Under NASA’s Supersonic Project and in collaboration with Lockheed Martin Corporation, Stanford University is developing a generic Multi-Disciplinary Analysis and Optimization (MDAO) framework for aircraft design. The present work contributes to this by constructing a new Response Surface Modeling (RSM) tool based on gradient-enhanced Gaussian Process Regression (GPR) for the design of low-boom supersonic aircraft using target equivalent area distributions. Gradient information for all of the aircraft's design variables is obtained through the solution of a continuous adjoint problem at the approximate cost of one direct flow solution. The current work explores the potential gains in fit accuracy when using this additional data to inform the RSM. Gaussian Process Regression, a Bayesian statistical technique, is a super-set of a popular RSM technique known as Kriging. The current work further explores the potential gains in fit accuracy when modeling complex design spaces with this flexibility. The viability of our approach is demonstrated with examples derived from ongoing design efforts.