Moon 2020 - 2030

A New Era of Coordinated Human and Robotic Exploration

ESTEC, Noordwijk, The Netherlands, 15-16 December 2015

DEVELOPMENT OF THE RESOURCE PROSPECTOR PLANETARY ROVER

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Keywords: planetary rover, lunar exploration, in-situ resource utilization

The Resource Prospector (RP) is an In-Situ Resource Utilization (ISRU) lunar rover mission under study by NASA. RP is planned to launch in 2020 to prospect for subsurface volatiles and to extract oxygen from lunar regolith. The mission will address several of NASA's "Strategic Knowledge Gaps" for lunar exploration. The mission will also address the Global Exploration Roadmap's strategic goal of using local resources for human exploration.

The distribution of lunar subsurface volatiles drives the mission requirement for mobility. The spatial distribution is hypothesized to be governed by impact cratering with the top 0.5 m being patchy at scales of 100 m. The mixing time scale increases with depth (less frequent larger impacts). Consequently, increased mobility reduces the depth requirement for sampling.

The target RP traverse will extend 1 km radially from the landing site to sample craters of varying sizes. Sampling craters with different ages will reveal possible volatile emplacement history. In 1 Ga, approximately 60-70 craters of 10 m diameter form per km2. Thus, the rover will need to sample at least ten of these craters, which may require a total traverse path length of 2-3 km.

During 2014-2015, we developed an initial prototype rover for RP. The current design is a solar powered, four-wheeled vehicle, with hub motor drive, offset four wheel steering, and active suspension. Active suspension provides capabilities including changing vehicle ride height, traversing comparatively large obstacles, and controlling load on the wheels. All-wheel steering enables the vehicle to point arbitrarily while roving, e.g., to keep the solar array pointed at the sun while in motion. The offset steering combined with active suspension improves driving in soft soil.

The rover's on-board software utilizes NASA's Core Flight Software, which is a reusable flight software environment. During 2015, we completed the initial rover software build, which provides low-level hardware interfaces, basic mobility control, waypoint driving, odometry, basic error checking, and camera services.

Development of the prototype rover has enabled maturation of many of the subsystems to TRL 5. During the next year, we will conduct integrated testing of concepts of operation, navigation, and remote driving tools. In addition, we will perform environmental tests including radiation (avionics), thermal and thermal/vacuum (mechanisms), and gravity offload (mobility).

National Aeronautics and Space Administration

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Resource Prospector (RP) Overview

Mission

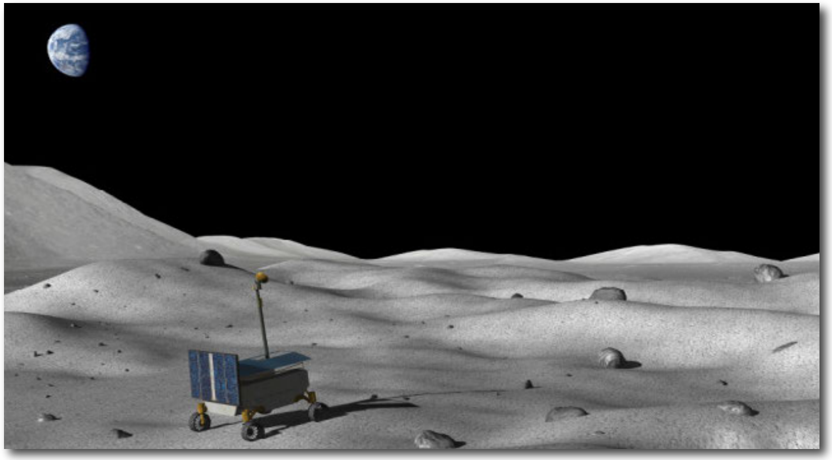
- Characterize the nature and distribution of **lunar polar volatiles**
- Demonstrate **in-situ resource utilization**: process lunar regolith

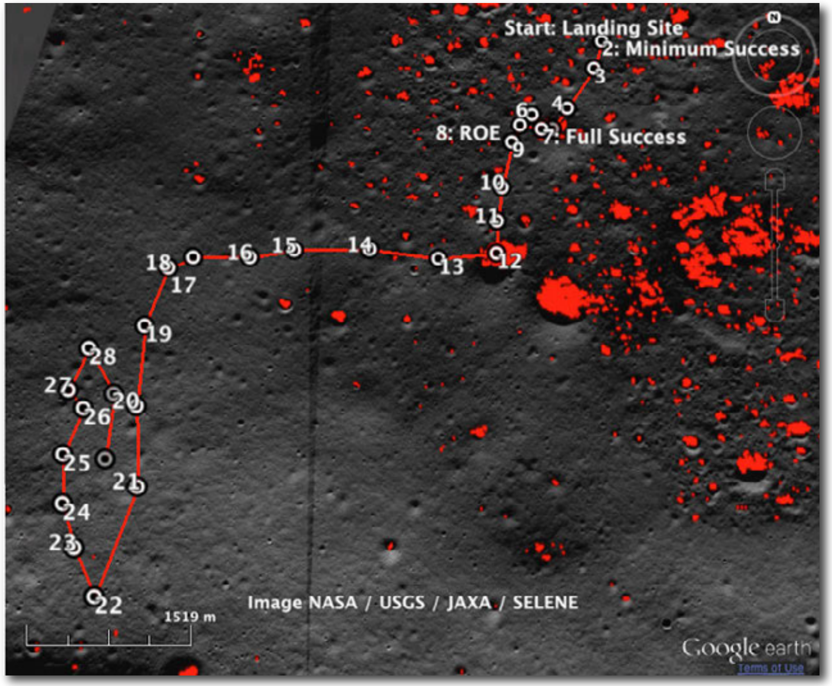
Key Points

- NASA HEOMD (AES program)
- Class D / Category 3 Mission
- Launch: 2020 (Falcon 9 v1.1)
- Duration: 6-14 Earth days
- Direct-to-Earth communications

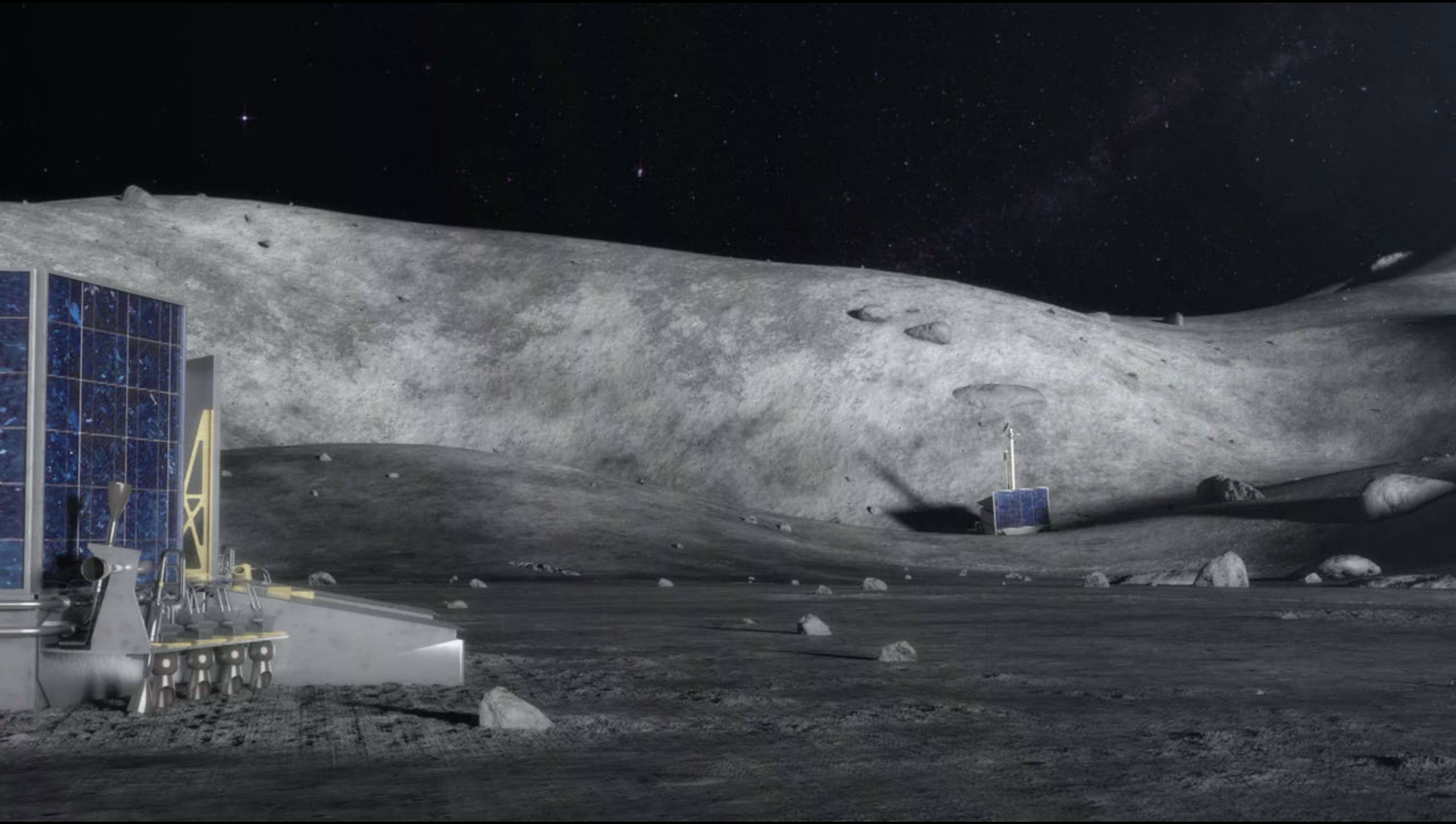
Rover

- Mass: 300 kg (including payload)
- Dimensions: 1.4m x 1.4m x 2m
- Speed made good: 0.5 cm/s
- Power: 300W (solar powered)





RP Mission Animation



Measurement Requirements

Minimum Success

- Make measurements from **two places** separated by at least **100 meters** (may require driving 300-400 m path length)
- Surface or subsurface measurements

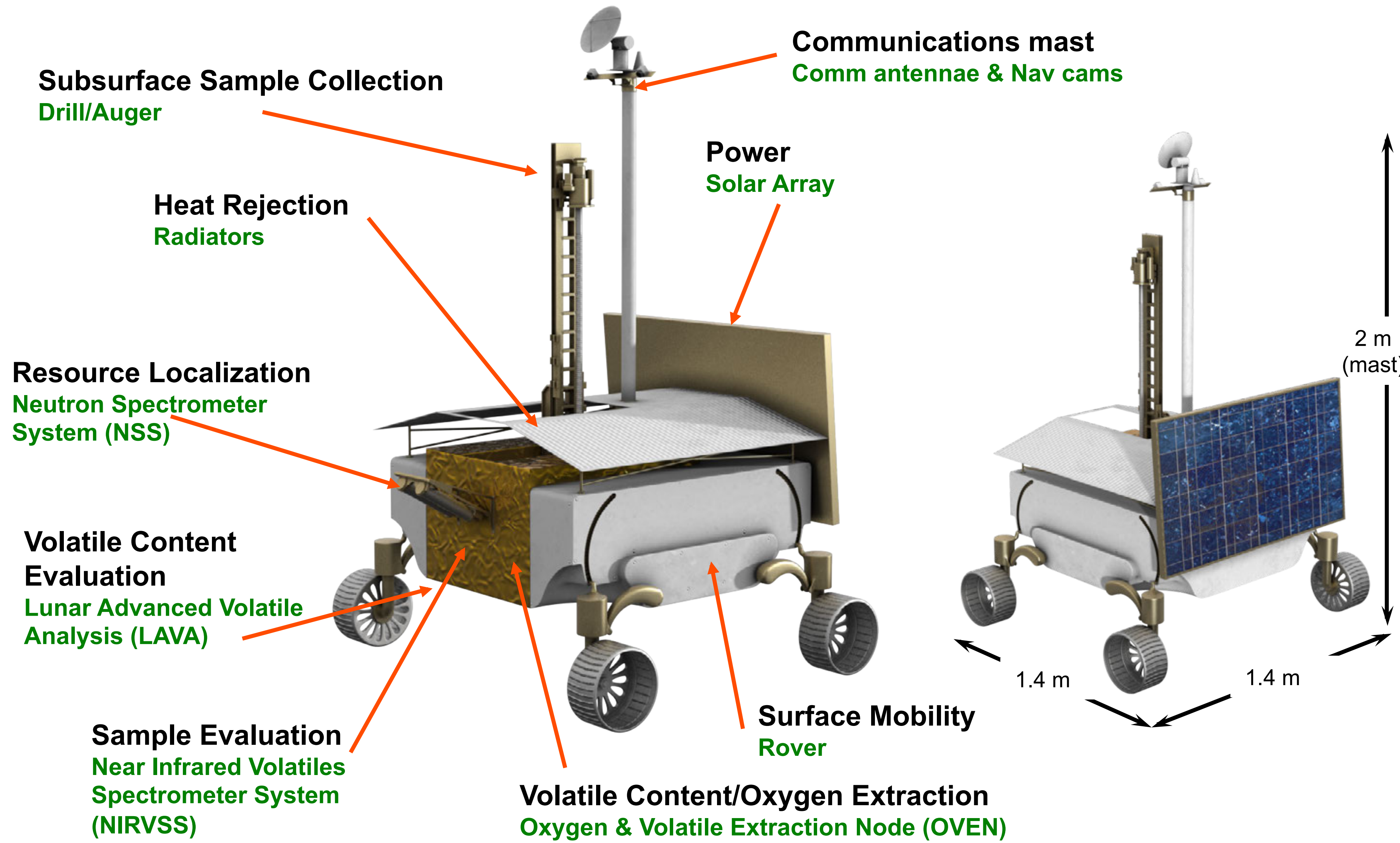
Full Success

- Measurements from **two places** separated by at least **1000 meters** (may require driving 3000-4000 m path length)
- Surface and subsurface measurements
- Measurements and sample acquired from **permanently shadowed area**
- Demonstrate ISRU

Stretch Goals

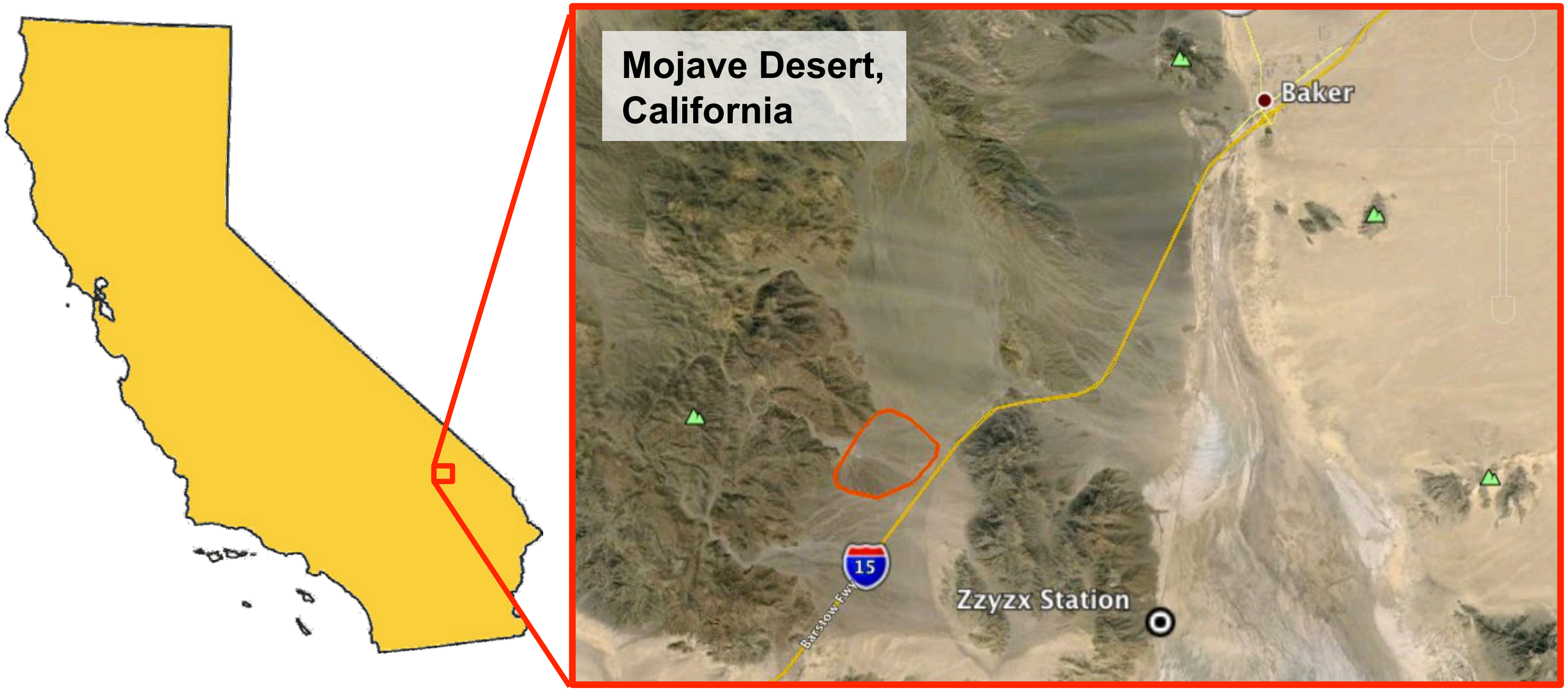
- Make subsurface measurements in at least 8 locations across 1000 m
- Process and analyze subsurface material in at least 4 locations across 1000 m distance
- Provide geologic and thermal context

RP Rover



Communications mast
Comm antennae & Nav cams
Subsurface Sample Collection
Drill/Auger
Power
Solar Array
Heat Rejection
Radiators
Resource Localization
Neutron Spectrometer System (NSS)
Volatile Content Evaluation
Lunar Advanced Volatile Analysis (LAVA)
Sample Evaluation
Near Infrared Volatiles Spectrometer System (NIRVSS)
Surface Mobility
Rover
Volatile Content/Oxygen Extraction
Oxygen & Volatile Extraction Node (OVEN)
2 m
(mast)
1.4 m
1.4 m

Mojave Volatiles Prospector (October 2014)



High-Fidelity Analog Field Test

- **Prospecting**. Mature prospecting ops concept for NIRVSS and NSS instruments in a lunar analog field test
- **Real-Time Science Ops**. Improve support software by testing in a setting where the abundance / distribution of water is not known a priori
- **Terrestrial Science**. Understand the emplacement and retention of water in the Mojave Desert by mapping water distribution / variability

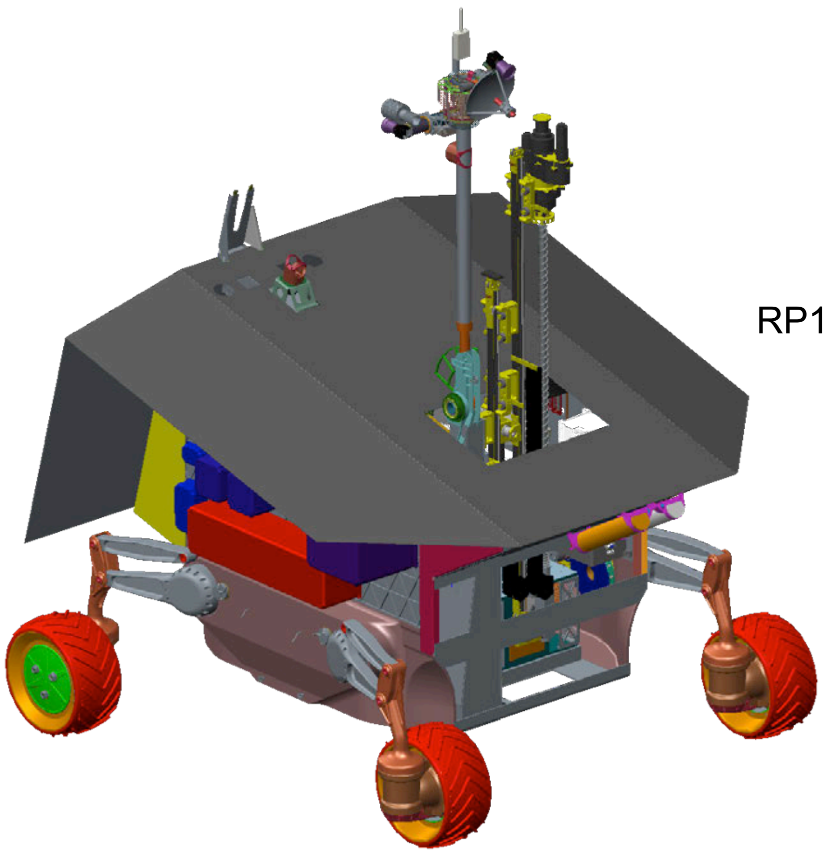
Prospecting Payload on K-REX Rover

Science Operations (NASA Ames)

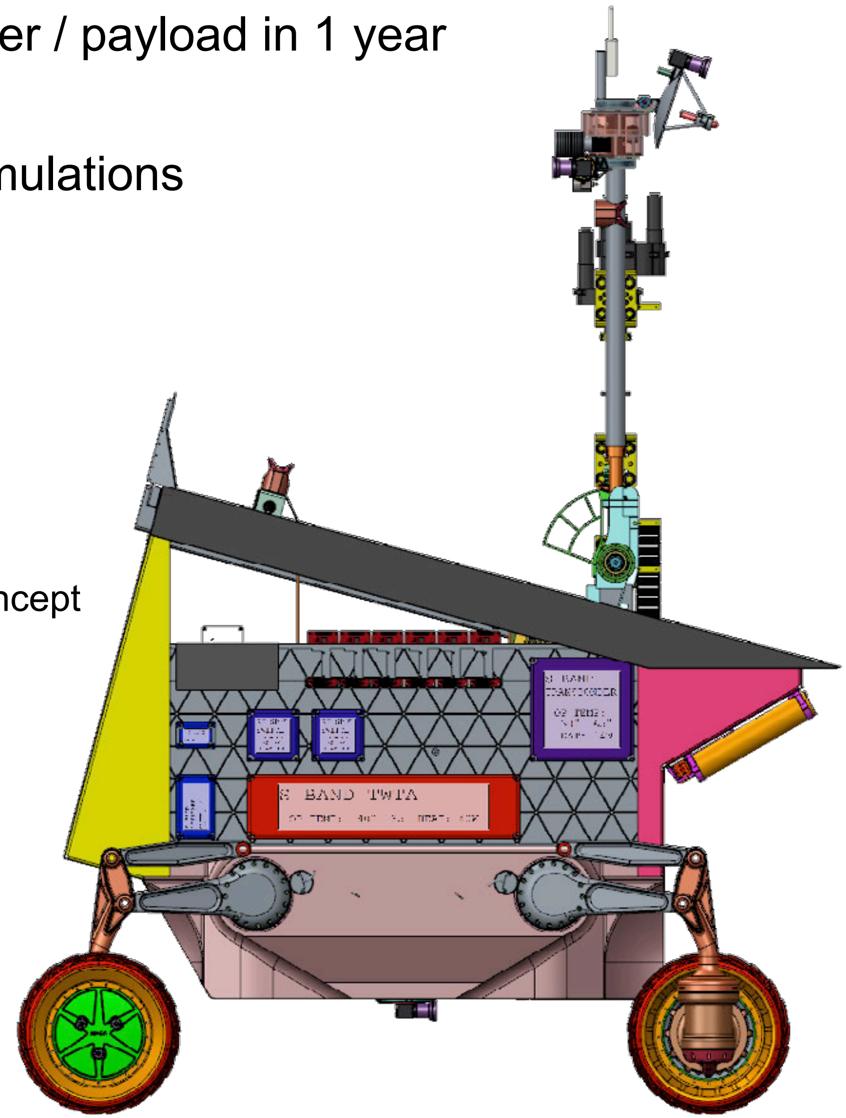
Mojave Volatiles Prospector

“RP15” Flight Project in a Year

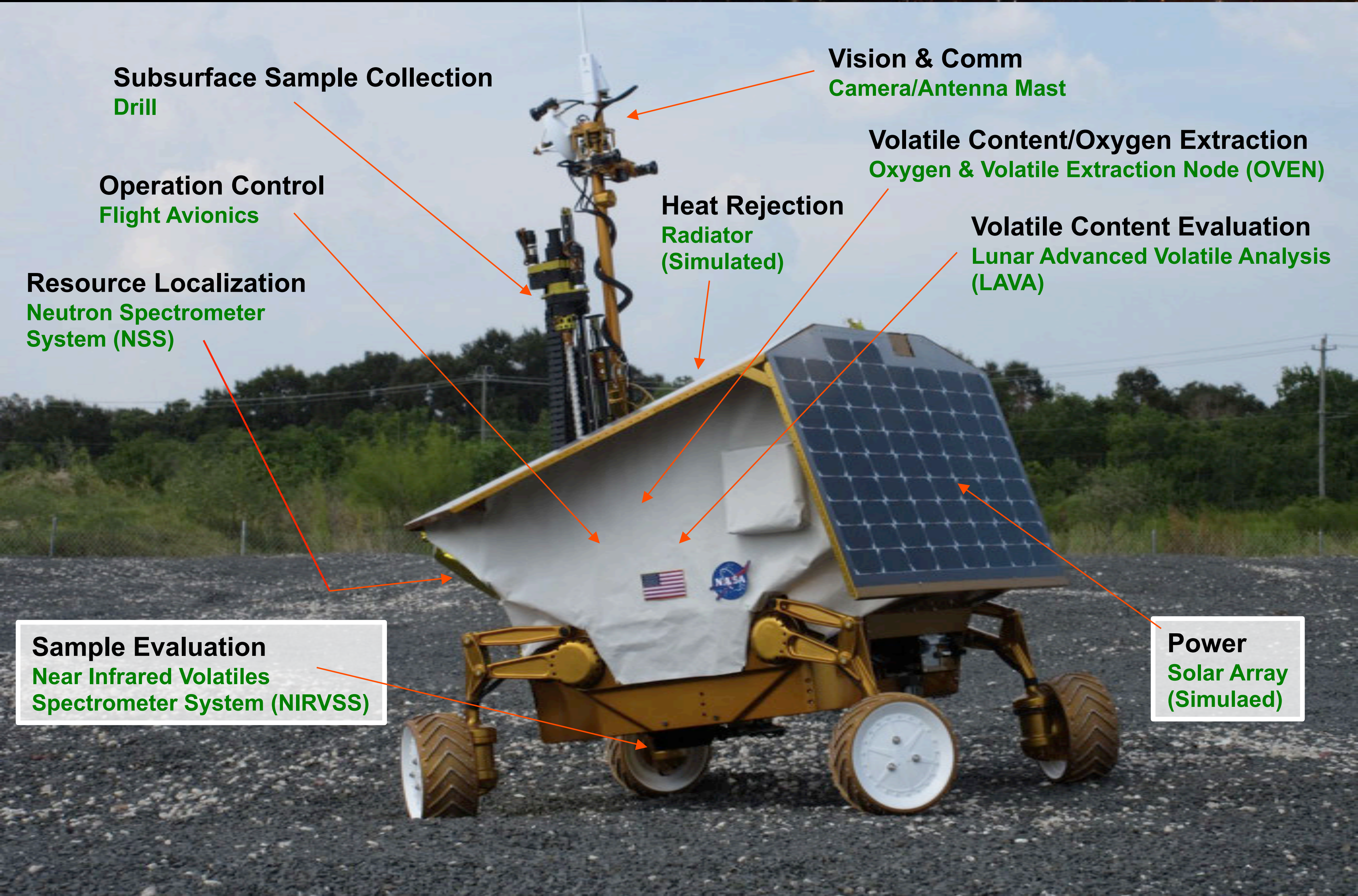
- Build, integrate, and test integrated rover / payload in 1 year
- Mature designs and retire risk for flight
- Perform subsystem and operational simulations



RP15 concept



RP Engineering Prototype



Driving Tests (August 2015)

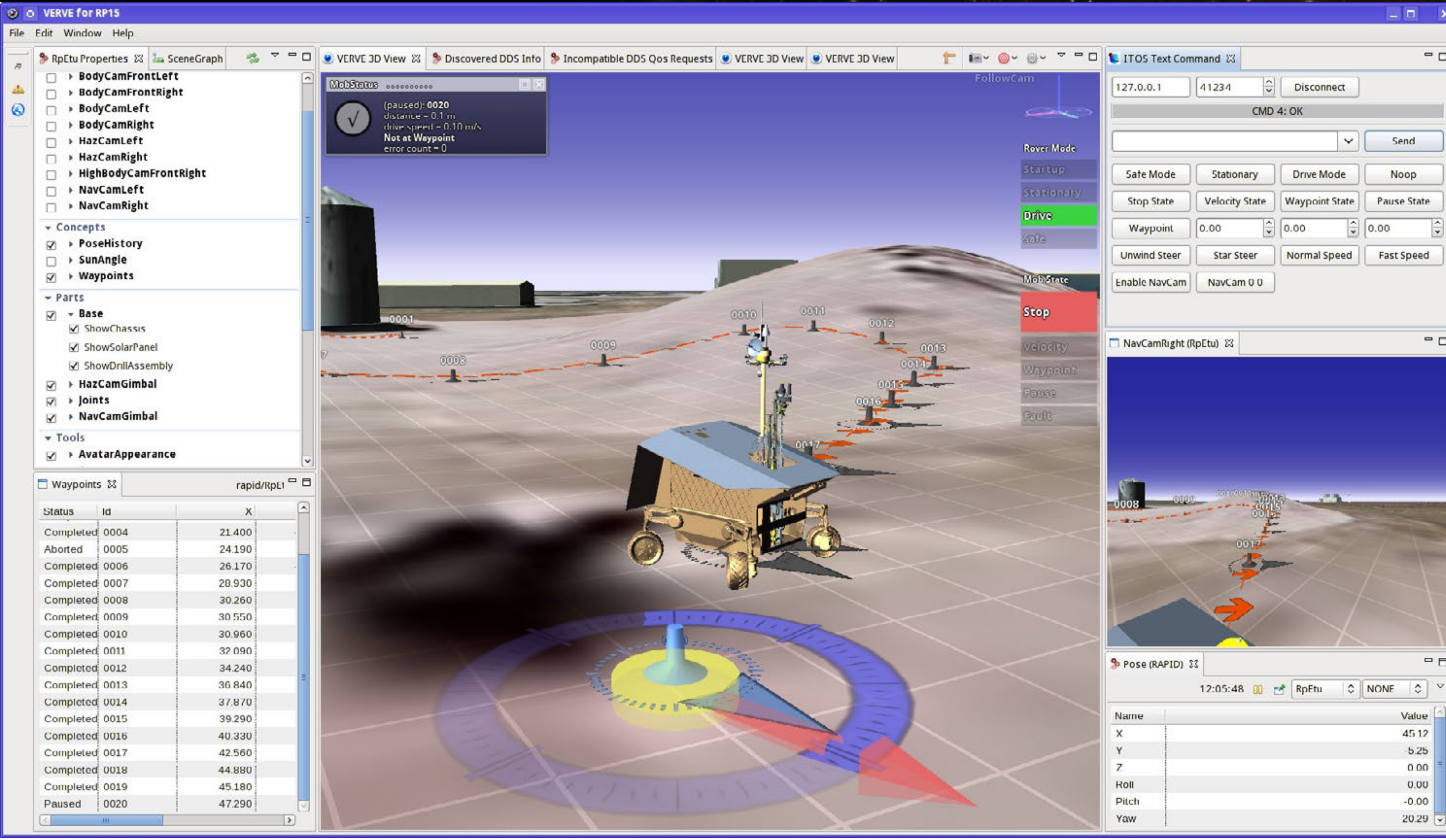
Distributed Operations Testing (August 2015)

NASA ARC Mission Control driving RP15 rover at NASA JSC

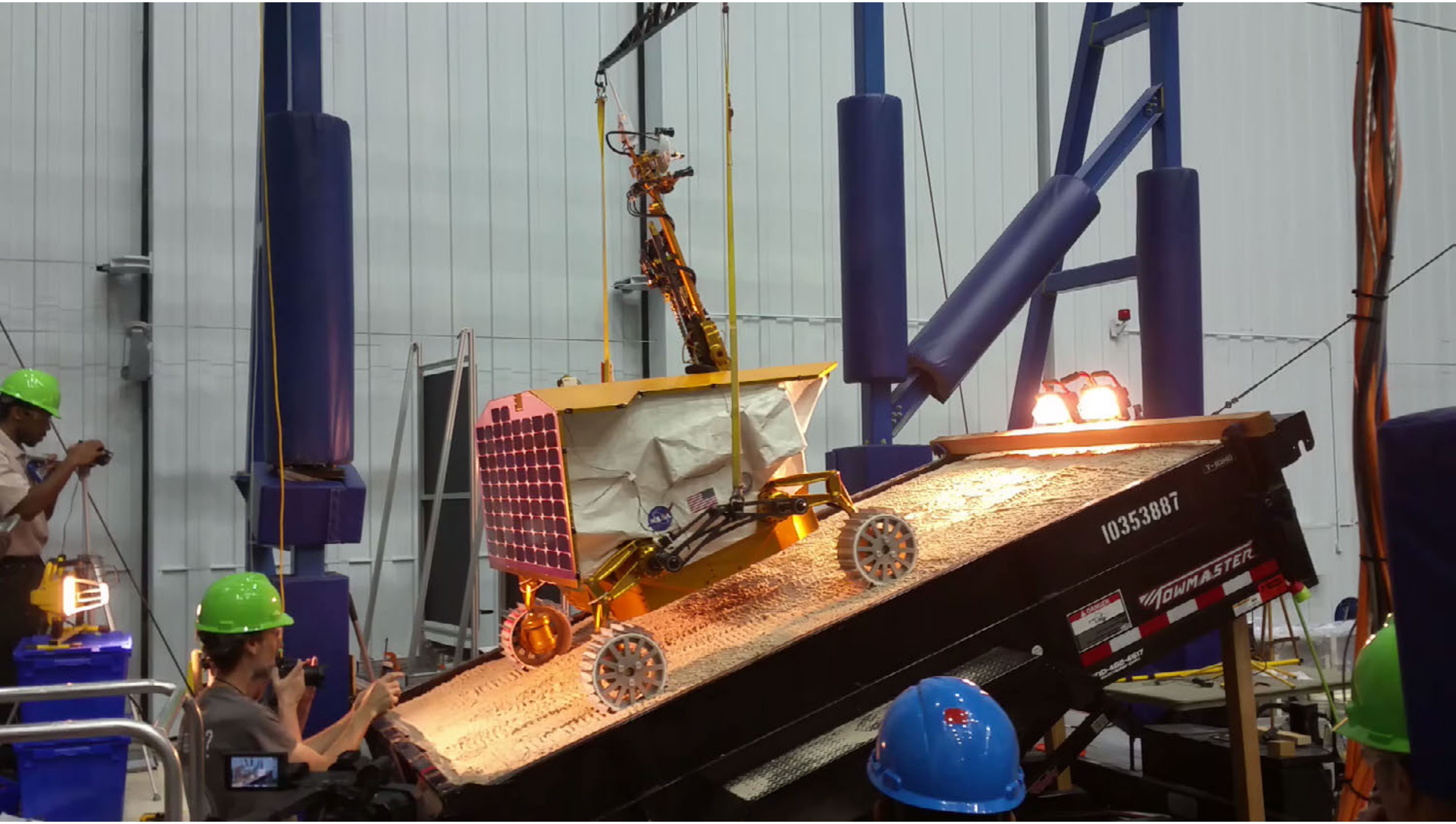
NASA JSC Rock Yard from the rover (left) stereo camera

NASA KSC Payload Control

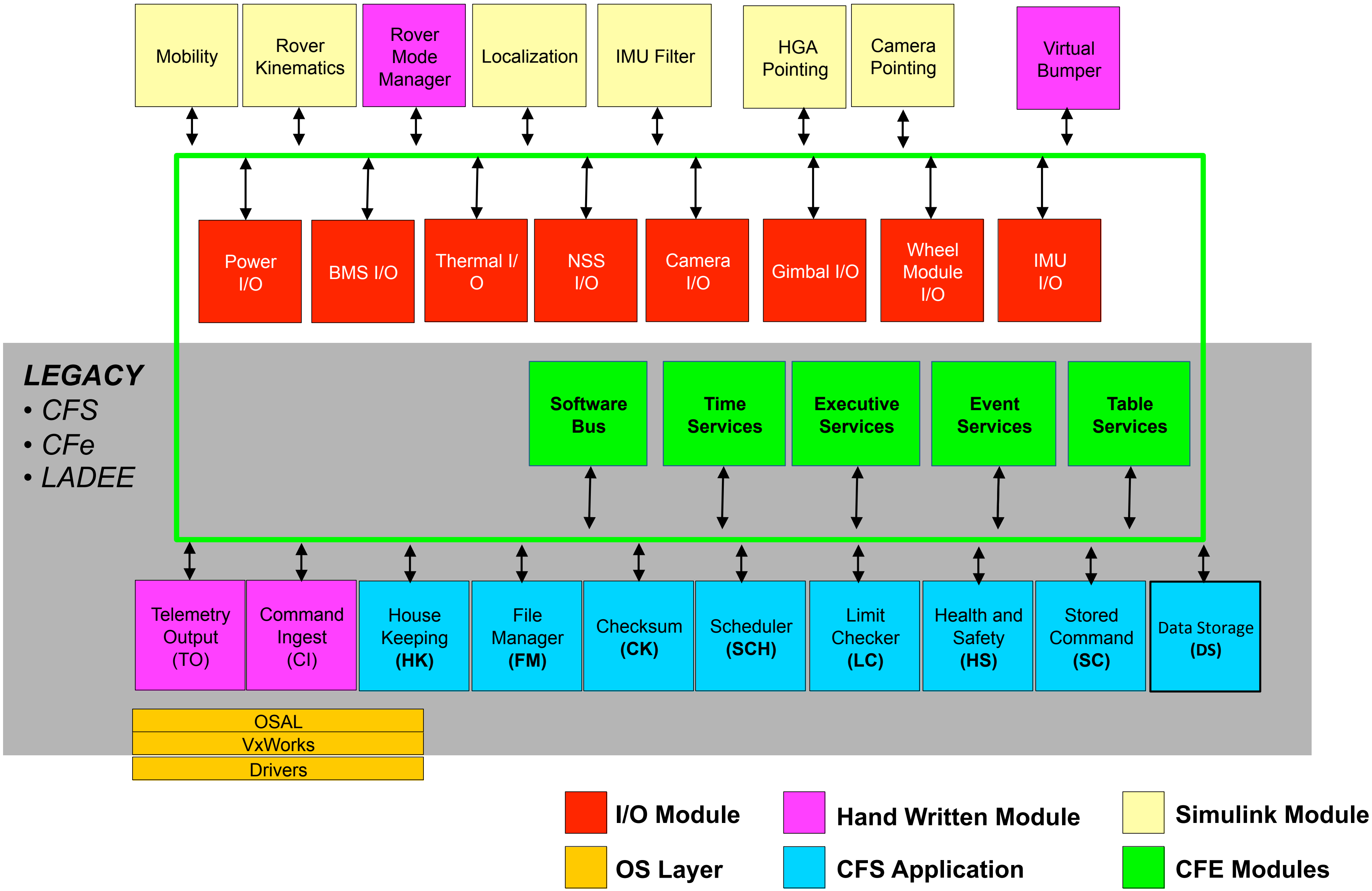
Rover Operator Interface (VERVE)



Reduced Gravity Driving (December 2015)



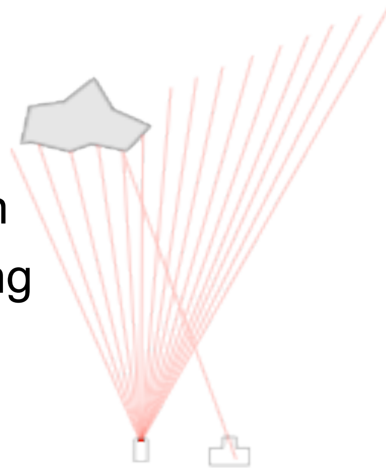
Flight Software Architecture

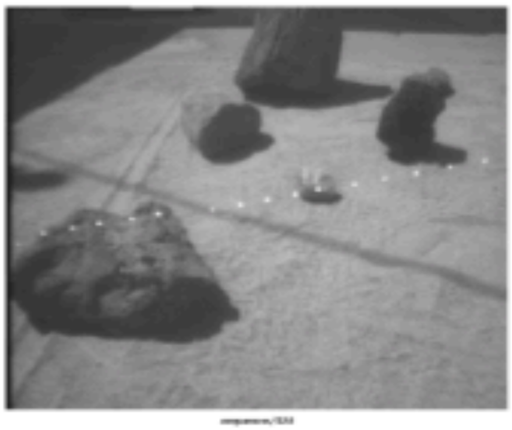


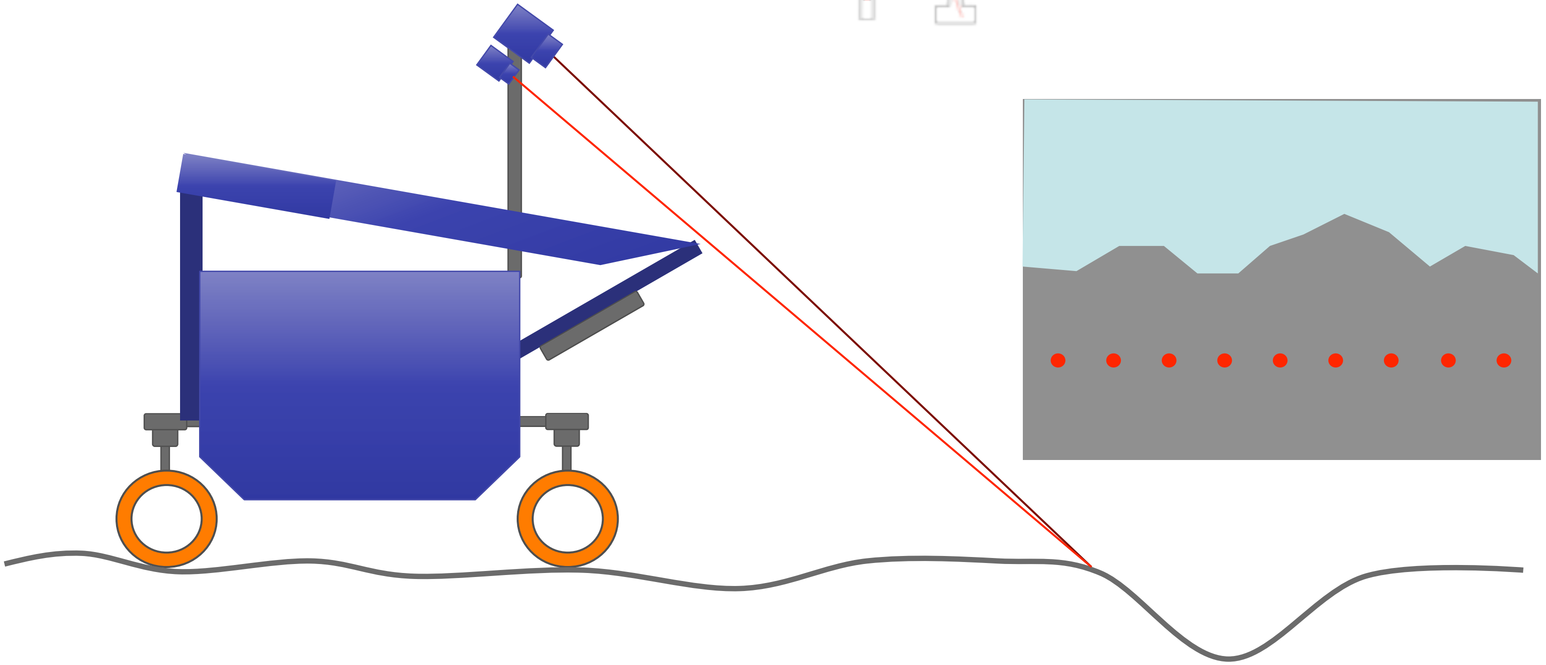
Hazard Detection

"Virtual Bumper"

- Project laser dots
- Detect dots in HazCam
- Minimal onboard computation
- Enables onboard safeguarding
- 98% success rate







Hazard Detection Testing (July 2015)

Issues and Concerns

Roving

- Traversing in soft soil – slip and embedding
- Active vs passive suspension
- Sharp thermal gradients across rover
- Variable thermal interface with surface

Drilling

- Slip / unintended motion
- Stances during drilling / stuck drill and options for stuck drill recovery
- Unknown near-surface regolith compaction profile / pre-load requirements

Navigation

- Performance of stereo vision for hazard detection and localization
- Performance of active illumination (flood lighting and laser projection)
- Positive and negative obstacles (size, shape, distribution, composition)
- Regolith / rock optical properties (reflectance, opposition surge, etc)

Questions ?