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Workshop Summary

Presented to LEAG Annual Meeting, October 4, 2007 --
Kelly Snook, NASA Headquarters

Workshop Agenda

Monday, June 25, 2007

8:00	Registration and Continental Breakfast	
8:15	Welcome, Introduction, Logistics	Steve Mackwell, host
8:20	**Panel**	
	Welcome and Workshop Overview	Geoffrey Yoder
	Lunar Exploration Analysis Group (LEAG) and Its Specific Action Teams	Clive Neal
	Curation and Analysis Planning Team For Extraterrestrial Materials (CAPTEM)	Chip Shearer
	MAWG Overview (special focus on MEPAG HEM-SAG) — esp. current scenarios	Jennifer Heldmann
9:10	LAT Overview — esp. description of current options, basic architecture elements	Andy Thomas
9:30	Constellation Overview — esp. current plans for surface systems	Wendell Mendell
9:50	Moon and Mars — Physical Challenges, Similarities and Differences	Abhi Tripathi
10:10	What we Learn from Rocks and Regolith	Carl Allen

Workshop Agenda (cont.)

10:30	In Situ Analysis and Sample Return: Complementary Components of Scientific Exploration	Chip Shearer
10:50	Apollo Sample Acquisition and Handling on the Lunar Surface — tools, ops	Harrison Schmitt/John Young
11:10	Science Backroom and Communications During Apollo	Gordon Swann/Gene Krantz/Jim Papike
11:30	Sample Handling, Preserving Scientific Integrity, Curation	Gary Lofgren
11:50	Advances in Field Robotics — Robonaut, Centaur, etc.	Ron Diftler (for Rob Ambrose)
12:10	Advances in EVA and Habitation Systems — FRED	Michael Gernhardt
12:30	Lunch on Site and Presentation on Advances in Navigation/Documentation	Terry Fong
13:10	Goals of Workshop, Desired Output, Description of Working Group Questions and Assignments, Grand Visions of Usefulness and Relevance (GVUR)	Kelly Snook
13:55	Break into Groups (by assignment)	
14:00	Working Groups — moderated, split by exploration scenario, same questions	(see list of moderators under group reports on Tuesday)

Workshop Agenda (Cont.)

Tuesday, June 26, 2007

8:00	Registration and Continental Breakfast	
8:30	Working Groups (continued)	Working Group Moderators
11:00	End Working Group Breakouts — Reconvene in Lecture Hall	
	Points of Flexibility in Lunar and Mars Architectures	Doug Cooke
12:30	Lunch on Site	
13:00	Breakout Group Reports and Discussion	Chris McKay Wendell Mendell Jennifer Heldmann Eileen Stansbery Pan Conrad Abhi Tripathi Clive Neal Jay Falker
14:30	Break	
14:45	Current State of Science in Lunar and Mars Architectures	Leshin/Mendell
15:00	Real-Time Results Synthesis and Future Steps	Snook/Yoder/Neal/ Shearer

Breakout Discussion Matrix

	Working group breakouts	Scenario A - Outpost 1 - Mendell	Scenario B - Outpost 2 - Stansbery	Scenario C - Outpost 3 - Falker Tripathi	Scenario D - Outpost 4 - Neal	Scenario E - MSLS - McKay	Scenario F - MSSS - Conrad	Scenario G - SSLS - Heldmann
1	**EVA PLANNING and TRAVERSING** - Navigation, data requirements, field crew vs. ground team planning, crew time optimization, hab workspace requirements, teleoperations and robotic assistance							
2	**Sample and data ACQUISITION** - Navigation, sampling strategies, sample preservation, in-situ measurements vs. sample collection, mass, power, and volume estimates							
3	**Sample transport -** Human transport, robotic transport, hab passthrough/transport							
4	**DOCUMENTATION** - Sample documenting automation - RF tagging or barcoding, Video/camera and audio requirements, real-time versus post documentation, time-stamping, real-time GIS capabilities in suit and/or rover							
5	**HYGRATION / SORTING** - Concepts for optimizing mass returned, space and crew time requirements, robotic assistance, data requirements, rock garden/sample shed concepts, optimizing crew/ground interactions				Day 2			Day 1
6	**LABORATORY ANALYSIS** - Minimum lab requirements (volume, functionality, sample preservation, glove box limitations, etc.), capabilities vs. mission duration, lab science vs. EVA science - optimizing crew presence							
7	**SAMPLE RETURN** - Preserving sample integrity, mass/power/volume of returned sample masses (reports from recent studies)							
8	**CURATION -** Issues impacting architectures?							

Prepared Questionnaire Example

TRAVERSING AND EVA [primary architectures: mobility, suits, comm/nav]								
Broad Activity	Issues	Options (d = other)			Time Phasing			Rationale
		a	b	c	Early	Buildup	Steady	
Navigation	Precision for rover	~10km	~1km	~10m	c	c	c	Assumes absolute knowledge of where rover is, assume crewed rover. Nav during Apollo at 100 m was tough.
	Precision for suited human	100's m	10's m	≤ 1m	c	c	c	
	Real time position mapping overlays?	rover	suit	hab	a,b,c	a,b,c	a,b,c	
	Other data overlays?	rover	suit	hab	a,b,c	a,b,c	a,b,c	Mineralogy, elevation, terrain
	Sync'd timecode display	rover	suit	hab	a,b,c	a,b,c	a,b,c	Timestamped data.
	Hertz neverlost guidance - "you are here" - real time	rover	suit	hab	a,b	a,b	a,b	You will know where the Hab is since there are multiple 500 day missions
	Telerobotic scouting	always	sometimes	never	b	b	b	Possible scenario: Can use 2 rovers to double your range (doubles your walkback/driveback distance).
Communications	2-way audio	suit	rover	hab	a,b,c	a,b,c	a,b,c	Assumes rover or suit talking to Hab. Assume flexible rover (crewed or uncrewed). Want to leave a rover on the surface that can be operated after crew leaves. Could also have chassis swappable for pressurized vs. unpressurized rover. Rover with consumables for astronauts = feasible. Also have back-up radio.
(traversing)	2-way video	suit	rover	hab	n/a	n/a	n/a	Video= important for documentation. May not have to transmit but can just record for sample documentation. 2-way video may be good for 2 astronauts to find each other (e.g. if lost) - requires 2-way btw suits. Audio and nav can take place of video.

Discussion Results - Traverse Planning

- Data Usage
  - Unanimous or almost unanimous
    - Extensive Site Survey at ~meter resolution
    - Instantanous or at least daily access to orbital/remote sensing data from hab
  - Split
    - Paper vs. non-paper maps
- Traverse Planning
  - Unanimous or almost unanimous
    - Crew and Ground plan traverses and sampling strategies together
    - Telerobotic scout prior to planning useful - mainly carried out by crew, but also ground control possible
  - Split
    - Time phasing dependent - early EVAs planned by ground, later EVAs planned by more autonomous crew
- IVA Requirements
  - Unanimous or almost unanimous
    - Advanced technologies recommended to replace traditional large table/map traverse planning - VR, light tables, wall screens
    - ~ 1 hr EVA planning time + ~1 hr EVA prep
    - Significant time also required for IVA prep in support of EVA
  - Split
    - Need for IVA support during EVA - scenario dependent
    - Need for samples in hab to inform traverse planning
    - Role of Ground - Favored ground support vs. ground authority and crew autonomy later in buildup. Scenario dependent.

Discussion Results - Traversing

- Traverse Navigation
  - Unanimous or almost unanimous
    - Rover navigation precision ≤10m, suit precision ≤10m (or ≤1m)
    - “Hertz Neverlost” type position display highly desired
    - Telerobotic scout sometimes useful
  - Split
    - Real time position mapping, data-overlay, and timecode display desired in suit, rover, and hab - general agreement that all are needed, but disagreement about when/where
    - One group saw no need for telerobotic scout, and others thought it was “always” needed
- Traverse Communications
  - Unanimous or almost unanimous
    - 2-way audio required between all agents in suits, rovers, and habs
    - 2-way video not required for all agents in real time, but recording and storage required for later study - most desirable between rover and hab in real time
    - Real time data access and display desired in suits, rovers and habs
    - Continuous time code acquisition needed
  - Split
    - Real time instrument data analysis and display dichotomous split - most favored this in suits, habs, and rovers (but some listed “none”)
- Traverse Flexibility
  - Unanimous or almost unanimous
    - Crew makes realtime traverse change decisions (in conjunction with ground, informing them)
  - Split
    - Rover ranges - pressurized, unpressurized, no rover
- Robotic Field Assistance
  - Unanimous or almost unanimous
    - Mostly agreed that robotic assistants should be controllable from all: suits, rovers, hab (ground) and robotic scout info should be viewable in real time
  - Split - role of robotic assistants, time phasing, and where robotic info is needed: suits, rovers, etc.

Discussion Results - Sample and Data Acquisition

- Documentation
  - Unanimous or almost unanimous
    - At least <1m and in several groups <10cm navigational precision for sample documentation
    - <10cm spatial resolution for instrument data - instrument dependent
    - HD or TV quality video
    - Multiple cameras - mounted, hand-held, tele-robotic
  - Split
    - Real time documentation?
- Sampling Tools and Samples
  - Unanimous or almost unanimous
    - “Some Enhancements” over Apollo-class sampling tools required, with significant “high tech” innovations needed for Mars (bio) or long-duration Lunar stays
    - “5-20 kg” or “≥50 kg” of samples collected PER 8-hr EVA (!!)
    - Tasks for robotic field assistants: analysis, heavy lifting, digging, drilling, breaking, carrying, documentation, transport, scouting - tasks somewhat time dependent
    - Subsampling capability in field is important - Field handling of samples depends heavily on samples
    - Advanced scientific judgment required for sampling required, but there is also a role for “dumb robotic rake samples” or other sample grabs
  - Split
    - Role of robotic field assistance - ranged from “none” to “max”
    - Planetary protection issues
- Data Acquisition
  - Unanimous or almost unanimous
    - ~ 5-30% of time spent on in-situ measurements per time spent at site
  - Split
    - Optimal amount of time spent at site of interest vs. time traversing
- Robotic Field Assistance
  - Unanimous or almost unanimous
    - Robotic field assistants should not burden crew - can slow them down
    - Could be useful - most recommended pre-deploy
  - Split
    - Role of robotics in field work

Discussion Results - Transport

- Human Transport
  - Unanimous or almost unanimous
    - Requirements different for Moon and Mars
  - Split
    - Percentage of samples that can be handled “bare-glove” - 0-5%, 5-50%, ≥50% - all over the map
    - Mass percentage of “environmentally sensitive samples”
    - Percentage of time spent handling “environmentally sensitive” samples (drilling, tele-robotic sampling, etc.)
- Rover Transport
  - Unanimous or almost unanimous
    - Required load capacity for rover: 40-100 kg (or more)
  - Split
    - Rover requirements for preserving sample integrity - separation from Human contamination unanimous, but other req’ts split
- Hab Transport/Passthrough
  - Unanimous or almost unanimous
    - Percentage of samples that could be handled in “dirty” human environment with bare hands and returned with humans - 0%
  - Split
    - Need for hab-internal glovebox and/or rover->hab sample passthrough - widespread disagreement

Discussion Results - Documentation

- Automated Documentation at Site
  - Unanimous
    - Synchronized time stamping on all data - instruments, photos, video, audio, etc.
    - Post-processed (possibly relative) position accuracy for sample documentation ≤ 1 cm
  - Split
    - In-situ measurements of samples available in real time in suits or on rover (to aid in sample selection or subsampling) - widely split
    - Real-time suit, camera, and instrument position/pointing accuracy - ~10m or ≤ 1 cm
    - Degree and resolution of video documentation (real-time vs. recorded)
- Subsampling at Site
  - Unanimous or almost unanimous
    - Some subsampling will be necessary
  - Split
    - Automated subsampling?
- Data Usage
- Other comments

Discussion Results - Sorting/High-Grading

- Sample Handling, Exo-curation, and Documentation (SHED) Facility
  - Unanimous or almost unanimous
    - SHED idea either good or “compelling” and needs further study
    - Sample contamination and cross-contamination a serious issue, even apart from human contamination
    - Any samples brought into hab/lab for study are not considered pristine for return
  - Split
    - Degree to which tele-robotic manipulation is possible, desirable, sustainable on lunar/Mars surfaces
    - Requirements and trades for SHED and Lab vs. in-situ measurements
    - Degree to which dust control within the lab is a problem
- Sample quantity, high-grading and Subsampling
  - Unanimous or almost unanimous
    - $\geq$ 300 kg of samples will be collected per mission
    - Samples to be returned should be subsampled, separated, handled, and stored outside human environment
  - Split
    - Crew time required for sample sorting documentation and high-grading - $\leq$ 2 hrs or $\geq$ 6 hours per 8 hour EVA

Discussion Results - Laboratory Analysis

- Minimum Analysis Capability
- Sample Passthrough
- Advanced Analytical Capability
- Synergy with ISRU

WIDESPREAD DISAGREEMENT or “DEPENDS” IN ALMOST ALL AREAS - difficult to present simply

Discussion Results - Sample Return

- Transport to Ascent Vehicle

Is robotic samle return separate from crew activities/return needed?

Discussion Results - Curation

- Mass Returned per Flight
  - Unanimous or nearly unanimous
    - Agree with CAPTEM Results but CAPTEM return mass should be taken as minimum and may evolve for longer stays
  - Split
    - Mars sample return mass different from Moon - need more biological (biochemistry, astrobiology,etc.) from Mars but some thought basic idea the same
    - Want more samples per returned flight
- Additional comments from individual groups
  - Need to curate Mars samples under Mars conditions
  - Sometimes need to curate Mars samples under Mars pressure conditions
  - Sometimes need to curate Mars samples under Mars ambient atmospheric conditions
  - Curation paradigm needs to change along with exploration paradigm and curation facilities need to be expanded. Curation of Mars samples will likely be very different
  - Container masses and types need new innovations
  - Cross contamination issues during collection extend to curation
  - “Biologically interesting samples” require new protocols, procedures

Broad Questions Identified in Real Time

- Maintaining sample integrity (CAPTEM) -
- Do we require the samples to be isolated from humans at all times (moon?) (mars?) ?
- Planetary Protection - how can the Moon be used for planetary protection issues on Mars?
- What do we need for sample triage? What are the basic requirements? What analytical instruments are desirable and possible for assisting in sample triage/sorting/discriminating? What criteria will be used to select samples? Better definition of SHED - do we need one? Map GES objectives to triage criteria.
- Is the cost of increasing the sample return mass lesser or greater than the cost of delivering mass to the surface to discriminate returned sample mass
- What is the appropriate role of robotics in the process of sample identification, traverse planning (scouting), acquisition, documentation, sample handling, and collection?
- How can we use Apollo lessons learned, samples, and protocols to improve (joint human/robotic) sample return from the moon. Triage simulations.
- Scientific data management
- How can we use Analog missions/field tests to address the issue of training and efficiency in the area of sampling? Need serious effort to design tests.
- Science-driven Navigation requirements - situational awareness. Site characterization - what do you need to know to characerize the site well enough to efficiently plan traverses and sampling strategies.
- Bandwidth / communications requirements?

Next Steps

- Workshop specific
  - Finish synthesizing data from questionnaires
  - Telecon with discussion group moderators
  - Draft final report
  - Circulate report to workshop participants
  - Publish final report on LPI website

- In Parallel at NASA HQ
  - Use results of workshop to develop OSEWG roadmap and terms of reference for Lunar Data/Mapping activity and Analog missions
  - Commission and conduct series of studies based on prioritized outstanding questions identified at workshop
  - Continue series of workshops on important topics identified at workshop - e.g. Sample Triage, Analogs
  - Identify points of relevance to ongoing architecture planning activities to develop and refine requirements
  - Input long lead-time or otherwise prioritized questions into specific research calls (LASER, Analogs, etc.)

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