The Use of Low-Cost ‘BalloonSats’ for STEM Education with 3D Printing

Jeremy Straub
Josh Berk
John Nordlie
Ronald Marsh
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Jeremy Straub¹, Joshua Berk², John Nordlie¹, Ronald Marsh¹
¹Department of Computer Science, University of North Dakota
²Department of Space Studies, University of North Dakota

Introduction

A new technology, known as 3D printing, allows the rapid fabrication of plastic structures of virtually any configuration. These structures are light-weight, durable and inexpensive. This paper considers the utility of utilizing 3D printing to create enclosures for ‘BalloonSats’ – small, low-cost spacecraft analog which can be utilized by students to understand space engineering, conduct near-space science (e.g., physics, bio-logical and other experiments) and touch the edge of space.

The utility of 3D printed structures for use in the near-space low-temperature and low-pressure environment is considered. This analysis falls into four key areas. First, the ability of the structures to comply with Federal Aviation Regulations, §101 is discussed. Second, the structure’s durability in a low-pressure environment (note that most 3D printed structures utilize an air-filled honeycomb design) is analyzed and strategies (e.g., venting) to ensure outgassing is non-destructive are considered. Third, the structure’s durability in a low-temperature environment is discussed. This includes consideration of the impact of rapid cooling and heating on the plastic material and the structural integrity of the material in low-temperature conditions. Finally, the structural failure of a 3D printed structure (due to pressure, temperature or manufacturing defect) is considered and its impact on safe ballooning operations is discussed. The paper closes by discussing the prospective benefits available from a 3D printed ‘BalloonSat’ and the technological pathway to achieving them.

Compliance with §101 Federal Aviation Regulations

For all types of payloads, the primary requirement for payload and (for light payloads) train construction, pursuant to FAR §101, is to not create a hazard. The potentially hazardous aspects of a 3D-printed payload come from two aspects of construction: durability and hardness.

Durability

The payload must be suitably durable such that it does not break apart during the flight, potentially releasing internal (or externally mounted) components or structural components.

Hardness

The 3D-printed structure will not have a soft sur-face and it may be desirable to cover this (fully or partially) with a soft material such as foam.

Durability in Low-Pressure Environment

Because of the typical construction methods used in 3D-printing, the durability of the structure in a low-pressure environment is problematic. The typical 3D-printing technique creates air pockets within the structure. An internal support lattice is used to provide structural support; creating numerous internal air pockets (instead of a single large one).

Two possible approaches exist to remediating this problem. The first is to design the exterior walls to be suitably durable such that they can retain the air pockets. This, however, is problematic as it increases the mass of the structure and requires extensive testing to ensure that the walls won’t burst or deform.

Alternately, venting can be used to remediate this problem. Vent holes must be cut into both interior (between lattice pockets) and wall surfaces.

Durability in Low-Temperature Environment

The primary issue created by the low-temperature environment is the increased brittleness of the structure. Testing to-date has not indicated this to be a significant problem. However, this testing has not considered the combined impact of the increased brittleness and the low-pressure environment (placing additional potential strain—particularly if venting is not used—on the structural components).

Remediating of this issue may involve two aspects: selection of a suitable material (as some materials may be more affected than others by the cold) and testing to validate material selection.

A secondary issue caused by the low-pressure environment is shrinkage and deformation. The former is caused due to the natural contraction of many materials in the cold; the latter may be caused if some components are affected by this more than others.

Structural Failure & Safety

Several aspects must be considered relative to the structural robustness of the 3D-printed structure and safety. These include pressure/temperature environment durability (previously discussed), filament cohesion and structural defects.

Because of the nature of 3D-printing, several fabrication issues can occur which can significantly decrease the structural integrity of a 3D-printed structure. While the causes for these issues vary (printer misalignment, filament jam, feeder issues, etc.) the result is multiple levels of printer filament do not properly bond with each other. In the worst case, this may create a small hole or deformation in the exterior of the structure (altering the planned venting pattern and possibly placing undesirable stress on the structure). Alternately, layers of structurally unsound partial filament deployment may occur. This may, again, create unanticipated venting locations. The structural integrity of partially filled areas is questionable.

Benefits from 3D Printed Balloon Sats

Three potential sources of benefit exist from a 3D-printed payload: low-cost (comparative to custom-designed and fabricated structures), greater accuracy (compared to ‘homework’ style structures) and flexibility.

Low Cost

A 3D-printed HAB payload structure may cost as little as $20 to $30 in 3D printer filament (printing charges, for those that do not have a 3D-printer and must use a vendor, may increase this somewhat).

Greater Accuracy

Most 3D-printers are able to reach micro-level fabrication accuracy. This allows a structure to be created that can conform directly to desired size and component mounting / housing requirements.

Flexibility

The 3D-printed structure can utilize atypical configurations to best suit mission requirements.

Conclusions & Future Work

This poster has presented initial work into the creation of a 3D-printed high altitude balloon payload. Principally, it has discussed several potential considerations for potential problems that must be remediated to allow safe operations of the 3D-printed payload.

Future work will include: (1) the fabrication of a test payload that will be deployed in another (vented) structure of known structural integrity in low temperature and pressure conditions, (2) analysis of this test and (3) the creation of a pre-vented payload template.

References


Conclusions & Future Work

This poster has been revised and updated from [2].