



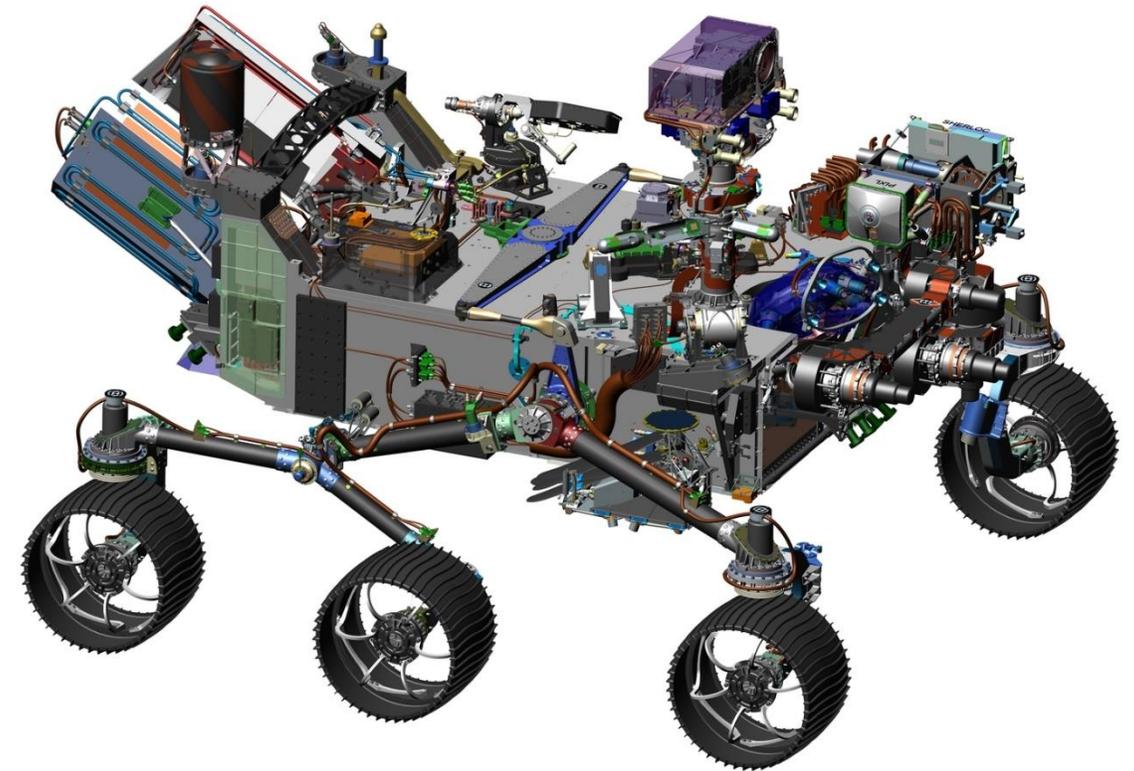
Concepts for the Mars 2020 Rover Onboard Scheduler

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- Background/Introduction
 - Plan
 - Activity Types
 - Activity Attributes
 - More Features
- Thanks to
 - Stephen Kuhn
 - Gregg Rabideau
 - Elyse Fosse
 - Glenn Reeves
 - Steve Chien
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 - Planner Team
 - Gregg/Eddie

- Mars 2020 Rover
 - Leverages heritage from Curiosity
 - Will collect core samples of rocks and soils and set them aside in a "cache" on Mars.



<http://mars.nasa.gov/mars2020/>

(Above picture is from this web site)

- **Sequence**
 - A file containing a list of time-ordered commands
- **Sleep**
 - At night, we shutdown the rover to recharge
- **Preheating**
 - Heating up an actuator so that it is warm enough to safely use
- **Parameter**
 - A saved value this is only changeable by ground command.

Prior Process on the Curiosity Rover



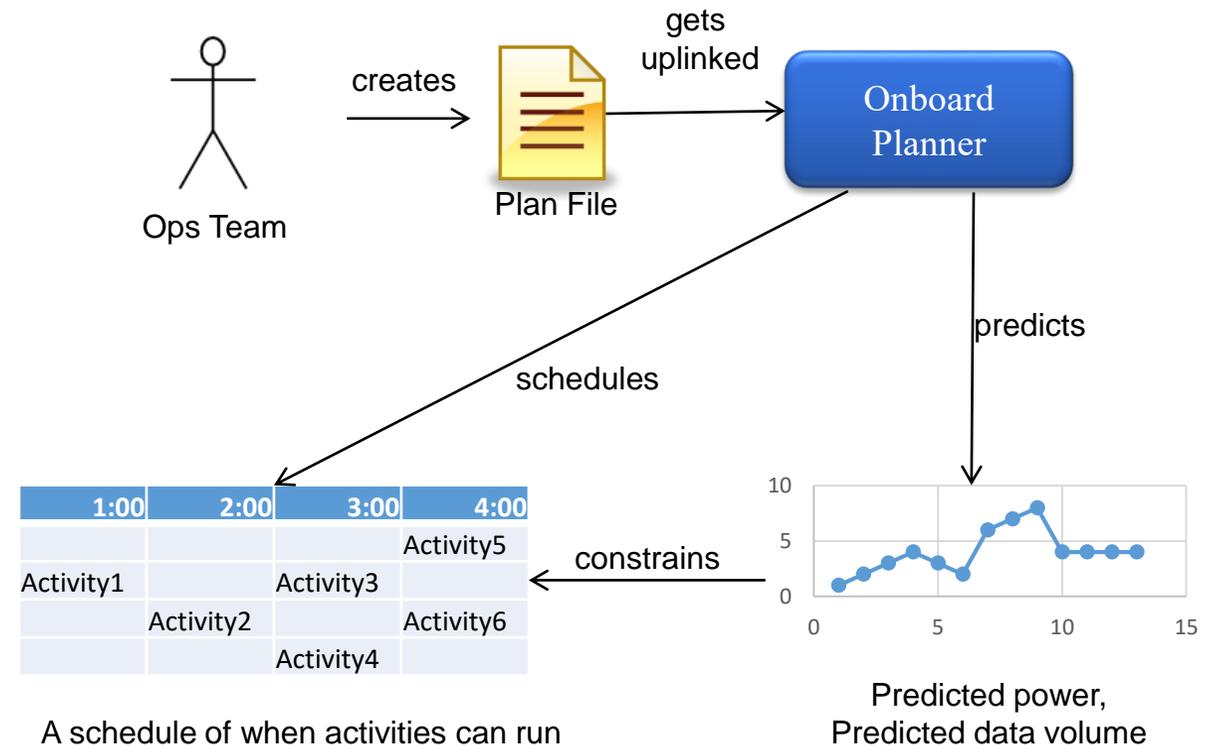
- Any action taken by the rover is directed by a series of sequences
- The process of creating sequences can take over 9 hours
- Due to uncertainty, the operations team had to insert margin for duration estimates
 - Resulting in wasted time and energy onboard
- Can't take advantage of onboard knowledge of available power and time
 - If a sequence finishes early or fails, time is usually wasted
- The operations team has to manage sleep activities and preheat activities

- Goals
 - Improve Operations Efficiency
 - Run more activities onboard
 - Less wasted resources (time, energy)
 - Allow the ground to generate uplink products within 5 hours from receiving spacecraft data
- Vision
 - The onboard planner autonomously
 - Runs more activities when more power is available
 - Starts the next activity sooner, if the current activity finishes early
 - Decides when the rover goes to sleep
- We are just starting to prototype
- Today, we'll share some thoughts on planner features appropriate for a Mars rover.

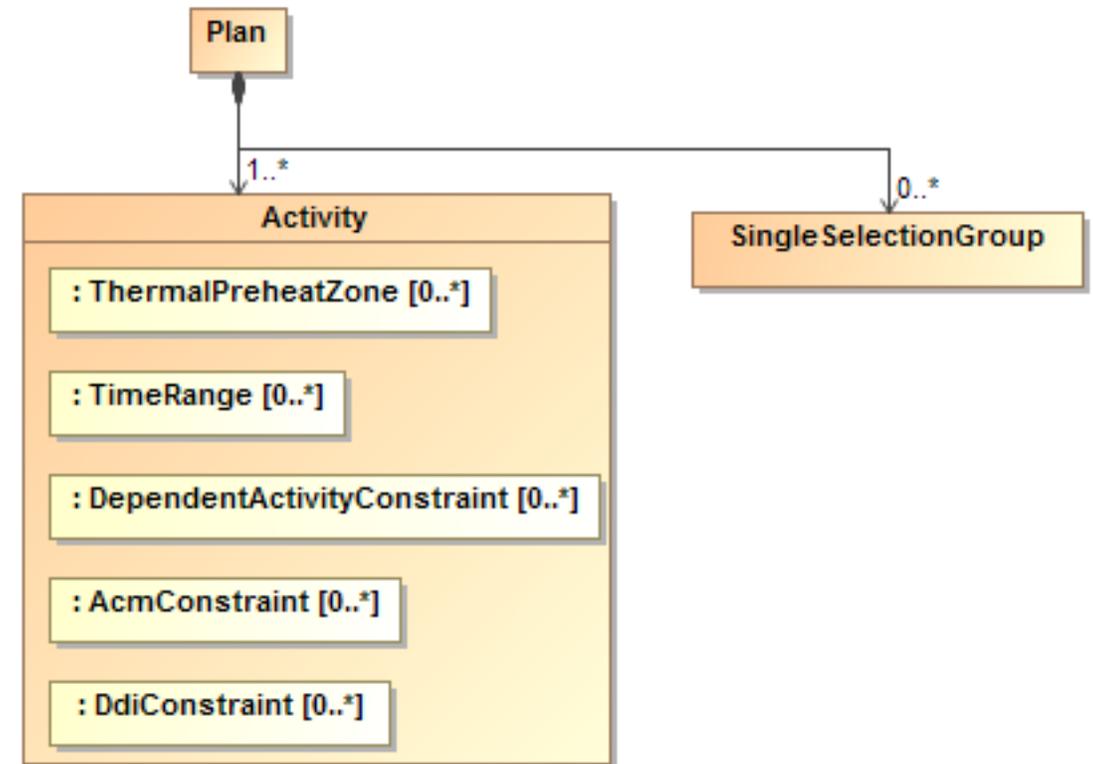
Onboard Planner Overview



- Planner is responsible for scheduling all onboard execution on the surface
 - Using the existing sequence engine underneath
- What the planner does
 - Reads a plan file
 - Determines resource values in the future
 - Checks for conflicts
 - Decides when activities can run



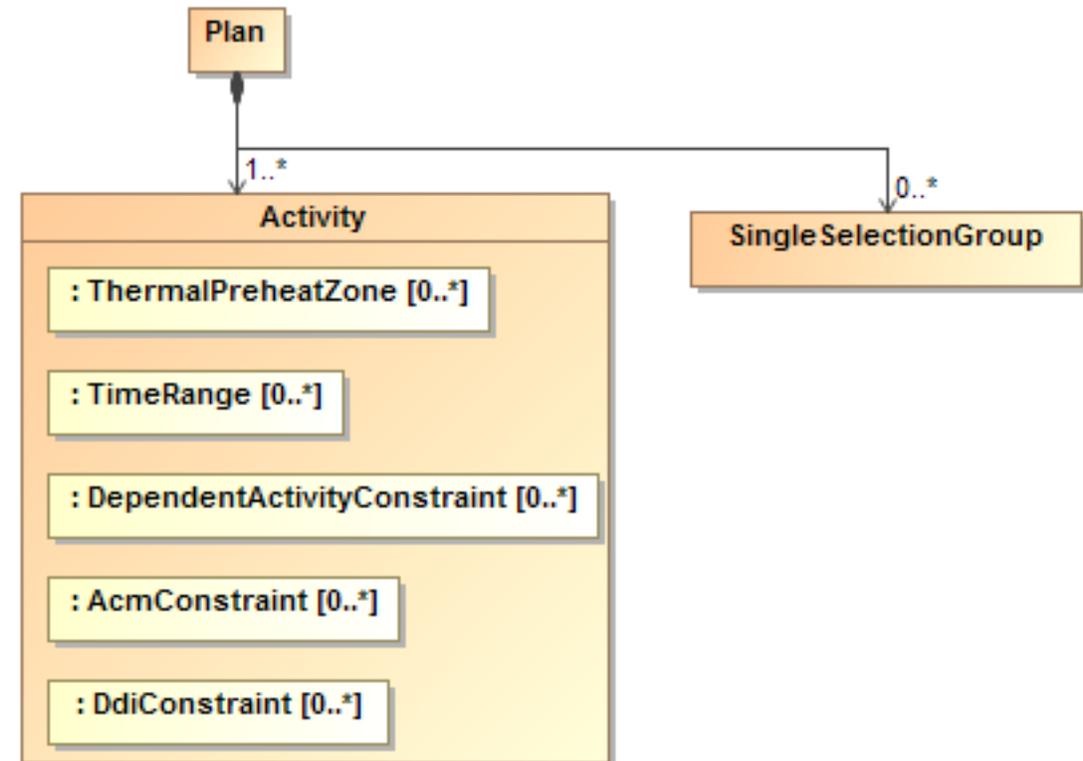
- Plan file: What is uplinked from the ground to the spacecraft
- A plan consists of activities
- A plan also contains
 - Handover time
 - Handover minimum state of charge
 - Next plan filename
 - End time
 - Maximum delta data volume





Activity Types

- Activity definition: The item that is scheduled
- Activity Attributes
 - Type
 - Unique activity id
 - Sequence
 - Priority
 - Priority range is divided into mandatory and optional ranges



- **Generic Activity**
 - Most common type of activity
 - Runs a sequence
 - Has a fixed duration
- **Expanding Activity**
 - Has a variable duration
 - Recall generic activities have a fixed duration
 - The minimum duration is specified by the ground
 - Typical use case is a drive
 - Planner determines when the activity can end based on available resources and constraints

- **Single Selection Groups**
 - A group of activities
 - At most one of the activities in the group is allowed to be scheduled
 - Purpose: If the most resource intensive activity in a group does not fit, run a less intensive activity instead.
- **Stay Awake Activity**
 - Prevents the planner from automatically shutting down the computer during this time period
 - A ground-created activity

Activity Types: Shutdown Related Activities



- Categories of shutdown-related activities
 - Planner
 - Automatically generated by the planner
 - Manual
 - Included in the plan file by the ground
- Each category has 3 phases
 - Shutdown
 - Sleep
 - Wakeup

**Planner Shutdown
Activity**

**Planner Sleep
Activity**

**Planner Wakeup
Activity**

Communication Window Activities



- Communication (Comm) windows are created by heritage commands.
- The planner queries the communication behavior manager to become aware of, and plan around comm windows.



Activity Attributes

Modeled Activity Attributes



- Modeled by the ground team
- Uplinked from the ground as part of the plan file for each activity
- Activity Attributes
 - Duration
 - Marginal energy usage
 - Peak Power usage
 - Delta data volume
 - Max number of sequence engines used

Activity Time Ranges



- An activity has multiple tuples containing
 - Start time range
 - Cutoff time
- In other words, an activity has multiple start time ranges
- For example:
 - Activity A can only start between
 - 10:00 -11:00 or 1:00 - 2:00

- An activity can have dependencies on prior activities
- Example: B can only start after A has successfully completed



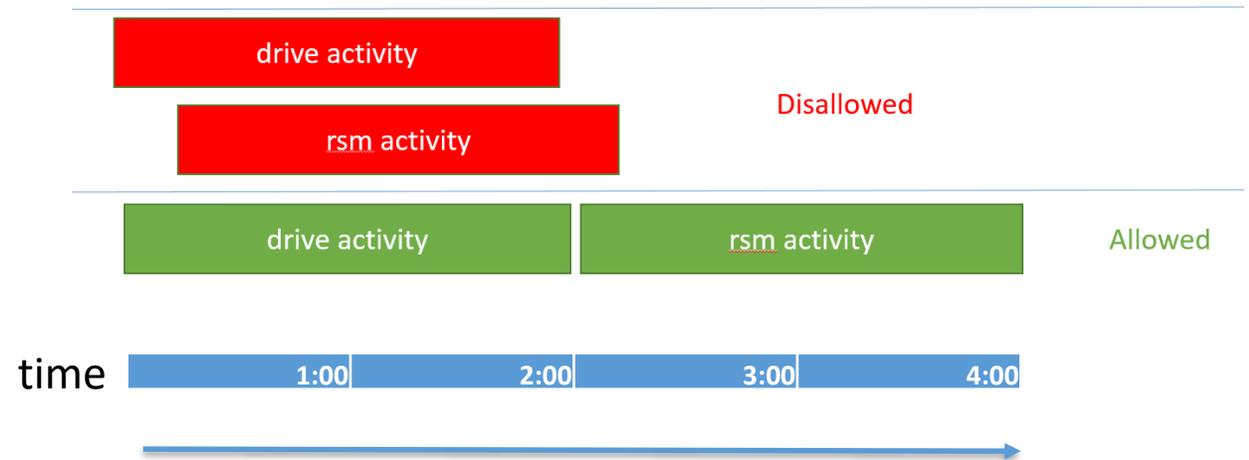
- The dependency has the following attributes
 - Prior activity's id
 - Prior activity's status (COMPLETED, SUCCEEDED, FAILED, ABORTED, ...)
- An activity cannot be scheduled unless the dependency is satisfied

Constraining Parallelism



- Sometimes we want to constrain activities so that they do not run in parallel.
 - For example, we don't want to drive while we move the mast (rsm)
- Activities that have the same resource usage bit set cannot be scheduled to run in parallel
- Resource usage bits will be specified for each activity by a future ground tool
- Many (~100) extra resource usage bits are available for ground-defined meaning
 - Ground can prevent arbitrary sets of activities from running in parallel.

- These activities cannot be scheduled in parallel because they have the same resource bit set



- Preheat definition: Heating up an actuator so that it is warm enough to safely use
- Each activity can contain
 - A list of the thermal zones the activity uses
- The planner must autonomously generate preheat activities for a given activity that specifies thermal zones
- Preheat activities are not uplinked as part of the plan
- Planner must not dispatch the activity unless zone is ok to use



- An activity may contain multiple ACM and DDI constraints
 - ACM: A saved onboard variable typically allowing or precluding some action
 - DDI: An unsaved onboard variable
- Because ACM and DDI values can change, they are only evaluated when assessing whether an activity can be immediately dispatched
- ACM/DDI constraints are not evaluated for scheduling future activities



More Features and Definitions

Limiting Data Storage Usage



- Project the modeled delta data volume generated by each activity into the future
- Use actual delta data volume for all activities in the past
- Do not schedule optional activities that would push us over the plan-specified maximum delta data volume.
 - Mandatory activities are allowed to push us over
- The planner is not involved with tracking data stored on instruments

Predicting Future State of Charge



- Knowns
 - For each uplinked activity, the plan file tells us
 - Activity's marginal average power (W)
 - The activity's duration (sec)
 - Planner-generated activities get marginal avg pwr (W) and duration (sec) from parameters and tables
 - Base marginal average power (W) when no activities are running is known from parameters
 - Present state of charge estimation gives us
 - The present estimate of the charge in the battery (W-hours)
 - The estimate of the total battery capacity (W-hours)
- Consumption (W-hours) is
 $(avg_power_W * duration_hours) = consumption (W-hours)$
- $predicted\ state\ of\ charge = \frac{present\ charge\ estimate - base\ consumption - \sum activity\ consumption}{estimate\ of\ total\ battery\ capacity}$

Peak Power Check



- Each activity has an attribute giving its peak power usage
- Activities cannot be scheduled in parallel if the total peak power usage is above a threshold (W).
- The threshold is a parameter.

Uses of State of Charge in Scheduling



- Soft min state of charge parameter
 - Optional and mandatory activities are not scheduled if they would cause a violation
 - Mandatory are allowed to execute past if already dispatched
- Hard min state of charge parameter
 - Any currently running activities that violate are aborted
- Handover state of charge plan constraint
 - Optional activities are not scheduled if they would cause a violation
 - Mandatory are allowed to be scheduled if they would cause a violation

- Criteria
 - Minimum sleep duration (parameter)
 - Minimum awake duration (parameter)
 - No activities could be scheduled during the proposed sleep
 - Without violating the minimum state of charge (parameter)
 - No optional activities could be scheduled during the proposed sleep
 - Without violating the handover state of charge plan constraint
 - To improve long-term battery health
 - Do not sleep past `maximum_state_of_charge` (parameter)

- A generic activity with a dependency that a prior activity finished with failure (aborted or completed with failure)
 - Contains a sequence from the ground
 - Establishes a known state
- For most activities, execution of a cleanup is off-nominal

- The planner aborts an activity when
 - Activity has not finished by its absolute cutoff time
 - Activity is running when we hit the hard state of charge limit (parameter)
 - An optional activity is running past the soft state of charge limit
 - An optional activity is running past its duration
- The effects of an abort
 - The activity's state changes to ABORTED
 - This allows the planner to schedule a cleanup activity if present

- Showed features needed to do onboard scheduling for a Mars rover
 - In particular, power estimation, sleeping, and pre-heating
- Discussed some relevant constraints that will be evaluated onboard
- Showed an enabling set of knowledge that needs to be uplinked from the ground
- We hope the planner improves the Mars 2020 mission by
 - Enabling more activities to run onboard
 - Better utilizing onboard resources, such as time and energy
 - Reducing the workload of the ops team with autonomous sleeps and preheats
- Future work: Planner prototyping effort
 - Determine RAM and CPU usage