# Asteroid Gravity Test System Using a Planar Air Bearing

**Leonard Vance**
**SpaceTREx Laboratory**, University of Arizona

## Motivation

The size and makeup of near earth asteroids make spacecraft sample and return missions hazardous. Since at least one of these asteroids (101955) Bennu regularly ejects particles, nanospacecraft could be deployed to capture these objects in flight, eliminating the need for touching down on the asteroid itself.

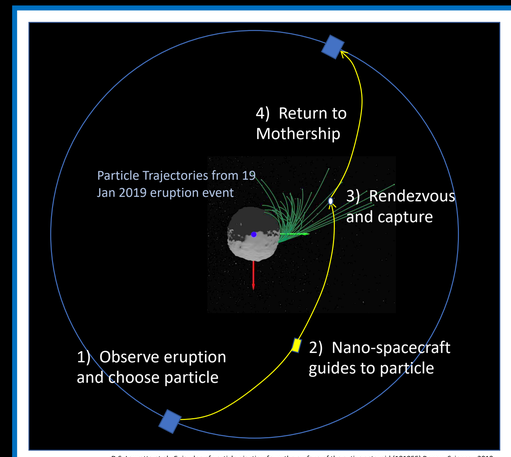
The proposed airbearing table is radially curved to mimic the low gravity of a centrally located asteroid, permitting evaluation of such a mission's navigation, guidance and docking.

## Previous Approach

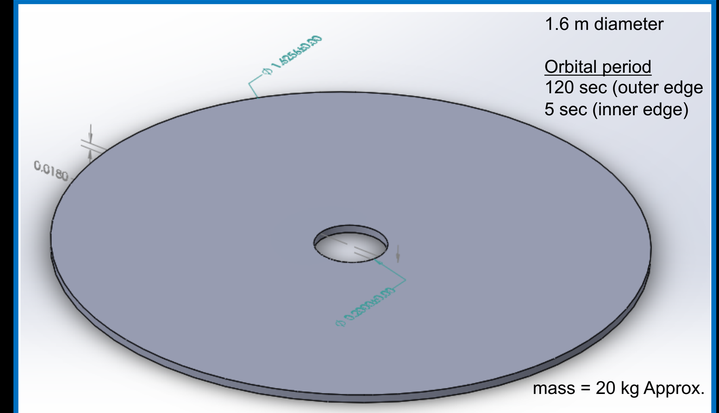
Planar Airbearing allowing 3 degree of freedom motion

## Updated Approach

Radially sculpted air-bearing table to mimic a low gravity asteroid environment




D.S. Lauretta et al. Episodes of particle ejection from the surface of the active asteroid (101955) Bennu. Science, 2019




**Airbearing table mimics low gravity system**

## Conclusion

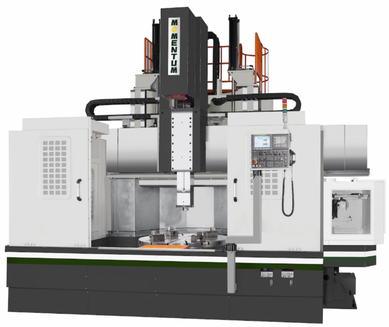
Capture of erupting particles is a plausible alternative to touchdown on the asteroid surface

Creation of a radially symmetric air bearing can reproduce aspects of the dynamic environment for system test

This air bearing table can also be used as a hands on teaching tool for Keplerian dynamics.

## Manufacturing

Table requirements well within existing tooling machine capability



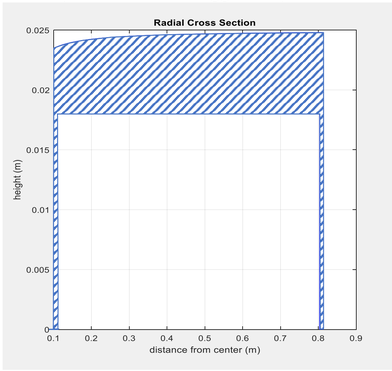
Specifications

| | | UNIT | MVL-12 | MVL-12M | MVL-12HD |
|---|---|---|---|---|---|
| Capacity | Max. Swing Diameter | mm (inch) | Ø1,600 (62.99) | | |
| | Max. Turning Diameter | mm (inch) | Ø1,600 (62.99) | | |
| | Distance from Std. Turning Holder Insert to Table Surface | mm (inch) | 0 ~ 1,205 (0 ~ 47.44) | 0 ~ 1,155 (0 ~ 45.47) | 0~1,175 (0 ~ 45.25) |
| | Max. Turning Height | mm (inch) | 1,200 (47.24) | 1,150 (45.27) | 1150 (45.27) |
| Table | Max. Workpiece Weight | kg (lb) | 8,000 (17,600) | | |
| | Table Diameter (Manual Chuck) | mm (inch) | Ø1,250 (49.21) | | |
| | Range of Table Speed (Low) | rpm | 34 ~ 103 | | 26 ~ 80 |
| | Range of Table Speed (High) | rpm | 104 ~ 312 | | 81 ~ 312 |
| | Max. of Table Torque | N·m (ft·lbs) | Std. 12,400 (9,151) / Opt. 19,000 (14,022) | | 19,000 (14,022) |
| ATC | Tool Size | mm (inch) | □ 25 / 32 / 40 (1" / 1.25" / 1.5") x 600 max. length | | |
| | Tool Type | - | T - Puller | BT - 50 / CAT-50 | T - Puller |
| | Number of Tool Stations | - | 12 (Random) | 12 ( 6 Turning + 5 Milling + 1 Cover) | 12 (Random) |
| | Cross-Section Of Ram | mm (inch) | 200 x 200 (7.87 x 7.87) | 240 x 240 (9.44 x 9.44) | |
| Travel | Horizontal Travel (X-Axis) | mm (inch) | -920+1,000 (-32.28+39.37) | | |
| | Vertical Travel (Z-Axis) | mm (inch) | 900 (35.43) | 1,000 (39.37) | |
| Feed Rates | Cross-Rail Travel | mm (inch) | 500 (19.68), 2 steps (3 positions) | | 500 (19.68), 2 steps (3 positions) |
| | Rapid Rate (X & Z Axis) | m/min | 1 0 | | |
| | Cutting Feed Rate | mm/min | 1 ~ 2,000 | | |
| | Feed Override | % | 0 ~ 150 | | |
| Motor | Main Spindle | kW (HP) | Std. 0400, 37 / 45 kW (49.6 / 60.3 HP) / Opt. 0650, 45 / 55 kW (60.3 / 73.7 HP) | | 0650, 45 / 55 kW (60.3 / 73.7 HP) |
| | Feed Servo Motor (X & Z Axis) | kW (HP) | 0 30, 7 kW (9.4 HP) | | |
| | Milling Spindle Motor | kW (HP) | N/A | 0 P30i (15/18.5 kW) | N/A |
| | Cf Axis Servo Motor | kW (HP) | N/A | 0 30, 7 kW (9.4HP) | N/A |
| Dimensions | Floor Space (L X W) | mm (inch) | 7,700 x 5,450 (303.149 x 214.566) | 5,650 x 6,000 (222.441 x 236.223) | 6,650 x 6,450 (261.811 x 253.937) |
| | Machine Max. Height (H) | mm (inch) | 5,100 (200.787) | 5,700 (224.409) | 5,260 (207.086) |
| | Machine Net Weight | kg (lb) | 23,500 (51,800) | 26,800 (63,500) | 25,400 (55,880) |

CNC Vertical Turning Lathe
Accuracy usually about 0.02mm

## Derivation of Surface

Table Cross Section
(Vertical Scale Exaggerated)




Diameter is chosen consistent with reasonable max handling size ($r_{max}$ = 1.6m)

Period of max radius orbit limited with ability to level platform ($t_p$ = 120 seconds)

Inner radius limited by ability of air bearings to plausibly maintain lift on a curved surface ($r_{min}$ = 0.1m)

$$a(r) = -g * slope$$ Inwards acceleration at max radius

$$a(r) = -\frac{k}{r^2}$$ Gravitational model

$$k = -\frac{4\pi^2 r_{max}^3}{t_p g}$$ Value of $k$ for chosen orbital period $t_p$

$$slope(r) = -\frac{a}{g} = -\frac{-k}{t_p g}$$ Slope required for that orbital period

$$y(r) = \int slope(r)dr = \int \frac{k}{r^2}dr = -\frac{k}{r} + y_0$$ Integration of slope to get outline

## References

D.S. Lauretta et al. Episodes of particle ejection from the surface of the active asteroid (101955) Bennu. Science, 2019