# The Space E-Commerce Revolution

**Craig Clark**
**Clyde Space Ltd**
**1Technology Terrace, West of Scotland Science Park, Glasgow G20 0XA; +44 (0) 141 946 4440**
**craig.clark@clyde-space.com**

## ABSTRACT

In the 1990s, the space community witnessed the revolution that is now the Small Satellite market. Small satellites were initially written off as not being large enough to have any real practical function; however, since the early 2000s, space companies large and small have been falling over themselves to get involved in Small Satellites. This class of spacecraft has proven to be very much more useful than the sceptics proffered. With the Small Satellite market doing very good business, many of us within the Small Satellite community are now wondering where the next revolution will come from. Most think that the smart money is on Picosatellites and Nanosatellites, but this class of spacecraft has yet to prove its technical capability, but it is clear that it is fast becoming the most economically viable method of accessing space.

This paper examines the commercial world of picosatellites. In particular, we will look at how the approach to standardisation on platforms such as CubeSats has resulted in the evolution of internet sales of satellite subsystems. As a direct result of standardisation, it has become viable for space companies to produce relatively large numbers of the same subsystem and, as a result, drive down the cost of those systems. This is forcing companies involved in the Picosatellite market to look to alternative methods of doing business in order to help reduce these costs even further. Ecommerce is turning out to be the ideal tool for selling microspacecraft subsystems and it has a huge number of benefits that help the customer make their product selection and also to provide after-sales support. Once picosatellites have proven their technical viability as a useful platform, the next revolution in spacecraft could well already be underway and it looks likely to be a web-based space market.

## INTRODUCTION

Following a rapid growth in the number of picosatellite and nanosatellite missions over the last 12 to 18 months, the number of off-the-shelf subsystems and services available for microspacecraft missions has also grown dramatically. This growth in demand for microspacecraft related hardware is leading to changes in the way that spacecraft hardware is being bought and sold.

In 2007, Clyde Space completed the development of their first 'CubeSat' subsystem. It was an Electrical Power System (EPS) that was physically and electrically compatible with the standard CubeSat format, and also compatible with the CubeSat Kit (from Pumpkin, Inc.). This standardisation of size and electrical connections has meant that it was possible for Clyde Space to produce the EPS in relatively large numbers; for example, our current production run is for 50 units. Due to the ability to mass produce a satellite subsystem such as this, the cost of the system is now low enough to be purchased outright with a credit card.

In fact, the author would love to say that the idea of credit card sales for CubeSat systems was his, but the reality is that most of our CubeSat customers want to pay with credit card and regularly request to do so. Therefore, it is the market that is driving the change in the way that these systems are sold, but with this change will come opportunity to make significant steps forward in microspacecraft cost, schedule and engineering design.

Within the next two years, we predict that it will be possible to perform the spacecraft systems design on our website, add the required subsystems to the online basket and then proceed to the check out to buy with a credit card.

In this paper the author will discuss the current changes that have been implemented to Clyde Space processes in order to satisfy the needs of microspacecraft producers. We will also discuss to the plans that we have to develop this capability into an online tool that will significantly reduce the cost and development time of space missions.

## INDEPENDENT INTERNATIONAL STANDARDISATION

There has been much effort over the last few years to standardise electrical and mechanical interfaces on subsystems. The objective being to reduce the design and integration time that is currently required when putting a mission together, and also to directly (materials cost) and indirectly (in-house labour cost) reduce the cost of the mission. In particular, there has been substantial effort in the development of 'plug and play' standards for the Responsive Space programme.

The standardisation of larger spacecraft buses is perhaps more complex than on smaller spacecraft. But even when taking this into account, it is still impressive to witness how a small number of independent organisations have managed to come together to agree a microspacecraft standard that has now become an international blue-print for picosatellite and nanosatellite missions.

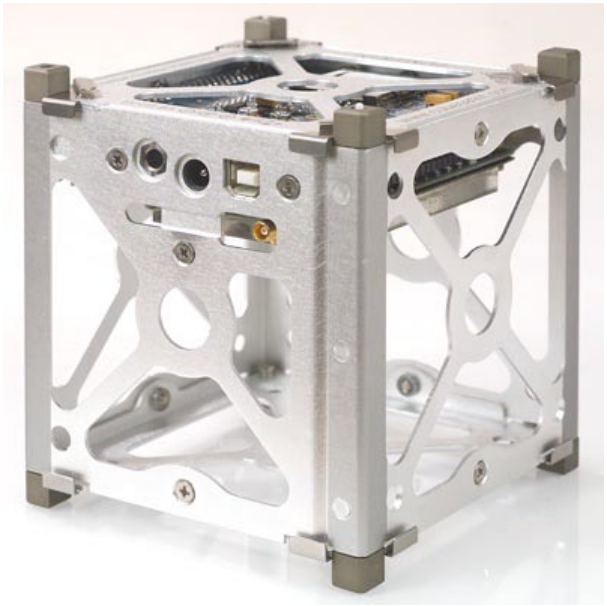

**Figure 1 CubeSat Kit structure from Pumpkin, Inc.**

The 10x10x10cm, 1kg (1U) CubeSat standard has evolved to become the basis for the most widely accepted family of picosatellite and nanosatellite designs. As a result of this standardisation, there are now regularly scheduled launch opportunities for CubeSats exist; 10s of CubeSats being launched every few months, and the number is increasing. The Calpoly 'P-POD' is the industry standard 'CubeSat' launch interface and the P-POD is finding its way to being a permanent passenger on most launch vehicles.

With the growing number of launch opportunities there are also a growing number of CubeSat missions (both activities are fuelling each other). Many of the missions are university projects where the spacecraft is used as a teaching tool, but there are also an increasing number of commercial and scientific missions. CubeSats are being viewed as an ideal platform to demonstrate the viabilities of new technologies in space. There is also an appetite with many involved in CubeSats to see just how far this size of platform can be pushed in terms of technological capability; it is very probable that there are still significant performance gains to be made with this platform and this will be demonstrated over the coming years.

The CubeSat picosatellite concept was originated by Professor Bob Twiggs who pioneered the concept of using very small spacecraft as an educational tool for universities, schools and other organizations. Our colleagues at Pumpkin, Inc. in San Francisco were quick to realise that there was opportunity to have a commercial interest in CubeSats and in 2003 sold its first CubeSat Kit. The latest revision of the CubeSat Kit 1U structure is shown in the picture opposite.

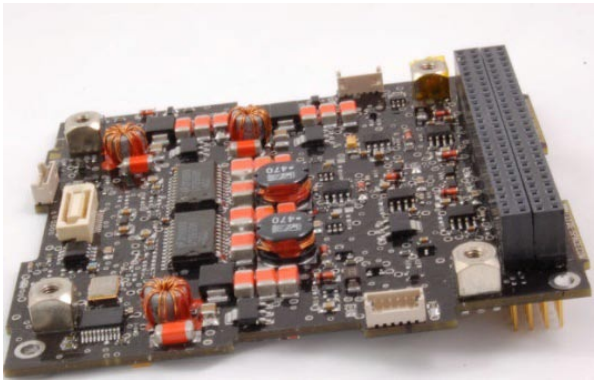

**Figure 2 1U CubeSat Power System without battery.**

The CubeSat standard has evolved since Prof Twiggs' original concept, and it is likely that it will continue to evolve, but there is now a community of parties with a vested interest in the specification of future direction of the CubeSat standard. The most interesting thing about this, however, is that this community seems keen to work together to take the CubeSat concept forward and progress is rarely hindered. This is perhaps a key factor in the success of this standard. As a result, there are an increasing number of commercial organisations producing CubeSat subsystems. Clyde Space is one of those organisations to see the attraction of this approach to spacecraft standardisation and the contrasting business model compared to the traditional space industry.

## WHERE CLYDE SPACE FIT IN

Clyde Space is a relatively young company, started in 2005 when founder, Craig Clark, became the first Surrey Satellite Technology Ltd (SSTL) employee to leave and start a spacecraft hardware business. Craig was Head of Power Systems at SSTL for many years, and Clyde Space was set up to provide Power Systems, batteries and solar panels for the small satellite community. At the time of starting Clyde Space, there was a real problem with CubeSat failures related to the electrical power system; it was clear to Craig that CubeSats should be the first in-house developed power system for Clyde Space.

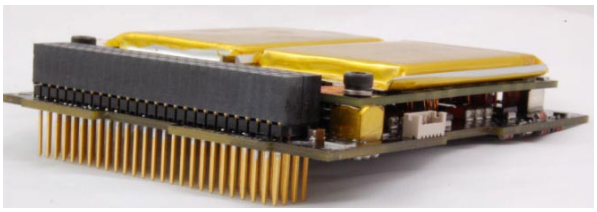

**Figure 3 1U CubeSat Power System with battery.**

Figure 2 shows the latest revision of the Clyde Space EPS. There are currently over TWENTY 1U EPS boards with customers and a further 50 in production. Some key features of the CubeSat EPS include Peak Power Tracking of the solar arrays with integrated charge management, regulated 5V and 3.3V, over current protected voltage buses and I2C for telemetry and telecommand. The system is designed for increased reliability, through careful design and selection of commercial components (to mitigate problems relating to radiation tolerance, etc.).

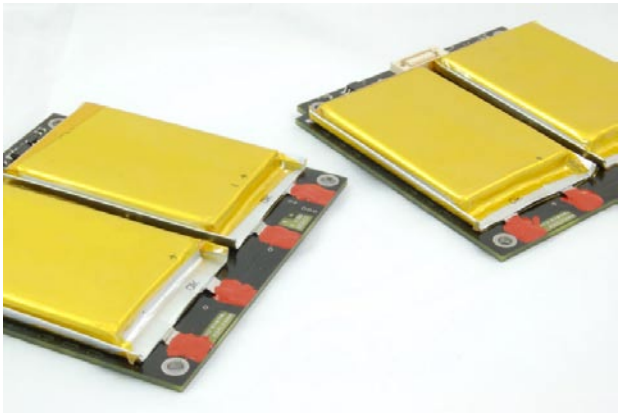

**Figure 4 Battery Daughter Boards; 1.25Ah at 8.2V**

At the same as developing the EPS, we also developed a battery that could be integrated with the EPS. Figure 3 show the 1U EPS with a 10Whr battery daughter board. Another daughter board (Figure 4) can be stacked on top to provide an additional 10Whrs.

In addition, Clyde Space also supplies the solar arrays for CubeSats, making it a one-stop-shop for CubeSat power components. (**Error! Reference source not found.** shows a 3U solar panel using EMCORE solar cells). We have also made 1U solar panels and solar panels with integrated magnetorquer coils.

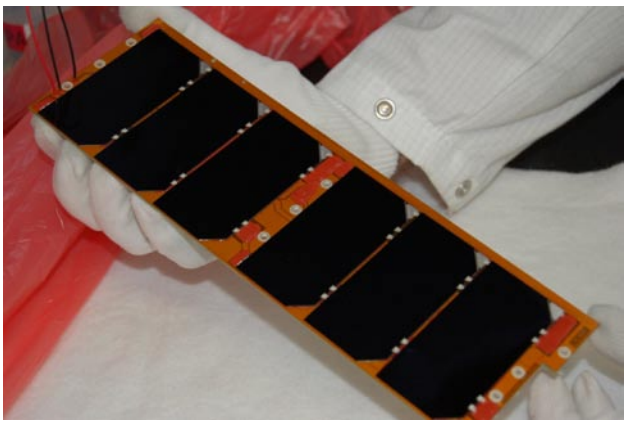

**Figure 5 Solar panel for a 3U CubeSat.**

Recent introductions to the range include a 3U EPS; this system has higher power ratings on the Peak Power Trackers to cope with the larger solar panels on a 2U and 3U CubeSat. (See Figure 6)

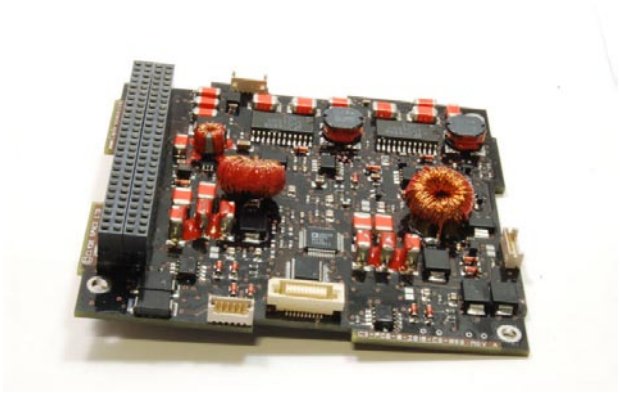

**Figure 6 3U/2U CubeSat Power System.**

Due to the larger components on the 3U EPS, it wasn't possible to fit a battery daughter board on this system. Therefore, a separate battery that was compatible with the CubeSat Kit needed to be developed. This battery is capable of being sized up to 30Whrs per unit, which is more than sufficient for most 3U CubeSat missions. The 3U Battery is shown in Figure 7.

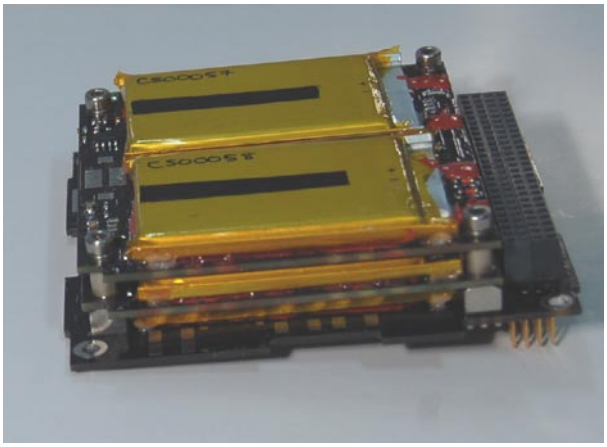

**Figure 7 3U/2U 30Whr Battery.**

In addition to the growing number of Clyde Space CubeSat components, we are also licensed resellers of Pumpkin's CubeSat Kit in Europe. Again, all of the CubeSat products produced by Pumpkin are ideal for high volume production and low-cost multiple sales. Some of the products from Pumpkin, Inc. are shown in the figure below and include the FM430 (On Board Computer), CubeSat Structures, Development Kits, solar panel mounting clips, launch interface kits, attitude control modules, plus a number of other items including breakout boards, interfacing equipment, etc.

**Figure 8 Some of the CubeSat product range from Pumpkin, Inc.**

## IMMEDIATE BENEFITS OF ECOMMERCE

Given the nature of the products described in the previous section, it becomes clear that this is indeed a very different approach to spacecraft, not just from a technical perspective, but also from a commercial perspective. As mentioned previously, there is a pressure from industry to introduce the ability to buy components using credit card. Therefore, at Clyde Space we investigated the options available to us in terms of credit card sales:

- The standard option was to have a credit card terminal at Clyde Space and process payments over the phone, but this method is actually only cost effective if you are making multiple transactions per day; CubeSats aren't quite at those kind of volumes yet.

- The second option was to use internet sales. This can also be expensive, especially when considering the percentage of the sale that 'Paypal' and 'WorldPay' will take for each transaction. When a customer is making a payment of over $1000, these percentages become significant. There is also the issue of the customer being directed off the main website onto a payment website, which is not ideal.

In the end we found a method of having an ecommerce element integrated with our website and not having to pay a premium to the banks for each transaction (although it is still more than we would like).

Now that we had decided on the route we would take to enable credit card sales, it was then apparent that the ability to have our products sold online on our website, combined with the technology available for online sales, could open up a whole new approach to the specification and selection of spacecraft systems.

### *Related Products*

Immediately, with online sales, it is possible to list related products on a webpage when a main product of interest is selected. This is not only important as a sales tool, but it is also important for the customer as they will have more information at their finger tips to help them select the systems, accessories and test equipment that they require to make their mission run as smoothly as possible.

For instance, with the 1U CubeSat EPS, most customers will buy ONE or more flight battery, but some also buy a workhorse battery to ensure that the flight battery is in optimum condition for the mission. Customers also require other items such as the solar panel to EPS

harness, solar panels, solar panel clips, magnetorquers integrated with solar panels…the list goes on. It is possible to communicate these additional items in text on a datasheet or proposal, but it is much easier to add the additional items to an online shopping basket and buy all of the required items in one transaction.


**Figure 9 Example of how 'related products' helps to guide customers to other required items.**

### *Product Specifications*

At Clyde Space we have reasonably detailed product datasheets, but due to the nature of the products that we have for CubeSats, it is not practical to have a datasheet per variation of CubeSat item. It is also not practical to have datasheets for small items such as harnesses, clips, extra connectors, etc. The nature of ecommerce, however, forces the vendor to detail each item so that the customer knows exactly what they are placing in their basket. This means that there is more information available at the customer's finger tips to enable an informed buy decision to be made.

This level of detail in the online product description enables the customer to place an order at any time of the day from any place in the world with internet access. Given the international nature of the space industry, this is a very powerful capability as it means that at a minimum, a day can be saved in the order placement, this could be critical for projects with tight schedules.

### *Frequently Asked Questions*

No matter how fast the response time from a company to a customer enquiry, there is nothing quite like having the information at your finger tips. We are often asked questions about our designs that we have not yet considered as something that would be on the minds of our customers. We try hard to ensure that as much information as possible is included in our User Manual, but it is sometimes not practical to include everything. In addition, many of our customers are undergraduate students, and they perhaps don't have the engineering experience that a professional engineer takes for granted.

Another useful resource for us and our customers is the Frequently Asked Questions (FAQ) page. This enables us to list the commonly asked questions about the system (and anticipate a few others) and have them listed on the website for immediate access for the customer. The FAQs can even direct the customer to other sites that have software or interfacing components that can be used to address whatever issue has been encountered. Again, this is a very powerful tool to have and is ideal for the CubeSat community.

### *User Forums*

Following on from the FAQ pages, another very useful tool that we have included in our website is a user forum. This is different from FAQs in that the forum needs to be moderated to ensure that the content is appropriate. However, as with most consumer products, users/customers can be extremely useful in ironing out bugs (we all get them) and suggesting future upgrades to the system.

### *Shipping*

As with most online stores, it is also possible to have information on the shipping costs immediately when making the purchase.

### *Stock Indicators*

At the time of writing this paper, a stock indicator on the Clyde Space website is not up and running yet, but this again is a very useful tool for customers. If there is an immediate need for a CubeSat system, the customer can see what we have in stock at any time. Stock availability has a huge influence on the lead-time of the component, and it could mean the difference between taking delivery in a few days from order, or 4-6 weeks from order. Stock indicators will also affect the timing of when the order is placed by a customer (i.e. may buy earlier or later than planned when knowing stock levels).

### *Export Control*

Given the nature of CubeSats, it is highly unlikely that a CubeSat or CubeSat component will be used for anything other than military benign applications. However, because it is 'space', there are still some items that fall under export control; for some areas of the World at least. Thankfully, however, most of our CubeSat components do not fall into risk categories and can be shipped to most countries without the need for export license.

The main exception to this is the solar panels. Due to the need to have the most efficient solar cells on the small available solar cell area of a CubeSat, we do need to be careful of where these items are sold. When selling within Europe, Japan and the USA this is not an issue however (depending on launch vehicle selection).

## FUTURE BENEFITS OF ECOMMERCE

Clyde Space is continuing to grow its microspacecraft and CubeSat product line through the development of new in-house systems and also through the licensing of existing subsystems from other organisations. The ultimate goal of Clyde Space in this respect is to have a full mission suite of subsystems available to buy on-line off-the-shelf. There are two main objectives in this goal:

1. To encourage CubeSat projects to use the Clyde Space website to buy the subsystems they require and also as a resource for their mission planning and design.

2. To make it possible for a complete Spacecraft to be created and then purchased online using a credit card.

Objective number '2' is key as it will involve the use of web-integrated mission design tools that will down select the appropriate subsystems for the mission. An analogy for this capability is like buying a Dell computer online, where it is possible to customise the system to individual requirements.

We see this capability being available on the Clyde Space website in two steps. These steps are covered in the following two sub sections:

### *Power Budget Analysis and Power System Sizing*

As mentioned previously, the core capability of Clyde Space is in power systems. Our expertise in power systems is not just in the design and manufacture of the components, but also in the sizing and specification of the system for a given mission profile. Therefore, we are planning to introduce an online mission design tool that will enable users to select the solar arrays, battery and power system for their mission.

The tool will provide the ability to view Beginning of Life (BOL) and End of Life (EOL) performance data. All users will be able to register on the website and save their mission design information online.

The mission design software will have a function where the hardware selected for the mission can automatically be added to the online basket ready for purchase. Again, the basket can be saved for purchase at a later date.

### *Mission Analysis and Design*

The next step, however, is more ambitious and will involve an online mission design tool. This element of the online design tool will be developed to coincide with the availability of complete subsystem suites and support systems from the online shop. This tool will include the power budget analysis feature already described, but will include other parameters such as pointing accuracy, on-board data rates, data storage, processing capability, uplink and downlink speeds, groundstation locations, etc.

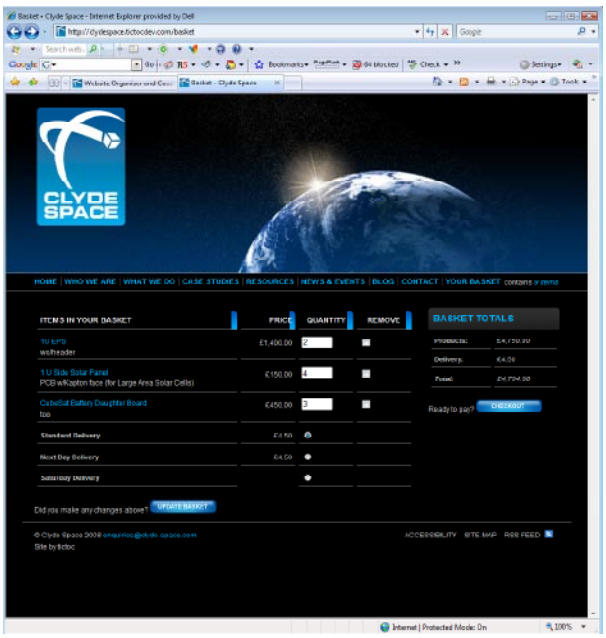


**Figure 10 Online shopping basket with CubeSat subsystems being purchased.**

From the information inputted buy the user it will then be possible to build up a picture of the mission requirements and how they relate to the available subsystems. It is likely that this will be an iterative process and refinements will need to be made by the

user throughout the process to, for example, optimise the link budget, etc.

Ultimately, there will be the ability to build up the necessary subsystems, add them to the online basket and buy the complete system when ready.

Another benefit of this would be the fact that all of the systems would be already tried and tested compatible with each other. This will reduce the amount of time spent by the customer in spacecraft testing and interface development, further reducing the time to launch of the mission.

## CONCLUSIONS

It is clear that there is a growing market for low-cost subsystems for microspacecraft, especially CubeSats. There has been a steady growth in the number of microspacecraft under development and, consequently, the demand for low-cost, off-the-shelf subsystems for these missions.

The standardisation of mechanical and electrical interfaces for microspacecraft platforms such as CubeSats has meant that many vendors are able to produce subsystems in large quantities to help keep the unit costs as low as possible. The next natural step has been to provide an online sales capability to meet this demand, enable the use of credit card sales and to continue to help keep costs low.

This paper has also shown how this can lead to a number of other useful online tools and services to help microspacecraft primes as users of these subsystems. In particular, plans to provide online mission design tools will assist customers with selection of subsystems to meet their mission requirements.

The development of online sales and design tools is a revolutionary step for space business, and it is the author's opinion that the satellite community will see its first internet procured satellite by the end of 2010. It is also expected that it will be possible to procure a spacecraft 'kit' off-the-shelf and have it delivered within a few days – this will be the commercial space industry's own low-cost, responsive space platform. It will be interesting to see if, in a few years' time, we will see micro and mini satellites being procured in the same way.

## ACKNOWLEDGMENTS

The author would like to thank the Clyde Space design team for their efforts in developing new systems for CubeSats, Andrew Kalman of Pumpkin, Inc. for being supportive of our developments and for trusting us to represent the great CubeSat Kit in Europe, our customers for forcing us to adopt new business practises resulting in our space ecommerce service and our web developers, 'tictoc', for developing such a great looking and easy to use website for us.

## REFERENCES

1. CubeSat kit website: www.cubesatkit.com, Andrew Kalman, Pumpkin, Inc.
2. Clyde Space Website: www.clyde-space.com.