VENTRAID: Ruggedized Modular Ventilatory Support with Inline Medication Mixing for Prolonged Field Care and Delayed Evacuation

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❑ BACKGROUND

- Delayed evacuation, prolonged field care, and limited respiratory resources create **major gaps** in respiratory stabilization for far-forward casualties.
- Portable ventilatory systems for **austere environments** must be reliable, lightweight, modular, and deployable.
- **Inline medication delivery** may improve field flexibility, but it must not compromise airflow performance or outlet mixing uniformity.

❑ LEARNING OBJECTIVES

- **Describe** the need for ruggedized, modular ventilatory support during prolonged field care and delayed evacuation.
- **Evaluate** inline mixing uniformity and pressure-drop tradeoffs for fieldable ventilatory subsystems.
- **Explain** how modular design enables future adaptive monitoring and control for far-forward respiratory stabilization.

❑ MATERIALS AND METHODS

- CFD was used to evaluate **AeroVent inline mixing chamber performance**.
- **Operating cases** included Baseline, Low Flow, High Flow, Medication-heavy (1:2), and Air-heavy (2:1).
- **Outlet concentration CoV and pressure drop ΔP** were used as paired performance metrics.
- **Geometry screening** guided compact, low-resistance, high-uniformity chamber refinement.

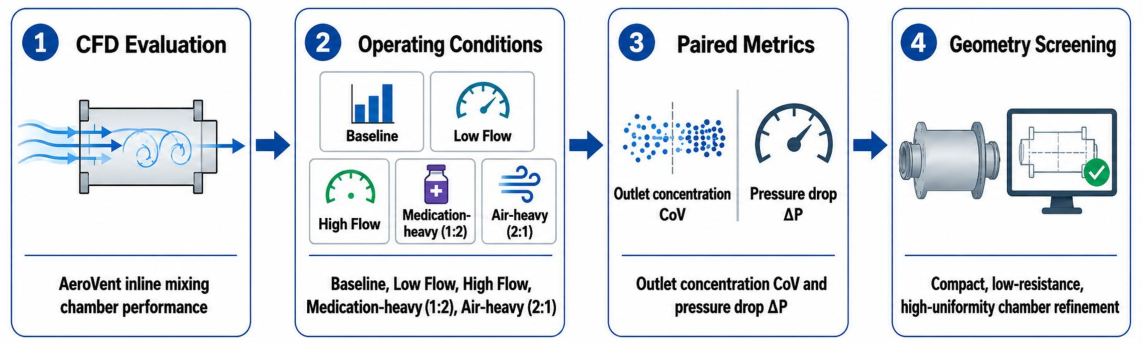

Fig. 1. AeroVent CFD evaluation workflow

❑ VENTRAID SYSTEM OVERVIEW AND RESULTS

VENTRAID (Ventilator-Embedded Neuromorphic Therapeutic Respiratory AI-Integrated Device)

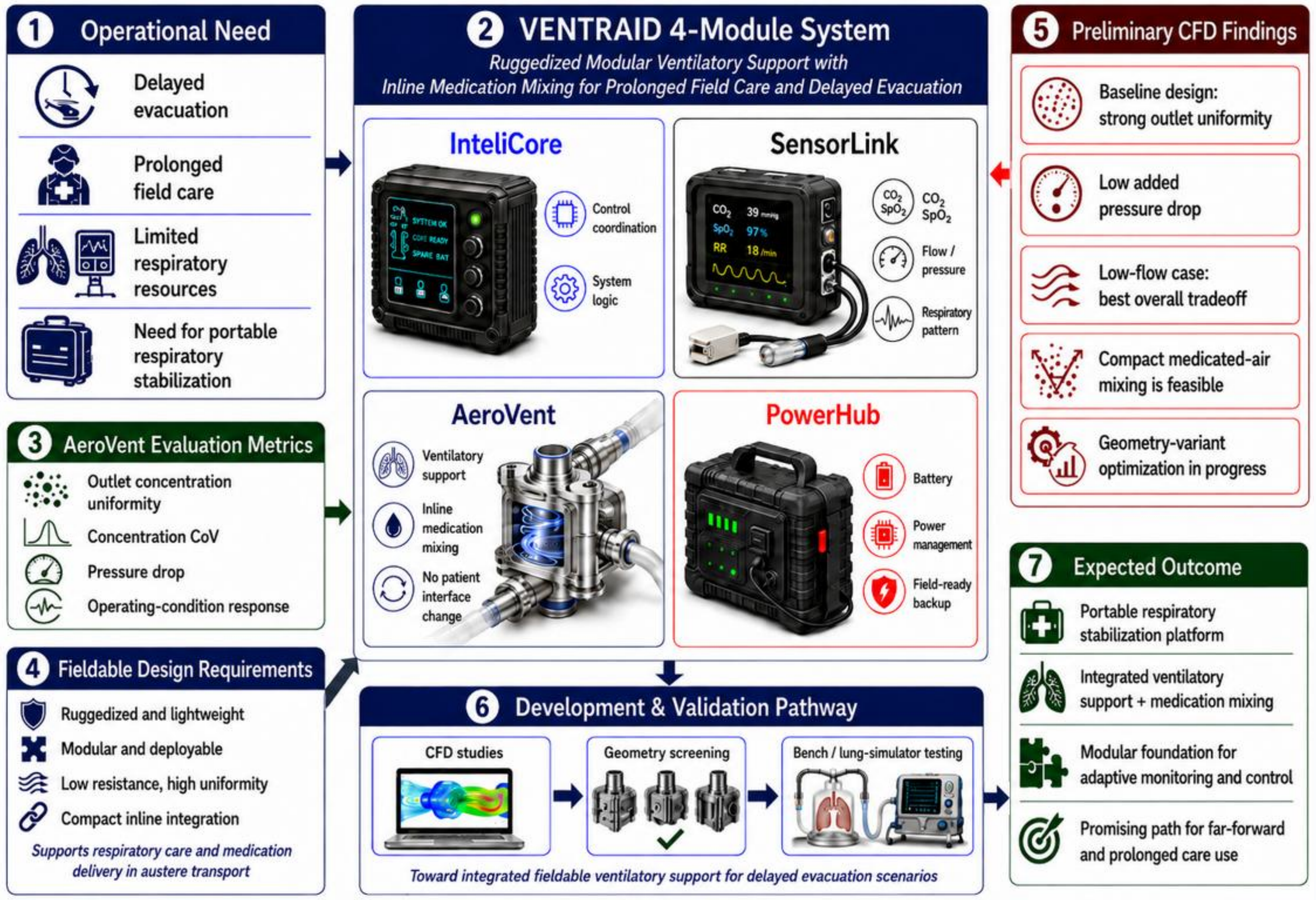

Fig. 2. VENTRAID modular architecture and CFD-guided AeroVent development pathway.

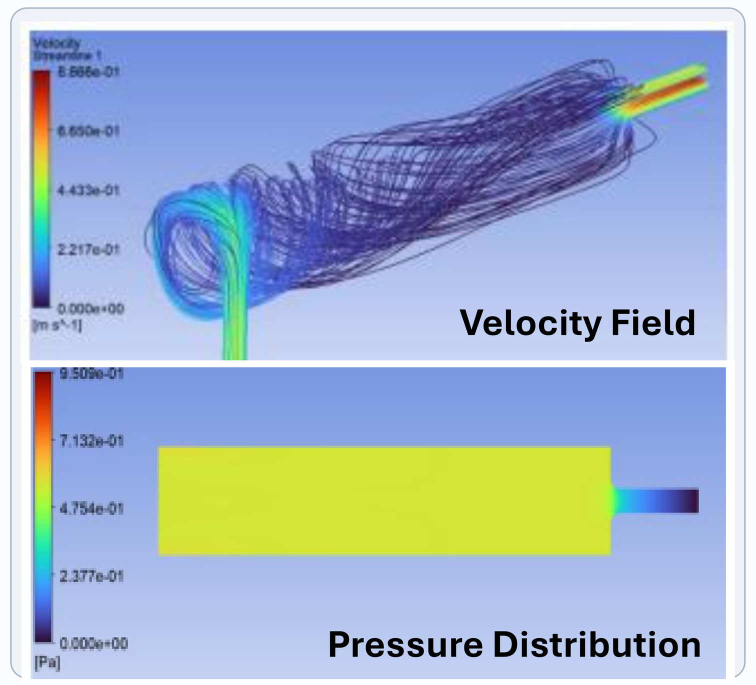

Fig. 3. Baseline CFD evaluation of AeroVent inline mixing performance.

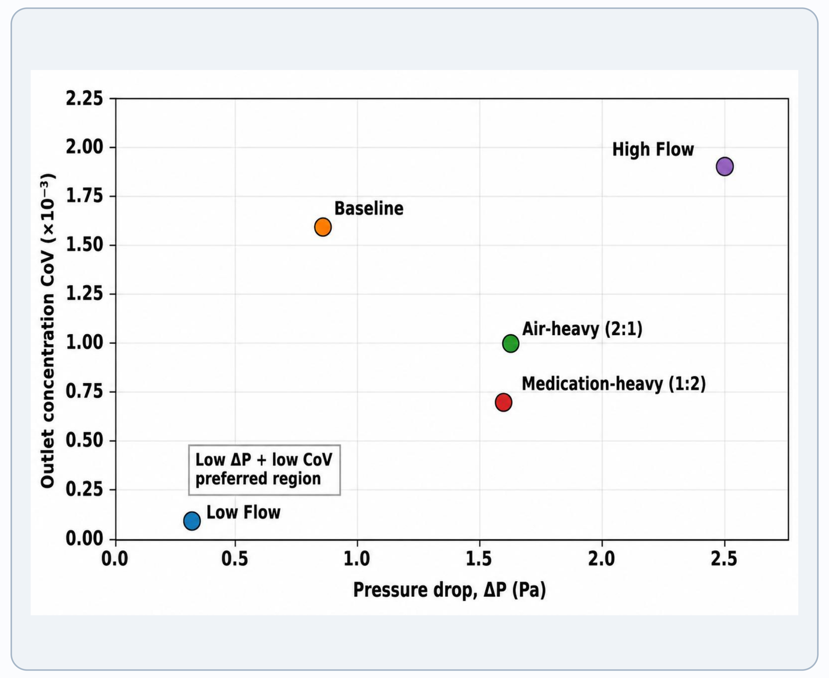

Fig. 4. AeroVent CoV–ΔP trade-off across operating conditions.

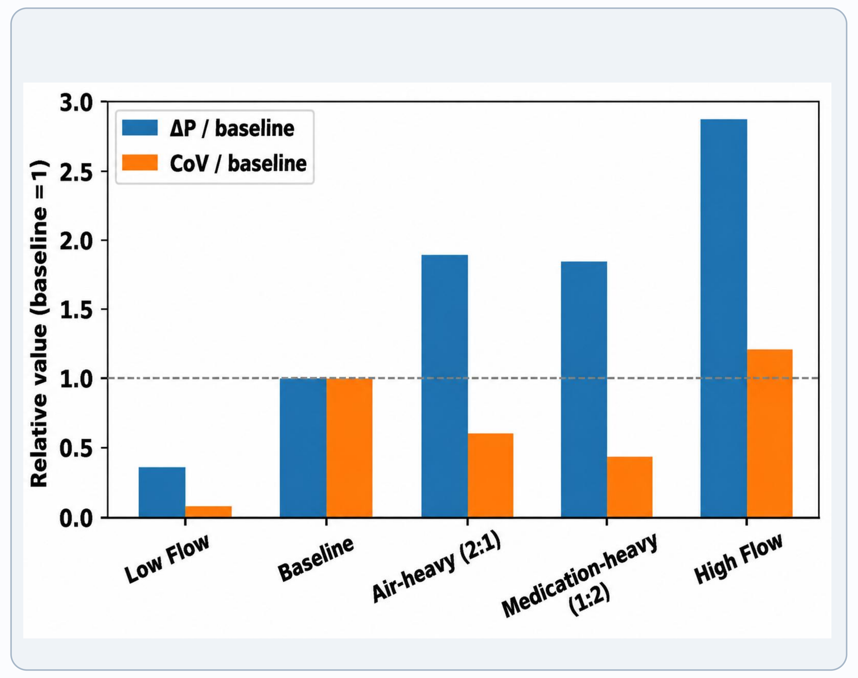

Fig. 5. Baseline-normalized CoV–ΔP performance.

- ❖ **Chamber geometry** influenced both mixing uniformity and hydraulic resistance.
- ❖ **Larger mixing volume** can improve concentration uniformity by increasing residence time.

❑ KEY FINDINGS

- **Baseline CFD** showed strong outlet uniformity with low pressure drop (**Fig. 3**).
- **Low-flow condition** provided the best CoV–ΔP balance (**Fig. 4**).
- **Medication-heavy** and **air-heavy cases** showed moderate tradeoffs (**Fig. 4**).
- **High-flow condition** was least favorable due to increased flow resistance (**Fig. 5**).
- **Geometry screening** identified compact designs that preserve mixing while reducing hydraulic penalty.
- **Preliminary FSI screening** favored Plane and Baffle concepts over Plenum due to deformation risk.

❑ IMPLICATIONS

- **Paired CoV–ΔP screening** provides a practical method for early AeroVent chamber development.
- **Outlet concentration uniformity** remained strong, while pressure drop was the more sensitive design constraint.
- **Future optimization** should preserve effective mixing while reducing flow resistance under clinically relevant high-flow conditions.

❑ NEXT STEPS / CONTACT

- VENTRAID provides a **practical foundation** for integrating respiratory support, dosing flexibility, and future adaptive monitoring/control logic.
- **Next steps**: VENTRAID supports integrated respiratory support, dosing flexibility, and future adaptive monitoring/control.

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