Active Thermal Architecture for Cryogenic Optical Instrumentation

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Small Spacecraft Technology Program

Abstract

The Active Thermal Architecture for Cryogenic Optical Instrumentation (ATACOI) project will advance the technology readiness level of thermal support systems for infra-red (IR) optical instruments targeting 6U CubeSat form factors and above. Specifically, the development of a deployable solar tracking radiator, a rotationally flexible fluid joint, and mechanical vibration and thermal isolation of Electro-Optic detectors in the range of 60-110 K. Such a unique thermal management system will enable a new generation of CubeSat based MWIR and LWIR exploration missions in the fields of Heliophysics and Earth Science otherwise thought impossible for such small satellites.

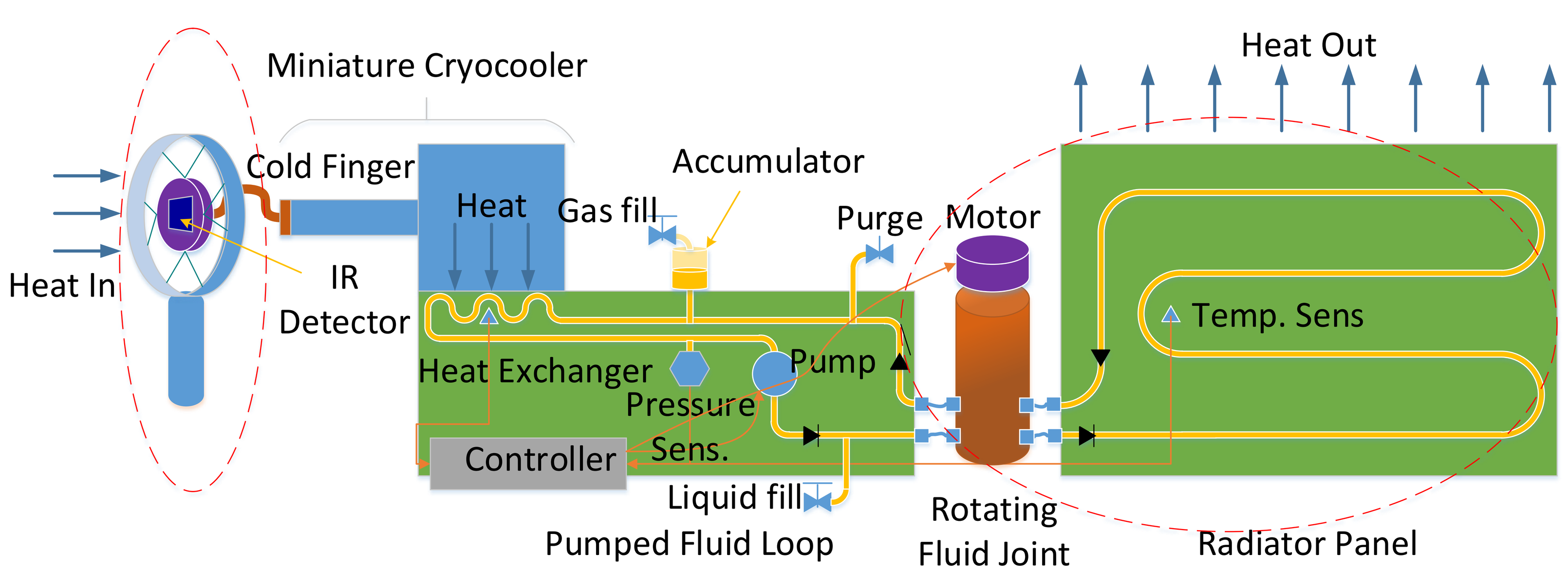
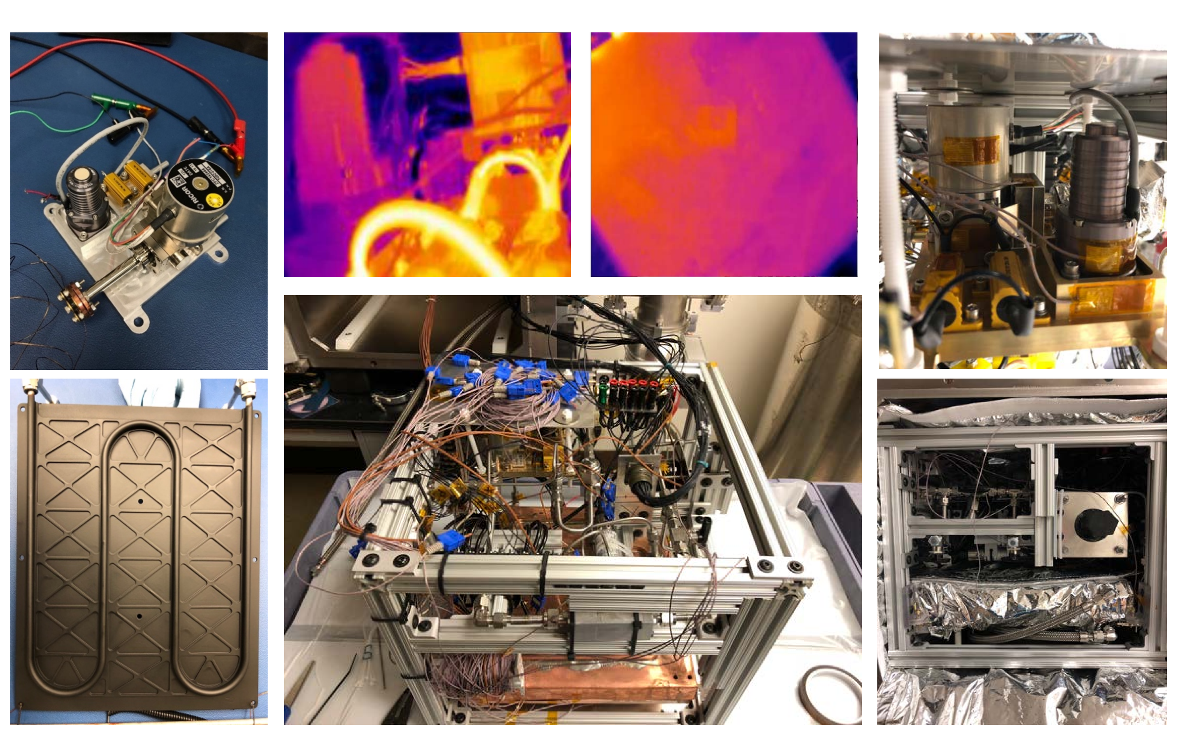


Figure 1: Technical Diagram

Relevance/Background

Cryogenic IR optical sensors are used in programs across the NASA Science Mission Directorate for diverse remote sensing purposes. This project uses "SABER Cube" and the "Earth Observation Nanosatellite–IR" (EON-IR) as reference missions. The technology gap for both missions is the cryogenic thermal architectures required to support the IR optical instrumentation, specifically the thermal accommodation of mechanical cryocoolers used to reduce the temperature of the focal plane detectors. The management of these thermal loads and jitter created by the cryocooler is a significant engineering problem in remote sensing thermal architectures. This project builds upon the previous work of the Active CryoCubeSat project. Active CryoCubeSat developed and tested a mechanically pumped fluid loop active thermal control subsystem for the management of large thermal loads on CubeSats.



Objectives

Objective	Performance Required	Performance Goal
A mechanism for deploying a stowed radiator panel from a 6U CubeSat.	Fluid line dia.: ≥ 5mm deploy distance: > 0 *Mass*: < 0.3 kg *Volume*: < 3x3x10 cm	Fluid line diameter: ≥ 6mm Deploy distance: > 20 cm *Mass*: < 0.2 kg *Volume*: < 2x2x3 cm
A one-axis pointing system for a deployed radiator panel	Pointing resolution: < 5° Commanded tracking Turning Range: ±90° Avg. Power: < 50 mW	Pointing resolution: < 2.5° Solar avoidance tracking Turning Range: Continuous Avg. Power: < 10 mW
A mechanical, thermal isolation of a cryocooler and IR-detector	Jitter Amp.: < 0.005° Detector Thermal Load: < 200 mW *Mass*: < 0.1 kg *Volume*: < 4x4x1 cm	Jitter Amp.: < 0.001° Detector Thermal Load:< 100 mW *Mass*: < 0.05 kg *Volume*: < 3x3x0.5 cm

Technical Description

The ATACOI system is based upon a two stage thermal architecture as shown in figure 1. The first stage (in green) consists of a mechanically pumped fluid loop which cycles a single phase working fluid between an internal additively manufactured heat exchanger to a deployed radiator through a rotationally flexible joint. The second stage (in blue) relies upon a tactical cryocooler to provide a cryogenic environment for the detector. The two stages interact at the base of the cryocooler with the internal heat exchanger.

Radiator Deployment and Pointing System:
- 2-axis deployment
- Solar tracking
- Rotationally flexible fluid joint

Thermal and Vibration Isolation:
- Vibrational damping and jitter mitigation
- Thermal isolation of the thermal architecture and optical bench

Full System Characterization:
- Thermal Vacuum Chamber Testing
- TRL raised to level 5

Key Technologies:
- Ultrasonic Additive Manufacturing (UAM)
- Miniaturized mechanically pumped fluid loop
- 2-axis deployed radiator with solar tracking
- Vibrational isolation of focal plane
- Concurrent methodologies for conceptual mission design

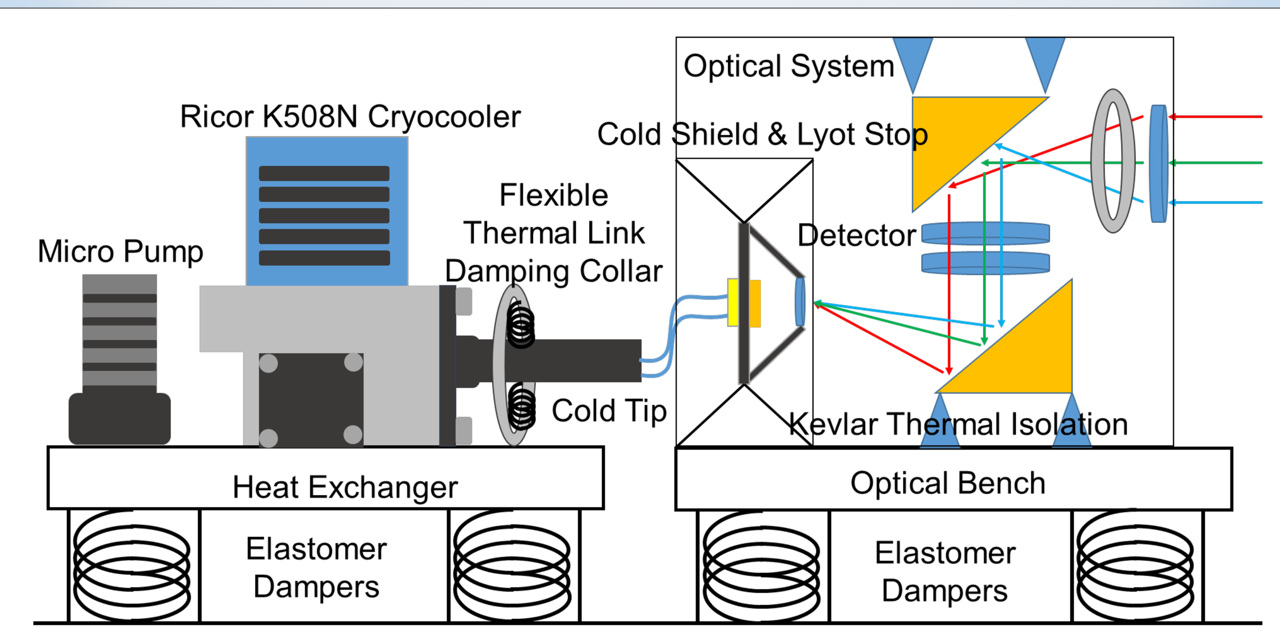


Figure 2: Concept of Vibration Dampening

Project Plan and Timeline

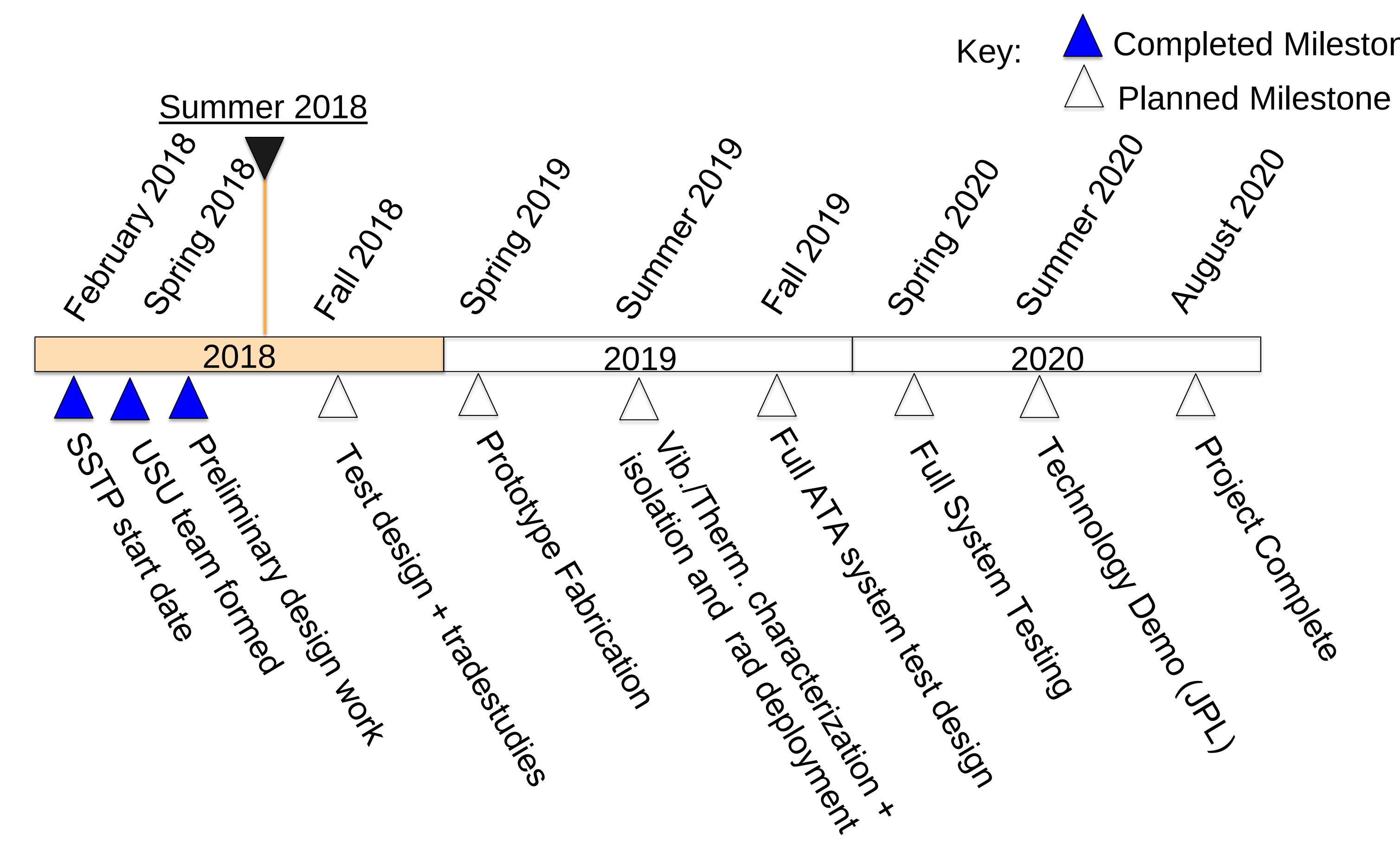


Figure 3: Project Plan and Timeline

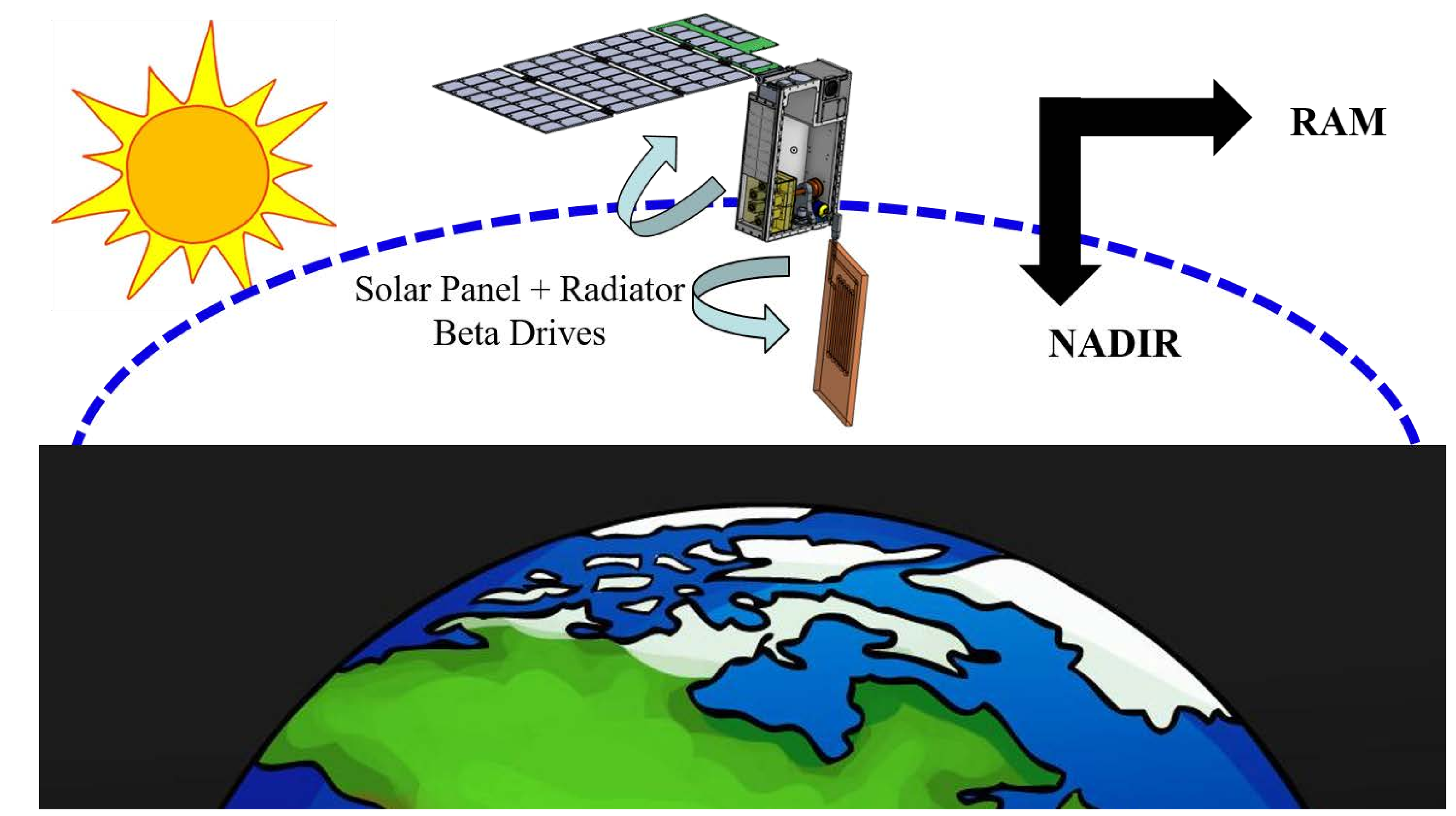


Figure 4: Concept of Operation

Awknowledgements

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