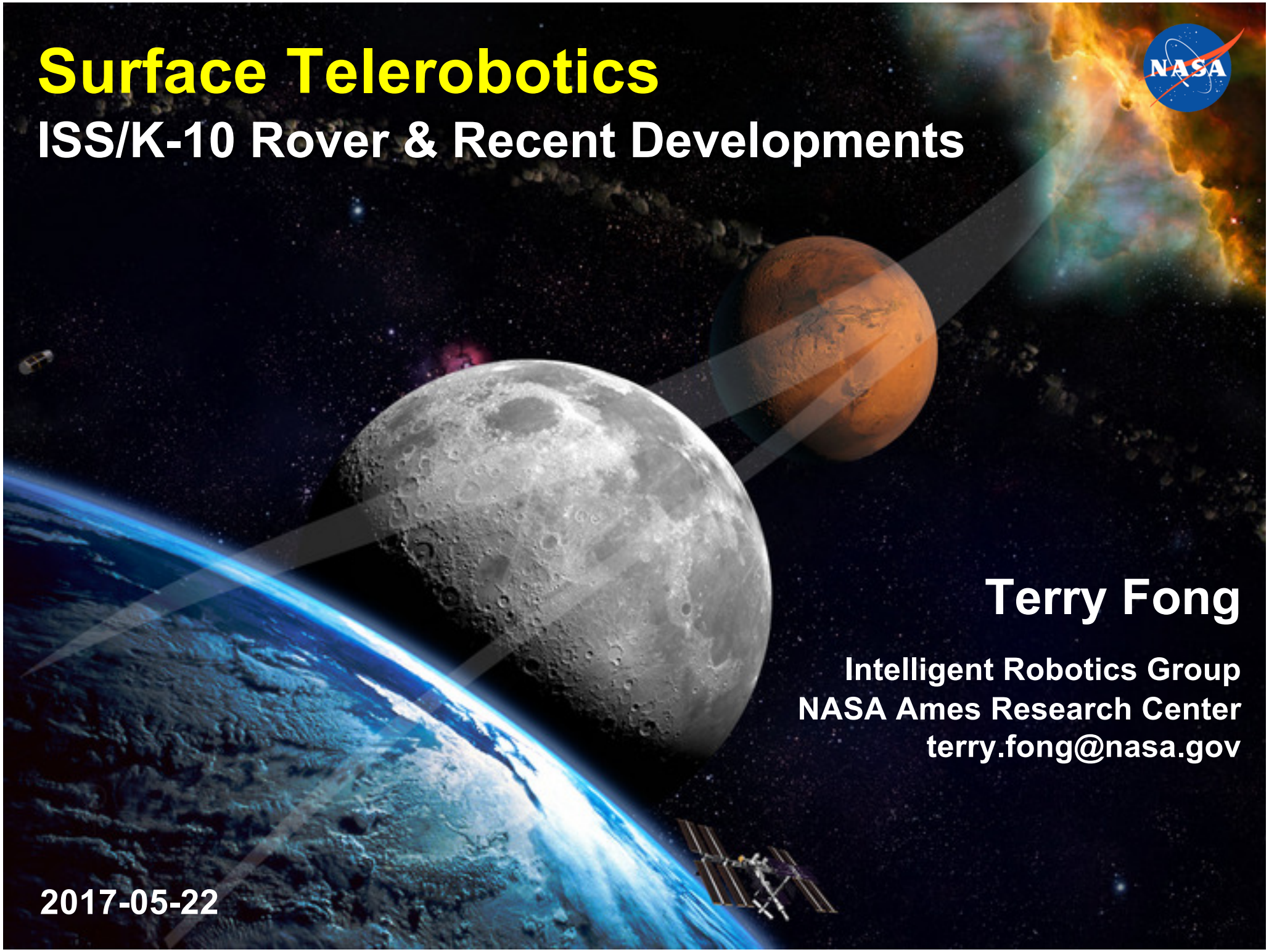
Surface Telerobotics

ISS/K-10 Rover & Recent Developments



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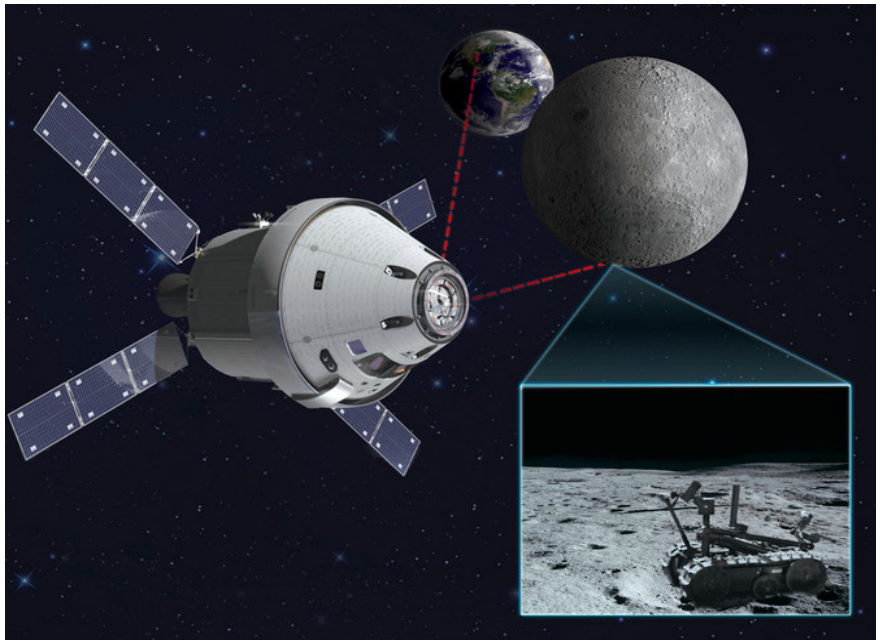
2017-05-22

“Fastnet” Lunar Libration Point Mission

Orion MPCV at Earth-Moon L2 (EM-L2)

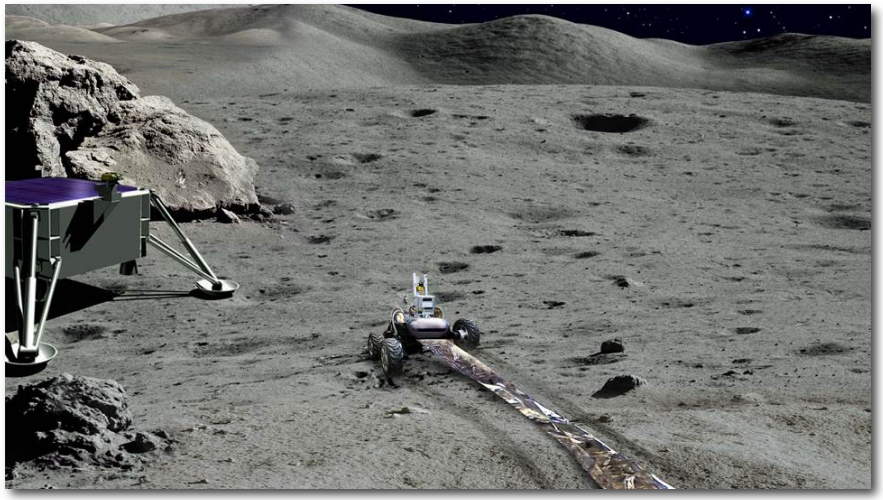
- 60,000 km beyond lunar farside
- Allows station keeping with minimal fuel
- Crew remotely operates robot
- Does not require human-rated lander

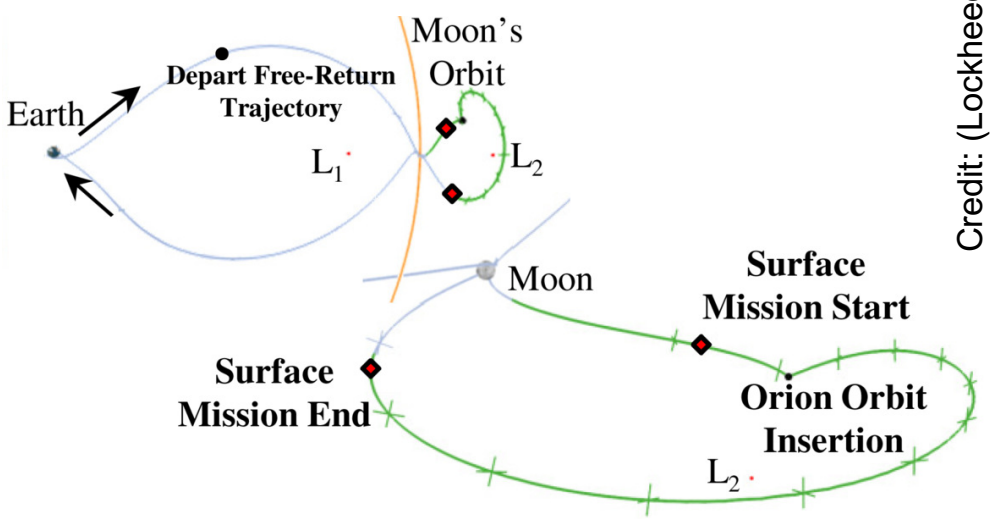


Credit: (Lockheed Martin / LUNAR)

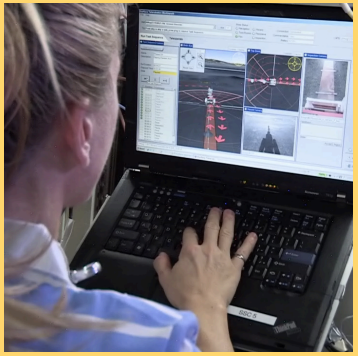
Human-robot conops

- Crew remotely operates surface robot from inside flight vehicle
- Crew works in shirt-sleeve environment
- Multiple robot control modes





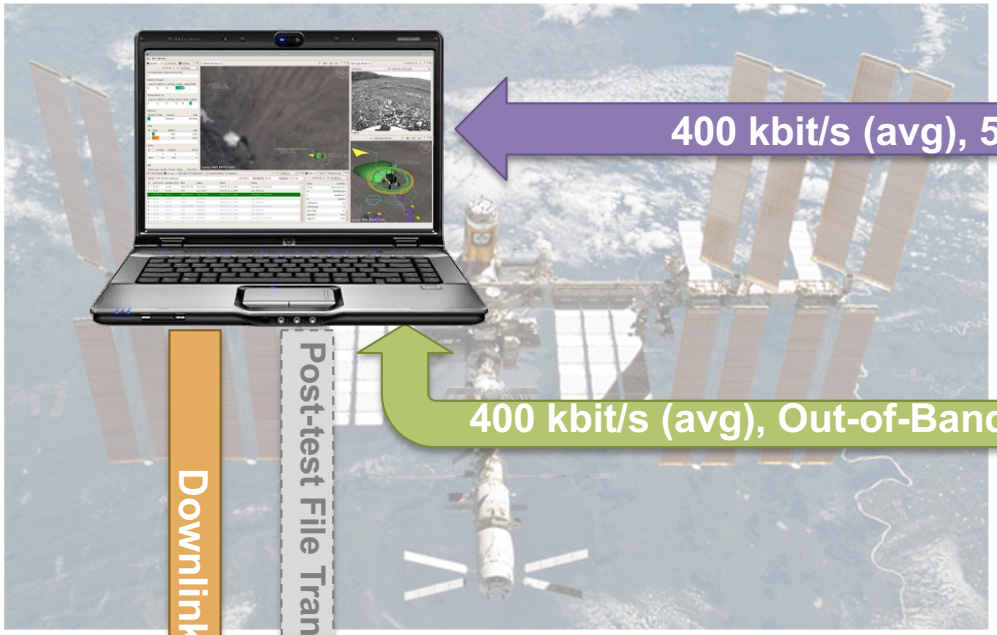
ISS Mission Simulation (2013)

	Crew Session 1	Crew Session 2	Crew Session 3
Pre-Mission Planning	**Site Survey**	**Telescope Deployment**	**Telescope Inspection**
			
Ground teams plan out telescope deployment and initial rover traverses.	Crew gathers information needed to finalize the telescope deployment plan.	Crew monitors the rover as it deploys each arm of the telescope array.	Crew inspects and documents the deployed telescope for possible damage.
Spring 2013	***June 17, 2013***	***July 26, 2013***	***August 20, 2013***

Expedition 36

Surface Telerobotics

ISS Test Configuration



400 kbit/s (avg), 500 msec delay (max)

"Live" Rover Sensor and Instrument Data (telemetry)

400 kbit/s (avg), Out-of-Band

Rover/Science Data (e.g. imagery)

Downlink

Post-test File Transfer

Uplink, data transfer to laptop storage

Uplink

Interface Instrumentation & Evaluation Data

Rover Plan (command sequence)

3 kbit/sec (avg), 500 msec delay (max)

K10 rover at NASA Ames

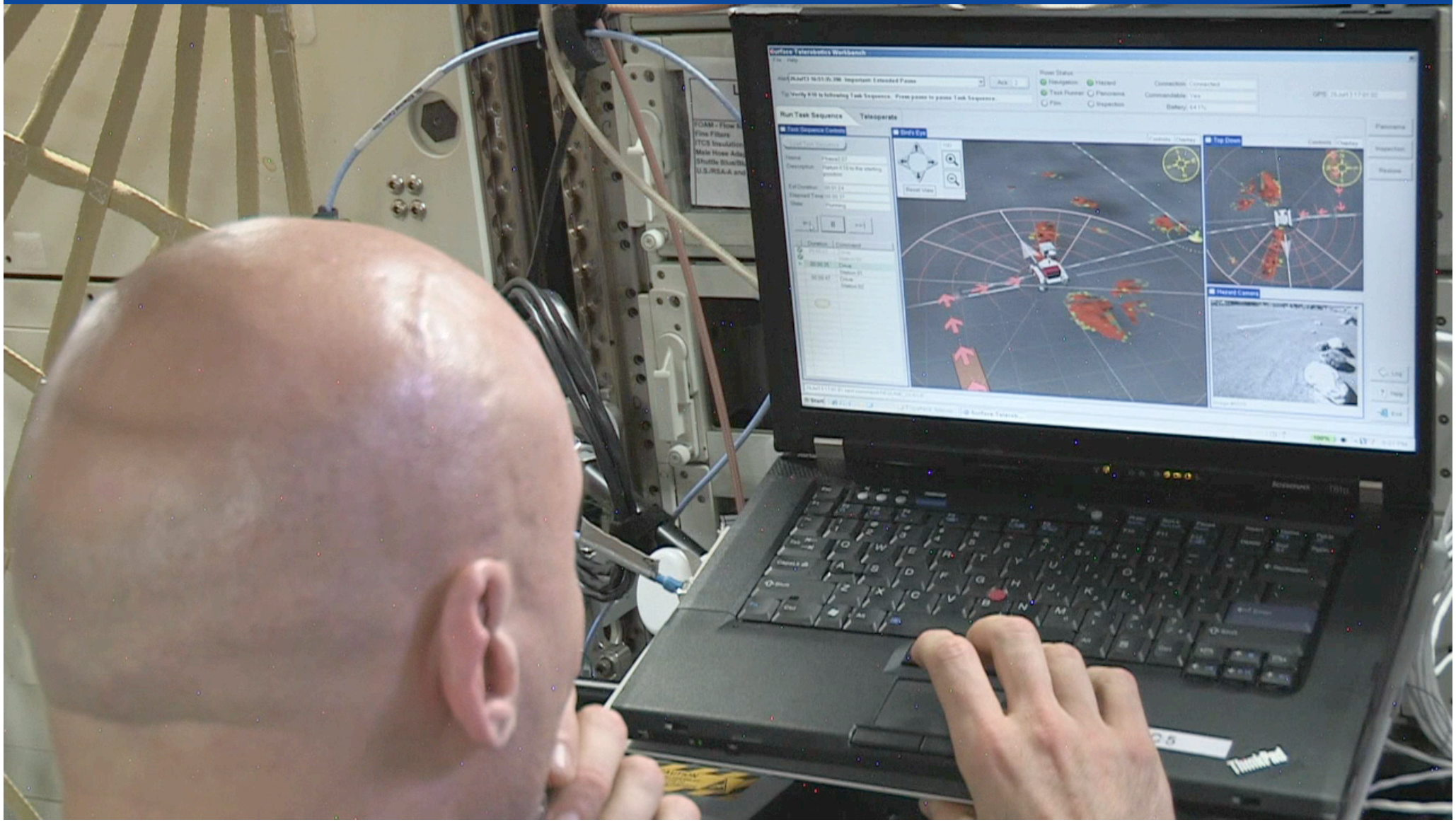
Crew Session #1 – K10 performing surface survey (2013-06-17)

Chris Cassidy uses the "Surface Telerobotics Workbench" to remotely operate K10 from the ISS

Crew Session #2 – K10 deploying simulated polymide antenna under the supervision of Luca Parmitano on ISS (2013-07-26)

ISS Mission Control (MCC-H) during Surface Telerobotics test
View of robot interface and K10 at ARC

Surface Telerobotics



Deployed simulated polymide antenna (three “arms”)

Crew Session #3 – Karen Nyberg remotely operates K10 (2013-08-20)

K10 documenting simulated polymide antenna

Assessment Approach

Metrics

- **Mission Success:** % task sequences: completed normally, ended abnormally or not attempted; % task sequences scheduled vs. unscheduled
- **Robot Utilization:** % time robot spent on different types of tasks; comparison of actual to expected time on; did rover drive expected distance
- **Task Success:** % task sequences per session and per task sequence: completed normally, ended abnormally or not attempted; % that ended abnormally vs. unscheduled task sequences
- **Contingencies:** Mean Time To Intervene, Mean Time Between Interventions
- **Robot Performance:** expected vs. actual execution time on tasks

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
- **Crew Questionnaires:** workload (Bedford Scale), situation awareness (SAGAT)

M. Bualat, D. Schreckenghost, et al. (2014) **"Results from testing crew-controlled surface telerobotics on the International Space Station"**. Proc. of 12th I-SAIRAS (Montreal, Canada)

Future Work: Spacecraft Constraints

Objectives

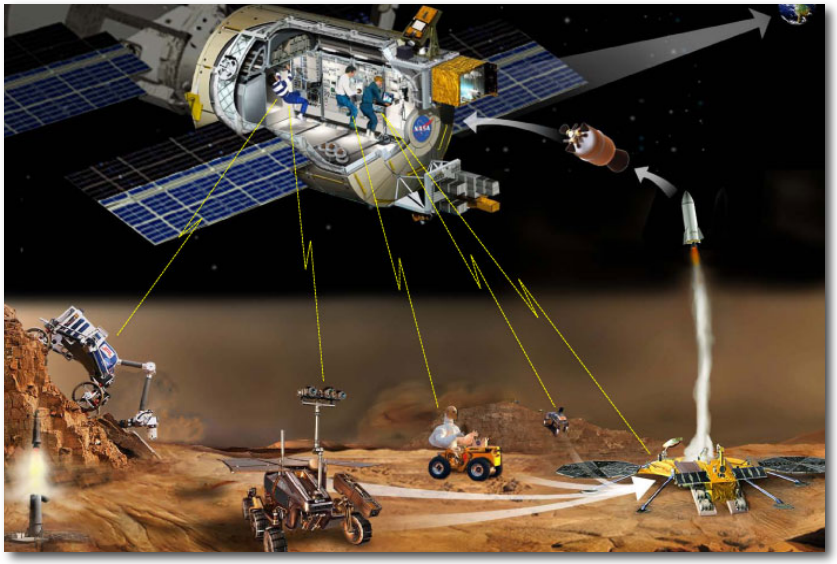
- Study **integration impacts** to spacecraft
- Assess viability of **off-loading rover processing** to spacecraft for certain tasks
- Test crew **real-time decision making**

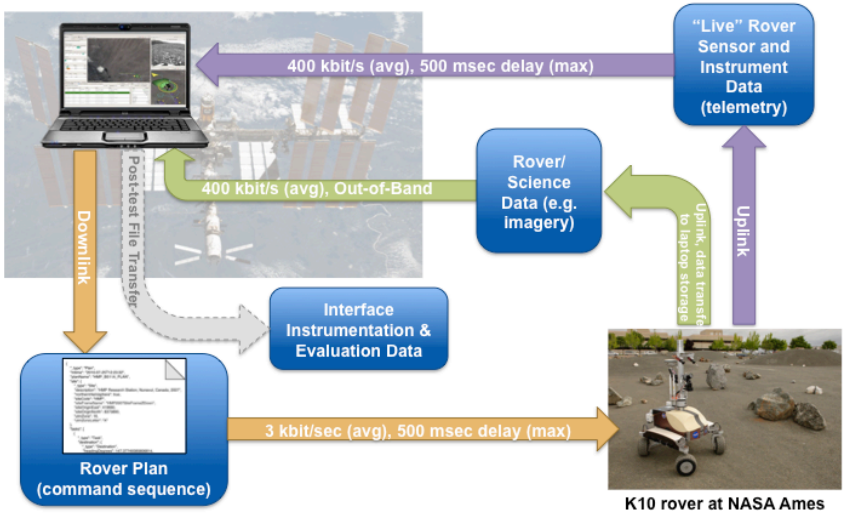
Approach

- Repeat **prior mission sim** with mods
  - More crew training on robot operations
  - Crew operates with little ground support
  - Human-in-the-loop contingency handling
- Give crew low-level control of rover
- Off-board some rover functions (hazard detection, localization, etc) to spacecraft

Metrics

- Crew: Work Efficiency Index, Situation Awareness, Bedford Workload Scale
- Robot: Mean time between/to intervention
- CPU load, RAM/disk, bandwidth





K10 rover at NASA Ames

Future Work: Different Surface Tasks

Objectives

- Examine **surface tasks** that are more unstructured, complex and unpredictable
- Assess **system capability** to support increased SA and control mode changes
- Enhance **operational knowledge** of crew-controlled surface telerobotics

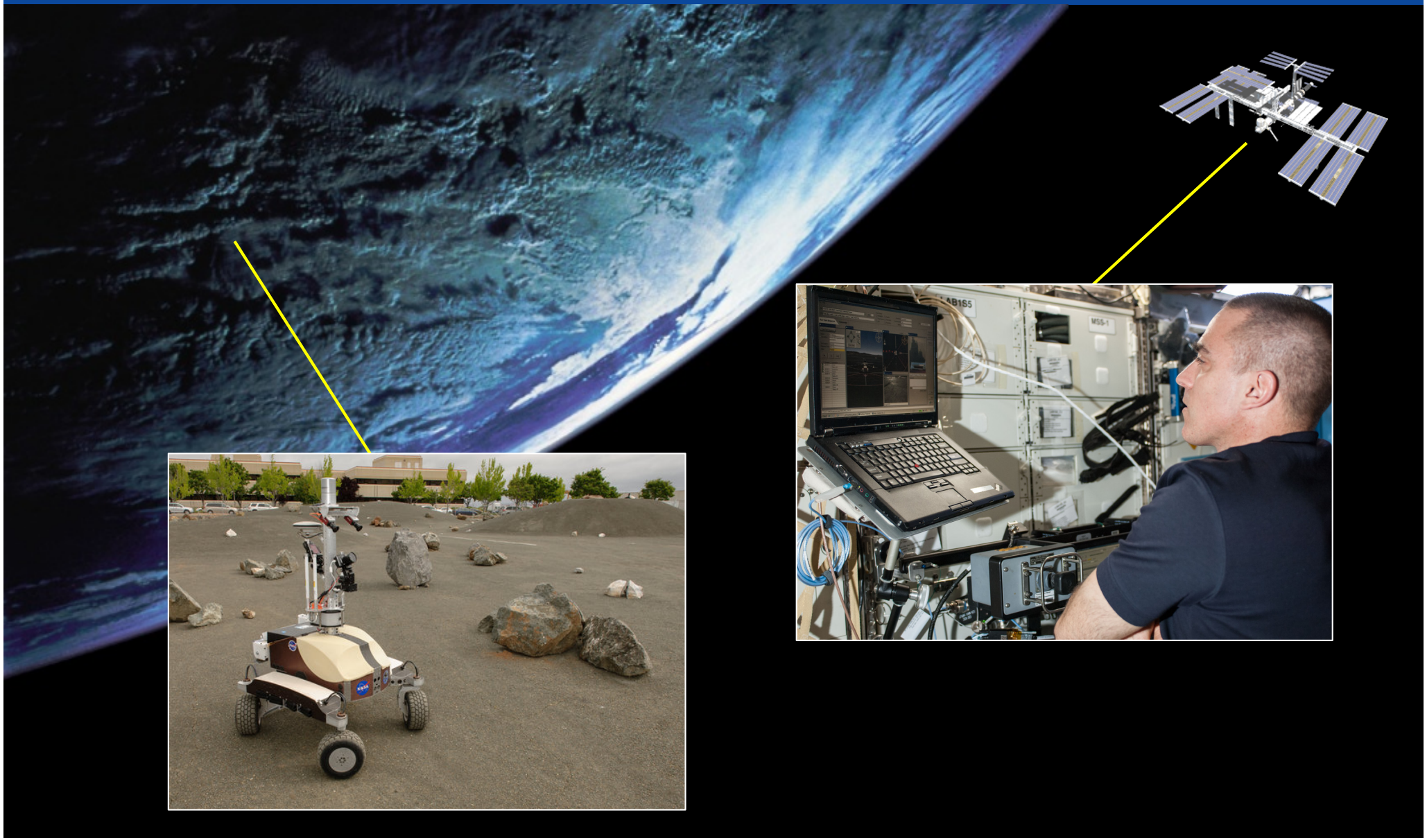
Approach

- Run **new mission sim** with:
  - Assembly/cabling of a functional instrument
  - Planetary fieldwork
- Enhance user interface for science ops

Metrics

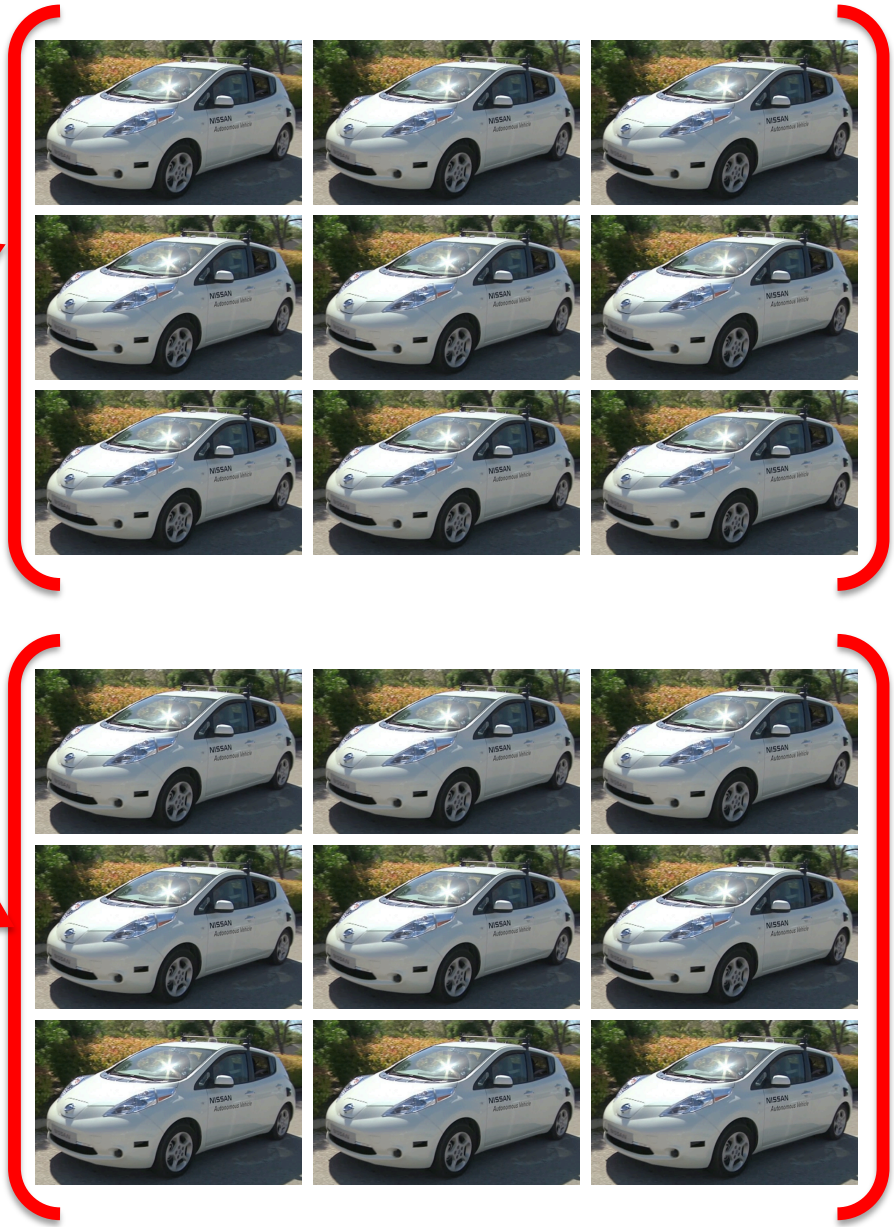
- Crew: Work Efficiency Index, Situation Awareness, Bedford Workload Scale
- Robot: Mean time between/to intervention
- Task: Time on Task, Idle Time, Success rate, % Incomplete

Astronaut / Planetary Rover (2013)

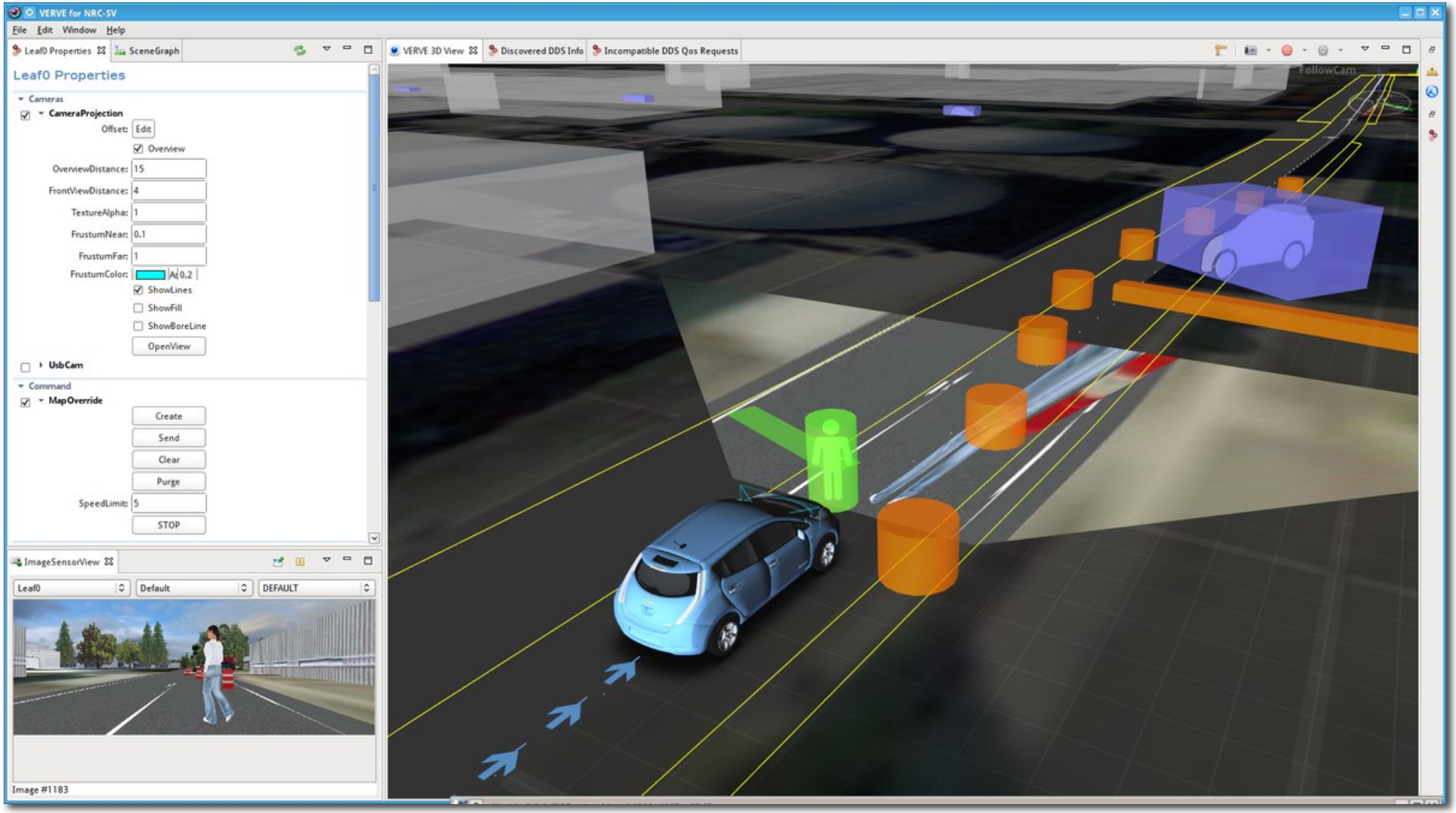


Support Center / Self-Driving Cars (2016)

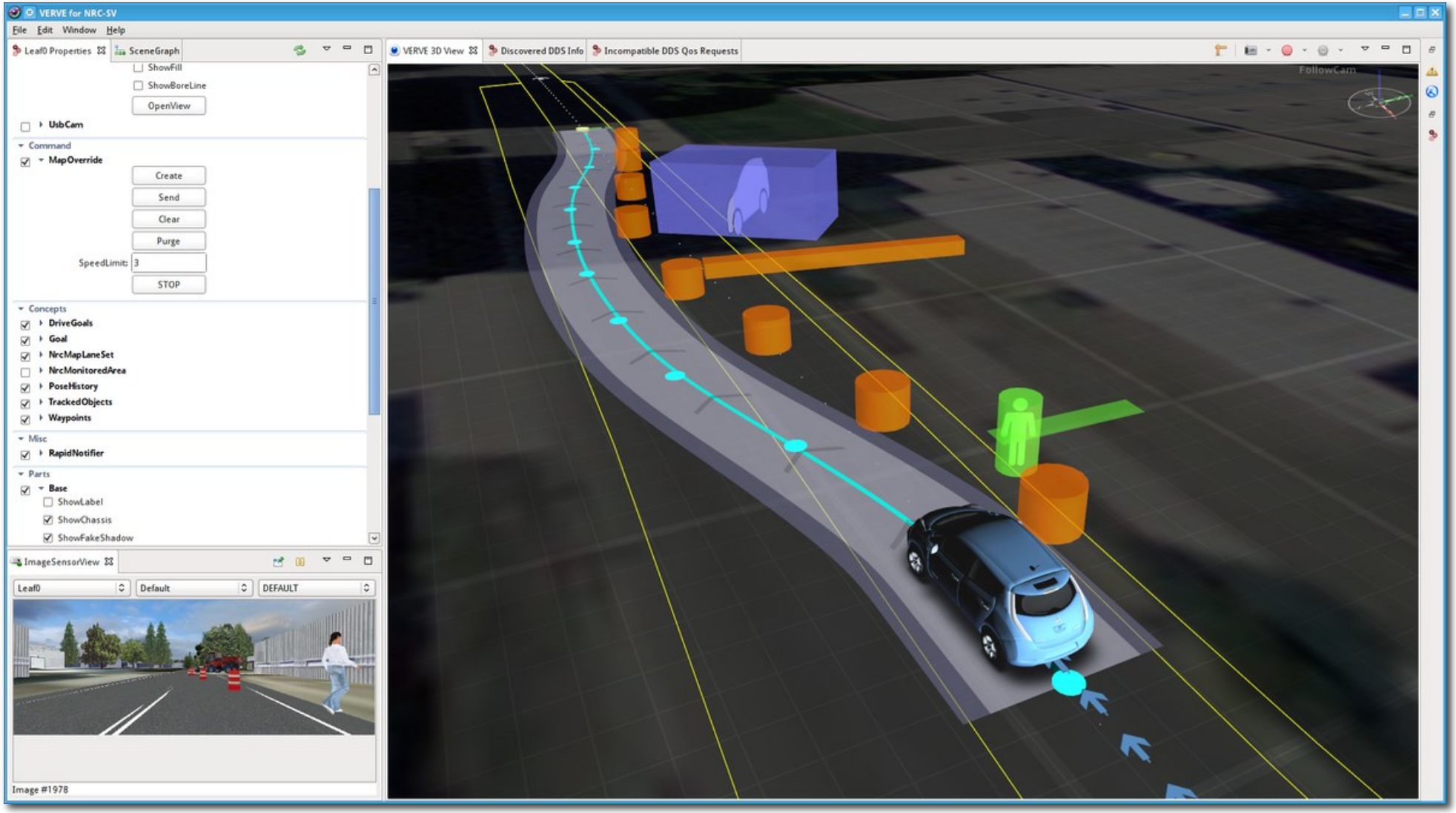
Support Center for a fleet of self-driving cars



Vehicle Assist: Situation Assessment



Vehicle Assist: High-level Guidance



NASA-Nissan Research

Keck Institute for Space Sciences study

"Exploration Telepresence"

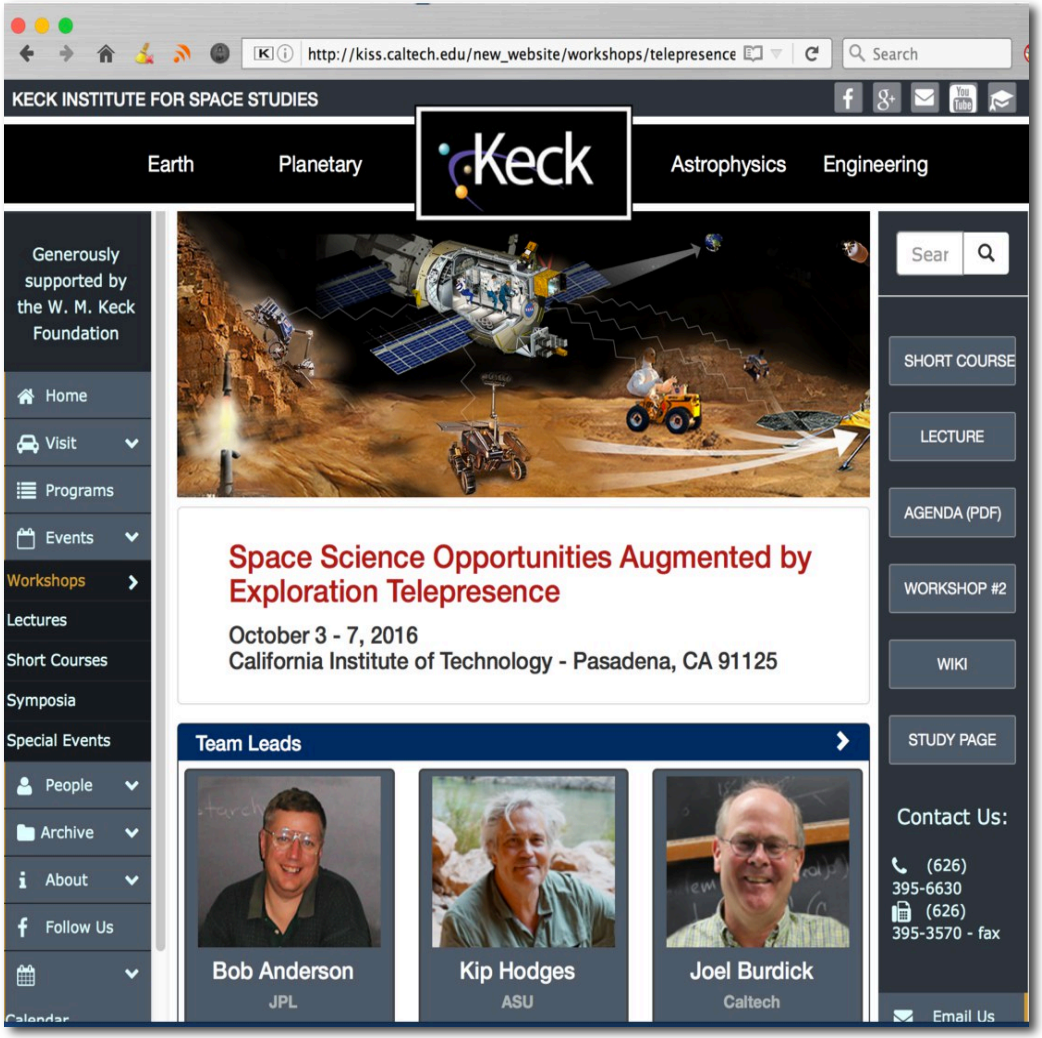
- Astronauts use robots as avatars to be remotely present at a field site
- Focus on field science (emphasis on geology)
- Multidisciplinary review

Workshop #1: October 2016

- Reviewed state-of-the-art
- Discussed pros and cons
- Identified science goals

Workshop #2: July 2017

- Develop research roadmap
- Design rigorous experiments to assess the approach



http://kiss.caltech.edu/new_website/workshops/telepresence/telepresence.html