Aerial Object Tracking from an Airborne Platform

Author: Andreas Nussberger
Presented by: Daniel Ambühl
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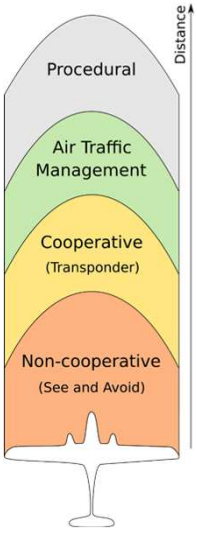
ICAS Workshop 2017, Winterthur, Switzerland

Motivation

- **Goal:** integrate «Remotely Piloted Aircraft Systems» into civil airspace
- **Challenge:** replace pilot «See & Avoid» capability by a technical system

→ **Sense & Avoid / Detect & Avoid**



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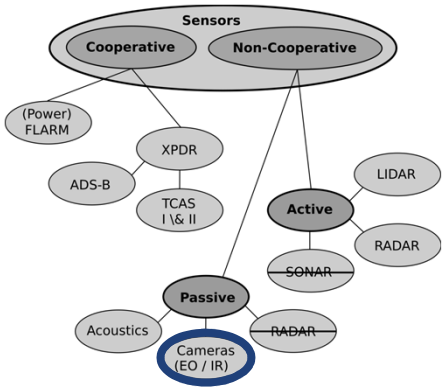
How to Detect Aerial Objects?

- **«Cooperative Traffic»**
  - Transponders, ADS-B, FLARM, TCAS, …
  - Required or optional depending on aircraft type, airspace, etc
- **«Non-cooperative Traffic»**
  - Cameras (EO, IR), RADAR, …
  - Usually smaller airspace users and gliders, para-gliders, balloons



→ **We focus on electro-optical sensors !**

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Where is the Aircraft?

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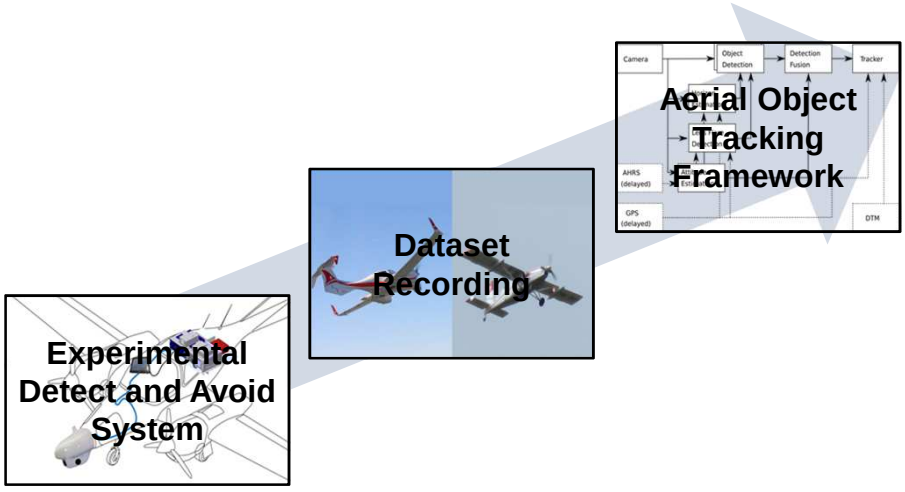
Outline



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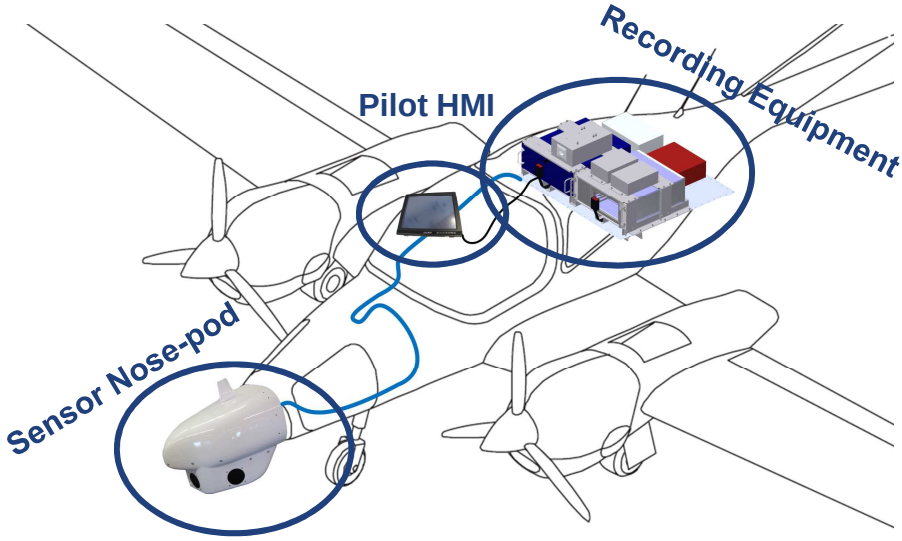
Experimental Detect and Avoid System



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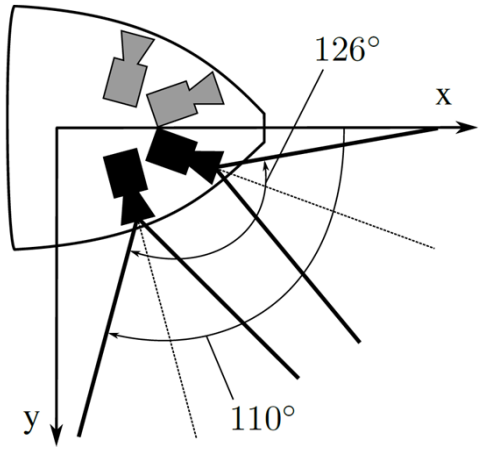
Custom Sensor Nose-pod

- **Included Sensors**
  - ADS-B
  - FLARM
  - GPS
  - IMU
  - 2x EO cameras
- **Camera Specifications**
  - 8 Megapixel
  - Grayscale
  - 8-bit / 12-bit
  - 20 fps / 10 fps



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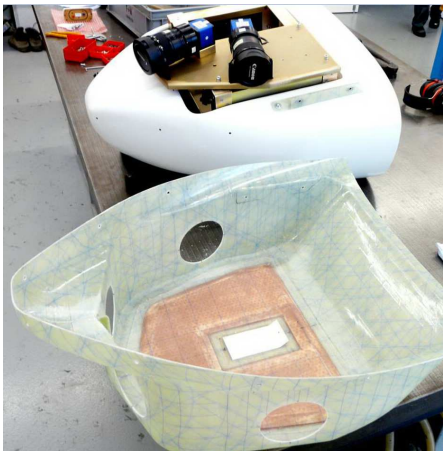
Custom Sensor Nose-pod



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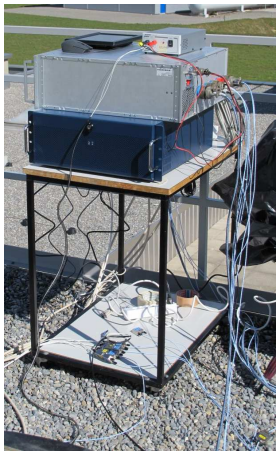
Recording Equipment



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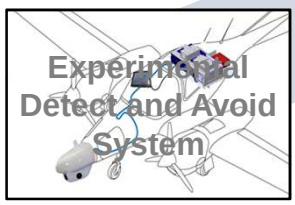
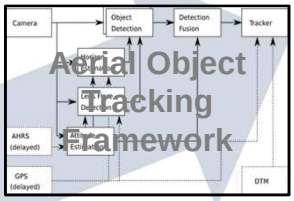
Outline





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Flight Tests

Ownship
Diamond DA-42 MPP

Traffic
Pilatus Porter PC-6

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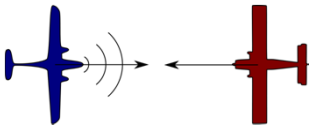
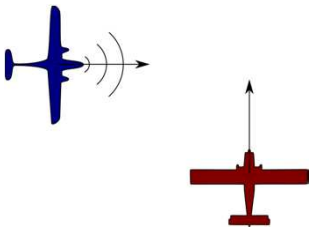
Dataset Summary

- **5h45min Total Flight Time**
- **2.2 TB of Data**
  - Cameras (8-bit / 12-bit)
  - ADS-B, FLARM
  - GPS, IMU
- **46 Scenarios**
  - 26x head-on
  - 20x crossing
  - 32x 8-bit
  - 14x 12-bit

- **Head-on Scenario**



- **Crossing Scenario**



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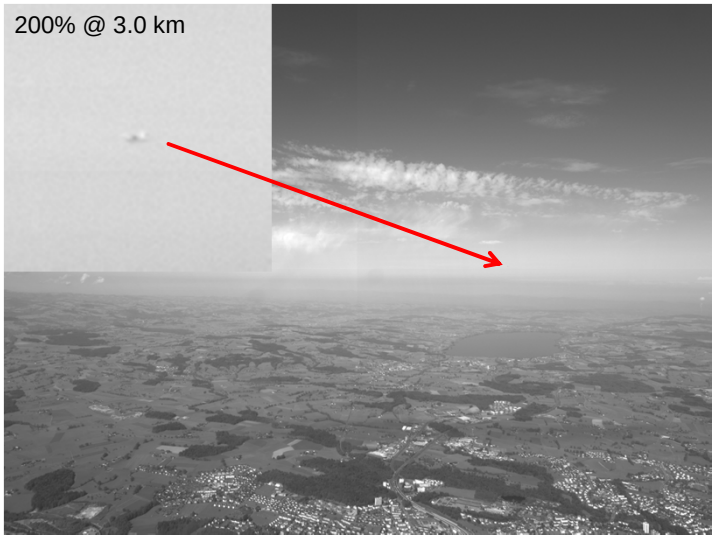
Challenge I: Small Objects



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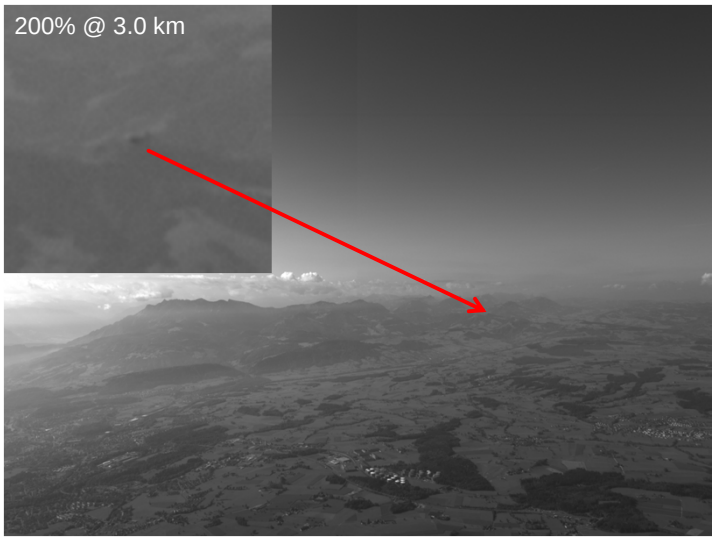
Challenge II: Objects in Front of Terrain



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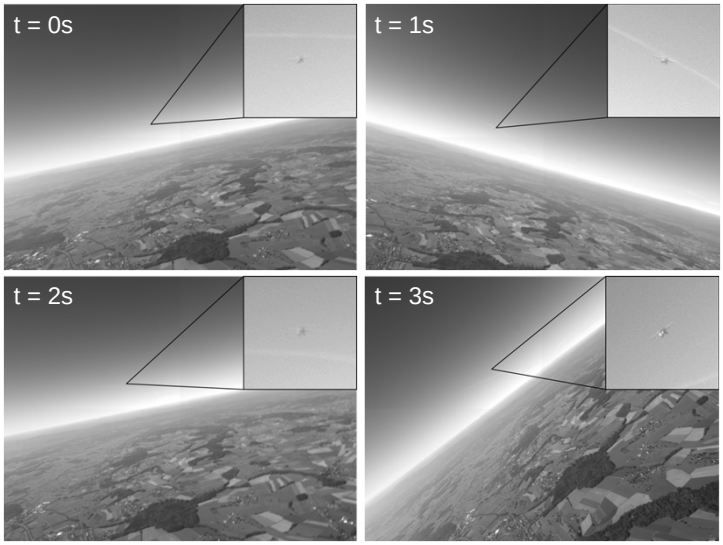
Challenge III: Ownship Egomotion



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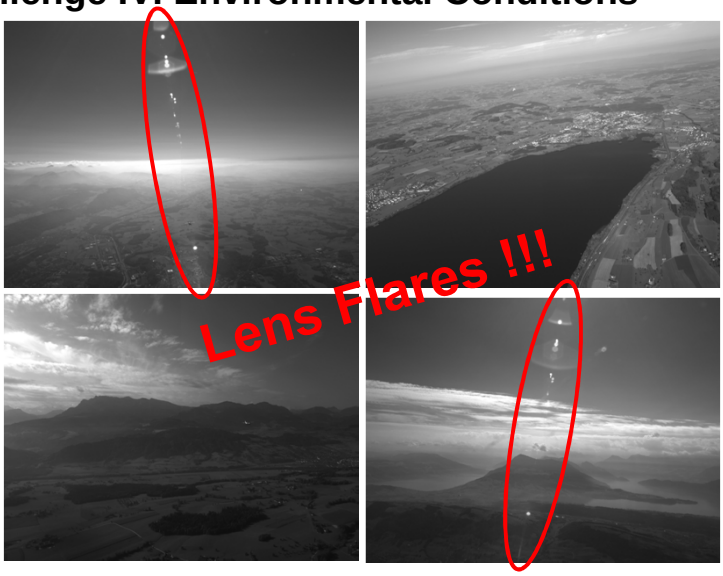
Challenge IV: Environmental Conditions



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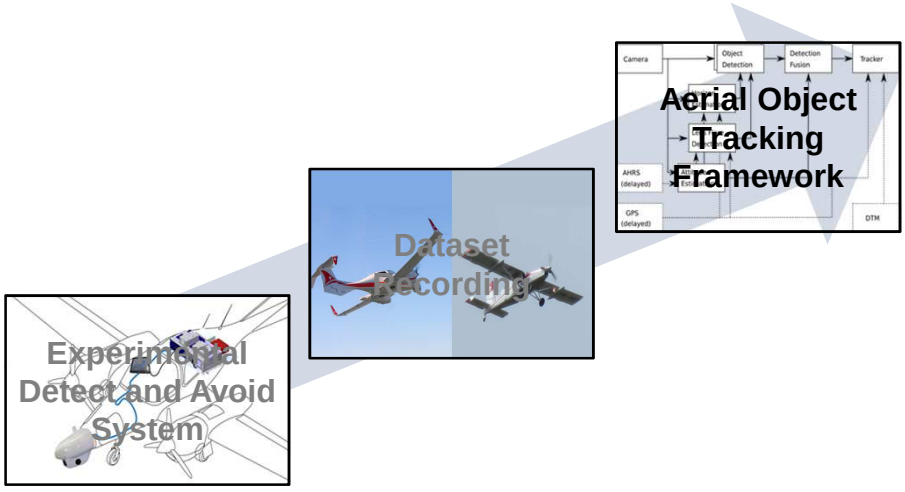
Outline



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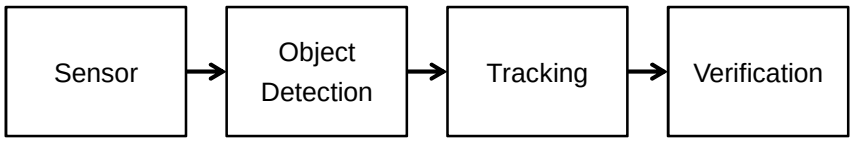
Processing Framework



A. Nussberger, H. Grabner, L. Van Gool
«Aerial Object Tracking from an Airborne Platform»
In Proceedings of International Conference on Unmanned Aircraft Systems, 2014

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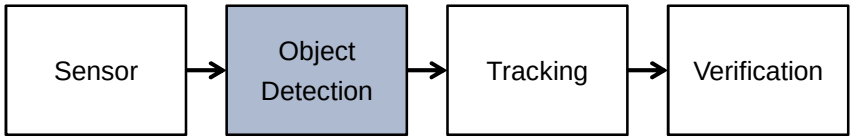
Processing Framework: Object Detection



↳ **Morphological filtering**

R. Carnie, R. Walker and P. Corke
«Image processing algorithms for UAV sense and avoid»
In Proceedings of International Conference on Robotics and Automation, 2006

↳ **Image differencing**

I. Saleemi and M. Shah
«Multiframe many-many point correspondence for vehicle tracking in high density wide area aerial videos»
International Journal of Computer Vision, 2013

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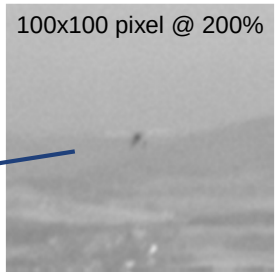
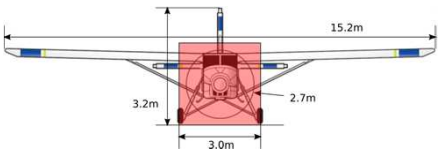
PC-6 Initial Detection during Headon





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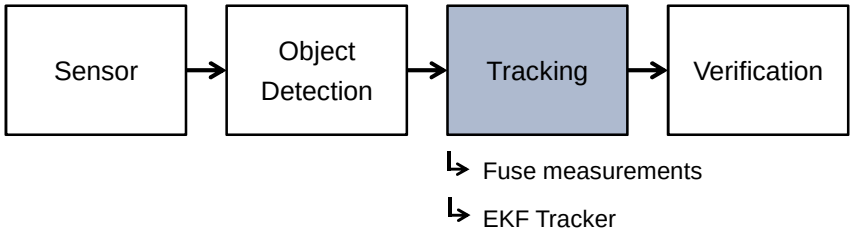
Processing Framework: Tracking



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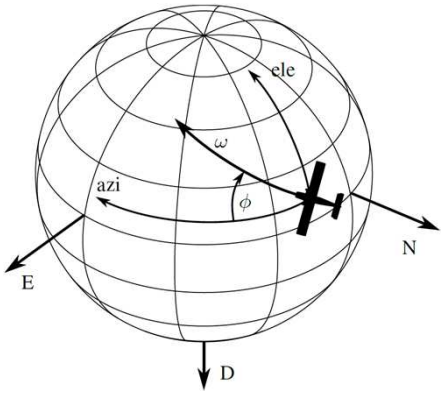
Processing Framework: Tracking



- **Fuse measurements from**
  - Multiple detectors
  - Multiple cameras
- **Tracking**
  - Extended Kalman Filter for each traffic
  - State: $x = [azi, ele, \phi, \omega]^T$
  - Motion model: constant angular velocity

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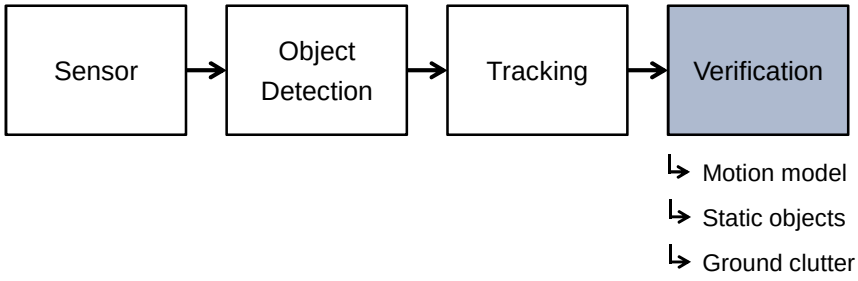
Processing Framework: Verification



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First Results …

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False Tracks from Lens Flares

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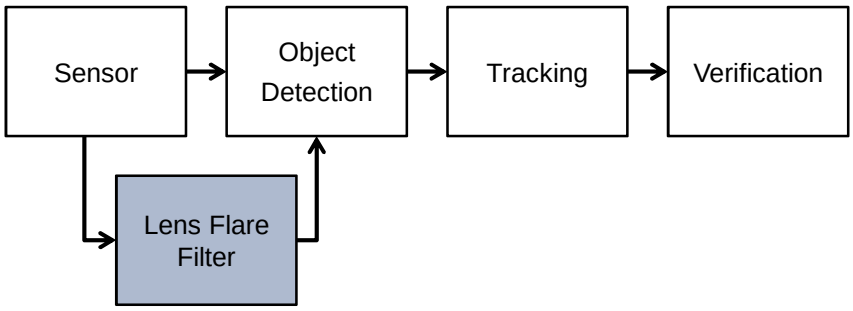
Processing Framework: Extension II

A. Nussberger, H. Grabner, L. Van Gool
«Robust Aerial Object Tracking in Images with Lens Flares»
In Proceedings of International Conference on Robotics and Automation, 2015



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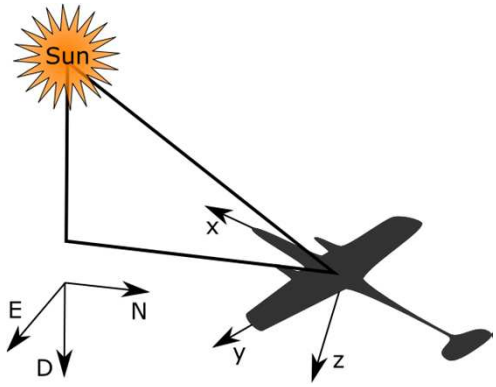
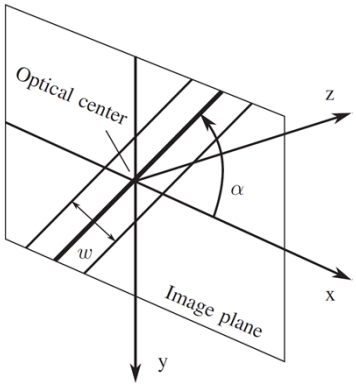
Identifying Lens Flares in Camera Images

Required meta data: date, time, position and attitude of camera





Navigation frame Body frame Camera frame

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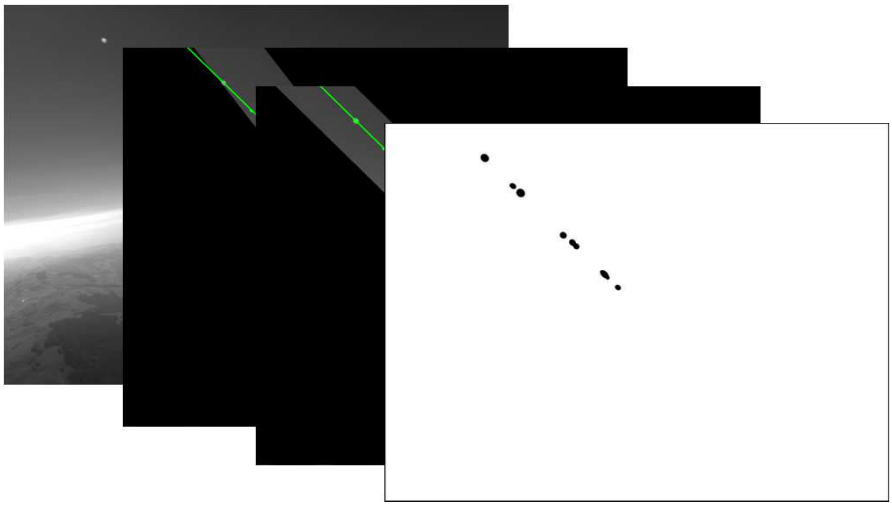
Identifying Lens Flares in Camera Images



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Results with Lens Flare Filter

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Overall Results

	Scenario Details (Note: LF = Lens Flare)			Default Parameters			Modified Parameters		
				Valid Track		FT	Valid Track		FT
	Type	Background	Duration	Distance	TTC	Num.	Distance	TTC	Num.
A	Head-on	Sky	26.2 s	1874 m	17.6 s	1	2177 m	19.6 s	0
B	Head-on	Sky	24.0 s	1622 m	14.5 s	0	1928 m	16.7 s	0
C	Head-on	Terrain	11.6 s	980 m	7.8 s	0	1436 m	12.3 s	0
D	Head-on	Terrain	22.4 s	1116 m	9.0 s	11	1617 m	12.9 s	0
E	Crossing	Sky	36.8 s	2830 m	35.3 s	2	2837 m	35.4 s	0
F	Crossing	Sky	48.0 s	2588 m	42.2 s	0	2680 m	45.3 s	0
G	Crossing	Sky	29.5 s	1831 m	17.7 s	2	2100 m	22.4 s	0
H	Crossing (LF)	Terrain	23.3 s	1637 m	15.2 s	1	2272 m	24.2 s	2
I	Crossing	Terrain	30.2 s	1489 m	14.0 s	2	2153 m	22.1 s	0
K	Crossing	Terrain	37.8 s	1593 m	23.4 s	4	2284 m	33.5 s	2
L	Crossing (LF)	Terrain	41.2 s	2884 m	39.6 s	0	2085 m	29.0 s	2
M	Head-on (LF)	Terrain	25.3 s	1419 m	11.0 s	0	1618 m	13.7 s	1
N	Wingrock	Sky	25.2 s	1932 m	16.0 s	0	1998 m	16.8 s	0
O	Wingrock	Terrain	26.4 s	1730 m	15.3 s	0	1497 m	13.1 s	0
P	Wingrock	Sky	26.3 s	1908 m	17.9 s	0	1788 m	15.7 s	0
Q	Wingrock (LF)	Terrain	25.8 s	921 m	9.1 s	2	897 m	7.6 s	2
Average	-	-	28.8 s	1777 m	19.1 s	2	1960 m	19.6 s	1

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Outlook: Extended Dataset Overview

- **More Scenarios**
  - > 100 scenarios
  - > 20h flight time
- **Environmental Data**
  - Lakes, roads, valleys, etc
  - > 50h flight time
- **Additional traffic types**
  - Glider
  - Paraglider
  - …

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Outlook: Extended Dataset Example

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Discussion