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Mission Operations Test Report - 2012

Johnson Space Center Exploration Medical Capability

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I. Executive Summary

The Human Research Program (HRP) has assigned the Exploration Medical Capability (ExMC) element the task of identifying and managing medical issues and related operational risks during exploration class missions. In March 2012, the Mission Operations Test (MOT) Team of the NASA Advanced Exploration Systems project requested assistance from the ExMC in the development of a simulated near-Earth asteroid (NEA) mission. The simulation would take place in a flight analog called the Habitation Demonstration Unit (HDU) – also called the Deep Space Habitat – located at the NASA Johnson Space Center (JSC). In addition to providing a list of medical equipment relevant to a NEA mission, the ExMC coordinated the development, integration, and execution of medical scenarios for the MOT Team's test to evaluate crew operations during exploration class space flight missions. This work also had direct applicability to the ExMC's Exploration Medical System Demonstration (EMSD) project.

The EMSD project demonstrates, on the ground and in flight, an end-to-end medical system for exploration class missions. The ExMC used the MOT to evaluate, in a ground-analog environment, how the existing International Space Station (ISS) medical resources (in mission-appropriate quantities) would function on an exploration mission. This was the first of several tests in preparation for formal ground-based testing of the EMSD capability in 2014 and space flight testing aboard the ISS in 2016. Insights gained from the completion of this simulation enabled the ExMC to make recommendations to overcome existing gaps in current exploration medical operations.

This report details the development, integration, execution, results, and conclusions from the ExMC's preliminary evaluation of the medical capability that could be integrated into the EMSD and used for an exploration class mission.

II. Introduction

The primary objective of the MOT was to discern how astronauts will autonomously execute their mission tasks with very limited access to ground-based resources due to the long communication delays that will be experienced during exploration class space missions. To do this, four crew members took part in a 10-day/8-night simulation to mimic the return phase of a NEA mission. The crew was housed within the HDU located at JSC during a 2-week period in September 2012. The crew participated in the management of multiple operational tasks, including the execution of medical procedures by minimally-trained caregivers with very limited immediate assistance ("remote guidance") from ground-based resources. With that, ExMC's specific aims for the MOT were:

A. To determine how the current ISS resources and protocols function in addressing the following three exploration-relevant medical events: a) corneal abrasion, b) renal stone formation, and c) periodic health evaluation.

B. To identify where automation can be applied to decrease: 1) the time to execute a procedure task, 2) the number of data transfer steps, and 3) the time to search for and retrieve health records.

III. Methods

A. Test Subjects

The protocols described in this report were reviewed and approved by the JSC Institutional Review Board.

B. Scenarios

The ExMC team selected the following three scenarios to be used in their evaluation: corneal abrasion, renal stone formation, and periodic health evaluation (PHE). The scenarios were selected, in part, based on the current standard-of-care practices used aboard the ISS and using likelihood-of-occurrence data generated by the JSC Integrated Medical Model (IMM).

Please note that a burn scenario was also conducted per the request from NASA JSC Human Factors; however, these data were not part of the formal analysis for this report. Data from this scenario can be found in Appendix B.

C. Equipment

The scenarios were conducted at the Medical Operations Work Station (MOWS) within the HDU at NASA JSC. The MOWS consisted of 1) a table top for conducting experiments and other life science activities, 2) a drawer system (located above the table top) for storage of resources, and 3) an examination table (located under the table top) that could be deployed when needed (Figure 1).

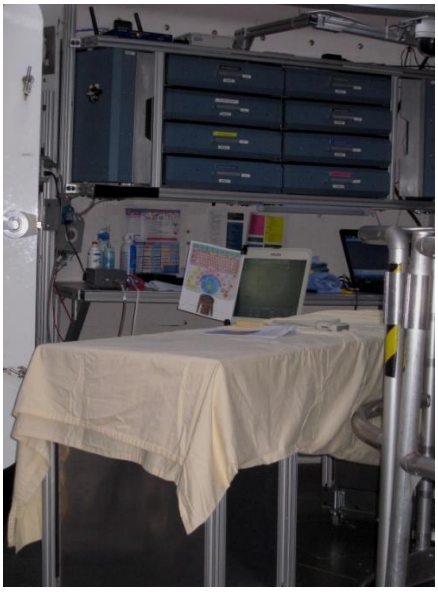


Figure 1: The MOWS with the examination table deployed.

The contents for the MOWS were calculated by the IMM. Briefly, the IMM generated a list of medical consumables and equipment quantities relevant to a 4-person, 395-day mission profile. The list was then used by JSC Human Factors to acquire (purchase, borrow) the equipment relevant to the current ISS medical capability.

A Philips CX-50 ultrasound device was used as the anatomical image collection tool for the scenarios conducted at the MOWS (Figure 2).

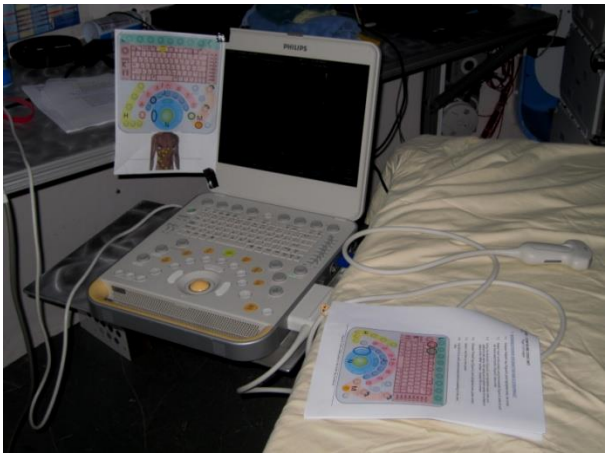


Figure 2: The CX-50 ultrasound device with cue card.

To simulate the collection of an ill crewmember's heart rhythm, the crew used and followed the modified procedures for the ISS blood pressure-electrocardiogram device (Schiller). No electrodes were used and no actual data were collected.

D. Support Personnel

For each data collection session, the ExMC Team had personnel in two locations:

1. *Outside the Habitation Demonstration Unit*

   The scenario moderator was located just outside the HDU and had the following duties:
   - On data collection days, set up the MOWS and corresponding equipment before the crew woke.
   - Provide the medical information to the designated crewmember for each medical event.
   - Manage the scenario and mitigate any scenario-related issues.

2. *Operational Training Facility within the Mission Control Center*

   Two medical flight controllers were located in the Operational Training Facility (OTF) and had the following duties: act as medical flight controllers and, if needed, provide guidance to the crew for each medical event.

E. Crew

The crew consisted of 4 subjects: 1 experienced astronaut acting as the commander (CDR), 1 subject acting as the pilot (PLT), 2 subjects acting as flight engineers (FE1 and FE2). Two of the 4 subjects were assigned as crew medical officers (CMOs) with PLT acting as the primary CMO and FE1 as the back-up CMO. Each CMO participated in a 1.5-hour medical training session approximately 7 to 9 days before the first scenario was conducted. Unless specified otherwise, the PLT acted as the CMO for the medical event.

F. Time Delay in Communication

The crew participated in 3 scenarios each week with each week having a specific communication delay of either 5 seconds or 50 seconds to simulate communication just past the moon or near the asteroid, respectively (Table 1).

Table 1: Time Delay in Communication for Each Week of the MOT

	Week 1	**Week 2**
Communication Delay	50 seconds	5 seconds

G. Protocol

The data were collected during specific times in the crew's timeline as designated by the MOT's simulation supervisor (SimSup). The PHEs were part of the official timeline and were seen by crew on their timeline viewer. The corneal abrasion and renal stone formation scenarios, however, were not part of the official timeline and were injected at specific time points to "surprise" the crew with an unanticipated medical event.

To start the PHE scenario, the CMO began the PHE procedure as called out on the timeline viewer. Each crewmember was given a "green card" of medical information (e.g., vital sign data, how they were feeling, etc.) at the start of their evaluation. Each green card was specific for each crewmember and was stored in a designated location as stated in a call or message sent by the medical flight controllers in the OTF. The CMO would then do the evaluation with the crewmember providing information from the green card as needed. The CMO would also use their communication capability (voice or text) and any other resources to complete the evaluation. The PHE scenario was considered complete as designated by the scenario moderator.

To start the corneal abrasion or renal stone formation scenarios, the scenario moderator would approach the designated crewmember as specified by the SimSup and present the green card for that scenario (e.g., what happened to them, how they were feeling, vital sign data, etc.), including answers to any questions that could be asked by the CMO. Once the green card was given, the scenario would start when the crewmember approached the CMO to inform them of their medical issue. The CMO would then do the evaluation with the crewmember providing information from the green card as needed. The CMO would also use their communication capability (voice or text) and any other resources at their disposal to mitigate the medical event. The corneal abrasion or renal stone formation scenarios were considered complete as designated by the scenario moderator.

Providing immediate assistance (remote guidance) in regards to effective medical care and proper ultrasound image collection from ground-based subject matter experts was very limited for the CMOs as the simulation was set up to have exploration-relevant communication delays of 5 and 50 seconds. Communication between the CMO and the medical flight controllers in the OTF was limited to voice and text. Video data were transmitted to the OTF and observed by the medical flight controllers.

H. Procedures

The medical procedures used for the MOT were based upon the certified procedures used aboard the ISS. The MOT procedures were updated to reflect the locations of the medical equipment within the MOWS. All medical procedures were accessed by opening the MOWS

medical check list file (C/L) on the MOWS laptop computer. The C/L was in a ".pdf" format and consisted of all of those procedures that are within the current version of the ISS Medical C/L.

To find a procedure within the C/L, the CMOs for this study were directed by the training team to find their procedures by searching for either the procedure name or number. If needed, the crew could consult with the medical flight controllers to assure they were using the correct procedure.

I. Audio/Video Configuration

The HDU was configured so audio and video data could be collected for retrospective analysis. The audio data consisted of verbal communication among the following two groups:

1. CMO and the ill crewmember
2. CMO and the remote guider (medical flight controller/sonographer) in the OTF

The video recorders were configured to capture images of the CMO working at the MOWS (Figure 3).

Figure 3: Camera view of MOWS within the HDU as the CMO works through a procedure at the MOWS laptop computer while fellow crewmember (on the table) waits for his PHE. The communication between the CMO and ground controllers is conducted through the CMO's headset.

J. Training

The CMOs received a 1.5-hour medical training session approximately 7 to 9 days before they conducted their first medical event during the MOT mission.

The first objective of the training was to familiarize the CMOs with the layout of the MOWS. Locations of equipment and consumables within each drawer and cabinet within the MOWS were shown and reviewed with each CMO.

The second objective of the training was to familiarize the CMOs with using ultrasound. A certified sonographer initially provided the CMOs with the experience of holding an ultrasound probe and comprehending the result of moving the probe over the body to obtain a correct cross-sectional ultrasound image of the anatomy. They were then introduced to the concepts of

scanning with ultrasound, how to use the ultrasound unit (record, save images and video), and move the probe (pan, tilt, rotate, and translate (slide)) over the body to see the cross-sections of several body organs. This was followed by each CMO operating the ultrasound system as they practiced image scanning and collection on a human volunteer. This included each CMO being briefed on the anatomic locations for the bladder along with the right and left kidneys.

K. Questionnaires

The CMOs were given questionnaires to assess the quality of the procedure content in regards to clarity and preciseness, regardless of the scenario conducted. In addition, levels of frustration for understanding the procedures, their ease of use, and whether their formats were intuitive were also assessed. The CMOs provided answers to statements based on the following sliding scale: 1-Completely Disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Completely Agree, and 6-Not Applicable. All data are averages (n=2) with the exception of the PHE that had an n=1. The latter was caused by two scenarios being conducted on the same day that was also the final day of the mission. This led the MOT coordinators having the crew only complete the questionnaire for corneal abrasion and not the PHE. The ExMC Team was not made aware of this occurrence until after the mission had been completed.

L. Data Analysis

The medical procedures for these scenarios were written in a similar style as existing ISS medical procedures. Crewmembers were directed to adhere to these procedures when simulating these medical scenarios. The time to complete tasks and data transfers for these procedures were recorded.

The data analysis was adapted via metrics generated by Jain.[2] Briefly, time value stream maps for each scenario were used to show how much time the CMO was both with and away from the crewmember undergoing examination. The individual steps can be classified as either being with the patient and therefore of direct clinical benefit, or away from the patient of indirect clinical benefit.

The time away from the patient was then sub-divided into themes (communication with ground, locating equipment, configuring equipment, interaction with the MOWS laptop), and compared to the time with the patient to understand the proportion of time being used in regards to all categories of interactions with the patient. These splits are presented as percentages within a pie chart.[2]

IV. Results

The times for the CMOs to complete the scenarios can be found in Table 2. The time to complete the corneal abrasion scenario was decreased by ~50% when the communication delay was reduced to 5 seconds. The time for completing the renal stone formation scenario was decreased by ~25% when the communication delay was reduced to 5 seconds and with a different CMO. It remains to be determined whether the shorter communication delay or having a different CMO had an impact on these data. The time to complete the first PHE, regardless of the communication time delay, was the longest of the four PHEs executed each week. The time to complete each PHE decreased as the CMOs continued down the timeline, regardless of which CMO was executing the evaluation.

Table 2: Time to Complete Each Scenario

	Week 1 (50 second delay)	Week 2 (5 second delay)
Corneal Abrasion	72 min 00 s	36 min 32 s
Renal Stone Formation	124 min 24 s	94 min 13 s*
Periodic Health Exam #1	33 min 55 s	24 min 46 s
Periodic Health Exam #2	14 min 51 s	21 min 04 s*
Periodic Health Exam #3	13 min 53 s*	17 min 30 s
Periodic Health Exam #4	10 min 36 s	13 min 07 s

min=minutes, s=seconds; *: FE1 was CMO

The data for corneal abrasion show that there was a decrease in CMO-patient interaction when the communication delay was reduced to 5 seconds (28% vs. 17%; Figures 4 and 5, respectively). Overall, the amount of time that the patient had to wait for the CMO during a corneal abrasion event was ~51 of the 72 minutes (71% of the time) during the first scenario and ~30 of the 36 minutes (83% of the time) in the second scenario. It remains to be determined whether the shorter communication delay or a learned effect from conducting the corneal abrasion scenario the previous week had an impact on these data.

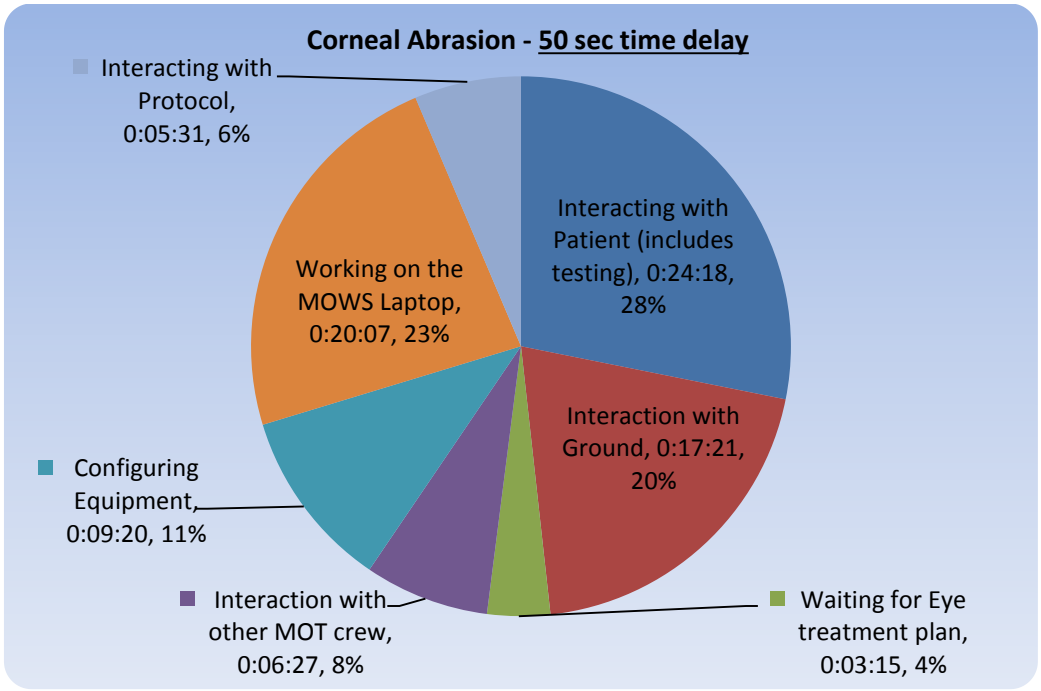


Figure 4: Corneal abrasion task distribution during 50-second communication time delay.

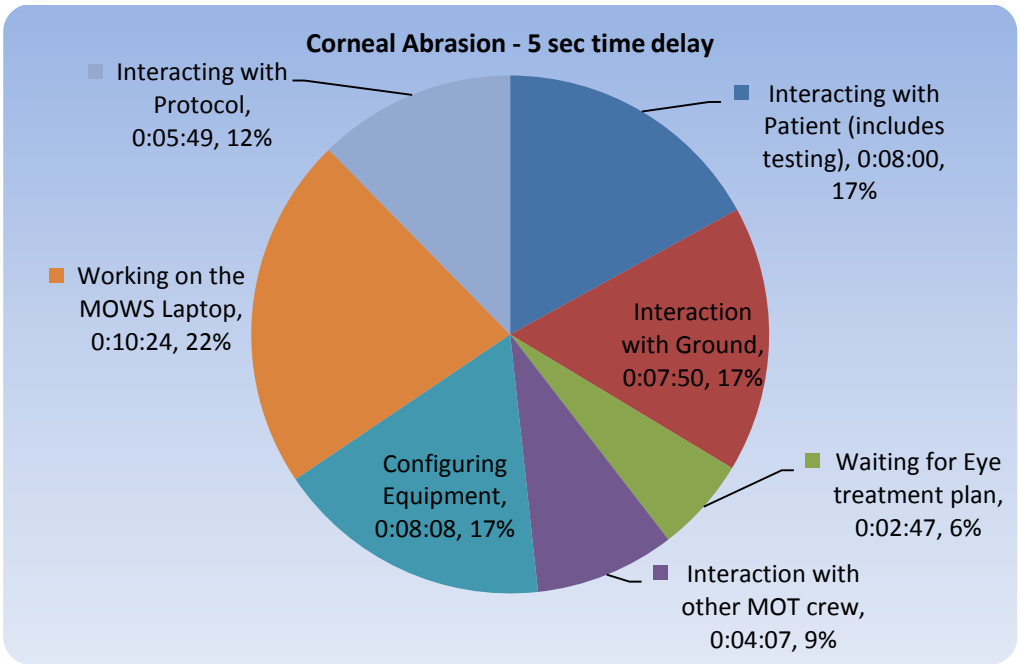


Figure 5: Corneal abrasion task distribution during 5-second communication time delay.

This CMO-patient interaction time for renal stone differed from corneal abrasion as that value increased from 37% to 47% (Figures 6 and 7). Overall, the amount of time that the patient had to wait for the CMO during a corneal abrasion event was ~79 of the 124 minutes (63% of the time) during the first scenario and ~50% of the 94 minutes (53% of the time) in the second scenario. It remains to be determined whether the shorter communication delay or a learned effect from conducting the renal stone formation scenario the previous week had an impact on these data.

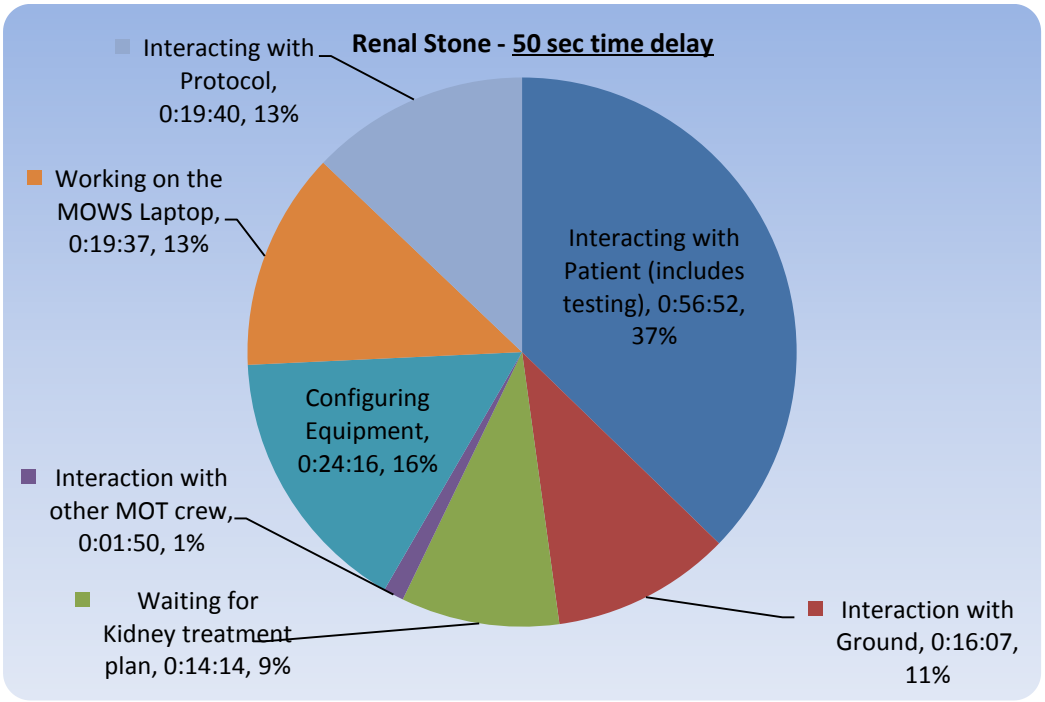


Figure 6: Renal stone formation task distribution during 50-second communication time delay.

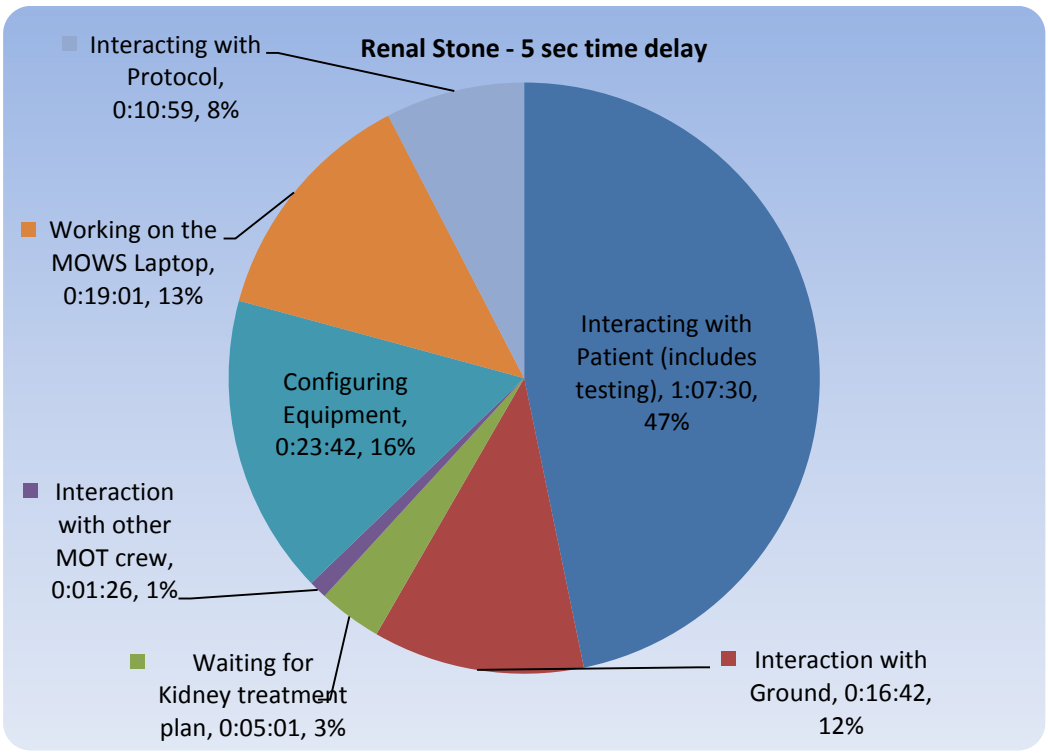


Figure 7: Renal stone formation task distribution during 5-second communication time delay.

For PHEs, the average percentage of CMO-patient interaction time during communication delay of 50 seconds was 25% (Figures 8-11). This was less than the average percentage of CMO-patient interaction time seen when PHEs were conducted during a 5-second communication delay (35.5%; Figures 12-15). On average, for the PHEs being conducted during the 50-second communication delay, the patient had to wait for interaction with the CMO ~75% of the total time for the event. This value decreased to ~64% for the PHEs conducted during a 5-second communication delay. Since the average time for all the PHEs conducted was approximately 18 minutes (range: 11 to 34 min), this means that the patient did not interact with the CMO for, on average, approximately 12 of those 18 minutes. It remains to be determined whether the shorter communication delay or a learned effect from conducting the PHEs the previous week had an impact on these data.

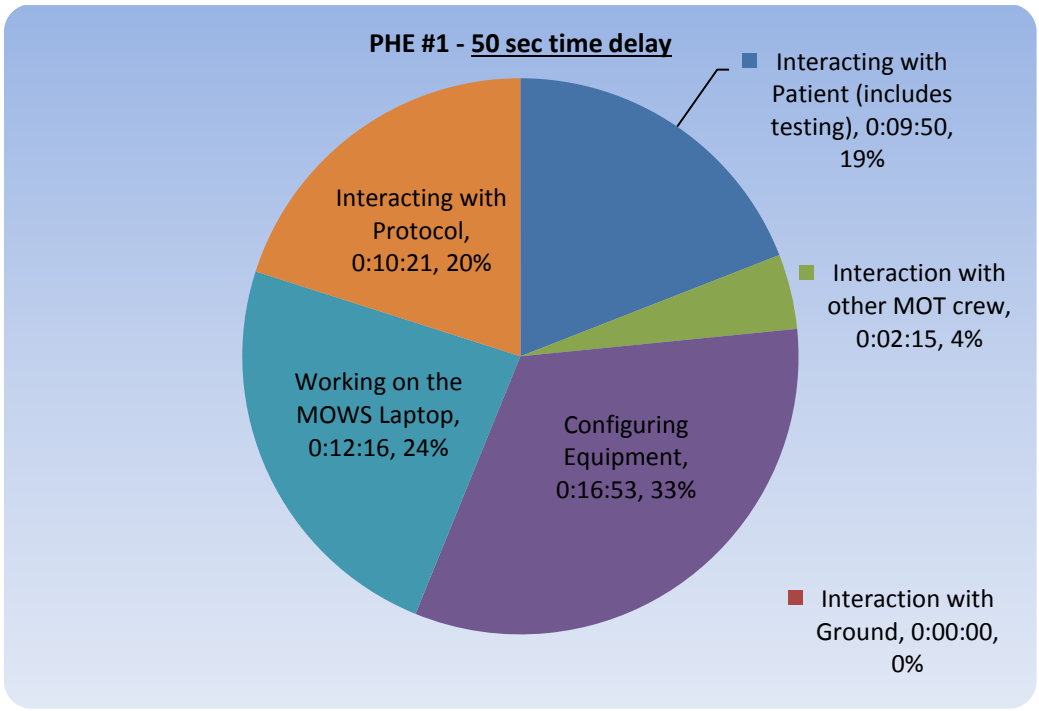


Figure 8: PHE #1 task distribution during 50-second communication time delay.

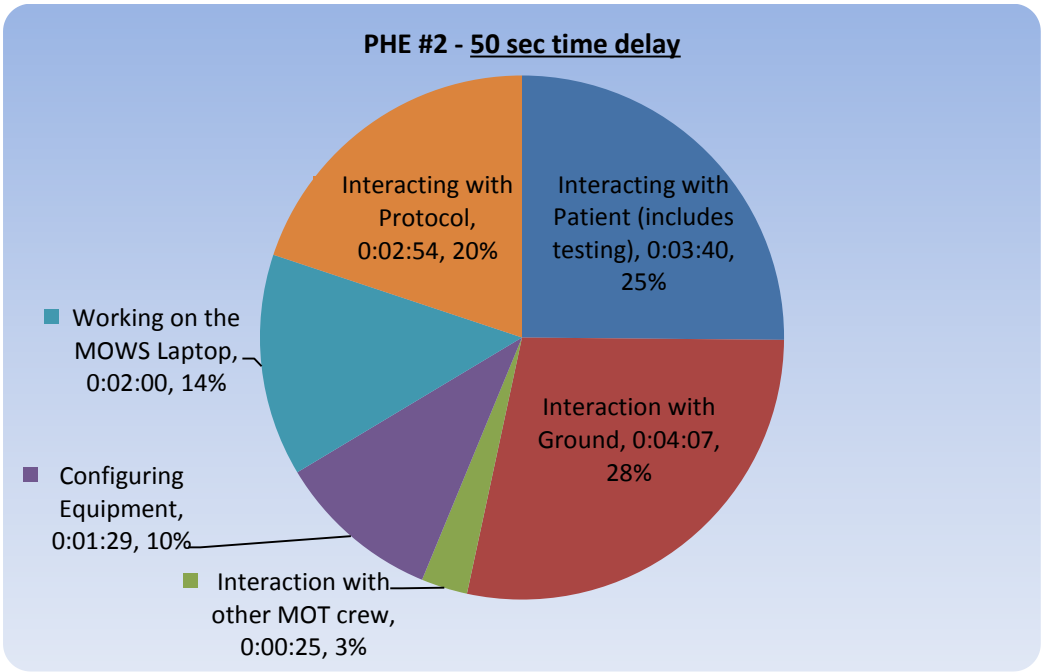


Figure 9: PHE #2 task distribution during 50-second communication time delay.

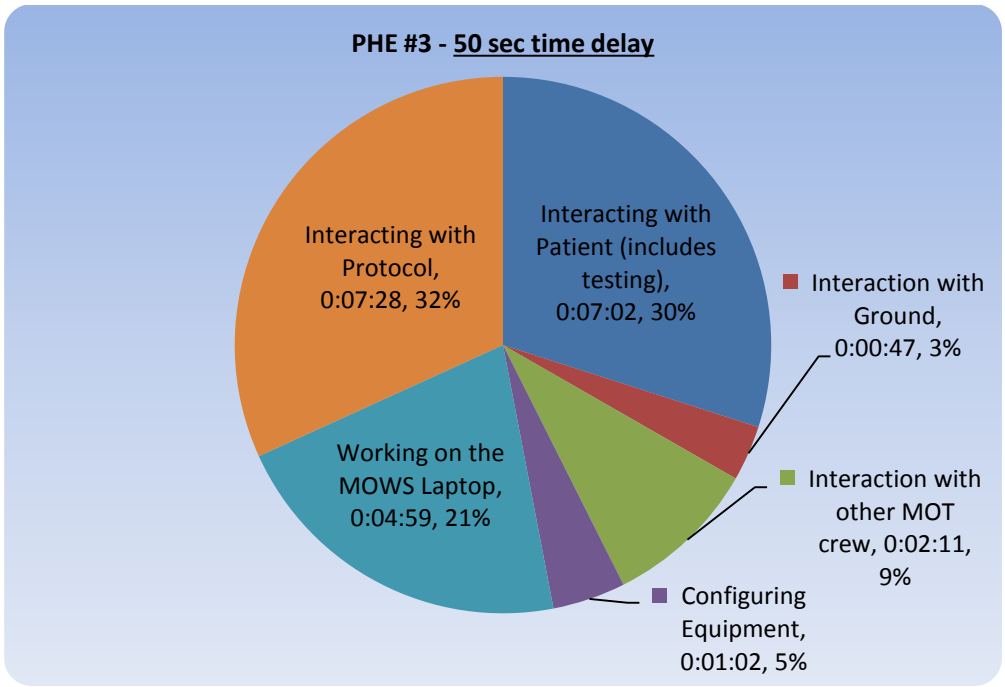


Figure 10: PHE #3 task distribution during 50-second communication time delay.

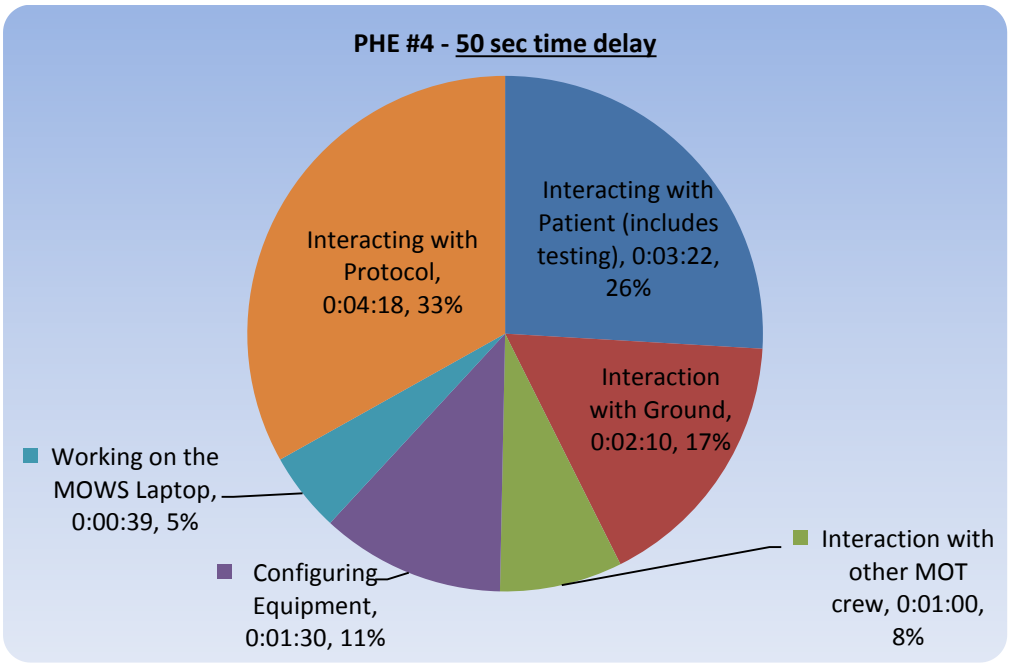


Figure 11: PHE #4 task distribution during 50-second communication time delay.

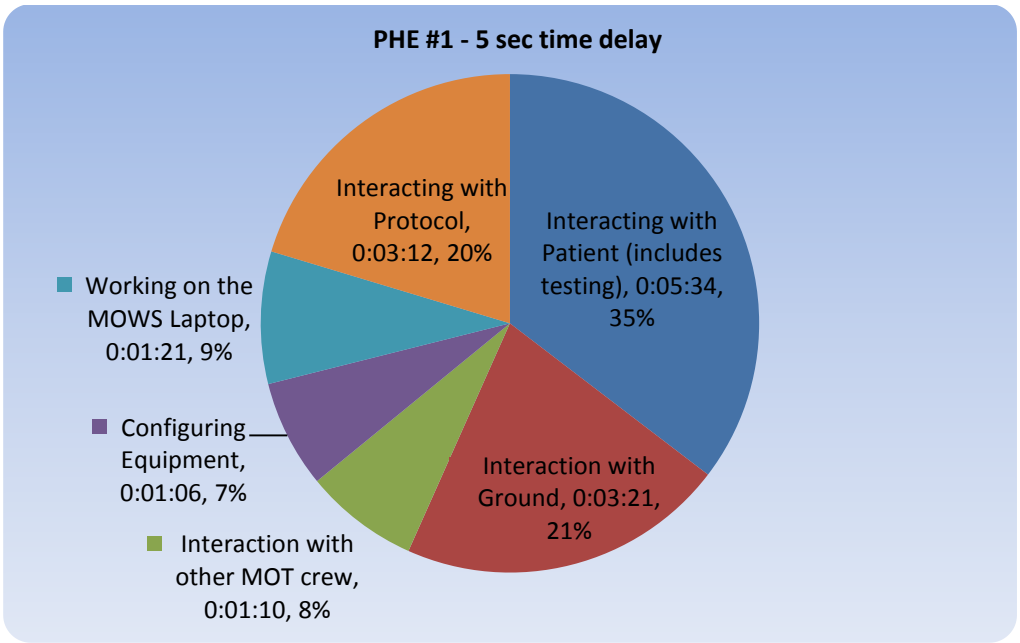


Figure 12: PHE #1 task distribution during 5-second communication time delay.

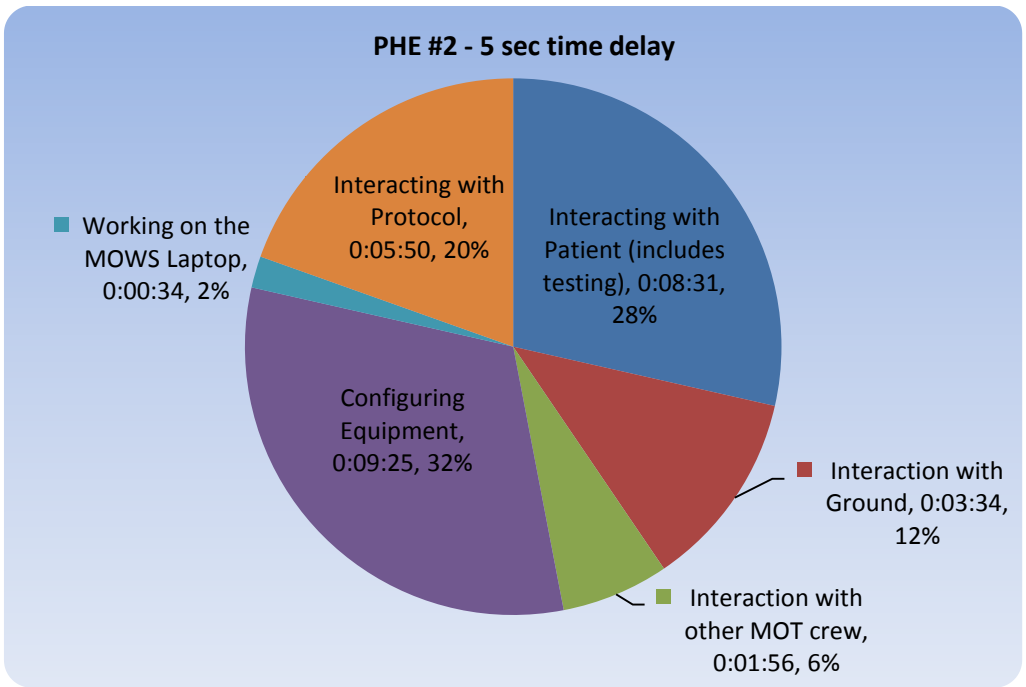


Figure 13: PHE #2 task distribution during 5-second communication time delay.

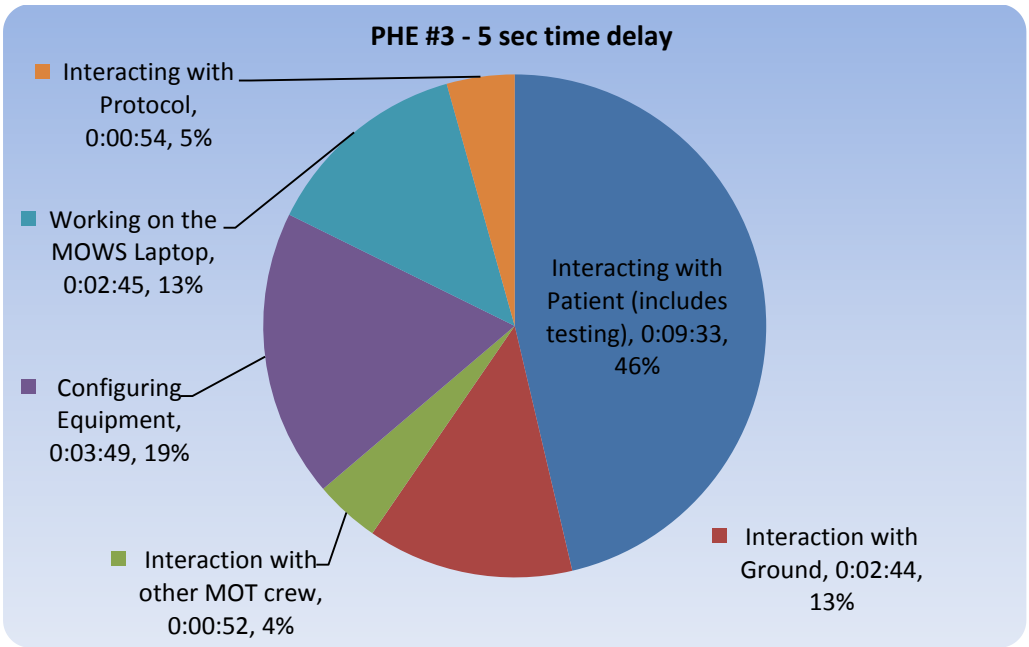


Figure 14: PHE #3 task distribution during 5-second communication time delay.

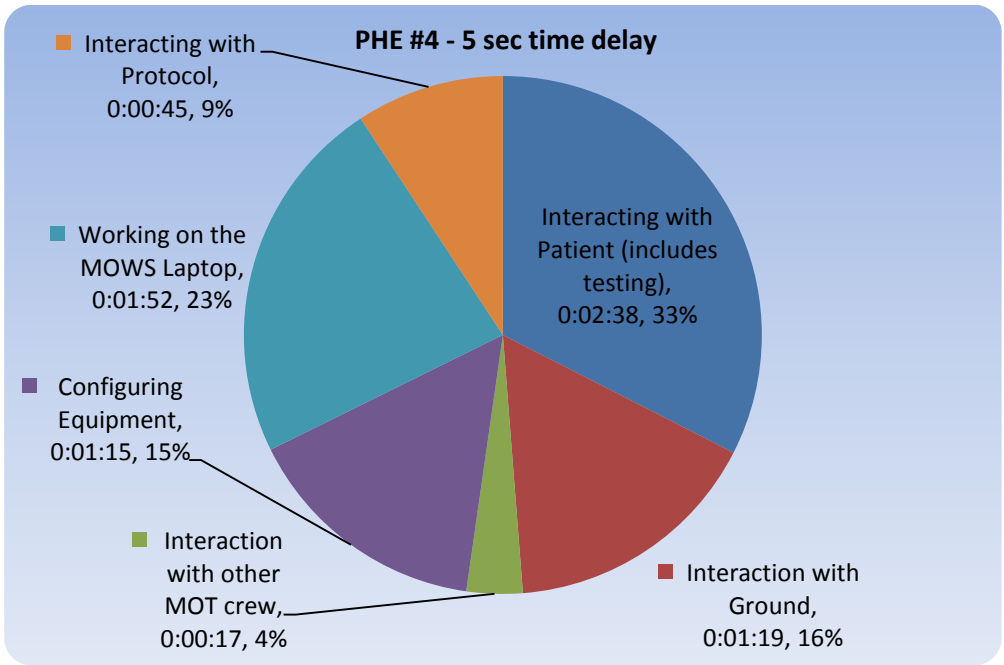


Figure 15: PHE #4 task distribution during 5-second communication time delay.

The overall communication between the CMO and crew was constructive and helpful. In some cases, where it appeared that the CMO was very busy, the CDR offered to relay information about the medical event to the ground by either voice or text to ground support to save the CMO time. The CDR and the other crewmember not involved with the medical event worked with the others to make sure the tasks of the CMO and ill crewmember were either being addressed or tabled for later completion.

The questionnaire data revealed that the CMOs liked the content and preciseness of the procedures, regardless of the scenario conducted (Table 3). The levels of frustration for understanding and navigating the procedures were indicated by the CMOs as being low. The ease of which the CMOs navigated the procedures was rated high. The intuitive format of the procedures may have played a role in that ease of navigation (Table 3).

Table 3: Questionnaire Data

	Procedure Content Precise	Procedure Content Understandable	Frustration understanding instructions	Useful information from pictures	Cue Card Usefulness	Ease of Navigation	Format Intuitive	Overall Rating
Eye Exam (for Corneal Abrasion)	4.5	4.5	1	4.5	N/A	4.5	4.5	5
Abdominal Pain (for Renal Formation)	4.5	4	1.5	4.5	4	3.5	4	4.5
Periodic Health Evaluation	5	5	1	4	3	5	5	5

The CMOs provided answers to the statements based on the following sliding scale: 1-Completely Disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Completely Agree, 6-Not Applicable

The quality of ultrasound images collected during the renal stone scenario was of diagnostic quality as demonstrated by the image of the right kidney in Figure 16.

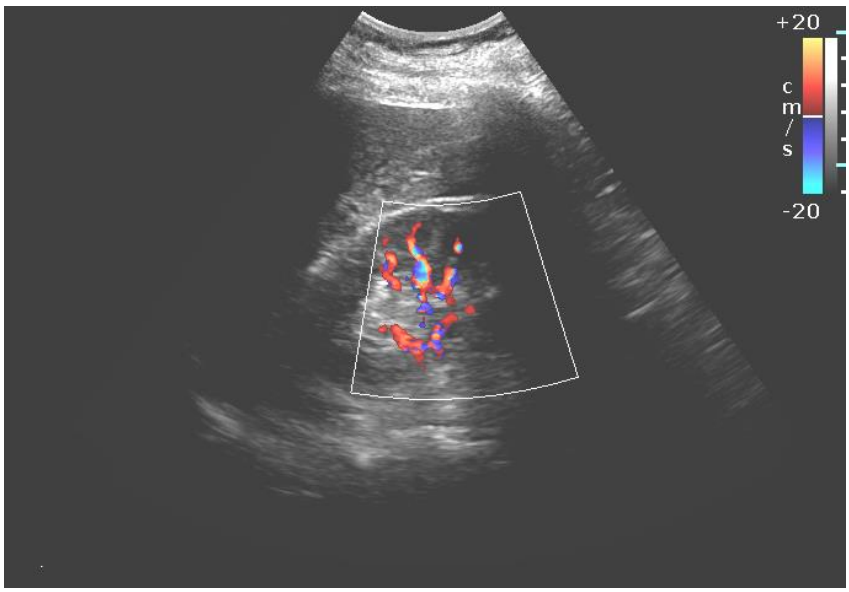


Figure 16: Clinically acceptable quality demonstrating a long-axis, right kidney with color.

V. Conclusion

The study indicates that the current ISS medical procedures for corneal abrasion, renal stone formation, and PHE can be effectively followed by minimally-trained caregivers (e.g., CMOs) with minimal remote guidance in simulated environments relating to exploration class space flight. It remains to be determined whether the current ISS medical capability is completely transferable to exploration class missions. The study has also revealed areas where automation can be applied to help CMOs expedite both clinical and operational tasks during medical events, be they nominal (e.g., PHE) or off-nominal (e.g., corneal abrasion, renal stone formation). Taken together, the data from the MOT Project addressed each of ExMC's specific aims for this study.

A. To determine how the current ISS resources and protocols function in addressing the following three exploration-relevant medical events: 1) corneal abrasion, 2) renal stone formation, and 3) PHE.

   Feedback from CMO questionnaires along with observational data collected by the investigation team during this study indicate that the subjects were able to follow the designated procedures and use the corresponding equipment for each medical event with little difficulty and with minimal-to-no training for most of the tasks within the protocols (The amount of medical supplies and equipment to conduct these procedures was sufficient). The time to complete these procedures, however, took much longer than expected, therefore indicating an area for improvement.

   Interestingly, the use of remote guidance was helpful with image collection during the renal stone scenario even during the 50-second communication time delay. Both CMOs were able to acquire the necessary images before the remote guider specifically directed them how to do so, meaning that it appeared the CMOs knew what was needed and were able to acquire the necessary target with little guidance; however, they did require confirmation from the remote guider regarding the quality of the image before they moved forward with further image collection.

   Although these results are positive in regards towards the application of the ISS medical capability to an exploration paradigm, it remains to be determined how well these ISS resources apply to the over 80 other medical conditions within the Exploration Medical Condition List.[3]

B. To identify where automation can be applied to decrease a) the time to execute a procedure task, b) the number of data transfer steps, and c) the time to search for and retrieve health records.

   The study identified the following areas where automation can be applied to decrease the time to execute procedures task, data transfer steps and search for health records:
   - Informing ground resources of a medical event be it planned (e.g., PHE) or unplanned (e.g., corneal abrasion, renal stone formation)
   - Call for privatization of communication loop between CMO and flight surgeon
   - Search for medical procedure
   - Indication of task completion within the procedure
   - Collection of medical data
   - Completion of data collection form
   - Delivery of medical data to flight surgeon and other ground-based personnel

Application of automation in the preceding areas may prove beneficial in increasing CMO-patient interactions and direct clinical benefit to the patient.[2] CMO-patient interactions for all of the scenarios in this study were low. In fact, the patient was waiting around while the CMO did their tasks for 63% to 83% of the time for 7 of the 8 scenarios conducted in this study. These data covered a waiting time range of 30 to 79 minutes. Use of automation and mitigation tools like that seen with the Advanced Diagnostic Ultrasound tool during the Autonomous Mission Operation (AMO) test[1] could play a role in increasing CMO-patient interactions and of direct clinical benefit to the patient.

The high level of collective improvisation by the crew led to a successful solution being observed by the investigation team. During the first corneal abrasion scenario, the CMO required a dark place to illuminate the fluorescein dye in the patient's eye to determine whether the patient's cornea was indeed scratched. They did not want to turn out the lights of the whole first floor of the HDU as they did not want to impact a fellow crewmember's activity so they entered the airlock, closed the door, and turned out the lights to carry on this task. The CMO was then able to diagnose the injured eye with no impact to the workflow of the MOT crew. Completion of this task in this manner demonstrated, in part, the importance of crew selection especially in regards to the power of collective thinking towards solid solutions in real time. Overall, these scenarios provide an opportunity for the JSC-Behavioral Health and Performance team within the HRP to study team dynamics and, thus, improve teamwork during medical scenarios.

VI. Next Steps

The ExMC will implement the lessons learned from this study into the development of its components for the EMSD, including the Assisted Medical Procedures system, electronic medical record, and Middleware. All of this will be done to improve automation and subsequently streamline task completion and foster more CMO-patient interactions to enhance crew health and performance.

VII. Reference Documents

[1]Hurst IV V, Garcia K, Ham D. Autonomous Mission Operation (AMO) Test Report. NASA Johnson Space Center's Human Research Program (HRP). July 2012

[2]Jain V. Measuring the efficiency of the current International Space Station Medical Capabilities. Master's Dissertation. Module: 7BBLM017. King's College, London, England. September 2012

[3]Watkins SD. Exploration Medical Condition List (EMCL). NASA Johnson Space Center. JSC-65722, June 2013.

VIII. Appendix A – Time Value Stream Maps

Time value stream maps visually showed how much time the CMO was both with the crewmember and away from the crewmember while undergoing examination. The time with the patient (green boxes in Figures 17 to 22) can be considered of direct clinical benefit while the time away from the patient (red boxes in Figures 17 to 22) can thus be considered of indirect clinical benefit.

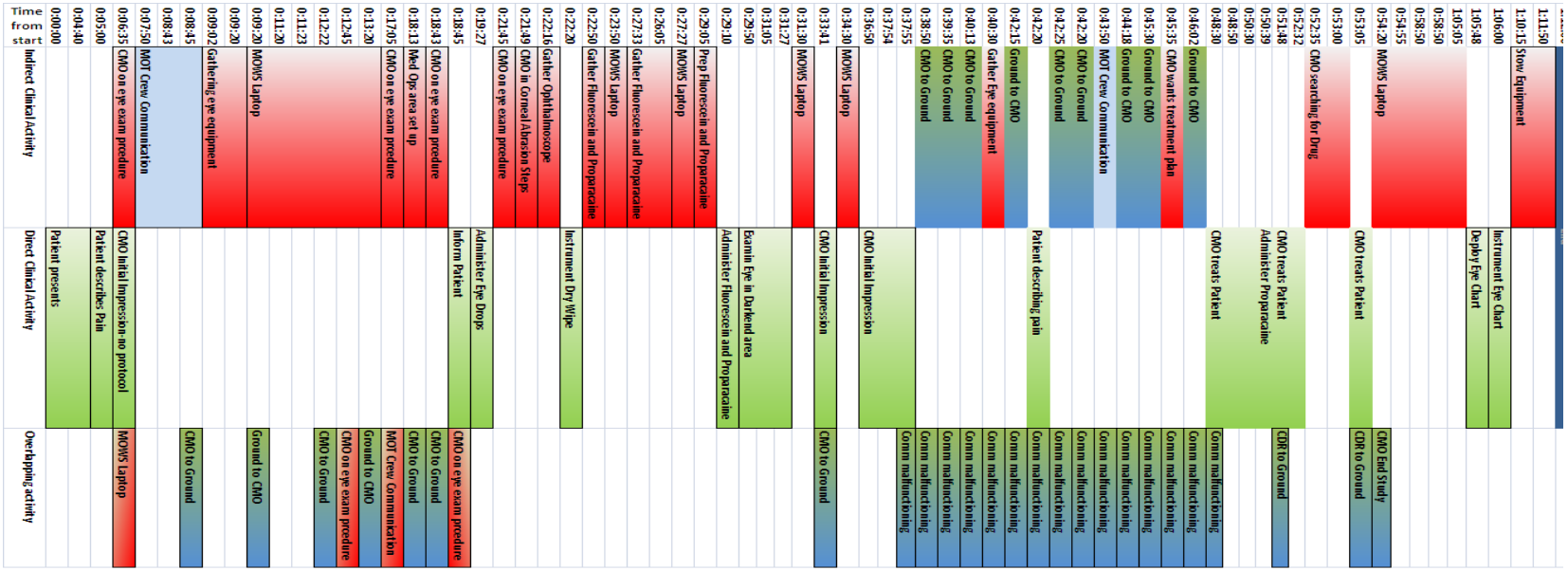
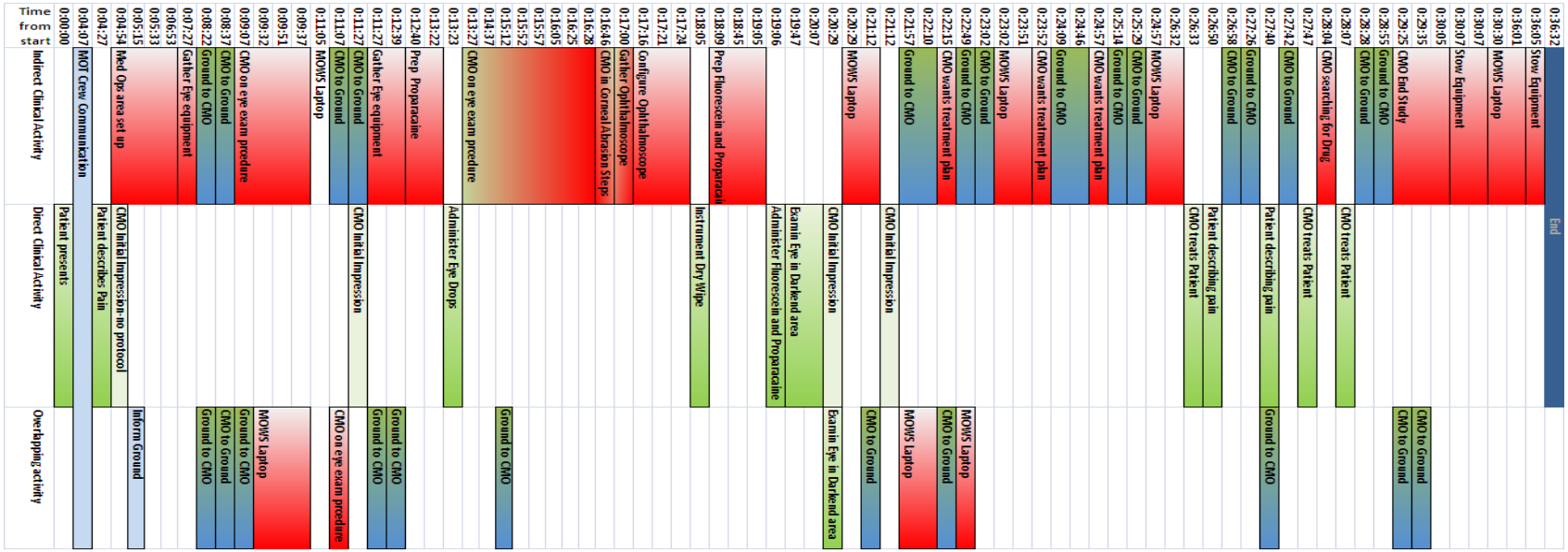
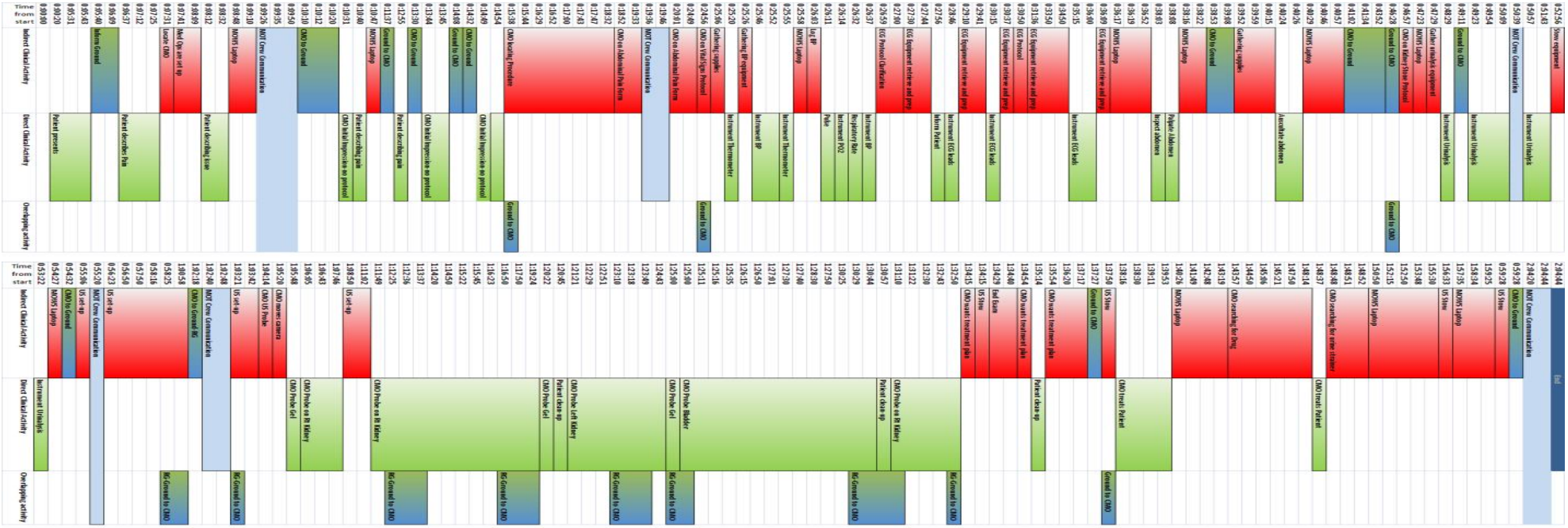


Figure 17: Time value stream map for corneal abrasion (50-second delay).


Time from start
Indirect Clinical Activity
Direct Clinical Activity
Overlapping activity
0:36:32
0:36:05 Stow Equipment
0:36:01
0:30:30 MOWS Laptop
0:30:07
0:30:07 Stow Equipment
0:30:05
0:29:35
0:29:25 CMO End Study
0:28:55 Ground to CMO
0:28:28 CMO to Ground
0:28:07
0:28:04 CMO searching for Drug
0:27:47
0:27:42 CMO to Ground
0:27:40
0:27:26 Ground to CMO
0:26:58 CMO to Ground
0:26:50
0:26:33
0:24:57 MOWS Laptop
0:25:29 CMO to Ground
0:25:14 Ground to CMO
0:24:57 CMO wants treatment pain
0:24:46
0:24:09 Ground to CMO
0:23:52 CMO wants treatment pain
0:23:51
0:23:02 MOWS Laptop
0:23:02 CMO to Ground
0:22:49 Ground to CMO
0:22:15 CMO wants treatment pain
0:22:10
0:21:57 Ground to CMO
0:21:12
0:21:12
0:20:29 MOWS Laptop
0:20:29
0:20:07
0:19:47
0:19:06
0:19:05
0:18:45
0:18:09 Prep Fluorescein and Proparacai
0:18:05
0:17:24
0:17:21
0:17:16 Configure Ophthalmoscope
0:17:00 Gather Ophthalmoscope
0:16:46 CMO in Corneal Abrasion Steps
0:16:28
0:16:25
0:16:05
0:15:57
0:15:57
0:15:52
0:15:12
0:14:37
0:13:27 CMO on eye exam procedure
0:13:23
0:13:22
0:12:40 Prep Proparacaine
0:12:39
0:11:27 Gather Eye equipment
0:11:27 CMO to Ground
0:11:07 CMO to Ground
0:11:05 MOWS Laptop
0:09:37
0:09:51
0:09:32
0:09:07 CMO on eye exam procedure
0:08:37 CMO to Ground
0:08:22 Ground to CMO
0:07:27 Gather Eye equipment
0:06:53
0:05:33
0:05:15
0:04:54 Med Ops area set up
0:04:27
0:04:07 MOT Crew Communication
0:00:00
Patient presents
Patient describes Pain
CMO Initial Impression-no protocol
CMO Initial Impression
Administer Eye Drops
Instrument Dry Wipe
Administer Fluorescein and Proparacaine
CMO Initial Impression
Examin Eye in Darkend area
Examin Eye in Darkend area
CMO Initial Impression
CMO Initial Impression
Patient describing pain
CMO treats Patient
CMO treats Patient
CMO treats Patient
Patient describing pain
Ground to CMO
Ground to CMO
Ground to CMO


Time from start
Indirect Clinical Activity
Direct Clinical Activity
Overlapping Activity
Slow equipment
MOT Crew Communication
Gather supplies
Gather IV equipment
Gather ultrasound equipment
Gather EKG equipment
Gather BP equipment
Gather Pulse Ox equipment
Gather Resp Rate equipment
Gather Temp equipment
Gather Urinalysis equipment
Gather Blood Gas equipment
Gather Blood Draw equipment
Gather Urine Dipstick equipment
Gather Urine Culture equipment
Gather Urine Cytology equipment
Gather Urine Pregnancy equipment
Gather Urine Drug Screen equipment
Gather Urine Toxicology

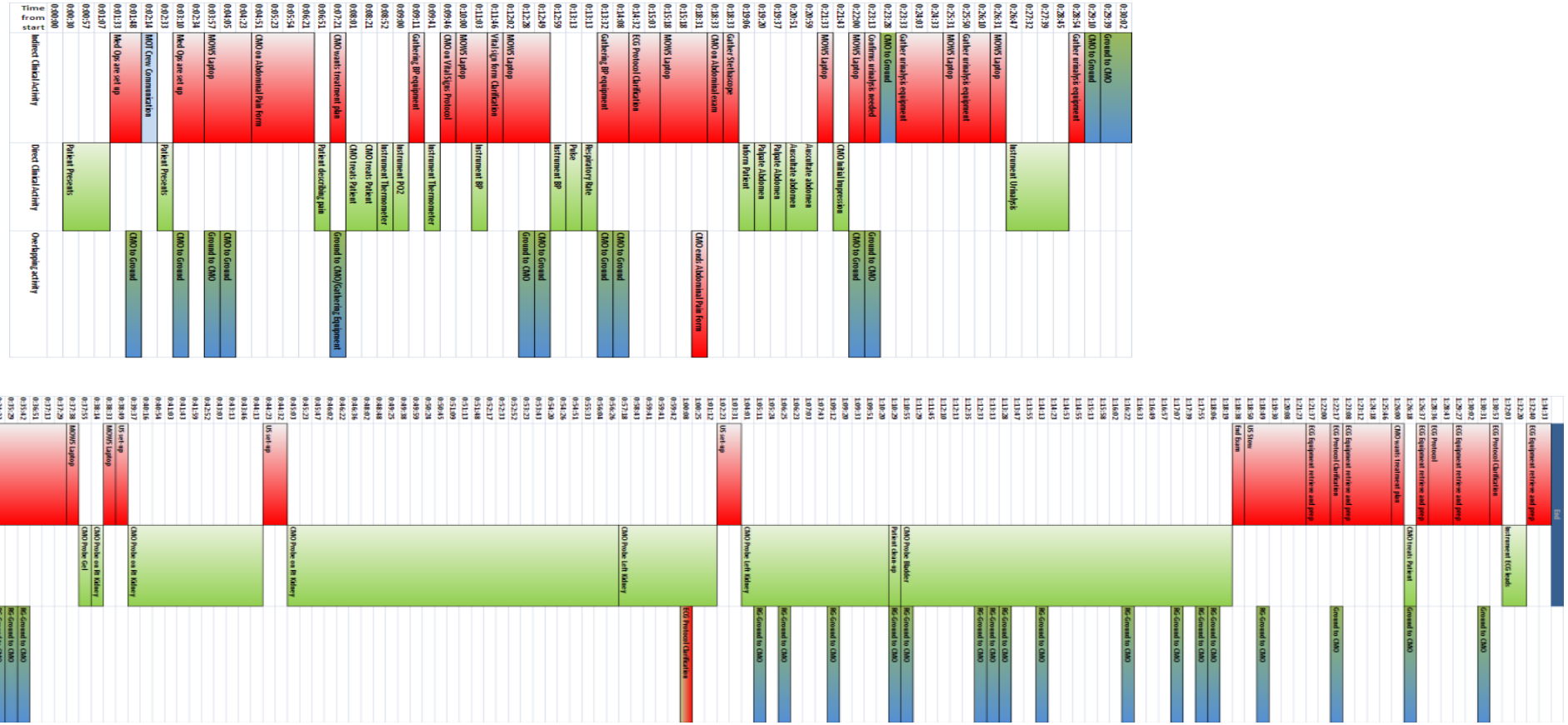


Figure 20: Time value stream map for renal stone formation (5-second delay).

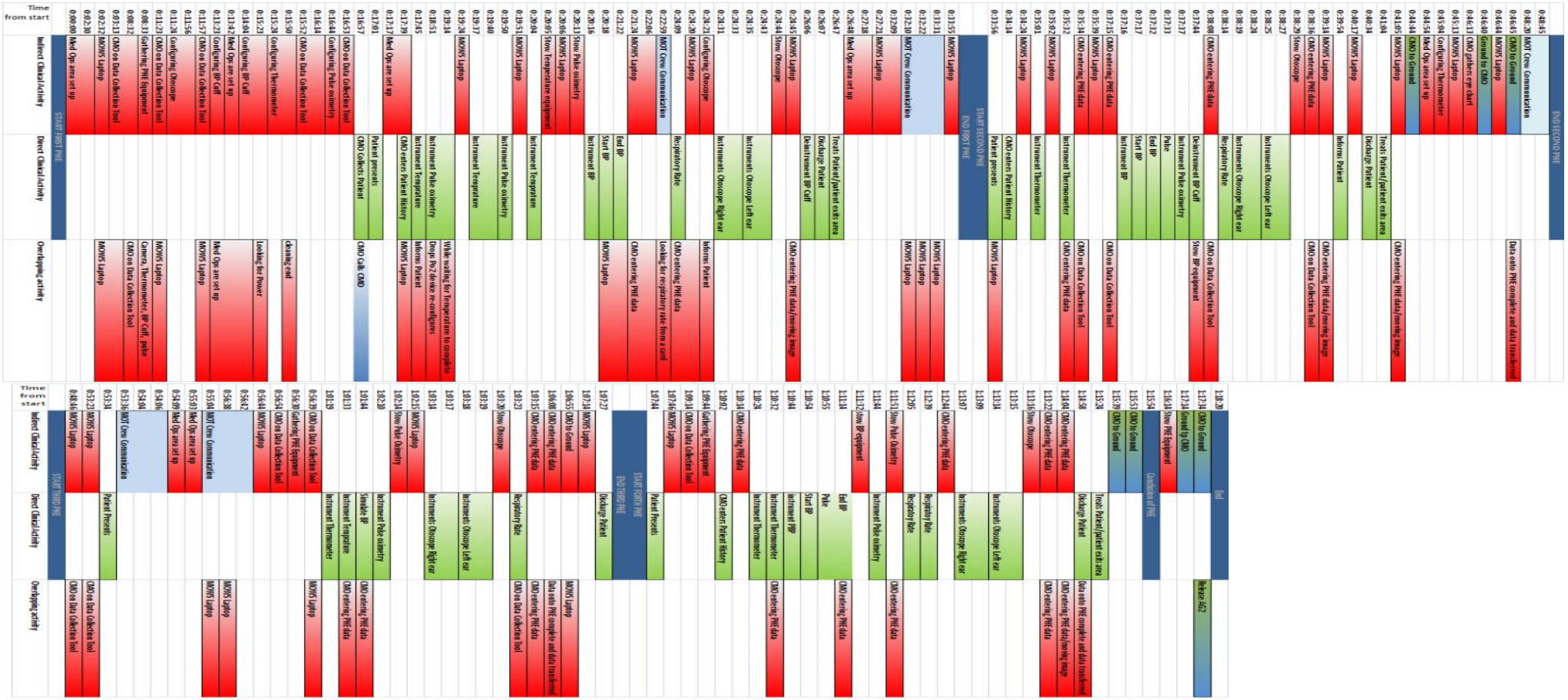
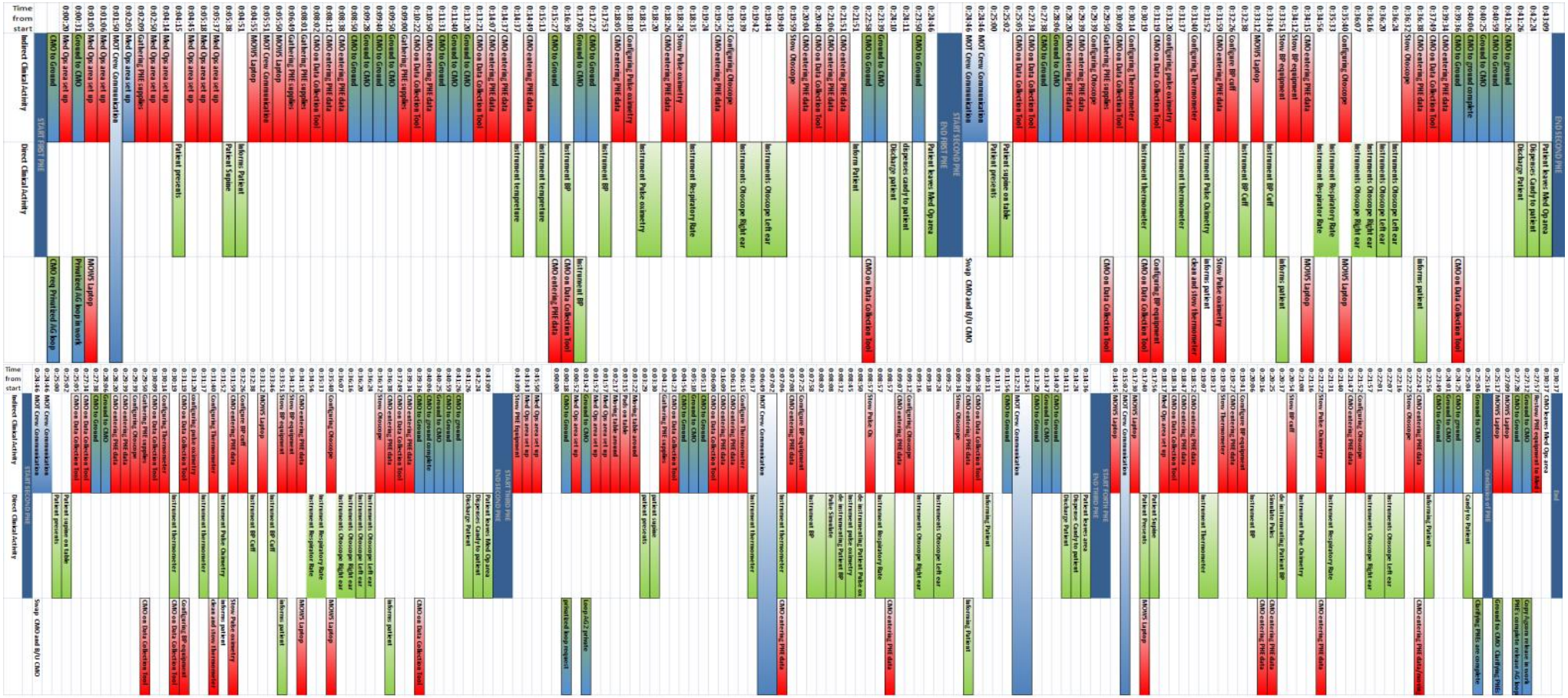


Figure 21: Time value stream map for PHEs #1-#4 (50-second delay).


Time from start
Indirect Clinical Activity
Direct Clinical Activity
Patient leaves Med Op area
Dispenses Candy to patient
Discharge Patient
Instruments Otoscope Left ear
Instruments Otoscope Right ear
Instruments Otoscope Right ear
Instrument Respiratory Rate
Instrument Respirator Rate
Instrument BP Cuff
Informs: patient
Informs: Patient
Patient Supine
Patient supine on table
Patient presents
Instrument Pulse oximetry
Instrument Thermometer
Instrument BP
Instrument temperture
Instruments: Otoscope Left ear
Instruments: Otoscope Right ear
Configuring Otoscope
Configuring Thermometer
Configuring Pulse oximetry
Configuring BP equipment
Configuring PHE supplies
Configure BP cuff
Configure BP equipment
Ground to CMO
Ground to Ground
CMO to Ground
CMO on Data Collection Tool
CMO entering PHE data
MOVIS Laptop
Printed AG boy in work
CMO req Printed AG boy
Swap CMO and B/U CMO
MOT Crew Communication
Stow BP equipment
Stow Pulse oximetry
Stow Otoscope
Stow Thermometer
Stow BP cuff
Simulate Pulse
Simulate Pulse oximetry
Simulate BP
Simulate Pulse Oximetry
Simulate Pulse Oximetry
Simulate Pulse
Simulate BP
Simulate Pulse
Simulate BP
Simulate Pulse
Simulate BP

IX. Appendix B – Burn Scenario Data

Per the request from the NASA-JSC Human Factors team, the ExMC generated a burn scenario as part of the crew managing the HDU following it being punctured by a simulated micrometeorite. The scenario lasted approximately 1 hour and the data below reflect how FE1 (back-up CMO) cared for the burned crewmember, PLT (primary CMO) during the puncture mitigation of the HDU.

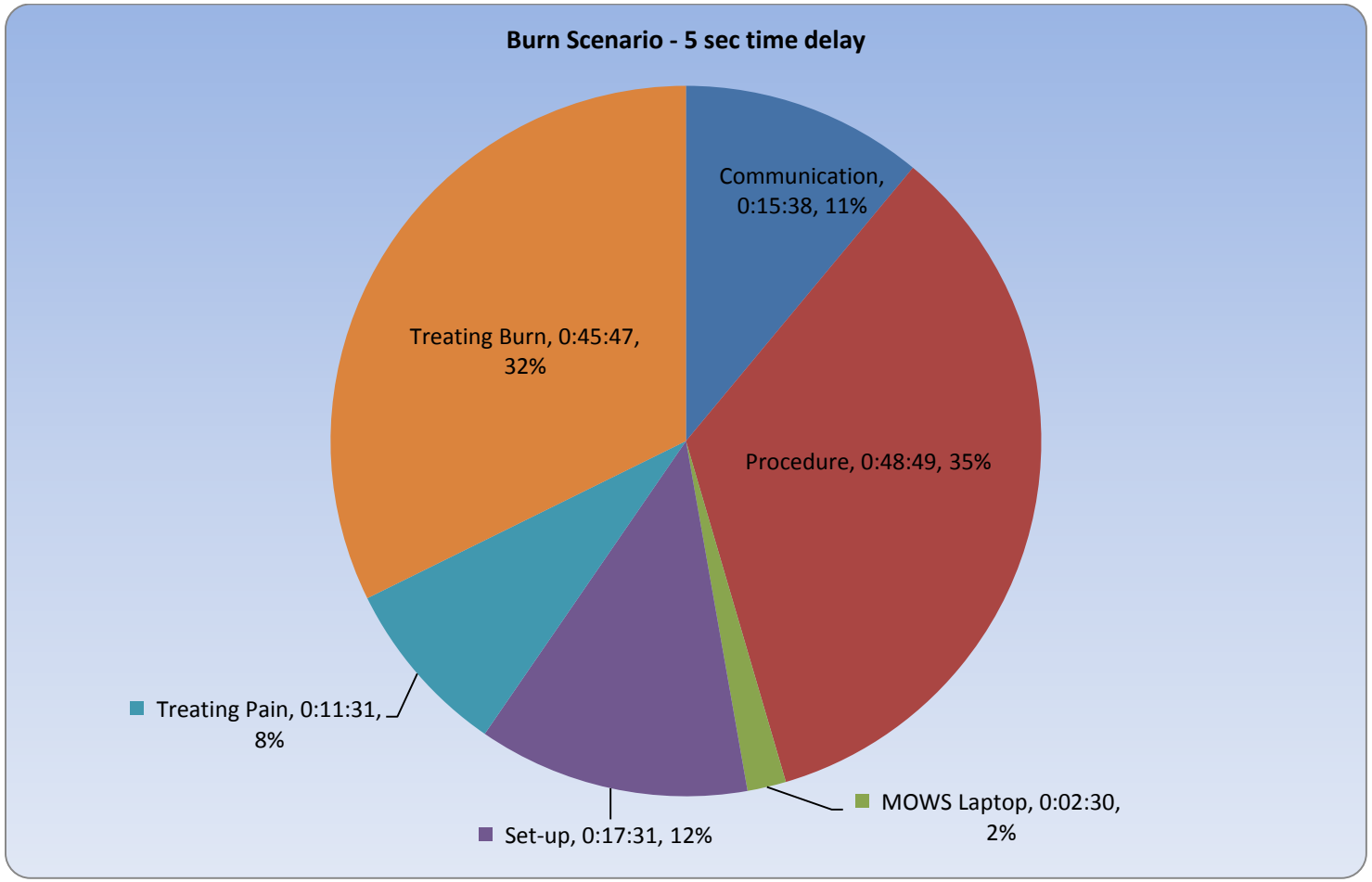


Figure 23: Burn scenario, task distribution during 5-second communication time delay.

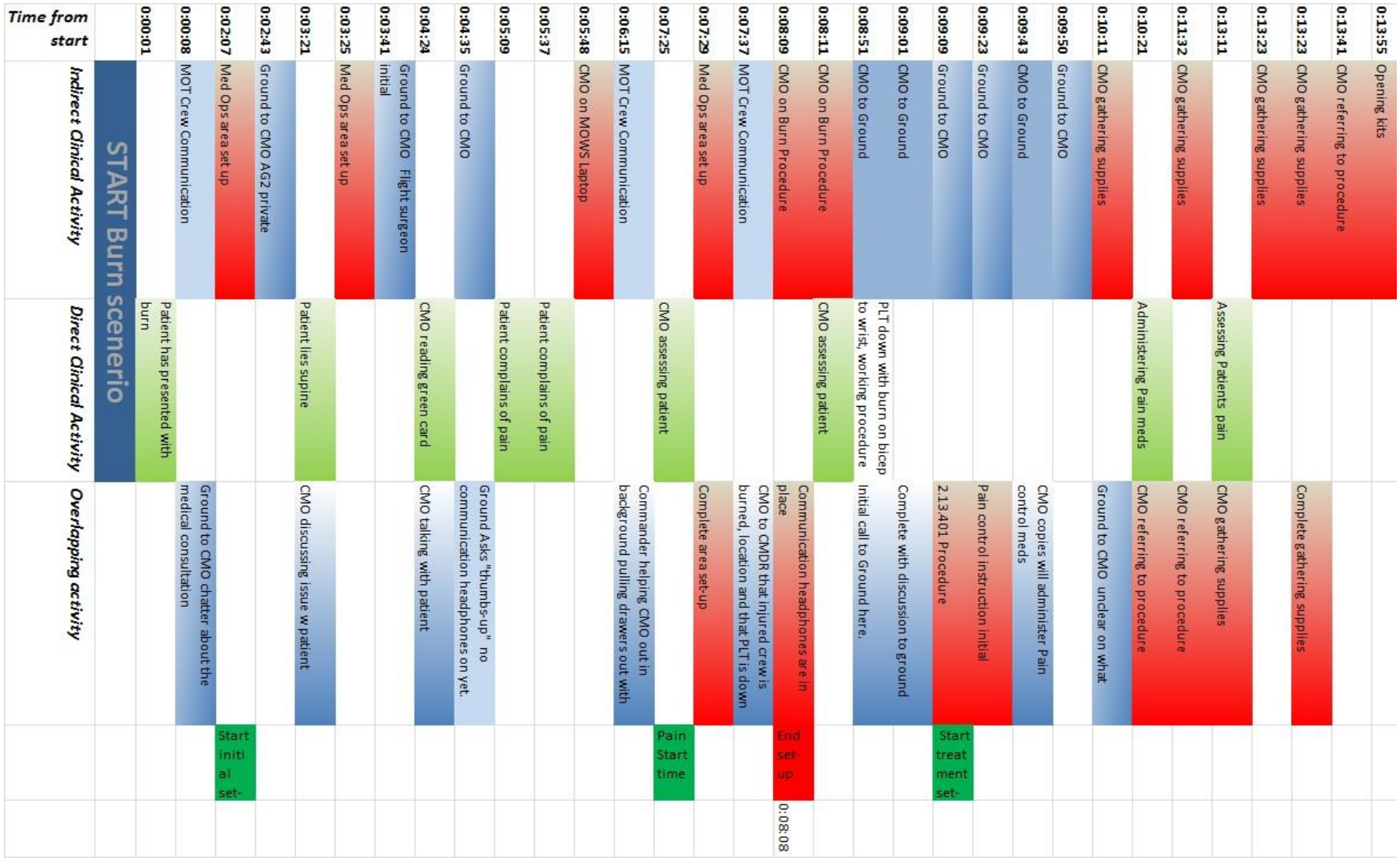


Figure 24: Time value stream map for burn scenario (5-second delay).

0:22:11	MOT Crew Communication		CMDR leaves MOWS area		
0:22:09	MOT Crew Communication		CMDR enters MOWS area offering help		
0:21:54	Stow BP equipment				
0:21:42	Stow BP equipment				
0:21:21		Instrument BP Cuff			
0:21:29		Instrument BP Cuff	CMO Entering BP 130/85		
0:21:01		Instrument BP Cuff			
0:20:49	Configure BP cuff				
0:20:13	Stow Thermometer		MOWS Laptop		
0:20:05	CMO entering Vitals data-99.3				
0:20:05		Instrument thermometer	CMO entering Temp data-99.3		
0:19:58		Instrument thermometer			
0:19:51	Configuring Thermometer		CMO referring to procedure		
0:19:45	CMO entering Vitals data		Typing in the data now		
0:19:17	CMO entering PHE data		0.97		
0:18:47		Instrument Pulse oximetry			
0:18:46		Instrument Pulse oximetry		Start Vitals	
0:18:32	CMO gathering supplies				
0:18:20	CMO to Ground		CMO gathering supplies		
0:17:41	Ground to CMO	additional step from Flight surgeon			
0:17:31	CMO gathering supplies				
0:17:30	CMO on MOWS Laptop				
0:16:40		Assessing Patients pain	Patient said "8"	End Pain time	0:11:31
0:16:34	Ground to CMO		Copy pain control "rate 1 to 10"		
0:16:11		CMO going to vital signs next			
0:16:09	CMO to Ground				
0:15:41	CMO referring to procedure				
0:15:25		Administering Pain meds			
0:15:12	CMO referring to procedure	reading aloud pain control-pain procedure	requires CMO turn away from patient and gloved hands on MOWS		
0:14:58		Assessing the burn	Treatment of patient begins		
0:14:46	CMO referring to procedure		reading aloud the steps and supplies he has avaliable.		
0:14:38	Gathering Antibiotic ointment				
0:14:20		Assessing Patients pain			
0:14:02		Donning Gloves			

0:33:22	CMO gathering supplies				
0:31:50	CMO referring to procedure		Looking for Iodine location in the procedure		
0:31:31	Ground to CMO		varify that is correct folder to document		
0:30:52	CMO to Ground		Image moving complete placed in Flight surgeon folder (found at the end		
0:30:26	Ground to CMO				
0:30:09	CMO to Ground		Calling for clarification to where to place image of burn		
0:29:53	CMO moving image data in Procedure		Looking for correct file in the procedure not clear		
0:29:54	CMO moving image data in Procedure				
0:28:50		CMO Documents with image			
0:28:47		CMO Documents with image			
0:28:40	CMO to Ground				
0:28:35	Ground to CMO		CMO messing with the camera (maybe image quality issue?)		
0:28:21	CMO to Ground		Good bloodflow to fingers		
0:28:03	CMO referring to procedure				
0:28:01		Assessing Patient complete			
0:27:54		Assessing Patient	doing the extended exam as requested by flight surgeon		
0:27:31	CMO to Ground				
0:27:11		CMO Documenting Burn with camera	Requesting extended physical exam_finger movment, capillary refill		
0:26:30		CMO Documents with image	Ground to CMO		
0:26:22	CMO to Ground		CMO referring to procedure		
0:25:46	Ground to CMO		Ground to CMO copies all		
0:25:42	CMO with Camera				
0:25:16	CMO to Ground				
0:25:06		CMO assessing area % of burn on body	8% surface area burn		
0:24:31		CMO assessing area % of burn on body	CMO referring to procedure		
0:24:25	CMO on Step 4 of Burn procedure				
0:23:53	CMO to Ground		Vitals read back to Flight Surgeon		
0:23:08	CMO referring to procedure		Vitals complete	End Vitals	0:04:22
0:22:32	Ground to CMO	CMO referring to procedure	Vital sign reference values FYI		
0:22:31	CMO referring to procedure				
0:22:11	MOT Crew Communication		CMDR leaves MOWS area		

0:44:52	Ground to CMO		Proceed to step 7		
0:44:46		CMO prep the bandages and ointment	CMO referring to procedure		
0:43:40		CMO prep the bandages and ointment	complete with bandage prep		
0:43:02		CMO prep the bandages and ointment			
0:41:40		CMO prep the bandages and ointment			
0:41:00		CMO prep the bandages and ointment	Simulation of the iodine and water cleaning area		
0:40:32		Instrument iodine and water cleaning area	CMO referring to treatment		
0:39:39	Ground to CMO		verifying he has 10 min remaining		
0:39:36	COM to Ground		Copies all will wait 15 min		
0:39:19	Ground to CMO		Will let CMO know when 15 min is complete		
0:39:01	CMO to Ground		MOT Crew Communication		
0:37:46	Ground to CMO		wait do nothing and simulate the activity of step 6		
0:37:41	CMO to Ground		Verify to wait do nothing and simulate the activity of step 6		
0:37:26	Ground to CMO		Reitterate that 15 min delay for simulation		
0:36:56	CMO to Ground		status of patient		
0:36:31	CMO referring to procedure				
0:36:21		Instrument iodine and water	cleaning simulation here		
0:36:11		Instrument iodine and water	cleaning simulation here		
0:35:51	Ground to CMO		Instrument iodine and water		
0:35:31	CMO to Ground		Advice to clean the area scrub the dead tissue ect		
0:35:09	CMO puts headset back on		CMO referring to procedure		
0:34:41	Ground to CMO		Simulate 15 min of cleaning advised		
0:34:31		Instrument iodine and water	CMO referring to procedure		
0:34:21		Patient complains of pain			
0:34:12		Instrument iodine and water			
0:04:09		Instrument paper towels beneath arm	Actual Burn treatment begins here...		
0:33:59	CMO returns				
0:33:41	Patient alone				
0:33:41	Patient alone				
0:33:11	CMO gathering supplies		CMO leaves MOWS area to gather paper towels...		
0:33:05	CMO gathering supplies		CMO referring to procedure		
0:33:22	CMO gathering supplies				
0:31:50	CMO referring to procedure		Looking for Iodine location in the procedure		

	Conclusion of Burn Simulation				
				End Burn simulation	1:06:00
	All equipment stowed				
1:06:01	CMO still in process of stow of equipmet and med ops area open				
1:01:35	CMO to Ground		Request release of AG 2		
0:59:32		Patient released	CMO stowing equipment		
0:59:02	Ground to CMO		CMO stowing equipment		
0:58:49	CMO stowing equipment				
0:58:31	CMO to ground		procedure wrap-up		
0:58:23		Patient sitting up	CMO stowing equipment		
0:58:11		CMO consulting with patient			
0:57:40	CMO procedure complete		Data transferred , CMO verbalized		
0:57:31	CMO to Ground		CMO on procedure		
0:55:26	CMO on procedure		Coying images of burn		
0:55:11	CMO to Ground		CMO on procedure		
0:55:08	Ground to CMO complete		CMO on procedure		
0:55:00	Ground to CMO		FS tells CMO to wrap up procedure save data		
0:54:35	CMO to ground complete			End Vitals	0:03:19
0:54:35	CMO to Ground		Status of patient and vitals		
0:54:03		CMO respiratory rate	CMO entering in vital signs		
0:53:47	CMO entering in vital signs		simulated this step Resp =18		
0:53:32	Stow BP equipment				
0:53:24		Instrument BP Cuff	126/84		
0:53:21		Instrument BP Cuff			
0:53:00	Configure BP cuff				
0:52:37	CMO entering Vitals data				
0:52:31		Instrument Pulse oximetry			
0:52:24		Instrument thermometer	CMO entering PHE data-99.3		
0:52:22		Instrument thermometer	Ground to CMO		
0:52:00	Configuring Thermometer				
0:51:58	CMO to Ground		CMO referring to procedure		
0:51:41		Assessing Patient	doing the extended exam as requested by flight surgeon Vitals and capillary		
0:51:16		Vitals signs begin	CMO referring to procedure	Start Vitals	
0:50:41	CMO to Ground				
0:50:21	CMO referring to procedure				
0:50:13	Stow supplies				
0:49:56		Applying tape to bandage	bandage in place complete	End treatment of	0:40:47
0:49:50		Applying tape to bandage	Headset wires seem to get in the way while treating the patient		
0:46:13		Applying gauze bandage			
0:46:13		Applying gauze bandage			
0:46:05		Administer Ointment			
0:45:56		assessing pain			
0:45:31		Administer Ointment			
0:45:28		Treating the Burn now			
0:45:24	CMO to Ground		Copies will proceed		
0:45:04	CMO referring to procedure				

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13. ABSTRACT *(Maximum 200 words)*

In March 2012, the Mission Operations Test (MOT) Team of the NASA Advanced Exploration Systems project requested assistance from the Exploration Medical Capability in the development of a simulated near-Earth asteroid (NEA) mission. The simulation would take place in a flight analog located at the Johnson Space Center. In addition to providing a list of medical equipment relevant to a NEA mission, the ExMC coordinated the development, integration, and execution of medical scenarios for the MOT Team's test to evaluate crew operations during exploration class space flight missions. This work also had direct applicability to the ExMC's Exploration Medical System Demonstration (EMSD) project. The EMSD project demonstrates, on the ground and in flight, an end-to-end medical system for exploration class missions. The ExMC used the MOT to evaluate, in a ground-analog environment, how the existing International Space Station medical resources would function on an exploration mission. Insights gained from the completion of this simulation enabled ExMC to make recommendations to overcome existing gaps in current exploration medical operations. This report details the development, integration, execution, results, and conclusions from ExMC's preliminary evaluation of the medical capability that could be integrated into the EMSD and used for an exploration class mission.

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