Atomic nuclei are key to understanding processes in extreme environments, from stellar explosions to the interior of nuclear reactors and fusion capsules. In this talk, I will discuss two central questions in nuclear physics, namely, understanding and predicting diverse nuclear properties from first principles or "ab initio" (tied to the underlying physics of quarks and gluons), and the origin of emergent orderly patterns in the intricate nuclear dynamics. In particular, I will talk about the multi-facet challenges of a large-scale first-principle nuclear modeling and the way an innovative symmetry-guided framework, recently developed at LSU, has significantly expanded the reach of ab initio theories. This is based on a discovery, within this framework, of a new fundamental (and surprisingly simple) feature common to all nuclei. This, empowered by petascale computing facilities, opens up a new region of nuclear isotopes for study and prediction, important for advancing our knowledge about the formation of elements and other astrophysical phenomena, neutrino physics, and applied research for nuclear energy.