Abstract: Nonequilibrium describes a physical process that is not able to reach a well-defined equilibrium state within a time scale relevant to a system. For gas flow around a hypersonic vehicle, nonequilibrium energy transfer and chemistry of the molecules directly affect the heat transfer to the vehicle. The thermal response of the material comprising the hypersonic vehicle Thermal Protection System (TPS) is analyzed using strong coupling to the external nonequilibrium flow. The coupling is performed through detailed modeling of the surface energy processes. Several examples are presented of application of the fully coupled modeling framework to gas-surface interactions relevant to hypersonic flight.

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