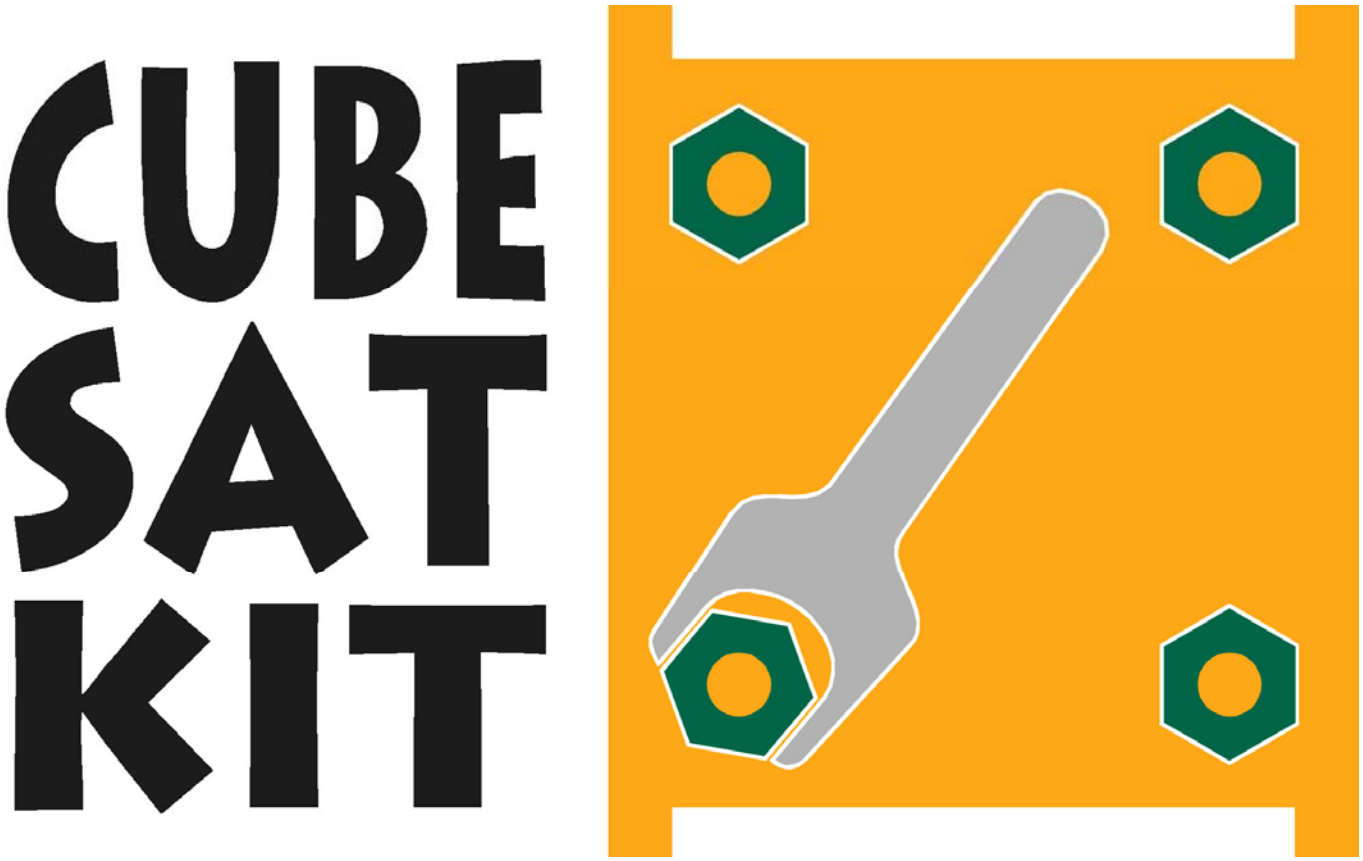


Overview of the 4th-generation CubeSat Kit™ Processor Architecture

Andrew E. Kalman, Ph.D.

Outline

- Part I: FM430 Generations I - III
- Part II: Gen. IV Peripheral Enhancements
- Part III: Gen. IV Core Enhancements
- Part IV: Gen. IV & the Future

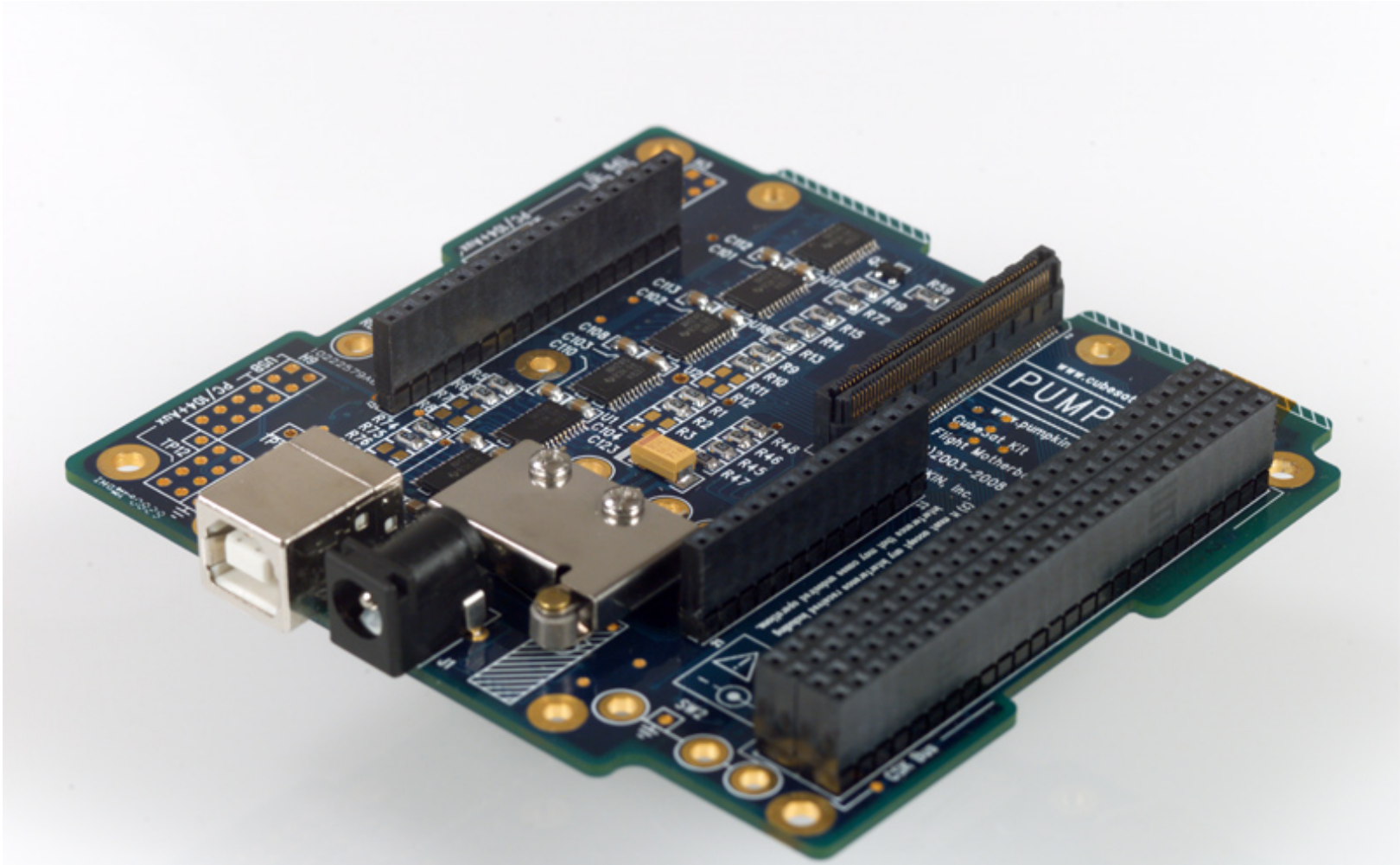
FM430 Generations I - III

Feature / Characteristic	I	II	III
CubeSat Kit Bus Connector	80 pins	104 pins	104 pins
Operating voltage	+3.3V		
Processor	MSP430F149	MSP430F169	MSP430F1611 MSP430F1612
Program & data memory	60KB & 2KB	60KB & 2KB	50KB & 10KB 55KB & 5KB
MSP430 DMA (x3) & DAC12 (x2)	No	Yes	Yes
MHX socket	Yes		
MHX socket compatibility	MHX-xx00 series		
USB (FT232BL)	Yes	Yes	Yes
SD Card socket & Flash File System	None	Not Really	Yes, < 1Mbps
+5V input protection	None	OV	OV, OC & RV
Auto-reset latchup protection	None	None	On 3 subsystems
Peripheral power control	MOSFET	MOSFET	MAX890L & BJT
Used with CubeSat Kit structure	2nd gen.	2nd & 3rd gen.	2nd - 4th gen.
PCB plating	Pb/Sn	Pb/Sn	Au flash
Flight heritage	None	**Libertad-1**	**Delfi-C3**

Gen. IV Peripheral Enhancements

Peripheral	Gen. IV
MHX socket compatibility	MHX-xx20 series (MHX-2400 is obsolete)
USB (FT232RL)	User-selectable CBUS2 & CBUS4 features
Real-time clock (I2C)	M4T81 series, with Alarm, IRQ, etc.
I2C pull-ups	To VCC, VCC_SYS or +5V_SYS
Backup battery	3V Lithium BR1225, user-replaceable
PCB corners	Rounded!

Part II – cont'd



Gen. IV CubeSat Kit Flight Motherboard (FMB)

Gen. IV Core Enhancements

Issue	Gen. IV Solution
Fixed +3.3V operating voltage	+2.8V to +5V power & I/O voltages (+1.8V to +5V via LV RTC change)
MHX supply fixed at +5V	PWR_MHX @ +5V_SYS or VCC_SYS
SD Card supply fixed at +3.3V	VCC_SYS @ +3.3V or user-defined
SD Card SPI data rate limited to < 1Mbps	>10 Mbps SPI clock rate (active isolation)
MSP430 program memory “not big enough” @ 60KB	Completely decouple processor, clocks, reset circuitry, USB lines and power system from Flight Mother Board and move it onto the Flight Processor Module
MSP430 “not fast enough” @ 8MHz	
MSP430F16x I2C port requires off-board isolation for concurrent SD Card operation	
Potential CubeSat Kit users unable to take advantage of CubeSat Kit features due to existing hardware and software IP centered on other architectures (e.g., 8051, AVR, PIC, M68xx, ARM7, Linux, BlackFin, other DSP, FPGA, rad-hard, etc.)	
FM430 processor change requires purchase of another FM430	
Some Flight Processor peripherals (e.g. ¾ of Gen. I - III FM430’s ADC12) unavailable due to multi-purpose pins	100-pin FPM connectors frees 40 of 48 I/O pins on CubeSat Kit Bus, enables dedicated peripheral control lines

Part III – cont'd

To/From Flight MCU on Processor Module

H10
LSS-150-02-L-DV

<->	IO.23	1	2	IO.47	<->
<->	IO.22	3	4	IO.46	<->
<->	IO.21	5	6	IO.45	<->
<->	IO.20	7	8	IO.44	<->
<->	IO.19	9	10	IO.43	<->
<->	IO.18	11	12	IO.42	<->
<->	IO.17	13	14	IO.41	<->
<->	IO.16	15	16	IO.40	<->
<->	IO.15	17	18	IO.39	<->
<->	IO.14	19	20	IO.38	<->
<->	IO.13	21	22	IO.37	<->
<->	IO.12	23	24	IO.36	<->
<->	IO.11	25	26	IO.35	<->
<->	IO.10	27	28	IO.34	<->
<->	IO.9	29	30	IO.33	<->
<->	IO.8	31	32	IO.32	<->
<->	IO.7 *	33	34	IO.31	<->
<->	IO.6 *	35	36	IO.30	<->
<->	IO.5	37	38	IO.29	<->
<->	IO.4	39	40	IO.28	<->
<->	IO.3 *	41	42	IO.27	<->
<->	IO.2 *	43	44	IO.26	<->
<->	IO.1 *	45	46	IO.25	<->
<->	IO.0 *	47	48	IO.24	<->
	+5V_USB	49	50	+5V_USB	
	+5V_SYS	51	52	+5V_SYS	
	VCC_SD	53	54	VCC_SD	
	VCC	55	56	VCC	
	DGND	57	58	DGND	
	AGND	59	60	AGND	
	VBATT	61	62	VBATT	
	VBACKUP	63	64	VBACKUP	
	VREP0	65	66	-FAULT_OC	-->
	VREP1	67	68	SENSE	-->
	VREP2	69	70	-RESET	<--
	RSVD0	71	72	OFF_VCC	<--
	RSVD1	73	74	SDA_SYS	<->
	RSVD2	75	76	SCL_SYS	-->
-->	USBDP/CB4	77	78	USER0	
-->	USBDM/CB2	79	80	USER1	
<--	-ON_SD	81	82	USER2	
<--	-ON_MHX	83	84	USER3	
<--	-OE_MHX	85	86	USER4	
<->	-OE_USB/-INT	87	88	USER5	
-->	HS0	89	90	USER6	
-->	HS1	91	92	USER7	
-->	HS2	93	94	USER8	
<--	HS3	95	96	USER9	
<--	HS4	97	98	USER10	
<--	HS5	99	100	USER11	

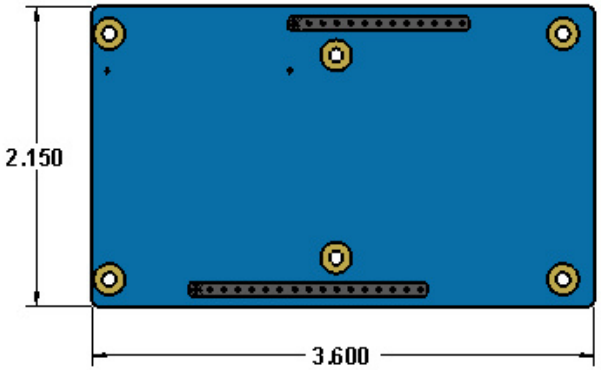
Gen. IV CubeSat Kit Flight Processor Module connector on Flight Motherboard.

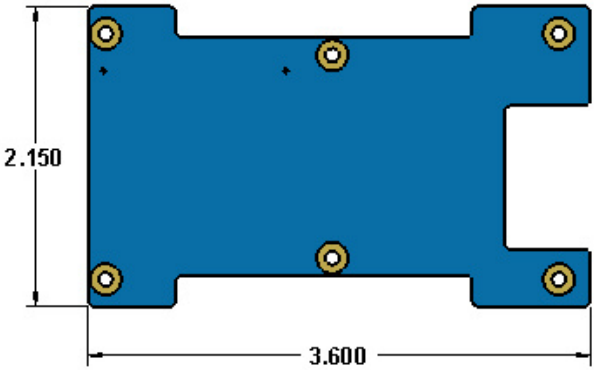
40 of 48 I/O pins are unallocated and always available to the user.

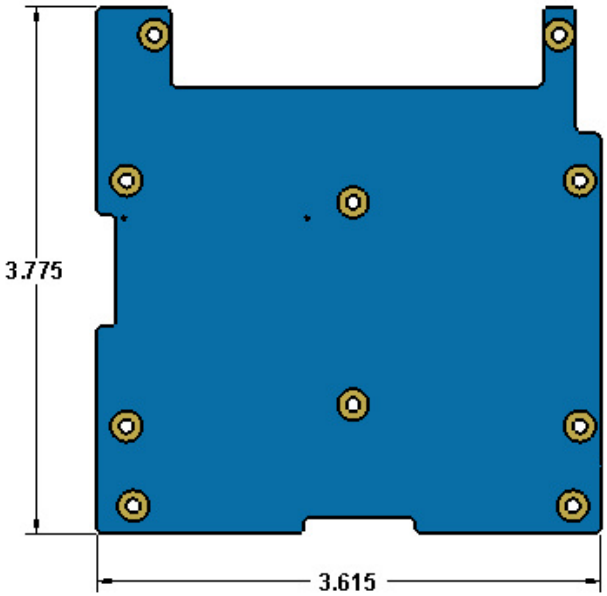
On-board peripherals have dedicated control signals (e.g., handshake signals HS[5..0], -ON_SD, etc.).

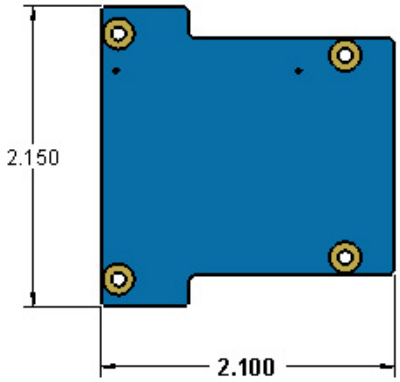
Entire CubeSat Kit Bus connector is available to Flight Processor.

Part III – cont'd



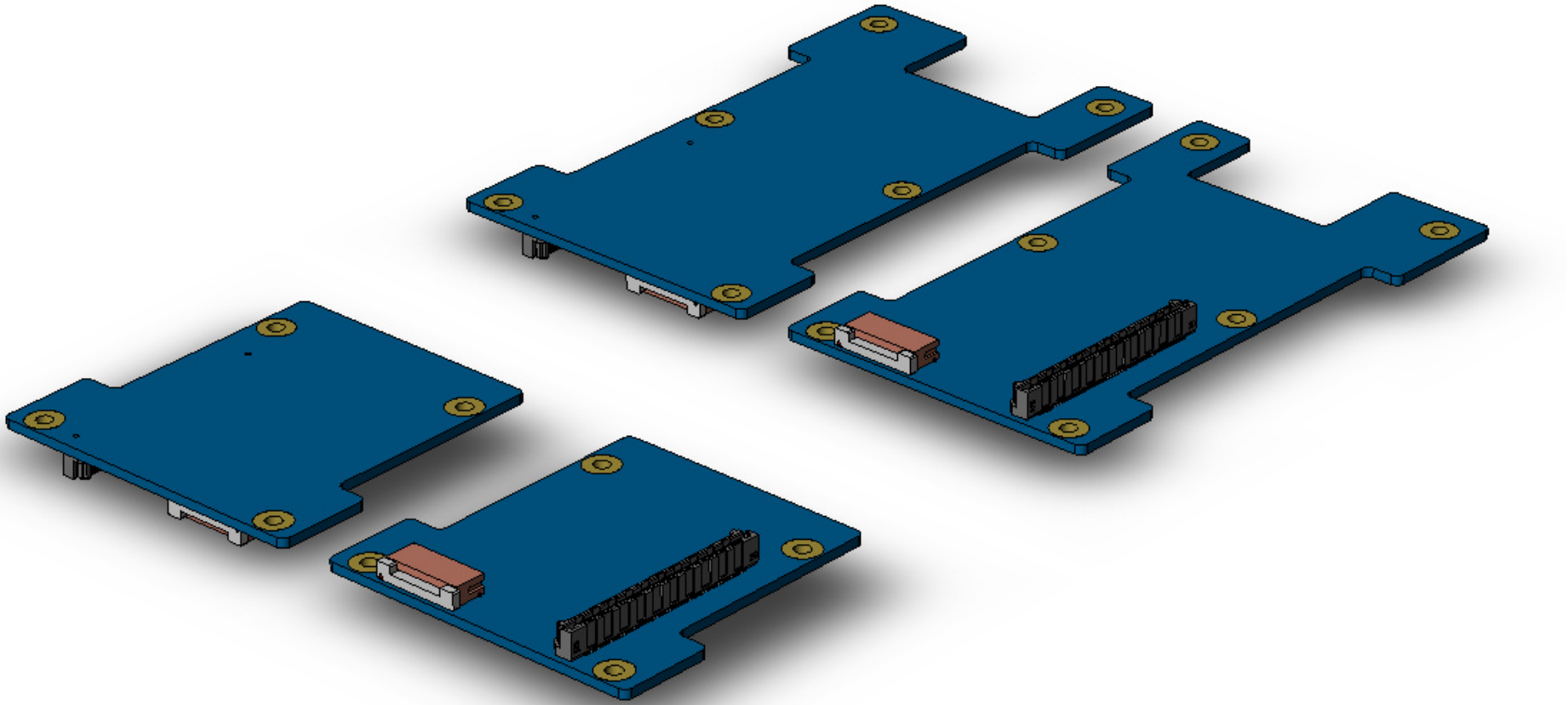






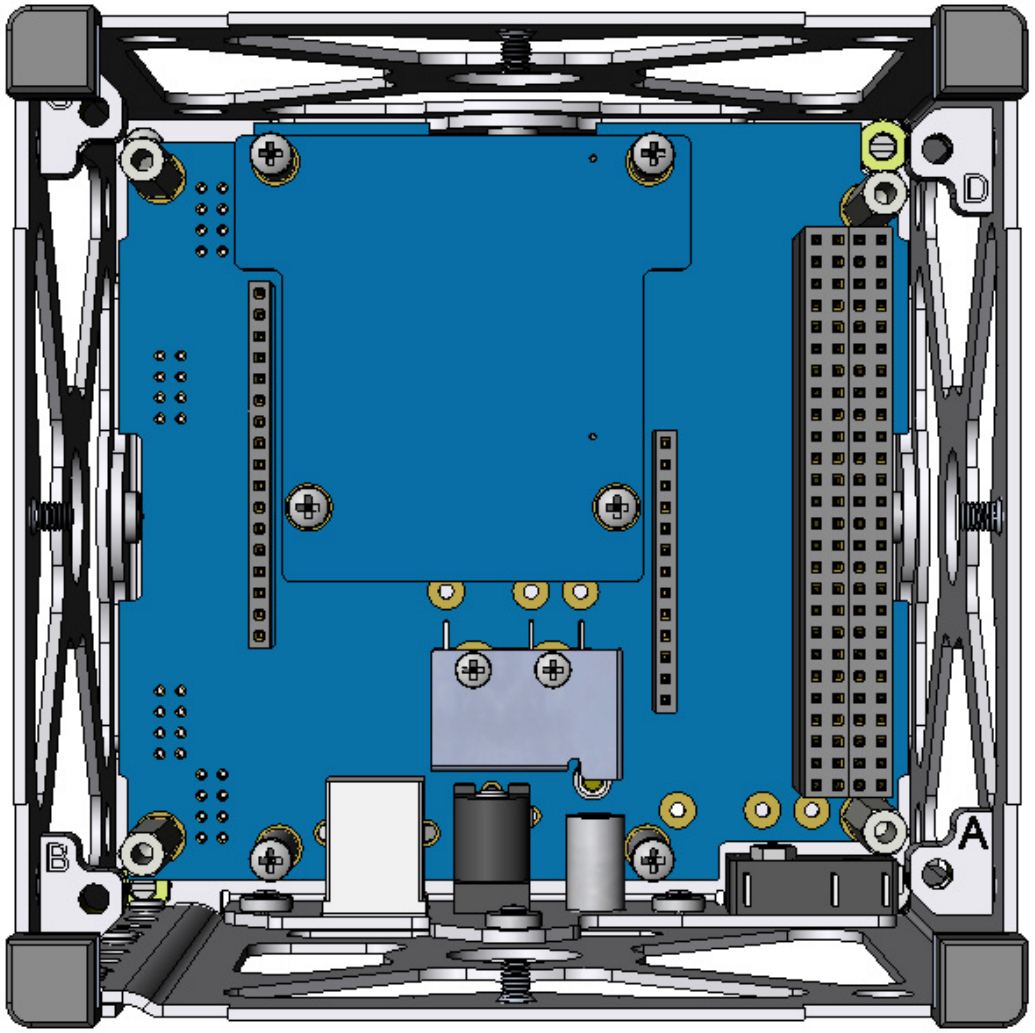
Examples of Flight Processor Module (FPM) PCB outlines for Gen. IV CubeSat Kit.

Part III – cont'd



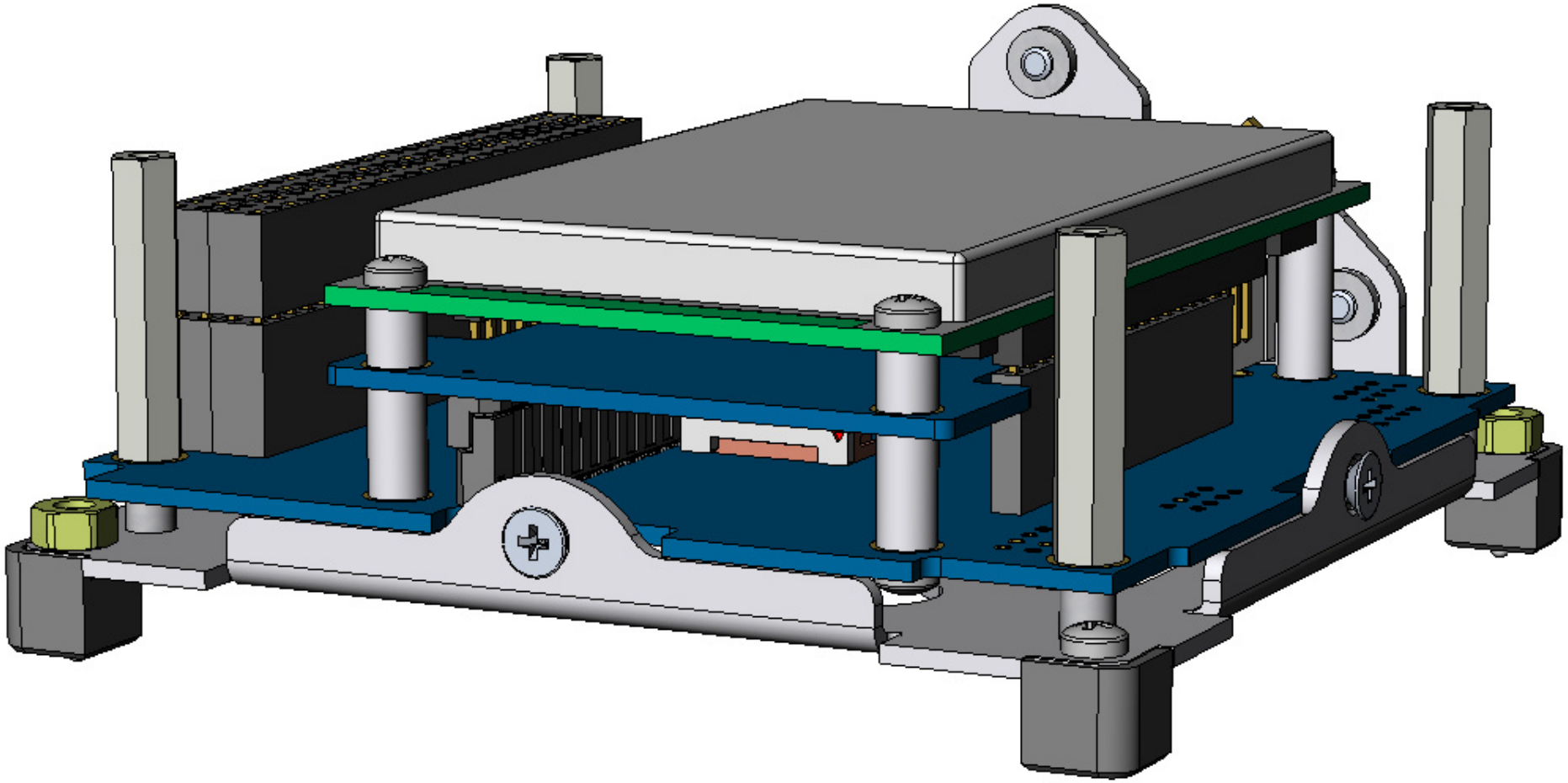
Top and bottom views of bare example Flight Processor Module (FPM) PCBs for Gen. IV CubeSat Kit.

Part III – cont'd



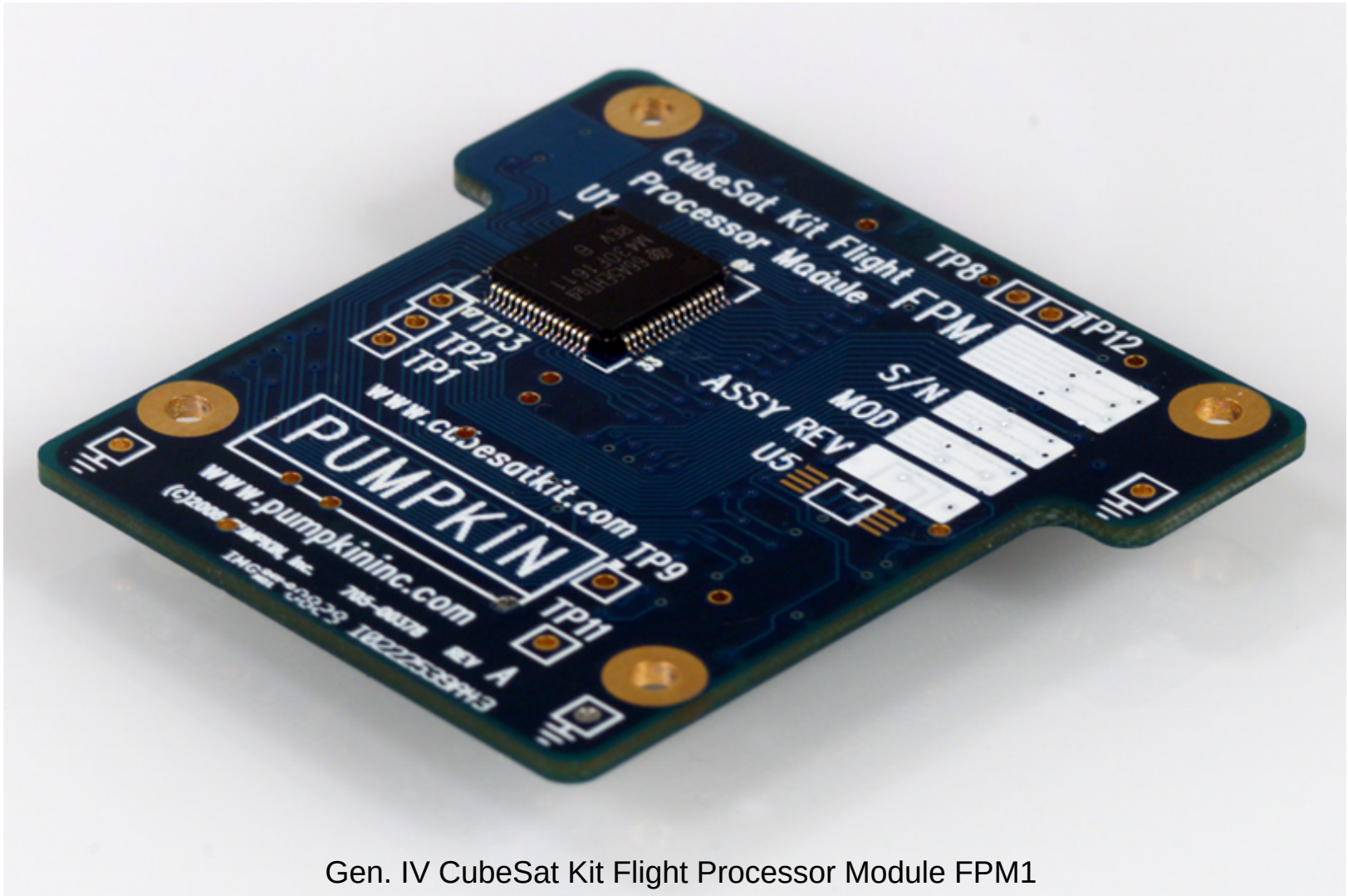
Top view of Flight Processor Module (FPM) mounted on Flight Motherboard (FMB) inside 1U skeletonized CubeSat Kit.

Part III – cont'd



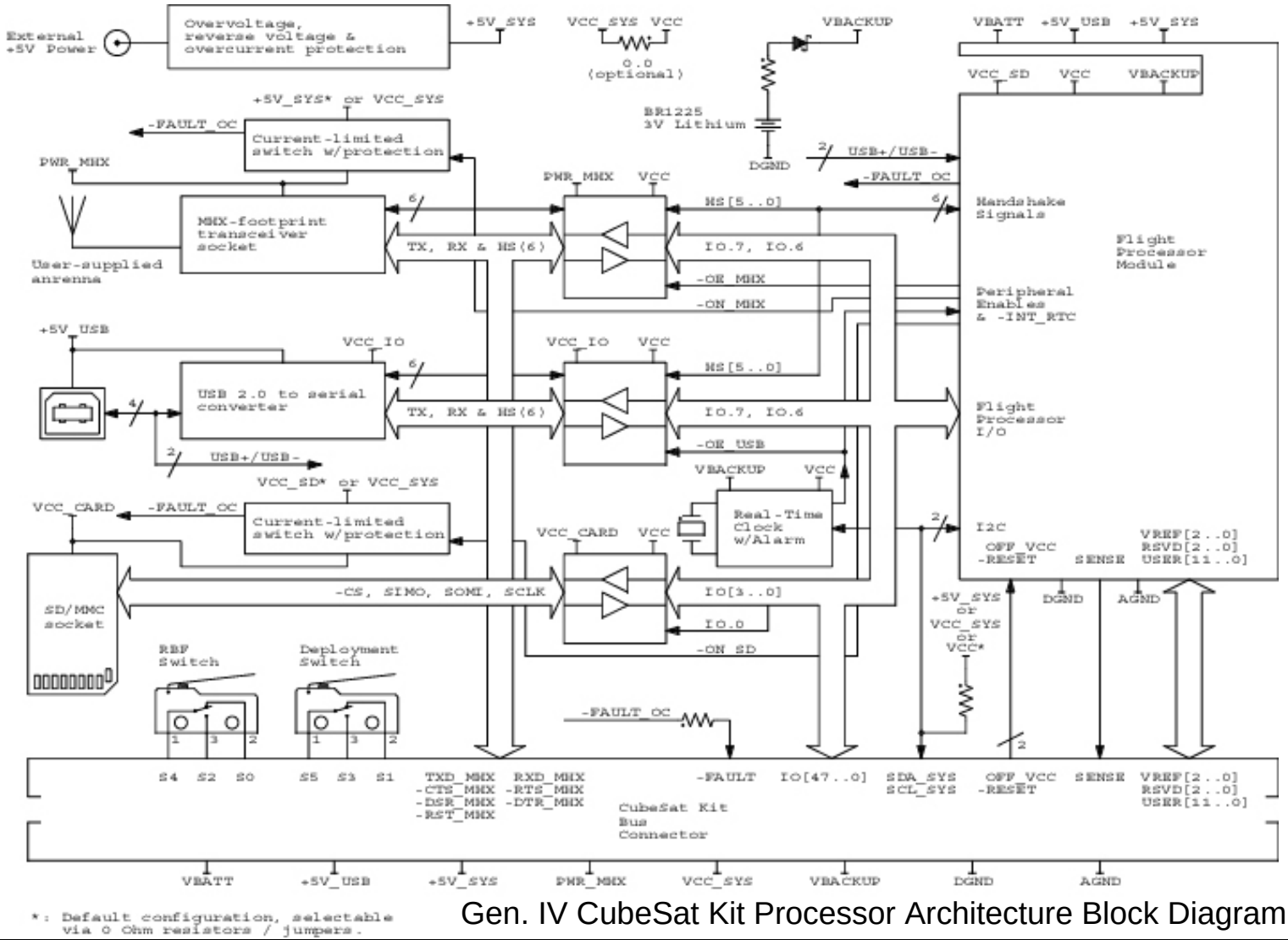
Flight Processor Module (FPM) mounted between Flight Motherboard (FMB) and MHX-2420 transceiver.

Part III – cont'd



Gen. IV CubeSat Kit Flight Processor Module FPM1

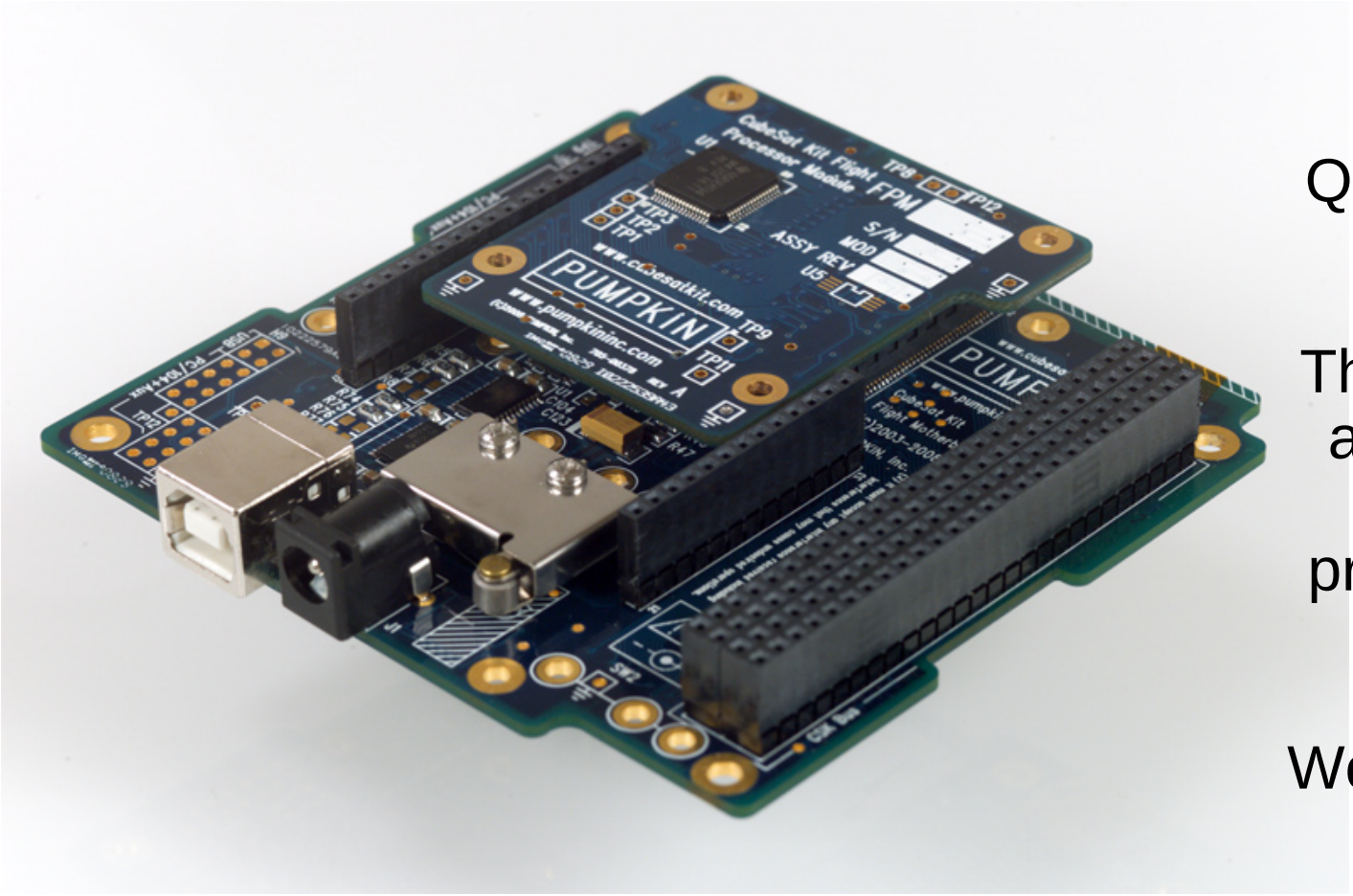
Gen. IV and the Future



Gen. IV CubeSat Kit Processor Architecture Block Diagram

Part IV – cont'd

- Virtually ***any*** microprocessor / microcontroller / CPU can be used as a CubeSat Kit's Flight Processor.
- Single-chip micros, processors with external memory, multi-processor systems, CPU+SDR, CPU w/TMR Flash memory, etc. are all candidates for FPM integration. If it fits within the physical and power envelope of the open FPM specification, you ***can*** fly it!
- Existing software ***and*** hardware designs can be ported to the CubeSat Kit with the design of an appropriate Flight Processor Module.
- FPM design relatively straightforward. E.g., MSP430F26xx FPM design required 26 hours layout time, weighs 10g. Has 116KB Flash, 8K RAM, 2 USCI (UART/LIN/IrDA/SPI and I2C/SPI), etc.



Q&A Session

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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 two United States patents and is a consulting professor in the Department of Aeronautics & Astronautics at Stanford University. Contact Dr. Kalman at aek@pumpkininc.com.
- Acknowledgements
  - Pumpkin's Salvo and CubeSat Kit customers, whose real-world experience with our products helps us improve and innovate.
- CubeSat Kit information
  - More information on Pumpkin's CubeSat Kit can be found at http://www.cubesatkit.com/.
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First presented at the CubeSat Developers' Workshop in Logan, Utah on Sunday, August 10, 2008, prior to the 22nd Annual AIAA/USU Conference on Small Satellites.