Autonomous Medical Officer Support (AMOS) ISS Technology Demonstration: Enabling Earth-Independent Procedure Guidance

Human Research Program
Exploration Medical Capability Element

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Agenda

- **Problem statement: exploration context**
- **AMOS description**
- **Tech demo**
  - Procedures
  - Results
- **Conclusion**
- **Forward work**


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SSC11

Training Paradigm Shift

Current

Preflight instruction → 26 hours, 6-18 months preflight

Inflight refresher

Inflight procedure

Proposed

Instructional JIT guidance

Preflight:
-JIT tool familiarization
-Selected procedures trained

Inflight:
-Review and use

Autonomous Medical Officer Support (AMOS)

- **Fulfills three functions:**
  1. **Prefight training**
  2. **Onboard just-in-time (JIT) or refresher training**
  3. **Guidance for autonomous medical procedures**
- **Intuitive menu-driven, human-centered, modular design**
- **Coded for flexibility and compatibility with ISS systems**
- **Current modules include kidney and urinary bladder ultrasound**
- **Integrated use tracking and evaluation features**
- **Platform technology - extensible to other subject areas**

Web version of AMOS software available at:
http://comfort2.eastus.cloudapp.azure.com/View/Index/5

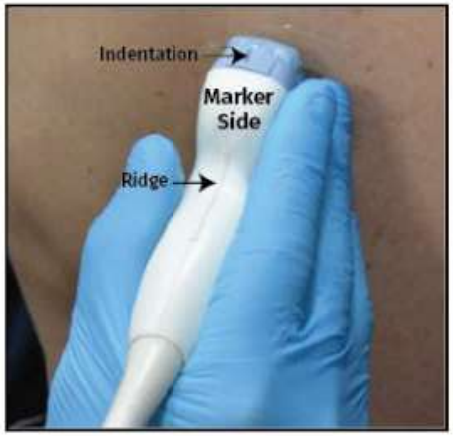
AMOS Purposes and Applications

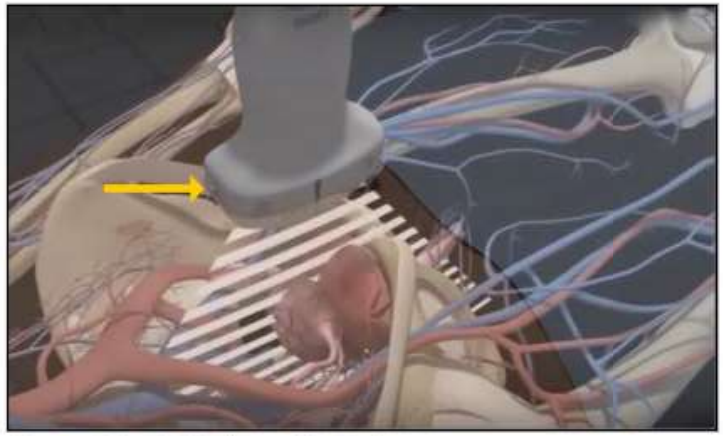
- Enhance telemedicine capability; introduce asynchrony
- Enable autonomous procedure performance
- Streamline the process of skill management
- Reduce preflight training load
- Repeated similar ISS Demos could reduce exploration kidney stone and urinary retention risks (improved monitoring)

Probe Handling: Reference marker

One side (edge) of the probe has a reference marker (a ridge you can see and feel, and an indentation as shown). This elevated ridge on one side of the ultrasound probe relates to one side of the ultrasound screen. The reference marker orients the ultrasound probe to the ultrasound image display. The respective side of the image (the marker side) is identified by the screen indicator.

Each single ultrasound image shows a 2D cut through tissue under the probe (as shown in right Figure with probe and skin on top, marker side on the left screen indicator).





Representation of a 2-D ultrasound imaging beam

The probe marker is oriented towards the subject's head ('up'). Therefore, the top of the bladder is on the left (indicator) side of the image in this vertical view of a bladder.

Right Kidney: Finding the Kidney and the Starting View

STEP 3 OF 11
OPTIMIZE THE RIGHT KIDNEY STARTING VIEW:

A. Apply probe at tzone purple 2 (grid in Figure to right) with probe marker towards the subject's head. (Review probe handing in Foundation section)

B. Look for the kidney (Note that kidneys move with respiration).

C. If not found at once, use rapid meandering up, down, and towards the side of the body. Once the kidney is found, reduce speed and range of probe movement.

D. Apply more gel, reapply probe to same location, and adjust the gain as needed.

E. Slowly move the probe to hover over the kidney, i.e., bring the kidney to the middle of the image with small adjustments.

F. Tune probe position for longest image (left-to-right dimension on the screen) to include upper pole (left on image) and lower pole (right on image) (Review in Foundation section).

G. Translate probe away from spine while keeping the kidney in longest view, optimizing for the widest image (up- down dimension on the screen).

H. Practice tilt-sweeping throughout the volume of the kidney. Longest and widest view is the Starting View (Review in Foundation section).

Ideal Starting View: Note the interruption of the darker tissue at the bottom center of the image, an indication of the longest, widest view.

Finding The Right Kidney and Its Longest, Widest Section. Press play to start video.

PROCEDURE MILESTONE: You have arrived at the Starting View for right kidney imaging- ready to begin right kidney imaging and data collection.

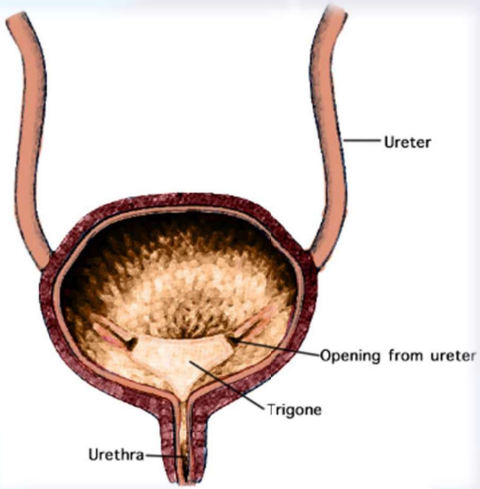
Tech Demo Procedures

- Flown as ExMC/HRP payload – supported by ROI
- AMOS installed with queso service pack (3/31 - 4/2/2020)
- Demos occurred 4/9/2020 (observed remotely - COVID-19) & 6/29/2022
- Crew Procedures:
  - BEFORE scanning, operator reviews AMOS "Foundations" material
  - Deploy Ultrasound2 per nominal procedures
  - Set up cabin video
  - Open AMOS application
  - Perform bladder scan (full), perform bladder scan (post void)
  - Perform kidney scan (right and left)

AMOS Tech Demo Objectives

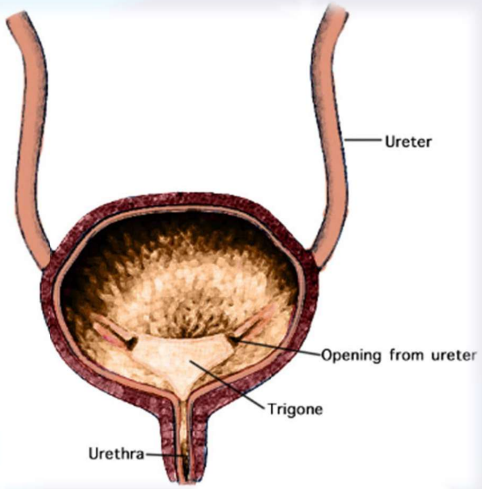
- ✓**Installation / use of AMOS in the ISS server environment (IT objective)**
- ✓**Use of AMOS for autonomous imaging in operational setting (telemedicine proof of concept objective)**
  - ✓Obtain click tracking data
  - ✓Collect ultrasound images - urinary bladder and kidneys (irrespective of quality or compliance)
- ✓**Collect crew feedback – AMOS implementation (telemedicine and AMOS improvement objective)**
- ✓**Record in-cabin and ultrasound scanhead video data – technical and human factors assessment (telemedicine and AMOS improvement objective)**
- ✓**Collect crew feedback – integrated training and procedure support (training, telemedicine, and AMOS improvement objective)**

AMOS – Bladder Results (N=2 operators/subjects)

	NUMBER OF INSTANCES (CINE-LOOPS)	PROCEDURE EXECUTION (0-3)	INCLUSION OF TARGET ORGAN VOLUME (0-3)	IMAGING PLANE ORIENTATION (0-3)	SWEEP SPEED ADEQUACY (0-3)	AVERAGE IMAGE QUALITY (0-3)	MEASURABILITY (0-3)	EFFECTIVE IMAGING CONTENT (0-3)	SUCCESS SCORE (0-3)	SUCCESS (Y/N)
Demo 1	12	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	Y
Demo 2	12*	2.5	3.0	3.0	3.0	2.3	2.3	2.5	2.4	Y

* Three instances were not included in the analysis; operator self-corrected labeling and replaced these images

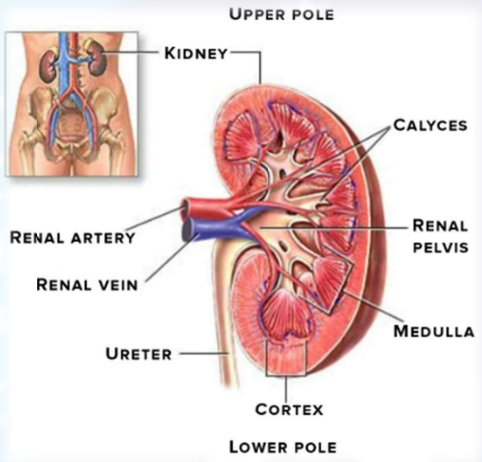
Demo 2 – Bladder Results (N=1 operator/subject)

	NUMBER OF INSTANCES (CINE-LOOPS)	PROCEDURE EXECUTION (0-3)	INCLUSION OF TARGET ORGAN VOLUME (0-3)	IMAGING PLANE ORIENTATION (0-3)	SWEEP SPEED ADEQUACY (0-3)	AVERAGE IMAGE QUALITY (0-3)	MEASURABILITY (0-3)	EFFECTIVE IMAGING CONTENT (0-3)	SUCCESS SCORE (0-3)	SUCCESS (Y/N)
Full bladder Horizontal	3	3	3	3	3	3	3	3	3	Y
Full bladder Vertical	3	3	3	3	3	3	3	3	3	Y
Post-void Horizontal	3	2	3	3	3	1	1	2	1.5	N
Post-void Vertical	3	2	3	3	3	2	2	2	2	Y
TOTAL NUMBERS AND AVERAGE SCORES	12	2.5	3.0	3.0	3.0	2.3	2.3	2.5	2.4	Y

Failure analysis (Demo 2 - bladder)

- **Operator initiated “end exam” as written in the procedure**
  - Instructions to skip “end exam” were in the execute note (**different location**)
  - Operator feedback: include an “if performing an additional exam” statement
- **Default preset was incorrect, operator did not notice**
  - Gain, depth, other settings incorrect
  - Still sufficient to rule out full bladder but did not meet ‘pass criteria’
- **Incorrect preset persisted into Kidney exam**
  - Intervention: requested that operator check the “verify settings” page

AMOS – Kidney Results (N=2 operators/subjects)

	NUMBER OF INSTANCES (CINE-LOOPS)	PROCEDURE EXECUTION (0-3)	INCLUSION OF TARGET ORGAN VOLUME (0-3)	IMAGING PLANE ORIENTATION (0-3)	SWEEP SPEED ADEQUACY (0-3)	AVERAGE IMAGE QUALITY (0-3)	MEASURABILITY (0-3)	EFFECTIVE IMAGING CONTENT (0-3)	SUCCESS SCORE (0-3)	SUCCESS (Y/N)
Right - Demo 1	10	3.0	3.0	2.0	3.0	2.6	1.8	3.0	2.8	Y
Right - Demo 2	6	2.3	2.3	2.7	2.5	2.5	2.2	2.3	2.4	Y
Left - Demo 1	6	2.9	3.0	2.0	2.5	2.6	1.7	3.0	2.8	Y
Left - Demo 2	6	2.4	2.4	2.3	2.5	2.5	2.1	2.3	2.4	Y

Demo 2 – Right Kidney Results (N=1 operator/subject)

RIGHT KIDNEY INSTANCE (CINE-LOOP #)	PROCEDURE EXECUTION (0-3)	INCLUSION OF TARGET ORGAN VOLUME (0-3)	IMAGING PLANE ORIENTATION (0-3)	SWEEP SPEED ADEQUACY (0-3)	AVERAGE IMAGE QUALITY (0-3)	MEASURABILITY (0-3)	EFFECTIVE IMAGING CONTENTS (0-3)	SUCCESS SCORE (0-3)	SUCCESS (Y/N)
Instance 1	3	3	3	3	3	3	3	3	Y
Instance 2	3	3	3	3	3	3	3	3	Y
Instance 3	3	3	3	3	3	3	3	3	Y
Instance 4 - Doppler	1	1	2	2	2	0	1	1.5	N
Instance 5 - Doppler	2	2	3	2	2	2	2	2	Y
Instance 6 - Doppler	2	2	2	2	2	2	2	2	Y
AVERAGE SCORES	2.3	2.3	2.7	2.5	2.5	2.2	2.3	2.4	Y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4051
GRIP
CHAIR
4078
4078
KIELI


esa
Columbus Toolbox
ThalesAlenia Space

Demo 2 – Left Kidney Results (N=1 operator/subject)

RIGHT KIDNEY INSTANCE (CINE-LOOP #)	PROCEDURE EXECUTION (0-3)	INCLUSION OF TARGET ORGAN VOLUME (0-3)	IMAGING PLANE ORIENTATION (0-3)	SWEEP SPEED ADEQUACY (0-3)	AVERAGE IMAGE QUALITY (0-3)	MEASURABILITY (0-3)	EFFECTIVE IMAGING CONTENTS (0-3)	SUCCESS SCORE (0-3)	SUCCESS (Y/N)
Instance 1	3	3	2	3	3	3	3	3	Y
Instance 2	3	3	2	3	3	3	3	3	Y
Instance 3	3	2	2	3	3	3	3	3	Y
Instance 4 - Doppler	2	3	2	2	2	1	2	2	Y
Instance 5 - Doppler	2	2	2	2	2	1	2	2	Y
Instance 6 - Doppler	2	2	1	2	2	1	1	1.5	N
AVERAGE SCORES	2.3	2.3	2.7	2.5	2.5	2.2	2.3	2.4	Y

Failure analysis (Demo 2 - kidney)

- **Operator inadvertently inverted image left-right**
  - –Does not affect image quality, correctable
  - –Reverses action on screen, likely disorienting
- **Complex interface (soft keys) likely explanation**
  - –Inadvertent setting change not noticed
  - –Subsequent exams affected

Interface Instruction Comparison

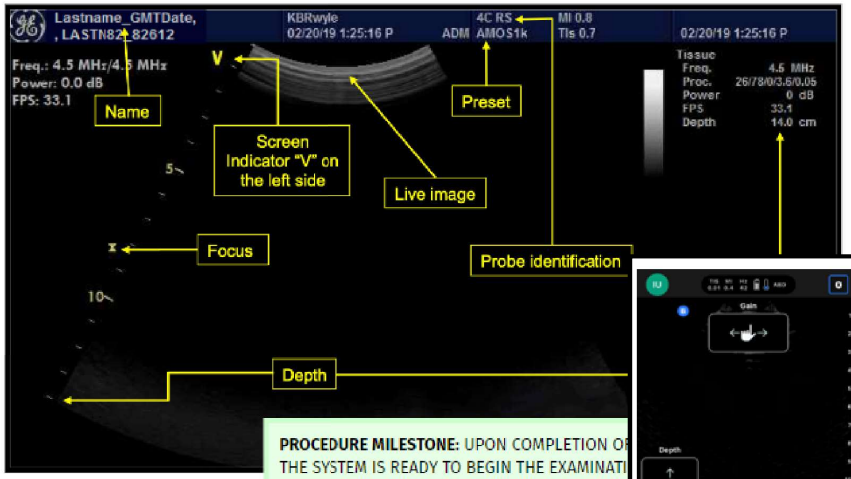
Ultrasound Machine

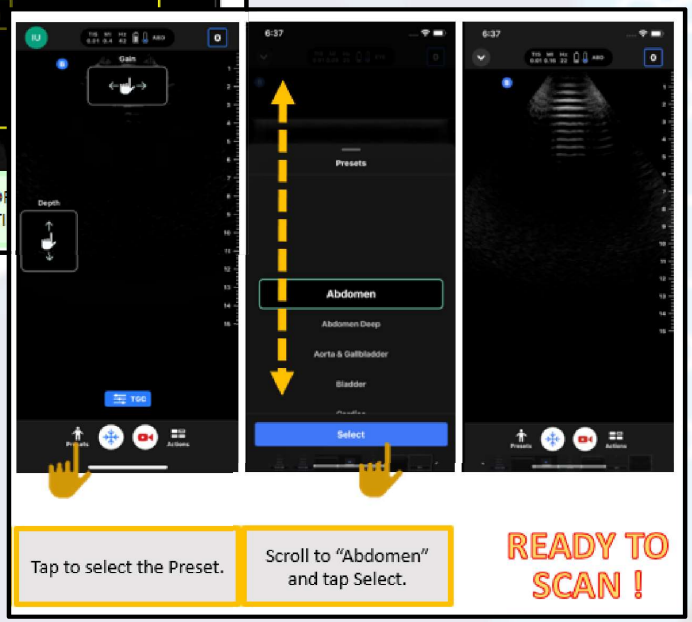
STEP 3 OF 4

VERIFY ULTRASOUND SETTINGS

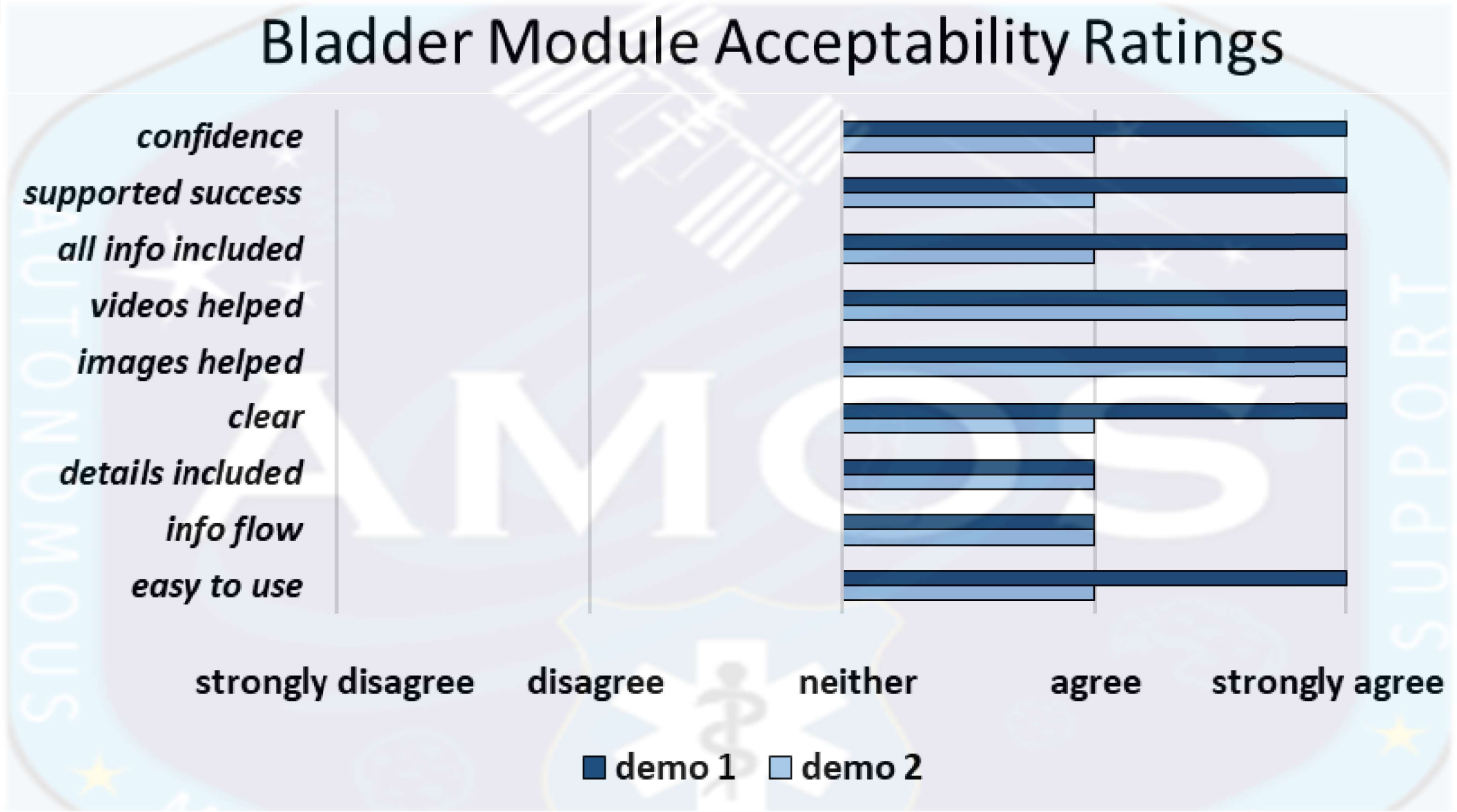
The screen must appear as shown here. **Verify that:**

- **Live image is displayed** (system not frozen due to inactivity): **parallel lines on image change when probe face touched with gel.**
  - If the system is frozen, push **BROWN2(** Freeze).
- **Verify the name: AMOS Demo _GMT Date**
  - If incorrect, follow End Exam steps B-D, and Create New Patient.
- **Probe is correctly identified as 4C RS**
  - If incorrect, replace probe with the 4C RS probe.
- **Preset selected is "AMOS1kb-Abdominal** (preset will show truncated "**AMOS1k**").
  - If incorrect, push **PINK2 (**Application); move **TRACKBALL** to highlight 4C RS probe; push **SET (**Trackball Area); move **TRACKBALL** to highlight correct preset; push **SET (**Trackball Area).
- **"Yellow V" (**Screen Indicator**) is on the left side.**
  - If incorrect, push **BROWN2 (**Freeze), then ***PURPLE3 Down (****Left*/*Right*), then **BROWN2 (**Freeze).
- **Depth is in 12-15 cm range** (14 in this example)
  - Push **BLUE2** Up to reduce, **BLUE2** Down to increase
- **Focus marker is at 5-9 cm range** (8.5 in this example)
  - Push **PURPLE5 Right (**Move Up) or **Left (**move Down).





Bladder Module Acceptability Ratings



Kidney Module Acceptability Ratings

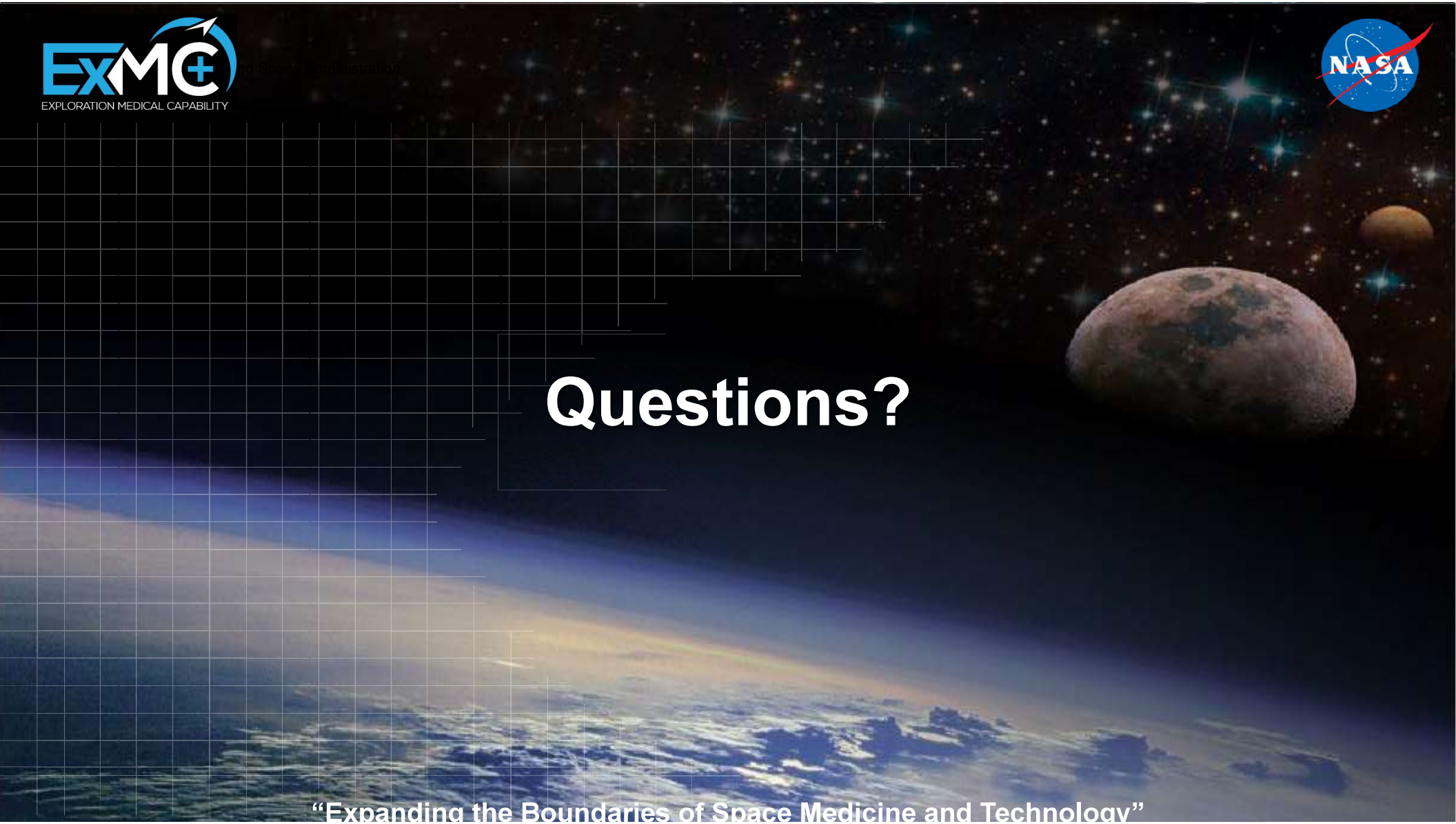
Conclusion

- Initial AMOS demonstrations highly successful
  - All objectives met
  - Bladder and kidney images = most acceptable to excellent
  - Crew feedback = excellent
- Procedure weakness exposed – related to modular nature
- Complex interface can negatively affect performance
- AMOS platform promising as autonomy-enabling tool
  - Exploration
  - Ideal for gradual integration into operations / gain confidence
    - Crew, Surgeon, Ops community, Programs

Forward Work

Recommending further AMOS testing and development

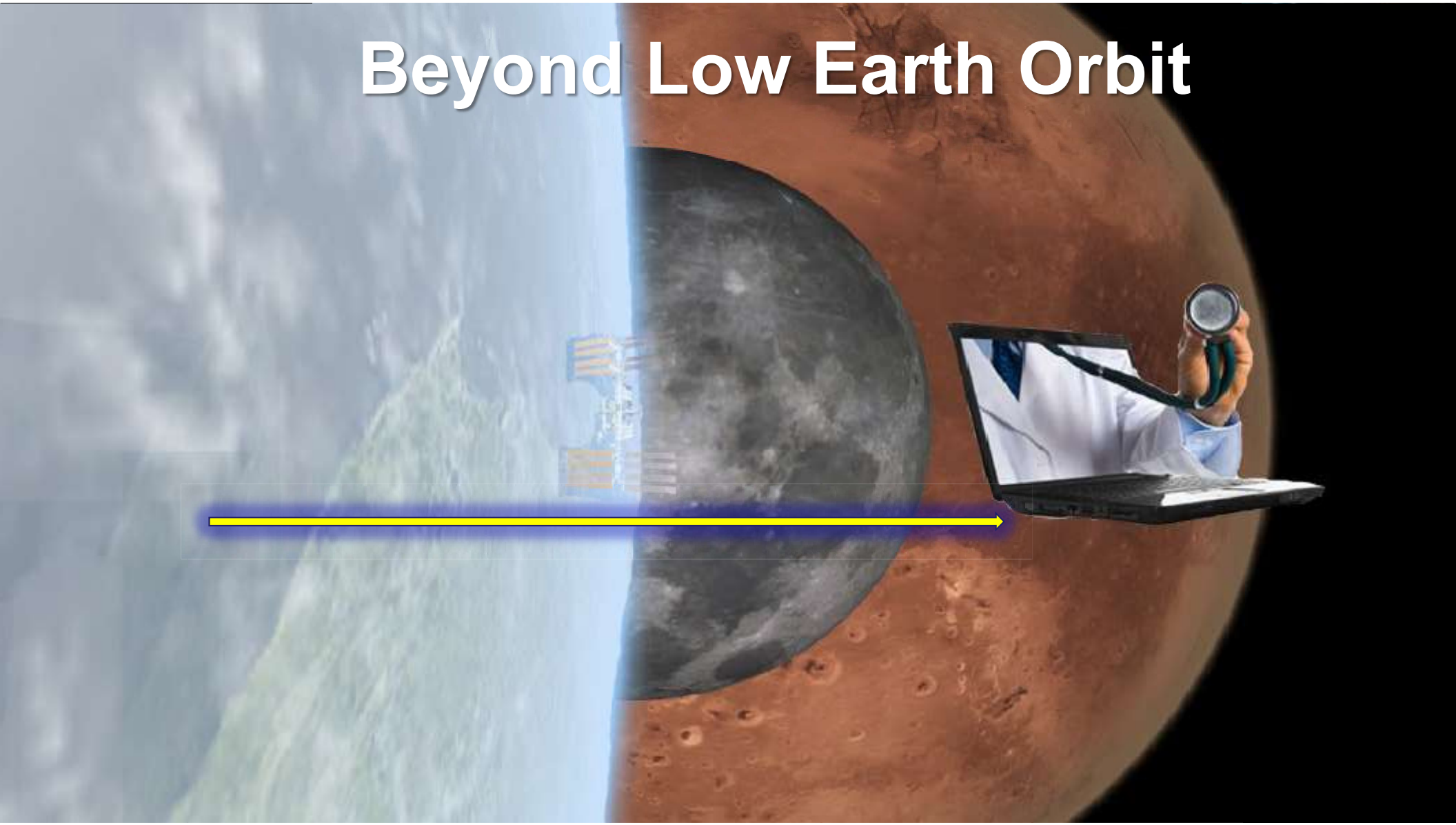
- **Near term: Repeated performance of AMOS kidney and bladder modules by crew with varied background and experience (validation)**
- **Longer term: Additional modules, integration with diagnostic functions, data systems, specific hardware, SME editing, analogs**


EXPLORATION MEDICAL CAPABILITY
NASA
Questions?
“Expanding the Boundaries of Space Medicine and Technology”

Backup

Now: ISS Operations

Beyond Low Earth Orbit



Training and autonomous guidance tool

Fundoscopy

Kidney and Bladder Ultrasound

ILMA Intubation

Ultrasound Guided IV Access

Diagnosis and Treatment

Demo 1 – Bladder Results (N=1 operator/subject)

EVALUATED DICOM INSTANCE GROUPS	NUMBER OF INSTANCES (CINE-LOOPS)	PROCEDURE EXECUTION (0-3)	INCLUSION OF TARGET ORGAN VOLUME (0-3)	IMAGING PLANE ORIENTATION (0-3)	SWEEP SPEED ADEQUACY (0-3)	AVERAGE IMAGE QUALITY (0-3)	MEASURABILITY (0-3)	EFFECTIVE IMAGING CONTENT (0-3)	SUCCESS SCORE (0-3)	SUCCESS (Y/N)
Full bladder Horizontal	3	3	3	3	3	3	3	3	3	Y
Full bladder Vertical	3	3	3	3	3	3	3	3	3	Y
Post-void Horizontal	3	3	3	3	3	3	3	3	3	Y
Post-void Vertical	3	3	3	3	3	3	3	3	3	Y
TOTAL NUMBERS AND AVERAGE SCORES	12	3	3	3	3	3	3	3	3	Y

Demo 1 – Right Kidney Results (N=1 operator/subject)

EXPLORATION MEDICAL CAPABILITY

RIGHT KIDNEY INSTANCE (CINE-LOOP #)	PROCEDURE EXECUTION (0-3)	INCLUSION OF TARGET ORGAN VOLUME (0-3)	IMAGING PLANE ORIENTATION (0-3)	SWEEP SPEED ADEQUACY (0-3)	AVERAGE IMAGE QUALITY (0-3)	MEASURABILITY (0-3)	EFFECTIVE IMAGING CONTENTS (0-3)	SUCCESS SCORE (0-3)	SUCCESS (Y/N)
Instance 1(0001)	3	2	1	3	2	0	2	2	Y
Instance 2 (0002)	3	2	2	3	3	1	2	2	Y
Instance 3 (0003)	3	2	1	3	2	2	2	2	Y
Instance 4 (0004)	3	2	2	3	3	2	3	2.5	Y
Instance 5 (0005)	3	2	2	3	2	1	2	2	Y
Instance 6 (0006)	3	1	2	3	1	0	1	1	N
*Instance 7 (0037)	3	3	2	3	3	3	3	3	Y
*Instance 8 (0038)	3	3	3	3	3	3	3	3	Y
*Instance 9 (0039)	3	3	3	3	3	3	3	3	Y
*Instance 10 (0040)	3	3	2	3	3	3	3	3	Y
AVERAGE SCORES	3	3	2	3	2.6	1.8	3	2.8	Y

Demo 1 – Left Kidney Results (N=1 operator/subject)

TARGET ORGAN; ACTIVITY; INSTANCE (CINE-LOOP #)	PROCEDURE EXECUTION (0-3)	INCLUSION OF TARGET ORGAN VOLUME (0-3)	IMAGING PLANE ORIENTATION (0-3)	SWEEP SPEED ADEQUACY (0-3)	AVERAGE IMAGE QUALITY (0-3)	MEASURABILITY (0-3)	EFFECTIVE IMAGING CONTENTS (0-3)	SUCCESS SCORE (0-3)	SUCCESS (Y/N)
Kidney Left Instance 1 (0010)	3	2	2	2	3	2	2	2	Y
Instance 2 (0011)	3	2	1	1	2	0	1	1.5	N
Instance 3 (0012)	2	1	1	1	2	0	1	1.5	N
Instance 4 (0013)	3	3	3	2	3	3	2	2.5	Y
Instance 5 (0014)	3	2	3	3	3	2	3	2.5	Y
Instance 6 (0015)	3	3	3	3	3	3	3	3	Y
AVERAGE SCORES	2.8	3	2.1	2	2.6	1.6	3	2.8	Y