CTMFD System 3D Illustrations

Centrifugally Tensioned Metastable Fluid Detectors (CTMFDs) use a rapidly spinning fluid to reach a negative-pressure metastable state, enabling sensitive neutron detection while remaining indifferent to gamma radiation. The core of the device is a diamond-shaped glass bulb filled with detection fluid, affixed to a holder on a brushless motor shaft. When the motor spins the bulb, the fluid is tensioned (stretched) into a metastable state; a neutron interaction can then trigger cavitation (bubble formation), producing an acoustic and visual event. The system outlined here integrates modern instrumentation (Raspberry Pi, camera, microphone) for monitoring these events. We present two 3D illustrations of the CTMFD system's confirmed chassis design – one with *external (visible) wiring* and another with *concealed internal wiring*. Both share the same component layout and dimensions, with labels indicating key parts, distances, and orientations.

Wired Version – External Cable Routing

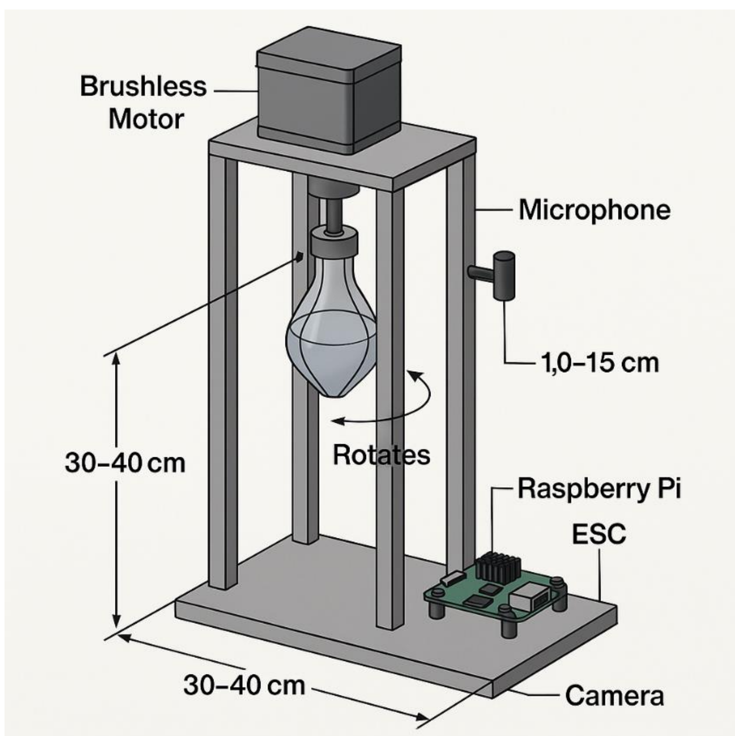

Figure 1: Suggested System

Figure 1: 3D schematic of the CTMFD system with ***externally routed wiring****. Key components are labeled, and approximate distances (camera at 30–40 cm, microphone at*

*10–15 cm) and directions are indicated. In this version, all cables between components are visible and labeled for clarity (motor-to-ESC, camera-to-Pi, mic-to-Pi, and power lines). The glass **detector bulb** (diamond-shaped) is shown suspended from the top-mounted **brushless motor**, and it **rotates** as indicated by the curved arrow.*

- **Open-Frame Chassis:** A vertical open-frame aluminum structure (approximately 30–40 cm tall and wide) supports the detector. The **brushless motor** sits on the top platform of the frame, and the **20-cc glass bulb** (the radiation detector volume) is mounted to the motor's shaft below. This open design provides line-of-sight access to the bulb for sensors and allows cables to run along the frame.
- **Raspberry Pi Zero 2 W & ESC:** At the base (or an external side panel of the frame) the **Raspberry Pi Zero 2 W** (single-board computer) is mounted alongside the **Electronic Speed Controller (ESC)** that drives the motor. In the illustration, these are placed on a plate at the bottom of the frame for easy access. The Pi controls motor speed via the ESC and also collects data from sensors (camera and microphone). Both the Pi and ESC are mounted externally (not inside a closed box) for cooling and accessibility.
- **Camera (30–40 cm from Bulb, Side-Facing):** A **camera** is positioned about 30–40 cm away from the bulb, aimed horizontally at the bulb's side. (For example, it can be affixed to a side arm or tripod extending from the frame.) This distance is labeled in the figure and ensures the camera captures the entire bulb in frame. The camera's lens faces the bulb directly to visually monitor cavitation events (bubble appearances and implosions). Its orientation is **side-on to the bulb** (perpendicular to the rotation axis) for an unobstructed view. A cable from the camera runs to the Raspberry Pi (for a Pi Camera module this could be a ribbon cable, or a USB cable for a webcam).
- **Microphone (10–15 cm from Bulb, Side-Facing):** A **microphone** is mounted on the frame, about 10–15 cm from the lower side of the bulb. It has a direct line-of-sight to the bulb's lower half, meaning nothing blocks the path between the mic and the bulb. This positioning (marked in the figure) lets it clearly capture the audible "pop" or shock wave when a neutron-induced bubble forms and collapses. The mic is oriented toward the bulb's side and connected to the Raspberry Pi (either via USB or through an analog-to-digital interface).

- **Visible Wiring:** In this wired version, all connections are routed externally and clearly labeled (as conceptually indicated in Figure 1):

    - **Motor to ESC:** Three-phase motor power cables run from the brushless motor on the top, down along the frame, to the ESC at the base. (These cables deliver power from the ESC to the motor; the ESC regulates the motor speed.) In the illustration, one can imagine these wires secured to the frame's side for support.

    - **Camera to Pi:** A ribbon or USB cable from the camera is shown going along the frame to the Raspberry Pi. This cable transmits video data and/or power to the camera. In the diagram, its path is drawn externally, making it visible.

    - **Microphone to Pi:** A thin cable from the microphone unit runs to the Raspberry Pi (carrying the audio signal or digital data). This is also routed on the outside of the frame in this version and can be seen along the frame arm where the mic is mounted.

    - **Power Supply Wiring:** A **power input** (from a DC source or battery pack) is provided to run the system. In Figure 1, a DC power jack or cable is indicated on the frame. From this **power input**, wiring splits into two leads: one going to the ESC (to provide high voltage for the motor) and another going to the Raspberry Pi (typically 5 V via a regulator or the ESC's built-in BEC). Both of these power wires are drawn externally. The result is that in this version, you can see the power cable feeding the ESC and a smaller 5 V line going into the Pi's power port.

All components are labeled in Figure 1, and their placement matches the functional needs of CTMFD. The externally routed wires make it easy to trace each connection (useful for debugging or initial prototyping), albeit at the expense of neatness. The **brushless motor and spinning bulb** at the top create the metastable fluid conditions for neutron detection, while the Raspberry Pi (with camera and microphone) monitors the bulb for any sign of a radiation event. This layout is robust and has all parts accessible, as would be desired in a research setting.

Concealed Wiring Version – Internal Cable Routing

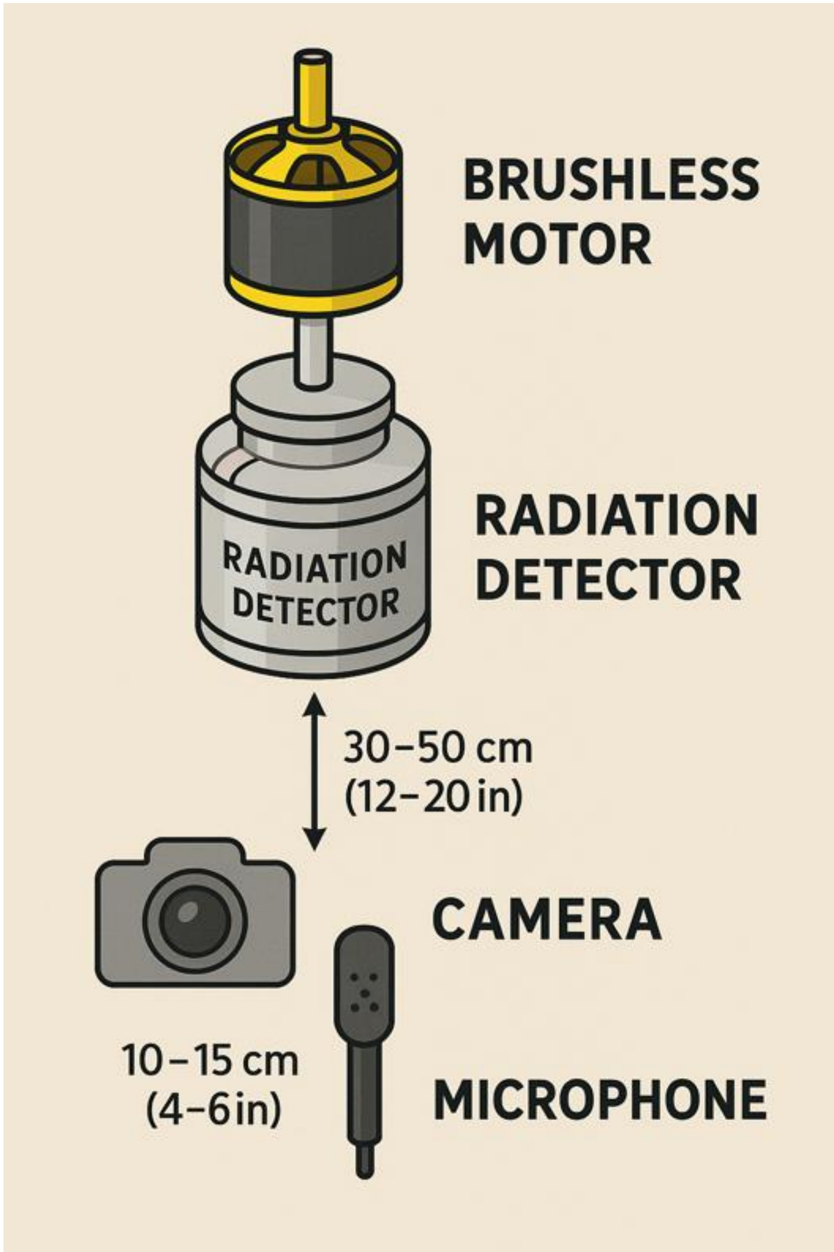

*Figure 2: 3D illustration of the CTMFD system with **concealed wiring**. The overall layout and component positions remain the same (motor and bulb on the open-frame, camera ~30–40 cm out, microphone ~10–15 cm out, Raspberry Pi and ESC on the exterior of the base). However, all cables are routed inside the frame's structural members, yielding a clean*

exterior. (In this conceptual cutaway view, the frame is partially transparent to show the internal cable paths.)

- **Same Chassis & Components:** The physical arrangement of all parts in this concealed-wiring version is identical to the wired version described above. The **motor** is on top, spinning the **glass detector bulb** below, mounted on the same open-frame chassis. The **Raspberry Pi Zero 2 W** and **ESC** are still mounted on the outside of the lower frame, in the same positions, and the **camera** and **microphone** remain at ~30–40 cm and ~10–15 cm from the bulb, respectively, facing the bulb's side. All functional distances and orientations (camera facing the bulb, mic aimed at the bulb's lower side) are unchanged. The difference lies in how the wiring is handled for a cleaner look.
- **Internal Cable Routing:** In this version, the electrical wiring is channeled *through the inside of the frame* rather than along the outside. The frame's hollow arms and platform have been used as cable conduits:
    - The **motor wires** are fed down through a hole in the top plate of the chassis. These wires run inside one of the vertical frame pillars to reach the ESC at the bottom. Essentially, the frame itself hides the motor-to-ESC cables; only a short length might be visible right at the motor and where it emerges to connect to the ESC.
    - The **camera cable** (running to the Raspberry Pi) is tucked inside either an arm of the frame or a cable channel drilled along the frame. For instance, the camera's bracket could have a port that leads the cable into the nearest frame tube, routing internally down to the base where the Pi is mounted. This means no ribbon or USB cable is seen on the outside; it's completely enclosed except for the end connectors.
    - The **microphone cable** is similarly routed through the interior. The mic is mounted on a small side arm that connects into the frame, and the cable is threaded through that arm into the interior of the vertical post, coming out near the Pi. This keeps the microphone wiring hidden as well.
    - The **power input wiring** is also concealed. If a DC power jack is used, it can be mounted flush on the frame's outer panel, with its wires immediately running inside the frame to split toward the Pi and ESC. In a battery-powered

scenario, the battery could be housed at the base with internal connections. In short, from the outside one would not see the power leads — they run inside the structure to their destinations.

- **Clean Aesthetics & Protection:** With all cables routed internally, the exterior of the CTMFD unit is clean and uncluttered. This not only looks more professional but also protects the cables from accidental snagging or damage. In Figure 2, the absence of visible wires on the frame can be noted – only the main components are seen. A partial cutaway or transparency in the illustration suggests the internal paths of cables (for example, an internal channel is shown where the microphone and camera wires travel inside the frame). The result is a tidy setup where only the sensors and devices themselves are visible externally, with the necessary connections all hidden within the chassis.

Both the wired and concealed-wiring versions share the same underlying design and functionality; the choice between them would depend on use-case. The **externally wired setup** (Figure 1) is easier to assemble or modify, useful during prototyping and testing when one might swap components or re-route connections. The **internally wired setup** (Figure 2) is suited for a finished product or deployment unit, where permanence and protection of cables are important. In either case, the CTMFD's critical geometry — a motor-driven fluid bulb on an open frame — remains consistent, as does the placement of the camera and microphone for monitoring the detector's activity. This configuration aligns with documented designs where the spinning fluid-filled bulb is attached to a motor in an open apparatus, and it leverages modern compact electronics to create a self-contained, field-capable neutron detection system.

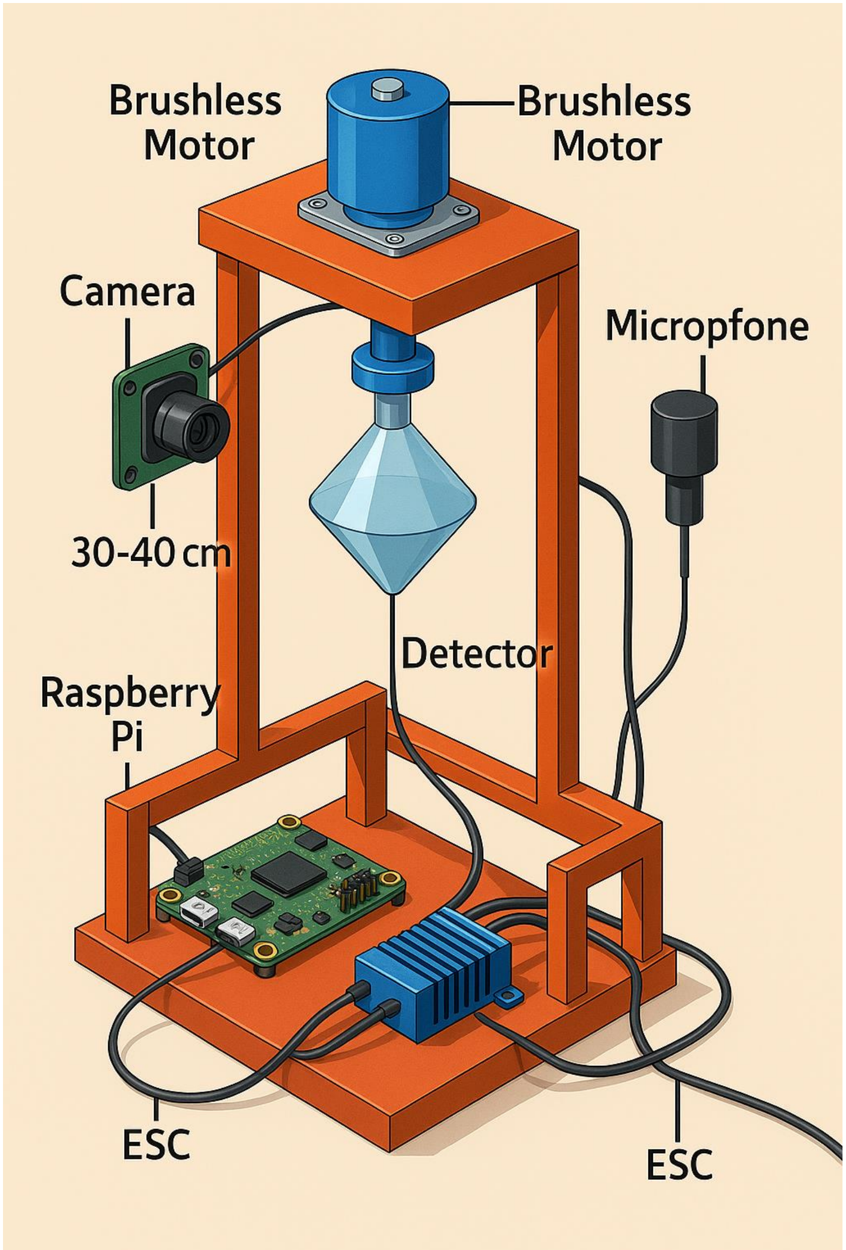

Figure 3: Final System