



PuzzleSat

By: Ralph A Stormer III



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Project Description

CubeSat missions, regardless of the foundation funding them, tend to fail during the mission lifetime, resulting in a dead mission. One reason for this occurrence is overuse of time at the beginning of the design process that leads to little time during the critical implementation time before the CubeSat is handed off to the Launch Team.

By creating a 3D printable engineering design model that allows for quicker development, the time spent at the beginning of the design process is shortened, thus allowing more time during the critical implementation stage of a mission. So that everyone trying to Build a CubeSat can use this solution, this engineering design model should be internally accurate in dimensions, easy to print, completely modular, compatible with the PC/104 PCB standard, and printable on small 3d printers. This solution in development is called PuzzleSat.

PuzzleSat is a 3d printable modular CubeSat shell and internal structure system. With this system, one can build CubeSat of varying forms and configurations, including 1U CubeSats, 3U \times 3U \times 3U CubeSats, and miscellaneous formations like rings, spheres, and cacti (a U refers to a standard CubeSat unit which is a decimeter cube (Walker, 2017)). As of the 7th iteration of the design, the system consists of 13 parts that interlock together to form a shell. All parts are based off plates that interlock to form the structural support for the PC/104 Printed Circuit Board (PCB) standard. This system is meant for engineering modeling of CubeSats, as to give developers an idea of how the final product would be wired and effectively look.

When PuzzleSat is fully developed and released to the community to use, the number of failed CubeSats should lower, thus allowing more tech to have Heritage, and advance the state of the art of CubeSats

Goal

PuzzleSat is a 3d printable CubeSat shell design that is internally accurate in dimensions, easy to print, completely modular and printable on small 3d printers. It is meant to be an engineering model for developers so that spatial concepts like wiring and board layout can be addressed and finalized sooner.

Strengths

PuzzleSat is a system of parts that when used together create rigid CubeSat body. As of the sixth iteration of the design the system consists of 10 parts (skeletal walls for the xy, yz, and zx planes, open walls for the xy, yz, and zx planes, half walls for the xy, yz, and zx planes, and an interlocking piece) that, when combined properly, can make almost all of the standard CubeSat configuration, 1U, 1.5U, 2U, 3U, and 6U, as well as nonstandard configurations, like larger cubes, spheres, and helixes.

The system is designed to support the PC/104 PCB with a 90mm x 96mm x 90mm open area inside. the design is also held to specs internally and externally, meaning no part of the system will exceed the desired CubeSat dimensions and will not impede the use of the PC/104 PCB.

All parts in this system are no larger than 100 mm in any orthogonal way, thus allowing the parts to be printable on printers like the Monoprice Mini Delta (a 3d printer with a circular printing bed with a diameter of 110mm and a maximum print height of 120mm).

Furthermore, all parts in this system will have little to no clean-up work needed after the print, so developers can print and go.

Justification

In the CubeSat community there are a lot of designs where one could find 3d printable systems that would result in flimsy structures or the entire CubeSat would be printed outright. For some developers, having a 3d printer that could print more than 15cm is not viable. For this reason, PuzzleSat's parts are all 11 cm or less at the maximum dimension, where the crucial parts are 10cm and below.

Background

CubeSat missions, regardless of the foundation funding them, tend to fail during the mission lifetime, resulting in a dead mission. One reason for this occurrence is overuse of time at the beginning of the design process that leads to little time during the critical implementation time before the CubeSat is handed off to the Launch Team.

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to print, completely modular, compatible with the PC/104 PCB standard, and printable on small 3d printers. this solution in development is called PuzzleSat.

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Place in Society

This is an engineering modeling tool for CubeSat engineers. It would be used in a development area as a spatial reference frame for new and veteran CubeSat engineers.

Features

PuzzleSat is designed with many features in mind. Those features are PC/104 compliance, completely modular, completely disassemble, printable on small 3D printers, relatively easy to print, and compliant with the CubeSat standard.

PC/104 Compliance

The PC/104 PCB in a standard electro-mechanical form factor used in many industries, including CubeSats. The boards are 95.89mm X 90.17mm X 1.57mm, meaning they snugly fit inside of a CubeSat's dimensional limit.

Completely Modular

Through PuzzleSat, rapid prototyping can achieve a whole new level of development. For example, some developers are working on a 1U CubeSat, but realize they need more space than what is available. With PuzzleSat, all they have to do is print out eight parts and their 1U could be a 1.5U or a 2U, depending on the parts printed, and carry on with their development

Completely Disassemble

Few things are more annoying than almost finalizing a system, then a change happens and to resolve the issue one must break what they have to fix it. For this reason, all PuzzleSat parts snap fitted together all have access points where the snap fit can be undone.

Relatively Easy to Print

All of PuzzleSat's parts have a specific way of placement during slicing that that results in a clean print that minimizes the use of scaffolding. This saves time and filament, and therefore money, that the developers could use elsewhere.

Printable on Small 3D Printers

To avoid alienating any developer of a CubeSat, all parts of PuzzleSat are able to be printed on small 3D printers. the reference size for a small 3D printer was the printing area of the Monoprice Mini Delta, a \$159.99 printer with a print area of ø 110mm X 120mm. One thing to note of, though, is that though the parts are printable, that does not mean that the best quality of the print is done using this printer.

Compliant with the CubeSat Standards

Finally, PuzzleSat creates CubeSats, so therefore every completed structure will conform to the size dimensions of the CubeSat created. for clarity, a 1U CubeSat made from PuzzleSat parts shall not surpass 100mm X 100mm X 100mm. A 1.5U CubeSat made from PuzzleSat parts shall not surpass 100mm X 100mm X 156.7mm. A 2U CubeSat made from PuzzleSat parts shall not surpass 100mm X 100mm X 213.5mm. A 3U CubeSat made from PuzzleSat parts shall not surpass 100mm X 100mm X 327mm. A 3U+ CubeSat made from PuzzleSat parts shall not surpass 100mm X 100mm X 327mm + ø 64mm X 13.75mm. Finally, a 6U CubeSat made from PuzzleSat parts shall not surpass 226.3mm X 100mm X 352.5mm.

Components

As of the sixth iteration of the design, PuzzleSat is a system of 13 parts, three common and four uncommon and six rare. The three common parts are the skeletal female, skeletal male and skeletal slide panels. The four uncommon are the holed female, holed male, holded slide panels, and the puzzle connect piece. The uncommon parts are the skeletal half female (S), skeletal half female (M), skeletal half male (F), skeletal half male (S), skeletal half slide , and the 3U+ can.

Common

The common parts are the parts that one would be printed out for every CubeSat size.

Skeletal Female

The skeletal female part is one of the main structural components of PuzzleSat. It holds the slots for a slide part as well as the openings for the snap fits of the male parts. The term skeletal refers to there being a bracing structure in between the outer rim of this panel. This part's secondary purpose is to act as a wall to the outside of the CubeSat.

Skeletal Male

The skeletal male part is one of the main structural components of PuzzleSat. It holds the slots for a slide part as well as houses the snap fits that integrate with the openings of the female parts. The term skeletal refers to there being a bracing structure in between the outer rim of this panel. This part's secondary purpose is to act as a wall to the outside of the CubeSat.

Skeletal Slide

The skeletal slide part is a thin slide that integrates with both male and female parts. This part allows for the PC/104 board to fit inside of the CubeSat without interfering with the other structural components. The term skeletal refers to there being a bracing structure in between the outer edge of this panel. This part's secondary purpose is to act as a wall to the outside of the CubeSat.

Uncommon

The uncommon parts are the parts that would be printed out for every CubeSat beyond a 1U.

Holed Female

The holed female part is one of the secondary structural components of PuzzleSat. It holds the slots for a slide part as well as the openings for the snap fits of the male part. The term holed refers to there being a large open area in the structure in between the outer rim of this panel. This part's secondary purpose is to act as an open passage for internal components, like wires, to safely move across different units in multi U CubeSats. As a tertiary use, it provides an area for the 3U+ can to attach to the CubeSat.

Holed Male

The holed male part is one of the secondary structural components of PuzzleSat. It holds the slots for a slide part as well as houses the snap fits that integrate with the openings of the female parts. The term holed refers to there being a large open area in the structure in between the outer rim of this panel. This part's secondary purpose is to act as an open passage for internal components, like wires, to safely move across different units in multi U CubeSats. As a tertiary use, it provides an area for the 3U+ can to attach to the CubeSat.

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The holed slide part is a thin slide that integrates with both male and female parts. This part allows for the PC/104 board to fit inside of the CubeSat without interfering with the other structural components. The term holed refers to there being a large open area in the structure in between the outer edge of this panel. This part's secondary purpose is to act as an open passage for internal components, like wires, to safely move across different units in multi U CubeSats. As a tertiary use, it provides an area for the 3U+ can to attach to the CubeSat.

Puzzle Connect

The puzzle connect part is the part that holds multi U CubeSats together. It is a single piece that one prints twice for each U past the first. It is designed to sit onto of another copy of itself, turned upside down, perfectly and provide snap fit on both sides to connect any 1U to either a .5U or another 1U system.

Rare

The rare parts are the parts that would print only if the CubeSat to be built was either a 1.5U or a 3U+.

Skeletal Half Female (S)

This part is a shortened variant of the skeletal female part. The S refers to the long side of this part is configured to integrate with a slide. This part combines with the skeletal half male (M) and either a holed slide or a skeletal slide to form a .5U extension.

Skeletal Half Female (M)

This part is a shortened variant of the skeletal female part. The M refers to the long side of this part is configured to integrate with a male. This part combines with the skeletal half slide and either a holed male or a skeletal male to form a .5U extension.

Skeletal Half Male (F)

This part is a shortened variant of the skeletal male part. The F refers to the long side of this part is configured to integrate with a female. This part combines with the skeletal half slide and either a holed female or a skeletal female to form a .5U extension.

Skeletal Half Male (S)

This part is a shortened variant of the skeletal male part. The S refers to the long side of this part is configured to integrate with a slide. This part combines with the skeletal half female (S) and either a holed slide or a skeletal slide to form a .5U extension.

Skeletal Half Slide

This part is a shortened variant of the skeletal slide part. The M refers to the long side of this part is configured to integrate with a male. This part combines with the skeletal half female (M) and either a holed male or a skeletal male to form a .5U extension. This part also combines with the skeletal half male (F) and either a holed female or a skeletal female to form a .5U extension.

3U+ Can

the 3U+ can is a cylindrical part that can integrate with a holed female, holed male, or holed slide. It is used as extra space for a CubeSat 3U+. The 3U+ can has dimensions of ø 64mm X 13.75mm.

Usage

PuzzleSat is a series of CAD files that will be distributed to the community. This said, those files can become real, made of many different materials, if a user has the resources to do so. The printing and building of parts, and therefore use of, PuzzleSat is strictly the choice of the developers. The intended use of PuzzleSat is that developers would print out enough parts to create a 6U plus the rare parts to form a collection of parts so that whenever a CubeSat is being developed, the parts are ready to be used.

Short Professional Biography

The Project Manager is Ralph Albert Stormer III, who completed his Bachelor of Science in Astronautical Engineering at Capitol Technology University. He has a large interest in Mechatronics, specifically in the space sector. Ralph's final career endeavor is to become an astronaut on the ISS or equivalent space station, maintaining the station both mechanically, and electronically. Ralph has been working on PuzzleSat for about two years, constantly designing and redesigning the system of parts as to create the best engineering tool for CubeSat development.

References

Stormer III, R.A. (4/21/2018). *Puzzlesat: senior design feasibility study* (Unpublished Feasibility Study). Capitol Technology University, Laurel, MD.