Progress Towards Electroadhesion Applications in Space

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Outline

Background on SRI
Background on Electroadhesion (EA)
Applications for In Space Inspection
Robotic Augmentation
Performance and Testing
Next Steps

Electroadhesion (EA) is a surface film effect that provides a universal and reversible surface attachment technology that does not require preparation of the target surface, works on many material types and can conform to most surfaces and textures.
What is SRI International?

*SRI is a world-leading R&D organization*

- An independent, not for profit corporation
  - Founded by Stanford University in 1946
  - Independent in 1970; changed name from Stanford Research Institute to SRI International in 1977
  - Sarnoff Corporation acquired as a subsidiary in 1987; integrated into SRI in 2011 (Now SRI-Princeton)
- 2012 revenues approximately $582M
- More than 2,500 employees
- More than 20 locations worldwide
SRI International’s Business Model

Creating client and partner value and rewarding our staff

Important Client & Market Needs

Independent and Contract R&D and the Creation of Intellectual Property

Royalties

34% of royalty and equity to staff

Licenses

Products, Systems, and Solutions

Spin-off Technology Ventures

Equity

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What can we expect from Electroadhesion (EA)?

The “Bottom Line Up Front”

Safe and practical terrestrially and in space

- Has been demonstrated to be safe for humans and electronics, in air and vacuum

Easy to use; behaves as one would expect

- Adhesion is a straightforward result of electrically turning on and off

Already being commercialized for terrestrial applications

- SRI has spun out a commercial entity, GrabIt, for industrial materials handling (in collaboration with industry partners)

Ideally suited to inspection and IVA/EVA support functions

- Terrestrial demonstrations have shown its utility for such operations

Ready for application to important problems today

- No technical impediments to fielding have been encountered under recent NASA and DARPA program activities
Technical Background on Electroadhesion

*How does it work?*

- **Reversible Adhesion**
  - Using electrostatic forces induced between surfaces
  - Details vary with different materials; but use same basic electrode structure
  - Works on broad range of materials – dielectrics to conductors, textured or not
  - Ultra-low power (~0.02 mW/N of force or weight supported)

**Principle of Electroadhesion Operation (top)**

**Clamping to Typical Space Materials (bottom)**

**Example Application:** “Spacecrawler” micro inspection robot
Applications and Benefits of Electroadhesion (EA)

• Potential Applications
  — IVA and EVA support for astronauts
  — Docking, robotic augmentation
  — Debris collection
  — Tool attachment, in space assembly
  — Placement of lighting, cameras, sun-shades
  — Inspection or patching of micro-meteoroid and orbital debris (MMOD) damage

• Benefits
  — Provides reversible adhesion, <50ms on/off
  — Withstands large forces
  — Works with many materials and fragile surfaces
  — Works with unprepared and textured surfaces
  — Works on dusty surfaces
  — Temporary or long duration grappling, holding, or manipulation without predefined interfaces

Example corner or edge attachment tool and flat-surface attachment tools for gripping
Astronaut Support using EA (IVA and EVA)

• Straightforward working surfaces
  – Minimal training
  – General applicability
  – No pre-planning needed

• Example EA surface functions
  – Boot anchoring
  – Sticky gloves
  – Sticky suit (anchor pads on space suit)
  – Tool anchoring to any surface
  – Capture of “loose stuff” – bolts, nuts, cover plates, wire harnesses

• Astronaut safety and attachment
  – No floating away or bounce in impact
Robotic Augmentation and Assembly

• EA Pads on dexterous and flat surfaces
• EA Pads on arms (for anchor points)
• EA Pads on tools and in new assembly approaches (as “glue” between modules)
• Surface crawling robots (IVA and EVA)
• Walking robots

(Note: SRI robots and UAVs can already include stereo HD Video real time processing.)
Other EA Applications

• Double stick EA surface placed in any work area – inside or outside spacecraft
• Simplified docking, assembly
• EA tags/labels for inventory control
• Debris Capture – IVA and EVA
  – DARPA Phoenix looked at GEO environment
  – ISS was considered for LEO environment demo
  – Spheres or small wall crawling robot are options for inside ISS to address dust and debris capture and mitigation

(Lower image courtesy of IR&D effort with SJSU Students)

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Technology Readiness for Space

- EA clamps have been demonstrated successfully in vacuum and over varied temps
  - (-40 to 150 °C, 10^-6 torr), with UV exposure (1-5 suns) and with an electron source active
- Results have shown consistently better clamping forces under vacuum conditions than atmospheric conditions
- SRI IR&D testing carried out with substrate materials commonly found on spacecraft (Anodized or bare aluminum, Kapton, Polyimide, Mylar etc.), resulted in measured forces of 0.2–1.4 N/cm² of pad area
- Terrestrial demonstrations (DARPA Phoenix program) have shown EA to be benign on solar panels, to spacecraft surfaces, and to RF antennas (whether RF systems were off or operating, even when switching EA on and off)

Example Application: Docking of space objects
Next Steps

• Tailor EA to requirements of specific uses or users
• Carry out engineering for a funded on orbit demonstration
• Demonstrate EA operation in LEO (possible in 2015)
  – CubeSat mission proposed for 2013 received excellent reviews; missed the funding line
  – Need interested parties (government or commercial) to raise the priority
  – ISS/NanoRacks provides straightforward opportunity for LEO deployment
  – ISS/Spheres provides straightforward opportunity within ISS
  – There are no technical impediments
• Users need to identify highest value application

SRI is ready to integrate and test EA for space applications