Runtime Updates to BPMN Mission Models in the Europa Lander Mission Concept using TRACE

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Introduction

TRACE (Traceable Robotic Activity Composition Executive) is an on-board procedural executive that uses the Business Process Model and Notation (BPMN) 2.0 language to model missions and execute those by interfacing with the functional layer of the flight software (FSW). Consequently, it excels in explicitly designing activity flows to be executed by the spacecraft and how the spacecraft should respond based on events in the context of its active activity flow(s). Most recently, TRACE is being used with the Europa Lander mission concept to prototype how it could be used to address autonomous operations of the spacecraft on the surface of Europa.

Contributions

Several new contributions have been made to TRACE since the last iteration of the Europa Lander mission concept [1]:

1. A BPMN implementation of the Realistic Surface Mission 1 (RSM-1), which focuses on autonomous excavation, sample collection, analysis, and downlink subject to energy, thermal, and communication constraints.
2. *A mechanism for ground operations to uplink an update to the BPMN mission model during the course of the mission.*

Model Updates

Model updates are achieved by sending the spacecraft a new BPMN mission model to be stored in its state database. During runtime, the executive will check for updates at a specific service task (shown in the `Uplink Sequence` in Figure 1) within the active mission model and apply them if certain conditions apply. The initial implementation only checks for the existence of the update, while Figure 2 illustrates the full capability.

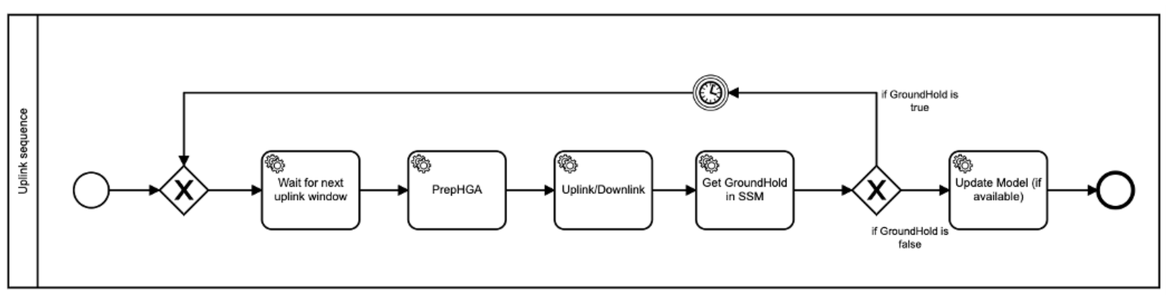

Figure 1: The `Uplink Sequence` contains a `Update Model (if available)` service task to apply model updates.

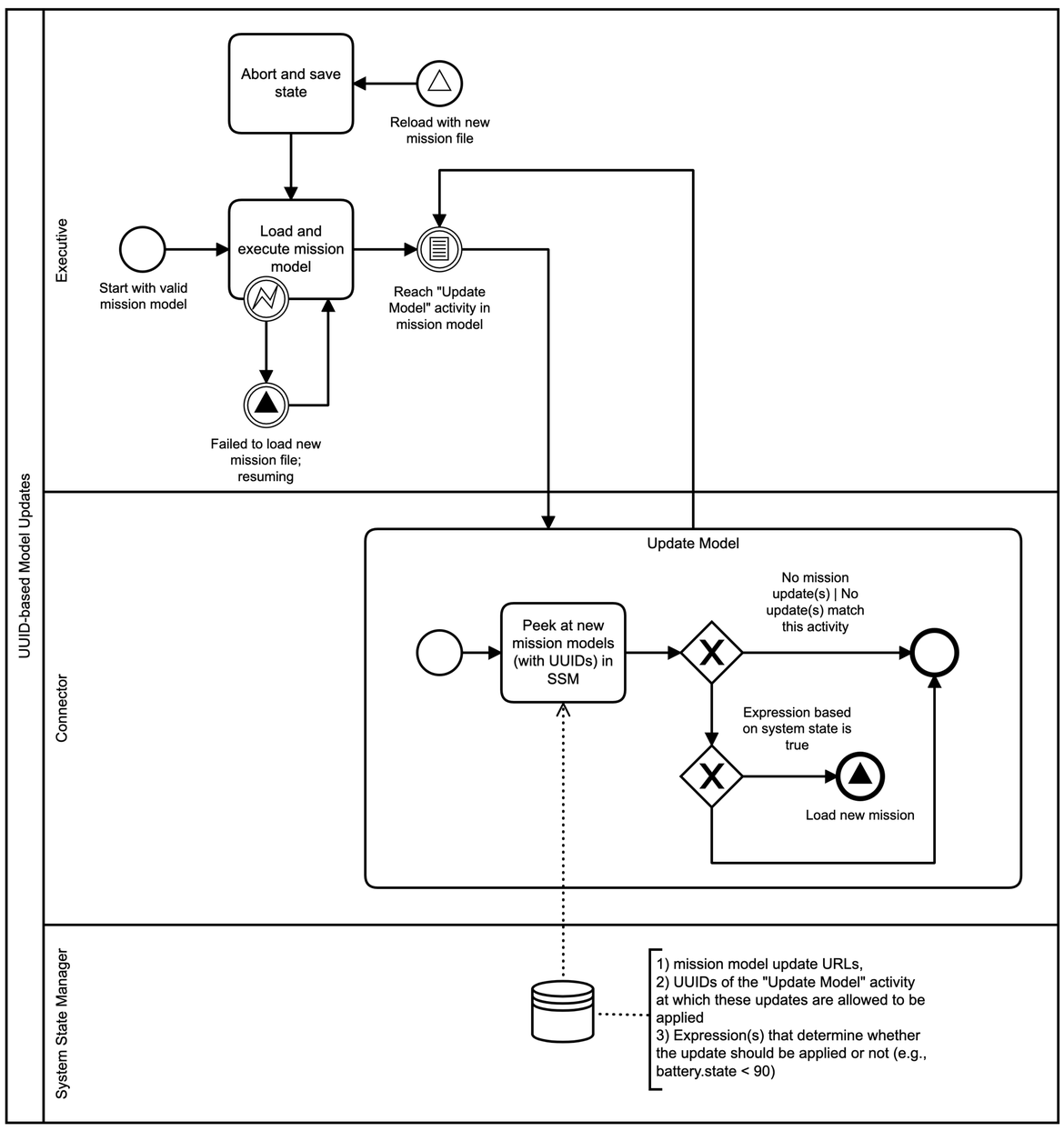

Figure 2: A BPMN diagram to illustrate how TRACE will fully implement runtime model updates.

The procedure in Figure 2 currently assumes that the spacecraft is quiescent during the update—all activities are off while the mission is being updated. In other words, the spacecraft is idle between downlink and uplink. Consequently, the only restriction on the mission model updates is that the `Update Model (if available)` service task must exist at the same place in the diagram (i.e., it must exist with the same unique identifier in the updated mission model).

Experimentation

Realistic Surface Mission 1 (RSM-1) experiments included an update of the second part of the mission (illustrated in Figure 3 and 4) that was applied during runtime.

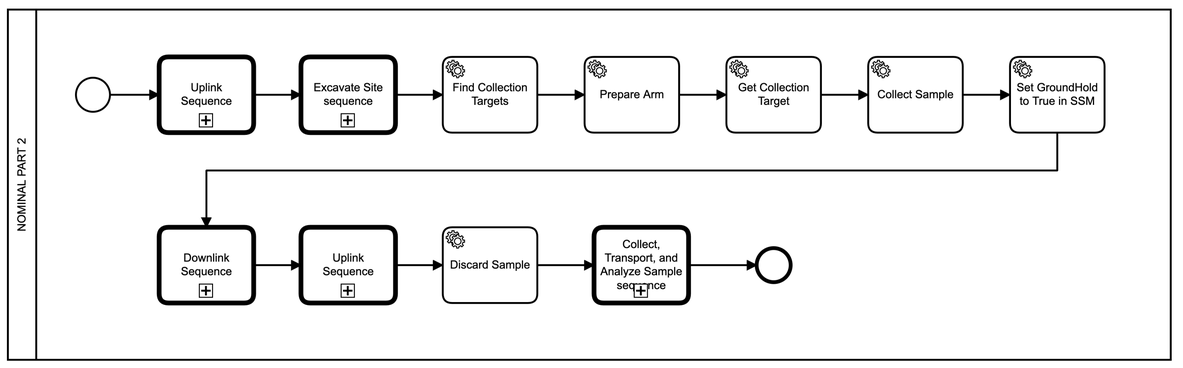

Figure 3: The original process flow for the second part of RSM-1.

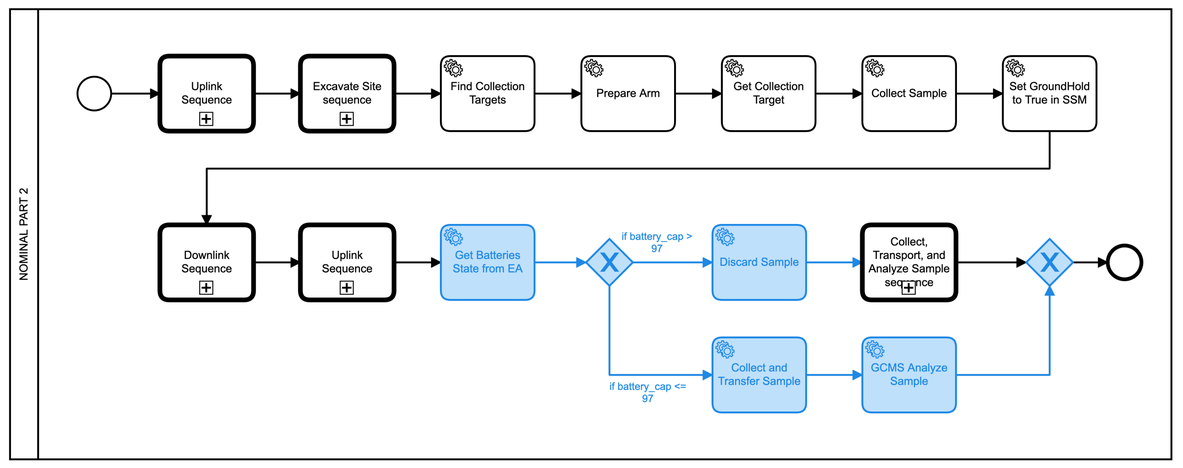

Figure 4: The updated process flow for the second part of RSM-1 with changes highlighted.

Figure 5 capture a moment in the simulation of RSM-1 using TRACE as the on-board executive. The active BPMN elements are highlighted in the diagram.

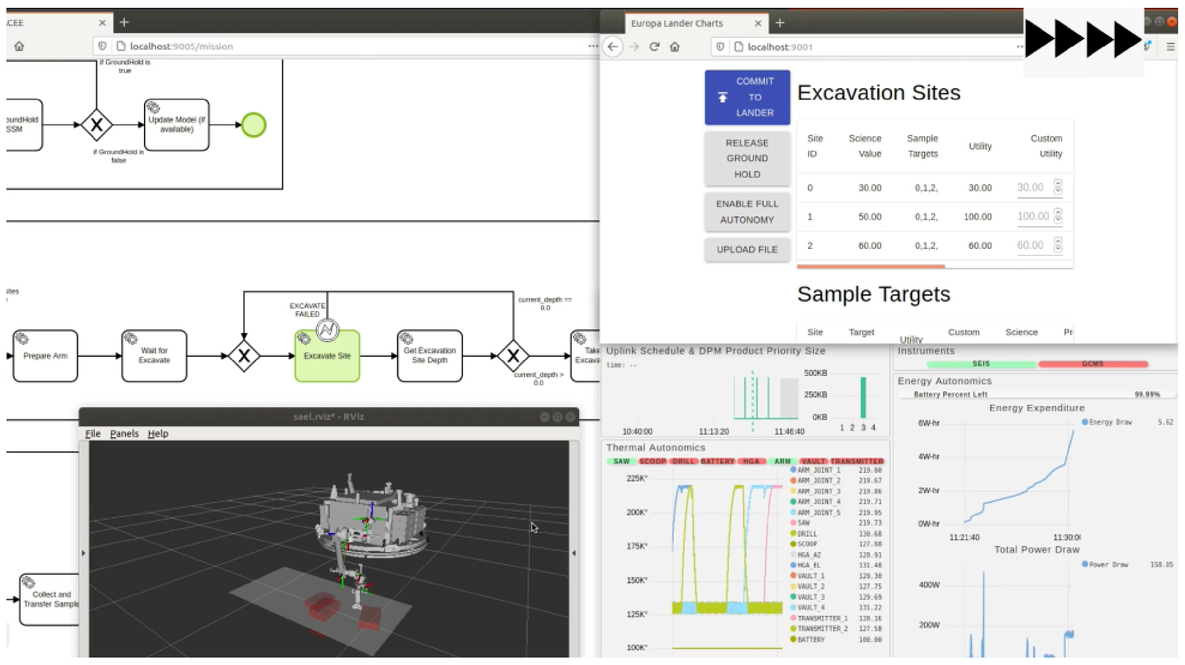

Figure 5: TRACE executing RSM-1 in simulation.

Acknowledgements

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References

[1] J.-P. de la Croix and G. Lim, "Event-Driven Modeling and Execution of Robotic Activities and Contingencies in the Europa Lander Mission Concept Using BPMN," in *International Symposium on Artificial Intelligence, Robotics and Automation in Space*, 2020.