

**2007 Lunar Regolith Simulant Workshop Overview  
Huntsville, AL  
October 10-12, 2007**

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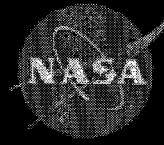
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**ABSTRACT**

The National Aeronautics and Space Administration (NASA) vision has as a cornerstone, the establishment of an Outpost on the Moon. This Lunar Outpost will eventually provide the necessary planning, technology development, and training for a manned mission to Mars in the future. As part of the overall activity, NASA is conducting Earth-based research and advancing technologies to a Technology Readiness Level (TRL) 6 maturity under the Exploration Technology Development Program that will be incorporated into the Constellation Project as well as other projects. All aspects of the Lunar environment, including the Lunar regolith and its properties, are important in understanding the long-term impacts to hardware, scientific instruments, and humans prior to returning to the Moon and living on the Moon. With the goal of reducing risk to humans and hardware and increasing mission success on the Lunar surface, it is vital that terrestrial investigations including both development and verification testing have access to Lunar-like environments. The Marshall Space Flight Center (MSFC) is supporting this endeavor by developing, characterizing, and producing Lunar simulants in addition to analyzing existing simulants for appropriate applications.

A Lunar Regolith Simulant Workshop was conducted by MSFC in Huntsville, Alabama, in October 2007. The purpose of the Workshop was to bring together simulant developers, simulant users, and program and project managers from ETDP and Constellation with the goals of understanding users' simulant needs

and their applications. A status of current simulant developments such as the JSC-1A (Mare Type Simulant) and the NASA/U.S. Geological Survey Lunar Highlands-Type Pilot Simulant (NU-LHT-1M) was provided. The method for evaluating simulants, performed via Figures of Merit (FoMs) algorithms, was presented and a demonstration was provided. The four FoM properties currently being assessed are: size, shape, density, and composition. Some of the Workshop findings include: simulant developers must understand simulant users' needs and applications; higher fidelity simulants are needed and needed in larger quantities now; simulants must be characterized to allow "apples-to-apples" comparison of test results; simulant users should confer with simulant experts to assist them in the selection of simulants; safety precautions should be taken in the handling and use of simulants; shipping, storing, and preparation of simulants have important implications; and most importantly, close communications among the simulant community must be maintained and will be continued via telecons, meetings, and an annual Lunar Regolith Simulant Workshop. While this presentation only addresses highlights of the Workshop, more details in the form of Workshop minutes and presentations will be posted on the MSFC website, <http://isru.msfc.nasa.gov>. A formal Workshop Report will also be released and posted in the near future.



National Aeronautics and Space Administration

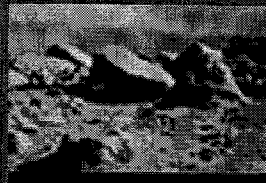
# 2007 Lunar Regolith Simulant Workshop Overview Huntsville, AL October 10 - 12, 2007

*Presented to:*  
*JUSTSAP 17<sup>th</sup> Annual Symposium*  
*Waikoloa, Hawaii*  
*November 11 - 15, 2007*

*Carole McLemore & John Fikes;*  
*MSFC ISFR/ISRU/Dust Project*  
*NASA/Marshall Space Flight Center*

*Presented by: Joe Howell*  
*NASA/Marshall Space Flight Center*

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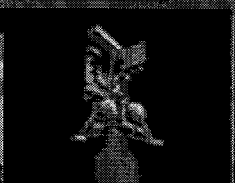
Regolith



Construction



Life Support



Propulsion



Power



Fabrication



# Regolith Simulant Team



## ◆ MSFC

- Carole McLemore (Project Manager)
- John Fikes (Deputy Project Manager)
- Dr. Doug Rickman (Project Lead Geologist)
- Christian Schrader/BAE (Geologist)

## ◆ U.S. Geological Survey

- Dr. Doug Stoeser (Geologist)
- Dr. Steve Wilson (Chemist)

## ◆ University of Colorado – Boulder

- Dr. Susan Batiste

## ◆ Orbitec (Madison, WI)

- Marty Gustafson (JSC-1A SBIR Phase III)
- Bob Gustafson (Agglutinates and Mars Simulant SBIR Phase II)

## ◆ Many other collaborators



# Specific Framework for Lunar Regolith



Role of Regolith

It Touches Everything

3 Aspects – (1) Understand It, (2) Deal With It, (3) Utilize It

## Interrelationships & Connectivity

Science  
(Properties & Processes)



Engineering  
(Design, Test & Operations)

Knowledge

Environment Simulation

Resource Utilization



Regolith Simulants  
(ESMD/SMD)

Dust Simulants

Bulk Simulants

Earth Based Environmental Testing

Human Health

HW/System Development & Verification



# History of Simulant Workshops



- ◆ **September 1989 Workshop on Production and Uses of Simulated Lunar Materials @ LPI/Houston hosted by D. McKay and J. Blacic**
  - Three Key Recommendations:
    1. It is strongly recommended that lunar simulant components be produced and made available to researchers as soon as possible.
    2. NASA should immediately designate a lunar simulant curator and establish a lunar simulant advisory committee.
    3. Every effort should be made to assist the research community with appropriate knowledge transfer concerning the feasibility and design of specific experiments requiring simulants.
  
- ◆ **January 2005 Simulant Workshop held in Huntsville and sponsored by ESMD and MSFC in collaboration with JSC**
  - Four Recommendations:
    1. Establish a common set of standards for simulant materials for NASA sponsored projects.
    2. Establish a process for the development, production, and certification of simulant materials.
    3. Develop a long-term simulant acquisition strategy.
    4. Proceed as quickly as possible with a unified, near-term ESMD simulant acquisition through an immediate redeployment of lunar mare simulant JSC-1.
      - Thirty-two (32) Lunar Regolith Properties were identified and ranked by importance based on consensus count by attendees



## *Why another Workshop and Why MSFC?*

### ◆ **Timing**

Previous Workshops were:

- Pre-ESAS
- Pre-LAT

### ◆ **Need Integrated Forum to Provide Status of Progress, Changes, and New Developments**



# ***MSFC's Role in Lunar Simulants***



- ◆ **MSFC is funded to develop, produce, characterize, and evaluate simulants for use in hardware and process technology developments with the goal of reducing risk**
  - **Funded by Jerry Sanders/JSC to develop high fidelity simulants for In Situ Resource Utilization (ISRU) projects**
    - Oxygen Production Hardware
    - Excavation Hardware
  - **Funded by Mark Hyatt/GRC to develop dust simulants for Dust Management projects**
    - Dust Mitigation Technology Hardware Developments
- **Other projects (e.g., CxP) need simulants as well now or will need them in the near future**
- **Partnering and/or Collaborating with Several Organizations (USGS, Orbitec, UCB, etc.) including Internationals**





# ***MSFC's Role in Lunar Simulants (Cont'd)***



## **◆ Products:**

- Various Simulants (User Driven) with Naming Convention
- Certified Test Protocols/Procedures
- Simulant Characterization Data Sheets
- User Requirements Documents
- Simulant Specifications
- Figures of Merit Tool (FoMs: Size, Shape, Density, and Composition)
  - Allows comparison or grading of simulants against a reference material such as an Apollo lunar sample or another simulant
- Simulant Users' Handbook and "Fit for Purpose" Matrix
- Consultation Services/Knowledge Capture
- Lunar Simulant Website

# 2007 Workshop Objectives



## Specific Objectives

1. Highlight ISRU and Dust Projects lunar simulant roles and objectives and how these fit into the broader ESMD scheme including the Constellation Project and their needs
2. Provide current status of NASA's and others' simulant activities including development and characterization
3. Share Apollo Lunar dust and regolith properties and data collection status and plans
4. Discuss proper simulant handling and usage
5. Bring together simulant developers and users to discuss requirements, uses, and issues (kick-off of many future meetings/discussions)
6. Collect users' simulant needs including types of simulants, dates required, and quantities needed -- inputs to Program/Project Key Performance Parameters

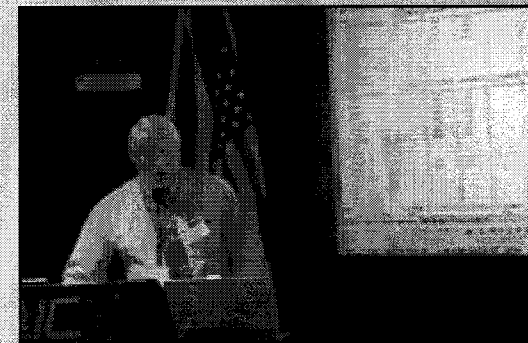
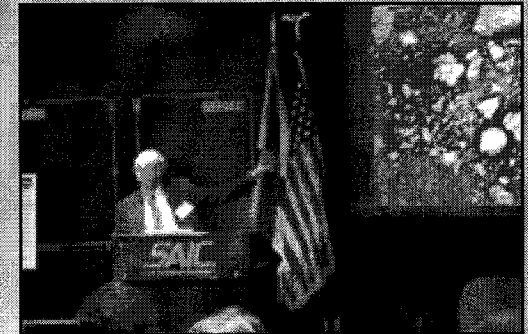




# October 2007 Simulant Workshop Presenters

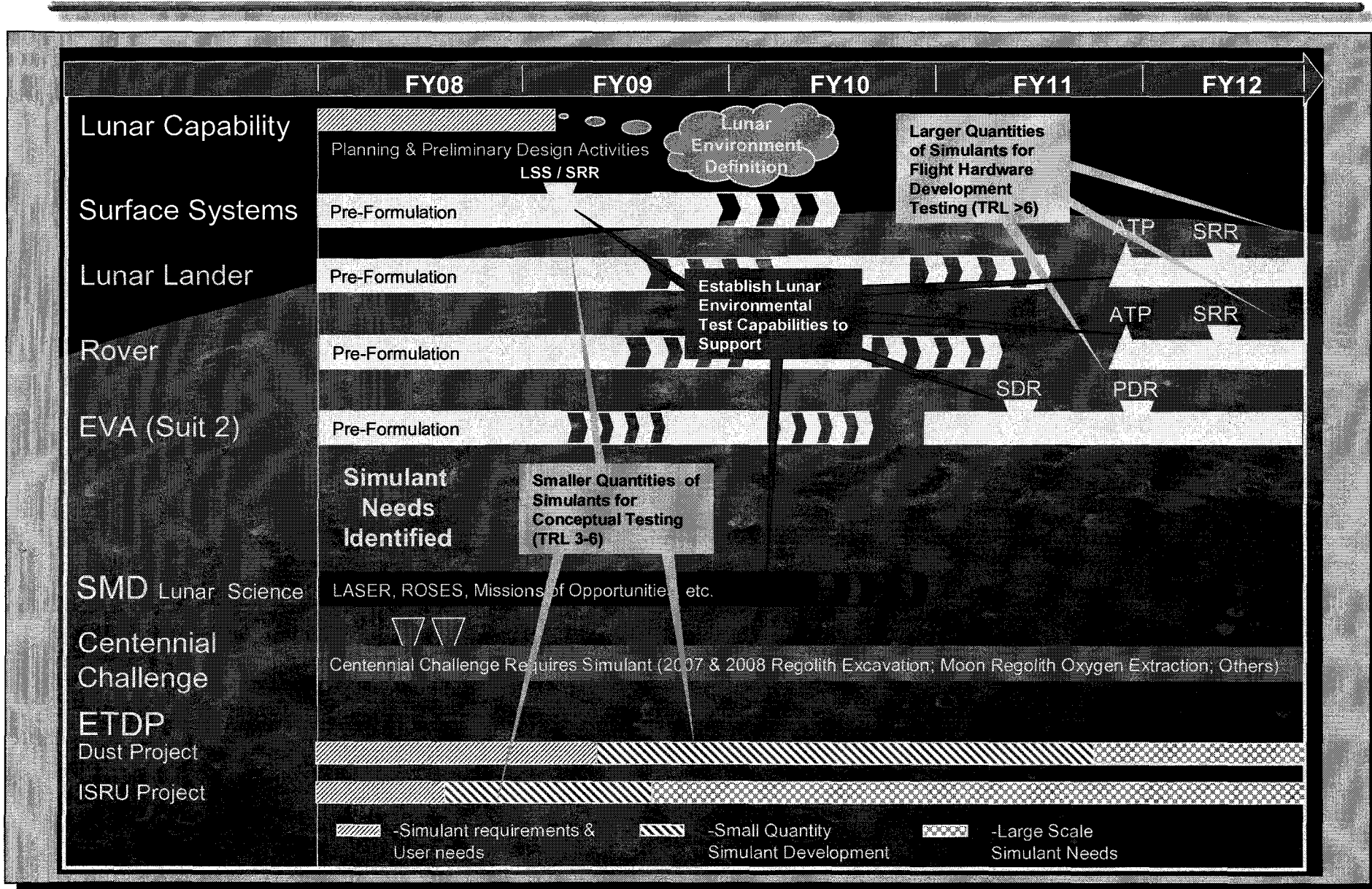


|                                |                     |                                                                     |
|--------------------------------|---------------------|---------------------------------------------------------------------|
| Jerry Sanders                  | JSC                 | ISRU Project Overview                                               |
| Mark Hyatt                     | GRC                 | Dust Management Project                                             |
| John Gruener                   | JSC                 | Lunar Surface Systems                                               |
| Sandra Wagner                  | JSC                 | Lunar Regolith Mgmt Plan for the Strategic Plan                     |
| Dan Garrison                   | JSC                 | Review of ISRU and Exploration Applied Lunar Research               |
| Tony Lavoie                    | MSFC                | Lunar Precursor Robotics Program                                    |
| Doug Rickman                   | MSFC                | MSFC ISRU & Dust Simulant Project Status                            |
| Doug Stoesser,<br>Steve Wilson | USGS                | NU-LHT-1M Pilot Highlands Soil Simulant                             |
| Marty Gustafson                | Orbitec             | JSC-1A Production and Distribution                                  |
| Bob Gustafson                  | Orbitec             | Dev. of High-Fidelity Lunar Regolith Simulants w/<br>Agglutinates   |
| Jim Richard                    | EVC                 | OB-1 Lunar Highlands Physical Simulant<br>Evolution and Production. |
| Elizabeth<br>Schofield         | Plasma<br>Processes | Plasma Reduction of Lunar Regolith                                  |
| Hans Hoelzer                   | TBE                 | Figures of Merit Demonstration                                      |
| Phil Metzger                   | KSC                 | Simulant Needs for Plume Ejecta Investigations                      |
| Carlos Calle                   | KSC                 | KSC Dust Mitigation                                                 |
| Robert Richmond                | MSFC                | Imaging (SEM) as a Tool for Testing Dust                            |
| John Lindsay                   | LPI                 | Dust Pathways. Forensic Engineering                                 |



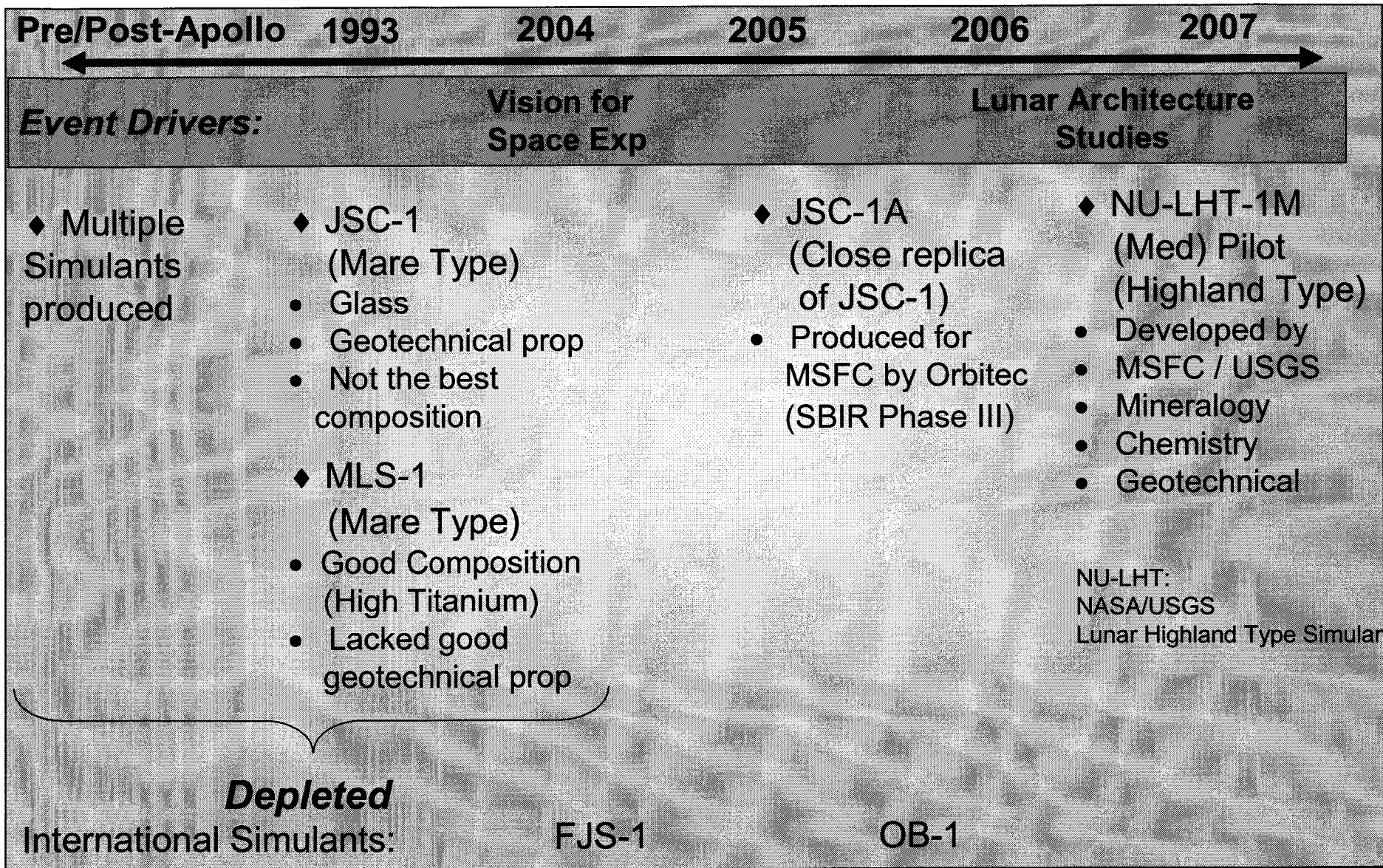


# ESMD & SMD Roadmap





# Family of Lunar Regolith Simulants



# Plans for 2008 & Beyond



## ◆ Goal

- Develop higher fidelity simulants and scale up production
  - Agglutinates with nano-phase iron
    - (Orbitec SBIR Phase II, USGS, and others already working on this)
  - Volatiles
  - Other properties important to simulant users

## ◆ Near-Term Schedule

- February 2008
  - NU-LHT-2M (Med) Prototype (Highland Type Simulant)
    - Developed by MSFC and USGS
    - Upgrade over Pilot (-1M)

## ◆ Summer 2008

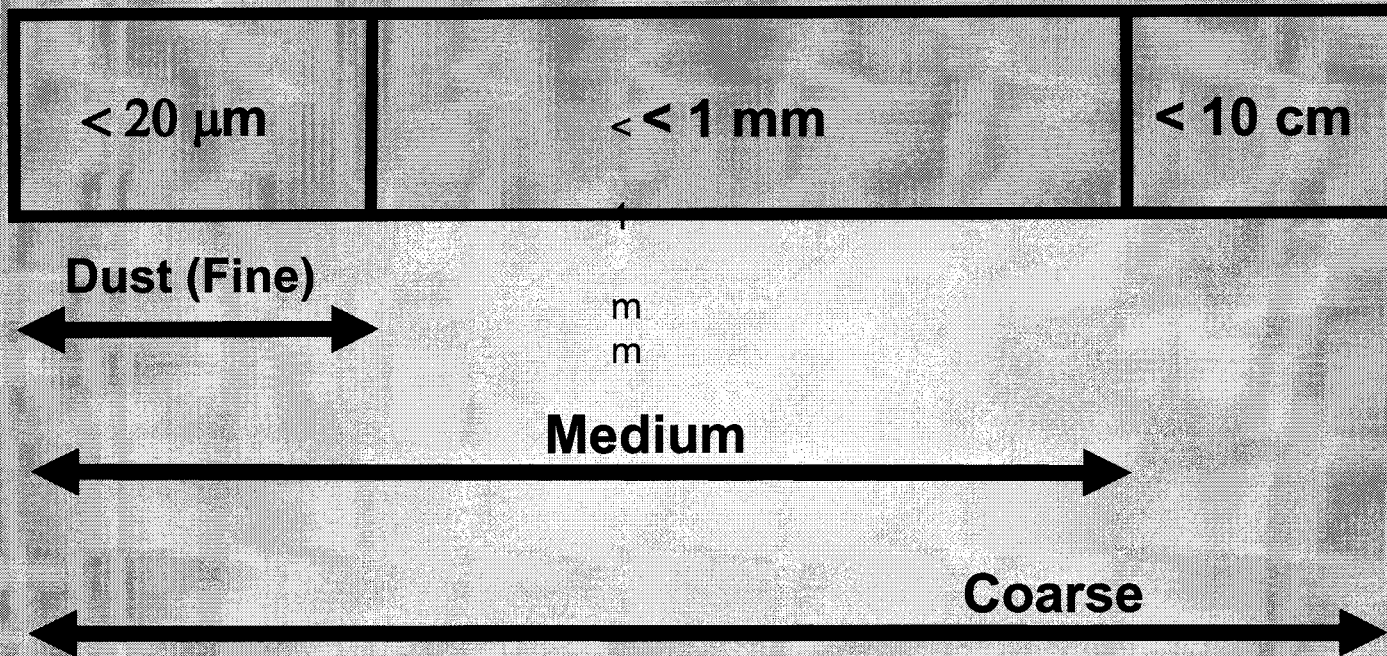
- NU-LHT-1C (Coarse) Prototype (Highland Type Simulant)
  - Developed by MSFC and USGS

## ◆ 2009 and Beyond

- Higher Fidelity Mare Simulant
- Dust Simulant
- Other Type Simulants



# Simulant Grain Size Reference





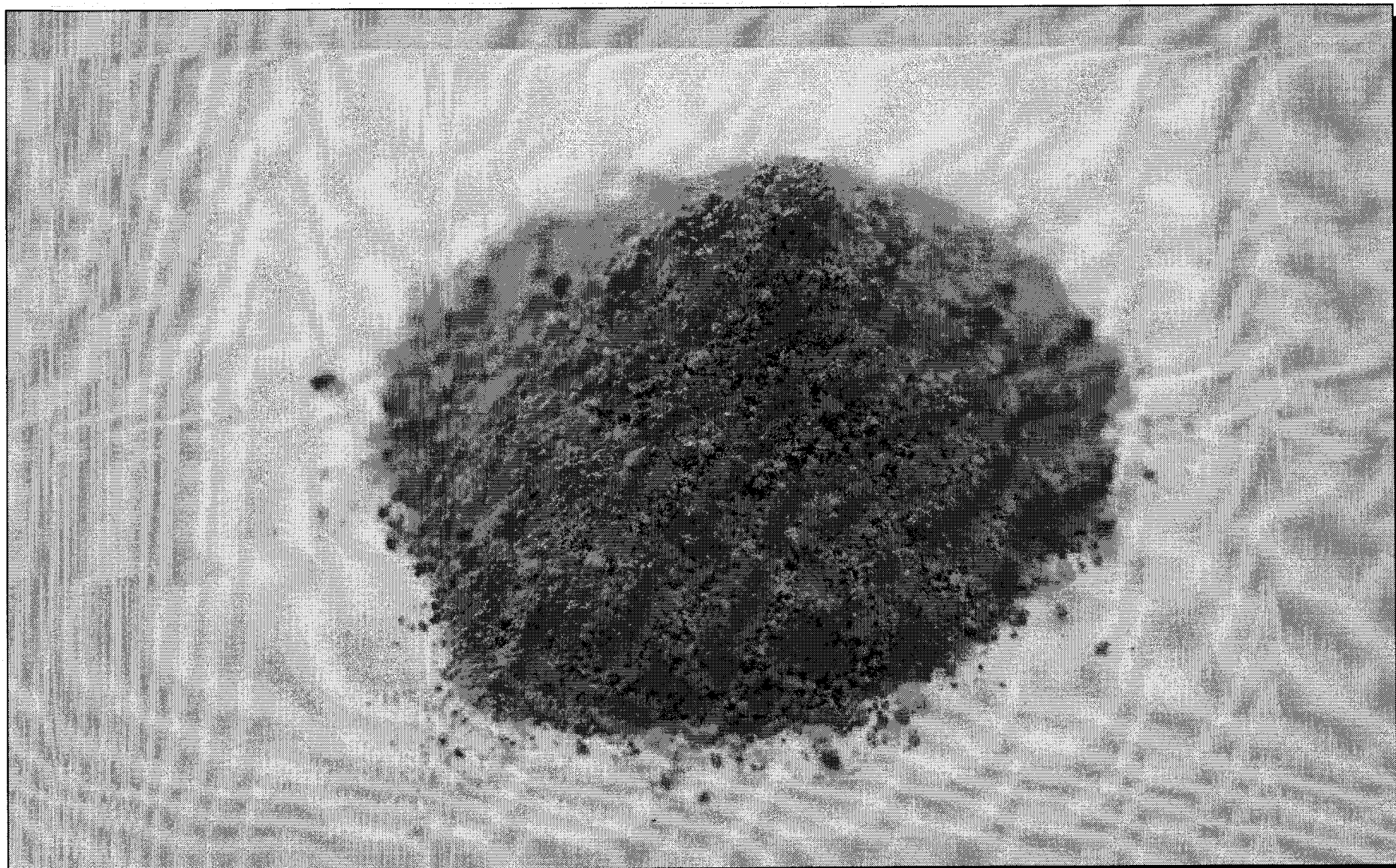
# *JSC-1A Simulant Picture*







# ***NU-LHT-1M (Med) Simulant Picture***





# 2007 Workshop Synopsis



- ◆ **Simulant Workshop brought together Government, Industry, Academia, and Internationals since Lunar Architecture announced**
- ◆ **Approximately 70 attendees including Exploration Program representatives (ETDP, CxP, LPRP, ARES), Simulant Users, Developers, and Producers, and Internationals**
- ◆ **Presentations were made on Day 1 and Splinter Sessions held on Days 2 and 3**
  - **Oxygen Production**
  - **Excavation**
  - **Dust**
  - **Facilities**
- ◆ **Workshop Minutes are forthcoming and will be posted on MSFC's website (<http://isru.msfc.nasa.gov>)**
- ◆ **2007 Lunar Regolith Simulant Workshop Report will be officially published as Technical Publication and posted on website**
- ◆ **Critical to continue interfacing and coordinating via monthly telecons/webex meetings**
- ◆ **Workshop will be held annually**
- ◆ **Feedback on Workshop has been positive**



# Conclusions



- ◆ **Simulant developers must understand simulant users' needs and applications**
- ◆ **Demonstrated that higher fidelity simulants are needed for Exploration Program**
- ◆ **Larger quantities are needed**
- ◆ **Simulants are needed now for advancing technology developments**
- ◆ **Simulants are needed in the future for hardware verification testing**
- ◆ **Simulants must be characterized**
- ◆ **A method for comparing simulants to assist in choosing proper simulant for users' applications and to allow for equitable comparisons of analytical results is required**
- ◆ **Users should confer with simulant experts to assist in selecting simulants**
- ◆ **Users should take precautions in order to safely handle simulants**
- ◆ **Shipping, storing, and preparation of simulants have important implications**
- ◆ **Must maintain close communication between simulant users and simulant developers**
- ◆ **Welcome any of you to join this community**



# *Other MSFC Related Technology Efforts*



## ◆ **Fabrication:**

- Electron Beam Melting
- Titanium Parts
- Starting to work with Aluminum Alloys
- Regolith Simulant Experiments (JSC-1A and NU-LHT-1M)

## ◆ **Non-Destructive Evaluation (NDE):**

- Microwave/Millimeter Wave Camera System (Univ of Missouri Rolla)
- Laser Ultrasound System

## ◆ **Repair:**

- SBIR Phase II (Adherent Technologies – Albuquerque, NM)



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