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Passive CubeSat Probes for Affordable, Low-Risk Inspection of Space Vehicles

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Introduction

Effective fault detection is vital for safe and reliable spacecraft performance. Traditionally, developers have relied almost exclusively on on-board instrumentation to detect faults in spacecraft performance. Remote inspection can provide a holistic complement to on-board instrumentation, but it is seldom incorporated into spacecraft missions due to its cost and risk. As a result, multiple spacecraft have been lost due to unchecked faults in areas without instrumentation.

One solution to this problem is the use of Passive Inspection CubeSats (PICs). CubeSats are small, inexpensive satellites that can range in size from 10 X 10 X 10 cm for a 1U CubeSat to 30 X 20 X 20 cm for a 12U CubeSat. CubeSats are becoming increasingly common as spacecraft developers are using them to perform functions that would be prohibitively expensive for traditional satellites.

CubeSats can be integrated into spacecraft and deployed to search for faults after high-risk events. A deployed, passive CubeSat can inspect its parent vehicle, providing significantly reduced risk and cost compared with other methods of remote inspection. When combined with onboard instrumentation, these passive, fly-away CubeSats can allow for quicker detection of faults before they spiral into catastrophic failures.

Methods

The purpose of this project was to demonstrate the validity of the passive inspection CubeSat method of remote inspection. Prior to this ORCA grant, students from the BYU Spacecraft Group, led by Patrick Walton, developed a system architecture for a technology demonstration of PICs remote inspection. To demonstrate this approach to spacecraft inspection, they received funding to build two 1U CubeSats (PICs-1 and PICs-2) that would be flown on the Virgin Orbit Launcher One vehicle. Once in space, the two CubeSats would be deployed from the Launcher One and would rapidly bootup and begin imaging the launch vehicle. To reduce the risk to the parent spacecraft, the CubeSats were designed to be completely passive, meaning that they have no ability to control their orientation. To capture the launch vehicle regardless of the tumble of the satellites, each CubeSat needed to have a spherical camera array. This was accomplished by integrating a camera into each of the 6 faces of the CubeSats.

My work enabled the integration of the previously designed subsystems into a unified launch vehicle capable of performing its primary mission tasks. Additionally, I performed functional and environmental tests on the assembled CubeSats to qualify them for flight and to verify that they would function as designed. Throughout the process, changes were made to the structure, assembly process, and subsystem design to resolve issues that surfaced during assembly and system testing.

Results

Originally, PICs-1 and PICs-2 were scheduled for flight in the summer of 2018; however, delays in developing and testing the Launcher One spacecraft caused NASA to delay the launch date until Spring

2019. This schedule slip has been beneficial for the PICs project because the two flight units have needed to be reassembled several times as components were damaged or redesigned.

A flight-ready passive inspection CubeSat is shown in figure 1a, along with additional units at various stages in the assembly process. Environmental testing, including thermal vacuum chamber and vibration tests, have indicated that the completed units will survive the stresses of spacecraft launch and deployment into space. Functional tests indicate that, although imaging timing needs to be improved, the CubeSats can capture images of sufficient quality to identify features of interest on the launch vehicle. These imaging results can be seen in figure 1b and c.

This grant has also enabled me to co-author a journal paper with members of the BYU Spacecraft group and faculty advisers. The paper is entitled “Passive CubeSat Probes for Affordable, Low-Risk Inspection of Space Vehicles” and will be submitted to the Journal of Applied and Remote Sensing (JARS) in January 2019 for inclusion in a special edition. The paper describes the advantages of passive inspection CubeSats and describes in more detail the subsystem design and performance.

Conclusion

Both remote inspection and onboard instrumentation are necessary to fully characterize the state of spacecraft and reduce the risk of mission failure. When launched in Spring 2019, BYU’s PICs mission will demonstrate the effectiveness of passive inspection CubeSats for implementing remote inspection safely and inexpensively in spacecraft missions.

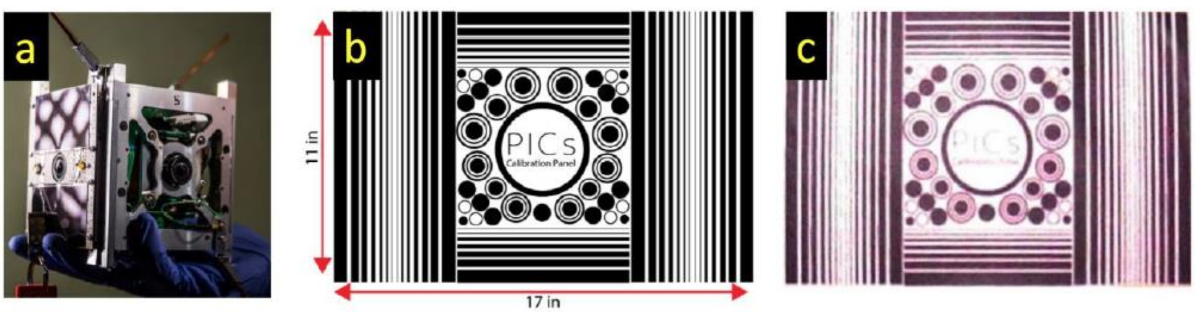

Figure 1 (a) An assembled passive inspection CubeSat. Results of the imaging test in which the CubeSat captured the (b) original target panel in the (c) recorded image at a distance of 2 m.

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