Thermal Design for the Advanced Camera for Surveys

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ABSTRACT

The Advanced Camera for Surveys (ACS) is a third generation science instrument scheduled for installation into the Hubble Space Telescope (HST) during the third servicing mission scheduled for 1999. ACS, along with the previously installed Space Telescope Imaging Spectrograph (STIS) and Near Infrared Camera/Multi-object Spectrograph (NICMOS), consume significantly more power than the first generation of instruments. Additionally, the larger apertures of these instruments make parallel operations scientifically exciting. These parallel operations demand that all of the instruments operate in their highest power states simultaneously for extended periods of time. These and other factors have resulted in much higher temperatures inside the aft shroud where the ACS will be installed. As a result, new approaches are required to transfer heat inside the instrument and reject it away from the telescope. This paper describes the unique thermal systems required by the ACS. These include capillary pump loops (CPL) and flexible and rigid heat pipes.

1. Introduction

The Advanced Camera for Surveys (ACS) is a third generation Hubble Space Telescope (HST) science instrument. Scheduled for installation by Shuttle astronauts during the third HST servicing mission in December 1999, it is currently under construction at Ball Aerospace and Technologies Corporation in Boulder, Colorado under the scientific direction of a Johns Hopkins University led science team.

ACS provides three imaging channels covering the near IR through the near UV spectra. A Wide Field Channel (WFC) incorporates two 2Kx4K CCDs to form a square field of view. A High Resolution Channel (HRC) incorporates a 1K square CCD. Finally, a Solar Blind Channel (SBC) uses a CsI photocathode microchannel based MAMA detector. For a complete description of the ACS, see *HST Advanced Camera For Surveys* by Ford et al. in these Procedings[1].

The primary thermal design driver for the ACS is the requirement to cool the CCD detectors in both the WFC and the HRC to -80°C. This requirement derives from the need to prevent thermally induced dark currents from becoming the dominate noise source. The thermal design incorporates thermo-electric coolers (TEC) to lower the temperature of the CCDs relative to their housing, flexible heat pipes to transport waste heat from the housing to a thermal interface plate on the surface of the instrument, a capillary pump loop (CPL) heat exchanger to transport heat from the interface plate and a radiator outside the telescope to reject heat to space.

The thermal design of the CCD subsystems and the flexible heat pipes are described in companion papers in these Proceedings[2,3]. This paper will describe the integration of the thermal components in the overall system.

2. Thermal Environment

HST was launched in 1990 with an original compliment of four axial science instruments. Axial instruments are located at the rear of HST in a cylindrical enclosure called the aft shroud. The aft shroud provides a light tight environment as well as thermal isolation from solar and earth flux. Each science instrument radiates internally generated heat to the aft shroud environment. Three factors have worked to gradually raise the aft shroud temperatures in the years since original deployment. First, the external surface of the aft shroud has deteriorated resulting in degraded emmisivity. While an expected result of residual oxygen erosion, this has reduced the ability to reject heat from the aft shroud. A second factor is that newer instruments installed during the second servicing mission consume significantly more power than the instruments they replaced. Thus, more power is dumped into the aft shroud by each operating instrument. Finally, a dramatic increase in operating efficiency and parallel operations of multiple instruments have increased the fraction of time when more than one instrument is in its high power operate state. These factors have combined to increase the temperatures inside the aft shroud.

This trend will continue when the ACS replaces the Faint Object Camera (FOC) during the third servicing mission. Its wide field of view, high sensitivity, broad spectral response and high spatial resolution will make the ACS an attractive instrument for both primary and parallel use. As a result, it is expected to be in its operate state far more than the FOC. At the same time, the ACS consumes more than 230 Watts compared to less than 150 Watts for the FOC. Sink temperatures are therefore expected to increase by more than 15°C over the original interface specifications.

The increased sink temperatures have necessitated an alternative to radiative heat rejection to the interior of the aft shroud for at least a portion of the heat load. An Aft Shroud Cooling System (ASCS) has been developed for this purpose. The ASCS consists of a Capillary Pump Loop heat exchanger and a radiator exterior to the aft shroud to reject heat to space. It will be used to carry the waste heat generated by the ACS CCD TECs. In addition, the ACSC will connect to the existing STIS instrument to carry away heat from its MAMA detector. Finally, provisions are available to transport heat away from the next generation science instrument (the Cosmic Origins Spectragraph, COS, has recently been selected for that mission) after it is installed during the fourth servicing mission in 2002.

While primarily designed to provide cooling to specific portions of the instruments inside the aft shroud, the ASCS mitigates the general rise in aft shroud temperature by shunting directly to space as much as 200 Watts that would otherwise radiate internally. This allows those components not directly connected to the ASCS to continue to operate within their thermal margins through the mission end-of-life currently defined as 2010.

3. ACS Thermal Design

Figure 1 shows a schematic representation of the ACS. In addition to the three detector subsystems already described, the ACS consists of two independent optical chains. The HRC and SBC share a common optical path with a fold mirror (M3) that directs light to the HRC when brought into the optical path. In order to reduce cost, the HRC and WFC share a common filter wheel. Each optical chain includes correction for the spherical aberration of the HST primary mirror. A calibration subsystem provides illumination for internal calibration of the detectors over their full spectral response.

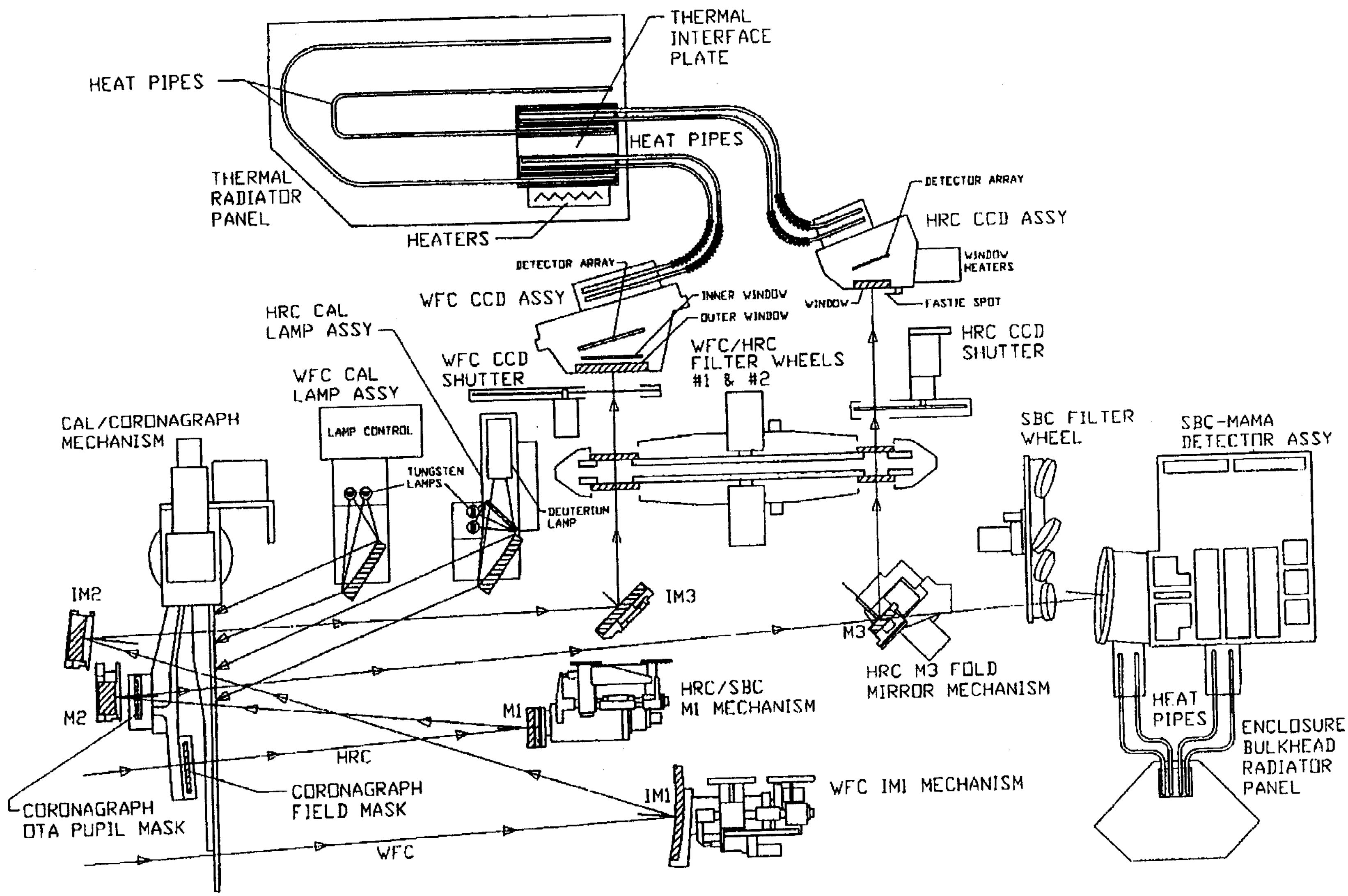

FIGURE 1: ACS Schematic

Waste heat from each of the CCD housings is transported via redundant heat pipes to a thermal interface plate (shown at the top of figure 1). In order to maintain optical alignment it is essential that the heat pipes do not cause the CCD housings to move as a result of mechanical loads imparted on the interface plate or a result of thermal expansion of the heat pipes. A flexible section is therefore included in each heat pipe. The HRC heat pipes have an effective transport length of approximately thirty two inches. The WFC heat pipes effective length of forty seven inches.

The thermal interface plate is also attached to a thermal radiator panel. This panel rejects heat to the aft shroud in case of a failure of the ASCS. In that case, the ACS could continue to operate, albeit at a reduced capability due to elevated CCD temperatures (as high as -72°C). The heat pipes embedded in the thermal radiator panel spread the heat to improve radiator efficiency.

The WFC CCD is cooled by two sets of TECs. A four-stage TEC cools the CCD chip carrier to its operating temperature. Four two-stage TECs cool an internal window and radiation shield to approximately -50°C. This reduces the parasitic heat load on the CCD. The WFC TECs produce approximately 27 Watts of waste heat which is transported to the thermal interface plate. The HRC CCD is cooled by a single four-stage TEC. It produces approximately 12 Watts. A control loop within the ACS electronics maintains the CCD temperatures at a commandable setpoint by adjusting the TEC current. While the requirement for each CCD is -80°C, a margin of 3°C was used during the design. Once on orbit, the operational set point will be chosen based on the actual performance of the entire system. There is scientific benefit to operating the CCDs at temperatures as low as possible to reduce both their dark current and improve charge transfer efficiency. Recent analysis suggest that an operating setpoint near –90 may be possible.

There is a periodic requirement (approximately monthly) to raise the temperature of each CCD to greater than -5°C in order to anneal the damage caused by radiation. Two methods are available to raise the temperature of the CCDs. First, a 100 Watt heater is available on the thermal interface plate. Second, the ACSC can be commanded to raise the thermal interface plate temperature.

The remaining heat generated by the ACS is radiated to the aft shroud. Two sets of rigid heat pipes transport heat from the SBC subsystem to a radiator panel at the rear of the instrument. Heat from the main electronics boxes (MEB), CCD electronics boxes (CEB) and the calibration subsystems are radiated from the enclosure panels of the two outward facing sides of the instrument. All optical components are mounted on a low CTE graphite epoxy bench that is maintained at a constant temperature by thermostatically controlled heaters.

Table 1 summarizes the total power dissipated by the ACS in its primary operate state under three different thermal environments. Cold Operate occurs when, as a result of time of year, spacecraft orientation and the modes of other instruments, the temperature of the aft shroud is at its lowest. Hot Operate occurs when the aft shroud is at its warmest and Nominal Operate is a median condition.

	Cold Operate (W)	**Nominal Operate (W)**	**Hot Operate (W)**
Support Electronics	198	195	199
WFC TEC	12	16	27
HRC TEC	4	6	12
Thermal Shelf Heaters	38	26	10
TOTAL	**252**	**243**	**248**

Table 1: ACS power dissipation in operate state