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Thermal conditions on the International Space Station: Effects of operations of the station Main Radiators on the Alpha Magnetic Spectrometer

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ABSTRACT

A thermal model of the Alpha Magnetic Spectrometer on the International Space Station (ISS) has been developed, and Thermal Desktop® (with RadCAD®) and SINDA/FLUINT software have been used to calculate the effects of the operations of the ISS Main Radiators on AMS temperatures. We find that the ISS Starboard Main Radiator has significant influence on temperatures on the port side of AMS. The simulation results are used in AMS thermal control operations.

1. Introduction

The Alpha Magnetic Spectrometer (AMS) is a general purpose high-energy particle physics detector. It was installed on the International Space Station (ISS) on 19 May 2011 to conduct a unique long duration mission (approximately 20 years) of precision cosmic ray measurements in space [1]. Fig. 1 displays the AMS location on the ISS. Overall, AMS has dimensions of $5 \times 4 \times 3\ m^3$ and mass of 7.5 tons.

The AMS Thermal Control System (TCS) contains more than 1000 temperature sensors and about 300 heaters to keep temperatures within the allowed limits. Fig. 2 shows the distribution of some of the temperature sensors and heaters. The sensors are read out about once per minute and the data set used in this article covers 19 May 2011 to 24 December 2013; hence, for each sensor, over a million readings are available. All temperature measurements have high and low destructive limits, alarm limits and warning limits. The destructive limits are the temperatures beyond which a component could be damaged. The alarm limits are the temperatures beyond which a component should not be operated. The warning limits are normally set 5 °C within the alarm limits.

On the ISS, AMS is affected by ISS configurations such as the positions of the Main Radiators, the positions of Solar Arrays and ISS flight attitudes. It is also affected by external variables, the most important of which is the Solar Beta (β) Angle. The β Angle is the angle between the solar vector and the plane of the ISS orbit. Fig. 3 shows the sun direction with different β Angles. Relative directions on the ISS are given according to aeronautical conventions (port, starboard, ram, wake) with attitude specified in yaw, pitch and roll (Y/P/R). The Main Radiator panels are $23\ m \times 11\ m$ each. The positions of the Main Radiators are controlled by the Port Thermal Radiator Rotation Joint (PTRRJ) and the Starboard Thermal Radiator Rotation Joint (STRRJ). In this paper, PTRRJ and STRRJ positions are used to describe the positions of the Main Radiators. The PTRRJ, which is far away from AMS, does not affect AMS temperatures significantly, except under rare conditions (such as very large positive β Angles). The STRRJ, which is near AMS, affects AMS temperatures strongly, especially for very negative β Angles. This paper studies the effect on AMS of different STRRJ positions at different β Angles. These results are used to plan AMS operations and AMS requests to the ISS program. The simulation can also be used to provide guidance for future experiments on the ISS.

2. External heat exchange

2.1. β Angle

The β Angle is one of the most important factors affecting AMS temperatures. As shown in Fig. 4, the β Angle has a period of one year from the seasonal change caused by the inclination of the Earth's axis to the ecliptic. This is superimposed on a period of 60 days caused by the precession of the ISS orbit. The AMS port

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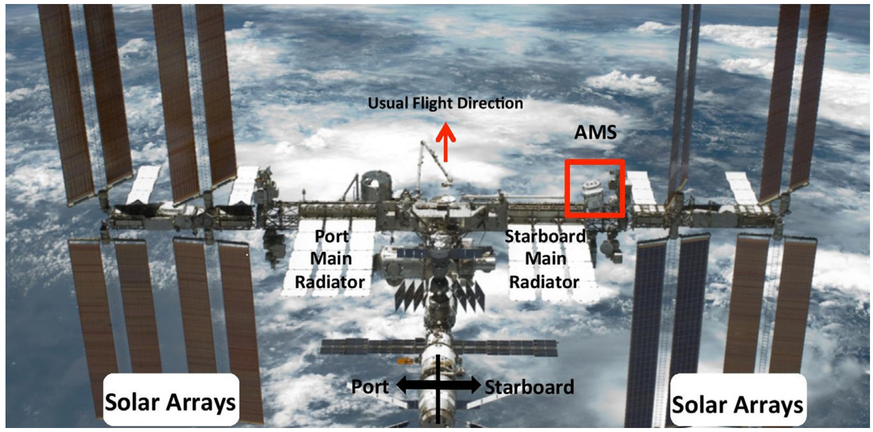

Fig. 1. The ISS and the location of AMS on the ISS. The locations of the ISS Port and Starboard Main Radiators and Solar Arrays are shown. For reference, the ISS is 110 m across and AMS 3 m. As seen AMS is mounted on the ISS with a 12° roll to Port.

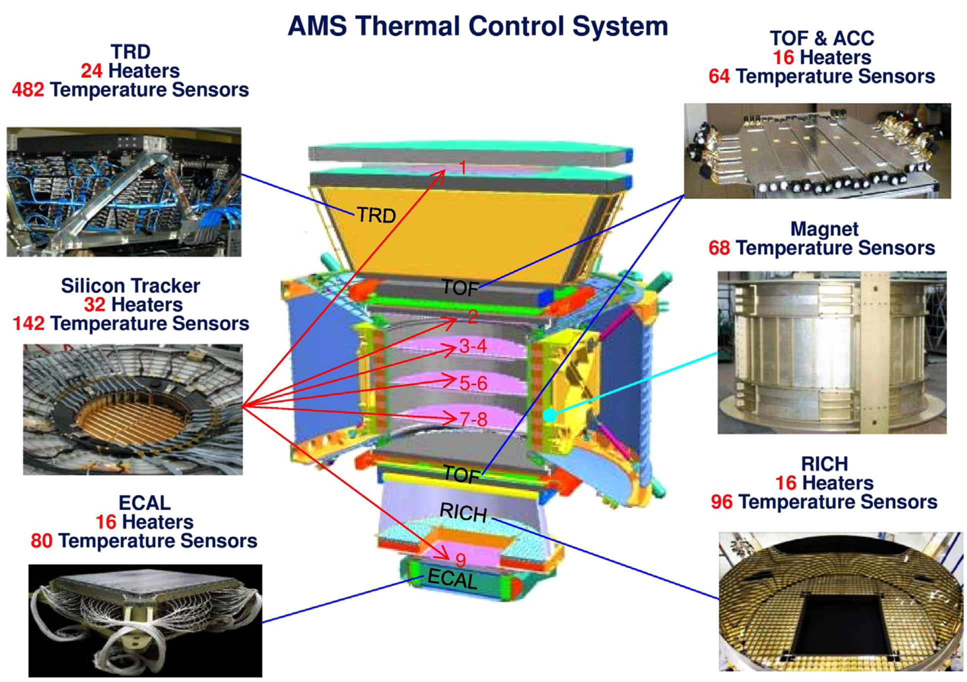

Fig. 2. Distribution of some AMS Thermal Control System components. There are more than 1000 temperature sensors and about 300 heaters in total.

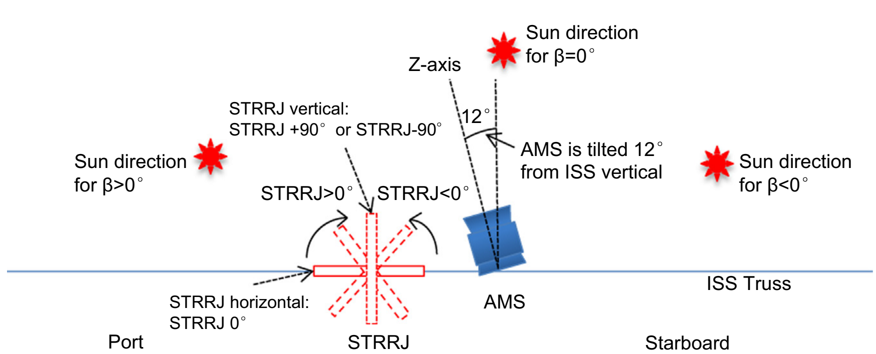

Fig. 3. Schematic view in the usual ISS flight direction. Geometrical relation among the Sun, AMS and ISS Truss and STRRJ. The sign conventions for β Angle (sun position) and STRRJ position are shown.