Abstract
Carbon fiber reinforced cyanate ester composites are of interest for space structural applications where not only specific strength and stiffness are required but also dimensional stability and resistance to microcracking. While most studies have focused on unidirectional laminates, woven composites have proved to be advantageous over the latter and consequently, have received increased attention for structural applications. In this study, we have investigated the performance of such composite for space applications, focusing on the accumulation of damage from extreme thermal and externally applied stresses. We subjected a five-harness satin weave fabric in [0/45]s to TMA, DMA and micromechanical testing in three and four point bending. Results show that the thermal stresses in the 13 MPa to 16 MPa range are not sufficient to induce damage in the material. Cyclic tests in bending and at room temperature show that tensile stresses of 150 MPa are required to induce damage.

1 Introduction
Cyanate ester composites are currently of great interest for space structural applications since they have proved to be more efficient than epoxies both in terms of moisture absorption and resistance to microcracking [1]. In this work we have characterized the performance of cyanate ester / carbon fiber composites under extreme mechanical and thermal loading conditions associated with its use in satellites.

2 Sample preparation and experimental setup
Samples of 0.5 mm thicknesses with varying widths and lengths were cut using a precision diamond saw. For TMA tests, samples of 5 mm width and length were cut and tested performed using a TMA Q400 thermo mechanical analyser. For DMA tests, samples of 5mm width and 55 mm length were prepared and tested using a DMA Q800 dynamic mechanical analyser. Finally, for micromechanical tests samples with width varying from about 3 to 5 mm with length varying from 20 to 30 mm were cut and subjected to three and four point bending tests using a Fullam. Before testing, samples were ground and polished to perform imaging of before and after testing.

3 Thermo Mechanical Analysis
Dimensional change vs. temperature plots were obtained from the TMA data analysis software. From these curves, the coefficient of thermal expansion (CTE) could be obtained by measuring the slope. No significant change in CTE was observed after 16 thermal cycles where one thermal cycle is represented as follows: 20°C → 150 °C → 20 °C. This result is consistent with previous work on various woven composites subjected to thermal cycling [2].

4 Dynamic Mechanical Analysis
Three point bending tests were performed under thermal cyclic conditions where temperature was varied from 20°C to -120°C. The storage and loss modulus were measured continuously by applying a small deformation during the thermal cycles. The modulus was measured at the “warm” end of the cycle (T = 20°C ) and at the “cold” end of the cycle (T = -120 °C) to ensure that the temperature did not affect the measurement of the modulus. We found that these thermal stresses were not high enough to induce any decrease in modulus, which would be an indication of damage.

5 Micromechanical testing
Micromechanical testing was performed using three point bending tests to assess damage accumulation.
with stress. The sample was subjected to cyclic flexural loading, where the amplitude was increased at each cycle up to failure. Load and deflection were converted to stress and strain using classical beam theory, yielding the stress-strain curve of the composite (Figure 4).

The unloading branch of each cycle was then used to measure the instantaneous modulus, which we normalized by the initial modulus $E_0$. The modulus of the composite decreases for applied strain exceeding a threshold of 0.002-0.015, corresponding to a stress of 287-867 MPa. Past this point the modulus decreased continuously with applied strain, an indication of damage accumulation with increasing applied strain. The modulus eventually reached almost zero, corresponding to total failure of the material.

6 Conclusions
This study showed that thermal cycling did not induce an increase of surface microcracking in carbon reinforced cyanate ester composites of configuration [0/45], and 0.5 mm thickness when subjected to cycling between 20°C and -120°C. Furthermore, no change in CTE of the material was observed when subjected to thermal cycling between 20°C and 150°C and no change in flexural modulus was observed when cycling between 20°C and -120°C. Micromechanical tests were performed under no thermal cyclic conditions and showed that failure occurred through mode II cracking between plies induced by shear stresses. These cracks softened the material significantly, eventually leading to rupture of the plies and total failure at a stress of about 0.9-1.2 MPa.

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8 References