PUMPKIN™
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NPB-1
New Product Brief

CubeSat Kit (Proposed)

Important Notice As of 2004, Pumpkin now offers a complete off-the-shelf CubeSat Kit for sale at http://www.cubesatkit.com/. The CubeSat Kit is an evolution[1] of the original kit proposed in this document. All information on the CubeSat Kit, including brochures, user manuals, technical drawings, drivers, etc. can be found on the CubeSat Kit website.

This notice is provided because of the legacy and search engine value of this document. Interested parties are advised to only skim this document, as the current CubeSat Kit differs substantially from this proposal in a variety of ways.

Introduction

Pumpkin, Inc. is considering adding a CubeSat satellite kit to its product lineup. *This kit, consisting of hardware, software and software tools, combined with other third-party development tools, is a turnkey solution for developing CubeSat satellites.* If sufficient interest in this kit is generated by the end of 2000, it will enter the Pumpkin product lineup.

Background

The goal of the CubeSat project (http://ssdl.stanford.edu/cubesat/) is to deliver 1kg payloads in a 10cm cubed package into earth orbit at low cost. Groups at Stanford University (http://ssdl.stanford.edu/) are already using Pumpkin's Salvo Real-Time Operating System (RTOS) on other satellite projects (e.g. EMERALD).

Salvo is particularly well-suited to CubeSat because of the tight mass and power constraints placed on each satellite, and the resultant limited choice of computing elements. By using low-

power, single-chip microcontrollers, a CubeSat's available payload can be maximized. We feel that Salvo, when combined with Microchip's (http://www.microchip.com/) PICmicro devices, is a perfect fit for the CubeSat.

Another Salvo advantage becomes clear when considering CubeSat's tight scheduling requirements (first launches in Q3 2001). Programming a CubeSat in C with an RTOS should substantially shorten development times compared to other programming methodologies.

Design Partnership

Pumpkin is partnering with design MASSIF to bring you the CubeSat kit.

Figure 1: CubeSat Kit Partners

Pumpkin has over 15 years experience in analog and digital hardware design and development, embedded programming and product design. Pumpkin will supply software, electronic hardware, documentation and web space for the project. design MASSIF has over 15 years of experience taking products from concept to market. design MASSIF's primary responsibility will be the mechanical design and packaging of the CubeSat kit. Both companies are actively involved in multiple projects in Silicon Valley.

Motivation

Both Pumpkin and design MASSIF are very excited to be involved in a space-related project, and are eager to see the CubeSat kit deployed into space. Additionally, Pumpkin is eager to promote Salvo as the premier RTOS solution for embedded, single-chip microcontrollers.

Figure 2: Salvo Tagline

The CubeSat Kit

We are proposing two CubeSat kits – an engineering model kit and a flight model kit. The engineering model kit is comprised of:

- Engineering model mechanical assembly (chassis)
- Engineering model main PCB with Microchip PIC16F877 microcontroller, oscillator, voltage regulator, breakout connectors, etc.
- Breakout PCB for connecting main PCB to PC-based software development system running Microchip MPLAB-ICD in-circuit debugger
- User PCB for adding your own electronics to the CubeSat
- Salvo RTOS
- Coupon for $350 off regular $850 price of HI-TECH PIC C compiler (required for use with Salvo)
- Documentation[2] (engineering drawings, schematics, etc.)

The flight model kit contains:

- Flight model mechanical assembly (chassis)
- Flight model main PCB with Microchip PIC16F877 microcontroller, oscillator, voltage regulator, breakout connectors, etc.
- User PCB for adding your own electronics to the CubeSat

As a CubeSat kit user, it's up to you to supply:

- Power source (e.g. batteries and/or solar cells)
- A custom user PCB, if required
- Additional PCBs for your own electronics
- Additional mechanical, electrical and other components

Customizable Architecture

We envision two distinct groups of CubeSat users:

- One group will find the processing power of the PICmicro on the main PCB to be adequate for their satellite(s). The CubeSat kits contain everything needed to develop a working satellite using a single 8-bit microcontroller.
- The other group will want much more processing power and sophistication than the PICmicro can deliver. For these groups, we suggest viewing the PICmicro as a sort of "system supervisor", with the primary functionality of the satellite handled by additional processor(s) on user-supplied PCBs. Most of their programming effort will be directed towards the development of software for these additional processors, using user-supplied third-party tools.

CubeSat kit users should consider the main PCB to be "closed" – i.e. during development no changes should be made to it, other than reprogramming the PICmicro device. Users are free to add to and/or modify the user PCB as they see fit. The user PCB contains a protoboard area, as well as pads to connect the system's power supply, etc. Users can even replace the user PCB with one or more of their own design. The breakout connector from the main PCB to the user PCB has all of the PICmicro's I/O pins, as well as various system signals like GND, PWR, etc. Therefore users have complete flexibility in terms of which parts of the CubeSat are connected to the PICmicro on the main PCB.

Additional processors (e.g. 32-bit microprocessors running embedded Linux) can be added via user-supplied user PCBs and/or additional PCBs. Communications with the main PCB, via serial link, SPI, I^2C, parallel slave port (PSP) or other means are possible over the breakout connector and appropriate programming of the PICmicro and the additional processor(s).

The primary voltage regulator,[3] located on the main PCB, will be oversized (1A output) to be able to supply the entire CubeSat with regulated power from the user's power supply.

Low-Cost Development Environment

The CubeSat engineering model kit is designed to interface directly to Microchip's MPLAB-ICD low-cost in-circuit development kit for the PIC16F87X series of PICmicro single-chip microcontrollers. MPLAB-ICD, together with Microchip's free

MPLAB-IDE integrated development environment, provides the user with a powerful means of debugging source code in an application, testing and debugging hardware and programming the target device, all through the PC's serial port.

To develop the engineering model, you:

- Attach the breakout PCB to the CubeSat's main PCB,
- Power the breakout PCB with a 9Vdc off-the-shelf power supply,[4]
- Connect the MPLAB-ICD's 6-wire communications cable to the breakout PCB,
- Connect a serial cable between the MPLAB-ICD and the development PC, and
- Optionally connect a serial cable between the development PC and the serial port(s) on the breakout PCB.

Then you edit, compile, download and test your multitasking Salvo application from within MPLAB. You can set breakpoints, watch registers, step through source code, examine I/O ports, measure timed events, etc. All of this is done without disturbing any components on the main or breakout PCBs.

Note The engineering kit is also designed to work with Microchip's more powerful[5] in-circuit emulators, PICMASTER and MPLAB-ICE.

Note The entire CubeSat Kit software development environment runs on IBM PC-compatible computers. Other platforms are not fully supported.

Chassis

We have designed an aluminum chassis to fit within the CubeSat's design constraints. The advantages of the aluminum chassis are relatively light weight, complete design flexibility, durability, material conductivity, close manufacturing tolerances, and low cost.

Variances from existing proposals

We have chosen *not* to connect the PICmicro on the main PCB with the USB connector as per the original CubeSat proposal. We

do, however, fit the USB connector and provide a means of connecting it to the user PCB.

Engineering and Flight Models

Figure 3, below, is a preliminary exploded view of the flight model. This shows the skeletonized chassis, the main PCB and its cover, and the user PCB which mates to the main PCB via a 0.050" header.

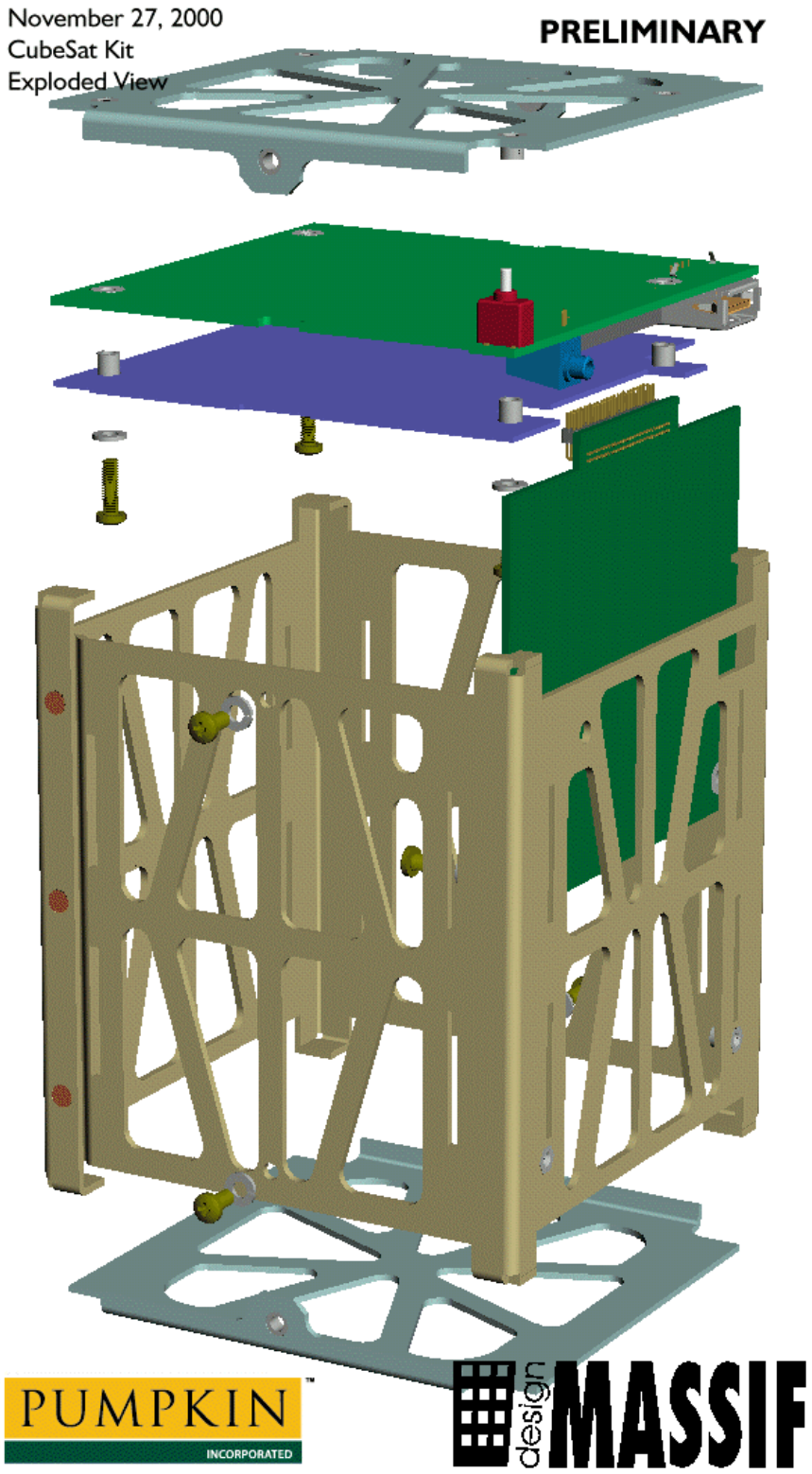

Figure 3: Exploded View, CubeSat Flight Model Kit (Preliminary)

Figure 4 below shows the assembled flight model. The "remove before flight" pin socket, the USB connector and the kill/interlock switch are all clearly visible in their final locations.

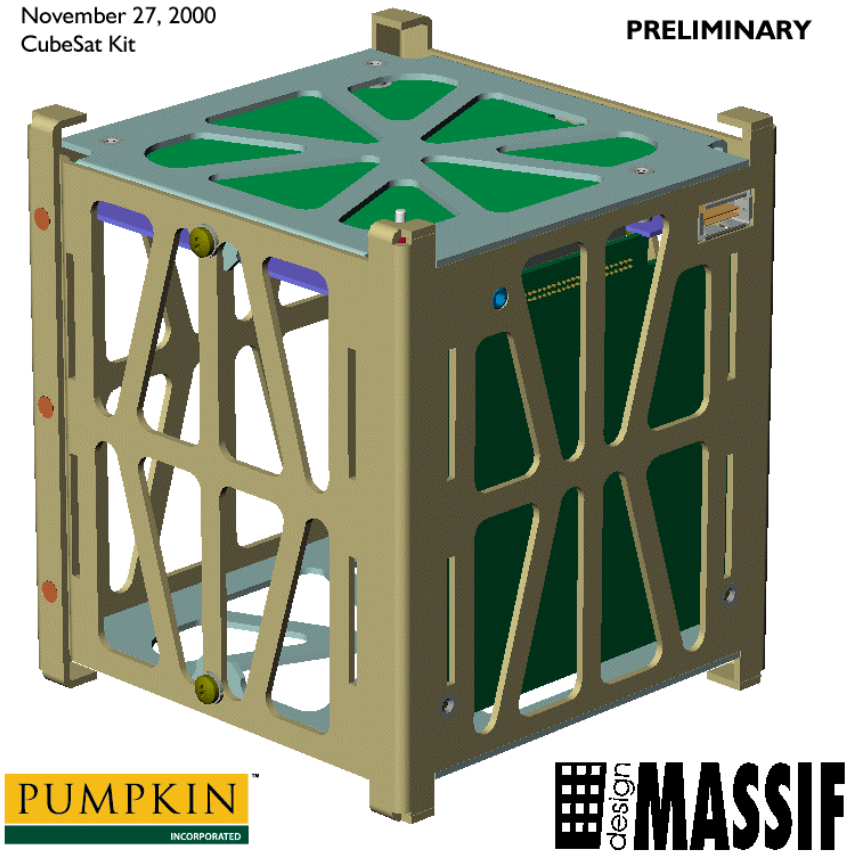

Figure 4: Assembled View, CubeSat Flight Model Kit (preliminary)

Mass and Volume

The 3D model of our CubeSat kit reveals the following preliminary data on the flight model:

- The skeletonized flight model, as in Figure 3, has a mass of 214 grams.
- The same flight model, but with solid walls on all 6 sides, has a mass of 309 grams.
- The mass of everything but the aluminum chassis, top and bottom covers and main PCB cover plates is 43 grams.
- The available volume inside is 738 cm^3.

Differences Between the Models

The primary differences between the two models are the PCB(s), and the extra items supplied with the engineering model. The flight model PCBs will not be designed for development or debugging – just for in-circuit programming. Flight model PCBs will have

tantalum capacitors in place of electrolytic ones, will be conformally coated, etc. There will be some minor variations in the lower cover where the main PCB is located.

Issues Facing the CubeSat Kit

Mechanical

There are many as yet unresolved issues facing the mechanical design. Some of them are listed below:

- How much skeletonizing should be done on the CubeSat's six sides?
- Are two panhead screws on each of two opposing sides an acceptable method for securing the top and bottom covers? Or will they interfere too much with solar panels?
- How do kit users plan to secure their hardware inside the CubeSat chassis? Do they want a regular array of pre-punched holes and/or standoffs?
- Do kit users want a series of card guides built into the CubeSat chassis to facilitate the mounting of additional PCBs?

Electrical

Similarly, there are also many as yet unresolved issues facing the electrical design. Some of them are listed below:

- Do kit users feel that the PIC16F877 is adequate for their basic needs? Salvo will consume approximately 1K ROM and 1 bank (96 bytes) of RAM for a typical application, leaving 7K ROM and 3 banks of RAM for the application.
- What speed should the PICmicro run at? 20MHz? 4MHz?
- Is a real-time clock option via an external 32.768kHz crystal desired?
- What voltage should the main PCB run at? 5V? 3V? User-selectable?
- Is some on-board non-volatile memory desired?
- Should the USB connector be placed on the main PCB, with access through the breakout connector, or

should the USB connector and all associated circuitry be left to custom user PCBs?

- Should the basic user PCB be designed as a passive, non-stackable, 8-bit PC/104 card? This would allow easy interfacing to the PICmicro through its Parallel Slave Port (PSP), and also provide a mechanical means for mounting additional PC/104 cards.
- Should PCBs stack parallel to the CubeSat's end covers, or parallel to a pair of sides? Is it acceptable to have user PCBs perpendicular to the main PCB, or should they all be parallel, a la PC/104 stacking model?

Design Target: Year's End 2000

Pricing

We propose the following preliminary pricing for the CubeSat kit:

- Engineering model: $1,645
- Flight model: $1,195

Note The engineering model's pricing includes a one-year subscription to the full version of Salvo, which retails for $1250. Salvo is royalty-free, and includes source code.

The total outlay for a CubeSat kit and the required third-party tools, complete with an engineering model and a flight model, is therefore:

Pumpkin CubeSat engineering model kit (includes Salvo)	$1,645.00
HI-TECH PIC C compiler[6]	500.00
Microchip MPLAB-ICD in-circuit development system[7]	159.00
Microchip MPLAB integrated development environment[8]	free
Pumpkin CubeSat flight model kit	1,195.00
Total:	$3,499.00

Additional flight models can be purchased separately so that the incremental cost to a CubeSat development program is just the cost of additional flight models. Those who already have PIC C and/or MPLAB-ICD will realize additional savings.

As a special limited-time offer, we will accept 25% deposits for CubeSat engineering and flight model kits in return for a 10% discount off the purchase price.

Timetable

We wish to fabricate first articles of the CubeSat kits locally in the Northern California Bay Area. Currently, lead times are approaching 8 weeks. Therefore, we wish to have the mechanical and electrical designs of the engineering kit *finalized by Dec 31, 2000*, and those of the flight kit finalized shortly thereafter.

We plan to deliver engineering kits in March 2001, and flight kits 1-2 months later.

Discussion Forums

A series of CubeSat User Forums have been created on the Pumpkin web site for the express purpose of discussing issues that surround the CubeSat kit. Announcements, notices, links to relevant files, etc. will all be posted to the Forums.

To access the forums, choose the Forums link from Pumpkin's home page. New users must register before they are allowed to post new topics or reply to existing ones.

Note We would like *all* discussions regarding the CubeSat kit to take place in the Forums, not via private email.

New Developments – 2002

Since this proposal was first written, Pumpkin's core business (the Salvo RTOS) has expanded to include Salvo distributions for processors other than PICmicro® MCUs. Salvo now supports the 8051 family as well as TI's MSP430. This means that the electronic portion of the CubeSat kit could be implemented with a variety of different processors. Note that some of these processors are (only) available in 3V versions (i.e. no 5V I/O).

Furthermore, the total outlay per kit (see *Pricing*, above) will differ because of differences in compiler / IDE and debugging tools costs.

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Microchip Technology Inc.	http://www.microchip.com/
Digi-Key Corporation	http://www.digi-key.com/

[1] The fourth major design revision, actually.
[2] Flight model documentation is contained in the engineering model kit.
[3] Low-dropout, LM294X series.
[4] The Microchip PICSTART Plus power supply can also be used. This power supply can power the entire engineering model.
[5] And much more expensive.
[6] Normally $850, but available for $500 with coupon enclosed in Engineering Model kit.
[7] Available through Digi-Key and other sources.
[8] Downloadable from Microchip's web site.