ARssist: Augmented Reality on a Head-Mounted Display for the First Assistant in Robotic Surgery
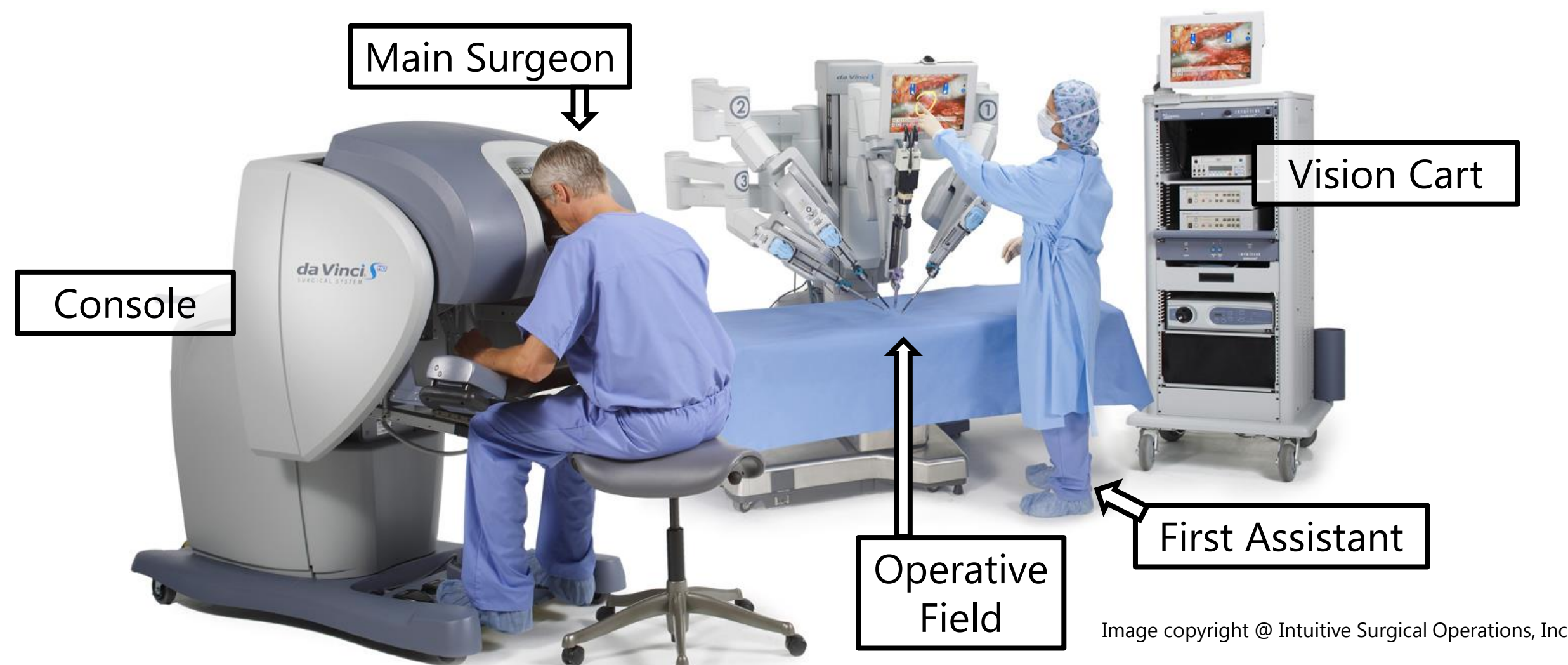
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JOHNS HOPKINS WHITING SCHOOL of ENGINEERING — LABORATORY FOR Computational Sensing + Robotics — dVRK

Objective:

- To improve **efficiency** and **comfort** of the first assistant, by
  - providing guidance to instrument manipulation when it is invisible
  - restoring the hand-eye coordination
  - bringing the stereo endoscopic video closer to the surgery site

The First Assistant (FA):

- An important member of the robotic surgery team

Main Surgeon · Vision Cart · Console · Operative Field · First Assistant
Image copyright @ Intuitive Surgical Operations, Inc

- The **tasks** for the first assistant include:
  - Insufflation and trocar placement
  - Dock and undock the robot
  - Instrument exchange
  - Manipulating laparoscopic instruments, e.g. stapler, grasper
  - Applying hemostatic instruments, e.g. vessel sealer
  - Specimen extraction
- The **current working condition** of the first assistant:

Bad Hand-Eye Coordination
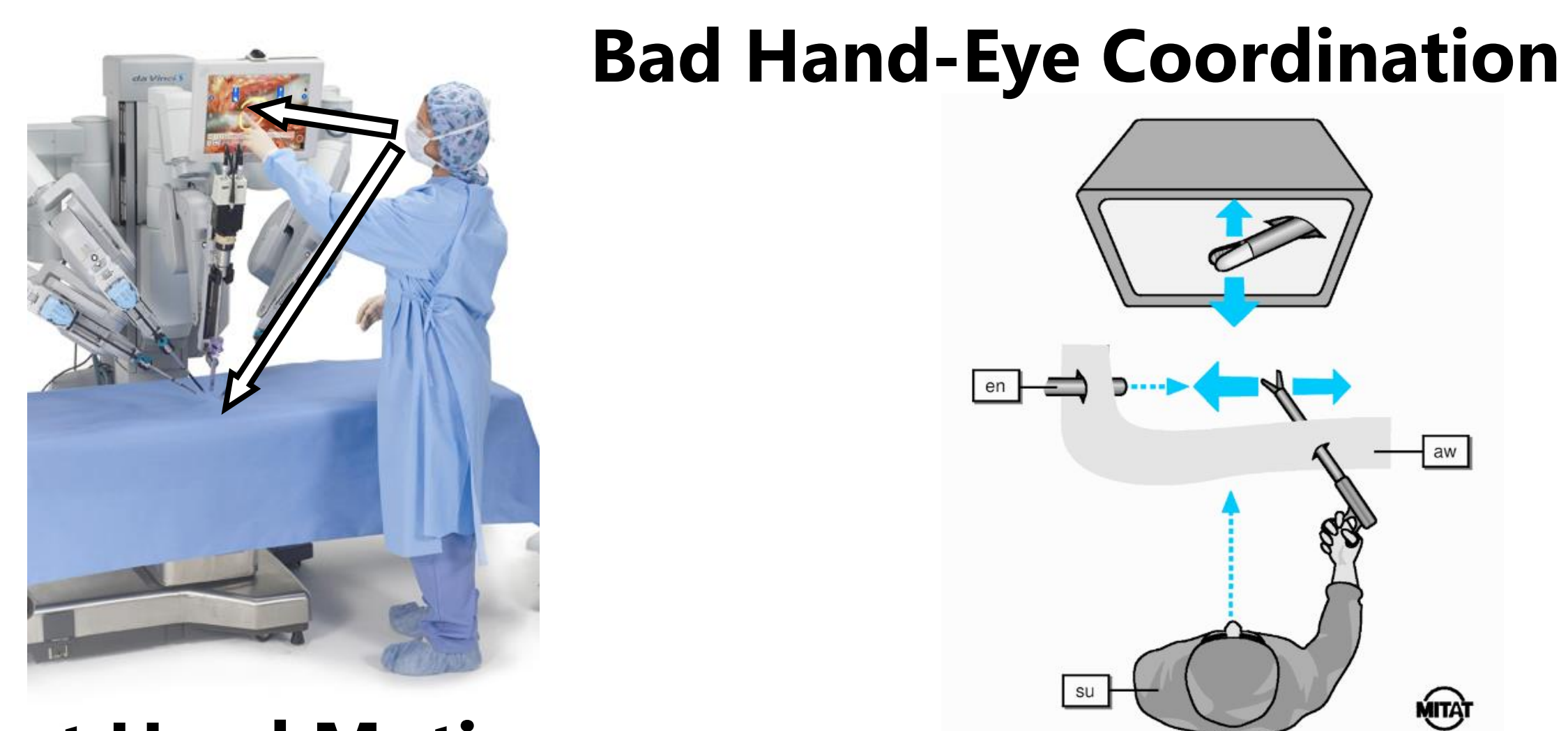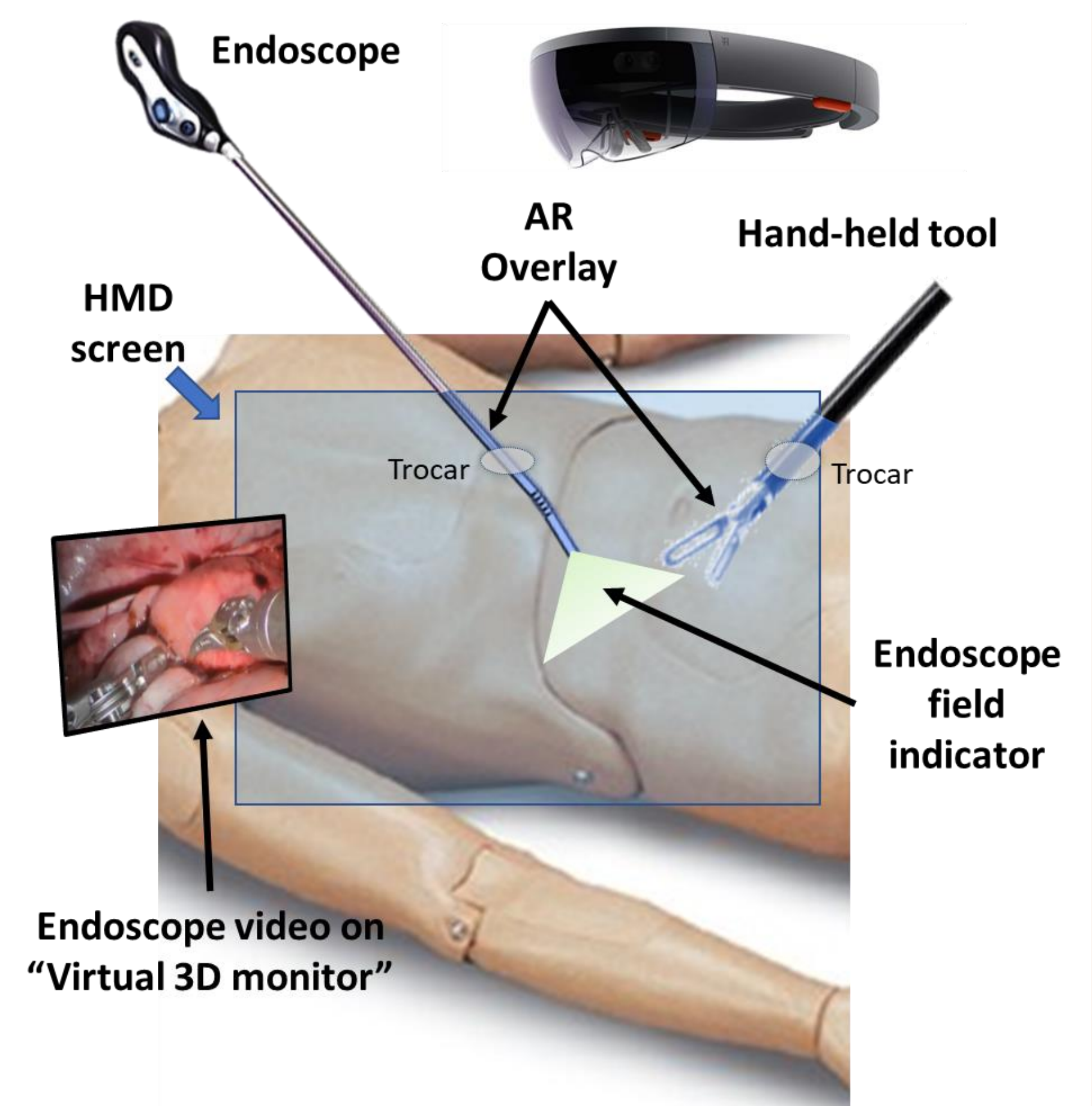

Frequent Head Motion

Image courtesy:
Wentink, Breedveld. "Eye-hand coordination in laparoscopy-an overview of experiments and supporting aids." *Minimally Invasive Therapy & Allied Technologies* 10.3 (2001): 155-162.

Visualization Results:

With a transparent phantom — With drape covered

Endoscopy

Endoscopy visualized as heads-up display

Endoscopy visualized in the frustum of the endoscope

Overlay with hand-held instruments

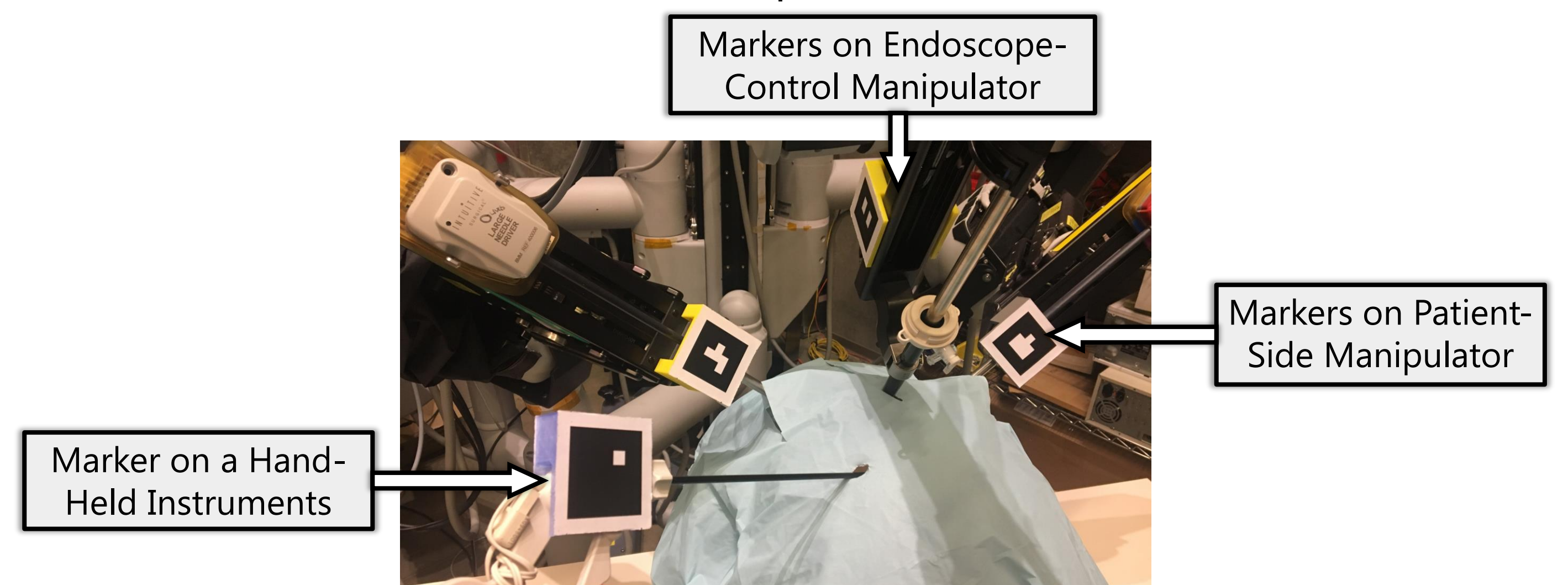Images captured with eye-simulating cameras behind HoloLens

We propose ARssist:

- An Augmented Reality application based on optical see-through head-mounted display
  - "Fail-safe"
  - Unhindered vision of the scene
- It visualizes:
  - Robotic instruments and hand-held instruments "inside" the body
  - Endoscope and its field-of-view indicator
  - Stereo endoscopic video (as heads-up display, as virtual monitor, or projected in the frustum)
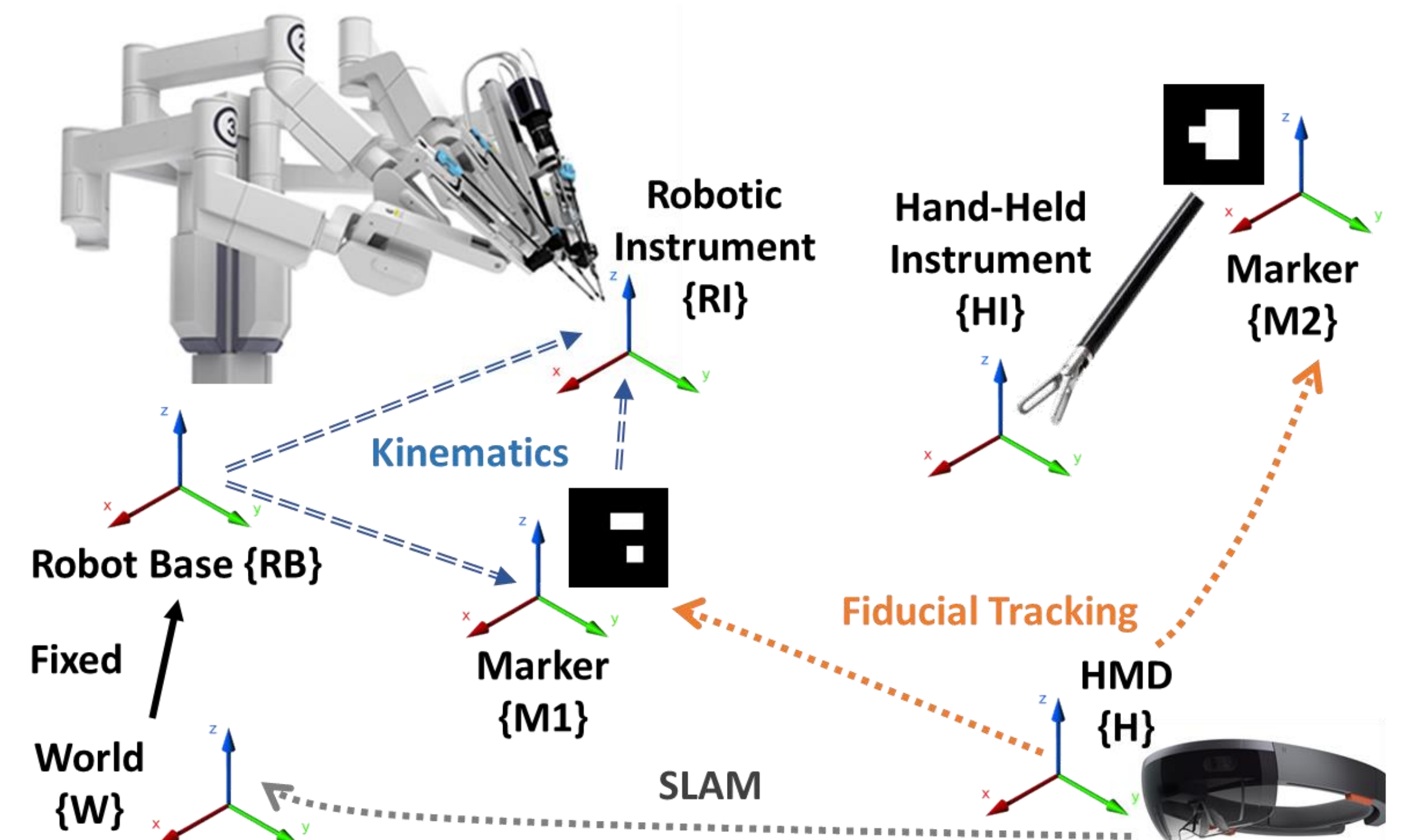

Endoscope · AR Overlay · Hand-held tool · HMD screen · Trocar · Trocar · Endoscope field indicator · Endoscope video on "Virtual 3D monitor"

Implementation:

- Microsoft HoloLens + da Vinci Research Kit (dVRK)
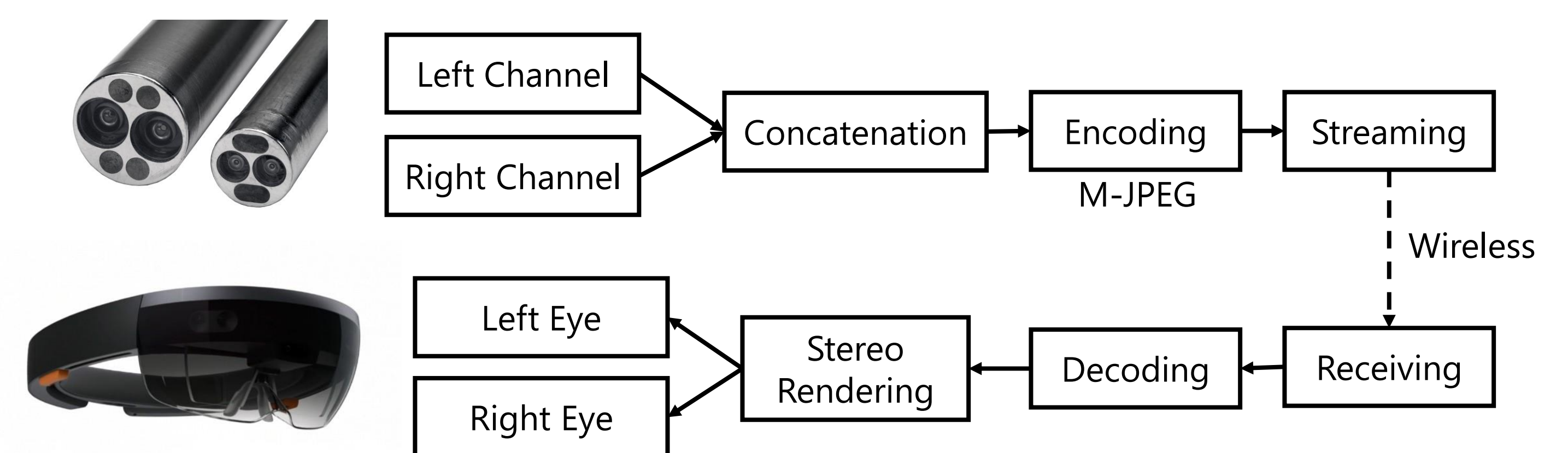- Attach fiducial markers to the manipulators

Markers on Endoscope-Control Manipulator · Markers on Patient-Side Manipulator · Marker on a Hand-Held Instruments

- Tracking of the instruments:
  - Prioritization and static error compensation

Robotic Instrument {RI} · Hand-Held Instrument {HI} · Marker {M2} · Kinematics · Fiducial Tracking · Robot Base {RB} · Fixed · Marker {M1} · HMD {H} · World {W} · SLAM

- Synchronized stereo endoscopy streaming

Left Channel · Right Channel · Concatenation · Encoding · Streaming · M-JPEG · Wireless · Left Eye · Right Eye · Stereo Rendering · Decoding · Receiving
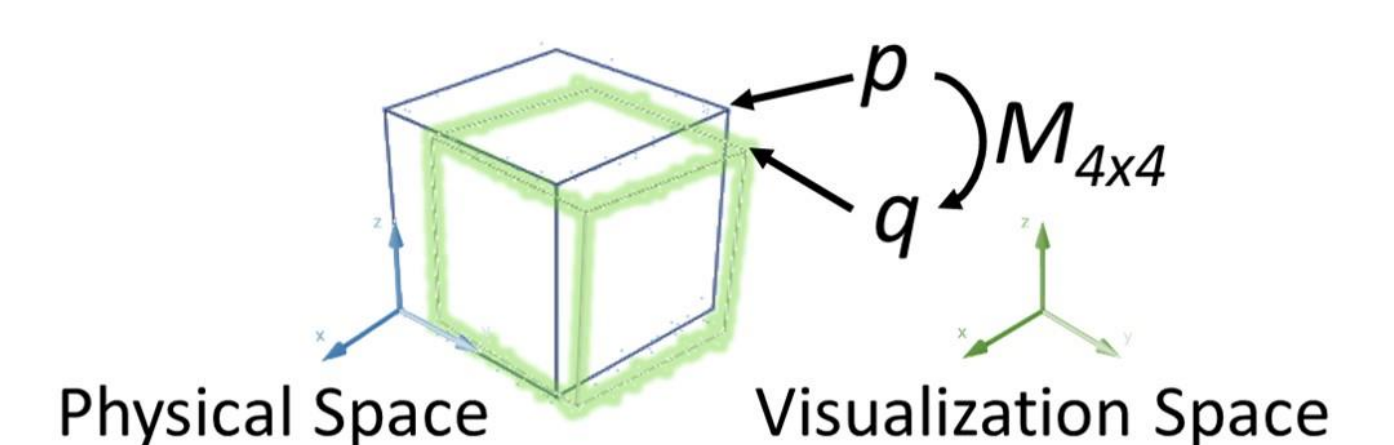
- Field-of-view of endoscope
  - Camera calibration
  - Field-of-view calculation
  - Different endoscope configuraion

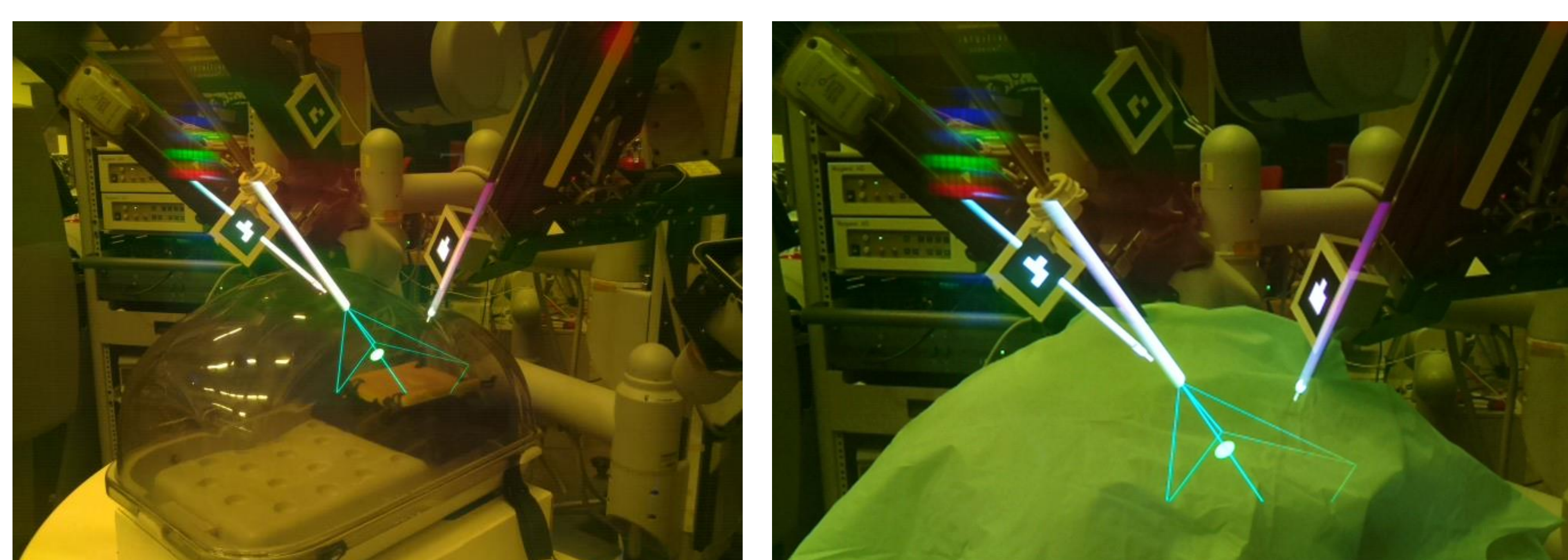$$FOV_v = 2 \cdot \arctan\left(\frac{h}{2f_y}\right) \ , \ FOV_h = 2 \cdot \arctan\left(\frac{w}{2f_x}\right)$$

- Display calibration of the OST-HMD

p q M_{4x4} · Physical Space · Visualization Space

- System performance
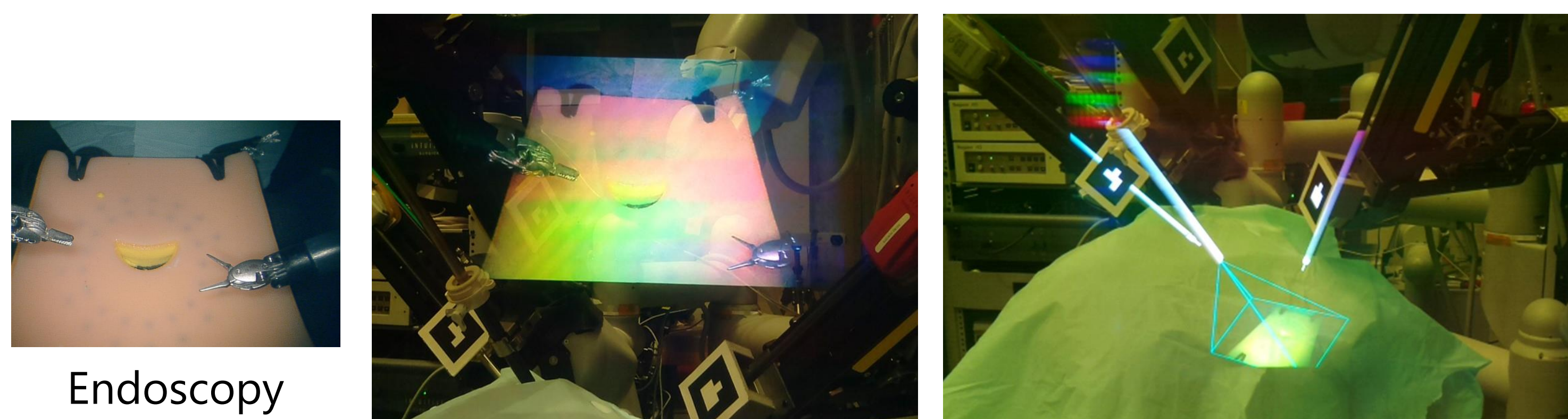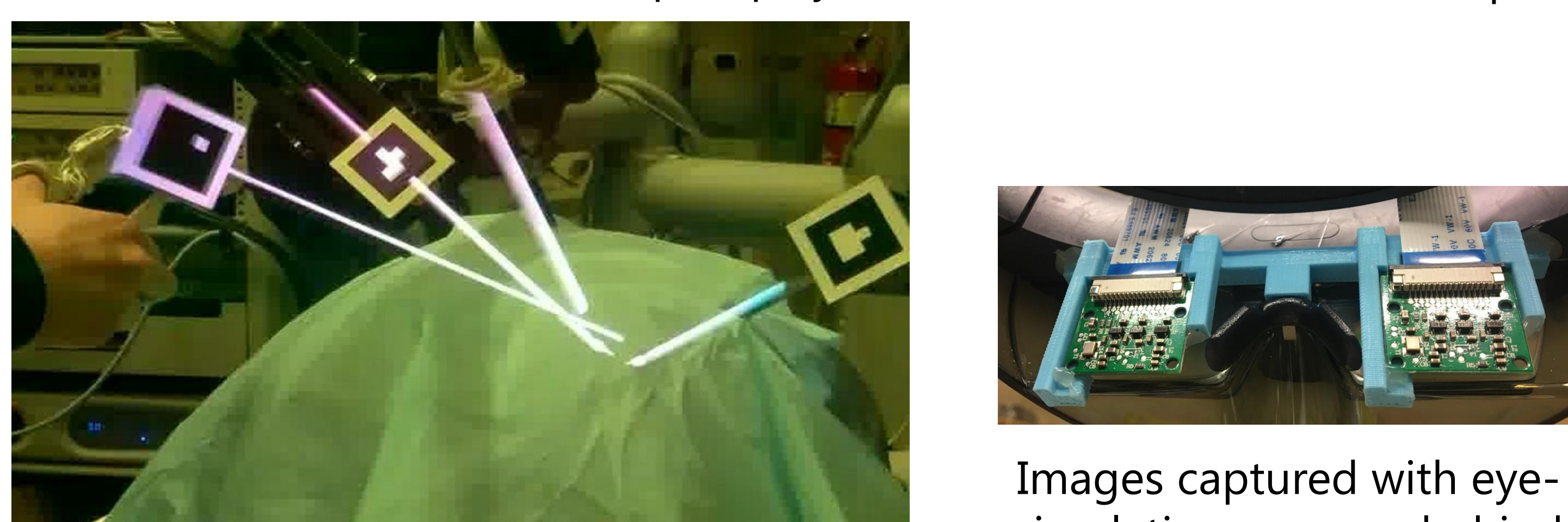 - Latency of overlay: 220.81+25.54 ms
  - Accuracy of overlay: 4.27+3.09 mm
  - Rendering framerate: 32.91+1.96 Hz
  - Tracking framerate: 13.64+0.78 Hz
  - Endoscopic video resolution: 2 x 640 x 360
  - Endoscopic video framerate: 26.57+3.10 Hz