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Let X be a quotient of the Siegel space of degree two by a congruence subgroup of $\mathrm{Sp}(4, \mathbb{Z})$. This is a three dimensional algebraic variety, and is an example of a Shimura variety. Results of R. Weissauer imply that the Picard group of X may be computed in terms of theta lifting of weight $5/2$ cusp forms on $\mathrm{SL}(2, \mathbb{R})$ to the symplectic group $\mathrm{Sp}(4, \mathbb{R})$. There are elements of the Picard group given by geometric cycles called Humbert surfaces. The theory of Kudla and Millson provides a correspondence between certain kinds of geometric cycles ("special cycles") on locally symmetric varieties and automorphic forms given by theta lifting. For Siegel modular threefolds the Humbert surfaces may be identified with special cycles of Kudla/Millson. We examine the questions: (1) do the Humbert surfaces generate the Picard groups? (2) can one explicitly compute the dimensions of these Picard groups? (Received September 20, 2006)