PURSUIT OF ZΩH — THE WEEKLY

This Week in

Rocket Science

NO. 007 • 15 NOVEMBER 2026 • NEWS OF 8 NOV – 15 NOV 2026 • 4 STORIES

THIS WEEK

Clumping aluminum, a green thruster, a glowing capsule

Frozen aluminum–water motors lose thrust to clumps, a nitrous oxide thruster needs the same preheat at any pressure, hot graphite outruns ablation models, and Hayabusa2's capsule shows its colors.

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01 PROPELLANTS

Ice-and-aluminum rocket motors lose thrust to clumping grains

ALICE is a solid propellant made of nano-sized aluminum and water, frozen together.[1] Ganeshkumar Venukumar and Dilip Srinivas Sundaram simulated motor firings, computing chamber pressure, thrust, characteristic velocity and specific impulse, and found ideal values far above those seen in tests.[1] Incomplete combustion accounted for a 6–11% loss, particles left inside the motor for 13–21%, and clumping for a further 10–16%.[1] The clumps, estimated at 2–4 µm across, raise the choked mass flow and cut performance.[1]

> WHY IT MATTERS
>
> *What burns in the flame and leaves through the nozzle is not the nanopowder but micron-sized clumps, and those clumps set the two-phase losses.*[1]

CAVEAT *The numbers come from simulations matched against earlier experiments, not from new firings.*[1]

[1] doi:10.2514/1.B40370

2–4 µm

estimated diameter of the aluminum agglomerates in ALICE motors (simulation)

SOURCE 1

ON THE ROAD?

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02

GREEN PROPULSION

A nitrous oxide thruster lights at about 450°C at every pressure

Nitrous oxide is a nontoxic monopropellant that decomposes over a catalyst, which makes it attractive for micro- and nanosatellites.[2] Chao-Feng Cheng and colleagues fired a 100-mN-class thruster across a range of inlet pressures.[2] Reliable ignition needed the catalyst bed preheated to about 450°C every time, within the 50°C resolution of the measurements.[2] Pressure mattered afterward: higher inlet pressure pushed the hot reaction zone through the bed faster, reached self-sustained decomposition sooner and raised characteristic velocity.[2] At 0.8 MPa, decomposition efficiency reached 82.78%.[2]

WHY IT MATTERS

Starting the thruster and running it well respond to different settings, which separates preheat choices from inlet-pressure and catalyst-bed choices.[2]

CAVEAT *Laboratory tests of a single thruster and catalyst bed.*[2]

[2] doi:10.2514/1.B40601

82.78%

N_2O decomposition efficiency at 0.8 MPa inlet pressure, 100-mN-class thruster

SOURCE 2

03

THERMAL PROTECTION

Hot graphite at Mach 9.8 makes less carbon monoxide than models say

In the hypersonic shock tunnel at Sandia National Laboratories, Joshua Hargis and colleagues blew air at 2.7 km/s, Mach 9.8 and 180 Pa over graphite wedges preheated electrically to about 1770–2200 K.[3] A laser absorption diagnostic that resolves thermal nonequilibrium tracked carbon monoxide temperature and concentration downstream.[3] Both gas–surface chemistry models tested overpredicted CO.[3] The equilibrium model overshot most, a sign the surface was reaction-limited or transitional; the air–carbon ablation model was high by a factor of 1.3 to 2.7, the gap growing as the wall cooled from 2150 to 1770 K.[3]

WHY IT MATTERS

Heat-shield design depends on gas–surface chemistry models, and this gives one a quantitative test under hypersonic flow.[3]

CAVEAT *One flow condition (total enthalpy 3.8 MJ/kg) and two types of graphite.*[3]

[3] doi:10.2514/1.J066885

1.3–2.7×

air–carbon ablation model's CO prediction vs. measured, as wall cooled 2150 → 1770 K

SOURCE 3

04

REENTRY

A hand-steered camera caught Hayabusa2's capsule glowing at 12 km/s

The Hayabusa2 sample-return capsule hit the atmosphere over South Australia on 5 December 2020 at 12 km/s, and a hand-tracked consumer camera filmed slitless spectral video from 80 to 49 km.[4] In the first ten seconds of heating, the shock layer glowed in CN, CH and C_2 Swan bands, the last a first for remote views of a capsule entry.[4] The heat shield was far cooler, its color temperature rising from 2720 to 3080 K.[4] C_2 and CH faded while heating still climbed, which the team ties to early pyrolysis of the carbon-phenolic ablator.[4]

WHY IT MATTERS

The capsule radiated one to two orders of magnitude less energy than natural fireballs, because its light came from the hot surface rather than from ablation vapor.[4]

CAVEAT *Preprint submitted to Earth, Planets and Space, not yet peer reviewed; the entry was in 2020, the analysis is new.*[4]

[4] doi:10.48550/arXiv.2611.16291

≈9200 K

rotational temperature of C_2 in the shock layer (vibrational ≈7800 K)

SOURCE 4

WORDS THIS WEEK

Specific impulse
Thrust delivered per unit of propellant flow, often quoted in seconds; the rocket equivalent of fuel economy.

Characteristic velocity
Written c*, a measure of how well a combustion chamber turns propellant into high-pressure gas, independent of the nozzle.

Monopropellant
A single propellant that releases energy by decomposing, usually over a catalyst, with no separate oxidizer needed.

Rotating detonation engine
A combustor in which one or more detonation waves race continuously around a ring-shaped channel, consuming fresh mixture as it is injected.

Ablator
Heat-shield material that protects a vehicle by charring, decomposing and eroding away, carrying heat off with it.

Thermal nonequilibrium
When a gas's energy modes (translation, rotation, vibration) have not settled to one temperature, common behind strong shocks.

SOURCES

1. PAPER G. Venukumar & D. S. Sundaram, "Effect of Particle Agglomeration on Propulsive Performance of Frozen Aluminum–Water Propellants," Journal of Propulsion and Power (9 Nov 2026). doi:10.2514/1.B40370
2. PAPER C.-F. Cheng et al., "Inlet Pressure Effects on the Catalytic Ignition Behavior of N_2O Monopropellant Thruster," Journal of Propulsion and Power (9 Nov 2026). doi:10.2514/1.B40601
3. PAPER J. W. Hargis et al., "Ablation Chemistry Model Evaluation via Hypersonic Shock Tunnel and Laser Absorption Spectroscopy," AIAA Journal (9 Nov 2026). doi:10.2514/1.J066885
4. PREPRINT S. Abe et al., "C_2 Swan, CH and CN emission, surface temperature and luminous efficiency of the Hayabusa2 sample-return capsule from ground-based spectroscopy," arXiv preprint (12 Nov 2026). doi:10.48550/arXiv.2611.16291

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