Additively Manufactured Propulsion System

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To Achieve The Full Potential that CubeSats Promise

- Must be more mass-efficient
- Increased bus power
- Have significant delta-V available
- Shorter design and build times
- Cost efficient
• Additive Manufacturing (AM) – A layer-by-layer process that uses CAD data to create a 3D object.
  • Past limitations with AM:
    • Inadequate material strength
    • Porous construction
    • Non-functional parts/used for fit checks
Current Capabilities with AM:

- High strength build materials
  - Nylon/Carbon Fiber (12 ksi tensile)
  - Titanium (Ti-6Al4V) (128 ksi tensile)
- Fully fused construction
  - allows for high pressure vessels
- Internal cavities
AMPS-H Motor Design

- Additively Manufactured monolithic design (nylon/carbon fiber)
  - Oxidizer tank (toroidal design)
  - Fuel grain
  - Pre/Post combustion chamber
  - Injector port
  - Oxidizer fill port
  - Relief valve port
  - Nozzle port
  - Igniter port
AMPS-H motor is made from carbon fiber reinforced nylon (Windform XT 2.0)

- 12 ksi tensile strength
- Selective Laser Sintering

Engineering Design Unit (EDU)

- 1U test article
- Bonded metal fittings
- Chemical Igniter
- Propellants
  - Nitrous Oxide
  - Nylon
- Ablative nozzle
Static Hot Fire Test
- Burn duration – 16 sec
- Peak Thrust 6.2 lbf (27.6 N)
- Total Impulse – 142 n-sec
Additively Manufactured Propulsion System - Hybrid (AMPS-H)

• Why a Hybrid?
  - Safety
  - Performance
  - Reliability
  - Cost
Secondary Satellite Propulsion Safety Issues
  - Risk to the Primary payload
  - Handling

Hybrids offer many safety advantages over other types of propulsion systems
  - Unlike solids - propellants are kept separate and typically in two different states (solid, liquid)
  - Unlike Liquids – simpler with fewer possible failure modes, non-carcinogenic, non-cryogenic
  - Unlike Hydrazine systems – uses non-carcinogenic propellants
Oxidizer

- Nitrous Oxide (laughing gas)
  - Mild oxidizer (propellant in whipping cream cans)
  - Decomposition requires high temperature and/or catalyst
  - Will not drip onto other components if a leak is formed
  - Self pressurizing

Fuel

- Nylon – AM build material
- Inert
- No leak paths - part of motor structure
Oxidizer Tank
- Factor of safety = 2.47 (Failed @ 2226 psig)
- Finite Element Analysis predicted failure within 3% of actual
Possible to Carbon Fiber Wrap the AMPS-H Motor Tank
- Increase margin of safety
- Reduce inert mass
- Carbon Fiber is a space proven material
• Ignition
  - Electric Based Design Utilizing a Catalyzed Heat Exchanger
    • Decomposes the nitrous oxide
    • Safe - no stored energy devices
    • Restartable
    • Reliable – no moving parts
    • Low power requirements
    • Compact
    • Currently undergoing testing
Design Simplicity
- 80% of the AMPS-H motor is a single monolithic part
- Minimize potential leak paths
Two Ways to Produce Delta-V

- High Specific Impulse Propulsion - > 400s
  - i.e. Ion, Plasma, Hall Effect, etc
  - Very efficient
  - Require long burn times to produce sufficient delta-V
  - Can take a long time to reach desired orbit
  - May consume portion of useful mission lifetime
AMPS-H Motor Performance

- High Thrust/Weight Ratio Propulsion
  - \( Isp \ (\text{vac}) \sim 270 \text{s} \)
- Enables Small Satellites to be Truly Operationally Responsive
  - Achieve desired orbit in timely manner.
  - Completely customizable through the AM process without adding cost and schedule
AMPS-H Motor Performance

What is possible?

- 6U, 12U, 27U bus chassis with integrated main thruster and cold gas RCS
- AM enables embedded propellant lines in chassis wall
- For a 6U Configuration
  - 2.5U-3U of payload volume
  - Delta-V ~ 784 m/s
    - (density = 1.3kg/U) (propellant mass = 2kg)
CONCLUSION

- Additively Manufactured Propulsion and Bus Chassis
  Enhances the Value of Cubesats by:
  - Safe, high delta-V propulsion
  - Integrated cold gas RCS
  - Operationally responsive
    - Parametric CAD-based design allows customization
    - Satellite bus manufactured within hours
    - Launch readiness within days
    - Rapid orbital changes
    - Also capable of deorbiting to minimize debris
6U Hot Fire Test 7:00-7:30 Tonight
@ The Logan Air Port