Using Artificial Intelligence and Machine Learning to Enhance Mission Design and Operations of the Habitable Worlds Observatory (HWO)

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Introduction

The Habitable Worlds Observatory (HWO):

- NASA's new flagship mission to explore exoplanet habitability, general astrophysics, and solar system science.

Artificial Intelligence (AI) and Machine Learning (ML)'s Role in HWO:

- Early integration of AI/ML enhances mission science and operations.
- Enables cutting-edge solutions for scheduling, health monitoring, and data downlink operations.

Impact of AI/ML Integration:

- Addresses critical science questions.
- Advances space mission technologies beyond current capabilities.

Purpose: Our task group seeks to **educate** other HWO working groups about **AI and ML capabilities** for **mission operations**, investigate how to **bridge technology gaps**, and **enable new capabilities** particularly in the areas of instrument **health monitoring**, **observational scheduling**, and **downlink** operations.

Spacecraft Health Monitoring

- Anomaly identification in downlinked telemetry to support operational analysis.
- Decision-making enhancement during ground-in-the-loop cycles.

Benefits of ML tools:

- Increase fault tolerance in spacecrafts
- Speed up anomaly detection, reducing operational response time.
- Improve diagnostic accuracy for system health.

AI/ML tools: LSTMs, CNNs, transformers, autoencoders, DNN architectures

Operation Scheduling

Long-range planning: balances resources over weeks/months, stable timelines for observations and data analysis readiness.

Short-range scheduling: refines long-term plans into detailed schedules for execution in days to week.

Benefits of AI/ML tools:

- Optimize system time and resource allocation.
- Improve operational efficiency and science yield.
- Reduce mission costs.

AI/ML tools: RL, heuristic search, CSP Solvers, hyperparameter optimization, genetic algorithms

Data Prioritization

Real-time data evaluation onboard HWO would enable:

- Near-instantaneous data processing and adaptive mission control.
- Identification of exoplanetary transits, biosignatures, and transient events autonomously.
- Reduces dependence on human-in-the-loop systems.
- Reduces strain on Deep Space Network (DSN).
- Maximizes observation time.

AI/ML tools: CNNs, LSTMs, transformers, DNN architectures