



Nicole Piontek Exit Presentation Summer 2020

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NASA Langley Research Center

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- **Hometown: Canton, MI**
- **University of Michigan**
 - Biomedical Engineering
 - Junior



- **Reliability and Maintenance Logistics Analysis for Crewed Deep-Space Missions Intern**
 - Fall 2019
 - Spring 2020
 - Summer 2020



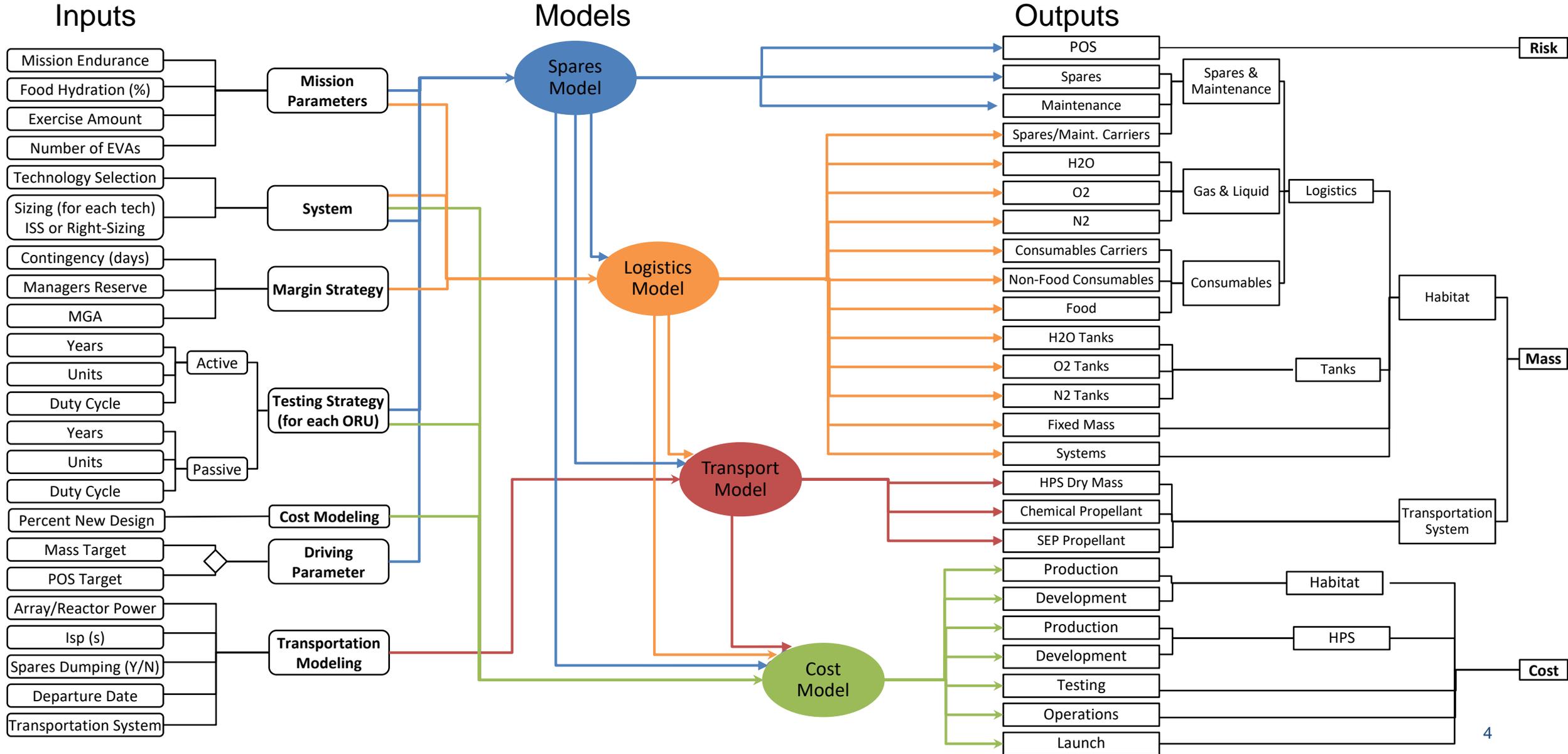


- **Future human spaceflight missions beyond Low Earth Orbit (LEO) will operate in a logistically isolated environment for longer than any previous mission**
 - System reliability and maintenance logistics will be critical considerations
 - It is necessary to have a data driven understanding

Objectives:

- **Perform an in-depth analysis of reliability and maintenance data and lessons learned for Environmental Control & Life Support Systems (ECLSS) from the International Space Station (ISS)**
 - Improve failure rate estimates
 - Evaluation of candidate system upgrades and their impacts on risk and maintenance logistics for Mars exploration missions
 - Evaluation and optimization of system test campaigns
- **Document and present analysis findings to ISS and AES management and discuss their implications for future systems development and mission/program planning**

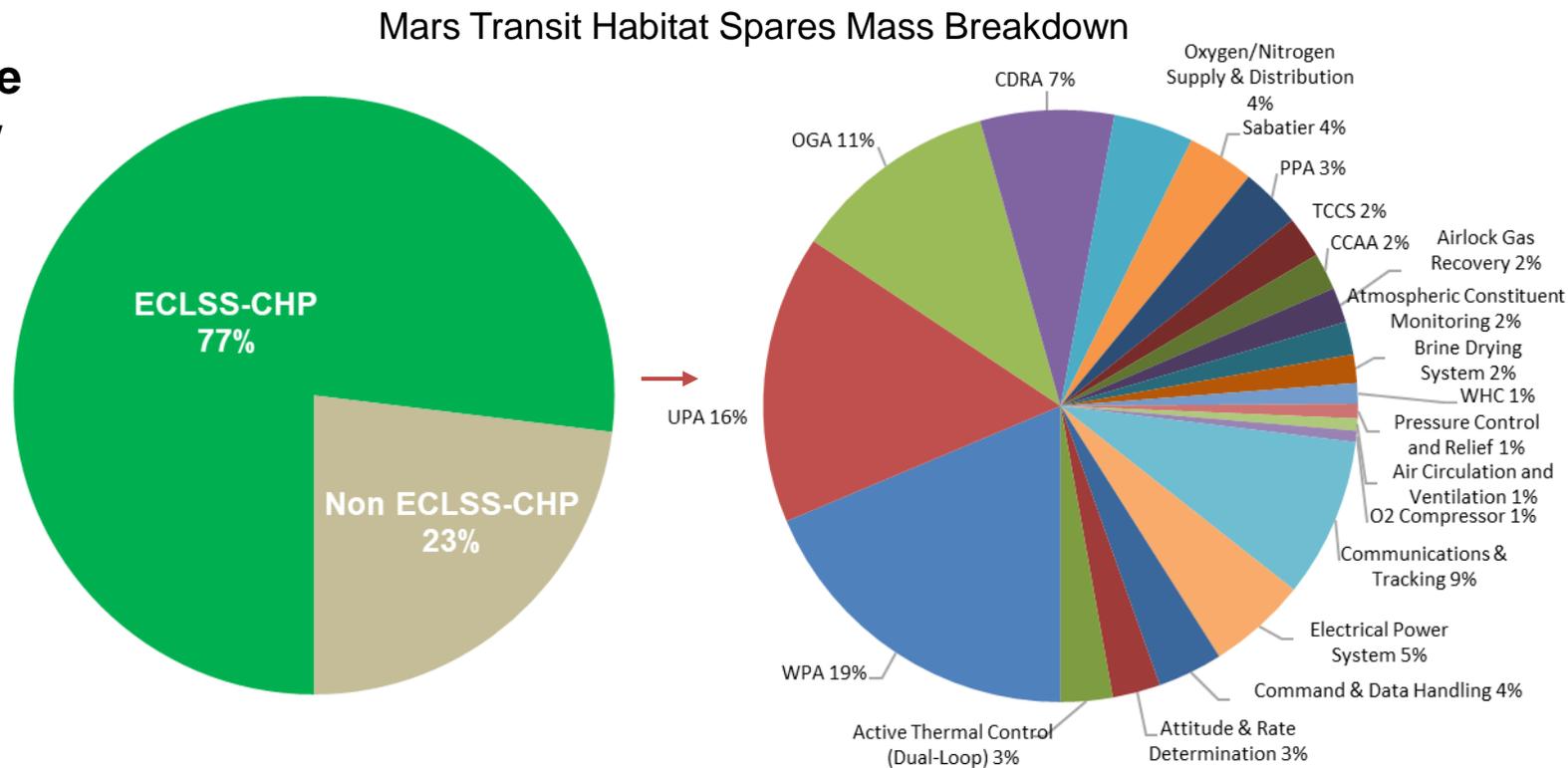
Supportability Analysis Flow Chart



Modeling Systems and Proposed Upgrades

- **Prior analysis has determined that 77% of spares mass for a Mars mission is Environmental Control and Life Support Systems – Crew Health and Performance (ECLSS-CHP) mass**
 - The systems and specific components that compose the 77% are known
 - Water and urine processing along with oxygen generation account for almost half of the spares mass

• **This summer the supportability team has been meeting with various system experts to understand the proposed system upgrades, how this will impact the system characteristics, and how the reliability of systems could be improved with further testing**





- An accurate understanding of the original system is necessary in order to be able to effectively model the system upgrades
- I collected all of the data we had for each system respectively and created presentations to be used during conversations with system experts to validate our assumptions and clarify any discrepancies that we had
- The proposed upgrades were captured with a description, the benefit, and objective, along with the way in which it would be implemented into our spares model
 - Typically this was a percent reduction in key metrics like mass, failure rate, or error factor
- In certain cases the upgrade resulted in a specific failure mode being removed
- I performed an analysis looking at different ways of modeling upgrades
 - This included looking at different parts the dataset and performing different types of analysis on that data

Part Name	Qty	Mass (kg)	% Change in Mass	Upgraded Mass	Jeffrey's Prior Y/N	Posterior Failure Rate (1/h)	% Change in Failure Rate	Upgraded Failure Rate (1/h)	Posterior Error Factor	% Change in Error Factor	Upgraded Error Factor	Life Limit (hrs)
Tank	1	56.09	0%	56.09	Y	6.06E-06	-	4.90E-06	4.00	-	5.61	
Filter 827	1	50.00	-50%	25.00	N	3.84E-04	-20%	3.07E-04	1.59	-	3.00	8,308

Notional



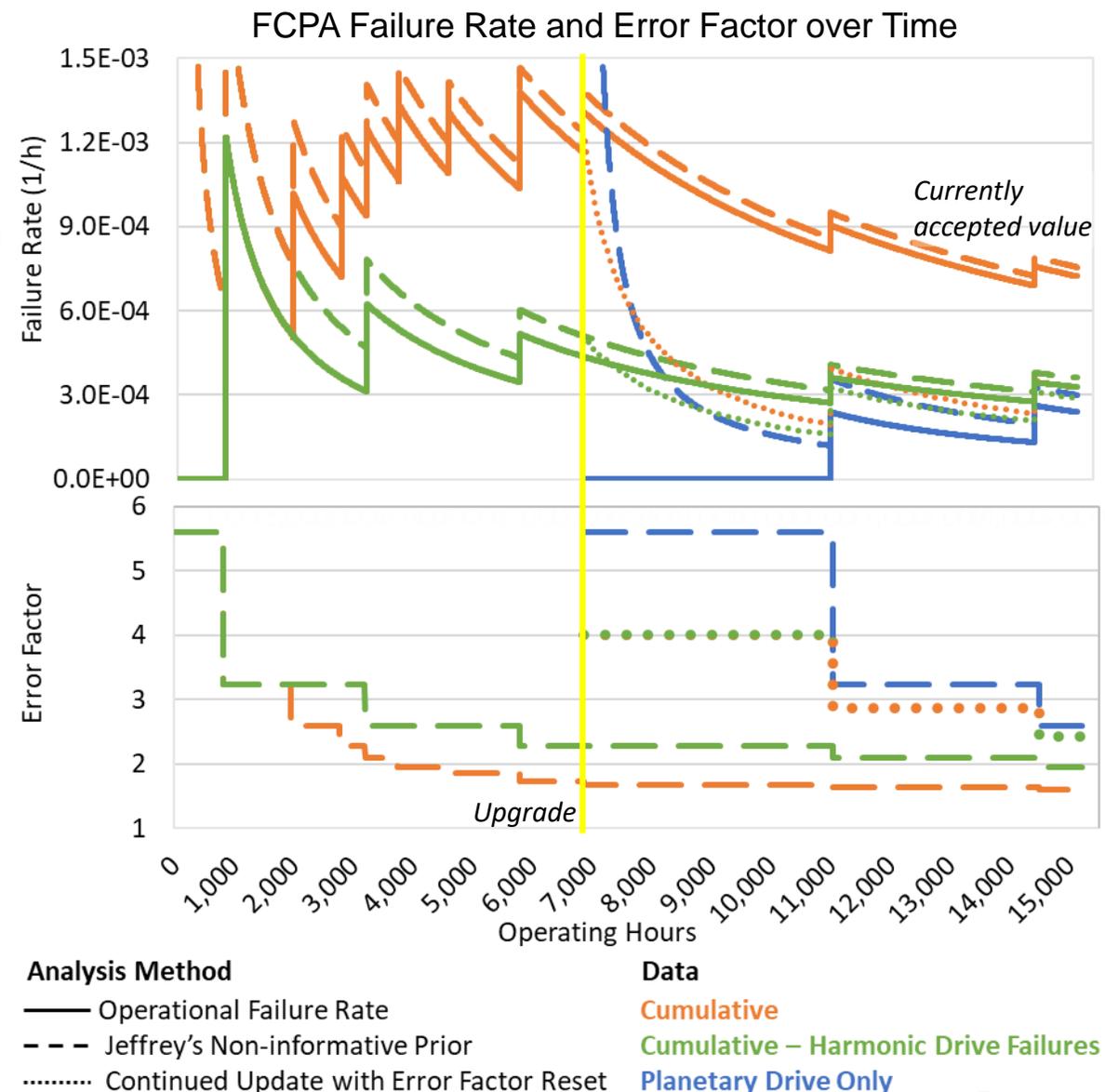
Proposed Methods of Modeling Upgrades

Background

- The Fluids Pump and Control Assembly (FCPA) is an one of many Orbital Replacement Units (ORUs) that make up the Urine Processing Assembly (UPA)
- FCPA failed much more than was expected
 - In its first ~7,000 operating hours (~0.8 operating years) FCPA failed 9 times
 - The FCPA was first installed with a harmonic drive, which was the root cause of 6 out of the 9 failures
- At ~7,000 operating hours, the harmonic drive was upgraded to a planetary drive
 - Since then, the upgraded FCPA has operated for ~8,000 hours with only 2 failures

Purpose of Analysis

- Determine how to model upgraded systems to account for previous experience and lessons learned while also recognizing their has theoretically been improvements made



Proposed Methods of Modeling Upgrades

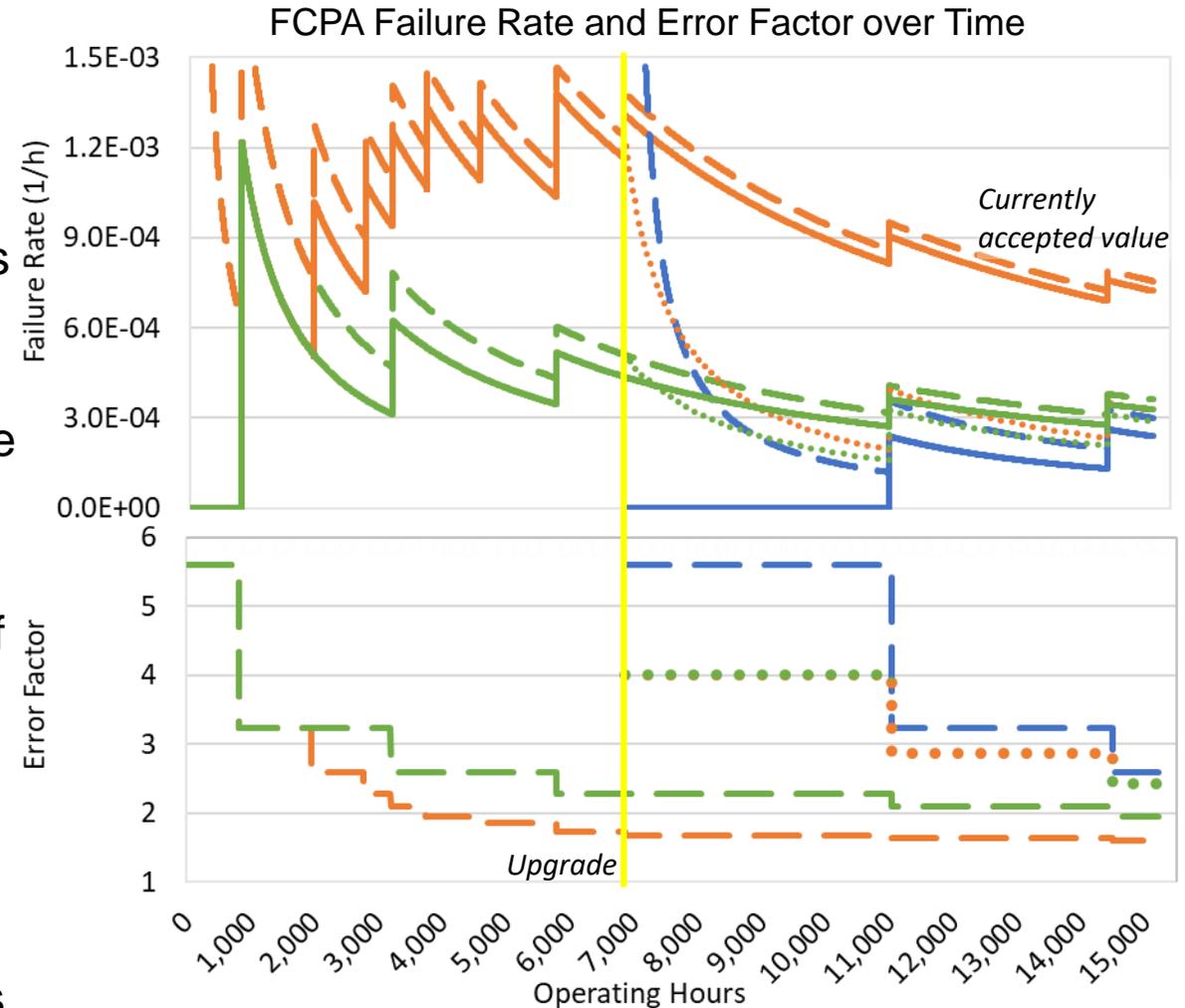


- **Compared different ways of quantifying this data**

- **Orange:** Cumulative – all operating hours and failure since the UPA was installed
- **Green:** Cumulative without Harmonic Drive Failures – all of the operating hours but removes all failures associated with the harmonic drive
- **Blue:** Planetary Drive Only – only the data since the planetary drive gear has been installed

- **Compared different ways of analyzing this data**

- Solid line: Operational Failure Rate – the number of failures over the operating time
- Dashed line: Jeffrey’s Non-informative Prior – only takes into account raw data and is not biased by any initial predictions
- Dotted line: Continued Update with Error Factor Reset – uses prediction as a guide and data refines this estimate



Analysis Method

- Operational Failure Rate
- - - Jeffrey’s Non-informative Prior
- Continued Update with Error Factor Reset

Data

- Cumulative
- Cumulative – Harmonic Drive Failures
- Planetary Drive Only



Initial Recommended Method of Modeling Upgrades

Initial Recommendation

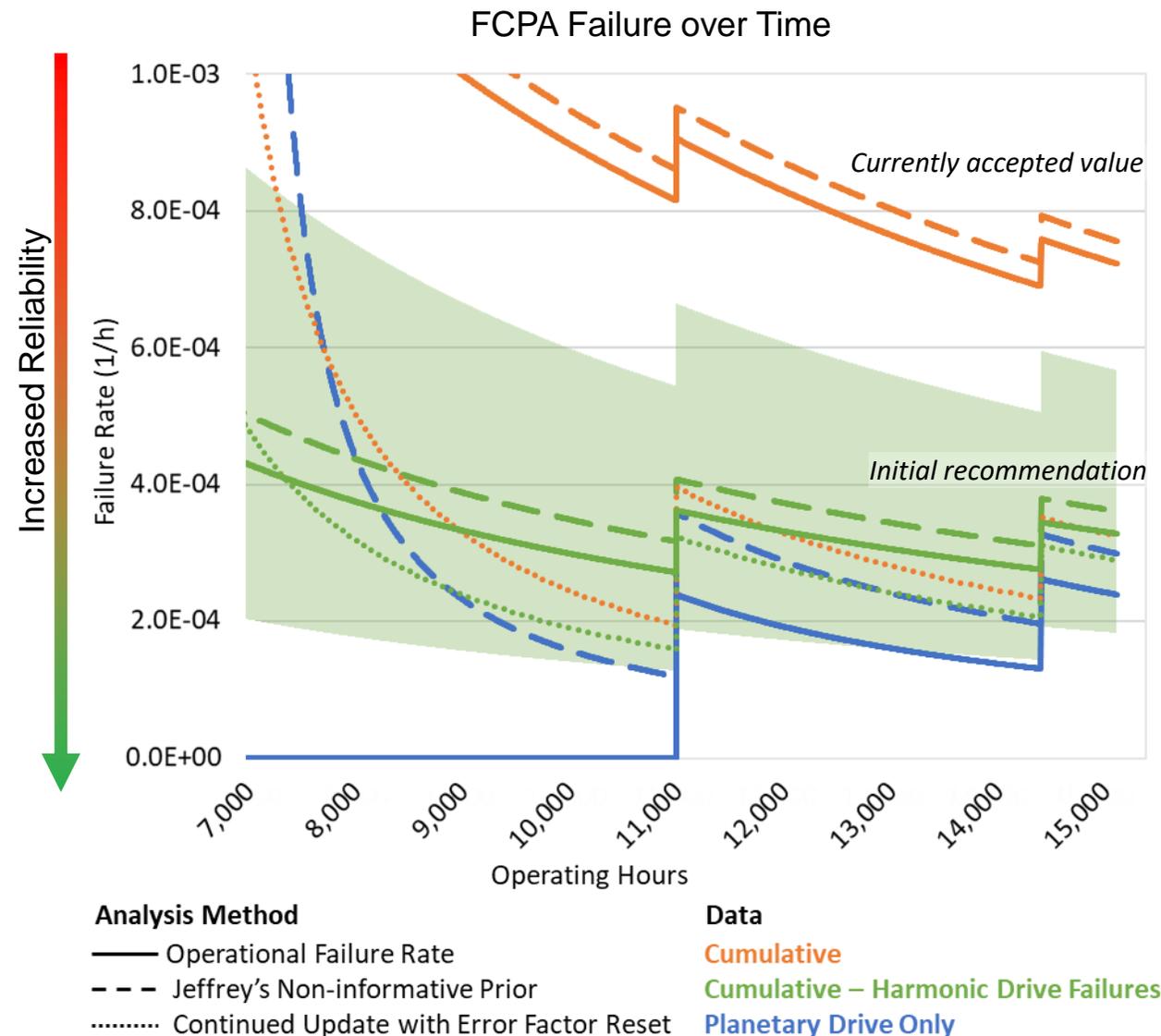
- Perform a Bayesian update using Jeffrey's Non-informative Prior on the cumulative data without harmonic drive failures (green dashed line)
 - Shaded region around this line represents the 80% credible interval to show the reduction in uncertainty

Rationale

- Gives the FCPA credit for the previous operating hours
- Accounts for the 3 other failures that were unrelated to the harmonic drive prior to the upgrade
- Slightly more conservative failure rate than treating the FCPA as a completely new system
- Reduced uncertainty from past experience is reflected in the lower error factor

Caveats

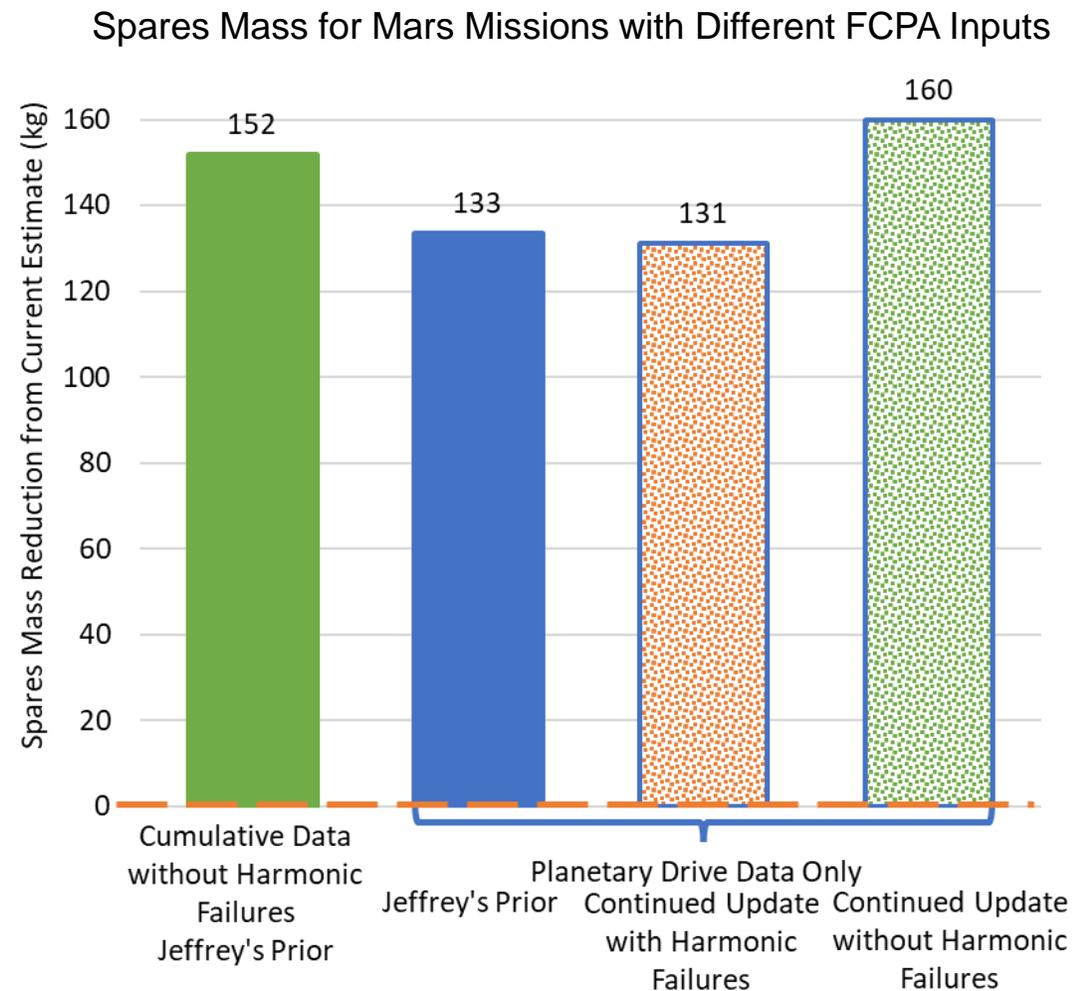
- Assumes planetary gear drive has only failed one time where it might have failed more if it operated for length of time represented





Impacts of Upgrade Modeling on Spares Mass

- **Continuing to use all of the data made the FCPA appear much less reliable because it was accounting for a failure mode that is no longer present**
- **Based on the currently accepted value, removing the failures associated with the harmonic drive allows for a 152kg reduction in spares mass**
- **Further investigation required to determine proper representation of upgrade**
- **There are probably other ORUs in situations like this where it was upgraded and because of the way the data is collected it is not being represented properly resulting in inaccurate penalization of the system**
 - Similar analysis done on UPA and WPA tanks where no failures have occurred but initial prediction is causing tanks to appear to be less reliable
- **Analysis resulted in improved understanding of reliability and ability to model current systems and upgraded systems**



Based on notional Mars mission with POS=0.99

Future Plans



- **Continue working with Supportability team as a Programmer at Bintera for Fall 2020**
- **Finish my degree at the University of Michigan**
 - Graduation Apr. 2022
- **Biomedical Engineering Pathways Intern at JSC**
 - Set to start in January 2021
- **Grad school**
 - Medical Engineering
 - Focus in bioastronautics or aerospace medicine



Nicole Piontek

- Biomedical engineering at the University of Michigan
- Supportability Intern Fall 2019 – Fall 2020

Main Project

- Determining Impact of Upgrades on System Reliability and Spares Mass

Thank you!

- Andrew Owens
- Supportability Team
- SMAB

Questions?



Contact Info



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