National Aeronautics and Space Administration

Flight Opportunities Program

Office of the Chief Technologist

Assessment of Existing Standardized Payload Containers for the Commercial Reusable Suborbital Research (CRuSR) program

August, 2010

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1 Introduction

1.1 *Objective of This Assessment*

The objective of this assessment is to gather information about existing containers and containerized solutions for payload handling with potential applicability to the CRuSR program.This assessment was performed by Jonathan Raiman during the summer of 2010 while he was an intern with the CRuSR program office at NASA Ames Research Center.

The assessment consisted of gathering input, feedback and lessons learned from various CRuSR team members and other NASA staff about existing container solutions in past and present NASA programs, e.g. the Space Shuttle, the International Space Station, and others.

An additional objective was to perform an initial conceptual design of a CRuSR specific generalized container solution based on the gathered data. This turned out to be difficult because the CRuSR program was in a blackout phase during most of the summer as a result of NASA's procurement process for buying flight services from the prospective flight service providers. This prevented necessary communication and information exchange with the potential vehicle providers, making a conceptual design exercise premature.

The assessment therefore focused on providing an overview of past, present, and potential standard payload containers comparing several proven options with possible Commercial-Of-The-Shelf (COTS) ones.

1.2 *What is CRuSR?*

The Commercial Reusable Suborbital Research Program (CRuSR) is a NASA entity within the Flight Opportunities Program of the newly established Office of the Chief Technologist (OCT). CRuSR aims to facilitate flight of technology demonstration and research experiments onboard commercial reusable suborbital vehicles currently under development in private industry (Figure 1 through Figure 3).

More information is available at:

- CRuSR program:
  http://flightopportunities.nasa.gov
- Flight Opportunities Program:
  http://www.nasa.gov/pdf/468392main_Kubendran_forum_Flight_Opp_v4.pdf
- NASA Office of the Chief Technologist:
  http://www.nasa.gov/offices/oct

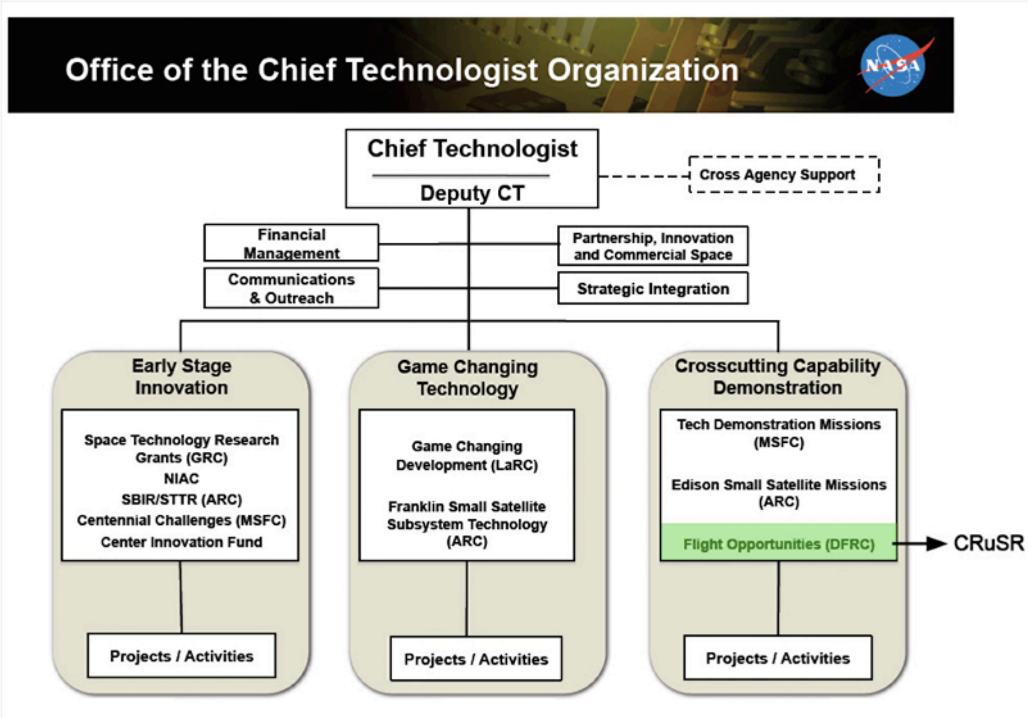


Figure 1 Flight Opportunities Program within the Office of the Chief Technologist.

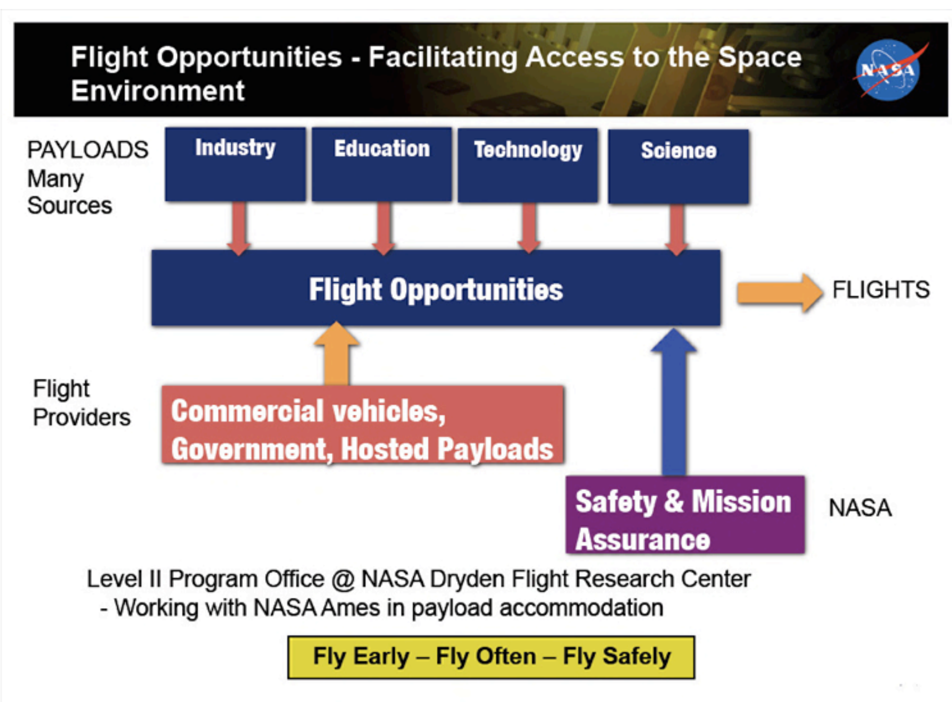


Figure 2 Outline of the Flight Opportunities Program.

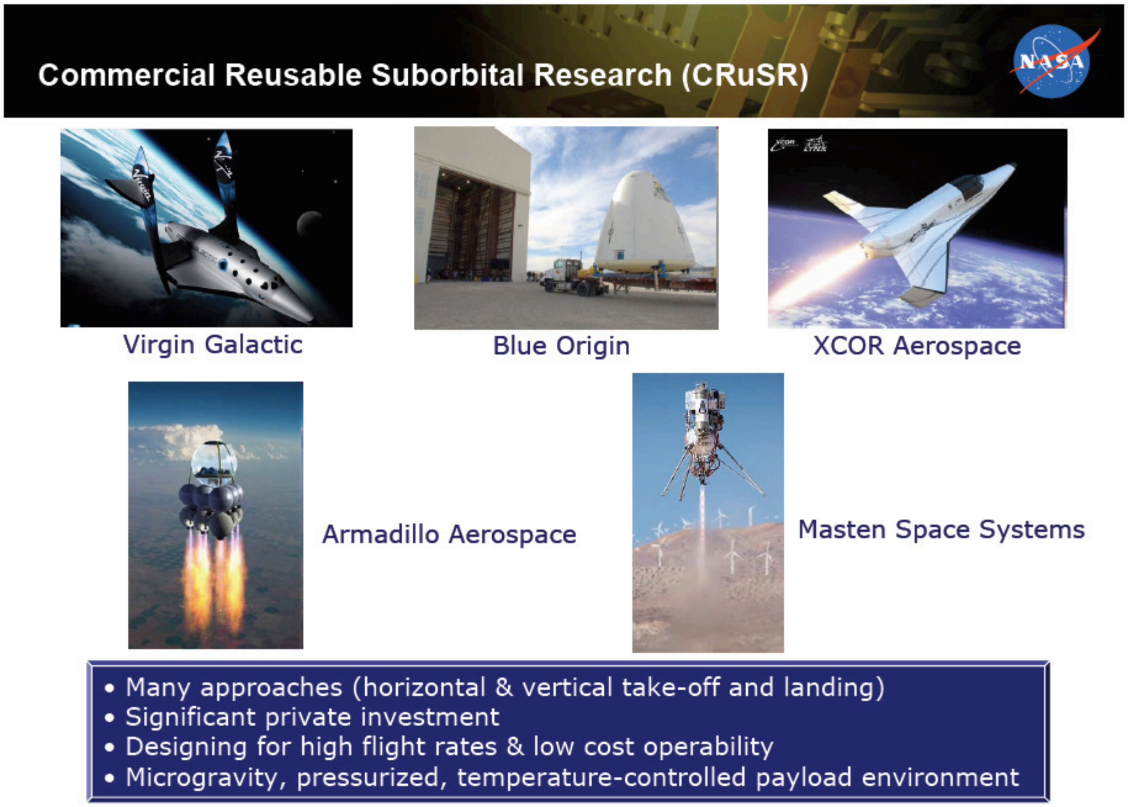


Figure 3 Overview of potential commercial reusable suborbital vehicles.

1.3 *Standardized Container Rationale*

Streamlining access to suborbital space
One of the objectives of the CRuSR program is to make technology demonstration and research in sub-orbital space a frequent, cost-effective, and safe process.

The nature of reusable suborbital vehicles allows them to fly often, sometimes several times a day. This will allow a very different kind of operational model closer akin to commercial airlines and FedEx/UPS operations compared to the traditional 1-off flights that may occur only a few times per year. As near-space research payload flights transition from 1-off flights to a high-throughput system, built upon use of reliable, rapid, and cheap platforms, the operational side of the transaction can begin to provide the frequent, low-cost and safe access that has long been only a dream for space researchers. Business viability and sustainability of the suborbital vehicles providers also depends on having more of a commercial airline model to lower their cost per flight.

To fully leverage the potential benefit of these vehicles, CRuSR will need to facilitate a fast payload flow. Standardized processes and generic payload accommodations are seen as a key part of the solution as they compensate for individual vehicle differences as seen from the payload provider and/or experimenter. More standardized payload interfaces are deemed essential to the CRuSR program, both with respect to operations and payload hardware in order to provide low-cost and frequent near-space access.

Standardized containers

Experiments come in all forms and shapes. Many fit inside a container and do not interfere with the flights. In some cases the experiment requires exterior phenomenon (atmosphere samples, telescope observations, lasers, outside antenna, etc) or extra resources (to melt metals or run power hungry devices, etc). CRuSR can solve the majority of these problems with containers that isolate the experiment, and an effective methodology to protect occupants and ship from any hazards.

NASA has long dealt with the difficulties and opportunities of flying payloads into space. In the past design efforts were focused on providing single standardized vehicles such as the Space Transportation System (STS) with modular containers in the Middeck (middeck lockers), the SpaceLab (standard single or double full-height racks with pull-out drawers) and in some cases within the STS Orbiter Bay (Get-Away-Special containers). This lowered the need for custom solutions to be designed and engineered. However, NASA has never developed a frequently reusable vehicle to access space and thus research payload flight opportunities often lagged for months or even years and reflight opportunities were very few, if any. The value of developing various standard containers for a single vehicle type have been demonstrated, however, CRuSR will have several vehicle types which tends to make the container design issue more challenging. However, if the challenges can be effectively addressed, the payoff of streamlined payload processing will be great.

Rapid turnovers and low costs are essential for developing commercial suborbital flights into a thriving community of researchers and opportunities accessible to all. To conquer sub-orbital space, containers must be cheap, easily replaceable, durable, and fit the greatest variety of research instrumentation and vehicle types.

2 Matrix of Potential Container Solutions

Figure 4 provides an overview of the containers that have been reviewed during this assessment. The matrix compares these options to scale and ordered by size. Certain fields are left empty because data is unavailable or because the option is variable. Each individual container is also briefly described in Appendix A together with some images to show the various use cases.

A suitable container for sub-orbital space must not only be chosen for its cost, weight, and volume, but also for its ability to integrate pressurization, sturdiness, power supply, and resistance to vacuum. Each container has additional benefits that should be considered on a case-by-case basis.

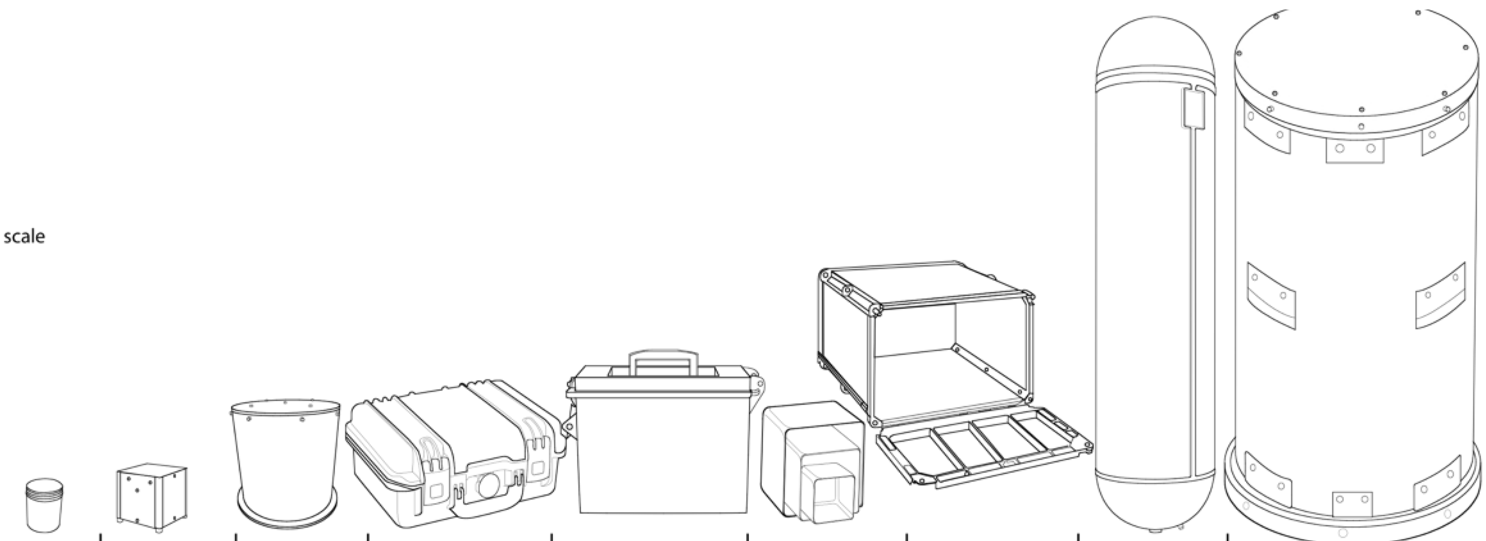
Several options appear too costly, too small, or too big, but specific advantages shine in given situations. Larger containers, such as the GAS canister, or the Pathfinder Pressure Canister, provide pressure and have power and data ports. They are heavier but better protect the contents if housed in a non-enclosed vehicle. The Cansat leaves many areas unanswered because it is a form factor. It is redesigned to answer specific criteria. ZERO Cases have little information in the matrix because they are customizable. They can be ordered with a different seals, thickness, or size. This versatility permits better integration with experimenters who may want to use the container as part of the structure to build their experiment.

Containers housed inside the vehicle obey different shape and size rules. Cansats, Cubesats, Rocksats, and Mid-Deck Locker (MDL) all have flat surfaces. These containers are easier to stack and stow. In a MDL the container stows drawers, but the envelope is not helpful to the interior design, unless the entire MDL is remade as one block with the experiment. ZERO Cases are custom built and thus fit a specific purpose.

Smaller containers also interact nicely with each other: the Cubesats fits in a Nanorack bus inside a MDL. Cansats can also be inserted in a foam cutout and many can be stacked in a MDL. The MDL can easily be compartmentalized. The smaller subdivisions are good for storing multiple educational payloads. Rocksats *brick* into each other to assemble the rocket.

Having flown in the Space Shuttle and the ISS, the MDL is the container with the most integrated solutions to accommodate experiments.

Drawings to scale



	CanSat	CubeSat	RockSat	Pelican Storm Case	Sports Utility Box	ZERO Cases Deep drawn	Mid-deck Locker	Pathfinder Canister	GAS Canister
Weight	<320g	980g	3288g	1910g	1723g	Variable	4603g	1814g	?
Volume	0.39L	1.4L	1.75L	17.2L	21.2L	Variable	57L	48.2L	140L
Inside Volume	Custom	100x100x100	220Hx220D	330Wx234Dx152H	304Wx152Dx247H	Variable	516Dx440Wx253H	1060Hx249D	591Hx422D
Usage	sounding rockets student experiment	ISS, Space Shuttle	Sounding Rockets	Combat zone, nautical expedition, photojournalism sensitive equipment	Combat zone, nautical expeditions Ammo box, sensitive equipment	ISS, Space Shuttle	ISS, Space Shuttle	Pathfinder UAV Observation, 30km high	Space Shuttle
Features	Custom	USB port, customizable	Customizable upon request.	Waterproof, Pressure Valve	Waterproof	Variable sizes available., customizable	Power from FASTRACK	Window, Controlled recirculating air system	Power Supply
Pressurized	Custom	No	No	Partial	No	No	No	Yes	Yes
Materials	Custom	Sheet Aluminum	Aluminum	Polypropylene Copolymer	Copolymer	Aluminum	Composite Aluminum	?	?
G-load	Custom	20G+	25G+	?	?	?	20G+	?	20G+
Fixture	Custom	P-POD	Sub-SEM ring assembly	None	None	Custom Bolts	FASTRACK, SpaceHab Lab, 19" Rack	Custom Ring	N/A
Manufacturer	Custom	Nanorack, Pumpkin	RockSat	Pelican	Sportsman	ZERO Manufacturing	NASA shuttle surplus	NASA	NASA shuttle surplus
Price	<$10	$6000	<$12000	$70.99	$28.9	$1000	$0	?	$0

Figure 4 Overview of Potential Payload Containers for the CRuSR Program. (image available at http://flightopportunities.nasa.gov)

3 Conclusions and Recommendations

Conclusions

This assessment provides an overview of some of the most commonly used containers and containerized solutions for payload handling within existing and past NASA's programs. In addition, it includes some Commercial Of The Shelf (COTS) containers that might be viable options for the CRuSR program, given its relatively benign environment and flight profile.

The pathfinding role of CRuSR in nurturing the emerging commercial reusable suborbital market puts particular emphasis on the need to include both the demand side (Science, Technology, Education) and the supply side (Flight Services Providers, integrators) in discussions about standardization of both payload containers and processing. Given the current blackout period, it was found to be difficult to narrow down any potential solutions at this point without further input/feedback from both sides, in particular the Flight Service Providers.

Numerous options are available, with their various advantages, but no clear choice can be made. At this point its not clear what the plans are for payload accomodation and handling from the providers side, whether the vehicles are pressurized or subject to vacuum, whether experiments may receive power from the vehicle and what interfaces would be available to accommodate these features.

The overview shows that containerized solutions come in all shapes and forms, from the small to the large. The Mid Deck Locker seems to be an interesting middle group but its too early to tell whether this might be a solution as it might lead to a standardization at the wrong volume/size level.

Recommedations

Based on these initial findings, it is recommended to:

Supply side:

- use this information in discussions with the Flight Service Providers to gather their input and feedback on how they see the use of standard container solutions for payload handling. CRuSR is in a unique position to drive industry-wide interoperability standards as it has relationships with all parties involved so it is in the interest of CRuSR to initiate and keep alive these discussions amongst all parties involved.

Demand side:

- Do a follow up study to gather more information from the demand side, i.e the various markets of Technology Demonstration, Science, and Education: what is actually in demand and what are specific form factors of interest to the market.

References

Image credit

Figure 1:	http://www.nasa.gov/pdf/468388main_Braun_OCT_Overview_v7_update.pdf
Figure 2:	http://www.nasa.gov/pdf/468392main_Kubendran_forum_Flight_Opp_v4.pdf
Figure 3:	idem
Figure 4:	NASA
Figure 5:	NASA
Figure 6:	http://www.sigve.haugsnes.net/index.php?page=pictures
Figure 7:	http://hakenberg.de/automation/cansat.htm
Figure 8:	NASA
Figure 9:	http://www.stensat.org/cubesat.jpg
Figure 10:	http://www.cubesatkits.com
Figure 11:	http://www.nasa.gov/centers/ames/multimedia/images/2006/genebox.html
Figure 12:	idem
Figure 13:	NASA
Figure 14:	http://spacegrant.colorado.edu/rockon/RockSat/RockSat.htm
Figure 15:	http://spacegrant.colorado.edu/COSGC_Projects/RockSat-C%202011/documents/RSC_userguide2011.pdf
Figure 16:	http://spacegrant.colorado.edu/COSGC_Projects/rocksat/images/RockSat2010_Banner.png
Figure 17:	NASA
Figure 18:	http://www.firstclasspack.com/wp-content/uploads/2009/12/storm_tire-300x300.jpg
Figure 19:	http://www.envirosafetyproducts.com/pelican-case-accessories-locks.html
Figure 20:	NASA
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Figure 22:	http://ecx.images-amazon.com/images/I/313MwoAPt8L._SS500_.jpg
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Figure 24:	NASA
Figure 25:	http://www.spaceflorida.gov/index.php/en/past-projects/fastrack
Figure 26:	http://www.nanoracksllc.com/?page_id=452
Figure 27:	http://www.flickr.com/photos/kentuckyspace/4178229446/
Figure 28:	http://www.nasa.gov/images/content/191025main_MERLIN1.jpg
Figure 29:	NASA
Figure 30:	NASA
Figure 31:	NASA
Figure 32:	NASA
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Appendix: Container Descriptions

Cansat

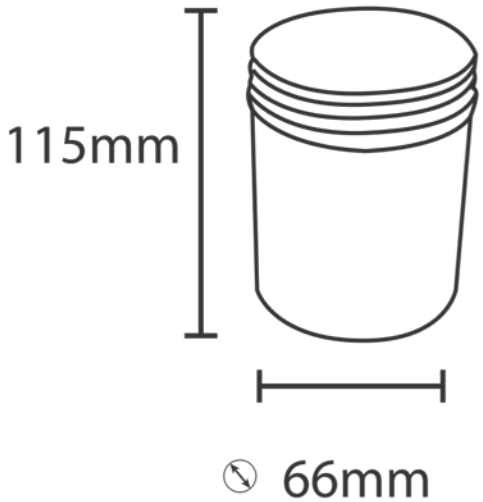

Figure 5 CanSat dimensions

Cansat is used on amateur rockets, Sounding Rockets, or stacked inside soft pouches aboard the Shuttle. Its is frequently used in educational settings and provides a good starting point for educational use of CRuSR type flights.

The Cansat ideally suits inexpensive and repeatable experiments. The envelope matches that of a soda can and is therefore easy to replicate and flexible when mass and volume are limited (see Figure 6 and Figure 7). This format also forces simplification and in turn cheaper builds. Limited space demands low power and small electronics. The Cansat is built for short duration flights and is designed to be autonomous to limit oversight from rocketry or other aspects.

Their small size limits the scope of their activity. Cansats shine when used for single observations or tests; a larger payload houses several of these smaller experiments. A Mid Deck Locker for example can carry 20 student-experiments and greatly reduce costs and complexity for the researchers involved. When flights will be more frequent and regular, Cansats can become an efficient vessel to carry onboard multiple payloads and split the price between several teams.

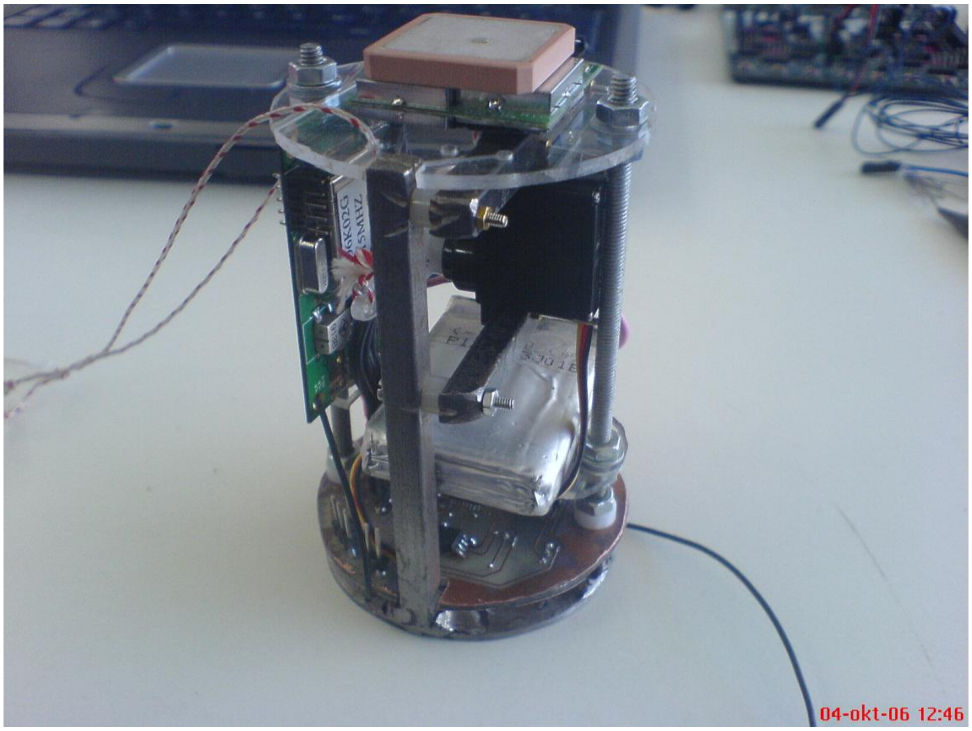

Figure 6 Cansat example.

Figure 7 Cansat example

CubeSat

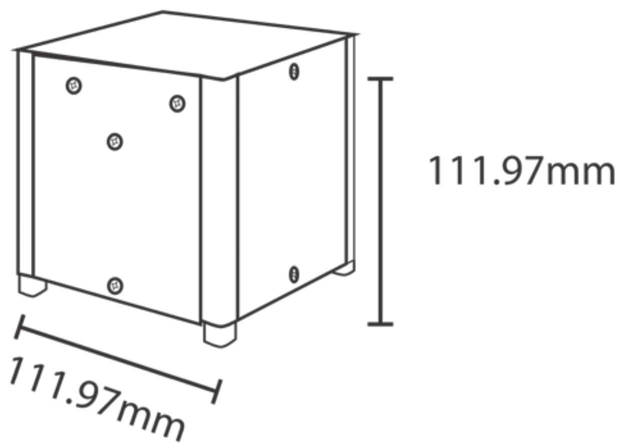

Figure 8 CubeSat dimensions

The CubeSat is an easy to implement vessel for microsatellites and payloads. CubeSats exists in 10 x 10 x 10 cm increments in 1U, 2U, or 3x1U configuration and more sizes are in development. Their accessibility and popularity made them the go-to container for experiments in orbit.

The Cubesat is spring loaded on a P-POD and ejected when in orbit. Researchers purchase $6000 kits and add solar panels (see Figure 9), radios, and different high-end miniaturized electronics to keep CubeSats in orbit.

Many experiments are made for CubeSats. Compatibility with this form factor quickly will make CRuSR a valuable player in ongoing space research at universities, research centers, and companies.

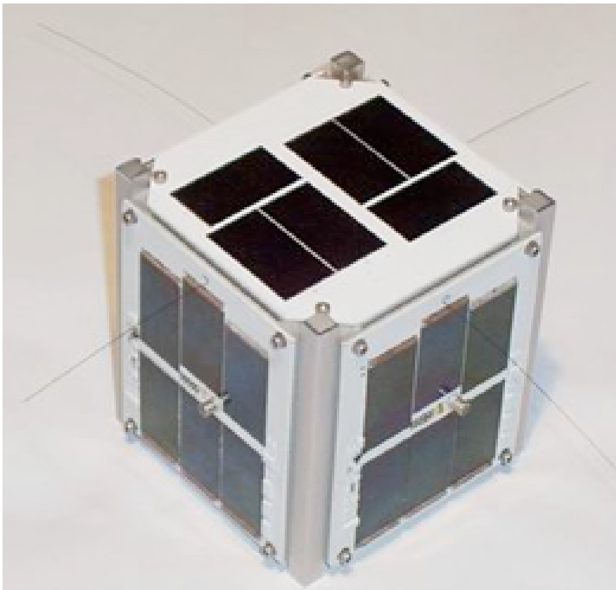
Figure 9 CubeSat 1U example

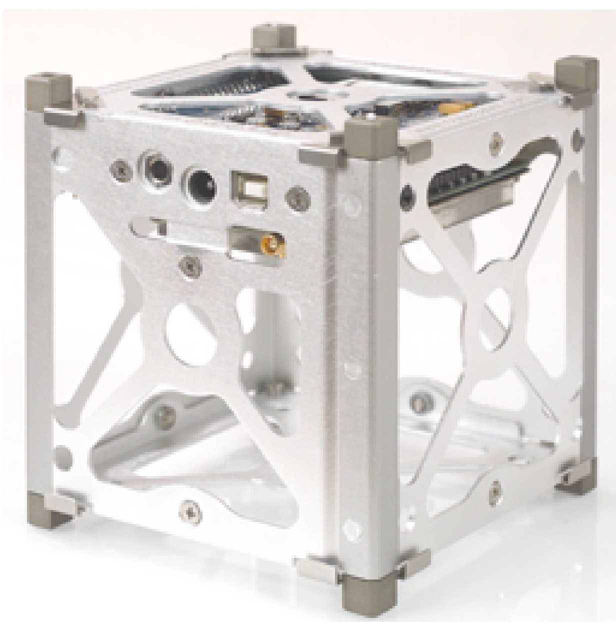
Figure 10 Cubesat 1U example


Figure 11 Internal components of a 3U CubeSat being put in a protective case

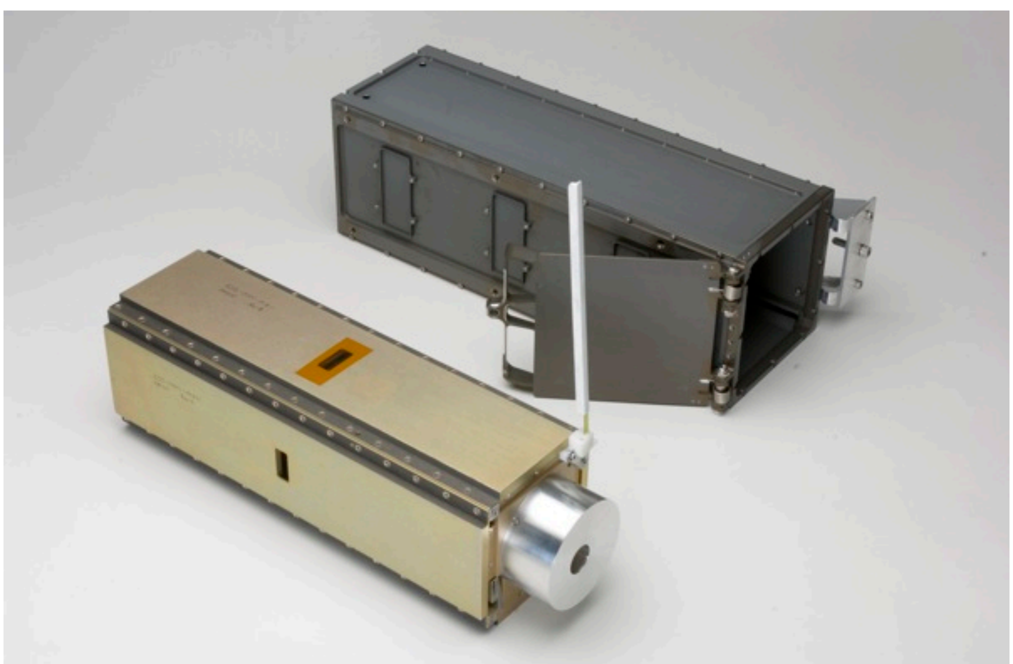
Figure 12 GeneSat 1 (3U CubeSat) and Mark II P-POD ejection mechanism

RockSat

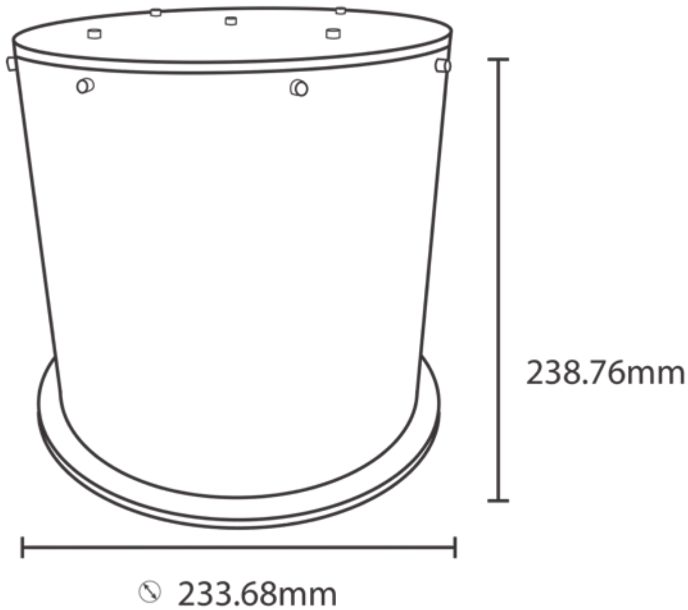

Figure 13 RockSat dimensions

RockSats fly aboard sounding rockets in a program led by the University of Colorado Boulder[1]. The RockSat program partners with educational institutions. The canister is sold as part of the sounding rocket program. As an integrator, RockSat provides student experiments with modular power supply, a thermal system, data storage, environmental sensors, and an internal rack. Rocksat canisters stack and integrate in the rocket, where they are subject to 25G+ at takeoff (see Figure 15).

[1] http://spacegrant.colorado.edu/rockon/

http://snebulos.mit.edu/projects/reference/NASA-Generic/NSTS_21000-IDD-MDK-RevB.pdf

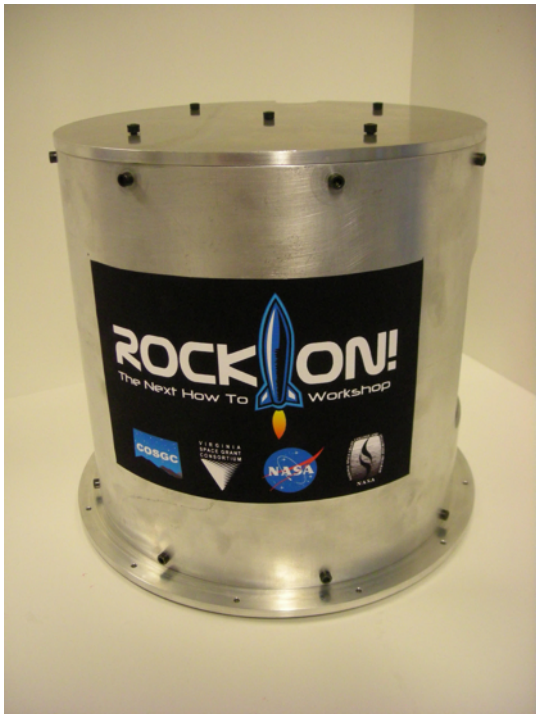

Figure 14 RockSat container as part of the NASA RockOn! Program

Figure 15 RockSat Sub-SEM ring for RockOn! Sounding rocket assembly


Figure 16 Sounding Rocket ready for launch

Pelican Storm Case im2100

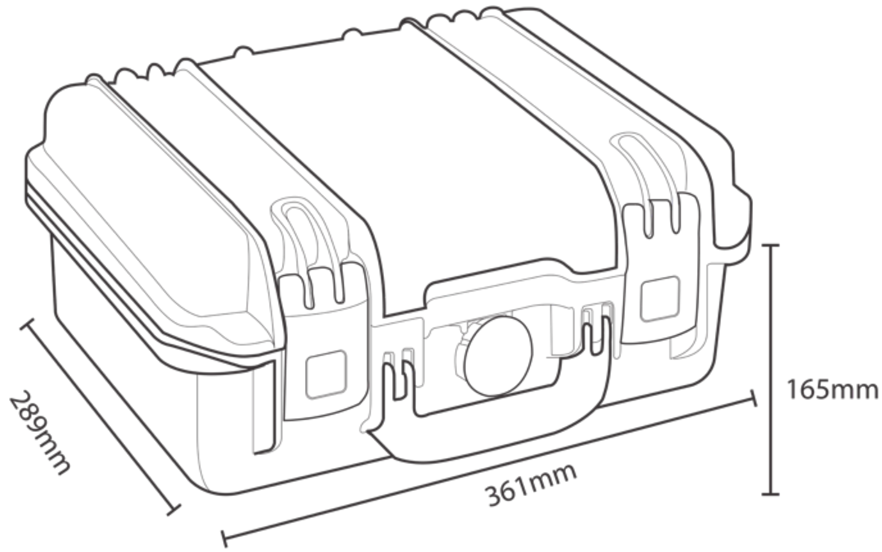

Figure 17 Pelican Box dimensions

Pelican cases come in many form and sizes, all waterproof and ruggedized. They are used on expeditions, in war zones and to protect cameras and sensitive equipment (see Figure 18). Pelican cases are known for their foam enclosures that allow an almost custom fit for any protected item. They are easily accessible to researchers to install their experiments and available online for $70. However, they have not yet flown in space. They are made of polypropylene copolymer and could react unexpectedly in vacuum.

Figure 18 Pelican boxes are rigid.

Figure 19 Pelican boxes allow foam enclosures inside.

Figure 20 Pelican Cases have watertight seals.

Sports Utility Dry Box

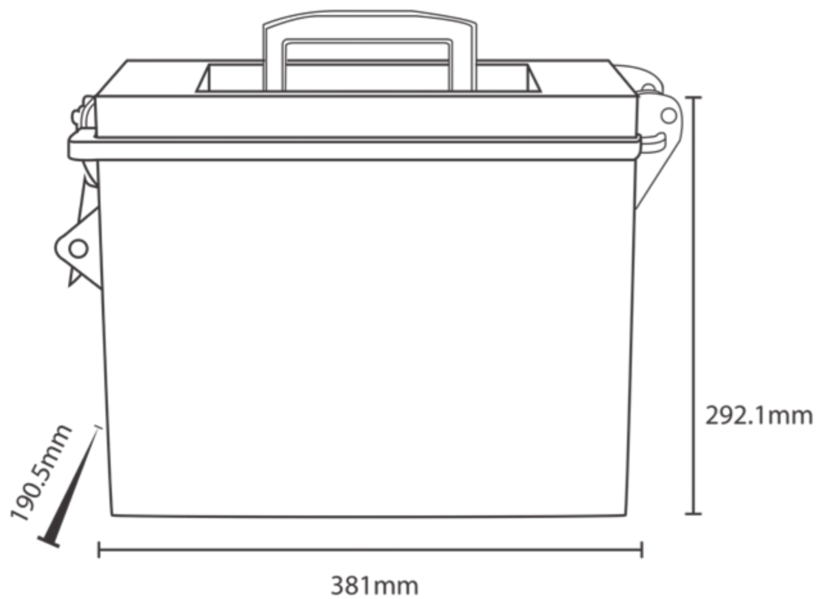

Figure 21 Sport Utility Dry Box dimensions

The Sports Utility Dry Box is a ruggedized waterproof ammo box. It is also used to protect and keep equipment on nautical expeditions, or in combat zones. They are easily accessible to researchers to install their experiments and available online for $29. However, they have not been flown into space. They are made of copolymer and could react unexpectedly in vacuum.

Figure 22 Sports Utility Dry Box.

Figure 23 Sports Utility Dry Box

Mid-Deck Locker

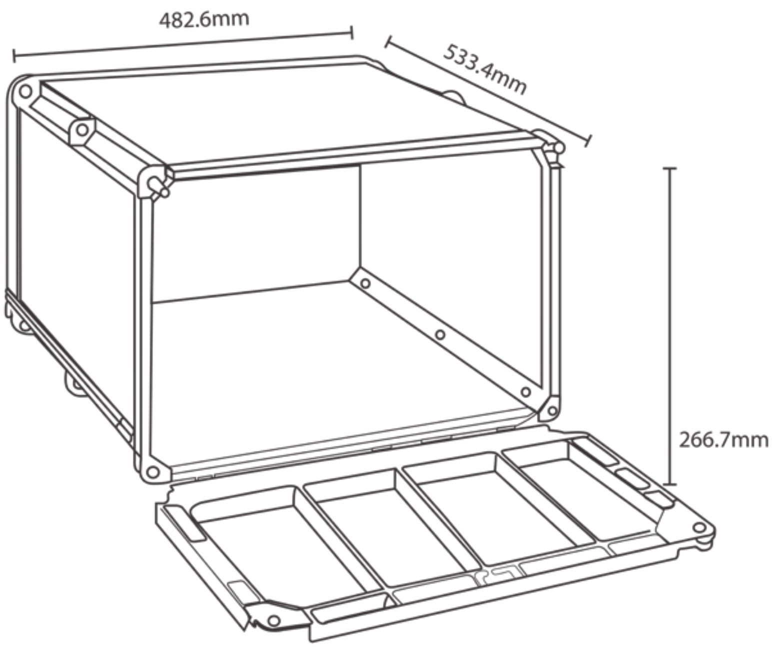

Figure 24 Mid-Deck Locker dimensions

The Mid-Deck Locker is the standard compartment onboard the ISS and the Shuttle. Originally these were used for storing clothes, personal items, and vehicle specific equipment. Experiments are run inside these lockers. The Animal Enclosure Module is an outfitted Mid-Deck locker with ventilation, feeding, and apparatus to observe the animals inside (Geckos for instance). Mid-Deck lockers are designed to fit in specific housings. Some attachments in the ISS and the shuttle provide power. The locker can be fixed on different racks[2].

It is adaptable to 19" rack systems, and third parties such as FASTRACK are developing racks with additional features (batteries) (see Figure 25). NANORACK[3] also offers a method to attach 16 Cubesats in a Mid-Deck Locker by providing a bus (see Figure 26). On either side of this central beam the 1U Cubes attach by USB and receive power and exchange data.

[2] Mid Deck Locker Interface Definition Document: http://snebulos.mit.edu/projects/reference/NASA-Generic/NSTS_21000-IDD-MDK-RevB.pdf
[3] http://www.nanoracksllc.com/

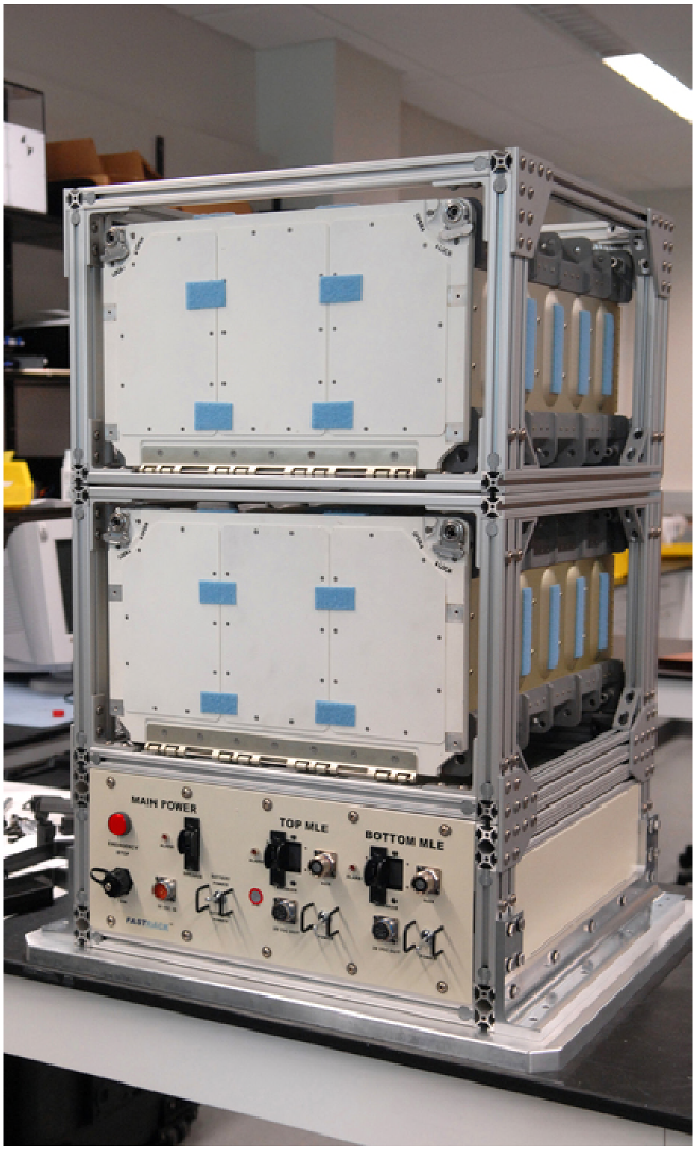

Figure 25 FASTRACK utilizing the Mid Deck Locker form factor

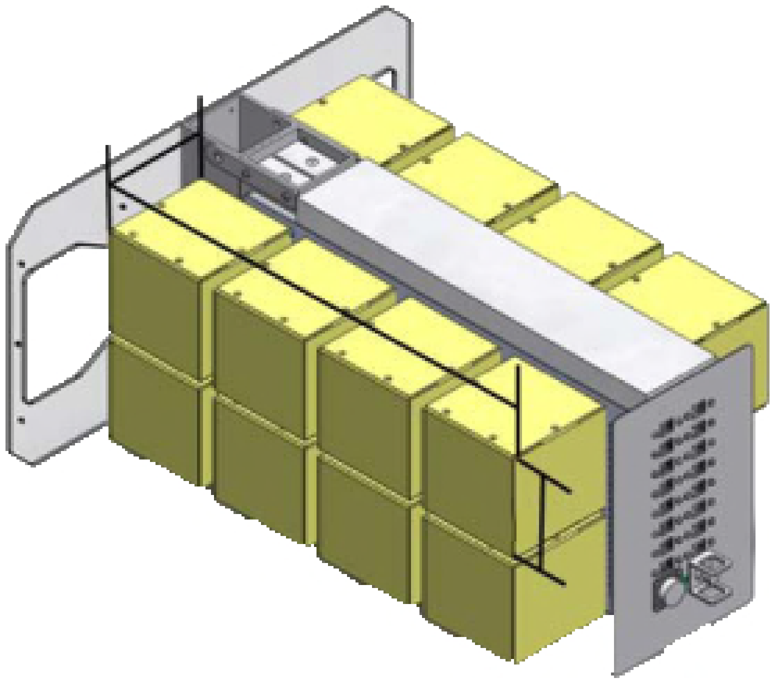

Figure 26 Nanorack configuration of 16 CubeSats using the Mid Deck Locker form factor

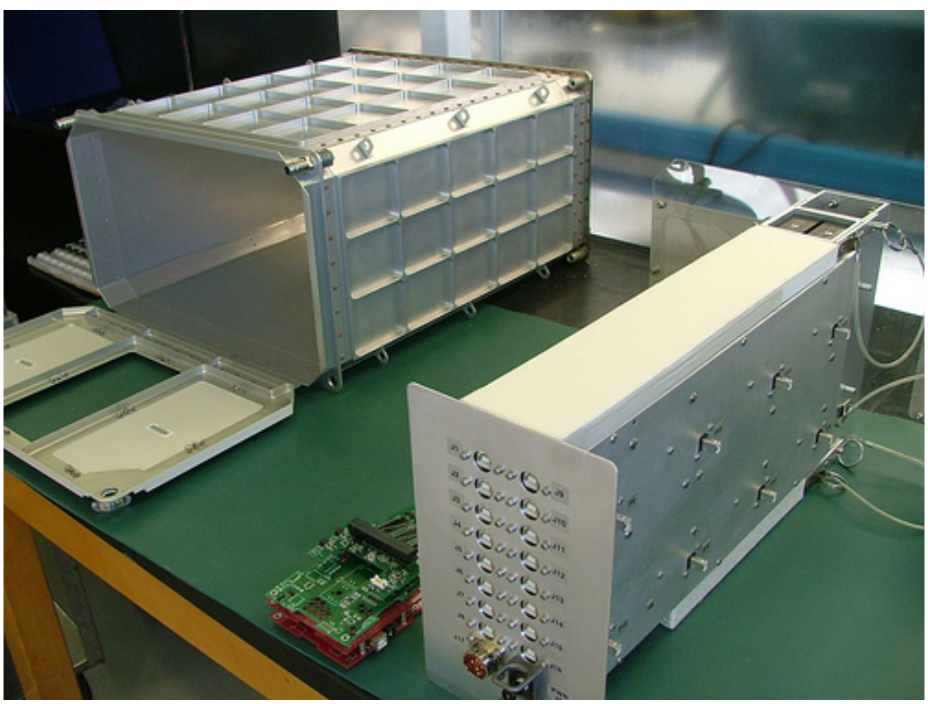

Figure 27 Nanorack configuration

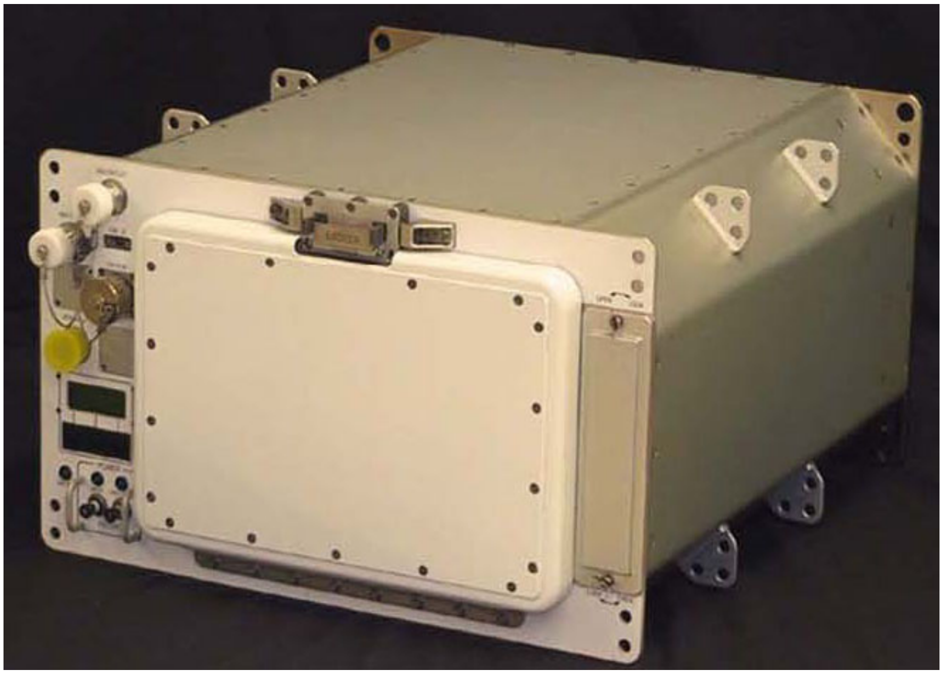

Figure 28 Merlin/Glacier Freezer

Pathfinder

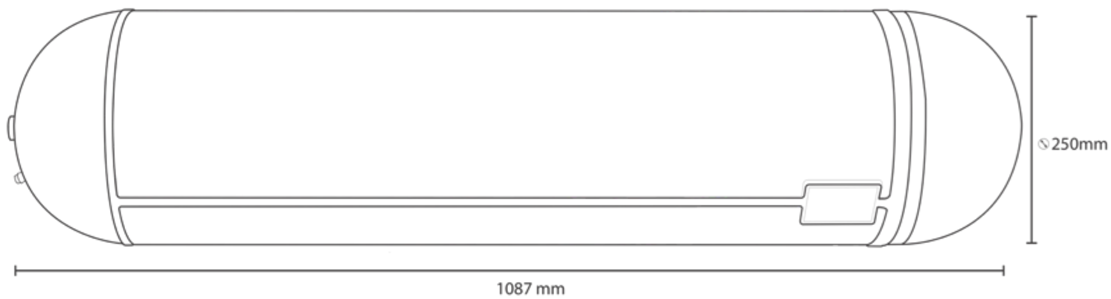

Figure 29 Pathfinder dimensions

The Pathfinder pressure canister is designed using elements found in the hard spacesuit seal design as a container for observation from a UAV. It houses a computer, battery, and a camera that looks out the window on the envelope.

The canister is lightweight and custom built for flight aboard the Pathfinder UAV using a bracelet / ring attachment to secure itself (see Figure 30 and Figure 32). The air inside is pressurized and temperature controlled using a controlled recirculating air system: the canister is an outer shell with the components inside in a box; air circulates in the canister to cool the box with the hot components. CRuSR may get access to vehicles without pressurized payload compartments. The Pathfinder Pressure canister can accommodate payloads in this situation.

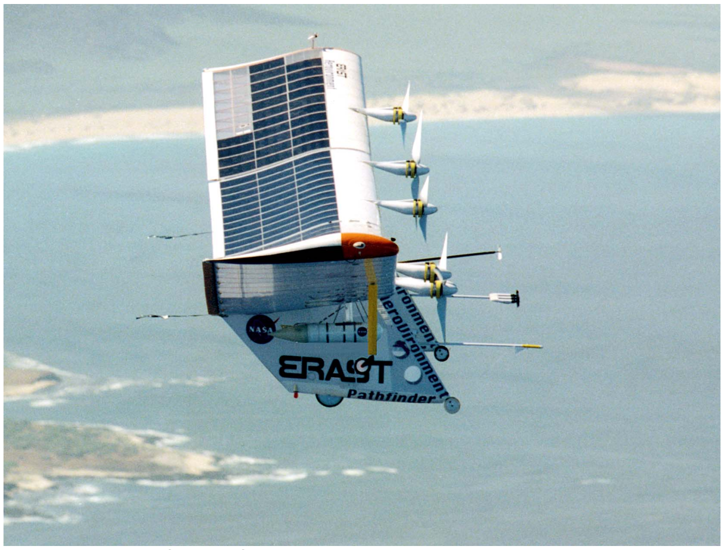

Figure 30 Pathfinder flying wing. Pressurized pod is visible under mid-section of wing

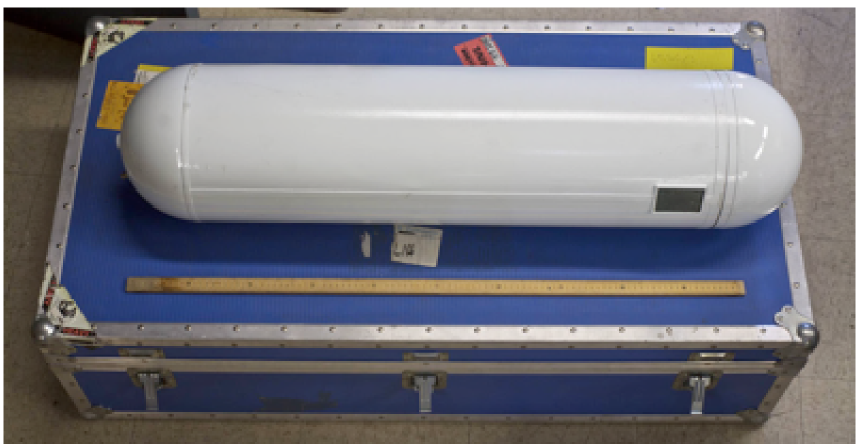

Figure 31 Pathfinder container. Small window is visible that was used for the camera

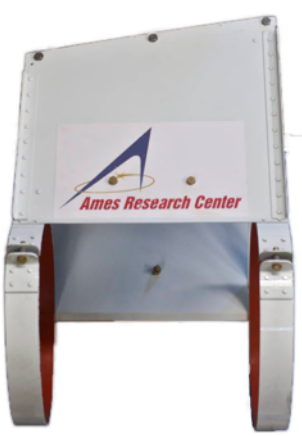

Figure 32 Pathfinder attachment ring

ZERO Cases Deep Drawn

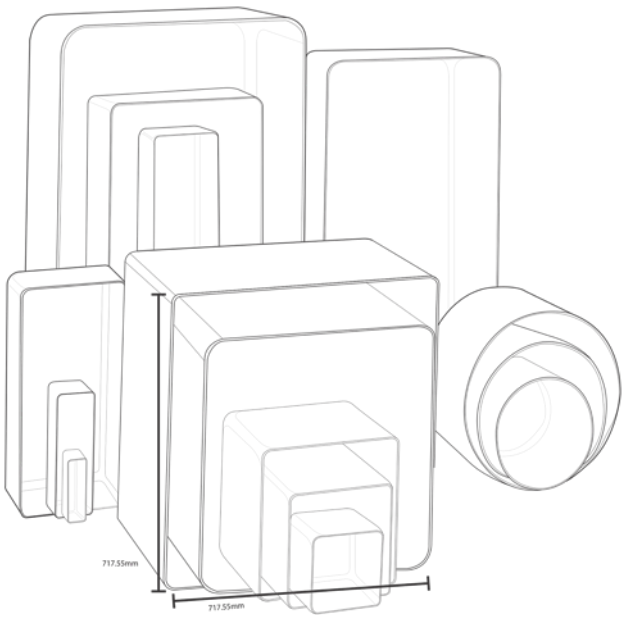

Figure 33 Zero Cases dimensions

ZERO Cases are widely available and easy to adapt to an experiment because of their canvas nature. Moreover these cases are available in all sizes for less than 2” to 28” by 28”[4].

Aluminum cases built without soldering are very robust and can easily insulate liquids, biological agents, or other moving parts from the vehicle. The cases are barren and easily accommodate personalized housings, but they also require an innovative fixture and cannot be easily stacked without a custom rack. Bolts, seals, lid designs are added at purchase. Cases cost close to $1000.

Researchers presently use ZERO cases in space experiments. CRuSR will surely benefit from designing a methodology for attaching these cases in the vehicles and corresponding ideal dimensions between researchers and flight providers.

[4] http://www.zerocases.com

Figure 34 ZERO Case Centrifuge Kit

Figure 35 ZERO Case Gel Pack Kit

Get Away Special Canister (GAS)

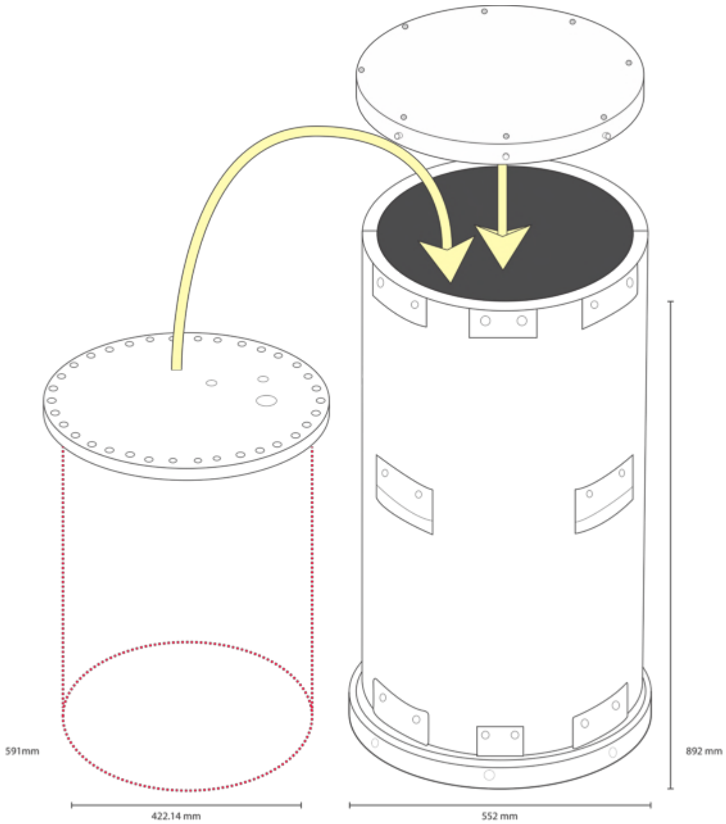

Figure 36 Get Away Special Canister dimensions

Get Away Special canisters hold experiments to solve solution center of gravity issues in the Shuttle. Ballast was needed to give the Shuttle the right re-entry angle. Instead of weights, GAS canisters, were used.

GAS canisters flew in over 100 missions. The canister gained features over time; a motorized lid was developed to expose experiments to vacuum. The interface plate in the canister gives experiments power and pressure (see Figure 37).

GAS canisters are too big and heavy for most vehicles CRuSR flies on but they might be useful in vehicles that cannot provide pressure or power.

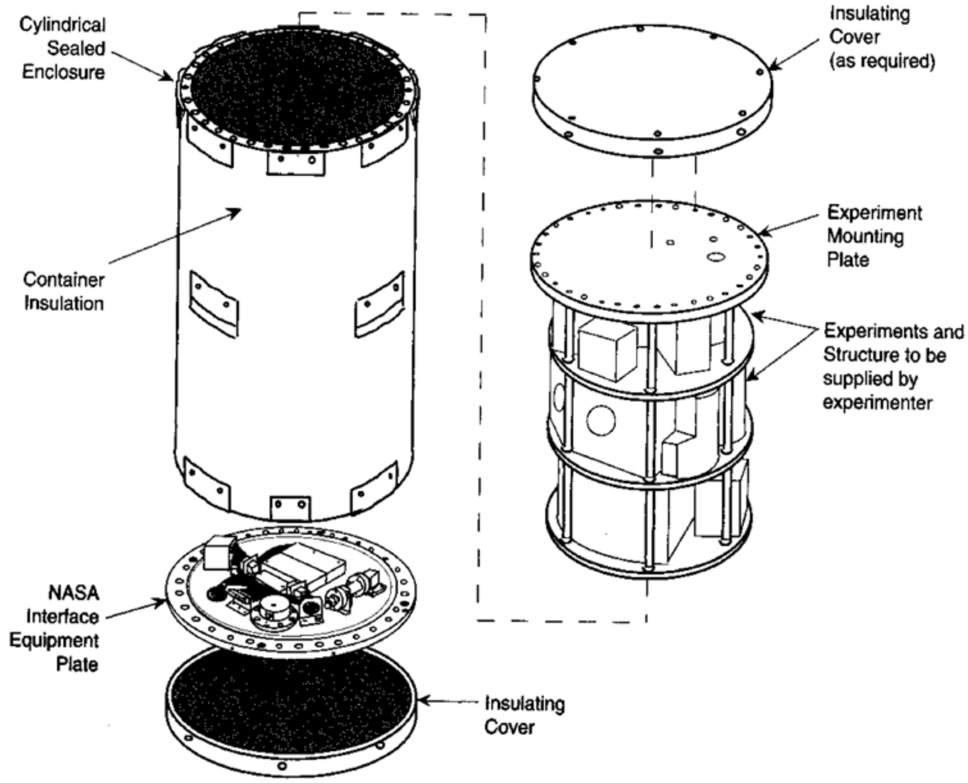

Figure 37 GAS Canister exploded view

Figure 38 GAS in Shuttle Bay