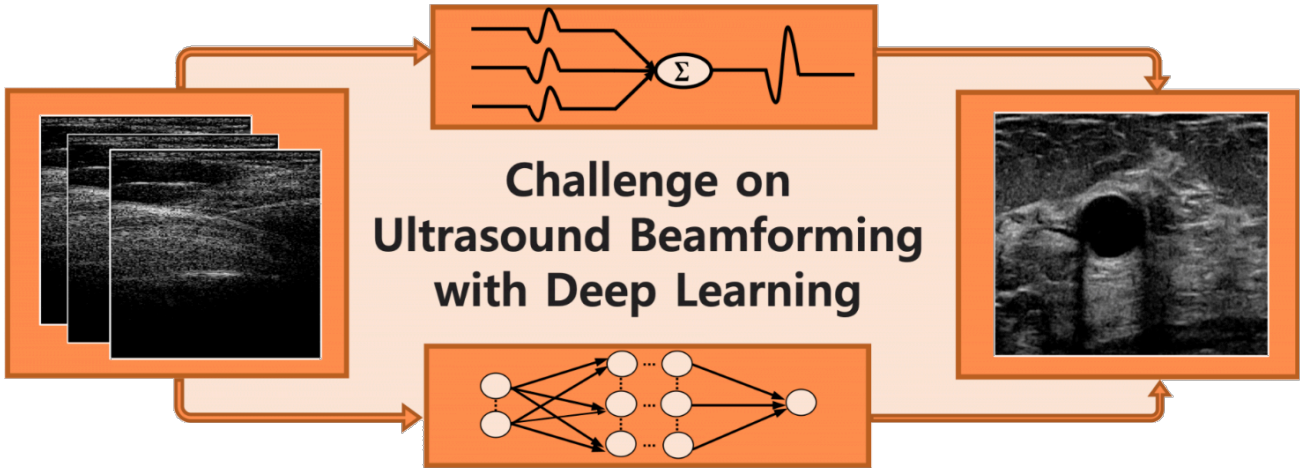

Challenge on Ultrasound Beamforming with Deep Learning

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Yonina C. Eldar[3], Ruud van Sloun[4], Massimo Mischi[4]

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[3]Weizmann Institute of Science, Rehovot, Israel
[4]Eindhoven University of Technology, Eindhoven, Netherlands

Overview: Three Optional Tasks

Task 1a	**Beamforming with deep learning after a single plane wave transmission**	Task 1a is explicitly focused on creating a high-quality image from a single plane wave to match a higher quality image created from multiple plane waves.
Task 1b		Task 1b gives more freedom to create an image that will be benchmarked against the highest contrast, SNR, gCNR, etc. These values can be better than those obtained from an image formed by multiple plane waves.
Task 2	**Beamforming with deep learning after a few plane wave transmissions**	Task 2 imposes a maximum of 10 plane waves but lets participants choose from provided angles to create the best image quality possible.
Task 3	**Beamforming with deep learning to achieve dynamic transmit focusing**	Task 3 enables participants to compare the results of a deep learning dynamic transmit focusing implementation that will be useful with current transmit beamforming techniques implemented on most clinical systems today.

More details: https://cubdl.jhu.edu/

Test Data

- 75 plane wave transmissions:
  - Phantoms, simulations, and *in vivo* data
  - 21 unique datasets
  - 6 different universities including:
    - Signal Processing Systems group, Eindhoven University of Technology, **Netherlands**
    - CREATIS, Insa Lyon, **France**
    - Department of Radiology, Mayo Clinic, **USA**
    - Research Group for Digital Signal Processing and Image Analysis, University of Oslo, **Norway**
    - Microelectronic Systems Design Laboratory, University of Florence, **Italy**
    - Department of Biomedical Engineering, Tsinghua University, **China**

TU/e Technische Universiteit Eindhoven University of Technology
Where innovation starts

CREATIS

MAYO CLINIC

UNIVERSITÀ DEGLI STUDI FIRENZE

UiO University of Oslo

清華大學 Tsinghua University

Experience Levels of Challenge Participants

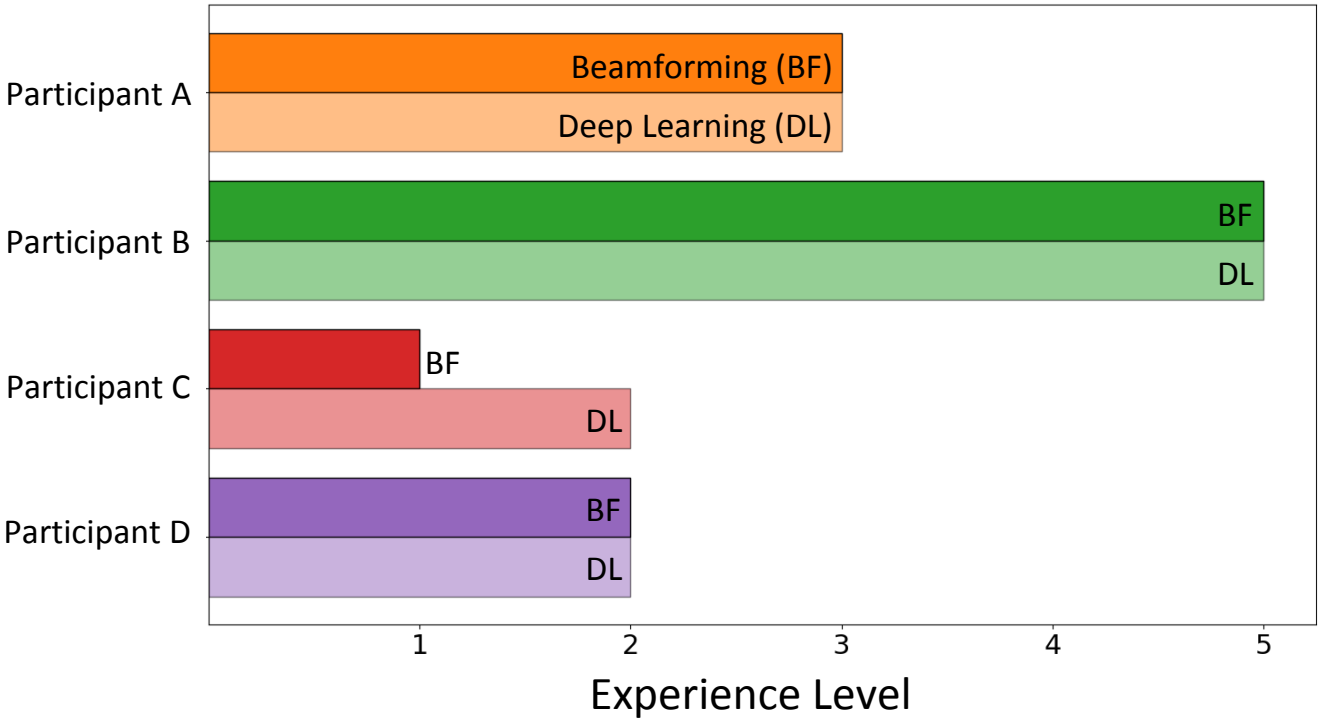
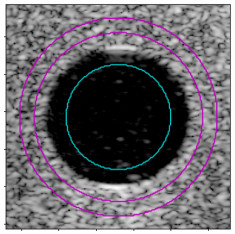
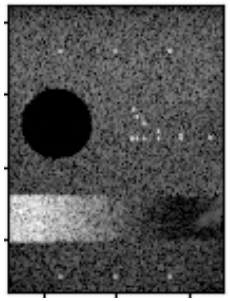


Image Quality Evaluation Metrics

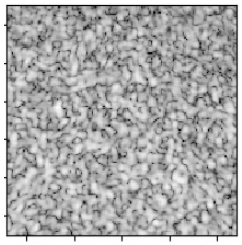
- Lesion targets (8 ROIs)
  - Contrast
  - CNR
  - gCNR



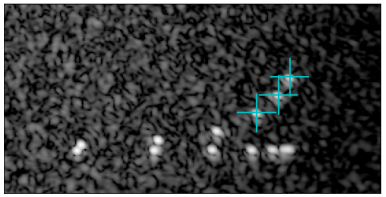
- Image targets (12 images)
  - L1
  - L2
  - PSNR
  - NCC



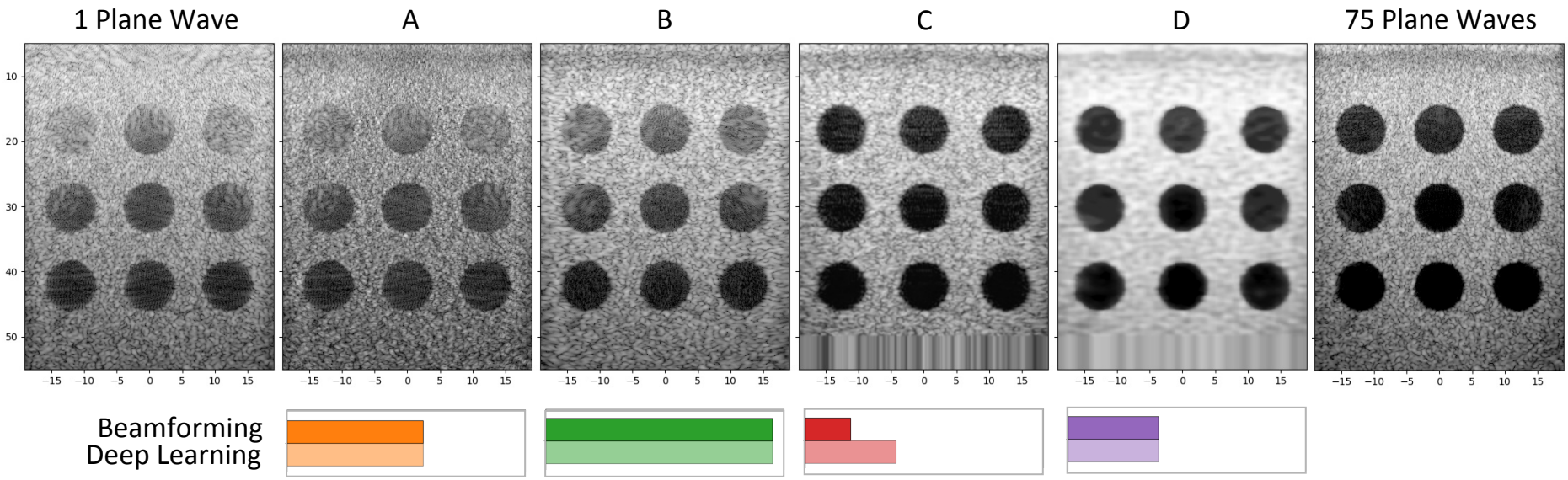
- Speckle targets (6 ROIs)
  - SNR



- Point targets (4 ROIs, 3-5 point targets per ROI)
  - Lateral (x) resolution
  - Axial (z) resolution
  - Average x and z FWHM per ROI

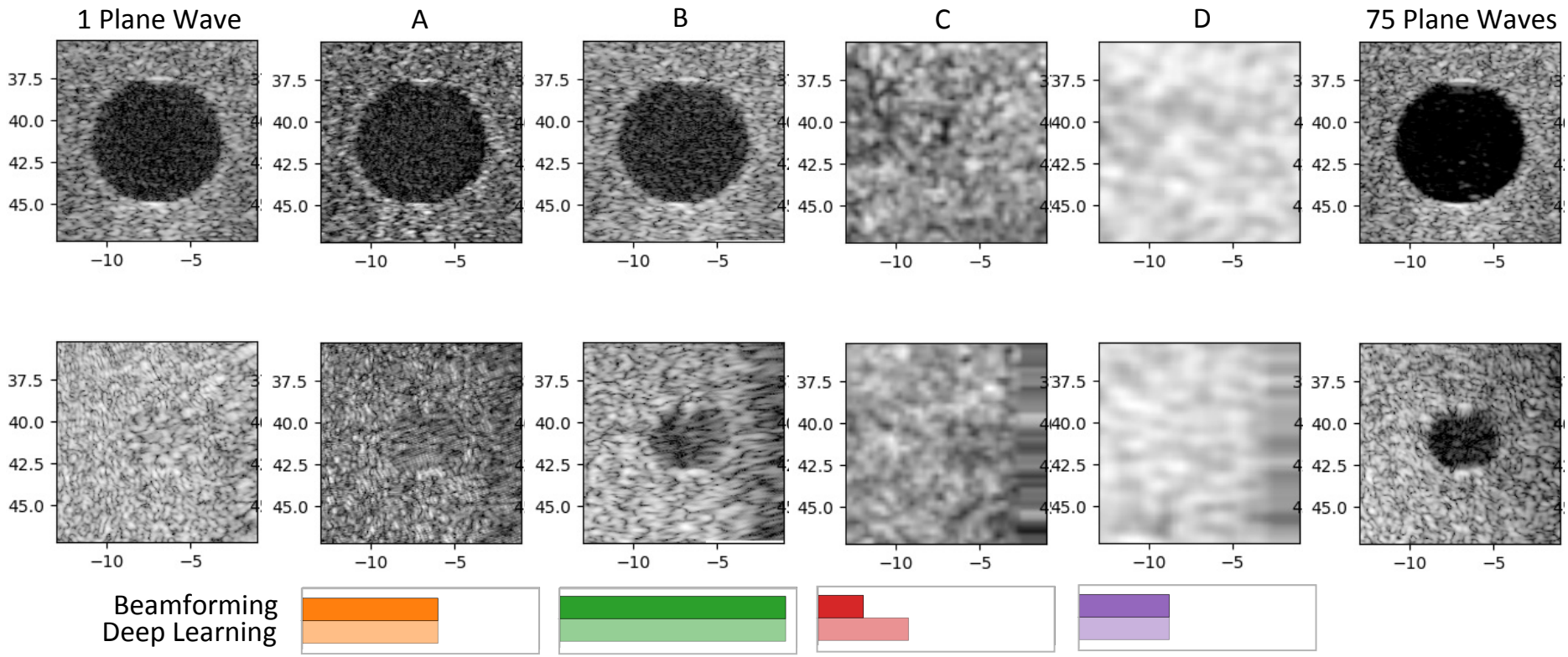


Initial Results: Publicly Available PICMUS[1] Data

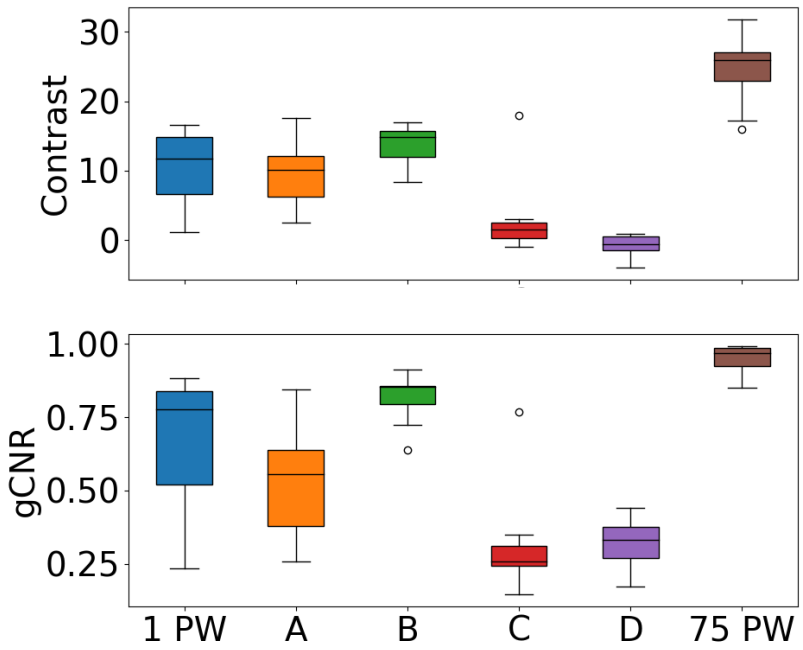


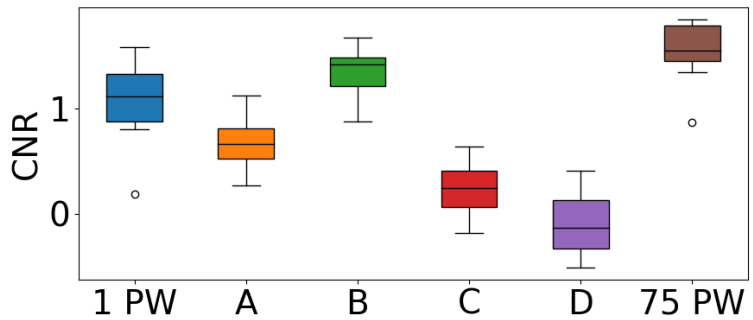
[1] PICMUS, "Plane-wave imaging evaluation framework for medical ultrasound," 2020. [Online]. Available: https://www.creatis.insa-lyon.fr/EvaluationPlatform/picmus/

Lesion Targets



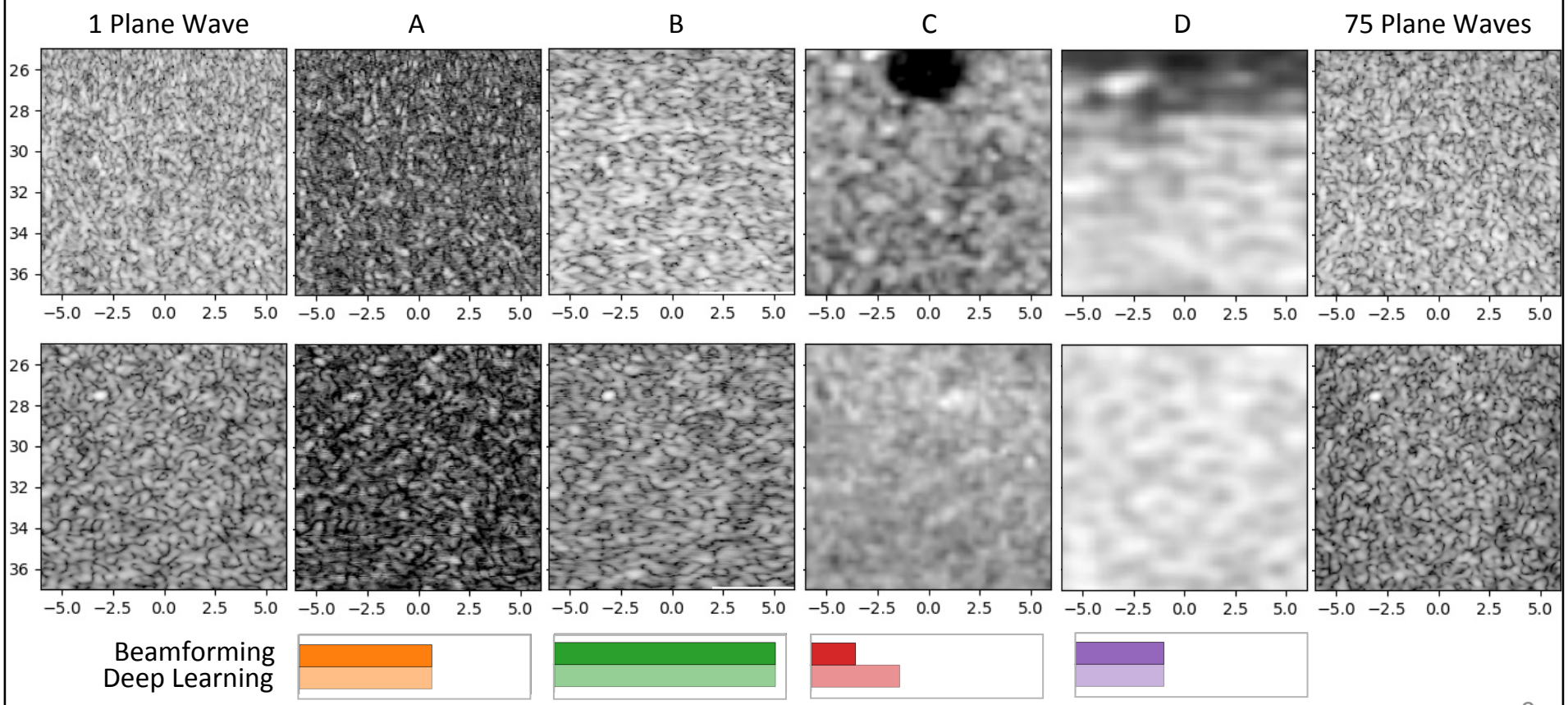
Lesion Visibility Results (8 ROIs)





Higher
(contrast, CNR, gCNR)
is better

Speckle Targets



Speckle SNR (6 ROIs)

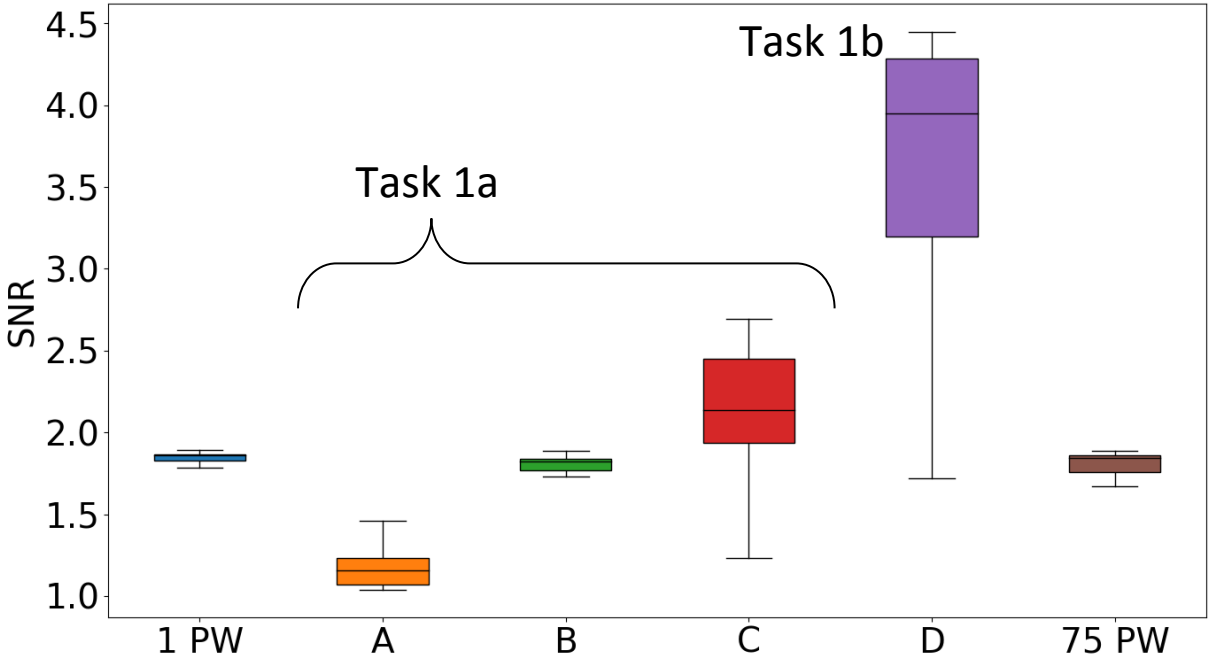
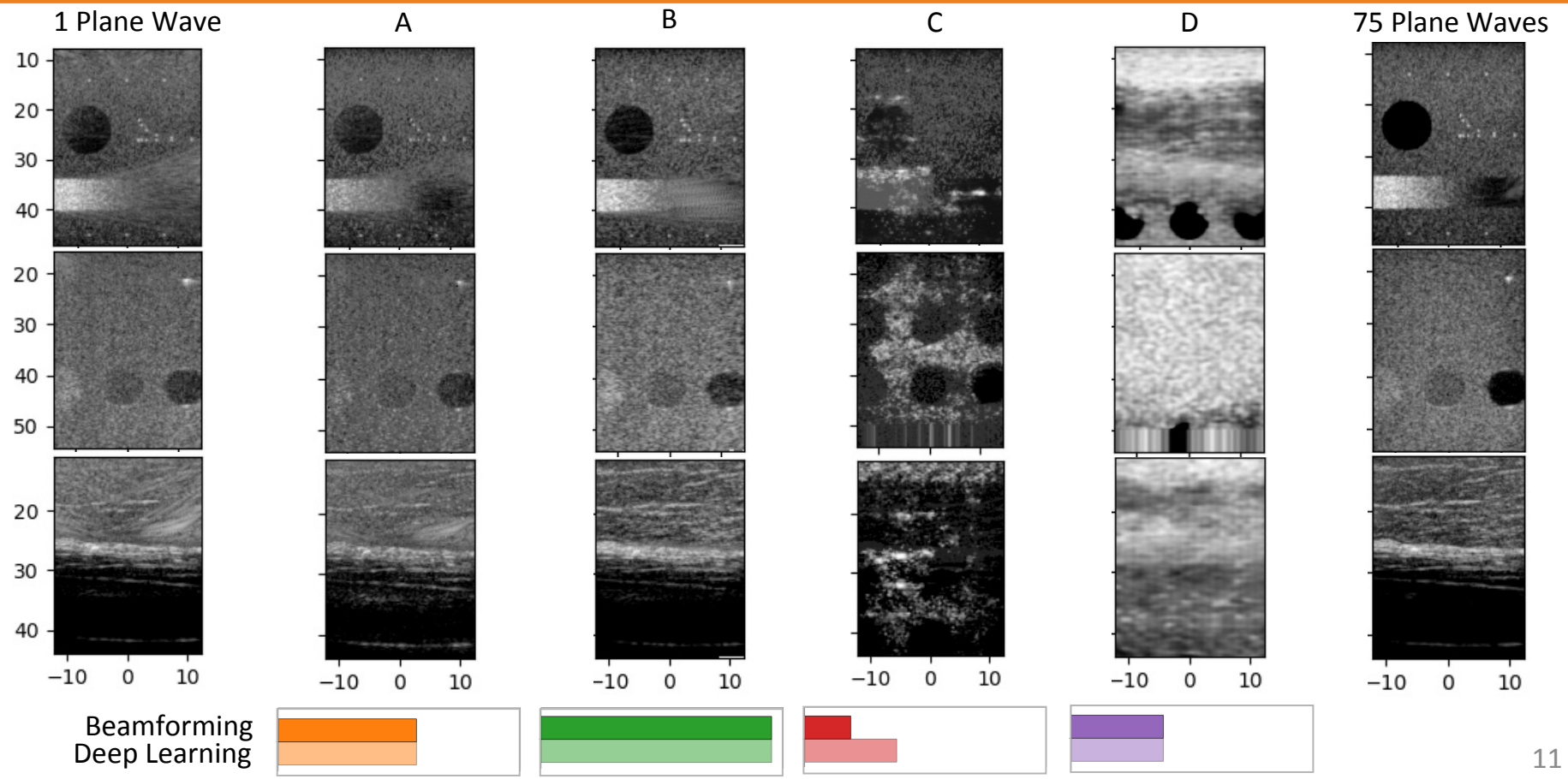
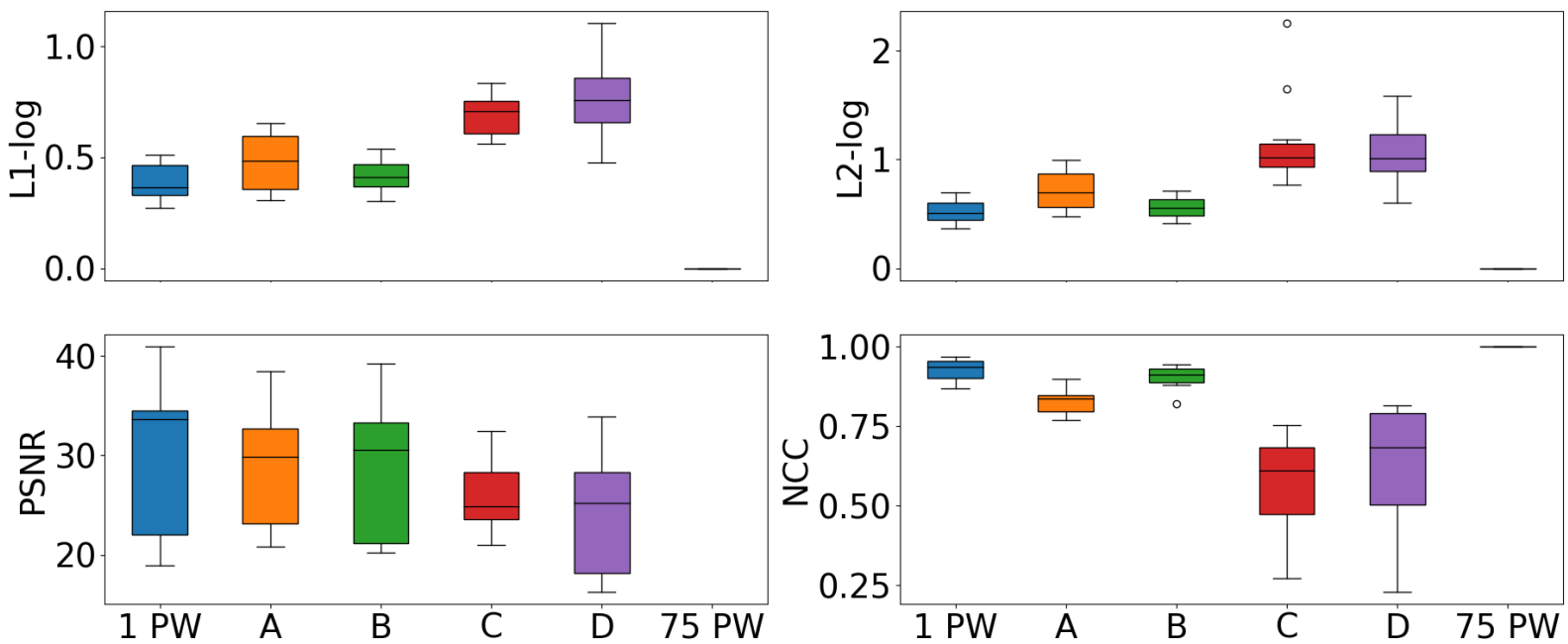


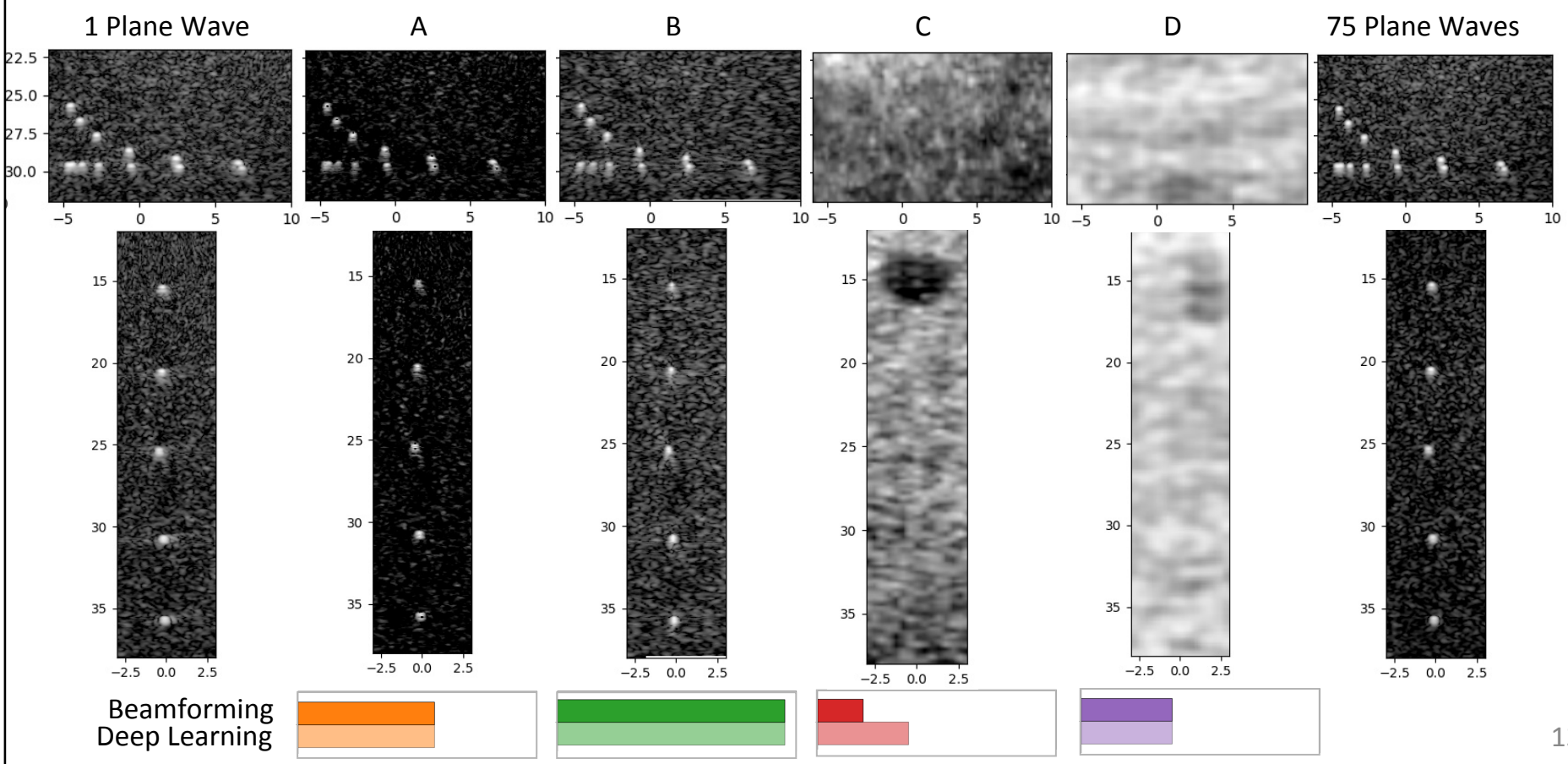
Image Targets



Comparison to 75 Plane Wave Image (12 images total)



Point Targets



Lateral and Axial Resolution (4 ROIs, 3-5 pts per ROI)

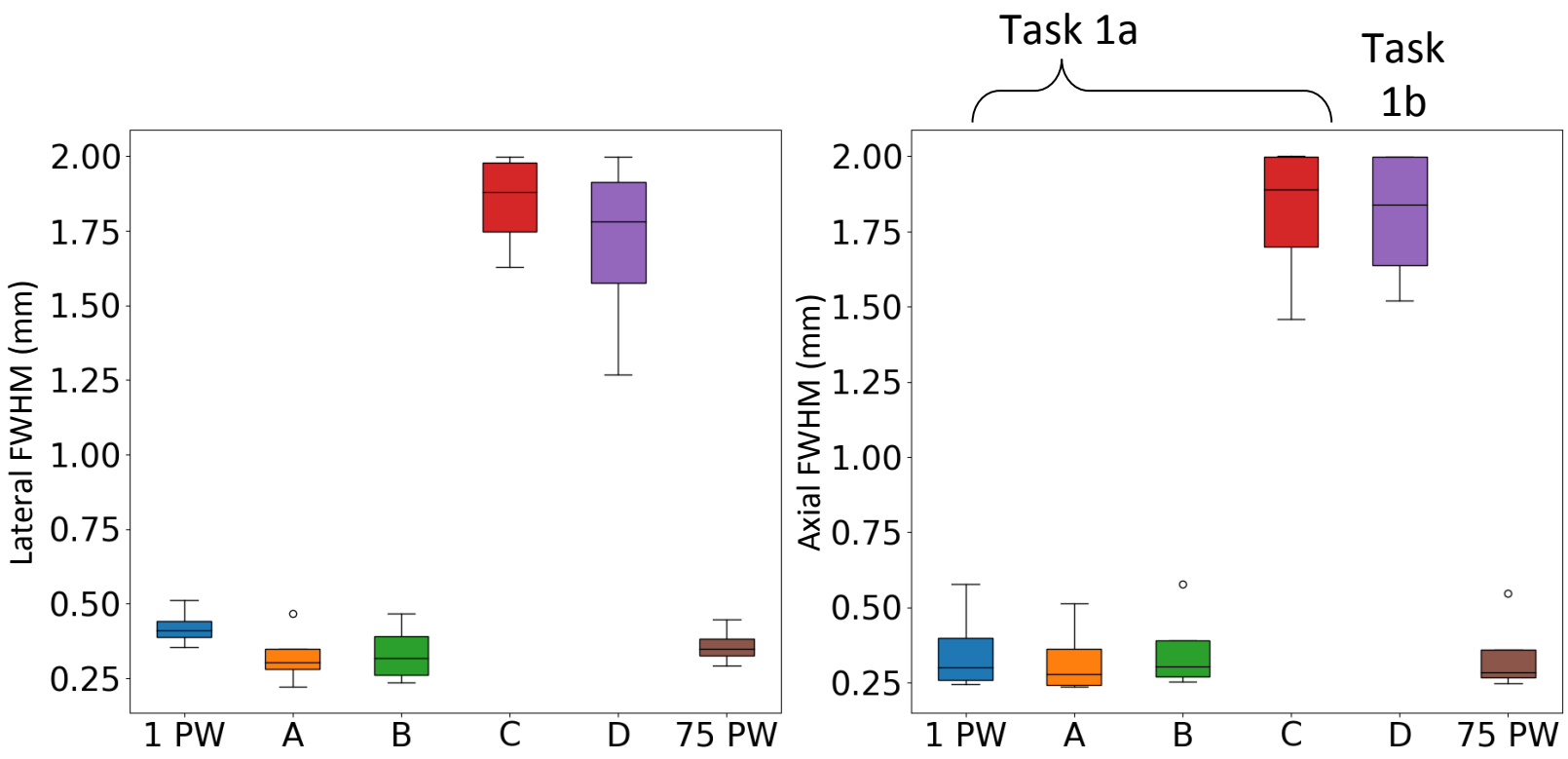
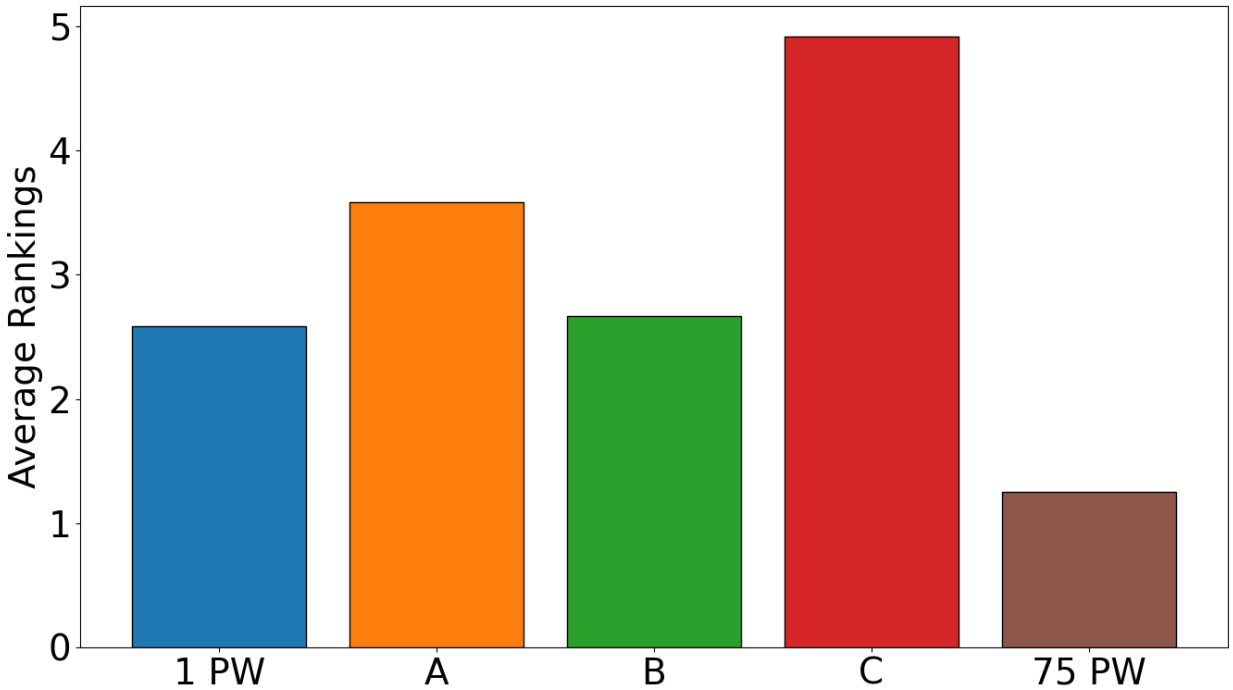


Image Quality Metric Ranks (Task 1a)

$$\text{Final Score} = \boxed{\frac{\sum \text{image quality metric rankings}}{T_{IQ}}} + \frac{\sum \text{Network complexity metric rankings}}{T_{NC}}$$



Rank Order:

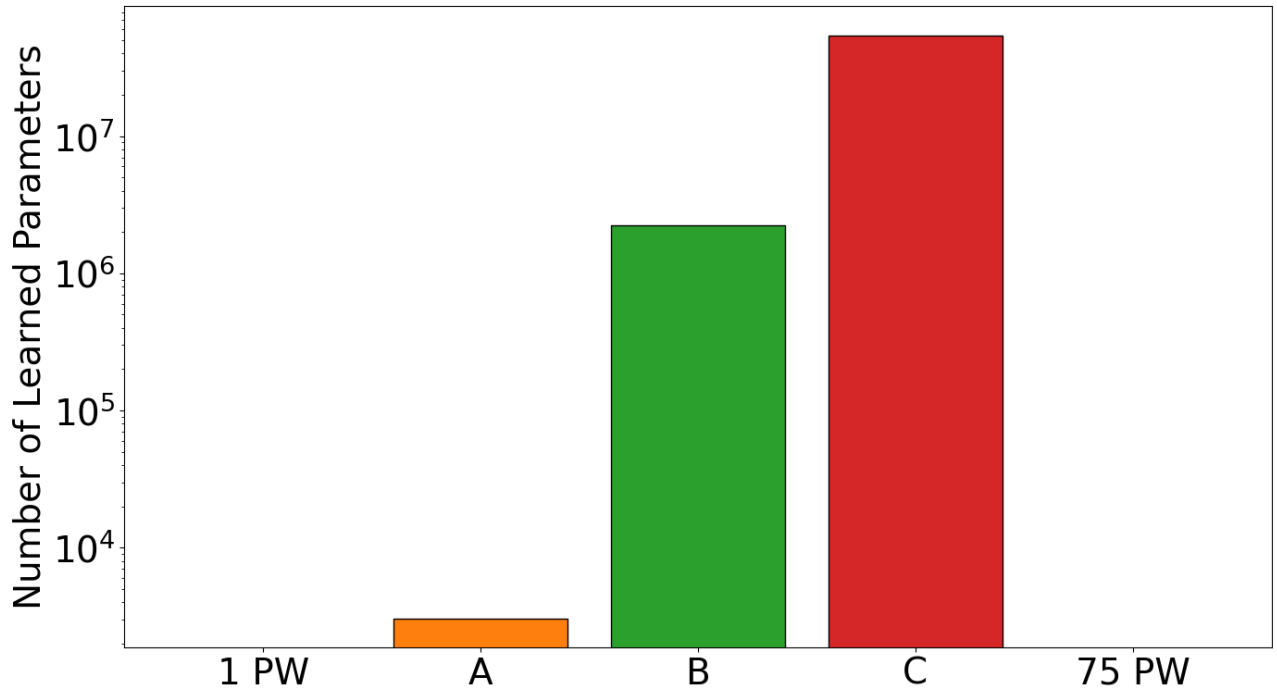
B

A

C

Number of Learned Parameters (Task 1a)

$$\text{Final Score} = \frac{\sum \text{image quality metric rankings}}{T_{IQ}} + \boxed{\frac{\sum \text{Network complexity metric rankings}}{T_{NC}}}$$



Rank Order:

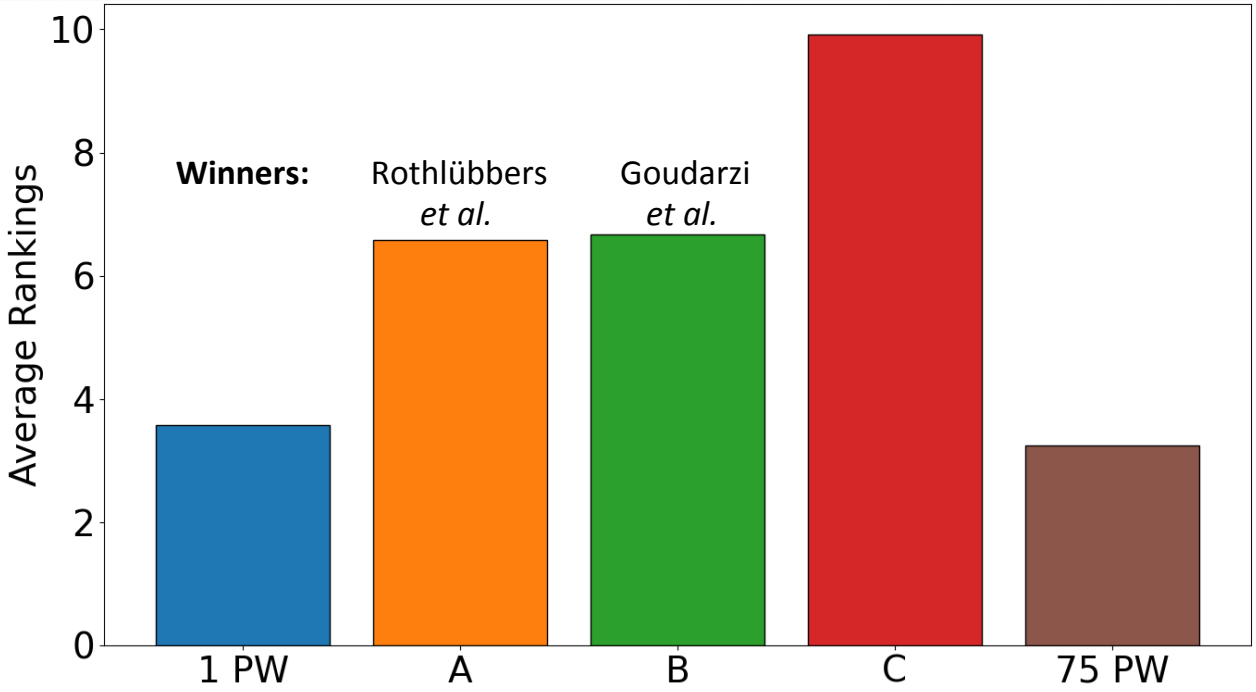
A

B

C

Overall Outcome for Task 1a

$$\text{Final Score} = \frac{\sum \text{image quality metric rankings}}{T_{IQ}} + \frac{\sum \text{Network complexity metric rankings}}{T_{NC}}$$



Rank Order:

A ≈ B

C

Acknowledgements

All 15 Data Contributors from 9 Institutions:

1. Alycen Wiacek
2. Ping Gong
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