Novel Approaches to Metabolic Consumption Modeling During ISS EVA Planning

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Background

- Extravehicular activity (EVA) planners at NASA's Johnson Space Center (JSC) meticulously plan all aspects of an EVA before it is executed on the International Space Station (ISS).
- Once given a proposed EVA timeline, a hand-curated model of metabolic consumption built on data collected during Neutral Buoyancy Lab (NBL) training events and historical EVAs is used to generate predictions for crewmembers.
- Metabolic consumption predictions are used by EVA planners to determine if operational timelines are feasible given the expected load on the spacesuit consumables during an EVA [1].
- Back-and-forth communication between planners and engineers may take months due to the nature of hand curation of data.
- The Personalized EVA Informatics and Decision Support (PersEIDS) project is a novel software utilizing unique modeling and estimation approaches to leverage historical EVA and ground-based analog physiological data for EVA planning and real-time EVA biomedical decision support [2].
- Recently, PersEIDS was tasked with bringing production-level software approaches and robust modeling capabilities to the ISS EVA biomedical planning process. Specifically, automating and standardizing the Certification of EVA Readiness (CoER) Report.

Historic Process of Generating Metabolic Rate Data

Collect crew member metabolic rate data during NBL training runs. Manually download data. → Flight Operations Directorate (FOD) provides EVA training timeline data in Excel format. → Analyze data in Excel to assign task categories within timelines. → Request "as planned" EVA and associated task categories from FOD. → Match task categories with the metabolic rate for individual tasks and cumulative metabolic rates.

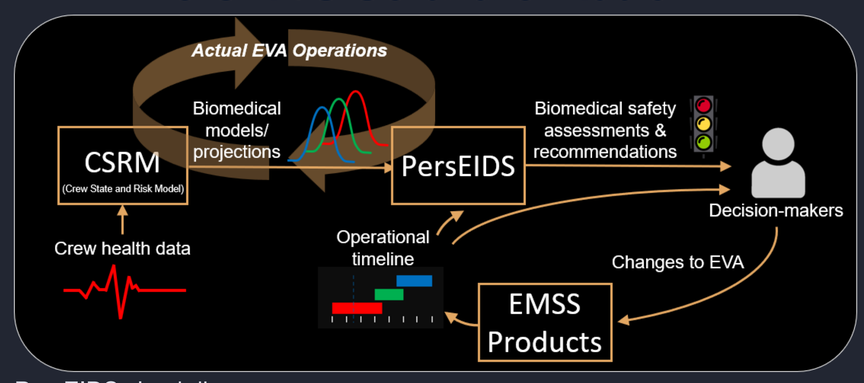
New Process of Generating Metabolic Rate Data

Capture each crew member's metabolic rate data sets from past NBL runs. Data stored to cloud database. → FOD provides EVA training timeline and task categories using MAESTRO timeline software. → "As Planned": EVA timeline and associated categories entered in PersEIDS. → Met rate, timeline, & task category data pulled from cloud DB. Match task categories with the metabolic rate for individual tasks and cumulative metabolic rates. → PersEIDS auto-generates Certification of EVA Readiness (CoER) Report.

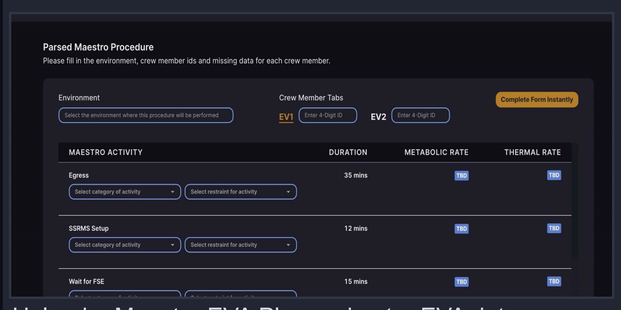
Outcomes and Future Work

- Will reduce operational hurdles and better integrate biomedical predictions into the EVA planning process.
- Database deployed to store crewmember EVA training data that allows automation of current EVA planning. For current ISS EVA CoER, using PersEIDS to predict EVA met rates will save 6-8 hours of planning and analysis per EV crewmember for each EVA.
- Lays groundwork for new data system architecture and modeling approaches for Lunar and Martian EVA planning and CoER processes.
- Future exploration EVA physiological prediction reports will include additional models to predict resources and the internal suit environment such as inspired carbon dioxide and thermal loading, as well as human performance.

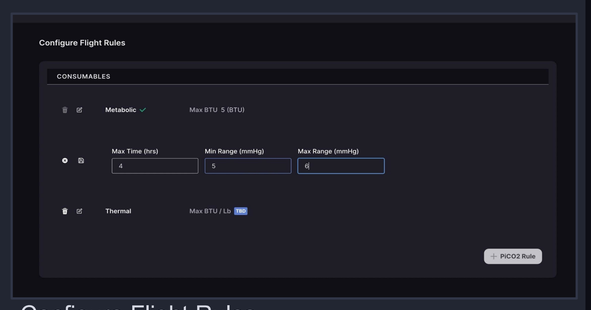
PersEIDS Software Platform



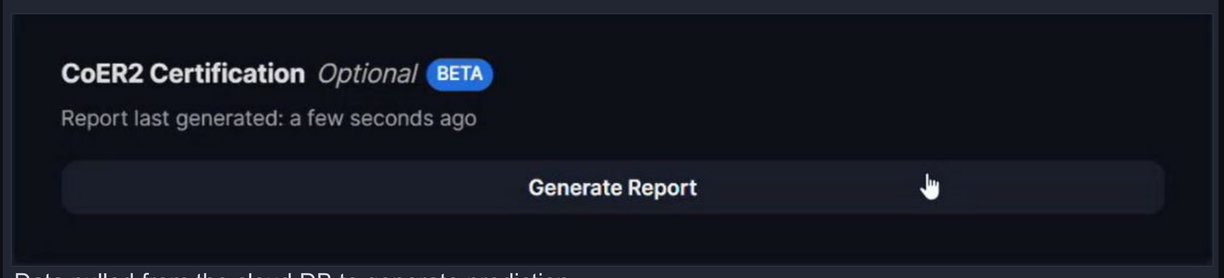
PersEIDS cloud diagram.



Upload a Maestro EVA Plan and enter EVA data.



Configure Flight Rules.



Data pulled from the cloud DB to generate prediction.

PersEIDS Certification of EVA Readiness Report

Controlled//SP-PRVCY

Certification of EVA Readiness

Estimated Metabolic Report

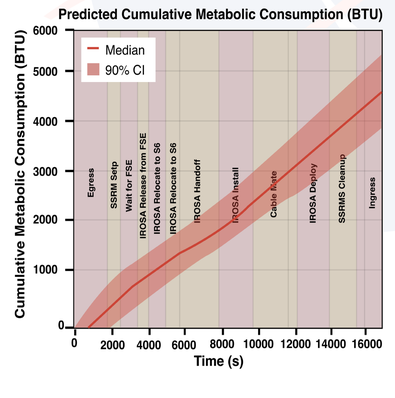
EV1: 3213

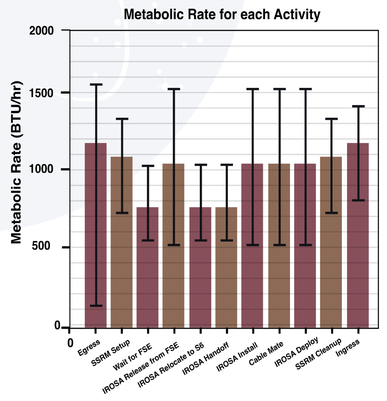
Procedure: *US EVA 88* | Environment: ISS

Proposed Activities & Metabolic Predictions

Title	Category	Restraint	Duration (mins)	Metabolic Rate (BTU/hr)
Egress	EVA Setup	Free-Float	35.00	1198.2 (CI: [189.2-1631.5])
SSRM Setup	Worksite Setup	Free-Float	12:00	1110.4 (CI: [808.5-1406.6])
Wait for FSE	Translation	On SSRMS	15:00	790.2 (CI: [624.3-1104.4])
IROSA Release from FSE	Bolts	On SSRMS	10:00	1062.1 (CI: [596.3-1612.])
IROSA Relocate to S6	Translation	On SSRMS	15:00	790.2 (CI: [624.3-1104.4])
IROSA Handoff	Translation	On SSRMS	50:00	790.2 (CI: [624.3-1104.4])
IROSA Install	Bolts	On SSRMS	30:00	1062.1 (CI: [596.3-1612.1])
Cable Mate	Bolts	On SSRMS	40:00	1062.1 (CI: [596.3-1612.1])
IROSA Deploy	Bolts	On SSRMS	30:00	1062.1 (CI: [596.3-1612.1])
SSRMS Cleanup	Worksite Setup	Free-Float	24:00	1110.4 (CI: [808.5-1406.6])
Ingress	EVA Cleanup	Free-Float	20:00	1199.9 (CI: [883.3-1491.8])

Expected Cumulative Metabolic Consumption: **4838.2 BTU** (90% CI: 4120.4-5536.2 BTU)





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- Given a proposed EVA timeline, PersEIDS generates a crew member specific **CoER Report**, predicting Metabolic Rate for each EVA activity and Cumulative Metabolic Consumption over time.
- CoER predictions are used to determine is a proposed EVA is "safe", based on cumulative metabolic consumption constraints.

References

[1] Paul, H. (2012, July). Energy expenditure during extravehicular activity through Apollo. In *42nd International Conference on Environmental Systems* (p. 3504).

[2] McGrath, T., Norcross, J., Morris, J., Piatt, F., Figueroa, F., Sparks, B., & Somers, J. T. (2023, July). A Decision Support System for Extravehicular Operations Under Significant Communication Latency. In *52nd International Conference on Environmental Systems (ICES)* (No. ICES-2023-327).

This work is funded by the NASA Mars Campaign Office