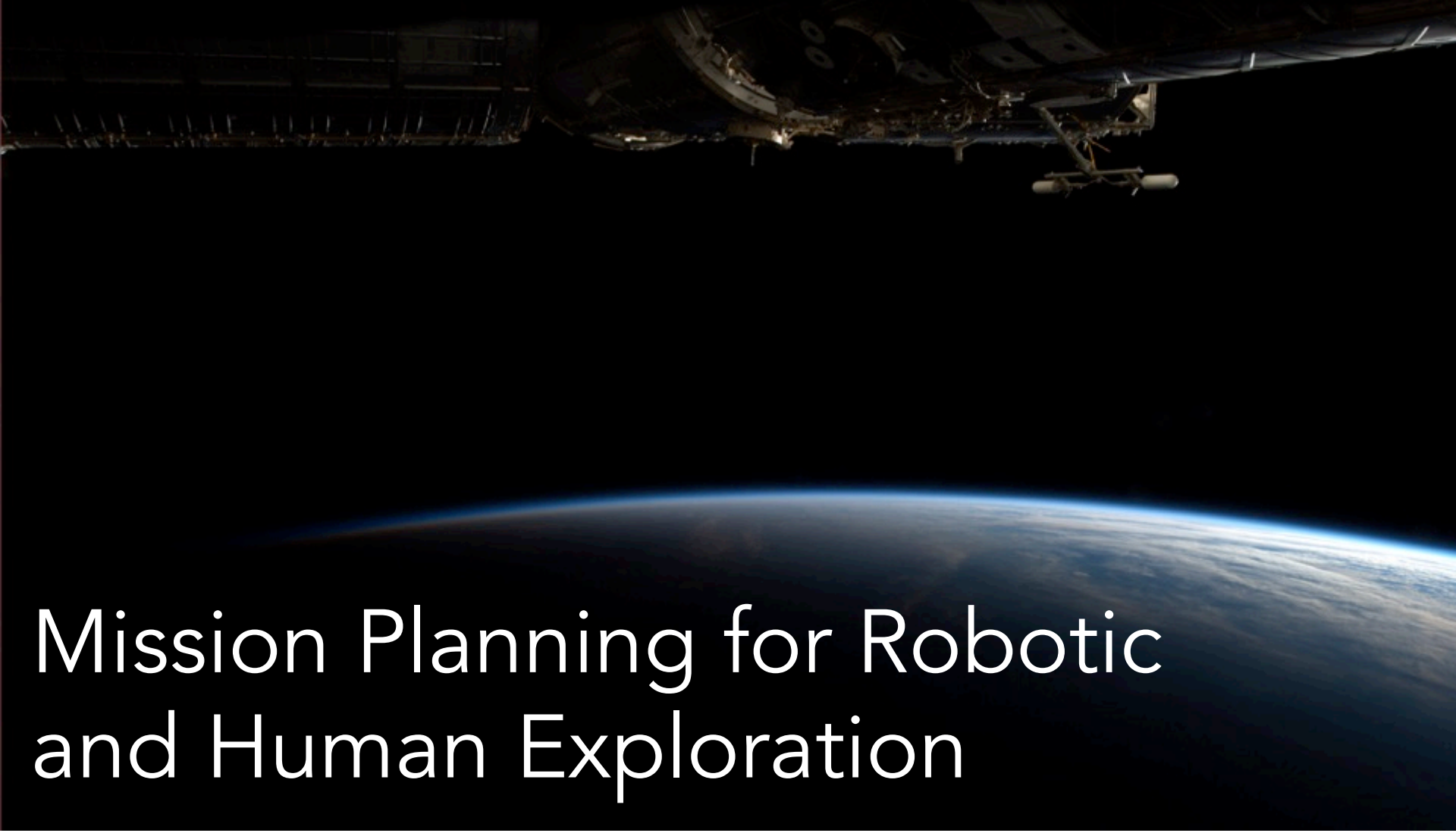

Mission Planning for Robotic and Human Exploration

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NASA Ames Research Center

Outline

- What is Mission Planning?
- Why is planning for space missions hard?
- Highlight of specialized mission planning software tools
- Future mission planning tools: Analogs and Mars

Spaceflight Mission Operations

Plan-Train-Fly Model

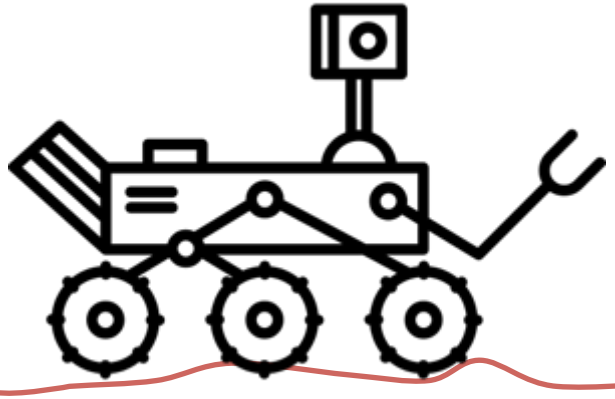
http://appel.nasa.gov/2009/03/01/plan-train-and-fly-mission-operations-from-apollo-to-shuttle/

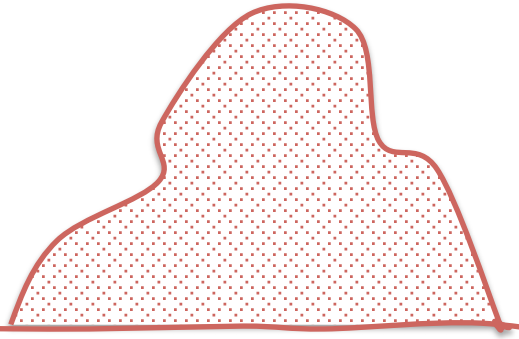
Types of Mission Planning

- Strategic: focuses on identifying goals & coordinating with major events.
- Tactical: focuses on how to achieve goals with the given resources.
- Operational: exact implementation of plan.
- Both robotic & human spaceflight missions follow this process.
  - Difference: Implementation of operational planning.

Mission Planning 101

Goal: Analyze composition of Martian rock for scientists back on Earth.

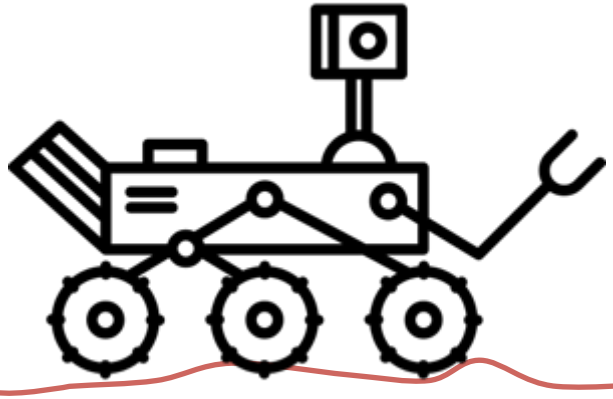


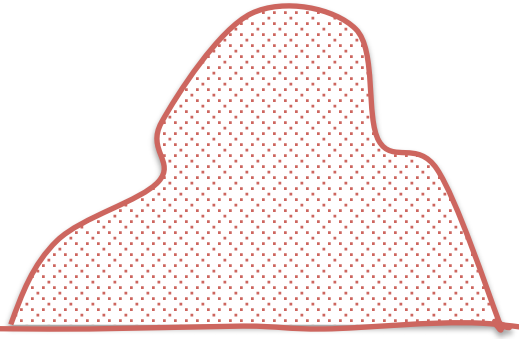


Mission Planning 101

Strategic: Allocate three days for rock analysis

- ✧ Drive to rock
- ✧ Sample rock
- ✧ Analyze rock
- ✧ Send analysis results back to Earth

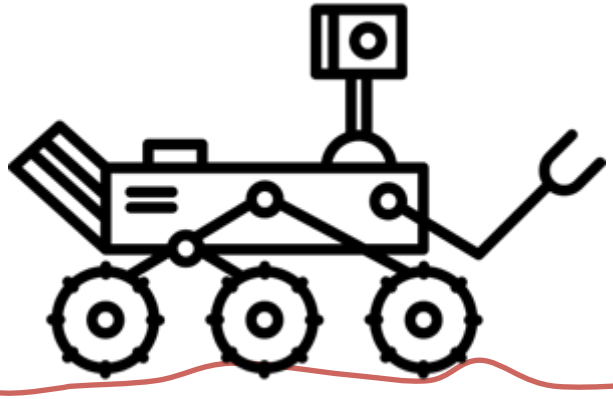


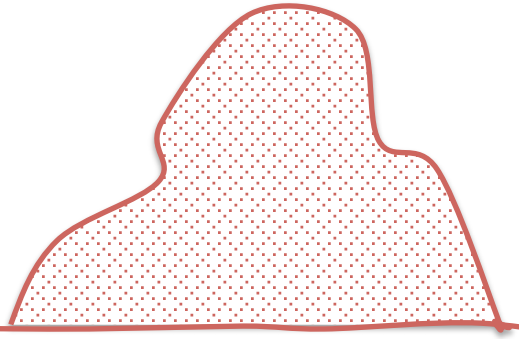


Mission Planning 101

Tactical: Drive to rock

- ✧ How far is the rover?
- ✧ Does the rover have enough power to drive there?
- ✧ When can we send the commands to drive?
- ✧ Has the rover arrived to the right location?





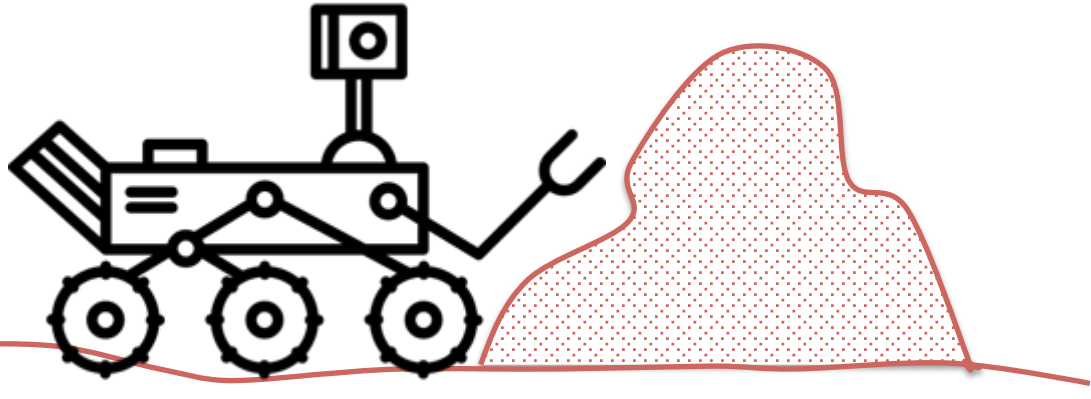
Mission Planning 101

Tactical: Sample rock

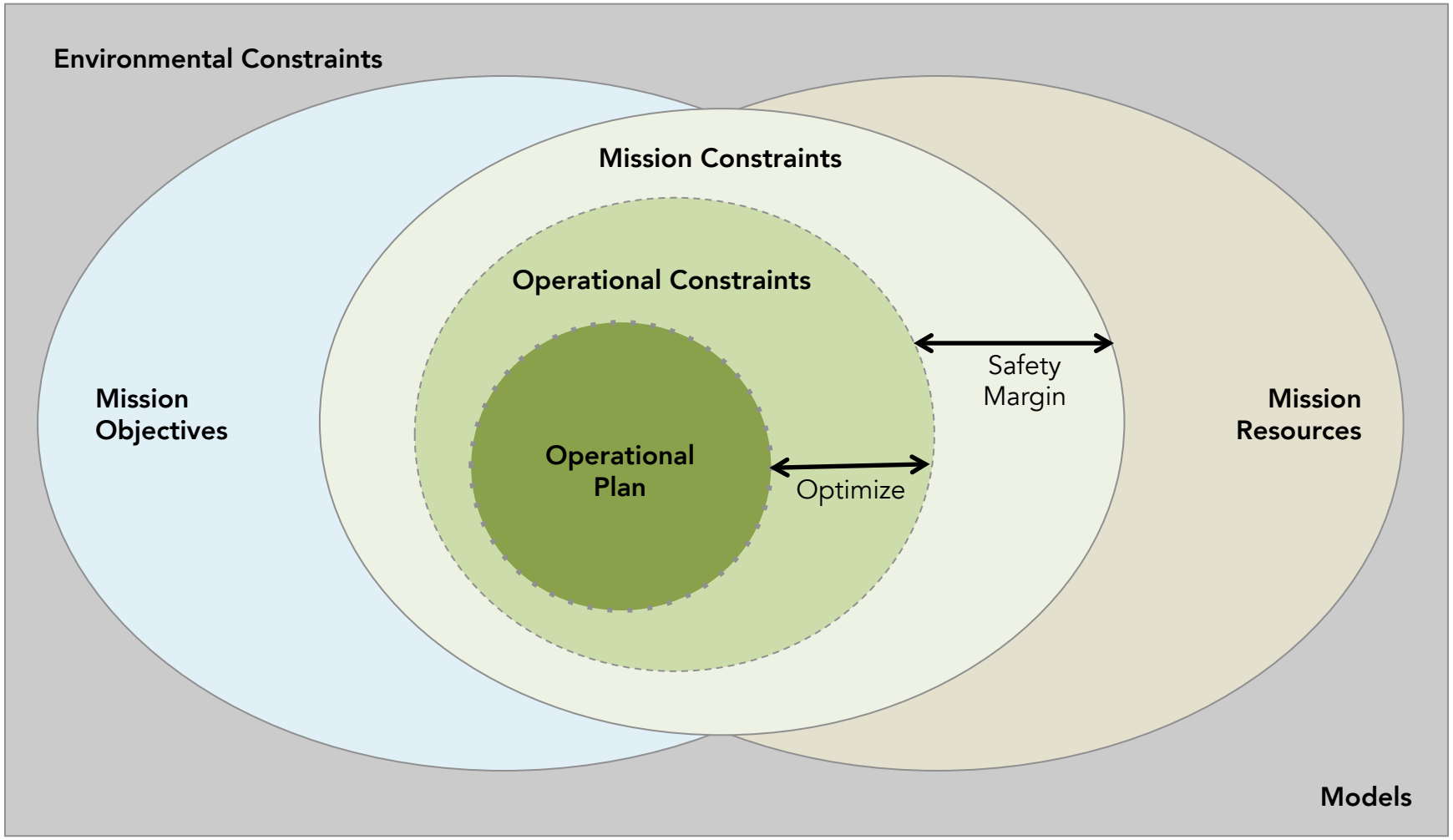
- ✧ Can rover sample rock? Is rover driving?
- ✧ How move rover arm to right sample area?
- ✧ Does the rover have enough power to sample?
- ✧ When can we send the commands to sample?
- ✧ Did the rover sample the right area?

Tactical: Analyze rock

- ✧ Does the rover have enough power to analyze?
- ✧ Does the rover have enough memory for data?
- ✧ When can we send the commands to sample?
- ✧ When can we get the data?

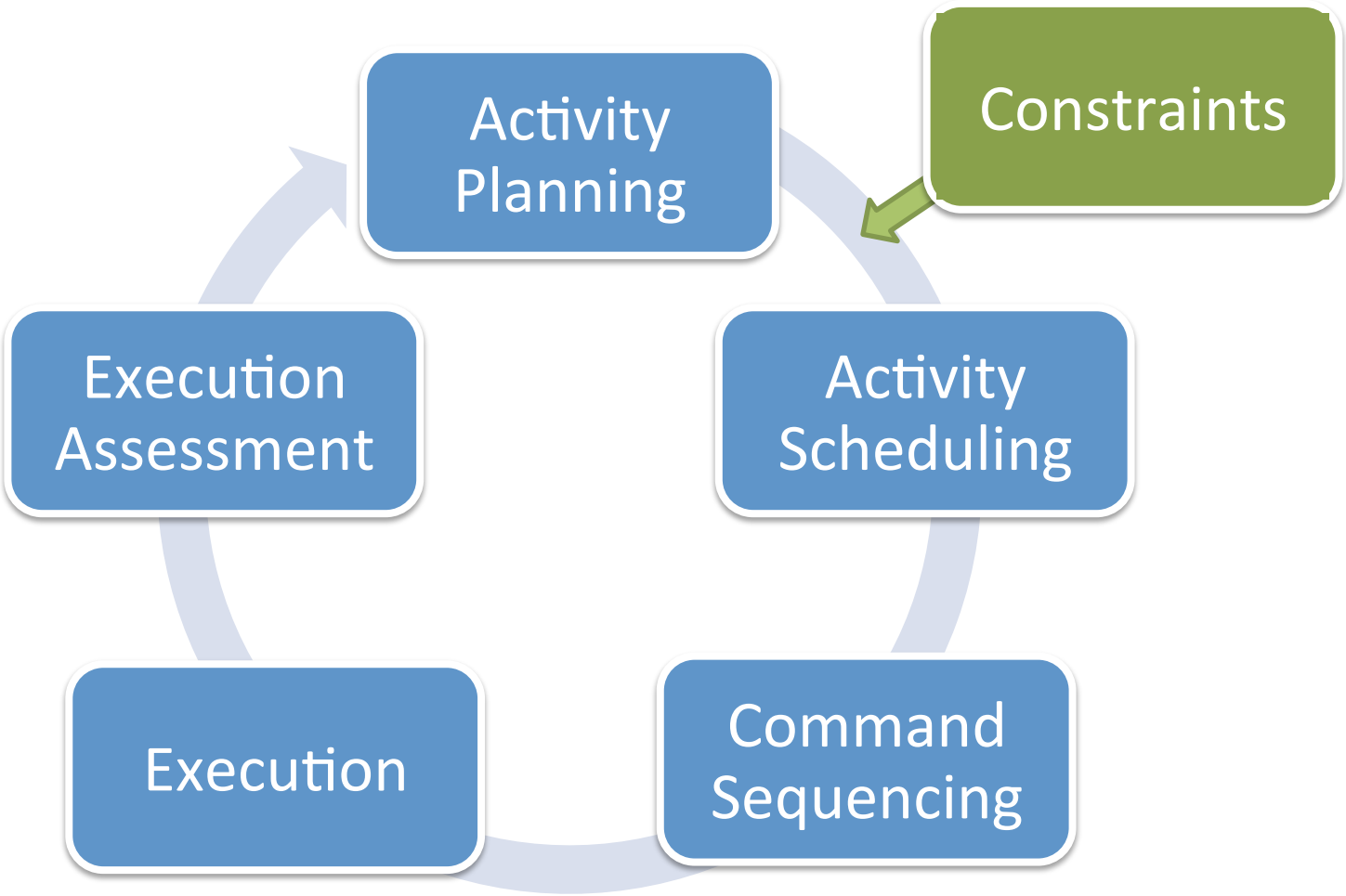


Mission Constraints



Marquez & Newman (2007) "Recommendations for Real-Time Decisions Support Systems for Lunar and Planetary EVAs" International Conference on Environmental Systems

Tactical & Ops Planning Flow



Can you imagine all the constraints, resources, and activities required for the International Space Station?!

SPIFe: Scheduling & Planning InterFace

Mars Rovers

Mars Exploration Rover:
Maestro & MAGPEN

MSLICE
Mars Science Laboratory Interface

International Space Station

Power Planning
& Analysis Tool

Score

APEX

2003 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015

LASS
LADEE Activity Scheduling System

Phoenix
Science Interface

SPIFe
Scheduling & Planning Interface for Exploration

Phoenix Lander

Assisted
Replanning

Analog Mission
Self-Scheduling

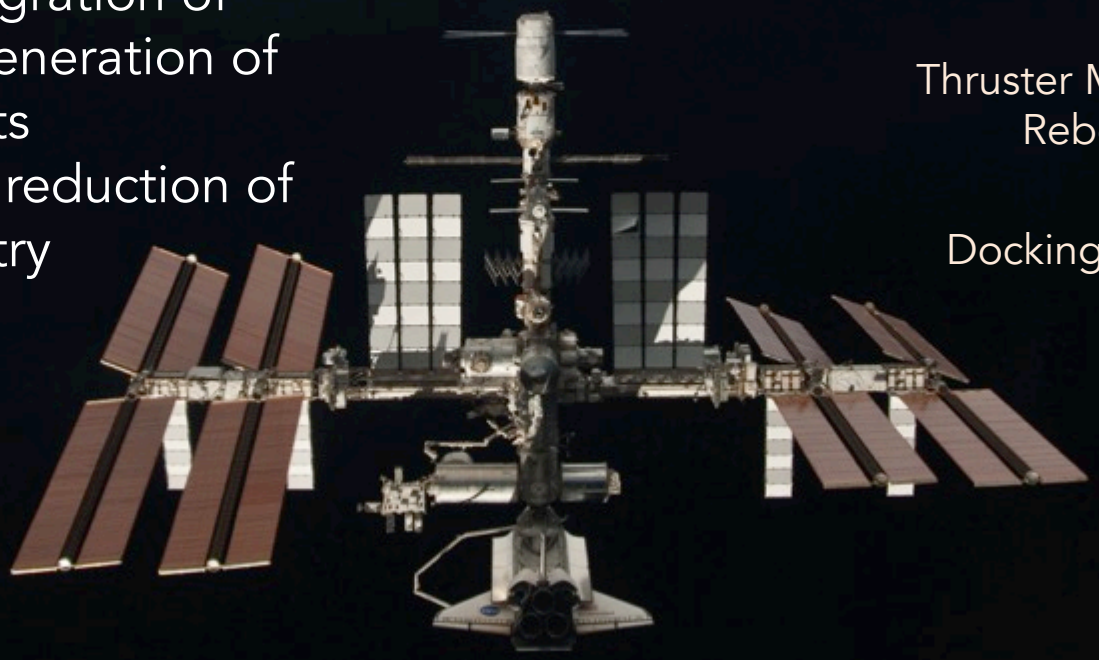
ISS
Self-Scheduling

Playbook

ISS Attitude Determination & Control

APEX

- Automatic integration of input data & generation of output products
  - Significant reduction of manual entry



Thruster Maneuvers, Reboosts

Docking Events

ISS Orbital Position & Orientation

- Streamline planning, integrating multiple tools
- Facilitates coordination process between International Partners

ISS Power Planning

PLATO

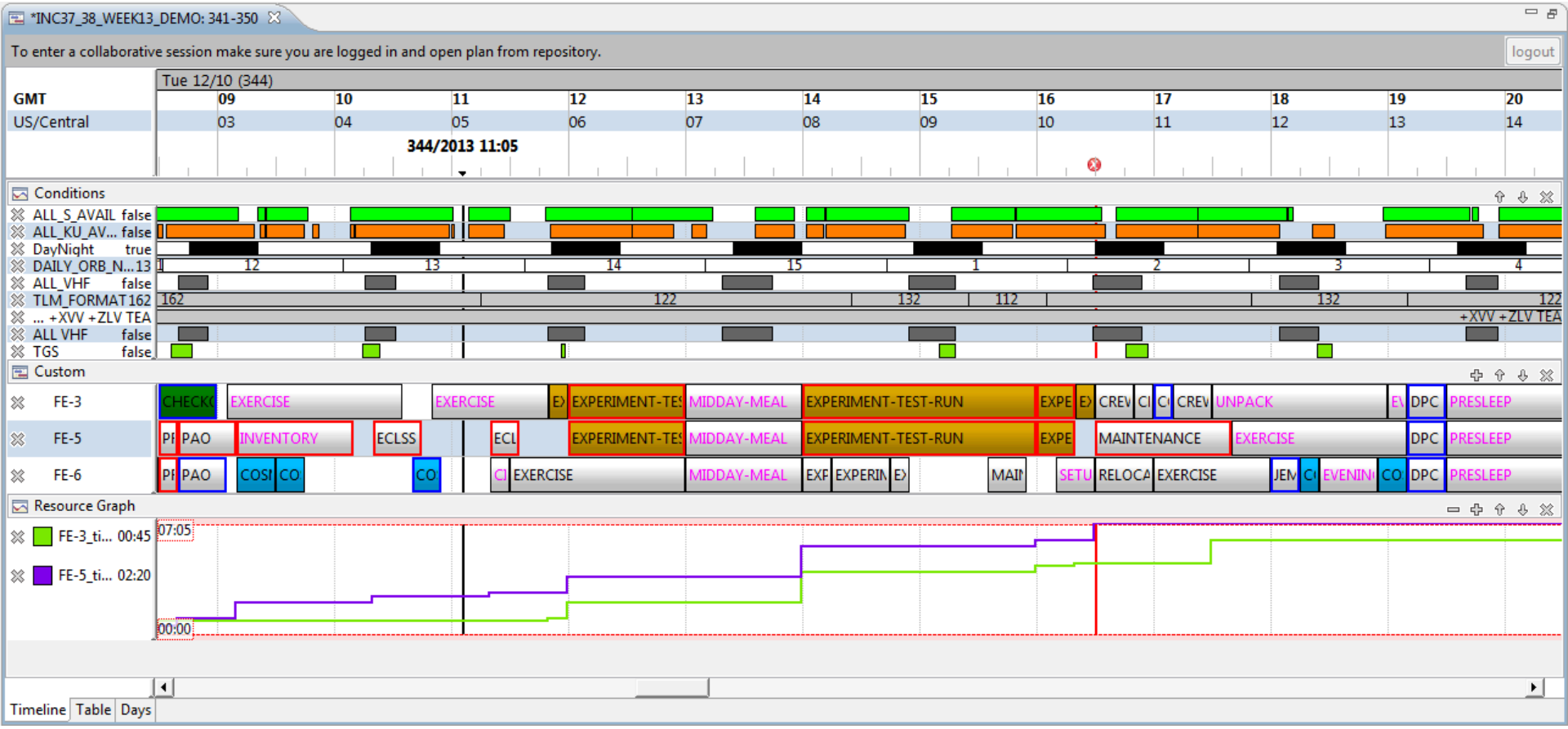
- Automatic integration of input data from various flight controller disciplines
- Integration of new and legacy power analysis engines
- Facilitating power management
  - Power produced vs. power consumed
  - Scheduling powerdowns
  - Automatic generation of shared products

ISS Crew Planning & Scheduling

Score (part of OPTIMIS toolkit)

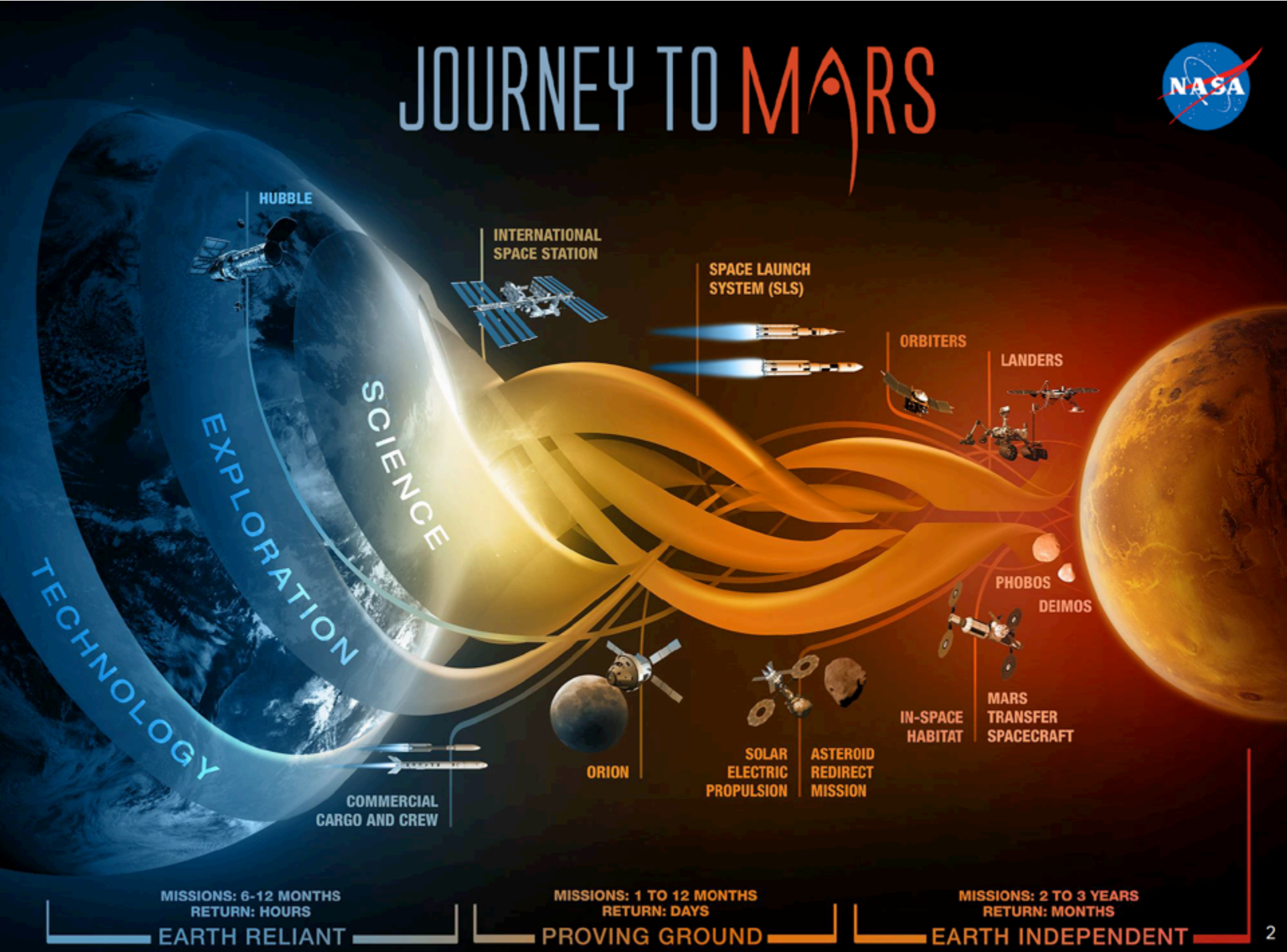
- Schedule integrates crew, ground, and payload activities alongside ISS state information (e.g., orientation, communication availability).
  - Contributions from multiple flight controller disciplines, Marshall Space Flight Center, and International Partners (Russia, Japan, European Union).
- Planning ranges from six months (1 increment) through one day (real-time planning).
- Integrates variety of external software interfaces and data; automated updates.
  - Plan Change Requests, Templates, Comm Availability calculations, Procedures.
- Flexible resource modeling and violations checking, enabling resource planning.
- Unique capabilities: real-time, simultaneous plan editing and seamless plan version control.

Score: Crew & Ground Planning



Integration of Planning SW Tools

Integrated Replanning: HTV


JOURNEY TO MARS
NASA
HUBBLE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM (SLS)
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
PHOBOS
DEIMOS
MARS TRANSFER SPACECRAFT
IN-SPACE HABITAT
ORION
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
COMMERCIAL CARGO AND CREW
MISSIONS: 6-12 MONTHS
RETURN: HOURS
EARTH RELIANT
MISSIONS: 1 TO 12 MONTHS
RETURN: DAYS
PROVING GROUND
MISSIONS: 2 TO 3 YEARS
RETURN: MONTHS
EARTH INDEPENDENT

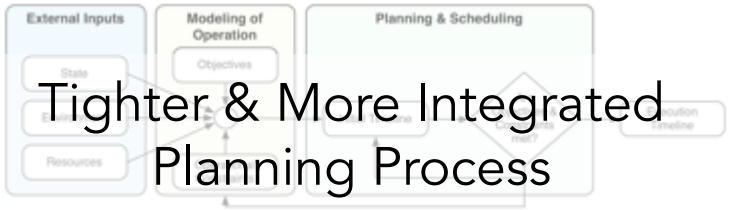
Preparing for Future Needs

Earth Analogs: BASALT

- Simulating Mars operations: low bandwidth & communication latency
- Evaluating different technological capabilities

Future Mission Planning Challenges

Support for Planning Execution & Crew-centric Re-Planning



Tighter & More Integrated Planning Process

<u>Integrated Human-Robotic Planning</u> with teams of diverse agents, requiring geospatial planning

Questions?

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