Thermal Control of the Balloon-Borne HEROES Telescope

Brian O'Connor[1]
NASA Marshall Space Flight Center, Huntsville AL 35812

The High Energy Replicated Optics to Explore the Sun (HEROES) telescope is scheduled to fly on a high altitude balloon from Fort Sumner, New Mexico in the Fall of 2013. Once it reaches an altitude of 40km it will observe the Sun, Crab Nebula, and other astrophysical objects in the hard X-Ray spectrum (20-75keV) for around 28 hours. The HEROES project is a joint effort between Marshall and Goddard Space Flight Centers (MSFC and GSFC), and will utilize the High Energy Replicated Optics (HERO) telescope, which last flew in 2011 in Australia. The addition of new systems will allow the telescope to view the Sun, and monitor the mechanical alignment of the structure during flight. This paper will give an overview of the telescope, and then provide a description of the thermal control method used on HEROES. The thermal control is done through a passive cold-bias design. Detailed thermal analyses were performed in order to prove the design. This will be discussed along with the results of the analyses. HEROES is funded by the NASA Hands-On Project Experience (HOPE) Training Opportunity. The HOPE opportunity provides early career employees within NASA hands on experience with a yearlong flight project. HOPE was awarded by the NASA Academy of Program/Project and Engineering Leadership, in partnership with NASA's Science Mission Directorate, Office of the Chief Engineer, and Office of the Chief Technologist.

Nomenclature

AMS	=	Alignment Monitoring System
BAMS	=	Bench Alignment Monitoring System
CDR	=	Critical Design Review
CSBF	=	Columbia Scientific Balloon Facility
^{o}C	=	Degrees Celsius
CPU	=	Central Processing Unit
GSFC	=	Goddard Space Flight Center
HERO	=	High Energy Replicated Optics
HEROES	=	High Energy Replicated Optics to Explore the Sun
HOPE	=	Hands On Project Experience
hr	=	Hours (time)
keV	=	Kiloelectron Volt
m	=	Meter
MSFC	=	Marshall Space Flight Center
Non-Op	=	Non-Operational
Op	=	Operational
PSA	=	Pressure Sensitive Adhesive
PYAS	=	Pitch and Yaw Aspect System
RAS	=	Roll Aspect System
Ref	=	Reference
SAS	=	Solar Aspect System
SCAMS	=	Star Camera Alignment Monitoring System
sec	=	Seconds (time)
W	=	Watt

[1] Thermal Engineer, MSFC ES22, Huntsville, AL 35812

I. Introduction

THE HEROES project is a joint effort between Marshall and Goddard Space Flight Centers (MSFC and GSFC). (Ref 1) It was awarded by the NASA Hands-On Project Experience (HOPE) Training Opportunity in 2012. The goal of the HOPE program is to provide early career NASA employees an opportunity to work on a flight project over the span of a year. The HEROES science objectives include observing solar and astrophysics targets in the hard X-Ray spectrum (20-75keV). The telescope is scheduled to launch on a high altitude balloon from Fort Sumner, New Mexico in early Fall of 2013. Once at the float altitude of 40km, the scientific observation phase of the flight will begin and is expected to last approximately 24hrs.

The HEROES telescope is an updated version of the High Energy Replicated Optics (HERO) telescope. (Ref 2) The HERO telescope has flown several times between 2001 and 2011, and has observed astrophysical targets such as the Crab Nebula and Cygnus X-1. The goals of the HEROES project are to design, analyze, fabricate, and integrate new subsystems onto the HERO telescope that will allow the telescope to observe the Sun and monitor internal alignment.

The thermal control approach of the HERO telescope is a cold-bias design using heaters to maintain the temperatures of sensitive components above their minimum limits. The implementation of this approach also consists of selecting appropriate optical coatings and insulation. The same approach was used in designing the new HEROES subsystems. The focus of this paper is to discuss this thermal design and present the thermal analyses that were performed to provide confidence in the design. At the time of writing this paper, the project has entered its Critical Design Review (CDR). Post-CDR thermal work will include additional analyses and testing. The HEROES pre-ship review is scheduled to occur in June 2013.

II. HEROES Design Overview

The HEROES telescope is an updated version of the previously flown HERO telescope. Figure 1 gives an overview of the HERO telescope. X-Rays from a target are focused, using optic modules located at the front, to multiple detectors located at the rear of the telescope. The focal length for the telescope is 6m. Each optics module consists of concentric iridium-coated nickel optics. In total, there are 8 optics modules, each with 13 or 14 optics, and 8 corresponding detectors. The optical bench is a 6m tube that holds the optics and detectors. The optical bench is attached to the gondola through the elevation flange. The elevation drive motor controls the pitch of the optical bench. The gondola is attached to the balloon through the reaction wheel, and the azimuth drive allows for yaw control. The telescope is powered using batteries attached to the gondola structure. The HEROES project will add new subsystems that will allow the telescope to point at the Sun and monitor the internal alignment of the optical bench.

Most of the new HEROES subsystems will be located either internal or external to the optical bench. Table 1 provides an overview of the new systems. Figure 2 shows the subsystems that are located external to the optical bench, and Figure 3 shows the subsystems that are located internal to the optical bench. The three main new subsystems are the Solar Aspect System (SAS), the Alignment Monitoring System (AMS), and the Star Camera Shutter System.

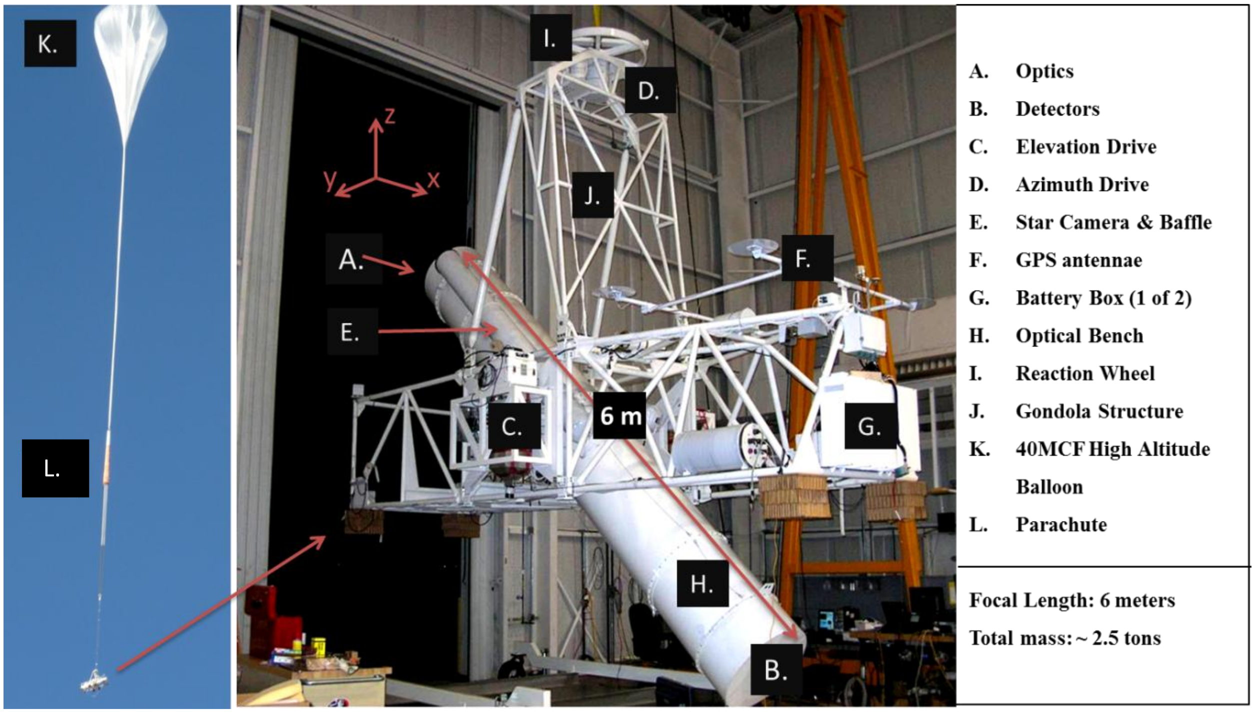

Figure 1: Overview of the Previously Flown HERO X-Ray Telescope. HEROES will Add New Systems Allowing the Telescope to Point at the Sun and Monitor Internal Alignment.

Table 1: Overview of the New HEROES Systems

Subsystem	Element	Components	Temperature Limits
Solar Aspect System (SAS) *Purpose: Provide aspect for pointing at the Sun.*	Pitch and Yaw Aspect System (PYAS)	2 cameras	Op: -40°C to 85°C Non-Op: -40°C to 90°C
	Roll Aspect System (RAS)	1 camera	Op: -40°C to 85°C Non-Op: -40°C to 90°C
	Computers	Electronic board stacks in two separate pressurized containers with fans.	Op: 0°C to 70°C
Alignment Monitoring System (AMS) *Purpose: Monitor the alignment of the optical bench and star camera.*	Bench Alignment Monitoring System (BAMS)	2 cameras	Op: -5°C to 55°C Non-Op: -20°C to 60°C
	Star Camera Alignment Monitoring System (SCAMS)	1 camera	Op: -5°C to 55°C Non-Op: -20°C to 60°C
		1 laser	Op: 0°C to 40°C Non-Op: -20°C to 60°C
Star Camera Shutter System *Purpose: Protect the star camera during solar observations.*		1 motor	Op: -20°C to 80°C Non-Op: -40°C to 80°C

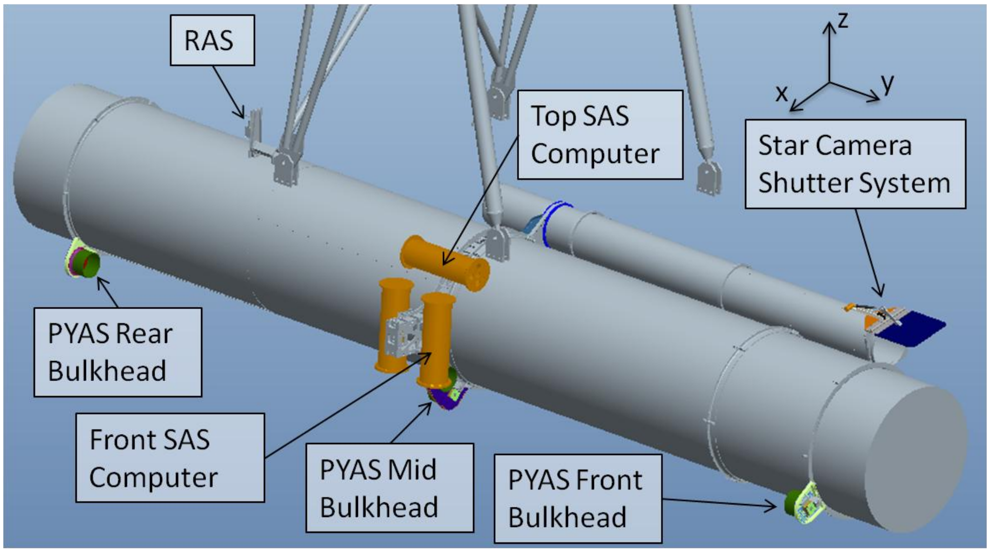

Figure 2: Location of New HEROES Subsystems Outside the Optical Bench. The Lower Portion of the Gondola is Hidden. Also Hidden are the PYAS Baffles, which Run Between the Bulkheads.

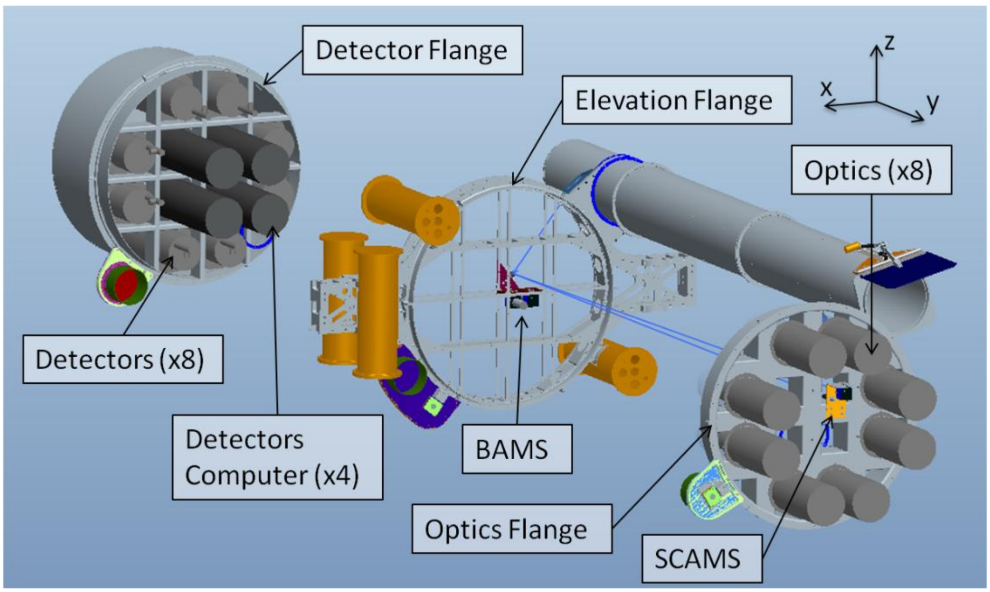

Figure 3: Location of New HEROES Subsystems Inside the Optical Bench. Some HERO Components are Shown for Reference. The Gondola and Optical Bench are Hidden.

III. Environments

HEROES is scheduled to launch from Fort Sumner, New Mexico in early Fall of 2013. Typical operations for flight consist of on-the-ground preparations before sunrise, then launch just after sunrise, followed by two to four hours of ascent to the desired float altitude of 37-40km. Once at float, the baseline science portion is 24hrs. Operating time for ground operations and ascent is about 5hrs. With this included, the baseline mission is 30-32hrs, including ascent and descent. However, previous missions have achieved 36hrs. If a long flight is realized, the payload is usually cut down from the balloon before sunset on the second day. Therefore, HEROES will need to survive almost two full periods of sunrise to sunset, and one full night.

Figure 4 shows the measured optical bench temperature during the 2011 flight from Alice Springs, Australia. During the ascent, the balloon passes through the troposphere, where the air temperature may drop to -80^{o}C. After which, the air temperature increases, but the pressure decreases to less than 2Torr at 40km. Once at float, because of the low pressure and low relative wind velocity, convective heat transfer is small compared to the radiative heat loads. During the day, the temperature of the optical bench fluctuates as the telescope points to different targets, and the projected area to the Sun and the Earth changes. At night, the solar load is absent, and the optical bench temperature decreases to a near steady value of -50°C. Once the Sun rises in the morning, the optical bench warms up.

Local Earth IR, albedo, and solar flux data were received from the Columbia Scientific Balloon Facility (CSBF). The data was used to define the worst case hot and cold float environments. Two possible hot environments were considered: one being over an open-cloudless desert, the other being over reflective-cold clouds.

- At Float Worst-Case Hot:
  Summer Solstice
  Solar flux = 1420 W/m^2,
  (Over desert) Earth IR = 290 W/m^2, albedo = 0.19
  (Over clouds) Earth IR = 175 W/m^2, albedo = 0.62
- At Float Worst-Case Cold:
  Winter Solstice
  Solar flux = 1327 W/m^2,
  Earth IR = 175 W/m^2, albedo = 0.62

The HEROES thermal analyses assumed convective heat transfer during float to be negligible; a sensitivity analysis was done to check this assumption. Therefore, all heat transfer to the environment was through radiation. Also, leading up to CDR, no analyses were performed for the ascent period of the flight. The current operations plan is to energize any heaters during this portion of the flight. Post-CDR analyses will be done in order to assess whether the heaters are sufficient to maintain the temperatures of sensitive components above their minimum limits during ascent.

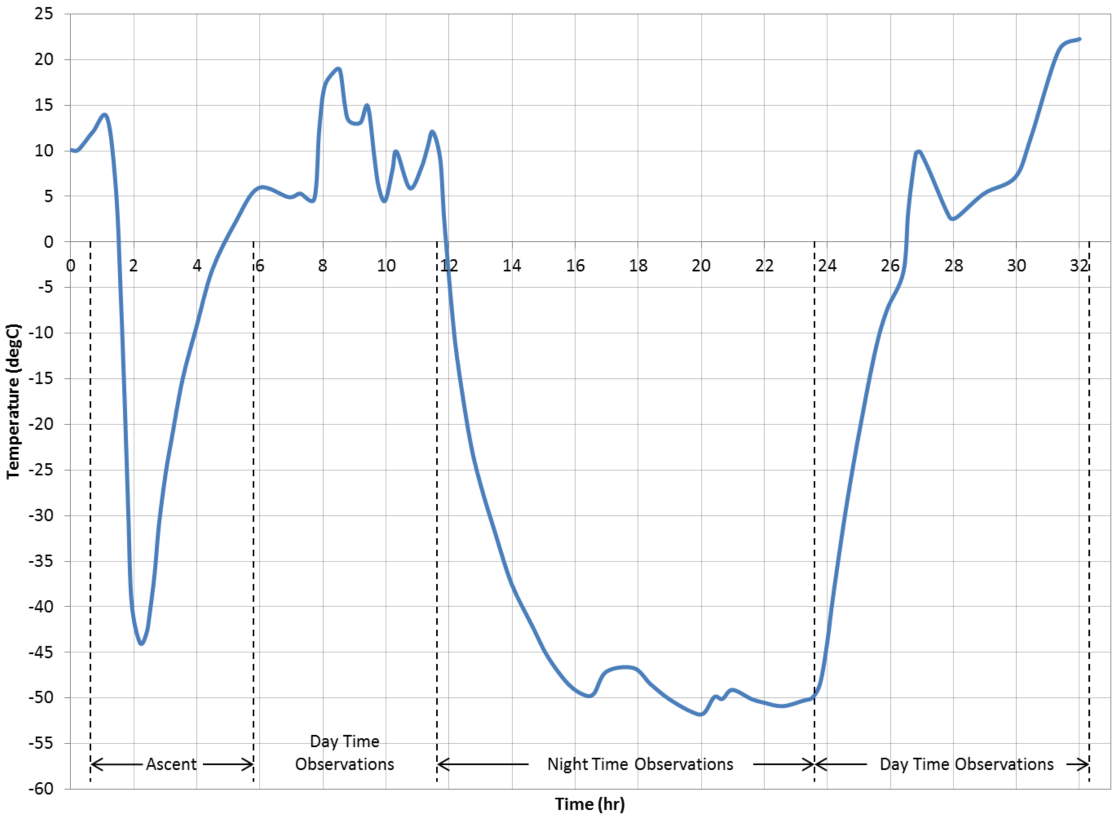

Figure 4: Optical Bench Temperature from the HERO 2011 Alice Springs, Australia Flight.

IV. HEROES Thermal Design Overview

The thermal control approach on the previously flown HERO missions consisted of a cold-bias design with heaters to maintain temperatures above the minimum limit. Most of the heaters were energized and de-energized via an operator on the ground. Data, including temperatures, were telemetered to a ground station during the entire flight. This thermal control approach will be followed for the new HEROES subsystems.

For the PYAS and RAS, two elements of the SAS, the three cameras are of primary concern. The temperature limits of these cameras are shown in Table 1. The thermal design of these subsystems involves thermally coupling the cameras to their structural mounts to allow for heat rejection. To minimize solar heating during the day, all structural components will be painted white. The white paint will either be the paint that was used on the previous HERO missions or A276. Previous HERO missions used Sherwin Williams white spray paint (#1400878). To survive the night, two Kapton heaters with pressure-sensitive adhesive (PSA) will be mounted to each camera. The heaters will be wired in parallel, and each camera will have two thermostats also mounted to the camera. The thermostats will be cross-wired with the heaters, so only one thermostat needs to operate to energize the heater. By cycling the heaters, the thermostats will save power compared to energizing a heater for the entire night. This thermostat architecture protects from a single fail-open scenario. In the case of a fail-closed scenario, an operator on the ground will de-energize the heater by switching the circuit relay open.

For the BAMS, an element of the AMS, the two cameras are also of primary thermal concern. The temperature limits of the cameras are also shown in Table 1. The two cameras are mounted to a single plate that will be bolted to the elevation flange. Two Kapton PSA heaters will be attached to the plate. The heaters will be wired in parallel and will be controlled by an operator on the ground. Since BAMS is inside the optical bench, and therefore will not see the Sun, the plate will not be painted white, but left as anodized aluminum.

The SCAMS, also an element of the AMS, contains a laser and camera. These two components will be mounted to a plate that will be bolted to the optics flange. Like the other subsystems, two Kapton parallel heaters with PSA will be attached to the plate. The heaters will also be controlled by an operator on the ground. Unlike the other subsystems, the SCAMS will be thermally isolated from the optics flange using low conductivity PEEK plastic washers. This is done to reduce the amount of heater power needed during the night. The plate will be painted white, in order to reject the dissipated heat.

The star camera shutter subsystem contains a hinged mechanism that is activated by a motor. Two Kapton heaters, as described above, will also be attached to the motor. The motor will then be wrapped with polystyrene foam, then closed off using white adhesive tape. The entire shutter mechanism will be painted white.

V. Thermal Modeling

In order to assess the thermal design of the HEROES subsystems, an analytical model was built to determine heater sizes, power consumption by the heaters, and expected temperatures of the components. Detailed thermal models of the new subsystems were built in Cullimore and Ring Technologies' Thermal Desktop, Version 5.4, and solved using SINDA/FLUINT, Version 5.4. First, the main components of the previously flown HERO telescope that affect the response of the new HEROES subsystems were modeled. This model was analyzed for the previous 2011 flight out of Alice Springs, Australia. Parameters, such as contact coefficients and optical properties that have not been measured, were adjusted to provide correlation to the flight data. Doing this provided confidence in the telescope model and environmental definitions. After this correlation effort, the models of the new HEROES subsystems were added. These were analyzed using the worst-case environmental definitions described above for the upcoming flight. The results are expected to bracket the maximum and minimum temperatures, as well as the maximum power consumption of the heaters. Further details of this modeling effort are described below.

A. Model Correlation

In creating the HEROES model, first the optical bench and the interior components of the optical bench that were a part of HERO telescope were modeled. This included the optics flange, elevation flange, detector flange, eight optics modules, and eight detectors. A picture of the model is shown in Figure 5. A model of a computer container that mounts externally on the optical bench was also created. This container is not shown in the figure.

The detectors and detector computers were modeled on the box level as solid objects, with the density adjusted to match the mass of the actual component. The model of the exterior electrical container was also done on a box level. The model consisted of the container walls and an internal air node. The internal heat dissipation of the electronic boards was applied to the air node. Each electrical container contained a fan to stir the air inside the container. The analysis assumed a low-forced convection heat transfer coefficient between the air node and the container walls.

This model was correlated to the 2011 Alice Springs, Australia flight of the HERO telescope, in order to provide confidence in the modeling of the environment and the structures to which the new HEROES subsystems will mount. Parameters, including contact coefficients between components and optical properties that have not been measured, were adjusted to provide correlation. The environment used for correlation was Alice Springs, Australia longitude and latitude, the solar flux for the day of flight. Since Alice Springs is in a similar desert environment as Fort Sumner, the nominal Earth IR and albedo from the data received for Fort Sumner were also used.

The results from the correlation are shown in Table 2. For most of the components, the temperature predictions are within a few degrees of the measured flight temperatures. For the optical bench, which is composed of a composite and aluminum tubes, the predicted temperature was off as much as 15^{o}C. This is attributed to not modeling the pointing profile of the telescope during the flight. The temperature of the optical bench is dependent on where the telescope is pointed and how much surface area is projected to the Earth and the Sun. The prediction of the computer board temperature using the internal air node in the model was also off as much as 15^{o}C for the max temperature prediction. This is attributed to the air node being more representative of the average temperature inside the electrical container. A higher dissipative component, like a CPU, may be at a higher temperature. Since there is close correlation for most of the HERO components, a reasonable explanation for the optical bench temperature, and a quantification of the difference between the predicted and measured computer temperature, it was concluded that the thermal model can be used to provide estimates for the temperatures of the new HEROES subsystems.

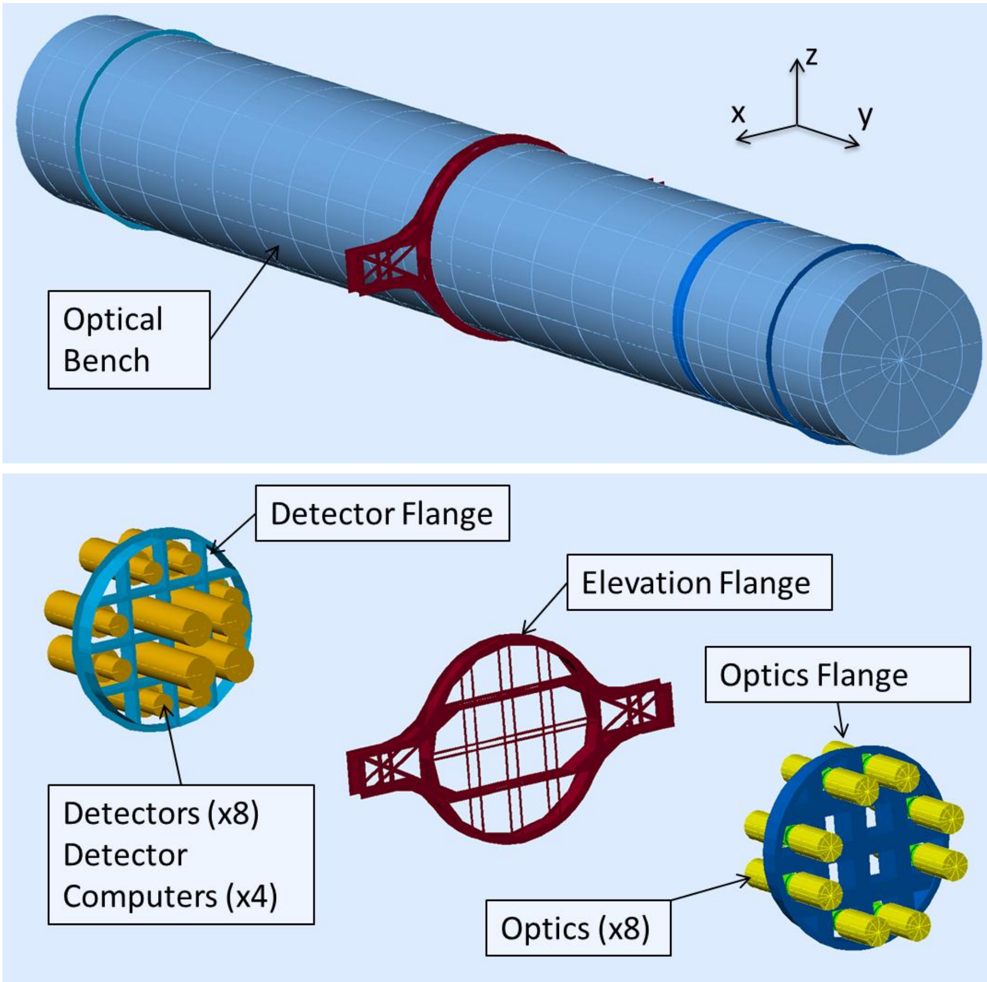

Figure 5: Thermal Model of the Previously Flown as the HERO Telescope. Before the new HEROES Systems were Added to the Model, the Systems Shown were Correlated to Previous Flight Data.

Table 2: Flight versus Predicted Temperatures of the HERO Components

HERO Component	Flight Max	Flight Min	Predicted Max	Predicted Min	Delta Max	Delta Min
Detectors	35°C	3°C	37°C	2°C	Δ-2°C	Δ1°C
Detector Computer	48°C	17°C	48°C	17°C	Δ0°C	Δ0°C
Optics Housing	38°C	-10°C	37°C	-9°C	Δ1°C	Δ-1°C
Optical Bench Composite Tube	20°C	-60°C	20°C	-50°C	Δ0°C	Δ-10°C
Optical Bench Aluminum Tube	35°C	-40°C	20°C	-48°C	Δ15°C	Δ8°C
Electrical Container	30°C	-10°C	30°C	-10°C	Δ0°C	Δ0°C
Electrical CPU Board*	55°C	3°C	40°C	3°C	Δ15°C	Δ0°C

*Electrical boards were not modeled. The board temperature is compared against an internal air node.

B. New System Details

After the correlation effort of the previously flown HERO components, the new HEROES subsystems were added. In order to reduce modeling complexity and meet schedule constraints, four separate models of the new HEROES systems were created. Each model used the same HERO model to which the separate HEROES subsystems were added. These subsystems were separated based on the assumption that they do not thermally affect each other. The first model contained the PYAS element. The second model contained the RAS and SAS computer elements. The third model contained the BAMS and SCAMS elements. Finally, the fourth model contained the star camera shutter subsystem.

Figure 6 shows two views from the model that contains the PYAS element. Shown are the middle PYAS and the front PYAS. These respectively mount to the elevation and optics flanges. Both models of the bulkheads were created by meshing their respective part files with plate elements. Both bulkheads will be attached to their flanges using multiple bolts. A detailed model of the PYAS camera assembly was created, and a total of three contactors are used in the camera. However, the electronic boards of the camera were not modeled. As was described in the thermal design overview section, each camera has two thermostatically controlled heaters placed on opposite faces, and the thermostatic sense locations were on the remaining two faces. Each camera is attached to the bulkhead using two 90^{o} brackets that mount to the side of the camera, and screws that will mount the front of the camera to the bulkhead. Both bulkheads will contain an enclosure that protects the camera from a direct solar load.

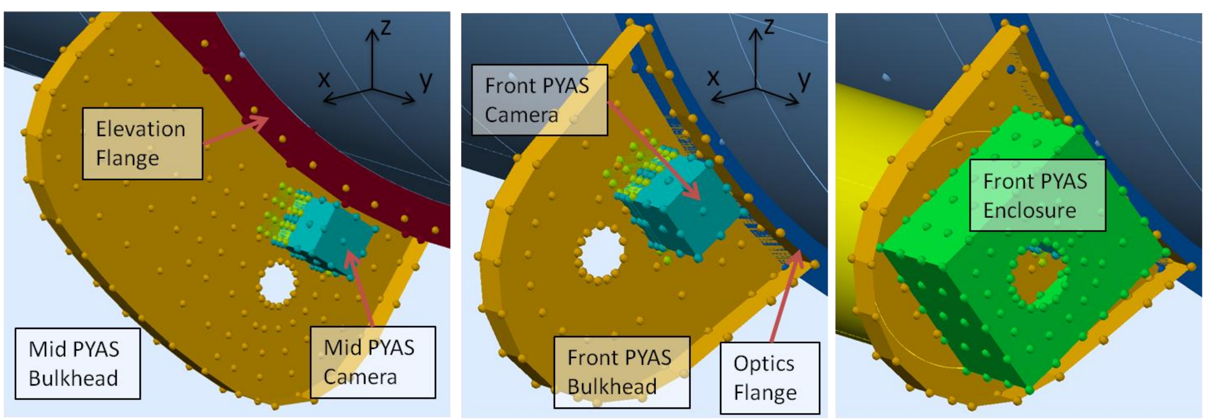

Figure 6: Thermal Model of the Middle PYAS (Left Picture) and Front PYAS (Middle and Right Picture). In the Left and Middle Pictures, the Camera Enclosures and Baffles Have Been Hidden. The Right Picture Shows the Camera Enclosure, A Similar Enclosure Is Used on the Middle PYAS.

Figure 7 shows two views of the model that contains the RAS element and the SAS computers, both of which are a part of the SAS subsystem. The RAS camera was modeled using the same method as the cameras described above. The RAS weldment consists of multiple welded members that will attach to a gusset located on the gondola of the telescope. The two SAS computers were modeled in a similar manner as the HERO computer used for correlation. This consisted of modeling the external structure of the computer, and the internal dissipation of the boards was applied to a single air node. These electrical containers will also contain fans to provide an internal convective environment.

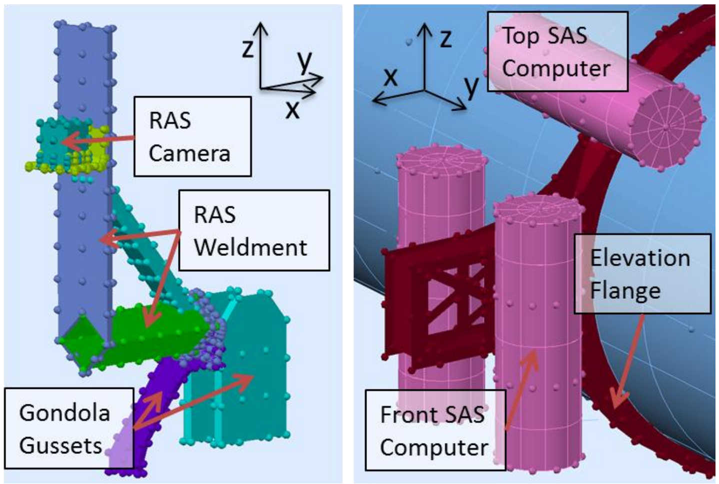

Figure 7: Thermal Model of the RAS (Left Picture) and the SAS Computer Cans (Right Picture). The Box that Covers the RAS Camera is Hidden.

Figure 8 shows two views of the model that contains the BAMS and SCAMS. The three cameras and single laser were modeled as a solid volume with the density adjusted to match their respective weights. The three cameras are connected to their mount plates using a bolted interface contact coefficient. The laser will be attached to the plate using a bulkhead feedthrough, where two nuts on either side of the plate will clamp the laser in place. The contact coefficient that this mounting scheme will provide is not well known. A high contact coefficient is desired, because it will allow for better control of the laser temperature. However, the analysis assumed a low value of 100 W/m^2 for conservatism. Post-CDR testing will be done in order to assess this contact value. As described in the thermal overview section, the BAMS plate is bolted to the elevation flange, while the SCAMS is isolated from the optics flange using low conductivity washers.

Figure 9 shows the model containing the star camera shutter system. The motor, gear box, and linear stage were modeled as solids with their density adjusted to match the mass of the system.

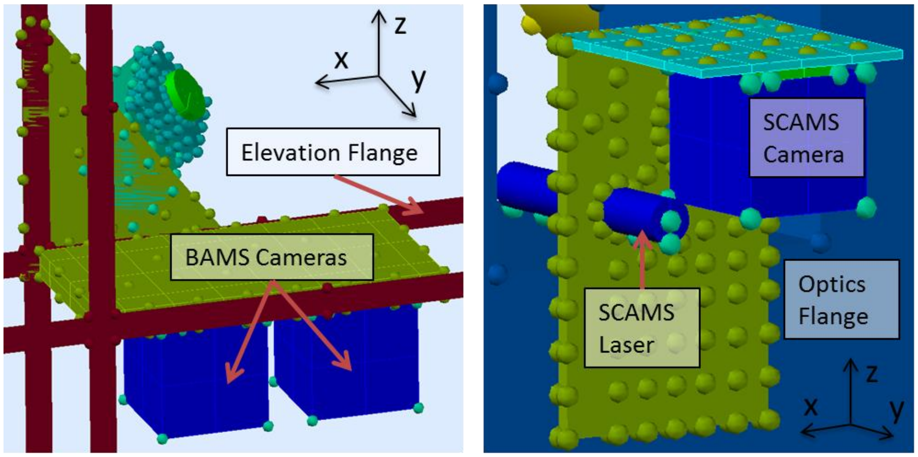

Figure 8: Thermal Model of the AMS Subsystem, Including the BAMS (Left Picture) and the SCAMS (Right Picture).

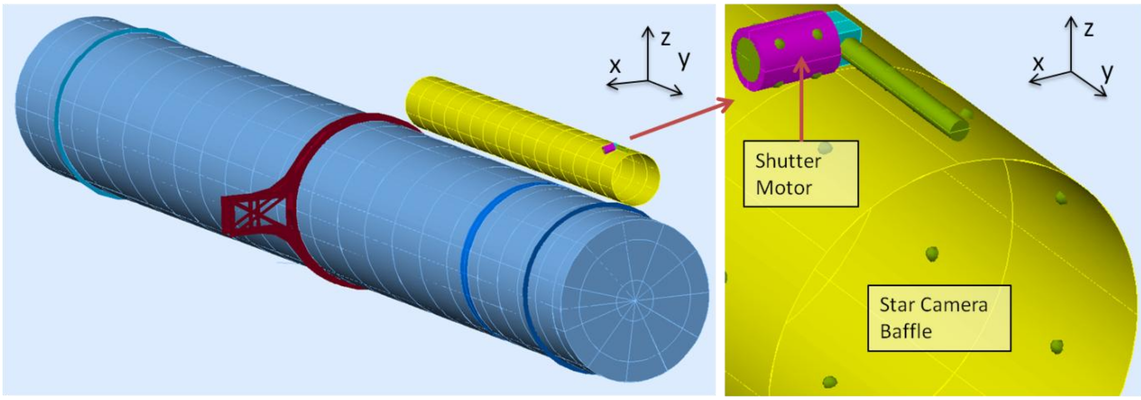

Figure 9: Thermal Model of the Star Camera Shutter Motor.

VI. Analytical Results

The HEROES thermal models were analyzed to the worst-case Fort Sumner environments to establish heater sizes and bracket the maximum and minimum temperatures. Table 3 shows the selected heater sizes for each of the subsystem components, and Table 4 shows the temperature predictions.

Table 3: New HEROES Systems Heater Sizes

Heater Location	Heater Size*	Usage
PYAS Front Camera	28W	Thermostat controlled, runs mainly at night
PYAS Middle Camera	56W	Thermostat controlled, runs throughout flight
RAS Camera	10W	Thermostat controlled, runs mainly at night
Front SAS Computer	20W	Ground controlled, runs mainly at night
Top SAS Computer	20W	Ground controlled, runs for entire flight
BAMS	20W	Ground controlled, runs for entire flight
SCAMS	10W	Ground controlled, runs mainly at night
Shutter Motor	5W	Ground controlled, runs mainly at night

*PSA Kapton heaters, most will be into two heaters that are wired in parallel

The PYAS front camera, located on the front bulkhead, is in more of an isolated environment than the PYAS middle camera, located on the middle bulkhead. Because of this, the front camera needs a relatively smaller heater and stays at a warmer temperature during the night than the middle camera. However, during solar observations, the front camera achieves a higher temperature than the middle camera. Figure 10 shows the transient plot of the front camera average, minimum, and max temperature. During the night as the environmental temperature decreases, the thermostat energizes and de-energizes the heater. While the heater is operating a gradient is produced in the camera. This is due to the location of the heater and the contacts within the camera.

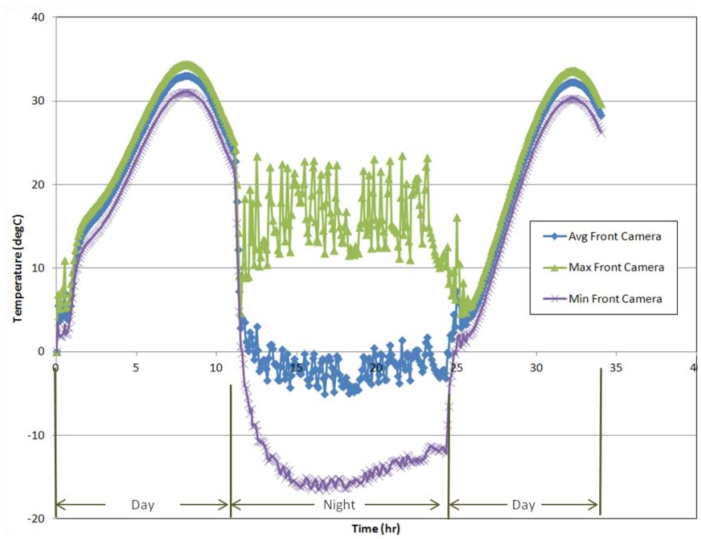

Figure 10: Thermal Model Results of the PYAS Camera. The Heater is Ran on a Thermostat.

The RAS camera is also in an isolated environment and does not need a large heater. Unlike the front PAYS camera, it does not get exposed to a high solar load, and its max temperature is lower. For all three SAS cameras there is at least a Δ15°C margin from their respective temperature limits.

For the AMS subsystems, the SCAMS uses a smaller heater than BAMS. This is because the SCAMS is more isolated via the low conductivity washers between the subsystem and the flange. Also, because the BAMS is coupled to the flange, its heater may need to run for the entire flight. Figure 11 shows the temperature profile of the SCAMS camera and laser for the worst-case cold environment. There is enough time during the day for the temperatures to reach a near steady value. At night, the SCAMS heater is energized to keep the temperatures above their minimum limits.

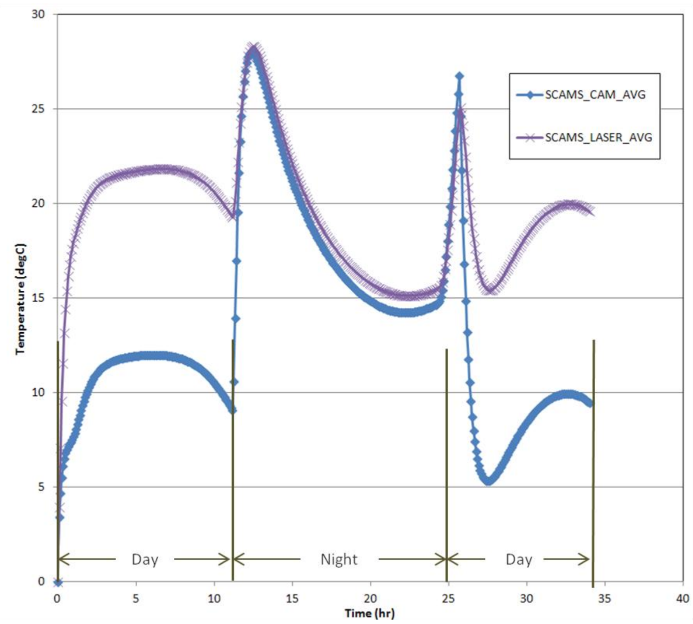

Figure 11: Thermal Model Results of the SCAMS Camera. The Heater is Energized at Night.

Table 4: New HEROES Systems Temperature Predictions for Worst-Case Fort Sumner Environments

	Operating Temperature Limits		**Worst-Case Temperature Predictions**		**Margin**	
Component	**Min Limit**	**Max Limit**	**Cold**	**Hot**	**Cold**	**Hot**
Front PYAS Camera	-40°C	85°C	-15°C	49°C	Δ25°C	Δ36°C
Middle PYAS Camera	-40°C	85°C	-25°C	28°C	Δ15°C	Δ57°C
RAS Camera	-40°C	85°C	-13°C	40°C	Δ27°C	Δ45°C
Front SAS Computer Internal Air	0°C	70°C	5°C	60°C	Δ5°C	Δ10°C
Top SAS Computer Internal Air	0°C	70°C	12°C	50°C	Δ12°C	Δ20°C
BAMS Cameras	-5°C	45°C	13°C	20°C	Δ18°C	Δ25°C
SCAMS Camera	-5°C	45°C	5°C	20°C	Δ10°C	Δ25°C
SCAMS Laser	0°C	40°C	15°C	30°C	Δ15°C	Δ10°C
Star Camera Shutter Motor	-40°C (non-op)	80°C	-25°C (non-op)	20°C	Δ15°C	Δ60°C

The heater size selected for both SAS computers was 20W. During solar observations, the front SAS computer is exposed to a higher solar and IR load than the top computer and achieves a higher temperature. Also, because of the low environmental heat load, the top computer may need to run its heater during the day if a cold environment is encountered. Accounting for the 15°C difference between the hot case predicted and measured computer temperatures, noted in the model correlation section above, gives a -5°C margin on the front computer and a 5°C margin on the top computer. Note this analysis does not include any uncertainty modeling, other than assuming worst case environments. Because of the negative and low margin, further work will be done on the computers post-CDR. This includes testing the computer in a thermal chamber that can achieve the skin temperature predicted by the analysis, and the difference between the skin and computer board temperatures can be measured.

The star camera shutter motor is also in an isolated environment, and not much heater power is needed to maintain its temperature above its minimum limit. In contrast to the other subsystems, the motor is expected to be turned off during the flight. Therefore, its minimum temperature is defined by its non-operational limit. During the day, the temperature will drop below its operating temperature limit, and the motor will need to be preheated before it is operated. During the night, its temperature will drop below its non-operating limit, and the heater must be operated all night.

VII. Upcoming Work

At the time of writing this paper, the HEROES project has entered its CDR. Upcoming work for the thermal design includes updating the analysis with minor changes, such as using measured optical properties instead of predicted. An analysis will be done to assess the selected heater sizes for maintaining temperatures during ascent. Finally, an analysis will also be performed for the nominal flight environment, which will give the ground controllers an indication of the expected temperatures and power usage.

Thermal testing for all of the new subsystems will be completed. This includes thermal-vacuum testing of the front PYAS, which will give confidence to the thermostat-controlled heater design and provide data for model correlation. Thermal-vacuum testing of the AMS cameras and laser will also be performed. Thermal-vacuum testing of the star camera shutter system will be done. This will address the concern that the shutter mechanism may seize when it gets cold. Finally, the SAS computers will be tested in a thermal chamber, which will address the temperature difference between the container walls and the individual components.

In leading up to the flight in early Fall of 2013, all the new systems will be integrated onto the telescope, and checkouts will be done on the heater circuits and temperature sensors.

VIII. Conclusion

The HEROES project was selected for 2012 NASA Hands-On Project Experience (HOPE) Training Opportunity. The goal of HOPE is to provide early career employees an opportunity to work on a flight project. HEROES is a balloon-borne X-Ray telescope that will look at solar and astrophysical targets. The current launch date is scheduled for early Fall of 2013. The HEROES project consists of taking the previously flown HERO telescope and adding new systems that will allow for the telescope to be pointed at the Sun and monitor the internal alignment. Currently, the project has entered its CDR.

The thermal control of the new subsystems is based on a passive cold-bias design that will use heaters to maintain temperatures above their minimum limits. The design method includes using optical coatings, heaters, isolating washers, and thermostats. A thermal model of the major HERO components that will participate in the thermal environment of the new HEROES subsystems was created and correlated to previous flight temperatures. After this, the new HEROES subsystems were added to the thermal model, then assessed using worst-case environments in order to bracket the expected temperature range and determine heater power usage. Most of the predicted temperatures are well within their limits, and the one that is not does not pose a major issue. Post-CDR thermal work includes additional analyses and testing of the new systems. It is expected that the telescope will be ready to fly in the early Fall of 2013.

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