

2008 Lunar Recon Orbiter

Obj/Reqt's Defn Team

Findings

March 3, 2004



LEVEL 0's: LRO

Advance U.S. scientific, security, and economic interests through a robust space exploration program. *Rationale: Established by President's Space Exploration Policy Directive (NPSD31) (Goal and Objectives – Goal), signed into effect on January 2004.*
1. Implement a sustained, safe, and affordable human and robotic program to search for evidence of life, understand the history of the solar system, and prepare for future human exploration. *Rationale: Established by NPSD31 (Goals and Objectives, first bullet).*
(1.1.) All exploration programs shall incorporate explicit opportunities for public engagement, education, and outreach. *Rationale: Just as Mercury, Gemini, and Apollo challenged a generation of Americans, a renewed U.S. space exploration program with a significant human component can inspire us – and our youth – to greater achievements on Earth and in space.*
1. Undertake lunar exploration activities to enable sustained human and robotic exploration of Mars and more distant destinations in the solar system. **1. Starting no later than 2008, initiate a series of robotic missions to the Moon to prepare for and support future human exploration activities.** **1. Mission objectives shall include landing site identification and certification on the basis of potential resources.** **2. Measurements shall be made to support applied science and research relevant to the Moon as a step to Mars, engineering safety, and engineering boundary conditions.** **3. Technology demonstrations and system testing shall be performed to support development activities for future human lunar and Mars missions.** *Rationale: Need to identify and certify the landing site on basis of potential resources, and to improve system safety and reliability.* 1. Conduct the first extended human expedition to the lunar surface as early as 2015, but no later than the year 2020. 2. Use lunar exploration activities to further science and research. *Rationale: Established by NPSD31 (Section B, The Moon.)*

NASA
SPACE SCIENCE
ENTERPRISE

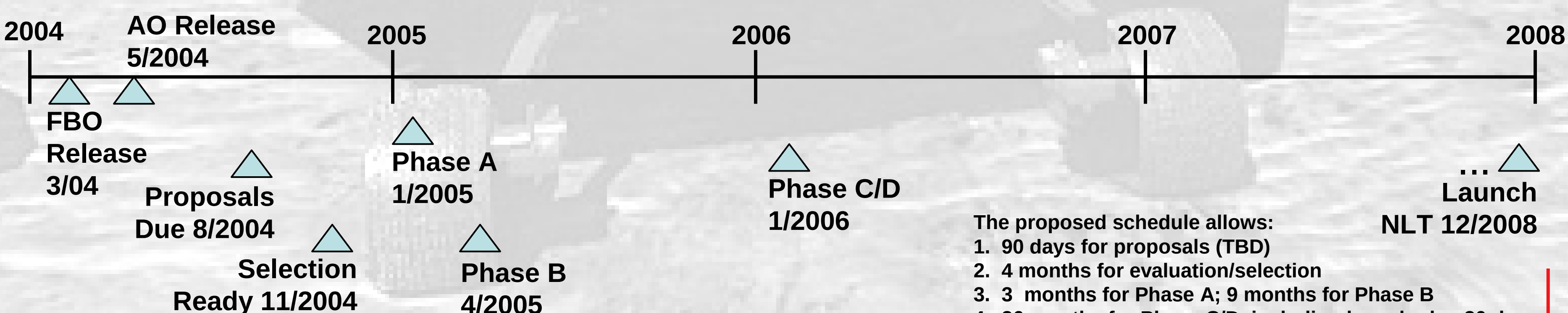
ORDT Charter and LRO Schedule

<u>Charter</u>

- Provide NASA with a prioritized set of measurements that can be attained with a *resource- and schedule-constrained* **Lunar Reconnaissance Orbiter** (**LRO**) mission to be launched before the end of the 2008 calendar year.

- Unlike traditional *Science Definition Teams*, the Objectives and Requirements Definition Team (**ORDT**) activity will be guided by the needs associated with future human-based exploration of the Moon as a "proving ground" and "test bed" for eventually sending humans to the surface of Mars (*for science*) and beyond.

- NASA will release an Announcement of Opportunity (AO) in April/May 2004 for the acquisition of the payload to respond to priority measurement requirements



The proposed schedule allows:

1. **90 days for proposals (TBD)**
2. **4 months for evaluation/selection**
3. **3 months for Phase A; 9 months for Phase B**
4. **36 months for Phase C/D, including launch plus 30 days**

The Team

- **LRO ’08 Objectives/Reqts Defn Team**
  - Dr. Jim Garvin (Chair, NASA HQ, Code S)
  - *Dr. Jeff Taylor (U. Hawaii)*
  - *Dr. Mike Duke (Col. School of Mines)*
  - *Dr. Steve Mackwell (LPI)*
  - *Dr. James W. Head III (Brown)*
  - *Dr. Mark Robinson (Northwestern)*
  - *Dr. Paul Lucey (U. Hawaii)*
  - *Dr. Bruce Campbell (Smithsonian, CEPS)*
  - *Dr. Bruce Banerdt (NASA JPL)*
  - *Dr. John Connolly (NASA JSC: representing Code T)*
  - *Dr. Terri Lomax (NASA HQ, Code U)*
  - *Dr. Tom Prettyman (LANL)*
  - *Dr. Brenda Ward (NASA JSC: representing Code T)*
  - *Dr. Ben Bussey (JHU/APL)*
  - *Dr. Chip Shearer (UNM)*
  - *Dr. Marc Norman (ANU/LPI)*
  - *Dr. Gordon McKay (NASA JSC)*
  - Ex Officio: *Dr. R. DePaula, Dr. R. Steven Saunders, Martin Houghton (GSFC), Craig Tooley (GSFC), Dr. John Grunsfeld, George Tahu, R. Wayne Richie (LaRC), Captain John Young (JSC)*

Agenda

Jeff Taylor gave Jim Garvin's overview presentation

Discussed the priority list of data sets to be acquired that came from the workshop

Went into more detailed rationale for each of the data sets including the desired accuracy and precision as well as current knowledge

Discussed example instruments for each data set

Discussed instrument parameters, mass, power, cost

Came up with strawman payload and discussed the feasibility of what we could be done for the current mission scope.

AGENDA

- **ORDT Suggested Agenda (March 3-4):** 8 AM to 7 PM (March 3), carryover to March 4
  - Intro/Background *(Garvin, Grunsfeld, et al.)*
  - Measurement gaps discussion (all)
  - Measurements needed as “foundation data sets” (Head, Banerdt et al.)
  - Measurements for “resource reconnaissance” (Lucey et al.): How to be definitive
  - Potentially available (for 2008!) measurement systems with high heritage (all)
  - Measurements Code U (OBPR) may need NOW (Lomax) from orbit
  - Group Discussion of achievable priorities for competition this year
  - Individual measurement approach discussions (group leaders)
    - *Imaging (Robinson, Lucey, Head)*
    - *Geodetic Topography/Gravity/Geophysics (Banerdt, Campbell)*
    - *Neutron Spectroscopy Methods (Prettyman, Taylor)*
    - *UV and IR methods (Lucey and others)*
    - *SAR and Microwave (Campbell and Head)*
    - *Other methods (Bussey, Shearer, Duke, Lomax, Norman)*
    - *Engineering demos on an orbiter? (Connolly, Lomax, GSFC Engineers)*
  - Group Synthesis and Prioritization (inputs from GSFC Project Engineers)
  - Draft Conclusions with “must have” Priority I vs other desirables (priority II)
  - Consider first robotic landed element targeted by LRO (lander/rover/penetrator or ?)
  - Adjourn Day 1 (~ 7PM)
  - Day 2: Complete draft presentation of measurement priorities as “findings”

Measurement Requirements

- ORDT divided measurement requirements into 5 (I,II, ...,V) categories:
  - ***I***: *must have for future of human exploration on Moon (**bioastronautics**)*
  - ***II***: *must have for **all** next steps in exploration (**geodesy**)*
  - ***III***: *must have for polar resources assessments (**volatiles**)*
  - ***IV***: *must have for landing site selection and safety (**characterization**)*
  - ***V***: *highly desirable to globally assess resources and their accessibility for human exploration (**global resources**)*

- *March 1-2 LPI Lunar Workshop provided valuable discussions of robotic lunar exploration requirements **before** the ORDT plenary on March 3/4*

ORDT Preliminary Findings

- Three primary **themes** (priority order), in addition to essential Life Sciences
  - Establishment of high resolution geodetic grid for Moon (in 3 dimensions)
    - Global geodetic knowledge (spatially resolved topography)
    - Detailed topographic characterization at landing site scales (especially in polar regions)
  - Polar region resources assessment (and associated landing site safety)
    - Largest unknown in present knowledge of lunar resources
  - High spatial resolution global resource assessment
    - Elemental composition
    - Mineralogy
    - Regolith characteristics

- Majority of top two themes (*plus life sciences!)* fall within first-order assessment of LRO Mission resource constraints (best available at time of writing)

- ORDT placed lower priority on partial duplication of anticipated Int'l Lunar Mission measurement sets (*Selene, SMART-1, Lunar-A, etc.)*

- Aside from essential Life Sciences* experiments, there are 6 high priority measurement sets that LRO should target via the Payload AO:
  - *Geodetic global topography*
  - *High spatial resolution Hydrogen mapping*
  - *Temperature mapping in polar shadowed regions*
  - *Imaging of surface in permanently shadowed regions*
  - *Assessment of meter and smaller scale features for landing sites*
  - *Characterization of polar region lighting environment*
  - **Life sciences: characterization of genetic response of organisms to deep space radiation*

ORDT Suggested Measurement Set Priorities (I, II, III, IV; V)

I. Characterize deep space radiation environment and impact on physiology of living systems

IIa. Global topography with 10-m vertical accuracy at 3-km equatorial cross-track and 30 m along-track sampling

IIb. Global orbit determination to 100 m along- and cross-track, 10 m radial (*only nearside achievable without sub-satellite*).

IIIa. Characterize surface morphology in regions of permanent shadow at ~50 m spatial resolution.

IIIa. Characterize abundance of hydrogen within the upper 1 m to 20% accuracy and ~5 km resolution, with 100 ppm detection limit.

IIIa. Characterize the temperature, from 35-200 K, of the polar cold traps to 1 km spatial resolution and 5 K precision.

IIIb. Identify putative deposits of appreciable near-surface water ice in polar cold traps at ~100 m spatial resolution.

IIIc. Measure illumination conditions, within 5 deg of the poles, to ~ 100 m spatial resolution and 5 hr temporal resolution.

"*waterline*"

IVa. Characterize surface morphology through visible imaging at 1 m feature identification resolution over targeted areas of 10x10 km.

IVb. Characterize topography with 10 cm vertical precision at 10 m posting over targeted areas of 10x10 km.

IVc. Characterize regolith rock abundance and structure to depths of 10 m on ~ 50 m spatial scales over targeted areas of 10x10 km.

IVd. Identify mineral species to 5% abundance at a spatial resolution of 15 m over targeted areas of 10x10 km.

Va. Analysis of S/C tracking information to determine global gravity to an accuracy of 20 mgal and spatial resolution of harmonic degree 120.

Vb. Measure the global magnetic field to better than 1 nT accuracy with temporal resolution of ~1000 s.

Vc. Characterize global concentration of key elements, to 5% precision, at spatial res. of 60 km.

Vd. Global 15-m spatial resolution visible imaging for morphologic analysis and context.

NB. AO must require a data reduction methodology and schedule for delivery of derived data products (Level 2 and 3).

LRO Strawman Payload Instruments : EXISTENCE PROOF EXAMPLE

Near-polar orbit a common attribute (no equatorial requirements)

Altitude of 50 km acceptable for all experiments

(I) Life science payload ~ 10 kg; low/mod data rate; 20 W – \$12 M
(IIa, IIb) Laser altimeter with good orbit determination (15 kg; 20 W; mod/high rate) – \$ 20 M
(IIIa1, IIIb, IVc) SAR (~50 kg; 60 W; high rate) – \$40 M
(IIIa2) Neutron imaging (20 kg; 5 W; low rate) – \$5 M
(IIIa3, IVc) Imaging radiometer (5 kg; 5 W; low rate) – \$7 M
(IVa, IVb) Narrow-angle camera (10 kg; 5 W; high rate) – \$7 M
(IIIc) Wide-field camera (2 kg; 5 W; low rate) – \$5 M

RESULT: 1 life science payload, 6 “other” instruments (as above)

Total instrument mass estimate: **112 kg**
Total instrument power estimate: **120 W**
Total cost ROM: \$96 M + \$20 M Phase E+ (data products) = **\$116M** (*with some margins*)

GSFC Working Parameters: ~200 kg payload, 200 W (uppers on Delta II)

Mission results:
Landing access to the poles thru resource inventory & global geodetic framework

Traceability: *Existence Proof (examples)*

Measure ments	Altimeter	Neutron Imager	SAR	IR Radio-meter	NA Imaging	WA Imaging	Precision Orbits	Rad. Sentinels
Global geodesy	Lidar		INSAR if repeat pass orbits				Nearside tracking, farside X-overs, Subsat.	
Polar H Mapping		Collimated Neutron imager						
Imaging shadowed areas	Lidar		P-band, 1 incid. angle	Bolometer "imager" (low res.)				
Temp. Sounding				Bolometer "imager"				
< 1 m Feature imaging					MOC or CTX class with TDI			
Illumination mapping	Lidar		If INSAR only	Bolometer "imager" (low res.)	Locally (MOC/CTX class)	MARCI or CTX class		
Radiation for Life Sciences		??						Code U ISGEN heritage

SUMMARY

- **“Must Haves” for LRO 2008**
  - *Nearside geodetic topography at < 2m rms (vertical) with 30 m along track (100m grid in polar regions); globally to 10m rms (vertical)*
    - Farside 10 m rms depends on tracking subsatellite (could be done later on subsequent mission via reprocessing)
  - *Geodetic topography assumes precision orbit determination (nearside) at ~ 10-20 m (rms)*
  - *Life Sciences experiment using radiation sentinel approach*

- **Essential for key Exploration decision points, such as human polar landings and resource evaluation**
  - *H mapping at < 5 km sampling in polar regions (sensitivity to 100 ppm H)*
  - *Temperature mapping at < 500m/pixel at better than 5 K over entire T range*
  - *Mapping of **all** Permanently shadowed regions at ~ 50m per pixel*
  - *Wide angle imaging of polar regions to characterize illumination variations*
  - *High resolution imaging for characterizing meter-scale features for all potential landing sites (polar and otherwise)*

BACKUPS

- Partial considerations of a *first* landed (robotic) lunar mission discussed:
  - *Lander/Penetrator mission in 2010 to "Ground-truth" LRO resource observations (ices, etc.)*
    - Lander/penetrator is ONLY way to confirm (or refute) lunar ices identified from orbit via LRO '08 measurements

- A 2nd lunar recon. orbiter to follow-up and extend LRO '08 desirable
  - *May be only means of achieving cost-effective full suite of desired measurements (especially if any are not selected in 2004 LRO AO)*
  - *Some crucial resource and global measurements not above "waterline" for LRO*

- LRO '08 should avoid duplication of measurement sets to be acquired via current and planned Int'l lunar missions:
  - *NASA should negotiate plans for exchange of essential data relevant to lunar Exploration plans (i.e, equatorial mineralogical and elemental mapping)*