Y dwarfs, the coldest class of substellar objects with Teff < 500 K, offer a unique window into exoplanetary atmospheres at the very lowest temperatures. I will present new Hubble Space Telescope results from a dedicated program, which delivered robust new astrometric solutions for 15 Y dwarfs by linking HST images to Gaia, along with the first homogeneous compilation of near-infrared photometry for over 20 Y dwarfs. With parallaxes measured to <2-5% precision and flux measurements spanning the YJH bands, the combination of precise distances and uniform photometric datasets revealed unprecedentedly tight and well-defined sequences in colour-magnitude diagrams for the Y-dwarf population. I will discuss the implications of these new insights into the atmospheric properties and diversity of these objects, together with comparisons to state-of-the-art models and future prospects with JWST.