Novel Approach to Simulating Diagnostic Capabilities in Medical Resource Risk Assessment

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Introduction

- The NASA HRP Crew Heath and Performance Probabilistic Risk Assessment (CHP-PRA) team develops various data models to help understand and quantify human systems risks in spaceflight.
- Presented here is a methodology for simulating the effect of not having diagnostic medical capabilities during spaceflight which is more analogous to the real-world effect than modeling diagnostic resources as medical treatment.

Motivation

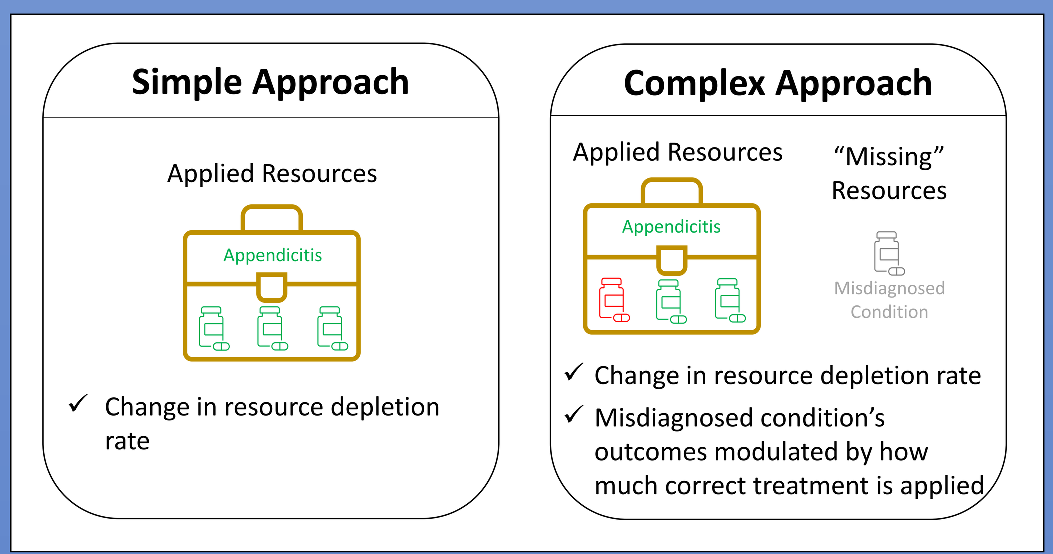
- Diagnostic resources represents a key subset of medical resources used for modeling medical risk in spaceflight.
- When diagnostics are removed from the medical kit, they become unavailable just like other resources. However, diagnostics differ from other resources as they can determine detection of medical conditions.
- One concern is removing a diagnostic is not representative by simply having that condition going partially untreated.
- The goal is to model the effect of not having a diagnostic capability as subsequent potential for misdiagnosis rather than simply a removed treatment resource.

Approach

- The Medical Extensible Dynamic Probabilistic Risk Assessment Tool[1] (MEDPRAT) computational model, that simulates medical events as they relate to crew health during a mission to characterize space flight human health and performance risks, used for this analysis.
- The ultrasound machine was used as the diagnostic.
- All abdominal medical conditions were assumed to be an appendicitis and treatment sets for an appendicitis was applied to other less severe conditions.

Condition name	Number of appendicitis resources in condition treatment (out of 27)	Percentage of appendicitis resources in condition treatment set
Abdominal Injury	21	78%
Abdominal Wall Hernia	21	78%
Abnormal Uterine Bleeding	5	19%
Acute Cholecystitis/Biliary Colic	24	89%
Acute Pancreatitis	22	81%
Lumbar Spine Fracture	5	19%
Nephrolithiasis	17	63%

- Considering the treatment overlap between appendicitis and the abdominal conditions, a more complex approach was taken to capture the misdiagnosed condition's outcome modulated by how much correct treatment is applied.



- While these two approaches may not be completely representative, this effort demonstrates how one might configure model input to simulate the effect of missing diagnostic resources as is required by NASA Standard 3001.

Contact Information

Find this CHP-PRA Analysis and others at https://ccmp.gitlab.grc.gov/chp-pra/results/

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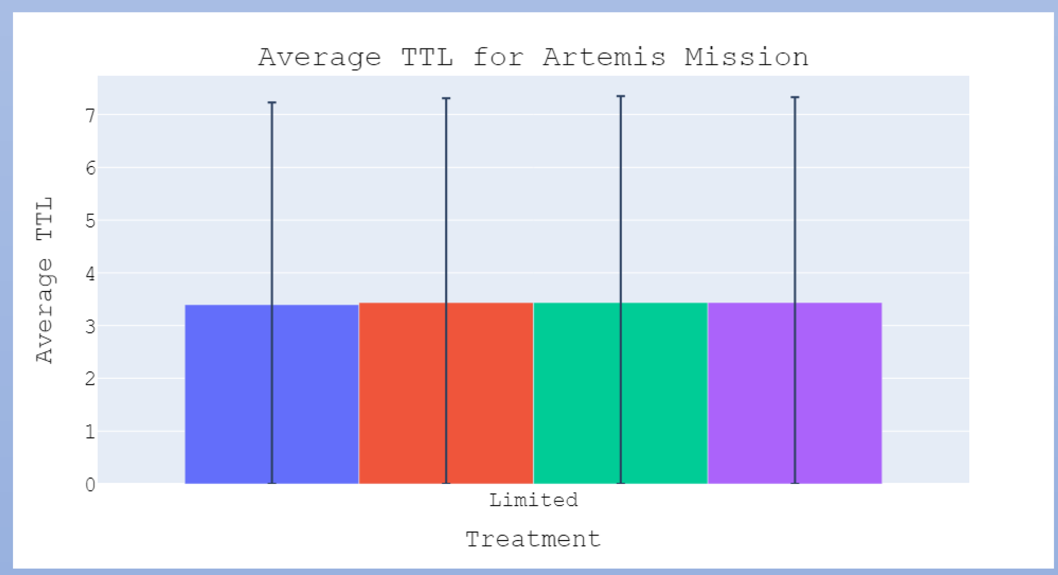
Results

Results are given for 300,000 trial simulations using iMED dataset. The Baseline (No Ultrasound) case treats the ultrasound device as a treatment resource. For reference, a baseline including the ultrasound device is provided.

- Baseline (Ultrasound)
- Baseline (No Ultrasound)
- Simple
- Complex

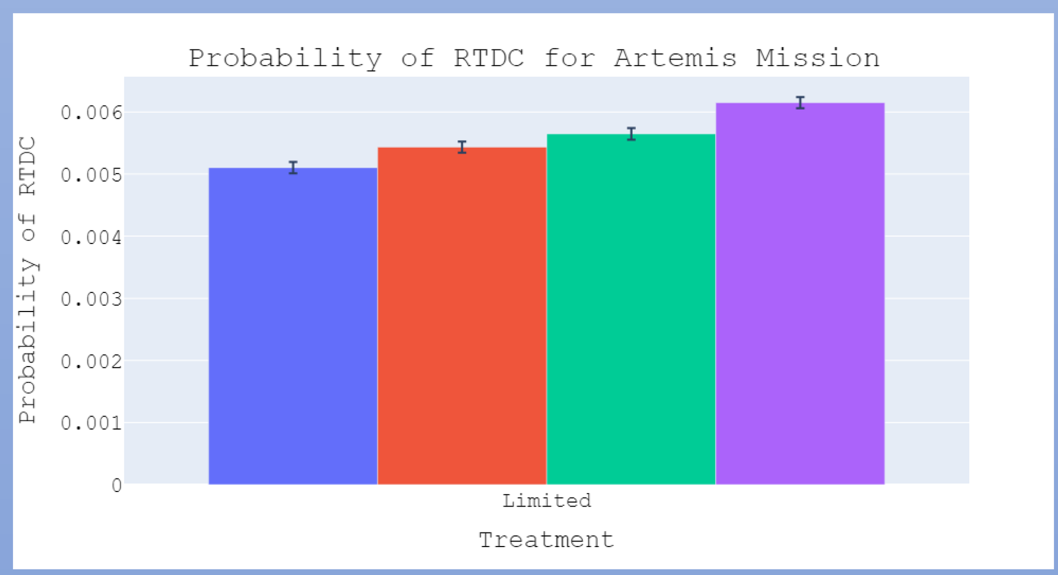
	Mission Duration	Number of Crew	Number of EVAs	EVA Crew Details
Artemis Mission	34 days	4	4	Two crew members on all four EVAs.
ISS Mission	182.625 days	6	6	One crew member on three EVAs. Another crew member on three EVAs.

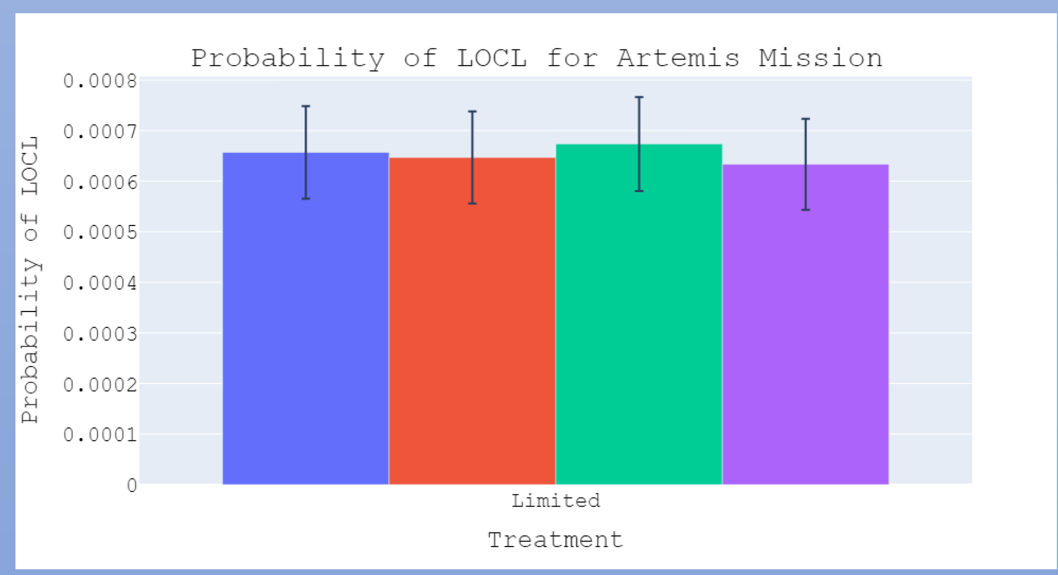
Artemis Mission



Notice no large difference for Task Time Loss (TTL) between all cases. Probability of Return to Definitive Care (RTDC) chart shows both approaches reporting higher RTDC but both approaches report less than 0.001 difference between the means compared to the mean of the Baseline (No Ultrasound).

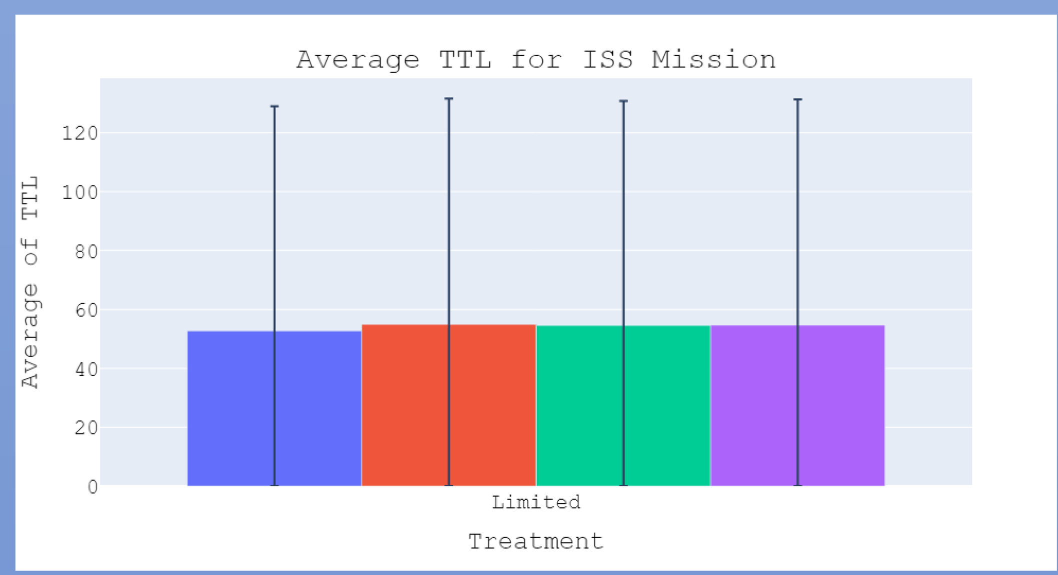
Note: Loss of Crew Life (LOCL) mission metrics can be sparse especially in short duration missions.

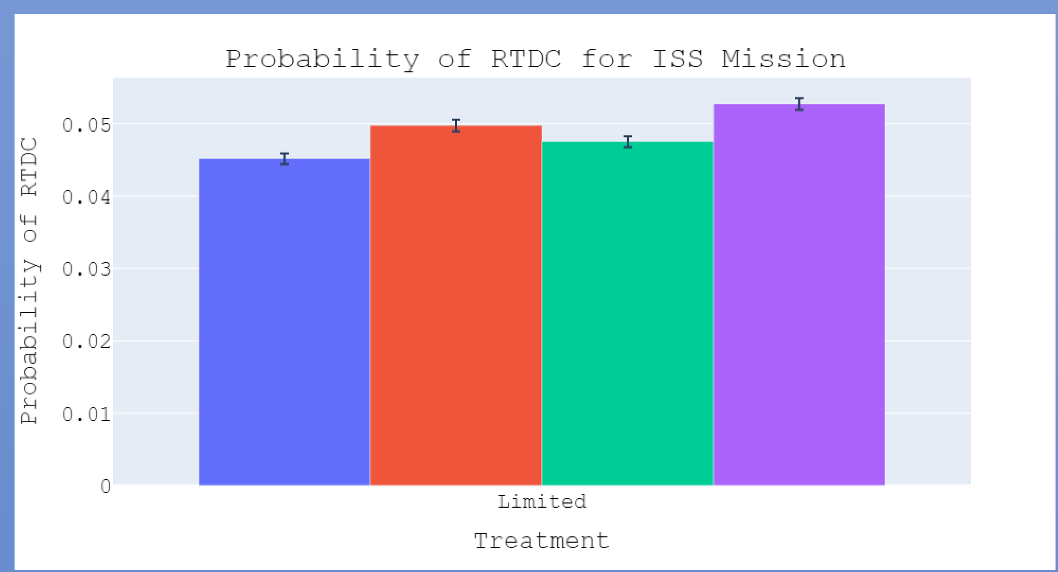


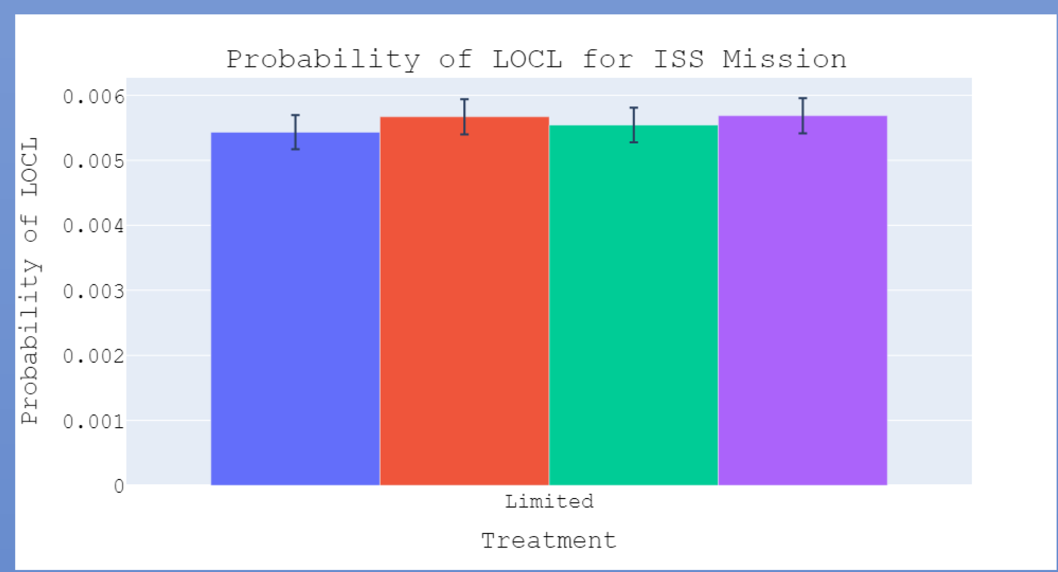


ISS Mission

For a longer mission, notice similar results. For probability of RTDC mission metric, the simple and complex approaches report slightly outside the Baseline (No Ultrasound) reported 95% Confidence Interval. However, the difference between the mean in either approach and the Baseline (No Ultrasound) is less than 0.005.







Conclusions

- It is possible to represent missing diagnostic capabilities, like an Ultrasound Machine, within the model to better simulate the effect in a real-world system where misdiagnosing occurs.
- For simple and complex approaches, changes in resource depletion rate effect treatment availability for other conditions during the mission, changing the risk profile.
- Applying this methodology provides a viable representation for removing diagnostic resources that allows a more complex description of the medical risk.

Future Work

- Expand this analysis to include all medical conditions that ultrasound machine is used as a diagnostic (not just abdominal conditions).
- Develop a similar concept but for another diagnostic capability such as Optical Coherence Tomography (OCT) and adjust eye related conditions.

References

[1] McIntyre, L., Leinweber L., Myers J., et al (2022) Novel Analytics and Parameter-Space Estimations for Human Spaceflight Medical Risk with MEDPRAT V2.0: Leveraging Computational Efficiency