Remote Science Activity Planning:

Redesign of Science Planning Process and Specification of Remote Science Activity Planning Tool

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Master of Human Computer Interaction Capstone Project
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Contents

Executive Summary

What process will scientists use to guide and convey scientific intent to next generation robotic planetary explorers? What information is crucial to the remote science planning process? As Masters students in Human-Computer Interaction with backgrounds in software development, quality and assurance testing, evaluation of software effectiveness, graphic design, and theater arts, we are investigating these questions by combining our collective work experience with proven HCI methods. We employed on the Contextual Inquiry, In-situ Observation, Interview, and Think Aloud methods to gather data relating to the science planning process and communication pathways supporting and creating activity sequences for the Mars Exploration Rovers (MER).

We began this investigation by studying mixed initiative constraint based planning both within the MER context and across other domains in order to uncover overarching breakdowns in the mixed initiative constraint based planning process. We were then presented the opportunity to focus on one of those breakdowns, the inability of the human planner to adequately encode intent to the computer planner, within the remote science operations domain. Specifically, we were presented with the task of aiding in the redesign of the Science Activity Planner (SAP) currently used by the scientists working with the Mars Exploration Rovers, Spirit and Opportunity. In addition to addressing the breakdowns we observed in the MER process in our redesign of SAP, we were given the additional design challenges of designing for future mission operations, incorporating the functionality of Constraint Editor, another piece of software used in the MER mission, into the tool which scientists will use to specify activities, as well as providing the scientists with the ability to plan interactively within a representation of the Interactive Martian Environment.

We continued to study the MER science planning process, with a narrowed focus on the way in which science intent is maintained throughout the science planning day. We then developed a new science activity planning process, addressing the problems we uncovered in our investigation of the MER science activity planning process as well as our additional design challenges. Our goal was to provide the scientists who will interact with future robotic planetary explorers with the ability to track and review science data, and to create and constrain rover activities in an interactive environment, capturing and conveying their intent at an appropriate level, for successful remote science operations. We believe this new process can support the current MER process, as well as the anticipated science activity planning process for future missions, and we have specified a tool to support this new science activity planning process.

Introduction

Robotic planetary exploration requires complex planning and problem solving in order to create an executable plan for the rover while maintaining complex relationships among rover resources and scientific intent. Recent missions have implemented a mixed initiative constraint based planning process to create stable, optimized plans for the rover to execute, allowing the maximum number of science objectives to be completed each day while maintaining appropriate resource levels. Mixed initiative constraint based planning is a complex planning system that requires extensive interactions between a human planner and a computer planner, working as a team to find the optimal solution for large problem spaces.

The Mars Exploration Rovers Mission (MER) implemented a constraint based mixed initiative planning process for the generation and validation of commands to be sent to the rover. In this process, rover activities are created by members of the Athena Science Team, the scientists responsible for choosing the science experiments performed on Mars and analyzing the data the rovers collect. Scientists specify the details of the activities and the conditions under which the activities must be executed using the Science Activity Planner (SAP). Constraints specified by the scientists are then applied to these activities by the Tactical Activity Planner (TAP) in another application, Constraint Editor. The TAP then imports the constrained activities into MAPGEN, an optimized scheduler which enforces the constraints placed upon the activities as well as the rover model. The TAP then uses MAPGEN to manipulate the plan until all stakeholders are satisfied with its content and it is ready to be sequenced for the rover. As the mission progressed, MER operations evolved, with slight variations in the planning process arising.

We studied the MER process at various points throughout the mission in order to understand these different planning paradigms and to understand the information flow from the scientists' initial conception of the science activity to the final stages of rover sequencing and to identify breakdowns within the current processes. We also studied mixed initiative constraint based planning in several other contexts in addition to MER in order to gain more knowledge about the process and to uncover large scale mixed initiative planning breakdowns, which we then addressed within the context of robotic planetary exploration science planning.

Project Focus

We have been presented with the opportunity to aid in the redesign of the Science Activity Planner (SAP) currently used in Mars Exploration Rover (MER) operations. The redesign goals arise from the breakdowns we have identified within the current MER mission, the functionality desired by the SAP development team, and the current assumptions about future planetary exploration missions. Specifically our redesign goals are to support a science planning process which requires distributed collaboration, to address the breakdowns within the science planning process we observed during the MER mission, to integrate the functionality of the Constraint Editor into SAP in order to provide the scientists with the ability to encode all of the necessary constraints onto their activities, and to provide the scientists with the ability to interactively plan within the Interactive Martian Environment. Our intention is to provide the scientists who will interact with future robotic planetary explorers with a tool to collaborate during distributed operations, to track and review science data, and to create and constrain rover activities in an interactive environment, capturing and conveying their intent for successful remote science operations.

Mixed Initiative Constraint Based Planning Research

Mixed initiative constraint based planning is a complex planning system that requires extensive interactions between a human planner and a computer planner which works as an optimal scheduler to maximize on one or more dimensions while maintaining given relationships (i.e., constraints) between activities. The primary goal of mixed initiative planning is to maximize the potential of human planners and computer planners by ensuring each do the tasks to which they are best suited. Human planners are experts at formulating goals and setting constraints, and computer planners can perform computationally intensive tasks to create plans which meet those goals and satisfy those constraints. When adequate solutions cannot be found, human planners must reason about constraints in order to solve problems, and relax constraints to satisfice. In order for this process to be successful, humans must be able to convey the right information to the computer, and humans must be able to understand the decisions that the computer has made.

We studied mixed initiative constraint based planning in several other contexts in addition to MER. We reviewed the mixed initiative planning literature, uncovering a wealth of data about the implementation of these systems and their impact on business operations. We performed Contextual Inquiries with mixed initiative constraint based planning systems in the autonomous robotics, bus scheduling, and restaurant scheduling domains to understand the practical implications of these systems and the ways in which real users interact with them. We interviewed mixed initiative planning experts, planner software developers, and expert human planners to try to capture the ways in which the human planner and the computer planner could complement one another and the instances where they were more likely to fail. We also created planning tasks to be completed by novice human planners with paper and pencil and with planning applications available to the general public in order to understand how people reason about constraint based planning and how well they can predict and interpret the decisions that computer planners make.

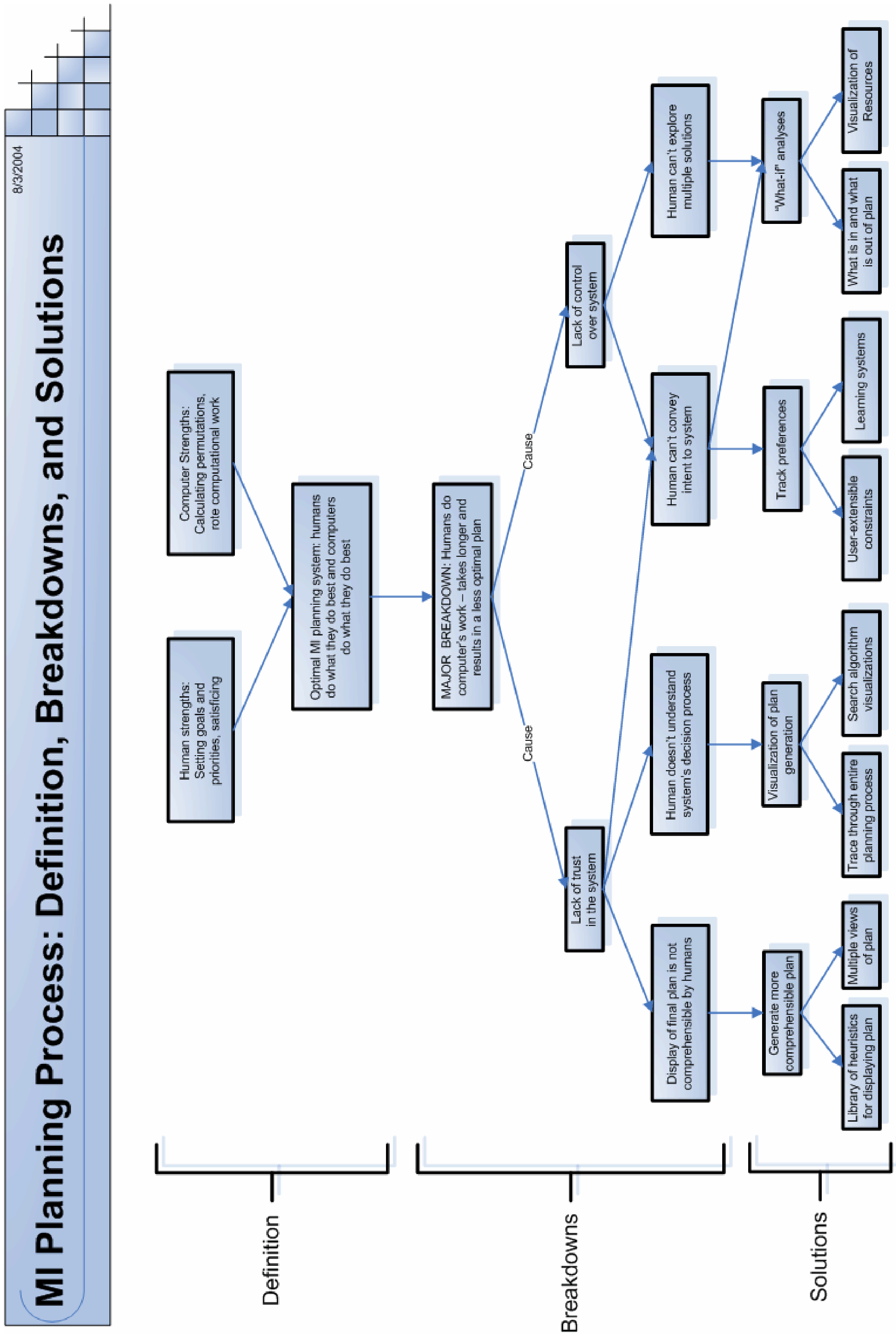
We consolidated all of our data, and concluded that the major breakdown in the mixed initiative planning process was that the human planner and the computer planner did not always perform the task for which they were best suited. Figure 2.1 shows our final conclusions about the mixed initiative planning process and the breakdowns we observed within the process. There were 2 main categories into which all of the breakdowns we uncovered within the mixed initiative planning process fell: human planners did not trust the computer planner, and human planners did not have adequate control over the system. Human planners were unable to use mixed initiative planning systems in the optimal way because they did not have the right level of control over the system or the appropriate level of understanding about the system.

Our data yielded 4 categories of breakdowns within the mixed initiative process which led to this conclusion: the display of final plan is not comprehensible to the human planner, the human planner is unable to understand the computer planner's decision-making process, the human planner is unable to convey intent to planning system; and the human planner is unable to explore multiple plan solutions.

In order for mixed initiative planning to be successful, the human planner must A. be able to convey intent to the planning system, B. understand how the computer planner is making decisions; comprehend the final plan the computer presents, and C. be able to explore multiple solutions to the planning problem they are trying to solve. We saw breakdowns in all of these areas within the analogous environments we investigated, and identified these areas as opportunities for improving the mixed initiative planning process. We modeled the data from the analogous environments, see Appendix A.

We explored multiple avenues for improving the mixed initiative planning process to address these breakdowns, with high-level solutions to investigate. We were then presented the opportunity to focus on one of those breakdowns, the inability of the human planner to adequately encode intent to the computer planner, within the remote science operations domain.

Figure 4.1 – Model of Mixed Initiative Planning Breakdowns



Mars Exploration Rover Science Activity Planning Process

The Mars Exploration Rover Mission

The Mars Exploration Rovers (MER), Spirit and Opportunity, are robotic geologists executing a series of science investigations on the surface of Mars. As the rovers complete the Surface Operations phase of their mission, a team of scientists on Earth, the Athena Science Team, choose activities for the rover to execute in order to conduct remote science experiments on Mars, with the goal of uncovering clues about the presence of water on Mars and its impact on the Interactive Martian Environment.

The Athena Science Team is composed of over 200 scientists from all over the world, with a subset of those scientists collaboratively defining rover activities at MER Mission Control at the Jet Propulsion Laboratory (JPL). The team is divided into 5 theme groups, geology, mineralogy, atmospheric, soil, and long term planning, with science team leads guiding the science activity planning within each group.

The rovers operate on a schedule based on Martian days, or sols, because the rovers are solar powered. Each sol is essentially split into 3 phases: downlink, science assessment, and uplink. During the downlink phase, mission control receives data from the rover, including the health of the rover and the data products resulting from the previous sol's science activities. During the science assessment phase, the scientists then review the data received from the rover and begin to plan the next sol's activities. Scientists must not only choose the activities that should be executed, but they must determine the relative priority of the activities to be executed and the retrieval of the data products that they will produce. The final phase, uplink, is when the activities specified by the scientists are sequenced and prepared for transmittal to the rover for execution. Our focus is on the science assessment phase of the sol, which can be further divided into 8 distinct periods, which we will refer to as the science activity planning process.

The mission was initially intended to last 90 sols (Martian days), due to expected rover resource limitations. However the mission has extended well beyond 90 sols, with Spirit recently passing sol 200, and Opportunity recently passing sol 108. We will refer to the first 90 sols of the mission as the Primary Mission and the remaining sols as the Extended Mission. We were provided with the opportunity to study the science activity planning process for several sols during both phases of the mission.

Observed MER Science Activity Planning Process

We first performed in-situ observations of the MER Science Activity Planning Process roughly half way through the Primary Mission. We were strictly observing the process, with no communication with the people we were observing, and no recording ability. We divided into two teams, with each team observing the entire planning process for 2-3 sols, operating on Mars time. We consolidated our observation data and defined the high-level process that we observed. We created a sequential flow model (Figure 5.1) of the MER Science Activity Planning Process based on our data from this observation.

MER Science Activity Planning Process

1. Science Context Meeting

The science activity planning process begins with the Science Context Meeting. At this meeting, the previous sol's successes and failures are reviewed, and the high-level science goal for the current planning sol is determined. For example, if the goal of the current planning sol is to drive the rover to a particular location, this would be presented at the science context meeting. There may also be a report from the long term planning theme group with a rough outline for the rover's resources and high-level activities for the upcoming sols. There is an opportunity for all scientists to voice their opinion about the current planning sol goals, and also for them to receive some rover health and

2. Science Downlink Assessment

The Science Downlink Assessment is the period during the planning day when the scientists review the data sent from the rover to inform their planning decisions for the current planning sol. They are typically working within their theme groups, and are using an application called Science Activity Planner (SAP) to review the activities from the previous sol and to begin to specify the activities for the current planning sol.

3. Science Downlink Assessment Meeting

During the Science Downlink Assessment Meeting, the scientists are provided with information on the health of the rover, as well as information on the health of each of the rover's instruments. The theme groups also report the results from the previous sol's data.

4. Science Activity Planning

Scientists create activities for next sol within SAP. They are able to specify some of the details of the activities which they are creating in SAP, but must distribute some of the specification to instrument specialists.

5. Science Operations Working Group (SOWG) Meeting

The SOWG Meeting is the time when scientists work together to choose the activities that the rover will execute on the surface of Mars. This meeting is lead by the SOWG chair, the scientist with the most authority over the planning process. The SOWG chair is aided by the SOWG documentarian, who must record all of the details of the discussion, including the scientific intent related to activities.

During this meeting, each theme group lead presents the activities that they would like the rover to execute, including the scientific purpose for the activity. The entire group then decides which activities to execute, and prioritizes the activities based on various factors including resource limitations and scientific intent. The scientists must also prioritize the retrieval of the data products resulting from the activities that they specify at this meeting. Activities can have a high uplink priority, meaning that it is very important for that activity to be executed, but a low downlink priority, meaning that the data from that activity can remain in the rover's memory until downlink resources are available to transmit the data product. Rover engineering activities and rover and instrument health are also reviewed.

6. Constraint Editing and Planning

An engineer, called the Tactical Activity Planner (TAP) applies constraints specified by the scientists using an application called Constraint Editor, and then imports the constrained activities into MAPGEN, an optimized planner. The SOWG documentarian works with the TAP to maintain scientific intent as the constraints are applied. Constraints can either affect only one activity or they may link multiple activities. Constraint Editor is able to apply both types of constraints, with functionality to apply constraints in bulk. When the constraint setting is complete, the rover plan is generated and manipulated. The activities in the rover plan can be a subset of the activities approved during the SOWG Meeting, and additional activities not specified in the SOWG may be added into the plan at this point in the process based on available rover resources.

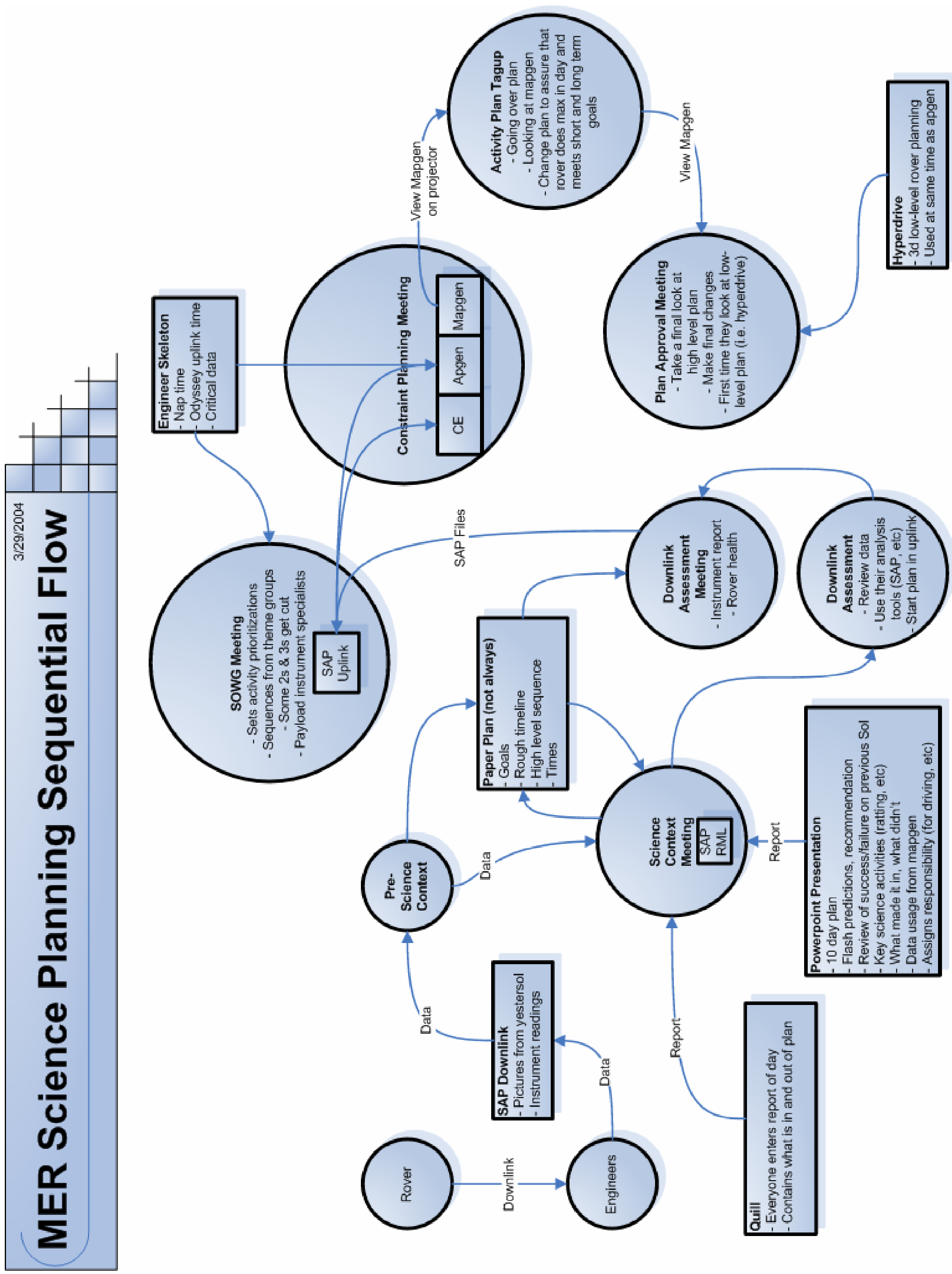
7. Activity Plan Tagup

During the Activity Plan Tagup, the TAP, SOWG chair, SOWG documentarian, instrument specialists, and other stakeholders review first iteration of plan. They review the sequence generated by the planner to ensure that scientific intent is maintained and that the desired resource levels are maintained. The TAP revises the plan using Constraint Editor and MAPGEN.

8. Final Activity Plan Review

During the Activity Plan Tagup, the TAP, SOWG chair, SOWG documentarian, instrument specialists, and other stakeholders review final iteration of plan before it is sequenced for the rover.

Figure 5.1 – Model of MER Science Activity Planning Process



Primary Mission

During the Primary Mission, the Athena Science Team members located at JPL, as well as all other people involved in rover operations, lived on Mars time, with each sol revolving around the communication windows with the rover and the science planning cycle. The science assessment phase was very long (10+ hours per sol), and was followed rigorously, with the participants learning much about the rover, the Martian environment, and the planning process as the mission progressed.

Early in the mission, the rover plan was not well defined early in the planning process, with many changes to the plan occurring at the SOWG and later in the process. As the rover executed more plans successfully, the scientists learned more about the planning process and the limitations of the rover, and accumulated executed activities to re-use in future plans. Re-using these previously executed activities added an additional validation to the planning process. In some cases, templates were created to facilitate planning and activity re-use. The use of templates depended upon the types of activities

Extended Mission

The Extended Mission differed from the Primary Mission in a number of ways. Due to budget constraints, the mission began to operate on Earth time, with only a subset of the Athena Science Team members who had been located at JPL during the Primary Mission able to remain working on the mission full time, making the theme groups much smaller. Additionally, the remaining members became experts at creating rover plans and predicting rover capabilities in the Martian environment, so the plan was often defined very early in the planning process, sometimes even days ahead of time. There was often a very detailed plan created in Microsoft Excel containing many of the details that would not have been available until after the Constraint Editing and Planning portion of the science activity planning process during the Primary Mission.

The planning process no longer revolved around the rover's schedule, but operated on more normal Earth working hours, and was often accelerated, with meetings combined or even eliminated. The new schedule sometimes created mismatches between when rover data was obtained and when it was needed. However, the experience of the team members and the corpus of previously executed activities lessened the impact of this mismatch in some cases.

MER Science Planning Process Breakdowns

The flow model we created from our observation data (Figure 5.1) depicted the process described earlier and captured the way in which various parts of the process impacted one another, but did not capture all that we observed, so we created an additional model (Figure 5.2), which we called a work flow model, to capture the flow of data throughout the planning process. We identified a number of breakdowns within the process relating to the data flow and science intent, and verified those breakdowns in subsequent observations at MER during the Extended Mission.

We focused on 5 primary breakdowns in the process:

1. Science Data Request Tracking - Scientists were unable to quickly obtain information about whether or not their activities were included in the plan uplinked to the rover, or if they were executed by the rover. Additionally, scientists were unable to locate data products related to executed activities or their downlink status.

2. Verification of Unique Data - Scientists and other planning stakeholders were unable to quickly know if they were going to repeat an activity that had already been executed by the rover, and we witnessed instances of unintentional planning of previously executed activities.

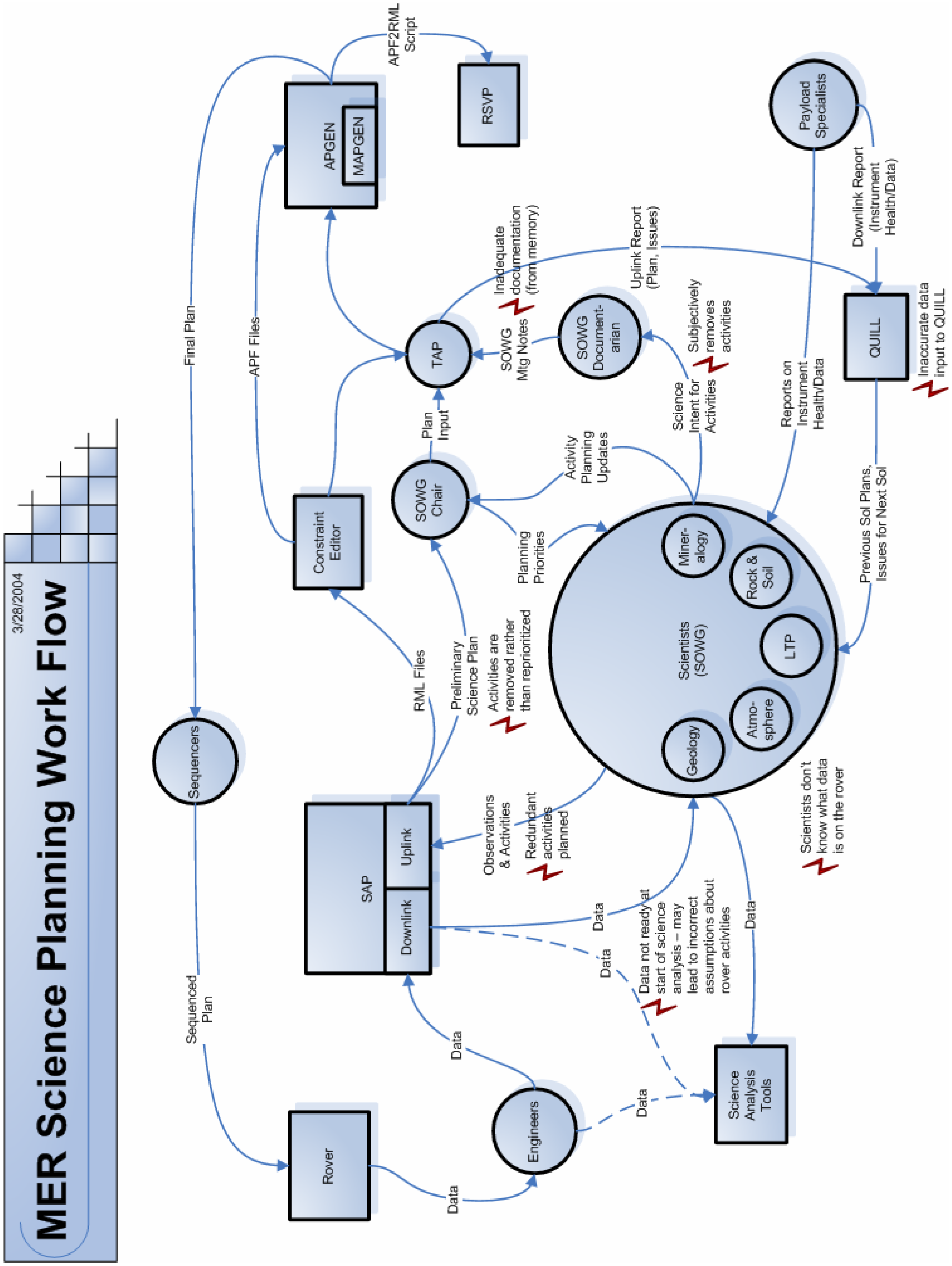
3. Science Activity Re-use - Re-using activities that were previously executed on the rover is a very desirable way to create valid plans. In the current process, it was often difficult for scientists to re-use activities because all of the information needed to specify that activity was not always captured within the details for the activity. For example, the activity's Sequence ID, the code specifying the exact sequence of commands the rover would execute to complete the activity, is not accessible within SAP, and we witnessed them being hand written and passed on slips of scrap paper.

4. Inadequate Science Intent Documentation - Although the activity details in SAP provides a place for the scientists to convey their science intent for the activity in a notes field, these fields were not always utilized and were not standardized. The SOWG documentarian had to rely on her note-taking ability and on her memory to retain much of the science intent. In addition, when bonus science activities were included in the final plan because of available rover resources, the additional scientists might have to be called upon late in the science planning process to review the intent for those activities.

5. Science Activity Subjective Removal - During the final stages of the science activity planning process, activities that had been specified were often subjectively excluded from constraint application and entry into the optimized scheduler based on human predictions about what the optimized scheduler might do with the plan. For example, we witnessed instances of the SOWG documentarian disregarding the constraints that were to be applied to a low priority activity and instructing the TAP not to import that activity into MAPGEN because she thought that it wouldn't fit into the final plan.

These breakdowns spanned the science activity planning process, and were so tightly connected to one another that we were forced to re-evaluate the science activity planning process at MER in order to alleviate them. We began to look for broad solutions that could address multiple breakdowns and improve the entire process, with an eye towards the additional redesign goals that the SAP developers presented to us and our assumptions about future missions. We were able to abstract the MER process and integrate the needs presented by our additional challenges and breakdowns in order to propose a new remote science activity planning process for future missions.

Figure 5.2 – Model of Data Flow in MER Science Activity Planning Process



Remote Science Planning Process

We designed a new mixed initiative planning process for remote science activity planning based on the breakdowns we witnessed in the MER process and our model of the MER process. We were able to abstract that process in order to support the planning paradigms that we observed, both Primary and Extended mission, and to add in elements we believe will enhance future missions. Figure 6.1 illustrates the remote science planning process that we envision for future missions.

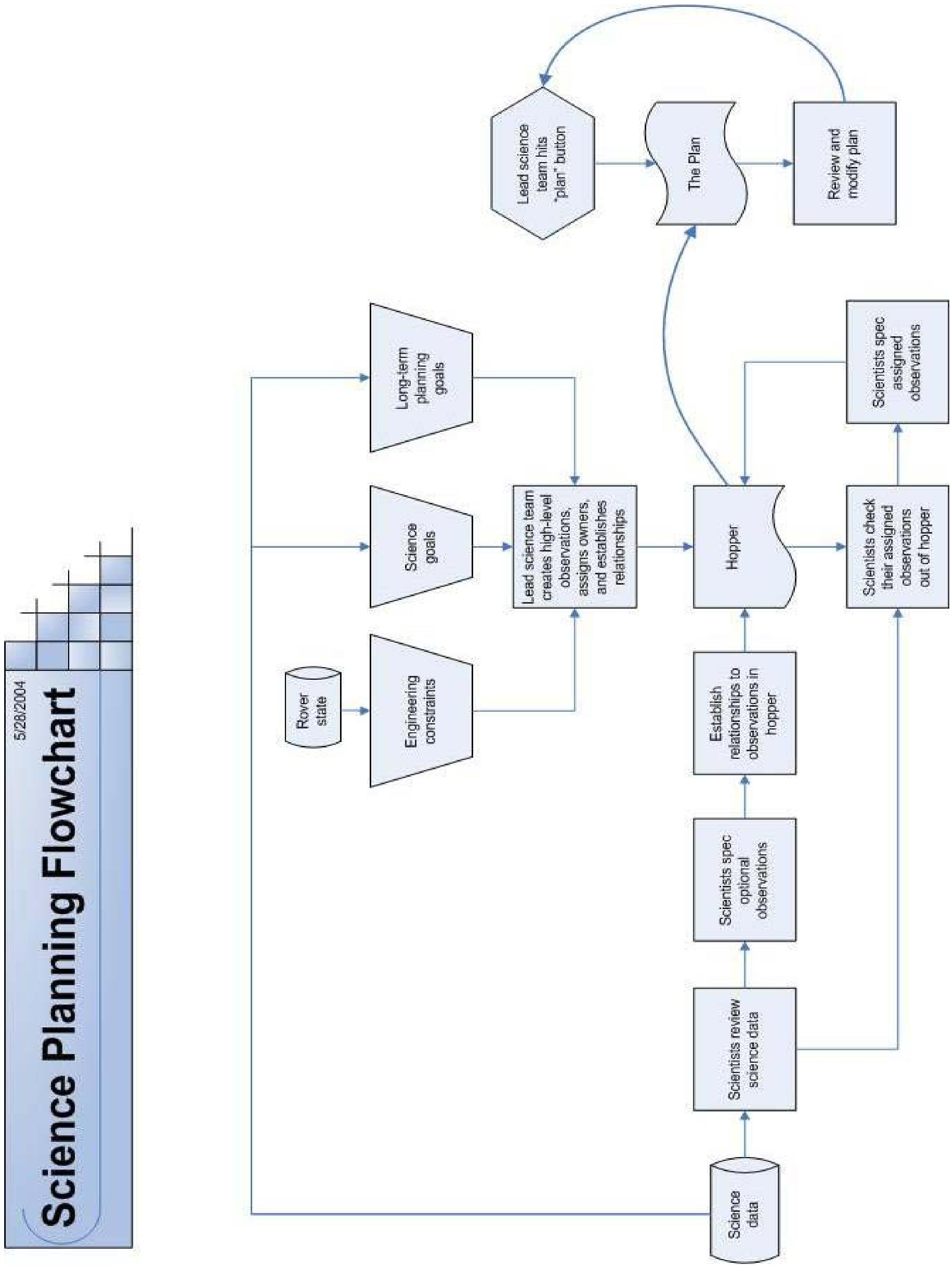
Future missions may not have the same power constraints as the current solar powered rovers. This might allow constant rover operation, thereby increasing the number of science activities that can be performed, and increasing the responsibilities of the scientists creating the activities. Logistically it would be very difficult to provide the level of support on the MER mission to a mission with continuous operation, so we assume that there will be an element of distributed planning and collaboration in future missions.

The main differences between the MER process and our process is that the scientists are working in a collaborative space throughout the planning day, scientists have greater control over the constraints which are placed on the science activities, and the scientists have access to a round trip data tracking system within their planning environment.

Throughout development of this process and of the subsequent tool we created to support it, we conducted 30 participatory design sessions with MER scientists and engineers to evaluate the usefulness of the process, to validate our assumptions about their process, to inform our design of process and interface, and, eventually, to test our interface designs. These sessions included a mix of interview, in-situ observation of science activity planning, and think aloud protocols with low- and hi-fidelity prototypes. We were typically subject to the rigors of the science planning schedule and the unexpected changes in the schedule resulting from robotic exploration and communication, so the sessions varied in length and in the ability of the scientists to interact with us. We present the data resulting from these sessions in Appendix B and C, and will refer to them throughout the discussion of the process and the development of the tool.

Once we were secure in our process, through discussions with scientists and with the SAP developers, we began to develop a tool to support this process. This was a challenging endeavor, as the functionality requirements for a tool to support a process this complex are many and very detailed.

Figure 6.1 – New Remote Science Activity Planning Tool



The Hopper – A Collaborative Planning Space

We provide the scientists with a shared activity space called the Hopper to support collaborative planning. The Hopper is the place where all of the activities that could potentially be included in the science activity plan for the current planning sol are stored. Within the Hopper, relationships can be established among the activities to encode science intent, for example, requiring that activities occur in a particular sequence. When all activity creation is complete and all necessary relationships have been established, the activities in the Hopper can be exported to the optimized scheduler to create the plan for the rover, with an opportunity for plan iteration.

The Hopper supports two science activity plan creation scenarios, a top-down process and a bottom-up process. In the top-down process, a lead science team synthesizes the engineering constraints, the science goals, and the long-term planning goals and then creates a high-level plan for the day in the Hopper. This high-level plan is a set of activities, which have been created, but not completely specified by the lead science team. Based on directives from the lead science team, the other scientists working on the mission are able to "check-out" the activities assigned to them and complete their specification. Once the specification is complete, the activities are returned to the shared space. In the bottom-up process, scientists are independently creating science activities and placing them into the Hopper throughout the planning day. In both processes, the Hopper holds the all of the components that could be planned, allowing scientists a general idea of what could happen on the current planning sol. This supports the templatized planning we witnessed during our observations, while still maintaining the ability for less rigid planning we also witnessed. We also intend for the Hopper to allow long-term planning, with the potential for multiple future sols to be accessible.

Scientists responded favorably to the concept of the Hopper, stating things like "this is what we need right now," (C-24), and "(it would be) nice to have a sense of where things are going, but they would probably change," (C-36). Other scientists were concerned about the Hopper presenting an "added layer of complexity" (C-23), and they expressed concern about the ability of one tool to support both top-down and bottom-up planning (C-36, C-37). This challenged us to make the Hopper use as easy as possible for the scientists, as well as to think deeply about the type of functionality necessary to support both planning processes without promoting confusion.

Scientific Intent

In our process, there is no additional constraint application step between the creation of science activities and the generation of the rover plan. We intend to provide the scientists with the capability to apply all of the necessary constraints to their activities either within the creation of the activity or within the Hopper. If the constraint applies only to that activity, for example choosing a particular time of sol when it should occur, then the constraint can be applied within the details of the activity. If the constraint links two or more activities together, then the constraint can be applied within the Hopper. This functionality should alleviate the problems with science intent being lost and with the subjective removal of activities from the planning process, (Figure 5.2).

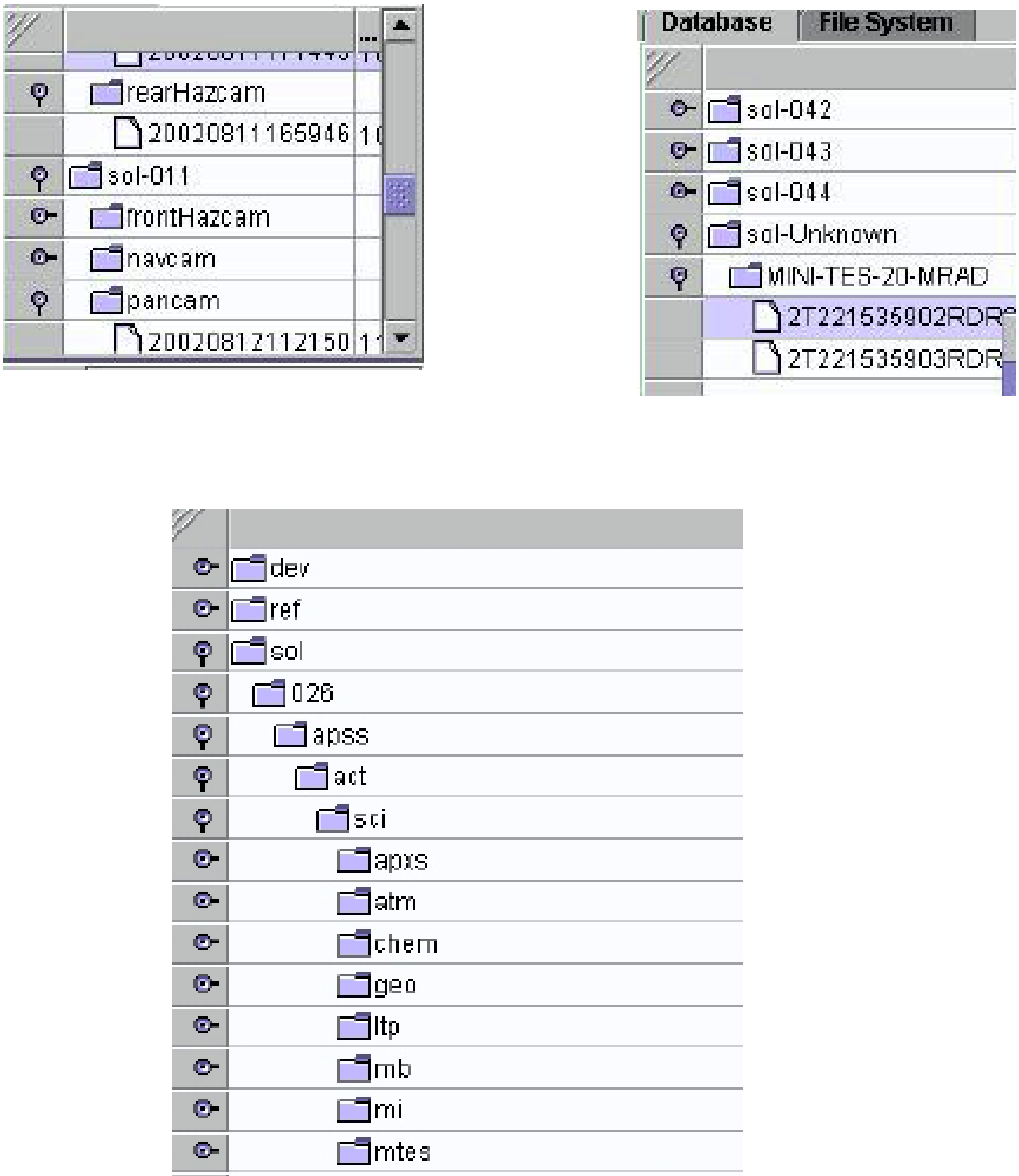
Most scientists who discussed this aspect of the process were in favor of providing more detail for their activities, commenting, “I like to be as specific as possible as efficiently as possible,” (C-170). The challenge will be choosing the right information for the scientists to specify.

Round Trip Data Tracking

The need for round trip data tracking arises from many different places. Scientists must review the previous sol’s data prior to choosing activities for the current planning sol, and must be familiar with the final plan from the previous sol in order to know what data was collected. Knowing what data is available for review is also an issue. Additionally, re-using activities that were previously executed on the rover is advantageous to scientists, both because it accelerates the planning process and because the successful execution of that activity validates the activity. Providing scientists with access to previously executed activities and their data products within the planning environment may alleviate the problems with activity re-use and with the verification of previously executed activities.

"Round trip data tracking is tough, but really cool," (C-25) is a telling statement from a scientist when talking about the review of plans for previous sols and accessing data products. Scientists realize the value of tracking previously executed plans, with one scientist stating, "we can re-use, that's why we're so fast (at planning) now," (C-234). Perhaps providing this information in a dedicated space within the planning environment will accelerate the process. Currently in SAP, scientists must load in a file for each previously executed sol, so they must remember which sol plan contains the activity that they are would like to re-use. Scientists were also interested in maintaining the relationship between data products and the plan, saying, "I like having the plan linked directly to the data product, because that is always a pain to try to figure out" (C-199). The data products in SAP are stored in a tree folder structure (Figure 6.2), with the scientists drilling down through the structure to find the data products in which they are interested. Scientists are accustomed to using the folder structures within SAP, although they are cumbersome.

Figure 6.2 – Views of the current folder structure in SAP.



Once we were secure in our process, through discussions with scientists and with the SAP developers, we began to develop a tool to support this process. This was a challenging endeavor, as the functionality requirements for a tool to support a process this complex are many and very detailed.

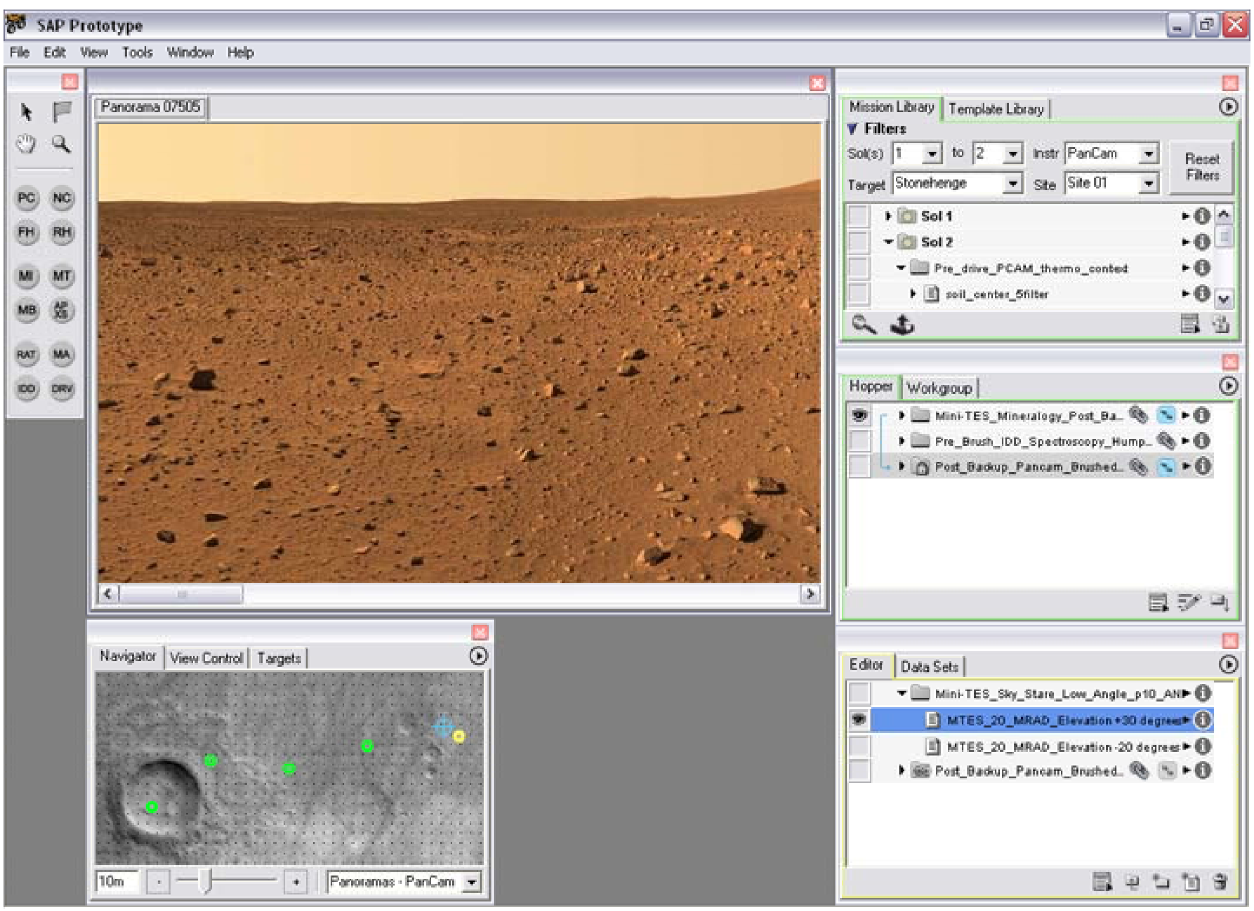
Remote Science Planning Tool

We have designed a tool to support the remote science planning process that we have defined. This tool (Figure 7.1) provides scientists with one tool for round trip data tracking, access to data products, science activity specification, verification, review, and science activity re-use.

The SAP developers presented us with many of the challenges they were facing in redesigning their tool. Some of their goals aligned with our goals of facilitating activity creation, data access and collaboration, and they provided us with the additional challenge of aiding in the creation of an interactive planning environment to enable scientists to plan in context. This capability does not currently exist in SAP, although there are some related interactions. We have specified interactions toward this goal of interactive planning in our remote science planning tool.

There are 2 primary areas in the tool: a series of palettes for activity storage and an Interactive Martian Environment. Each area provides scientists with the ability to specify and verify new activities, as well as to review existing activities.

Figure 7.1 – New Remote Science Planning Tool



Activities

Activities are the essential data structure that our tool handles. Activities have varying numbers of parameters, depending on the rover instrument that executes them, and they may stand alone or be grouped with other activities. Observations are containers for activities that are related to one another. There are 2 ways of interacting with the parameters of an activity, the Activity Properties window and the representation of the activity within the Interactive Martian Environment.

Activity Properties

The Activity Properties window (Figure 7.2a) contains all of the specifications about a single activity. We have created 3 individual tabs within this window to separate details that are applicable to all activities, parameters that are specific to the rover instrument, and the constraints applied to the activity. There is also a link to the data products associated with an activity. We will discuss access to the Activity Properties window as we progress through the other components of the tool.

Figure 7.2a – Activity Properties Window

Our Activity Properties window differs from the current SAP Activity Properties window in several ways. We have expanded the number and type of general details available and adjustable within the details window, we have included some constraint editing functionality, and we have afforded scientist with the opportunity to compare the details of multiple activities.

We have added additional information into the general details, allowing the Sequence ID for the commands that the rover will execute to complete the activity to be accessible from the details of the activity. The design decision arose from our meeting with Payload Uplink Specialists, (PULs), who match the appropriate Sequence ID to activities. PULs reported difficulty in finding the correct Sequence ID for the activity that they intended to re-use, with Sequence IDs often transferred on slips of scrap paper. We present the Sequence IDs with a drop down menu because they are typically a set list, created as they are preparing for the mission, so incorporating new ones is less appropriate, although the developers should not exclude this possibility. We recommend that the scientists still maintain the ability to type in the desired Sequence ID as an accelerator. However, presenting the Sequence IDs in a drop down menu also promotes error prevention, since scientists are not forced to type their answers. Subsequent participatory design sessions confirmed that our solution for placement of the Sequence ID was satisfactory to the users (C-180).

During our participatory design sessions, scientist expressed the need to specify the target of an activity (C-240), so this is another field that should be included in the Activity Properties window. We recommend that this component also be a drop down menu with a type-in option, since there is a defined list of targets on which an activity can be applied, and the potential need for an accelerator. We assume that target creation is an activity well suited for the Interactive Martian Environment, so that functionality does not need to be incorporated here.

We have provided scientists with the ability to apply constraints that apply only to the activity that they are specifying in Activity Properties window. This is to support our process, to address the design challenge of incorporating Constraint Editor into SAP, to address the breakdowns we witnessed at MER, and in response to the scientist' desire for a greater ability to set the details of their activities. The current SAP Activity Properties window contains text fields to capture the scientific intent for activities. We witnessed breakdowns in the use of these fields, with scientists using these fields inconsistently and with some scientists avoiding the notes fields completely to pass on their intent verbally at the SOWG or to the PULs. Activity re-use further complicates this problem because these notes are not always updated when an activity is re-used. Our recommendation is to follow the guidelines set by Constraint Editor for constraining activities, with the potential for additional constraints defined by the scientists involved in the next mission as they determine how the instruments and activities will interact (C-224).

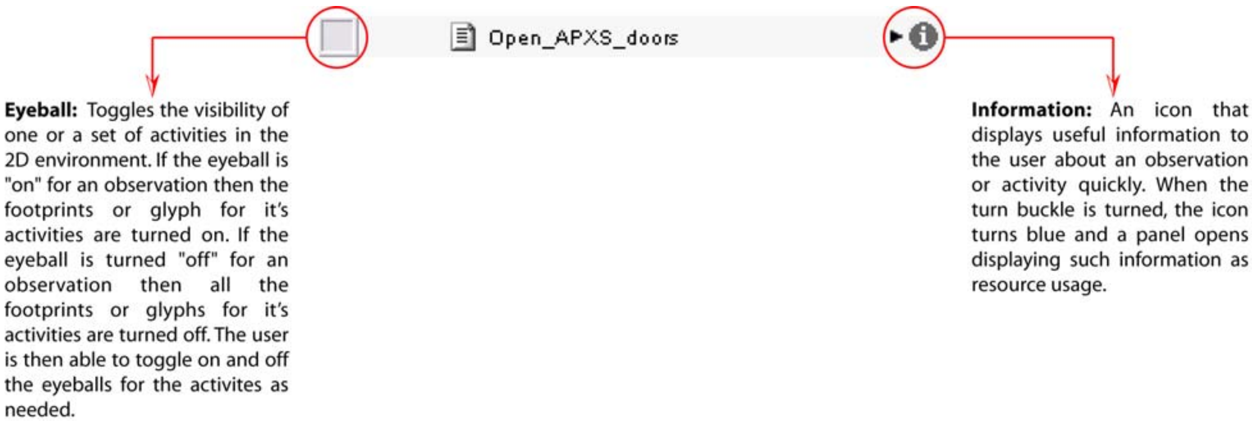
We have also included the ability for multiple Activity Properties windows to be opened at once, a capability which we expect to be valuable to the scientist based our experiences with them and our MER observations. The current SAP has one Activity Properties window that changes content based on the activity that is selected. We initially specified this design requirement after exploring SAP and finding it difficult to compare activities. The SAP developers were not convinced that this functionality was appropriate, because they believed that it would create too much clutter for the scientists. We spoke to many scientists about this issue, but were unable to conclude that it was desirable or undesirable. Comments like “it’s not a feature that is currently missed but it would probably be used if the functionality was there,” (C-227) were common. We have been discussing the possibility of having one persistent Activity Properties window with the ability to open additional windows if the scientist needs to compare details in the next version of SAP, allow the developers to collect data on the usage of multiple windows to inform future designs.

We are unwilling to discard the notion of multiple Activity Properties windows without appropriate user data because of the high value of activity re-use for our scientists, and the difficulties that we witnessed with comparing activities for re-use in SAP now. Currently, scientists must alternate the selection on the activities that they are trying to compare, forcing them to keep the details of each activity in memory. Additionally, the details window resets with each selection, requiring the user to navigate to the desired field for comparison (C-228). We recommend that this resetting functionality is not maintained in the next version of SAP.

Activity Representation in the Palettes

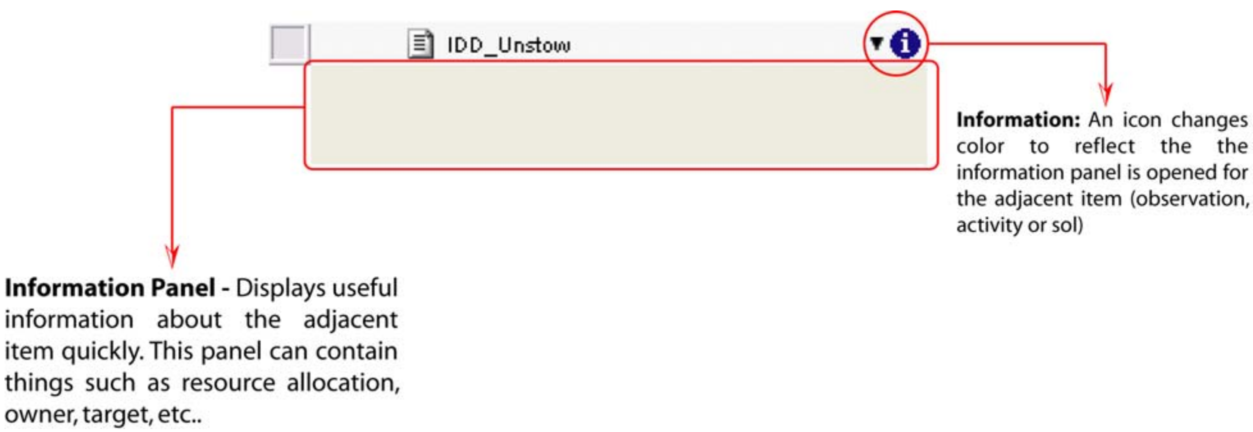
Within all activity palettes, activities are represented with their name and an icon (Figure 7.2b). Activity Property windows can be accessed by selecting the activity and choosing an additional Properties button located on the palette, or by double-clicking on the activity.

Figure 7.2b – An activity within a palette.



Details about the activity can be accessed directly in the palette through the Information turn buckle (Figure 7.2c). We have not specified the information that will be presented in this panel because we believe it will be highly dependent on the specifics of the mission our tool is supporting, possibly something like resource information or priority.

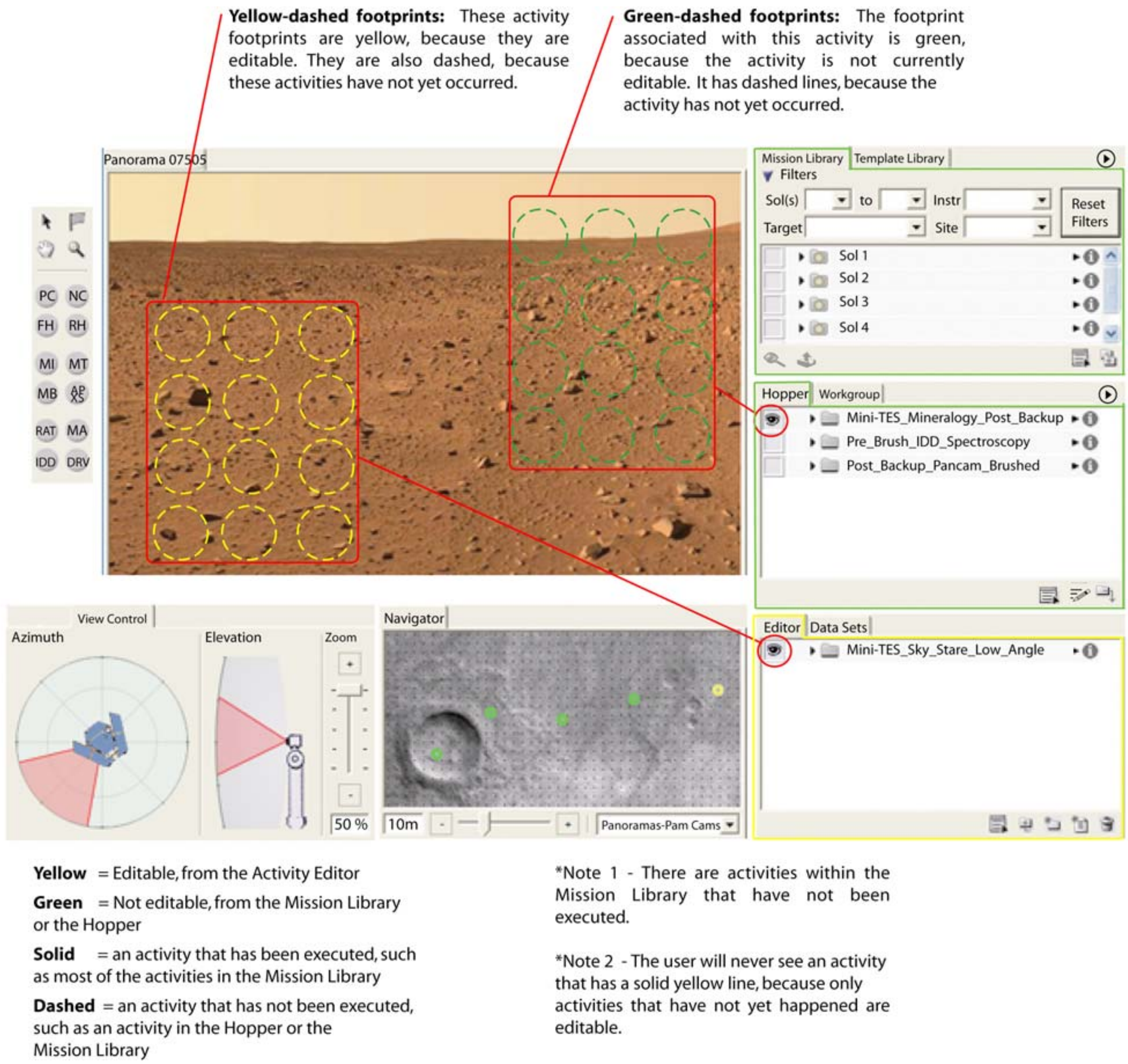
Figure 7.2c – An activity within a palette with the information panel open.



Activity Representation in the Interactive Martian Environment

Activity palettes are the main access point for scientist to interact with all activities, and the Interactive Martian Environment allows the creation, manipulation, and review of any activities that have parameters that allow them to be mapped to particular locations within the Interactive Martian Environment. Activities are represented within the Interactive Martian Environment (Figure 7.2d) as either a footprint displaying the parameters of the activity within the environment, or as a glyph, an abstract representation of the activity.

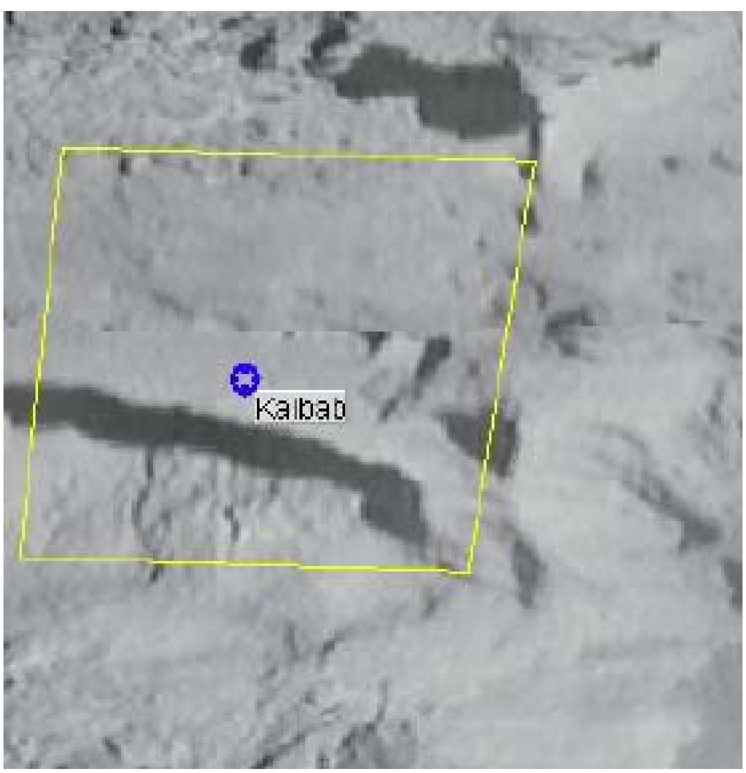
Figure 7.2d – An activity represented within the Interactive Martian Environment.



The view of activities within the Interactive Martian Environment is controlled through the eyeball toggle located to the left of each activity represented in the palette (or activity container, like observation or sol). Once the eyeball is turned on, a representation of the activity appears in the Interactive Martian Environment. The color and line style of the footprint indicates the whether or not the activity is located in a public or private space, and if the activity has been previously executed on the rover, respectively. Users responded well to theses signals once they were explained. Additionally, as new activities are created within the Interactive Martian Environment, they appear in one of the activity palettes, the Editor, maintaining same view control interaction. It is our intention that the footprints within the Interactive Martian Environment will be manipulated to adjust the parameters of the activity.

Currently in SAP, in order to view the footprint of an activity (Figure 7.2e), the scientist must find an image that would contain the footprint, and then select the activity within the activity editing environment, preventing visual clutter from inhibiting the scientists work. We wanted to allow the scientists to see multiple activity footprints within the same Martian landscape. We followed the example Photoshop provides for allowing users control over their view, and provided eyeball toggles for all activities in the palettes to control the view in the Interactive Martian Environment. Users responded very well to this analogy, (C-194, C-275, C-277). Due to the difficulties in implementation for this feature, we were unable to perform adequate user testing to conclude the viability of this feature with respect to visual clutter. We recommend that further development is completed to allow data collection on the scientists ability to manage their view.

Figure 7.2e – An activity represented within current SAP.



Activity Palettes

There are 3 main types of activity palettes within the tool to distinguish areas for public and private activities, as well as distinguishing between the mission history and the current planning sol: Libraries, Shared Workspaces, and Personal Workspaces. Scientists were pleased with this separation, and they thought that the division was intuitive, (C-318, C-327). Through these palettes, the Activity Properties window for an activity can be accessed either by double-clicking on the activity, or by selecting the activity and them selecting the properties icon located at the bottom of the palette. We have specified one component of each of the palettes, using an iterative design process resulting from participatory design sessions with our scientists.

Libraries

Mission Library

The Mission Library is the repository for all of the activities in the mission's history (Figures 7.3a and 7.3b). It includes all activities, both planned and unplanned, and executed and unexecuted for each sol in the mission. The Mission Library is the main data tracking component in the tool. Scientist will be able to browse each sol and view: the activities in the final plan that was sent to the rover and executed, the data products associated with those activities and their downlink status, the activities that were sent to the rover but were not executed, and the activities that were created but not sent to the rover. In addition, there can be customizable folders for any other necessary mission data, for example Mosaic images in the MER Mission, (C-200).

The data within the Mission Library is organized by sol, but searching through each sol to locate the data that you're interested in can be a cumbersome process when the mission contains many sols, so we have included within the main Mission Library window a series of filters to allow the scientist to find only the data that they are interested in finding. When the filtered data is returned, the sol structure is still maintained so that the context of the activity is available to the scientist, but all other data within that sol is hidden. Additionally, the Mission Library should include an advanced search function to allow scientists more precise access to specific data and the ability to locate data when they only remember a few details about the activity.

Since the Mission Library represents a history of the mission, new activities cannot be created there, and the activities within it cannot be edited or deleted. In order to create a copy of an item to edit it for re-use, a scientist can drag and drop an activity into their Editor, a Personal Workspace palette, or they can select the activity and use the Copy-To Editor icon located on the bottom of the palette to copy the activity to their Editor.

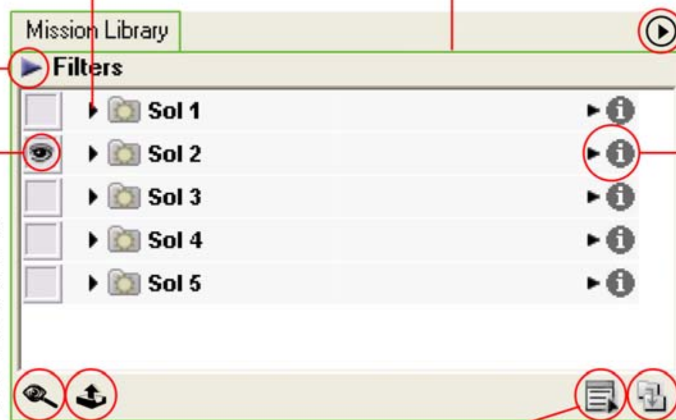
Figure 7.3a – Details about the Mission Library

Turn buckle: Allows the user to open or collapse a sol, observation and activity to view or not view observations, activities or data products.

Outline color: The mission library as well as the hopper are outlined in a particular color and any footprints or glyph that are toggled on from them will appear in the same color in the 2D environment.

Filter turn buckle: Allows the user to view or not view the options to filter through the data products within the mission library.

Drop-down menu: Displays a drop-down menu containing an option to perform an advanced search on the information within the mission library.



Eyeball: Toggles the visibility of one or a set of activities in the 2D environment. If the eyeball is "on" for an observation then the footprints or glyph for it's activities are turned on. If the eyeball is turned "off" for an observation then all the footprints or glyphs for it's activities are turned off. The user is then able to toggle on and off the eyeballs for the activites as needed.

Information: An icon that displays useful information to the user about an observation or activity quickly. When the turn buckle is turned, the icon turns blue and a panel opens displaying such information as resource usage.

Properties: De-ghosts when an observation or activity is selected. Once the icon has been pressed, a non editable properties window opens. The properties window contains information pertaining to the selected observation or activity. Due to the fact the hopper can be viewed by several users, no changes to an observation or activity can be made in the Hopper.

View in SAP: De-ghosts when a data product is selected. Once the icon has been pressed, the data product opens in the 2D environment in the tab that currently has focus.

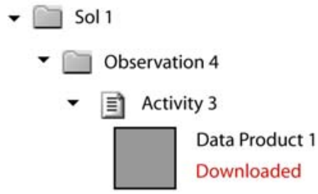
Copy to Editor: De-ghosts when a sol observation or activity is selected. Once the icon has been pressed, a copy of the selected sol, observation or activity and places it into the Editor. If a sol is selected then all of the observations and activities associated with it are copied as well. If an observation is selected then all of the activities are copied as well. If an activity is selected it is copied directly to the Ediotr. Information associated with the sol, observation and/or activities such as data products and targets is removed.

Export: De-ghosts when a data product with a image associated with it is selected. Once the icon has been pressed, a dialog box appears asking the user to specify what type of application they want the image to open in and be compatible with.

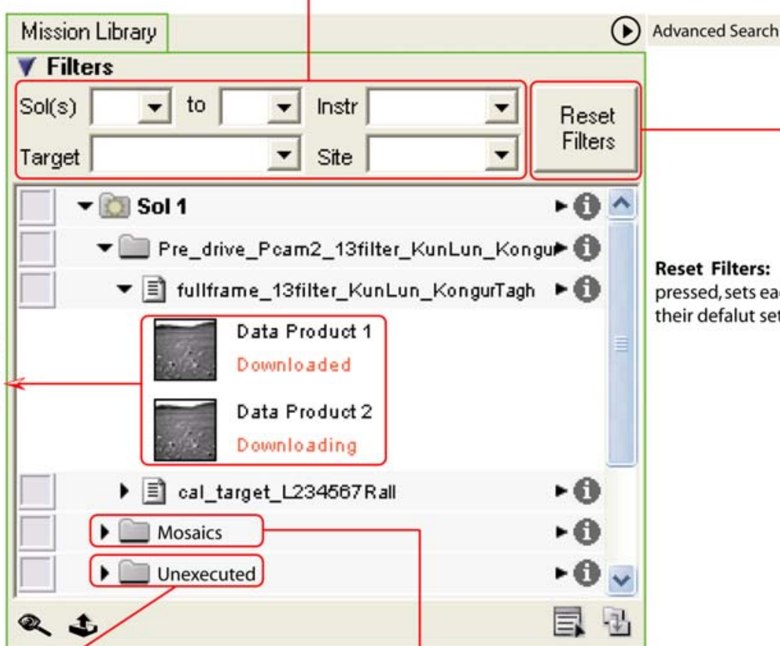
Figure 7.3b - Details about the Mission Library

Filters: Provides the user with the ability to filter through the the library and quickly locate the data that they are interested in. After each field is changed the data is filtered to reflect. The starting state for each filter is as follows: Sol(s) - 0 to - yestersol, Instr - All, Target - All, Site - All.

Example: After the desired filters were selected, only the folders containing the desired information is displayed. All other folders are hiddened.



Advanced Search: Provides the user with the ability to further filter through the the library and quickly locate the data that they are interested in with more options then the ones provided in the pallette.



Reset Filters: A button, that when pressed, sets each of the filters back to their defalut settings.

Data Products: A thumbnail of the data product and it's status is located within the activity that captured it.

Unexecuted Folder: All the activities that are not executed by the rover for each sol are placed into a folder. Adjacent to each activity there will be at least one icon indicating why the activity is in the folder. The icon represents that the activity either didn't get planned, didn't get executed or was unplanned and it expired.

Mosaics Folder: A folder designed to contain a series of images that form a mosaic. Due to the fact that the data products from multiple activites create a single mosaic, this folder makes it easier for the user to locate these images.

Scientists were pleased with the concept of the Mission Library, “it was intuitive for me to go to the filter” (C-91). They also provided useful feedback for improvement on our initial design regarding our filters. Initially, we had included filters for the type of target, but scientists expressed that their real filtering needs were for target names, so we adjusted the filters to reflect their needs (C-92, C-86). Scientists also expressed concern at the amount of space the filters used in the interface, so we implemented a turn buckle to allow the scientists to control their view of the filters. Finally, scientists expressed a desire to have an advanced search function (C-93, C-94, C-97).

Additionally, scientists were very pleased with the anticipated ease of activity re-use through the Mission Library. In addressing the breakdowns that we observed within the MER process, one primary goal was to provide the scientists with quick access to validated activities for accelerated and accurate planning. One scientist reports that "one of the biggest issues with the whole system is a scientist spending a lot of time specifying something and then a whole new group using a whole new tool to redo the same work" (C-181). We intend to alleviate this problem by facilitating re-use within the Mission Library, and scientists were pleased over all with this concept.

Template Library

Currently in SAP, there are shared folders dedicated to storing activity templates, which have been approved for rover use to accelerate and templatize planning. Scientists have reported that this was important, but had some problems, for example, "the ability to pull activities in is good, we made a bunch of templates, but they are hard to find," (C-172). The Template Library within our tool maintains the current SAP intent. The functionality should be similar to the Mission Library, but with a few important differences. The activities within the Template Library cannot be viewed within the Interactive Martian Environment because they have no specific location within the Interactive Martian Environment to be mapped onto. Also, these activities cannot have associated data products since they are templates, rather than executed activities. Activities cannot be edited within the Template Library, since this is a public space. The use of filters within this palette and the organization of the palette would best be determined through a more careful study of the usage of the current SAP template hierarchy, a task which was outside of the scope of this project.

Shared Workspaces

The Hopper

The Hopper is the central repository supporting the collaborative planning process we anticipate during future missions (Figures 7.4a and 7.4b). It stores the activities to be used in the plan creation for the current planning sol. This is the primary place where scientists can gain insight into the best guess at the flow of the current plan, similar to the way that the skeleton plan has emerged as the MER mission has progressed. As was mentioned during the description of the Hopper's role in our new science activity planning process, we received positive feedback about the usefulness of the Hopper, however there was a concern that the Hopper would provide an added layer of complexity (C-23). We attempted to address these concerns by providing the context of the current sol's plan within the long term planning goals and by adding features to clarify the status of activities within the Hopper.

We have provided access to multiple future planning sols. While some scientists were unsure of the feasibility of this, stating "A C-day planning cycle? I will believe that when I see it." (C-163), others were pleased with the concept, saying "I like this current sol, sol +1 thing, " (C-160). This leads us to believe that the importance of this feature will depend on the exact timeline for planning in the next mission.

The Hopper is able to provide intelligent ordering of the activities within it, presenting them chronologically based on the constraints applied to them. If there are no constraints on activities, then these activities appear at the bottom of the Hopper, which scientists seemed to like, (C-165, C-168). Also, all activities with constraints have constraint icons to allow users to easily distinguish between those with an explicit ordering and those without. All constraints related only to one activity are represented with a single icon. We also attempted to display the ordering constraints within the Hopper using arrows and a toggle button to show and hide the arrows, but users responded negatively to this feature (C-12, C-13, C-14, C-15, C-16), and due to technical limitations, we were unable to adequately test the scale of this representation, so this interface element may require more iteration if it is to exist. Scientists were pleased with the concept of applying constraints within the Hopper, (C-166).

The Hopper will also provide a place for persistent activities, or activities which can be repeated on multiple sols, so that these activities will always be available to the planner. This should facilitate the planning process by presenting the entire set of possible activities during the optimization phase of the planning process when the final plan is being generated. Additionally, the Hopper can eliminate activities that have expired, or can no longer be executed or have missed the window to achieve their science goals. Scientists were also pleased with these concepts (C-164), although they were concerned about accessing expired activities, (C-161). Expired activities would be stored in the Mission Library so that they would be accessible for the scientists.

Since the Hopper is a public space, a scientist would typically have to check an observation out of the Hopper and into their Editor to modify the activity, but we have provided an accelerator, Quick-Edit, to alleviate scientists concerns about the Hopper forcing an extra step into the process, (C-150).

Figure 7.4a - Details about the Hopper

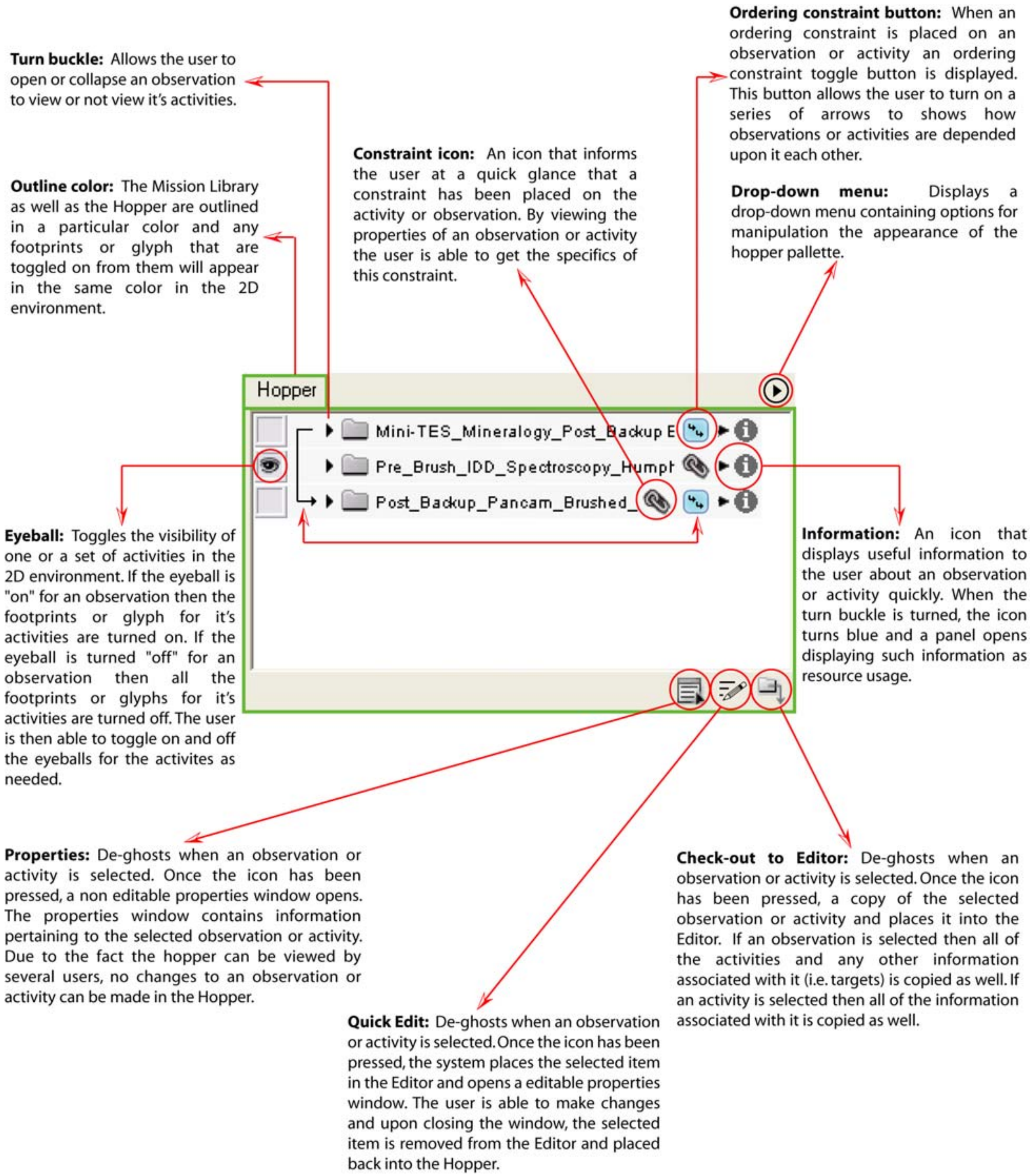
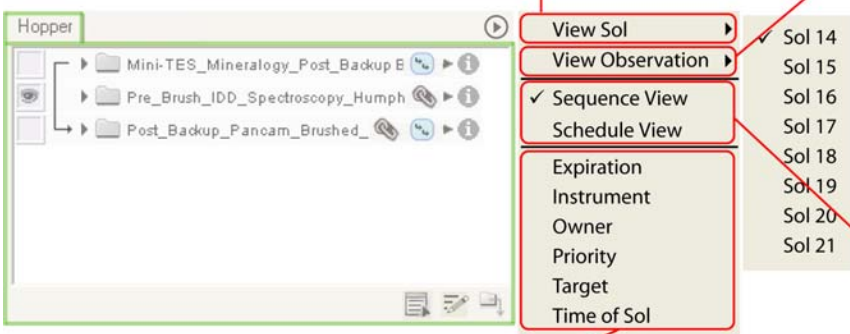


Figure 7.4b - Details about the Hopper

View Sol: A menu that allows scientist to plan 7 sols into the future or to view the plans that other scientists have created thus far.

Observation View: Allows the user to toggle between two views of the observations in the Hopper. The user is able to view all of the observations or simply the ones that have been assigned to the user's science group.



Column Headers: Allows the user the freedom of displaying as many or as few columns in the hopper window as they want. The check marks next to the column headers indicates which column is currently being displayed/viewed

Expiration - Informs the user when the activity or observation is no longer able to be performed by the rover. This date is calculated by the system based on it constraints.

Instrument - Lists the instrument that the activity will utilize in the execution of that activity.

Owner - States which science group created that observation or activity.

Priority - A number/text that informs users how important this activity is to the plan (must happen today, can happen at any time, etc.) or how important this observation is in relation to other observations.

Target - States the location that the activity will be take at.

Time of Sol - States the time when the user wants the observation or activity to occur (for example 19:00)

Hopper View: Allows the user to toggle between two views of the plan, the schedule view and the sequence view. The schedule view allows the user to easily view time of sol, timing and sol event constraints by integrating the ideas of a ghatt chart and a scheduler. The check mark beside the view indicates to the user which view is currently being displayed/viewed.

We have also explored additional representations of the Hopper, including a Schedule View, which is meant to provide the scientists with the all of the activities and observations that must happen at a particular time. We explored multiple versions of this view (Figures 7.4c, 7.4d, a7.4e), with each one varying in the amount of information presented to the scientist. We have not collected enough data to conclude which representation is best, but we include them as possibilities for future development of the view. We also explored several other Hopper views, including a Gantt view, which we hope the SAP developers will continue to explore.

Figure 7.4c – A version of the Hopper's Schedule View

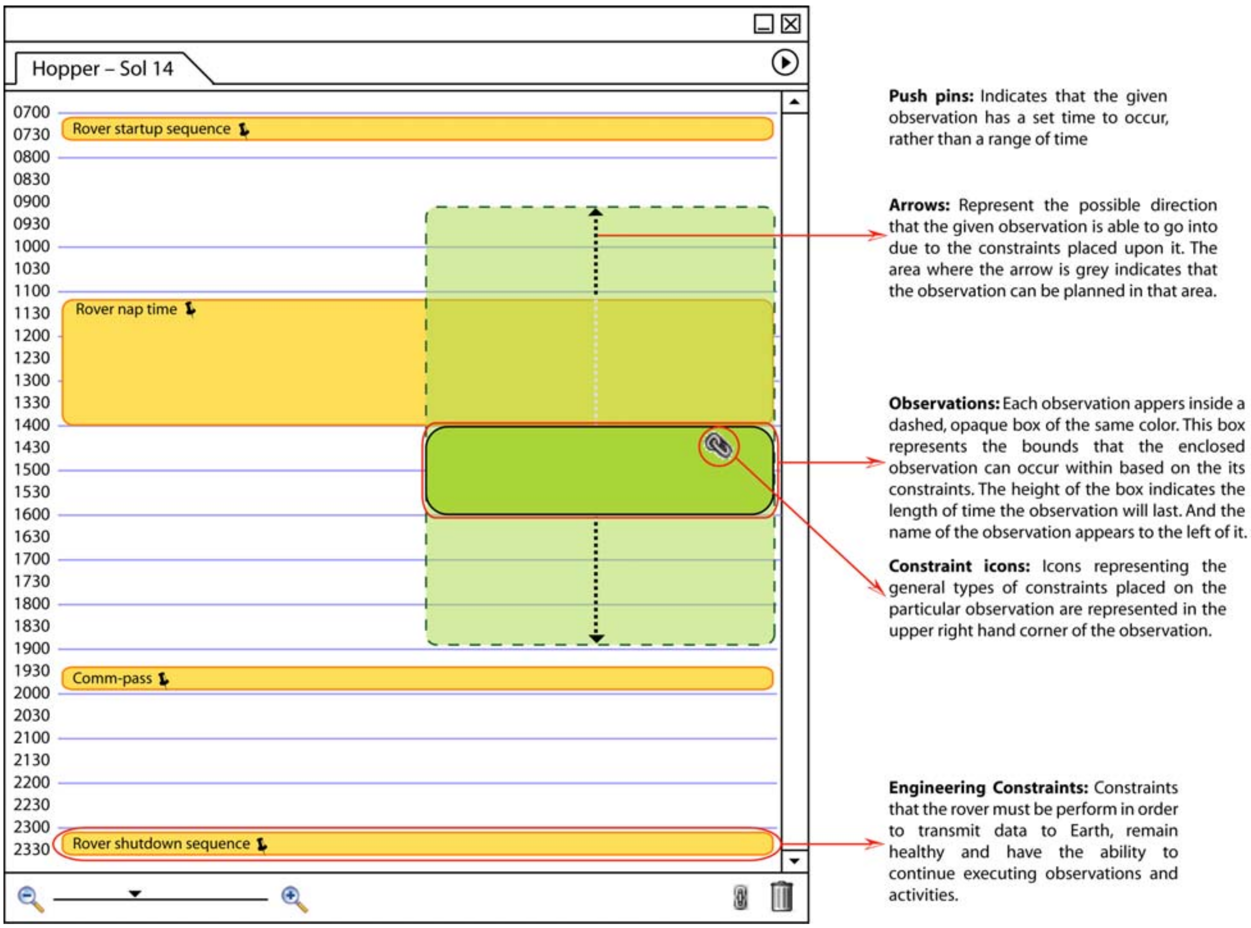


Figure 7.4d - A version of the Hopper's Schedule View

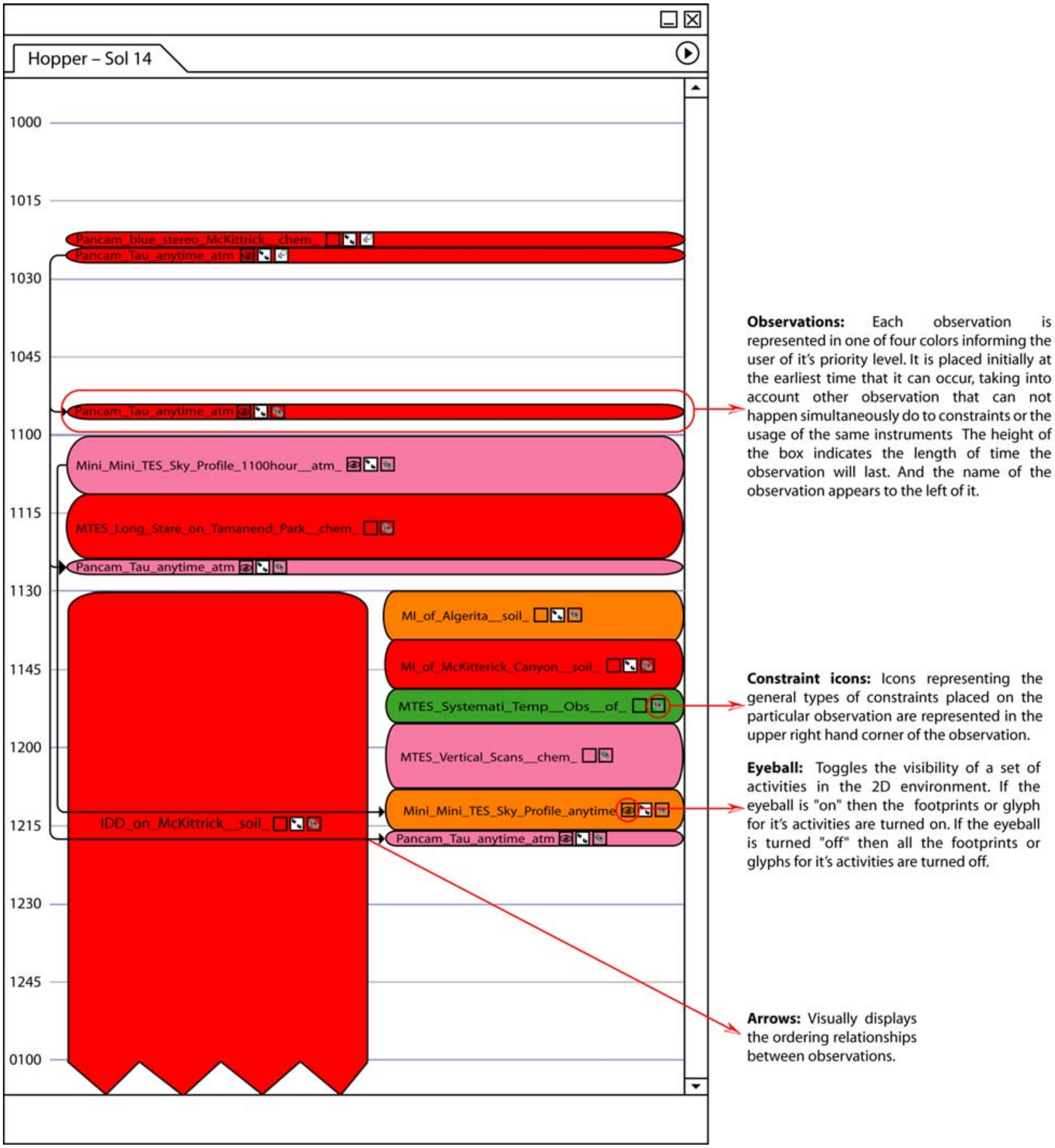
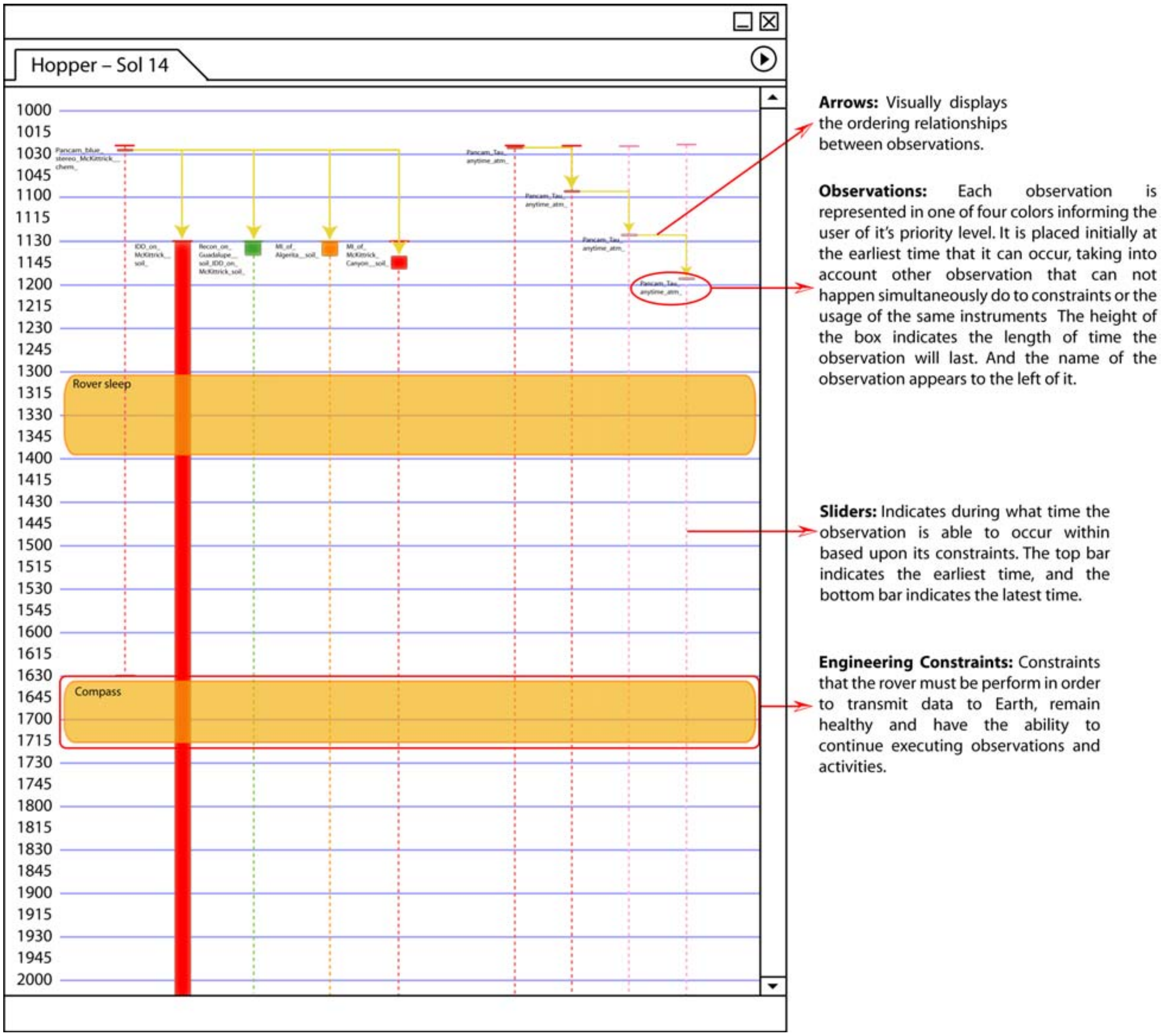


Figure 7.4e - A version of the Hopper's Schedule View



Workgroup

Science Theme Groups currently plan collaboratively in shared folders dedicated to those groups within SAP in the current MER process. The Workgroup palette should support this same collaboration in our tool. The functionality should be similar to the Hopper, but without the expiration and long term planning capabilities. The organization of the palette should be informed by the organization of the theme groups for future missions, and the structure would best be determined through a more careful study of the usage of the current SAP theme group space, a task outside the scope of this project.

Private Workspaces

Editor

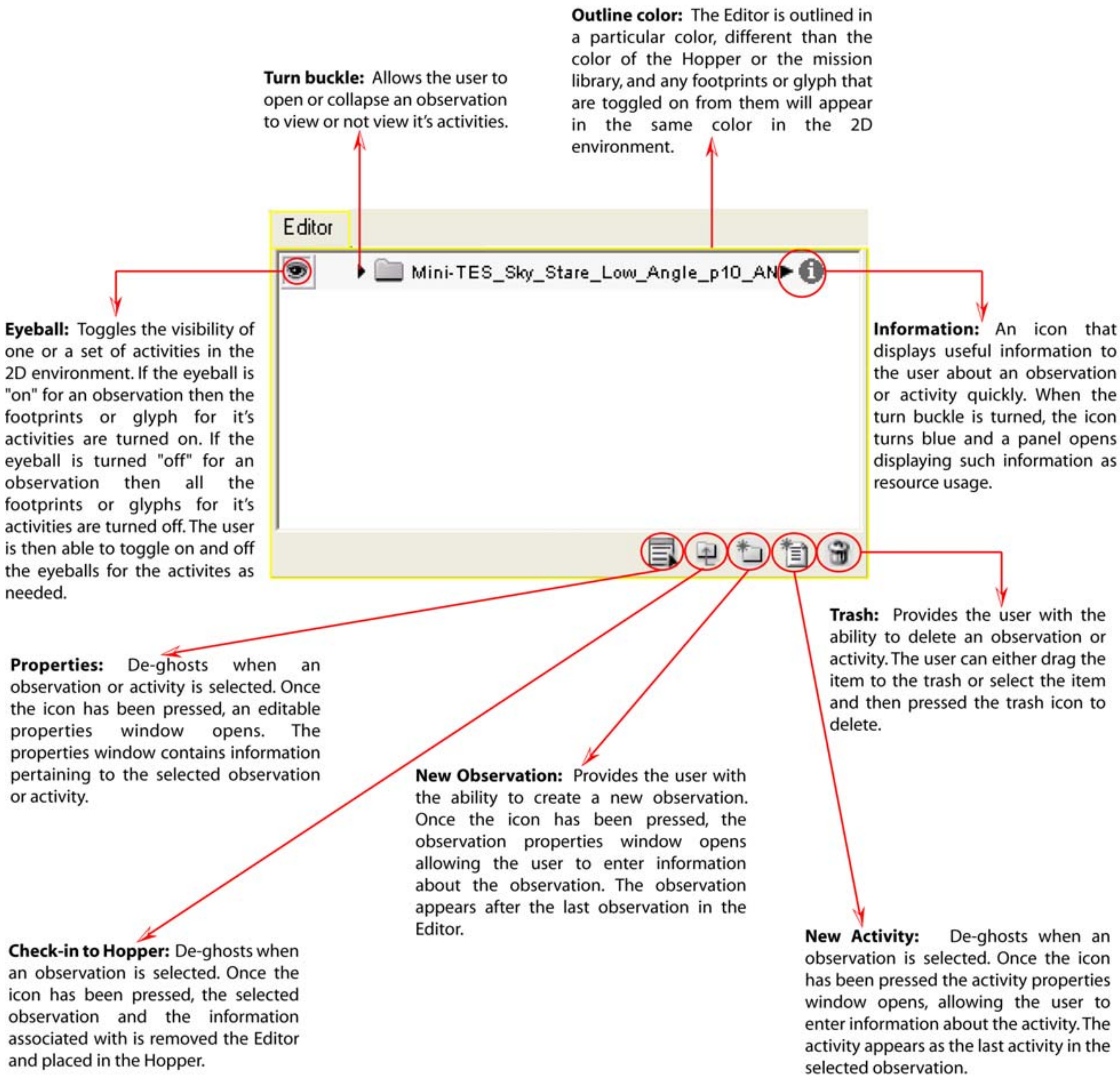
The Editor is the only palette where activities can be edited, created from scratch, or deleted. They may be edited either within the Interactive Martian Environment or through the Activity Properties window. The Editor provides scientists with the ability to create new activities with the New Activity Icon. Clicking on this icon creates a new Activity Properties window for the scientist to specify their new activity. Toggling the eyeball for this new activity will allow the scientist to edit the activity interactively within the Interactive Martian Environment. There should also be an affordance to create a container for activities, for example the New Observation Icon that we have included. Scientists are also able to drag and drop activities to and from the Hopper for specifying, and they are able to drag and drop activities from the Mission Library to the Editor to re-use activities. Activities can also be checked into the Hopper by selecting the activity and then clicking the Check-In to Hopper icon located at the bottom of the tab. During our user testing, we were also able to validate our delete interaction method, as we witnessed users selecting an activity and then clicking on the trash can icon to attempt to delete the activity, (C-261, C-262).

During our user testing, scientists were able to drag and drop activities seamlessly across the palettes. We do provide standard feedback about where activities can be dropped (for example, activities in the Mission Library cannot be dropped into the Hopper), and there was a request that we make the allowed drop targets more explicit, (C-266).

Custom Data Set

The Custom Data Set palette is a place for scientists to create directory structures to hold activities and data products, as well as possibly shortcuts to activities and data products contained in the Mission Library. We believe that scientists currently have the ability to maintain a personal space, so we wanted to carry that forward into this design. We have not had the opportunity to study the way in which the scientists organize their data sets currently, so we recommend that the SAP developers study this in order to inform the basic structure for this component.

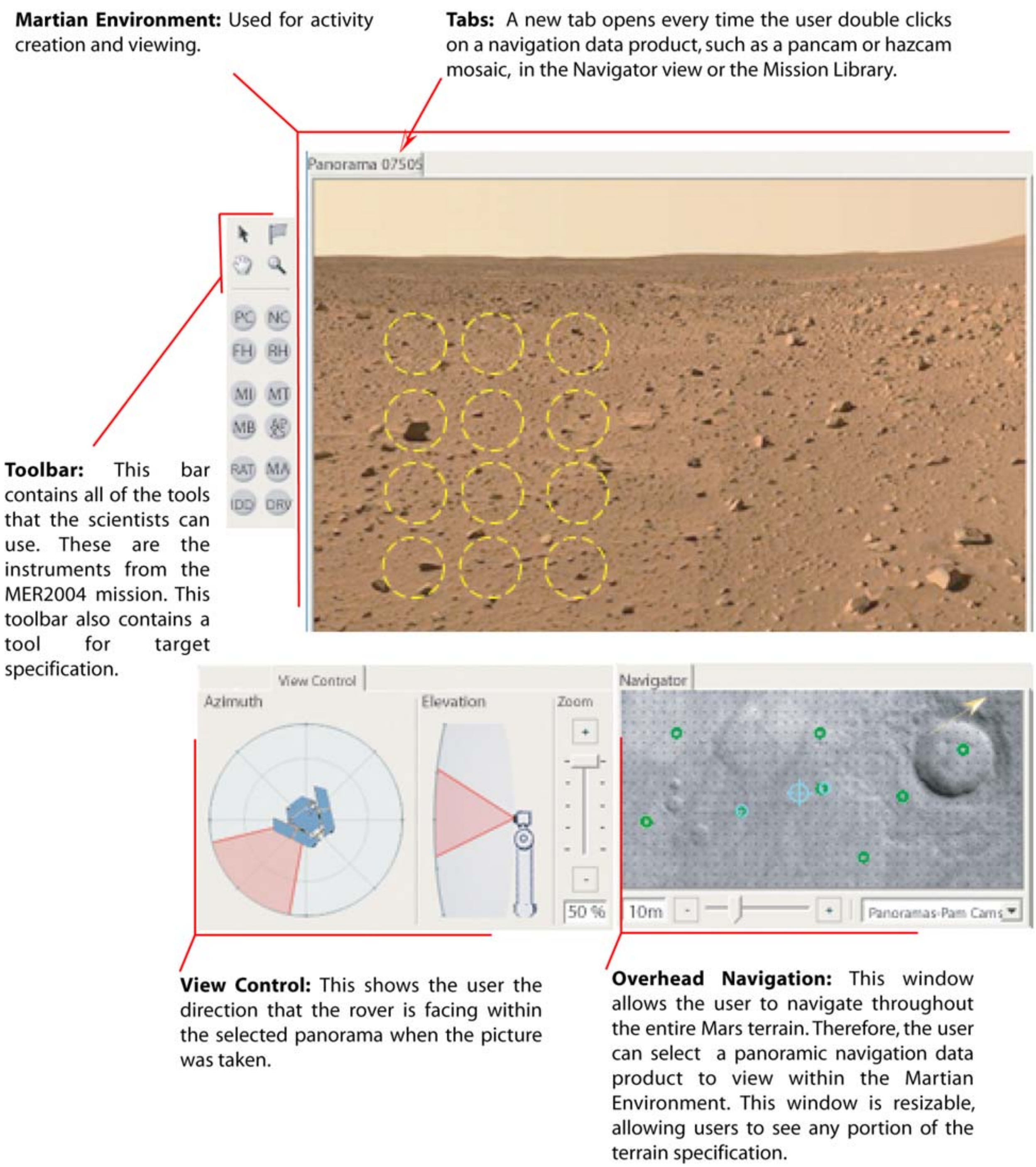
Figure 7.5 – Details about the Editor



Interactive Martian Environment

The Interactive Martian Environment (Figure 7.6) was designed in response to the SAP developers' goal of creating a way for scientists to plan within an "immersive" environment. There are 4 components: a Viewer Window containing tabs with panoramas of Mars for science activity planning; a toolbar to create new science activities and targets within the panoramas, and navigation tools for the Viewer Window; a View Control tab to allow scientists to control the portion of the mosaic that they see in the Viewer Window; and a Navigator with a map of the location of all of the panoramas to see in the Viewer Window.

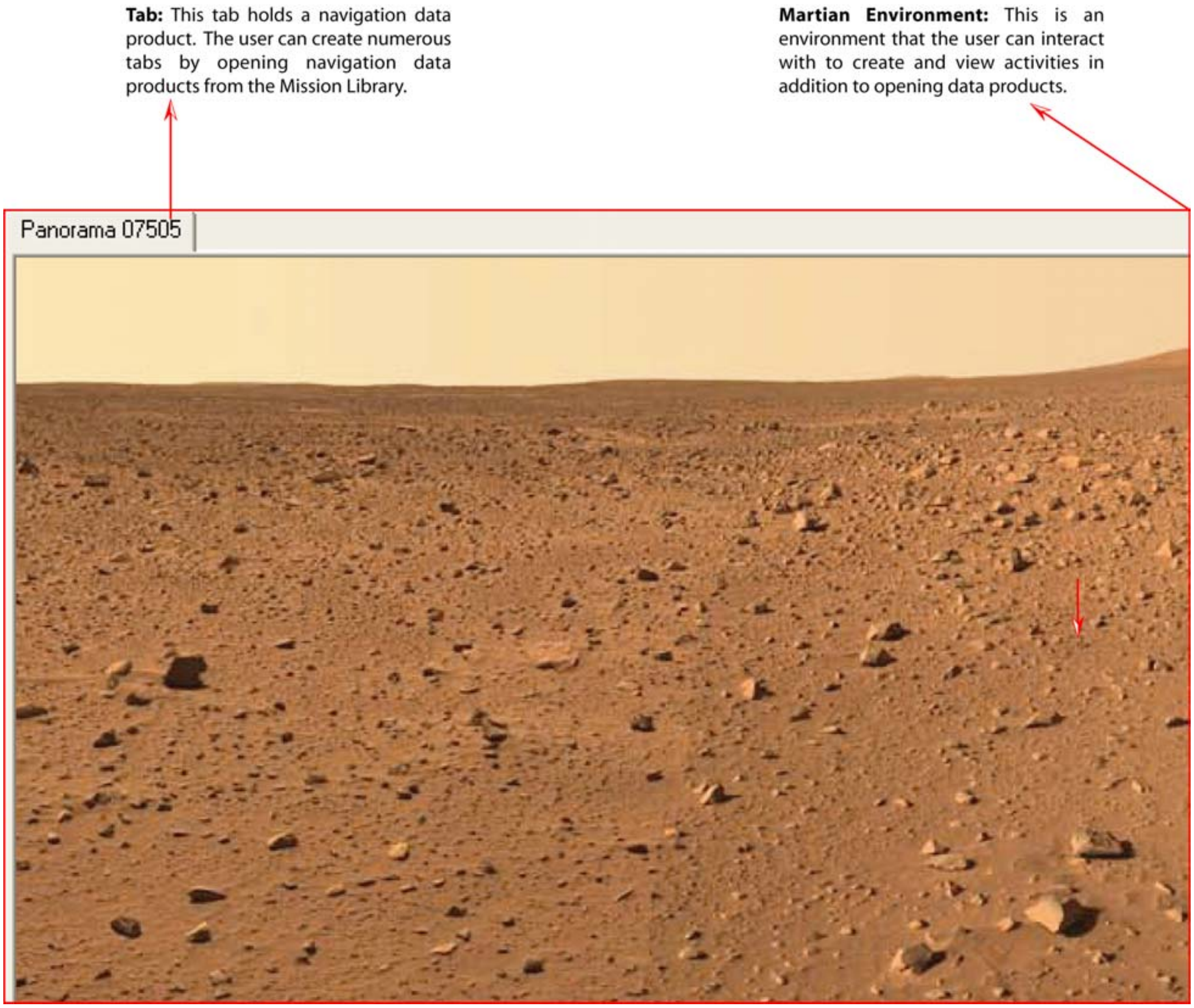
Figure 7.6 – Representation of the Interactive Martian Environment



Viewer Window

The Viewer Window (Figure 7.7a) is the scientists' access to the Interactive Martian Environment. It displays panoramas of the surface of Mars that the scientists can use for activity planning. It is similar to the view that is currently in SAP, where users are able to open data products from the rover in order to view the footprints of a single activity that occurs within that part of the environment, however we are providing scientists with the ability to view more than one activity at a time. Also, in SAP, the scientist must choose the appropriate image data product to view the activity, but our intent is to present the scientist with the view for the current planning sol's most likely location.

Figure 7.7a – Details about the Viewer Window

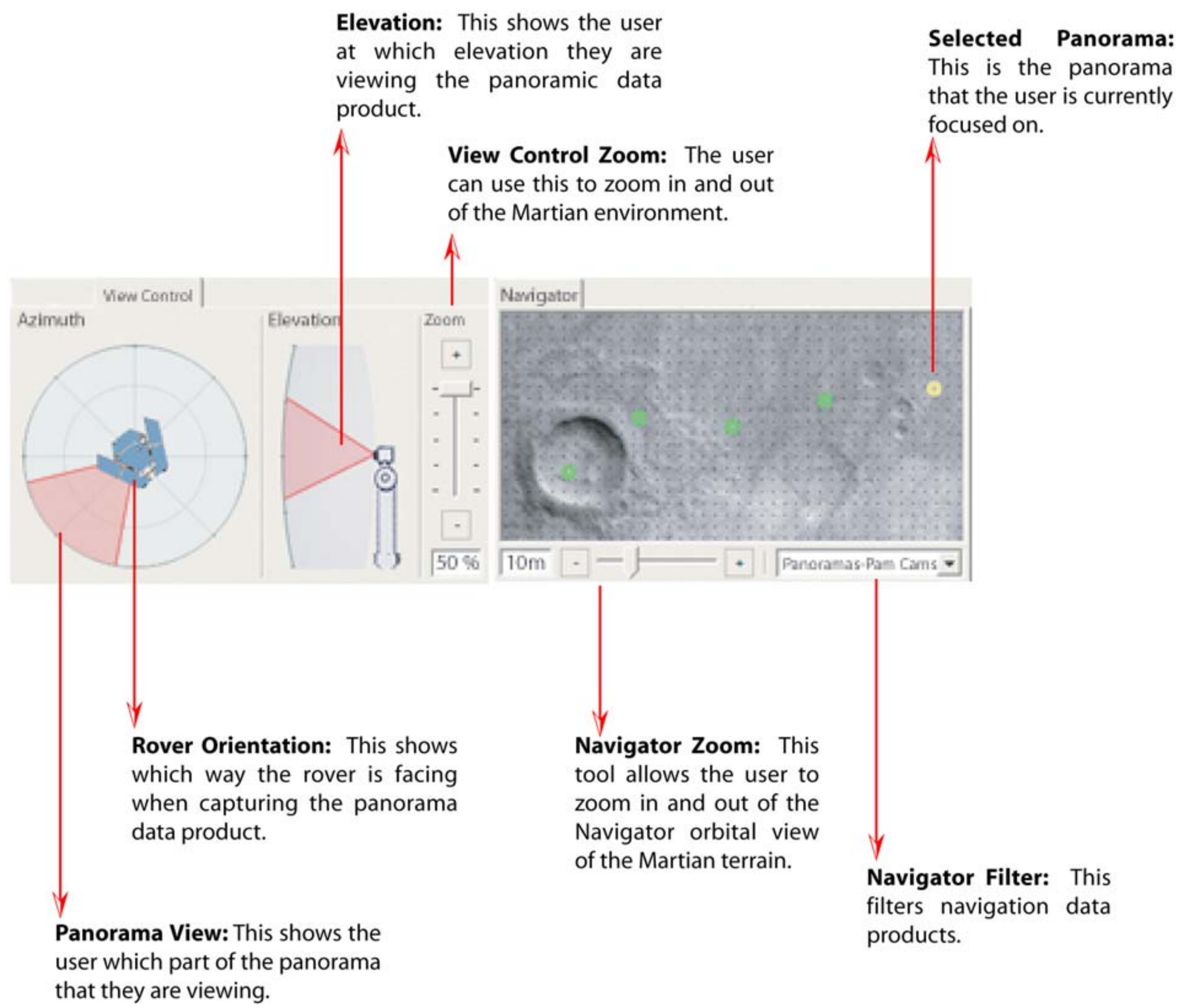


The Viewer Window is controlled by the Navigator and by the View Control palettes (Figure 7.7b). Since the Viewer Window displays panoramas of the Martian surface, the View Control allows you to navigate through the panorama to choose the angle of the panorama to view. Users are also able to navigate within the panoramas directly as well by using the toolbar. Scientists responded favorably to this concept, although they were unable to test it due to the complexity of implementing this type of functionality.

Figure 7.7b - Details about the View Control and Navigator

View Control: This allows the user to find both their view within the data product and the rover's orientation within the navigation data product that they are currently focused on.

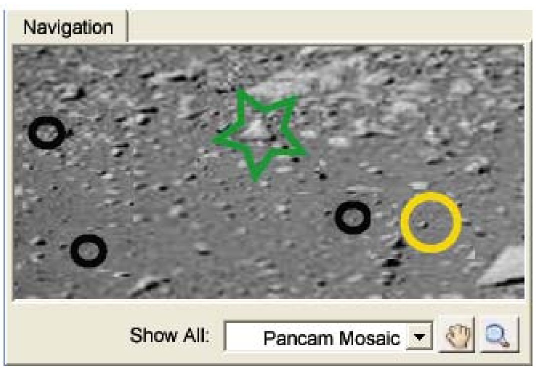
Navigator: This allows the user to move around the known Martian terrain. This information is available from orbital data.



The Navigator provides a top down view of the surface of Mars, probably using orbital data, to create a data map of all of the locations on the surface where images exist. Scientists are able to select the panorama to view in the Viewer Window from the Navigator. When scientists were presented with this view, they were excited, and relayed to us that they were informally creating similar documents to track their data, (C-321). The SAP developers also expressed an interest in expanding this map to hold more than just the panoramas viewable in the Viewer Window.

The Navigator also provides the scientists with guidance in choosing the panorama that will contain the activity they are trying to view in the Interactive Martian Environment. When the scientists selects an activity in the palette, a small cross-hare appears in the Navigator to indicate where that activity occurs within the Martian terrain, indicating to the user which possible panoramas will contain that activity. We initially represented the activity with a star in the Navigator (Figure 7.7c), but scientists found this to be very confusing and always wanted to click on the star, which was not the interaction we intended, so we tried to make the cross-hare appear less clickable. If the activity is not in the current view in the Navigator, a light arrow appears to provide the scientist with navigation clues.

Figure 7.7c – An old representation of an activity in the Navigator



Targets

Targets are locations in the Interactive Martian Environment specified by scientists. Targets are represented within the Interactive Martian Environment as small flags (Figure 11a). Flags were chosen to represent targets because they seemed to afford clustering when there are multiple targets located in a small area. Additionally, all of the targets are available within the Target palette (Figure 11b), with the same eyeball toggle as in the activity palettes to control whether or not the target flags are visible in the Interactive Martian Environment.

Figure 11a – Representation of targets in the Interactive Martian Environment

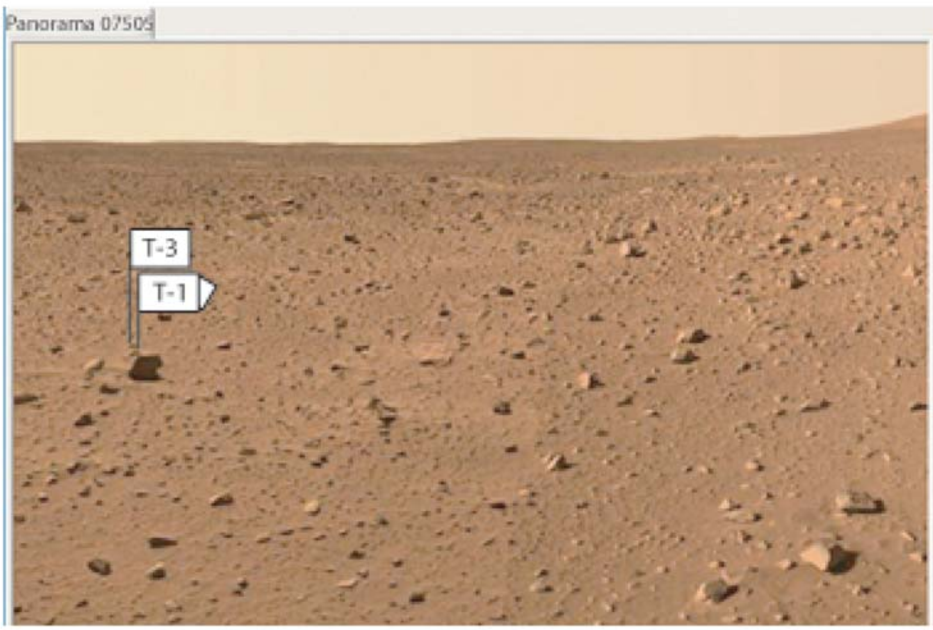
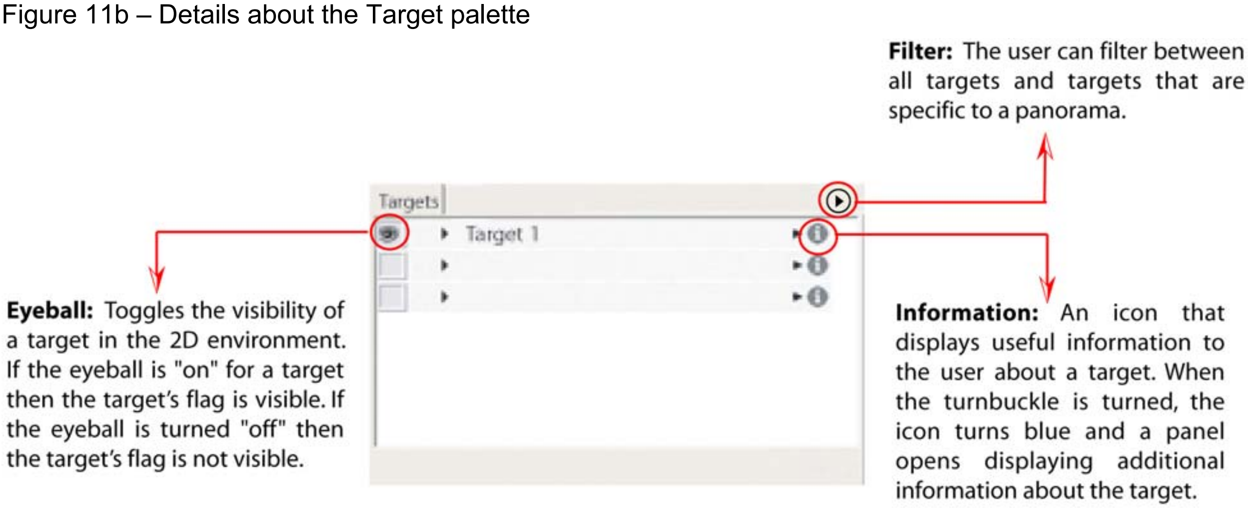


Figure 11b – Details about the Target palette

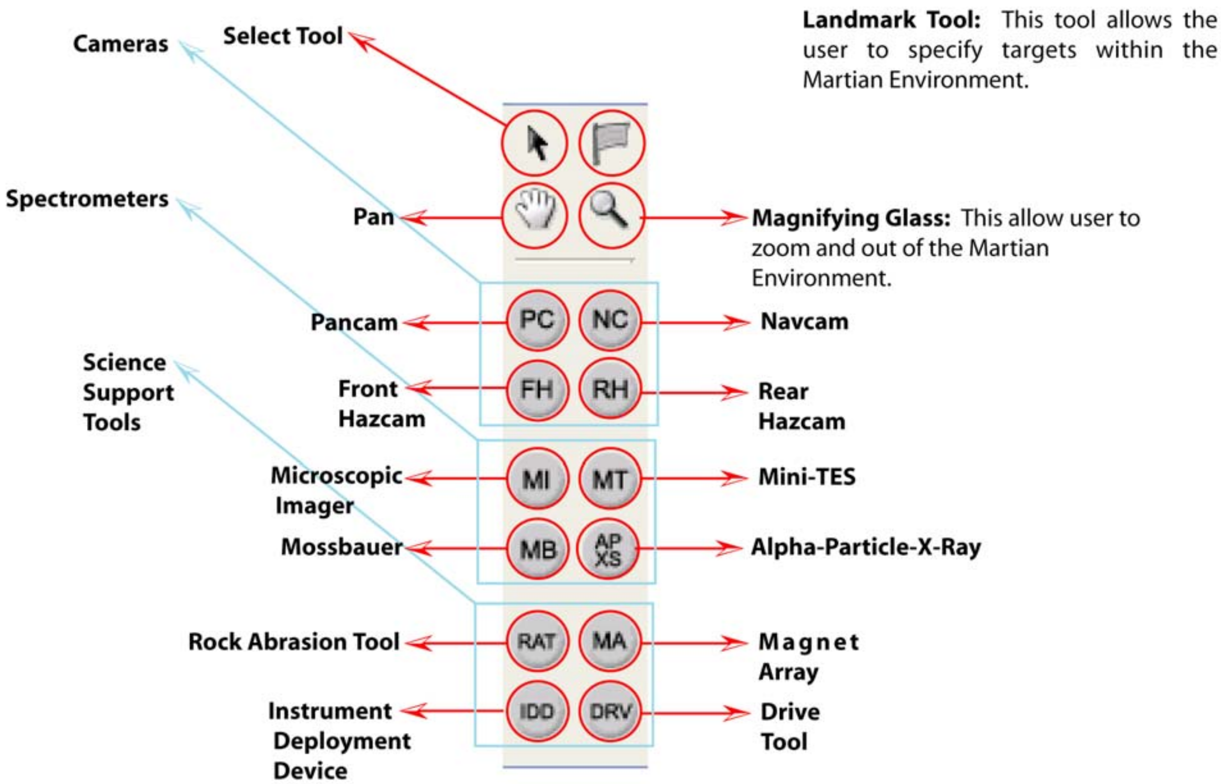


Target Window: This window contains a list of targets. The user can filter for targets within a specific panorama or all targets.

Toolbar

The Toolbar (Figure 12) allows scientists access to science instruments for creating science activities within the Interactive Martian Environment, as well as tools for navigating the Interactive Martian Environment, and creating new science activity targets within the Interactive Martian Environment. The basic interaction method is for the scientist to select an item from the palette, and then apply that item to the Interactive Martian Environment. This will be more explicit in the next section when we present example interactions.

Figure 12 – Details about the Toolbar in the Interactive Martian Environment



Tool bar: These tools are used to interact with the Martian Environment. The user may create targets and activities. This tool bar also allows users to select activities and adjust the view of the Martian Environment.

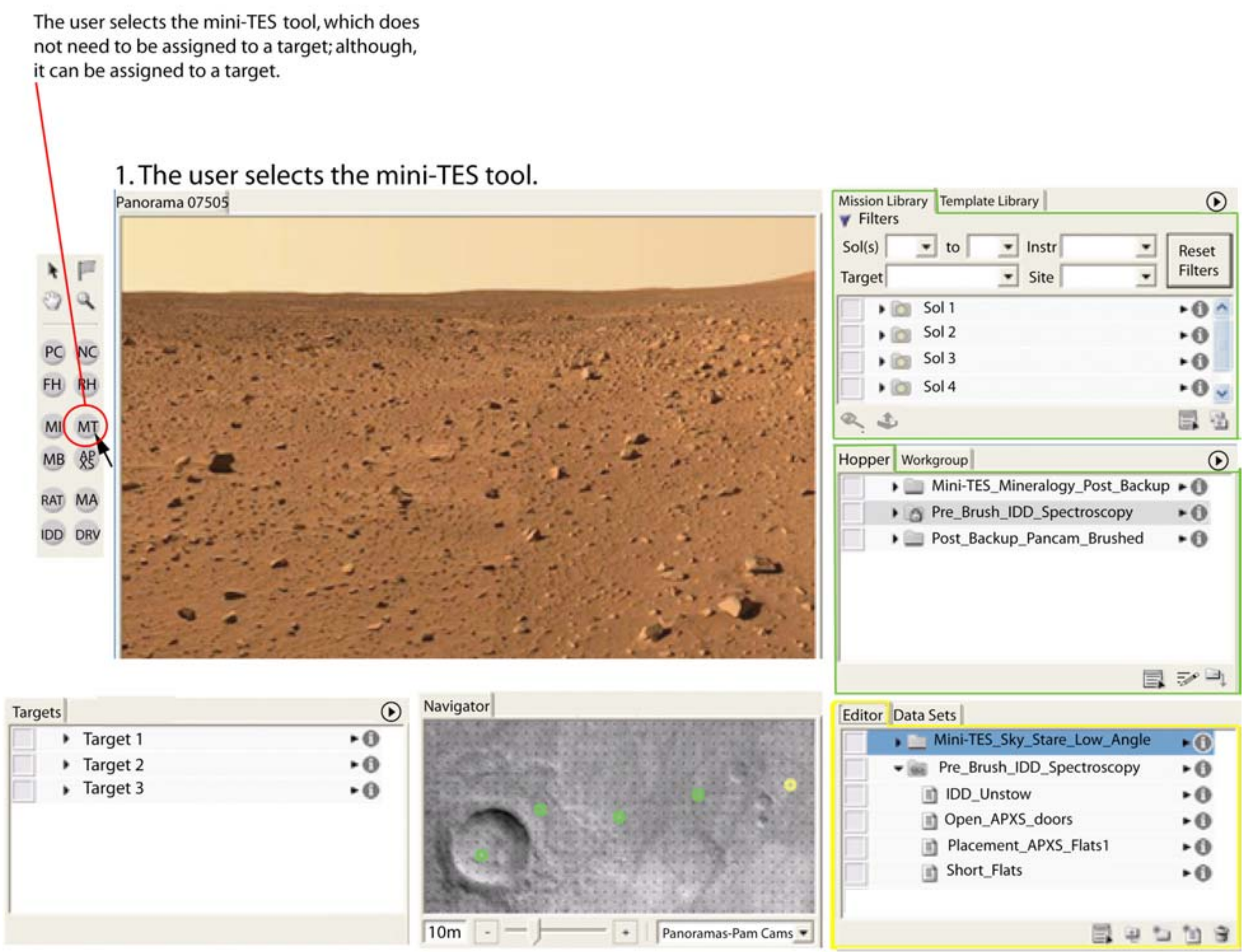
All of these components work together to support the remote science planning process that we designed. We will now present example interactions to illustrate the way in which scientists will complete the tasks essential to remote science activity planning – activity creation, activity editing, data product review, and working within the Interactive Martian Environment.

Interactive Remote Science Planning

Here we present example interactions with the redesigned remote science planning tool. These illustrations demonstrate the way in which scientists will complete the tasks essential to remote science activity planning - Activity Creation, Activity Editing, Accessing Data Products, and Tools in the Interactive Martian Environment.

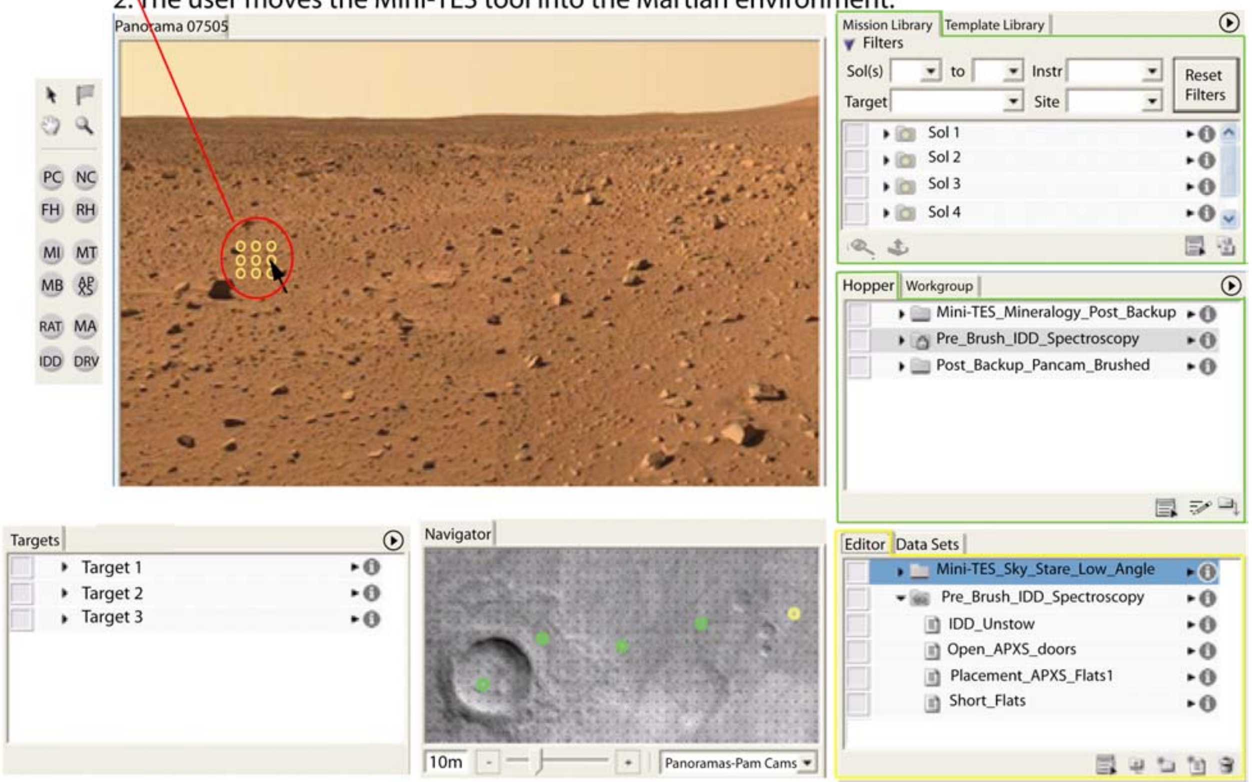
Activity Creation

Creating an Activity Without a Target



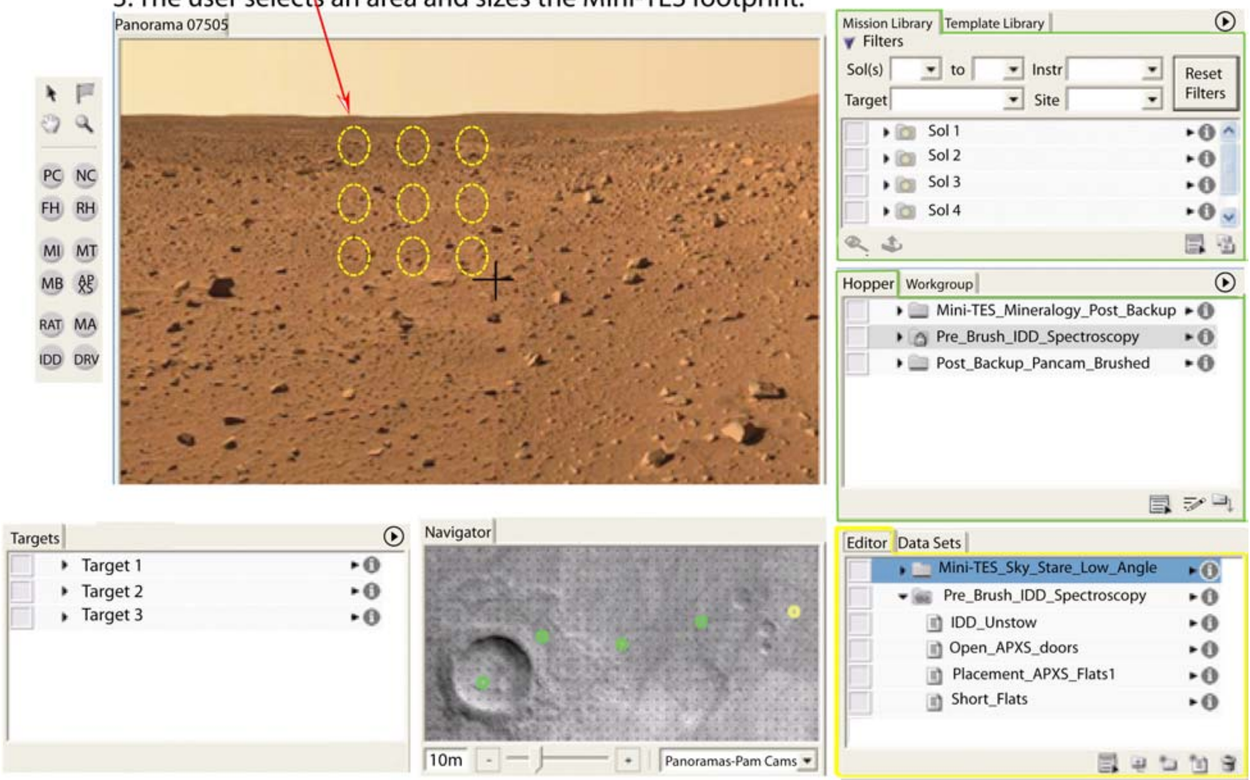
The cursor changes to reflect the user's tool selection which is currently a Mini-TES.

2. The user moves the Mini-TES tool into the Martian environment.



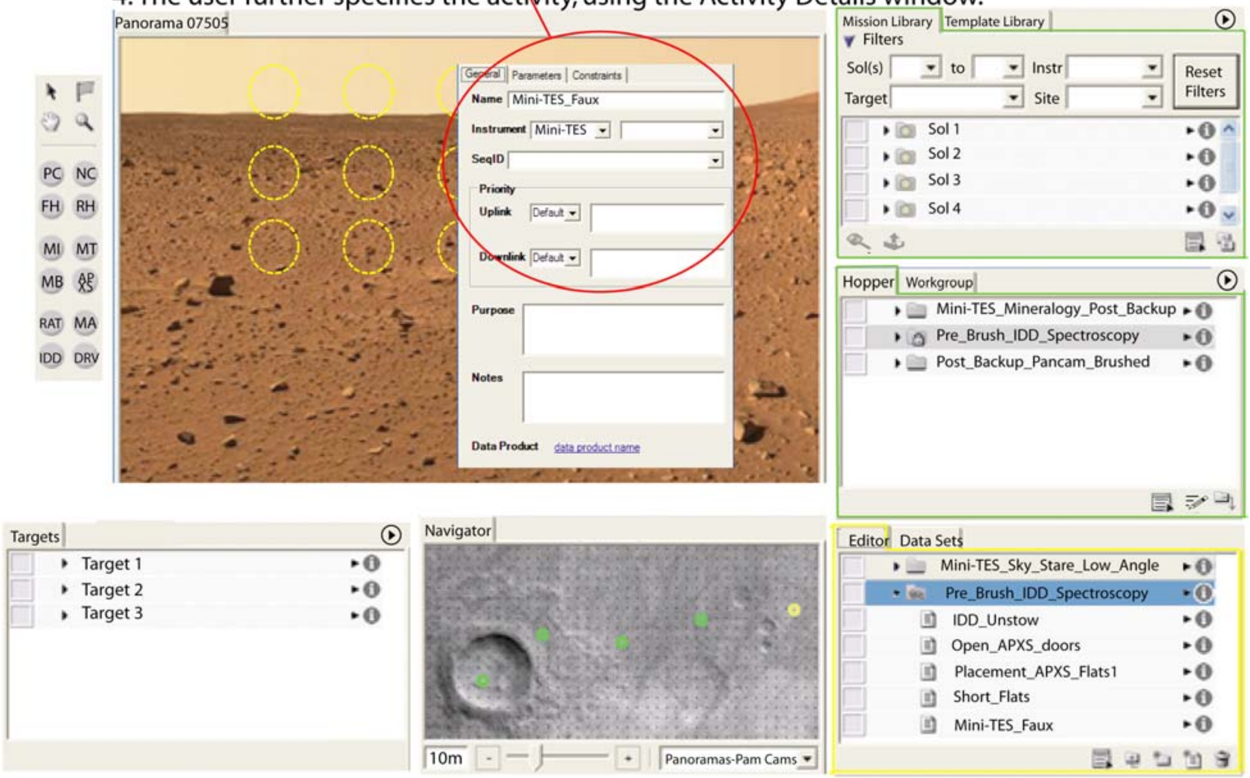
The size of the Mini-TES footprint is adjustable. The user can drag the the corner of the Mini-TES to select the size.

3. The user selects an area and sizes the Mini-TES footprint.

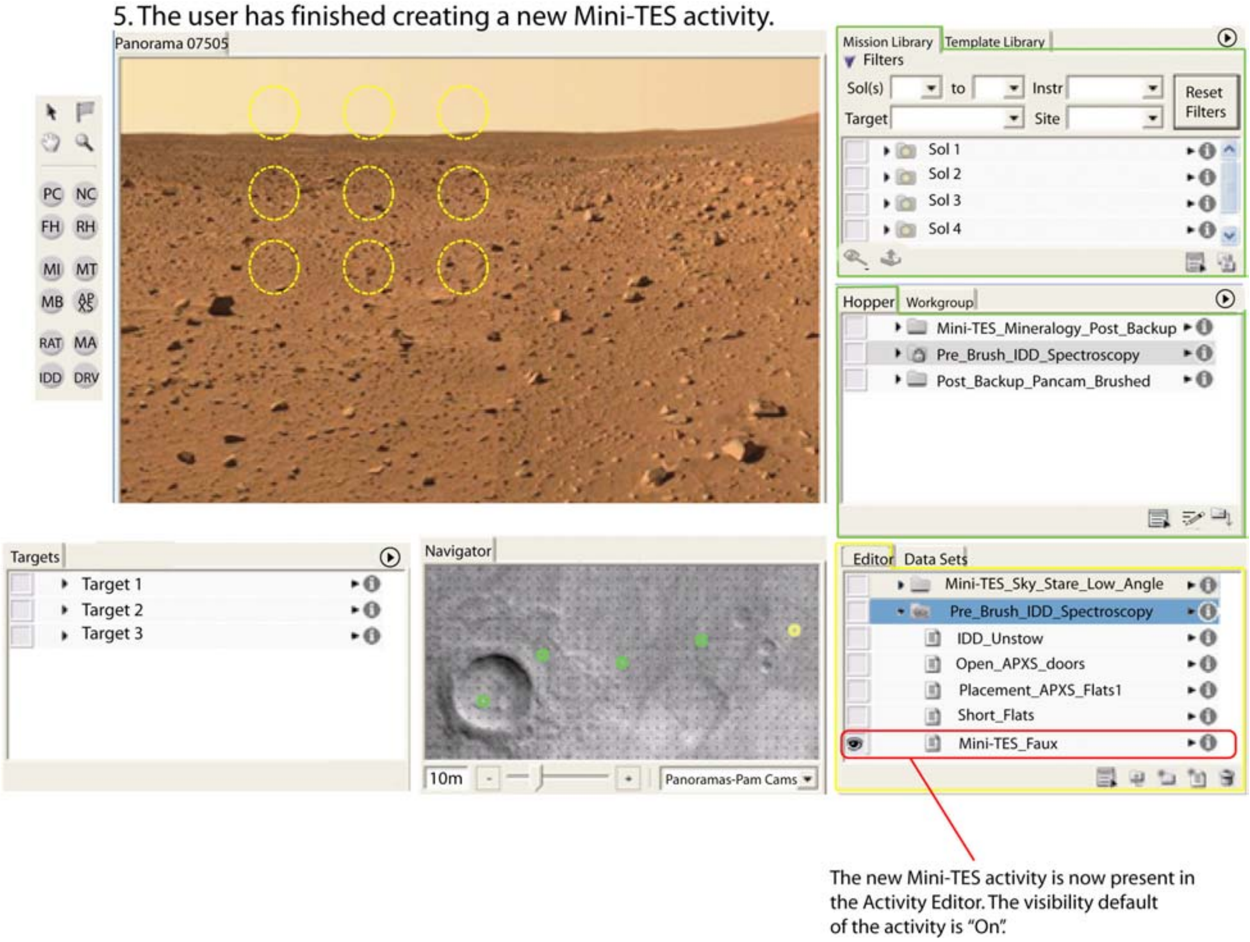


This window appears when the user drops the cursor, after placing the Mini-TES within the Martian environment. If parts of the activity are already specified, they populate the correct field within the Activity Details window.

4. The user further specifies the activity, using the Activity Details window.

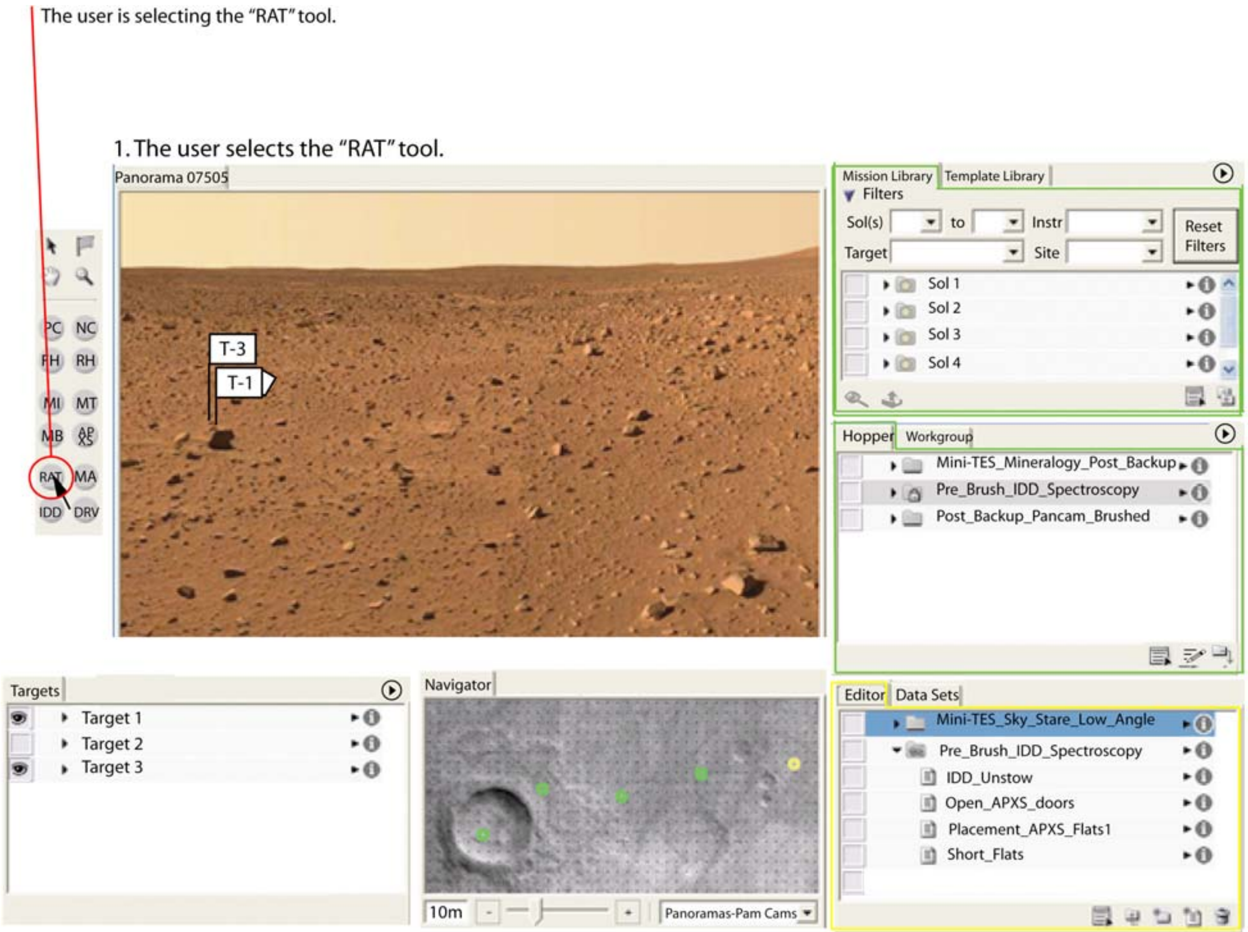


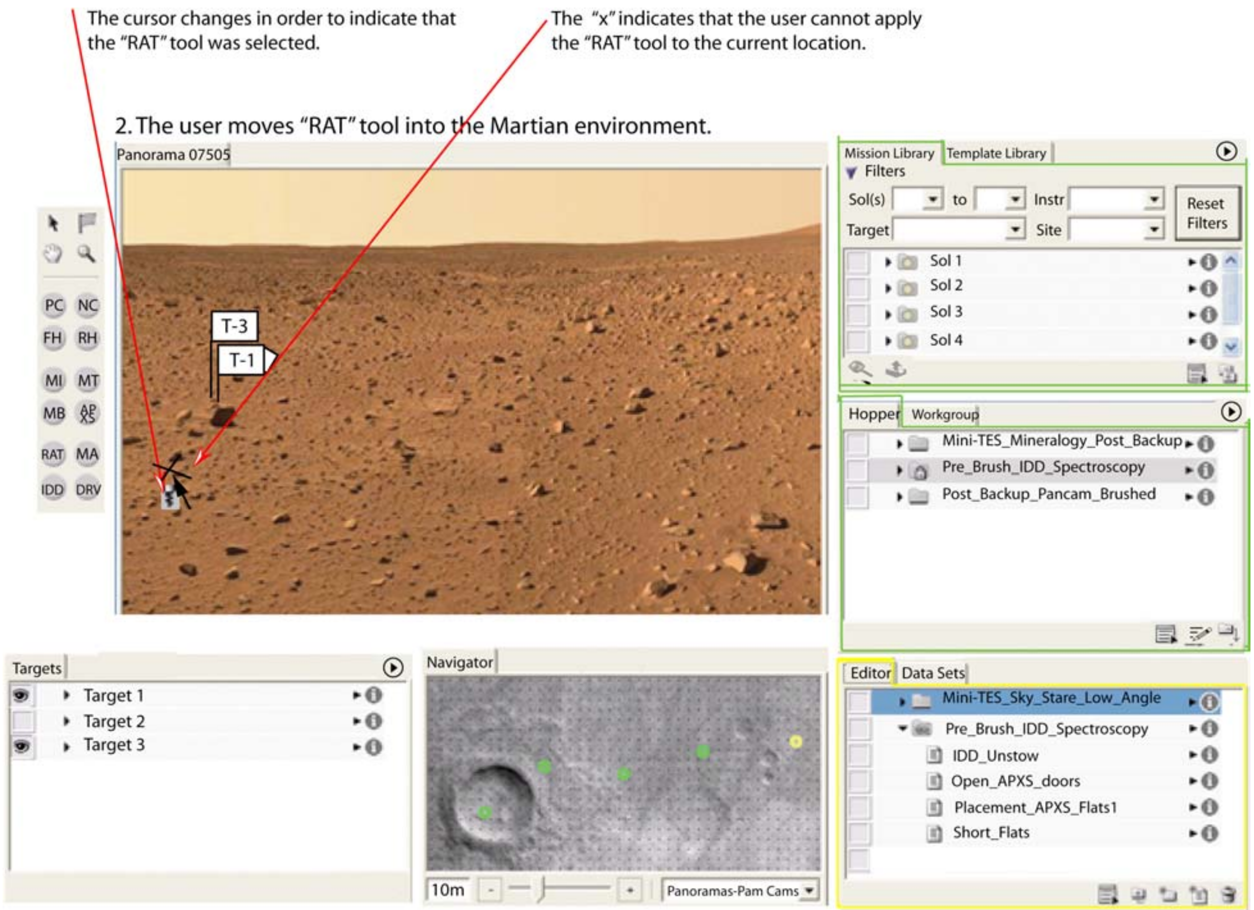
5. The user has finished creating a new Mini-TES activity.



Activity Creation

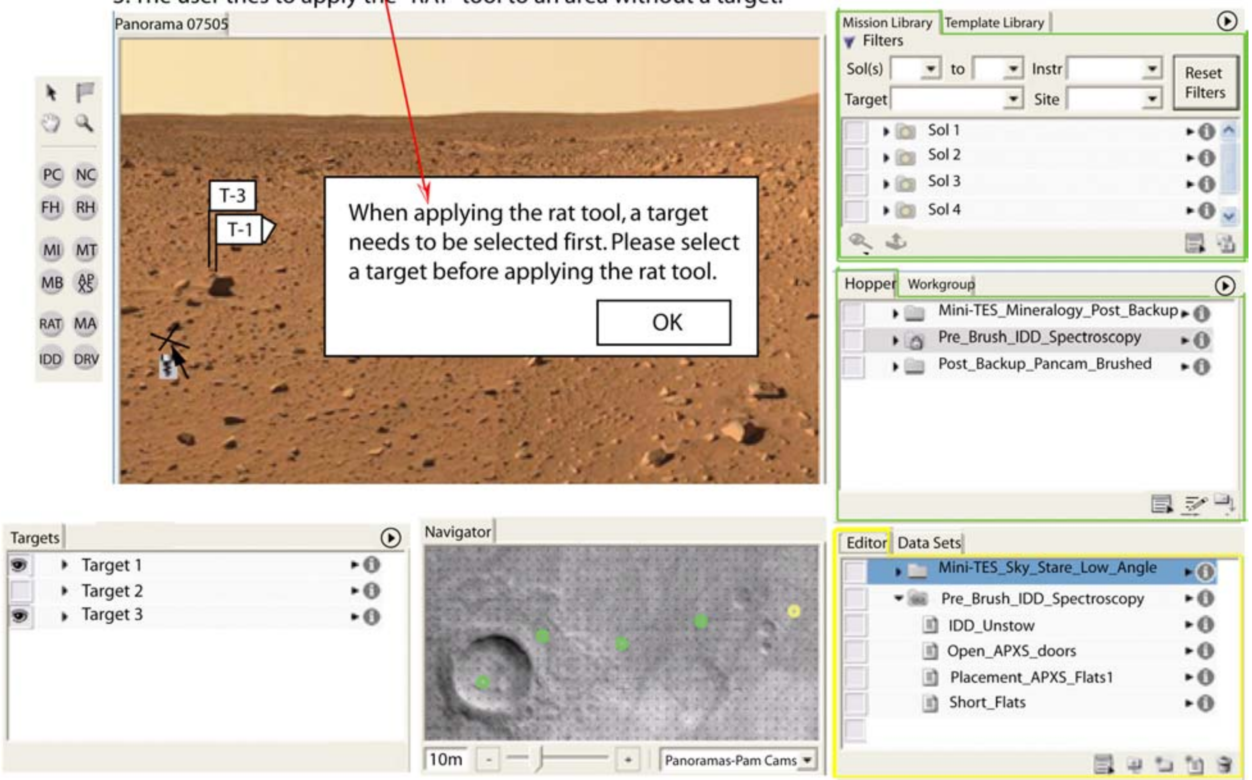
Creating an Activity With a Target.




The cursor changes in order to indicate that the "RAT" tool was selected.
The "x" indicates that the user cannot apply the "RAT" tool to the current location.
2. The user moves "RAT" tool into the Martian environment.
Panorama 07505
T-3
T-1
PC NC
FH RH
MI MT
MB
RAT MA
IDD DRV
Mission Library
Template Library
Filters
Sol(s)
to
Instr
Reset Filters
Target
Site
Sol 1
Sol 2
Sol 3
Sol 4
Hopper
Workgroup
Mini-TES_Mineralogy_Post_Backup
Pre_Brush_IDD_Spectroscopy
Post_Backup_Pancam_Brushed
Targets
Target 1
Target 2
Target 3
Navigator
10m
Panoramas-Pam Cams
Editor
Data Sets
Mini-TES_Sky_Stare_Low_Angle
Pre_Brush_IDD_Spectroscopy
IDD_Unstow
Open_APXS_doors
Placement_APXS_Flats1
Short_Flats

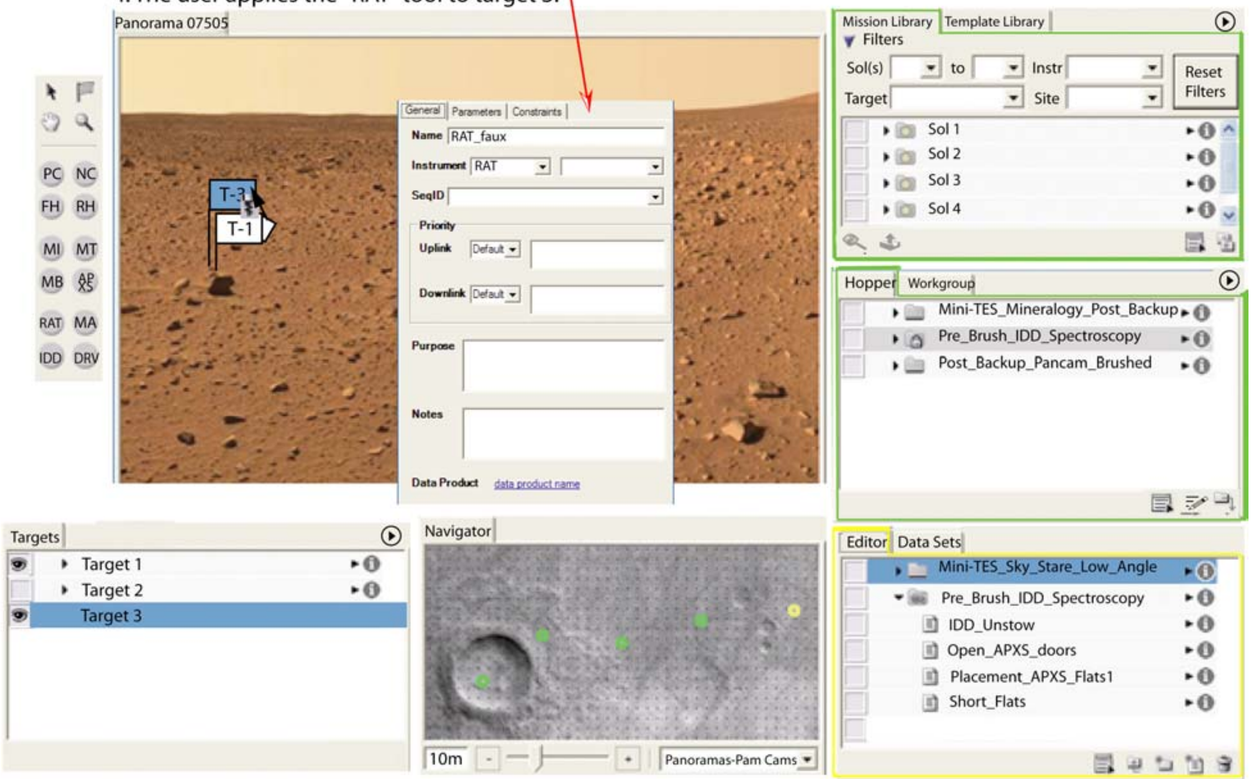
This is the error message that appears when the user tries to apply the "RAT" to a non-targeted area.

3. The user tries to apply the "RAT" tool to an area without a target.



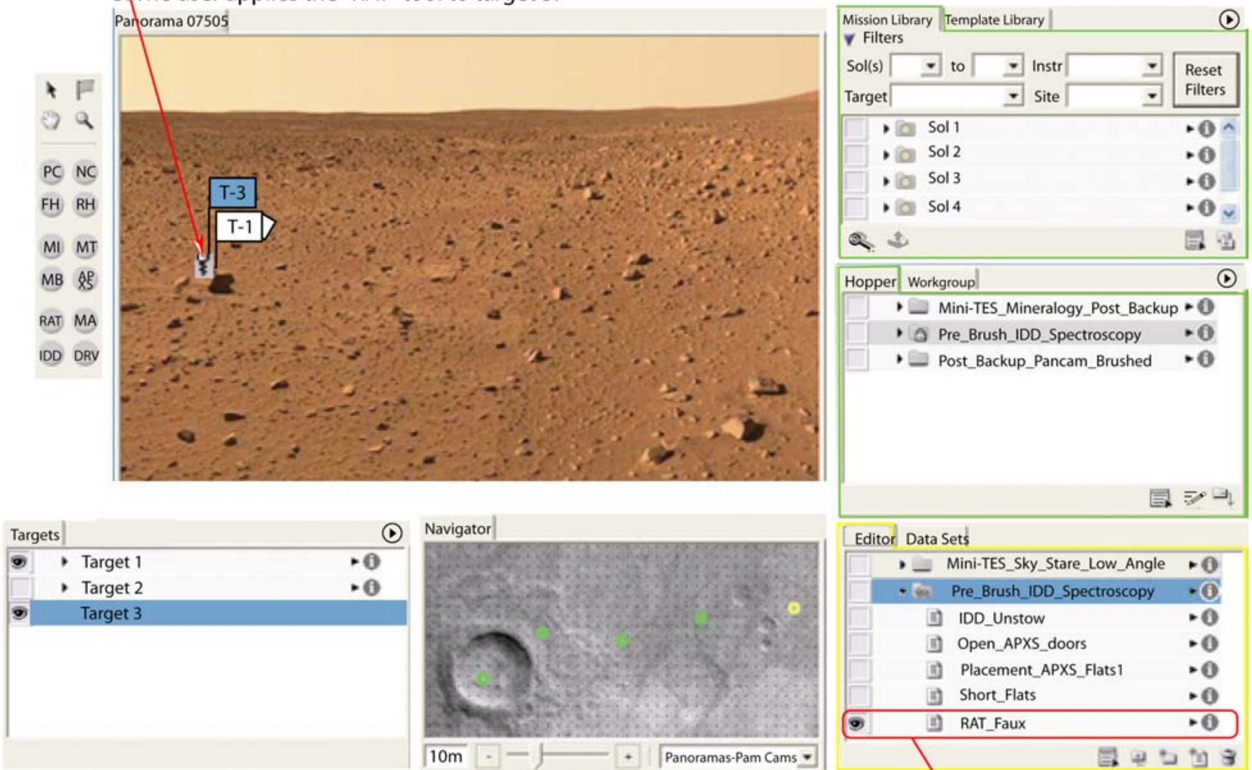
This is Activity Details window. The user is able to specify the rest of the" RAT "activity here.

4. The user applies the "RAT" tool to target 3.



A glyph is present in the environment where the "RAT" activity was assigned.

5. The user applies the "RAT" tool to target 3.

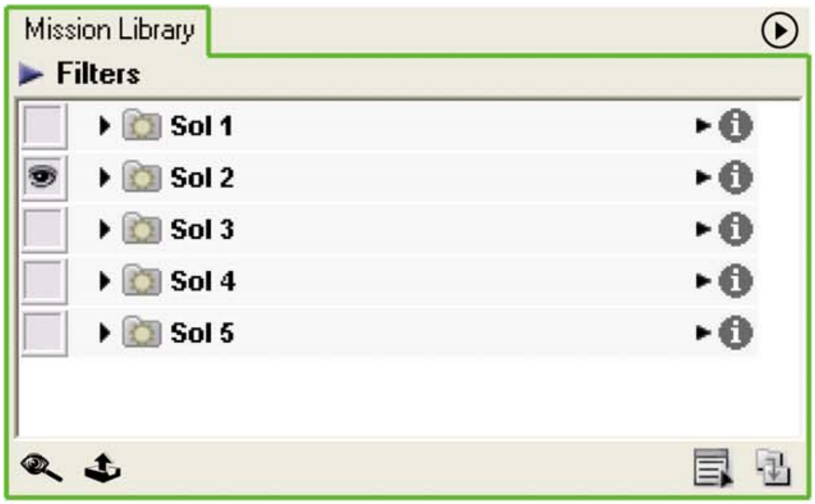


The new "RAT" activity is now present in the Activity Editor within this observation folder. The visibility default of the "RAT" activity is "on".

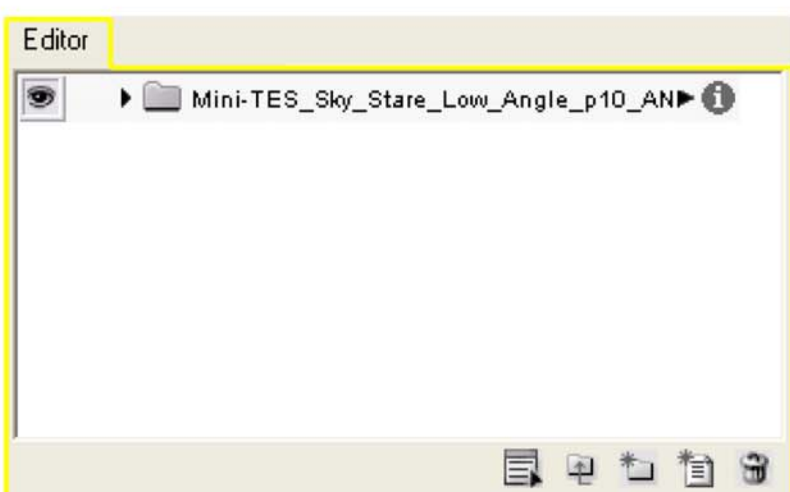
Activity Editing

Editing an activity from the Hopper.

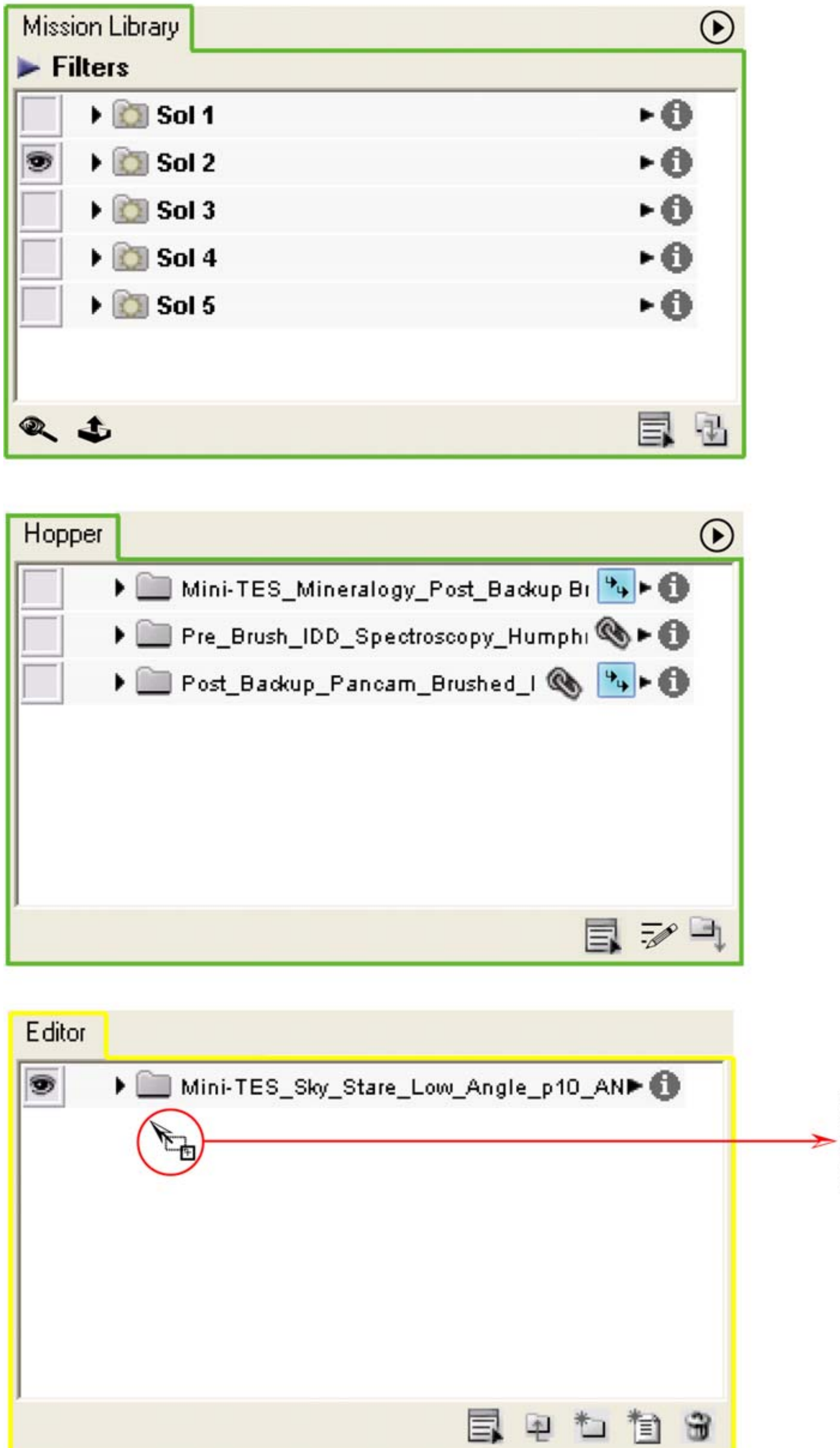
Checking-out an observation or activity using drag and drop
Step 1



Click-and-drag the selected observation or activity toward the Editor.



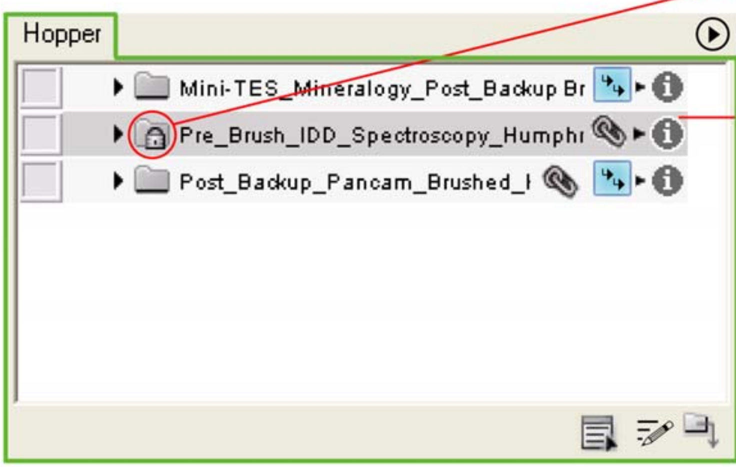
Checking out an observation or activity using drag and drop
Step 2



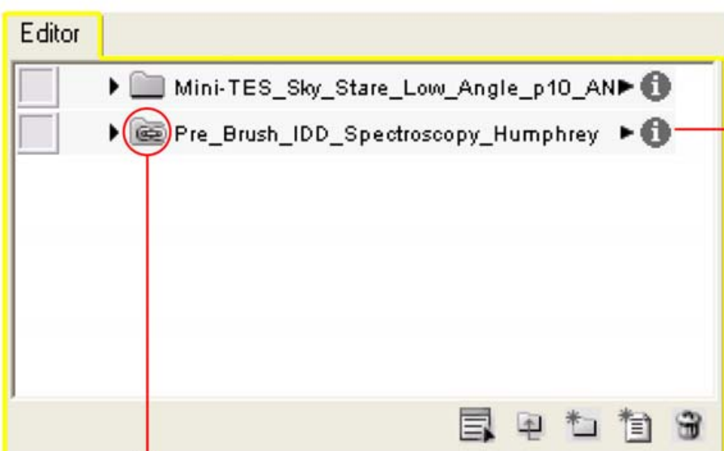
Once the cursor has been dragged into the Editor, it changes to reflect that the observation or activity can be dropped anywhere in this area.

Checking out an observation or activity using drag and drop
Step 3

A lock icon appears on the observation folder to reflect that this observation or some part of it is being edited in the Editor. Therefore, no other user is able to check this observation out but they are able to to view the properties of it.



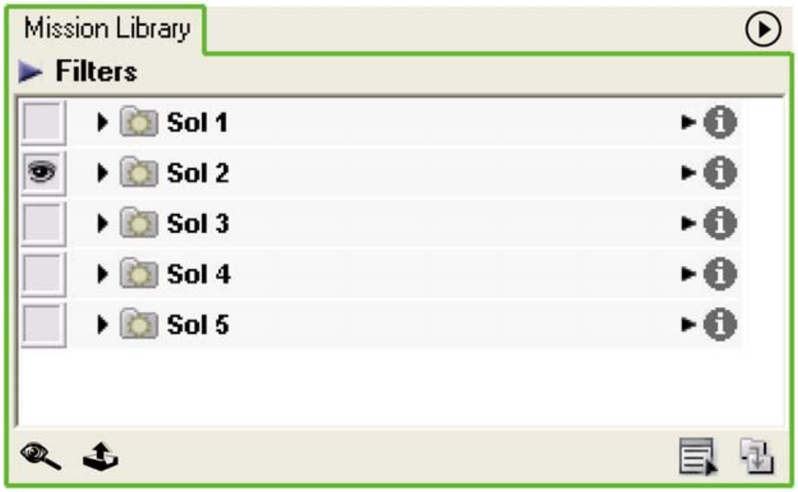
Any item(s) that are copied to the Editor have a grey border around them to indicate to the user that these item(s) are being edited.

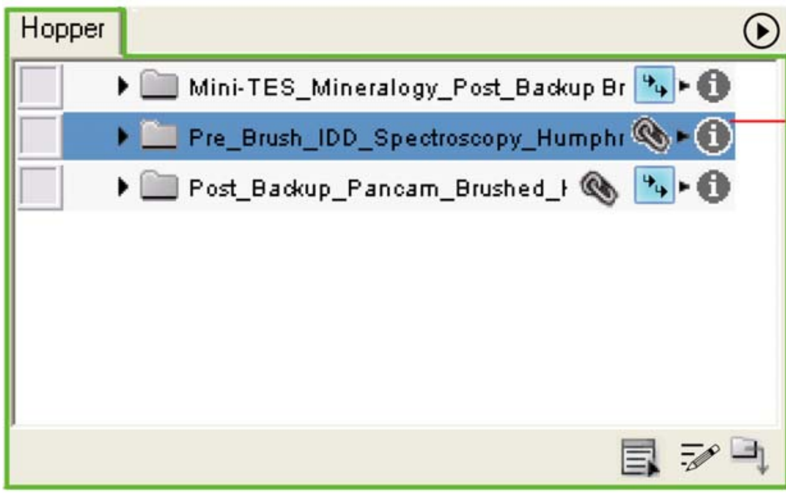


The selected item appears in the editor along with all of the items associated with it such as activites, constraints and details. If the selected item is an activity, then the observation that is associated with is also copied to the editor but not all of the other activies within that observations

A chain icon appears on the observation folder to reflect that it is linked to an observation in the hopper

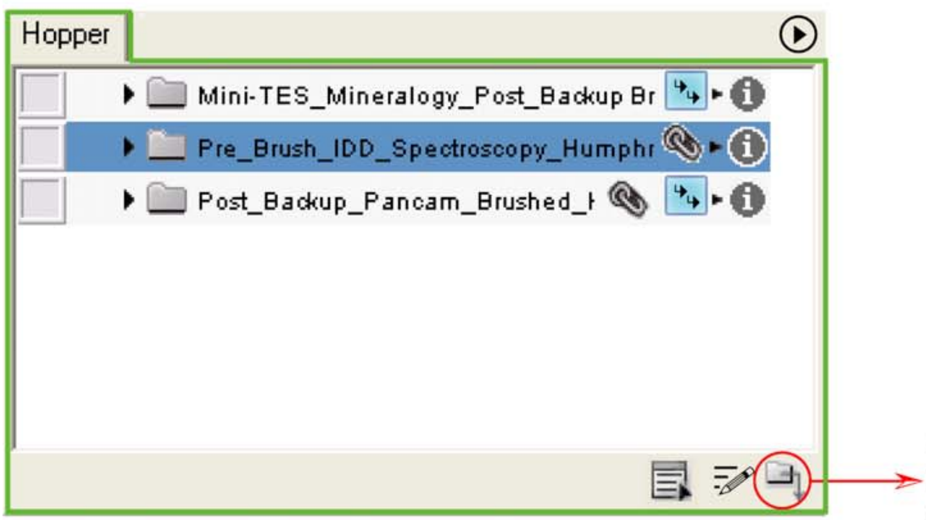
Check-out observation or activity using icons
Step 1



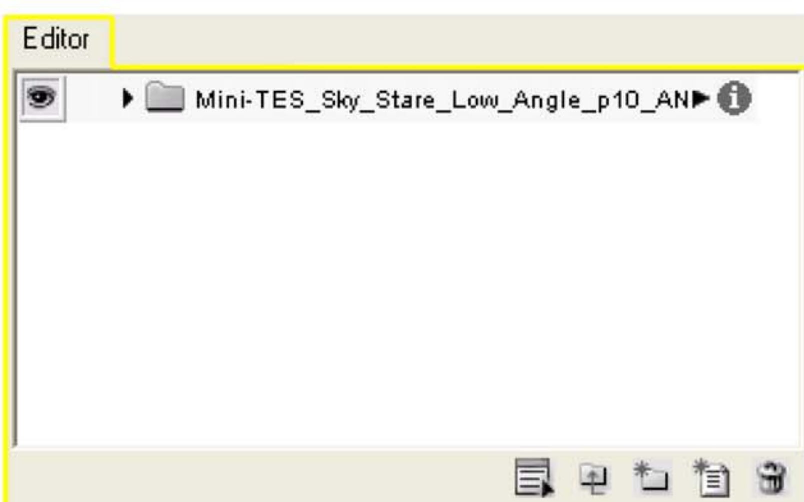


Select the desired item to be edited. The item becomes highlighted in blue to show that has been selected.

Check-out observation or activity using icons
Step 2

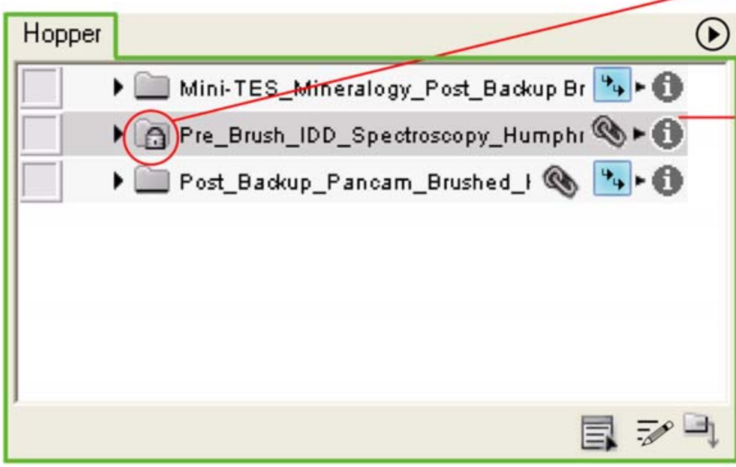


Click the Check-out of Hopper icon to place a copy of the selected item into the Editor.

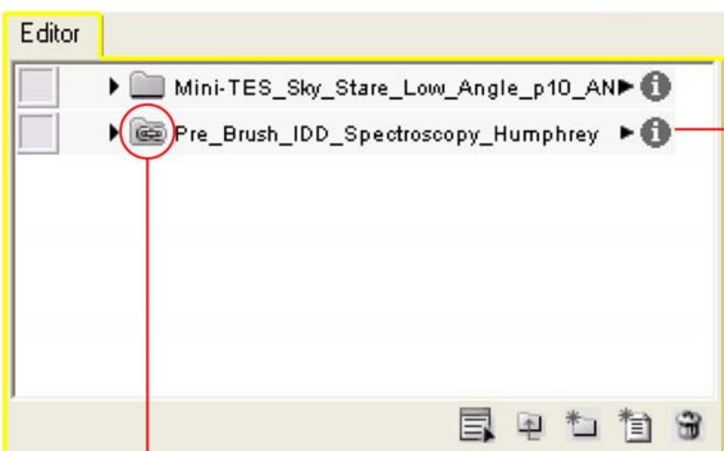


Check-out observation or activity using icons
Step 3

A lock icon appears on the observation folder to reflect that this observation or some part of it is being edited in the Editor. Therefore, no other user is able to check this observation out but they are able to to view the properties of it.



Any item(s) that are copied to the Editor have a grey border around them to indicate to the user that these item(s) are being edited.



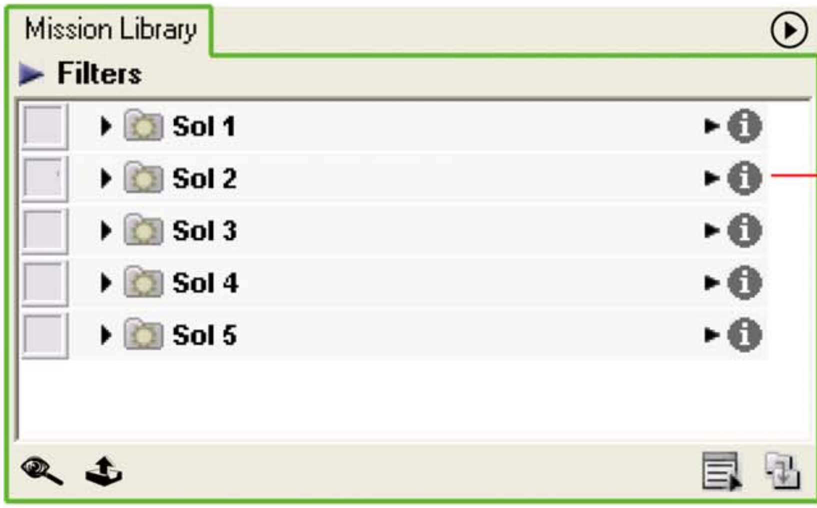
The selected item appears in the editor along with all of the items associated with it such as activites, constraints and details. If the selected item is an activity, then the observation that is associated with is also copied to the editor but not all of the other activies within that observations

A chain icon appears on the observation folder to reflect that it is linked to an observation in the hopper

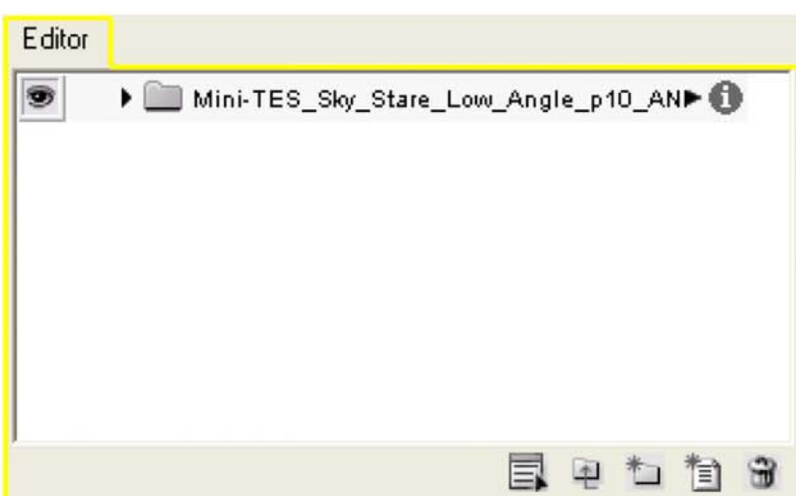
Activity Editing

Re-using an activity from the Mission Library.

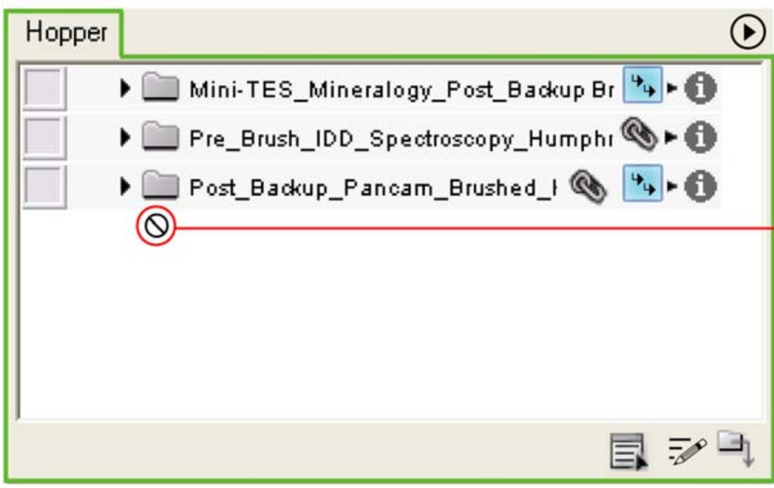
Reusing a sol, observation or activity using drag and drop
Step 1



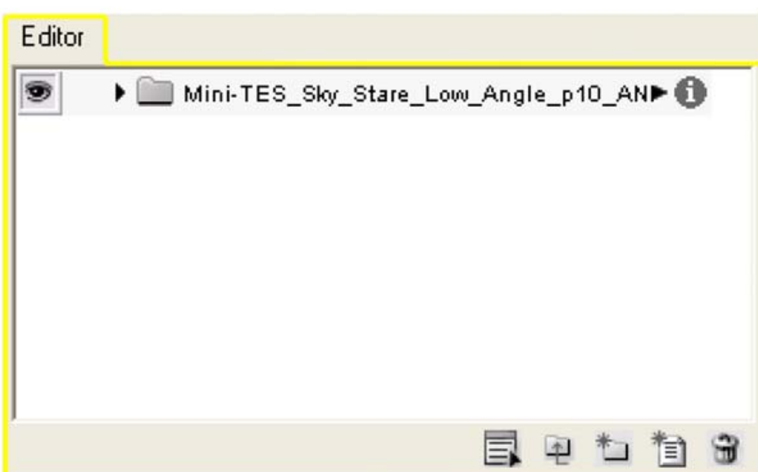
Click-and-drag the selected sol, observation or activity toward the Editor.



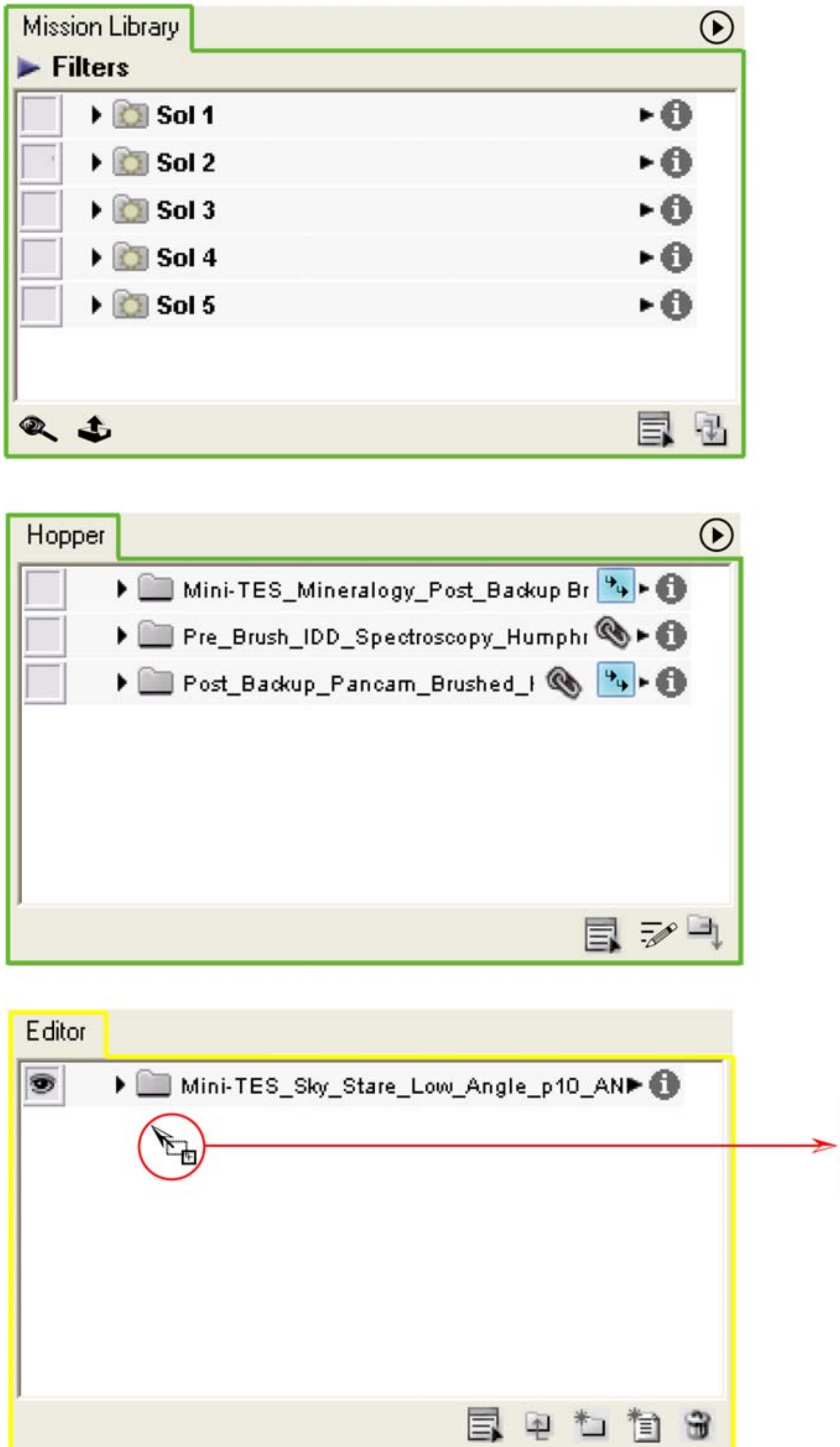
Reusing a sol, observation or activity using drag and drop
Step 2



While the cursor is within an area that the selected item is not permitted to be placed, the cursor changes.

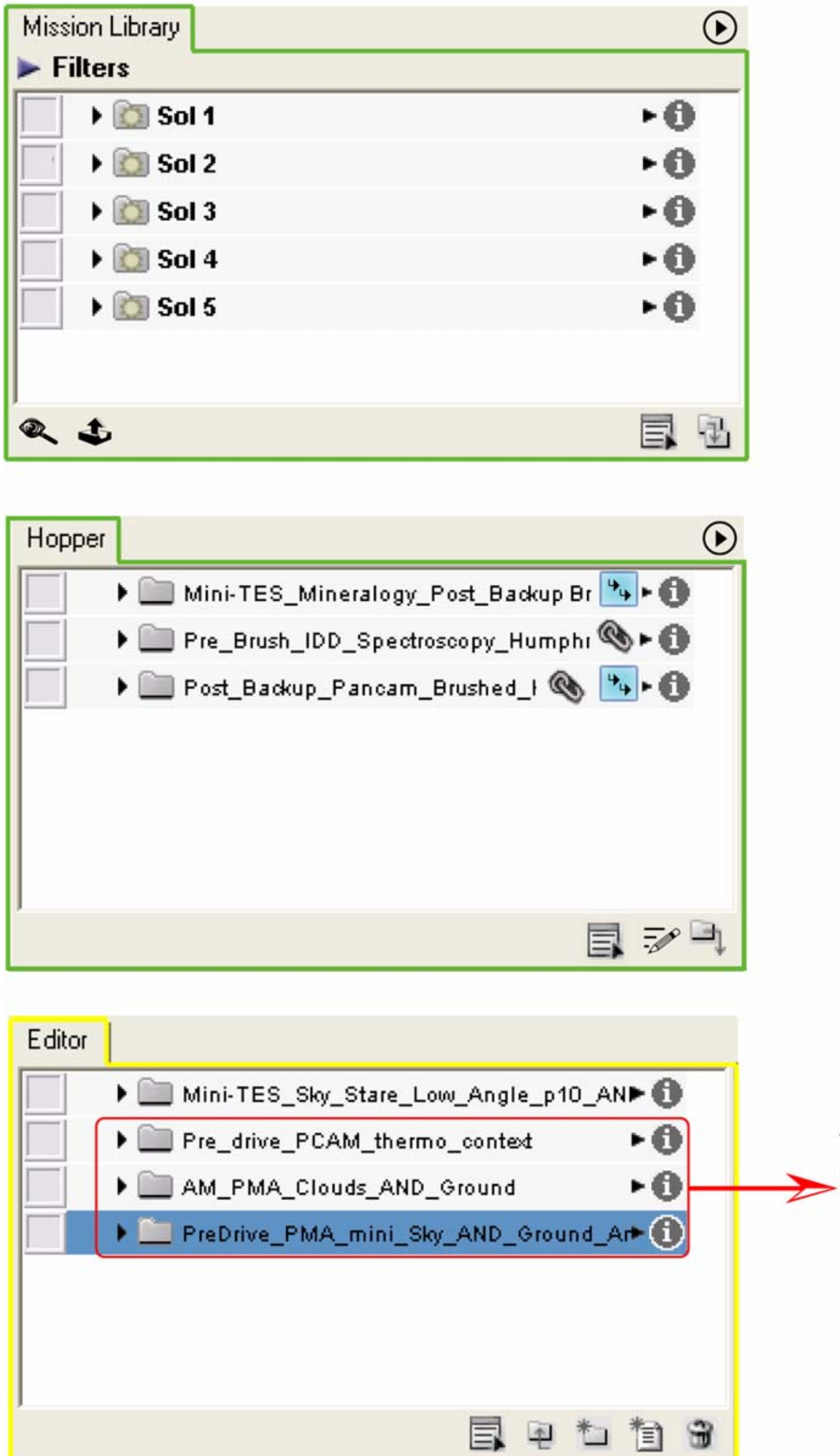


Reusing a sol, observation or activity using drag and drop
Step 3



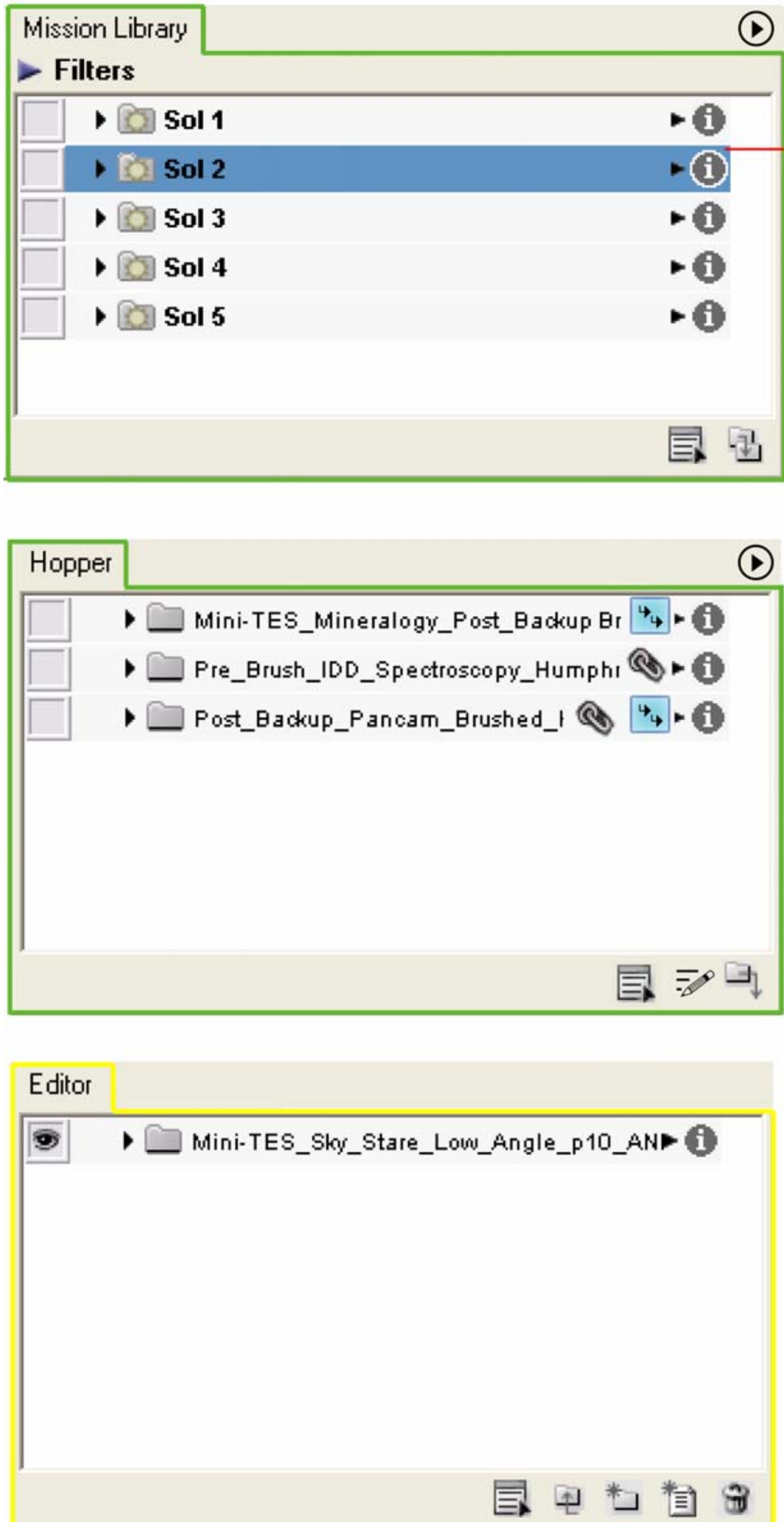
Once the cursor has been dragged into the Editor, it changes to reflect that the sol, observation or activity can be dropped anywhere in this area.

Reusing a sol, observation or activity using drag and drop
Step 4



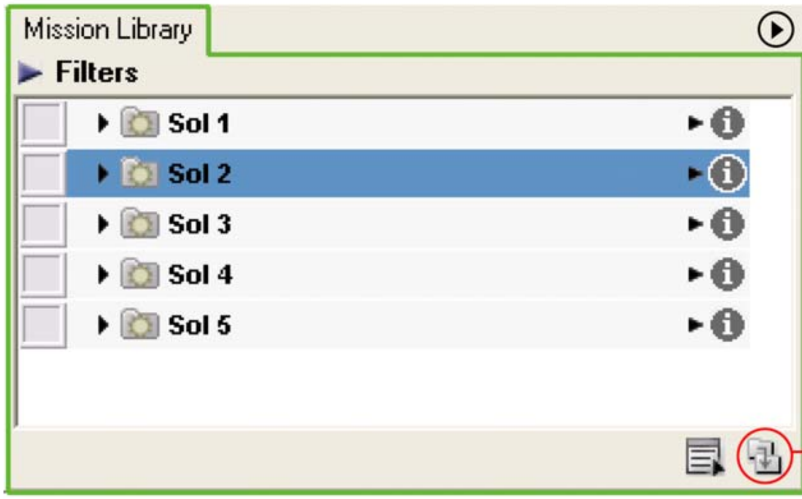
The dragged item(s) appear in the Editor. Changes must be made to each of these to reflect the changes in target, site, parameters, etc.

Reusing a sol, observation or activity using icons
Step 1

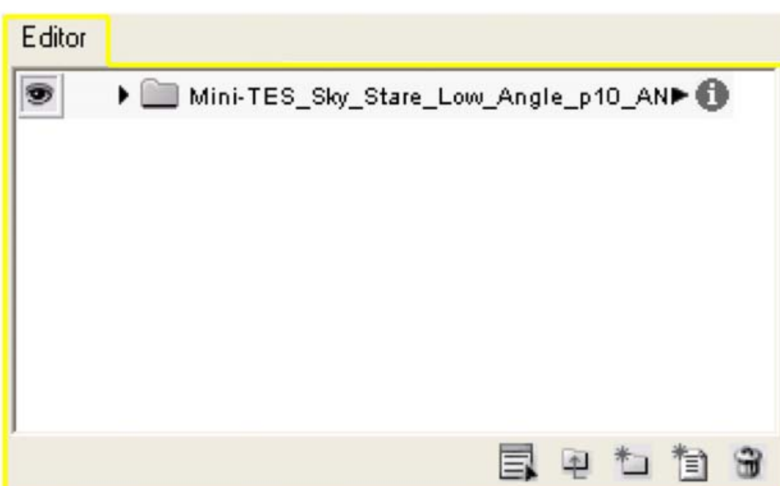


Select the desired item to be edited. The item becomes highlighted in blue to show that has been selected.

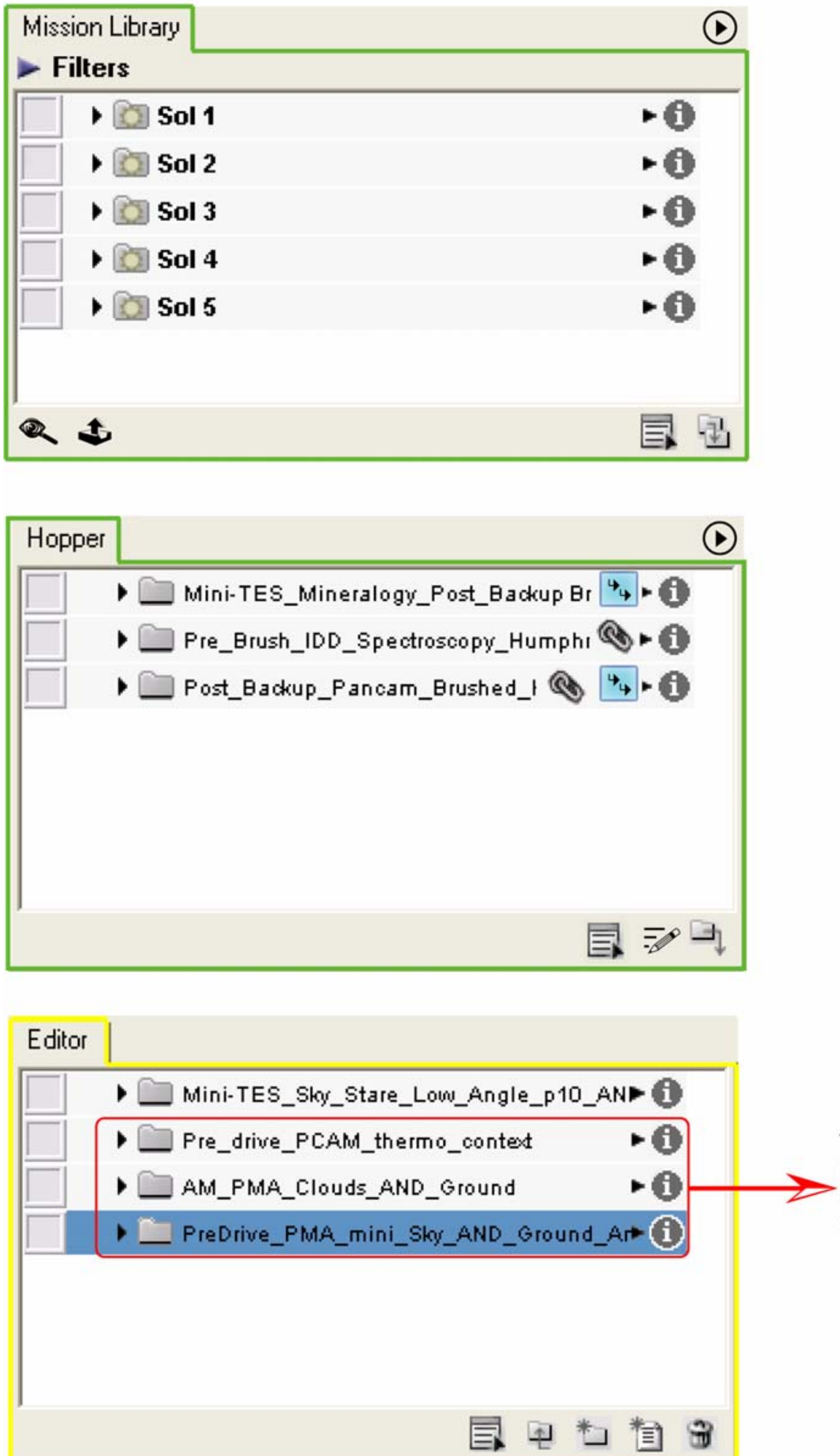
Reusing a sol, observation or activity using icons
Step 2



Click the Copy to Editor icon to place a copy of the selected item into the Editor.



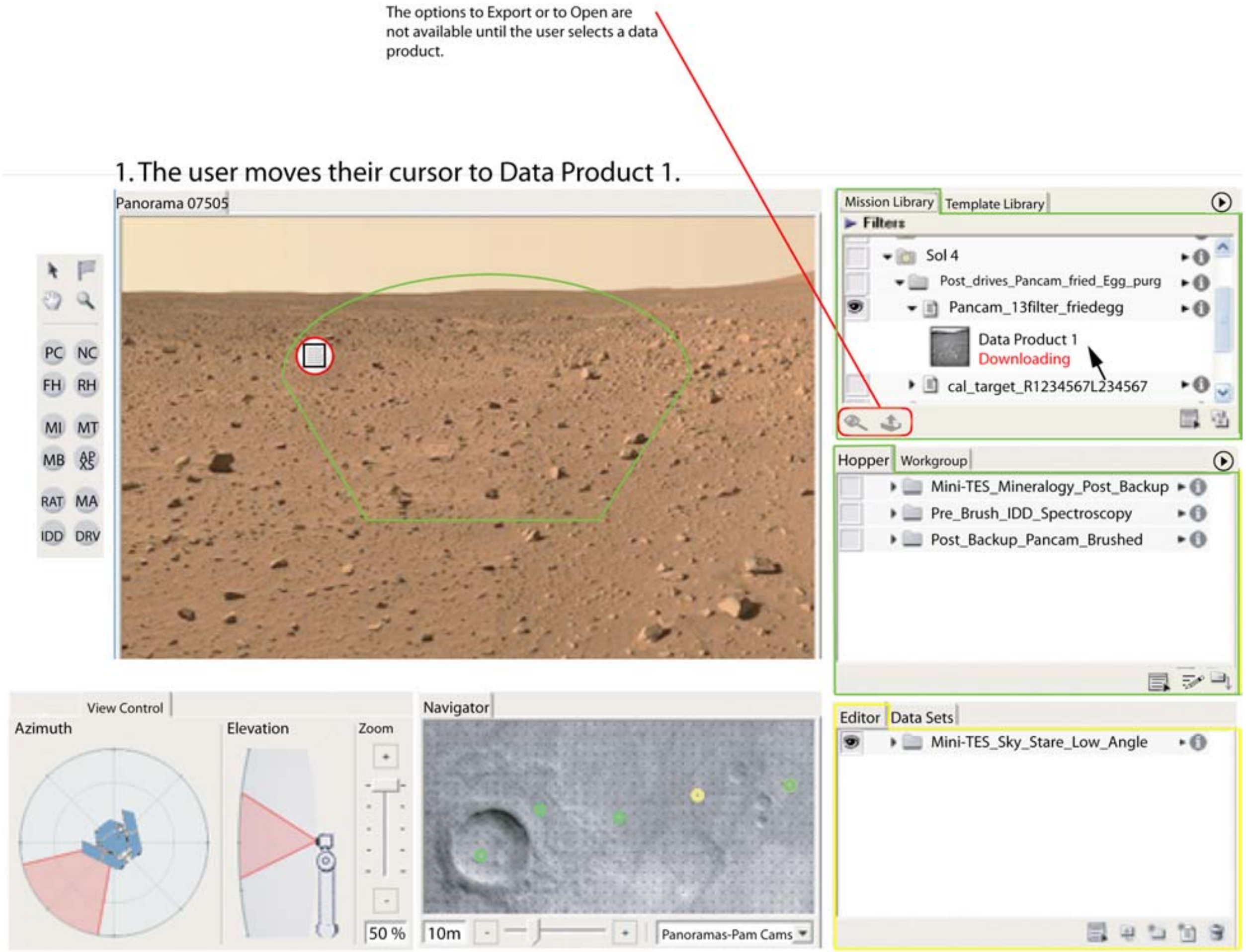
Reusing a sol, observation or activity using icons
Step 3



The copied item(s) appear in the Editor. Changes must be made to each of these to reflect the changes in target, site, parameters, etc.

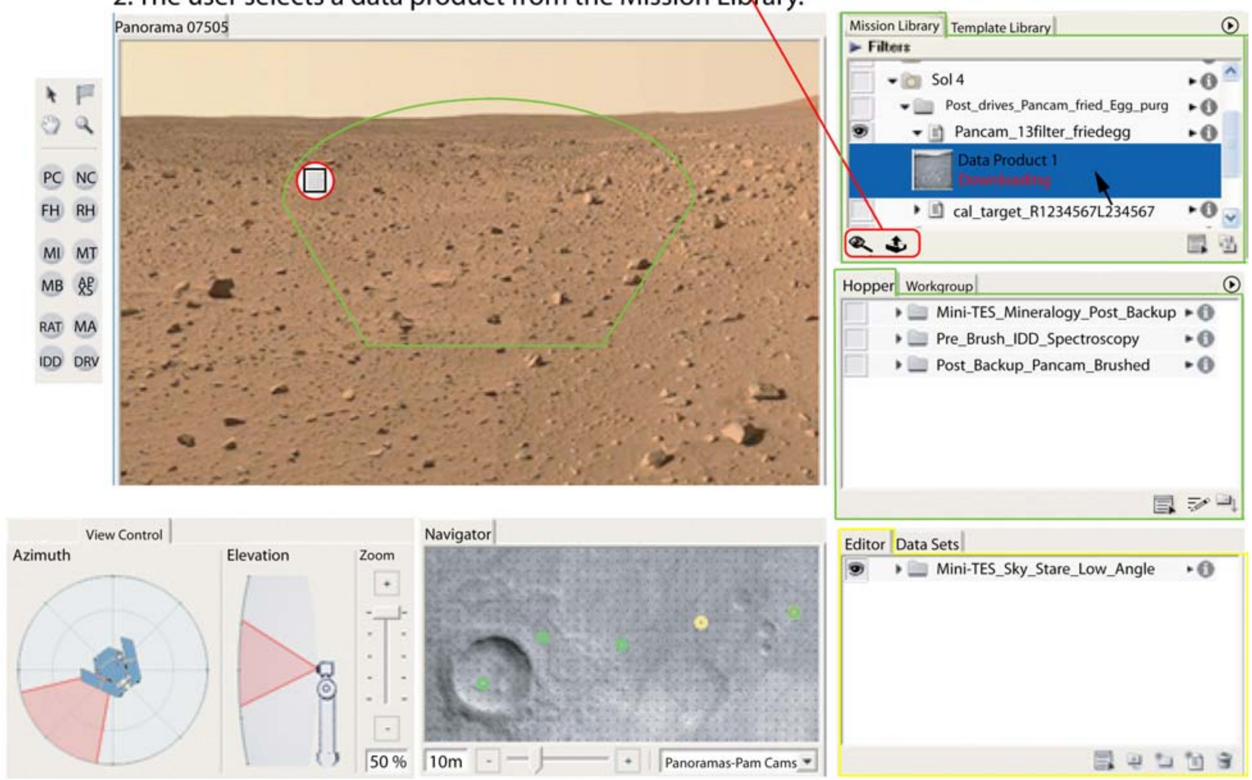
Accessing Data Products

Accessing a Data Product from the Mission Library.



The Export and Open options become de-ghosted. These are options that the user can now select.

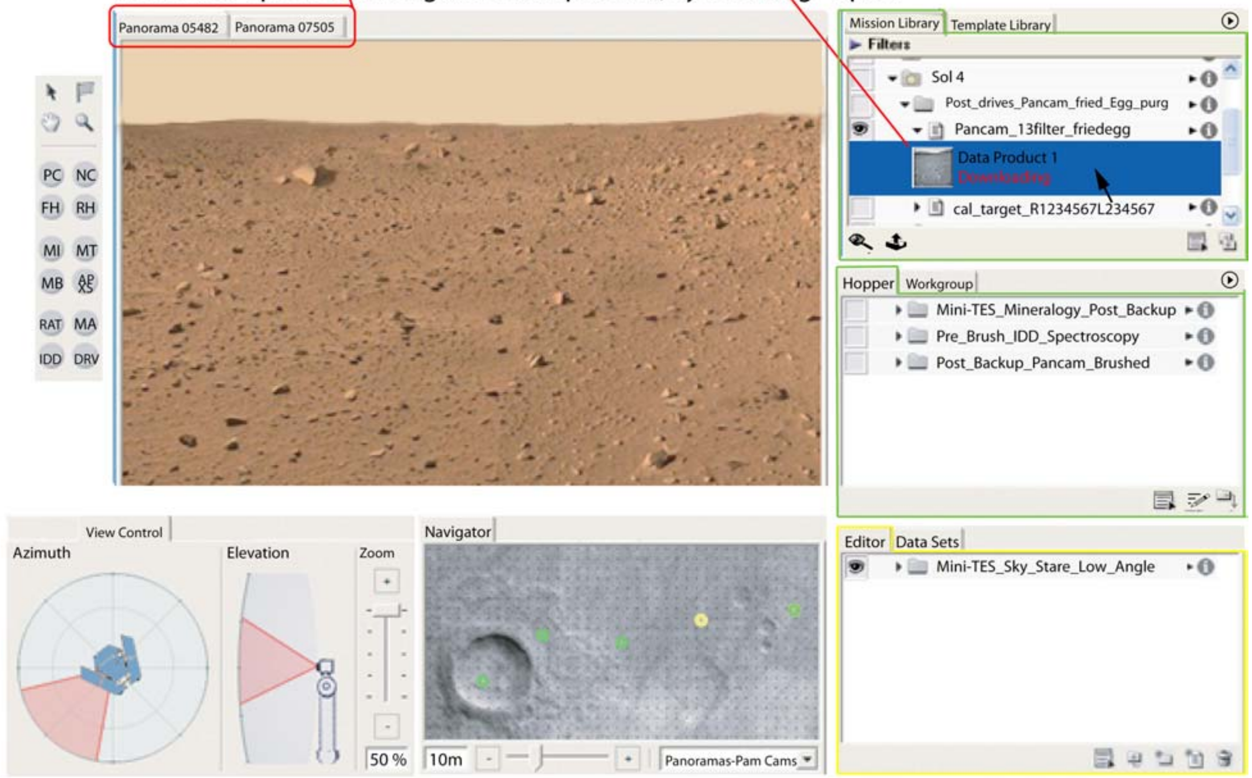
2. The user selects a data product from the Mission Library.



A new navigation data product is open (Panorama 05482). The user is currently viewing the tab on the left. The data product that the user was viewing before has shifted to the right.

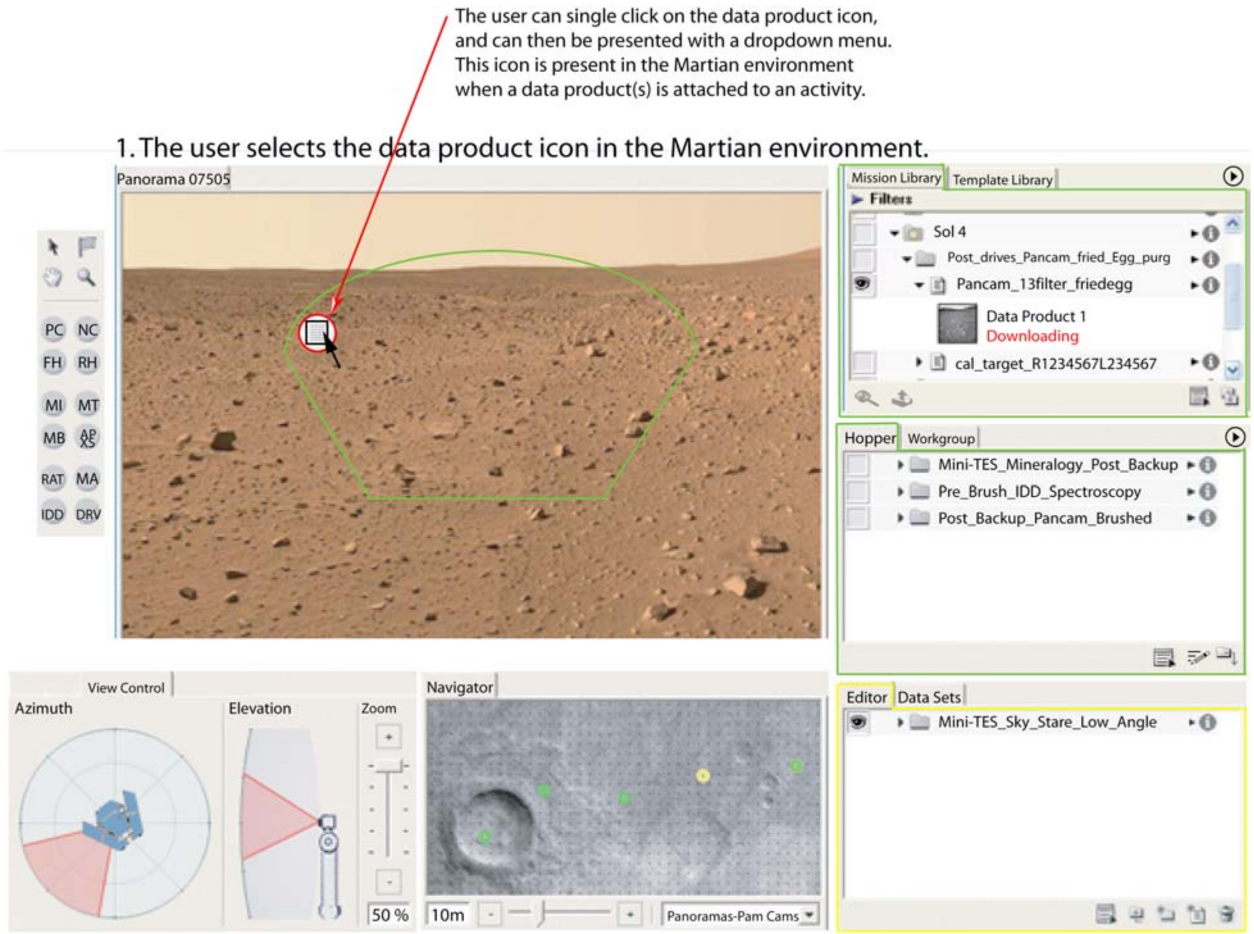
If the data product can be used for navigation, it will open in the Martian Environment.

3. The user opens this navigation data product, by selecting "Open".



Accessing Data Products

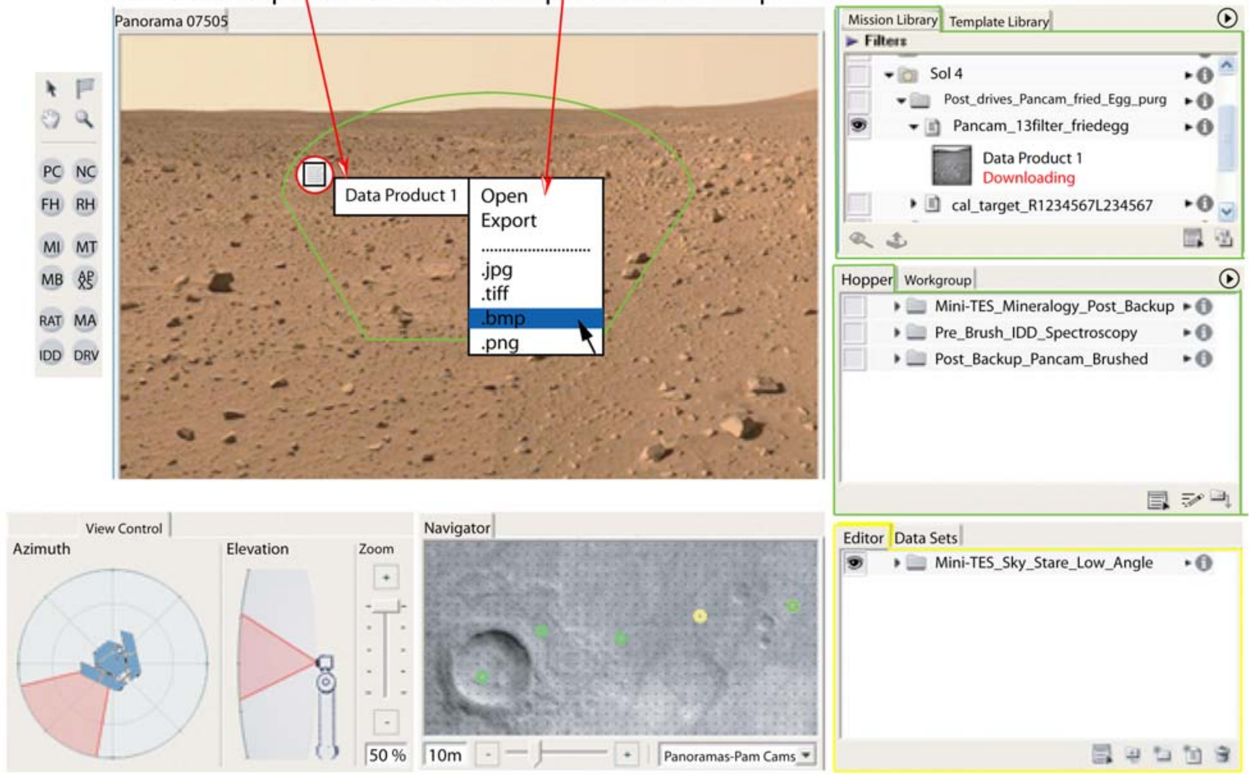
Accessing a Data Product from the Interactive Martian Environment.



This pull-down list will contains all of the available data products associated with this footprint.

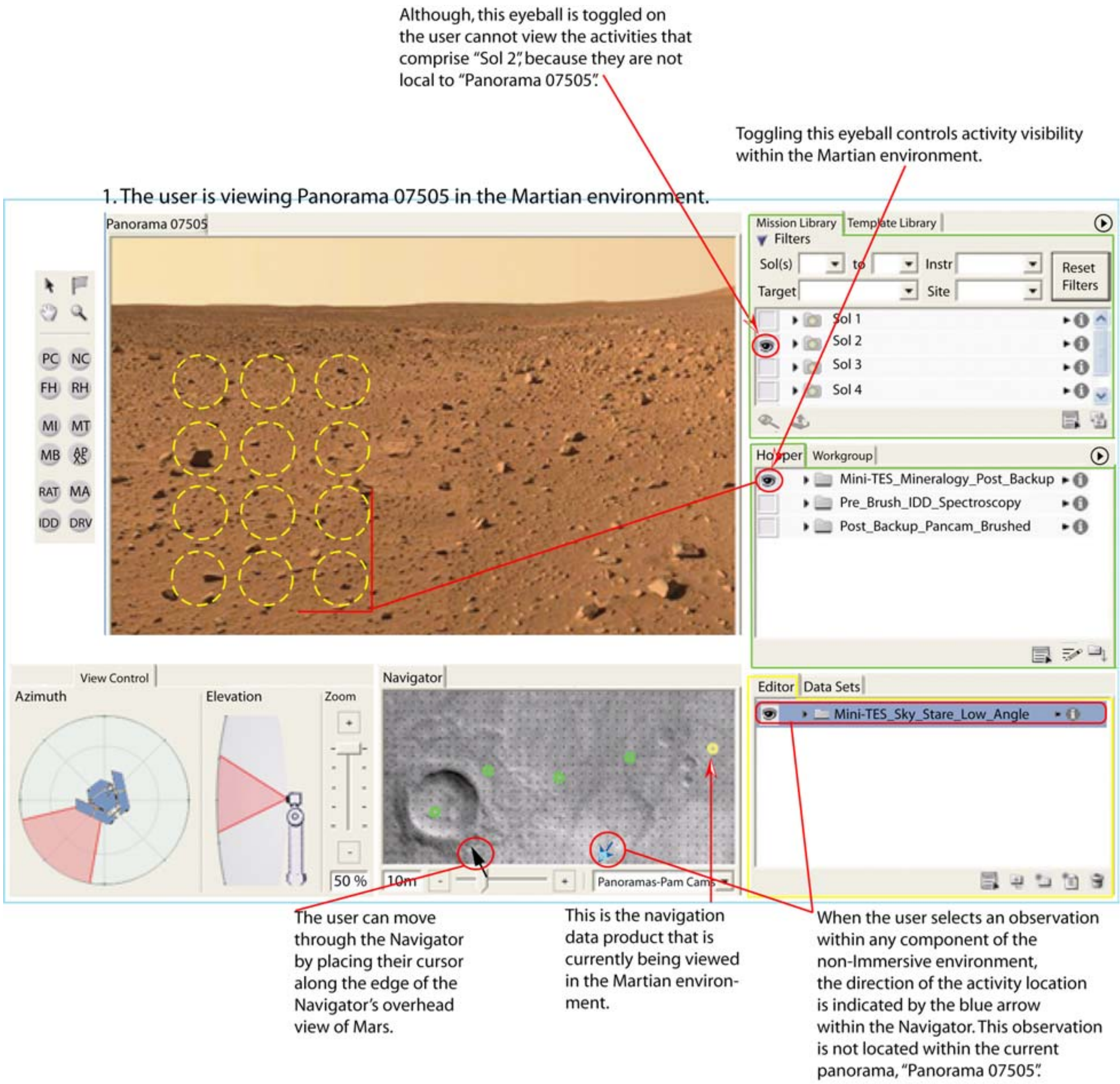
This pull-down allows the user to either open or export the data product of their choice.

2. The user exports the Pancam data product as a ".bmp".



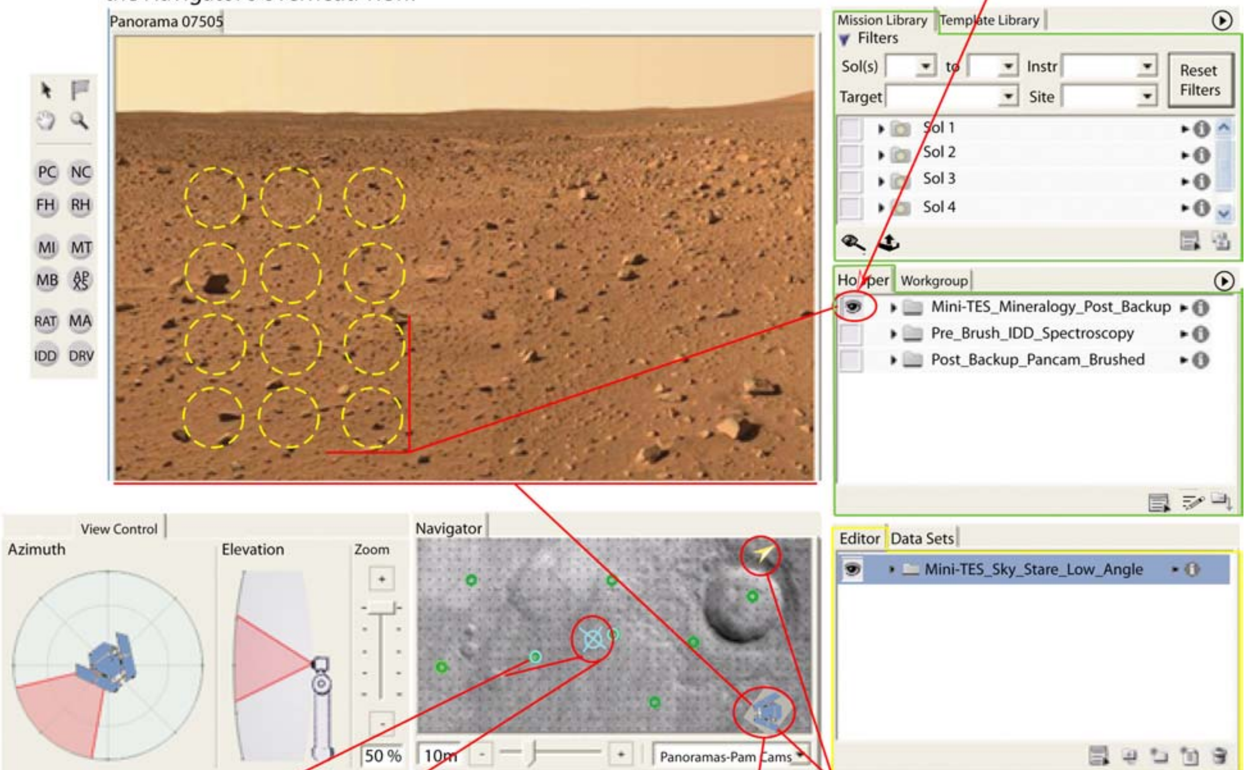
Tools in the Interactive Martian Environment

Navigating the Interactive Martian Environment



Toggling these eyeballs controls activity visibility within the Martian environment.

2. The user is navigating to the activity selected within the Editor, by using moving their cursor to the edge of the Navigator's overhead view.



The blue color of these panoramas indicates that that Mini-TES observation in the Editor is visible from these panoramas.

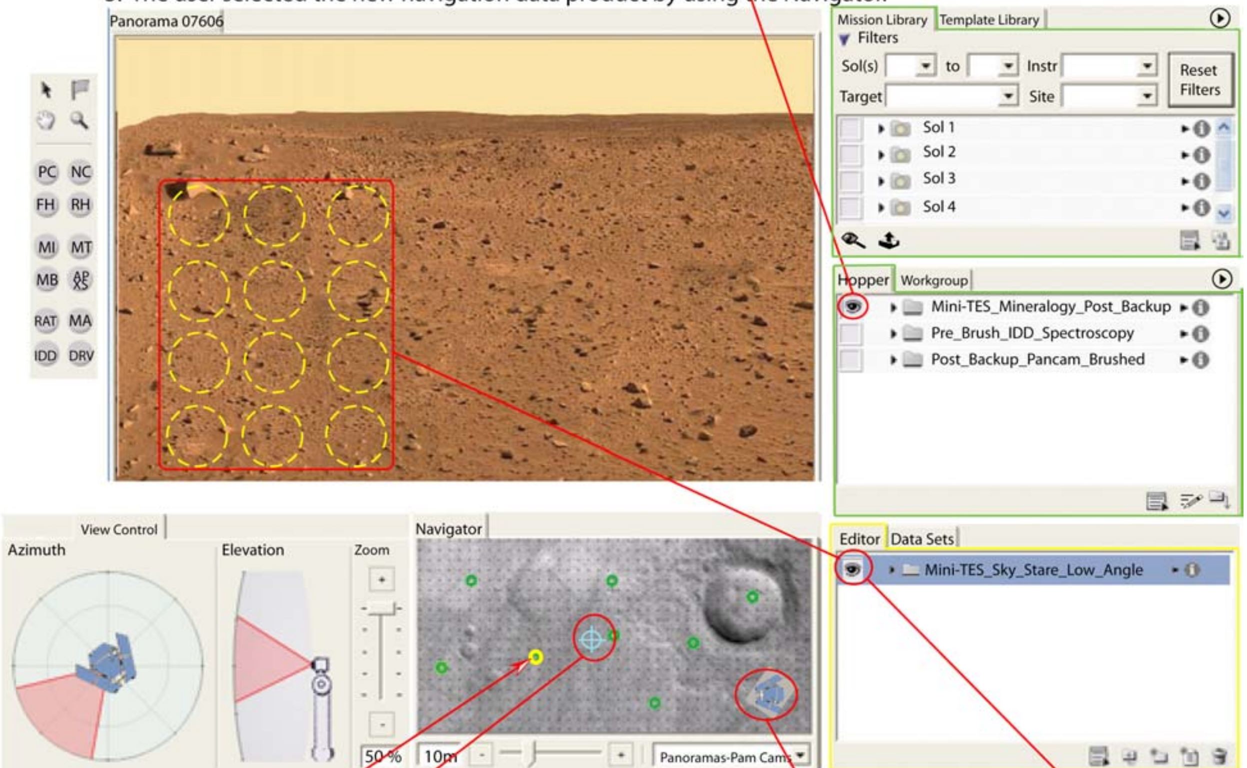
The location of the activity that is currently selected in the Editor is indicated by this crosshair.

This yellow arrow shows the way that the user should navigate in order to find the navigation data product that they currently have selected.

This shows the rover's current state and orientation within the Martian environment.

This activity is no longer visible within the Martian environment, because the user has moved to a different panorama.

3. The user selected the new navigation data product by using the Navigator.



This is the new panorama that the user selected.

The location of observation that is currently selected in the Editor is indicated by this blue crosshair.

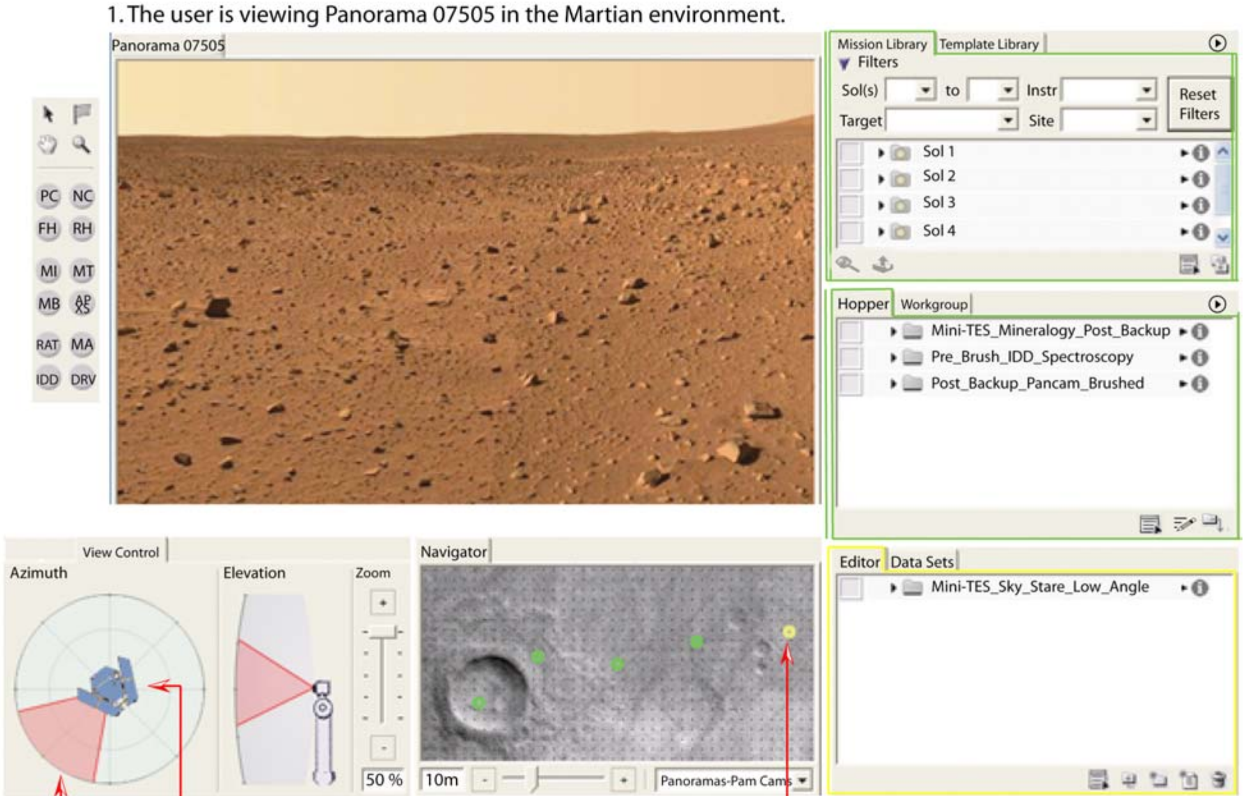
This shows the rover's current state and orientation within the Martian environment.

This observation is visible within the Martian environment, because the eyeball is toggled on, and the user has opened the correct panoramic data product.

Tools in the Interactive Martian Environment

Using the View Control

1. The user is viewing Panorama 07505 in the Martian environment.



This shows which portion of the navigation data product that the user is viewing within the Martian environment. The user can slide the red triangle to adjust the view.

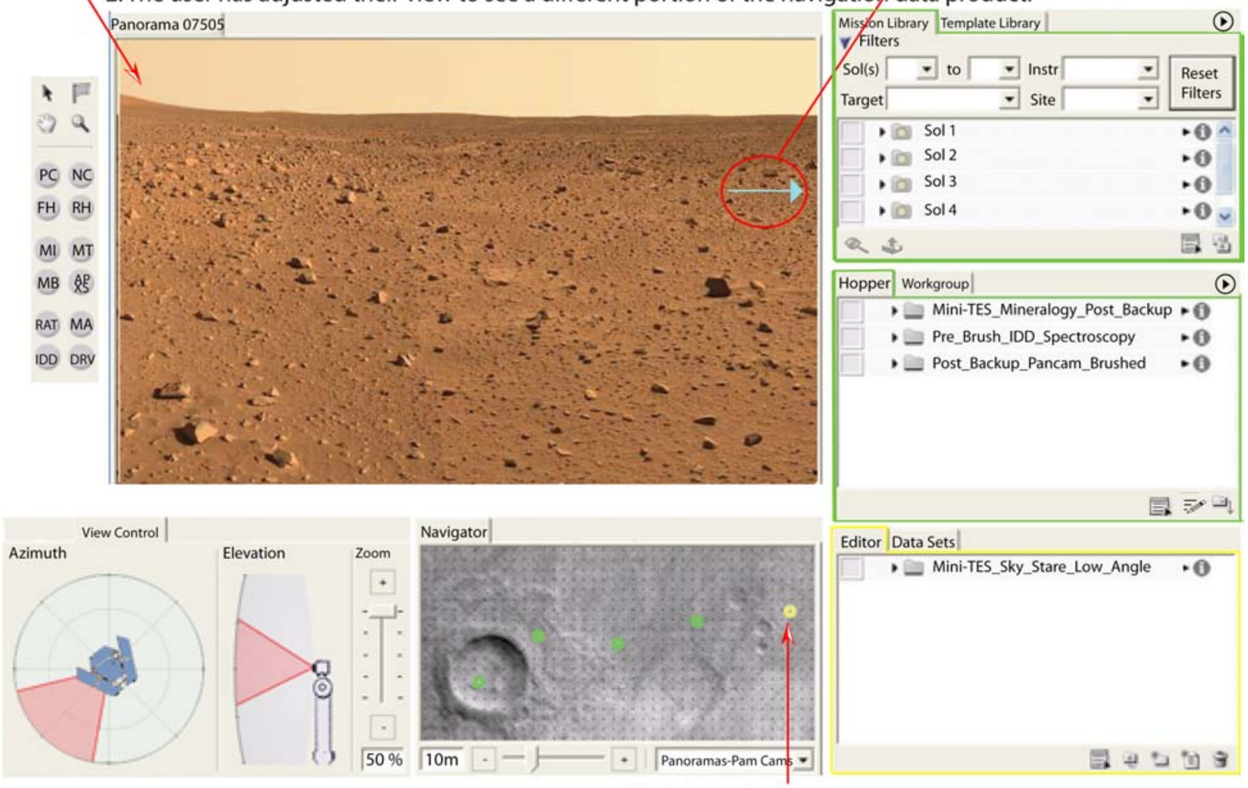
The rover direction indicates which way the rover was facing when the panoramic data product was taken.

This is the navigation data product that is currently being viewed in the Martian environment.

The Martian environment has updated. The user is now looking at a different portion of the same panorama.

When the user moves their cursor to the edge of the screen, they will be able to adjust the view of their navigation data product. This blue arrow provides feedback that tells the user the way that they are moving within the panorama.

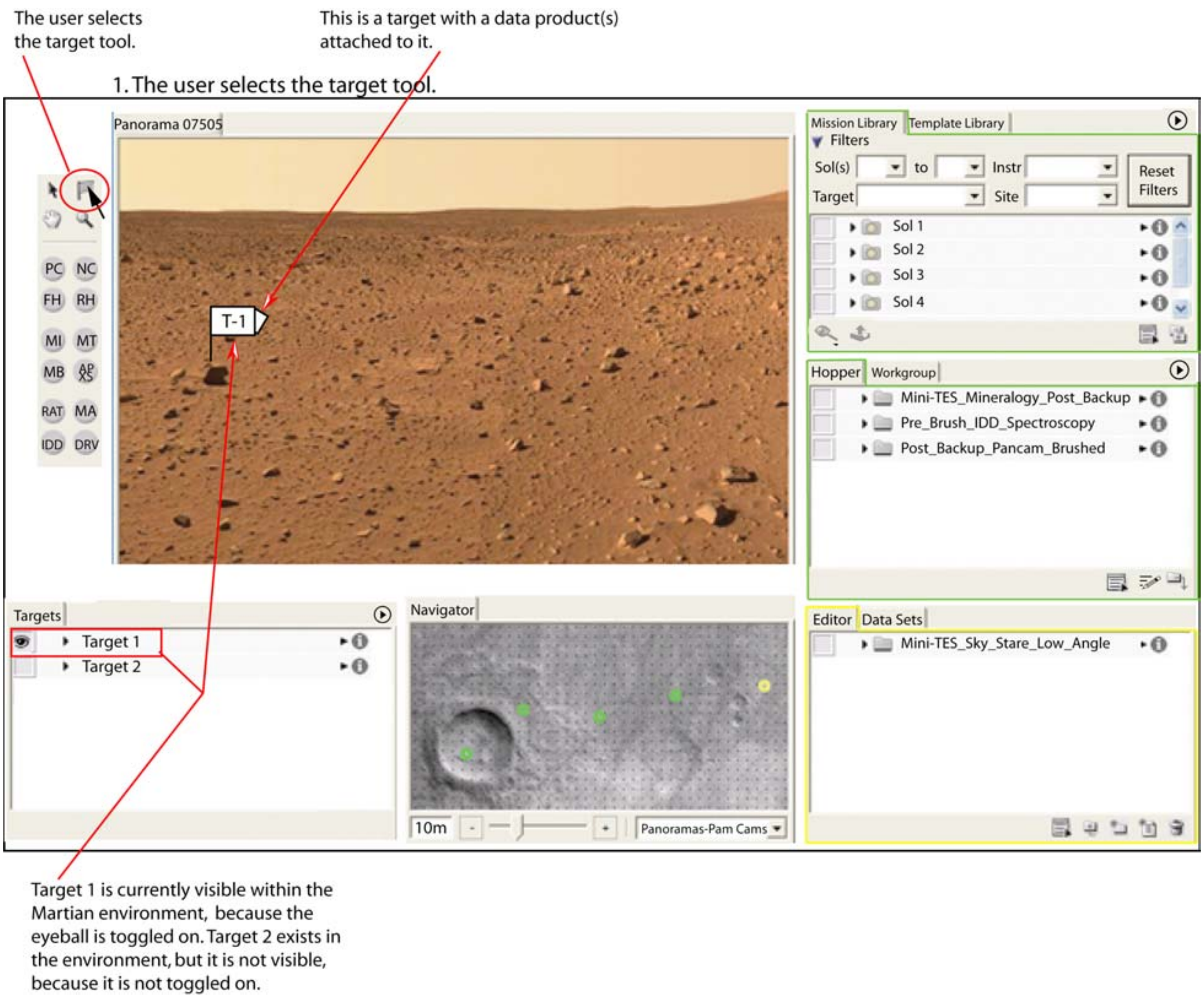
2. The user has adjusted their view to see a different portion of the navigation data product.



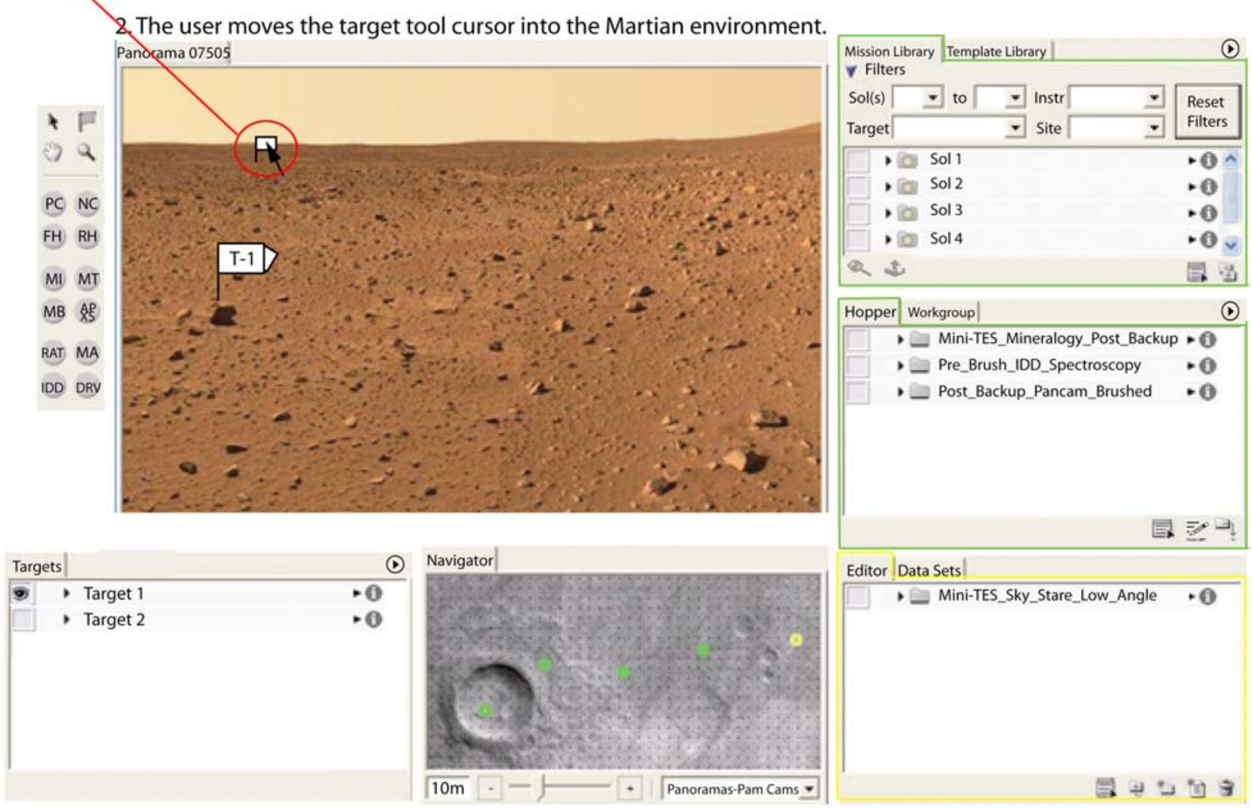
This is the navigation data product that is currently being viewed within the Martian environment.

Tools in the Interactive Martian Environment

Creating a Target



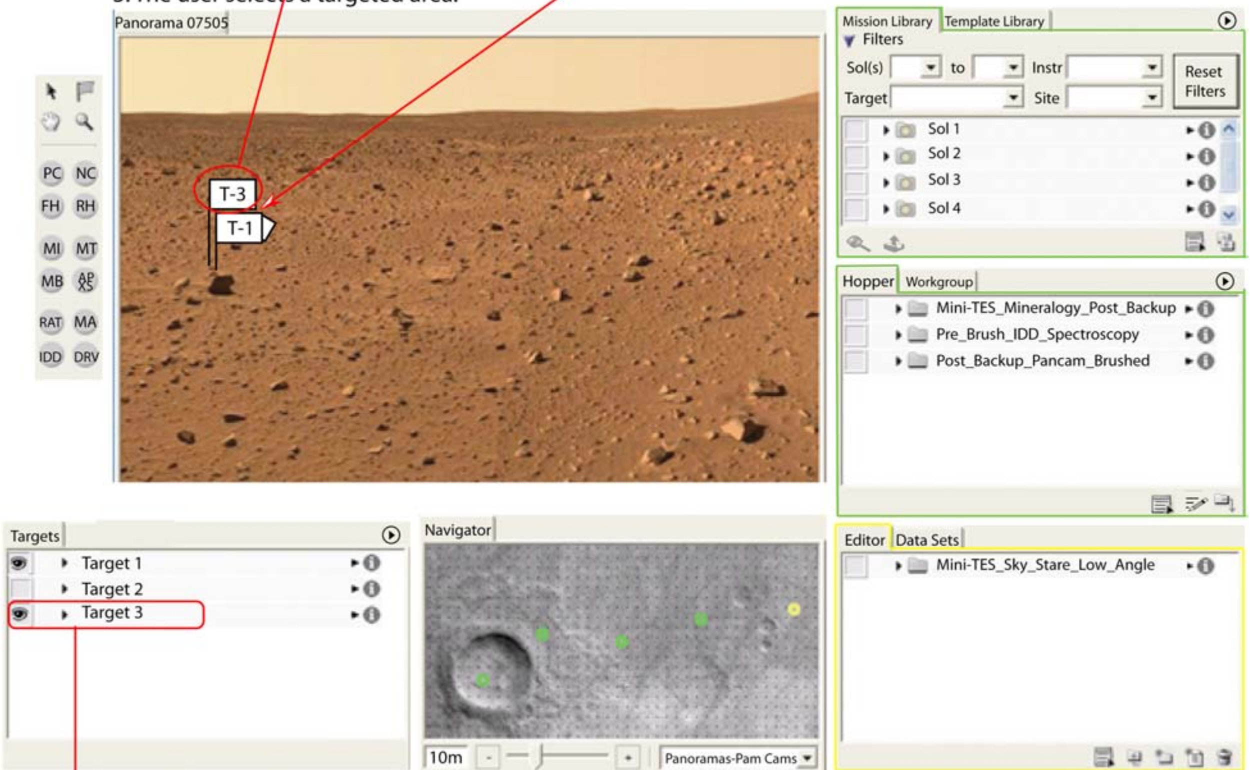
The cursor changes to indicate that the user has selected the target creation tool.



This flag does not have a data product associated with it.

The placement of Target 2 is close to the placement of Target 1; therefore, the target flags automatically stacked so that both flags would be visible.

3. The user selects a targeted area.



After creating a target in the Martian environment the user will also find the target listed in the target window. The default is "on"; however, here the user can control the visibility of their targets by toggling the eyeball on and off.

Future Considerations

We have only addressed a few of the many complex interactions that a remote science planning tool will include. We were unable to adequately design and test solutions for all of the design challenges within the context of our project. We have recommendations for two additional areas that should be addressed in preparation for remote science planning in future missions: resource visualization and ordering constraint application.

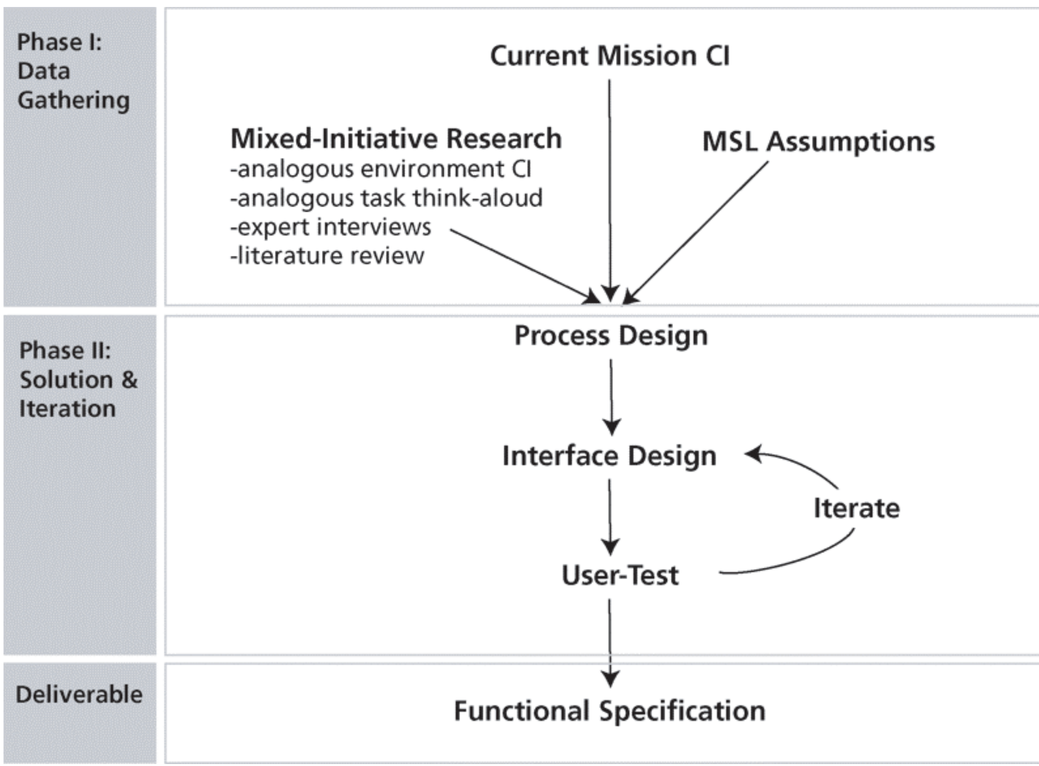
A key component of successful remote science operations is ensuring that all of the rover resource levels for metrics like power and memory are maintained. Currently in MER, scientists are specifying activities within resource budgets, and a large part of the final plan creation revolves around ensuring that all budget constraints are maintained. Future remote science planning tools will have to provide scientists with accurate resource estimates for activities, as well as accurate resource budgets for the current planning sol. We believe that the Hopper is the most suitable place for conveying resource information and visualization during the science activity planning process, since it is the only palette which contains a rough plan for the day, however the Mission Library may also provide information on overall resource usage for previously executed plans. We also suggest that activities contain resource budgets and estimates, based on user requests, (C-41, C-80, C-151). Providing the right level of resource information at appropriate points during the planning day and within the ideal context is a large, but important problem that we were unable to address.

One of our design challenges was to incorporate the functionality of Constraint Editor into SAP. We were able to provide scientists with the functionality to specify constraints on individual activities, but did not specify a mechanism for scientists to apply ordering constraints or to apply bulk constraints on individual activities. We intended to use the same interaction method that Constraint Editor uses, which is to allow the scientists to drag activities into graphical bins to complete the integration of Constraint Editor and SAP, but due to the technical complexity of prototyping this interaction we were unable to design and test this interaction. We recommend that the SAP developers import as much of the Constraint Editor functionality as possible to provide the same options for Constraint Editing in future missions as were available in the MER mission.

Our understanding is that there will be another team of human-computer interaction practitioners to continue the SAP redesign, and we are aware that these issues are important to the SAP developers, so we are confident that these issues will receive the attention they warrant.

Conclusions

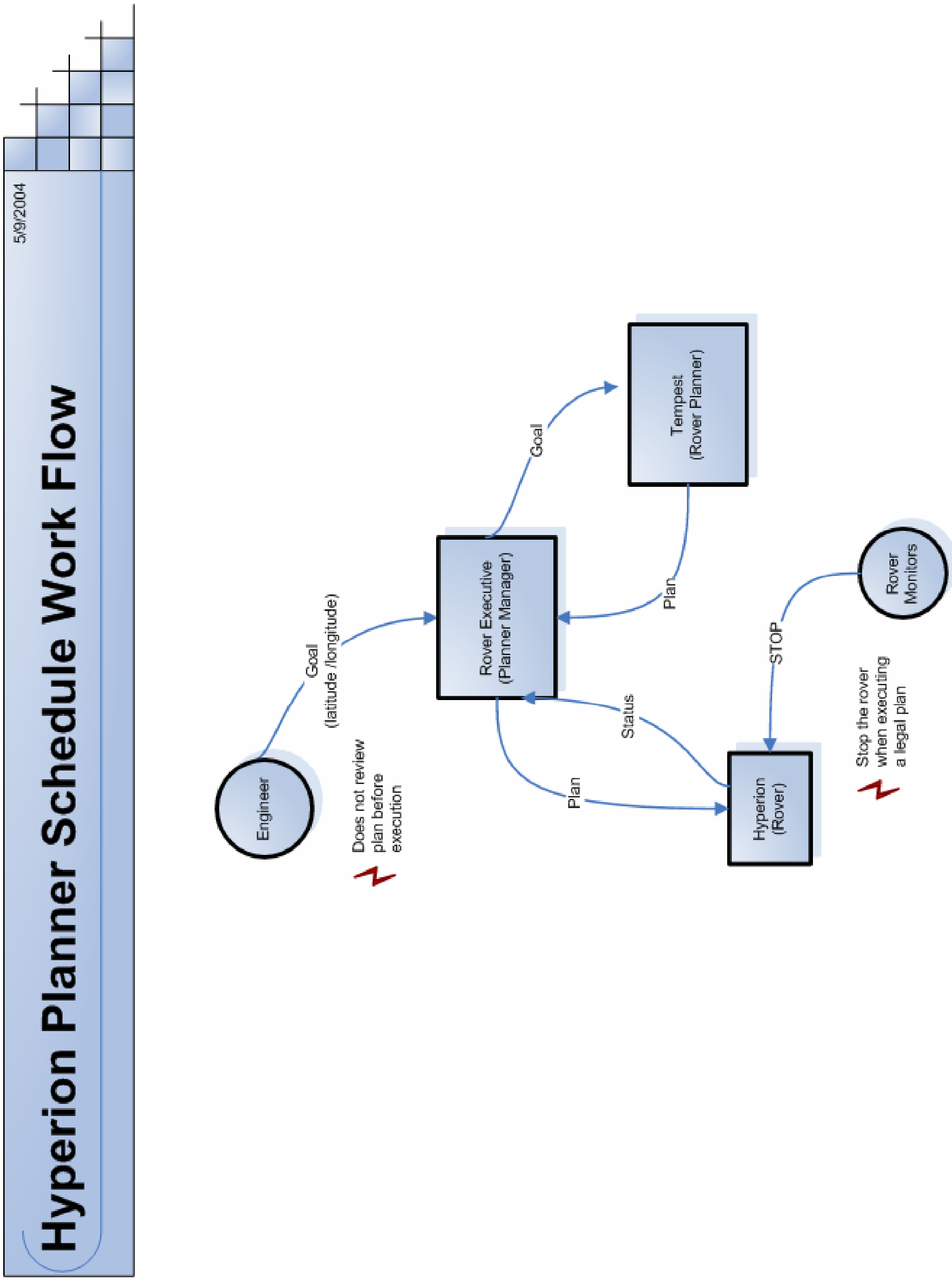
In this project, we were presented with the task of identifying breakdowns within the missed initiative planning process and then provided with the opportunity to address one of the breakdowns we identified in the redesign of a tool for remote science activity planning, SAP. In response to these challenges, we developed a remote science activity planning process and designed a tool to support that process, addressing the breakdowns we witnessed in remote science activity planning on the MER mission and SAP usage, and incorporating the design goals of the SAP developers to allow scientists to plan interactively within a Martian environment.

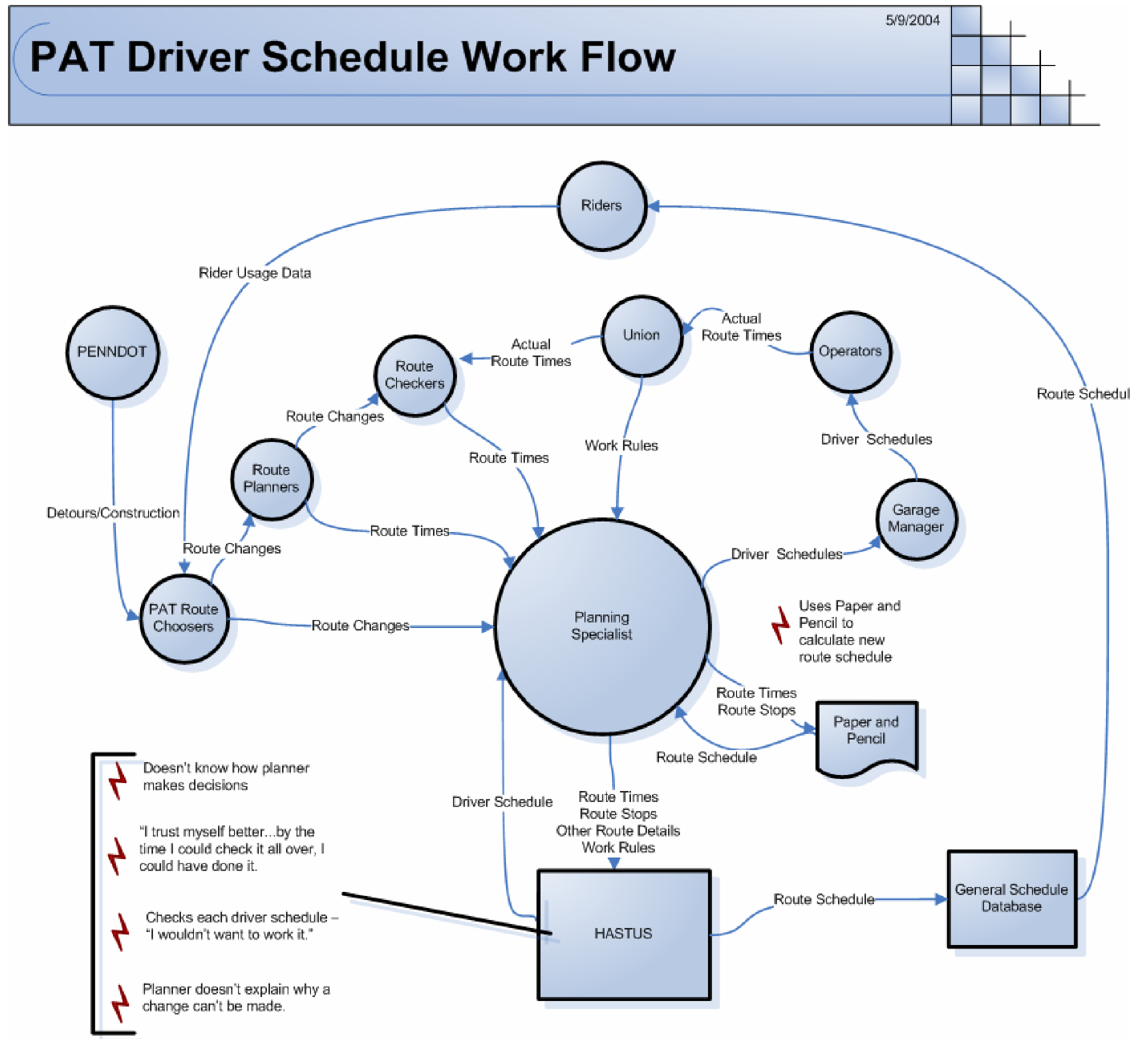


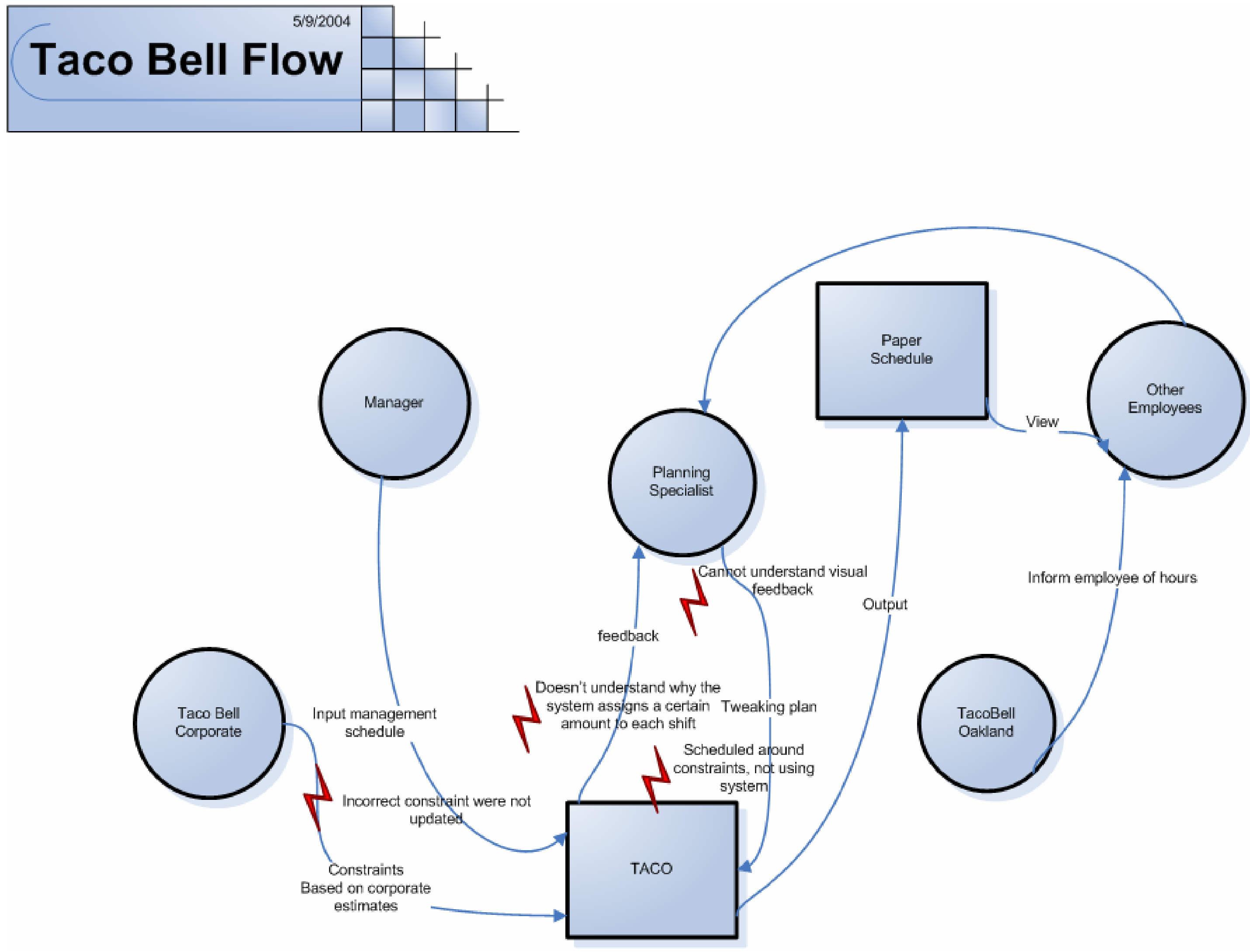
We researched mixed initiative planning within the context of MER mission operations, and other analogous contexts, in order to build our domain knowledge and uncover overarching breakdowns in missed initiative planning systems, then applied that knowledge to our process redesign and tool specification in an iterative design process. Our tool provides scientists with one application for the scientists who will interact with future robotic planetary explorers to collaborate during distributed operations, to track and review science data, and to create and constrain rover activities in an interactive environment, capturing and conveying their intent for successful remote science operations.

Successful remote science operations and the tools necessary to support them cover a much broader area than the scope of this project, but we believe that we have addressed some important issues in this domain to improve remote science activity planning for future planetary exploration missions.

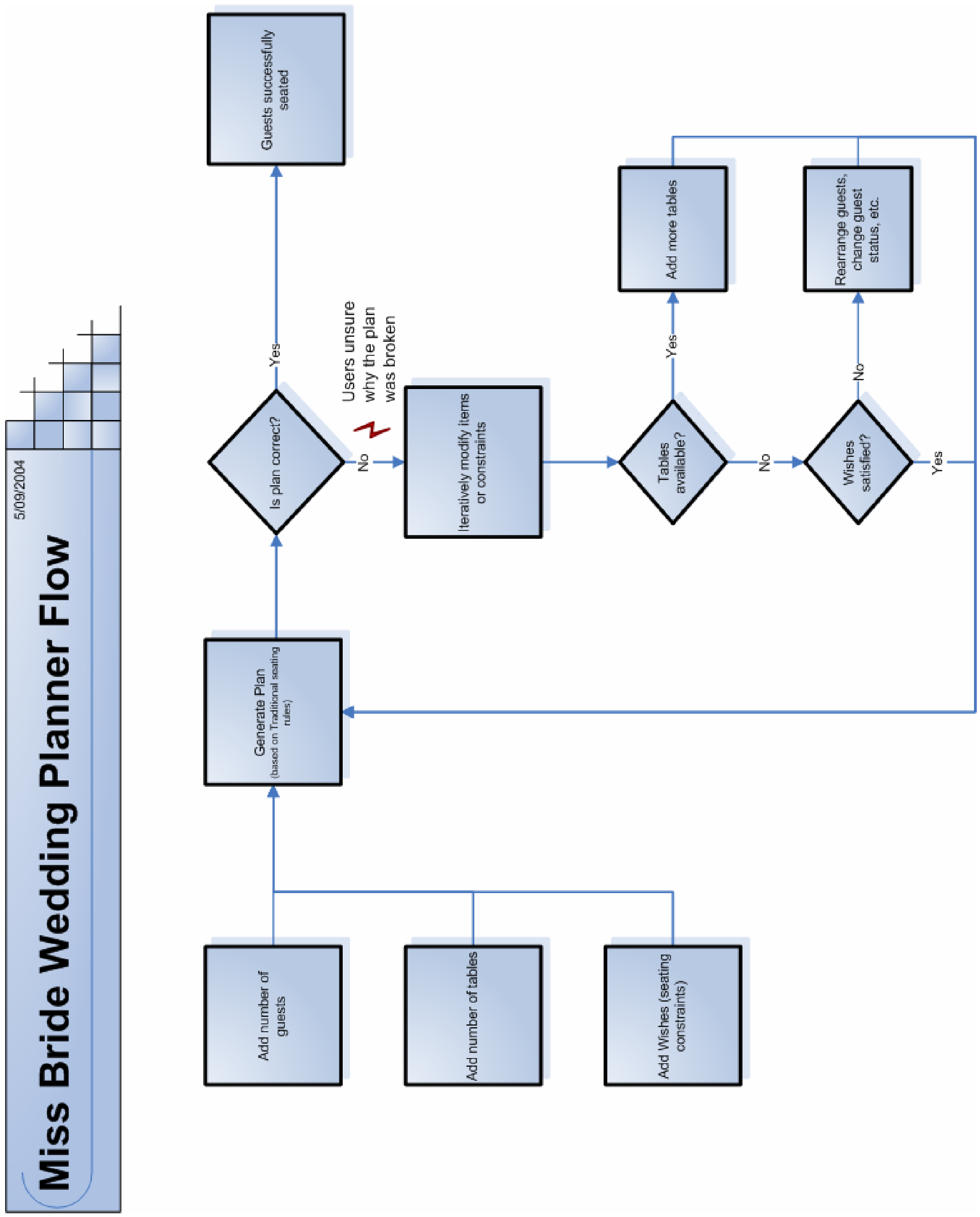
Appendix A – Mixed Initiative Planning Models



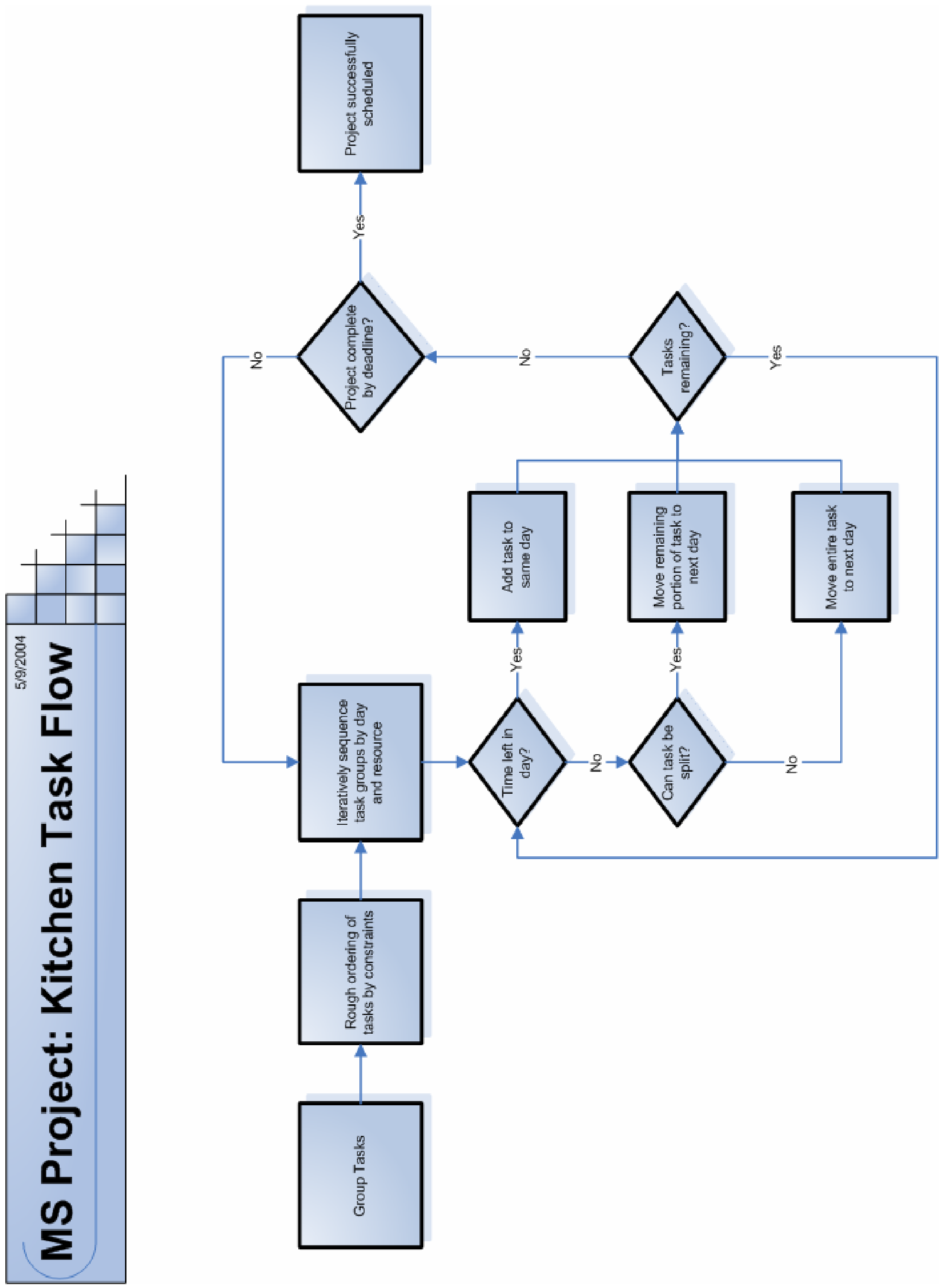

5/9/2004
PAT Driver Schedule Work Flow
Riders
Rider Usage Data
PENNDOT
Detours/Construction
PAT Route Choosers
Route Changes
Route Planners
Route Changes
Route Checkers
Actual Route Times
Union
Actual Route Times
Operators
Route Times
Work Rules
Route Times
Route Changes
Planning Specialist
Driver Schedules
Garage Manager
Driver Schedules
Route Schedule
Uses Paper and Pencil to calculate new route schedule
Route Times Route Stops
Paper and Pencil
Route Schedule
Driver Schedule
Route Times Route Stops Other Route Details Work Rules
HASTUS
Route Schedule
General Schedule Database
Doesn't know how planner makes decisions
"I trust myself better…by the time I could check it all over, I could have done it.
Checks each driver schedule – "I wouldn't want to work it."
Planner doesn't explain why a change can't be made.



5/9/2004
Taco Bell Flow
Manager
Planning Specialist
Paper Schedule
Other Employees
View
Taco Bell Corporate
Input management schedule
Incorrect constraint were not updated
Constraints Based on corporate estimates
feedback
Cannot understand visual feedback
Output
Inform employee of hours
Doesn't understand why the system assigns a certain amount to each shift
Tweaking plan
Scheduled around constraints, not using system
TACO
TacoBell Oakland

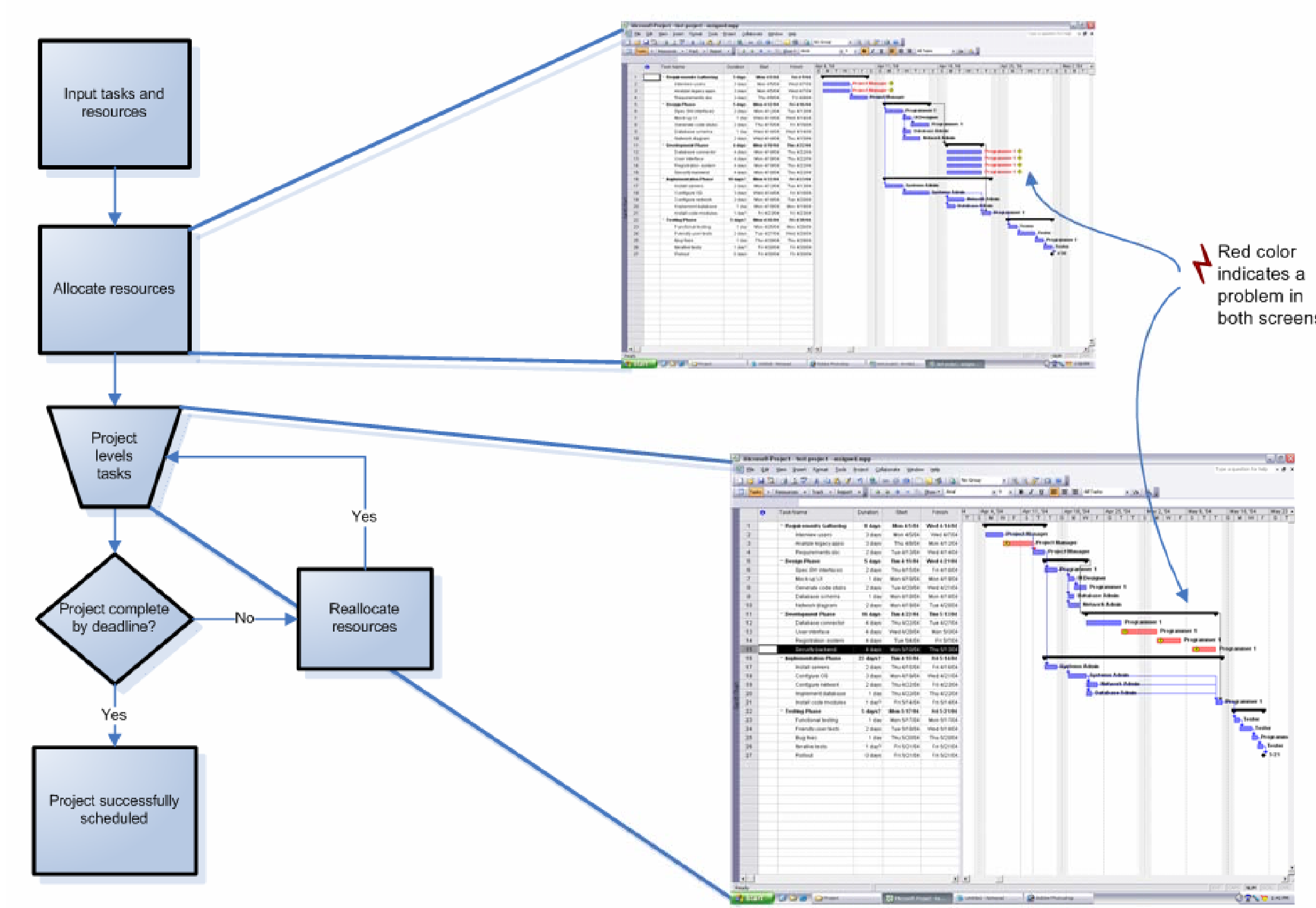


Miss Bride Wedding Planner Flow
5/09/2004
Add number of guests
Add number of tables
Add Wishes (seating constraints)
Generate Plan (based on Traditional seating rules)
Is plan correct?
Yes
Guests successfully seated
No
Users unsure why the plan was broken
Iteratively modify items or constraints
Tables available?
Yes
Add more tables
No
Wishes satisfied?
No
Rearrange guests, change guest status, etc.
Yes


MS Project: Kitchen Task Flow
5/9/2004
Group Tasks
Rough ordering of tasks by constraints
Iteratively sequence task groups by day and resource
Time left in day?
Yes
Add task to same day
No
Can task be split?
Yes
Move remaining portion of task to next day
No
Move entire task to next day
Tasks remaining?
Yes
No
Project complete by deadline?
No
Yes
Project successfully scheduled

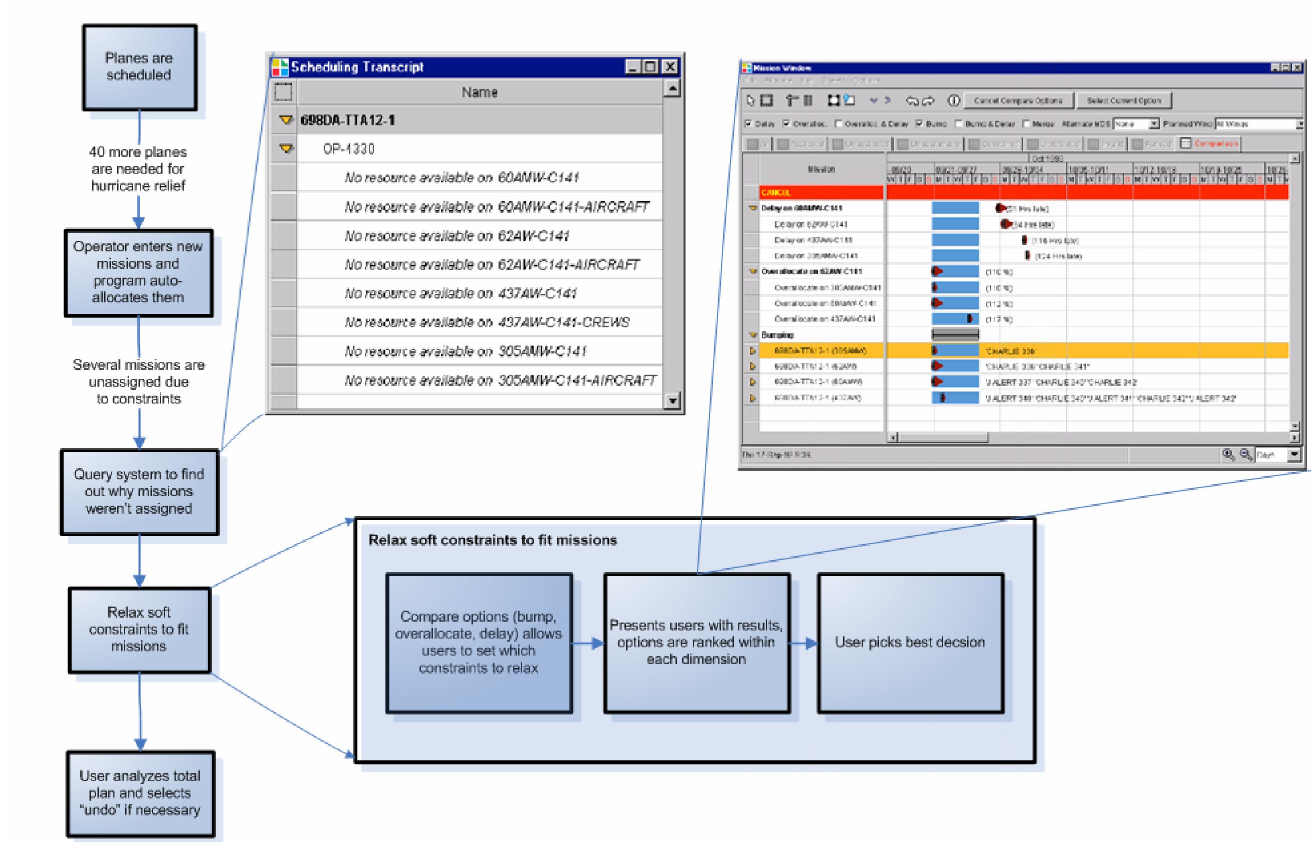
5/9/2004

MS Project: Software Task Flow



5/9/2004

AMC Barrell Allocator – Steve Smith & Laurence Kramer



Appendix B – JPL Observation 1Subset of Notes

Interviews and Observations

Scientists (4): 2 minerologists, 2 geologists

PULs (4) : 2 Pancam, 1 Minites, 1 APXS (and more)

TAPs (2): 2 SAP developers

Rover Planners (2): 1 Lead Developer of RSVP, 1 Rover onboard software developer

SAP User Roles: Scientists

Athena Science Team Members

Previously defined role - Review data in downlink browser, Create observations and activities in uplink browser

New extended mission roles - Place observations and activities in to SAP in sequence for plan

Relying on templates more as mission progresses, both from previous sols and from templates

SAP User Roles: Payload Uplink Specialists

All PULs - Aide scientists in creating observations and activities

Review observations and activities created by scientists and check parameters, Assign and verify seqIDs

Some PULs - Make scientific intent more explicit in SAP and in other tools, Obtain science intent information primarily by talking to scientists and attending all meetings, less emphasis on SAP notes

SAP User Roles: TAPs

Previously defined role - Obtain unordered observations and activities from SAP to constrain in Constraint Editor and plan in M/apgen

Extended mission role - Obtain detailed plan, Infer order of observations from their presentation in SAP, Verify constraints set by scientists

Extended Mission Process

Pre-Science Context Meeting

Small group of scientists create a very detailed plan and enter into SAP

Observations are place in temporal order in SAP

Skeleton plan is created in Excel template

Science Context Meeting

LTP ppt presentation similar to Primary Mission (but not always)

Presentation of detailed plan in SAP and/or Excel Skeleton

Sometimes combined with SOWG meeting

SOWG Meeting

Similar to primary mission, but with less discussion and less prioritizing

Constraint Editing and Planning

TAP uses monolith constraint to tightly constrain observations and/or activities based on order presented in SAP

Tight constraints essentially create plan before entry in m/apgen, but user preferences are captured this way

Activity Plan Tagup

TAP, SOWG chair, SOWG documentarian payload specialists review first iteration of plan

Constraint Editing and Planning

TAP revises plan based on Activity Plan Tagup

Final Activity Plan Review

TAP, SOWG chair, SOWG documentarian payload specialists review final iteration of plan in Mapgen and RSVP

Key Differences from Primary to Extended

- Operations are on Earth time
- Operations used to focus on rover cycle, now sometimes you have to plan before resource and naviagtion data has been obtained (I.e. restricted sol: can't do a planned drive, only hazard avoidance)
- Plan is well defined early in the day
- Smaller group of stakeholders present
- The LTP is defined in much more detail
- Geologist: "Now, we never say 'What am I going to do today?"
- Planning happens much more quickly
- TAP completes his job in 1/3 of the time
- Planning is much more templatized
- Use both from previous sol plans and from templates like the drive quartet

Potential reasons

- More honed team, more experienced, getting better at creating valid plans
- Easier, faster, valid templates are reliable
- Strategic planning using a strategy of exploration (ex. Drive Quartet racing to Columbia Hills)

Which process to support?

Primary Mission

Participants still learning about the process

Participants living on Mars time

Long science planning day

Plan is less structured earlier in the day, greater potential for oversubscription

Extended Mission

Participants are more confident and experts in process

Participants living on Earth time

Compressed science planning day

Plan is well defined earlier in the day, oversubscription less likely

Support Both!

Each process will probably occur in future missions, and should be supported

Primary mission tools will help to support other research projects that use SAP, as their research cycles are more analogous to primary mission.

You don't know if Extended Mission will occur!

One scientist views both processes as the same to SAP

What does this mean to us?

Hopper functionality and design must support both templatized and non-templatized plans.

Plan templates must be easy to create, find, understand, and use.

Previous sol plans must be easy to find, understand, and re-use.

Parameter checking must be facilitated to ensure that subtle changes are captured and verifiable

Example: Make sure that the observation from the previous sol you're copying is the one that was sent to the rover and not the less developed version.

Extended Mission Science Intent

Most communication is still verbal

SAP observation notes often ignored , it's a long process to read them, and they're not always valid because they weren't updated from template or previous sol plan

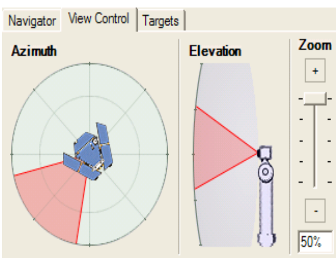
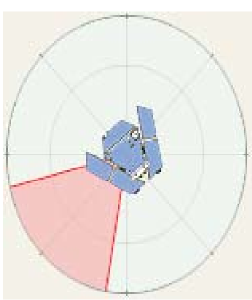
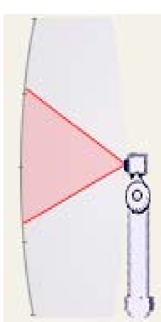
Information passed on scraps of paper

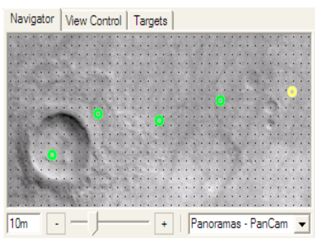
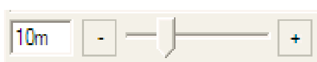
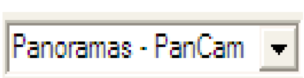
Recommendation: allow access to seqIds so that they are more readily available to PULs

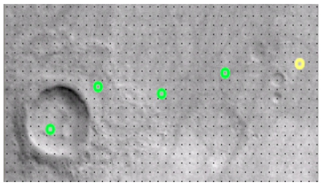
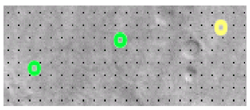
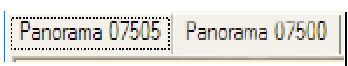
Appendix C – Data Points from JPL Trips 2, 3, and 4

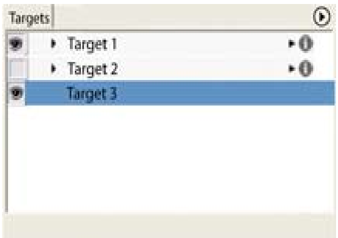
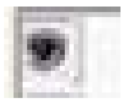
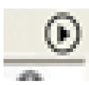
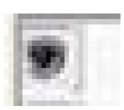
<See electronic file>

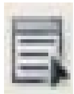
Appendix D – Interaction Specification

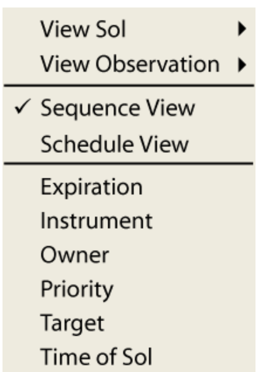
Picture	Component	Primary Mode of Interaction	Accelerator
	**Toolbar**	**Single Click -** The user can select any one of these tools and then apply them to the Martian environment.	N/A
	**View Control**		
	Red-Triangle within the Azimuth of View Control	**Click and Drag -** The user can click on the red triangle and drag it to adjust the view within the Martian environment.	Placing cursor on the left or right edge of the Martian environment also allows the user to navigate. The azimuth view will update.
	Red-Triangle within the Elevation of View Control	**Click and Drag** - The user can click on the red triangle and drag it to adjust the view within the Martian environment.	Placing cursor on the top or bottom edge of the Martian environment also allows the user to navigate. The elevation view will update.

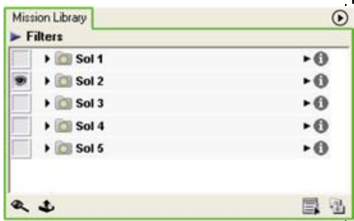
Picture	Component	Primary Mode of Interaction	Accelerator
	Zoom slider within View Control	**Click and Drag** -The user can adjust the slider by selecting the handle with the cursor and dragging it. Releasing it completes the view adjustment. Moving the slider up will zoom into the Martian environment. Moving the slider down will zoom out of the Martian environment.	**Text Entry** - The user can enter the exact number into the text field below the slider. They may also single click on the "+" or "-". **Single Click** - The user can single click the plus, "+", and minus, "-", buttons above a below the slider to adjust the zoom a single increment or decrement at a time
	**Navigator**		
	Zoom slider within the Navigator	**Click and Drag** - The user can adjust the slider by selecting the handle with the cursor and sliding it. Releasing it completes the view adjustment. Moving the slider right will zoom into the overhead Navigator view. Moving the slider left will zoom out of the overhead Navigator view.	**Text Entry** - The user can enter the exact number into the text field below the slider. They may also single click on the "+" or "-". **Single Click** - The user can single click the plus, "+", and minus, "-", buttons above a below the slider to adjust the zoom a single increment or decrement at a time
	Navigation data-product filter	**Single Click** - The user can single click on the down arrow, and the menu will drop down. The user can then select the data product by which they would like to filter.	**Text Entry** - The user can also type data product by which they would like to search into the text field.

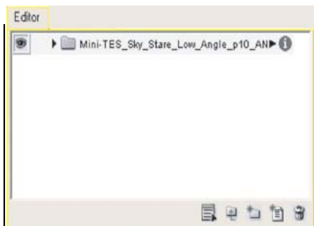
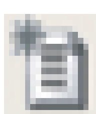
Picture	Component	Primary Mode of Interaction	Accelerator
	Navigation overhead view	The user can place their cursor on any edge of the view and they will be able to navigate in that direction.	N/A
	Navigation data products	**Single Click** - The user can single click on any circle in order to open the navigation data product within the Marian environment Viewer.	The user can also open navigation data products via single click selection within the Mission Library.
	Tabs (Navigator palettes)	**Single Click** - Single click on one of the tabs to change component selection.	N/A
	**Martian Environment**	Placing cursor on the left or right edge of the Martian environment also allows the user to navigate. The azimuth view will update.	**Single Click and Drag** - The user can click on the red triangle and drag it to adjust the view within the Martian environment.
	Data Product	**Single Click -** Allow the user to access a pull down with open and export options.	N/A
	Tabs (Martian environment)	**Single Click -** Single clicking allows the user to change panoramas.	N/A

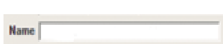
Picture	Component	Primary Mode of Interaction	Accelerator
	**Target Window**		
	Eyeball within the target window	**Single Click -** Toggles the eyeball on or off to controls the view of targets in the Martian environment.	N/A
	Palette menu, filter	**Single Click** - Displays a drop down which can filter between all targets, and those local to the panoramic data product that is currently being view.	N/A
	Turn-buckle	**Single Click** - Displays what observations and activities are associated with the target.	N/A
	Information	**Single Click** - A Single click will drop down additional information about the target.	N/A
Non-Immersive: across components			
	Eyeball within the windows	**Single Click -** Toggles the eyeball on or off to controls the view of targets in the Martian environment.	N/A
	Information	**Single Click** - A Single click will drop down useful information about an observation and/or activity quickly.	N/A
	Drop-down menu	**Single Click** - Displays a drop-down menu containing palette view options.	N/A

Picture	Component	Primary Mode of Interaction	Accelerator
	Properties shortcut	**Single Click** - a non editable (Mission Library and Hopper) or editable (Editor) properties window opens. The icon de-ghosts when an observation or activity is selected.	N/A
	Observation Turn buckle	**Single Click -** Allows the user to open or collapse an observation to view or not view it's activities.	N/A
	**Hopper**		
	Quick Edit icon	**Single Click** - The system places the selected item in the Editor and opens a editable properties window. Once the window is closed the item is placed back in the Hopper. The icon de-ghosts when an observation or activity is selected.	N/A
	Check-in Editor	**Single Click** - A copy of the selected observation or activity and places it into the Editor. The icon de-ghosts when an observation or activity is selected.	N/A

Picture	Component	Primary Mode of Interaction	Accelerator
	Ordering constraint button	**Single Click** - When an ordering constraint is placed on an observation or activity an ordering constraint toggle button is displayed. Toggling it "on" shows a series of arrows that show how that observation or activity is constrained (by order) to other observations or activities	N/A
	inside the drop down menu: "View Sol"	**Single Click** - The user is presented with a list of sols in a pull down menu.	N/A
" "	inside the drop down menu: "View Observation"	**Hover Over** - The user is presented with two options for viewing what observations are displayed in the hopper. The user can either view ALL the observations or only the ones assigned to their science group.	N/A
" "	inside the drop down menu: "Sequence View"	**Single Click** - The user changes the view of the Hopper to the Sequence View.	N/A
" "	inside the drop down menu: "Schedule View"	**Single Click** - The user changes the view of the Hopper to the Schedule View.	N/A
" "	inside the drop down menu: Filter	**Single Click** - Single clicking selects or deselects. Numerous filters can be selected at the same time.	N/A

Picture	Component	Primary Mode of Interaction	Accelerator
	**Mission Library**		
	Turn-buckle: Mission Library Filter	**Single Click** - Allows the filters to be visible within the Mission Library.	N/A
	Filter dropdowns	**Single Click -** This reveals a drop-down with possible options by which the user can filter.	**Text Entry** - The user can also type a valid sol, target, site, or instrument into the proper field.
	Reset Filters	**Single Click** - Allows the user to clear all of the filter fields.	N/A
	Drop-down menu	**Single Click -** The user can access the Advanced Search menu by single clicking on the menu.	N/A
	Check-in Editor	**Single Click -** The icon de-ghosts when a sol observation or activity is selected. Once the icon has been pressed, a copy of the selected sol, observation or activity and places it into the Editor.	N/A
	View in SAP	**Single Click** - The icon de-ghosts when a data product with a image associated with it is selected. The data product opens in the 2D environment.	Double clicking the product within the Mission Library can also open it.

Picture	Component	Primary Mode of Interaction	Accelerator
	Export	**Single Click** - The icon de-ghosts when a data product with a image associated with it is selected. After single clicking, dialogue box appears.	N/A
	**Activity Editor**		
	Check-in Hopper	**Single Click** - The icon de-ghosts when an observation is selected. After single clicking the icon, the selected observation and the information associated with is removed the Editor and placed in the Hopper.	N/A
	New Observation	**Single Click -** Provides the user with the ability to create a new observation. After single clicking, the observation properties window opens allowing the user to enter information about the observation.	N/A
	New Activity	**Single Click -** Provides the user with the ability to create a new activity. After single clicking, the activity properties window opens allowing the user to enter information about the observation.	N/A

Picture	Component	Primary Mode of Interaction	Accelerator
	Trash	**Drag and Drop -** The user can drag the activity or observation to the trash and drop it to dispose of it.	**Single Click** - After the user has selected an activity or observation, they can single click the trash can to throw the activity away.
	**Activity Editor**		
	Tabs	**Single Click -** Single clicking the tabs allows the user to change between General, Parameters, and Constraints information.	N/A
	Pull-downs	**Single Click** - This gives the user access to Instrument, Seq ID menu, Uplink and Downlink priority menus.	**Text Entry** - The user can also type a valid instrument, Seq ID, Uplink or Downlink priority into the proper field.
	Purpose and Notes fields.	**Text Entry** - The user can make their intent explicit in text form.	N/A
	Activity Name	**Text Entry -** The user can type the name of the activity; though, it might pre-populated this field.	N/A