Science Operations During Planetary Surface Exploration: Desert-RATS Tests 2009-2011

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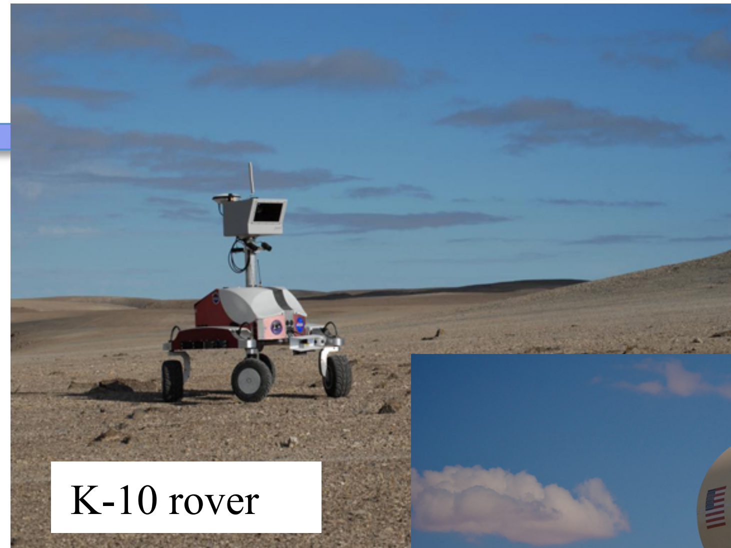
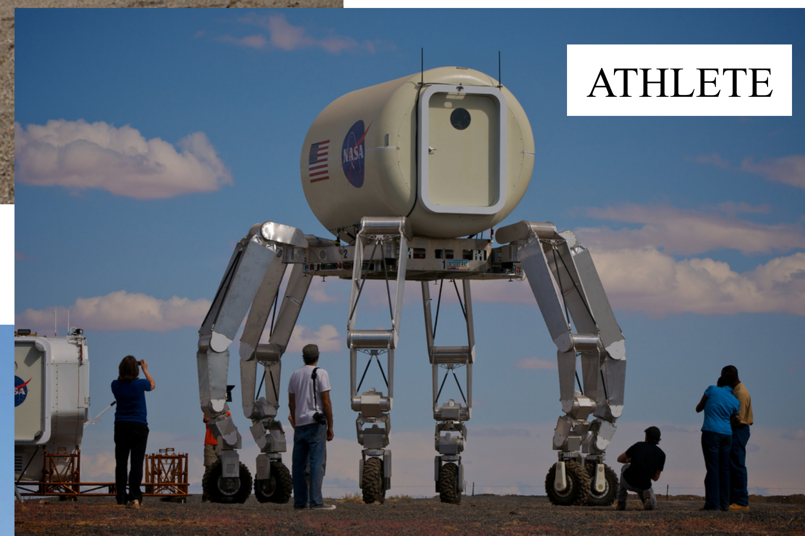
Desert-RATS

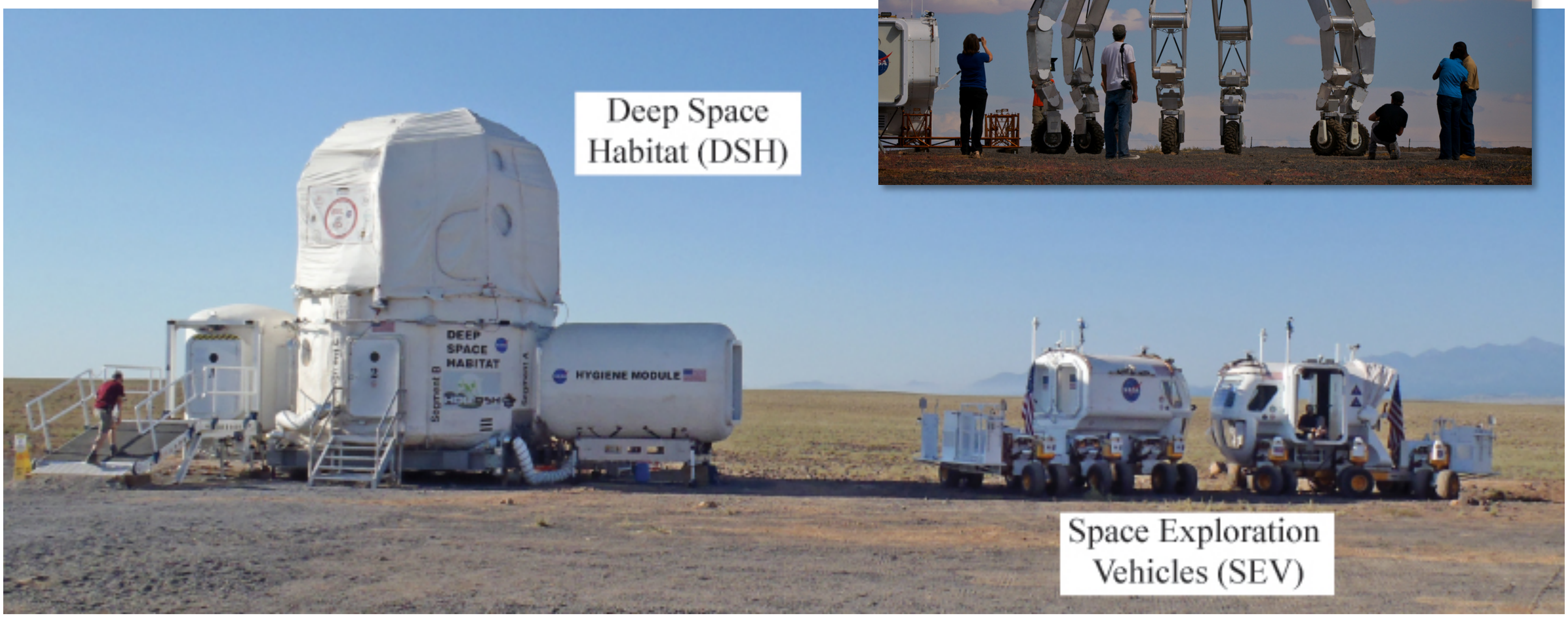
- NASA’s Research and Technology Studies (RATS) team evaluates technology, human-robotic systems and extravehicular equipment for use in future human space exploration missions
- Tests are conducted in simulated space environments, or analog tests, using prototype instruments, vehicles, and systems
- NASA engineers, scientists and technicians from across the country gather annually with representatives from industry and academia to perform the tests
- Test scenarios include future missions to near-Earth asteroids (NEA), the moon and Mars.
- Mission simulations help determine system requirements for exploring distant locations while developing the technical skills required of the next generation of explorers

Hardware tests

- Vehicles
- Habitats
- Utility machinery
- Robotic precursors/ assistants

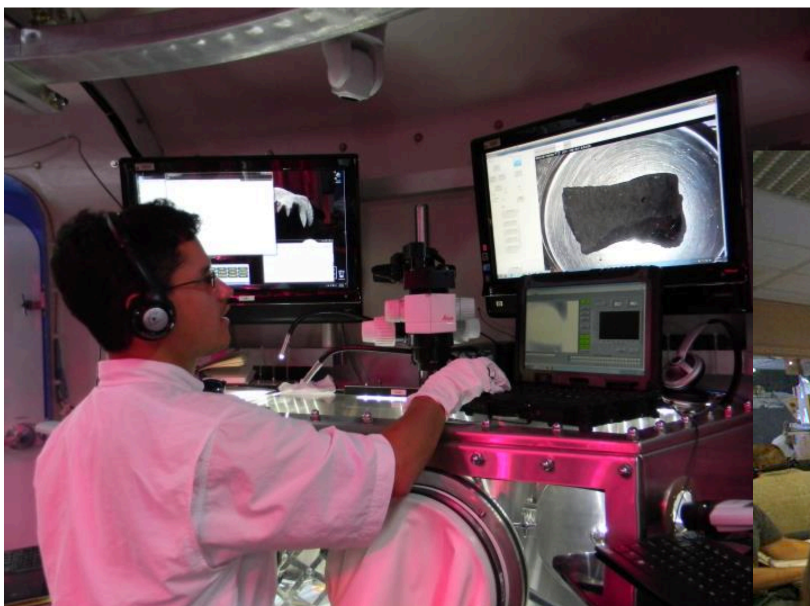






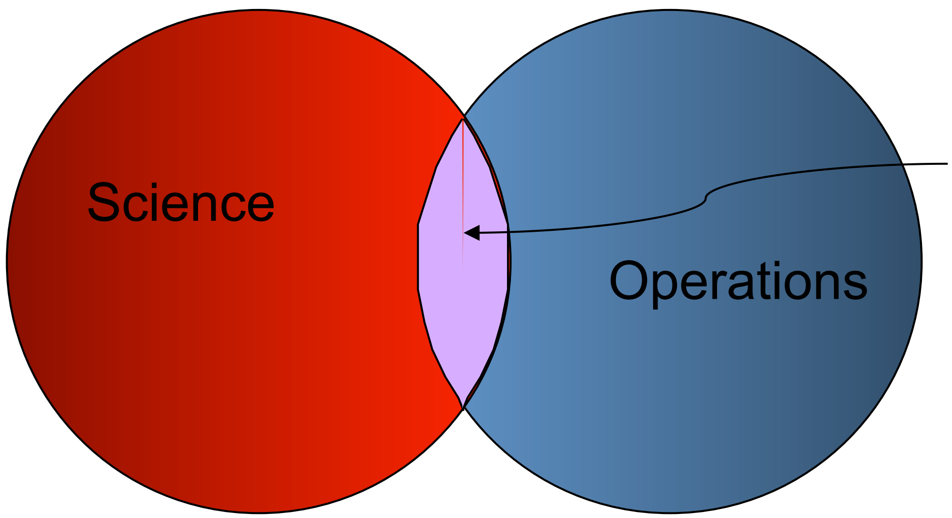
Systems tests

- Communication
- Power
- Human elements
- Tools & instruments
- Science



DRATS Science Team

- DRATS science operations use a field geology investigation as a driver for defining and testing a variety of science operations approaches



The overarching goal of all RATS science tests is to figure out what goes on in here, and how to ensure it gives us the best science return possible…

- Science team in “science backroom” works in conjunction with crew to execute traverse and accomplish the objectives

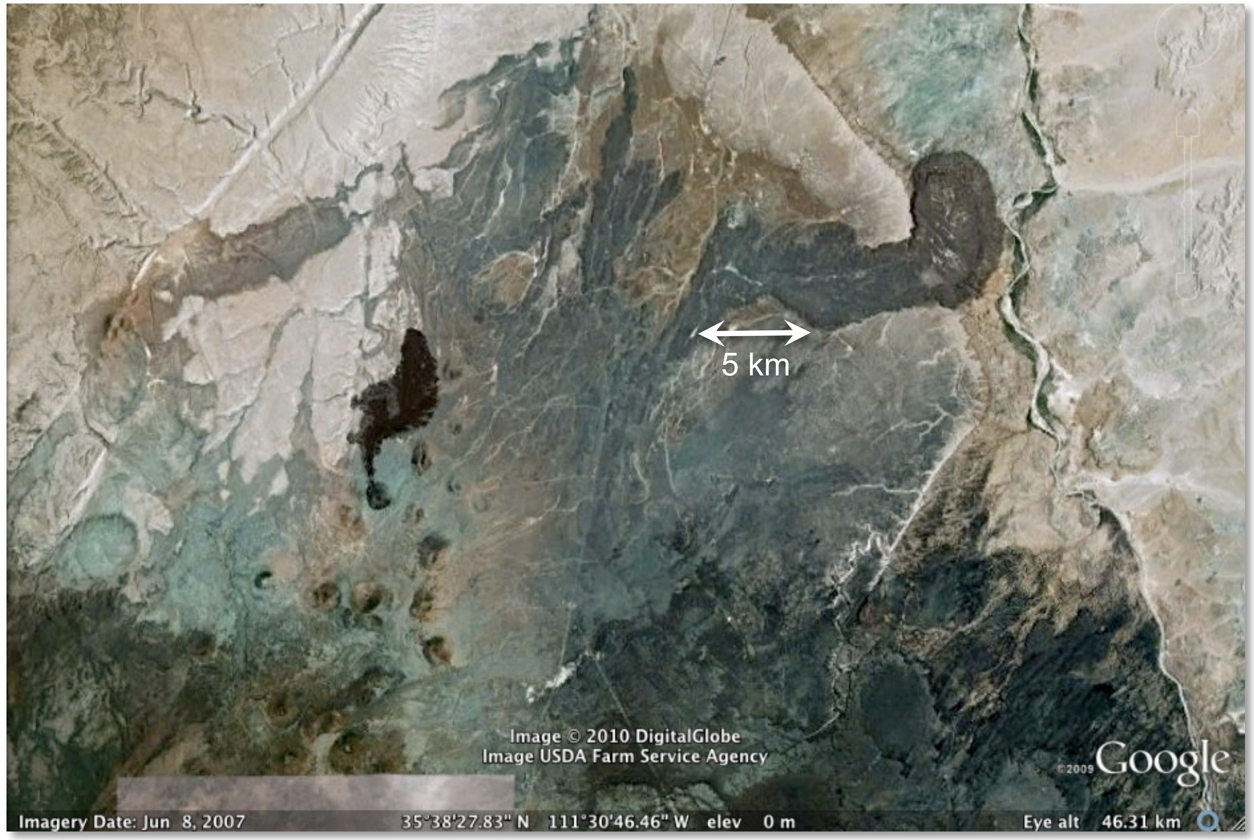
Science Objectives

- Determine the origin (nature) and relative ages of geologic units to determine the geologic history of the site
- Locate and collect suitable samples that will further elucidate these issues when analyzed in a terrestrial laboratory

- Science team uses orbital imagery to plan a traverse and define geological questions in advance
- Crew members conduct geologic field investigations
- Crew and Science Operations Team communicate with each other regarding contextual observations, sample descriptions, and working hypotheses
- The Science Operations Team goal is to determine the geologic history of each area using only the pre-mission orbital data and the contextual and sample data sent to the ground by the crewmembers

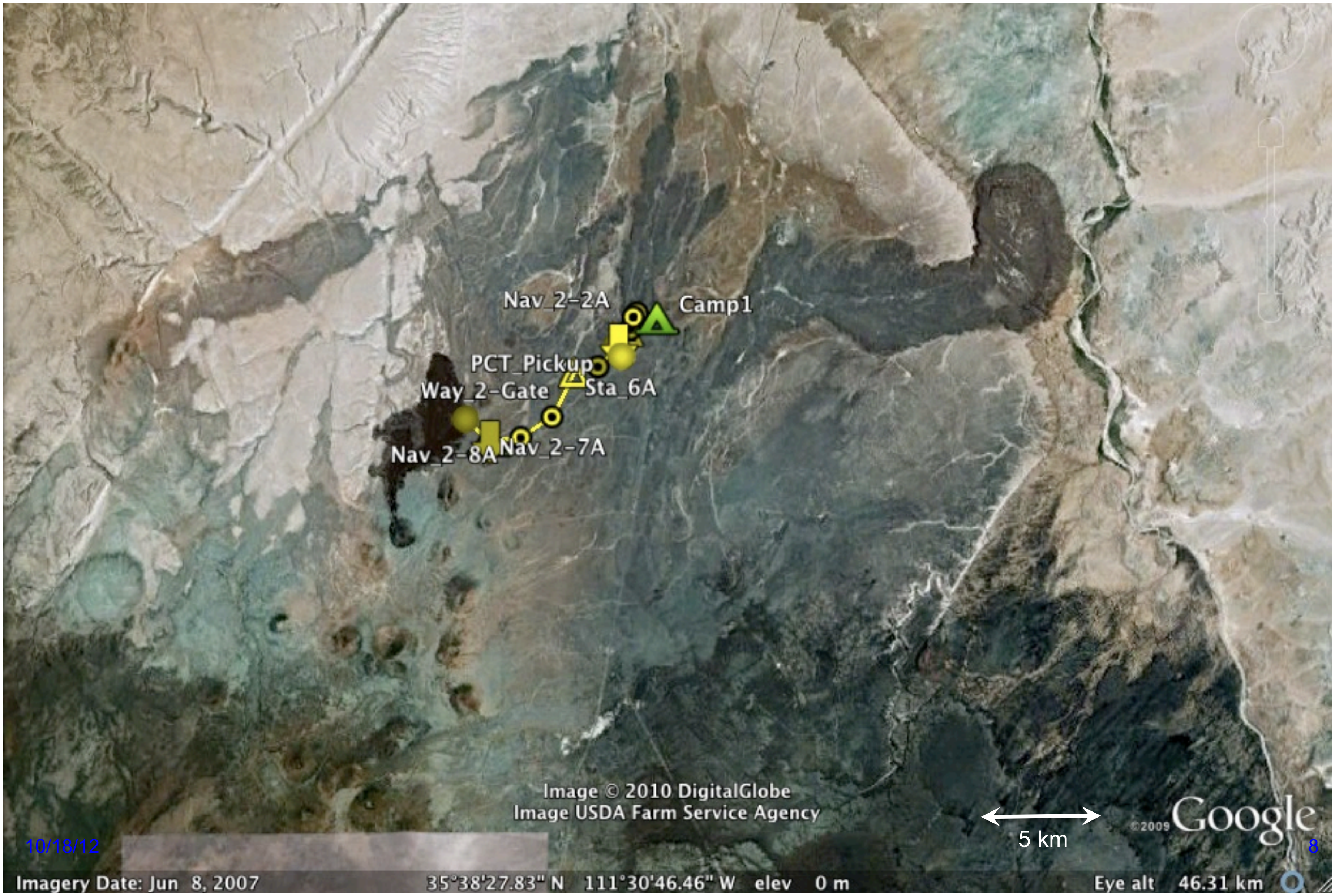
Geologic overview: Black Point Lava Flow

- The Black Point Lava Flow is part of the San Francisco Volcanic Field, a group of geologically young (6 Myr – 1 kyr) volcanoes, lava flows, and cinder cones near Flagstaff, Arizona
- The Black Point Lava flowed eastward over older Permian and Triassic sedimentary rock sequences well known around the vicinity of the Grand Canyon.



- The area was originally identified as a candidate lunar analogue site during the Apollo era
- At that time, the east end of the lava flow and the valley of the Little Colorado River were examined for training and simulations of lunar missions
- Several explosion craters were blasted out of the top of the lava flow to simulate an impact crater field on the lunar surface

Traverse overview (example)



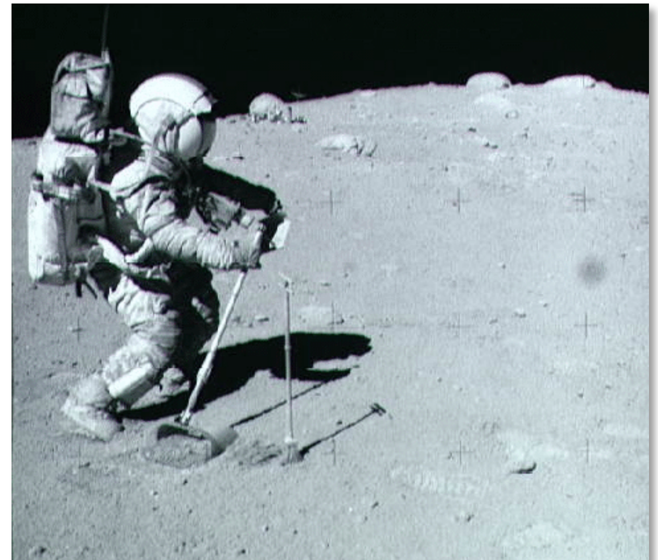
Traverse (example)

Science Observations (example)

- Characterize flow margin outcrops in order to determine stratigraphic differentiation with adjacent flow and/or internal characteristics indicative of eruptive style.
- Characterize unit vc1-vf1 (or vc1-vc1) contacts in order to determine the chief characteristics that demarcate the gradation between cone and flow.
- Document and compare “thick” versus “thin” outcrops of unit vf1 to determine if these represent contrasting flow chemistry.
- Examine various “plains” surface in order to determine the range of depositional processes and material provenance.
- Characterize the b4/vf1 contact in order to determine whether the unit b4 is of sedimentary or volcanic origin. If the former, look for evidence of contact metamorphism.
- Document and compare the characteristics of the dissected unit in two locations to determine consistency in the character and formation of dissections.

2009 & 2010 Desert-RATS test: Lunar Surface

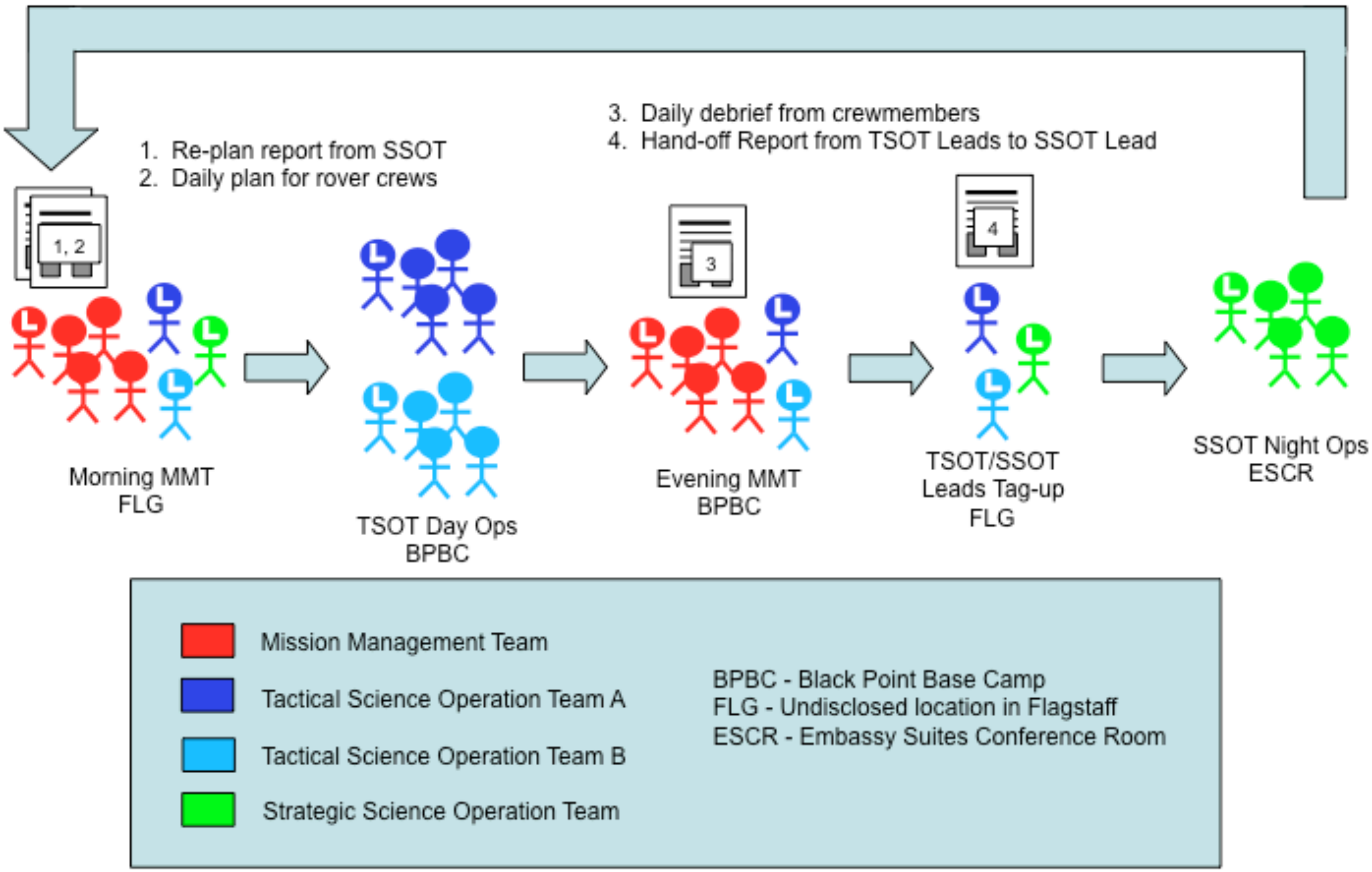
- 14-day field test involving 2 small pressurized rover prototypes, each with a 2-person crew
- Both operations tested 2 small pressurized rovers, adding contrasting operating conditions in 2010
  - Variable communications states (continuous vs 2x a day at ≈0730 and 1730)
  - Variable modes of rover operations (mutually supporting team, or working in different portions of the field area)
- Of the 14 test days, 12 were devoted to traverse science operations and (in 2010) 2 to operations in the Habitat Demonstration Unit (HDU)



2009 & 2010 Science Backroom Objectives

- Evaluate methodologies for measuring science productivity and efficiency while working with crew on a planetary surface (2009), and as a function of communications conditions and rover deployment approach (2010)
- Evaluate an extended operations approach for managing science activities, using teams to oversee the implementation of a particular day’s plan (Tactical Science Operations Team) and evaluate daily results and conduct replanning (Strategic Science Operations Team) (2010)
- Involve a new generation of scientists in human planetary science operations testing and development (both years)

Tactical and Strategic Science Ops



During 2-a-day comm, the TSOT did not meet as there was no-real time data flow. MMT Science rep would brief at the SSOT at the start of shift briefing.

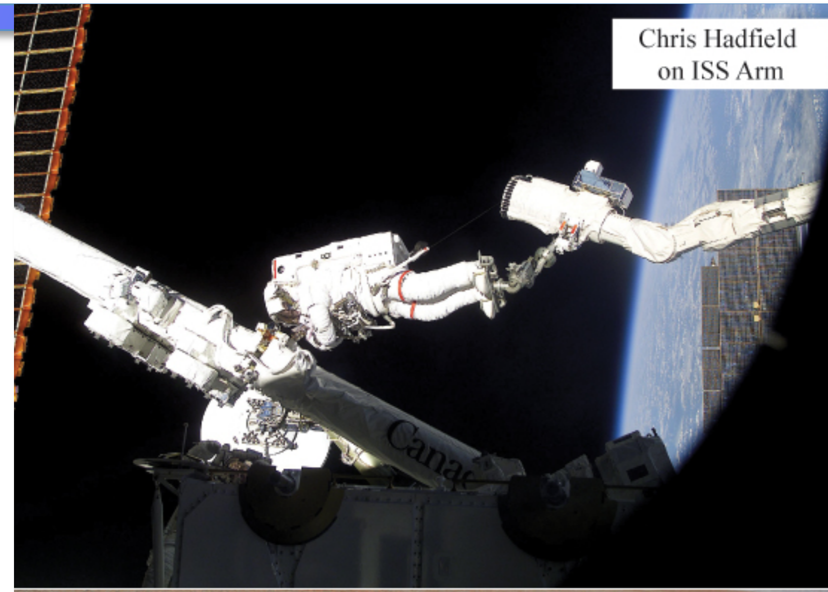
2011 Desert-RATS: Near-Earth Asteroid

- 14-day field test involving 2 small-pressurized rover prototypes, each operated with a 2 or 3 person crew in conjunction with a crewmember located in a simulated Deep Space Habitat
- Test focused on delayed communications with Houston and exploration strategies for microgravity targets
- Hardware included Space Exploration Vehicles (SEV) and Deep Space Habitat (DSH)
- Crew included 8 members, 4 astronauts and 4 geologists

Technology modifications

Communications

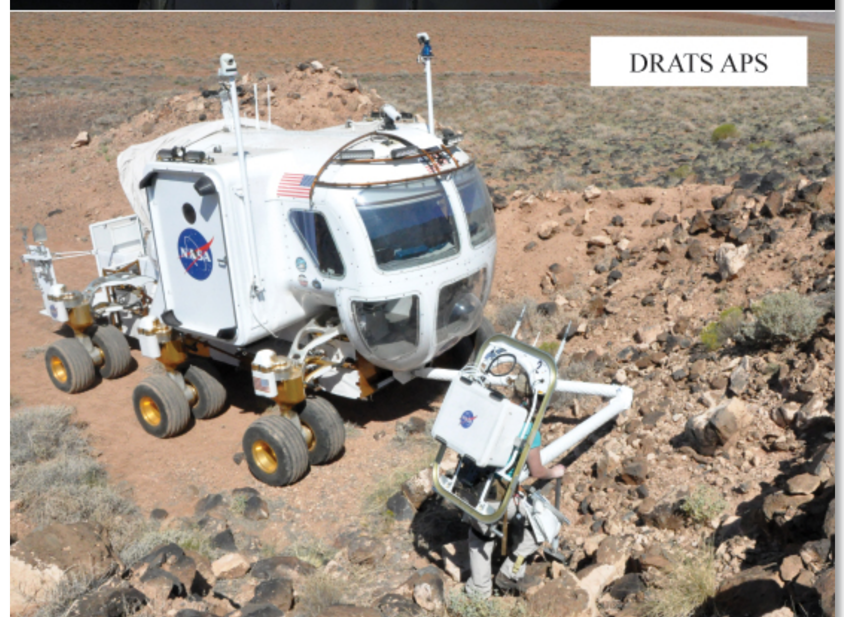
- 50 second, one-way; simulates target ~0.1 AU from Earth
- Houston could speak directly with extravehicular (EV) or intravehicular (IV) crewmembers
- Texting capabilities were tested between Houston and EV and IV crewmembers



Chris Hadfield on ISS Arm

Microgravity EVAs

- Astronaut Positioning System (APS): EV crewmember manuevered into position by robotic arm attached to SEV
- “Super” Simplified Aid for EVA Rescue (SSAFER): allowed EV crew to maneuver independently of SEV



DRATS APS

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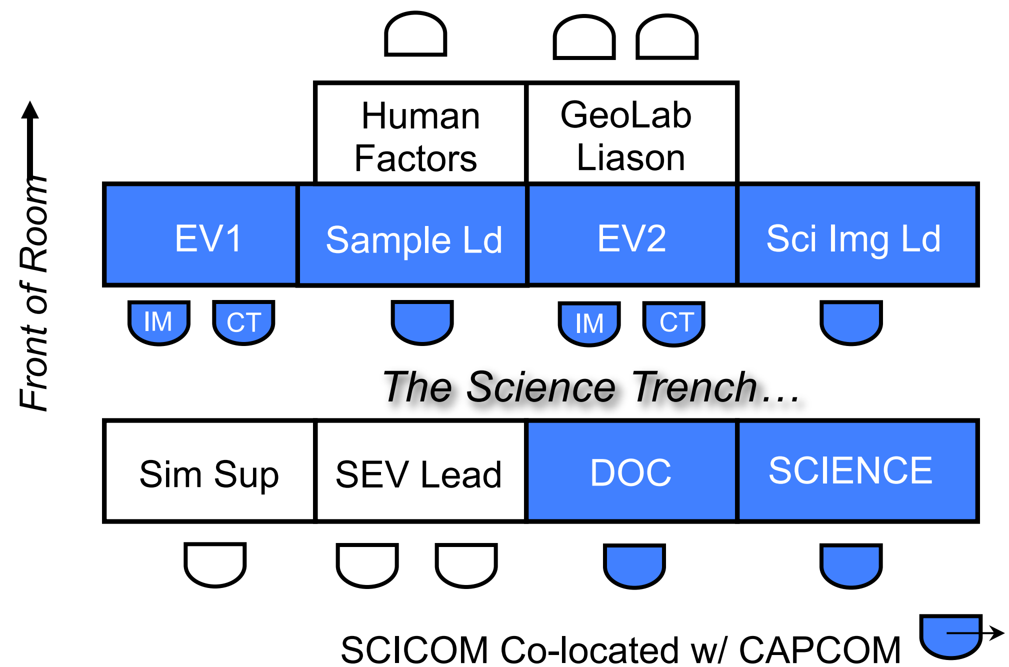
Mark Lee testing SAFER


DRATS SSAFER

2011 Science Backroom Objectives

- Investigate the effect of varied data bandwidth on the quality of science interpretations
- Investigate the effect of various EVA scenarios on efficiency of science collection and accuracy of interpretation
- Investigate the use of tools such as texting and chat rooms as a way to communicate with the crew when normal, real-time voice communication was not possible
- One 3-day segment included a Science Operations Team located at ESTEC in the Netherlands



The 2011 Desert RATS operation ran a control center that was integrated with the remote operations center

Science Team success metrics

- Did the Tactical Science Operations Team and the Strategic Science Operations Team understand what was going on in the field with regards to geologic context and samples collected?
- What was the workload of the individual science team member?
- Was the science operations process operating well enough for the Mission Manager and the Test Director to understand what was working, what wasn't and how science operations would be affected by big picture decisions they make in the course of the mission?
- Would the data collected by the crewmembers be useful to the science community not just now, but in the future?

Solving the Science Problems

- The Science Operations Team was able to make the critical geologic observations to solve the various geologic problems posed in the field area
  - For example, Science Team was able to to understand that Hot Dog Hill was a primary eruptive center, not a squeeze up or a random pile of basalt blocks left behind by erosion
    - This was a critical science activity, and it led to original science observations
  - This was a combination of good observations by the crew, their ability to communicate what they saw both verbally and with the various imaging system, and the scientific skills possessed by the Science Team in Houston

Lessons learned: Communications

- Continuous comms with stable, high-fidelity voice and image data permitted interaction between the science operations team and crew, producing superior quality science compared 2-A-Day comm
- A diligent science team working jointly with a well-trained, scientifically competent astronaut crew can devise methods to compensate for broken or intermittent comms, particularly when these conditions are expected
- Conducting tactical science operations with a comm delay proved far less onerous that was imagined prior to the test
- Texting works! The ability to text up to crewmembers smoothed out science information flow between the Science Team and the crew and made operations more efficient
- Integrating the Science Team in the same room as the Mission Operations Team was very successful, resulting in good communications and decision making between the Science Team and their Operations counterparts

Lessons Learned: Science team training

- Team consisted of a very qualified, highly motivated mix of RATS veterans and novices, and science professionals from all levels from NASA scientists to faculty members to grad students to post-docs to high-school level science teachers
- We ran very long days, often well in excess of 11 hours
- Maintaining team integrity throughout the mission led to smoother operations, and meant people got beyond the learning curve and were able to do their jobs
- Proficient team leadership is crucial to success; competent leadership ensured timely decisions and problem resolution which permitted team members to proceed, even in the absence of fully functioning systems
- Institute/schedule a pre-exercise training period or significantly lengthen pre-mission training to prevent team members having to learn their duties while concurrently trying to evaluate operations

Lessons Learned: Tactical vs Strategic

- Crucial to have a consolidated tactical data input database, integrated with image capture, note-taking, and real-time chatrooms for science subdisciplines. Having different (beta-test) software for each function is cumbersome and confusing, leading to data loss.
- Science understanding takes time that is not available during tactical operations. The strategic team was able to undertake discussions of science hypotheses, and to decide subsequent courses of action for the crew in order to improve science return from the field.
- Caveat: Second-shift operations are even more trying on science team members

Lessons Learned: ESA Backroom

- Logistics, timing and training were big issues - the ESA Team had barely a week to assemble, get the operational hardware and software going and run their part of the operation, so training was, at best, pushed
  - It speaks volumes about the quality of the team they assembled and their commitment to participating that they were able to do a great job under difficult conditions
- They had budget issues that limited simple things like V-Comm licenses and travel expenses for their team members that made operations more difficult than they had to be
  - To support these ops means you have a realistic budget input for the logistics things
  - It doesn't work to be penny wise and pound foolish…

Lessons Learned: Metrics

- Developing mathematically rigorous numerical data for inherently non-numerical activities is difficult and can lead to inconsistencies between individual raters
- D-RATS still has issues with applying the metric scales defined to geological operations, especially when the basic field conditions are so far out of synch with the real mission considered
  - There were time consuming discussion every day by the science teams as to was actually being rated, and how the numbers would be understood by folks not in the room at the time we were doing the rating
- There was also a lot of frustration at trying to work through difficult discussions at the end of a long day
  - If these things are important, you cannot do them in a sloppy manner, particularly if you are asking a group of conscientious scientists to do their best
  - Further, the data gathering that we do on each EVA, and for the whole science operation, means that there is not sufficient time to do the evals in real time

D-RATS 2012

- RATS 2012 simulated the microgravity environment that future explorers will experience at an asteroid
- Took place at the Space Vehicle Mockup Facility, or SVMF, at NASA's Johnson Space Center in Houston.
- Crew of four used NASA's prototype multi-mission Space Exploration Vehicle (SEV), the Active Response Gravity Offload System (ARGOS), the Virtual Reality (VR) Laboratory and the Analog Mission Control Center to gather data.
- Communications and data transmissions conducted over a 50-second time delay (each way)
- No geologic science objectives or science backroom team

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- Historical synopses of Desert RATS 1997–2010 and a preview of Desert RATS 2011 (Ross et al.)
- NASA Desert RATS 2010: Preliminary results for science operations conducted in the San Francisco Volcanic Field, Arizona (Gruener et al.)
- The traverse planning process for D-RATS 2010 (Hörz et al.)
- Desert Research and Technology Studies (DRATS) 2010 science operations: Operational approaches and lessons learned for managing science during human planetary surface missions (Eppler et al.)
- Comparing Apollo and Mars Exploration Rover (MER)/Phoenix operations paradigms for human exploration during NASA Desert-RATS science operation (Yingst et al.)
- The effect of different operations modes on science capabilities during the 2010 Desert RATS test: Insights from the geologist crewmembers (Bleacher et al.)
- Field geologic observation and sample collection strategies for planetary surface exploration: Insights from the 2010 Desert RATS geologist crewmembers (Hurtado et al.)
- Tools and technologies needed for conducting planetary field geology while on EVA: Insights from the 2010 Desert RATS geologist crewmembers (Young et al.)
- GeoLab—A habitat-based laboratory for preliminary examination of geological samples (Evans et al.)
- Evaluation of dual multi-mission space exploration vehicle operations during simulated planetary surface exploration (Abercromby et al.)
- Crew roles and interactions in scientific space exploration (Love and Bleacher)
- Reusable science tools for analog exploration missions: xGDS Web Tools, VERVE, and Gigapan (Lee et al.)
- Social network analysis and dual rover communications (Litaker and Howard)

Conclusions

- Science is an crucial part of exploration, and needs to be integrated with technology tests to understand and plan for exploration scenarios
- Beyond-LEO scientific activities have a very different nature than ISS scientific activities, and sometimes drive operations in unexpected ways
- Technology and human factors sometimes have precedence over science, and scientist need to learn how to work in their framework
- New tools, technologies, and protocols need to be developed to help crew and science backroom work together in real time (or near-real time) to achieve greatest science return
- Now is the time to develop and test these solutions to feed into future exploration planning!