



Aeronautics and Space Administration



ASSESSING THE ADDED VALUE OF MINIATURE X-RAY IN THE SETTING OF US IN SPACEFLIGHT

Human Research Program
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“Expanding the Boundaries of Space Medicine and Technology”



IMPACT v1.0 Condition List (IMCL)

Abdominal Wall Hernia	Barotrauma (Ear/Sinus Block)	Burn - Mild, Thermal	Dental Luxation/ Avulsion (Tooth Loss)	EVA Related Hand Injury	Fracture - Cervical Spine
Abnormal Uterine Bleeding	Benzodiazepine or Opioid Overdose	Burn - Moderate To Severe, Thermal	Dislocation - Finger	EVA Related Heat Illness	Fracture - Distal Leg
Acute Coronary Syndrome	BHP - Adjustment Disorder	Cerebrovascular Accident	Dislocation - Shoulder	EVA Related Paresthesia	Fracture - Femur
Acute Radiation Syndrome	BHP - Anxiety	Cerumen Impaction	Diverticulitis, Acute	EVA Related Shoulder Injury	Fracture - Hand
Allergic Reaction (Mild To Moderate)	BHP - Depression	Choking/Obstructed Airway	Dust Exposure - Lunar	EVA Related Suit Contact Injury	Fracture - Wrist
Altitude Sickness	BHP - Grief Reaction	Cholelithiasis/Biliary Colic, Acute	Ebullism	Eye - Retinal Injury	Fracture- Thoracic/ Lumbar Spine
Anaphylaxis	BHP - Psychosis Secondary To Depression	Dental Abscess	Epistaxis	Eye Foreign Body	Gastritis/Reflux/ Esophagitis
Appendicitis	BHP - Sleep Disturbance	Dental Crown Loss	EVA Related Decompression Sickness	Eye Irritation/Corneal Abrasion/Ulceration	Gastroenteritis/ Acute Diarrhea
Arthritis, Acute	Burn - Chemical Eye	Dental Filling Loss	EVA Related Dehydration	Eyelid And Anterior Eye Infection	Glaucoma, Acute Angle-Closure
Atrial Fibrillation/ Atrial Flutter	Burn - Chemical Skin	Dental Fracture/Exposed Pulp	EVA Related Fingernail Delamination	Fracture - Arm	



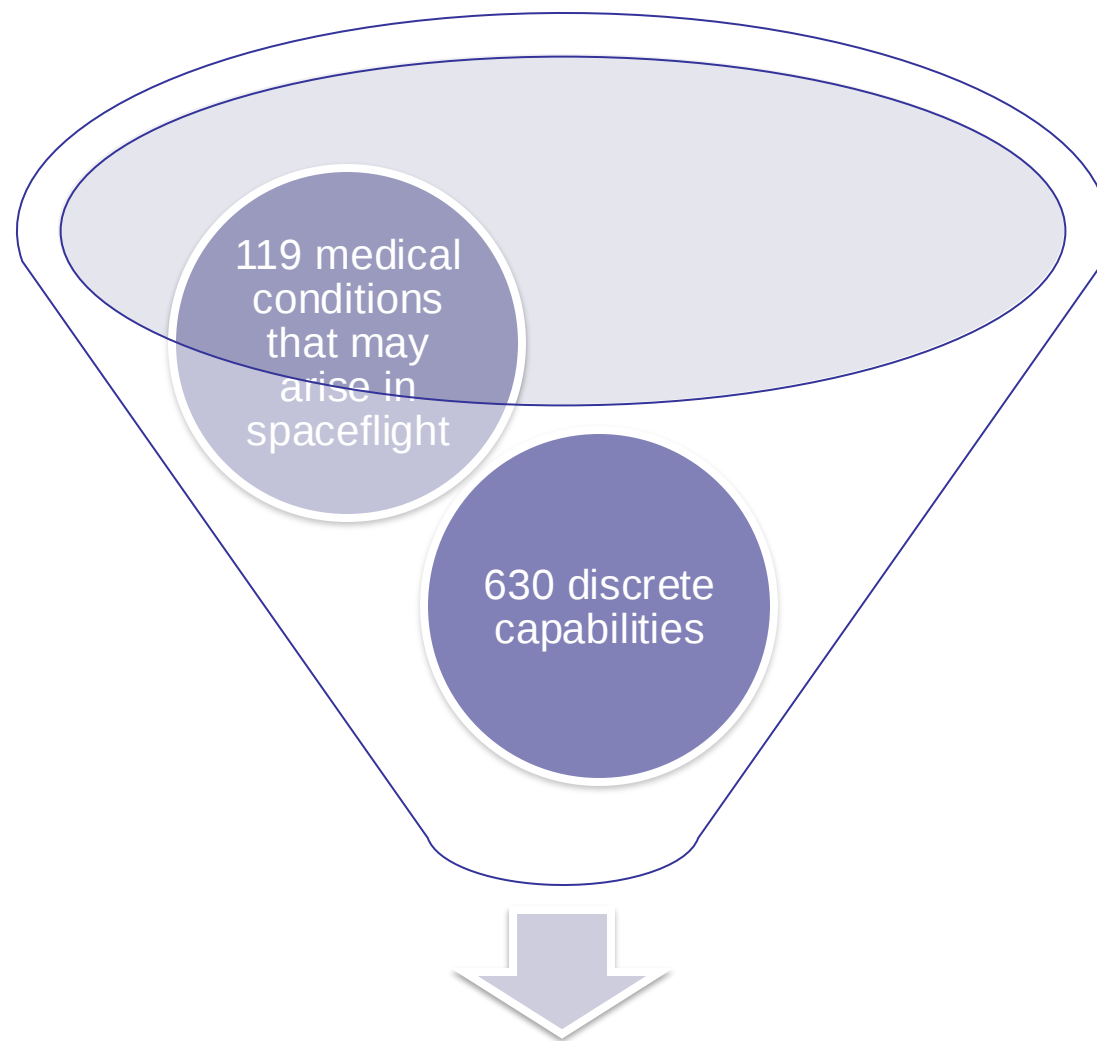
IMPACT v1.0 Condition List (IMCL)



Gravity Well - Entry Motion Sickness	Nephrolithiasis	Respiratory Failure	Small Bowel Obstruction	Spaceflight Associated Neuro-Ocular Syndrome (SANS)	Toxic Inhalation Exposure
Gravity Well – Neurovestibular Disturbance	Neuropathy - Central, Impingement Related	Respiratory Tract Infection - Lower	Space Adaptation - Back Pain	Sprain/Strain - Back	Toxic Inhalation Exposure - Combustion Products
Gravity Well - Orthostatic Intolerance	Otitis Externa	Respiratory Tract Infection - Upper	Space Adaptation - Constipation	Sprain/Strain - Lower Extremity	Trauma - Abdominal Injury (Blunt)
Headache	Otitis Media	Seizures	Space Adaptation - Epistaxis	Sprain/Strain - Neck	Trauma - Chest Injury (Blunt)
Headache - Co2 Induced	Pancreatitis, Acute	Sepsis	Space Adaptation - Headache	Sprain/Strain - Upper Extremity	Trauma - Minor Head
Hearing Loss	Vaginal Yeast Infection	Shock - Cardiogenic	Space Adaptation - Insomnia	Streptococcal Pharyngitis	Trauma - Severe Head
Hearing Loss - Noise-Related	Venous Thromboembolism	Skin Abrasion	Space Adaptation - Nasal Congestion	Sudden Cardiac Arrest	Traumatic Hypovolemic Shock
Hemorrhoids	Prostatitis, Acute	Skin Infection - Bacterial	Space Adaptation - Space Motion Sickness	Tendinopathy/Enthesopathy/Bursitis/Over-Use Injuries - Lower Extremity	Urinary Tract Infection
Herpes Zoster Reactivation (Shingles)	Rash, Spaceflight Associated	Skin Infection - Viral/Fungal	Space Adaptation - Urinary Retention	Tendinopathy/Enthesopathy/Bursitis/Over-Use Injuries - Upper Extremity	
Mouth Ulcer	Reactive Airway	Skin Laceration	Space Adaptation - Urinary Incontinence	Toxic Dermal Exposure	



IMPACT'S EVIDENCE LIBRARY

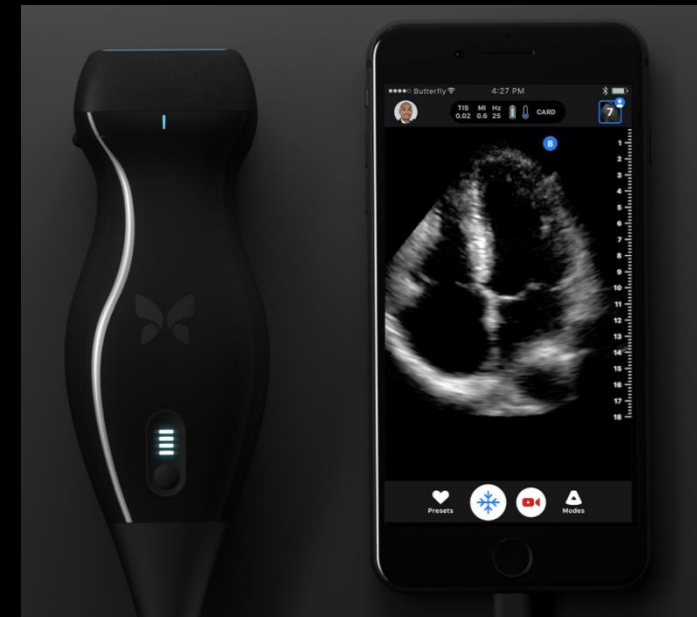


904 discrete resources



NASA astronaut Leroy Chiao performs an ultrasound examination of the eye on cosmonaut Salizhan Sharipov.

<https://www.nasa.gov/missions/station/ultrasound-scans-in-space-transform-medicine-on-earth/>



*Butterflynetwork.com



Remedi REMEX-KA6

Fujifilm Xair



MinXRay



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<https://www.mfsurgical.com/wp-content/uploads/2023/04/REMEDI-KA6-Brochure.pdf>

https://dicomsolutions.com/product/minxray-impact-portable-x-ray-machine/?srsltid=AfmBOopcOv4r_sQ8JJMTsEKZOqbkgTntW-LQnRYA1kvQjyNk8RfHs0R

<https://www.fujifilm.com/uk/en/healthcare/x-ray/portable-x-ray/fdr-xair>



SME CONSENSUS



XRAY > US for either diagnosis or management for 21 conditions

XRAY = US for either diagnosis or management for an additional 15 condition

US > XRAY for either diagnosis or management for an additional 27

63/119

XR > US

DIAGNOSIS

- Arthritis, acute
- Choking/obstructed airway
- Dental abscess
- Dental crown loss
- Dental filling loss
- Dental fracture/exposed pulp
- Dental luxation/avulsion (tooth loss)
- Dust exposure – Lunar
- Fracture – Cervical spine
- Fracture – Thoracic/lumbar spine
- Gastritis/reflux/esophagitis
- Neuropathy – Central, impingement related
- Toxic inhalation exposure
- Toxic inhalation exposure – combustion products

MANAGEMENT

- *Choking/obstructed airway*
- *Ebullism*
- EVA related decompression sickness
- Fracture – cervical spine
- Fracture – distal leg
- Fracture – femur
- Fracture – hand
- Fracture – wrist
- Fracture - thoracic/lumbar spine
- *Trauma – chest injury (blunt)*

XR = US

DIAGNOSIS

- Abdominal wall hernia
- Acute coronary syndrome
- Appendicitis
- Atrial fibrillation/atrial flutter
- Cholelithiasis/biliary colic, acute
- Diverticulitis, acute
- Ebullism
- Eye foreign body
- Nephrolithiasis
- Trauma – abdominal injury (blunt)
- Trauma – chest injury (blunt)
- Traumatic hypovolemic shock

MANAGEMENT

- Appendicitis
- Cholelithiasis
- Diverticulitis, acute
- Nephrolithiasis
- Reactive airway (now removed from list)
- Seizures
- Cardiogenic shock
- Sudden cardiac arrest
- Trauma - chest injury (blunt)
- Traumatic hypovolemic shock



TRADESPACE ANALYSIS



- With two technologies that may compete or complement each other, sophisticated tradespace analysis becomes critical
 - IMPACT is designed for this exact ability—to build in new technologies and use the modeling to help guide consideration of inclusion in a medical system
- This is especially true in a system that uses partial weighting



HISTORICAL MODELING



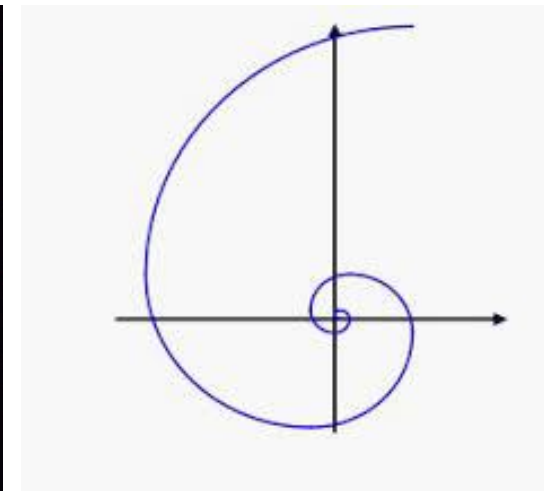
- IMPACT 1.0 utilized a ***partial weighting*** scheme where each capability (and resource assigned) contributes *partially* to the diagnosis and management of a condition
 - i.e., if the condition has 10 capabilities and cutting pills is one of those 10, even if you cannot take a history, perform a physical exam, send any labs, or provide any pharmacologic agents, the condition is considered 10% **treated**



IMPROVED PARTIAL WEIGHTING



- To iterate upon this for IMPACT 1.1, we created a ***Fibonacci partial weighting*** contribution schema where each diagnostic and therapeutic capability is weighted on a 5-point scale
 - Weighing capabilities closer to exponential than linear but using whole numbers (1, 2, 3, 5, 8)





FIBONACCI AGILE ESTIMATION



#	1	2	3	4	5	6	7	8	9	10	11	12	13
F	0	1	1	2	3	5	8	13	21	34	55	89	144

Total of 5 Numbers													
SIM #1	19	5.26%	10.53%	15.79%	26.32%	42.11%							
SIM #2	31		6.45%	9.68%	16.13%	25.81%	41.94%						
SIM #3	50			6.00%	10.00%	16.00%	26.00%	42.00%					
SIM #4	81				6.17%	9.88%	16.05%	25.93%	41.98%				
SIM #5	131					6.11%	9.92%	16.03%	25.95%	41.98%			
SIM #6	212						6.13%	9.91%	16.04%	25.94%	41.98%		
SIM #7	343							6.12%	9.91%	16.03%	25.95%	41.98%	

#	1	2	3	4	5	6	7	8	9	10	11	12	13
F	0	1	1	2	3	5	8	13	21	34	55	89	144

Scale of 5 Numbers													
SIM #1	8	12.50%	25.00%	37.50%	62.50%	100.00%							
SIM #2	13		15.38%	23.08%	38.46%	61.54%	100.00%						
SIM #3	21			14.29%	23.81%	38.10%	61.90%	100.00%					
SIM #4	34				14.71%	23.53%	38.24%	61.76%	100.00%				
SIM #5	55					14.55%	23.64%	38.18%	61.82%	100.00%			
SIM #6	89						14.61%	23.60%	38.20%	61.80%	100.00%		
SIM #7	144							14.58%	23.61%	38.19%	61.81%	100.00%	



PARTIAL WEIGHTING DEFINITIONS



- 1 – Minimally influences diagnosis or management (D/M).
- 2 – Affects D/M. **Easily improvised.**
- 3 – **Significantly** affects D/M but condition can be managed to some degree of accuracy without it. Can be **improvised with moderate difficulty.**
- 5 – Significantly affects D/M but condition can be managed to some degree of accuracy without it. **Very difficult to improvise.**
- 8 – **Critical** for D/M. **No improvisation** can compensate for the lack of this capability.



PARTIAL WEIGHTING EXAMPLE



BRANCH 165 PARTIAL WEIGHTING	JS BC	AN BC	PP BC	SP BC	ES BC	AA BC	DL BC	DN BC
<u>ICL26 Cholelithiasis/Biliary Colic, Acute</u>								
<u>CP1 - Ground Based Support Communications</u>	2	3	2	3	3	2	3	
<u>CP1 - History - Collect History of Present Illness</u>	8	8	8	8	8	8	8	
<u>CP1 - Imaging - Ultrasound</u>	8	5	3	3	3	8	8	
<u>CP1 - Interpretation - Laboratory Results</u>	5	3	3	3	3	5	3	
<u>CP1 - Interpretation - Physical Exam</u>	8	8	8	3	8	8	8	
<u>CP1 - Interpretation - Ultrasound - Abdominal</u>	8	8	3	5	8	8	8	
<u>CP1 - Interpretation - Ultrasound - Pelvic</u>	3	2	3	3	2	1	2	
<u>CP1 - Laboratory - Amylase</u>	5	2	2	5	2	5	2	
<u>CP1 - Laboratory - BMP</u>	5	1	3	5	1	5	2	
<u>CP1 - Laboratory - CBC</u>	5	1	2	5	1	5	2	
<u>CP1 - Laboratory - Liver Function Test</u>	5	2	2	5	2	5	5	

- At least 5 physician SMEs independently weighted each capability for the best- and worst-case of each condition and the median weight, standard deviation, and interrater agreement were determined
- Poor agreement required consensus meeting between SMEs to decide a final weight other than the median as the final weight for each capability



ADDING MINIATURE X-RAY



- As previously stated, there are 63/119 conditions that could utilize US or miniature x-ray to varying degrees
- We are able to build in new capabilities for miniature x-ray and then re-weight the partial weighting of US and miniature x-ray according to the importance for diagnosis or management of a given condition
 - Sometimes they may both be important and weighted highly (i.e., both are a 5 or 8)
 - Sometimes they are both useful and their weighting decreases as they are alternates for each other (i.e., both are a 3 or 5)
 - Sometimes one is drastically better, however, the other may have some utility as an alternative (i.e., one is a 2 and the other is an 8)



ADDING MINIATURE X-RAY



- Before using SME time to re-weight and build in both capabilities to 63 conditions, we first wanted to perform a pilot study with MEDPRAT
- First, we utilized the results for an exploration mission DRM
 - 1120 days (180 days Mars transit → 760 days on Mars surface → 180 days Earth transit)
 - 4 crew (3M/1F)
 - 1 surface EVA for 2 crew q2d for a total of 190 EVAs per person
 - No microgravity EVAs



ADDING MINIATURE X-RAY



- Before using SME time to re-weight and build in both capabilities to 63 conditions, we first wanted to perform a pilot study
- First, we utilized the results for an exploration mission DRM
- Then, set medical system parameters
 - 60 kg total / Volume unconstrained
 - Fujifilm – 3.5 kg (13.8L)
 - MinXray – 8.5 kg (20.9L)
 - Remedi – 2.4 kg (10.1L)



ADDING MINIATURE X-RAY



- Next, we looked at the top 10 conditions that led to LOCL, RTDC, and TTL, and re-weighted the 9 conditions within those top conditions for which miniature x-ray may have utility

Dental Abscess

Wrist Fracture

Ebullism

Respiratory Failure

EVA-related DCS

Lower Respiratory Tract
Infection

EVA-related shoulder injury

Toxic Inhalation Exposures

Eye Foreign Body



BASELINE MEDICAL SYSTEM



- 390-500nm Wavelength Lamp
- Audiometry Supplies
- Foam Ear Plugs
- Computer
- Tympanometry Probe Tips
- Sharps Container
- Non-sterile Gloves
- Skin Cleanser
- 16G/18G/23G Needles
- Bayonet Forceps
- Foley Catheter
- Rhino Rocket
- Cotton Swabs
- Myringotomy Blade
- Needle Driver
- Otoscope
- 5ml/10ml/20ml Syringes
- Toothed Forceps
- Vascular Access Supplies
- Iontophoresis Patch
- Sterile Surgical Lube
- Ultrasound Gel
- Ultrasound Probe
- Tourniquet
- Sterile Saline Flush
- Antimicrobial Hemostatic Intravenous Patch
- 4in Rolled Gauze
- Tegaderm 4.75in
- 2x2 Gauze
- 4x4 Gauze
- 4x4 QuickClot Dressing
- 3.0/4.0 Absorbable Suture
- 3.0/4.0/5.0 Nylon Suture



BASELINE MEDICAL SYSTEM



- Beclomethasone (nasal)
- Dexamethasone (IV)
- Fentanyl (IV)
- Promethazine (IV)
- Tobramycin Drops (Oph)
- Dextran/Hypermell ose Drops (Oph)
- Fluoresceine (Oph)
- Acetaminophen
- Amoxicillin
- Fluconazole
- Levofloxacin
- TMP/SMX
- Valacyclovir
- Benzonatate
- Bisacodyl
- Bismuth
- Caffeine
- Escitalopram
- Famotidine
- Electrolyte Salts
- Loperamide
- Loratadine
- Lorazepam
- Melatonin
- Modafinil
- Naproxen
- Ondansetron
- Prednisone
- Promethazine
- Pseudoephedrine
- Simethicone
- Zaleplon
- Zolpidem
- Bupivacaine (SQ)
- Lidocaine (SQ)
- Hydrocortisone (top)
- Lidocaine (top)
- Mupirocin (top)
- Lidocaine (patch)



BASELINE MISSION OUTCOMES



- Risk of LOCL: 0.107 (-0.22-0.42) events/mission
- Risk of RTDC: 3.36 (1.52-5.18) events/mission
- Risk of TTL: 1320 person days (1054-1587 person days out of 4480 total person days)

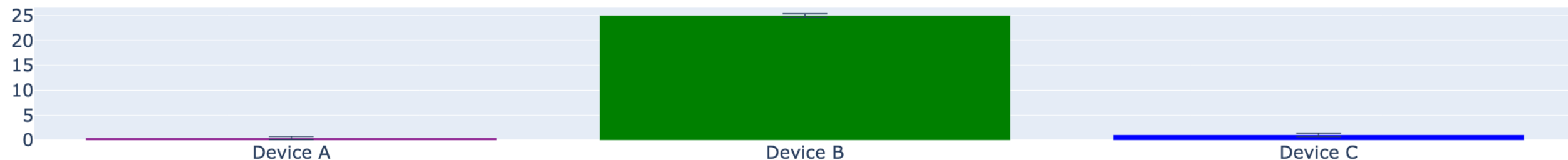


RESULTS - RTDC



- **Baseline Risk of RTDC: 3.36 (1.52-5.18) events/mission**

Percent Change in Mean Removal to Definitive Care Compared to Evidence Library Baseline



- RTDC – Device A (Fujifilm) : 3.37 (1.54-5.20)
- RTDC – Device B (MinXray): 4.19 (2.14-6.25)
- RTDC – Device C (Remedi): 3.39 (1.55-5.23)

Results are preliminary, have not been subject to review, and must not be used on a decisional basis.

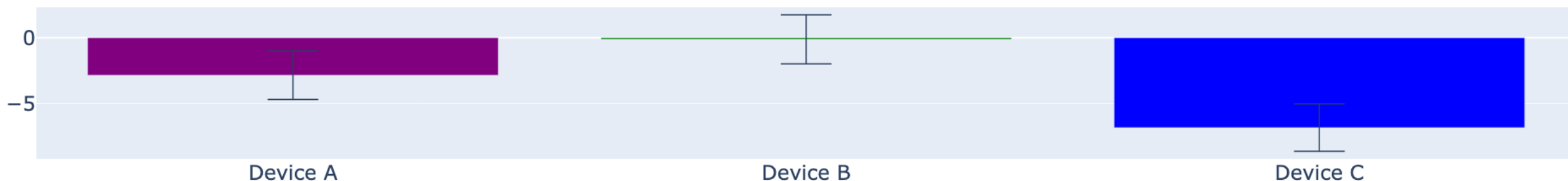


RESULTS



- **Risk of LOCL: 0.107 (-0.215-0.430) events/mission**

Percent Change in Mean Loss of Crew Life Compared to Evidence Library Baseline



- LOCL – Device A (Fujifilm): 0.104 (-0.213-0.421)
- LOCL – Device B (MixXray): 0.107 (-0.214-0.428)
- LOCL – Device C (Remedi): 0.010 (-0.211-0.410)

Results are preliminary, have not been subject to review, and must not be used on a decisional basis.

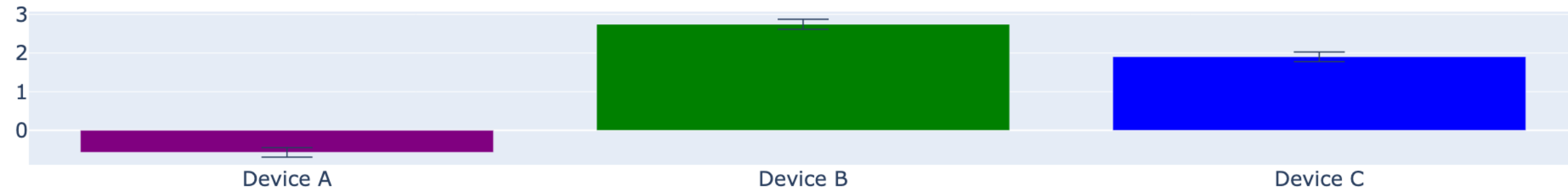


RESULTS



•Risk of TTL: 1320 (1054-1587 person days)

Percent Change in Mean Task Time Loss Compared to Evidence Library Baseline



- Risk of TTL – Device A (Fugifilm): 1313 (1046-1580) days
- Risk of TTL – Device B (MinXray): 1357 (1080-1633) days
- Risk of TTL – Device C (Remedi): 1346 (1078-1613) days

Results are preliminary, have not been subject to review, and must not be used on a decisional basis.



RESULTS - TRADESPACE



FUGIFILM

- Audiometry Supplies
- Instrument Disinfectant
- Foley
- Bayonet Forceps
- Rhino Rockets
- Needle Driver
- Suture Scissors
- Toothed Forceps
- US Probe
- US Gel
- 3.0/4.0/5.0 Suture

MINXRAY

- 390-500nm Wavelength Lamp
- Audiometry/Tympanometry Supplies
- **Computer**
- Sharps
- Non-sterile Gloves
- Skin Cleanser
- 16G/18G/23G Needles
- Vascular Access Supplies
- Some steroids
- Fentanyl

REMEDI

- Audiometry/Tympanometry Supplies
- **Computer**
- Beclomethasone
- Dextran Drops (Oph)
- Decreased all of the topical meds
- Decreased all of the pain meds
- Decreased skin cleanser
- Decreased suture supplies



Acknowledgements

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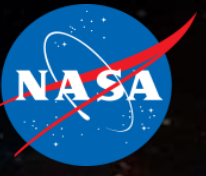
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Questions?