

Surface Telerobotics

Human Exploration Telerobotics (HET) Project
Technology Demonstration Mission (TDM) Program
Space Technology Mission Directorate (STMD)



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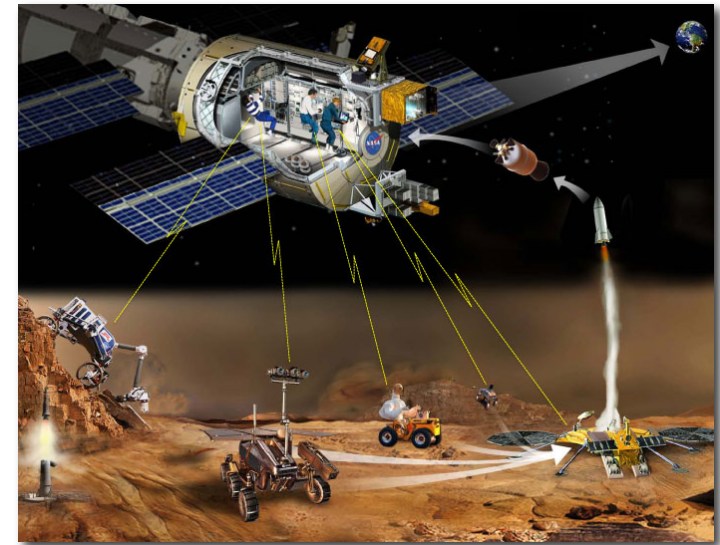
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Motivation

Surface Telerobotics is an **engineering test** of a human-robot “opscon” for future deep-space human exploration missions

Candidate Missions

- **L2 Lunar Farside.** Orion crew module test flight (~2020) to Earth-Moon L2 point
- **Near-Earth Asteroid.** NEA dynamics and distance make it impossible to manually control robot from Earth
- **Mars Orbit.** Crew must operate surface robot from orbit when circumstances (contingency, etc.) preclude Earth control



(NASA GSFC)

What will the test achieve?

- Obtain baseline engineering data
- Validate & correlate prior ground simulations
- Reduce the risk that mission planning is based on inaccurate assumptions

Surface Telerobotics

Objectives

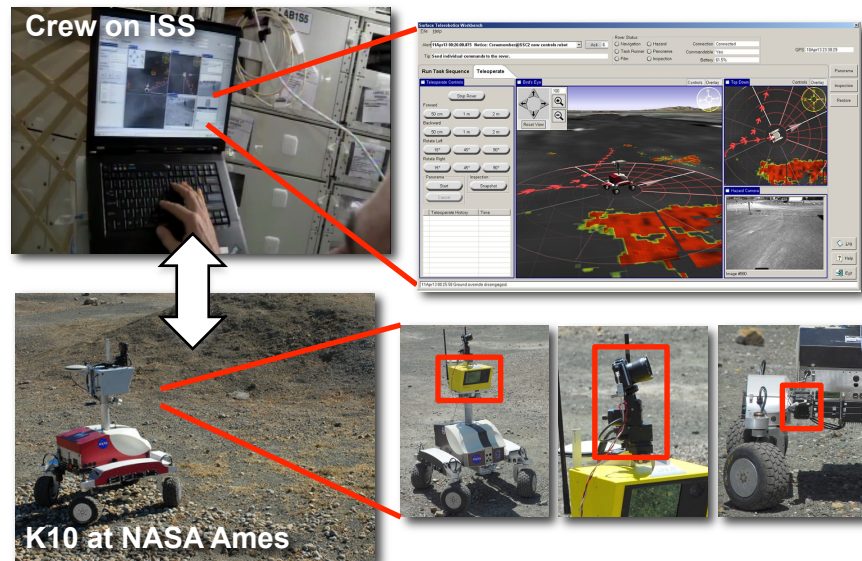
- Demo **crew-centric control** of surface telerobot from ISS (first operational system) based on L2 Lunar farside mission concept
- Test **human-robot “opscon”** for future deep-space exploration mission
- Obtain **baseline engineering data** of system operation

Approach

- Leverage best practices and findings from **prior ground simulations**
- Collect data from robot software, crew user interfaces, and ops protocols
- Validate & **correlate to prior ground sim** (analog missions 2007-2011)

Implementation

- **K10 planetary rover** in ARC Roverscape (outdoor test site)
- ISS astronaut + Mission Control
- L2 mission sims (3): **June-Aug 2013** (ISS Incr. 36: 10.5 hr total crew time)



Key Points

- **Complete human-robot mission sim:** site selection, ground survey, telescope deployment, inspection
- **Telescope proxy:** COTS 75 micron polyimide film roll (no antenna traces, no electronics, no receiver)
- **3.5 hr per crew session** (“just in time” training, system checkout, telerobot ops, & crew debrief)
- **Two control modes:** basic teleop and pre-planned command sequencing (with continuous monitoring)
- **Limited crew user interface:** no sequence planning, no science ops capability, no robot engineering data



Objectives

1. Demonstrate that crew can remotely operate surface robots from inside a flight vehicle to perform exploration work

- Ability to supervise planetary robot from space craft (make correct decisions, take appropriate action)
- Awareness of intent and outcome of rover autonomous actions for waypoint driving, image acquisition, payload deployment
- Ability to detect and respond appropriately to robot problems affecting achievement of mission objectives

2. Mature technology required for crew control of surface telerobots (specifically robotic control interfaces for crew)

- Information and capability for supervisory control of robot
- Information and capability for mission tasks of site selection, antenna deployment, and antenna inspection
- Usefulness and understandability of robot's autonomous functions for waypoint driving, image acquisition, and payload deployment
- Availability and timeliness of information (communication & data distribution)

3. Identify requirements and gaps for research and technology development programs

- Identify HRP risks and gaps relevant to Surface Telerobotics
- Document evidence of HRP risks or HRP risks avoided observed during sessions

L2 Lunar Farside (Waypoint) Mission Concept

Orion at Earth-Moon L2 Lagrange point

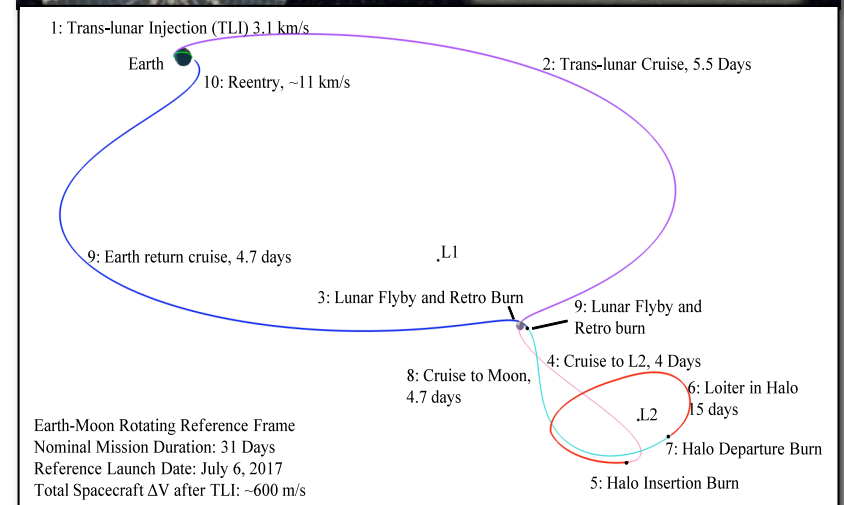
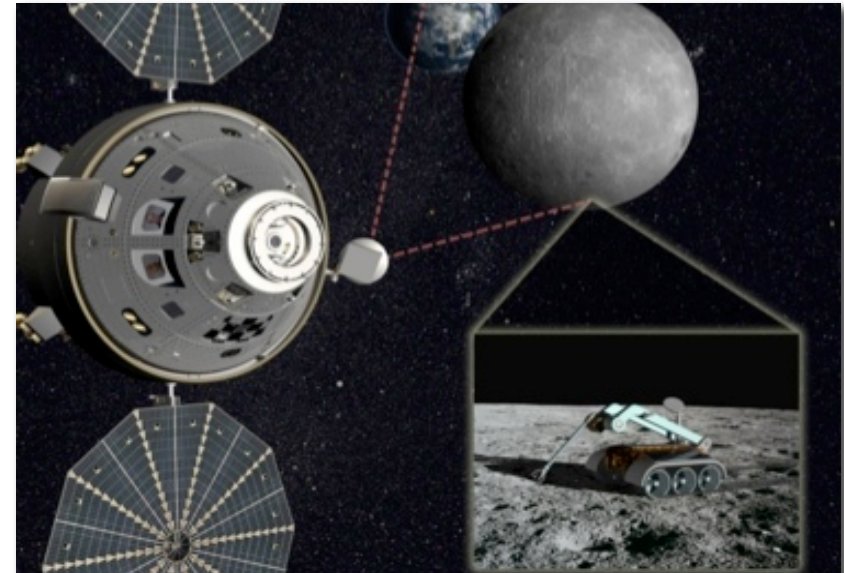
- 60,000 km beyond lunar farside
- Allows station keeping with minimal fuel
- Crew remotely operates robot on lunar farside
- Less expensive than human surface mission
- Does not require human-rated lander

Primary objective: lunar telescope

- Use telerobot to setup radio telescope
- Requires surface survey, antenna/receiver deployment, and inspection/documentation
- Lunar farside provides radio quiet zone for low-freq measurements cosmic dawn

Secondary objective: sample collection

- Use telerobot to perform field geology
- Requires scouting, sampling (possibly subsurface), and sample caching/return
- South Pole Aitken (SPA) basin sampling is the highest priority lunar science objective



(Lockheed Martin / LUNAR)

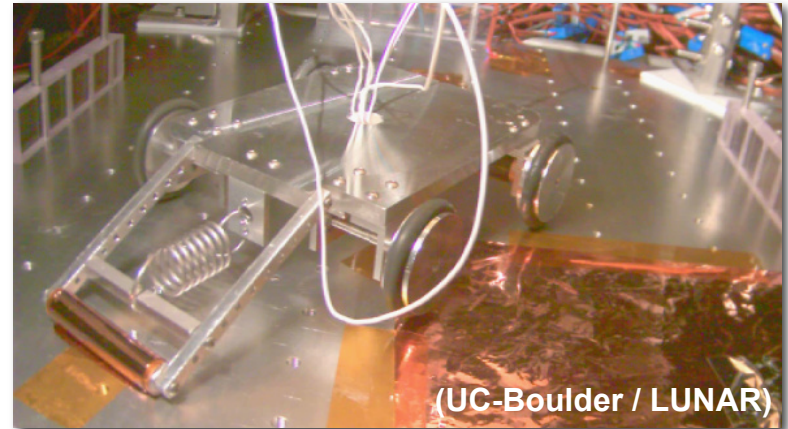
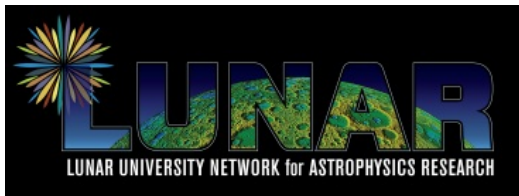
Polyimide Antenna Technology

Concept

- Metallic conductor deposited on surface of polyimide film (e.g., DuPont Kapton)
- Suitable for frequencies up to 100 MHz
- Polyimide remains flexible at lunar daytime temperatures, thus can be deployed by unrolling

Testing (to date)

- Vacuum chamber with thermal cycling & UV exposure similar to lunar surface conditions (Univ. of Colorado Boulder / NLSI LUNAR)
- Outdoor signal test (New Mexico)

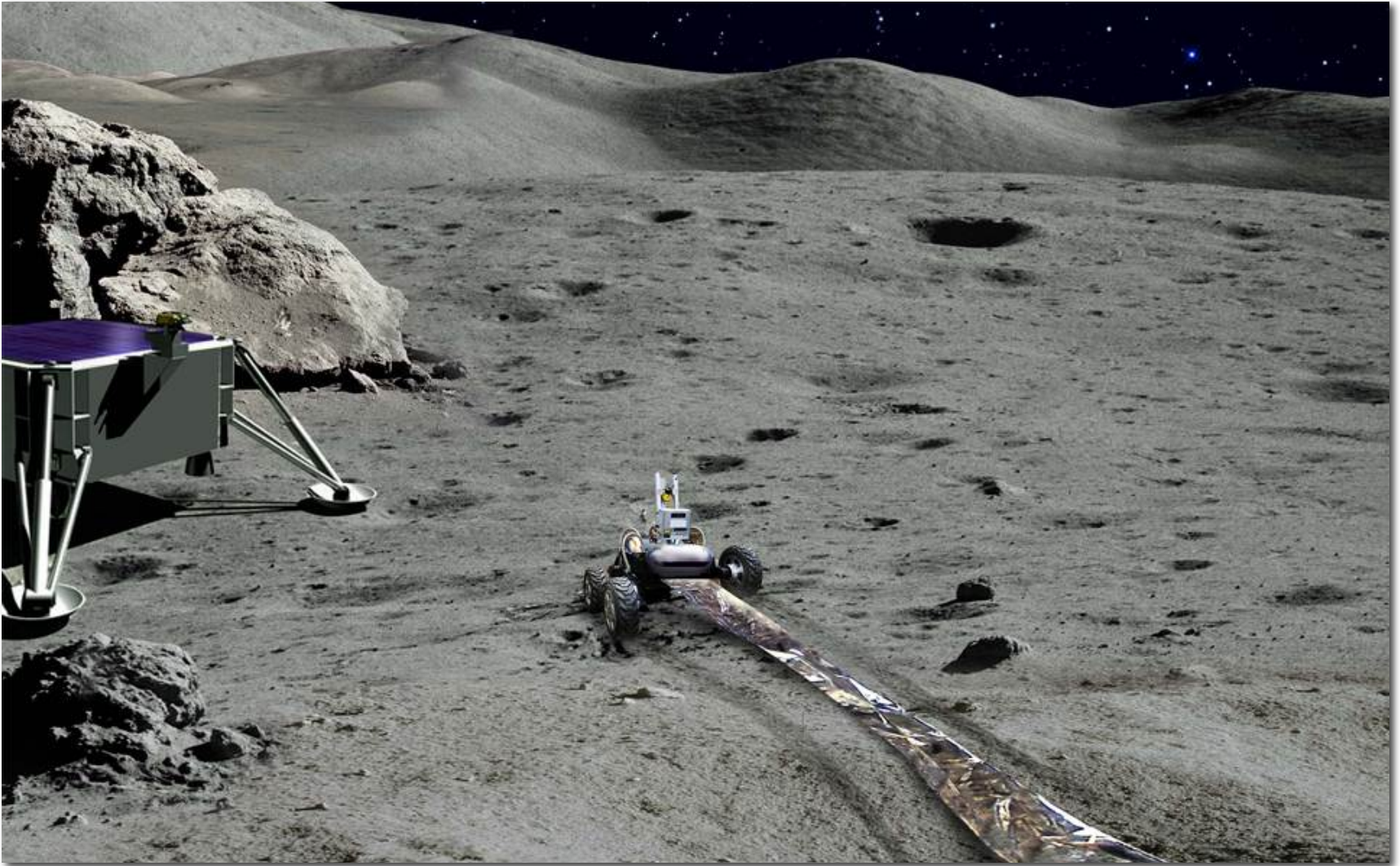


Rolling out polyimide film inside vacuum chamber with teleoperated mini-rover



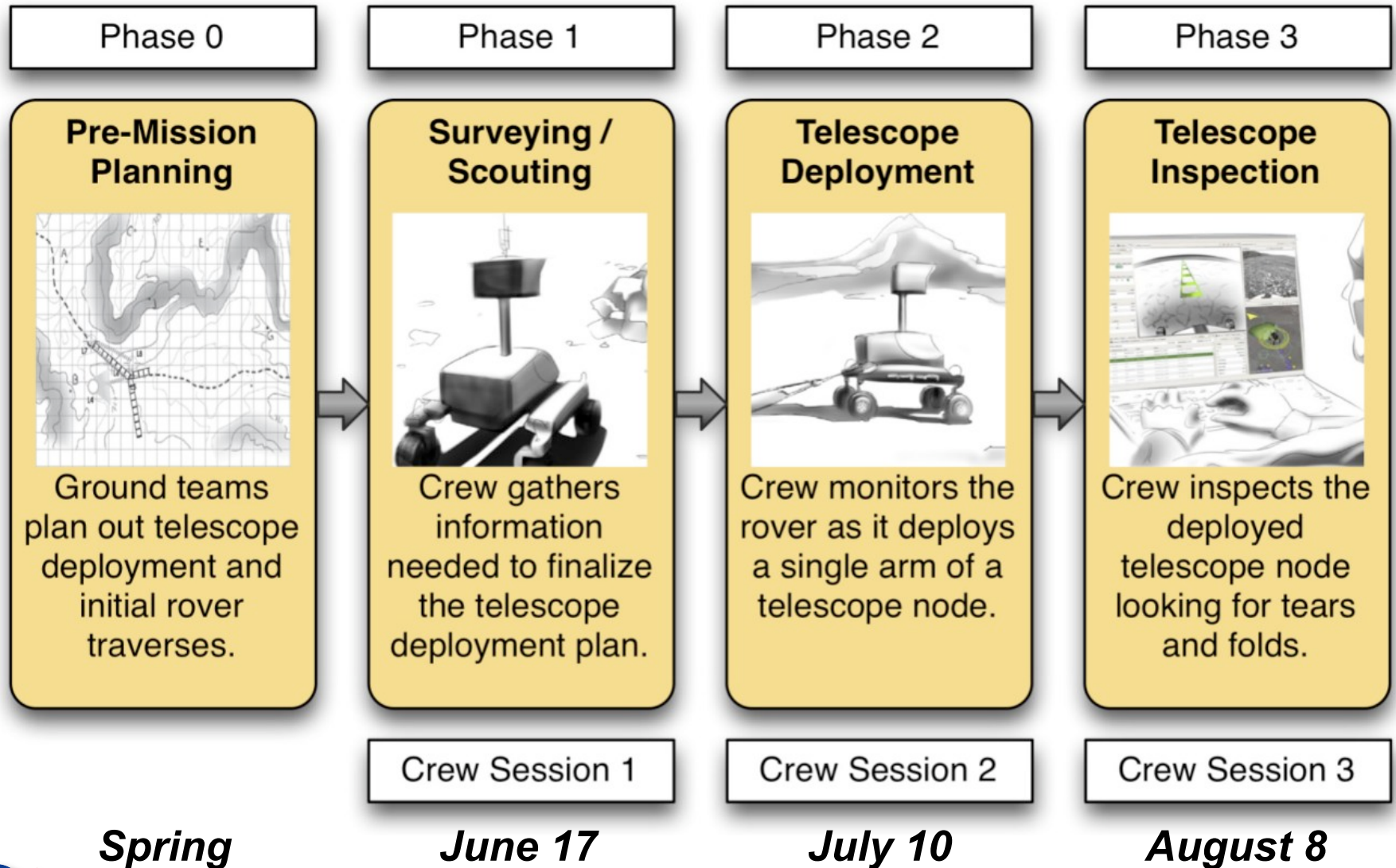
Outdoor test in New Mexico

Telerobotic Telescope Deployment Concept



(JPL / LUNAR)

Waypoint Mission Simulation (2013)



K10 Planetary Rover @ NASA Ames

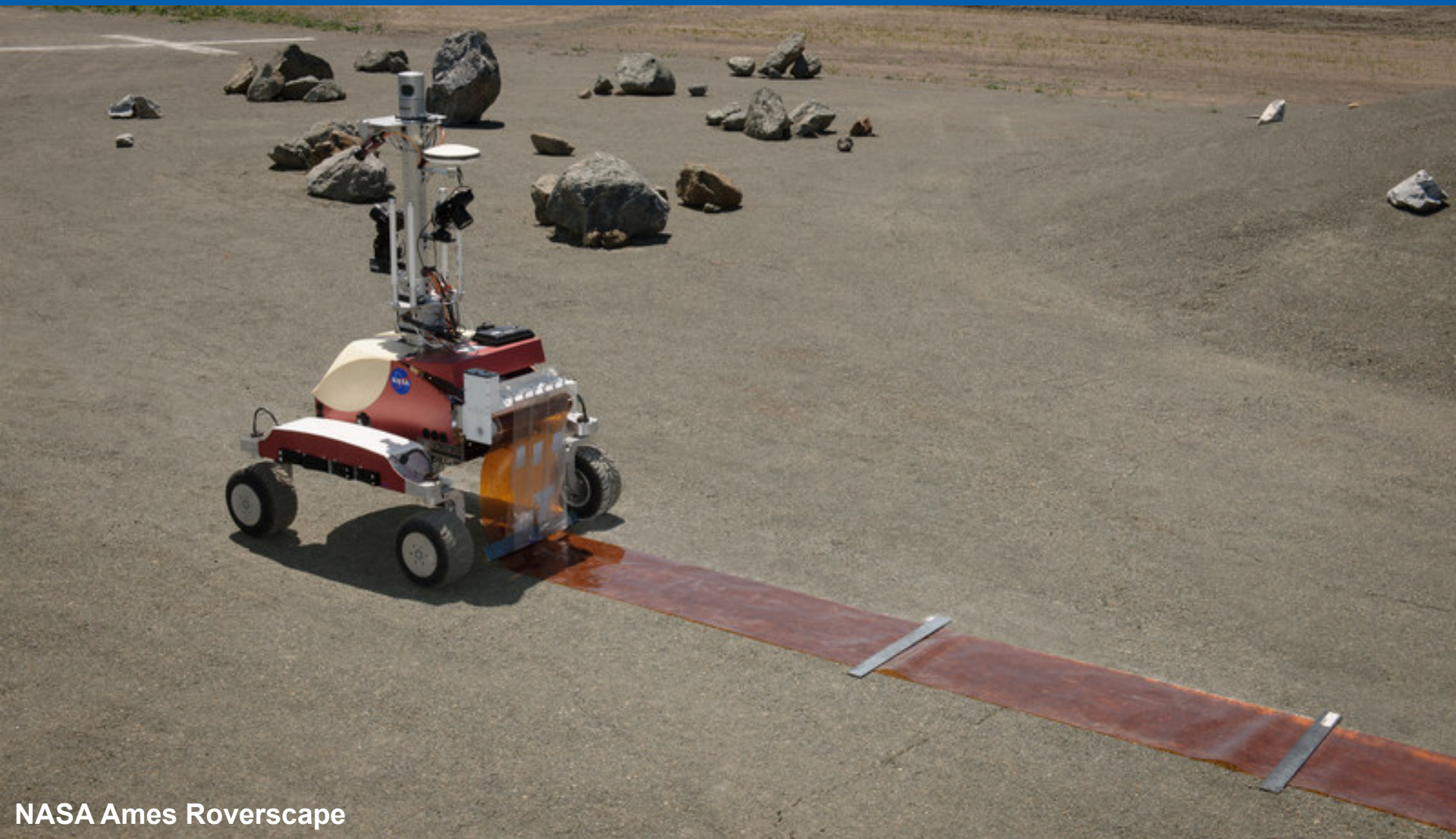


K10 Specifications

- 4-wheel drive, 4-wheel steer
- Split rocker chassis
- Size: 1.3 x 0.9 x 1.0 m (HxWxL)
- Speed: 0.9 m/s (on 10 deg slope)
- Power: 1900 W (Li-ion batteries)
- Weight: 100 kg (with 25 kg payload)

NASA Ames Roverscape

Deployed Telescope Simulation

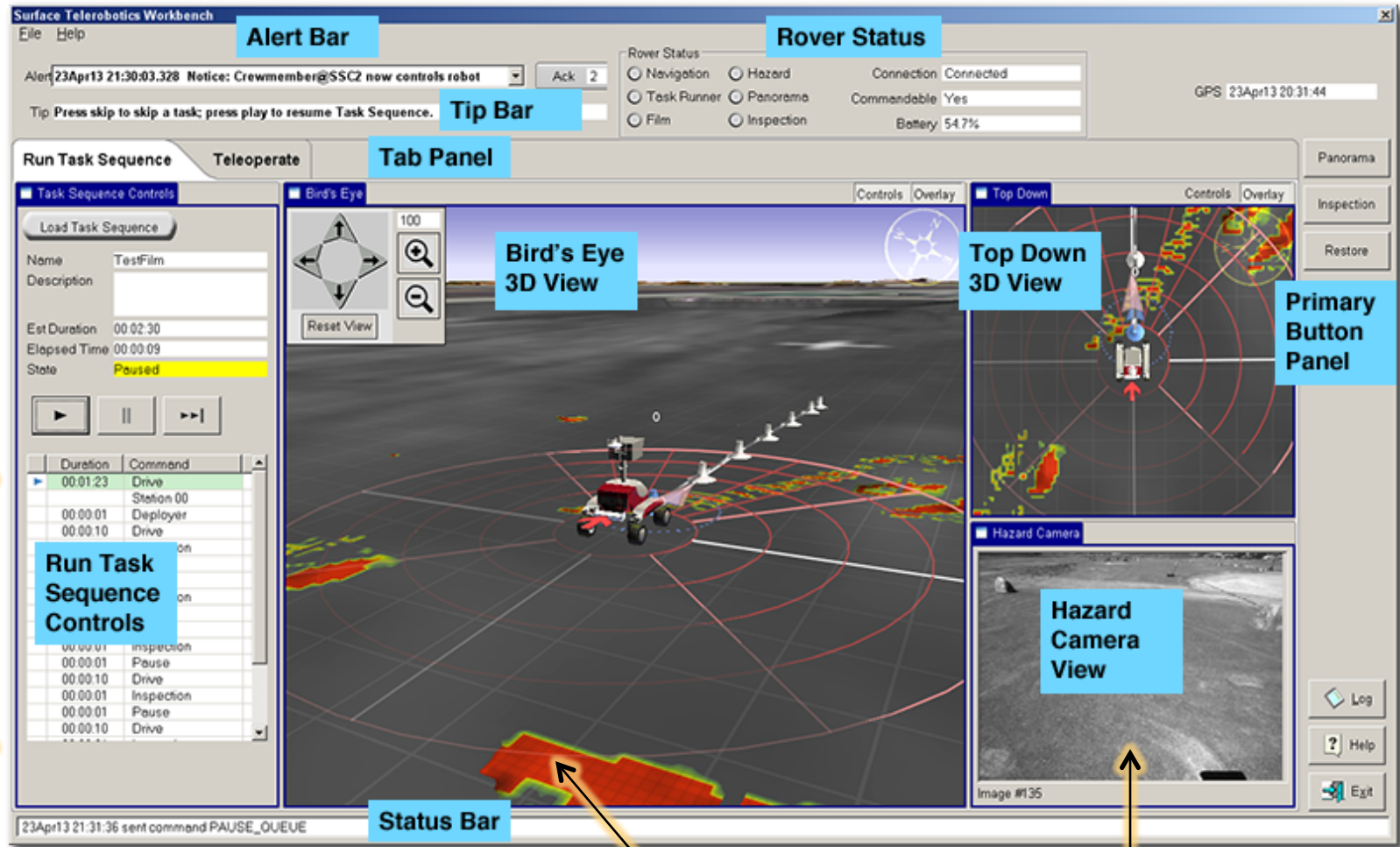


NASA Ames Roverscape

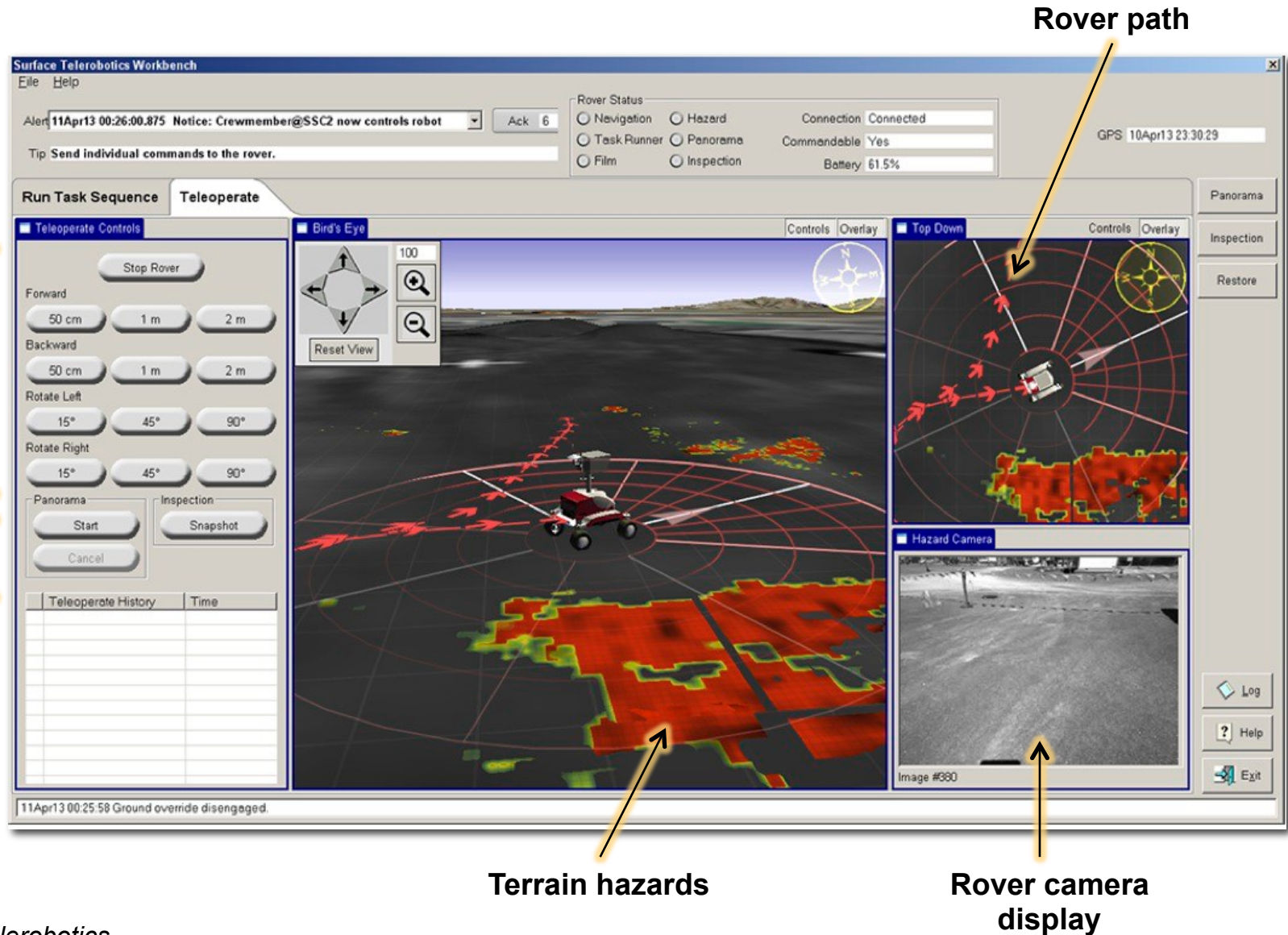


Surface Telerobotics

Robot Interface (Task Sequence Mode)

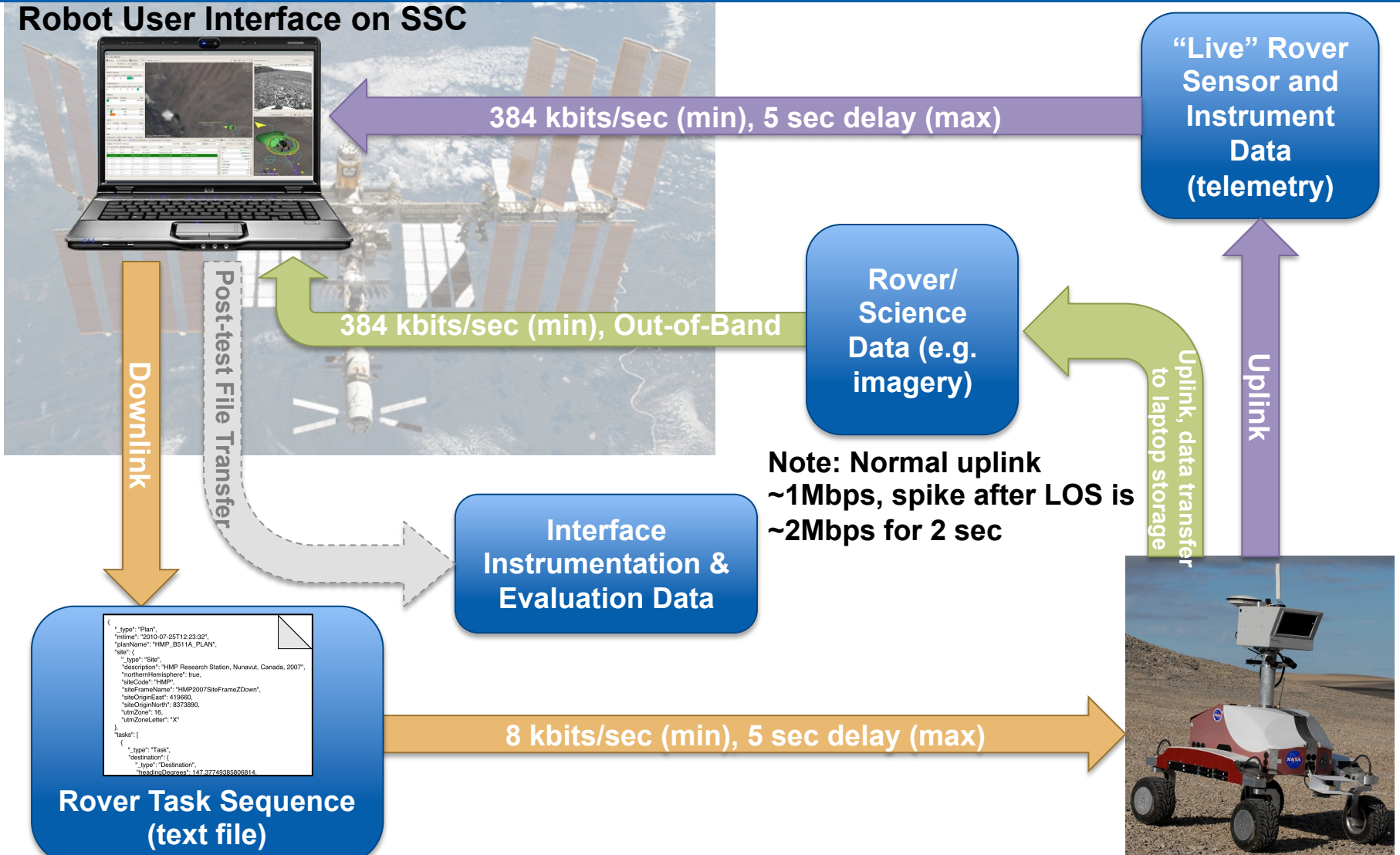


Robot Interface (Teleop Mode)



Data Communications

Robot User Interface on SSC



K10 rover
at NASA Ames

Tasks & Activities (ISS Crew)

Each crew session is 3.5 hours

Review, Training, Conference (1 hour)

- Watch Intro Video, Read Big Picture Words (15 min)
- Run through Just-in-time Training module (30 min)
- Crew conference with PD team (15 min)

Surface Telerobotics Ops (2 hours)

- Downlink task plans to robot and monitor execution
 - Interrupt execution for problems (e.g. cannot reach waypoint)
- Handle contingencies as needed (run “teleop” plans)
 - Teleop to avoid obstacles
 - Perform additional data collection as needed to reacquire data
- As observation data arrives, verify that data is valid
- Interact with ground support as needed

Debrief with mission control (0.5 hours)

Technology Advancement

Subsystem	Start	End
Supervisory control user interface (ST Workbench)	5	6
In-line metrics, summarization, and notification systems	4	6
Science data analysis interface (xGDS)	5	6
Autonomy for short-delay interactive supervisory control (RoverSW)	5	7
Command/telemetry messaging (RAPID)	5	7
Time-delay mitigation	4	7

TRL 4 = Component and/or breadboard validation in lab

TRL 5 = Component and/or brassboard validation in relevant environment (simulation of target operational environment)

TRL 6 = System/subsystem model or prototype demonstration in a relevant environment (under critical conditions). Engineering feasibility fully demonstrated.

TRL 7 = System prototype demonstration in an operational (space) environment. Well integrated with operational hardware/software.

Test Protocol

Data Collection

Obtain engineering data through automatic and manual data collection

- automatic** **Data Communication:** direction (up/down), message type, total volume, etc.
- Robot Telemetry:** position, orientation, power, health, instrument state, etc.
- User Interfaces:** mode changes, data input, access to reference data, etc.
- Robot Operations:** start, end, duration of planning, monitoring, and analysis
- manual** **Crew Questionnaires:** workload, situation awareness, critical incidents

Metrics

Use performance metrics* to analyze data and assess human-robot ops

- Human:** Bedford workload rating scale & SAGAT (situation awareness)
- Robot:** MTBI, MTCL for productivity and reliability
- System:** Productive Time, Team Workload, and task specific measures for effectiveness and efficiency of the Human-Robot system

** Performance metrics used for prior analog field tests: 2009 robotic recon, 2010 lunar surface systems, 2010 robotic follow-up, 2009-2011 Pavillion Lakes research project, etc.*



Schedule

11/29/11	ISS Payloads Office authorization received
1/30/12	ISS Research Planning Working Group approval received
9/5/12	PCM (PLUTOs, Flight Director, MSFC, Ames)
11/13/12	SSC Lab testing
11/26/12	JSL Lab Testing for first Comm Test
11/29/12	SSTF-based end-to-end test
1/28/13	First ISS-to-ground Comm Test
3/13 – 5/13	Engineering and Ops Readiness Tests at Ames
4/3/13	Crew Usability Test – SSTF to Rover at Ames
5/8/13	JSL Lab Testing for Crew Ops
6/10/13	Second ISS-to-ground Comm Test (due to ODAR, etc.)
6/17/13	Crew Ops session #1 – Site survey
7/22/13 (<i>tbc</i>)	Crew Ops session #2 – Antenna deploy
8/5/13 (<i>tbc</i>)	Crew Ops session #3 - Inspection

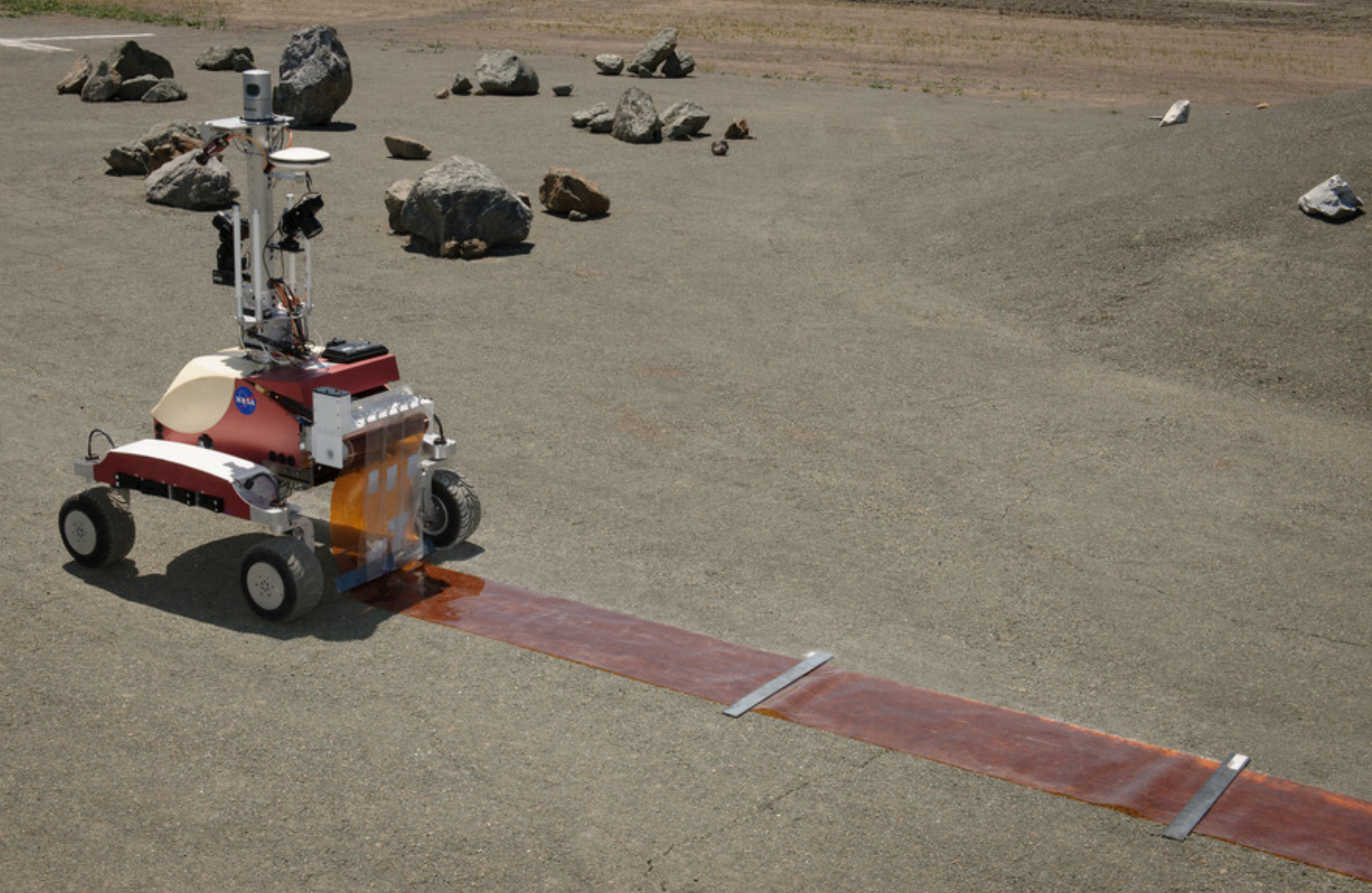




K10 rover at dawn in the ARC “Roverscape”



K10 performing surface survey with cameras & lidar



K10 deploying simulated polymide antenna



Chris Cassidy studies the “Surface Telerobotics Workbench” (2013-06-17)





**Chris Cassidy uses the “Surface Telerobotics Workbench”
to remotely operate K10 from the ISS (2013-06-17)**



ISS Mission Control (MCC-H) during Surface Telerobotics test (2013-06-17)
View of robot interface (top left) and K10 at ARC (top right)



**“PLUTO” Multi-Purpose Support Room at JSC:
provides data comm & crew laptop support**





**Multi-Mission Operations Center at ARC:
manages Surface Telerobotics test sessions**





**K10 support team at ARC:
provides rover engineering & test logistics**





**Remote Operations Center at UC-Boulder:
mission simulation science team**

