ALTIUS
SPACE MACHINES

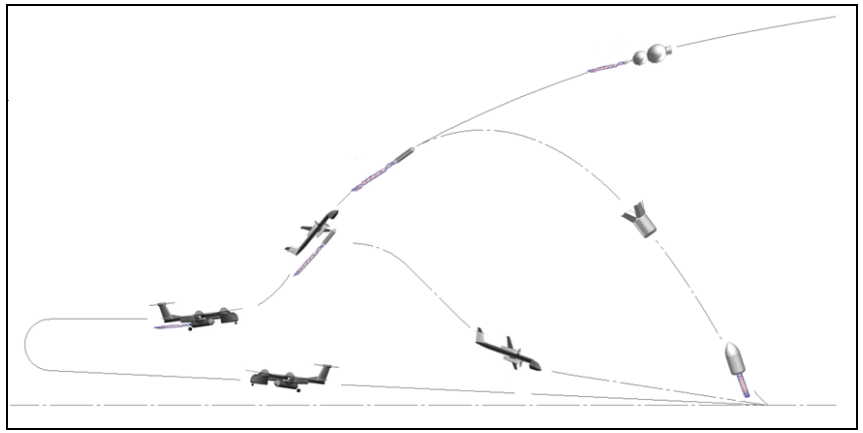
Altius Space Machines
Introduction and Status

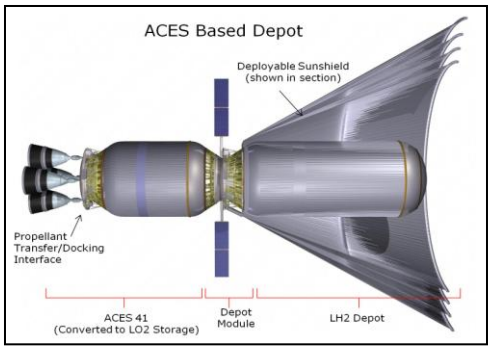
Jonathan Goff
8 April 2011
jongoff@altius-space.com

Space Access 2011
Phoenix, AZ

Personal Background

- Part of original founding team for Masten Space Systems
- Former MSS Lead Propulsion Engineer and CAD Monkey
- Proprietor of Selenian Boondocks space technology/policy blog
- Propellant Depot and Space Technology Advocate



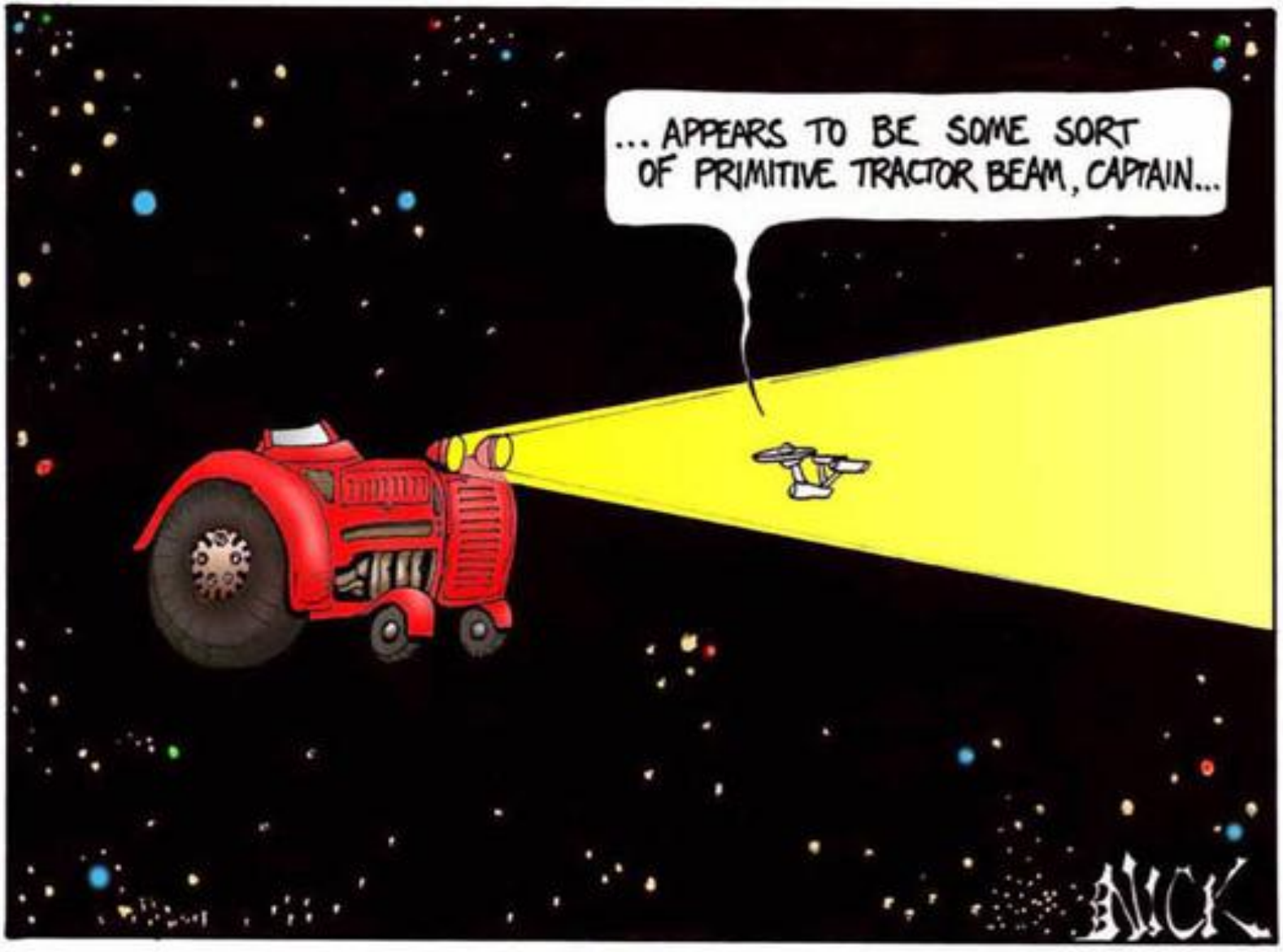


Altius Space Machines Introduction

- Left Masten in July 2010 to start Altius Space Machines
  - Currently located in Louisville, CO
- Hunch: Many key spacefaring technologies can be profitably developed today
  - Affordable Space Access is a problem that can be attacked from both ends and the middle.
- Bootstrapping via contract engineering, but standing-up a product-focused company
- Use of “Friday Time” to balance creativity and focus.

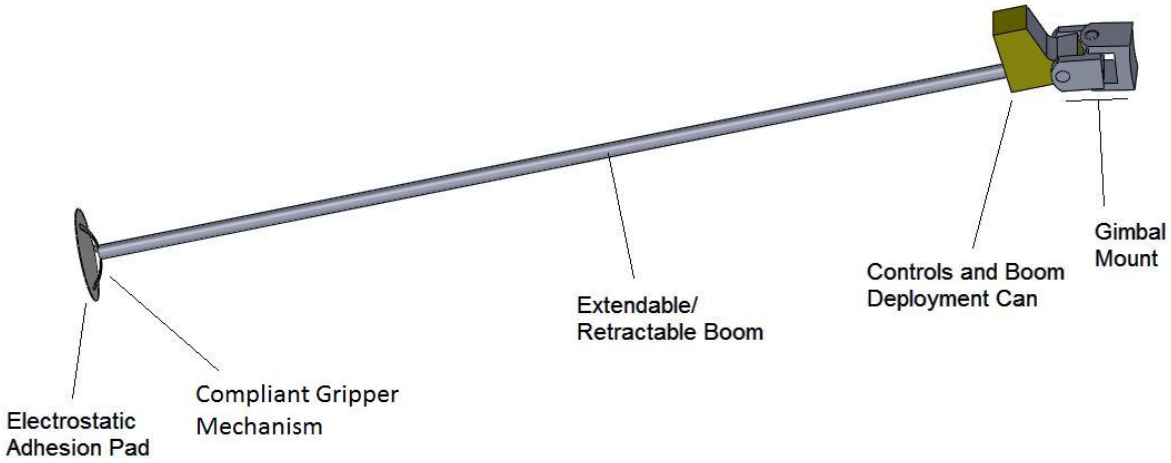
First Product Area: Rendezvous and Docking Systems

- Lack of flight-rate demand is a key hurdle to low-cost space transportation
  - RLVs need ~50flt/yr to close economic case
  - Robust RLV operations require at least 2-3 vehicles per outfit
  - Robust RLV Industry requires 2-3 healthy RLV outfits
  - What can provide demand for 200-350 flights per year? *People, "Provisions", and Propellant*
- A key obstacle to high-tempo space transportation is the rendezvous and docking bottleneck
- We may not be able to do Warp Drive, but what if we could do a Tractor Beam?


... APPEARS TO BE SOME SORT OF PRIMITIVE TRACTOR BEAM, CAPTAIN...
BUCK

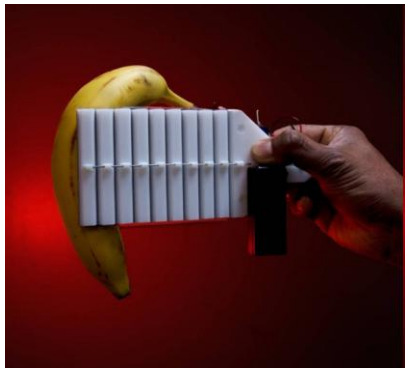
Electroadhesive “Sticky Boom” Rendezvous

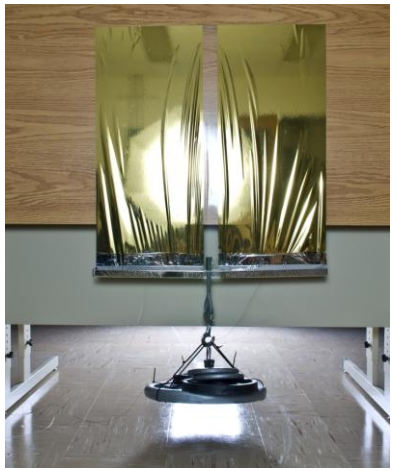
- Sticky Boom is a non-cooperative rendezvous and docking/capture system
  - Means it can reach out and stick to things that don’t have docking adapters
- Sticky Boom has three main parts:
  - An Electrostatic Adhesion pad
  - A compliant gripper mechanism
  - An steerable, extensible/retractable boom (or tether or combination of both)

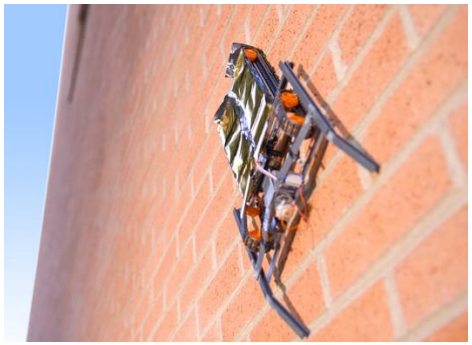


Electrostatic Adhesion Technology

- Electrostatic Adhesion (EA or Electroadhesion) is a technology for electronically adhering to surfaces
- Can grip conductive and non-conductive materials
  - 1-2psi normal adhesion pressure on metals
  - ~10-20% adhesion pressure on non-conductors
  - Adhesion also dependent on conforming the pad to the target surface
- Fast acting (< 50ms on/off)
- Built-in proximity/contact detection
- High voltage (500V-5kV, low current, low power (~20 μW/N clamping)
- Patented by SRI International
  - Altius has a signed Memorandum of Collaboration with SRI International
  - Altius and SRI have jointly filed a provisional patent for Sticky Boom



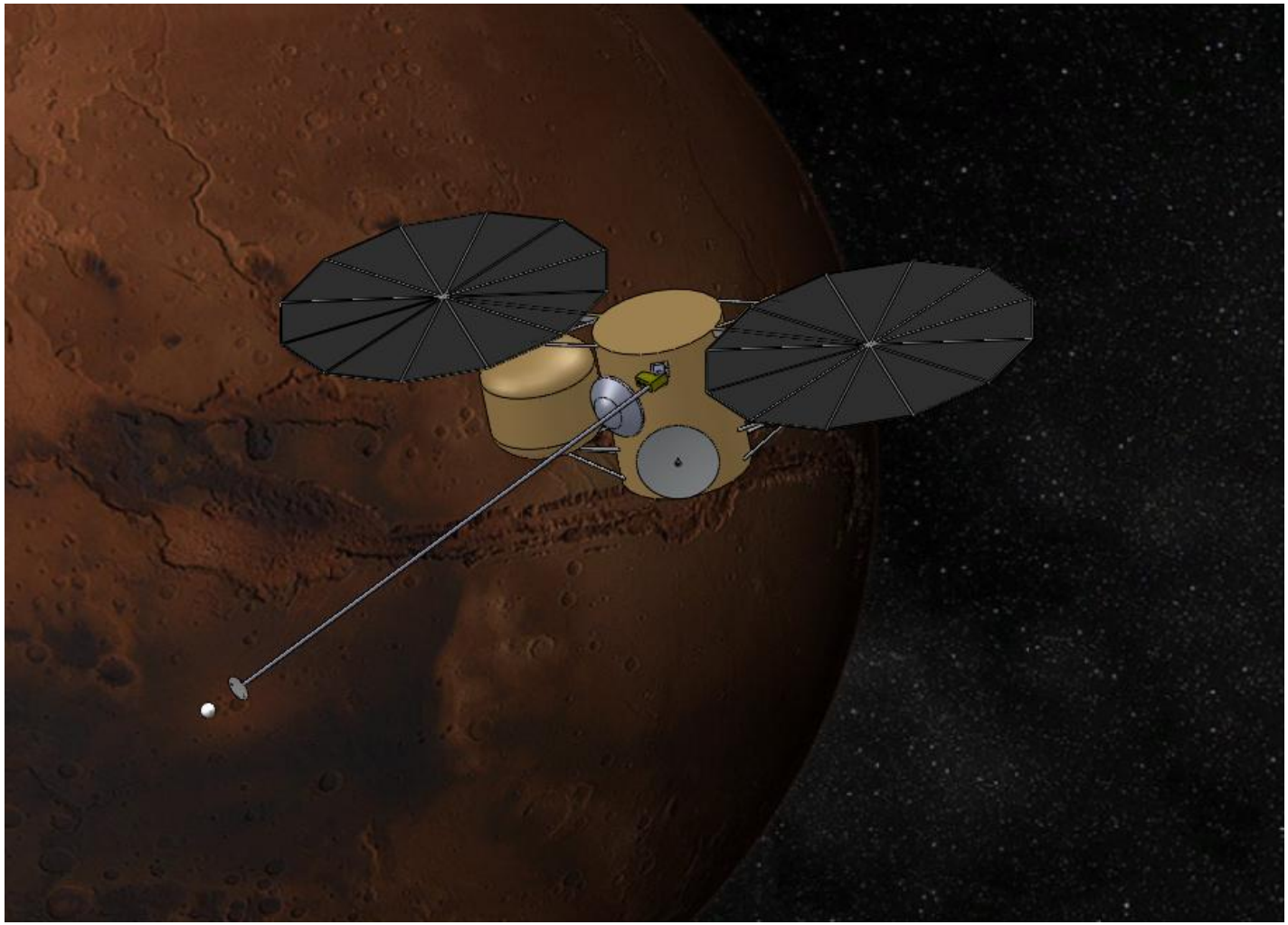




Sticky Boom Benefits

- Electroadhesion enables Sticky Boom to grab objects made of any material, shape, and size
- Enables non-cooperative capture on almost any object imaginable
- Long boom (10-100m+) enables “contact at a distance”, which greatly reduces collision risks
- Can tolerate much wider ranges of relative velocity and relative rates
- Reduces risk of plume impingement (all relative motion within boom radius provided electromechanically—not propulsively)
- May enable simpler rendezvous sensors

Sticky Boom for Mars Sample Return

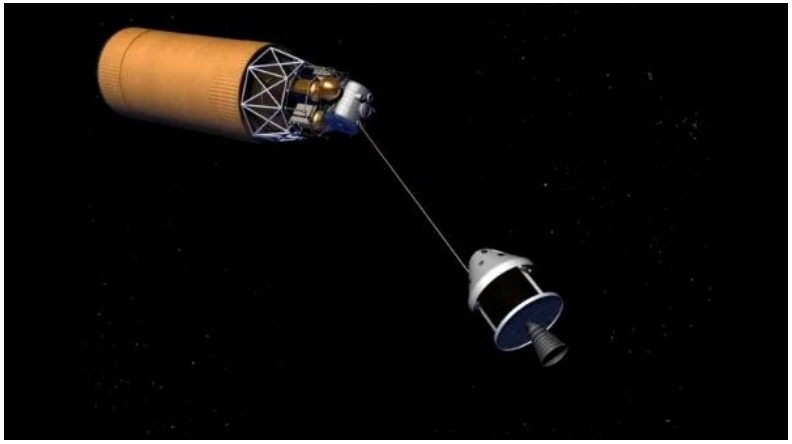


Some Non-Cooperative Capture Applications

- Can grip practically anything
- Can attach-to and “de-spin” massive, tumbling, uncontrolled targets
- Examples:
  - Spacecraft not design for rendezvous and docking enabling:
    - Life extension services
    - End of life services
    - Orbital servicing
  - Space Debris
  - NEOs and Space Rocks
  - Tools lost during EVAs

Space Station Prox-Ops and other HSF Applications

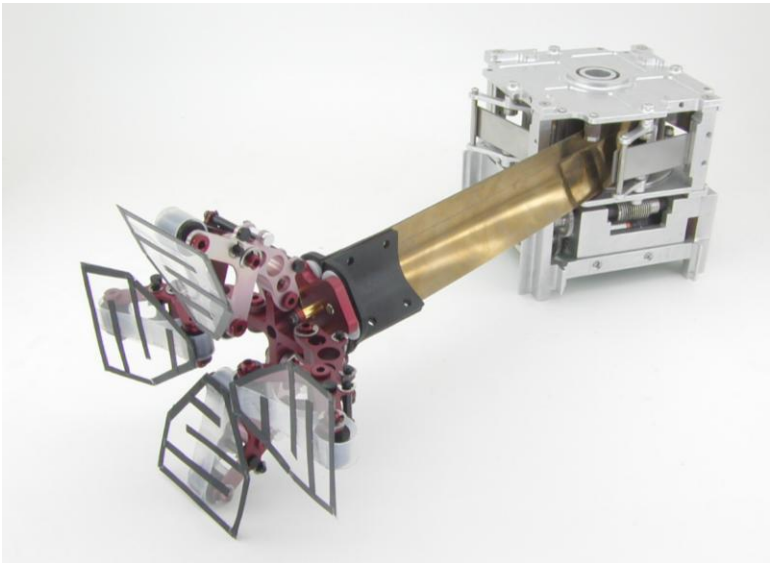
- Contact at a distance enables much safer rendezvous and docking operations
  - Goal: Making orbital rendezvous a relative "non-event"
- Can enable smaller, more frequent deliveries
  - "Daily milk-run"
  - ISS sample return
- May eventually enable lighter, simpler docking/berthing systems
- Sticky Boots, Gloves, and Stray Tool Catchers for EVA



Current Status and Near-Term Plans

- SBIR Phase 1 Contract began 18 Feb 2011
  - Phase 1 Effort focused on:
    - "Space environment testing" of EA technology on a range of relevant spacecraft materials
    - Development of grappler mechanism and selection of boom concept
- A handheld "proof-of concept" prototype was developed in early March to flush out "unknown unknowns" and provide demo unit for a NASA Technology Day in Washington DC on March 15th.
- Proposal submitted for Zero Gravity aircraft flight opportunity this fall
- Talking with potential NASA, DoD, and Commercial Customers
- Technical ***Goals***:
  - Vomit Comet testing of proof-of-concept system (early TRL-5) Q2/Q3 2011.
  - Vomit Comet testing of higher-fidelity system (full TRL-5) in 2012
  - Space testing (Suborbital, Rideshare, or ISS) by (TRL 6/7) 2013/2014
  - Available for use in actual missions 2014/2015

Proof of Concept Demo Units



"Rocker-Bogie" Style Proof of Concept w/ TRAC-style Boom-Deployer

Handheld Sticky Boom Demonstrator at NASA Technology Day, 15 Mar 2011

Sticky Boom Development Implications for Altius Space Machines

- Business Goal: Develop a team capable of designing, fabricating, testing, and integrating custom Sticky Booms into 3rd Party spacecraft
  - Technology Demo Missions
  - Satellite Servicing
  - Space Science Missions
- Need to pull together business and technical teams
  - Technical Specialties including: Spacecraft Mechanisms and Actuators, Space Electronics, Space-rated Manufacturing and Testing, Composites Design and Fabrication, Dynamics and Orbital Mechanics
  - Business Specialities include: Project Management, Operations, and Marketing
- Near-term focus is pulling together enough contracts and key team members to start developing this team

Machine Up.

jongoff@altius-space.com

Backup Slides: Friday Time

“Friday Time”

- “Friday Time” is time set aside each week for independent research projects that don’t have to be aligned with critical path
  - Borrowed shamelessly from Google
- Goal is to promote continuing development of our employees, while also laying foundation for future product lines or spin-offs
- Trying to strike the balance between focus on the critical path while still encouraging creativity

Some “Friday Time” Topics

- Advanced manufacturing concepts
  - Turns out my Master’s thesis wasn’t completely irrelevant!
  - Enhancements for Forming, Spinning, and even a method for enabling High-Strength, Ultra-Tight Tolerance 3D Printing of Aluminum
- Active TPS and Micro Reentry Vehicles
- Liquid Rocket Engine Fabrication Advances
- MHD Aerobraking/Aerocapture
- MHD-Powered Electric Pump Cycle
- Propellant Depots and Related Technologies