2020 Small Satellite Conference

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The Active Thermal Architecture:

Active Thermal Control for Small-Satellites

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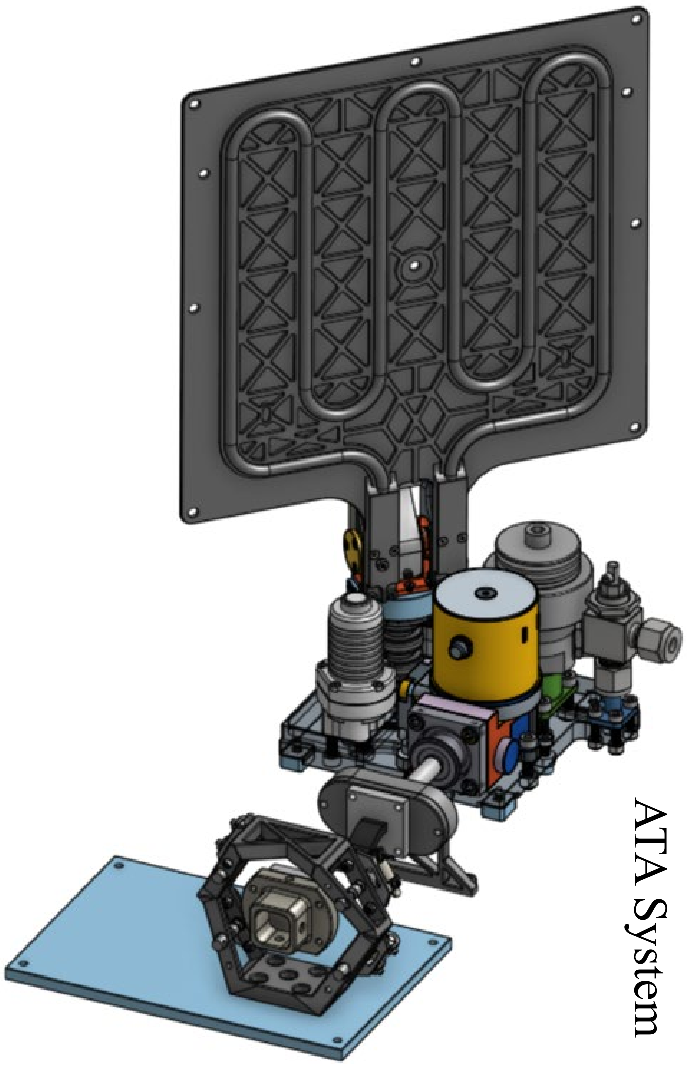
Outline

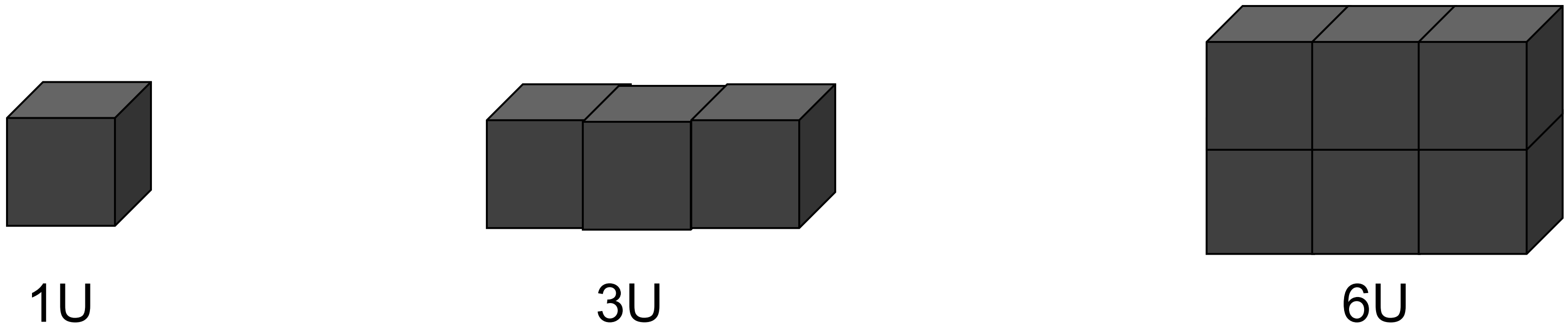
- CubeSat Thermal Management
- Project Overview
- CONOPS & Theoretical Basis
- Relevance & Future Missions
- ATA Design
- Progress
- Future Work



ATA System

Thermal Management for CubeSats

Thermal management is critical to enabling cryocoolers and cryogenic instrumentation for advanced CubeSat missions.



- ~1 Watt/U----Passive surface properties
- ~6-20 Watt/U----Conduction paths, Heat Pipes, Surface properties
- ~20+ Watt/U----Pumped fluid loops, Deployed radiators, and active solutions

The ATA system is designed as a 1U system with the capability to reject >60 W of thermal power with an interface rejection temperature of <50 ^{o}C.

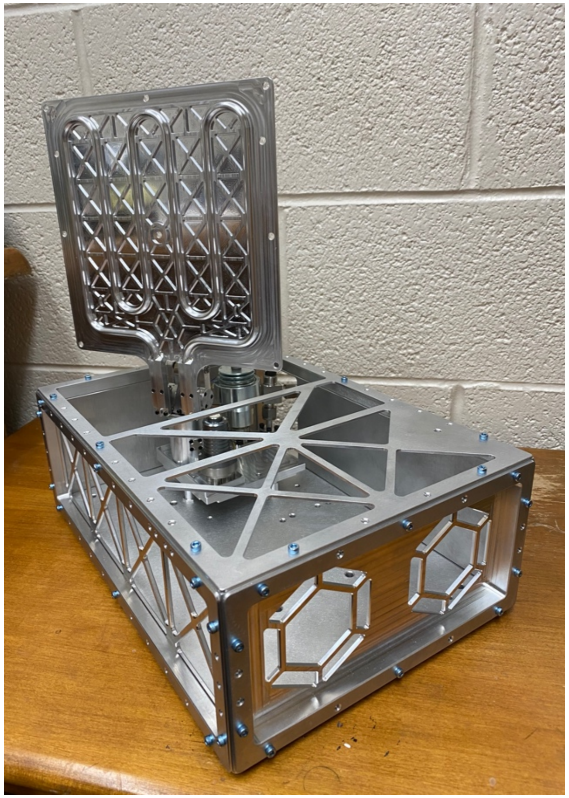
Project Overview

The Active Thermal Architecture (ATA) project is a NASA SmallSat Technology Partnership (SSTP) grant with Utah State University and the Jet Propulsion Laboratory.

The ATA project has developed a relevant ground-based prototype consisting of:

- A 1U Active thermal control subsystem
- An Integrated tactical cryocooler
- A 4U deployable tracking radiator
- A 6U demonstration CubeSat chassis
- Integrated passive vibration isolation & damping
- A prototype electro-optical isolation mount

This ATA project is a continuation of the Active CryoCubeSat effort which developed the baseline MPFL technology for the Active Thermal Control system.



ATA Prototype

Project Goals and Objectives

Project Objectives:

- Further develop a 1U miniature mechanically pumped fluid thermal control system targeted at CubeSat's & Small Satellites via UAM fabrication.
- Develop a mechanism for deploying a stowed radiator panel from a 6U CubeSat.
- Develop a one-axis pointing system for a deployed radiator panel
- Develop a mechanical and thermal isolation system for an integrated cryocooler and an IR-detector assembly.
- Develop a relevant prototype of the system
- Test system performance in a relevant TVAC environment. Raise TRL to 5 or 6 (TBR).

ATA Project Requirements	
Required Performance	Performance Goal
Two-Stage Flexible Fluid Joint/Hinge Deployed Radiator	
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
Tracking Radiator	
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
Vibration Isolation/Cancellation	
Jitter Amp.: < 0.005° **Detector Thermal Parasitic: < 200 mW** **Mass: < 0.1 kg** **Volume: < 4x4x1 cm**	Jitter Amp.: < 0.001° Detector Thermal Parasitic:< 100 mW Mass: < 0.05 kg Volume: < 3x3x0.5 cm
Enabled Optical Instrumentation Capabilities	
Cryogenic Instrumentation: Detector Temperatures ≥ 60K MWIR, LWIR Bands (3 – 15 μm)	
IR optical instruments with IFOV > 0.01°	
IR Optical instruments with integration times < 20s	

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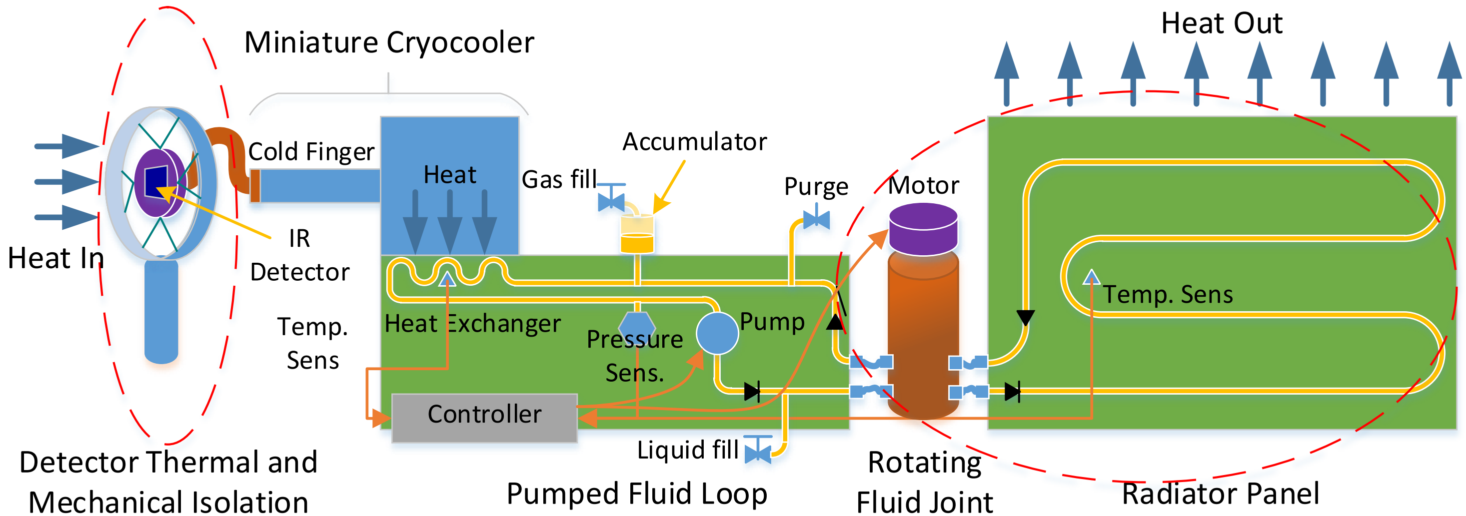
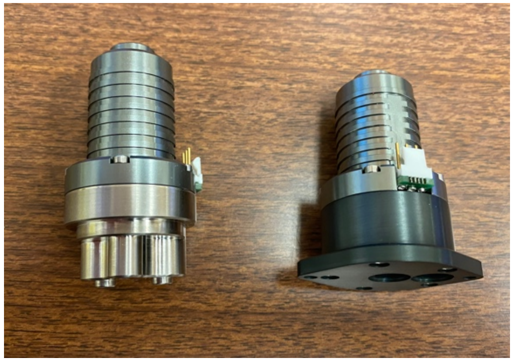
Theoretical Basis



- Single phase 2x-stage Active Thermal Control
- MPFL Cycles working fluid between a cold radiator and a hot heat exchanger. Providing general thermal management.
- A miniature cryocooler provides an isolated cryogenic environment



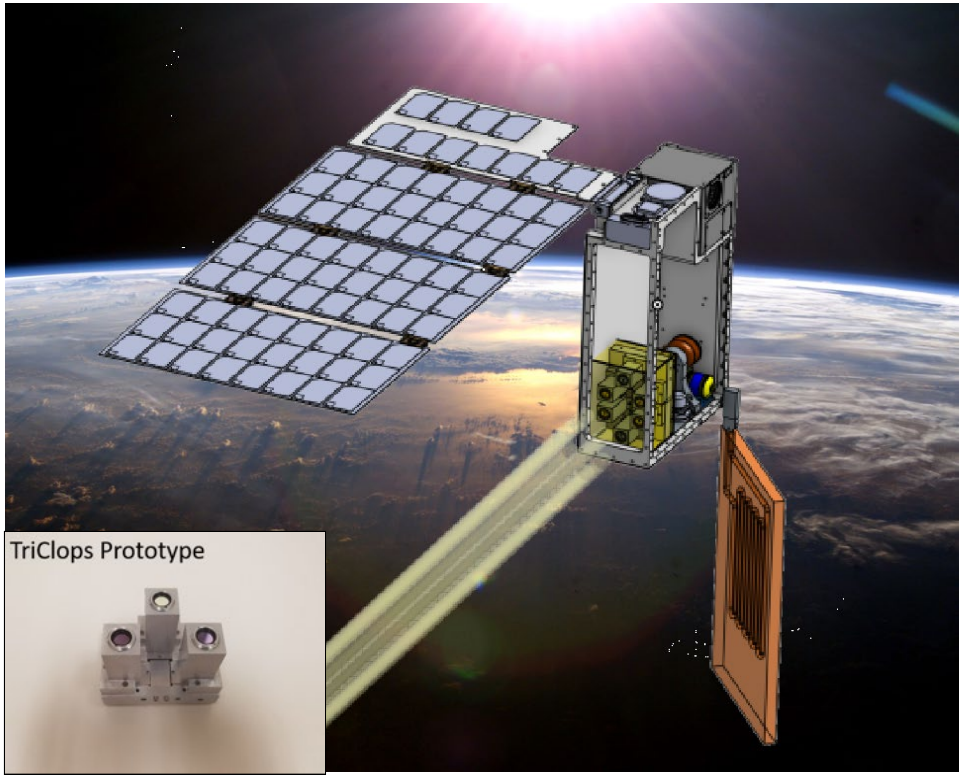
The ATA system is designed to use either the MGD1000 Micro-Geared pump (Left) or the TCS M510 rotary pump (Right)

Relevance & Future Missions

The ATA system was originally conceived as a thermal support technology for advanced Electro-Optical instrumentation for future Earth-Science & Helio-Physics missions.

Several such missions have been proposed:

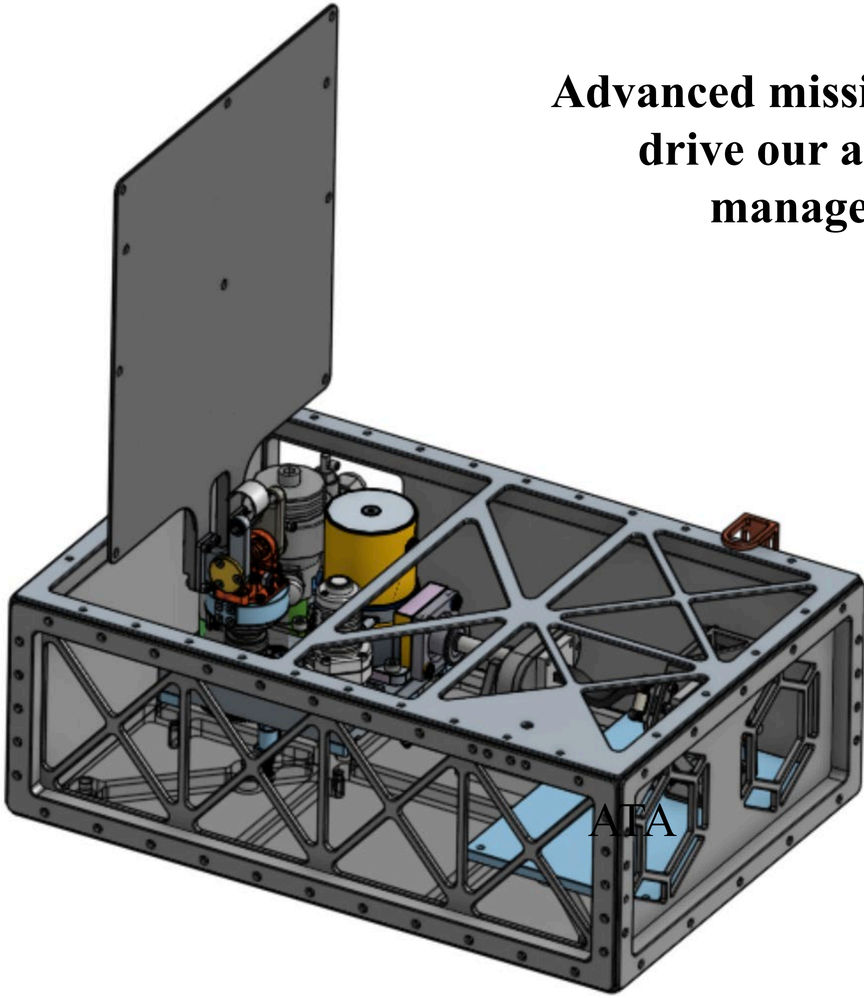
- SABER-Lite (Tri-Clops) a simplified/miniaturized replacement for the aging SABER instrument on the TIMED satellite.
- NOAA EON-IR. A LWIR E-O instrument for sounding data of the temperature and water vapor profiles in the lower troposphere.

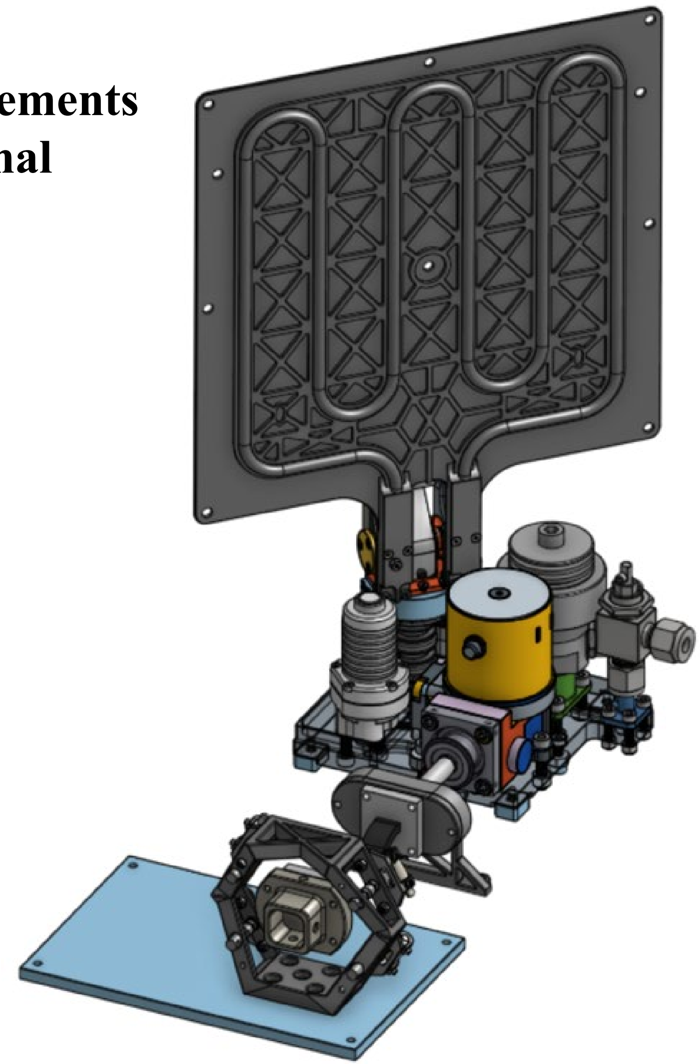


A concept mission for the ATA system in support of a limb viewing electro-optical instrument. Inset shows the prototype of the Tri-Clops broadband IR instrument developed at USU.

ATA Design

Advanced mission power requirements drive our approach to thermal management & Design.

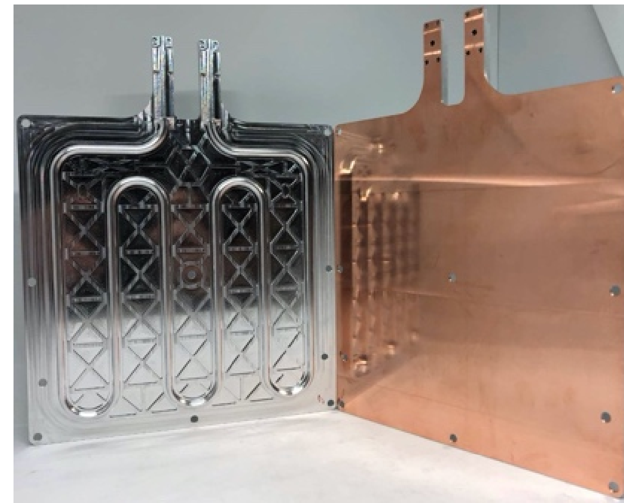




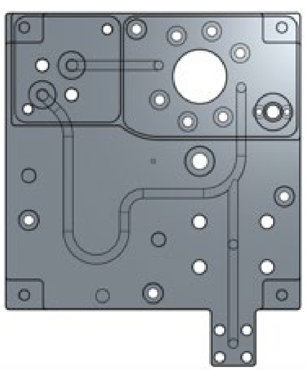
ATA Integrated Prototype & 6U Chassis

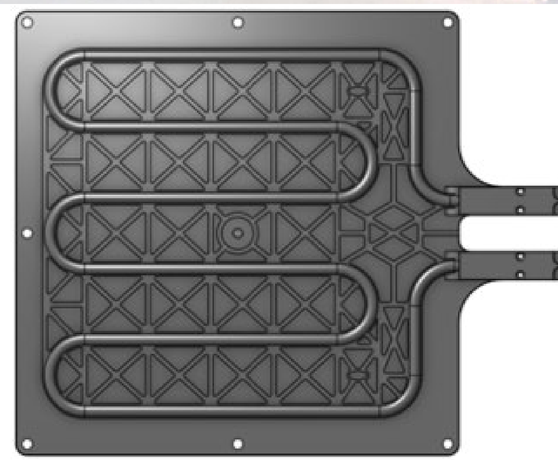
Ultrasonic Additive Manufacturing

UAM techniques allow the working fluid channels of the MPFL to be embedded directly into the CubeSat chassis and radiator. Additive/Subtractive 3D printing techniques such as UAM allow for:



- Rapid design & fabrication
- Improved thermal performance
- Miniaturized & simplified flow paths
- The development of unique designs otherwise impossible with traditional fabrication techniques





Deployment Mechanism

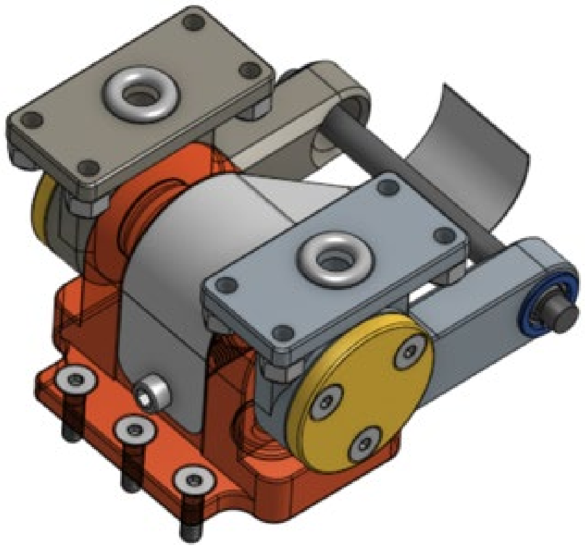
The one-time deployment of the radiator is accomplished via the use of stacked Contorque springs assembled in a fixed spool design.

Design highlights:

- Simple, integrated, compact design
- Robust design with little chance of failure
- Constant torque throughout deployment
- Stackable (Tunable) springs and torque
- Full torque is maintained in deployed state
- Easily resettable

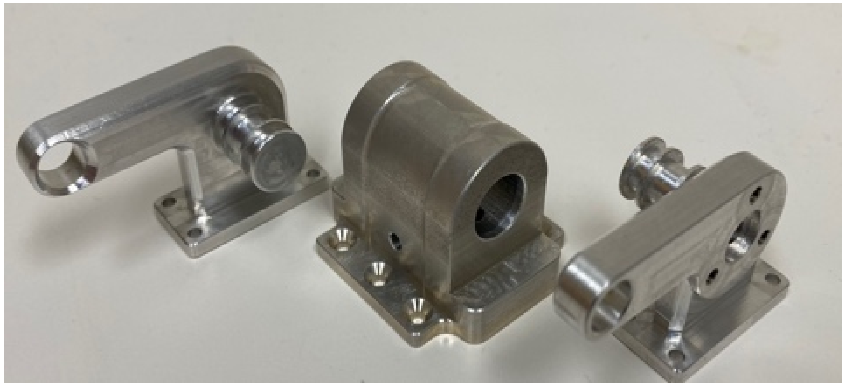
90° Rotary Union (NANO90)

The Radiator's initial deployment is accomplished via a horizontal 90° rotary fluid joint. The Nano90 is a customized two-channel manifold mount single axis rotary union.



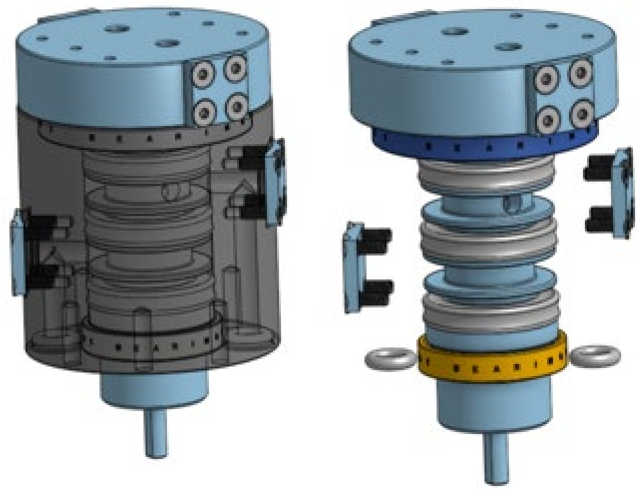
The Nano90 features a dual seal horizonal piston O-ring design. The working fluid is transported from the continuous rotary union to the Nano90 and than into the deployed radiator.

The radiator deployment mechanism is integrated into the Nano90 system and features the deployment "Moment" arms for the Contorque springs.



Continuous Rotary Unions

The ATA MPFL system relies upon a flexible rotary fluid joint to transport the working fluid to the external radiator. Because of the unique and miniaturized design of the ATA system a custom rotary union was developed for continuous tracking of the deployed radiator.

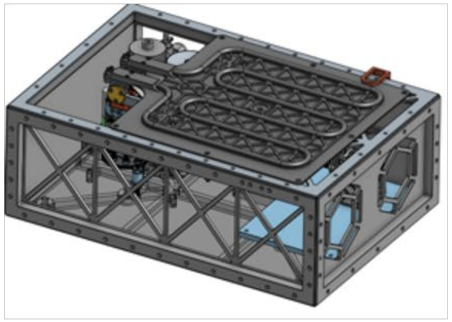


The rotary union is a 3x seal rotating piston O-ring design. The rotary union is miniaturized for CubeSat applications and customized to support manifold mounting to the heat exchanger and the initial Nano90 deployment mechanism.

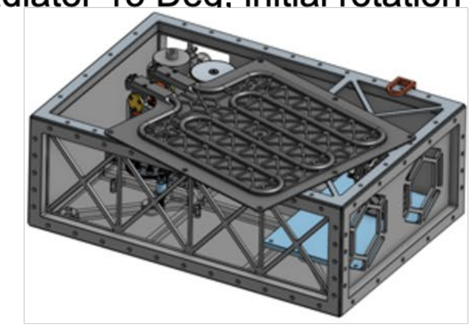
The ATA system features custom static and dynamic O-ring seals designed for miniaturization and the space environment.

ATA Radiator Deployment

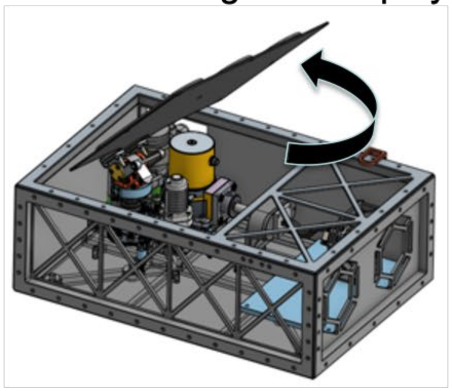
ATA System in:
Stowed State



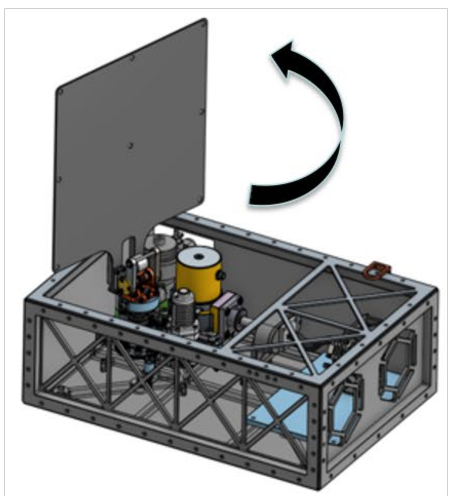
Release Launch Locks
Radiator 15 Deg. initial rotation



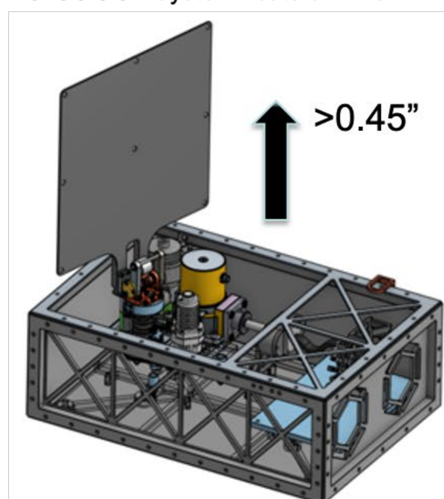
Radiator begins to deploy



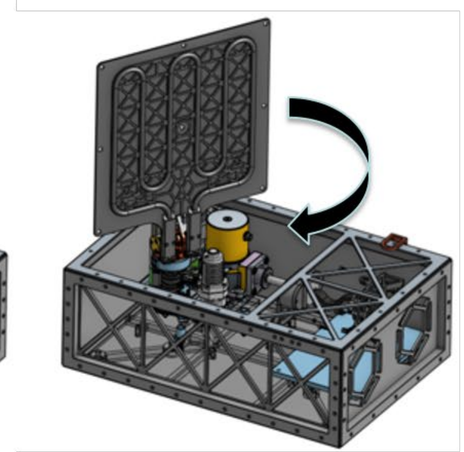
Radiator Full Deployment



HX Launch Locks
release. System floats on wire

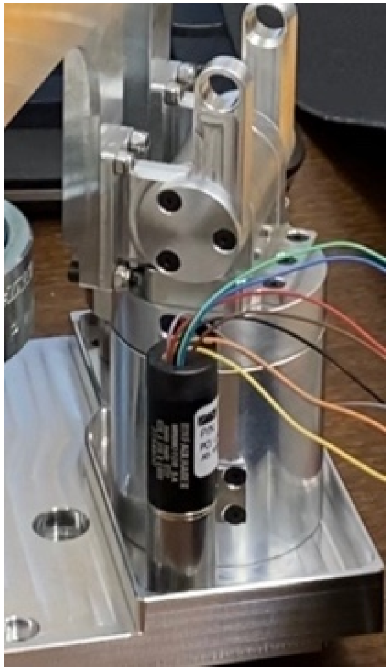


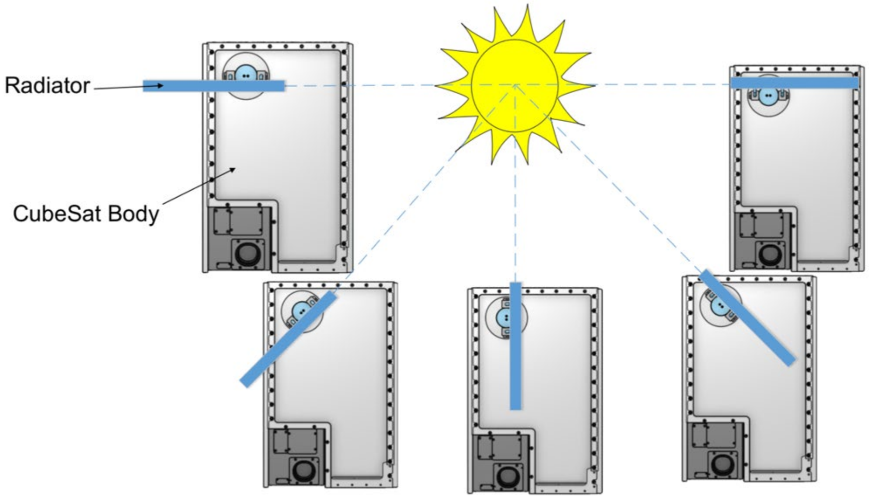
Radiator Continuous
dual direction rotation

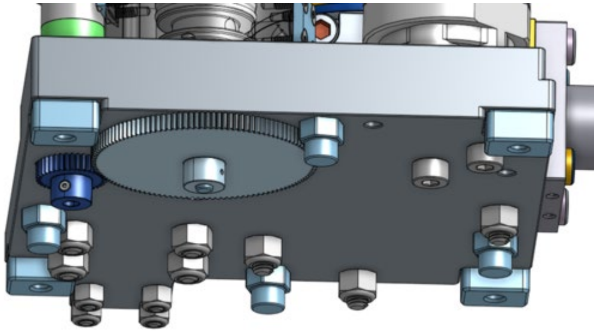


ATA Radiator Tracking

- Once deployed the ATA radiator is tracked with a rotary union stem-core design that allows a micro-motor to continuously drive the core of the rotary union and therefore the deployed radiator.
- A 3x-to-1x spur gear system located under the heat exchanger along with a planetary gear system in the micro-motor provide the necessary torque.
- The radiator can be tracked edge-on to the sun to minimize the impact of the space thermal environment, or angled face on to the sun to act as a control/feedback power input.

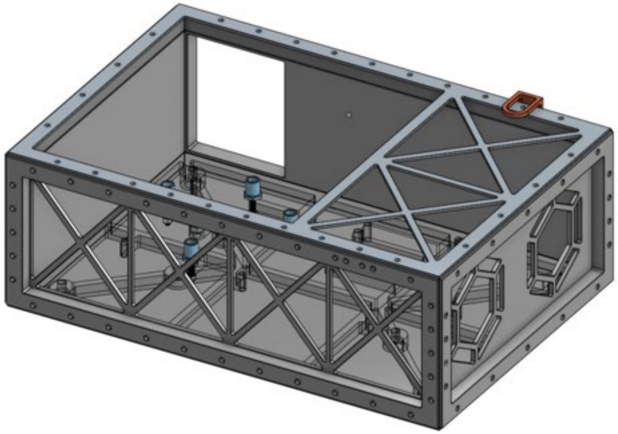




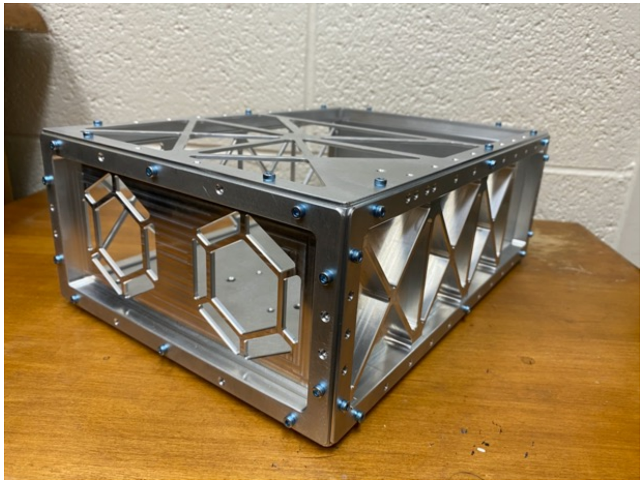


ATA CubeSat Chassis

The ATA CubeSat chassis is based on a standard 6U structure and designed to be a relevant ground-based prototype for the integration and characterization of the ATA system.



- A vibrational transfer function similar to a real 6U CubeSat chassis
- An exact 6U internal volume
- A solid (one piece-machined) frame
- Light-weighted & Wire-Framed external panels for viewing and access
- Realistic panel, strut, and ribbing thickness
- A customized platform for the ATA prototype

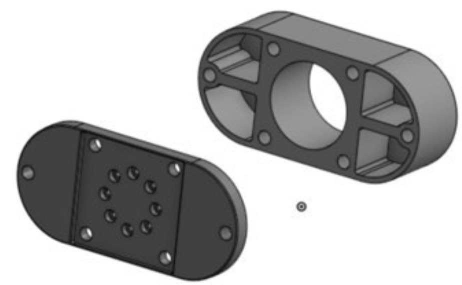


Vibration Isolation & Damping

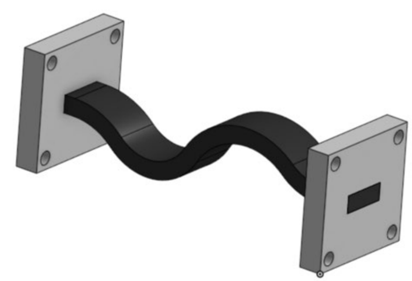
The ATA is an active system and therefore generates and exports vibration. To mitigate the effect of this vibration on the CubeSat the ATA system features several passive isolation & damping technologies.

- Wire rope vibration isolation for the heat exchanger plate and optical bench. These isolators allow the system to float with respect to the CubeSat chassis.
- A cold tip particle damper to absorb vibrational energy from the active cold finger of the cryocooler.
- A Pyrolytic Graphite Sheet (PGS) thermal link to conduct heat from the detector to the cryocooler while mechanically isolating the detector.

Wire-Rope isolators and particle damper



Custom ATA cold tip particle damper



PGS Thermal Strap

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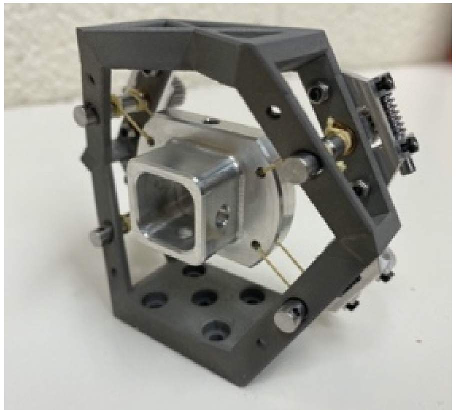
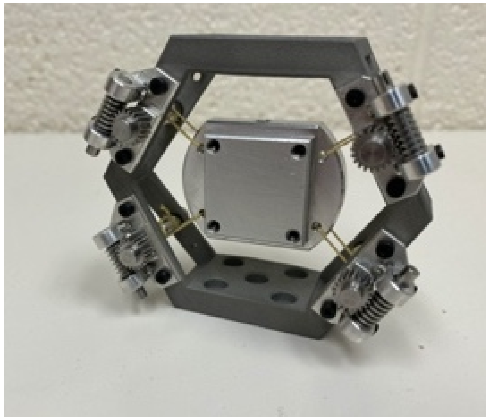
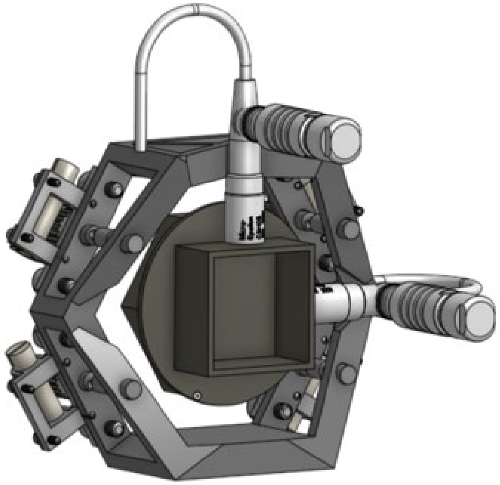
ATA Electro-Optical Detector

The ATA features a prototype Kevlar-wire isolation mount for a dummy detector. The Kevlar string provides an excellent stiff & strong mechanical support while providing unmatched thermal isolation. The Kevlar can be tensioned/adjusted via worm-gear machine screws and a custom 3D printed frame.

The exact effect of the ATA's exported vibration will be characterized via 2-axis Capacitive displacement sensors. This will characterize the jitter frequency and amplitude of the detector and the custom isolation mount.







Progress

The ATA team has completed most of the major project milestones. These include:

- Complete mechanical and electrical designs
- COTS trade-studies and down selection
- Mechanical/Electrical fabrication of all components
- Full system build and integration
- Leak testing of all dynamic and static seals
- Benchtop testing of the radiator deployment and tracking mechanisms
- Development of detailed testing procedures
- Design of the final TVAC and characterization tests

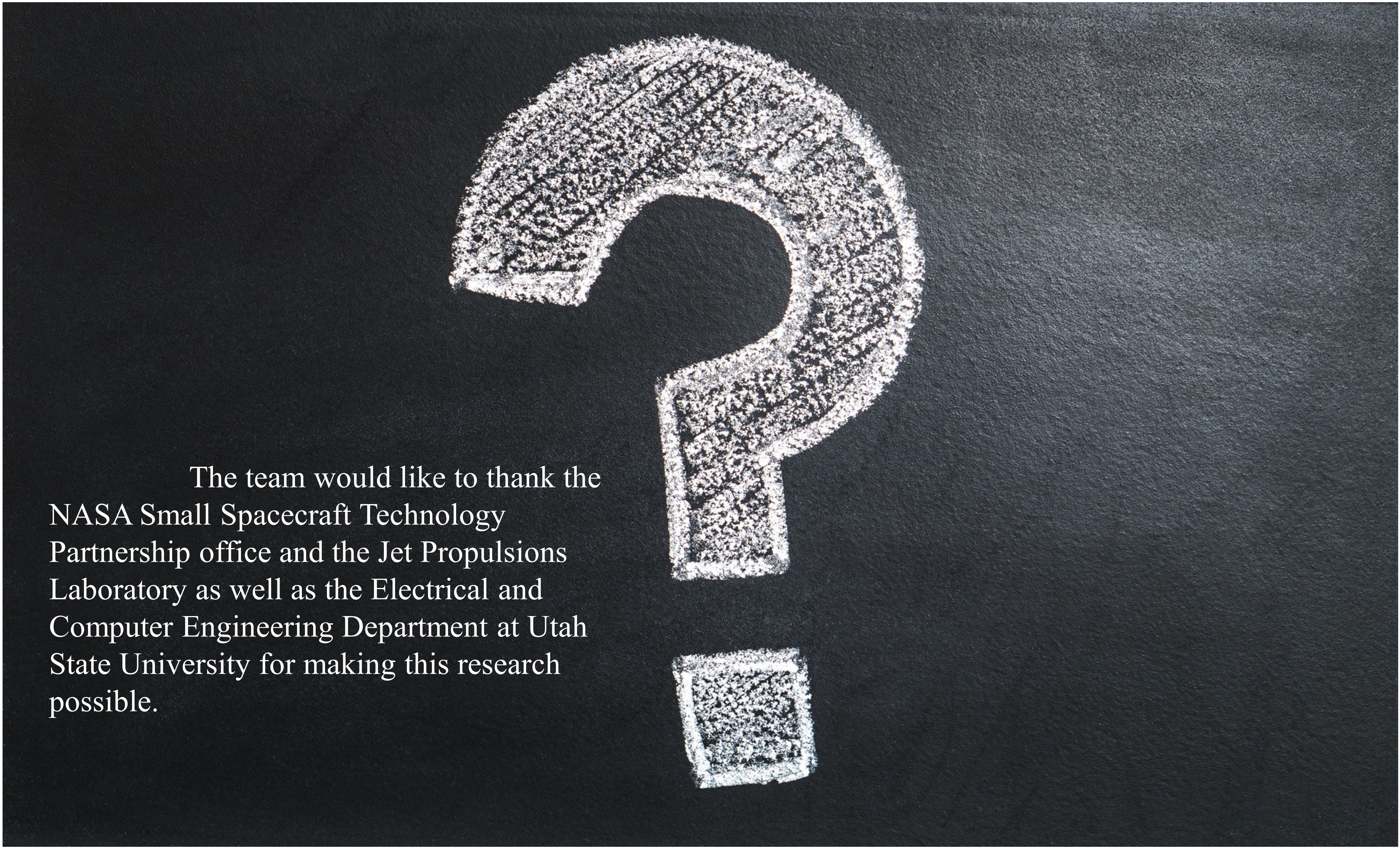
The final testing of the ATA system has been delayed due to COVID-19.

Future Work & Goals

The full characterization of the ATA system requires four distinct tests. These tests are in progress and should be completed by early Fall 2020.

- A force-dynamometer characterization of the ATA's exported vibrations
- A full Helium leak check
- A soft & hard stow launch vibration test
- A full technology demonstration in a relevant TVAC environment with a cold-deploy of the radiator
- A Thermal Desktop model of the ATA system

It is the ultimate objective of the ATA team to continue the development of advanced active thermal control systems in support of future SmallSat missions.



https://medium.com/wadepthealth/frequently-asked-questions-about-covid-19-march-8-2020-5b71232941dc