NASA PHASE I PROJECT SUMMARY

Firm: Creare
Contract Number: NNX13CG38P
Project Title: Ultra-Miniaturized Star Tracker for Small Satellite Attitude Control

Identification and Significance of Innovation:

To further its science goals, NASA needs to develop subsystems for smaller, less costly satellite systems. One such subsystem is the attitude determination and control system (ADCS). Precision ADCSs require highly accurate attitude determination sensors for three-axis stabilization, which are currently unavailable for small satellites. Current star trackers for large satellites are too large, too costly, and too power hungry for use with small satellites. Creare and Embry-Riddle Aeronautical University (ERAU), in collaboration with Distant Focus Corporation (DFC), propose to develop an Ultra-Compact Star Tracker (UST) that meets NASA's needs by employing a novel multi-mirrored reflective optical design. During Phase I, we conclusively demonstrated the feasibility of our UST. We developed a UST design that is estimated to have mass less than 650 g and a volume of less than 400 cm^3, and to consume less than 500 mW of power, while providing an attitude determination accuracy of better than 1 arc second.

Technical Objectives and Work Plan:

In the Phase I project, our goal was to demonstrate highly accurate attitude determination using the novel folded optics in a representative configuration. We mounted a powerful 4 MP CMOS image sensor to an existing folded optic lens with characteristics well suited for star tracker applications. The star tracker was optimized for high pixel resolution and high sensitivity, ensuring imaging of a number of stars sufficient to achieve attitude determination in any orientation. We developed a star detection and centroiding algorithm, and implemented a catalog search algorithm for attitude determination. We conducted optical system calibration and testing by imaging the night sky, verifying system sensitivity and overall attitude accuracy. We also conducted a detailed system design for implementation in Phase II.

Technical Accomplishments:

We constructed a brassboard UST prototype and conducted several tests where we imaged various sections of the night sky, providing quantification of the RMS attitude-determination error. From these measurements, we were able to ascertain that the individual star positional accuracy was approximately 3 arc seconds. We further concluded that pointing accuracy will be 1 arc second or better in pitch and yaw and 10 arc seconds or better in roll. Finally, we determined that our star tracker, while imaging from the ground on a dark winter night, was sufficiently sensitive to be able to capture enough stars to determine attitude in any section of the sky; specifically, stars dimmer than visual magnitude 7 were imaged and automatically identified in the data.

NASA Application(s):

Many NASA science missions are exploring the use of pico- and nano-satellites as alternatives to expensive, large satellites. In order to enable their mission profiles, these satellites need high-accuracy attitude determination sensors. Our star tracker will enable highly precise attitude determination (i.e., 1 arc second or better) in a package that is significantly smaller, has much lower mass, and uses less power than any alternative star trackers on the market. As the market for and uses of small and nano-satellites increases, the demand for our star tracker will increase to enable missions that are not possible with today's technology.

Non-NASA Commercial Application(s):

Both the military and commercial ventures are looking to small satellites to provide a cost-effective space mission platform. However, the majority of missions still require high-attitude accuracy. There is therefore a need for compact, high-accuracy star tracker technology. Furthermore, the military is looking at star trackers for high-altitude unmanned aerial vehicle (UAV) attitude determination. These will typically need to provide arc second accuracy in a small form factor with low power demands, which makes our proposed miniaturized star tracker ideally suited. Furthermore, our reflective optics can readily be adapted to act as a powerful telescope for imaging applications in both the visible band and in the near and far infrared spectrum. This opens up applications in reconnaissance, surveillance, and search and rescue operations.

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