CENTRIFUGING-PIPE CONVEYOR FOR REGOLITH

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Space Resources Roundtable

and the

Planetary & Terrestrial Mining Sciences Symposium

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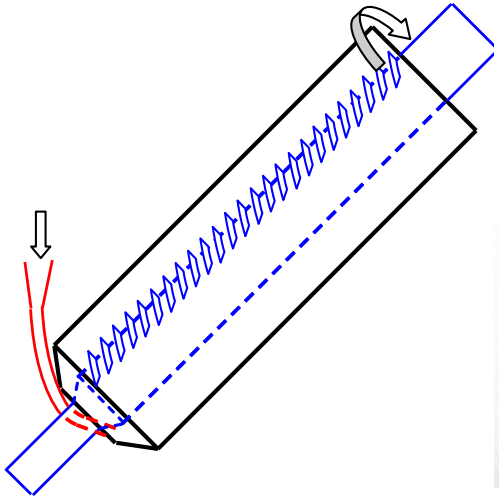

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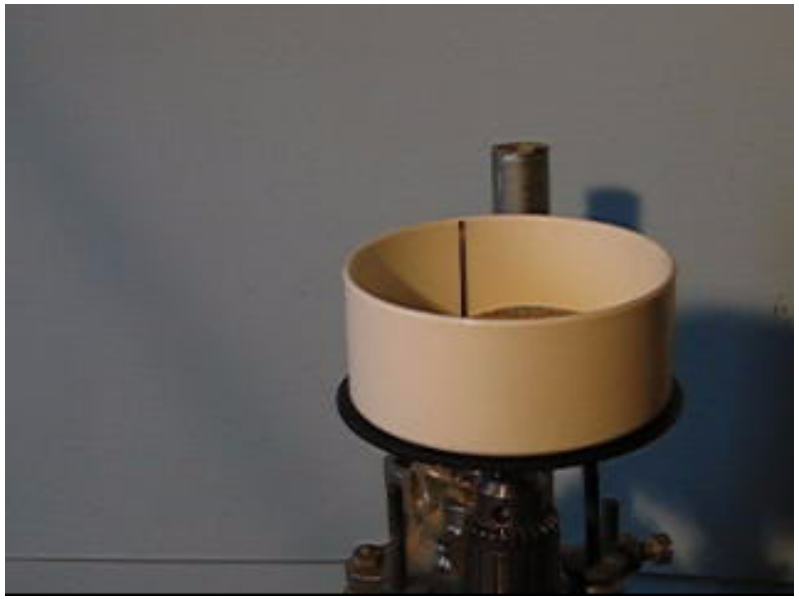
CENTRIFUGING-PIPE CONVEYOR FOR REGOLITH

Motivation: Originally proposed for a heat exchanger (in horizontal transport mode as a method to create a thin layer -- ideal for heat transfer)

Current work is a NASA sponsored SBIR Phase -1 Project to evaluate the feasibility of using a Centrifuging Pipe Conveyor for inclined transport of cohesive material under low-g

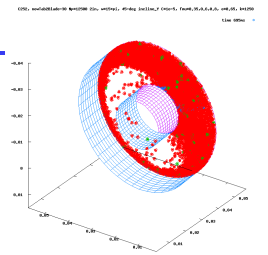
This is work in progress , Goals are to:

1) Demonstrate that the method works as originally proposed – i.e. Horizontal Flow
2) Attempt inclined and vertical transport to test feasibility



Sand centrifuged on a cylinder wall

A Second technology is also being demonstrated/ exercised in this project:
An enhanced DEM simulation model for cohesive granular solids under development under a Phase-2 SBIR contract. The examples shown here are from the Phase-1 version of the code (w/o graphics capability)



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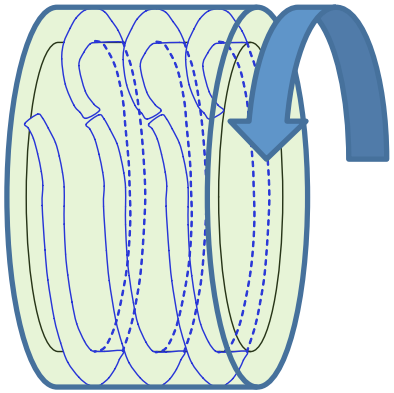
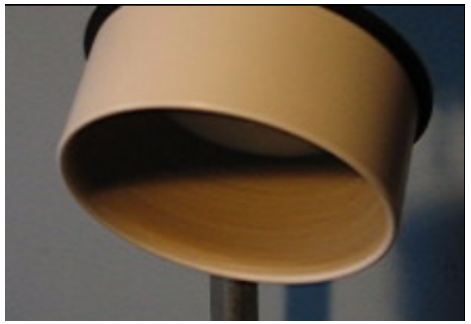
A centrifuging-solids-flow heat exchanger was proposed for a Phase-2 SBIR; not funded, but the solids flow concept is now being evaluated for transport



Rapidly rotated cylinder centrifuges material to outer wall, stationary blades provide axial step once per revolution

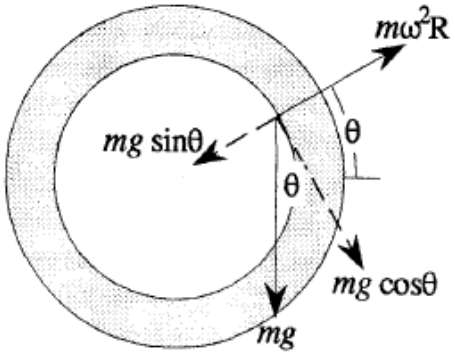
Horizontal rotating cylinder can have a stable, stationary layer of granular material on wall if

$$\omega_p^2 R_i/g > 1/\sin\varphi_r$$



Vertical rotating cylinder can have a stable, stationary layer of granular material on wall if

$$\omega_p^2 R_i/g > 1/\tan\varphi_r$$



Force balance at a point on the inner surface of a centrifuging granular layer

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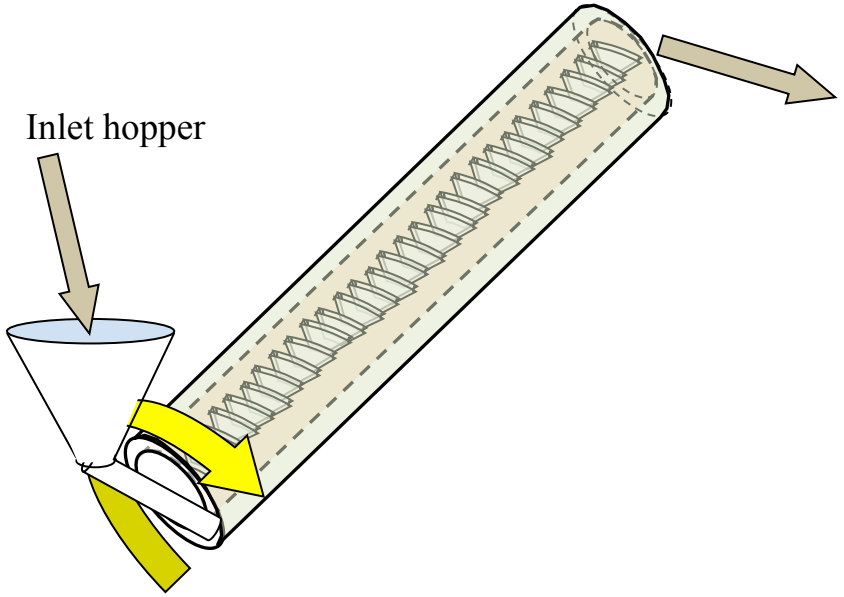
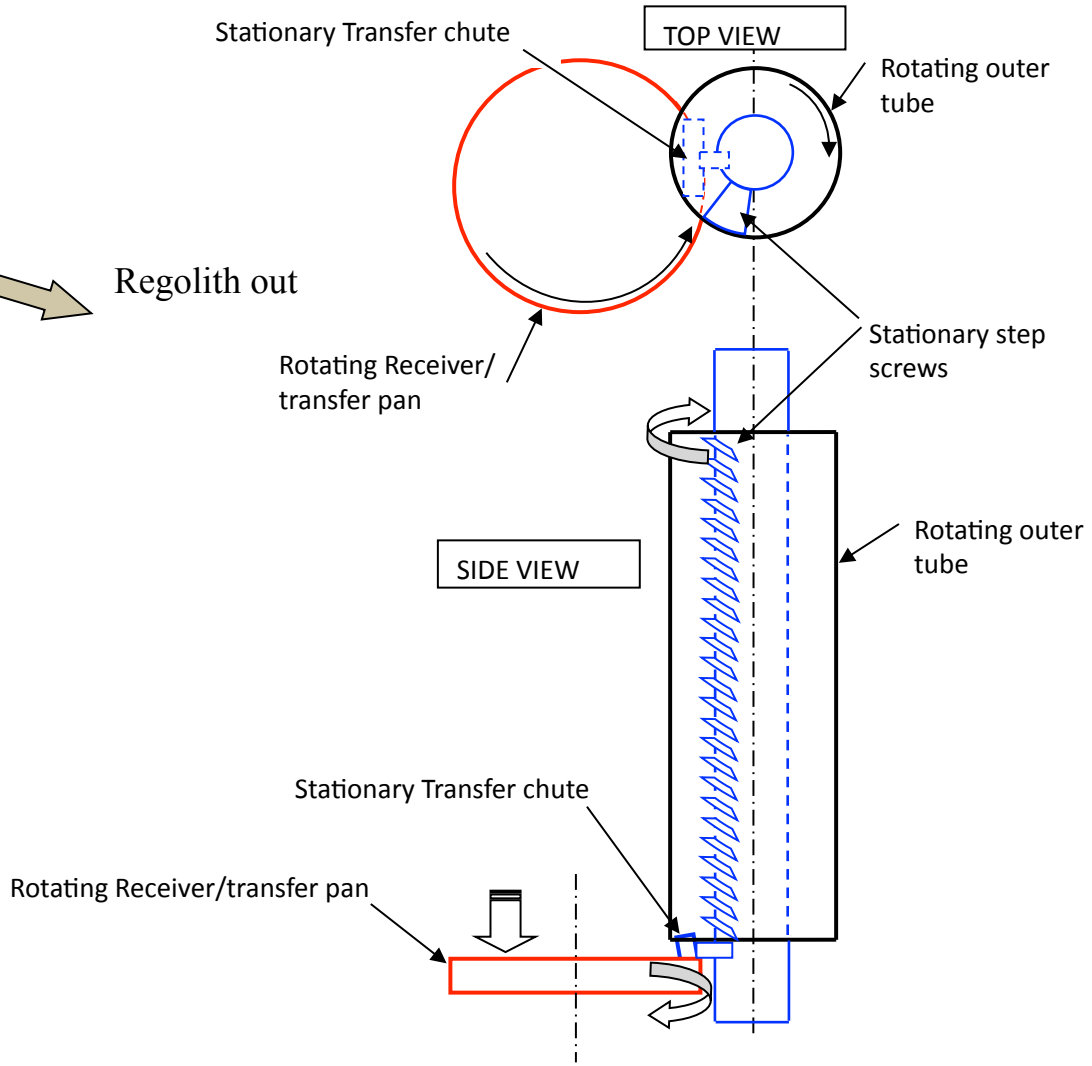
Concepts for Centrifuging-pipe conveyor for granular solids

Concept Schematics



Inclined Transport



Vertical Transport

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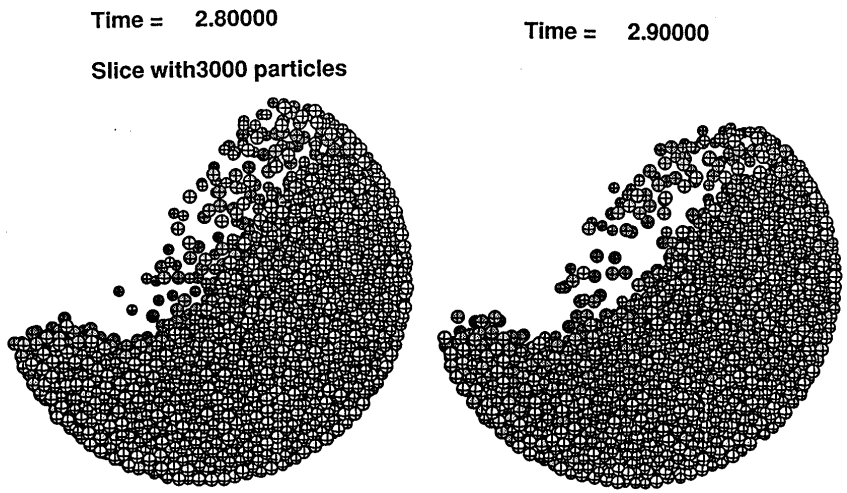
Centrifuging granular solids



DEM simulation of frictional spheres (μ = 0.2) in a half-filled pipe rotating with Ω_i = 1.0 (i.e., just fast enough to cancel gravity at the top if the granular material moved at the same angular velocity around the axis as the pipe-wall). Where $\Omega_i^2 = \frac{\omega_d^2 R_i}{g}, \quad \Omega_i > 1$

$\omega_p^2 R_i/g = 1$ is too slow to achieve centrifuging layer in horizontal pipe

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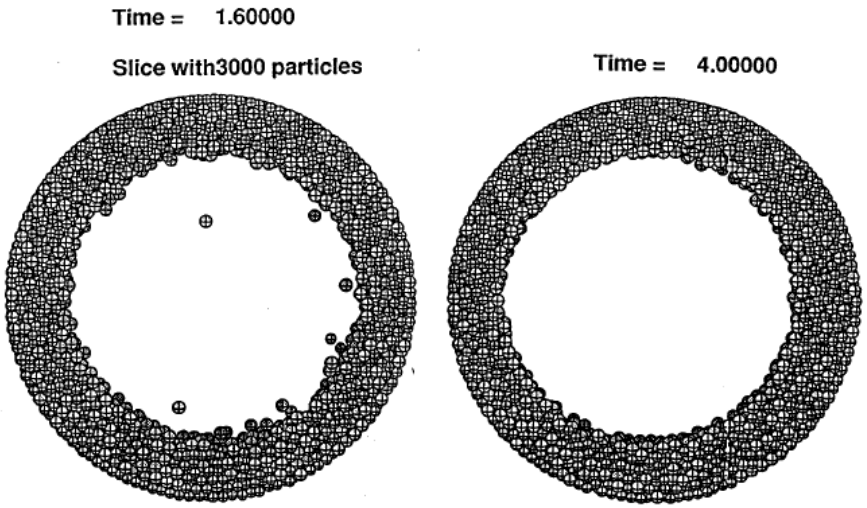
Centrifuging granular solids



Slipping flow, $\Omega_i^2 = 2.2$, μ, = 0.2, (a) after 5.5 revolutions of the drum and (b) after 14 complete revolutions, starting with the material stationary and the drum rotating. Where, $\Omega_i^2 = \frac{\omega_d^2 R_i}{g}, \quad \Omega_i > 1$

Boundary between 'raining' and slipping flow: $\Omega_{s/r}^2 = \frac{\sqrt{2}}{2}\left(1 + \frac{1}{\tan\phi_r + 0.125}\right)$

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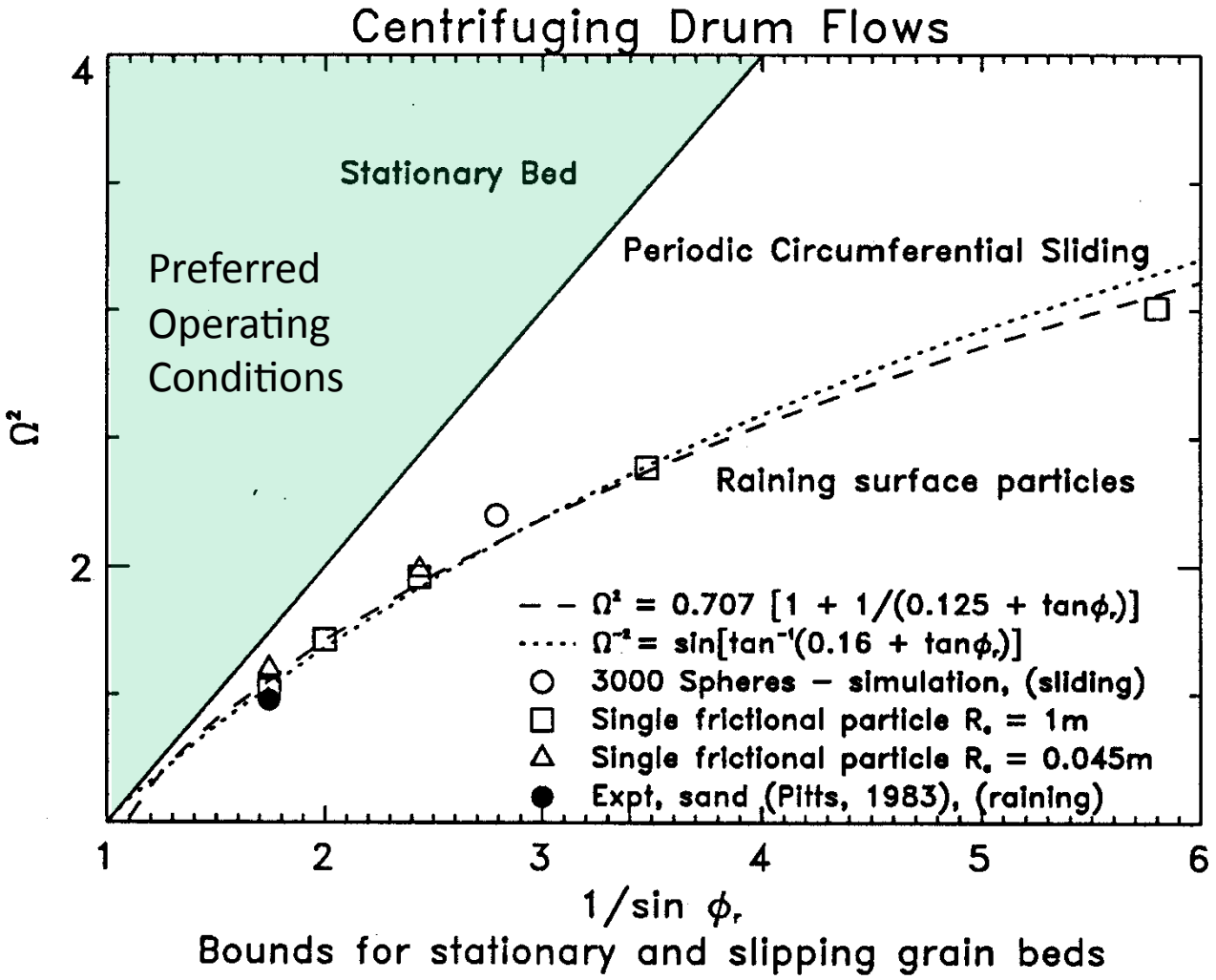
Centrifuging granular solids



Bounds for stationary and slipping grain beds

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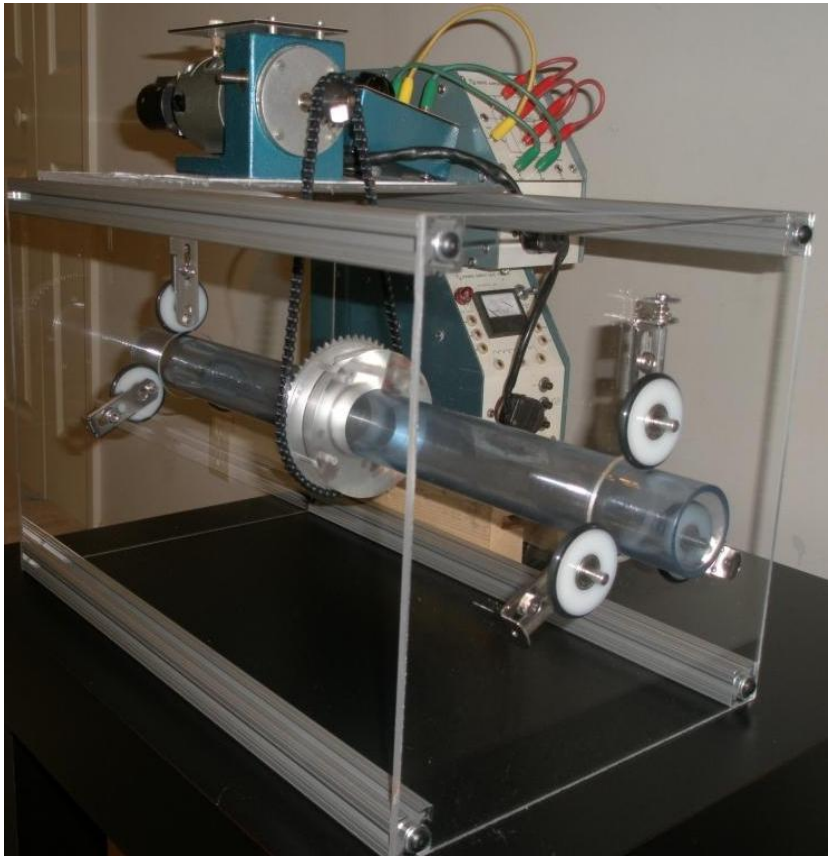
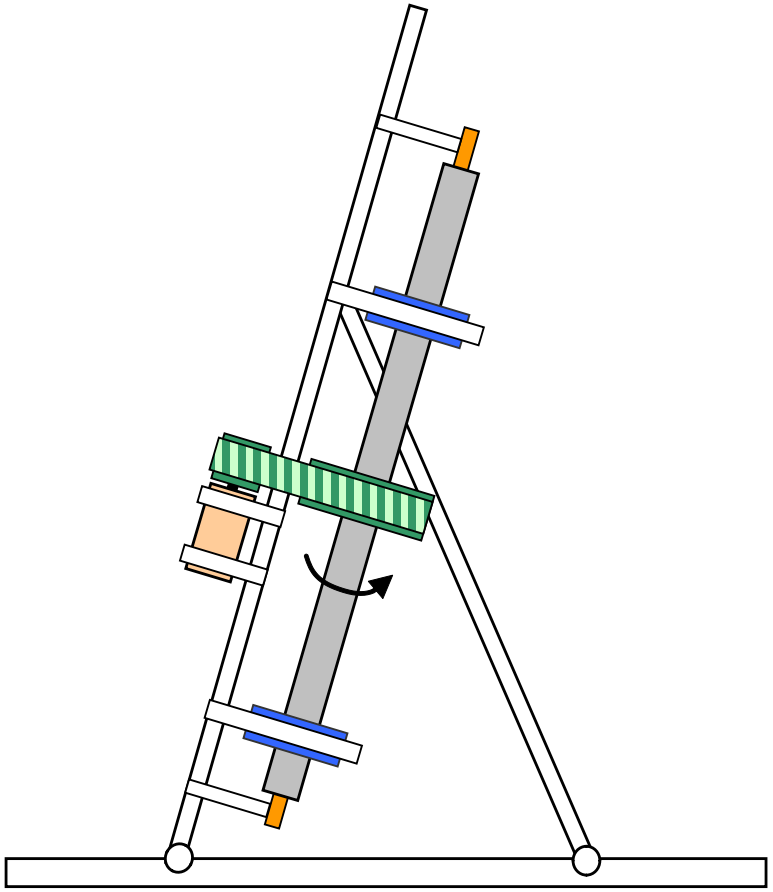
Bench Scale Rigs Are Being Built



3-Wheel Support, chain drive @ Tuskegee U



Ball-bearing Support, belt drive , Golden, CO

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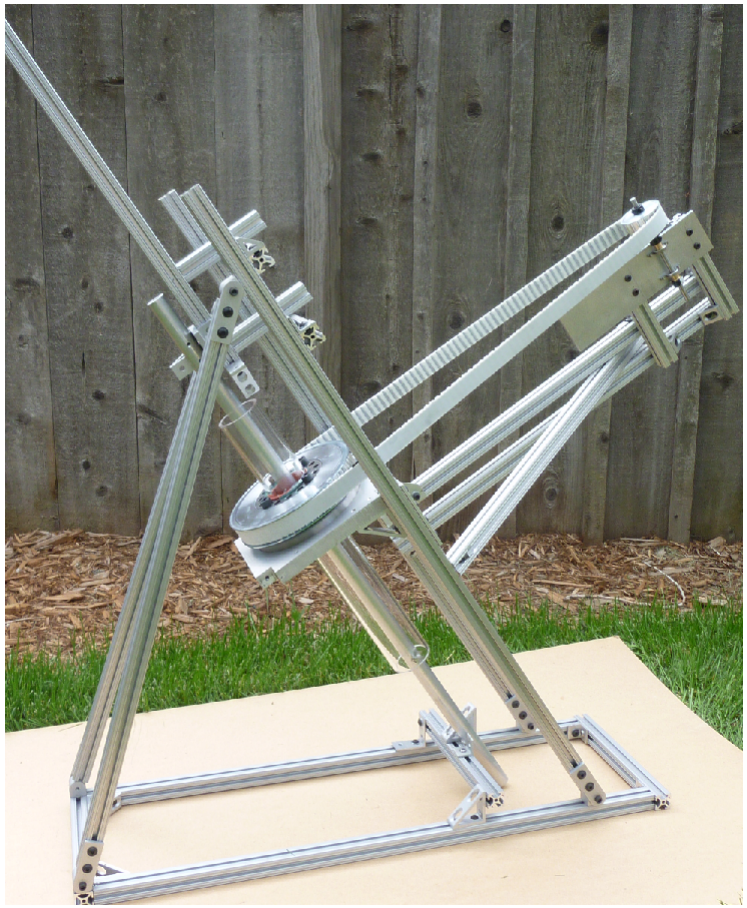

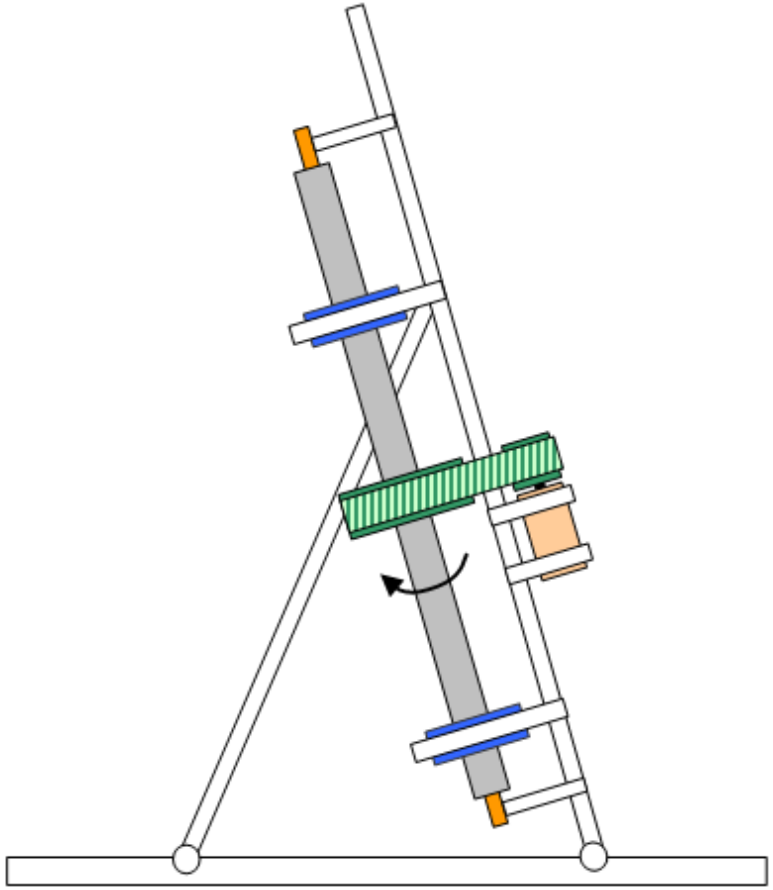

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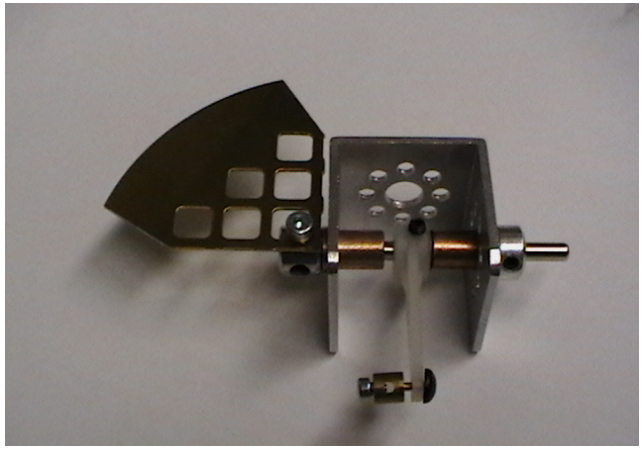
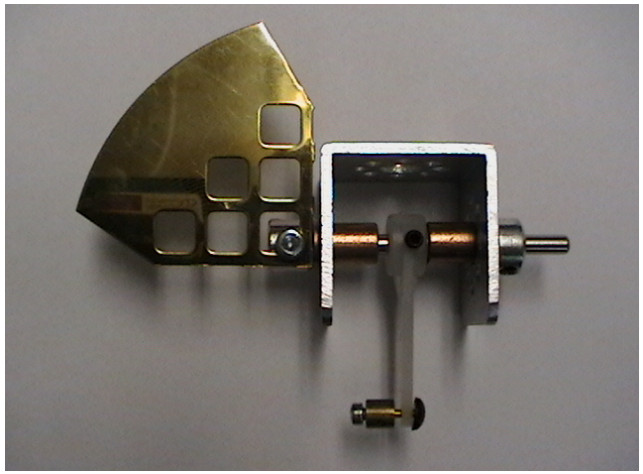
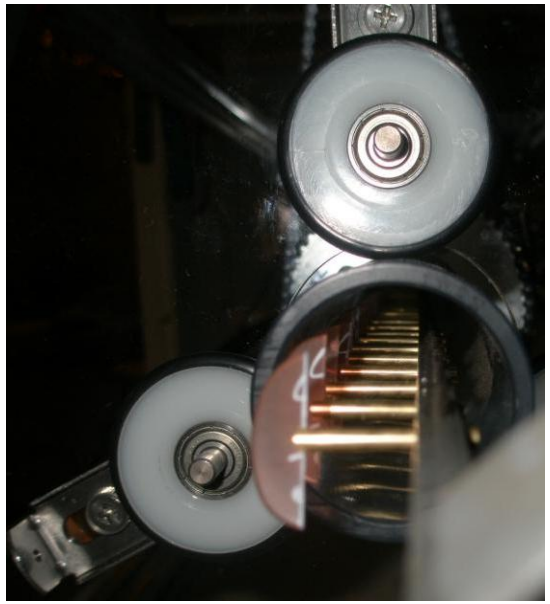
Various Blade Configurations Are Being Evaluated



Adjustable Blade: angle can be adjusted during operation



Fixed Angle Blades



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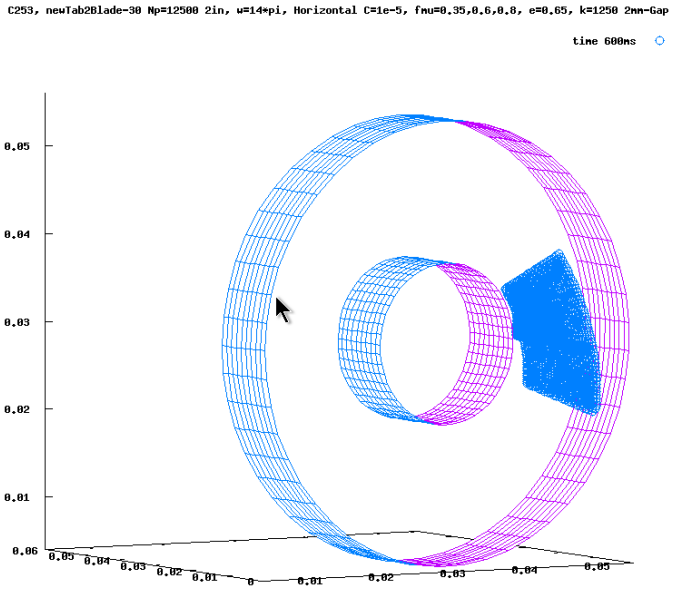
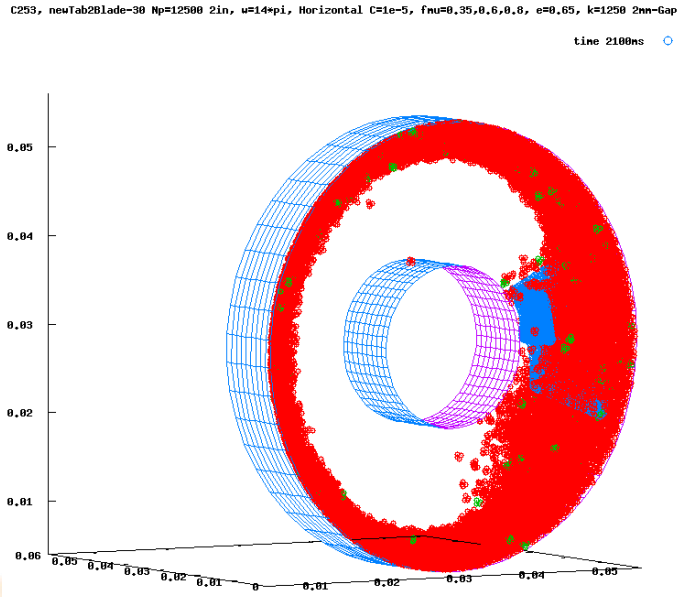
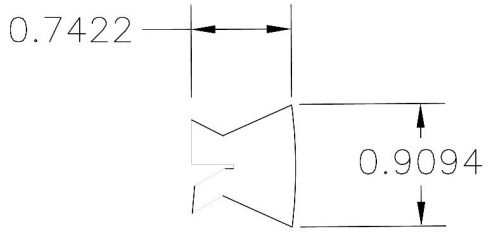
Simulations are being used to evaluate effectiveness of blades







Blade in Chris Dreyer's inclined centrifuging test rig

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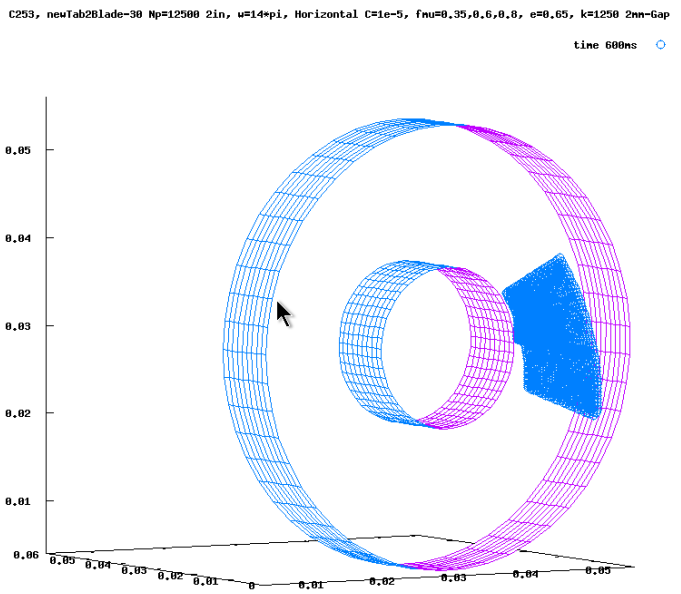

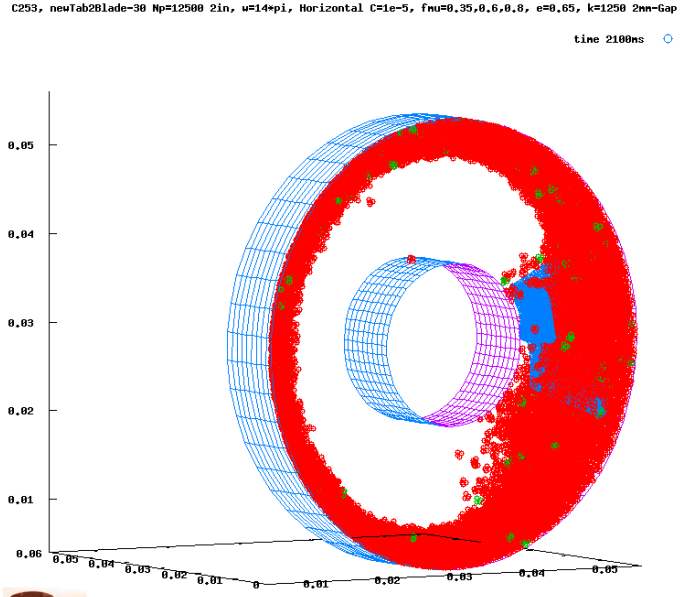

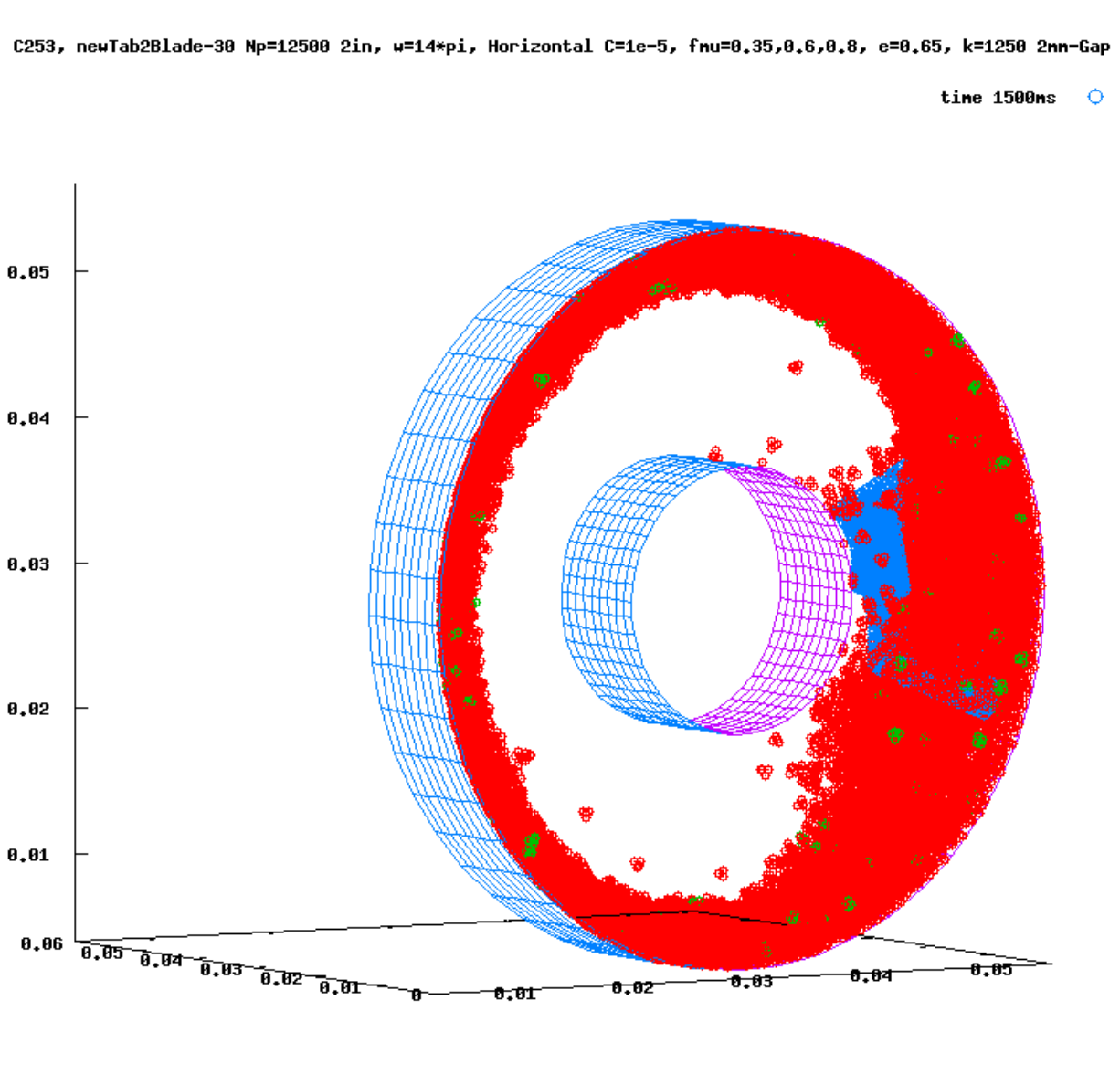

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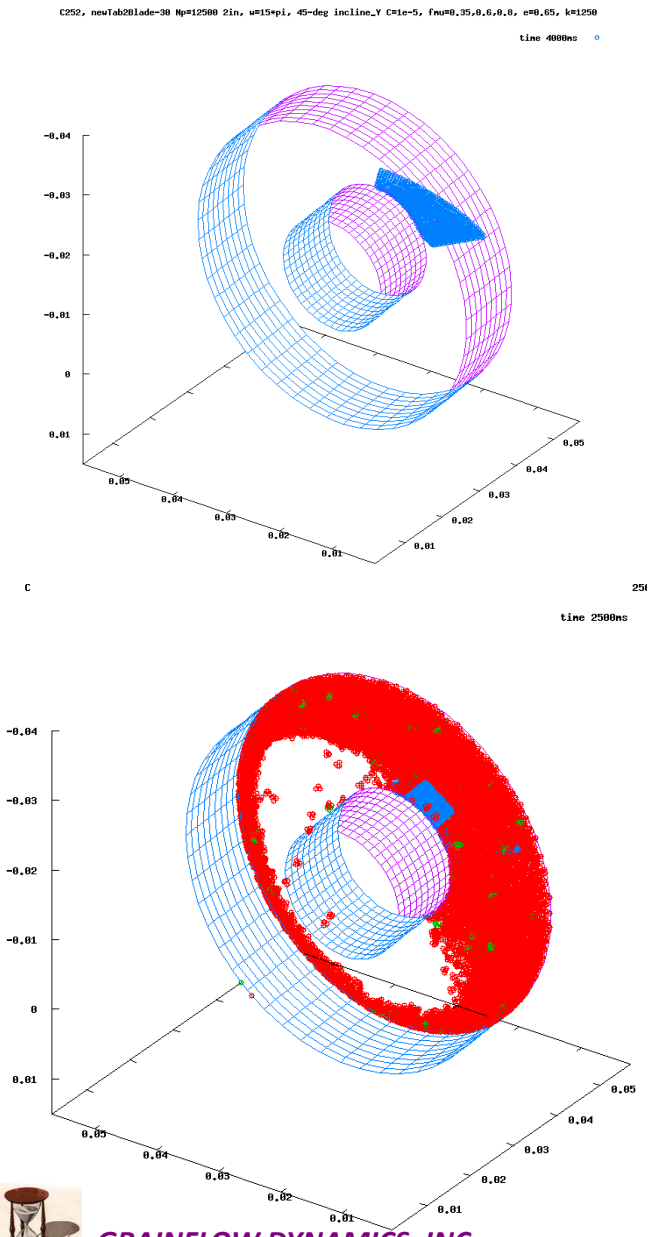

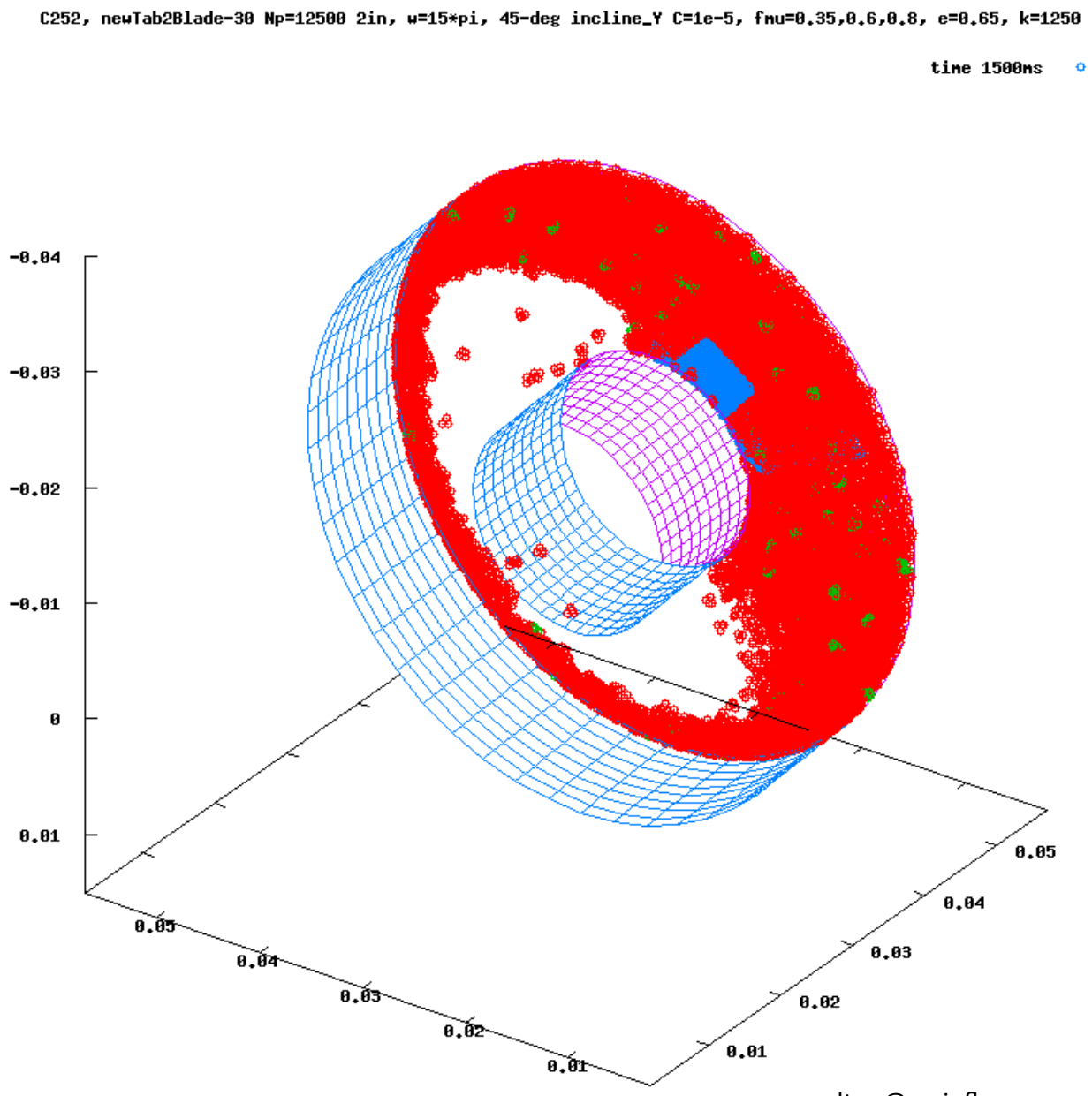

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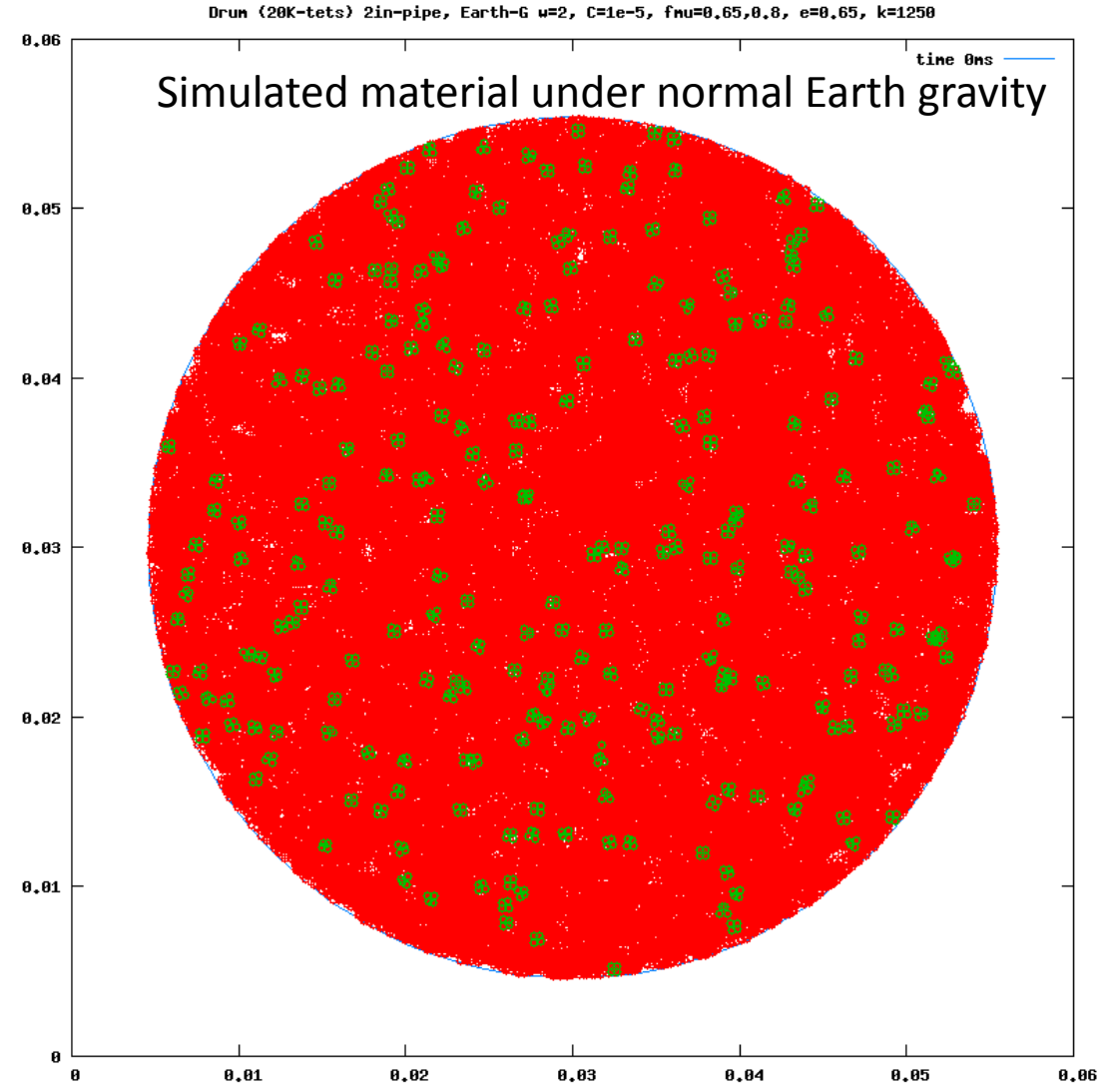
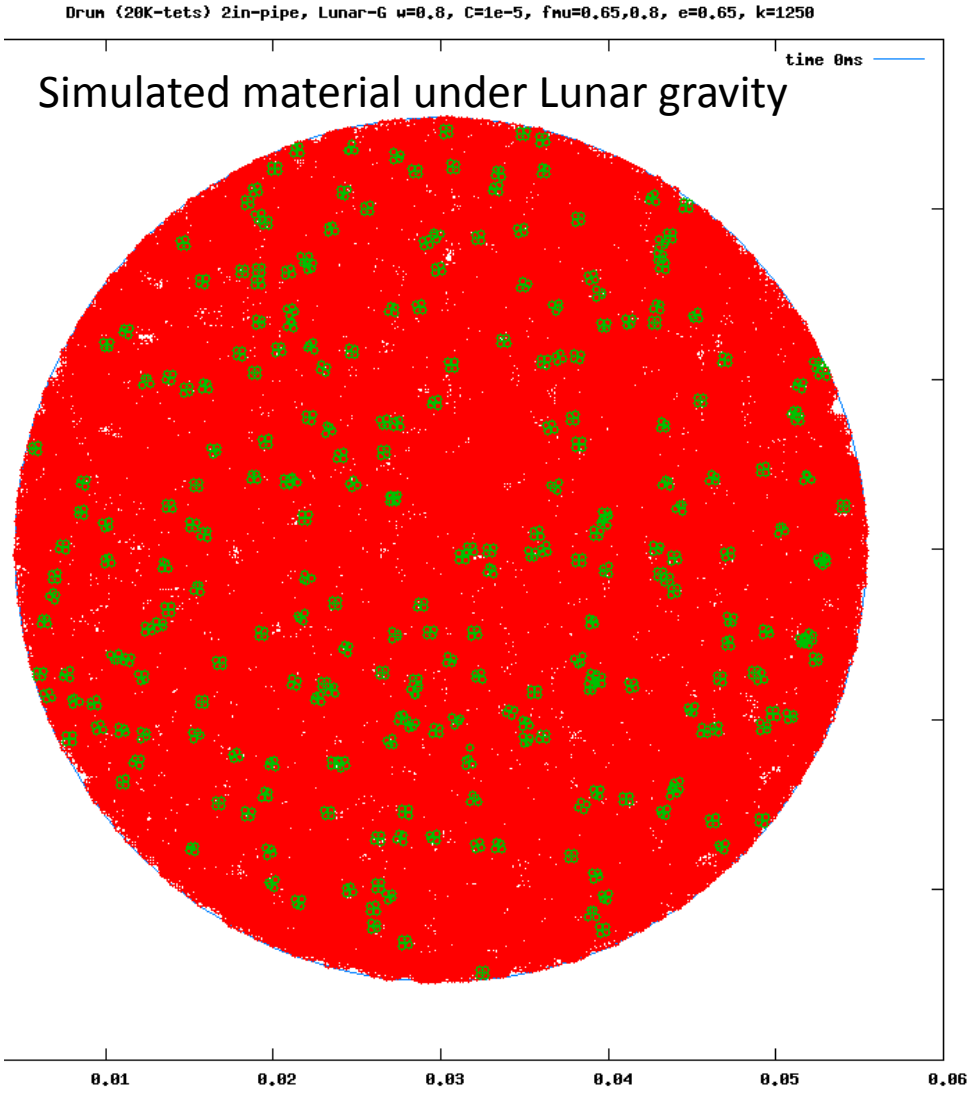
Simulated Regloith Material is Weakly Cohesive

As gravity decreases the same material ‘behaves’ more ‘cohesively’





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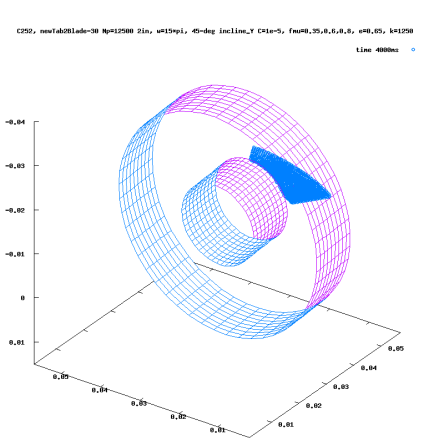
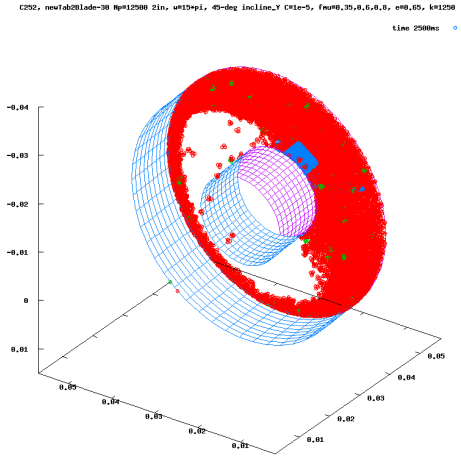
Centrifuging Pipe Conveyor for Granular Solids

- Applicable for more cohesive materials than conventional screw conveyors
- Low friction for horizontal conveying
- Nearly independent of gravity (if above threshold rotation rate)
- Vertical orientation and/or very steep inclinations need additional 'deflectors' for optimal performance (deflect 'falling' material back onto wall)
- Adaptable to beneficiation or size separation (with screen as outer wall)
- Other options increase potential benefits (proprietary for now) .





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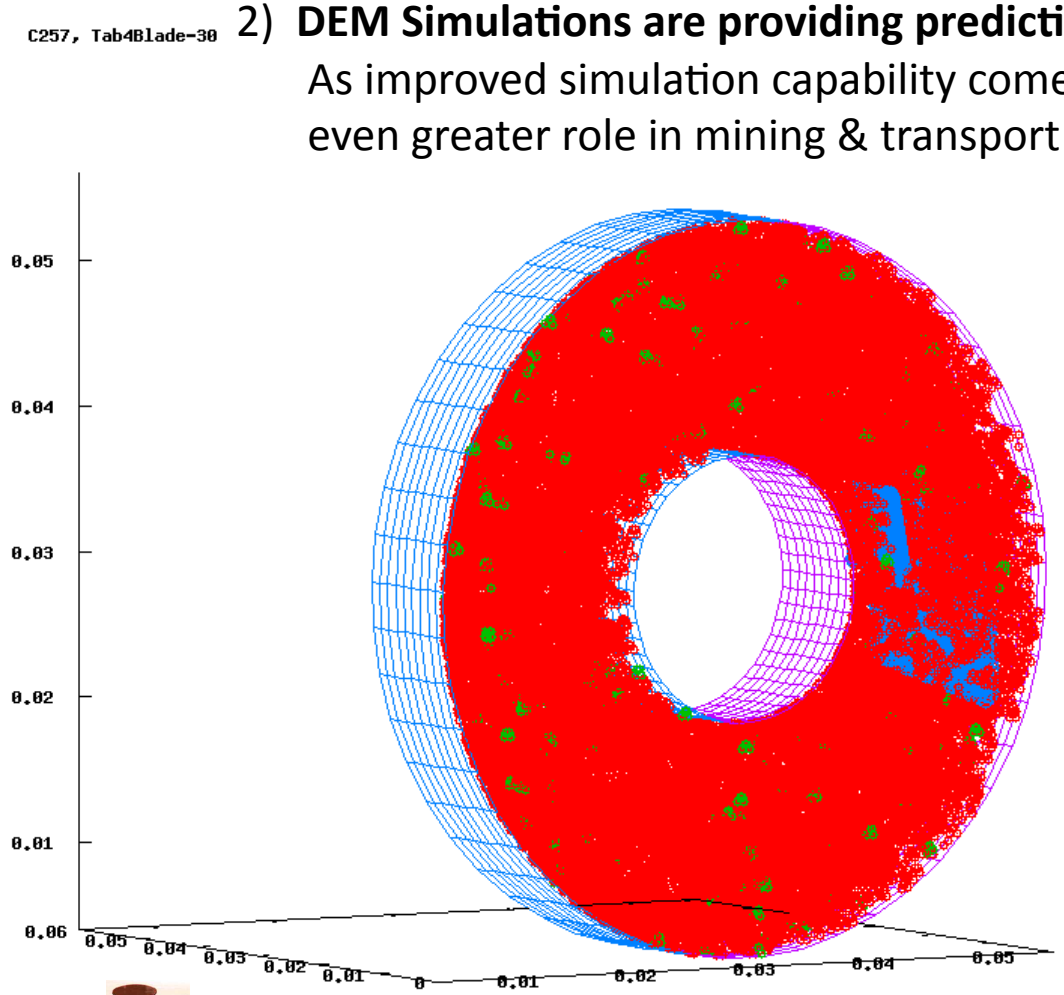
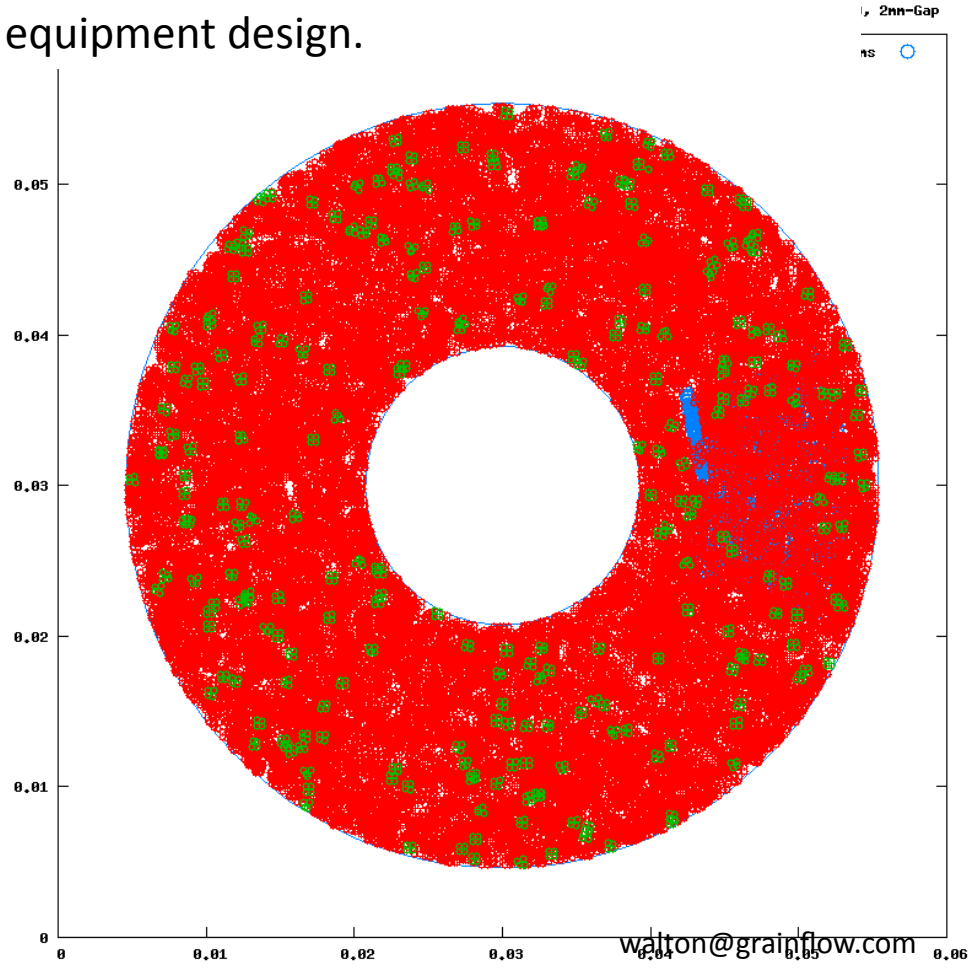
Two separate technology stories tested/demonstrated

1) **Centrifuging Pipe Conveyor** – not quite as robust as originally envisioned,
   - Additional enhancements can improve performance
   - May also be a viable platform for beneficiation / size-segregation

2) **DEM Simulations are providing predictive guidance to assist in development**

As improved simulation capability comes on line the simulations can take on an even greater role in mining & transport equipment design.





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