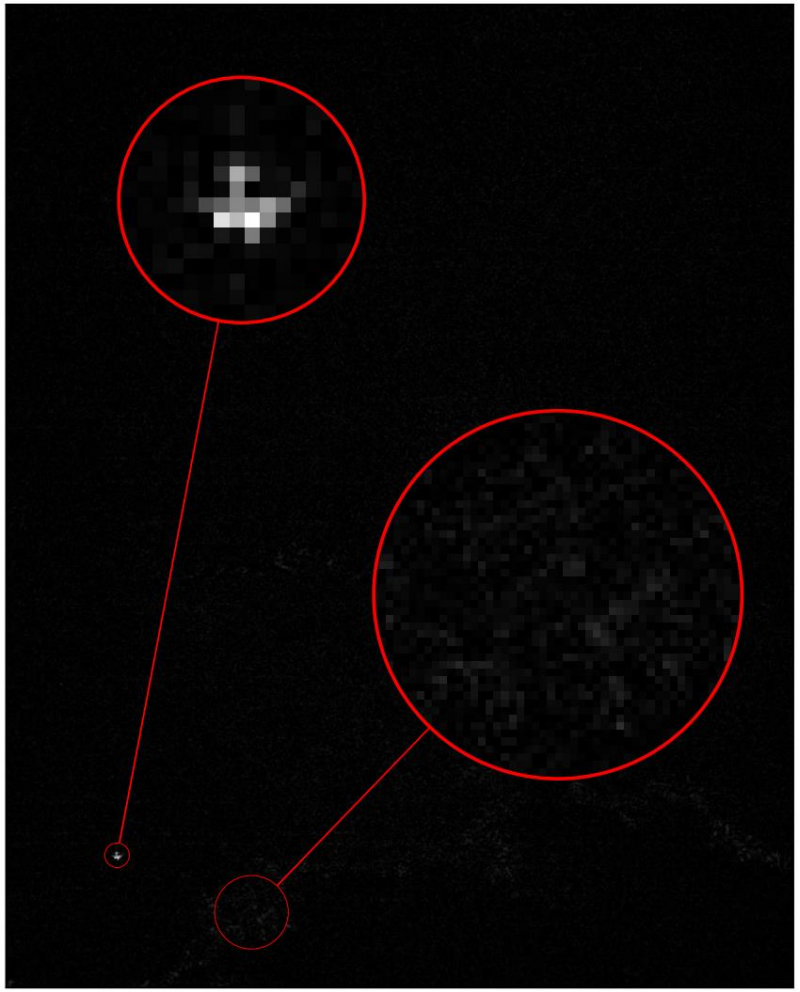
Original image



Background

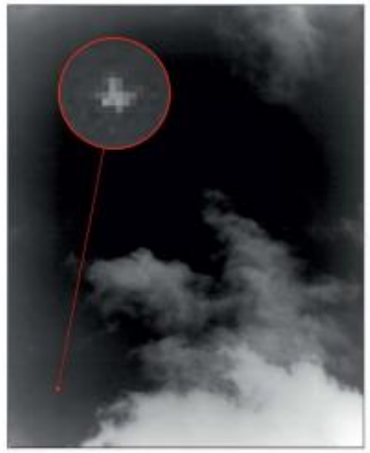


Aircraft (& noise)



Proposed algorithm

(A) Original image

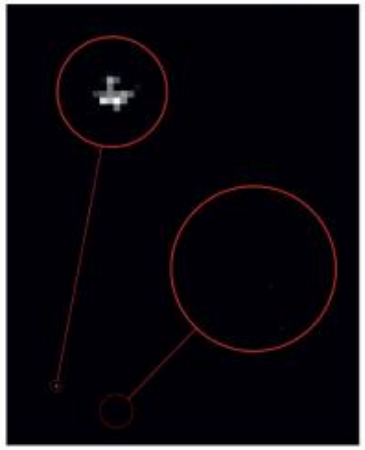


Step 1: Median Filtering

(B) Median filtered image

Step 2: Image Substraction

(C) Subtracted image



Step 3: Thresholding

$$T = \bar{x} + k\sigma$$

(D) Binarized image

Step 4: Hit or miss transform

Binarized image without single pixel detections

-1	-1	-1
-1	1	-1
-1	-1	-1

Step 5: Classification

'Safe' or 'unsafe': Unsafe if any positive pixel in image

Optimization of parameters

Threshold optimization:

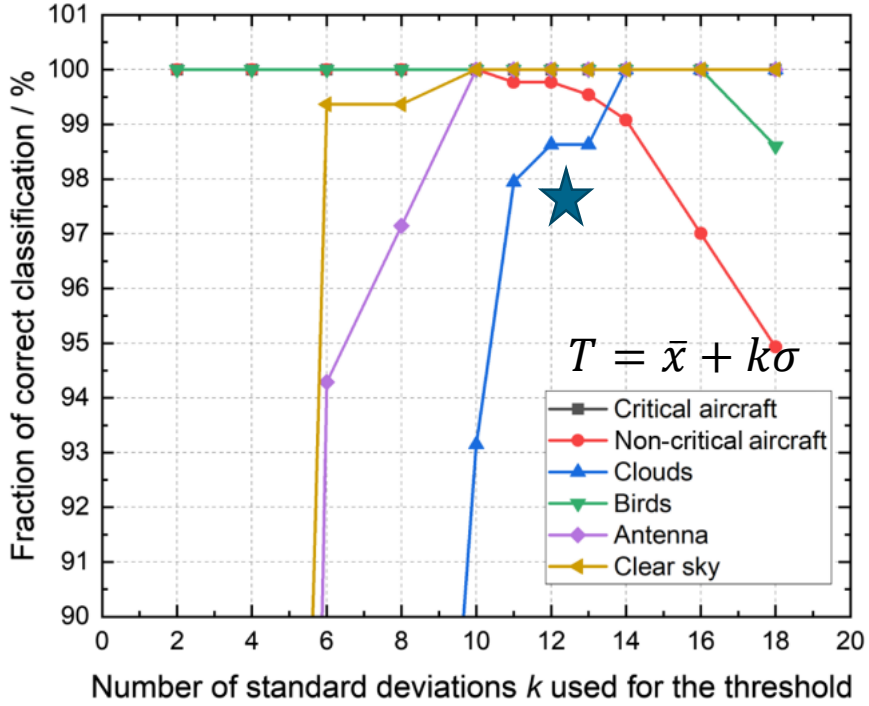


Fig. 4. Fraction of correct classifications as a function ("safe" or "unsafe") of the optimized parameter k for the different image categories.

Classification with optimized threshold:

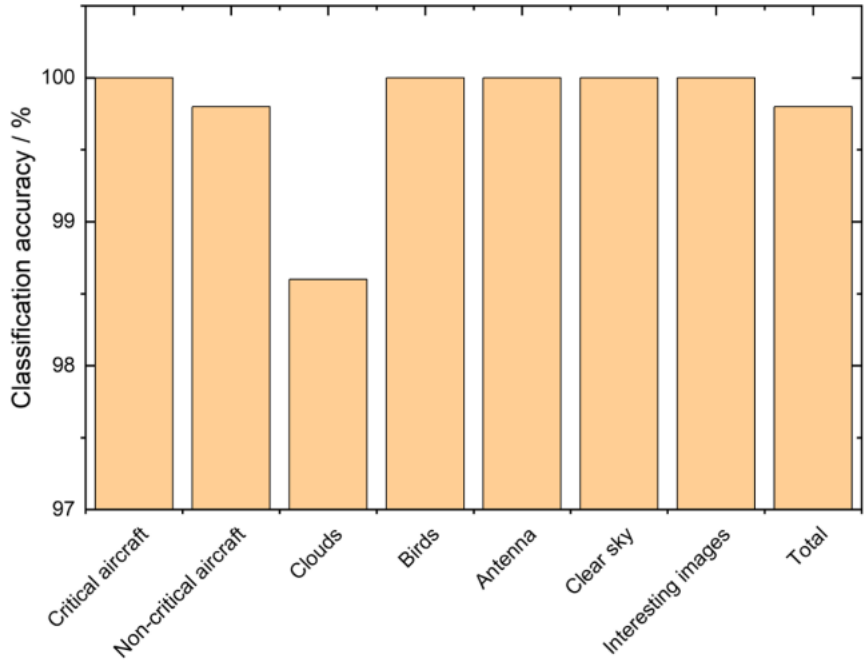
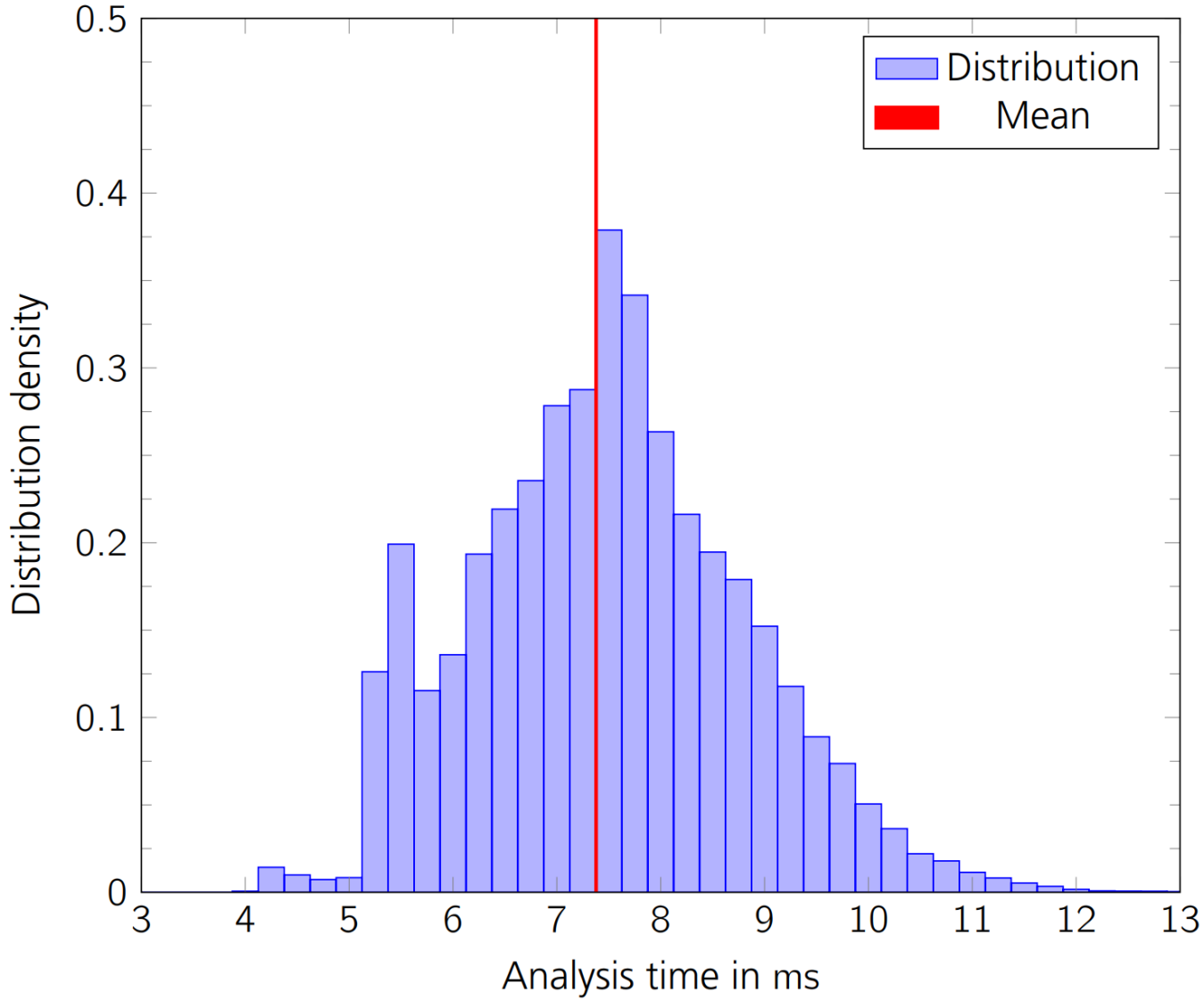


Fig. 5. Results of classification accuracy (safe/unsafe) for the proposed image processing algorithm with $k = 12$.

Speed

- Image analysis takes ~7ms on a standard PC



Limitations of this work

- No helicopters, hot air balloons, gliders in dataset
  $\rightarrow$ detection is likely but untested
- No detection of objects „behind“ clouds
- Detection only works in front of a sky background
- Algorithm only tested at one place (Stuttgart/Germany)

Further reading

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applied optics

Algorithm for detecting airborne objects with a thermal infrared camera to ensure a safe operation of laser-optical ground stations

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- Article contains source code (Python) and link to repository with raw images (classified dataset)
- Anyone is free to use the algorithm, feedback or suggestions are appreciated