# INNOVATIVE ELECTROSTATIC ADHESION TECHNOLOGIES

*(Flexible Electrostatic Tools for Capture & Handling [ FETCH] )*

**Tom Bryan, Todd Macleod, Larry Gagliano**

*NASA Marshall Space Flight Center*

# Background

Capture is quite difficult for Orbital object handling and satellite servicing:

- Most satellites and upper Stages are not designed for docking, refueling, and Disposal
- Billion dollar satellites become inoperable due to fuel depletion
- Thousands of abandoned Satellites, spent Upper-stages and discarded structures create daily threats to operational Satellites, ISS, Exploration
- New Capture technology will impact hundreds of existing satellites in service by extending mission lifetimes and allowing handling of threatening derelict orbital objects

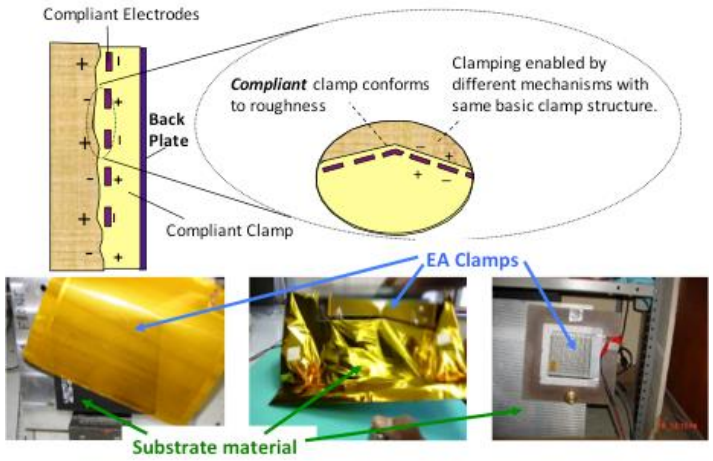
The Challenge:

Conventional robotic arms and grippers have difficulty finding suitable capture structures

The Answer: **Electrostatic Grippers**

*Why Explore Electrostatic Grippers?*

1. Able to grip and release various materials on command
2. Able to conform to different surfaces due to flexibility
3. Fewer moving parts, potential to be more reliable

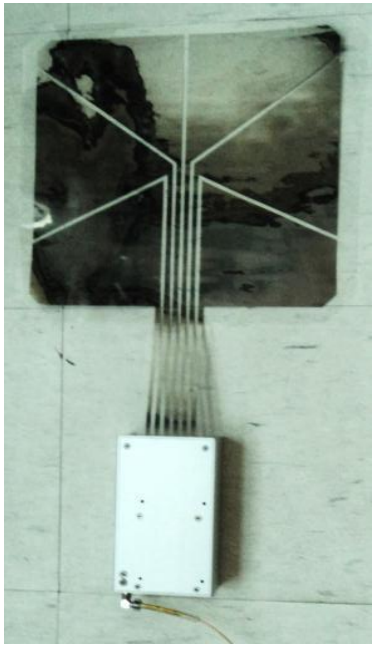


# Innovative Technology – Electrostatic Adhesion

## Modes of Manipulation

| | Pull | Shear | Twist |
|---|---|---|---|
| **Sheet Metal** | Poor | Exceptional | Exceptional |
| **Painted Metals** | Poor | Inconclusive | Inconclusive |
| **Photovoltaics** | Poor | Inconclusive | Inconclusive |
| **MLI** | Poor | Exceptional | Exceptional |
| **Kapton/Mylar** | Poor | Effective | Effective |
| **Wood** | Poor | Poor | Poor |
| **Paper** | Effective | Effective | Effective |

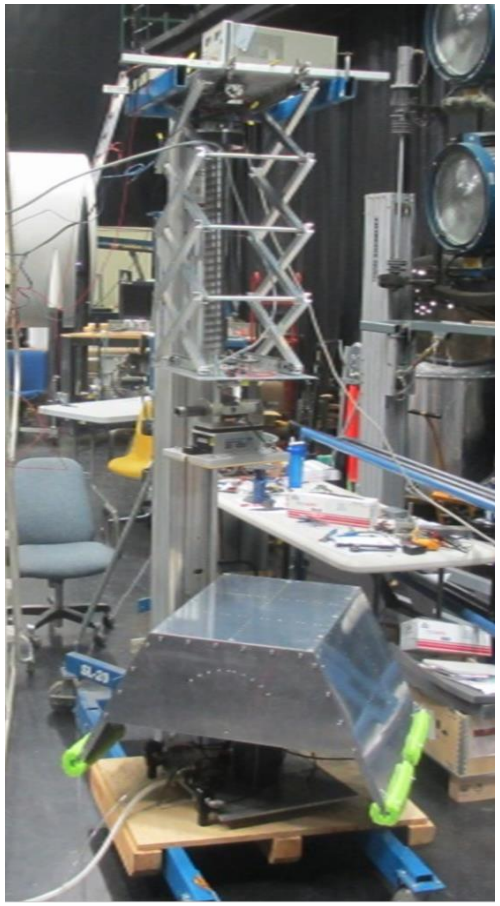
- Results of testing using ElectroGrip© 11.5” x 11.5” DR5 Electrostatic chucks
  - 2-4kV high Voltage range with 6 poles & 3 phases
  - Close Proximity Sensing up to about ½ meter
- 3-phase gripper performance increases marginally in low moisture @ 1 atm. (from 51% RH vs. 0.1% RH at 68ºF)
- Toggling down period of voltage cycling rate from quick to slow induces notable stronger Johnsen-Rahbek attraction effect



**ES\EA grippers by ElectroGrip, Co. and GrabIt, Inc**

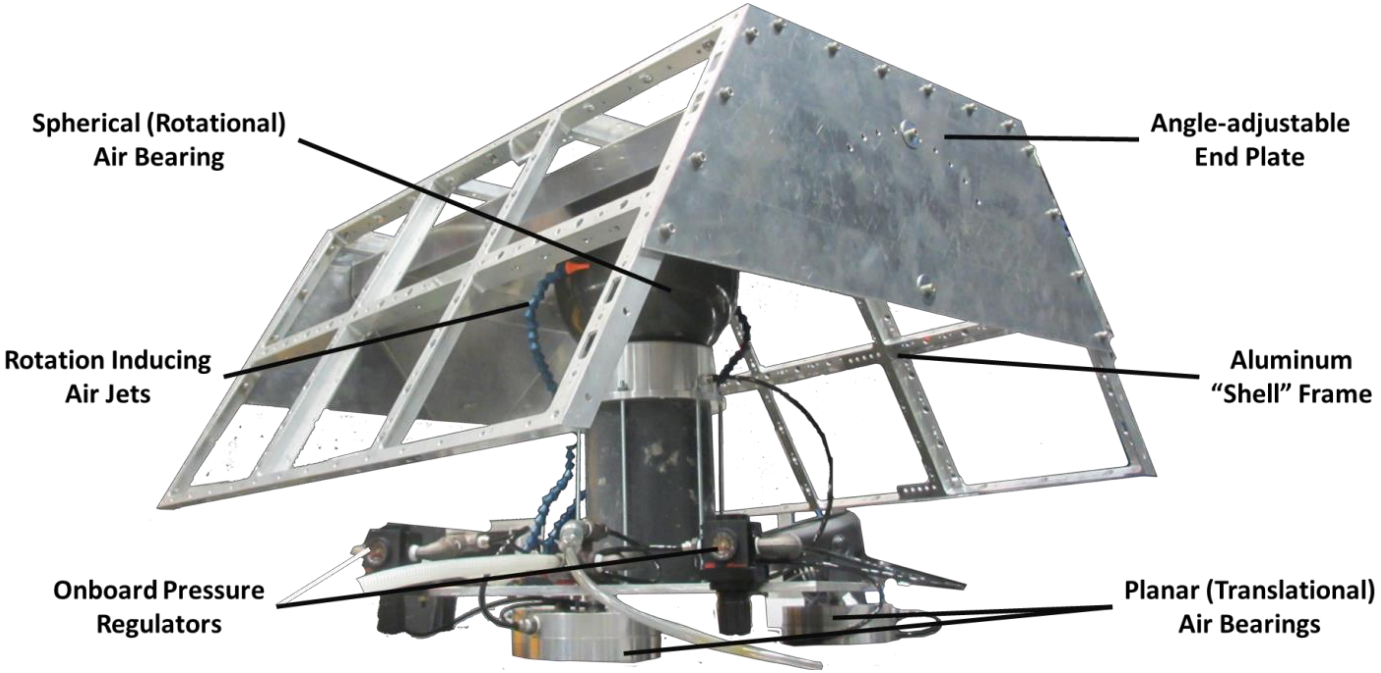
# Technology Development


To **use** the Innovative gripping capability of Electro-Static Adhesion to Capture Unstable Satellites and Orbital Objects, we need a retractable boom that allows the retrieval vehicle to observe from a safe stand-off distance and extend and synchronize the flexible ES Gripper with the unstable object's center of rotation to grip with minimal impact and use its grip to de-spin before moving the object toward the retrieval vehicle by boom or releasing and re-capturing it.



# Proof of Concept Ground Testing
## (On MSFC Flight Robotics Lab Flat Floor)

Re-Active (Unstable) Satellite Simulator: To evaluate the planned capture mechanism and methodology, a 5-axis air-bearing simulator was built that can support various simulated spacecraft surfaces at different angles and spun up by de-coupled air jets. Misalignments between the ES Gripper and the simulator will result in relative motion or gripping failure. A collection of optical pointers, smart cameras and lidars will be tried.



# Conclusion

- Electrostatic grippers are able to interface with conductive and nonconductive materials
- Highly finished surfaces (e.g. sheet metal) provide better gripper—object contact for less static charge loss, provides greater grip force
- Electrostatic grip strength increases with the square of voltage
- Shearing & twisting operations are more effective modes of manipulation than normal pull
- Greater risk of gripper peeling and detaching with normal pull operations, believed to be related to mounting configuration
- Docking simulations on frictionless flat floor conclude the electrostatic robotic end effector as a viable primary contact/capture arm, with a secondary robotic arm to perform servicing operations