Multidisciplinary Senior Design
Project Readiness Package

Prepared by [Martin Pepe] on [rev: 7-18-19_Prelim.]

Project Title	Heat Switch – Mechanical Heat Switch for Deep Cryogenic Applications
Project Number	**P20129**
Primary Customer	RIT Center for Detectors – Michael Zemcov.
Sponsor	(CfD) - Center for Detectors
Faculty Champion	Michael Zemcov (ofc; 17- 3179) 475-2338, zemcov@cfd.rit.edu
Other Support	Model Shop, Maker's Lab, CfD lab space (17-3140), Electronics lab space.
Project Guide	Marty Pepe, (585) 298-0246 (c), mjpastro@gmail.com, mxpddm@g.rit.edu
IP Considerations	Open

Project Information

Overview

The primary effort on this project is to build a flight ready super-cold 'finger' (4*K) for a sensor package, capable of withstanding the rigors of rocket (& balloon) acceleration and vibration. It would be 'charged' before flight and provide ***xx*** minutes of cooling for a load of ***yy*** watts. This work is a follow-on to P19129 Heat Switch which was a lab demonstration 'Proof of Concept', and it's *original* goals (link >). http://edge.rit.edu/edge/P19129/public/Home

Cryogenic cooling below 10K requires special technologies and devices that use thermodynamic cycles that cannot operate near room temperature. It is necessary to pre-cool these deep cryogenic refrigerators using buffer stages, and good thermal contact between the device and bath is required to minimize the time required to cool the system. However, in order to operate the refrigerator must be thermally disconnected from the bath to allow the thermodynamic cycle to proceed. A ``heat switch'' is necessary to achieve this. A variety of heat switch designs exist, each with their particular benefits and problems.

Below is a combined list of customer and engineering requirements, but not limited to total project needs as might be required to accomplish this deliverable.

Preliminary Customer Requirements (CR) / Preliminary Engineering Requirements (ER)

- **CR;** Create a miniature mechanical heat switch design for **space flight** sensors, detectors and CCD applications. Design & build a hardened ***Flight Ready*** Heat Switch sub-assy. for the rigors of flight. Given a typical rocket vibration & acceleration profile envelope. Identify acceptable system flight envelop with the customer, for performance requirements and specifications.
    - ER;

- **CR;** Make necessary improvements to the (lab prototype) ratchet mechanism to improve travel. Measure existing prototype travel, and quantify improvement (s). Including proper material selection to minimize friction and wear ('lessons learned' from Lab prototype).
    - ER;

- **CR;** Create a dummy thermal load (power resistor) of under 5 Watts to simulate the thermal load of a sensor (ie; CCD, etc.). Make it Programmable in ~100 mW increments to quantify thermal performance.
    - ER;

- **CR;** Design and partition the flight electronics between ground based and flight modules. Include signals to indicate system 'launch ready - GO' at time of launch, and 'abort' operation.
    - ER;

- **CR;** Simulate thermal conduction, and switching life cycle / failure mode performance for (at least > 1000) cycles (1K). ER; Use the proper Sim tools (COSMOL, MatLab or AutoCad / Solidworks). Identify the top three failure modes of the system, and a strategy to mitigate them to minimize system failure (ie; operation, but at reduced performance).
    - ER;

- **CR;** Finally, work with the customer to discriminate between **'gotta have'** and 'nice to have' deliverables based on the customer's experience and the Lab Prototype testing.
    - ER;

- **CR;** Generate a computer-controlled system test fixture to operate the test bed above, and take data on the heat switch characterization, operation and performance. Optionally may need to add some cryostat control. Demonstrate typical 'Flight Ready' operation.
    - ER;

- **CR;** Simulate thermal conduction, and switching life cycle / failure mode performance for (at least > 1000) cycles (1K). Use the proper Sim tools (COSMOL, MatLab or AutoCad / Solidworks). Identify the top three failure modes of the system, and a strategy to mitigate them to minimize system failure (ie; operation, but at reduced performance).
    - ER;

- **CR;** System Integration by the team of the above mechanical & electrical hardware and all system and data taking software. Integrate the above mechatronic system to accomplish all of the above requirements, including project deliverables (below).
    - ER;

- **CR**; Investigate E beam welding and gold plating to improve thermal conduction characteristics if required. Identify associated cost / benefit opportunities.
    - ER;

Constraints

Heat switch assembly prototype must fit & operate within an existing cylindrical envelop of a rocket payload bay [profile **TBD**] & the CfD Lab cryostat

Lab Cryo link - [Size & model; Infrared Labs, Md# HDL – 8, Ser# 3374, irlabs.com.]

Additional Project Deliverables;

Minimum requirements:

- *All design documents (e.g., concepts, analysis, detailed drawings/schematics, BOM, test results), including a back-up site for ALL documentation (drawings, schematics, etc.)*
- *Deliver a working flight integrated system.*
- *Technical paper*
- *Poster*
- *Team is expected to participate in Imagine RIT*

Additional required deliverables:

- *Write four manuals;1) Training, 2) Maintenance, 3) Service manual, and 4)Flight operations.*

Budget Information

System Total cost; ~ $TBD, funded by MSD & CfD.

Intellectual Property

Intellectual Property Open

U.S. Citizenship

There are no special U.S. citizenship requirements.

Project Resources

Anticipated Student Staffing by Discipline

lease provide a brief explanation of the expected activities for each required discipline. "Other" includes students from any department on campus besides those explicitly listed. For example, we have done projects with students from Industrial Design, Business, Software Engineering, Civil Engineering Technology, and Information Technology.

Department	**Expected Activities**
Biomedical Engineering	0
Computer Engineering	1
Electrical Engineering	1
Industrial & Systems Engineering	1
Mechanical Engineering	2 – At least **one** ME with a mechatronics background preferred.
Other	1 - CfD grad student (TBD)

Required Resources

Describe the resources necessary for successful project completion. When the resource is secured, the responsible person should initial and date to acknowledge that they have agreed to provide this support. We assume that all teams with ME/ISE students will have access to the ME Machine Shop and all teams with EE students will have access to the EE Senior Design Lab, so it is not necessary to list these. Limit this list to specialized expertise, space, equipment, and materials.

Faculty	Mike Zemcov CfD, CfD Grad student (TBD), Ken Snyder (test equipment), Maker Lab (Mike Buffalin)
Environment	CfD building, 2nd floor lab. 2) Flight envelope test – ***Possible*** URRG flight to 10K ft. RIT rocket club **TBD,** Potterville, NY
Equipment	Std PCs for code & sub-system development. Bench DC power supplies, meters, scope & waveform generator, etc.
Materials	Most project materials provided by CfD and/or common COT distributors for hardware and electronics components.
Other	Cryostat (in-house @ RIT), Infrared Labs, Mdl # HDL 8, flight platform TBD.

Example of a Cryogenic Heat Switches (from P19129);

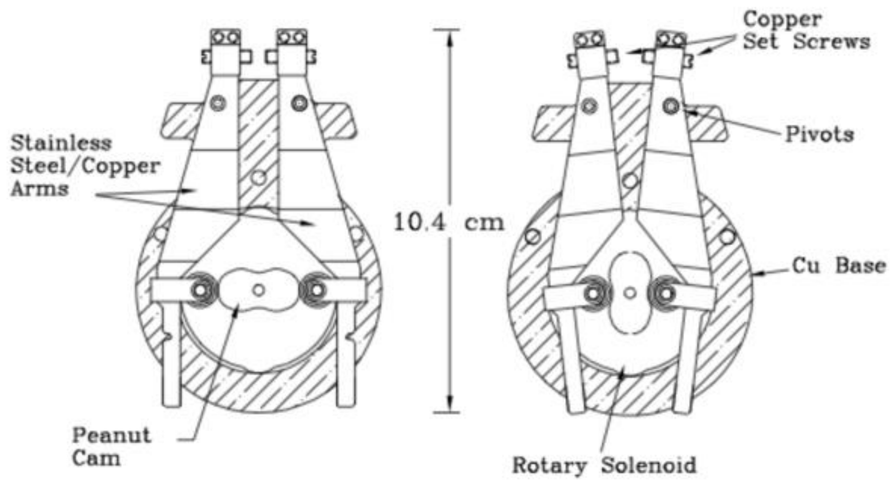


Figure 3.8 Top views of the heat switch in the open and closed position. The peanut-shaped cam is turned by a ratcheted 95° rotary solenoid. The jaws of the heat switch make contact to flats milled into the copper post coming out of the ADR. The heat is then drawn down the copper arms, through the copper foil (not shown), and into the copper base of the heat switch.

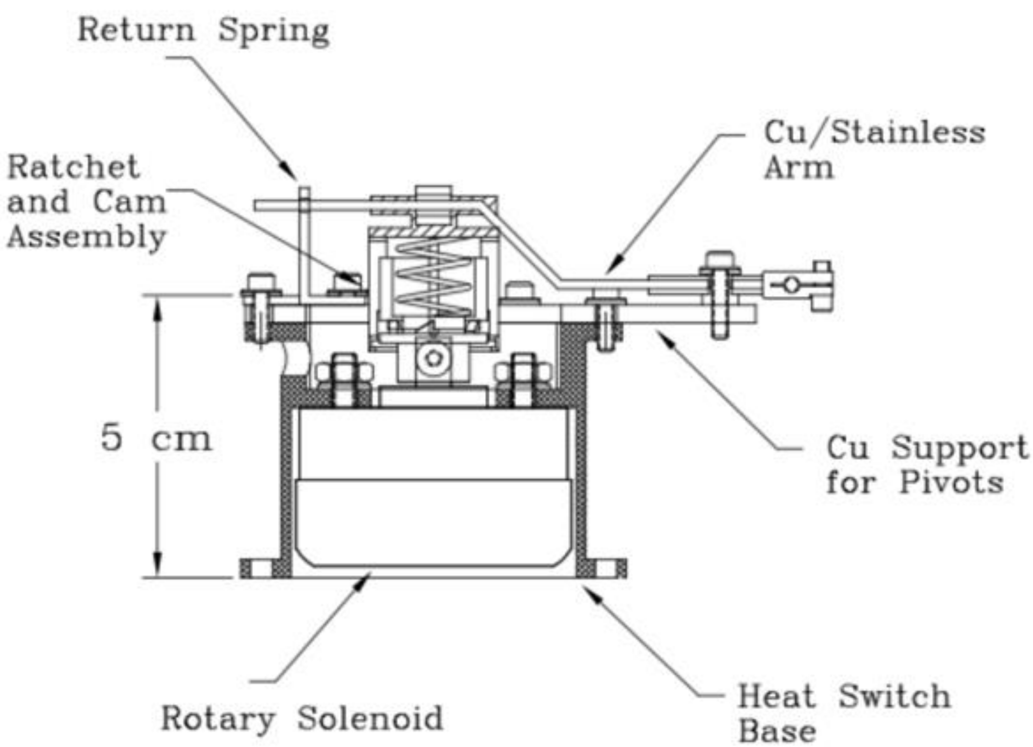
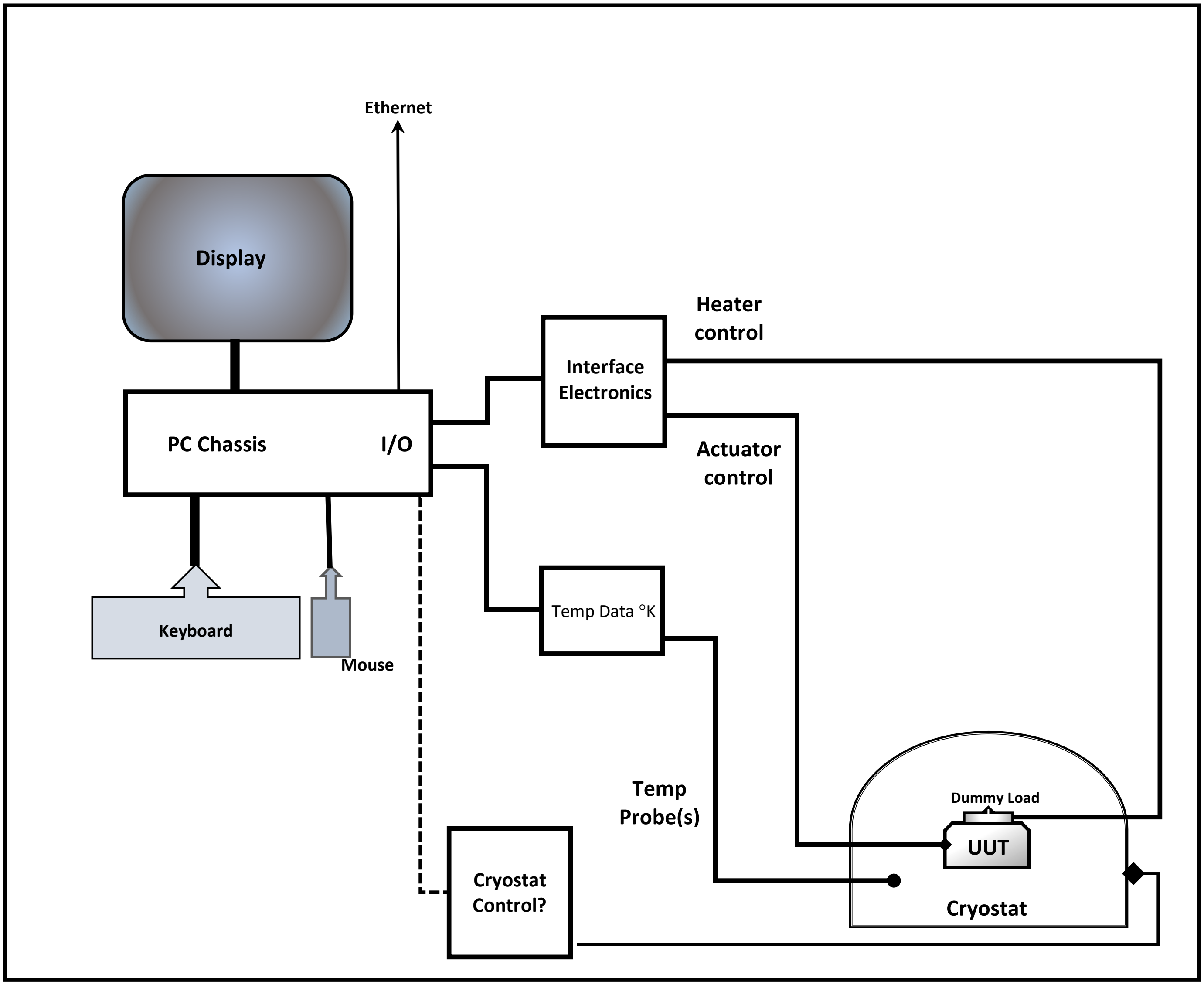
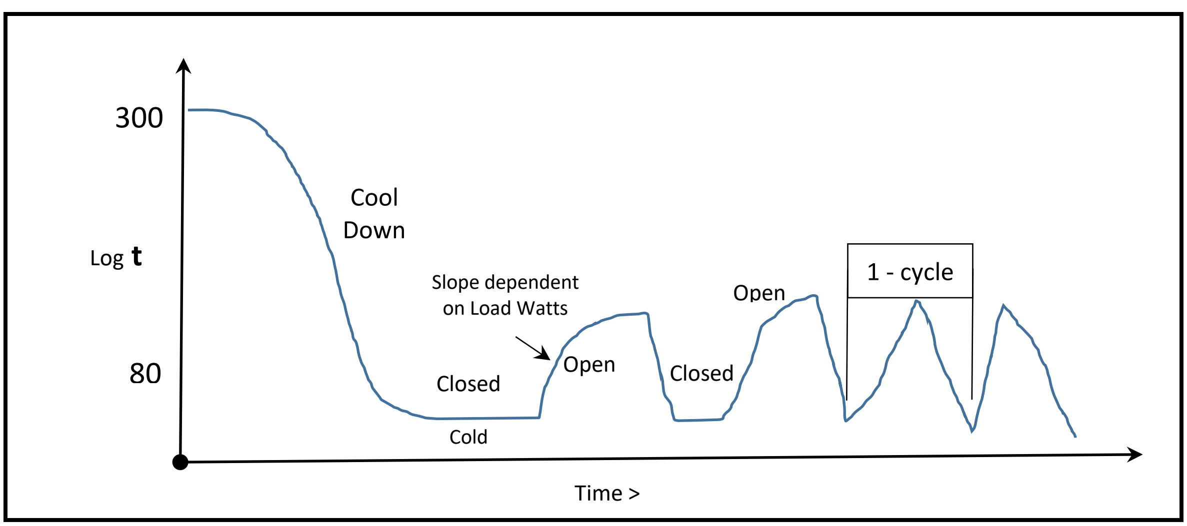


Figure 3.9 Side view of the heat switch.

Figure 1- Example of a System Block Diagram;



Typical Lab Thermal Cycling;



misc;

Search & Links;

Reference Files & Photos;

Goggle ‘G’ drive Link – {P19129 Cryo Heat Switch}

Cryostat contact info;

Infrared Labs
1808 E. 17th St.
Tucson, Az 85719
IRLabs.com

***Machine shop contact:**

Craig Arnold
Phone: 585-475-4295
ceaeme@rit.edu
Building 9, Room 2436

How to access CAD Models and Drawings

All CAD models and drawings are located in the main flash drive folder. The files are spit into 3 categories: The main assembly files, the drawing files in Solidworks form, and the drawing files in PDF form.

The main assembly files are located under the folder “Final Assembly Solidworks File”. From there, the main assembly file containing everything for the flex pivot orientation is called “MASTER Assembly”. This assembly file opens automatically and will contain the flex pivot orientation along with the cryostat plate and the resistor stand and resistor.

The drawing files are split into the Solidworks drawing and pdf form. For each of these, the drawings are broken down by assembly type. For the arms, they are split into the PTFE and Flex Pivot Configuration.

It should be noted that only blanks are here because that is what the machine shop actually needs for production. This information is also noted in the manufacturing process document.

Parking Lot;

Used for ‘lessons learned from prototype testing;

Used for potential mechatronics / electronics;