HD VS. 4K DRIVEN REMOTE TOWER OPTICAL SYSTEMS
WHAT IS THE BETTER OPTICAL SENSOR?

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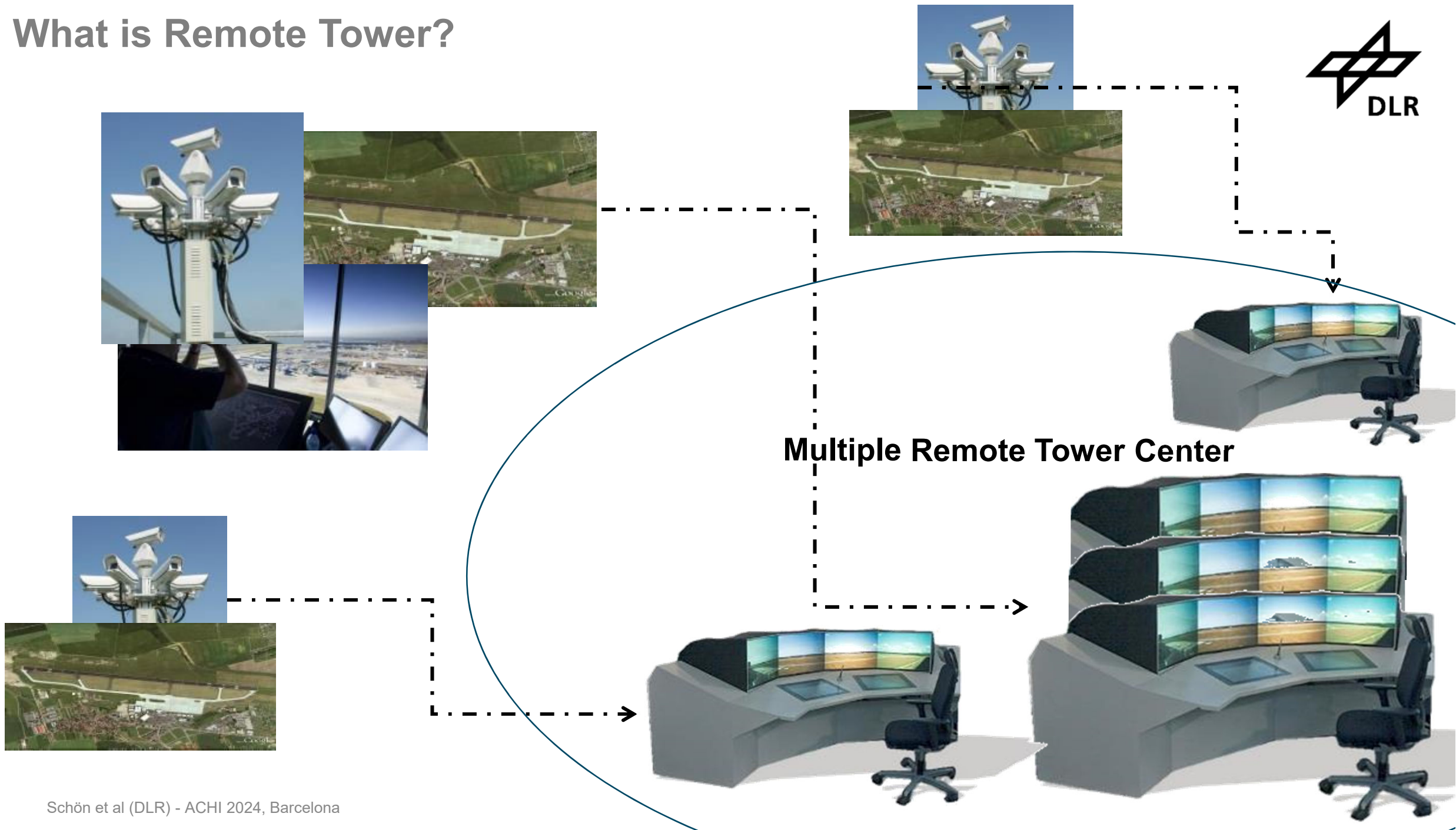
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German Aerospace Center DLR

ACHI 2024

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What is Remote Tower?

Multiple Remote Tower Center

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Conventional Remote Tower

Remote Tower Controller Working Position at RTC Leipzig
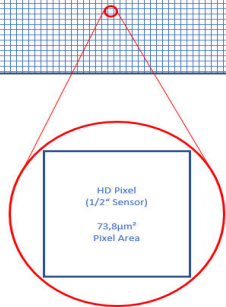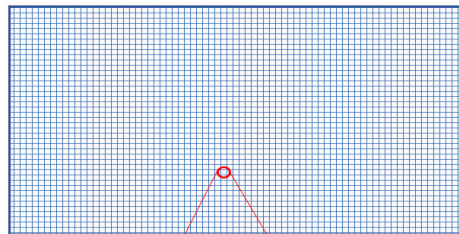Source: DFS GmbH

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Basic Building Blocks of a Remote Tower Optical System (RTOS)

Aerodrome location

Operator at RTM remote location

Optical Sensors → Image Encoder / Processing → Network → Image Decoder / Processing → [*Augmented*] Optical Sensor Presentation

PTZ Function ← Control HMI

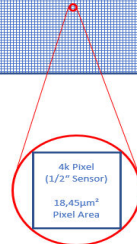System Border

Time Source

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Source: EUROCAE ED-240B (2023)
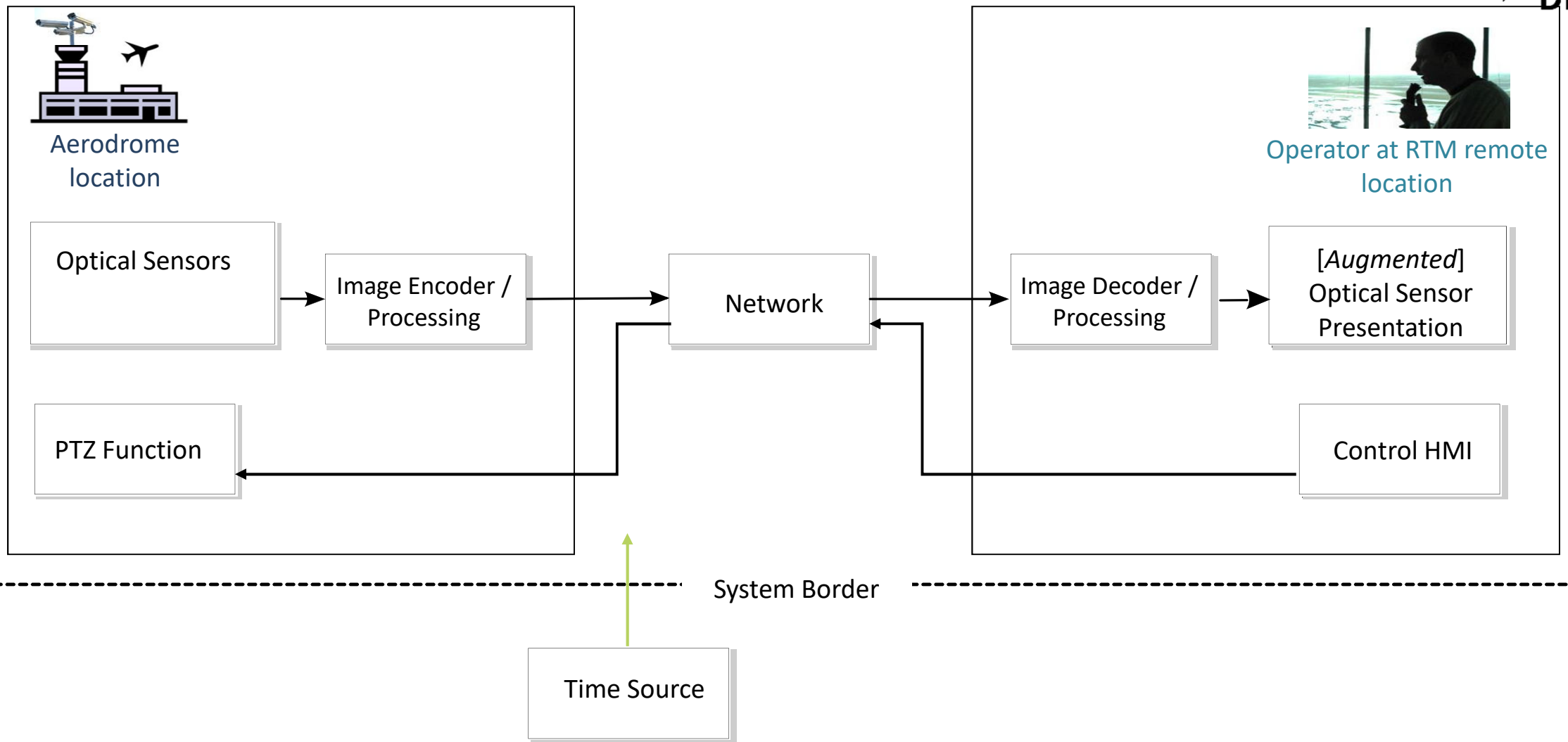
- Senzor Size and Light Sensitivity

- Bandwidth and Processing Resources

- High Dynamic Range

½ inch sensor – HD resolution

½ inch sensor – 4k resolution
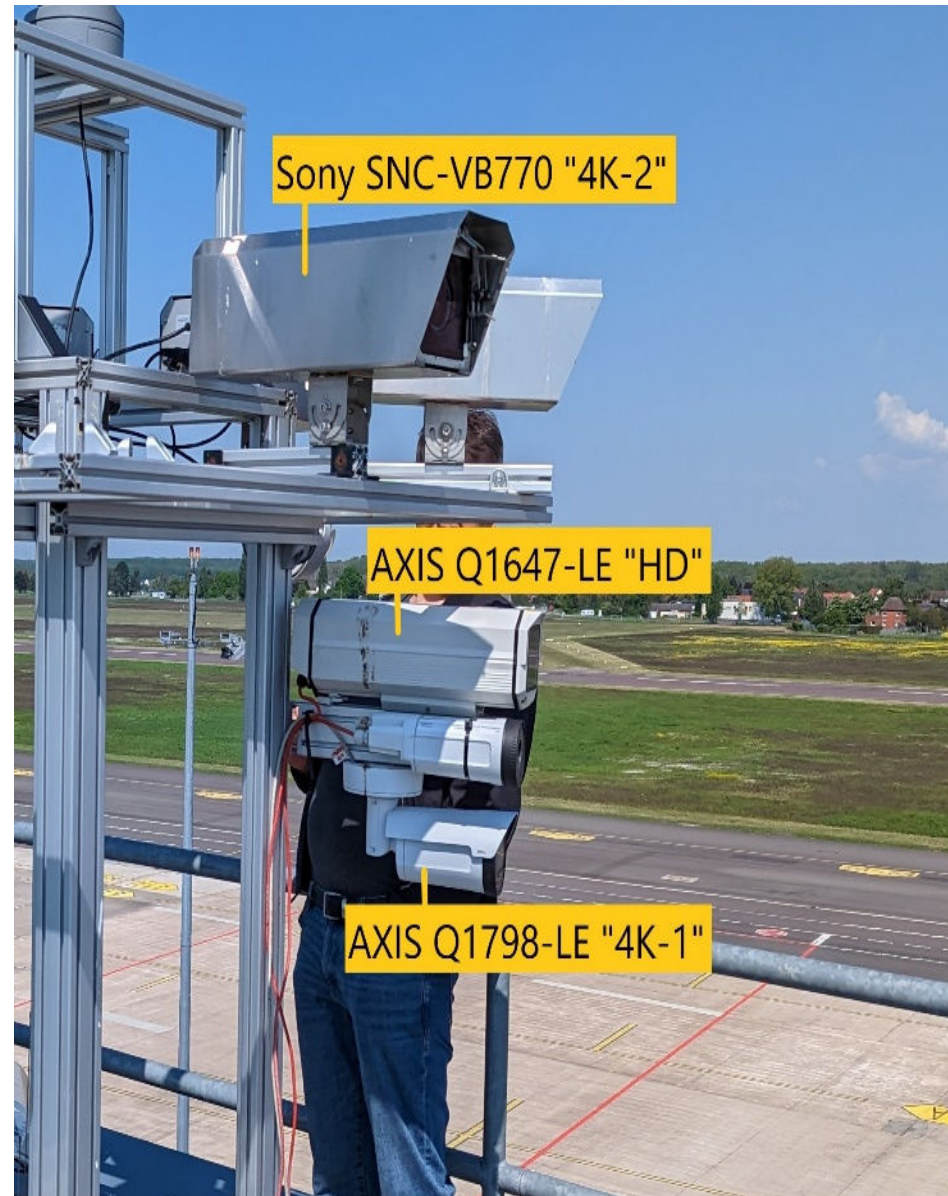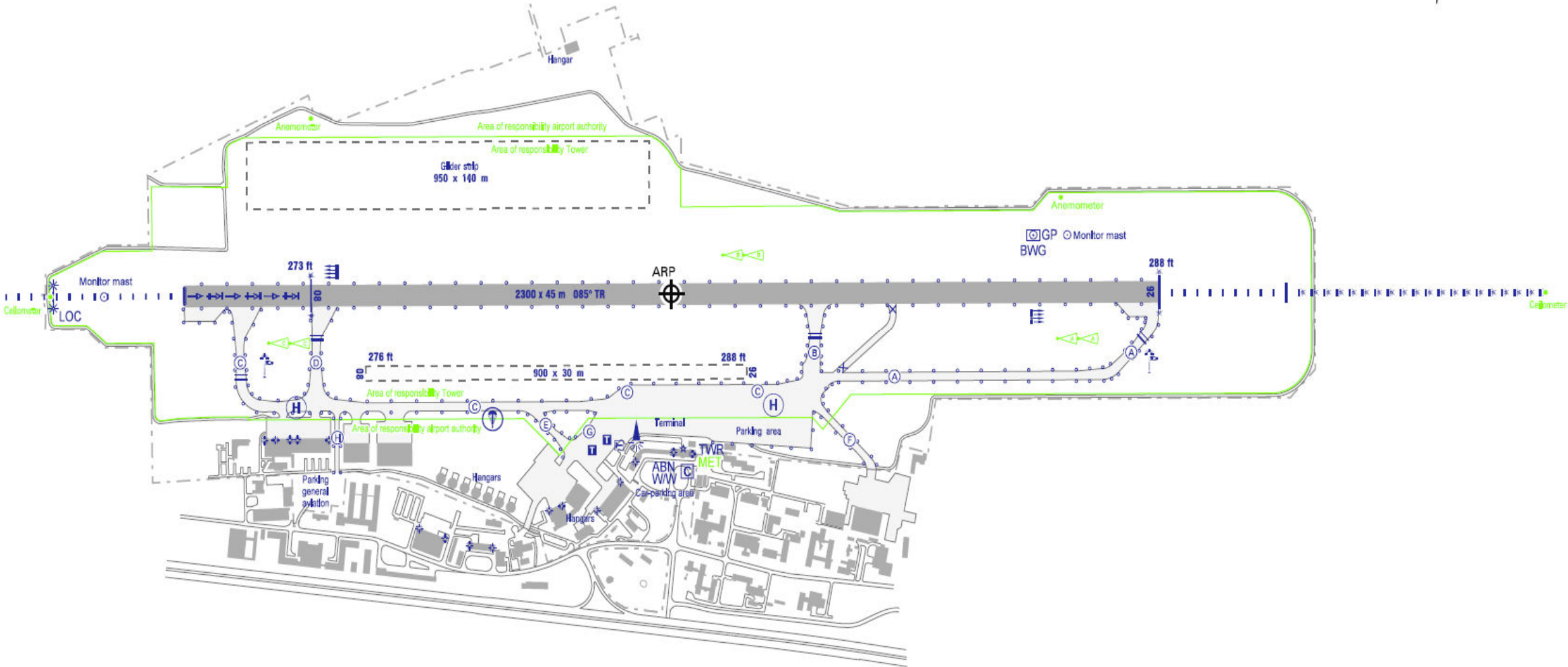
HD Pixel
(1/2" Sensor)

73,8µm²
Pixel Area

4k Pixel
(1/2" Sensor)

18,45µm²
Pixel Area

"Photon Rain"

Small Pixel

Medium Pixel

Large Pixel
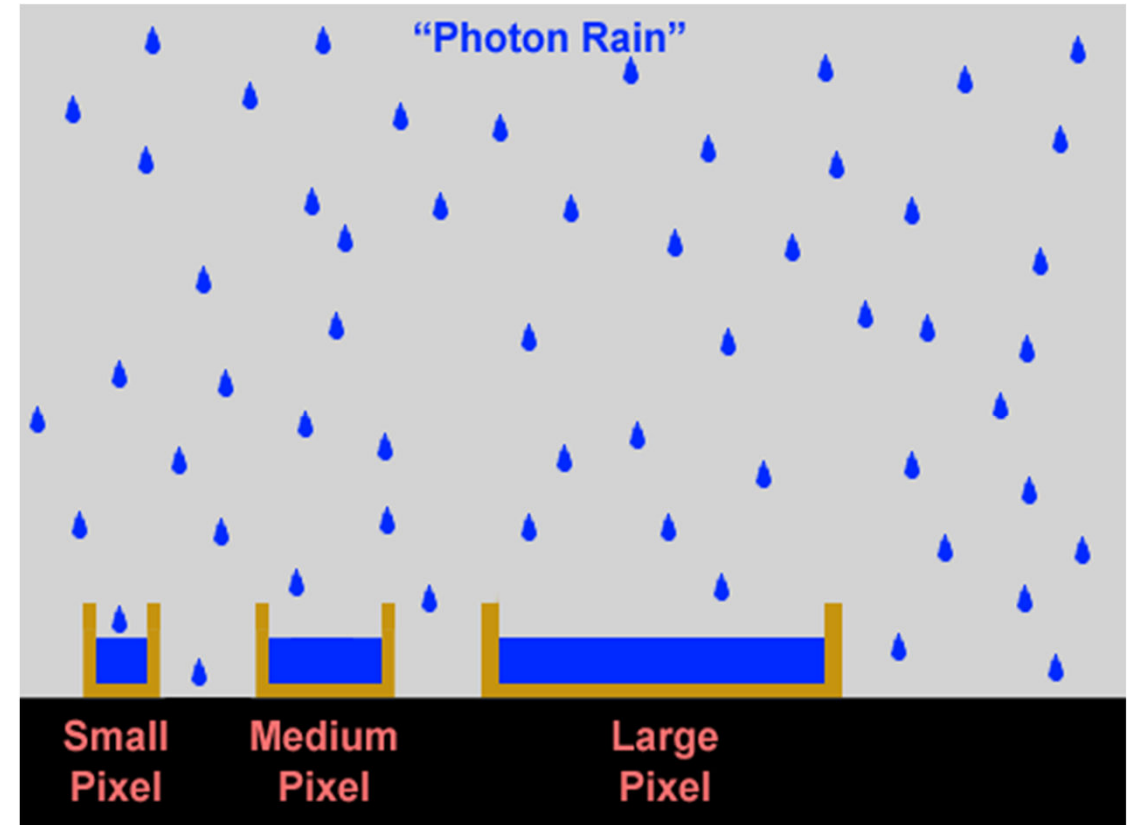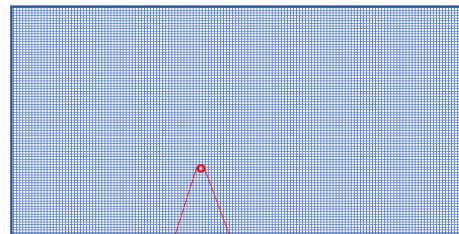
Camera Specs

	HD	4K-1	4K-2
Lens	F1.4	F1.7	F1.4
HDR	yes	yes	yes
Image sensor size	1/2 inch (12,7 mm)	4/3 inches (33,9 mm)	1 $^3/_8$ inches (35 mm full frame)
FoV [p]	1920 x 1080 Full HD	3840 x 2160 UHD	3840 x 2160 UHD
FoV [°]	43° x 24°	60° x 33°	54° x 32°
Resolution in pixel per degree [ppdeg]	45	65	68
Total number of pixels	2,073,600	8,294,400	8,294,401
Target frame rate (fps)	30	30	30
Total number of pixels per second (pps)	62,208,000	248,832,000	248,832,001
Video compression	H.264 High	H.264 High	H.264 High
Max bitrate [Mbit/s]	50	50	32
Average max bit per 1000 pix per camera	804	201	129

Sony SNC-VB770 "4K-2"

AXIS Q1647-LE "HD"

AXIS Q1798-LE "4K-1"

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Hypotheses

- $H_{0,1}$: There are no differences between HD and 4K cameras in terms of their detection range performance.

- $H_{0,2}$: There are no differences between HD and 4K cameras in terms of their recognition range performance.

- $H_{0,3}$: There are no differences between HD and 4K cameras in terms of their perceived video quality

- CAVOK with Clouds*
- Blue Sky
- Opposite-Sun
- Rain
- Dusk
- Significant Clouds**
- Low Visibility

- CAVOK Sun-yes Clouds-No
- CAVOK Sun-yes Clouds-Yes
- CAVOK Sun-No Clouds-Yes
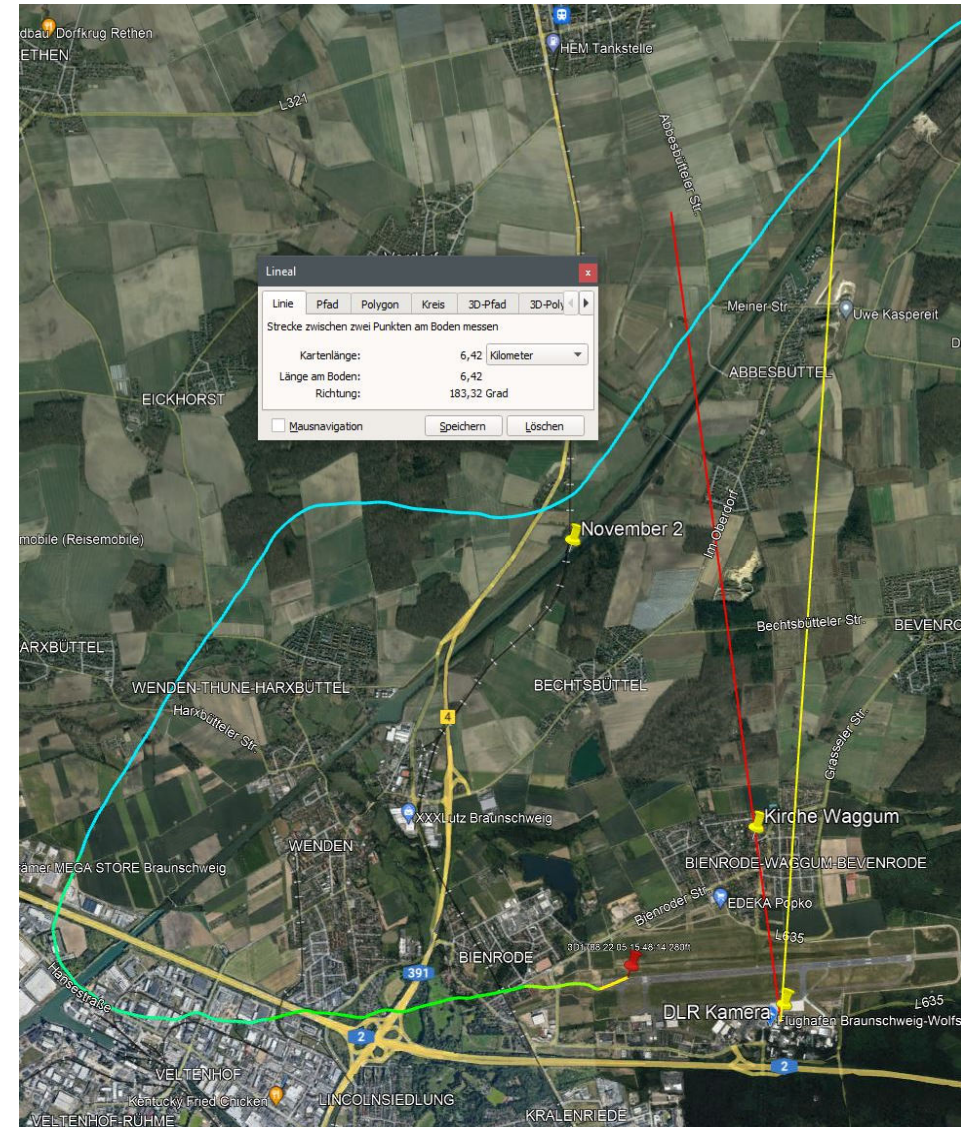
Experimental Set Up

- **Detection & Recognition Range performance**

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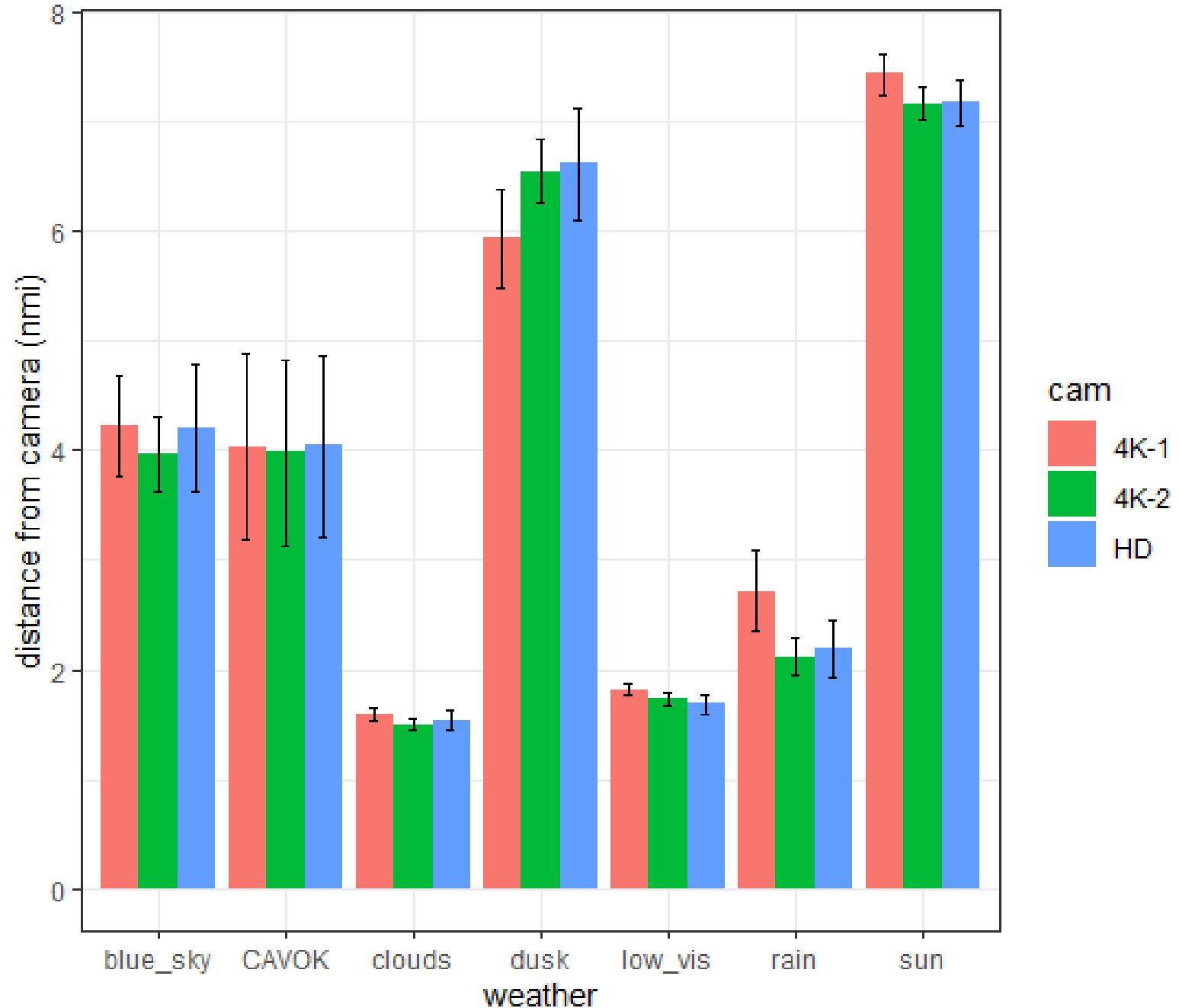
- **Motion**: Movements smooth vs. flickering
- **Noise**: noise vs. noise-free
- **Color**: colors bleeding vs. natural
- **Edges**: blurring vs. sharp
- **Textures**: blurring vs. sharp

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Results

- RWY26 <u>Detection</u> Range Performance [nmi]

- via "Cam" and "Weather" condition

	df_n	df_d	F	p		η^2_G
Cam	2.00	14.00	2.017	0.170		0.027
Weather	1.57	10.97	489.115	0.000	***	0.965
Cam*Weather	12.00	84.00	6.434	0.000	***	0.208

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Results

- November 1&2 <u>Detection</u> Range Performance [nmi]

- via "Cam" and "Weather" condition

| Weather	Cam	nmi
CAVOK Sun-yes_clouds-no	4K-1	2,74
	4K-2	2,18
	HD	1,97
CAVOK Sun-yes_clouds-yes	4K-1	3,33
	4K-2	3,18
	HD	3,66
CAVOK Sun-no_clouds-yes	4K-1	3,37
	4K-2	3,46
	HD	3,39
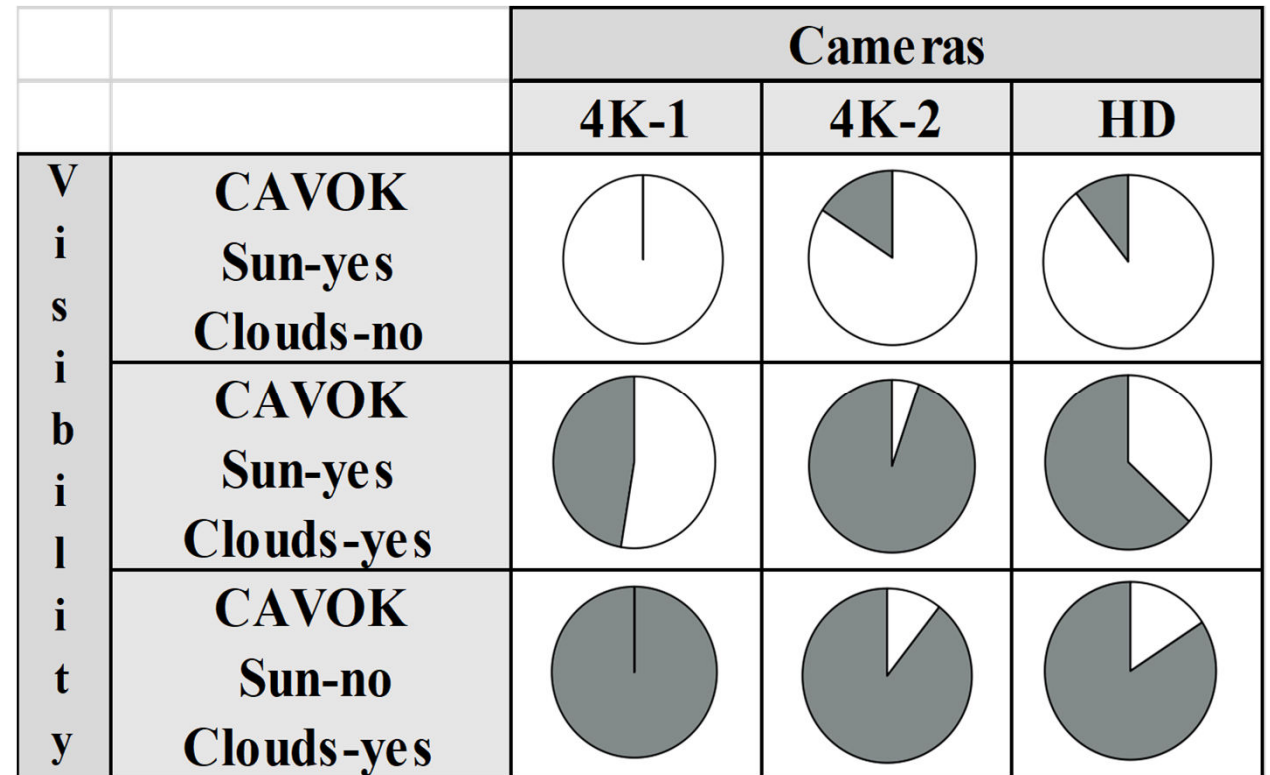
Pie Chart Matrix for Detection Performance for Small Aircraft (grey = "detected", white = "not detected")

Results

- RWY26 <u>Recognition</u> Range Performance [nmi]

- via "Cam" and "Weather" condition

	df_n	df_d	F	p		η^2_G
Cam	2	10	12.720	0.002	**	0.136
Weather	6	30	29.801	0.000	***	0.644
Cam*Weather	12	60	5.286	0.000	***	0.224
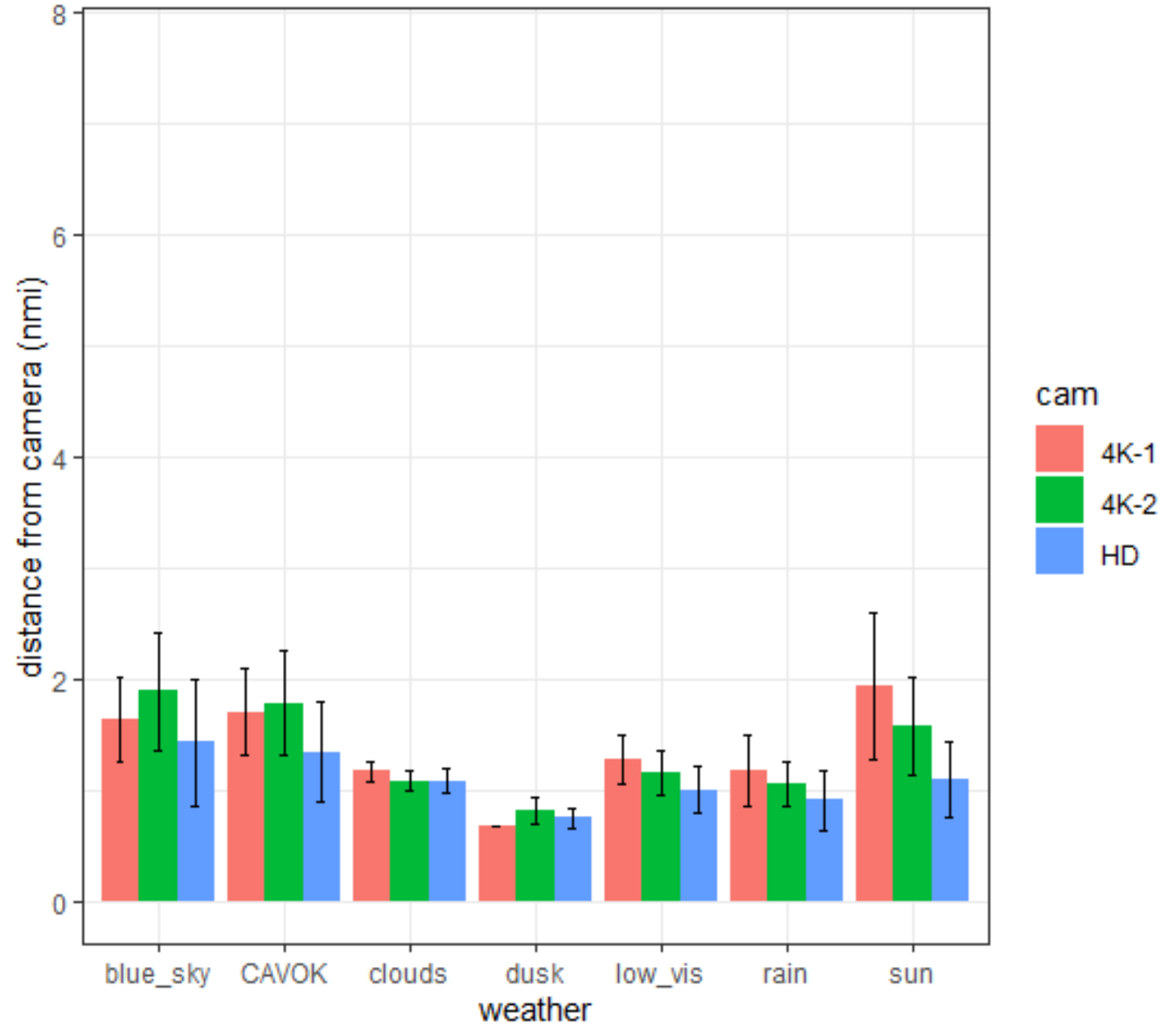
Perceived Video Quality (general)

Bitte bewerten Sie die Qualität des Videos.

sehr schlecht ... ... sehr gut
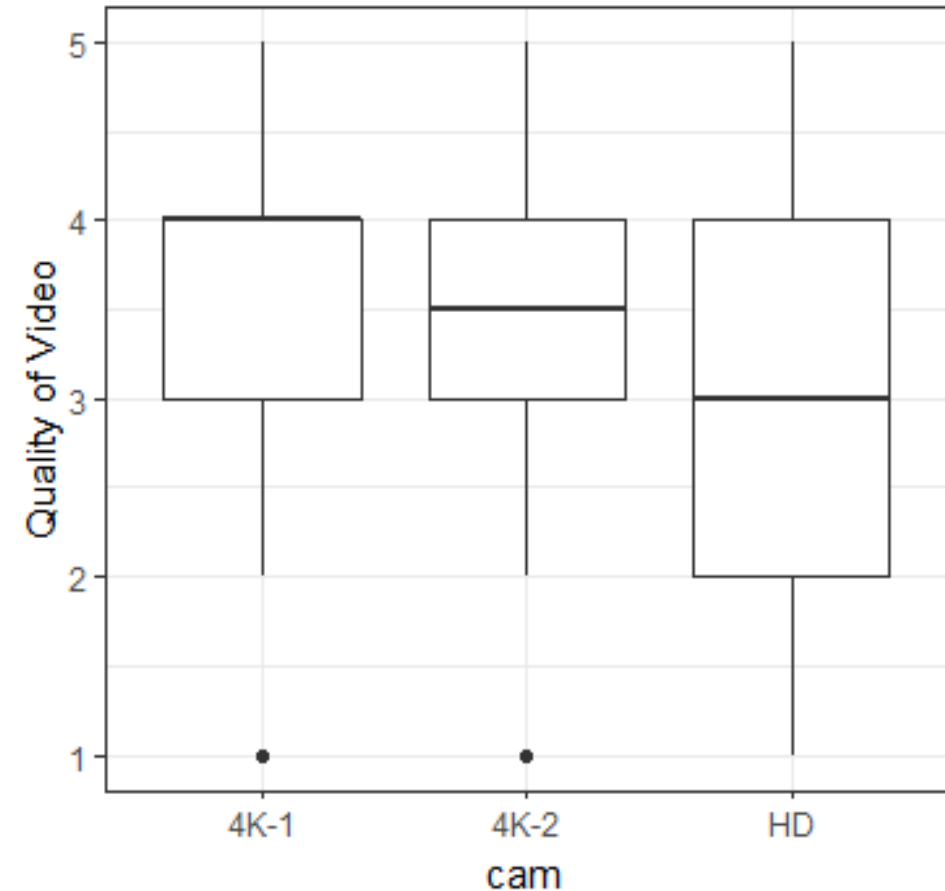
pairwise t-tests

Group 1	Group 2	n1	n2	t	df	p	p-adjusted		D	95% CI
4K-2	HD	126	126	3.33	125	0.001	0.003	**	0.294	[0.119, 0.468]
4K-2	4K-1	126	126	-2.15	125	0.033	0.100		-0.206	[-0.017, -0.396]
HD	**4K-1**	126	126	-5.10	125	0.000	0.000	***	-0.500	[-0.306, -0.694]

Boxplot diagrams with median and IQRs showing the ratings for three different cameras via all 10 weather/visibility conditions and all video quality categories

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Results
Readability of the Lettering sign

Bitte bewerten Sie die Lesbarkeit des DLR-Schriftzuges.

sehr schlecht ... ... sehr gut

Weiter
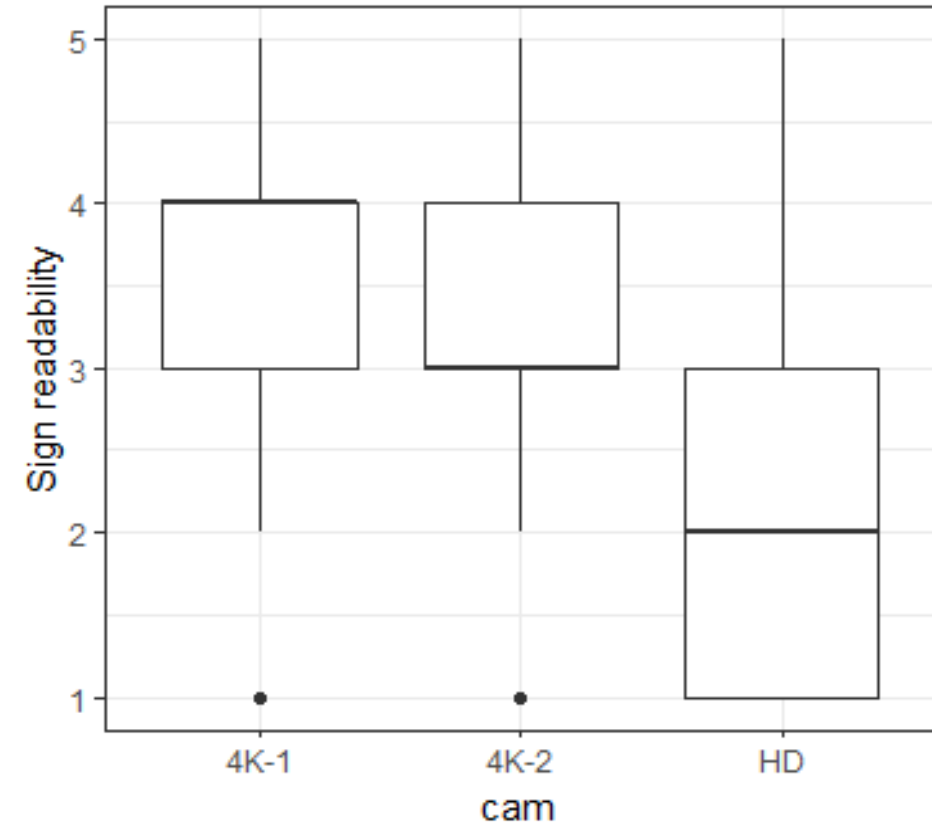
pairwise t-tests

Group 1	Group 2	n1	n2	t	df	p	p-adjusted		D	95% CI
4K-2	HD	126	126	18.6	125	0.000	0.000	***	1.440	[1.290, 1.600]
4K-2	4K-1	126	126	-0.36	125	0.723	1.000		-0.040	[0.182, -0.261]
HD	**4K-1**	126	126	-12.0	125	0.000	0.000	***	-1.480	[-1.240, -1.730]

Boxplot diagrams with median and IQRs via three different cameras for over all seven RWY26 weather/visibility conditions

Conclusions & Outlook

- no 100% clear answer

- Detection & Recognition differences in this setting were rather marginal

- slight advantages for the 4K camera

- 4K cameras in this setting deliver a better perceived video quality

- In a 360° composition of several individual cameras it is to be expected that the slight advantages of 4K technology would become even more apparent

- Codec H.264/H.265 or AVI) and bitrate needs to be investigated in a separate study

THE END

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