

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

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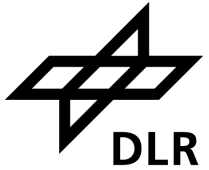
Meeting of the ILRS Networks and Engineering Standing Committee (NESC), January 23rd, 2025





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

Lasers in public airspace



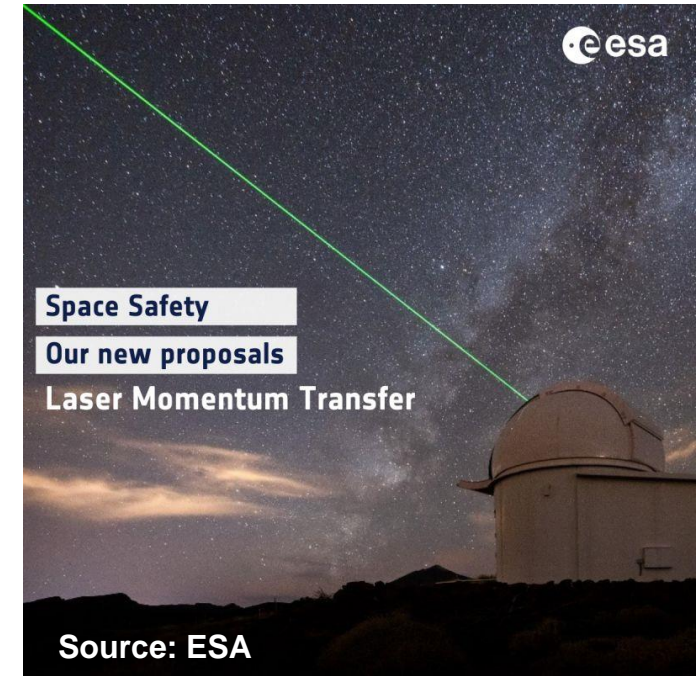
Source: DLR

Satellite/space debris laser ranging



Source: DLR

Laser communication



Space Safety

Our new proposals

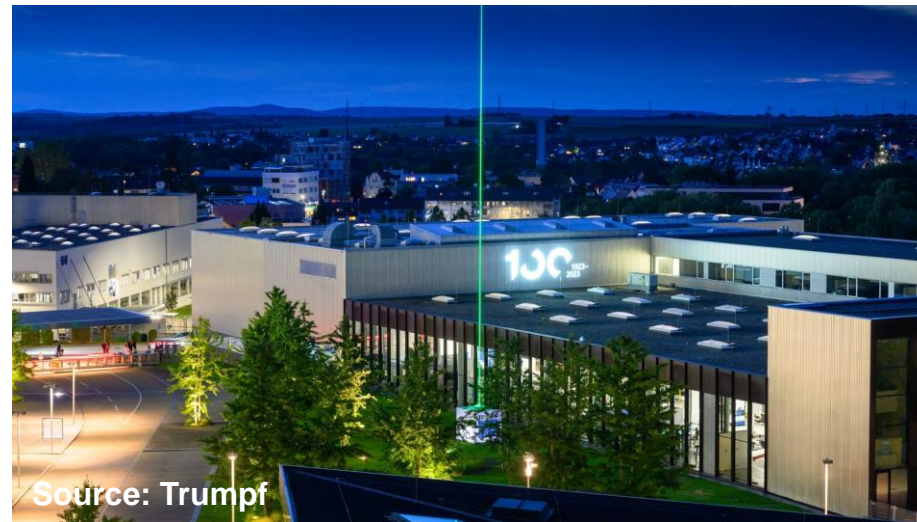
Laser Momentum Transfer

Source: ESA

Laser momentum transfer



Source: private



Source: Trumpf

For fun/advertisement...

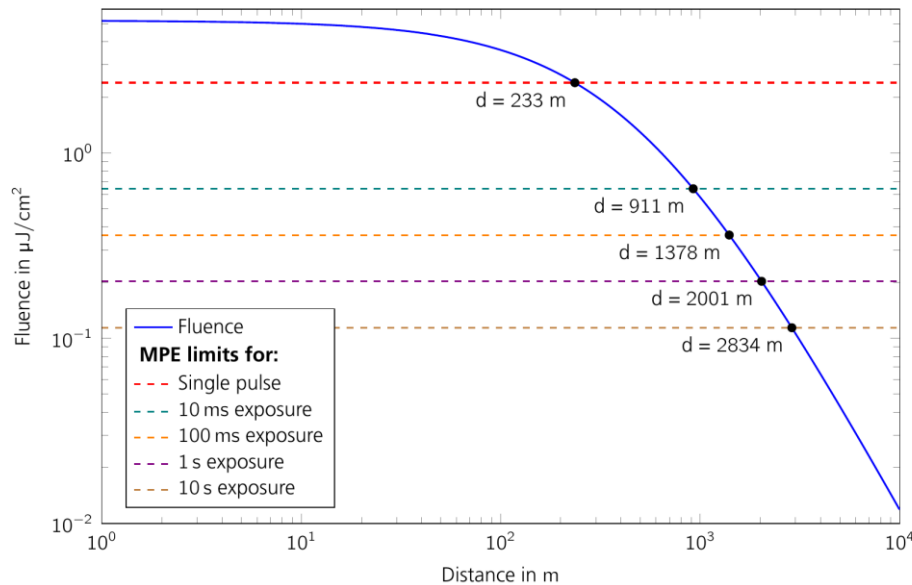
(Atmospheric) LIDAR

Nils Bartels, January 23rd, 2025

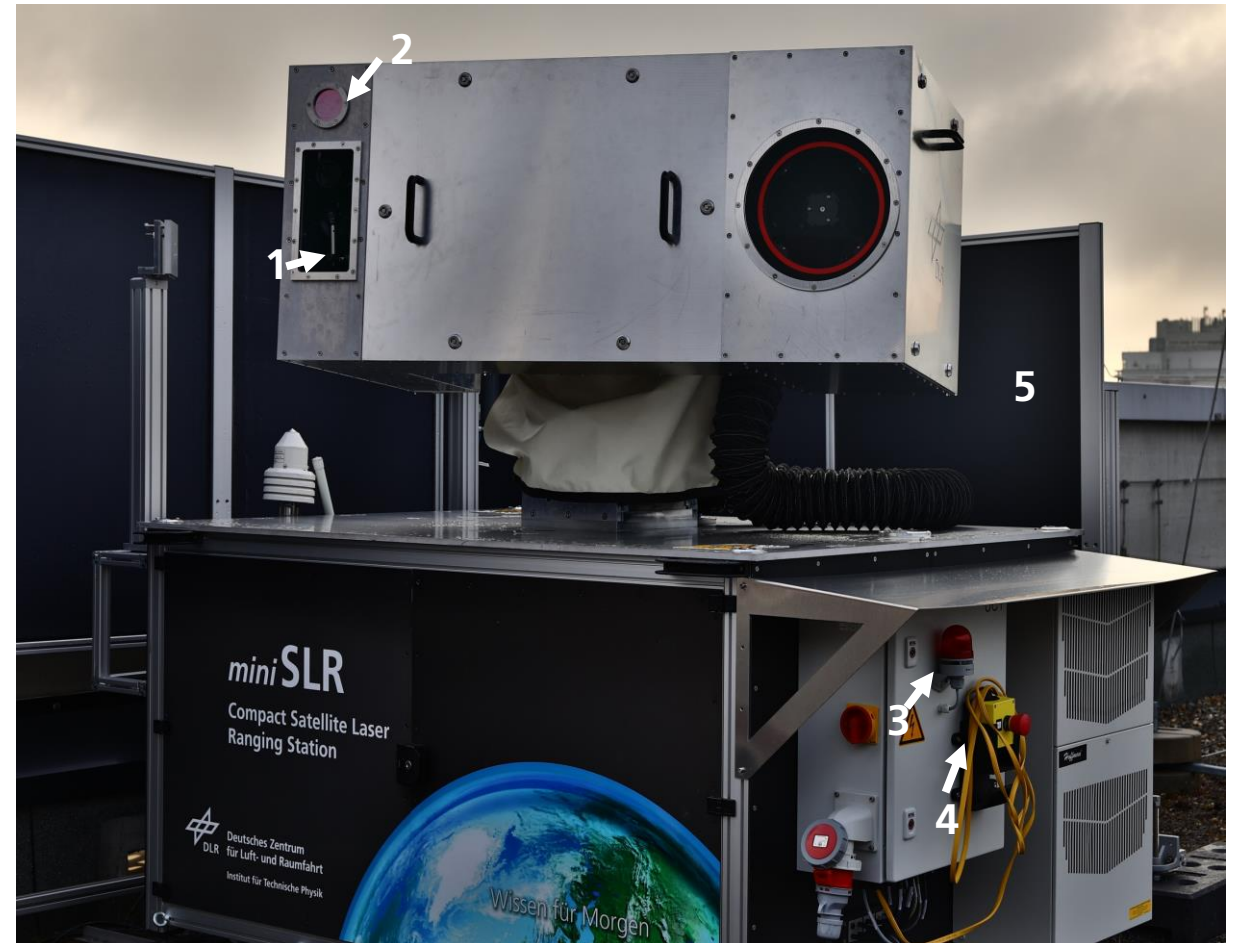
Laser safety at miniSLR[®]

Laser parameters miniSLR[®]

Wavelength	1064 nm
Pulse energy	85 μ J
Pulse duration	500 ps
Pulse repetition rate	50 kHz
Beam divergence	50 μ rad
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).

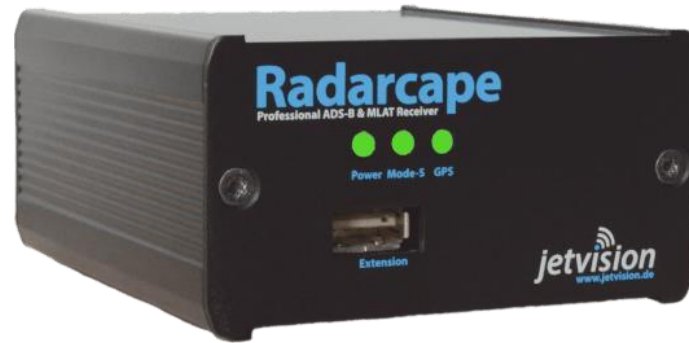
Laser safety at miniSLR[®]

Radar (as data stream from air traffic control)



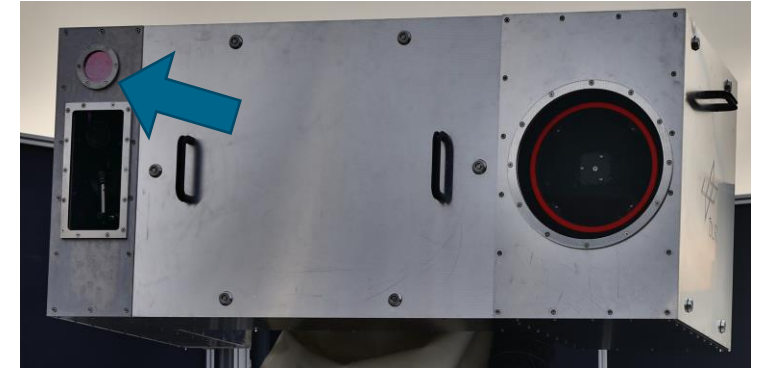
Quelle: <https://www.dfs.de/homepage/de/flugsicherung/betrieb/ortung/>

ADS-B receiver



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

Thermal infrared camera



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

Dataset

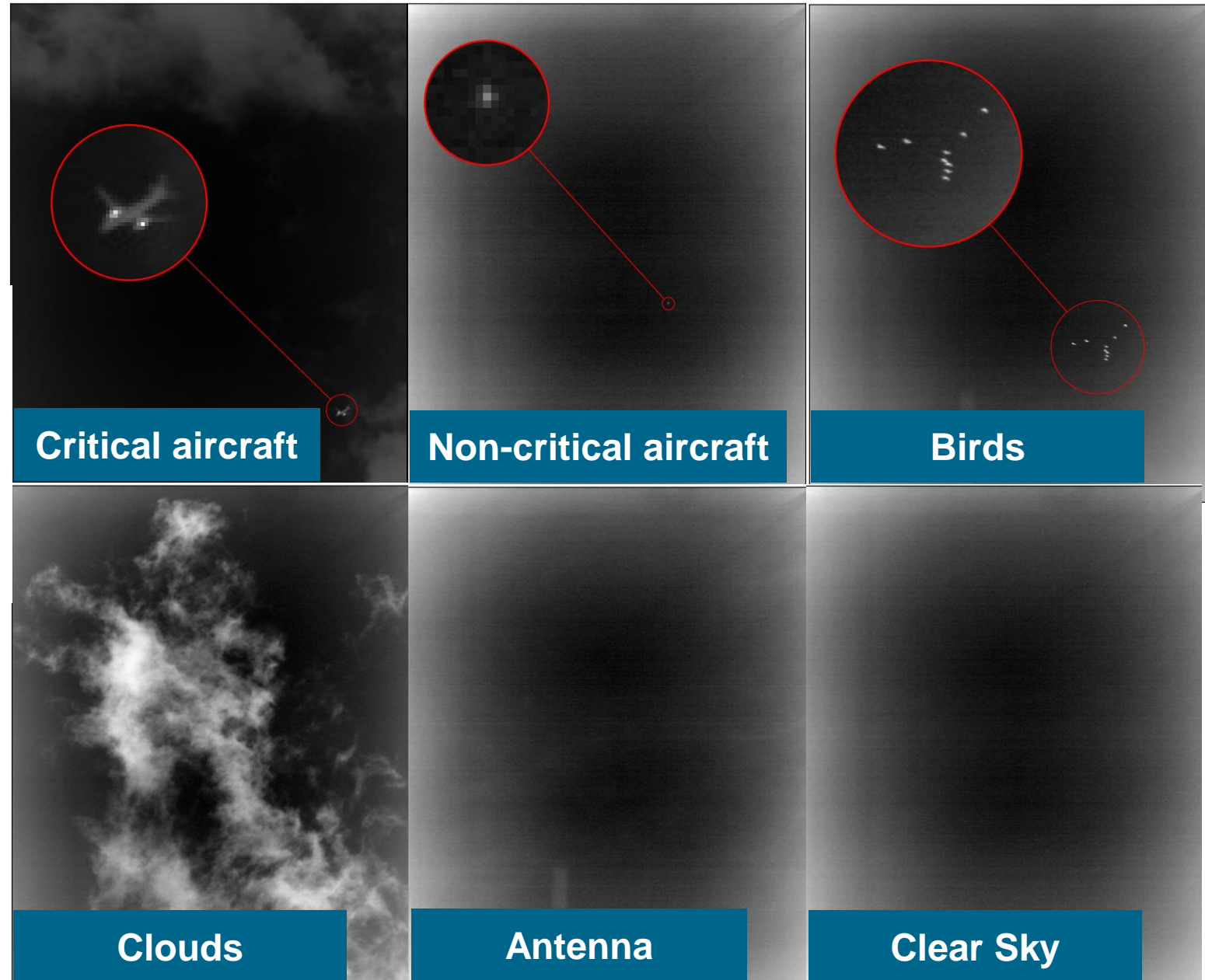


Table 3. Number of Images and Targeted Classification of Different Categories in the Generated Dataset

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



The screenshot displays the 'Image Analysis Framework' GUI. The main window includes a control panel with buttons for 'Load images', 'Run Analysis', 'Show Stats', and 'Edit Algorithm Parameters'. A dropdown menu shows 'BackgroundSupressionAndStdThresholdWithErosion' and '1_Critical_Aircraft'. Checkboxes for 'Show images with detections' and 'Show images without detections' are checked. Metadata on the right shows 'Filename: img_2023-06-27_074816.fit', 'Timestamp: 2023-06-27T07:48:15.961516', and 'Image 13 of 359'. The main area shows a grayscale image of a cloudy sky with a small aircraft. A vertical histogram on the right shows a peak at approximately 350. A 'Statistics' window is open, displaying a table of detection results.

	Detections	No Detections
1_Critical_Aircraft	356 (99.16 %)	3 (0.84 %)
2_Non_Critical_Aircraft	417 (96.08 %)	17 (3.92 %)
3_Clouds	6 (4.11 %)	140 (95.89 %)
4_Birds	140 (97.90 %)	3 (2.10 %)
5_Antenna	0 (0.00 %)	35 (100.00 %)
6_Clear_Sky	0 (0.00 %)	158 (100.00 %)
7_Interesting_Images	7 (77.78 %)	2 (22.22 %)

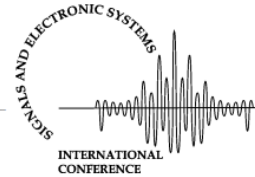
Algorithm: BackgroundSupressionAndStdThresholdWithErosion
Parameters: {'median_filter_size': '5', 'nr_of_std': '8'}

Results



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

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KRAKÓW, SEPTEMBER 14-17, 2008



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?

11	7	4	5	3	3	2	2
38	22	10	7	4	3	3	2
73	60	29	13	7	5	3	2
69	69	52	29	12	7	4	3
62	66	66	59	27	11	7	3
66	60	60	66	62	25	8	4
58	54	56	62	74	42	13	6
49	49	51	54	58	50	25	9

Original image

4	min
7	
10	
11	
22	median
29	
38	
60	
73	max

Sort and rank

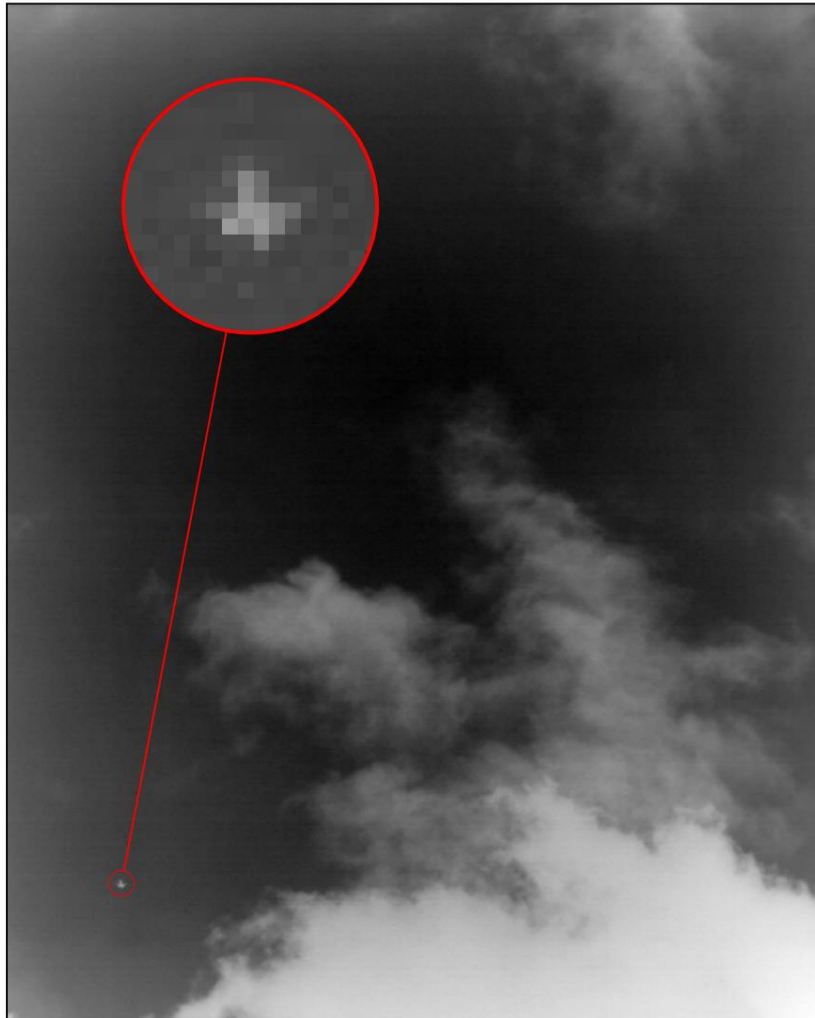
	22						

Median image

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

Median filter for noise reduction

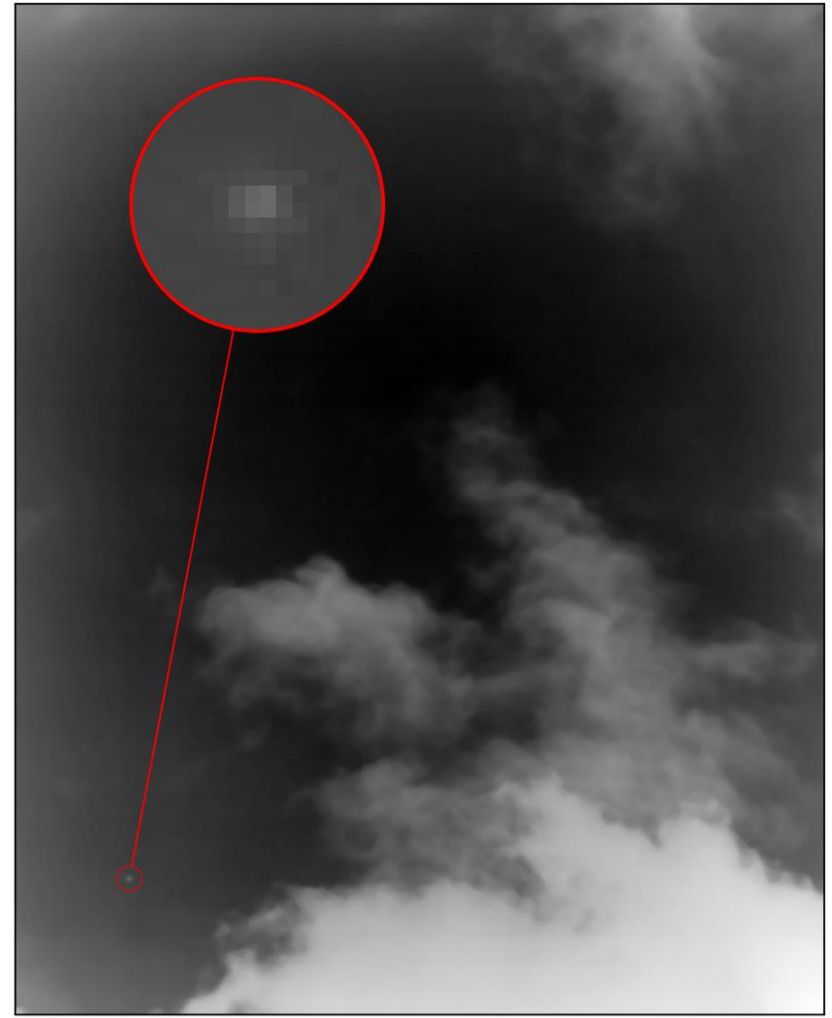
Original image



Median-Filter

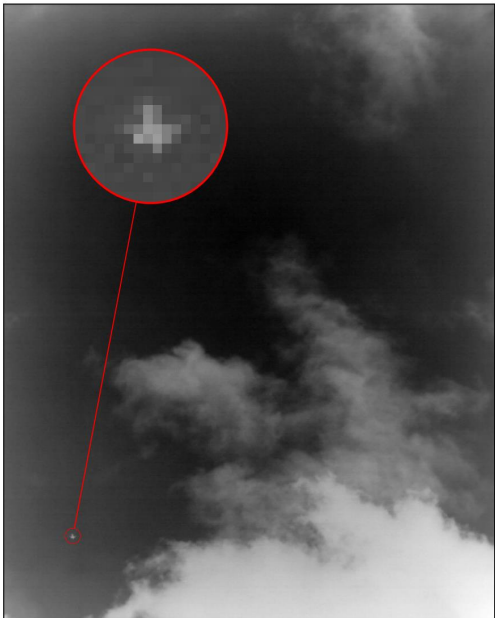


Image after 5x5 median filtering

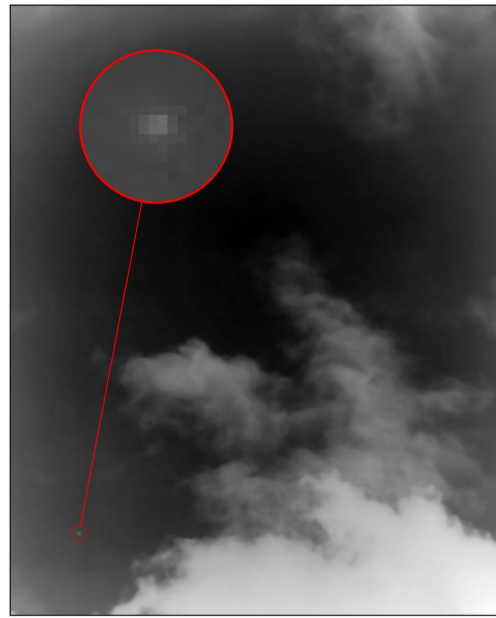


Median filter for background subtraction

Original image



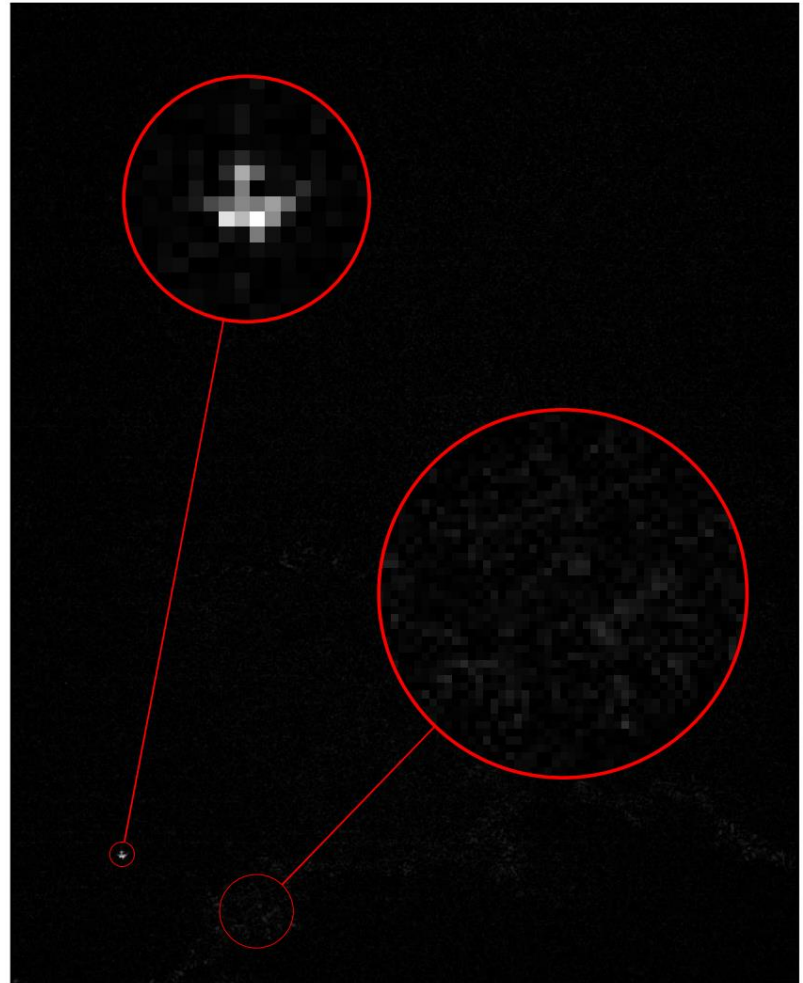
Background



-

=

Aircraft (& noise)



Proposed algorithm

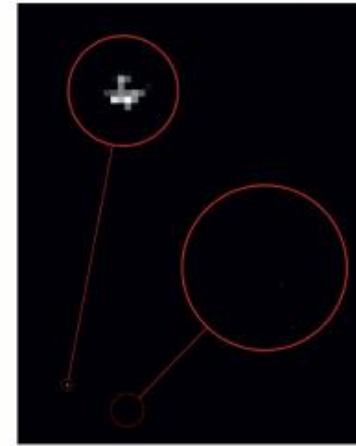
(A) Original image



(B) Median filtered image



(C) Subtracted image



Step 3: Thresholding \downarrow $T = \bar{x} + k\sigma$

(D) Binarized image



Step 5: Classification

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

Step 4:
Hit or miss
transform

Binarized image
without single pixel
detections

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



Threshold optimization:

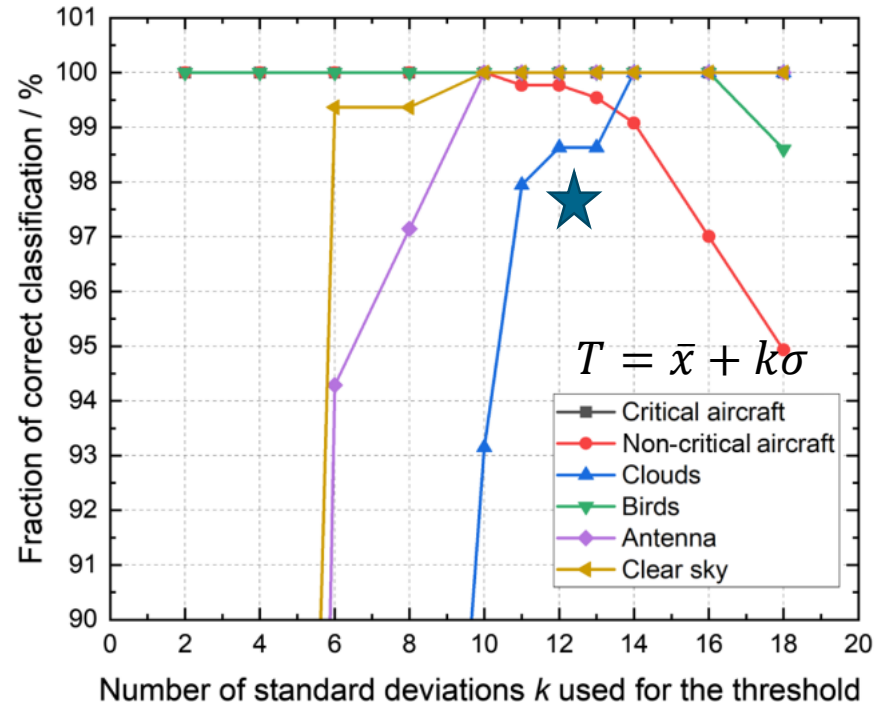


Fig. 4. Fraction of correct classifications as a function (“safe” or “unsafe”) of the optimized parameter k for the different image categories.

Classification with optimized threshold:

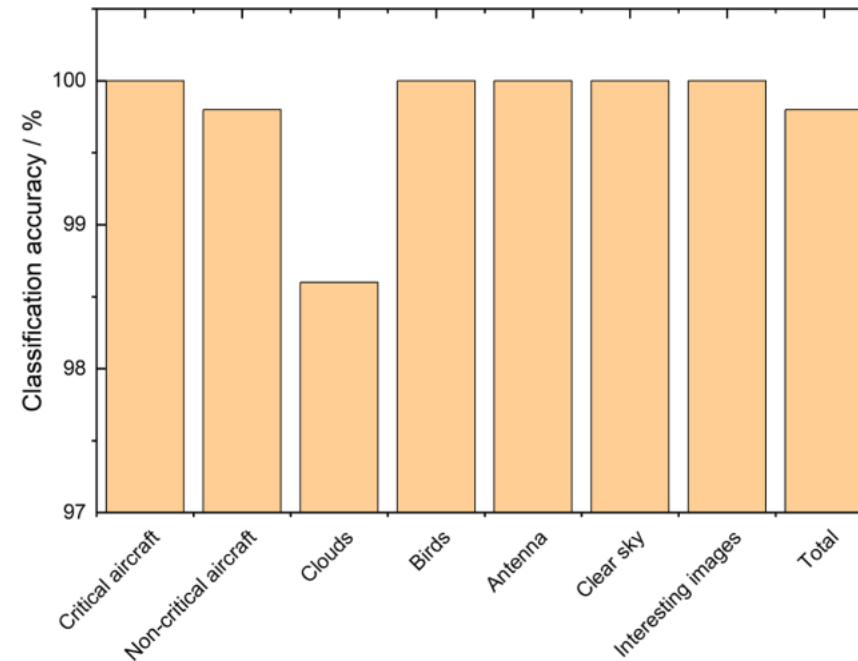
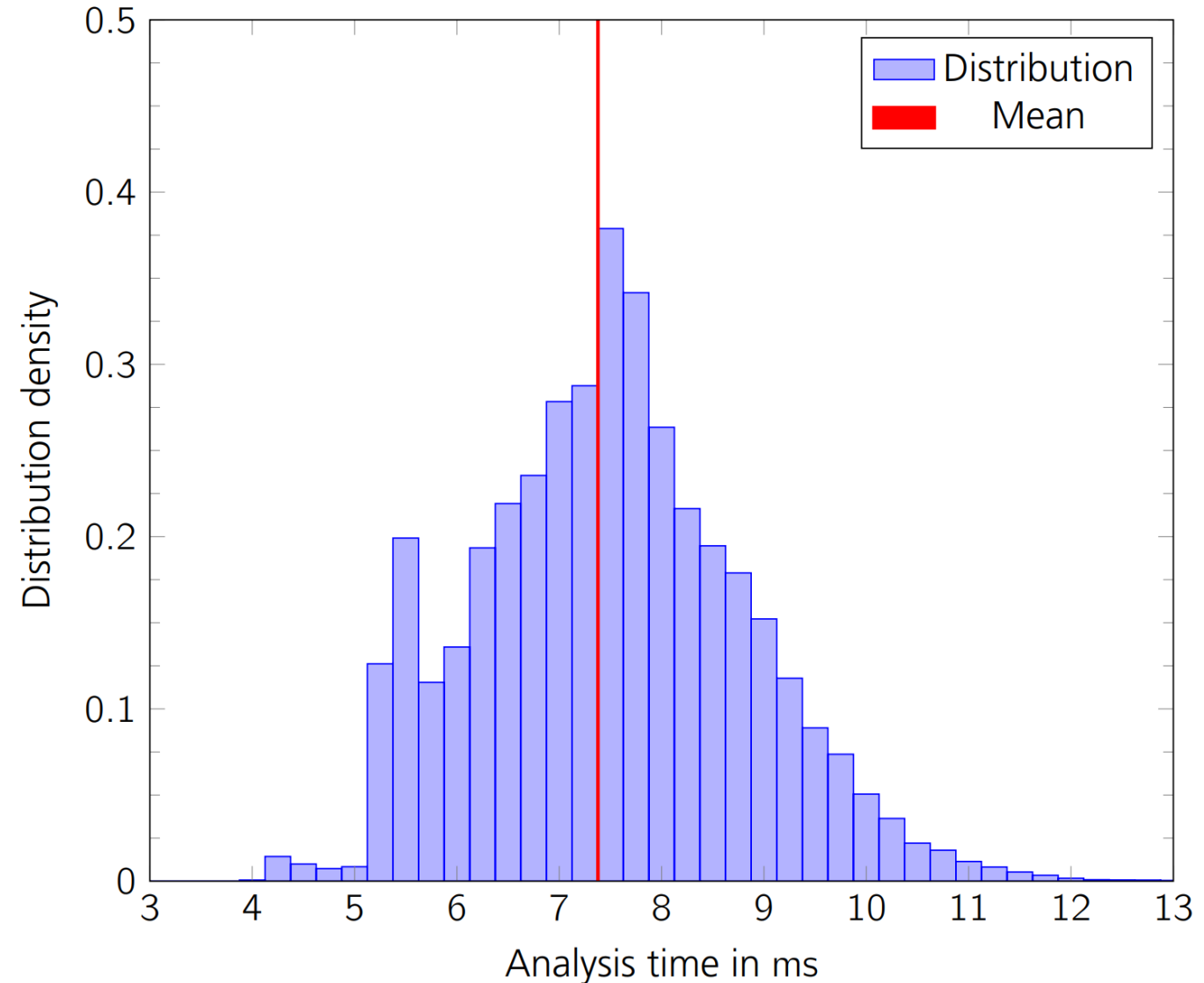


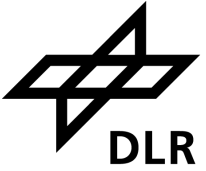
Fig. 5. Results of classification accuracy (safe/unsafe) for the proposed image processing algorithm with $k = 12$.

Speed

- Image analysis takes ~7ms on a standard PC



Limitations of this work



- No helicopters, hot air balloons, gliders in dataset
→ 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



<https://doi.org/10.1364/AO.529222>

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