Project Title: A Contextually Affordable and Modular Prosthetic Hand Platform for Partial Hand Amputees in India

The Problem: The Upper Limb Neglect Paradox

Upper limb amputation presents a profound public health challenge in India, particularly among young, rural males from low-income backgrounds whose livelihoods depend on strenuous manual labor. Existing prosthetic solutions suffer from a critical mismatch with the user's context: high-end myoelectric devices (costing 90000 Rupees to over 42 lakh Rupees) are prohibitively expensive, delicate, and unsuitable for the dusty, rugged environments of agricultural and industrial work. Conversely, conventional low-cost or body-powered options are often non-functional, uncomfortable, or lack durability. The systemic failure lies not just in the initial cost, but in the total cost of ownership, as 62% of existing devices eventually require repairs, which are often inaccessible or too expensive. This situation creates a cycle of economic devastation and psychological trauma for amputees, demanding a solution rooted in radical affordability and real-world robustness.

The Solution: A Modular, Tiered Prosthetic Architecture

We propose the development of an **Affordable and Functional Upper Limb Terminal Device** built on a **Modular, Tiered Architectural Platform**. This design decouples the mechanical hand from the control interface, creating an accessible ecosystem with an estimated component cost for the entry-level model of under **5000 Rupees** (less than 60 US Dollars). Our solution strategically combines the robustness of mechanical systems with the efficiency of low-cost, decentralized manufacturing and smart electronics. The core innovation is the **Three-Tiered Control Strategy**, allowing the same durable mechanical hand to be controlled by three distinct, progressively advanced interfaces, catering to diverse physiological needs, technical expertise, and financial capacities of the user population.

The Three Control Tiers:

a. **Tier 1 (Ultra-Low-Cost): Push-Button Control:** This entry point utilizes one or more simple push-buttons or toggle switches integrated into the prosthetic socket. The switch provides a basic binary (on/off) signal to the microcontroller, triggering a pre-programmed open or close sequence for the hand. This approach minimizes both cost and complexity, making a functional, motorized device available to the largest number of users, especially those who cannot generate usable myoelectric signals.

b. **Tier 2 (Intermediate): Body-Actuated Switch Control:** This system employs a simplified, single-cable harness connected to a small electronic switch inside the forearm shell. A gross body movement (such as a shoulder shrug) pulls the cable just enough to activate the switch. Activating the switch sends a signal to the microcontroller to power the servo motor, closing the hand. This hybrid retains the intuitive physical feedback of a harness while replacing the physically demanding task of generating grip force with an effortless, motor-powered grasp.

c. **Tier 3 (Advanced): Low-Cost Myoelectric (EMG) Control:** This tier integrates low-cost, commercially available EMG sensors (for example, MyoWare). The microcontroller reads the EMG signal's amplitude. **On-Off Control:** If the amplitude crosses a pre-set threshold, it activates the motor to close the hand. **Proportional Control:** The speed or force of the motor can be made proportional to the intensity of the muscle contraction. By using affordable, open-source-friendly sensors and microcontrollers, this provides intuitive myoelectric control accessible at a fraction of the cost of commercial systems.

Technical Blueprint and Innovation

The mechanical integrity is ensured through **Fused Deposition Modelling (FDM) Three Dimensional Printing** using a hybrid material approach: rigid, low-cost **PLA** for structural components, and flexible, high-friction **TPU** for integrated springs and gripping surfaces, enhancing durability and feel. The actuation system leverages ubiquitous, low-cost DC servo motors (for example, TowerPro MG995) coupled with a high-ratio **Worm Gearbox** integrated into the palm. This gearbox is essential for torque amplification, allowing us to achieve a functional pinching force (target eight Newton-meters) while critically enabling a **self-locking** feature to maintain grip without continuous battery drain—a vital feature for all-day use in energy-insecure environments. The hand employs an **underactuated tendon-driven system**, allowing the fingers to passively conform and securely grasp irregularly shaped objects with a single motor, minimizing complexity and weight.

Design for Maintainability (DfM) and Sustainability

Crucially, the design is underpinned by **Design for Maintainability (DfM)** principles to address the systemic failure of post-sale support. The device is fully **modular**, with individual finger assemblies, the actuation block, and the control module designed as easily replaceable units (analogous to Orbital Replacement Units - ORUs). All internal components are **standardized, Commercial-Off-The-Shelf (COTS)** parts, ensuring local sourcing and low-cost repair by local technicians using simple tools. By using India-specific anthropometric data for parametric scaling, we guarantee superior ergonomic fit, directly reducing a major cause of prosthetic rejection. The entire project is committed to an **Open-Source Development Model**, fostering community collaboration and enabling local entrepreneurs and Non-Governmental Organizations to adopt, fabricate, and support the device independently. This shifts the definition of affordability from the initial purchase price to the long-term, sustainable total cost of ownership.