MMPAT

IT Symposium Summary & Abstract

Summary

The Multi Mission Power Analysis Tool (MMPAT) provides variable-fidelity power modeling capabilities useful throughout the project lifecycle. It can be employed as a stand-alone desktop tool providing tabular and graphical output or integrated with activity planning tools such as APGEN.

Abstract

In these days of shrinking budgets and compressed schedules it is important to employ analysis tools that are fast, easy-to-use, flexible, and support variable fidelity so that space vehicle trade studies, design studies and activity planning can done as quickly and inexpensively as possible. It was with this in mind that the Multi-Mission Power Analysis Tool (MMPAT) was developed. MMPAT provides a robust solution to spacecraft Power/Thermal performance analysis in a package that is easy to use and provides fast, accurate results at a level of fidelity appropriate to each stage of the project lifecycle. It is a multiplatform application for Windows, Solaris and Linux and is distributed as either a desktop application with a Graphical User Interface (GUI) that provides both tabular and graphical output or as a linkable library package. Among its users are MER, Deep Impact, the Mars Surface Mobility Studies, and MSL.

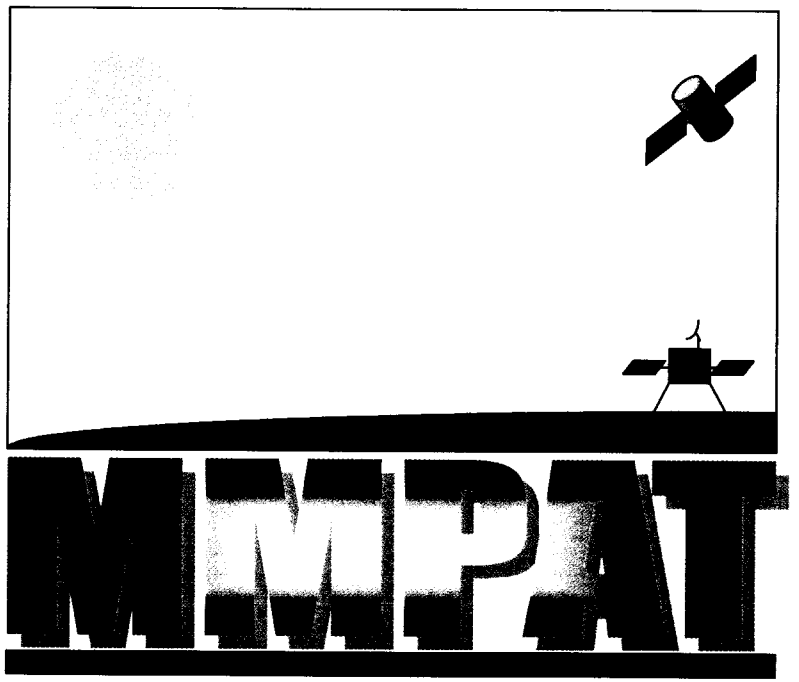
MMPAT's tremendous flexibility is achieved through the use of a parameter-driven interface, user-selectable levels of fidelity and a broad scope of capabilities. For example, the parameter-driven interface allows the user to select from an included list of batteries or solar cells, or to easily specify a custom version. This allows the user to employ actual test data or analyze how a future technology would impact subsystem performance. Different levels of fidelity can be selected to accommodate different phases of the mission lifecycle. For example, early in the lifecycle the user can choose to initially model the battery with a fixed temperature. Then later when more information is available, use a simple daily temperature profile. And then finally, when the design starts to mature, use a more complex thermal model incorporating multiple nodes and thermostatically-controlled heaters.

The broad scope of MMPAT's capabilities is one of its most important features and makes it possible to simulate a wide variety of power subsystem configurations. MMPAT's models include: multiple secondary battery chemistries; battery/spacecraft thermal model; thermostatically-controlled heaters; multiple solar cell types; solar array thermal model; articulated, sun-track-capable solar array; cell-by-cell solar array shadowing; power equipment list (PEL); simple radio-isotope thermal-electric generator (RTG) model; basic orbital mechanics for: lander, orbiter and heliocentric orbiter; multiple power-bus control methods.

Integrating MMPAT with other applications or simulation frameworks can be accomplished with minimal effort through its application program interface (API). When linked in this way, time

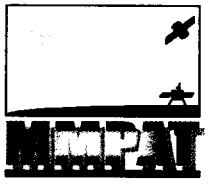
ordered commands are received by MMPAT from the calling program and results are returned at each time step. MMPAT has already been integrated with the APGEN and SEQGEN planning tools by the MER and Deep Impact projects, and is available for use on other projects.

Multi-Mission Power Analysis Tool



Project Planning Office
Modeling & Simulation Technologies Group
Jet Propulsion Laboratory
October 24, 2002

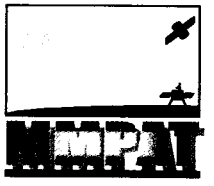
The Agenda



PPO/JPL

- Overview
- Contributors
- Overview
- Applications
- Key Features
- Software Structure
- Models
- Current Status
- Examples
- Summary

Contributors
Development



PPO/JPL

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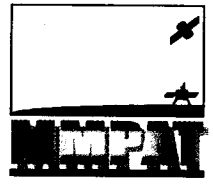
- David Hanks (366)
  MMPAT Developer
- Eric Tailor (366)
  MMPAT Developer
- John Baker (311)
  Manager,Formulation Phase
  Project Support Office
- Mark Kordon (366)
  Task Manager,
  MST Group Supervisor

Contributors

Domain Experts



PPO/JPL

- Roy Gladden (314)
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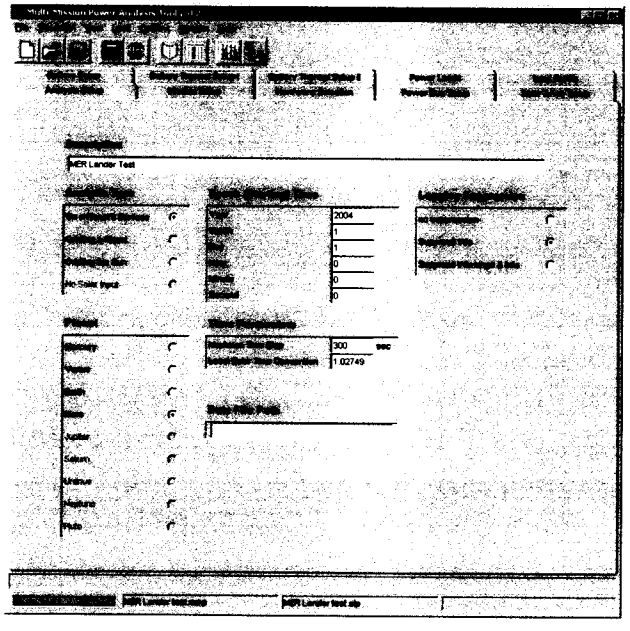
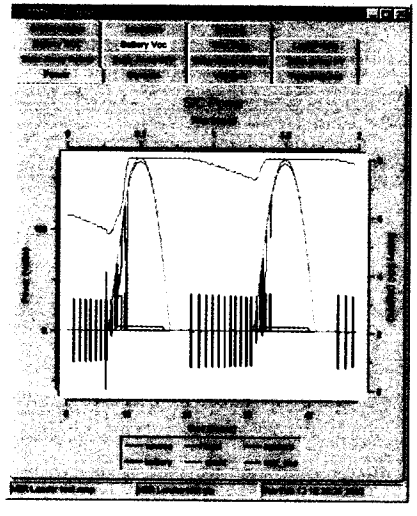
  MMO Sequence System Engineer
- Adrian Adamson (313)
  MER Power System Engineer
- Loren Jones (346)
  DI Power System Engineer
- Pierre Maldague
  APGEN CogE
- Steve Wissler
  APGEN DI Engineer
- Chuck Phillips
  MER Thermal Engineer
- Richard Ewell (346) Pathfinder Power
  Model Developer
  MER Power Subsystem Lead
- Donald Rapp (354)
  Solar Power on Mars
  Senior Research Scientist/Principal Engineer

MMPAT Overview

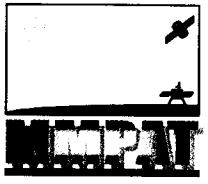
PPO/JPL





- Software Simulation of Spacecraft Electrical Power Subsystem
  - Models the behavior of a power source and an energy storage device as they interact with the spacecraft loads over the mission timeline.
- Models Multiple Mission Types
  - Planetary Lander, Planetary Orbiter, Heliocentric Orbiter
- Used by the Deep Impact and MER Flight Projects.
  - Integrated with APGEN for MER & DI Operations planning

Power Modeling History



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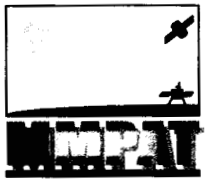
- Unique power models are developed for most spacecraft missions.
- Each power model produces similar output.
- Development of these models can be time-consuming and costly.
- Turnaround time for architecture or scenario changes can be slow and costly.

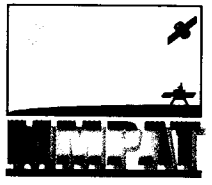
High-Level Requirements



PPO/JPL

- Develop a model that:
  - is applicable to a variety of missions, mission types, and hardware configurations.
  - is a JPL "in-house" capability.
  - provides high fidelity results *early in the design phase* on the par with or superior to LM-developed software.
  - supports rapid trade studies during formulation and implementation phases.
  - supports mission planning and sequencing efforts during operations.

Additional Requirements



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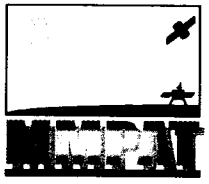
- Intuitive ***graphical user interface*** (GUI) for relatively easy use.
- ***Fully parameterized inputs*** to provide flexibility and high re-use value.
- Built-in power subsystem configurations to provide a ***flexible*** modeling environment.
- ***Well-defined interface*** for use with other software programs, such as APGEN.
- Highly ***upgradeable and expandable*** to facilitate the addition of new or improved algorithms.
- Thoroughly ***documented*** to support peer and content reviews and to provide training.

Applications



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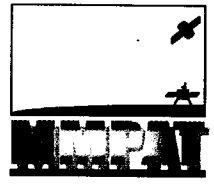
- Useful throughout the mission lifecycle:
  - Pre-Phase A – Phase D:
    - ***System Engineers*** can perform system-level trade studies.
    - ***Mission Planners*** can use the model to evaluate mission scenarios.
    - ***Power Subsystem Engineers*** can use the model to size various power subsystem components, such as solar arrays or batteries.
  - Phase E, Operations :
    - The model provides insight into the actual condition of a spacecraft's power subsystem during flight.
    - In concert with APGEN the model supports development of feasible activity plans.

Key Features

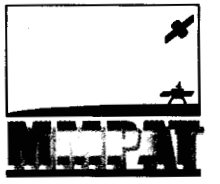


PPO/JPL

- Multiple Mission Types: lander, orbiter, helio orbiter
- Runs faster than real time
- Intuitive Graphical User Interface (GUI)
- Multiple levels of Fidelity
- Integrated Thermal Models
- Integrated Orbital Dynamics
- Graphical and tabular output
- On-line help
- No licenses, no cost to use
- Runs on Windows, Linux, Solaris and eventually Mac

Slide by: Mark Kordon

Software Structure



PPO/JPL

- Tcl/Tk has been used to develop the graphical user interface.
  - Look and feel of a commercial Windows application.
  - "Tabbed" input structure
  - "Tabbed" graphs with zoom & "tear-off" capabilities
  - Portable across platforms.
  - Socket interface already in place for interface to other systems.
- C-code contains the real "guts" of the model.
  - Modular and "OO-like" coding approach.
  - Deploys as a linkable library for inclusion in other tools such as APGEN

Architecture: GUI

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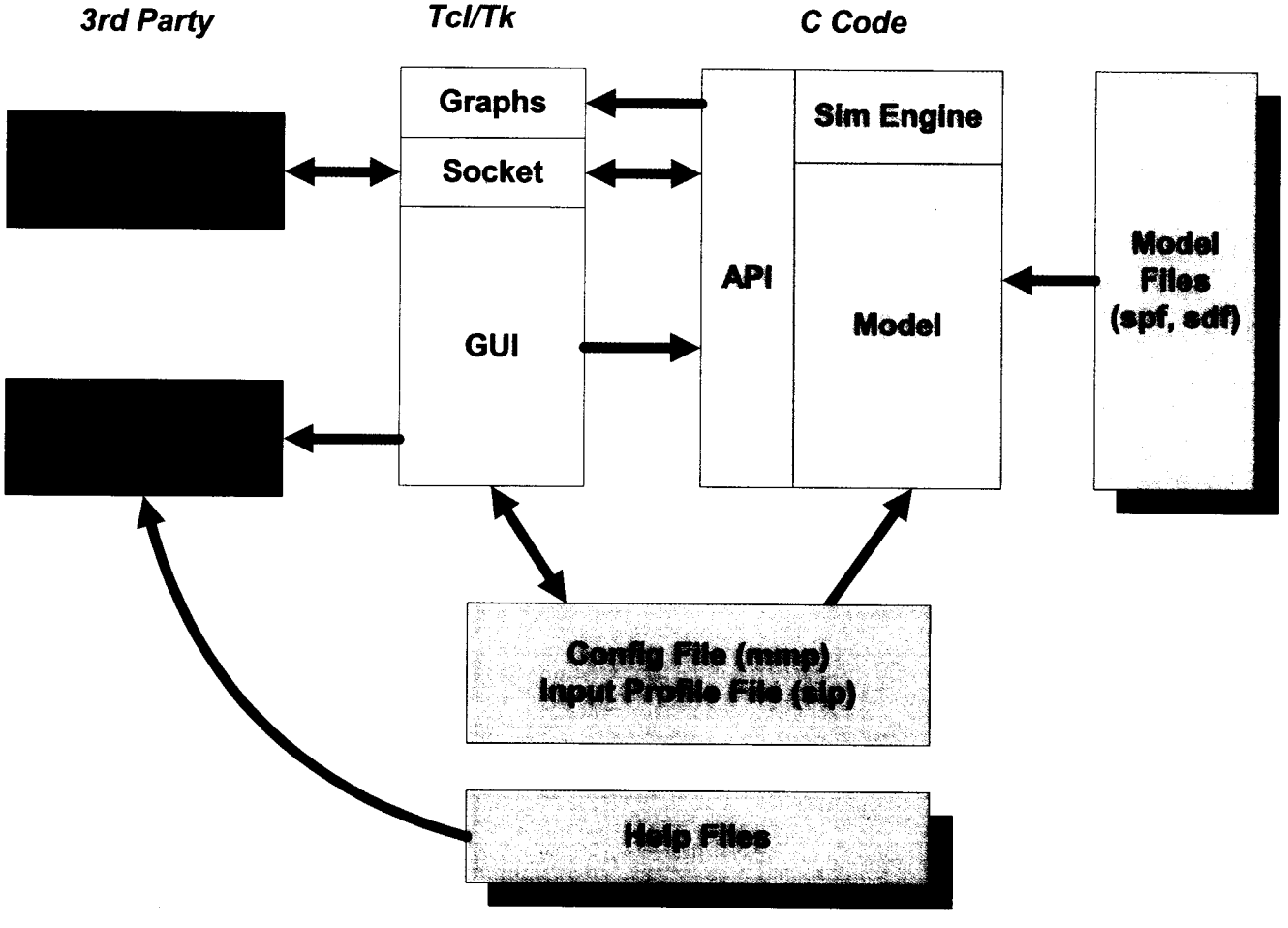

Architecture: Library

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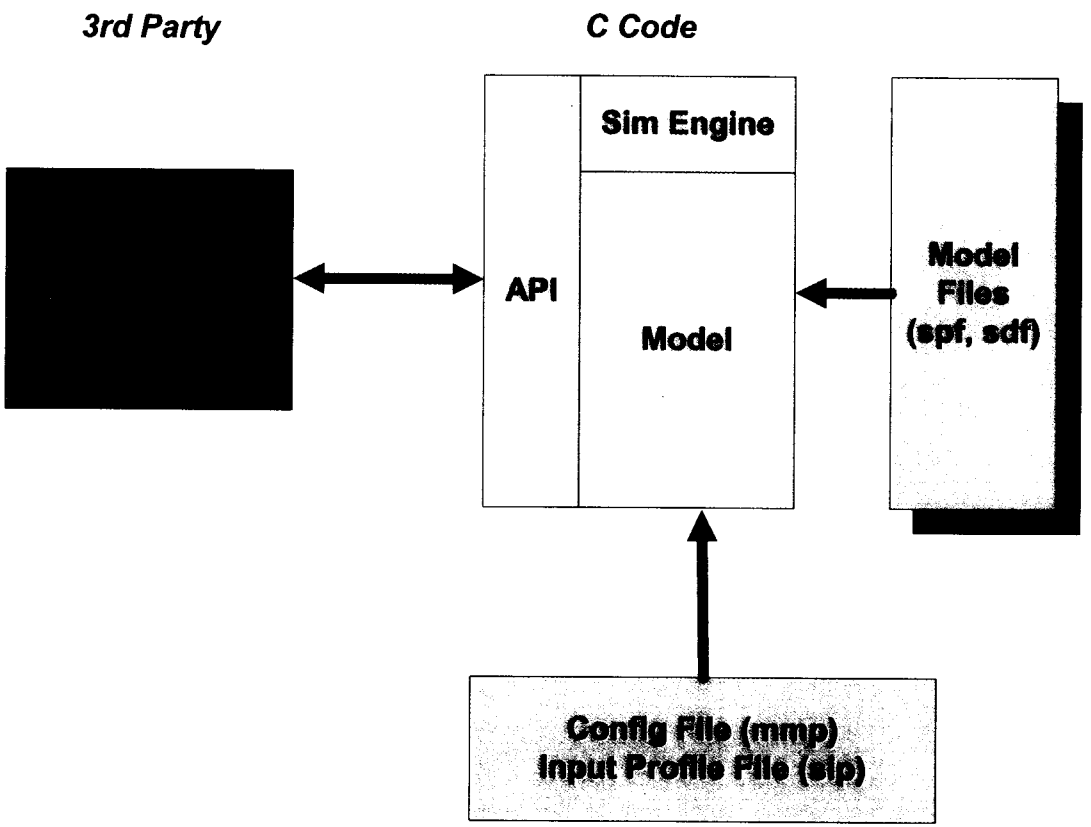
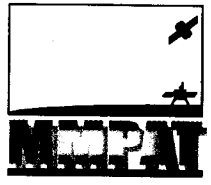


Deployment



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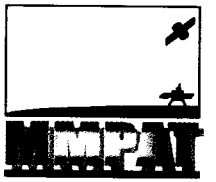
- Multiple S/W Configurations
  - standalone application
  - linkable library
  - distributed simulation
  - client/server (TBD)
- Multiple Platforms
  - Windows
  - Linux
  - Solaris
  - MacOS X (TBD)

Models



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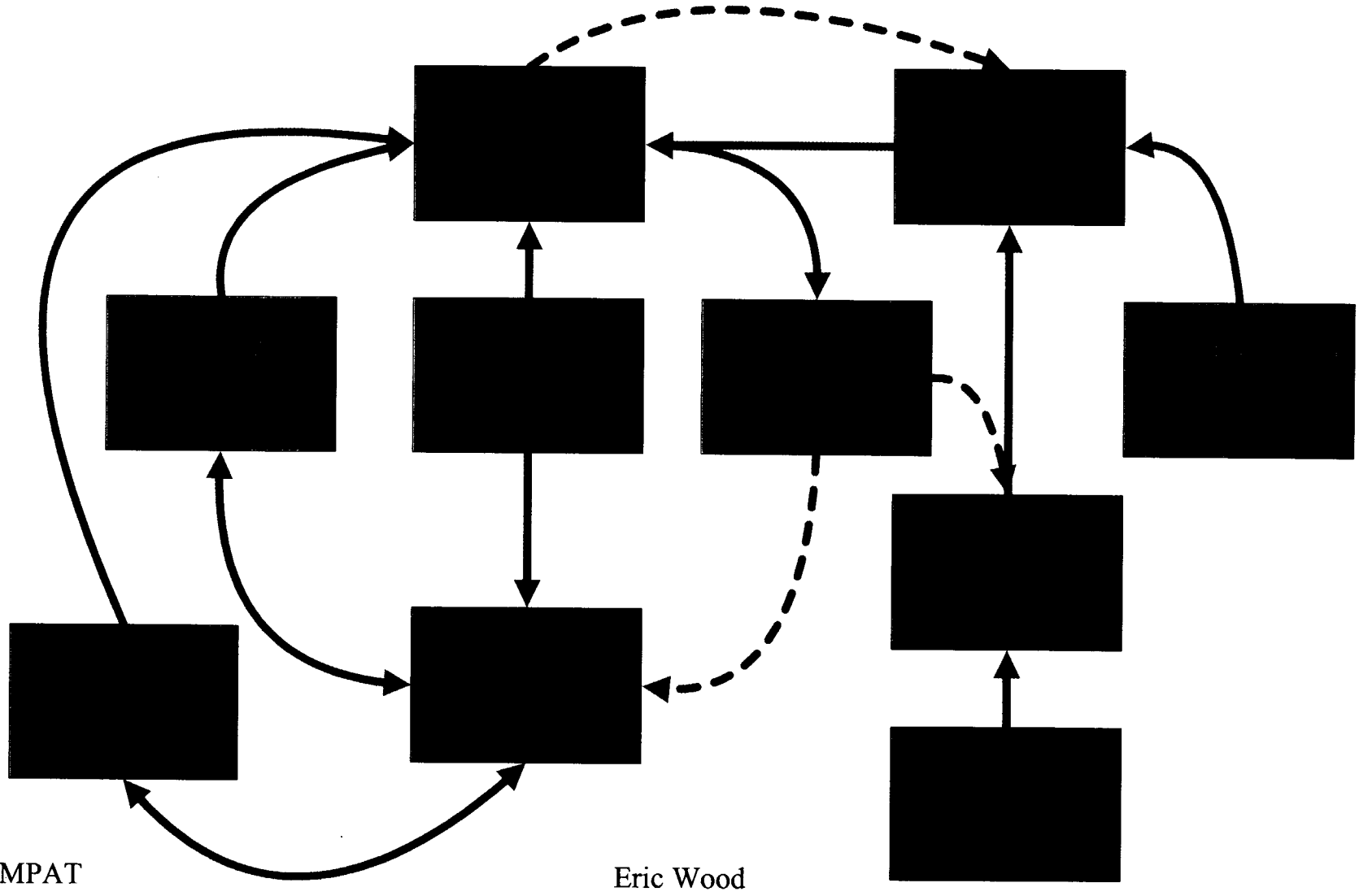
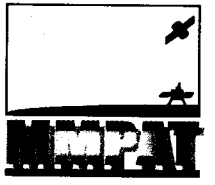
- Power Bus Control
- Secondary Battery
- General Thermal
- Heater/Thermostat
- Solar Array
- Solar Array Thermal
- Power Equipment List

High-Level Model Structure

PPO/JPL



Power Bus Control Models



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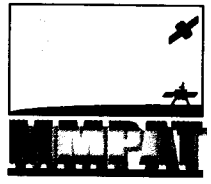
- Shunt Limiter
- Solar Array Switching
  - VT Control
  - KI Control
  - KI control w/Voltage Limit

Secondary Battery Model

PPO/JPL

- Table Driven
- Multiple Chemistries
  - NiH2
  - Li Ion
- Voltage: Function of Temp, Current & SOC
- Dissipation:
  - Function of Temp, Current & SOC
  - Charge Efficiency & Discharge
- Charge Efficiency:
  - Fixed
  - Function of SOC
- Capacity:
  - Fixed
  - Function of Temperature

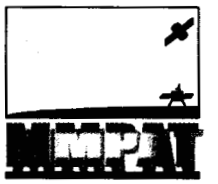
General Thermal Model



PPO/JPL

- Transient Finite Difference Thermal Analysis
- Computed, Fixed & Table Driven Node Temperatures
- Fixed & Power-Model-Driven Node Dissipations
- Fixed Radiative Links
- Fixed & Table-Driven Conductive Links
- Generalized Thermostat & Heater Modeling
- Dissipations Exportable to SINDA
- Used for Battery Performance and Heater/Thermostat States

Heater/Thermostat Model

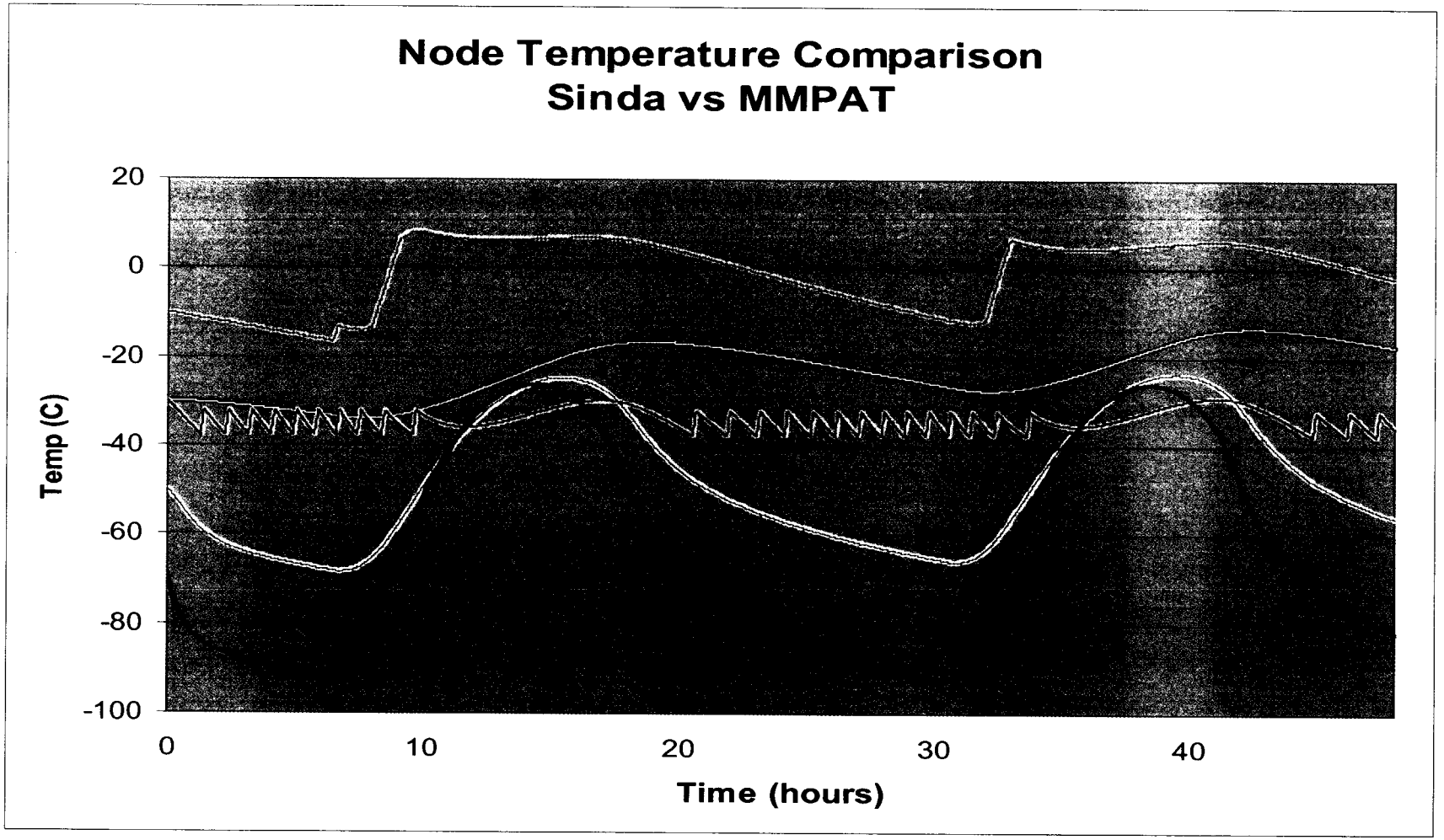


PPO/JPL

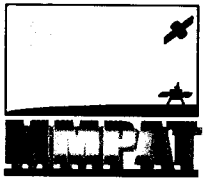
- Predicts States of Thermostatically-Controlled Heaters
- Heater Dissipations Passed to General Thermal Model

Thermal Accuracy

PPO/JPL



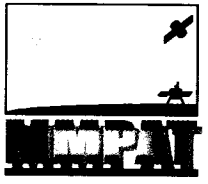
Solar Array Model



PPO/JPL

- Test Data Driven
- Multiple String Lengths
- Multiple Segment Resistances
- Cell-by-Cell Shadowing
- Direct, Diffuse & Reflected Irradiation
- Planetary Atmospheric Effects
- Two Body Orbital Mechanics

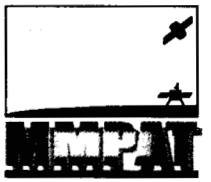
Solar Array Thermal Model



PPO/JPL

- Transient Finite Difference Thermal Analysis
- Solar Input
- Power Removal
- Optional Shunt Dissipation
- Radiative Links to Environment
- Free/Forced Convective Links to Environment
- Thermal Mass
- Multiple Sub-Panel Thermal "Cases"

Power Equipment List



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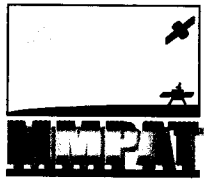
- Each Load State Specifies
  - Pure Power Load
  - Constant Current Load
  - Resistive Load
  - Node in which to Dissipate
  - Power Converter Dissipation

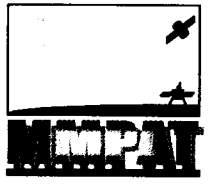
Current Status



PPO/JPL

- Available Immediately
  - No License fee
  - Windows Self-Installer
  - Sample Configurations
  - Training, Consulting & Enhancement Available
- In Use by
  - Deep Impact.
  - Mars Exploration Rover
  - Mars Surface Mobility Study team

Using MMPAT



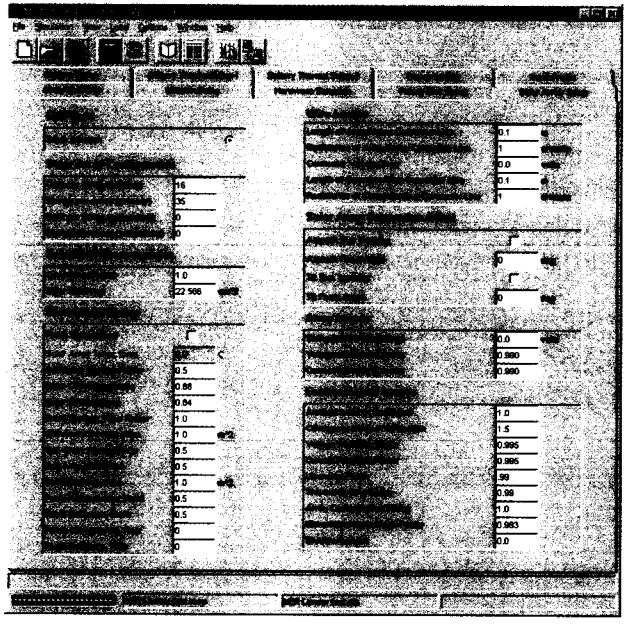
PPO/JPL

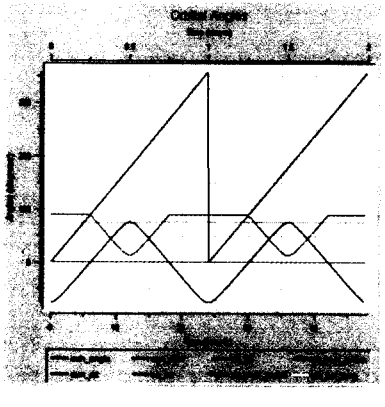
- Stand Alone
  - Configure initial parameters using the MMPAT GUI.
  - Create input profile (using either MMPAT GUI or a spreadsheet) for time-based changes to loads & other parameters.
  - Run scenarios using GUI.
  - Review results on GUI graphs and/or spreadsheet.
- With APGEN
  - Configure initial parameters using the MMPAT GUI.
  - Create activity plans using APGEN.
  - Run scenarios using APGEN linked to MMPAT.
  - Review results using APGEN and/or spreadsheet.
  - Optionally feed dissipations to hi-fi SINDA model.

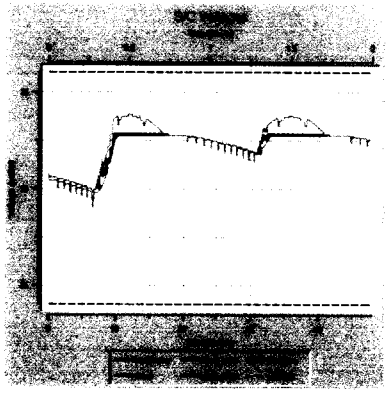
Examples

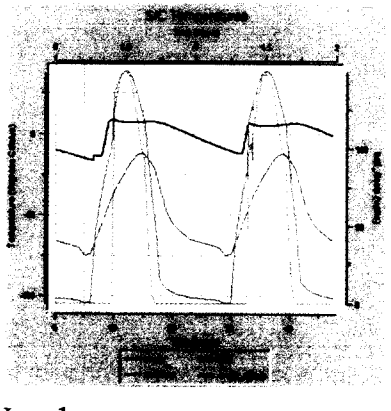
PPO/JPL

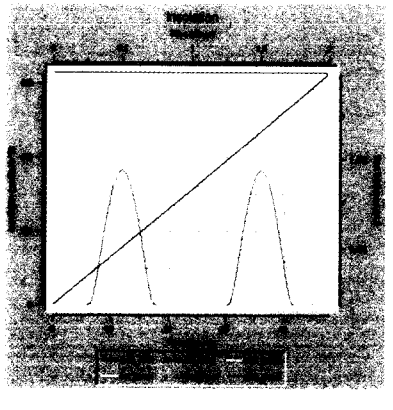
- Polar Landing Date Selection
- Detailed Daily Power Planning









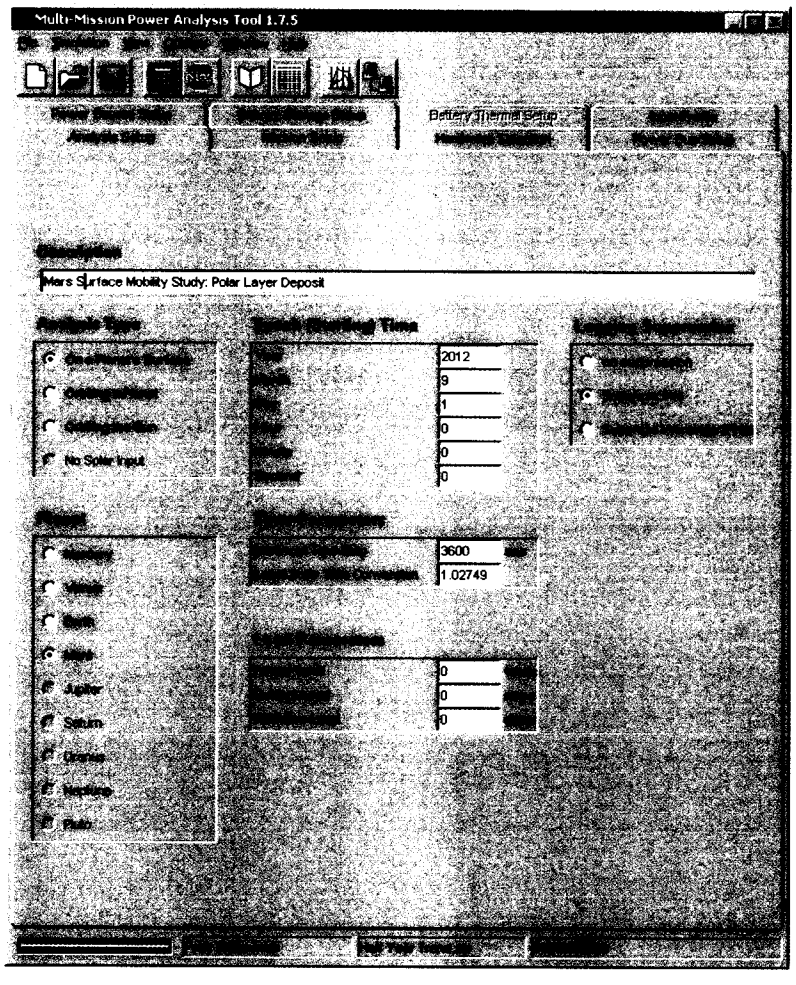


Polar Landing Setup

PPO/JPL

Setup for long-term study of appropriate landing dates for Polar Layer Deposit mission.

Solar power available to a polar site varies widely with time of year.



Polar Landing Results

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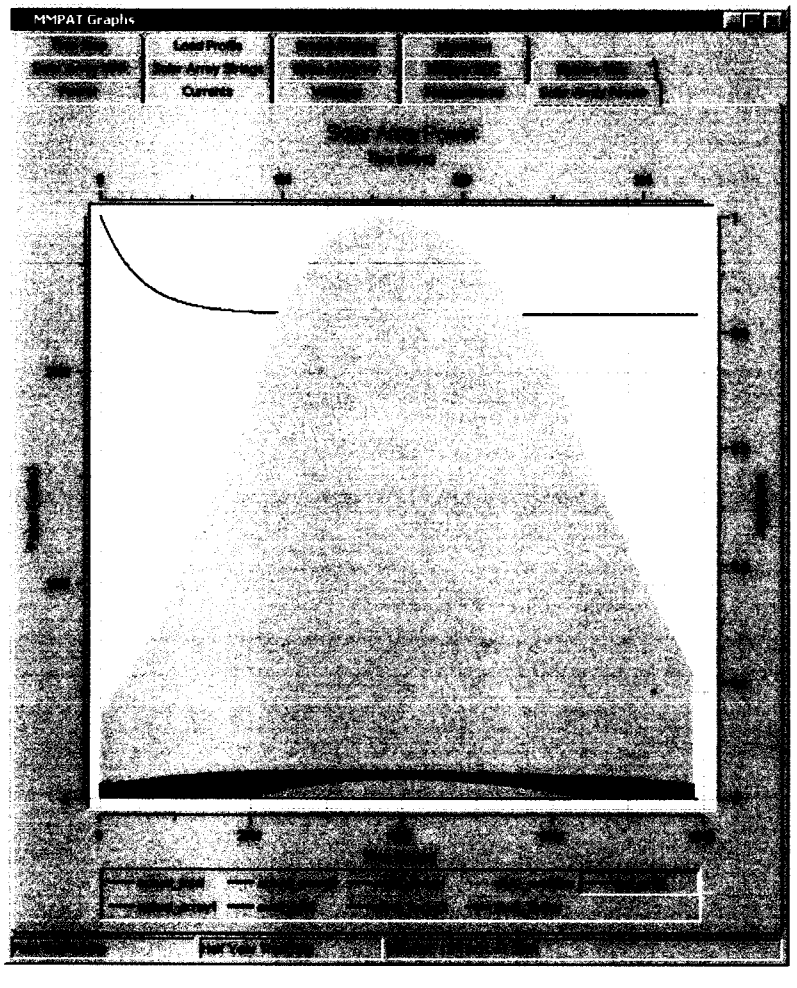
Graph showing **daily watt-hours** at polar landing site over a half-year period.

Used in mission planning process to select date of landing.



Detailed Planning Setup I

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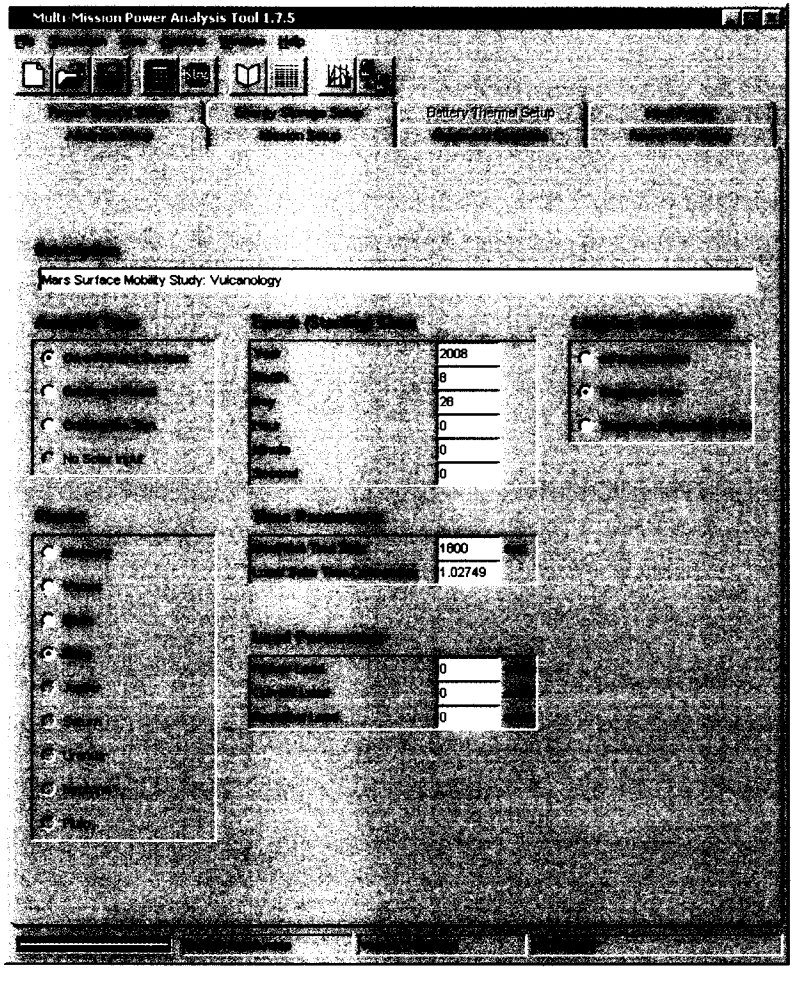
Initial setup screen for final stages of Mars Vulcanology study.

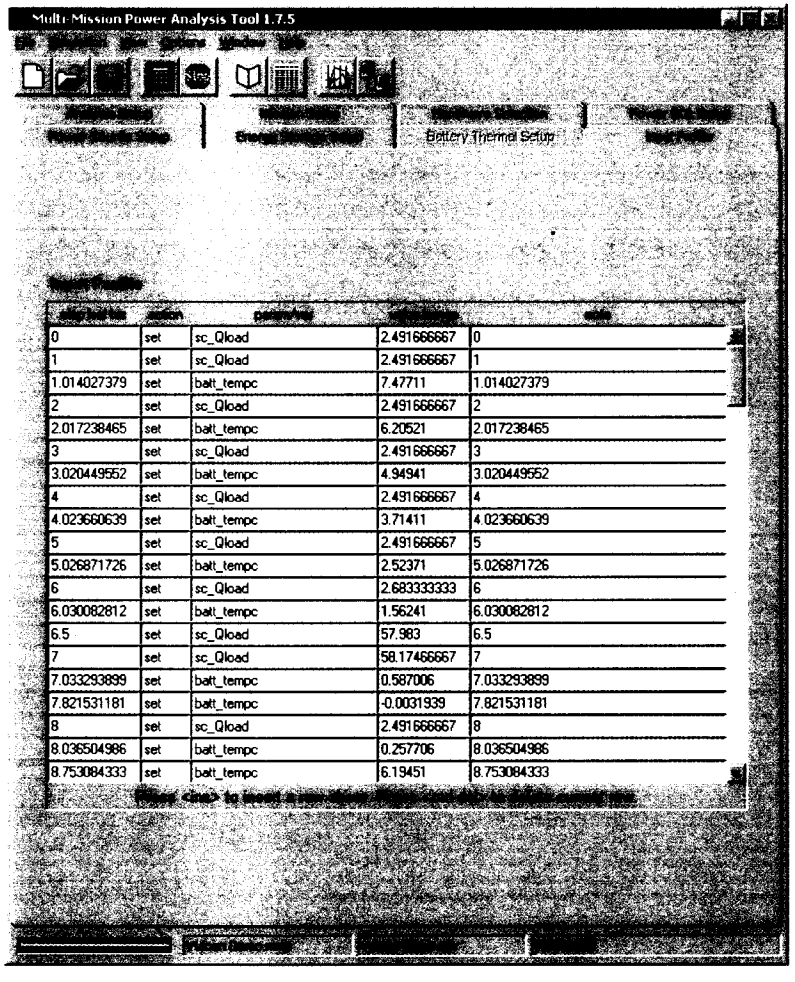


Detailed Planning Setup II

PPO/JPL

Input Profile for Mars Vulcanology study showing the merged power and battery-temperature profiles generated by Systems Engineering and Thermal Engineering, respectively.

The Input Profile can change any parameter at any point in time.



0	set	sc_Qload	2.491666667	0
1	set	sc_Qload	2.491666667	1
1.014027379	set	batt_tempc	7.47711	1.014027379
2	set	sc_Qload	2.491666667	2
2.017238465	set	batt_tempc	6.20521	2.017238465
3	set	sc_Qload	2.491666667	3
3.020449552	set	batt_tempc	4.94941	3.020449552
4	set	sc_Qload	2.491666667	4
4.023660639	set	batt_tempc	3.71411	4.023660639
5	set	sc_Qload	2.491666667	5
5.026871726	set	batt_tempc	2.52371	5.026871726
6	set	sc_Qload	2.683333333	6
6.030082812	set	batt_tempc	1.56241	6.030082812
6.5	set	sc_Qload	57.983	6.5
7	set	sc_Qload	58.17466667	7
7.033293899	set	batt_tempc	0.587006	7.033293899
7.821531181	set	batt_tempc	-0.0031939	7.821531181
8	set	sc_Qload	2.491666667	8
8.036504986	set	batt_tempc	0.257706	8.036504986
8.753084333	set	batt_tempc	6.19451	8.753084333

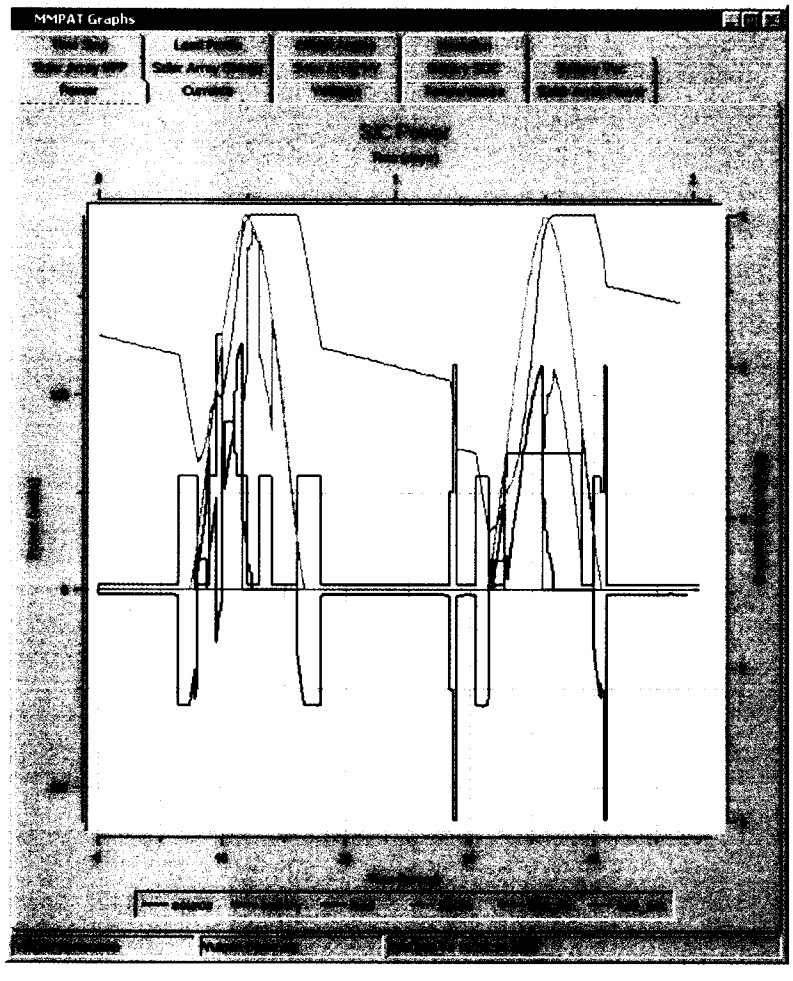
Detailed Planning Results

PPO/JPL

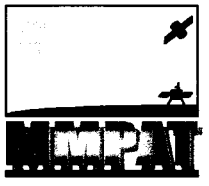
Graph showing an overview of two days of the Mars Vulcanology study.

Important elements include:

-
- **battery state-of-charge**
- **load profile**



MMPAT Summary



PPO/JPL

- Power Subsystem Model: Solar, Battery, PEL, Thermal
- Friendly Graphical User Interface
- On-Line Help
- Mission Types: Lander, Orbiter, Heliocentric
- Multiple Platforms: Windows, Unix, Mac (TBD)
- Multiple Configurations: Stand-alone, Library
- Integrated with APGEN
- File-Level Interface to SINDA
- Available Now