

High Tide_ / technical and evidence pack

11 October 2026. Team 4555. ENEC track.

1. Design basis

High Tide proposes an angled, segmented air-diffuser corridor outside strong intake capture flow. It starts after the existing offshore warning. It aims to guide jellyfish toward an environmentally suitable exit while keeping the seawater path open. Two fixed mirrored arrangements allow a change in selected exit. The layout is fictional. No facility drawings or internal operating data were available.

The sponsor's design target is adult blue blubber jellyfish, *Catostylus mosaicus*, with a 30–45 cm bell. The firm body description does not establish buoyancy. Identify local animals and measure body properties before biological testing.

The contribution proposed for testing is exit verification plus segmented actuation, current response and complete animal accounting. Bubble curtains and guide structures have prior art. No patentability or global novelty claim is made.

2. Evidence status

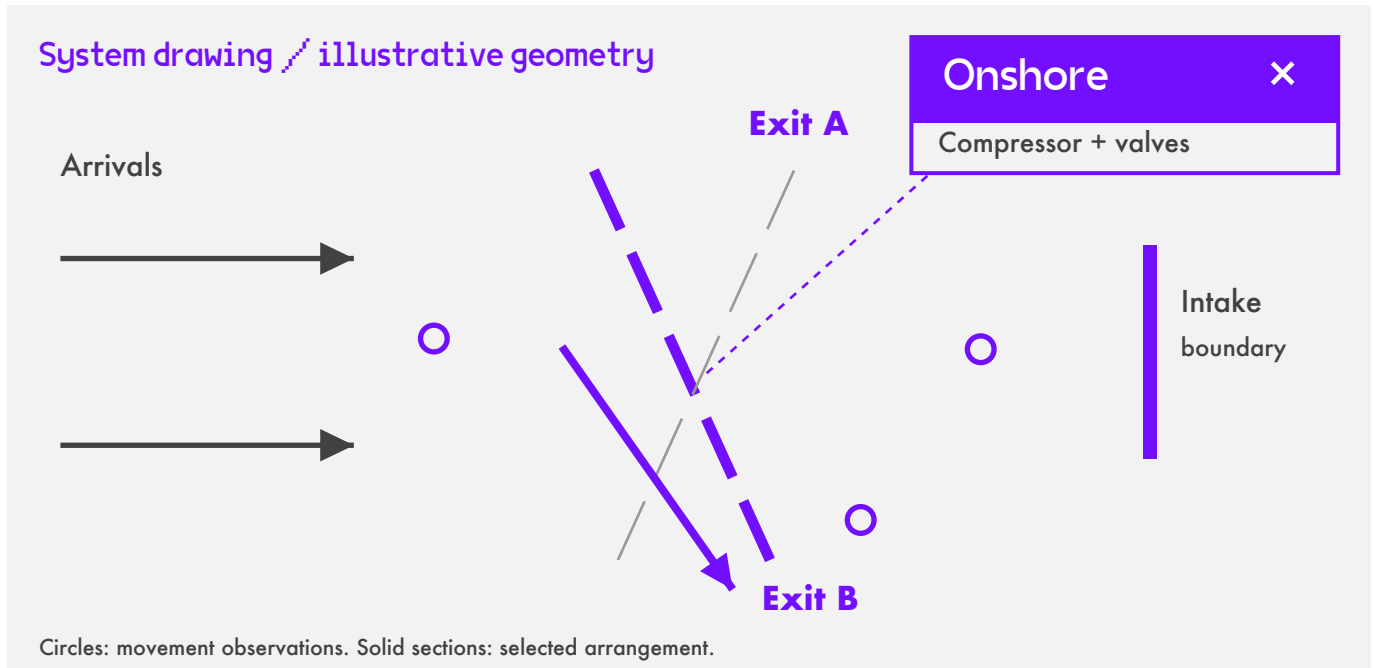
Published evidence: Haberlin, McAllen and Doyle (2021) report mixed bubble-curtain outcomes. An 8 m high-flow curtain at 5 m depth deflected compass jellyfish. A roughly 800 m low-flow installation did not reduce small hydromedusae abundance. Waves increased transport across the curtain in flume work. This motivates experiments and sets a wave-related caution. It does not validate adult *C. mosaicus* or the proposed layout.

Operating context: EDF reports four automatic unit stops at Gravelines on 10–11 August 2025 after jellyfish partially blocked filtration. EDF reported no consequence for installation safety. This is an international example, not a Barakah event or loss estimate.

Design proposal: segmented actuation, measured exit outcome, removable frames and onshore service equipment.

Model assumption: every flow coefficient, geometry dimension, body-response multiplier and guide-passage fraction below.

Completed result: executable digital model, scenario exports, conservation checks, reproducibility and time-step checks. No water-channel, biological or site trial is complete.



3. Geometry and equations

Coordinates use metres and seconds. Arrivals enter at $x = 0$ m, with y uniformly assigned from 12 to 48 m. The nominal approach is $y = 0$ to 60 m. The intake boundary is $x = 95$ m and $y = 18$ to 42 m. The extended tracking domain ends at $x = -35$ or 140 m, or $y = -60$ or 120 m.

The fictional approach velocity is $u = 0.22$ m/s. Intake attraction adds $0.22 \exp(-((y-30)/18)^2) \max(0, (x-55)/40)$ m/s in x . The cross-current is $+0.025$ m/s before reversal and -0.025 m/s after it. Only the cross-current reverses. The approach component remains toward the intake. These values are illustrative, not a tidal prediction.

Unresolved velocity adds $0.035 \sin(0.17t + \text{phase})$ m/s in x and $0.035 \cos(0.13t + 1.7 \text{ phase})$ m/s in y . The deterministic phase differs by particle. This is a smooth disturbance term, not a wave, turbulence or swimming solver.

Each fixed array follows $x = 43 + s \tan(\theta)(y-30)$, where $\theta = 30$ degrees and s is $+1$ for Exit B or -1 for Exit A. Signed normal distance is $d = (x-x_{\text{line}})/\sqrt{1+\tan^2(\theta)}$. Each array has six sections across the 60 m corridor.

For bubbles, assumed surface spreading adds velocity $A r \exp(-0.5(d/5)^2) \text{sign}(d) n$, where $A = 0.55$ m/s and n is the unit normal to the array. The response $r = R (0.7 + 0.6 z)(0.375/D)^{0.25}$. R is adjustable, z is a deterministic uniform value, and D is illustrative bell size in metres. This arbitrary size dependence is sensitivity only. It is not an empirical scaling law. The sign change permits outward flow on both sides. It does not guarantee reflection or successful diversion.

The controlled candidate selects Exit B before reversal plus a switching delay, then Exit A. A section and its neighbours activate when an active particle is within 13 m in x of the selected array. The default delay is 10 s. Sensing and valves are idealised. No camera detection error or valve transient is represented.

The fixed bubble candidate runs all six sections of the Exit B arrangement. Distributed flow applies an assumed cross-flow $s A r \exp(-((x-43)/13)^2)$ m/s. It does not model a pump intake. The porous guide reduces the approaching normal velocity by 95% within a 1.2 m contact band for 85% of particles. The remaining 15% pass by assignment. This is a contact surrogate, not a resolved screen model.

Forward Euler integration uses $dt = 0.25$ s. Continuous arrivals occur at deterministic intervals. The default is one animal per second for 900 s. Body size is 0.375 m. No collision, deformation or density-dependent interaction is modelled.

4. Accounting and fair comparison

Each particle has a unique identity. The mutually exclusive outcome partition is arrivals = intake + outside nominal exit + retained + other boundary. Intake crossing is terminal. A particle outside the nominal y corridor remains tracked until it leaves the extended domain or reaches the intake. Outside exit is an instantaneous location, not a safe-release claim. Other boundary departures do not count as verified clearance.

Ever-exited, returned, repeated return events and guide-contact events are history measures. They overlap outcome categories and must not be added to the conservation sum. A return is re-entry into the nominal y corridor. Small recrossings caused by the smooth disturbance are included.

All candidates share arrival positions, random seed, geometry, current history, horizon and initial conditions. Three seeds are exported: 42, 7 and 91. Fixed and controlled bubbles share the same assumed peak strength. Duty is different. The comparison is not matched electrical energy. The guide has an independent contact approximation, so the table cannot establish which hardware is best.

The actuation index integrates active sections divided by six, multiplied by $(A/0.55)^2$ and time. Units are full-array-equivalent weighted seconds. This is not kWh, cost or measured energy. Guide actuation is zero in this index, but guide drag, service and injury risks are omitted.

Blocked exits are represented by reflecting nominal boundaries. Active-flow candidates switch off and report unsuitable conditions. The installed guide remains. Loss of power stops active flow; the model retains natural and intake flow. Neither response is a plant-safety function.

5. Results and interpretation

See the full CSV for 165 runs: 11 scenarios, five candidates and three seeds. Scenarios cover normal flow, threefold arrival surge, cross-current reversal, delayed switching, weak flow, strong intake attraction, disturbance, power loss, blocked exits, zero response and return flow.

For the reversal case, seed 42 and 900 arrivals, no diversion records 338 intake, 0 outside exit, 456 retained and 106 other. Fixed bubbles record 0 intake, 33 outside exit, 722 retained and 145 other. Controlled sections record 78 intake, 266 outside exit, 390 retained and 166 other. The result exposes a trade-off. Lower retention here comes with increased intake entry relative to the fixed candidate.

These counts do not validate full-scale efficiency. The default actuator coefficient is uncalibrated. Outside-exit animals can return. Domain departures have unknown later outcomes. A 15-minute experiment cannot prove persistence through a real tide.

A surge scales independent particles. The model does not establish a maximum sustainable arrival rate. Physical crowding, flow modification and contact must be measured before any high-volume capacity claim.

6. Verification completed

All 165 scenario runs conserve unique animals at every recorded step. Repeating the default run with the same seed reproduces identical output. Setting response to zero makes fixed bubbles, controlled bubbles and distributed flow match the no-diversion counts. Blocked-exit scenarios record no exit crossing.

Halving Δt from 0.25 s to 0.125 s was checked for normal, reversal and disturbance cases across all five candidates at seed 42. The largest difference in an outcome category was 2 animals out of 900, or 0.222 percentage points. This is a numerical consistency check, not physical validation. Switching delay and reversal state were checked directly.

Browser checks and export checks are recorded in the verification file delivered with the sources. Node.js 24.19.0 runs the engine. The browser uses the same engine module. Execute `node model/verify.mjs` to reproduce the scenario export.

7. First engineering calculations

Arrival rate estimate: $\lambda = \text{concentration} \times \text{normal current} \times \text{relevant approach area}$. For an illustrative concentration 0.05 animals/m³, current 0.2 m/s, width 20 m and occupied depth 2 m, $\lambda = 0.4$ animals/s, or 1,440 animals/hour. These are assumed inputs, not a field density or capacity rating.

Travel check: with 20 m sideways distance and 60 m travel before intake capture, at 0.2 m/s toward intake, available time is 300 s. Mean sideways transport must exceed 0.067 m/s before adding a margin. This estimate neglects curved flow and animal behaviour.

Hydrostatic pressure at 3 m depth: $\rho g h = 1,025 \times 9.81 \times 3 = 30.2$ kPa gauge. Atmospheric pressure is about 101.3 kPa absolute. Required supply must exceed 131.5 kPa absolute plus diffuser and pipe losses. Depth varies with tide.

For assumed standard air flow 0.05 m³/s, ideal isothermal compression from 101.3 to 131.5 kPa requires $p_1 Q \ln(p_2/p_1) =$ about 1.32 kW. This is an ideal lower bound with no losses. Dividing by an assumed 60% efficiency gives about 2.2 kW before extra losses, controls and auxiliaries. No equipment selection or field energy estimate follows from it.

For distributed water flow, $P = \Delta p \times Q / \eta$. At an illustrative 10 kPa, 0.1 m³/s and efficiency 0.6, P is about 1.67 kW. These assumptions do not establish adequate diversion flow. Pump-inlet protection requires separate design.

8. Cost and service basis

No procurement prices are asserted. The bill-of-materials CSV separates compressor, receiver, valves, diffuser frames, hoses, anchors, sensing, controls, power, installation and service. Quantities depend on the selected site and trials. Source dated supplier quotes after the required air-flow and pressure are measured.

For the illustrative 60 m-wide model, one 30-degree array spans $60/\cos(30 \text{ degrees}) = 69.3 \text{ m}$. Two full arrangements require 138.6 m of diffuser line before hose routes. Six sections per array imply 12 independently valved sections. This geometric example is not a recommended full-scale installation.

Inspect leaks, fouling, air uniformity, frame level and mooring movement. Compare retrieval time, vessel access, labour and replacements with the guide and distributed-flow candidates. Lower maintenance remains an intended benefit.

9. Validation gates

Gate 1: Water-channel screening. Test soft dome surrogates with stated bell size, shape and measured buoyancy. Compare no diversion, angled bubbles, porous guide and distributed flow under the same approach flow and arrival sequence. Record trajectories, intake crossing, exits, returns, contact, retained population, water flow and electrical power. Vary current, angle, density, disturbance and reversal. Repeat at least five times per initial condition as a screening plan. Increase replication after variance is known.

Proposed screening thresholds, to be agreed before testing: reduce intake entry by at least 50% against no diversion; retained population changes by no more than 5% of arrivals over the final steady observation window; demonstrate no decline beyond the site's allowed intake-flow margin. The site flow margin is unknown. These are proposed research gates, not achieved results or site limits.

Reject a configuration with persistent accumulation or an unsuitable exit. Compare the same actuator peak and report measured energy. A smaller tank can expose failure, but bubble-plume scale similarity remains a limit.

Gate 2: Supervised biological tests. Confirm species and use suitable animal-care expertise and permissions. Assess immediate and delayed injury and survival, including shear, bubbles, pressure, crowding and contact. Define welfare stopping rules before exposure. Include relevant non-target organisms. Surrogates do not prove safety.

Gate 3: Site assessment. Obtain bathymetry, depth-varying current, waves, capture-flow conditions, temperature, water quality, navigation and environmental requirements. Track return through relevant tidal phases. Assess anchors, hoses, electrical protection and service access. A discharge exit needs temperature and recirculation checks.

Gate 4: Limited monitored pilot. Agree acceptable intake flow, animal outcomes, retention, energy and service thresholds with the site team. Operate only inside the tested envelope. If no suitable diversion route exists, assess collection and relocation separately.

10. Claim register and AI use

Supported: the challenge starts after existing warning; the sponsor specifies a 30–45 cm target; published bubble deflection is conditional; the supplied model runs and produces the recorded outputs.

Proposed: reduced manual handling, serviceable sections, suitable-exit selection and current-responsive control.

Unproven: adult target-species response, safe release, injury reduction, full-scale capacity, energy demand, maintenance savings and field performance.

AI use: Codex supported literature checks, writing, model and test code, original vector diagrams, layout and video assembly. The narration uses macOS synthetic speech. No generated footage is presented as field footage. Team members must verify and explain the solution, decisions and results in their own words.

Team names were confirmed by the applicant. No individual credentials, project roles, awards or prior trials are claimed. All engineering drawings are original illustrative schematics. The supplied style guide informs typography, colors and graphical treatment. It does not imply institutional endorsement.

11. Sources checked

C01. ATRC / ENEC challenge statement. Reopened 11 October 2026.

<https://challengeon.atrc.ae/en/challenges/atp2026/pages/enec-challenge-statement?lang=en>

C02. ATRC application timeline. Reopened 11 October 2026.

<https://challengeon.atrc.ae/en/challenges/atp2026/pages/timeline?lang=en>

E01. EDF. Après l'épisode des méduses en août 2025: retour d'expérience et actions renforcées à Gravelines. Published 29 June 2026. Reopened 11 October 2026. <https://www.edf.fr/apres-lepisode-des-meduses-en-aout-2025-retour-d-experience-et-actions-renforcees-a-gravelines>

E02. Haberlin D., McAllen R., Doyle T.K. (2021). Field and flume tank experiments investigating the efficacy of a bubble curtain to keep harmful jellyfish out of finfish pens. *Aquaculture* 531, 735915.

University abstract reopened 11 October 2026.

<https://doi.org/10.1016/j.aquaculture.2020.735915>

E02 access page. <https://research.ucc.ie/en/publications/field-and-flume-tank-experiments-investigating-the-efficacy-of-a/>

The wider research leads in the original handoff are not treated as newly verified evidence here. No numerical claim depends on inaccessible papers.