Investigations on the geometric quality of commercially available cameras for UAV applications

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UAV System Tests

- Out of the box systems
  - DJI Zenmuse X4S (20 Mpix)
  - DJI Zenmuse X5S (20,8 Mpix)
- High-End system
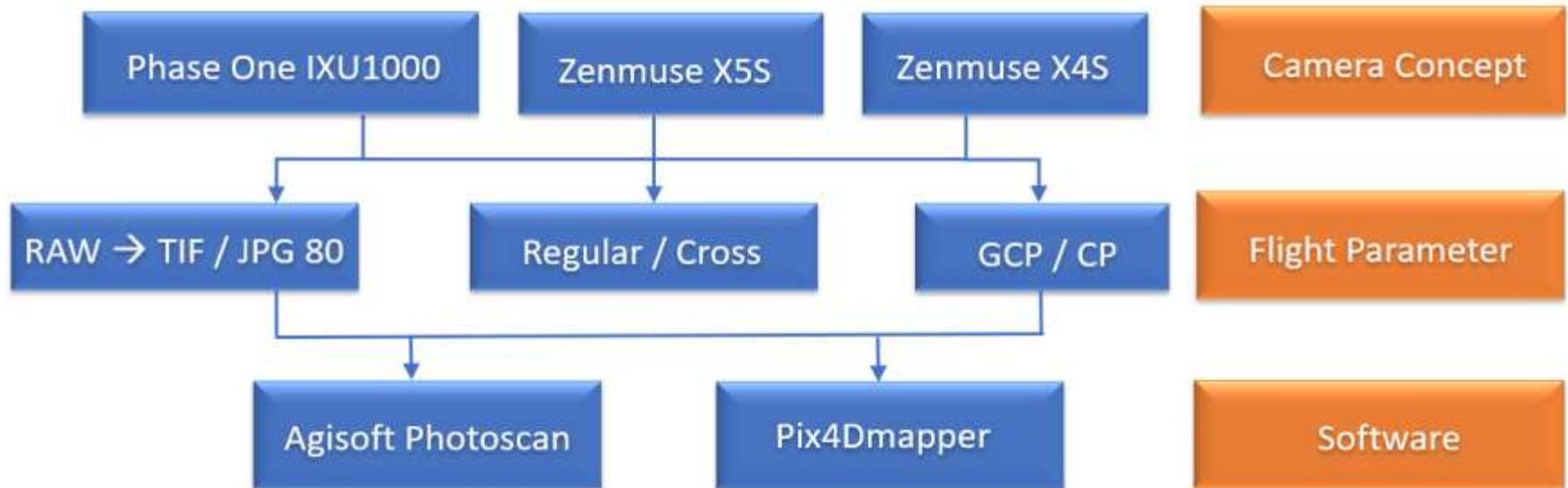 - Phase One (IXU 1000) → 100 Mpix

UAV System Tests

Zenmuse X5S

Phase One
IXU 1000

Zenmuse X4S

Influencing Parameters

The focus of the investigations is set on parameters influencing the geometric quality of the results (image orientation / dense point cloud).

UAV-Test Field Zollern Colliery

45 Ground Control Points (GCP) –
Position and hight accuracy approx. 2mm

Industrial Monument – Zollern Colliery (Dortmund, Germany)

Source: lwl.org

Flight Concept

- Identical ground sample distance (GSD=14mm) for all UAV systems (flight configuration: Regular / R).

- Further cross-flights (Cross / C) where the flight altitude deviates from the regular arrangements by 20% in each case.

Camera	PhaseOne IXU1000	DJI Zenmuse X5S	DJI Zenmuse X4S (Phantom 4 Pro)
Regular (R)	120m	60m	50m
Cross (C)	148m	72m	60m

Flight Configuration

Flight arrangement: Regular (R - blue) und Cross (C - red) (Block Zenmuse X4S/Phantom 4Pro)
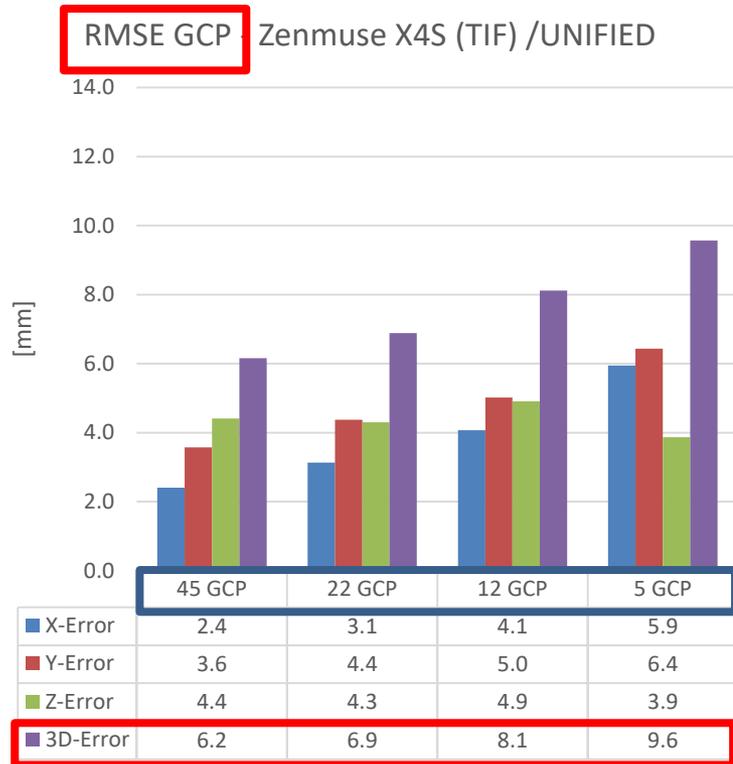
Investigating Geometric Quality

Image orientation (bundle block adjustment) with Agisoft PhotoScan und Pix4Dmapper resulting in

- Root Mean Square Errors (RMSE values) at
  - Ground control points (GCP) and
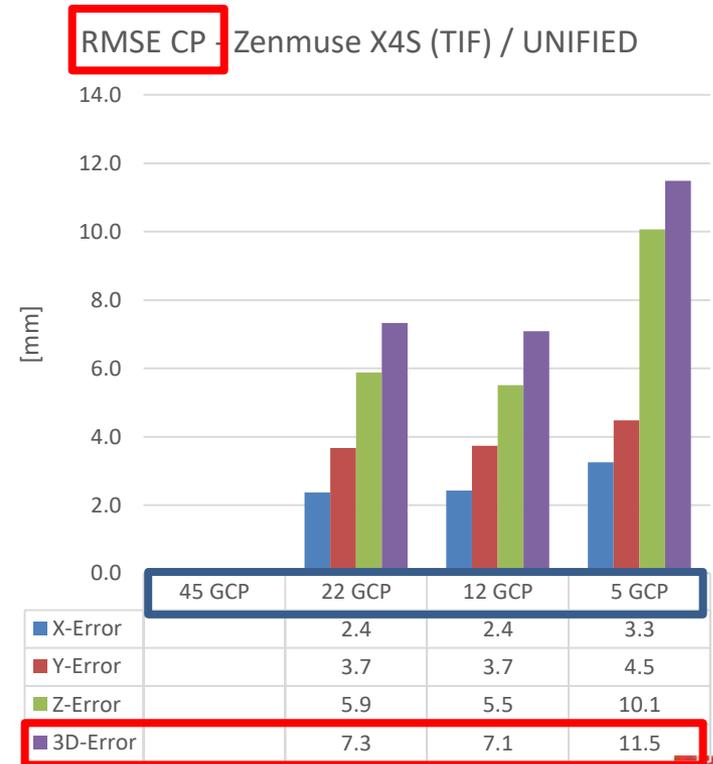 - Control (check) points (CP)

RMSE-Werte (RC-TIF-UNIFIED)

FIG

Zenmuse X4S

RMSE GCP - Zenmuse X4S (TIF) /UNIFIED

	45 GCP	22 GCP	12 GCP	5 GCP
X-Error	2.4	3.1	4.1	5.9
Y-Error	3.6	4.4	5.0	6.4
Z-Error	4.4	4.3	4.9	3.9
3D-Error	6.2	6.9	8.1	9.6

Ground Control Points

RMSE CP - Zenmuse X4S (TIF) / UNIFIED

	45 GCP	22 GCP	12 GCP	5 GCP
X-Error		2.4	2.4	3.3
Y-Error		3.7	3.7	4.5
Z-Error		5.9	5.5	10.1
3D-Error		7.3	7.1	11.5

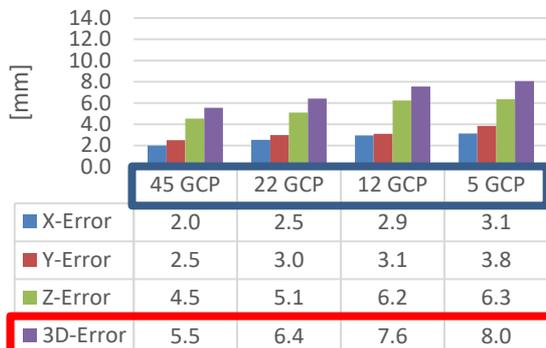### Check Points

RMSE-Werte (RC-TIF-UNIFIED)

RMSE GCP - Phaseone IXU 1000 (TIF) / UNIFIED
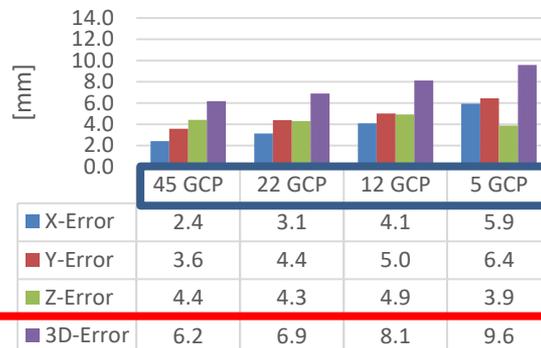
	45 GCP	22 GCP	12 GCP	5 GCP
X-Error	2.0	2.5	2.9	3.1
Y-Error	2.5	3.0	3.1	3.8
Z-Error	4.5	5.1	6.2	6.3
3D-Error	5.5	6.4	7.6	8.0

RMSE GCP - Zenmuse X4S (TIF) /UNIFIED

	45 GCP	22 GCP	12 GCP	5 GCP
X-Error	2.4	3.1	4.1	5.9
Y-Error	3.6	4.4	5.0	6.4
Z-Error	4.4	4.3	4.9	3.9
3D-Error	6.2	6.9	8.1	9.6

RMSE GCP - Zenmuse X5S (TIF) / UNIFIED

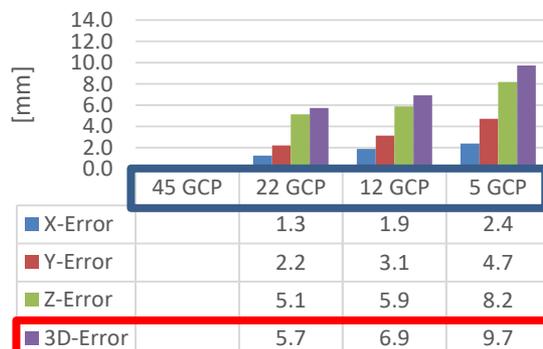|	45 GCP	22 GCP	12 GCP	5 GCP
X-Error	2.8	2.4	2.9	5.1
Y-Error	3.7	4.3	4.6	7.1
Z-Error	6.4	6.7	8.4	0.4
3D-Error	7.9	8.3	10.0	8.8

RMSE CP - Phaseone IXU 1000 (TIF) / UNIFIED

	45 GCP	22 GCP	12 GCP	5 GCP
X-Error		1.3	1.9	2.4
Y-Error		2.2	3.1	4.7
Z-Error		5.1	5.9	8.2
3D-Error		5.7	6.9	9.7

RMSE CP - Zenmuse X4S (TIF) / UNIFIED

	45 GCP	22 GCP	12 GCP	5 GCP
X-Error		2.4	2.4	3.3
Y-Error		3.7	3.7	4.5
Z-Error		5.9	5.5	10.1
3D-Error		7.3	7.1	11.5

RMSE CP - Zenmuse X5S (TIF) / UNIFIED

	45 GCP	22 GCP	12 GCP	5 GCP
X-Error		3.7	3.6	5.6
Y-Error		5.8	5.4	9.9
Z-Error		11.2	15.8	29.6
3D-Error		13.2	17.1	31.7
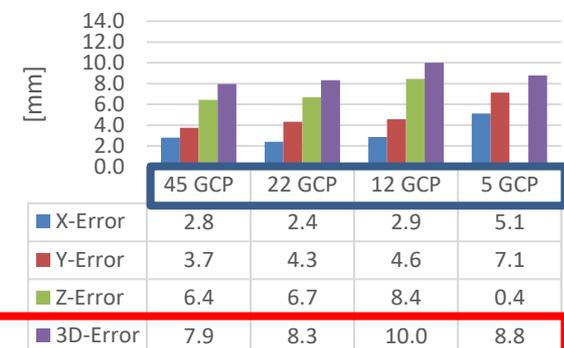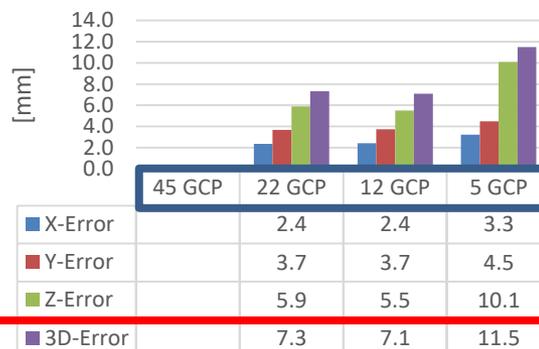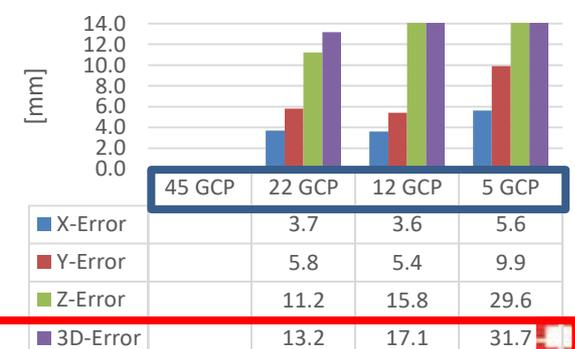
Results

- The investigations show clear differences in the achievable quality of the cameras.

- Though the high-priced Phase One system shows the best results, the most cost-effective system, the Zenmuse X4S, delivers only slightly worse results.

- The Zenmuse X5S performs significantly worse than the other systems, mainly resulting from the mechanically unstable camera concept with interchangeable lenses.
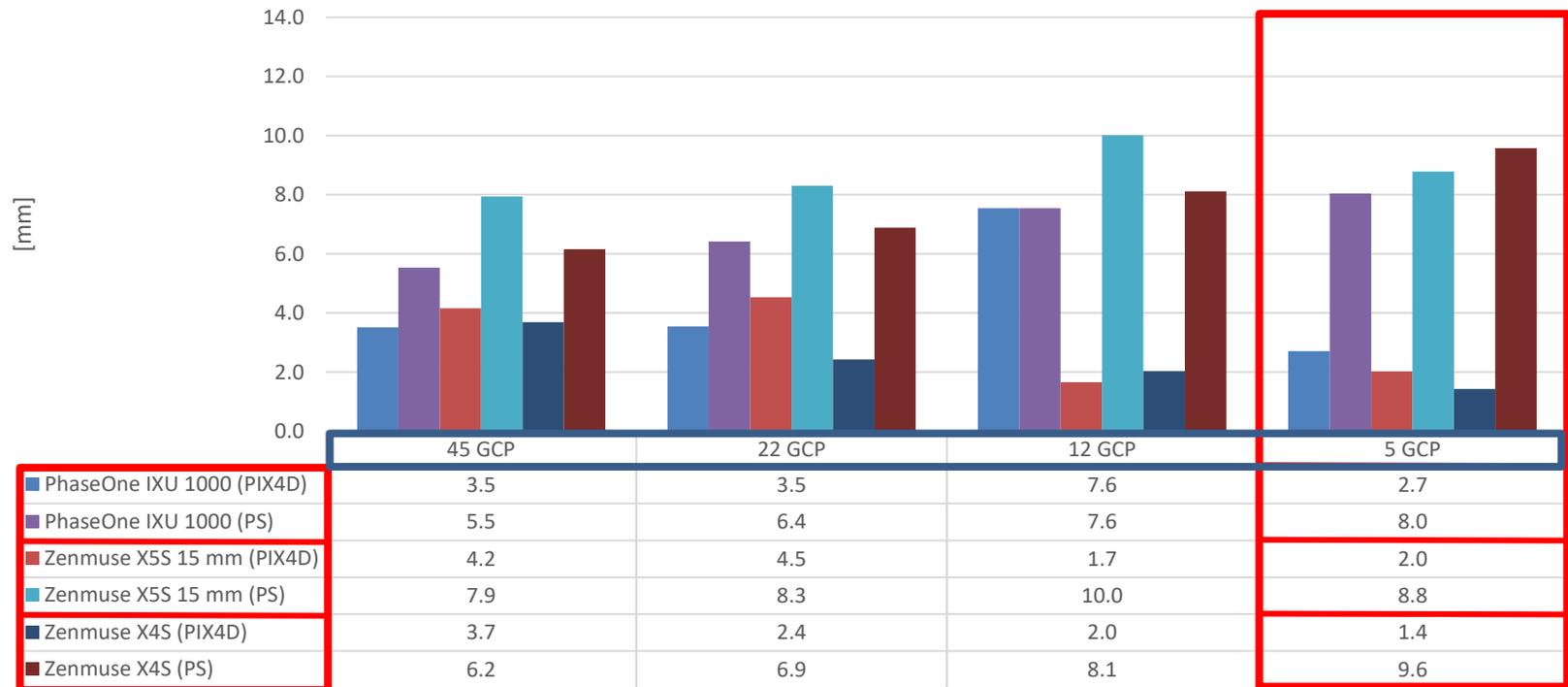
Software Comparison

- Identical projects calculated with Agisoft Photo-Scan as well as Pix4Dmapper.

- Projects correspond in their configuration to the specifications for the respective software (using default parameters).

Software Comparison
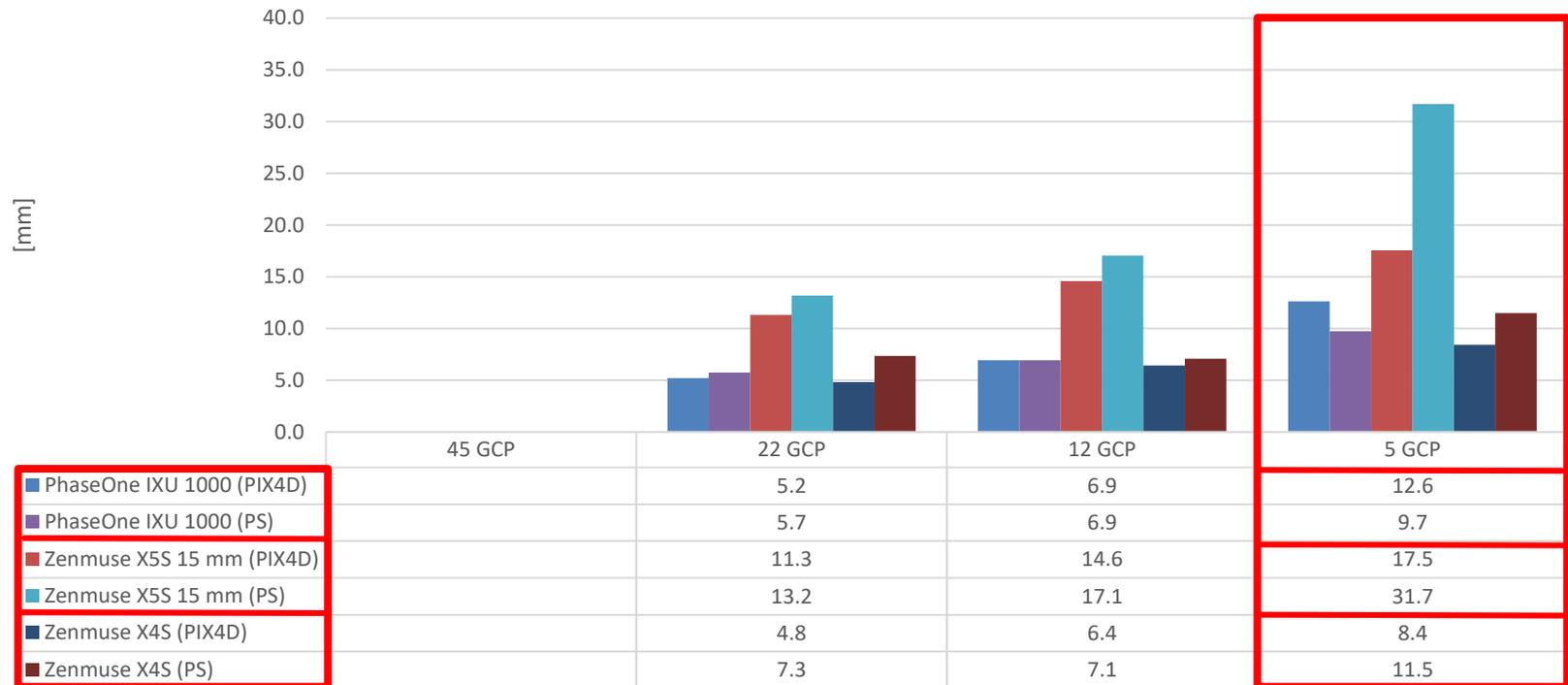
PIX4D vs. PhotoScan: RMSE GCP - (TIF) / UNIFIED

	45 GCP	22 GCP	12 GCP	5 GCP
PhaseOne IXU 1000 (PIX4D)	3.5	3.5	7.6	2.7
PhaseOne IXU 1000 (PS)	5.5	6.4	7.6	8.0
Zenmuse X5S 15 mm (PIX4D)	4.2	4.5	1.7	2.0
Zenmuse X5S 15 mm (PS)	7.9	8.3	10.0	8.8
Zenmuse X4S (PIX4D)	3.7	2.4	2.0	1.4
Zenmuse X4S (PS)	6.2	6.9	8.1	9.6

3D RMSE values at ground control points (GCP)

Software Comparison

PIX4D vs. PhotoScan: RMSE CP - (TIF) / UNIFIED

	45 GCP	22 GCP	12 GCP	5 GCP
PhaseOne IXU 1000 (PIX4D)		5.2	6.9	12.6
PhaseOne IXU 1000 (PS)		5.7	6.9	9.7
Zenmuse X5S 15 mm (PIX4D)		11.3	14.6	17.5
Zenmuse X5S 15 mm (PS)		13.2	17.1	31.7
Zenmuse X4S (PIX4D)		4.8	6.4	8.4
Zenmuse X4S (PS)		7.3	7.1	11.5

3D RMSE values at control (check) points (CP)

Results

- The comparison of the software products Pix4Dmapper and Agisoft PhotoScan shows significant differences in the results of image orientation.

- Is there something going wrong with the softwares?

- This is in some way astonishing and needs further investigations.

- Software providers should help to find reasons for these effects!

CONCLUSION

- The investigations carried out show the necessity of UAV test fields for carrying out UAV system tests.

- The area of the industrial monument Zollern colliery, Dortmund, offers a suitable scenario for carrying out such tests.

- The basis for this is a geodetic precision network with a total of 45 ground points.

Cảm ơn bạn đã quan tâm!

Thank you very much
for your attention!

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