Moog CSA Engineering
CubeSat Payload Accommodations and Propulsive Adapters
11th Annual CubeSat Developer’s Workshop
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Agenda

- CubeSat “Wafer” adapters for small launch vehicles
  - CubeStack launched on Minotaur I ORS-3
  - NASA NLAS adapter manifested on Super Strypi ORS-4
- FANTM-RiDE smallsat rideshares
- ESPA 6U Mount
- CubeSat deployment sequencer
- CubeSat propulsion
  - Controlled re-startable solids from DSSP
- Propulsive adapters
  - CubeSat delivery stages built on CubeStack and ESPA
CubeSat “Wafer” Adapters

• Steve Buckley wafer configuration pioneered by NASA Ames with NanoSat Launch Adapter System (NLAS)
  – 25.4 cm (10 inches) tall with 986-mm (38.81-inch) primary interface
  – Accommodates dispensers for up to eight 3U equivalent cubesats in combinations of 3U and 6U

• Configured for cubesat deployments in two directions only
  – All deployed satellites remain in same orbit
  – Radial and anti-radial maneuvers coupled with out-of-plane maneuver allow clustering of payloads to reduce risk of re-contact with primary payload and rocket body
CubeStack

CubeSat adapter developed by LoadPath and Moog CSA under contract to AFRL Space Vehicles Directorate

- Eight 3Us, or four 6Us, or combinations of 3Us and 6Us
- Qualified by test in 2011
CubeStack Maiden Launch

Dual CubeStack launched on ORS-3 November 19, 2013

- “Enabler Mission” delivered payload stack consisting of STPSat-3, and 28 cubesats
- Air Force Minotaur 1 tested space-based rocket tracking technology and autonomous flight termination system
CubeStack Version 2

Second generation design

• Bulkhead design eliminates lower deck
• Weight reduced by 15%-20%
• Improved access for integration
NLAS Adapter

• NASA Nanosat Launch Adapter System includes adapter, 6U dispenser, and sequencer

• Adapter prototype design by NASA Ames Research Center
  – Final design, fabrication, and test by CSA in 2010

• Manifested on ORS 4
  – Super Strypi launch in 2014
  – University of Hawaii HiakaSat as primary payload
  – 13 CubeSat secondary payloads
FANTM-RiDE™

Configurable enclosure for multi-manifest missions

• Collaboration between TriSept Corporation and Moog CSA
• Mix and match CubeSats with microsats and other nanosats in ESPAsat-sized box (24”x24”x28”)
  – 3U and 6U spacecraft can be attached 2 deep along interior dispenser walls, leaving space for central microsat
  – Compatible with multiple launch options including ESPA
• Integration services provided by TriSept
FANTM-RiDE™

Dispenser designed to be “mass tuned”

- Maintain same mass properties regardless of contents
- Allows for late schedule additions and/or removals from the launch schedule without affecting coupled loads analyses
ESPA Six U Mount

SUM mounts on ESPA port
• Standard secondary interface 15” bolt circle
• Compatible with Athena II Rideshare Adapter, Atlas V Aft Bulkhead Carrier, CubeStack, and new vehicles in development
ESPA with Six SUMs

• Each SUM holds two P-PODs or one 6U dispenser
  – Inboard or outboard mounting on port

• Enables increased capacity for ESPA
  – Six 400-lb satellites and twelve 3U satellites
CubeSat Deployment Sequencer

- Moog multi-payload sequencer
  - Modular architecture
  - Compatible with P-POD, PSC, SNC, RUAG systems
- Redundant high-current output signals to drive multiple spacecraft release mechanisms

Moog Broad Reach board set and architecture
- Flight heritage
- Modularity for addition of sensor and telemetry interfaces
CubeSat Agile Propulsion System (CAPS)

Flexible modular CubeSat propulsion system with DSSP electric solid propellant technology

• Can fire up to 12 different micro-thruster elements, each with lifetime exceeding 250 pulses
  – Ignition power delivered via capacitor discharge → extremely high power, short duration impulse
  – Pulse frequency dependent on power input, can reach 0.04 Hertz

• Controller is miniature bi-level PCB stack < 2¼” in height
  – Thrusters can be board-mounted or installed in modular housings that wire to controller
  – CAPS accepts a 5V to 12V DC supply and has a simple SPI communications interface
  – Power consumption (1-3 W) is dependent on user-programmable arm rate
CAPS flight demonstrations

- 1U flight demo mission in work to demonstrate 3U system
  - Team of Morehead State, Sonoma State, DSSP, Moog, and Little H-Bar Ranch

- SpinSat mission by NRL and DSSP to characterize on-orbit performance of electrically controlled solid propellant technology
  - Scheduled for Station deployment this year
Propulsive CubeStack

Wafer adapter (CubeStack or NLAS) augmented with propulsive “stage” for CubeSat delivery

• Adapter functions as Orbital Maneuvering Vehicle
• One or more wafers added to propulsive stage with Cubesat payloads
• Concept development for lunar cubesat deployment
CubeStack Delivery Stage

Spacecraft Avionics – Mission Control
- C&DH Integrated and Redundant Systems
  - Processor Boards
  - Digital & Analog I/O storage and GPS
  - Solar Array Interface
  - Torque Rod Drivers
  - Power Switching
- IMU MEMS w/GPS / Antenna
- EPS - rechargeable LI battery packs
- Sun Sensors - coarse and fine
- ACS Reaction Wheels
- Comm Ka/Ku band

Propulsion
- Monopropellant High Performance Thrusters
  - MONARC 1N, 5N, 22N vast flight heritage
  - $\text{N}_2\text{H}_4$ $I_{sp(ave)} = 230$ sec
  - ref….I $\sim 19,780$ kg-sec (86 kg propellant)
  - ref….$\Delta V \sim 415$ m/sec (230kg wet mass)
- Bipropellant option MMH/NTO
- Green propellant option (AF-M315E or LMP-103S)
- Rolling Metal Diaphragm Tanks
  - Supplied prefilled unpressurized
  - Zero Slosh
  - 99.9% expulsion efficiency
ESPA Delivery Stage

• Orbiting Medium Explorer for Gravitational Astronomy (OMEGA) proposal to NASA used ESPA delivery stage
  – Allowed spacecraft to be simplified, reducing cost and weight
  – Each spacecraft required very small μN thruster for precise stationkeeping instead of large, complex propulsion module to establish orbit

• Configurations in work for CubeSats
Summary

- CubeSat “Wafer” adapters for small launchers
- FANTM-RiDE CubeSat rideshares
- ESPA SUM for EELV and Falcon 9 CubeSats
- CubeSat deployment sequencer
- CubeSat electric solid propulsion
- Propulsive adapters and CubeSat delivery stages