Size Beneficiation of Regolith for Simplicity and Efficiency

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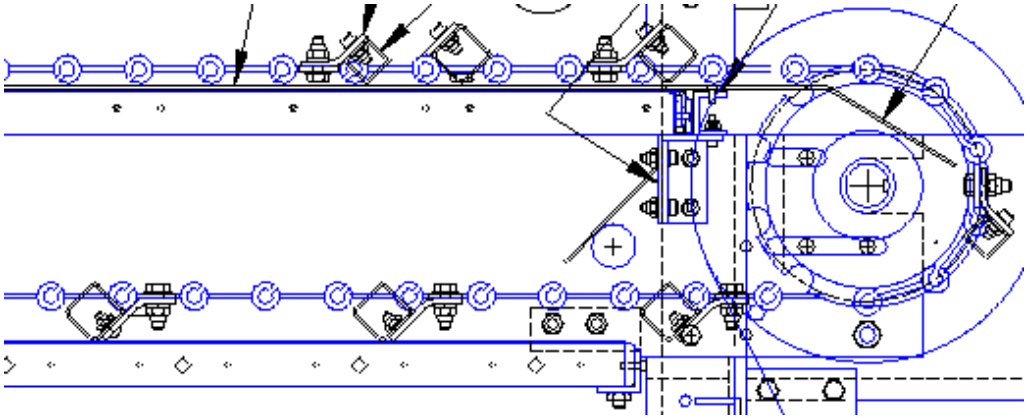
by Allen Wilkinson



Size Beneficiation of Regolith for Simplicity and Efficiency

- **Motivation**
  - Particle Size control is at the heart of all terrestrial granular processing
  - Mars Phoenix Lander needed particle size control for science
  - Provide design principles that enable a variety of possible size sorters
  - Provide the best system for ROXYGEN
  - Size sorting has been de-scoped

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- **Line of Reasoning**
  - Simplicity and Reliability
    - Sieving is the workhorse sizing method terrestrially
      - Clean size range bounds
      - Pay attention to blinding and wear
  - Gravity Independence
    - Sieving depends on granular flow, Shear & Bearing Forces
  - Energy Efficiency
    - The lower the kinetic and potential energy required the better
  - Volume and Mass
    - If large volume, make it foldable (ala Lunar Rover)

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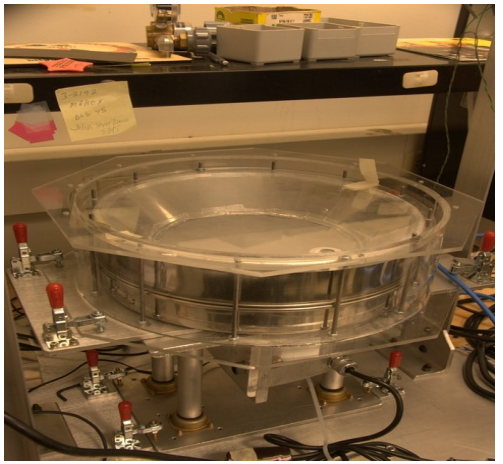
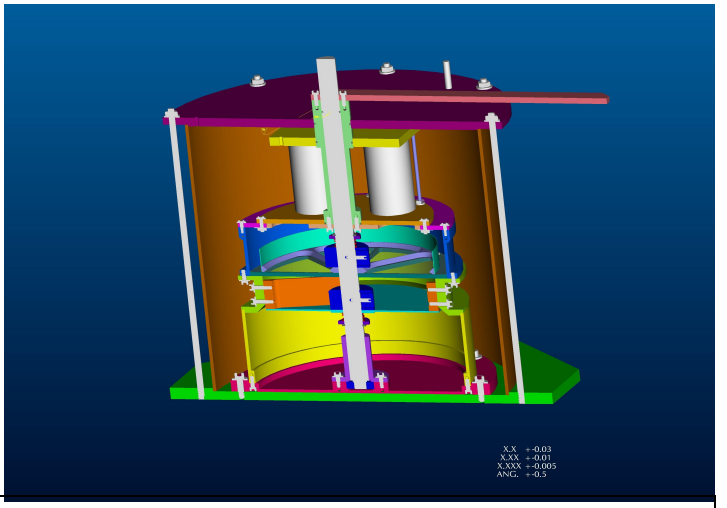
First Tests





	~Horizontal Vibratory	Rotary (flour) shearing sifter
1/6th-g Aircraft	• Less productive • Too much floating of material • Rushed design • Single batch limits	• More Productive • Centrifugal Force reduced Shearing Area • Gap under screen - Flex => De-Blinding • Swept table to dispense - Multi-Batch possible
Vacuum	• Less productive • Both vertical & horizontal vib done	• More productive • Flowed better than 1 atm

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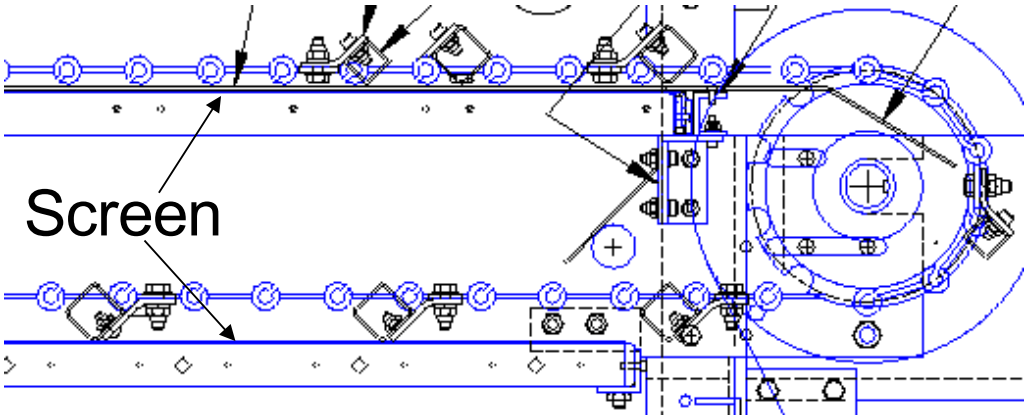
- **1 MT O_2 per year shearing sifter system**



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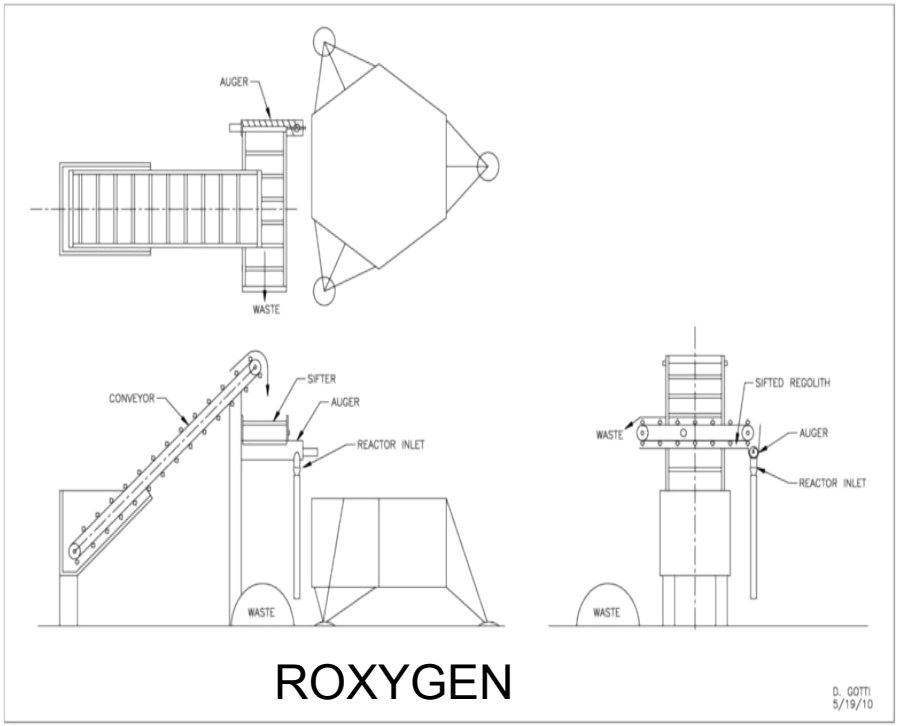

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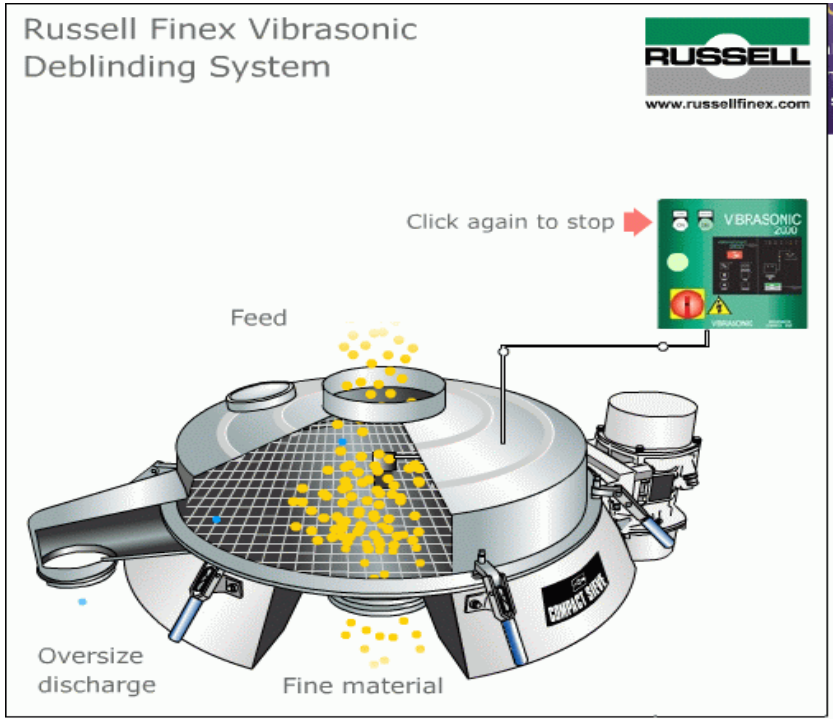
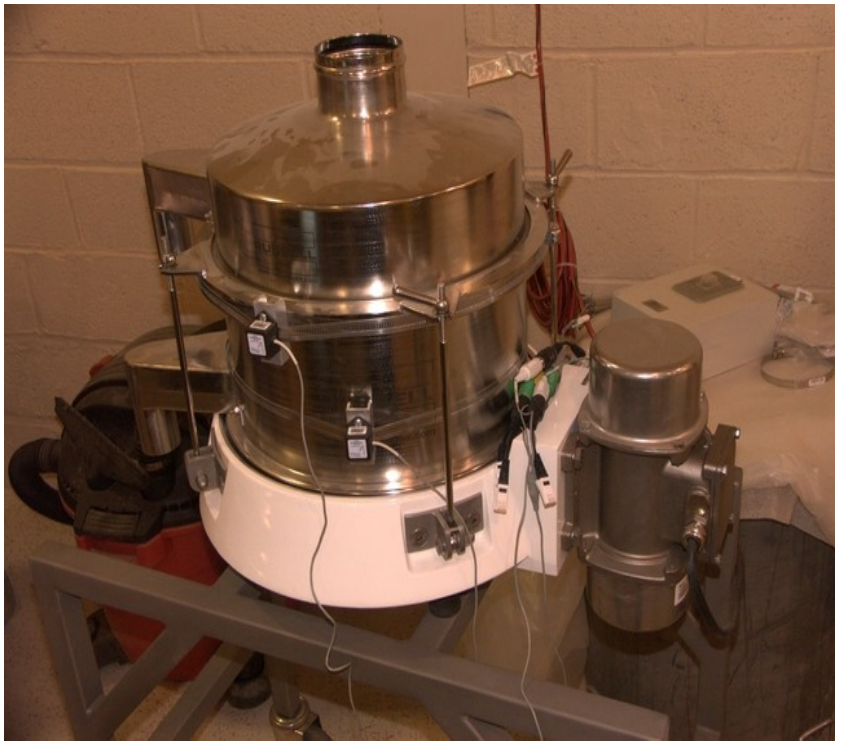
- **Commercial vibratory sifter system**
  - ☼Student low-g flight claimed success
  - ☼Give it a second look, low wear
  - ☼Continuous feed separates prod.
  - ☼Good de-blinding





- Bought two stage sifter for 1-g and 1/6th g
- Allows size range bounds

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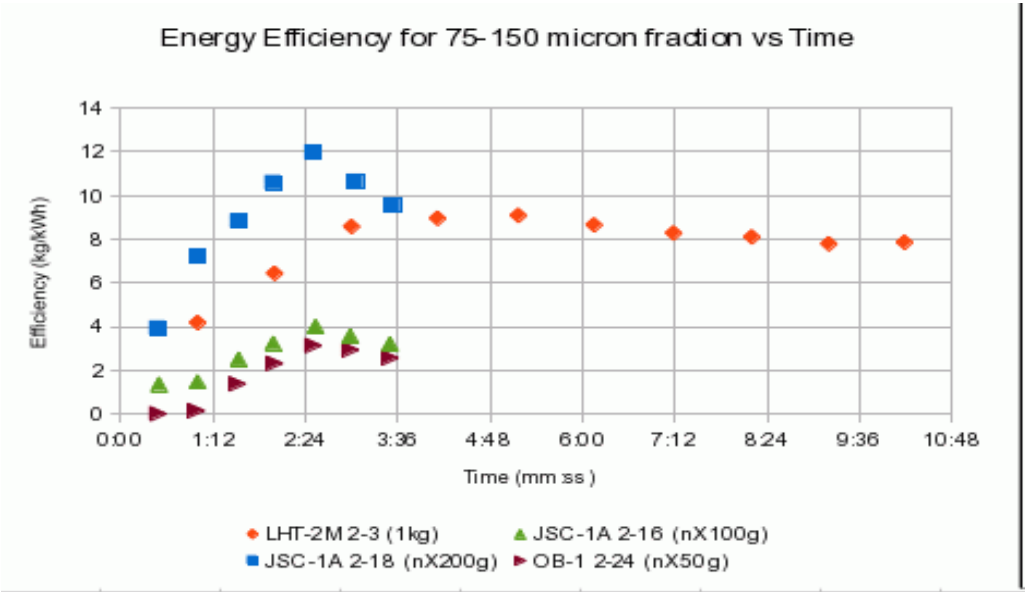
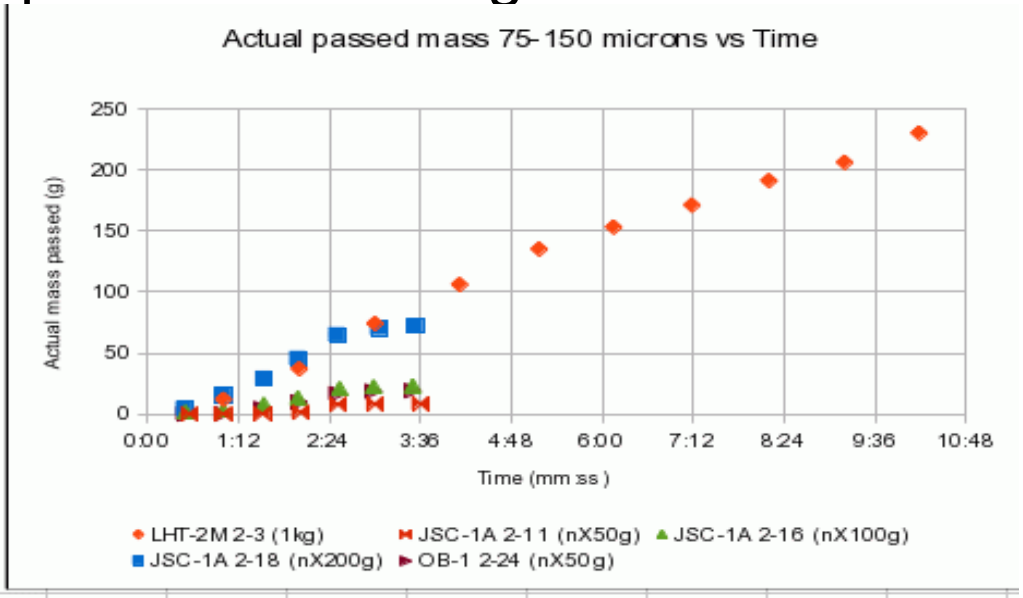
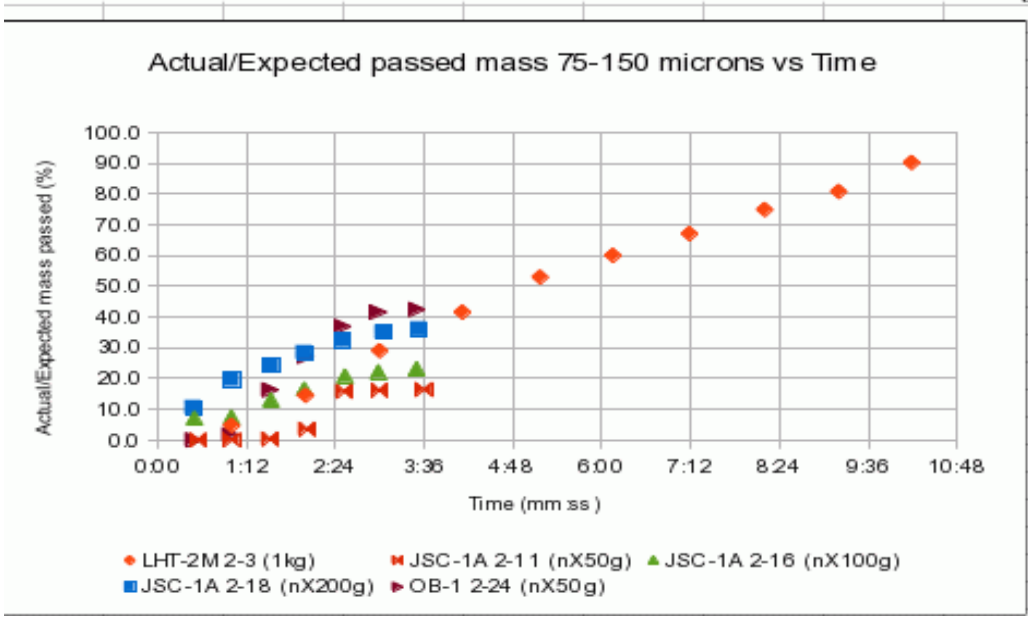
- **Measurements to-date:** 75-150 µm fraction 2-stage Vib. Sifter



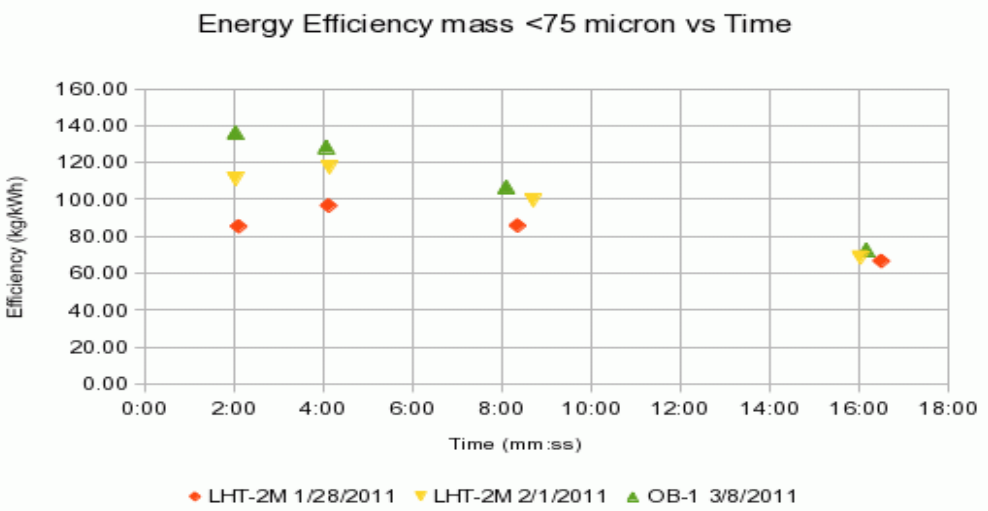


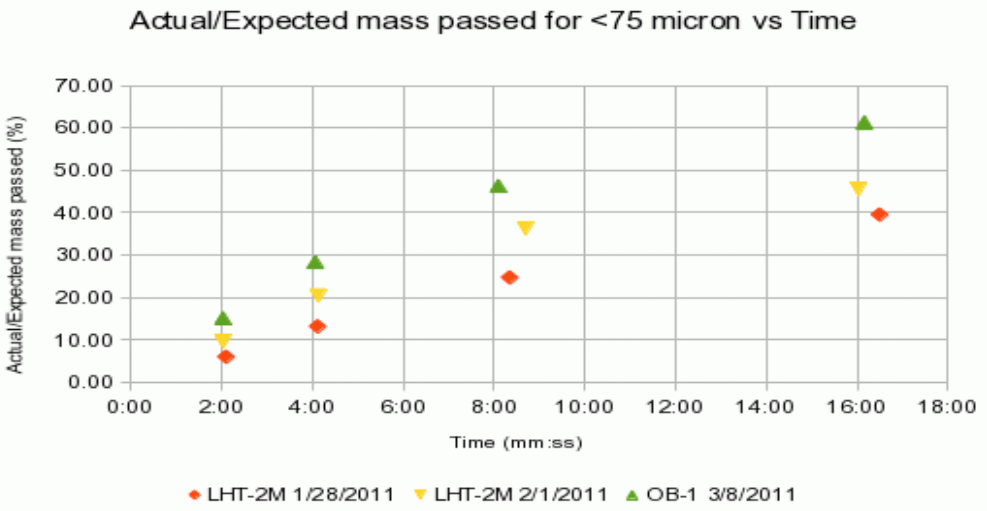


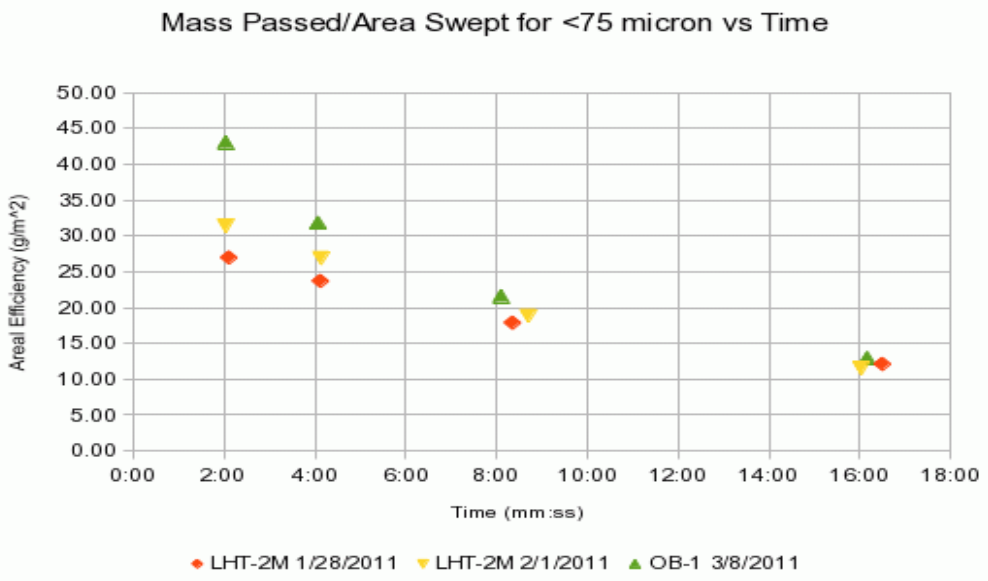
Ultrasonic De-Blinding not used

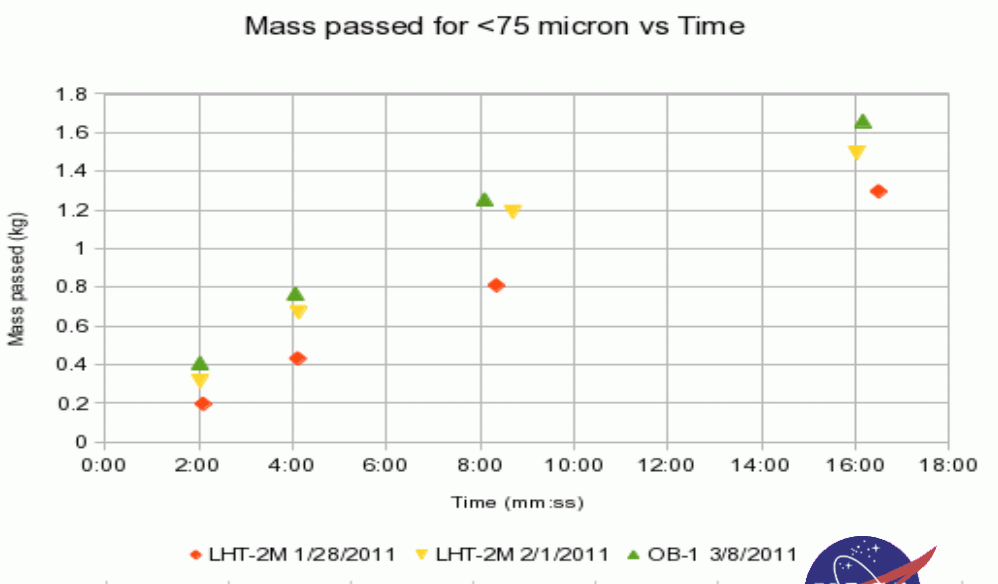
Size Beneficiation of Regolith for Simplicity and Efficiency

- **Measurements to-date:** <75 µm fraction 2-stage Shear Sifter









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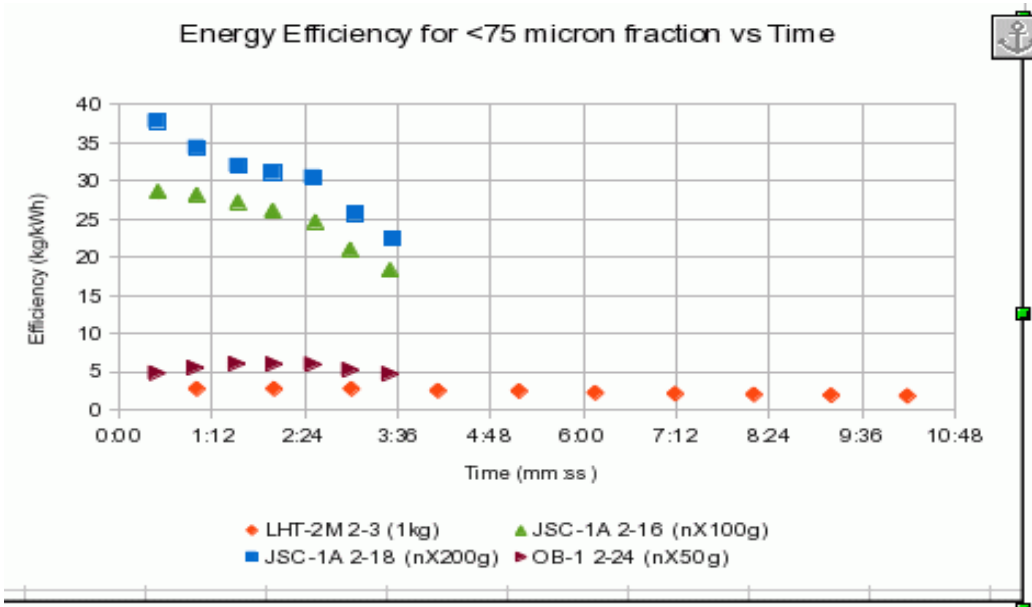
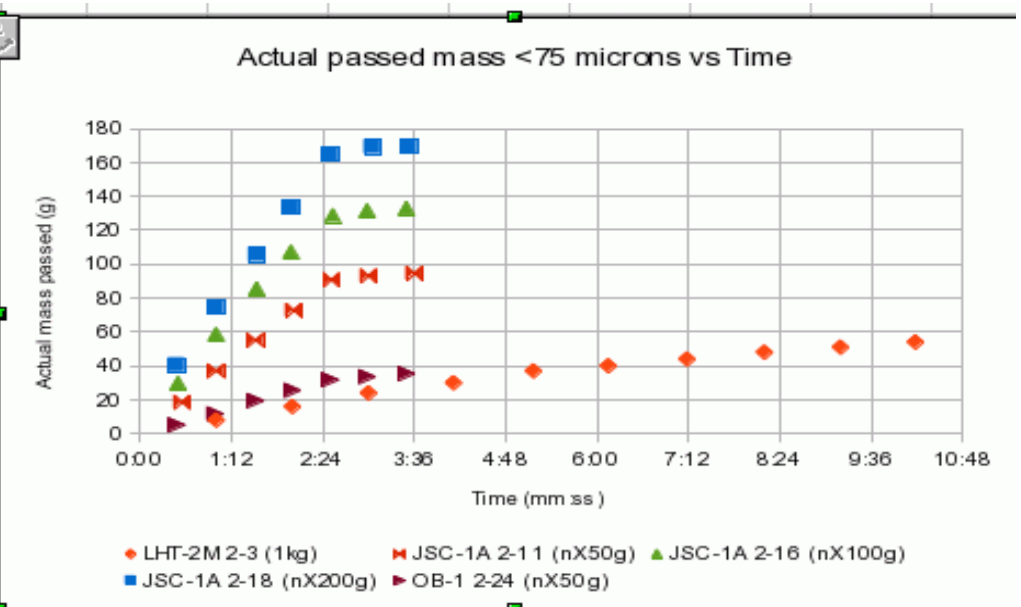
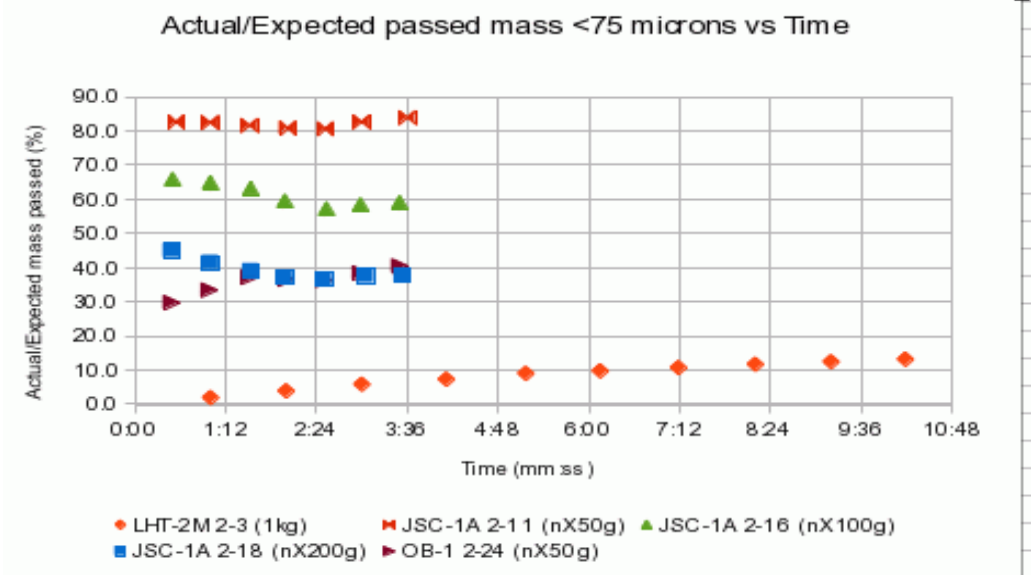
- **Measurements to-date:** <75 µm fraction 2-stage Vib. Sifter







Ultrasonic De-Blinding not used

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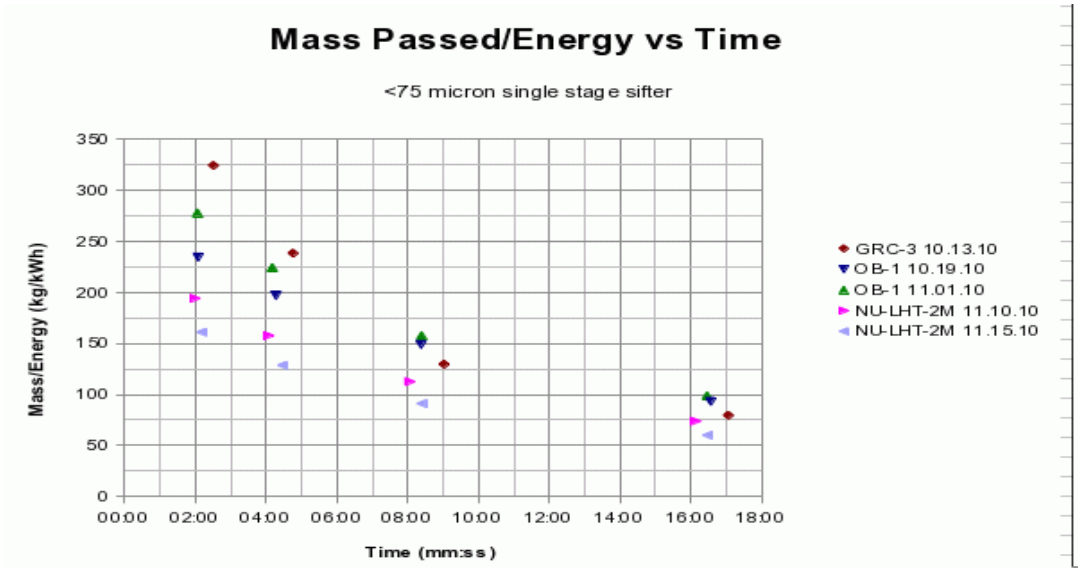
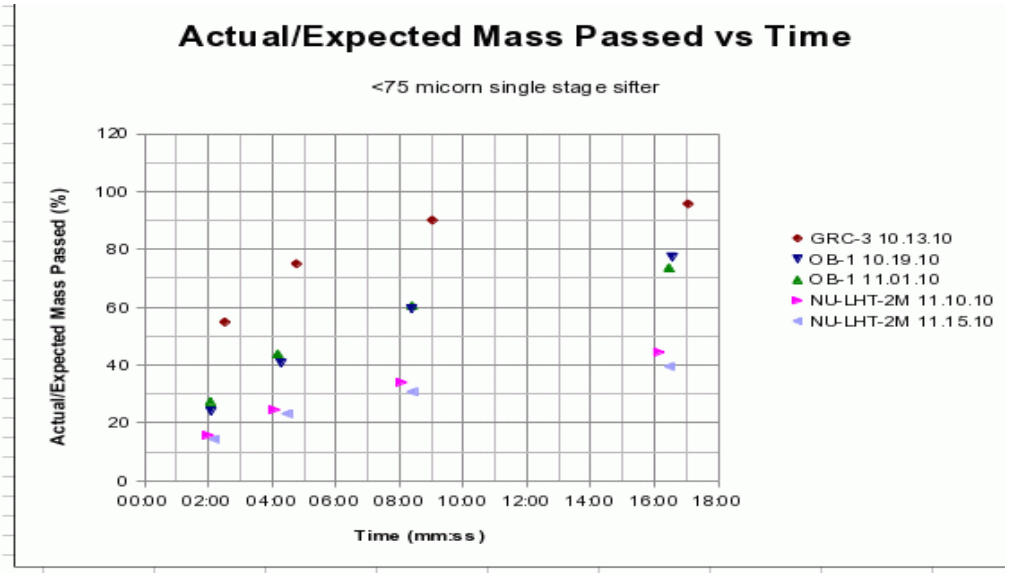
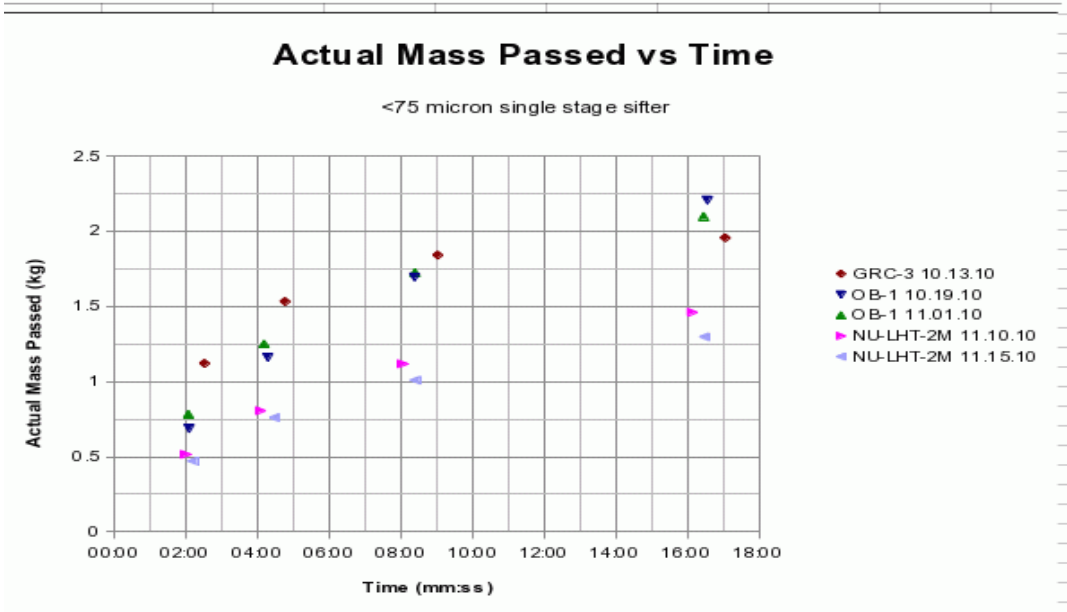
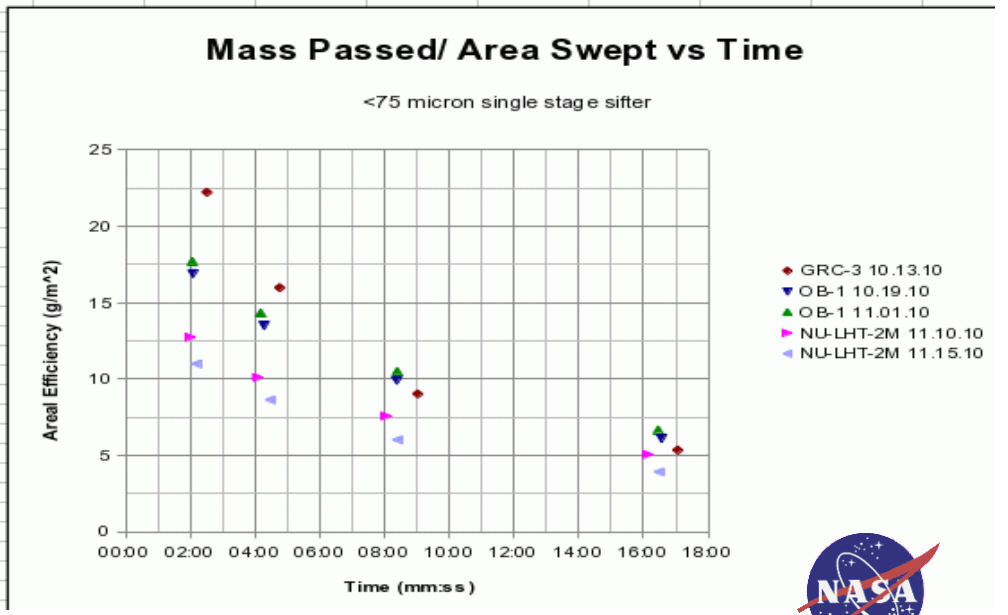
- **Measurements to-date:** <75 µm fraction 1-stage Shear Sifter









Size Beneficiation of Regolith for Simplicity and Efficiency

- **Measurements to-date:** Summary numbers
  - ☼ Expected 41% LHT-2M, 35% OB-1, & 45% JSC-1a to pass 75 μm
  - ☼ Expected 25% LHT-2M, 18% OB-1, & 20% JSC-1a to be in 75-150 μm band
  - ☼ 1-Stage 75 μm Shear Sifter (8 kg batch loads)
    - ►25-80% OB-1 & 17-50% LHT-2M, expected material passed, @2 & 16 min.
    - ►250-100 kg/kWh OB-1 & 175-65 kg/kWh LHT-2M Energy Cost @2 & 16 min.
      - ■ Best Energy Efficiency at 2 minutes, downhill from there
    - ►17-6 g/m^2 OB-1 & 11-4 g/m^2 LHT-2M Areal Efficiency @ 2 & 16 min.
  - ☼ 2-Stage 75 & 150 μm Shear Sifter (no access to 75-150 band until expt. end)
    - ►92% OB-1 & 70% LHT-2M, expected material passed @16 min, 75-150 band
    - ►177 kg/kWh OB-1 & 185 kg/kWh LHT-2M energy cost 75-150 band @16 min.
    - ►~32 g/m^2 OB-1 & LHT-2M Areal Efficiency @16 min, 75-150 band

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- **Measurements to-date:** Summary numbers (cont'd)
  - ☼ 2-Stage 75 & 150 μm Shear Sifter (<75 μm fraction)
    - ►15-60% OB-1 & 9-42% LHT-2M, expected material passed @2 & 16 min
    - ►135-70 kg/kWh OB-1 & 100-65 kg/kWh LHT-2M Energy Cost @2 & 16 min.
    - ►~42-13 g/m^2 OB-1 & 29-12 g/m^2 LHT-2M Areal Efficiency @2 & 16 min

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- **Measurements to-date:** Summary numbers (cont'd)
  - ☼ 2-Stage 75 & 150 µm Vib. Sifter (<75 µm fraction, no ultrasonic de-blinding)
    - ► LHT-2M 1 kg load recycled repeatedly for each of 10 minutes
      - ■ 2-13% of expected material passed @1 & 10 min.
      - ■ 2.8-1.84 kg/kWh Energy Cost @1 & 10 min.
    - ► OB-1 in 5 ea. 50 g loads at 30 second intervals
      - ■ 30-37% of expected material passed during each load
      - ■ 4.7-6.0 kg/kWh Energy Cost for each load
    - ► JSC-1a in runs with 50, 100, & 200 gram loads at 30 second intervals
      - ■ ~80, ~60, & ~40% of expected mat'l passed, respectively
      - ■ n/a, ~25, & ~33 kg/kWh Energy Cost, respectively

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- **Measurements to-date:** Summary numbers (cont'd)
  - ☼ 2-Stage 75-150 µm Vib. Sifter (75-150 µm fraction, no ultrasonic de-blinding)
    - ►LHT-2M 1 kg load recycled repeatedly for each of 10 minutes
      - ~10% of expected material passed additionally for each minute
      - ~8 kg/kWh Energy Cost for most of each min. of 10 min.
    - ►OB-1 in 5 ea. 50 g loads at 30 second intervals
      - 1-37% of expected mat'l passed (delay in 1st mat'l off the 2nd screen)
      - 0.14-3.1 kg/kWh Energy Cost (same delay)
    - ►JSC-1a in runs with 50, 100, & 200 gram loads at 30 second intervals
      - 0-16, 7-21, & 10-32% of expected mat'l passed, respectively
      - n/a, 1.4-4.0, 3.9-12 kg/kWh Energy Cost, respectively

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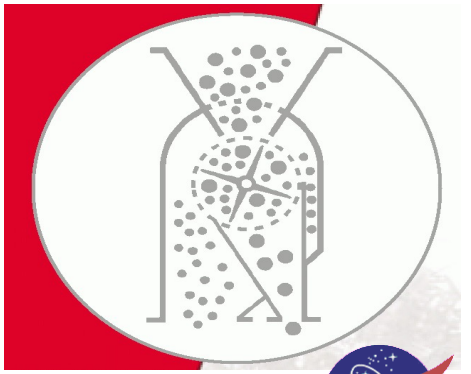
- **Closing Summary**
  - ☼ Extensive performance quantification of 2 sifter concepts at single scale size
    - ► Subtleties of trade-offs appear
      - ■ Loading size versus energy efficiency versus fractionation efficiency depend on which size fraction you select.
  - ☼ Shearing sifter is more energy efficient than vib. sifter, likely due to high kinetic energy cost to shake the whole structure
  - ☼ Shearing sifter design has fine points that are easy to gloss over
    - ► Bar shape, bar clearance, screen flexure for de-blinding
  - ☼ Wear and puncture of screens is driver for strong abrasion-resistant screens
  - ☼ Low-g of vib sifter not done
  - ☼ Ultrasonic mode sifting not done yet in 1- or low-g
  - ☼ SBIR barrel centrifugal shearing sifter not tested yet
    - ► Phase 1 won't suffice to decide if this concept is viable.



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- **Closing Summary (cont'd)**
  - ☼ Shearing Sifters come in all sizes
    - ►1 cup to cubic meters
    - ►Batch or continuous feed