

# Operation and Performance of Desktop Vacuum Chamber DVC1

Andrew E. Kalman aek@pumpkininc.com

President & CTO, Pumpkin, Inc.



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# What we all want is ...



Plum Brook Station Space Power Facility



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Slide 2



# 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
- 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



For sale on eBay in 2010: \$1M



# 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



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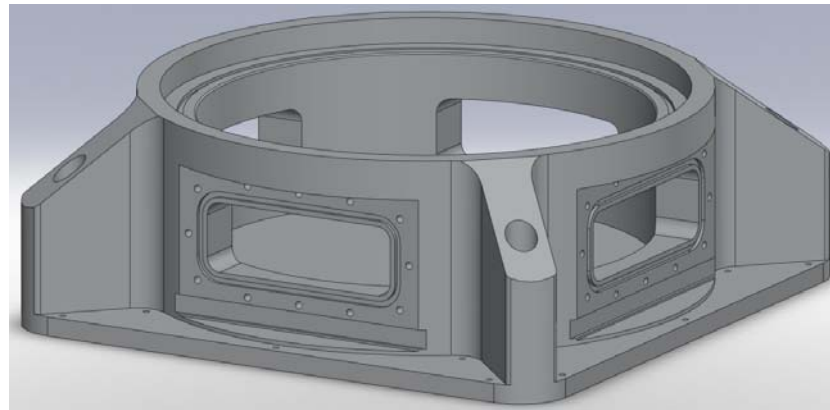
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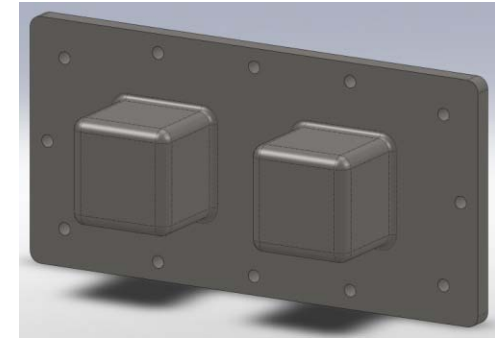
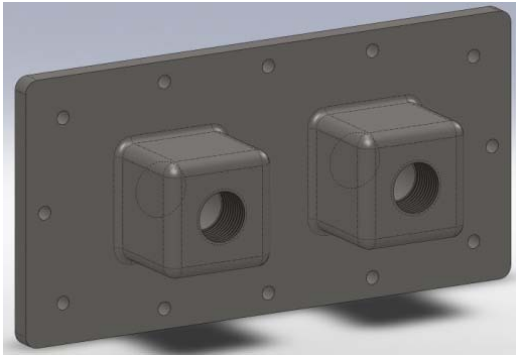


# DVC1 Monolithic Base

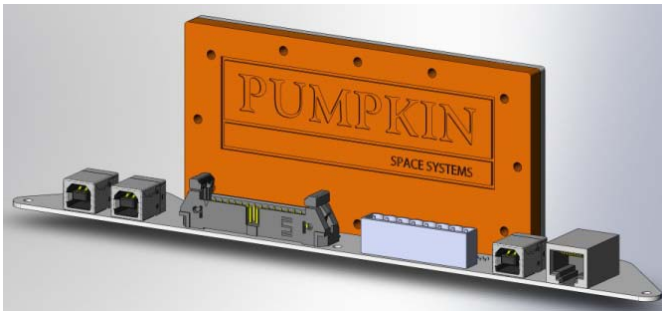
- Large interior volume for sensors, wiring and cabling, thermal components, etc.
- Al base is traditional material
- UHMW PE base allows good thermal insulation
- 4 ports allow modular access to interior
- Support securing to
  - Rubber isolators
  - Mounts on inch- and metric-pattern optical tables



# DVC1 Feedthroughs

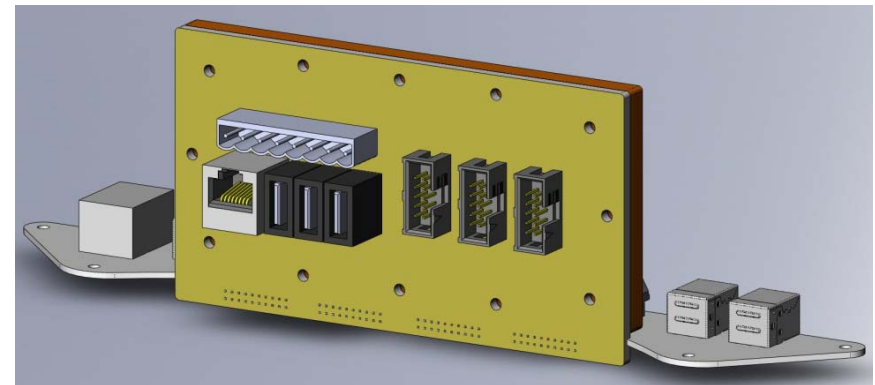
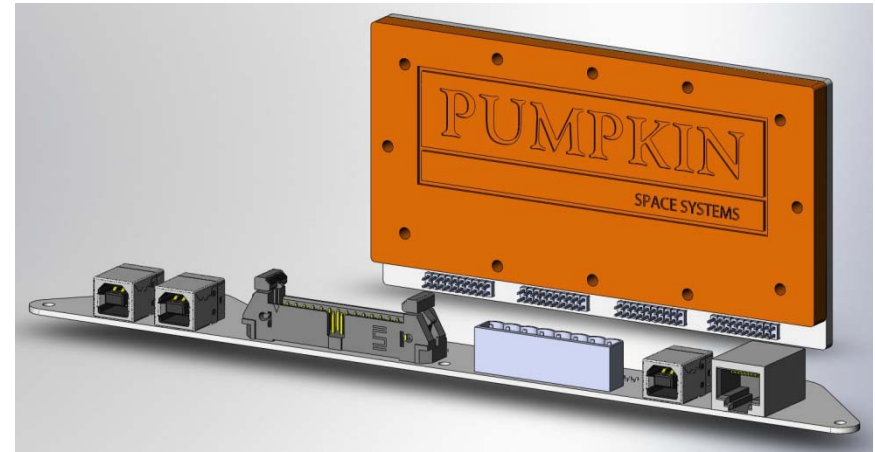


- SS feedthrough plate with ¼ in NPTF threaded holes
- SS unthreaded feedthrough plate for custom holes
- PCB-based multi-interface electrical feedthrough plate
- Al blanking plate



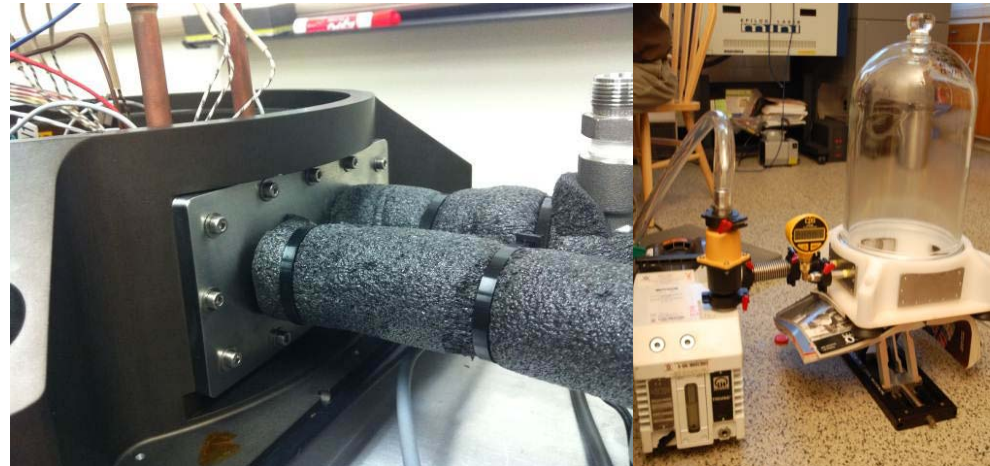
# DVC1 Electrical Feedthrough

- 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<sup>3</sup>/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 <sup>2</sup>	3,993 cm <sup>2</sup>
• Chamber volume:	1,002 in <sup>3</sup>	16,413 cm <sup>3</sup>

# 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  $1\text{E}-3$  Torr) and hot cathode ( $3\text{E}-3$  to  $5\text{E}-10$  Torr)



KJ Lesker 979  
atm to  $1\text{E}-10$  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



# 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 + Teflon 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



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Slide 16







## Q&A Session

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



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Slide 17



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Slide 18



# 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](mailto: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.

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Slide 19