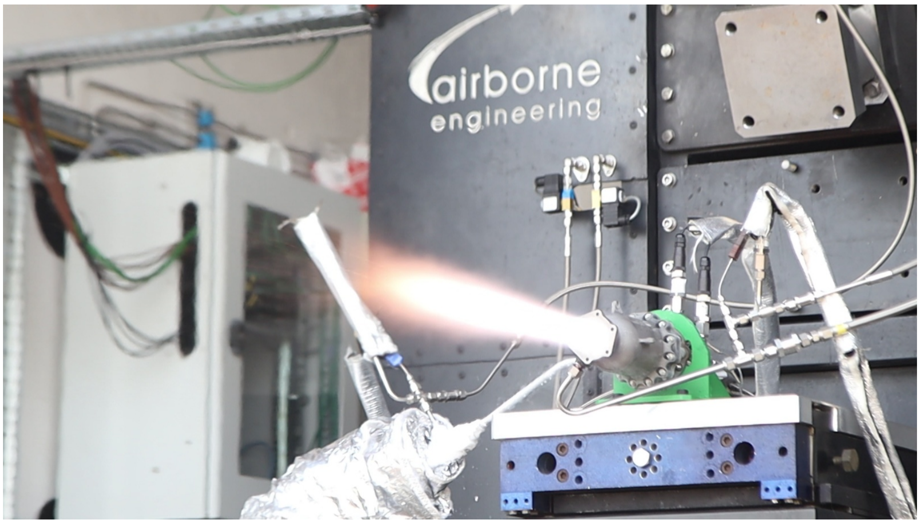
**Race2Space 2026**

# Engineering Campaign Report

## Development, Manufacturing, and Hot-Fire Testing of the Kimchi Engine




Representative Kimchi Engine firing. [TO CONFIRM: verify that this video frame corresponds to Test 8, dataset 20260622-112, before external submission.]

Primary Report

Wonbee Park

| | |
|---|---|
| Document class: | Engineering campaign report |
| Campaign: | Race2Space 2026 |
| Representative test: | Test 8 / 20260622-112 |
| Propellants: | Liquid oxygen / isopropyl alcohol |
| Issue date: | August 2026 |

This report is an evidence-led account of a student propulsion campaign. It distinguishes preliminary design, final detailed design, external manufacturing, facility operation, student integration work, and measured test results.

# EXECUTIVE SUMMARY

The Race2Space 2026 Kimchi Engine campaign converted a student-led liquid-propulsion objective into integrated hardware and a measured LOX/IPA hot-fire result. The work was broader than an engine calculation: it required design evolution, manufacturing-support coordination, an engine mount and test hardware, domestic ground-test readiness, an augmented spark igniter (ASI), liquid-oxygen operations planning, site integration, troubleshooting support, and a traceable data package. The central result is Test 8, dataset 20260622-112, which produced a sustained pressure and thrust response suitable for steady-state analysis.

During the defined steady window, $T_0 + 4.0$ to $12.5$ s, mean chamber pressure was $14.05 \pm 0.18$ bar(g) and mean thrust was $1194 \pm 33$ N. Mean LOX and IPA mass flows were 0.450 and 0.250 kg/s, respectively, giving 0.701 kg/s total flow and O/F 1.80. Measurement-based effective specific impulse was $173.8 \pm 5.2$ s. The chamber-pressure response above the 5% threshold lasted 13.4621 s, and positive thrust integrated over that interval was 13.15 kN s. All values were rechecked against the raw 10 kHz HDF5 record and the existing analysis scripts [1, 2].

| $14.05 \pm 0.18$ | $1194 \pm 33$ | **13.46** | **13.15** |
|---|---|---|---|
| **bar(g) chamber pressure** | **N thrust** | **s pressure response** | **kN s impulse** |
| steady-window mean ± time standard deviation | baseline-corrected; same window | 5% $p_c$ threshold | positive thrust integral |

| Evidence axis | What was demonstrated | What is not claimed |
|---|---|---|
| **Technical depth** | Configuration control from PDR to CDR, injector/feed interpretation, measured performance, and test-derived lessons. | A peer-reviewed propulsion model or a complete uncertainty budget. |
| **Personal contribution** | Project leadership, early PDR concept design, readiness coordination, ASI development, mount/test-hardware preparation, integration, analysis, and documentation. | Sole authorship of the final detailed engine design, metal printing, or facility firing control. |
| **Execution** | Physical hardware integration and an eight-attempt campaign culminating in a representative sustained hot-fire response. | Flight qualification, production readiness, or completed VTVL capability. |

### Interpretation discipline

The ± terms above are time-domain standard deviations over the steady window, not sensor-calibration uncertainties. The 13.0 s command/template duration is not substituted for the measured 13.46 s pressure-response duration. The effective $I_{sp}$ is calculated from measured thrust and flow and does not include a complete stand-dynamics, sensor-calibration, atmospheric, or propellant-holdup uncertainty model.

*Source: Raw dataset 20260622-112 and reproduced analysis metrics; see Evidence Matrix C10-C15.*

# 1 RACE2SPACE CONTEXT AND PROJECT OBJECTIVE

Race2Space provided a bounded, safety-controlled setting in which a student engine could be connected to professional ground-test infrastructure. The campaign objective was not simply to "fire an engine." It was to establish a complete evidence chain: define an engine and its interfaces; secure manufacturable hardware; make the article ready for LOX/IPA operation; integrate with the Airborne Engineering Ltd (AEL) facility; execute repeated tests under facility control; and reduce the data to defensible engineering conclusions [3, 4].

The project also served a longer trajectory. The preliminary design framed the engine as both a Race2Space test article and a foundation for future lander-class propulsion work [5, pp. 2–3]. The present campaign provides measured propulsion evidence for that direction, but it is not presented as flight readiness. Repeatability, calibrated uncertainty, transient control, throttle mapping, and vehicle-level interfaces remain subsequent gates.

| Define | Make ready | Integrate | Fire | Learn |
|---|---|---|---|---|
| PDR and final configuration boundaries | Manufacturing support, mount, ASI, LOX and test hardware | Engine-to-facility interfaces and checkout | AEL-controlled campaign execution | Raw data, verified metrics, design/test feedback |

# 2 TECHNICAL ROLES AND SCOPE OF CONTRIBUTION

The table below is deliberately verb-specific. It separates Park's work from the final detailed-design contribution of a teammate and from work performed by Innospace and AEL personnel. That distinction is a technical strength: a campaign succeeds when interfaces and responsibilities close, not when one person is credited with every operation.

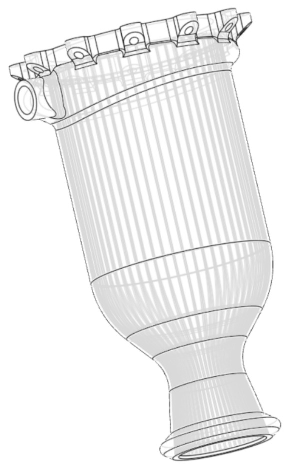
| Workstream | Wonbee Park - claimed contribution | Other credited responsibility |
|---|---|---|
| **Project direction** | Led the student campaign, set the evidence objective, coordinated readiness, integration, and documentation. | Team members contributed subsystem and field work. |
| **Preliminary engine** | Designed the initial PDR engine concept and documented the early LOX/IPA architecture. | Technical review and team input supported the PDR. |
| **Final engine design** | Supported interfaces, requirements, manufacturing readiness, and campaign integration; did *not* claim detailed-design ownership. | A teammate was responsible for the detailed final CDR engine design. |
| **Manufacturing** | Secured and coordinated manufacturing support, interfaces, follow-up, and hardware readiness. | Innospace performed the metal additive manufacturing. |
| **Ground hardware** | Prepared the engine mount and test hardware; coordinated fittings, sensors, plumbing, assembly, and interface checks. | Vendors and teammates supported fabrication and assembly tasks where applicable. |
| **Domestic readiness** | Coordinated the LOX test stand, LOX sourcing/handling readiness, ASI development and testing, leak/water-flow checks, and integration reviews. | Safety decisions and operations involved responsible adults, suppliers, and facility stakeholders. |
| **AEL campaign** | Supported installation, assembly, between-run troubleshooting, and team-side technical decisions. | AEL personnel operated the facility and firing control. |
| **Data and reporting** | Organized the Test 8 record, reproduced performance metrics, interpreted campaign lessons, and authored this evidence package. | AEL's acquisition system and test personnel produced the facility data record. |

### Language used throughout

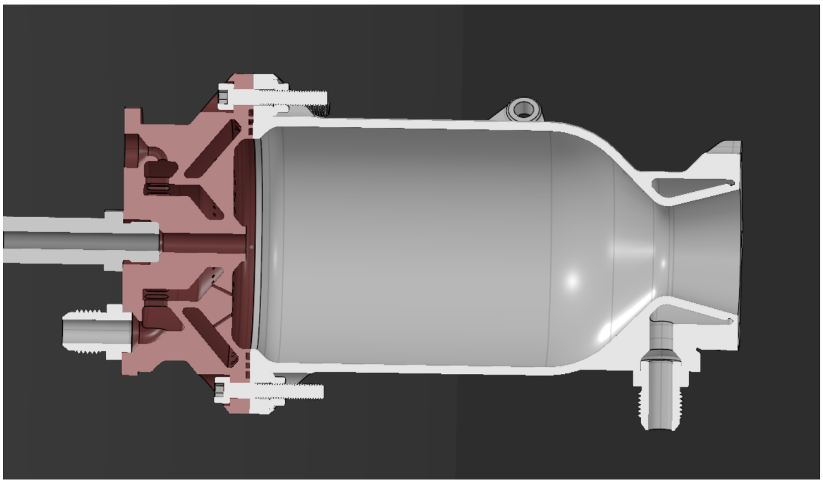
**Designed** is reserved for attributable design work; **manufactured** for the organization that made hardware; **prepared, coordinated, integrated, supported,** and **analyzed** for Park's campaign roles.

# 3 DESIGN EVOLUTION: AUTHOR-DESIGNED PDR CONCEPT VS. TEAMMATE-DESIGNED FINAL ENGINE

The January PDR and April CDR describe different configurations, not two descriptions of one frozen design. Park's PDR concept emphasized a broad throttle objective, fuel regenerative cooling, and a 103-element coaxial-shear injector. The later final engine reduced the design point to 1300 N, adopted a more compact hot-gas path and an impinging injector, and closed a fixed configuration for manufacture and facility integration [5, 6]. The final detailed design is credited to the teammate who owned that work.



**PDR concept.** Park's preliminary regeneratively cooled configuration.



**Final CDR engine.** Compact fixed geometry used as the final design basis.

**Figure 1:** Configuration evolution from the author-designed preliminary concept to the teammate-designed final engine. The images are rendered crops of the source reviews, not photographs of identical hardware states.

*Source: PDR Figure 1 and CDR Figure 1.*

| Attribute | PDR concept - January 2026 | Final CDR configuration - April 2026 |
|---|---|---|
| **Design ownership** | Preliminary engine designed by Wonbee Park within the student team. | Detailed final engine design by a teammate; Park led/cross-connected other campaign work. |
| **Operating intent** | 1.0-2.5 kN and roughly 40-100% throttle; 10 s competition burn target. | 1300 N design point; 440.6-1300 N analytical throttle envelope. |
| **Chamber target** | 6.2-14.8 bar; 114.32 mm chamber diameter; 43.21 mm throat. | 6-15 bar analytical range; 76.36 mm chamber diameter; 28.86 mm throat. |
| **Injector concept** | 103-element coaxial-shear arrangement with replaceable oxidizer posts. | Center-fed impinging architecture with fixed metering geometry. |
| **Purpose in this report** | Evidence of early design depth and project initiation. | Design baseline for the final hardware, interfaces, and design-vs-test discussion. |

### Neutral engineering interpretation

The change is reported as convergence under schedule, manufacturing, facility, and interface constraints. It is neither evidence that the PDR was the final engine nor an argument that one designer's configuration was superior.

# 4 FINAL KIMCHI ENGINE CONFIGURATION

The final CDR baseline was a pressure-fed, regeneratively cooled Inconel 718 engine with LOX feeding the injector directly and IPA passing through the cooling jacket before injector entry. The CDR target was 1300 N at 15 bar chamber pressure and 0.700 kg/s total mass flow; its fixed hot-gas geometry used a 76.36 mm chamber, 28.86 mm throat, 40.72 mm exit, and 0.50 mm hot wall [6, pp. 3–14]. These values are carried here as **design targets**, not as measurements of the fired article.

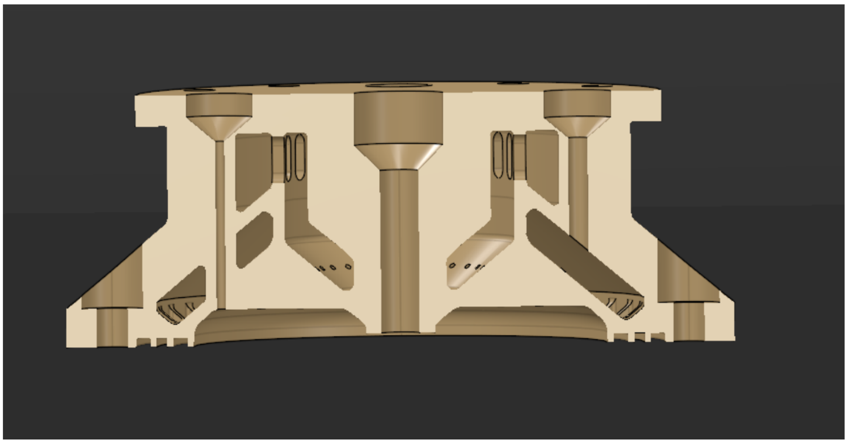


**Figure 2:** Final injector cutaway showing the center feed, internal manifolds, impinging passages, and instrumentation access. Detailed final-engine design is credited to the responsible teammate.

*Source: Kimchi Engine CDR, Figure 7.*

| Parameter | Design target / document basis | As-tested / measured in Test 8 |
|---|---|---|
| **Propellant pair** | Corrected campaign basis: LOX/IPA. | LOX/IPA, confirmed in the data channels and project record. |
| **Thrust** | 1300 N design point. | $1194 \pm 33$ N steady-window mean. |
| **Chamber pressure** | 15.0 bar design point; document does not establish a gauge/absolute comparison basis here. | $14.05 \pm 0.18$ bar(g) steady-window mean. |
| **Total mass flow** | 0.700 kg/s design point. | 0.70054 kg/s mean, reported as 0.701 kg/s. |
| **Mixture ratio** | CDR table value is not used as an as-tested target because the source also carries the known fuel-label error. | O/F 1.8008 mean, reported as 1.80. |
| **Specific impulse** | 208.6 s predicted vacuum value. | $173.8 \pm 5.2$ s measurement-based effective value; not a like-for-like vacuum comparison. |

**Configuration-control correction**

The CDR repeatedly labels the fuel as ethanol. The confirmed campaign propellant was IPA in every test. This report therefore corrects the fuel name while retaining the CDR only as the final design-geometry and analytical-target source.

The injector chapter specified an intended minimum-throttle pressure-drop rule of $\Delta p_{\text{inj}}/p_c = 0.30$. Post-campaign review later showed that this intent was not consistently translated into the implemented sizing. That disconnect is treated as a requirements-and-verification lesson in Section 9, not as an individual fault or a retrospective rewrite of the CDR.

# 5 MANUFACTURING, ENGINE MOUNT, AND HARDWARE INTEGRATION

Manufacturing was an interface-management problem as much as a geometry problem. Innospace performed the metal additive manufacturing. Park's contribution was to secure and coordinate that support, maintain the required interfaces, help move the engine through manufacturing and post-processing readiness, prepare the mount and test hardware, and support assembly. This wording matters: coordination and integration are technical work, but they are not the same as personally operating the additive-manufacturing equipment.


(a) Physical final engine aligned on the green mount fixture. The image makes the printed chamber, injector stack, lines, and mount interface simultaneously inspectable.

(b) Manufactured Kimchi Engine articles in protective cases before campaign integration.

**Figure 3:** Hardware evidence linking external metal additive manufacturing to student-side mount and system integration.

*Source: Campaign photograph IMG_6435.JPG and project HWP image BIN0012.*

| Innospace | Park / student campaign | AEL |
|---|---|---|
| Metal additive manufacturing of engine hardware. | Manufacturing-support coordination; mount and test-hardware preparation; fittings, sensors, plumbing, assembly, and integration support. | Facility interface acceptance, test-cell operation, firing control, and site procedures. |

## 5.1 Interface closure

The mount had to transmit thrust into the facility structure while preserving access to the feed lines, instrumentation, and igniter. The CDR model used a dedicated bracket and six M10 facility-side fasteners, but the campaign still required physical fit, service access, line routing, sensor installation, and checkout [6, pp. 20–26]. Park prepared the engine mount and test hardware and supported the physical integration; the final design analysis and the facility's acceptance responsibilities remain separately credited.

## 5.2 Evidence of workmanship and coordination

The close-up photograph is important because it links the abstract CAD stack to a real, serviceable assembly. It shows that the campaign crossed the boundary from design documentation to hardware that could be handled, mounted, connected, inspected, and repeatedly returned to a test-ready state. The report does not infer undocumented process parameters or claim that visual appearance alone proves structural or leak integrity.

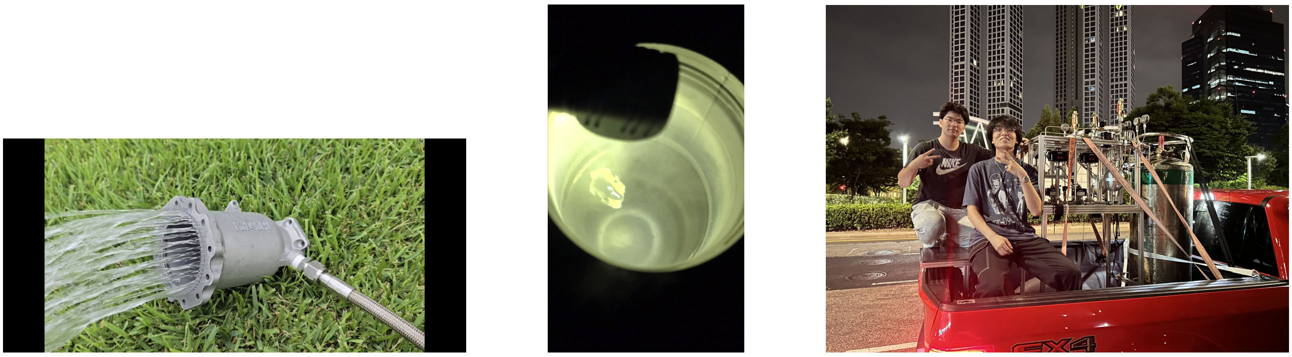
# 6 PRE-CAMPAIGN TEST READINESS IN KOREA

The UK hot-fire was enabled by a domestic ground-test-readiness campaign. Park coordinated a LOX test stand, LOX sourcing and operational preparation, ASI development and testing, the engine mount, plumbing/fittings/sensors, leak and water-flow checks, assembly, and facility-interface review. These activities are presented as a linked readiness chain rather than a list of errands: a missing interface or unsafe procedure would have prevented meaningful use of the manufactured engine.

| | Readiness gate | Engineering purpose | Park's role |
|---|---|---|---|
| **1** | LOX stand and test envelope | Establish a controlled place to exercise cryogenic interfaces and operating logic before travel. | Coordinated preparation. |
| **2** | LOX sourcing / handling readiness | Close compatibility, responsibility, storage/transfer planning, and written procedure needs. | Coordinated suppliers and readiness; no unsupported operator claim. |
| **3** | ASI development and test | Provide an igniter with known interfaces and a checked sequence for the main engine. | Developed and tested the ASI at the confirmed project-record scope. |
| **4** | Mount and hardware | Carry loads, provide service access, and adapt the article to the test stand. | Prepared mount and test hardware. |
| **5** | Lines, fittings, and sensors | Convert drawings into a complete, inspectable fluid/instrumentation stack. | Prepared and coordinated parts and interfaces. |
| **6** | Leak / water-flow / assembly checks | Find connection, distribution, sequence, and maintainability problems before hazardous operation. | Supported checks, assembly, and closure. |

**Safety evidence, not a handling manual**

This report intentionally omits step-by-step hazardous-material handling instructions. The evidentiary point is that compatibility, assigned responsibility, procedure definition, interface checks, and readiness gates were treated as engineering prerequisites, consistent with the campaign's official safety documentation [3, 4].




(**a**) Water-flow observation through the engine/injector article.

(**b**) Ignition-system test image. [TO CONFIRM: exact condition/date.]

(**c**) LOX-system readiness/transport record. [TO CONFIRM: exact activity/date.]

**Figure 4:** Selected domestic-readiness evidence retained in the HWP project record. The images document physical preparation without turning this report into a hazardous-operations manual.

*Source: Project HWP images BIN0018, BIN0024, and BIN0025; resized copies.*

## 6.1 What readiness changed

Domestic preparation reduced the work that had to be invented at the firing site. It created a known engine-side hardware state, a checked ignition subsystem, a parts and interface inventory, and a team vocabulary for leak checks, assembly, and sequence review. The remaining work at AEL could therefore concentrate on facility integration, controlled firing, diagnosis, and between-run changes rather than first-time discovery of every engine interface.

# 7 RACE2SPACE 2026 CAMPAIGN EXECUTION

The campaign comprised eight firing attempts. The first seven are intentionally not reconstructed here as seven miniature failure reports. They form a compact iteration sequence: the team installed and checked the article, observed each controlled firing, reviewed the available evidence, supported troubleshooting and approved changes, and returned the hardware to the stand. The detailed sequence changes, test-by-test failure causes, and frequency-domain interpretation belong in the separate Test Analysis Supplement.

| Site intake | Interface closure | Tests 1-7 | Between-run learning | Test 8 |
|---|---|---|---|---|
| Hardware inspection and responsibility check | Mount, lines, sensors, igniter, and facility connection | Controlled attempts; observations retained for the Supplement | Team-side troubleshooting support under AEL control | Sustained response and representative dataset |

(**a**) Engine and test-cell work during campaign preparation. Team members and AEL personnel are shown in the shared operating environment.


(**b**) Campaign marker identifying the Boostlab Kimchi entry and supporting organizations.

**Figure 5:** Physical evidence of campaign participation and field integration. Exact camera time is not used as the test timestamp.

*Source: Campaign photographs IMG_6413.JPG and IMG_6375.JPG.*

## 7.1 Operating boundary

AEL personnel operated the test facility and firing control. Park's field contribution was on the student side of the boundary: installation and assembly support, hardware/interface knowledge, troubleshooting support, coordination of decisions, data organization, and documentation. This distinction protects both safety truth and technical attribution. It also shows the campaign skill being evaluated: working effectively with a professional facility without appropriating the facility's responsibilities [3].

**Primary Report / Supplement boundary**

This Primary Report carries the campaign arc and the representative sustained result. The Supplement carries the detailed Test 1-8 chronology, sequence deltas, causal analysis, and startup/frequency plots. A short account here is a scope decision, not the deletion of difficult evidence.

# 8 REPRESENTATIVE HOT-FIRE RESULT: TEST 8

Test 8, data file 20260622–112, is the representative result because it contains a sustained chamber-pressure and thrust response with a defensible steady window. The raw record contains 401,840 samples per channel at 10 kHz. Pressure and thrust means use $T_0 + 4.0$ to 12.5 s; pressure and thrust were baseline-corrected using the pre-command interval defined in the analysis script [1, 2].

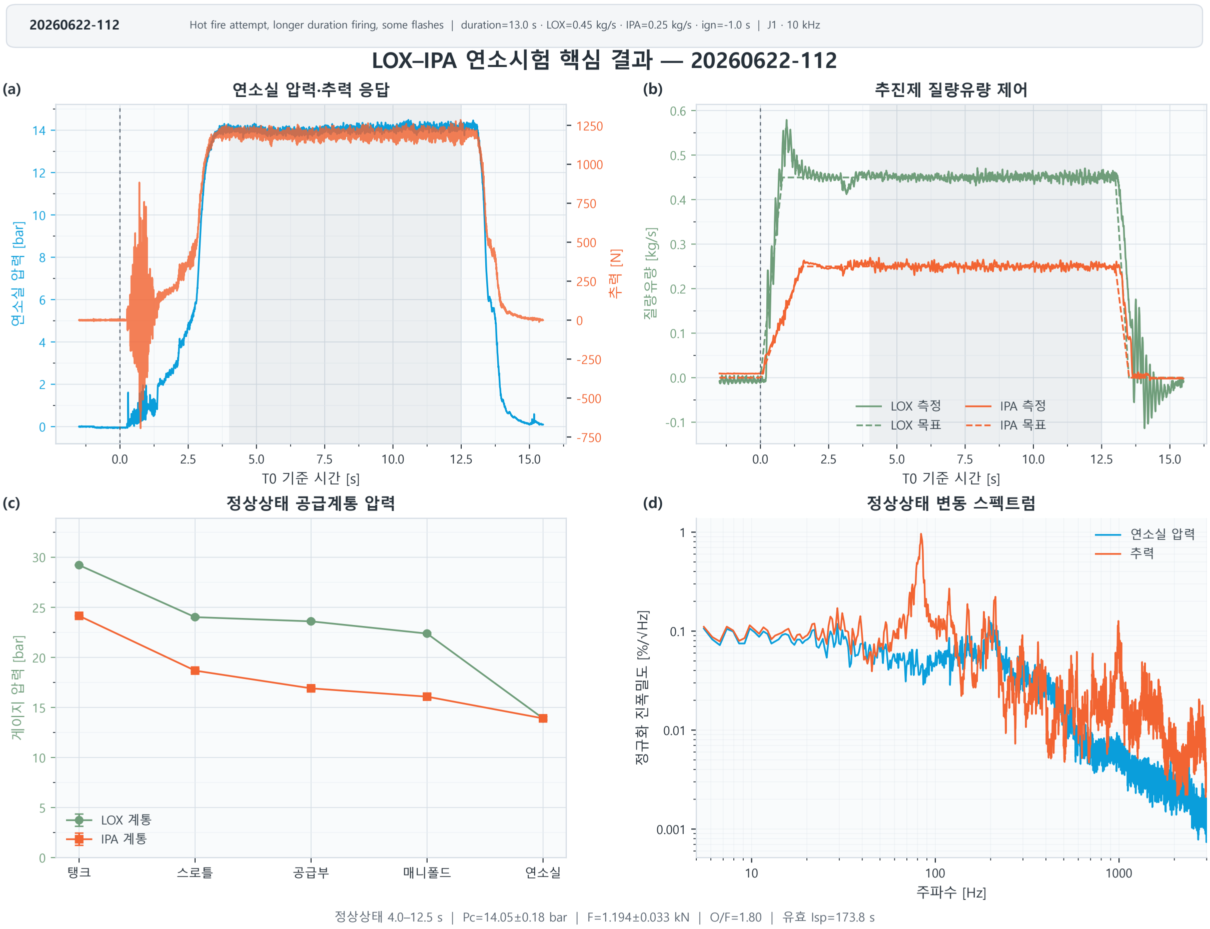



**Figure 6:** Integrated Test 8 measurement summary: chamber pressure and thrust, commanded/measured propellant flow, steady feed pressures, and normalized spectra. The gray band marks the statistics window.

*Source: Verified analysis of raw HDF5 dataset 20260622-112.*

| Metric | Reported result | Definition |
|---|---|---|
| Chamber pressure | $14.05 \pm 0.18$ bar(g) | Mean $\pm$ time standard deviation, 4.0-12.5 s. |
| Thrust | $1194 \pm 33$ N | Baseline-corrected mean $\pm$ time standard deviation, 4.0-12.5 s. |
| LOX / IPA mass flow | 0.450 / 0.250 kg/s | Measured steady means; total 0.701 kg/s. |
| Mixture ratio | O/F 1.80 | Mean of measured LOX/IPA flow ratio. |
| Effective $I_{sp}$ | $173.8 \pm 5.2$ s | $F/[(\dot{m}_{LOX} + \dot{m}_{IPA})g_0]$; measurement-based. |
| Pressure response | 0.7044-14.1665 s | 13.4621 s above 5% of steady mean after 20 ms moving average. |
| Positive impulse | 13.15 kN s | Positive baseline-corrected thrust integrated over the 5% pressure-response interval. |

# 9 POST-CAMPAIGN TECHNICAL FINDINGS AND LESSONS LEARNED

## 9.1 What the representative result establishes

The result establishes that the integrated article and facility produced a sustained LOX/IPA response at approximately the final design-point total mass flow. Chamber pressure and thrust remained sufficiently bounded over 8.5 s to support steady statistics. The mass-flow controllers tracked their steady requests with mean biases of about +0.14% for LOX and +0.12% for IPA. These are campaign-level achievements: they connect manufactured hardware, facility integration, ignition, flow control, structural support, measurement, and post-test analysis.

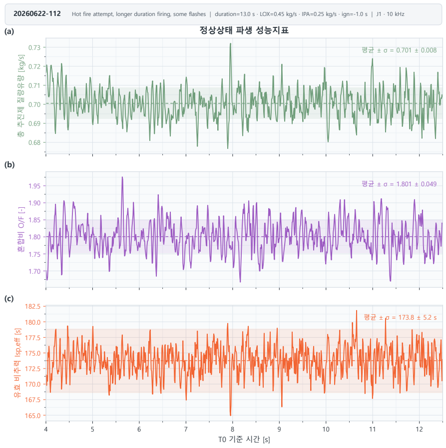



**Figure 7:** Derived Test 8 quantities: total propellant flow, mixture ratio, and measurement-based effective specific impulse over the steady interval.

*Source: Verified analysis of dataset 20260622-112.*

## 9.2 Flow control was necessary, but not sufficient

The AEL stand controlled mass flow. Accurate flow tracking therefore demonstrated that the facility followed the requested delivery values; it did not automatically demonstrate that the injector created the intended pressure drop, spray, mixing, or ignition quality. Post-campaign review found a mismatch between the intended minimum-throttle $\Delta p$ criterion and the implemented injector sizing. Excessive effective flow area led to lower injector pressure drop than intended. Test 8 steady means also show different measured manifold-to-chamber pressure differences on the two propellant sides (LOX 8.47 bar and IPA 2.17 bar), which reinforces the need to verify hydraulic closure rather than infer it from total flow alone.

The correct lesson is systemic. Requirements must be translated into auditable sizing, checked across the full throttle envelope, verified by component-level flow tests, and carried into a test matrix that can distinguish delivery control from atomization/mixing behavior. Detailed sizing calculations and the causal mapping across Tests 1-8 are reserved for the Supplement.

| Observation | Campaign lesson | Next verification gate |
|---|---|---|
| Stable requested mass flow did not by itself settle injection quality. | Separate facility control performance from injector hydraulic and combustion performance. | Calibrated component flow map and spray/pressure-drop verification before integrated hot-fire. |
| Intended $\Delta p$ rule was not fully reflected in implementation. | Make requirement-to-orifice-area traceability reviewable and sign off the worst-case throttle point. | Independent sizing review plus as-built metrology. |
| Startup contained a longer transient before the steady window. | Treat ignition/sequence timing as its own development problem, not as noise inside a steady result. | Repeatable startup criterion and synchronized high-rate diagnostics; see Supplement. |

### Measurement limits

The reported standard deviations describe time variability, not total uncertainty. Effective $I_{sp}$ does not include full sensor calibration, thrust-stand dynamics, atmospheric correction, or propellant accumulation in lines. Spectral peaks are observations, not identified combustion or structural modes without transfer-function and repeat-test evidence.

# 10 TECHNICAL EXCHANGE AND EXTERNAL BENCHMARKING

The campaign included contact with Bristol HyPower and the Westcott propulsion environment. Those activities are relevant only where they show a concrete engineering benchmark: configuration control, test-facility interfaces, evidence-based readiness, or a practice that can be carried into a future Race2Space Korea or VTVL program. The available source set does not yet tie a dated visit to specific attributable observations.

**[TO CONFIRM before submission]**

Record the date, host, participants, and one or two specific technical practices learned at Bristol HyPower and Westcott. Avoid tourism or general travel narrative. Until those details are confirmed, this section intentionally makes no stronger claim.

# 11 CONCLUSION AND CONTINUATION TOWARD VTVL

The strongest evidence from Race2Space 2026 is the connection between stages of work. Park initiated an ambitious PDR concept, accepted a transition to a teammate's final detailed engine design, coordinated manufacturing support and hardware readiness, prepared the mount and test hardware, developed the ASI, organized domestic LOX readiness, supported assembly and field troubleshooting, and reduced the representative firing to a checked data record. Innospace's manufacturing contribution and AEL's facility/firing-control responsibility remain explicit.

Test 8 recorded $14.05 \pm 0.18$ bar(g), $1194 \pm 33$ N, 0.701 kg/s total LOX/IPA flow, and a 13.46 s pressure response. More important than a single peak number, the campaign produced a traceable feedback loop from requirement to design, hardware, operation, measurement, and corrective lesson. The injector pressure-drop issue demonstrates the value of that loop: a mass-flow setpoint can be met while a separate atomization/mixing requirement remains under-verified.

For VTVL continuation, the next program should convert this campaign evidence into repeatability and control authority:

1. freeze an as-built injector flow-area and pressure-drop map with independent review;
2. repeat ignition and steady operation with a calibrated uncertainty budget and test-stand dynamic characterization;
3. demonstrate controlled throttle points and transients, not only one sustained operating condition;
4. qualify mount, valve, sensing, and control interfaces for vehicle-level loads and fault handling; and
5. preserve the same explicit ownership, safety, and data-traceability boundaries used in this report.

**Bounded claim**

Race2Space 2026 is a verified ground-test milestone and an engineering-development baseline. It is not presented as vehicle flight qualification or a completed VTVL system.

# REFERENCES

[1] Kimchi Team and Airborne Engineering test personnel. Test 8 raw hot-fire dataset: 20260622-112. HDF5 data file, 10 kHz acquisition, 2026. 401,840 samples per channel; user-provided read-only campaign record.

[2] Wonbee Park. Verified normal-combustion analysis package for 20260622-112. Analysis scripts, metrics tables, and vector figures, 2026. Steady-state window T0+4.0 to 12.5 s; results reproduced against the raw HDF5 for this report.

[3] Race 2 Space and Airborne Engineering Ltd. Race 2 space final arrangements, safety information and risk assessment 2026. Technical report, Race 2 Space, 2026. User-provided official campaign operations document.

[4] Airborne Engineering Ltd. Airborne safety information. Technical report, Airborne Engineering Ltd, 2026. User-provided facility safety document.

[5] Korean Student Association of Propulsion. Race 2 space 2026 preliminary design review. Technical report, KSAP, January 2026. User-provided project document, dated 5 January 2026.

[6] Kimchi Team. Kimchi engine critical design review. Technical report, Kimchi Engine Program, April 2026. User-provided final design review. The fuel label in this source is superseded by the confirmed as-tested LOX/IPA configuration.

**Document basis.** Claims, source locations, confidence, and attribution boundaries are recorded in `EVIDENCE_MATRIX.md`. Items requiring confirmation before external submission are recorded in `OPEN_ITEMS.md`.