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Presentation Overview

- Project Trades Model core ideas and benefits

- Showcase a Project Trades Model for an extended Mars rover mission (MSL)
Old Problem, New Solution

Traditional Approach

- Create/adopt stand-alone models
- Tradeoffs made sequentially
- Assumptions change over time

Result: Point design

_tradeoff_

_tradeoff_

< 5 designs

PTM Approach

- Create/adapt models addressing system issues
- Tradeoffs deferred until systemic impacts examined
- Assumptions consistent at decision time

Result: Tradespace frontier

Trade relationships identified

100-1000 designs

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PTM: Core Ideas

PTM is a Analysis of Alternatives (AoA) approach

- Identify the mission/system MoEs and KPPs
- Identify LCC drivers
- Determine the "threads of calculation" needed to quantify these
- Implement the calculations by integrating appropriate space system design, cost, and operations models / simulations

Our implementation for MSL
- "Best practice" legacy models / simulations
- Some new models / simulations
- Distributed system integrated via Web Services
Each PTM is tailored to a mission, but contains many reusable elements
Trades Dimensionality Challenge

- System/Subsystem Types and Sizes
- Payload Packages
- Landing Lat/Long, Ls
- System Ops Strategies
- Launch Vehicles
- Mission Risk and Reliability
- Science Strategies
- Terrain
- Scenarios (length, activities, etc.)

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Explorations made possible

Architecture 1

Architecture 2

Architecture 3

Architecture 4

Architecture n

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Project Trades Model: Benefits

- Decrease trade study cycle time
- Provide rigorous, consistent, quantitative evaluation of alternative architectures (designs, technologies, science and operational scenarios)
- Focuses on overall mission effectiveness and affordability
- Traceability of decisions
- Make project disconnects standout early
- Gain confidence in an architecture
  - Calculate design and operations margins
  - Address cost risks
Scope of MSL PTM

Project Trades Model (PTM)

Launch System  Mission Ops Sys  Flight System  Operations  DSN

Carrier System  EDL System  Surface System  Payloads

Power  C&DH  Telecom  Structure/Thermal  Propulsion  GN&C

Entry  Descent  Landing

Rover Power  Rover Avionics  Rover Telecom  Mechanical/Thermal  Mobility

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PTM Builds Bridges

*Connects islands of analytical capability*

- APGEN
- ROAMS
- Terrain (Maker2)
- Mobility & Structure
- Launch Vehicle Database
- Mars Data
- MEL/PEL
- Instrument Database
- MER-based Phase E Workforce Estimator
- Satellite Orbit Analysis Program (SOAP)
- Telecom Link Analysis Tool
- DSN Availability Model (TIGRAS)
- Upper EDL Model
- Developmental Cost Models
- Team X Instrument Cost Model

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Landed Mission Science Scenario

~26 sols scheduled
~39 sols with 33% downtime

(1) Navigation sensing
(2) Roving
(3) Data collection
(3) Uplink/downlink
(n) ...

t=0
~6-13 sols planned
~9-20 sols with 33% downtime

Checkout & Calibration

Site Blocks

Vignettes
Rock Analysis
Subsurface Wheel Digging
Night Ops
Site Recon
Quiescence

Activities
(1) Location fix
(2) Camera slew
(3) Mini-TES imaging
(4) Uplink/downlink
(n) ...

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Traverse Lengths
Traverse Lengths
Traverse Lengths

Number of traverses

Traverse distance (km)

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Traverse Lengths

TRAVELE LENGTHS

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Traverse Lengths

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Traverse Lengths
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Traverse Lengths

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Traverse Lengths

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Number of traverses

Traverse distance (km)

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Cost Estimation

Mission Costing Tools:
- Early Pre-Phase A
- PMCM
- Hybrid Grassroots

Software Costing Tools:
- Flight SW Cost Model
- JPL Generic SW Cost Model

Operations Costing Tools:
- Team G
- MER-Based Phase E Workforce Estimator
- SOCM

Instrument Costing Tools:
- Team X ICM
- Grassroots Template

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Detailed PTM Cost Structure

PTM Int. Summary

Mission Costing Tools
- EPPA
- PMCM
- Hybrid Grassroots

Instrument Costing
- Mission costing tool, MEL/PEL ID, IDB ID, Total duration
- Relevant instrument cost data

Software Costing
- SW checklist
- SW costs, FTEs
- SLOC
- FTEs

Operations Costing
- Ops checklist
- FTE by type
- FTE by type
- FTE by type
- Mission length, level of autonomy

Team X ICM
- Instr. Names, Total duration, mass, booleans
- Instr. Costs, mean & std. dev.

Instr. Cost Tool n
- Instr. Names, Mass, Quantity
- MEL/PEL ID

System Attributes
- Instr. Names, Mass, Quantity

Instrument Database
- + extra info
- Alt 1
- Alt 2
- Alt 3

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Conclusions

- Enables team to more effectively explore trade space to find the best combination of life-cycle cost and mission effectiveness
- Shows HQ what is feasible with different funding levels
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Science Metric Selection: Science Data Returned (Gb)

Project Cost ($M)
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Science Metric Selection: Science Data Returned (Gb)
Observations

- PTM “components” may not be available inside or outside the organization
  - Develop, adapt, and standardize
  - Legacy models typically not “integration-ready”
  - Excellent cooperation from tool owners/originators allows fast progress

- Most successful application occurs when project trades modeling is a leadership priority
  - Trade trees are reasonably well-defined
  - Decision criteria (MoEs, KPPs, LCC) are identified early

- Development increases system thinking and raises understanding of interrelationships

- Archives inputs/outputs, assumptions, and captures rationale

- Capability to pursue uncustomary trades
Detailed PTM Telecom Strategy

PTM Int. Summary

Run ID
Telegram strategy
Lat/long
Start Epoch
Orb type

Orb file auto-modifier

Modified *.orb + run ID + telecom strategy (email)

Database

Run ID
Symbol rate info
Data rate info

APGEN Web Service

Cumulative science data downlinked
Cumulative science data collected

APGEN

SOAP

Electra Telecom Tool

Run ID
Pass info
*.txt

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