

Executive Summary

The Aero Mavericks, an aerospace student organization at UTA, aim to design a hybrid M-Class motor for the IREC competition. As a step toward this goal, this project focused on the development of an H-Class motor. Drawing on historical data from rocket propulsion systems, a test campaign was designed for a small-scale research motor, HX-1. Key components of the motor and its supporting systems were evaluated through hydrostatic and cold flow testing to characterize injector performance and optimize the combustion process, targeting a near 1:1 mixture ratio of paraffin wax fuel and nitrous oxide oxidizer. With these tests we get an average mass flow rate with an error and change in flow coefficient.

Background

The hybrid configuration was chosen as the simplest acceptable solution which avoids the danger of manually mixing fuel and oxidizer to create a homogeneous propellant which has been a significant barrier to our SRAD program in the past, and is more simple than the old Liquid rocket engine proposal and easier to scale than developing a half-cat derivative. The oxidizer that our rocket will use is nitrous oxide. Nitrous was chosen because it is a non-toxic propellant that can be stored in a liquid-vapor mixed phase at room-temperature simply by maintaining pressure. As the oxidizer is consumed in the combustion chamber, the vapor pressure will continuously be regenerated to saturation conditions through flash boiling of the liquid phase. This self-pressurizing property can also be used to fill our run tanks without the need of a ullage tank or pump. Compared to other chemicals, the combustion of nitrous is relatively clean without the release of nasty exhaust chemicals such as hydrochloric acid or metal-oxides.

This program will grant our competition teams access to Student Research and Development (SRAD) competitions like IREC and FAR-OUT as well finally bridge the UTA competitive with other regional schools which have already developed a similar system. Switching over to hybrid propulsion will also reduce the environmental impact of our launch operations by eliminating the emission of various hazardous chemical agents like hydrogen chloride.



Figure 1. Prepped Combustion Chamber of HX-1

Experimental Setup

The HX-1 is a small-scale H-class research motor developed by the Aero Mavericks Hybrid Division as the first experimental platform in a broader campaign leading to the Longshot M-class vehicle for IREC. Rather than achieving flight-ready performance, HX-1 is designed to generate empirical data to validate models, characterize injector hydraulics, and improve system-level understanding of oxidizer flow behavior. The system uses nitrous oxide as the oxidizer and paraffin wax as the fuel, and is built around a modular architecture that incorporates a swappable single-element injector, a radiatively cooled combustion chamber, and a COTS-based high-pressure feed system. Key design requirements included sustaining pressures of at least 800 psi without leaks, enabling interchangeable injector diameters for rapid iteration, and collecting sufficient data to experimentally determine discharge coefficients and flow characteristics under realistic operating conditions.

To support these objectives, the system was instrumented with pressure transducers and a load-cell-based mass measurement system, with data acquisition handled through an Arudino and HX711 ADC architecture. The system first underwent hydrostatic testing using water to validate structural integrity and leak-tightness, where early failures—including fitting leaks and O-ring extrusion at 950 psi—were identified and corrected before achieving a successful hold at 900 psi. Following validation, cold flow testing was conducted using nitrous oxide, with multiple injector sizes tested across several runs to measure pressure behavior and mass flow rates during tank blowdown. These results provide the experimental basis for determining discharge coefficients, validating flow models, and selecting optimal injector configurations for future hot-fire testing and subsequent engine iterations.

Experimental Test Plan

The HX-1 system combines several core technologies into a hybrid rocket test platform. It uses nitrous oxide as the oxidizer, a modular injector with interchangeable orifice sizes, and a high-pressure fluid delivery system built mostly from commercial off-the-shelf components. The system is supported by a fully instrumented test stand with pressure sensors, mechanical gauges, and a load-cell-based mass measurement system to capture real-time data. A microcontroller-based data acquisition and control system enables remote operation, allowing tests to be conducted safely behind a designated safety line while continuously recording system behavior. Unlike a flight-optimized engine, HX-1 is designed as a data-driven experimental platform focused on improving modeling and guiding future designs. Its swappable injector system allows rapid testing of different geometries, enabling direct comparison of flow behavior, especially for complex two-phase nitrous oxide flow. The design reflects several tradeoffs: using COTS components reduced cost and complexity but led to issues like leakage and O-ring failures; a pressure limit of 800 psi was chosen for safety over maximum performance; and simplified flow models introduced uncertainty, requiring experimental validation. Analytical models were used to estimate performance and size injectors, while hydrostatic and cold flow tests validated structural integrity, measured mass flow rates and pressure drops, and generated data—such as pressure traces and tank mass loss—used to calculate discharge coefficients, refine models, and improve future engine iterations.

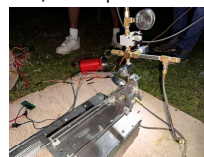


Figure 2. Test system and stand for cold flow test

Experimental Results

The hydrostatic test was conducted on April 5th, 2026 and passed on the fourth pressurization attempt, with the system successfully holding 800 psi using water as the test medium. Two failure modes were encountered and remediated during the test: fitting leaks resolved with pipe dope, and O-ring extrusions at 950 psi requiring O-ring replacement. These failures indicate the current face seal and manifold design is not rated beyond 800 psi, and a redesign targeting 1000 psi is required before the hotfire. Pressure transducer calibration was completed concurrently, yielding seven data points across the 0–800 psi range and a linear fit for both P1 and P2.

Six cold flow runs were conducted across three injector sizes — 2.6 mm, 3.02 mm, and 3.69 mm — on the same day. Tests 1 and 3 recorded zero tank weight loss and are treated as inconclusive, likely due to insufficient scale resolution at short run durations. The four remaining tests yielded computed C_d values between 0.02 and 0.05, well below the 0.6–0.8 expected for a sharp-edged orifice, which points to a systematic measurement limitation rather than a true hydraulic result. Test 6 — a 200-second blowdown through the 3.69 mm injector consuming 5.43 lbs of nitrous — is considered the highest-quality data point and the primary basis for injector selection going forward. Despite the instrumentation limitations, P1 and P2 confirmed consistent pressurization across all runs with no anomalous pressure drops or leaks under live nitrous conditions.

Conclusions

The HX-1 campaign successfully completed hydrostatic and cold flow testing on April 5th, 2026, representing the first live propellant flow test in Aero Mavs Hybrid Division history. The system demonstrated structural integrity at 800 psi, validated both pressure transducers, and confirmed normal operation of all fluid and electronic subsystems under nitrous oxide flow. While reliable discharge coefficient values were not obtained due to scale resolution limitations, the campaign produced the operational experience and system validation necessary to proceed to ignition testing. The 3.69 mm injector tested in the extended Test 6 run serves as the primary injector candidate for the hotfire. Prior to the hotfire, two design actions are required: redesign of the face seals to achieve a 1000 psi proof pressure, and replacement of the manual tank scale with a continuously logging load cell to enable accurate mass flow characterization. The HX-1 campaign has established that the Aero Mavs Hybrid Division is capable of conducting safe, structured propulsion tests, and the team is positioned to proceed to the Longshot ignition campaign with the procedural and technical foundation developed here.

References

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