Storage and transfer of cryogenic liquefied gases on volume scales from under 10 liters for lab use, up to hundreds of millions of liters for industrial applications is of paramount importance across a vast range of industries. Traditionally, these commodities have been stored at or near the normal boiling point due to relative ease of operation and safety-related considerations; however, this also means that some percentage will always be lost due to environmental heat leaking into the vessel and causing boil-off. These losses become more concerning as scales increase, and are of particular importance for high-cost commodities such as helium and hydrogen. Additionally, the normal boiling point has marked the highest liquid density achievable, which became a strong driver of end-use system designs such as space launch vehicles. Recent development and testing of an Integrated Refrigeration and Storage (IRAS) system for liquid hydrogen has proven that next generation cryogenic storage operations such as zero boil-off and densification are feasible on a large scale. This IRAS system married an 850 Watt at 20 Kelvin reverse Brayton cycle commercial cryogenic refrigerator with a 125,000 liter LH2 storage tank via internal tubular heat exchanger; thereby allowing heat to be removed directly from the hydrogen, and by extension, provided a means to control the bulk thermodynamic state.

Zero boil-off, in-situ liquefaction, and densification down to the triple point was performed during testing, and data such as fluid temperature profiles and tank pressure were gathered. Details regarding the design, setup, and testing of the IRAS system will be discussed, as well as various physics models created to predict the behavior of the system during transient and steady state operation.