Operation and Performance of Desktop Vacuum Chamber DVC1

Andrew E. Kalman   aek@pumpkininc.com

President & CTO, Pumpkin, Inc.

What we all *want* is …

Plum Brook Station Space Power Facility

What we all *need* is …

- Need for vacuum testing of systems and components
- Traditional testing inefficient / inconvenient
  - Giant chamber – long cycle times, expensive, etc.
  - Limited access to internal payloads
  - Typically small access ports / no windows

For sale on eBay in 2010: $1M

- Desire a solution that is
  - Affordable
  - Transportable
  - Easy to connect to
  - Accepts standard ports
  - Has standard consumables
  - Can feed through interfaces of interest and use in the CubeSat community

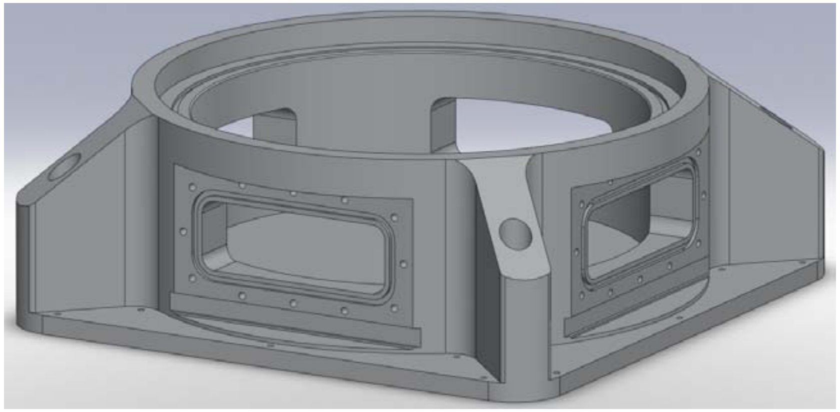
DVC1 2010 Product Goals

- Micron-level (1E-3 Torr) vacuum
- Accommodate 3U CubeSat with sensors, cabling, etc.
- Allow electrical communication with CubeSat system, i.e. reduce feedthrough costs*:
  - 3xUSB: $2,055
  - 3xDB9: $2,037
  - 1xEthernet: N/A
  - 8x500V/4A: $ 960
- Allow fluid transport (e.g., for cooling)
- Allow flexibility in choice for vacuum, cooling, etc.

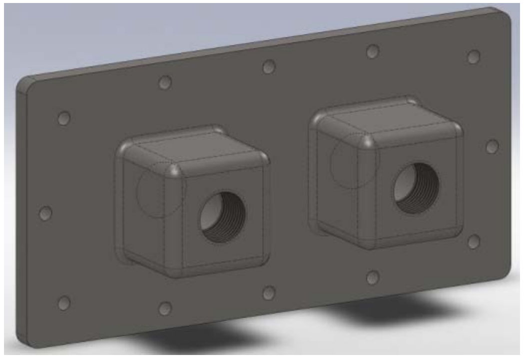
* KJL: IFTKG01201018B, IFDGG091058B, FTADD09, EFT0021038

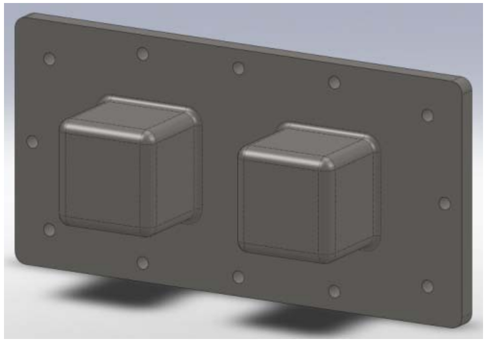
DVC1 Monolithic Base

- Large interior volume for sensors, wiring and cabling, thermal components, etc.
- Al base is traditional material
- UHMW PE base allows good thermal insulation
- 4 ports allow modular access to interior
- Support securing to
  - Rubber isolators
  - Mounts on inch- and metric-pattern optical tables

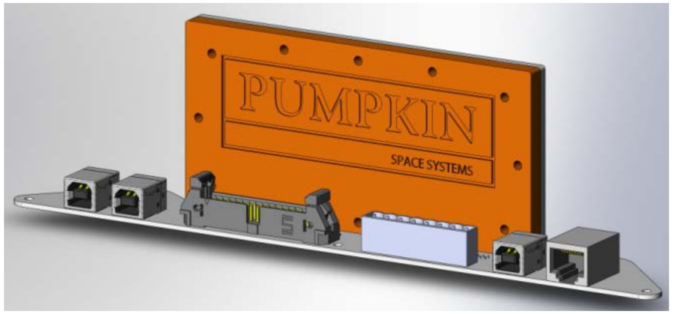


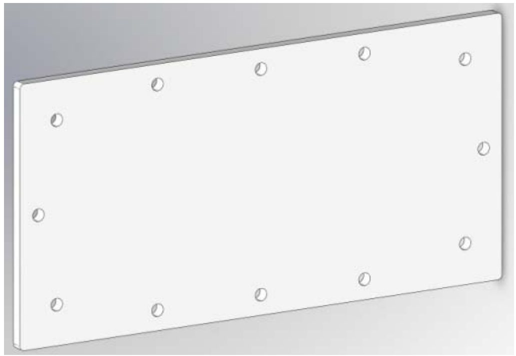
DVC1 Feedthroughs





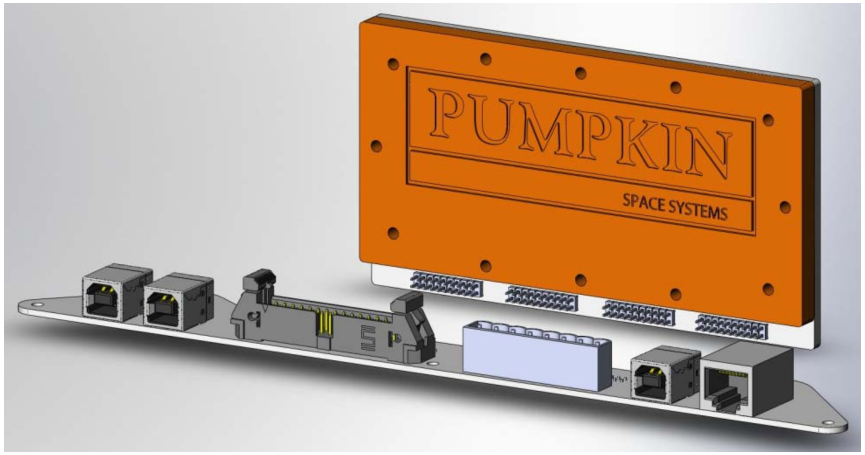
- SS feedthrough plate with ¼ in NPTF threaded holes
- SS unthreaded feedthrough plate for custom holes
- PCB-based multi-interface electrical feedthrough plate
- Al blanking plate

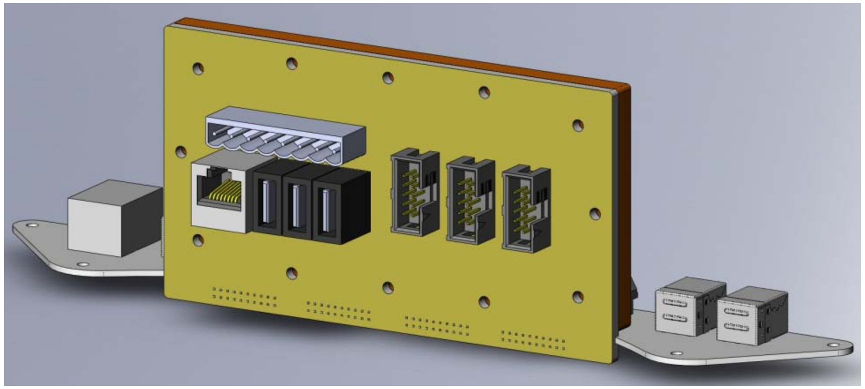




DVC1 Electrical Feedthrough

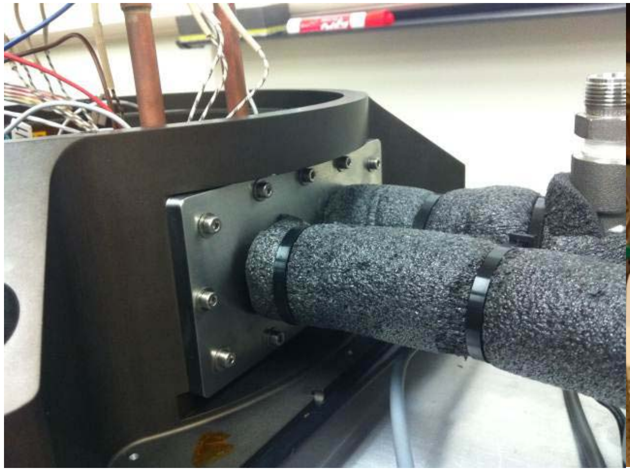
- Three USB 2.0 interconnects
- Fifteen pairs of low-power signal connectors (3 groups of 5 pairs)
- One 10-BaseT Ethernet interconnect (RJ45)
- One 8-pin high-power screw terminal connector block





2010 DVC1 Results

- Utilized oil-sealed Oerlikon-Leybold TRIVAC-B® D16-B rotary vane pump (16m^3/hr)
- Reached 1μ / 1E-3 Torr in 10 minutes – *roughing vacuum range*
- True for both anodized Al and UHMW PE versions
- In use @ SRI Int'l for CubeSat payload testing



1E-3 Torr Is Not Good Enough!

- 1E-3 Torr is the domain of A/C service, not space
- Goal is well into the HV range (1E-4 to 1E-8 Torr)
- Sealing with O-rings (e.g., KF flanges) is a reasonable compromise over Conflat (CF) copper-gasket flanges
- Mean free path lengths at HV dictate a different approach to pumping
- What is the DVC1 capable of? Relevant DVC1 characteristics:
  - Total O-ring length: 82 in 208 cm
  - Chamber surface area: 619 in^2 3,993 cm^2
  - Chamber volume: 1,002 in^3 16,413 cm^3

Turbopump to the Rescue

- If a $2,000 rotary vane vacuum pump is good for 1E-3 Torr, an $8,000+ turbopump and controller must be good for HV vacuum, right? Right? RIGHT! *This changes everything*.

Pfeiffer TPH 050 turbopump w/DN 63 ISO-K flange

RPM: 90,000

70mm intake diameter

Pumping rate: 50l/s N_2

Ultimate vacuum: 4E-8 Torr w/Viton® seals

Pfeiffer TCP 121 turbopump controller

How do we Measure HV?

- Many gauge choices.
- We settled on a wide-range combination micro Pirani (atm to 1E-3 Torr) and hot cathode (3E-3 to 5E-10 Torr)

KJ Lesker 979
atm to 1E-10 Torr
transducer

microPirani &
Hot Cathode (HC)
dual-range
transducer

KF16 flange

RS232/RS485
interface

KJ Lesker
PDR900 Series
controller

DVC1 Modification

- DN 63 ISO-K flange and bolt circle added to DVC1 base
- Turbopump bolts directly to DVC1
- Turbopump mounts upright

A scatter shield over that turbopump intake would be nice …

2012 DVC1 Results

- Start turbopump at 1E-1 Torr
- Pumpdown of 16l chamber to
  1E-5 in <120s
- Best recorded ultimate vacuums, bare Al chamber:
  - With one Pumpkin 716-00681 USB/Ethernet/30+8 feedthrough:
    8E-6 Torr
  - All-SS feedthroughs:
    3.5E-6 Torr

DVC1 chamber, transducer, transducer controller, turbopump, turbopump controller, cabling, vacuum hoses, valves and roughing pump all mounted on roll cart

Conclusion

- DVC1 pumpdown is *fast* with turbopump
  - <2m to 1E-5 Torr w/roughing pump + turbopump (Pumpkin, bare Al)
  - <10m to <2E-3 Torr w/oil-sealed rotary vane pump (Pumpkin, anodized Al)
  - 2.5hrs to 3E-3 Torr w/roughing / scroll pump (SRI, anodized Al)
- O-ring equipped DVC1 chamber is easily capable of E-6 Torr range operation
- DVC1's design is versatile and adaptable to a wide range of requirements, handles 3U-size CubeSats
- Pumpkin 716-00681 USB/Ethernet/30+8 feedthrough panel's impact on vacuum performance at E-6 Torr levels appears to be acceptable
- Operating a vacuum chamber in the HV realm requires substantially greater investment and care than in the roughing vacuum realm

DVC1 Future Work

- Test chamber is clearly leaking.
  - Suspect: NPTF + Telfon tape fittings
  - Solution: replace with KF16/KF25-compatible feedthrough – all sealing exclusively via O-rings
- Compare pumpdown speeds and ultimate values of the different flavors of DVC1:
  - Aluminum
  - Hard-anodized Aluminum
  - Ultra-high Molecular Weight Polyethylene (UHMW PE)
- Quantify impact of Pumpkin 716-00681 USB/Ethernet/30+8 feedthrough panel on:
  - Pumpdown speed
  - Ultimate vacuum
- Use another DVC1 w/lid to vacuum bake O-rings for pre-conditioning

Thanks To

- Pumpkin customer SRI International for feedback on chamber design and user experience
- Pumpkin partner Digital Solid-State Propulsion (DSSP) for turbopump and controller

Q&A Session

Thank you for attending this Pumpkin presentation at the 2012 CubeSat Developers' Summer Workshop!

Notice

This presentation is available online in Microsoft® PowerPoint® and Adobe® Acrobat® formats at:

www.pumpkininc.com/content/doc/press/20120812_Pumpkin_CSDWLU_2012-2.ppt

and:

www.pumpkininc.com/content/doc/press/20120812_Pumpkin_CSDWLU_2012-2.pdf

Appendix

- Speaker information
  - Dr. Kalman is Pumpkin's president and chief technology architect. He entered the embedded programming world in the mid-1980's. After co-founding Euphonix, Inc – the pioneering Silicon Valley high-tech pro-audio company – he founded Pumpkin, Inc. to explore the feasibility of applying high-level programming paradigms to severely memory-constrained embedded architectures. He is the creator of the Salvo RTOS and the CubeSat Kit. He holds several United States patents. He is a consulting professor in the Department of Aeronautics & Astronautics at Stanford University and directs the department's Space Systems Development Laboratory (SSDL). Contact Andrew at aek@pumpkininc.com.
- Acknowledgements
  - Pumpkin's Salvo, CubeSat Kit and MISC customers, whose real-world experience with our products helps us continually improve and innovate.
- CubeSat Kit information
  - More information on Pumpkin's CubeSat Kit can be found at http://www.cubesatkit.com/. Patented and Patents pending.
- Copyright notice

First presented at the CubeSat Developers' Workshop in Logan, Utah on Sunday, August 12, 2012, prior to the 26th Annual AIAA/USU Conference on Small Satellites.