To date, deep learning architectures have not been applied to model space vehicle hardware telemetry and to use those models as engineering prognosis tools. This research investigated the neuron activation probabilistic functions at the output of multi-hidden layer deep belief neural networks (DBN) to determine if output neuron activations can be used as detectors of patterns not seen by DBN neurons that learned from nominal data exclusively. The neuron probability activation functions at the output of DBNs were examined by case studies.

The first case study trained and optimized a DBN with nominal main engine telemetry from five independent space shuttle missions. Anomalous (cryogenic valve leak) temperature telemetry signals from Space Transportation System 135 (STS-135) were inputted to the nominal DBN. Analysis of the DBN output showed that the magnitude of the derivative of the output neuron activation probability curve increased sharply in the region where the temperature leak started to trend approximately one sigma away from nominal mean temperatures. This finding suggests the derivatives of the neuron activation probability function at the output of a DBN may be used as a detector for off-nominal patterns. The second case study trained a DBN with fifteen highly non-linear telemetry signals (temperatures, pressures, valve positions, phase, mode, and flowrates) from space shuttle main engine#1 during STS-100 engine start hardware transients. After training the nominal DBN, the same signals were inputted to the DBN and the nominal neuron output probability curve \( P_N(t) \) was examined. A simulated step function in one of the telemetry signals was introduced with nominal patterns into the DBN and the off-nominal output probability curve \( P_A(t) \) was compared to \( P_N(t) \). Analysis of neuron \( \frac{\partial[P_N(t) - P_A(t)]}{\partial t} \) showed a sharp spike at the time location where the simulated off-nominal pattern was inserted. This finding suggests system processes containing highly non-linear signals may be modeled by DBNs and can be represented by a single curve as a combined model of nominal system processes. This model neuron activation function can then be compared to a DBN output activation function having embedded anomalous signals and be used as a detector of anomalous patterns.

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The public is welcome to attend.