A Retrospective Snapshot of the Planning Processes in MER Operations After 5 Years

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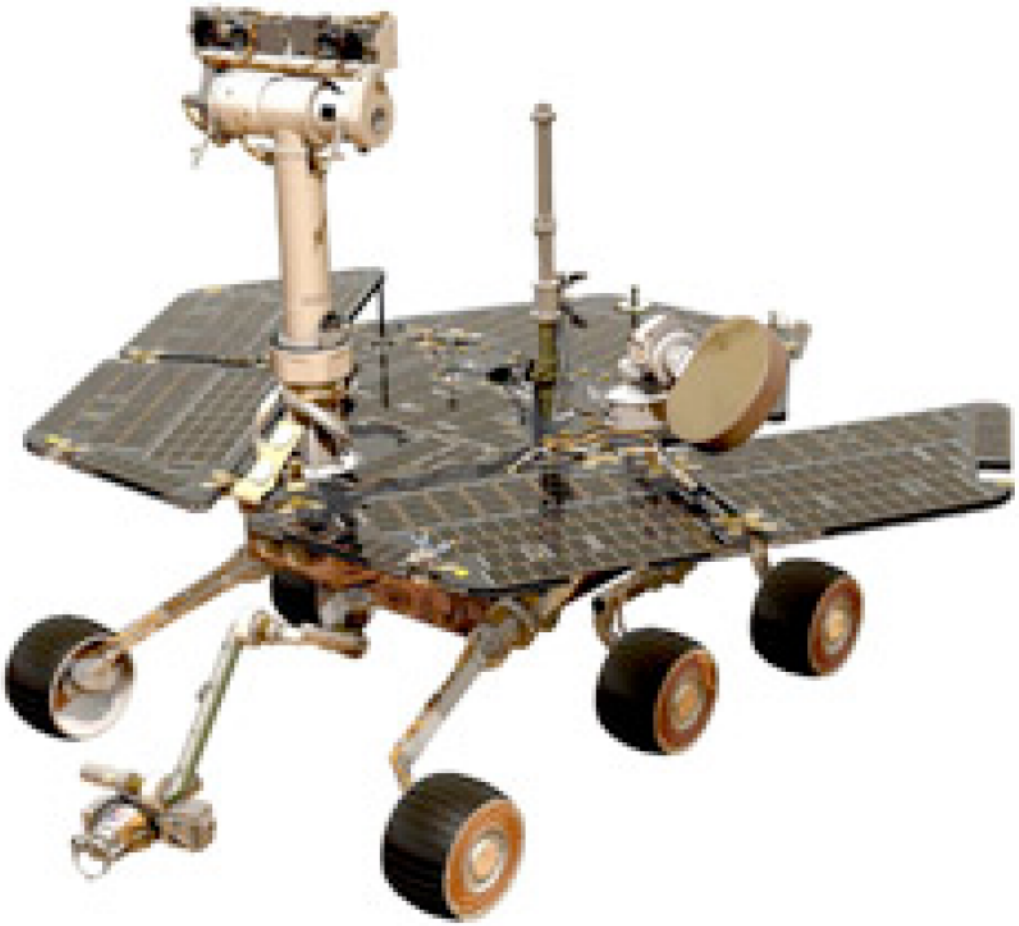
Motivation

- To document all of the planning processes that happen on a surface operations mission, e.g. the Mars Exploration Rovers (MER).
- To show how all of these planning processes interact.
- To illustrate how the use of tools evolves.

Outline

- Properties of the Mars Explorer Rovers (MER)
- High level view of an operations shift
- Determining activities
- Generating the activity plan
- Building the master and submaster sequences
- Building Mob/IDD sequences
- Integrate and test the final upload
- Conclusions

Mars Exploration Rover



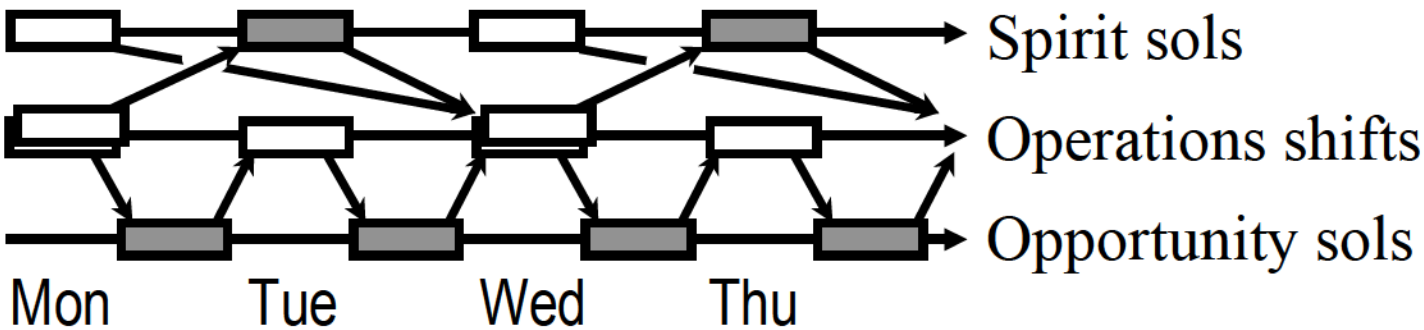
Exogenous Events On Mars

- 02:00±0:30 – MRO AM over-flight
- 03:00±0:30 – ODY AM over-flight
- 06:30±0:20 – Dawn
- 11:30±2:00 – Uplink time
- 14:00±0:30 – MRO PM over-flight
- 15:00±0:30 – ODY orbiter PM over-flight
- 18:56±0:20 – Dusk

Exact times vary from sol to sol depending on Season, DSN scheduling, and orbit geometries of relay orbiters

Sols on Mars vs Operations Shifts

- **A sol on Mars is 40 minutes longer than a day on Earth**
- **Switching from 24/7 Mars time to 8/5 Earth time operations resulted a planning multiple sols per operations shift**



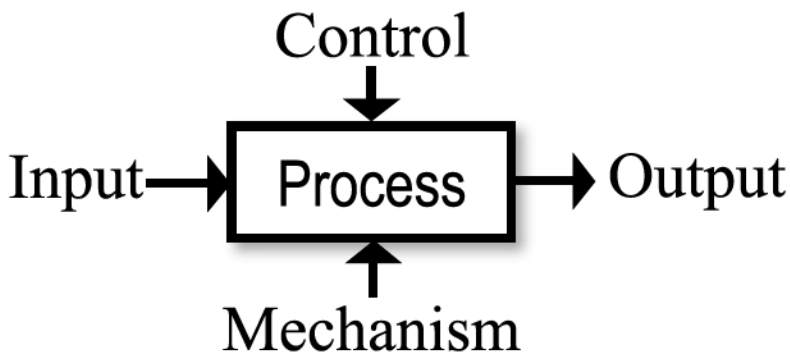
- **Friday shifts typically cover 2 or 3 sols to cover the full weekend**

Planning Activities on MER

- **Strategic**
  - Planning communications passes
  - Planning operations shifts and staff assignment
  - Long term science planning
- **Tactical**
  - Skeleton Planning
  - Observation Planning
  - Activity Planning
  - Activity Plan Annotation
  - Master Sequence Editing
  - Mob/IDD Planning
  - Plan Integration and Test

IDEF0 Formalism

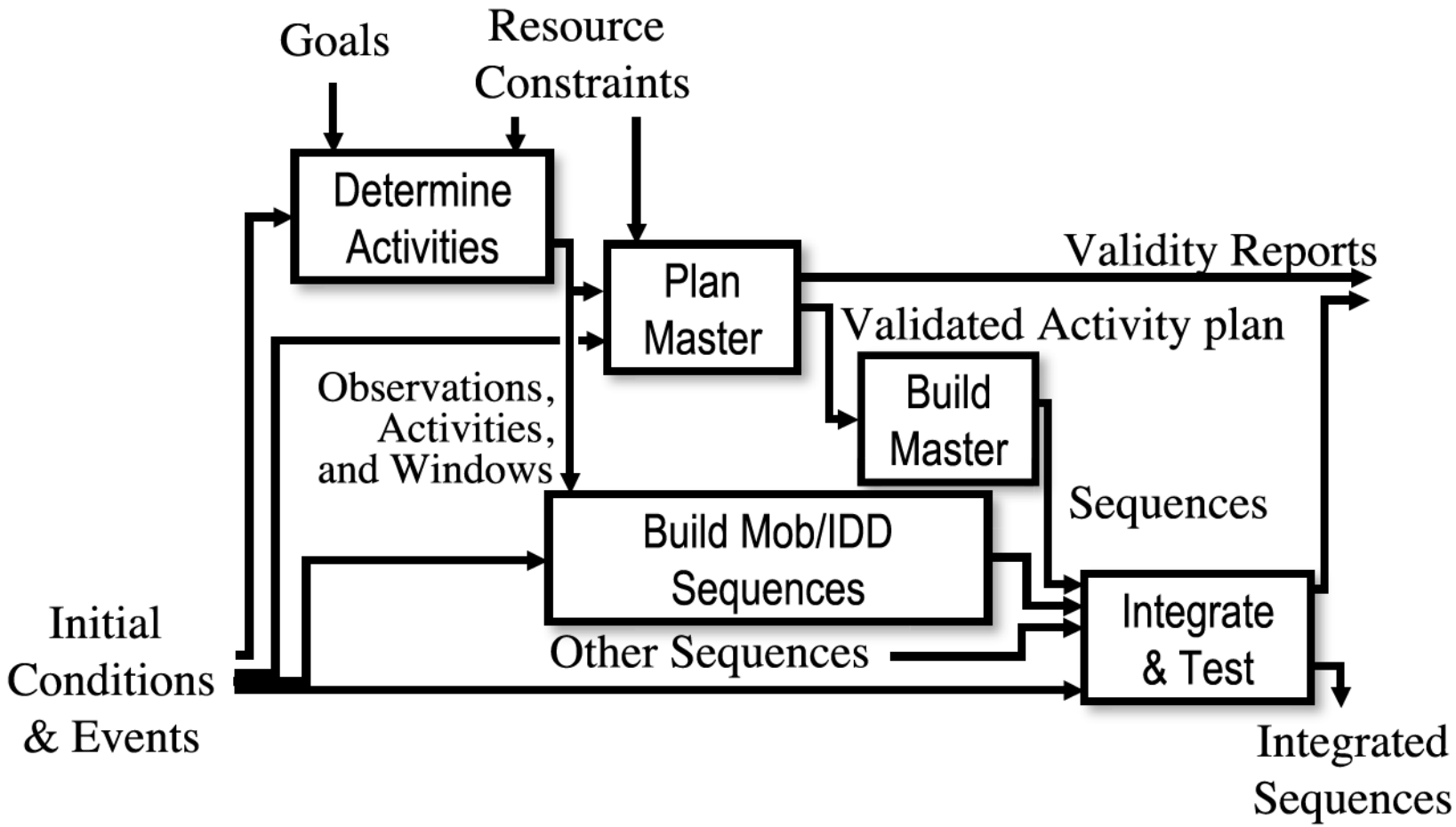
- **Purpose: to illustrate process interactions**
- **Graphical Syntax:**



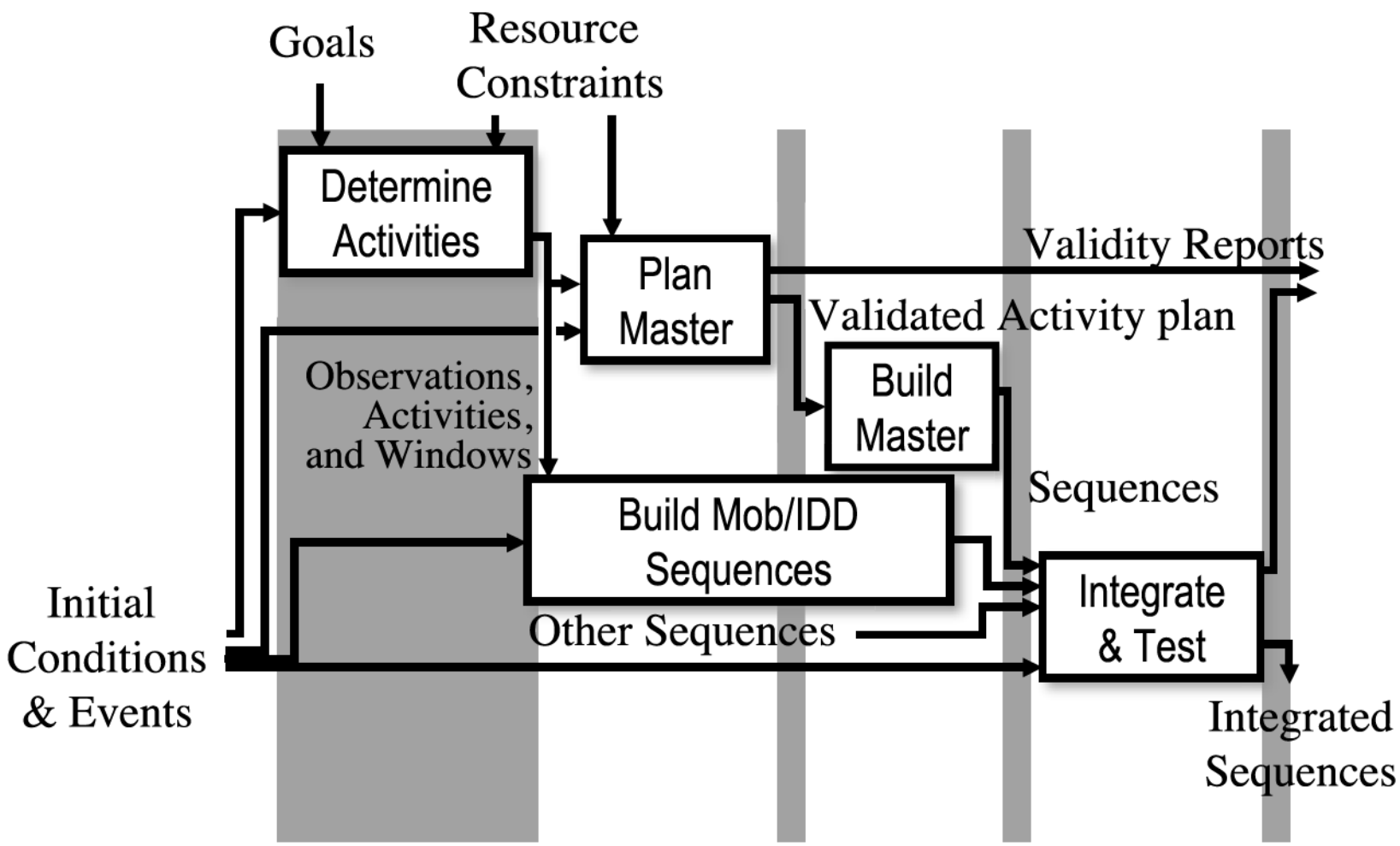
- **Input - Data from another process**
- **Control - Issues affecting a process**
- **Mechanism - An editor supporting the process**
- **Output - Data that feeds into another process**

An Operations Shift

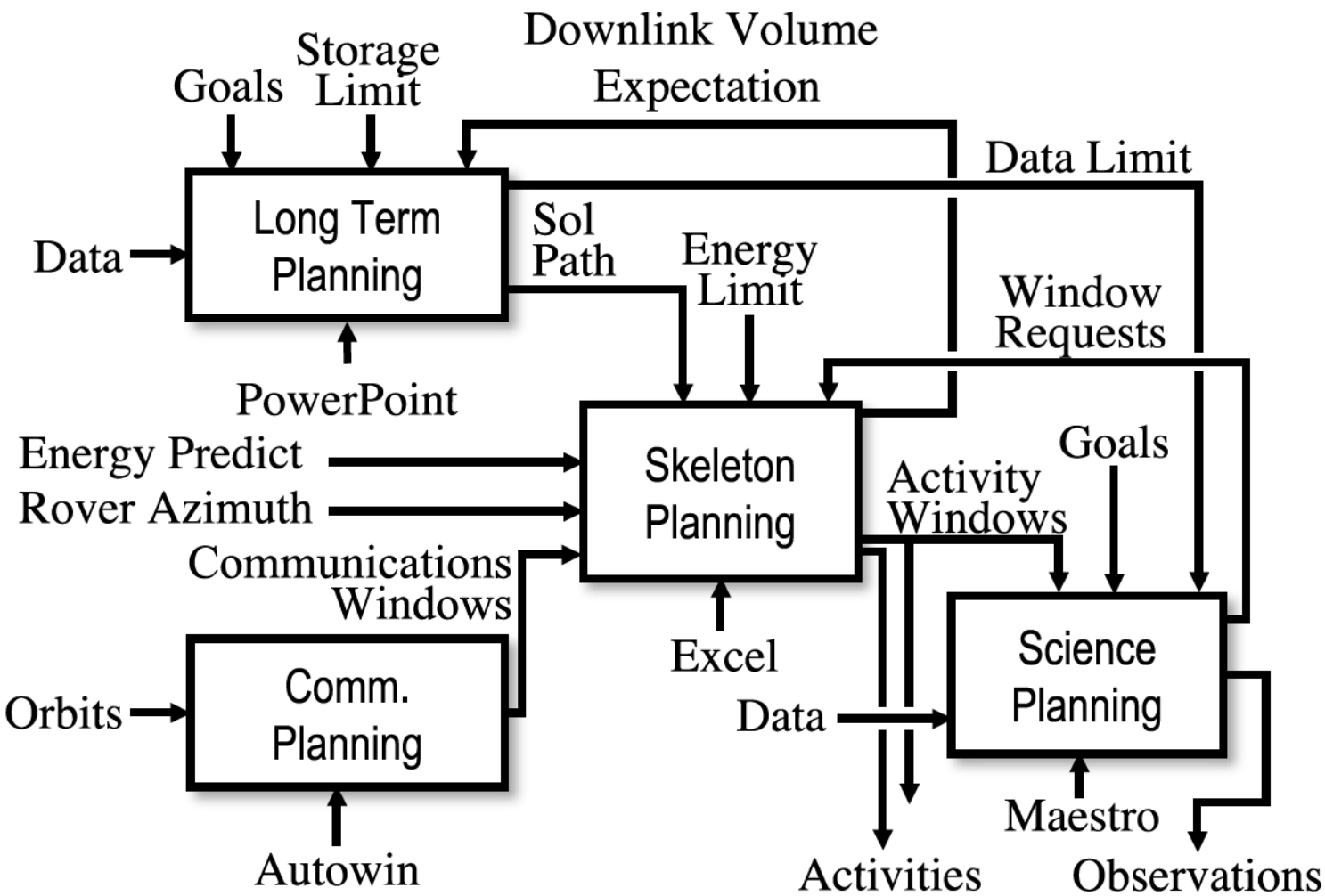
- **The daily planning process on MER**



Meetings


Goals
Resource Constraints
Determine Activities
Plan Master
Validity Reports
Validated Activity plan
Observations, Activities, and Windows
Build Master
Sequences
Build Mob/IDD Sequences
Other Sequences
Integrate & Test
Initial Conditions & Events
Integrated Sequences

Determine Activities



Skeleton Planning (Excel)

- **Inputs: communications windows, rover azimuth, expected energy, and expected downlink volume**
- **Outputs: Engineering activities and activity windows**

Sol Path →

	A	B	C	D
1	Opportunity: Sol 1839		Energy Predict: 2.9 Ahr	
2				
3	Remote Sensing			
4		Start	End	DUR
5	HGA	10:05	10:35	0:30
6	Eng Keepout	10:37	10:50	0:13
7	Comm Blip	10:39	10:44	0:05
26	Remote Sensing	10:50	11:50	1:00
27	BCB History	11:48	11:50	0:02
28	Margin + Cleanup	11:50	12:02	0:12
30	NAP	12:02	15:56	3:54
34	ODY Prep	15:56	16:04	0:08
35	RUHF (66Mb @ 144 az & 128k)	16:04	16:19	0:15
41	NAP	16:26	18:18	1:51
61	Wake for Deep Sleep	18:18	18:30	0:12
62	Deep Sleep	18:30	7:00	12:30
65	NAP	7:00	9:55	2:55
84	AM Science	9:55	10:19	0:24
85	HGA	10:00	10:20	0:20
86	Handover	10:22		

Window Adjustments

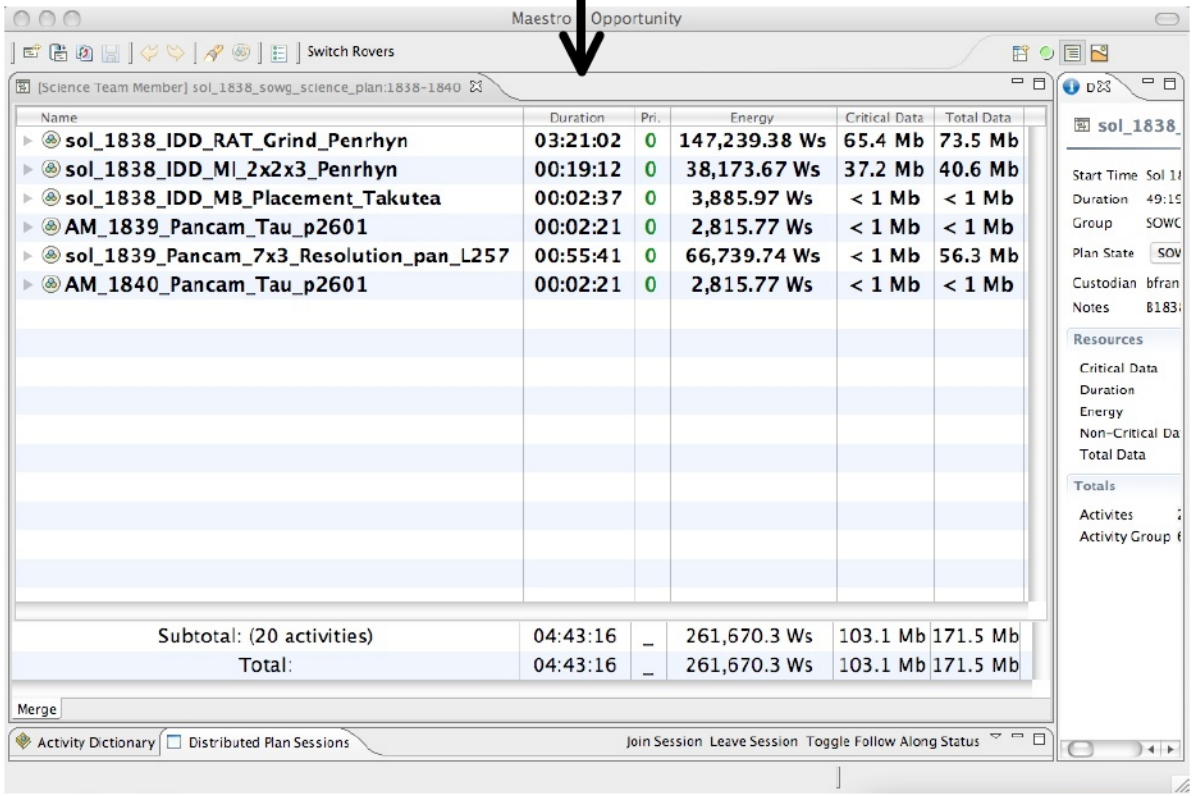
Science Planning (Maestro)

- **Inputs: Past observations (data) that motivate new observations**
- **Outputs: Observations**

Activity Windows

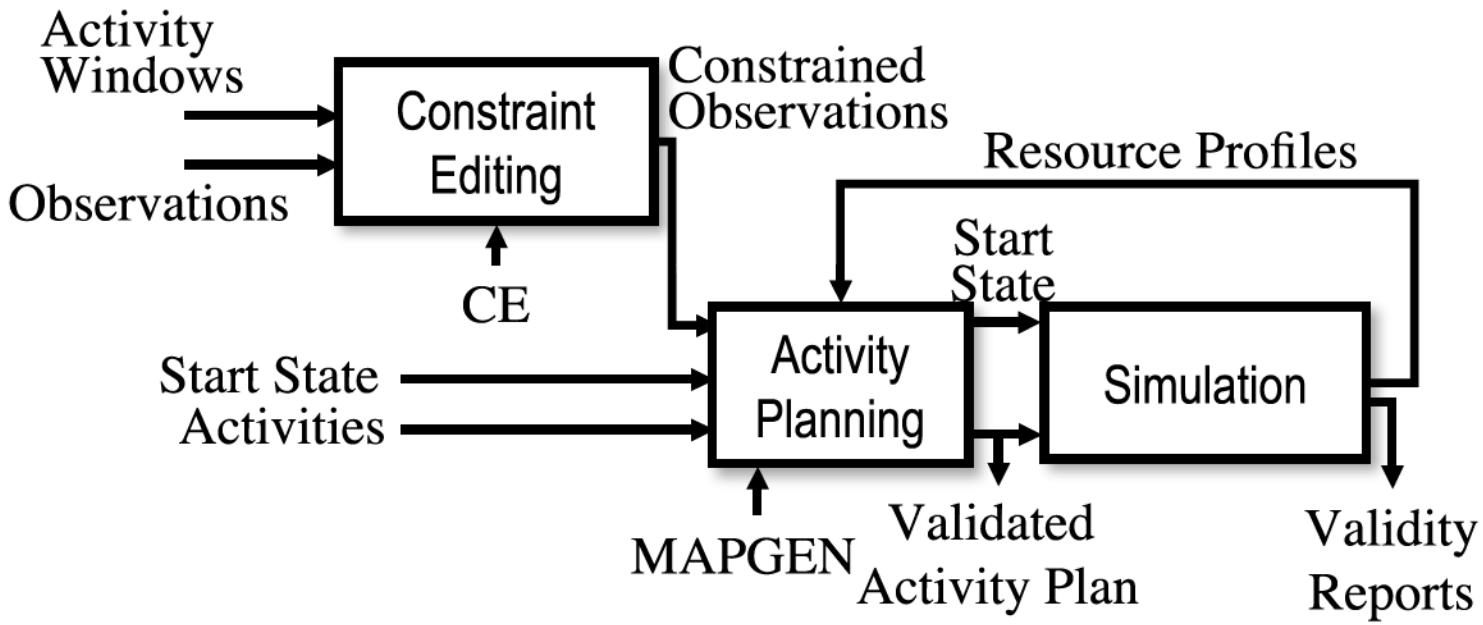
Goals

Data Limit



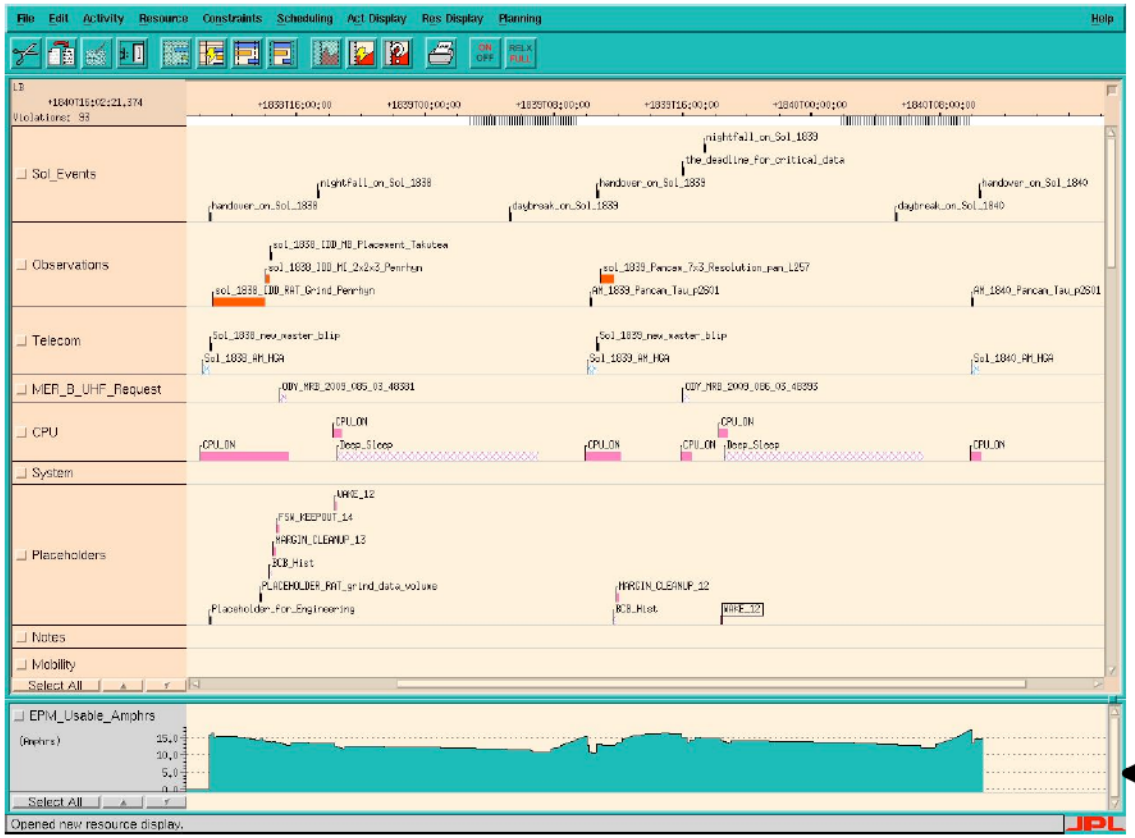
Plan Master

- **Once we have the observations and activity windows, the next step is to generate the master activity plan.**



Activity Planning (MAPGEN)

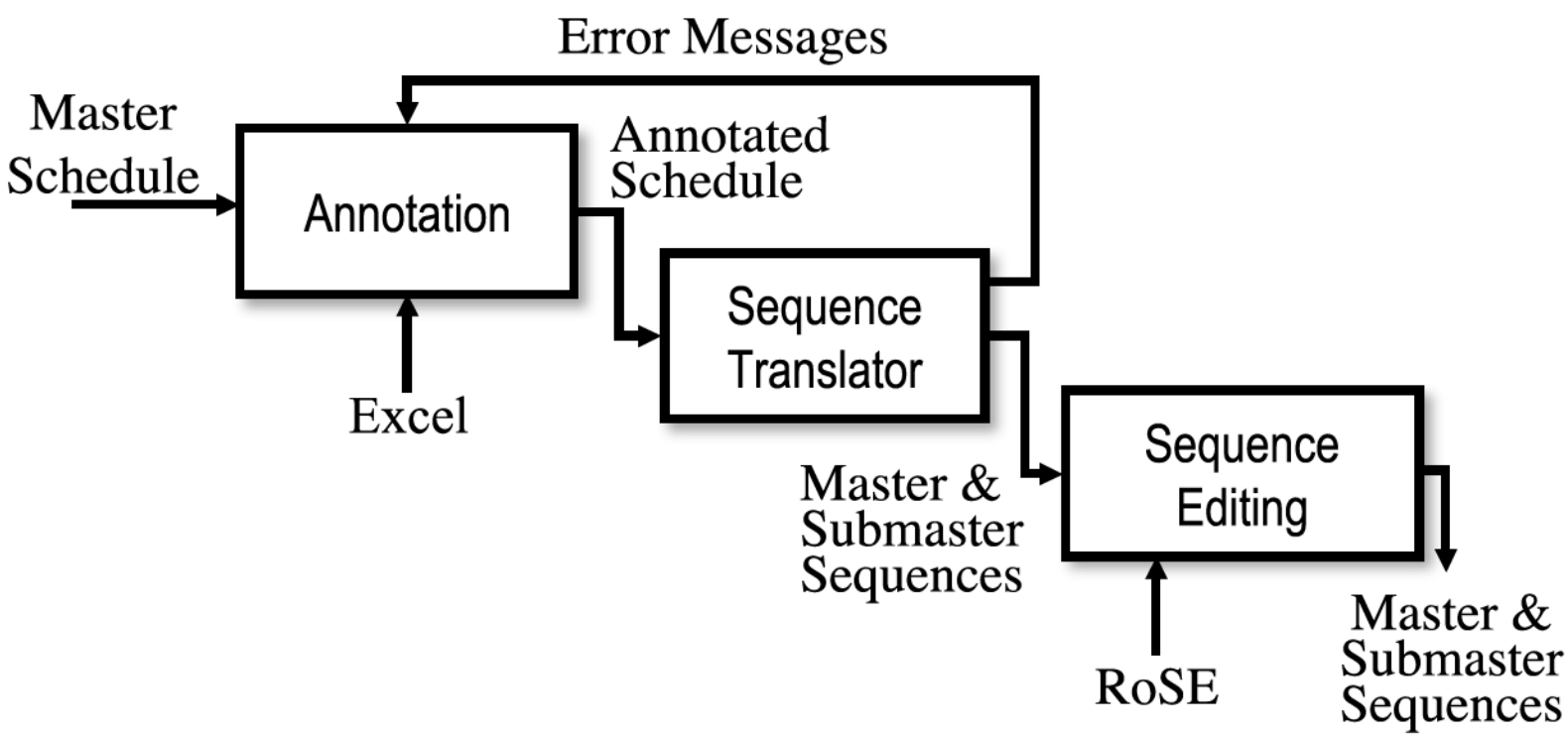
- **Inputs: start state and temporally constrained activities**
- **Outputs: validated activity plan**



Resource Profiles

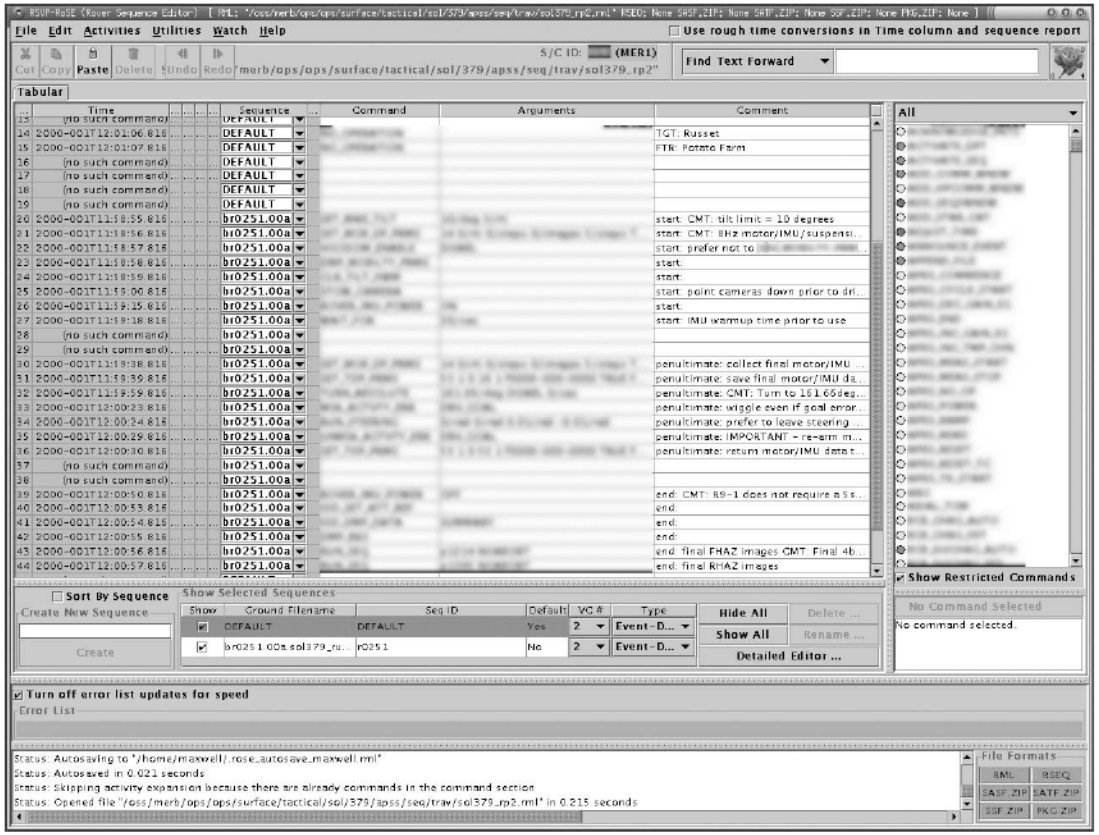
Build Master

- **Annotation using Excel to adjust timing and add engineering requests**
- **Manual inspection and correction in RoSE**



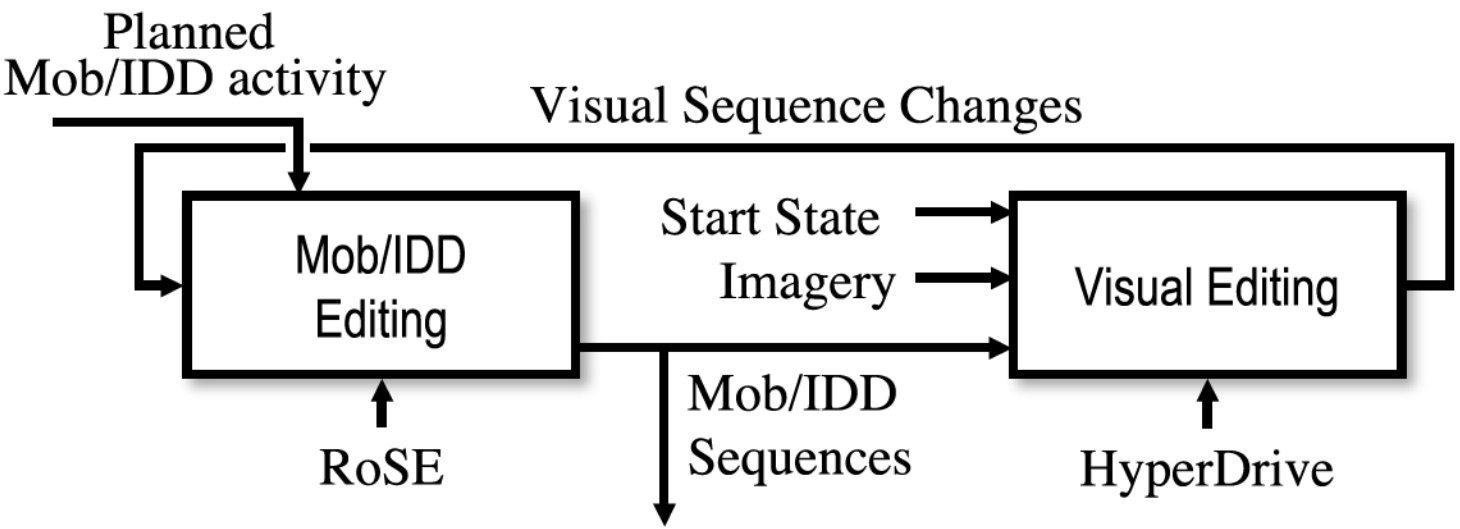
Rover Sequence Editor (RoSE)

- **A textual command editor with syntactic checking**
- **Input&Output: Rover Sequences**



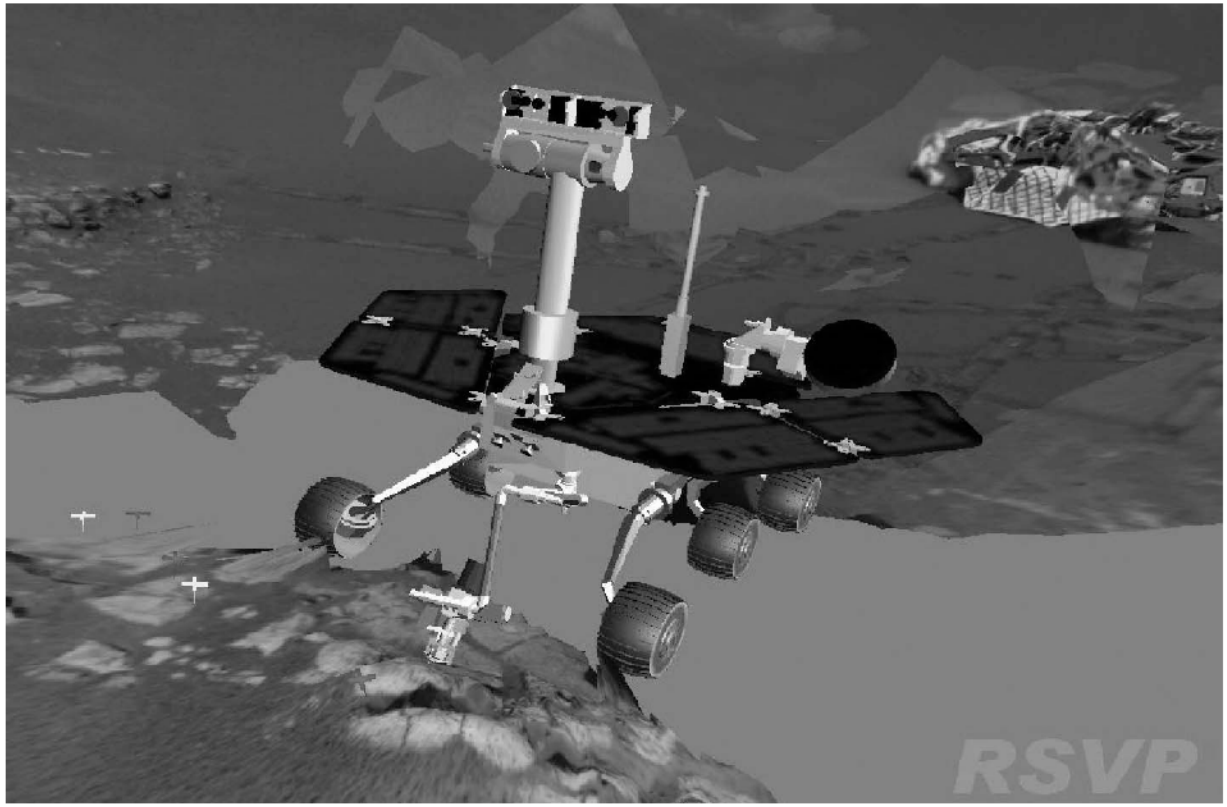
Build Mob/IDD Sequences

- **Mob/IDD planning involves the interaction of a sequence editor and a visualization tool for inspecting expected sequence execution.**



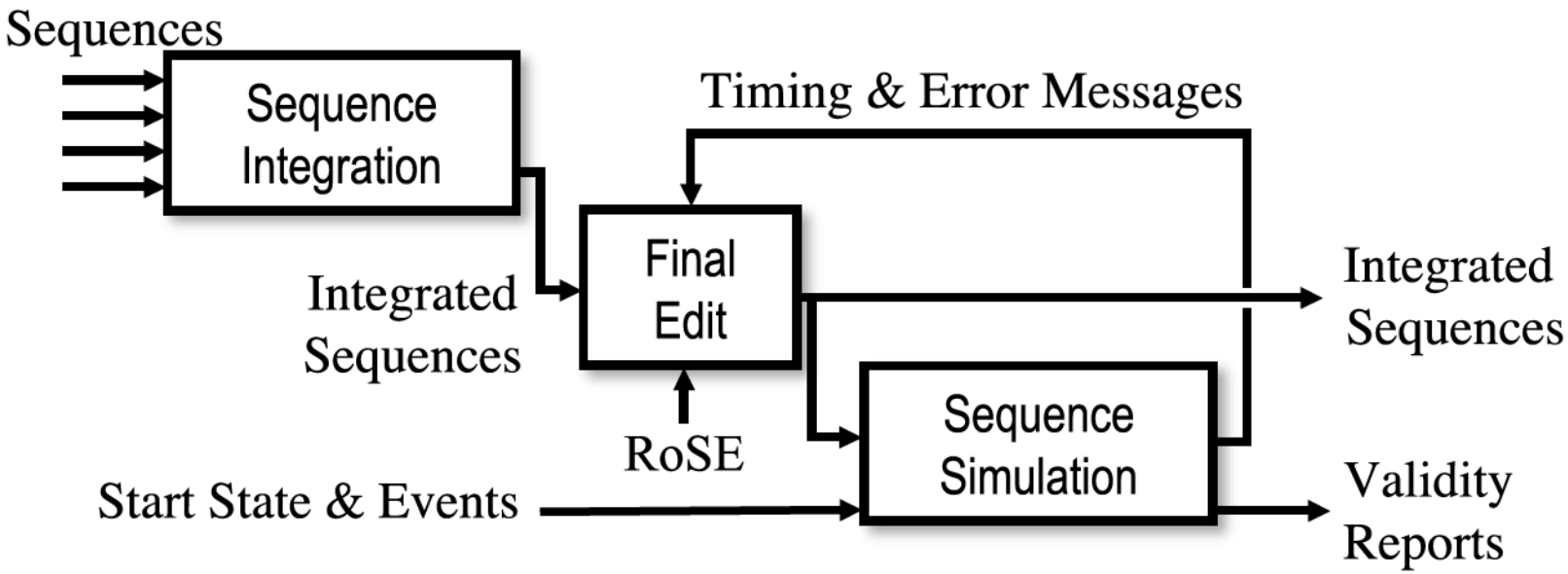
Visual Editing (HyperDrive)

- **The visualization in HyperDrive depends on collected stereo imagery from previous sols.**



Integrate and Test

- **At the end of the operations shift, all sequences are integrate, and the result is simulated to check for correctness.**
- **There is one last chance to edit the sequences at this point.**



Conclusions

- Tool interfaces should be as simple as possible, commensurate with the task at hand
- Rover capabilities and operational strategies both evolve over time
- Sometimes flight rules can be waived

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