The observations of the GW170817 electromagnetic counterpart suggested lanthanides were produced in this neutron star merger event. Lanthanide production in heavy element nucleosynthesis is subject to large uncertainties from nuclear physics and astrophysics unknowns. Specifically, the rare-earth abundance peak, a feature of enhanced lanthanide production at A~164 seen in the solar r-process residuals, is not robustly produced in r-process calculations. The proposed dynamical mechanism of peak formation requires the presence of a nuclear physics feature in the rare-earth region which may be within reach of experiments performed at, for example, the CPT at CARIBU and the upcoming FRIB. To take full advantage of such measurements, we employ Markov Chain Monte Carlo to “reverse engineer” the nuclear masses capable of producing a peak compatible with the observed solar r-process abundances and compare directly with experimental mass data. Here I will present our latest results and demonstrate how the method may be used to the learn which astrophysical conditions are consistent with both observational and experimental data. Uncertainties in the astrophysical conditions also make it difficult to know if merger events are responsible for populating the heaviest observed nuclei, the actinides. Here I will discuss a potential direct signature of actinide production in merger environments. However, an r process which reaches the actinides is also likely to host fission, which is largely experimentally uncharted for neutron-rich nuclei. The influence of fission on lanthanide abundances, and the potential for future experimental and theoretical efforts to refine our knowledge of fission in the r process, will be discussed. The question of where nature primarily produces the heavy elements can only be answered through such collaborative efforts between experiment, theory, and observation.