Internship at NASA Goddard Space Flight Center: Dust Mitigation for the James Webb Space Telescope

Summer 2014

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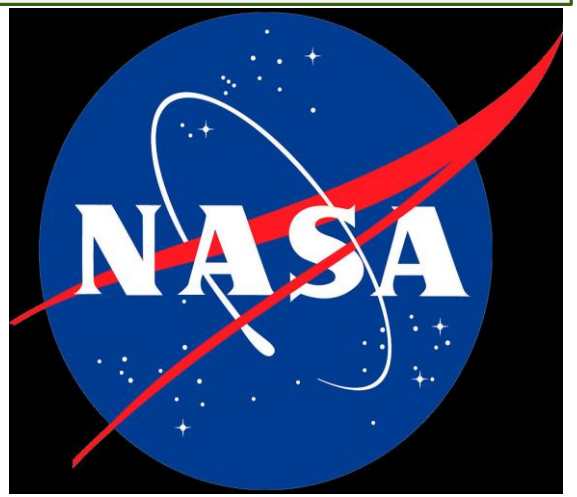
Introduction to Project

- Official Title: Laboratory Calibration State of the Art Non-Tactile Electronic Contamination Removal
- Unofficial Title: Non-Tactile Surface Cleaning Tool
- Funded through James Webb Space Telescope
- Three interns summer 2014



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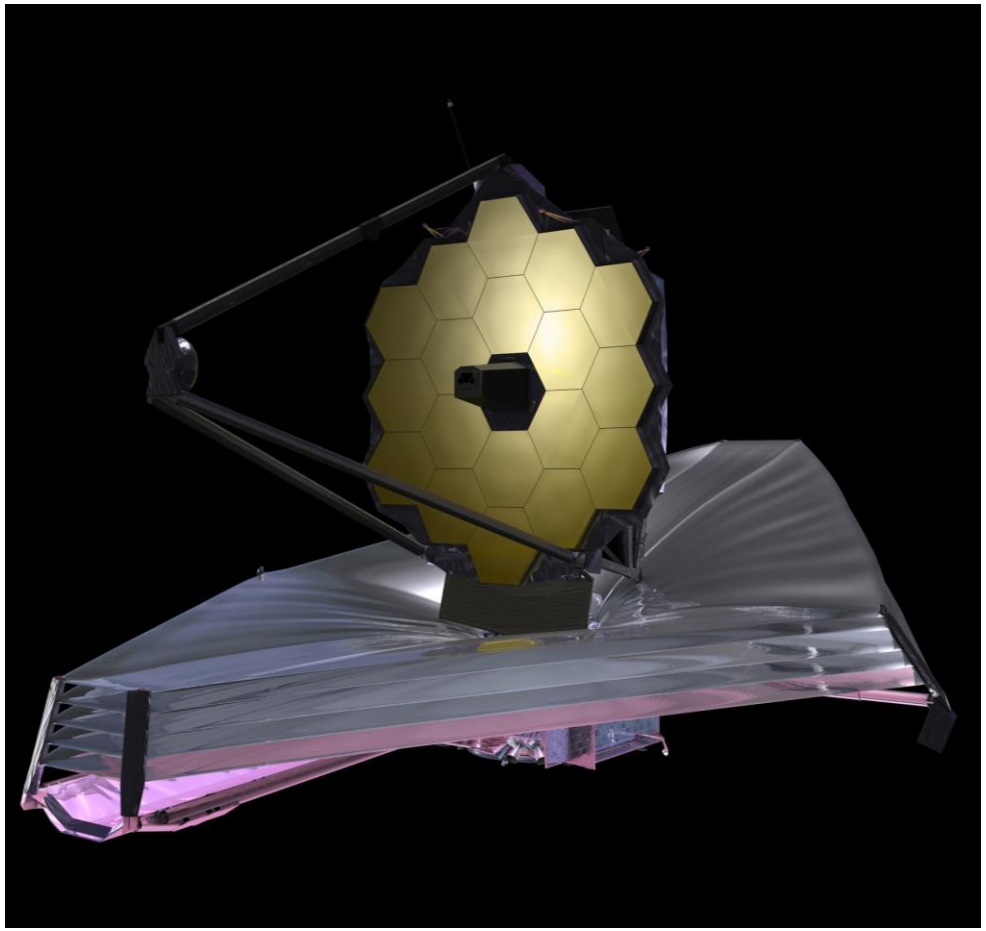
Overview

James Webb Space Telescope

- Planning started in 1996
- Successor to Hubble Space Telescope
- Senior Project Scientist: John Mather
- Infrared telescope
- Sensitive to light 0.6-28 micrometers
- 6.5 meter primary mirror, plated with beryllium
- Collaborative effort between NASA, ESA, CSA
- Set for launch in 2018
- L2 Point



Abstract

Summary

- Preventing dust particles from contaminating spacecraft is a major concern
- Contamination can be controlled through use of clean rooms, but dust still accumulates over time
- Tactile methods could damage surfaces
- Create handheld dust mitigation device that is capable of non-tactile interaction with surfaces in one atmosphere
- Use electron gun, two fractals, and two copper coils

Background

Dust Mitigation

- Past success using electron gun, fractals, and coils
- Electron gun
  - Thermonic emission
  - Purpose is to negatively charge the surface of the mirror
- Fractals and Coils
  - Golden mean, 0.618
  - 3rd order, copper
  - Purpose is to create positive electromagnetic field
- Resonance
  - Crucial to functionality in one atmosphere

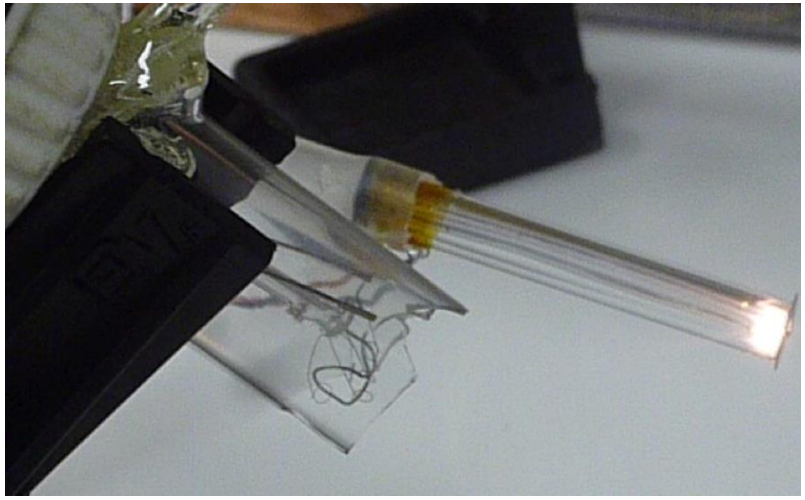
Methods & Procedure

Overview

- Design hand held device that can accommodate all elements needed to non-tactilely clean surface
- 3D modeling software: PTC Creo, Google Sketch
- Design device that accommodate
  - Electron gun
  - Two fractals, two coils
  - Tube for flow of nitrogen
  - Two 9 volt and two D cell batteries
- Made of ABS plastic

Methods & Procedure

Electron gun



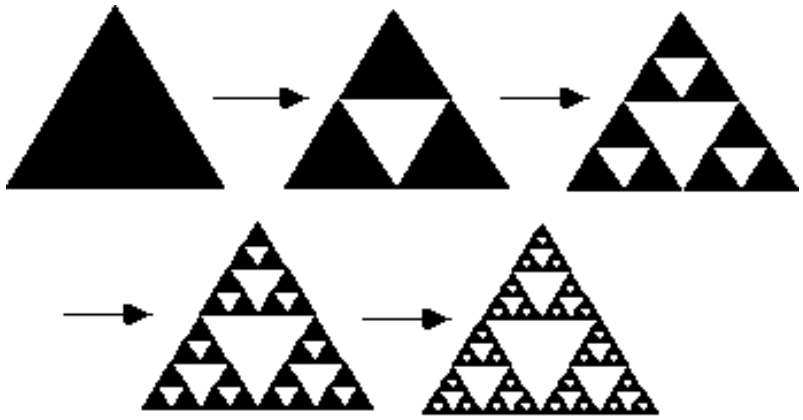
Electron gun with tube of nitrogen connected. Two copper wires in tubing connected by the tungsten filament and to the power supply. To prevent separation of the wires that would cause the filament to break, the wires are secured by an additional glass piece at the front (right) end of the tube.

Hand-made, tunable spark gap. The gap ranges from 0 to 3.5 mm and is used to produce resonant potential. Input was from <5 volts DC and <1 amps and the output was approx. 1000 volts AC.

Methods & Procedure

Fractals

- Fractal – curve or geometric figure, each part of which has same statistical character as the whole
- Golden mean/ratio, ϕ – found in nature and ancient architecture
- (1+sqrt(5))/2=1.618
- (1-sqrt(5))/2) = 0.618
- Contained in Fibonacci Sequence
  - $x_n/x_{n+1} = 0.618$
  - $x_n/x_{n-1} = 1.618$



Methods and Procedure

Fractals – 2D vs. 3D

2D

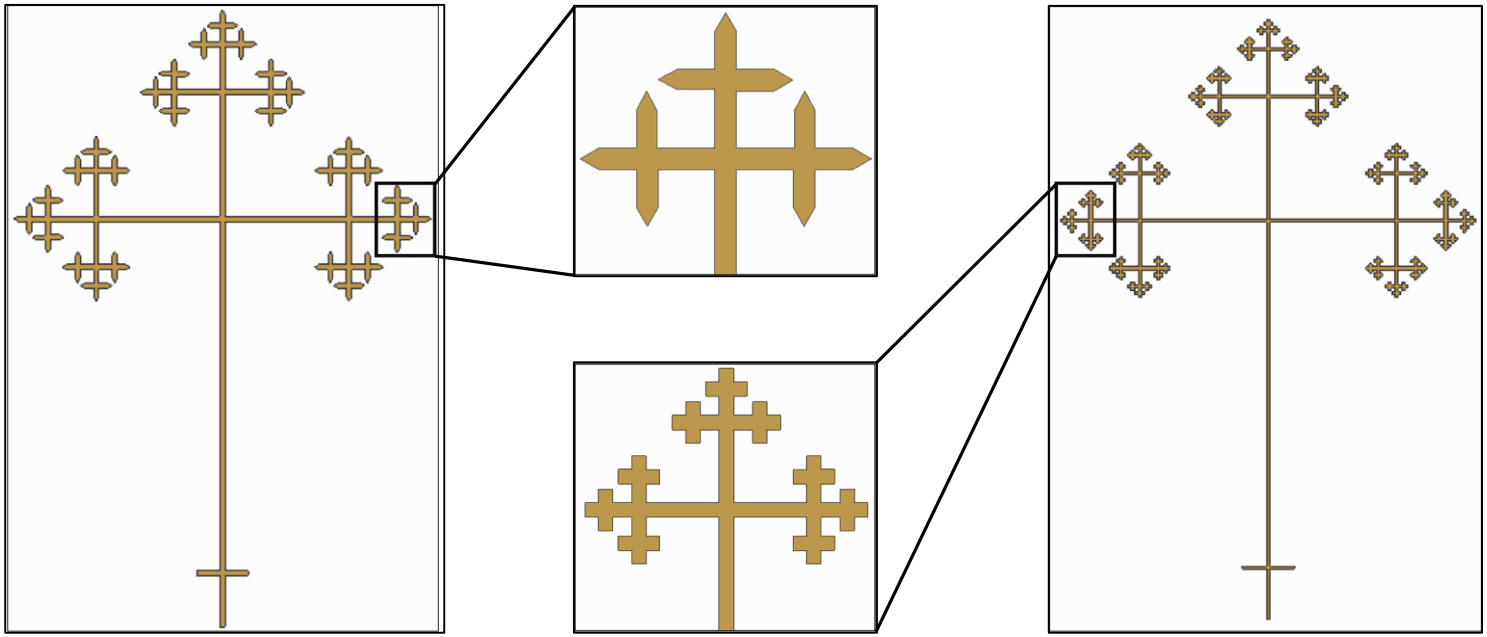
- 1st order=3 nodes
- 2nd order=9 nodes
- 3rd order = 27 nodes
- 4th order = 81 nodes
- 5th order = 243 nodes
- 6th order = 729 nodes

3D

- 1st order = 5 nodes
- 2nd order = 25 nodes
- 3rd order = 125 nodes
- 4th order = 625 nodes
- 5th order = 3,125 nodes
- 6th order = 15,625 nodes

Methods & Procedure

Fractals – 2D; 3^n where n is the order

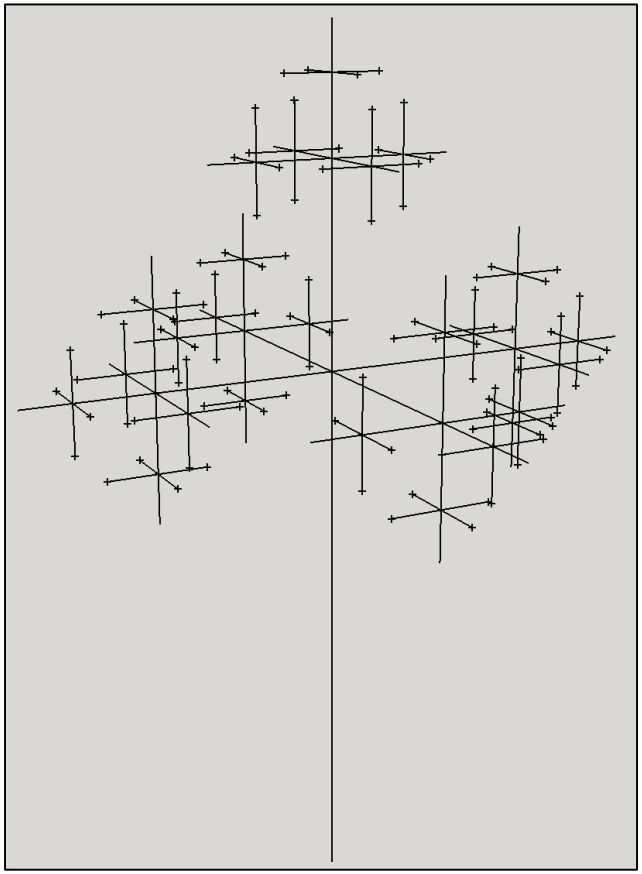


The fourth order fractal with pointed ends. The 4^{th} order fractal has 81 nodes.

The fifth order fractal with square ends. The 5^{th} order fractal has 243 nodes.

Methods and Procedure

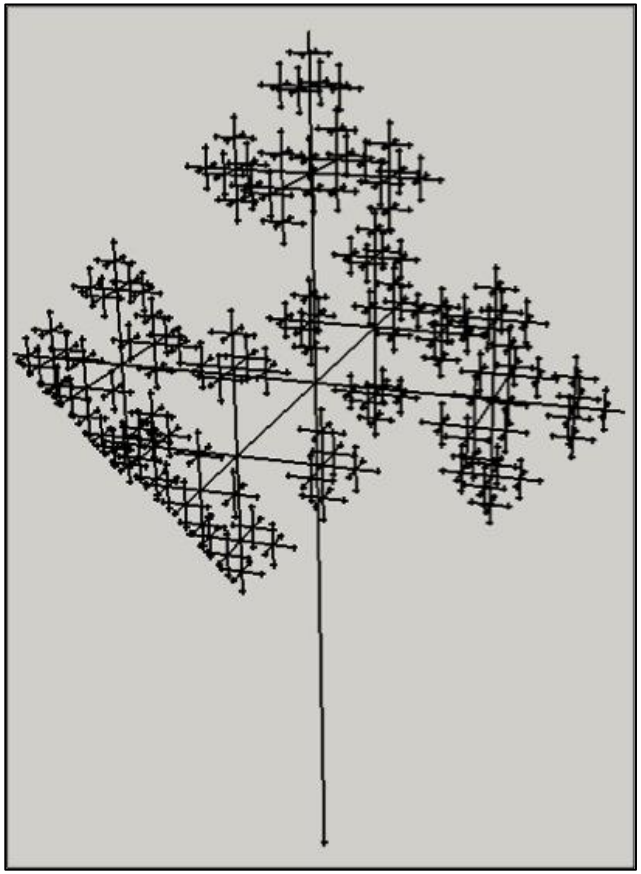
Fractals – 3D; 5^n where n is the order



Left: 3rd order fractal: 125 nodes

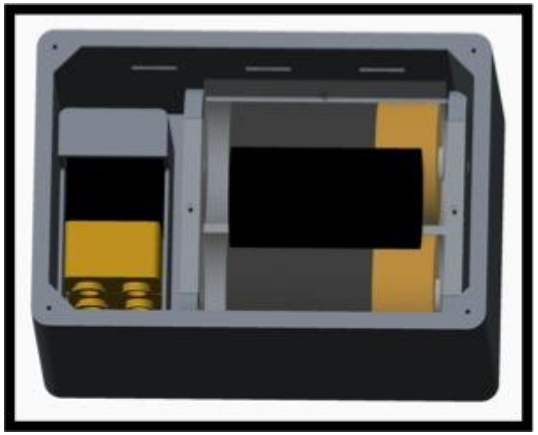
Right: 4th order fractal: 625 nodes

Note: All 3D fractals were modeled using Google Sketch

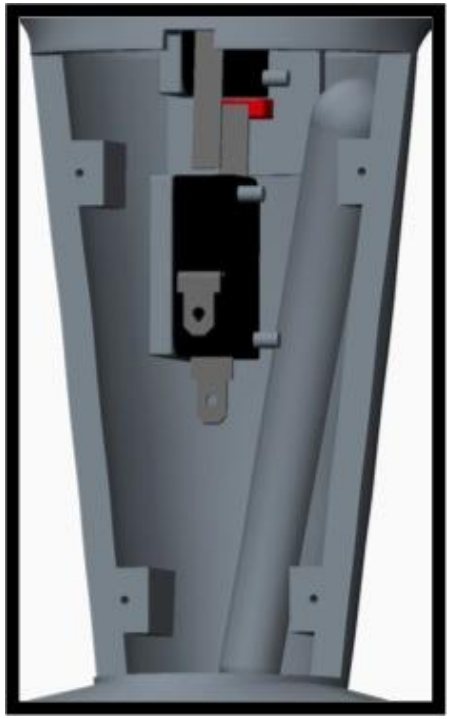


Results

Left: Exploded view of final wand rendering. Note: View is from rear left of device.



Top right: Shows battery storage pack.



Bottom right: Shows internal tubing for nitrogen gas, switches, which are controlled by buttons to power the system.

Results

- Final design enhanced safety, ease of use and ergonomics.
- Enables internal features to be easily accessed
- Removable bottom contains 2 power sources – one for filament, one for fractals and coils
- Handle contains wiring and internal tube for nitrogen flow
- Top of device contains fractals and dust collection coils, with removable caps

Future Research & Use

- Use of 6^{th}, 7^{th} and 8^{th} order 2D fractals
- Use of 5^{th} and 6^{th} order 3D fractals
  - Alternative uses in air locks in space
  - Space suits
  - Uneven surfaces
- Full functionality in clean rooms
  - With use of nitrogen gas
- Full functionality in microgravity
- Patent pending

Credits

Fred Minetto, NASA GSFC

Nicole Racine, UMBC

Holly Johnson, UMBC

Dr. Santosh Seelan, UND

Caitlin Nolby, NDSGC

University of North Dakota

NASA GSFC

Questions?