SUMMARY OF TECHNICAL INTERCHANGE MEETINGS (TIMs) DESIGNED TO ENABLE EARTH INDEPENDENT MEDICAL OPERATIONS (EIMO)

Human Research Program
Science Integration Office

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Expanding the Boundaries of Space Medicine and Technology

Background

- **The Exploration Medical Capability Element (now Science Integration Office) in NASA's Human Research Program hosted an EIMO Definition Workshop in January 2023**
- **Senior Leadership from NASA provided the foundation for a series of Technical Interchange Meetings (TIMs) conducted in 2023-2024.**
- **The TIMs were designed to stimulate discussion around specific topics with the goal of enabling Earth Independent Medical Operations (EIMO).**

Constituent EIMO Components

Source: https://ntrs.nasa.gov/api/citations/20240002454/downloads/EIMO%20TM%20LEADERSHIP%20TIM_10JAN2023.pdf

Why Does NASA Need to Enable EIMO?

MCC + Mission Evaluation Room

- 85 systems experts
- 660 years combined specific systems experience
- ~2 years to operator certification
- Additional years to specialist certification
- In-depth understanding of single systems
- Training builds academic engineering background
- Continuously using skills, studying flight rules

Astronauts

- 4 crew members
- 91 years combined relevant work experience
- 2 years ASCAN training
- ~ 2 years flight-assigned training
- Time Gap between training and flight; degradation of knowledge may be significant

Source: https://ntrs.nasa.gov/api/citations/20220014610/downloads/Crew%20Health%20and%20Performance%20101%20-%20September%202022.pdf

TIMs Conducted

TIM	THEMATIC FOCUS	DATE
I	EIMO Definition Workshop	10 January 2023
II	Datascope	21 August 2023
III	CMO Training	26 October 2023
IV	Supply & Resource Management	27 February 2024
V	Task Load Management	21 May 2024

EIMO DEFINITION WORKSHOP (TIM I)

Topics

- Factors driving new paradigm?
- Medical risk reduction & resource constraints
- When have we achieved EIMO?
- “What’s possible” *vs*. “what’s necessary”
- Other stakeholders/partners?
- Long-term collaboration structure
- Specific EIMO outputs

Takeaways

- **Gradual shift:** Terrestrial to space-based assets
- **Versatility:** Support CHP across multiple habitats, vehicles, and suits
- **Comms-delay:** Behavioral and team dynamics
- **Knowledge, Skills, Abilities (KSAs):** Specialization/expertise *vs* improvisational proficiency and reliance on just-in-time learning
- **Transparency:** Communications regarding medical risk
- **Trade-offs:** Medical risk and medical system resource allocations
- **Medical resources:** Redundancy, sophistication, resilience
- **Stakeholders:** Astronauts, biomedical engineering (BMEs), commercial spaceflight partners, dentistry, nursing, robotics, rehabilitation, ethics and policy experts, Moon to Mars Program Office, NASA HQ
- **Needs:** Capability gap analysis, integrated EIMO roadmap; Concept of Operations and requirements for a Mars-level medical system (primary target = Transit Habitat) that enables progressive Earth independence and autonomy

DATASCOPE (TIM II)

Topics

- Is generative AI the “way to go”?
- What AI modalities should be tested?
- Can terrestrial LLM “training” use synthetic datasets to bridge the spaceflight data gap?
- What would a ground test bed look like?
- What skillsets and expertise should direct this work?
- Future EIMO TIMs-other considerations?
- Strategies for engaging thought leaders?

Takeaways

- **Multimodal AI:** No single AI modality solution
- **Trust gap:** Verification & validation of AI tools
- **Build or break:** Federated lab structure
- **Industry partnership:** Leverage Industry partner development velocity
- **More deliberations will be helpful:** Future TIMs needed, outreach essential
- **This is achievable:** While not deployable today technology will gain acceptance

CREW MEDICAL OFFICER TRAINING (TIM III)

Topics

- CMO training time for exploration missions will increase (10x to 20x), is this sufficient?
- What training could be added to enable EIMO?
- How has terrestrial medical training evolved and can new methods/tools be used?
- What role could extended reality (XR) tools play? Other nascent technologies?
- Training responses to specific medical scenarios vs. generalized skills with broad applicability?
- Just-in-time training vs. partial/delayed ground support?
- Risk-based analysis for clinical skills suitable for JITT vs. formal proficiency maintenance?
- On-board reference materials - what type and strategy for prioritization?

Takeaways

- **Training metrics:** Validated competencies *vs.* hours trained
- **Skills:** Broad, translatable; procedural skills prioritized
- **Extended reality:** Simulate the space environment; content development collaboration between SME's and the VR developers;
- **Training reinforcement:** Ability of the crew to review their performance and generate a self-assessment
- **Likelihood, consequence and procedure matrices:** Across the expected medical condition list will prioritize the resources and the type and amount of training to buy down risk
- **MacGyvernaut:** EIMO CMO similar to approach practitioners have utilized for decades, particularly in remote & rural areas with resource constraints.

SUPPLY & RESOURCE MANAGEMENT (TIM IV)

Topics

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Given mass/volume/power constraints, what are the key considerations when conducting trade space analyses for medical supplies to enable EIMO?
Are multi-function medical devices (*e.g.*, TempusPro, LifeBot) a viable option? Key considerations include: mass/power/volume trade space; interoperability; point failure rate and loss of capability; repair/troubleshooting one device *vs* many
How can a clinically integrated medical supply chain be optimized? Should blockchain distributed ledger methods be developed to track supplies from inception to consumption?
What type(s) of storage/packaging solutions make the most sense to enable EIMO? Key considerations: must utilize inert materials designated "generally regarded as safe" (GRAS); maintenance of product stability, content uniformity; ease of packaging; label durability/longevity; minimize mass, volume & waste
What technologies other than RFID could be leveraged, *e.g.*, Diamond Dust, Near Field Communication (NFC) tags, QR codes for supply and resource management?
Is an analysis of the micro-logistics (stowage, usage and disposal) of medical supplies and resource packs warranted? How can micro-logistics of medical supplies be optimized given the constraints expected on exploration missions?
In a tradespace analysis, is it worth bringing all the extra capacity to support additive manufacturing in-mission (*e.g.*, 3D printer) rather than just bringing more supply?

Takeaways

- **Useful lifetime:** Medications and equipment
- **Prevent/leverage redundancy:** Equipment (repairs/spares); "creative uses"
- **Data/bandwidth:** Define constraints related to medical system
- **Balance training:** Align & optimize on-board resources
- **Resource usage:** Track in future versions of IMPACT
- **Multi-function medical devices:** Interfacial, interoperability and training efficiencies
- **Performance Metrics:** Optimized standard *vs* good enough threshold
- **Radiation:** Focus of another TIM
- **Blockchain distributed ledger:** "Append-only" solution (immutability, trust in data provenance, transparency)
- **Inventory management requirements and data standards:** RFID & bar code standardization and interoperability
- **Potential solutions:** "Develop from the right"; use of legacy systems
- **Consolidate tracking tools:** Management of medical supplies, pharmaceuticals
- **Micro-logistics optimization:** Medical supplies and resource packs
- **Integration and cross-communication:** Mars Campaign Office, Moon 2 Mars Program, etc.

Slide 8

BLL(SWSL0 Could we shorten these to bullet format instead of full sentences?
Boley, Lynn L. (JSC-SD211)[KBR , 2024-12-30T17:31:23.259

BKL(SWSL0 0 Agreed. I was hoping that Jay would highlight the ones he wanted to emphasize and we could condense.
Berens, Kurt L. (JSC-SD112)[KBR, 2024-12-31T16:13:50.318

TASK LOAD MANAGEMENT (TIM V)

Topics

Current task/mission contributors to crew wo[BLL(SWSL0]d what contributors are expected in future, long-duration spaceflight missions?
What measures/tool(s) could be used to assess and manage task load for crew on exploration class missions? What current tools would apply and/or need modification? Bedford Workload Scale, NASA Task Load Index (TLX) What parameters can be passively monitored to determine if crewmembers are hurried, anxious or bored resulting in attention deficit? Should a baseline be established to determine off-nominal performance and if so, how much baseline information is needed to create a sensitive, predictive and reliable system?
What individual/team factors can contribute to performance errors and how can these be measured?
What medical duties and procedures occur today that you would expect will change in the exploration mission scenario? Which of these are expected to be more burdensome on the crew in an EIMO setting and how could advanced technologies [ex: AI,VR/AR] alleviate this burden? (Health maintenance, Diagnostics, Therapeutics, Inventory control, Data management/EMR)
How would an EIMO Clinical Decision Support System (CDSS) be optimally designed to provide modalities and levels of distinction for notifications based on importance, e.g., routine, elevated, critical, that are appropriate and proportional to risk-urgency, i.e., intuitive, and resistant to habituation and/or 'alarm fatigue'?
What countermeasures for cognitive overload will be most effective and what would in-mission application of the preferred countermeasures look like? What metrics could be tracked to determine success?

Takeaways

- **Workload/overload factors:** environmental stressors, microgravity, inadequate task volume, poor design of equipment and procedures, inadequate training, aggressive/unrealistic scheduling, poor time estimation for task completion, intrusion into protected time.
- **Perceived workload:** anxiety, task order/complexity and planning fallacy
- Multiple medical devices may pose a significant cognitive load
- **Developmental tools:** Bedford Workload Scale and the NASA TLX.
- **In-flight assessment tools:** unobtrusive continuous workload monitoring, heart rate variability and functional near infra-red spectroscopy (fNIRS)
- **Self-assessment surveys:** Terminal surveys very useful; real-time assessment tools preferred
- **Passive monitoring:** Preferred (trust/privacy essential) as task monitoring adds to cognitive load
- **Individual performance:** mood, affect, cognitive performance and connection to family
- **Team performance:** communication, coordination, cooperation, psychosocial adaptation and team cohesion
- **Positive outcome *vs* performance error:** high-performing individuals and teams make few errors and often errors have minimal consequence in medical scenarios
- **No "forcing function":** gradual transition of medical care must be practiced in ground analogs and on ISS
- **Time sensitive emergencies:** on-board knowledge, skills and abilities (KSA) and "just-in-time" training material
- **Artificial intelligence-based systems:** significant role in covering the ground support gap
- **Exploration mission procedures:** dental cleanings will need to be developed and tested
- **Alert system design:** allow crew to modify alert thresholds and provide flexibility in assignment/categorization
- **Behavioral health countermeasures:** preventative optimization or interventional approach;resilience training, coping skills
- **Human factors conscious design teams:** maintaining behavioral health, *e.g.*, exercise, lighting, sleep quarters, nutrition
- **Teamwork training (Team Care):** beyond self-care, culture where it is ok to acknowledge task overloading
- **Cognitive readiness status:** parameters for critical mission training should be key considerations

Slide 9

BLL(SWSL0 Again, can we shorten these to bullet format? Might need to divide this slide. Seems WAY too busy and hard to read.

Boley, Lynn L. (JSC-SD211)[KBR , 2024-12-30T17:33:07.616

BKL(SWSL0 0 Agreed.

Berens, Kurt L. (JSC-SD112)[KBR, 2024-12-31T16:14:06.678

CONCLUSIONS

- Significant paradigm shift needed to maintain crew health and performance during exploration class missions
- Proposed methods must be deployed in ongoing operations and “tested, reviewed & practiced” with reliable back-up to facilitate Enterprise-wide comfort and acceptance
- Serious constraints on data transmission with expanding medical informatics and increasing data streams will necessitate a Clinical Decision Support System
- Training regimens, material and tools must evolve to be responsive (“just-in-time”) and enable/mesh with autonomous operations and utilize proficiency metrics
- Advanced probabilistic risk assessment tools will be essential to optimize the medical system capability while balancing mass/power/volume constraints
- Management of task (and corresponding cognitive) load using real-time assessment tools and passive monitoring of individual and team performance is imperative
- Gradual shift in the balance of medical responsibility, management and authority from terrestrial to space-based assets

EIMO TIMs SUBJECT MATTER EXPERTS

TIM I	TIM II	TIM III	TIM IV	TIM V
Abercromby, Andrew	Alibaruho, Macresia L.	Asadi, Amran	Anderson, Arian	Anderson, Arian
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Aunon-Chancellor, Serena	Burrell, Timothy	Aunon-Chancellor, Serena	Augustine, Philip M.	Augustine, Philip M.
Baumann, David	Costes, Sylvain V.	Bernatovich, Michael	Aunon-Chancellor, Serena M.	Bradshaw, Teresa L.
Beven, Gary	Courtney, Michelle	Bradshaw, Teresa L.	Bernatovich, Michael A.	Dempsey, Donna L.
Berdich, Debbie	Delaune, Paul B.	Clarke, Mark	Bradshaw, Teresa L.	Dev, Sheena
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Easter, Benjamin	Fernandez, Mark R.	Dempsey, Donna	Courtney, Michelle	Gore, Brian F.
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Frank, Jeremy	Follett, Norman	Ebert, Douglas	Gaathon, Ophir	Hilmers, David Carl
Frieling, Michelle A.	Frank, Jeremy D.	Gantwerker, Eric	Gebre, Samrawit G.	Holden, Kritina L.
Lehnhardt, Kris	Garrett, Shaina M.	Garner, Clifton	Harrivel, Angela R.	Le, Truong
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McCoy, Torin	Lehnhardt, Kris	Harrison, Michael	Horvath, Bryce L.	Maddox, Ian
Rucker, Michelle	Lemery, Jay	Hilmers, David	Jackson, Marjorie C.	Marquez, Jessica J.
Sams, Clarence	Maddox, Ian	Jones, Billy	Langford, Karyn	McCoy, Torin
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Thompson, Moriah	Mullins, John	Kuyumjian, Raffi	Lemery, Jay	Nusbaum, Derek M
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Zapp, Neil	Rice, Michael	Lemery, Jay	Mathew, Sincy	Richardson, Rachel C.
	Rucker, Michelle	Martin, Annie	Nusbaum, Derek M.	Robinson, Steve
	Sanders, Lauren M.	Mulavara, Ajitkumar	Piontek, Nicole	Russell, Brian
	Schkurko, Courtney M.	Nevins, Natalie	Reichard, John	Saenz, Shelagh
	Schmitt, Brandon D.	Piper, Steven	Rhym, Bianca M	Thompson, Moriah S.
	Scott, Ryan T.	Richardson, Rachel	Rowell, Andrew	Vera, Alonso H.
	Suresh, Rahul	Rosenberg, Marissa	Rucker, Michelle A.	Whitmire, Alexandra
	Tashakkor, Scott B	Shah, Kaushal	Schkurko, Courtney M.	Wu, Jimmy
	Uohara, Michael	Smith, Tiffany	Smith, Jeffrey D.	
	Vazirani, Manish	Stratton, Emily	Smith, Larona K.	
	Vera, Alonso H.	Whitmire, Alexandra	Stratton, Emily R.	
	Yu, Jane	Wu, Jimmy	Uhl, Steven A.	
		Yang, Justin	Vera, Alonso H.	
		Zerdoum, Aiden	Wagoner, Matt	
			Wu, Jimmy	

Thank you

to all of the Subject Matter Experts who participated in our TIMs!