COCPIT: Collaborative Activity Planning Software for Mars Perseverance Rover

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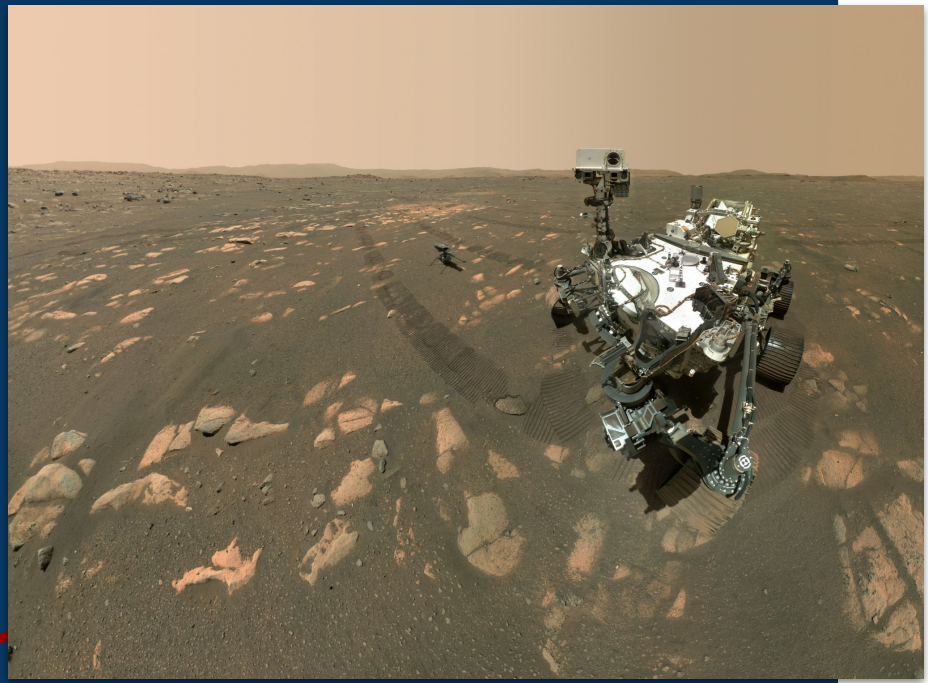
Introduction



- Perseverance Rover landed on Mars February 2021
- Surface operations team members are distributed between North America and Europe
- COCPIT is part of the Mars 2020 Ground Data Systems

Pyrzak, G; Puncel, R; Vona, M; Lopez-Roig, R. “The Mars 2020 Ground Data System Architecture”, in IEEE Conference on Aerospace, Big Sky, MT 2022.

COCPIT

Component-based Campaign Planning, Implementation and Tactical

Responsible for

- Activity planning
- Continuously verifying constraints
- Document Science Intent
- Model data and power resources
- APIs to interface with GDS tools
- Target association

Architecture

Collaborative web-application

Extends and customizes the Playbook planning and execution tool developed at NASA Ames Research Center

Dev Stack

- Frontend
  - JavaScript, HTML, CSS, Backbone.js, d3, svg, Web Sockets
- Backend
  - Node.js, nginx
- Database
  - Redis for temporary storage
- Infrastructure
  - Docker, AWS, XML for permanent storage in S3, Single Sign-On Authentication Layer, Elastic Search

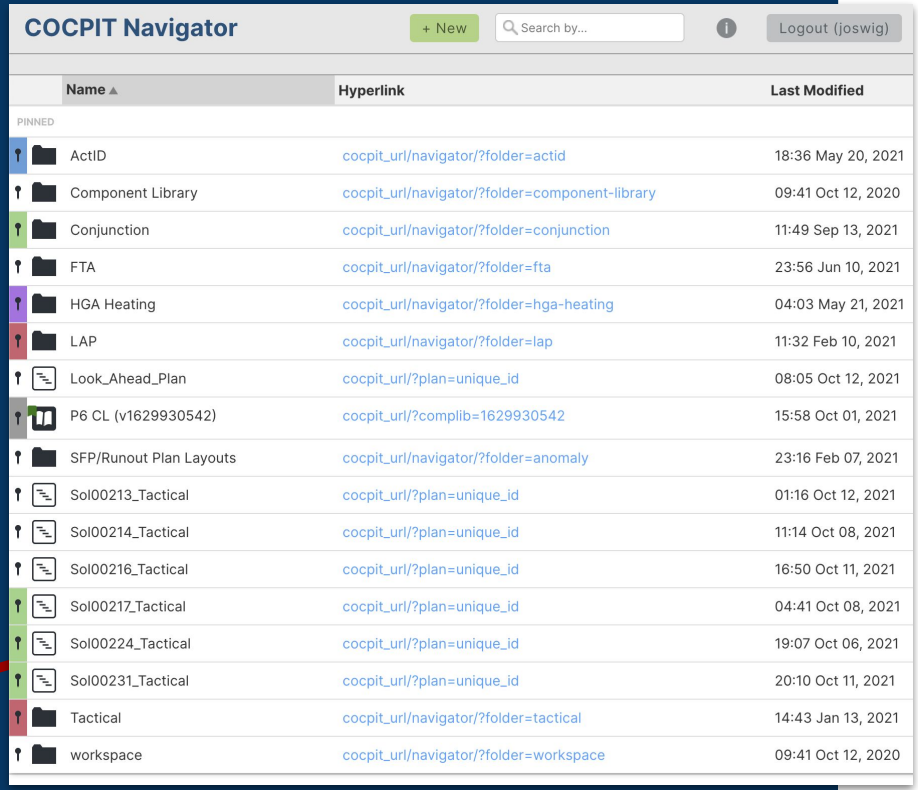
Marquez, J.J., Hillenius, S., Deliz, I., Kanefsky, B., Zheng, J., and Reagan, M., "Increasing Crew Autonomy for Long Duration Exploration Missions: Self-Scheduling" in IEEE Aerospace Conference, 2017

Planning Phases

COCPIT supports all planning phases

1. Parcel Development
   - Define and validate reusable Activities
2. Strategic Planning
   - Create plan fragment templates
   - Consider timing constraints
   - Asses heating requirements and resources
3. Campaign Implementation
   - Look-Ahead Plan for the next ~5 Sols
   - Includes communication passes
   - Ensure progression of science goals
   - Evaluate options, guide tactical planning
4. Tactical Uplink
   - Plan next sol(s) to be executed by the rover
   - Incorporate changes based on received data (i.e. status and latest images)
   - Ensure constraints are met
   - Generate sequences to send to rover
5. Tactical Downlink
   - View currently executing plan
   - Receive and analyze data

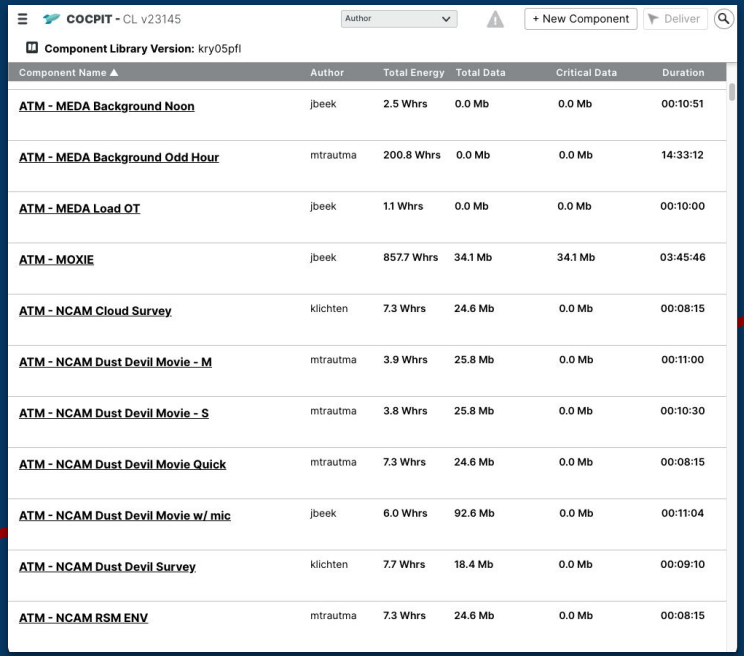
Navigator

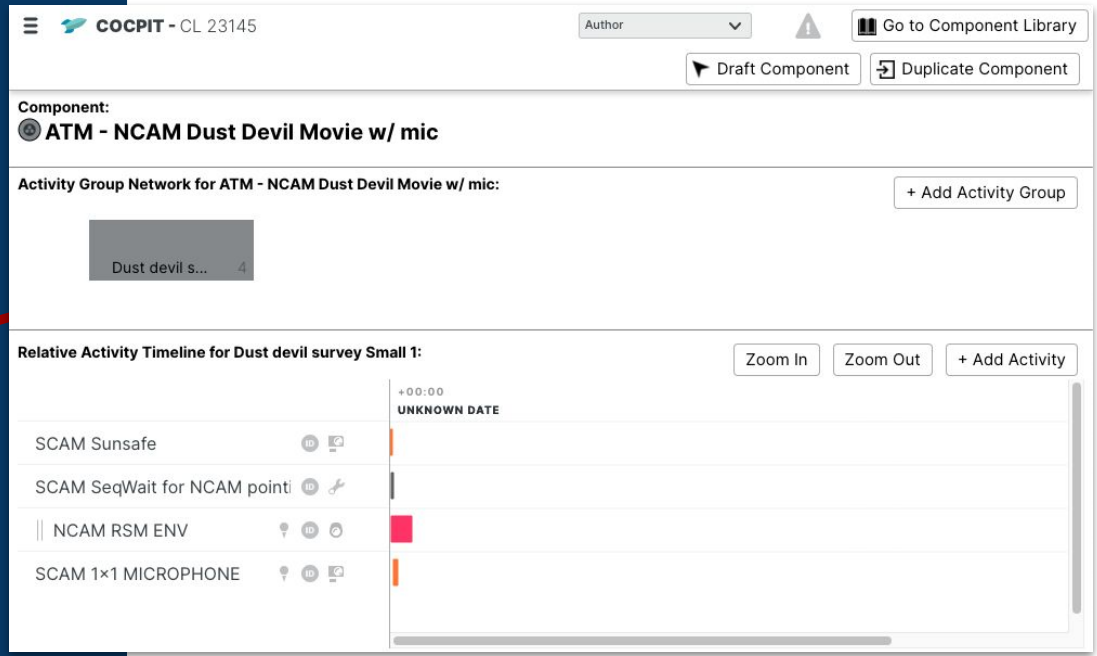


- Companion application
- Management of plans, component libraries and folders
- Supports planning workflows
  - Bookmarking
  - Plan level operations
  - Color tagging
- Query search for metadata and archival information

Component Library

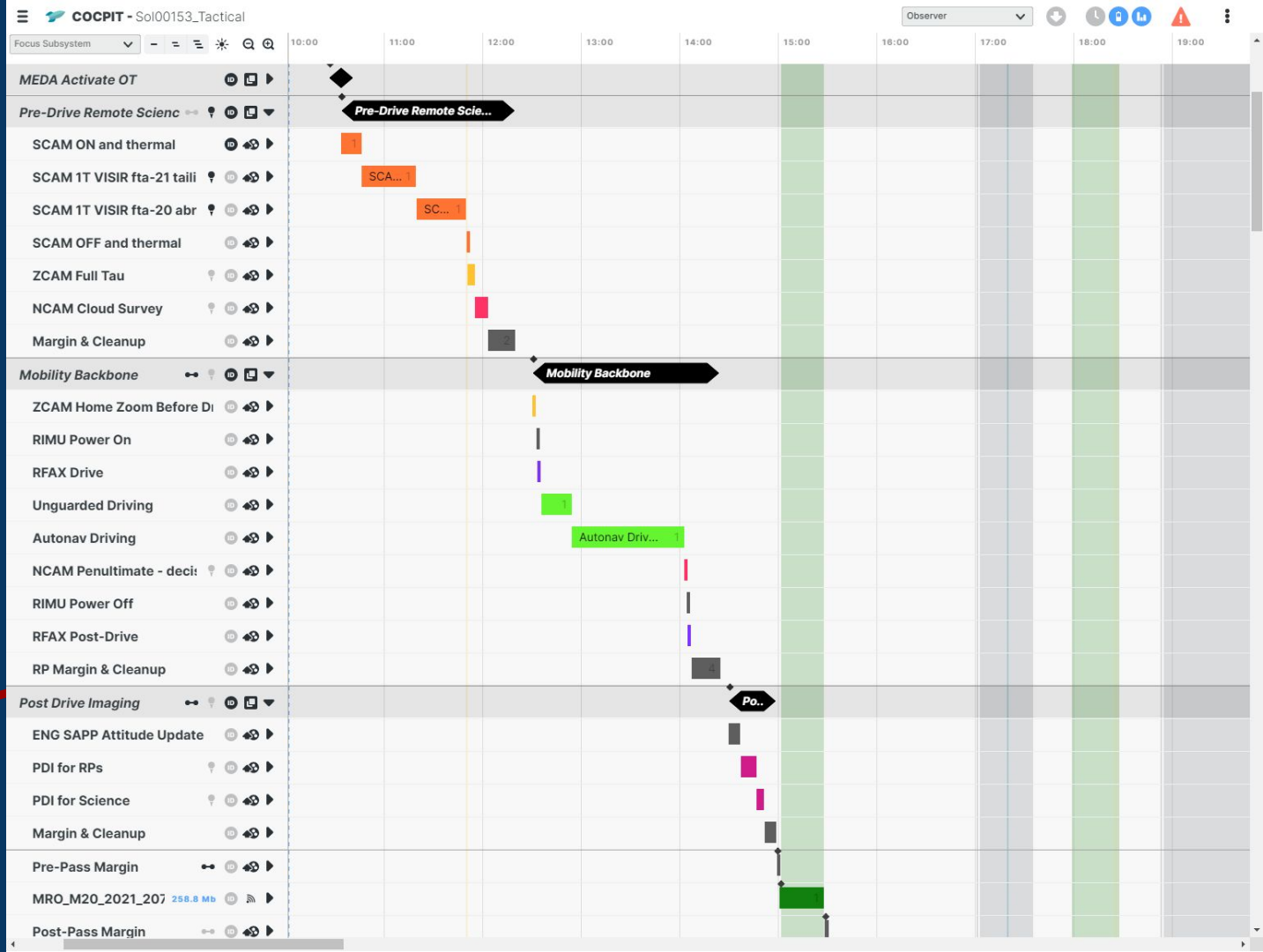
- Collection of reusable components with resource information (energy, data, duration)
- Planning units for Campaign Implementation and Tactical Planning phases



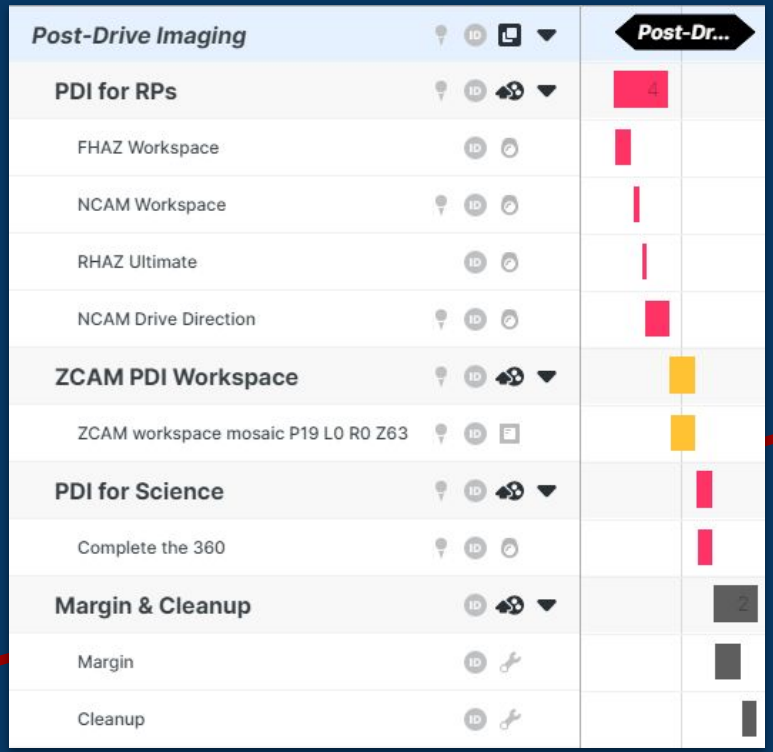


Timeline

- Main view to manipulate and review the plan
- Hierarchical and chronological order
- Row labels have shortcuts to important information
- Vertical Overlays show comm passes and when rover is asleep
- Blue dash lines show handovers
- Time window constraint representation



Plan Structure

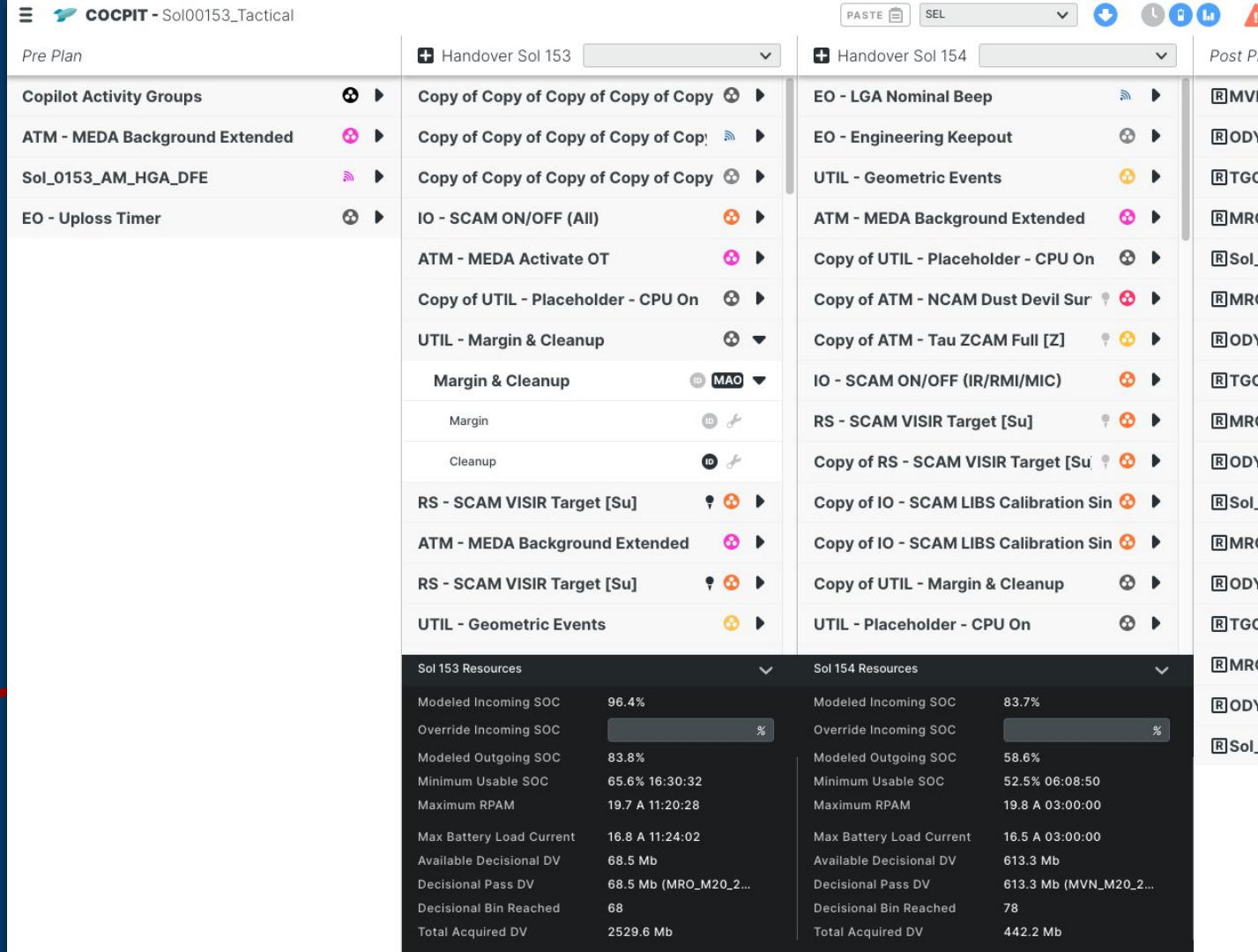


- Planning Unit Types
  - Components contain Activity Groups
  - Activity Groups contain Activities
  - Activities are of many different Types

- Components are plan fragments that can be added to and removed from plan
- Timeline shows Activity Groups and Activities as children (not Components)
- During planning, Activity Groups can be grouped into Merge Sets (back rectangle with diamond corners)

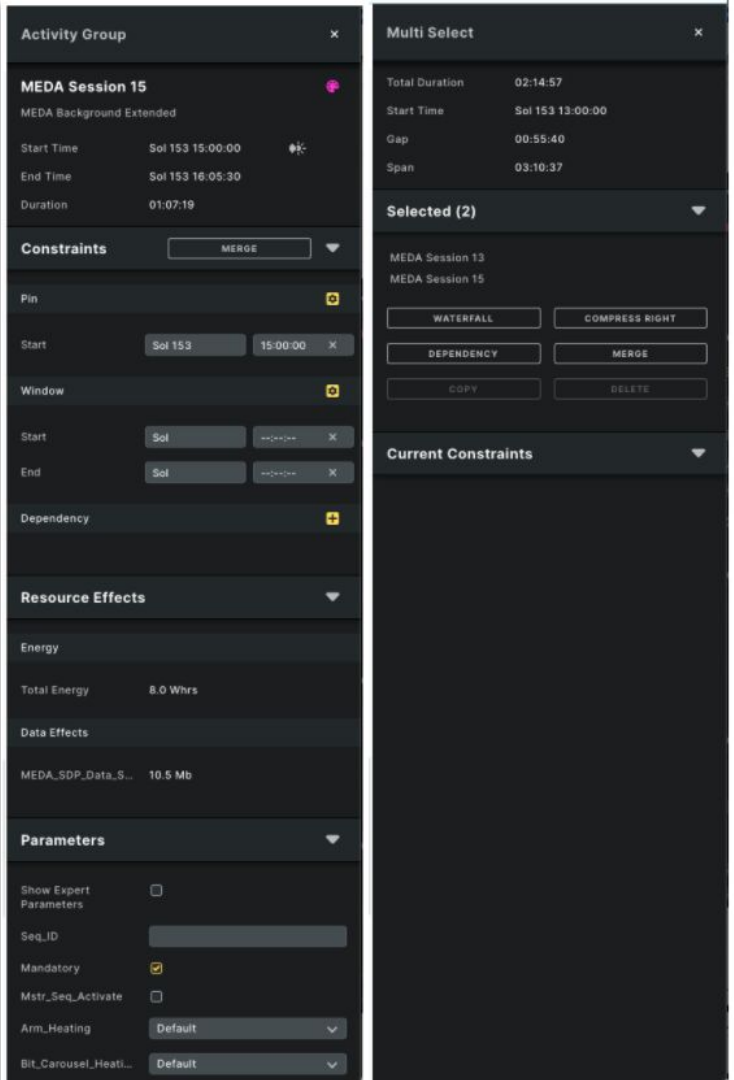
Overview

- Alternate view showing Components, Activity Groups and Activity hierarchy
- Column per Sol
- Shows Planning Units outside of the bounds of execution
- Per-Sol Data and Power Resources



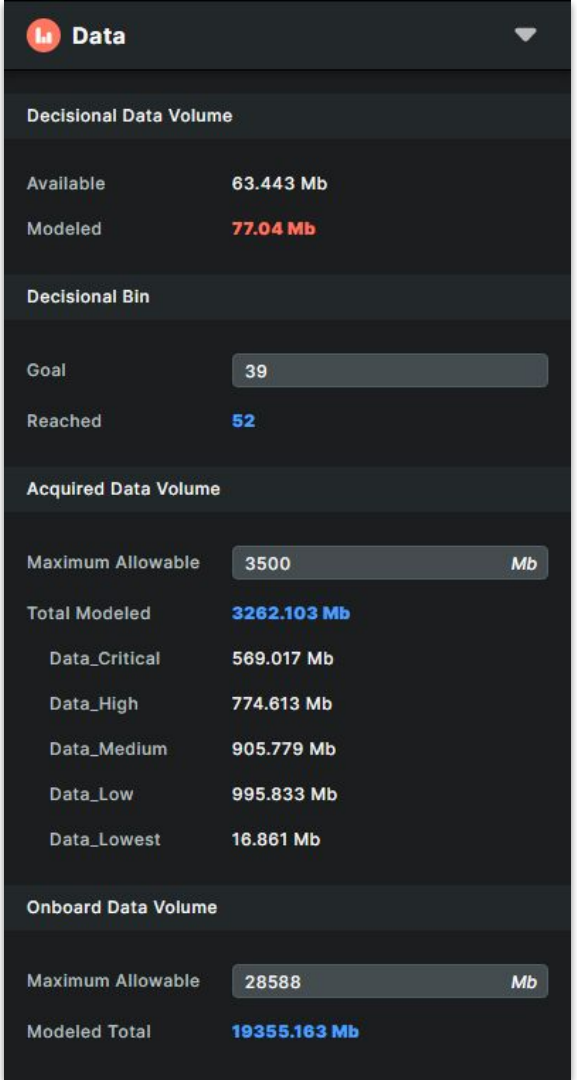
Details Panel

- Selection-aware panel for editing
- Each planning unit type shows the relevant sections, operations and parameters for its type
- Respect permissions by role and type of planning unit
- Multiselect shows metrics and supported operations for selection
- Same details panel available in all COCPIT views



Data Modeling

- COCPIT models data generated, reprioritized, retransmitted and downlinked by rover
- Activity parameters contribute to the calculation of data (using formulas in AD)
- Crucial to understand when the data will be available for analysis Earth
    - Decisional Data is data needed for next tactical planning cycle
- Activities show data contributions
- Data Resource Panel shows aggregated values per criticality at the plan-level and a specific time in the plan



Collaboration & Interfaces

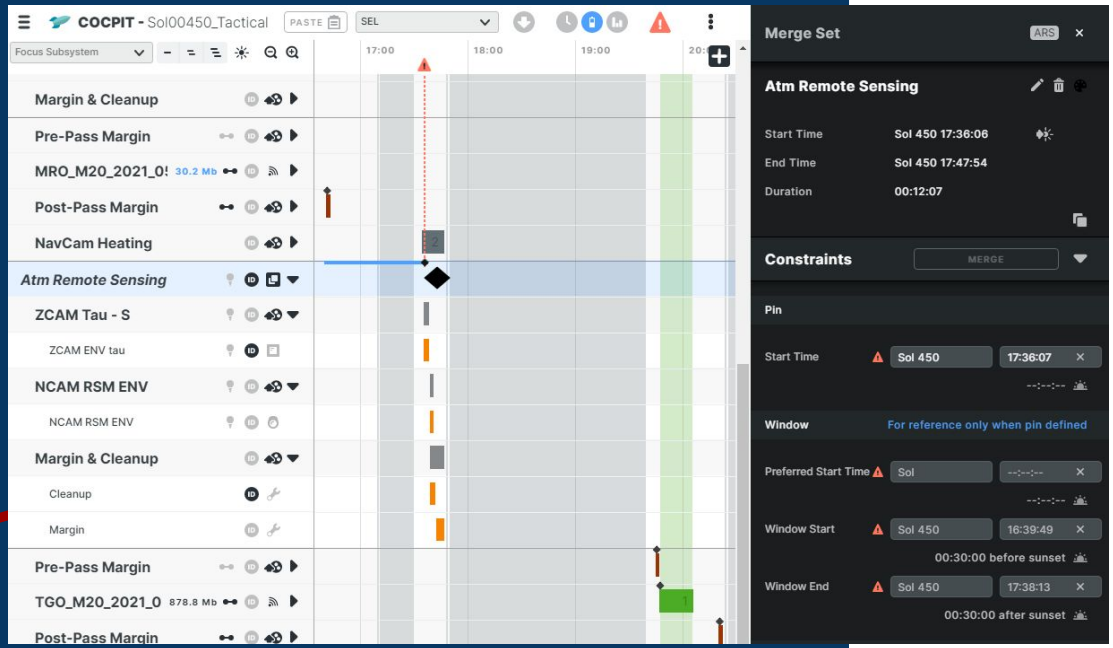
Collaboration

- Team Members around the world can access the live plan with a web browser
  - Changes are distributed to all clients automatically to keep them up to date
- Role-based permissions control actions

Interfaces

- COCPIT's Application Programming Interfaces (APIs) allow other tools to submit changes programmatically
- A pub/sub service sends notifications to tools that are interested in receiving plan changes
- Plan Patch allows Rover Planners to optimize rover motions by adding, removing and reordering activities with a bulk change operation

Temporal Constraint Network



Constraint Types

- Pin to start at a specific time
- Execution Window
  - Earliest Start, Latest End, Preferred Start
- Dependency
  - Start before or after another planning unit

COCPIT uses a Temporal Constraint Network to evaluate the set of constraints in the plan and warns users if they are inconsistent or circular.

Autonomous Scheduling

Planning vs. Scheduling

- COCPIT users are responsible for planning: selecting desired activities, setting parameters and constraints
- An autonomous scheduler determines actual start times for each planning unit

Scheduling Considerations

- Predicted duration
- Timing and dependency constraints
- Data volume and power limits
- Mechanical state requirements and effects
- Allowable parallelism

On the ground and on-board

- Ground software Copilot is heavily integrated with COCPIT
- Perseverance flight software will also support autonomous scheduling
- Both are informed by data in the COCPIT plan

Sequencing

- After plan is finalized, it is used to generate the sequences that run on the rover.
- Individual activities are converted to sequences. Activity parameters determine which commands and arguments are generated.
- The structure of the plan is used to build master and submaster sequences that coordinate the flow of execution of other sequences.
    - Timing constraints map to commands to pause until a given time.
    - Merge Sets and Groups map to submaster sequences.
    - Wake and Sleep activities map to commands instructing the spacecraft when to wake up and shut down.

Summary

As missions become more complex, tools must allow more integration, automation and collaboration to enable less work hours for operators and more science on Mars.

COCPIT and Playbook are modern planning and scheduling tools paving the way for software supporting humans and robotic exploration of Moon, Mars and beyond.

Thank you to the COCPIT management, design, test, infrastructure, and development team for working tirelessly to make this software successful. Anthony Robertson, Ryan Goetz, Kathryn Yu, Roxana Gonzalez Burgos, Joshua Camacho, Jimin Zheng, Sara Schnadt, Adrian Galvin, Basak Alper Ramaswamy, Guy Pyrzak, Hoan Luu, Natalie Rezek, Jon Blossom and Usha Guduri.