An Open Source, Standardized Research Platform for the International Space Station

Christopher K. Cummins
Chief Financial Officer, NanoRacks LLC

In the not too distant past, anyone who wanted to manipulate or analyze data for a scientific or engineering project would need to know low level programming languages, especially if there was a real sensor or hardware in the loop. Consequently, 8086 machine language was commonly taught in physics and engineering programs. But with the advent of scientific programming environments like MatLab™, Mathematica™ or R, most researchers no longer need to take the time or suffer the brain damage required to acquire such arcane knowledge. Instead, they can employ a relatively simple and widely used scientific programming environment so that they can focus on being creative about their research. While these programming environments are simple and flexible, they allow for very complex applications. And since the users themselves generally write the application programs, they are free to share their work for free or to charge for it.

Space research is just now crawling out of the equivalent of the machine language era. Until very recently, only a handful of specialists around the globe understood space research hardware, and in most cases their expertise was confined to a specific launch vehicle or to the Space Station. As a result, all space research hardware was custom designed and fitted, a painstaking and expensive process.

Even today, standard operating procedure requires custom designed research hardware built with great care, and should a client require the use of a different launch vehicle or even a different part of the space station than the one for which it was originally designed, the time consuming and expensive process of redesigning and redeveloping the hardware to national space agency specifications must begin yet again, most likely with a new team of engineers.

The auto industry deployed large scale mass production a century ago, so why has space research been so slow to create and benefit from an open source, standardized platform for scientific research? In essence, industrial standardization so common in everything from cars to laboratory hardware has never before been necessary in space research: a Russian scientist would fly experiments only on Russian vehicles; an American only on NASA vehicles.

But as the era of segregated, national space programs is clearly over, the time for standardization of the research infrastructure has arrived.

In the past neither time nor cost were overriding concerns, but this is no longer the case. A single research project funded by NASA may well ride up on the last of the space shuttle flights, be re-flown on a Russian Progress resupply vehicle, and then be installed and activated in U.S. National Laboratory on ISS. Later, a follow-on experiment might be flown on SpaceX's DragonLab, not to mention also launch on an Indian or Japanese launch vehicle. Other research projects may soon get their first microgravity exposure on an American suborbital vehicle, manned or unmanned, and then be accommodated on a private orbital platform like that from Bigelow, or perhaps even on the distant time horizon it will benefit from an entire Chinese infrastructure of vehicles and platforms.

In all cases, time and cost are critical deciding factors that enable or perhaps prevent a scientist from conducting an experiment at all. Therefore, it makes complete economic and operational sense to assure that the research hardware is built only once, allowing the researcher to focus on the scientific objective of the payload rather than on the 'box,' just as using a scientific programming environment enables researchers to quickly and easily write programs to address their scientific objectives, rather than dwelling ad nauseum in the depths of machine language programming.

Other industries serve as helpful examples of standardization. When freight is sent from Asia to North America, it doesn't matter which airline or even cargo ship is chosen: the pallets are a standard size and the shipping rules are the same, which assures the fastest development time, optimal standardization, and lowest cost.

Figure 1
The NanoRacks Platform

My colleagues and I created NanoRacks for just this reason. NanoRacks is a company whose purpose is to flourish by introducing commercial standardization to space research hardware and operations. We believe it is imperative that researchers should not have to re-design and re-build custom made hardware just because their launch vehicle is from Orbital Sciences while a future version will be flown onboard the Progress, and when the hardware gets into orbit it may first be used in the Russian lab, then the Japanese lab, and then the U.S. lab.

NanoRacks intends to provide the benefits of a standardized research platform, which is indeed what the entirety of space industry should be aiming for as well. We did not invent the idea of standardization on space station, as starting around the turn of the century NASA introduced the Express racks that are designed to produce a commercial interface, and that is what NanoRacks is further exploiting by reaching out to a broader community.

Founded in August 2009, NanoRacks has accomplished an amazing amount in its first year. NanoRacks designed and deployed two research platforms (NR-1 and NR-2) on the International Space Station in the U.S. National Laboratory. These first two racks are similar and each can house 16 CubeSat sized payloads.

The CubeSat form factor was chosen specifically because it is well known to a growing number of corporate and university researchers and engineers worldwide. Measuring 10 cm by 10 cm by 10 cm and weighting in at less than 1Kg, the CubeSat has been proven in the microsatellite industry to be a productive standard. Despite their small size, CubeSats are designed to operate as free flying satellites.

Whether one flies with India, Russia, the US, or other nations, many different types of launch vehicles can now host CubeSats, and customers can also build satellites that are multiples of a single CubeSat form factor (1U or 2U or 4U).

As a result of the success of the CubeSat standard, a supplier market for structures, power supplies and communications systems has also grown to accommodate the standard. The typical CubeSat derives power from solar arrays, deployed after launch, and ground communications are provided by the user/operator using a low power radio.

Standardization in the CubeSat marketplace also came about with the development of the *Poly Picosat Orbital Deployer* (P-POD) launch vehicle integration system, a standardized interface between CubeSats and launch vehicles.

Today there are dozens of CubeSat development teams around the world, and among the technologies being developed are new thruster systems, miniaturized avionics, communications systems, passive and active attitude control systems, and power systems. Some development teams are graduating to more complex platforms, and there are early studies being made for planetary missions.

At the moment, in fact, the number of projects is far greater than available launch slots, which presents a problem for CubeSat developers, but may be an emerging opportunity for launch providers.

New companies are emerging to service this market, including kit manufacturers and subsystem vendors, and one quick count found at least 34 participating institutions (universities, national labs, and corporations) as well as a handful of suppliers of applicable hardware and software.

If a similar community could be developed that would drive market growth and innovation for the International Space Station and other orbiting research platforms, the results would likely be a significant expansion of current space commerce.

This is the business model behind the NanoRacks Research Platform

The NanoRacks Research Platform provides a standardized CubeSat-like development environment for ISS researchers. A student, a researcher, or a business developer can design payloads that fit within the CubeSat form factor, now known as a CubeLab™. A student may want to design a single 1U project, whereas a corporate researcher might wish to make use of a 2U or 4U payload for pharmaceutical research. Using this form factor, the NanoRacks payloads can be accommodated on any launch vehicle, and the 'plug and play' model requires the standardized hardware to be built only once.

Using an off-the-shelf CubeSat kit to build a CubeLab™, users can develop experiments, integrate the experiments with the CubeLab™, and deliver the 1 kg project for flight aboard any available vehicle visiting the ISS. Each CubeLab™ module simply plugs into one of the 16 standard USB connectors in each rack, which thus provides structural, electrical and data connectivity in one simple operation. NanoRacks takes care of the interfaces to the rest of the station and the rest of NASA.

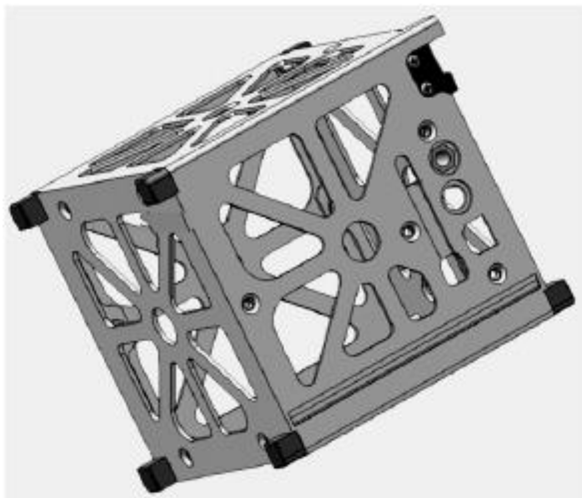

Figure 2
CubeLab™ Frame

Power is supplied to the NanoRacks Platform via a standard power connector that plugs into an ISS EXPRESS Rack, and data connectivity is handled via an ISS EXPRESS Rack Laptop. The company also schedules the astronaut time required for connecting or disconnecting the CubeLabs™, and in a departure from a long standing NASA policy, NanoRacks (and NASA) are responsible for hardware safety, but NOT for payload success.

Hence, the likelihood of success is not a selection criterion. Rather, it is a commercial model where the researcher has responsibility for experiment success.

The key question, of course, is whether there is sufficient market demand for the system opportunities at a profitable price point. To date, no commercial system on the ISS has demonstrated a profit, so why should NanoRacks be different?

One element of our answer is our low price point. A commercial customer can fly to the ISS to perform a research project for thirty days at a price of $50,000 per 1U, and the price is lower for student projects. Previously, there was not a mechanism in place to accept small, simple payloads on the ISS at a price that made economic sense. On the Russian Mir, the price would have been upwards of $200,000.

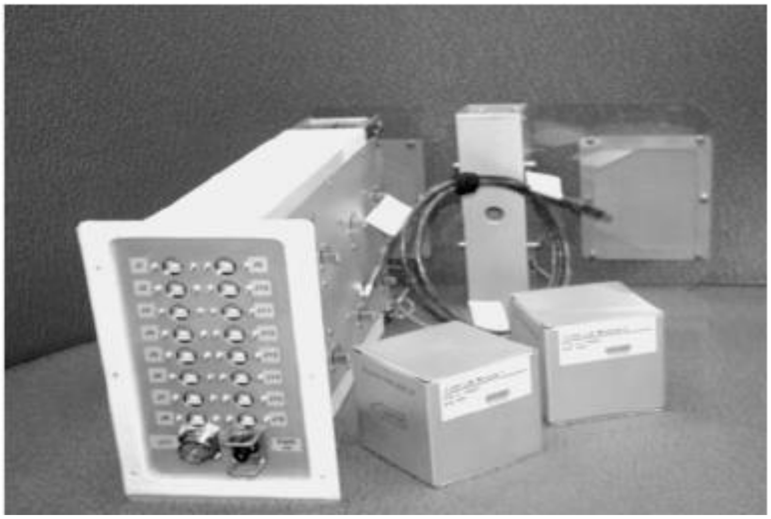

Figure 3
NanoRacks Platform with payloads ready to plug and play.

At this price, a customer is able to 'tinker' with the design and endure failures before hitting on a success.

Another aspect of the answer is the rapidity and frequency of getting experiments onto the space station. A new experiment can take as little as 6 months to go from payload reservation to operation aboard the Space Station, and repeat experiments can be accomplished in even less time.

We anticipate between 4 and 6 missions a year, which means new plug and play CubeLabs™ will replace old CubeLabs™ every 2 to 3 months.

Using our current financial assumptions and market projections, we expect an occupancy rate of about 70% in 2014 which is about three and half times our break even occupancy rate.

NanoRacks platforms are an open architecture system, and much as the open architecture of personal computers and software created enthusiastic and large markets, we anticipate that an open architecture space science system will lower costs and free researchers from dependence on a proprietary, expensive system.

Good communities are also central to good open standards. Our goal is to become a focal point for customers wanting to use space stations for lower cost, smaller projects. Like many of the newer scientific programming environments mentioned in the introduction, we expect to see a set of toolbox- or toolkit-like CubeLabs developed, which will provide basic research utilities such as imaging and measurement. NanoRacks will develop some of these, and we're enthusiastic for third parties to develop others.

Similarly, many researchers may want to create permanent NanoRacks-class research facilities for sustained and repeatable research. In particular, commercial researchers are likely to demand the assured ability to conduct repeated experiments as a foundational issue before they are willing to commit corporate funding. For example, the new capabilities offered by the NanoRacks Research Platform may be extremely attractive to newly funded stem cell researchers who are likely to want to exploit differences in how cells organize themselves in microgravity versus how the cells organize on Earth.

Hence, NanoRacks Platforms will enhance the ability of the ISS to conduct repeat experiments, while further lowering costs to researchers by providing the ability to exchange sample containers instead of returning entire CubeLabs.

We'll know that NanoRacks has truly succeeded when there are a great many users who 'Think in Zero G,' and who associate NanoRacks with their successes. That will occur because we've given them the chance to learn what zero gravity really means through inexpensive, repeated experimentation. They will have adapted to an environment without up or down, without convection, where properties such as elasticity are often more important than density, and where a glob is a more natural liquid form than a puddle. Then who knows what they'll discover and invent!

The goal of NanoRacks is to develop an extensive, international community of researchers who use ISS as a fully functioning multidisciplinary laboratory, much as has been the case with CubeSats. We anticipate that the use of the NanoRacks Research Platform can be both a stepping stone to future commercial free-flyers such as the one announced by SpaceX, and as an end product in and of itself. The resulting establishment of a cadre of young space science researchers in the near term will serve as a major resource for future exploration activities.

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Christopher K. Cummins

NanoRacks' CFO/COO Christopher K. Cummins is an experienced financial innovator with an aerospace background who has been involved in the financing side of commercial space since 1981. Prior to being a pioneer in developing fund-linked products at Citigroup, Mr. Cummins consulted to various aerospace companies and worked at NASA/JSC developing cost and schedule estimates for the ISS. Mr. Cummins holds a MS in Statistics from NYU, a MBA from Yale, and a BA in Physics and in Government from Cornell. http://www.nanoracksllc.com/