The Parametric Commons: Architecting Common Denominator Geometry for the Era of Bounded 4D Hyperobjects

1. Introduction: The Emergence of the Bounded 4D Hyperobject

The industrial paradigm is undergoing a phase transition, moving from centralized, subtractive mass production toward decentralized, additive manufacturing (AM). In this new era, the fundamental unit of trade and utility is no longer the physical object, nor is it the static digital file (the STL mesh). Instead, we are witnessing the rise of the **Bounded 4D Hyperobject**. To understand the necessities of a modern "commons," one must first understand this ontological shift. A "hyperobject," in this context, is not merely a 3D geometry; it is a computational definition of a family of objects that exist within a multidimensional parameter space.[4] The "fourth dimension" here is not temporal execution, but the *potentiality* of the design space itself—the bounded set of all possible permutations allowed by the geometric code (e.g., OpenSCAD script) before it is collapsed into a specific physical instance.[6]

This report serves as an exhaustive analysis of the most sought-after hyperobjects across household, industrial, commercial, and hybrid sectors. It argues that for the additive manufacturing ecosystem to mature from a hobbyist curiosity into a resilient global infrastructure, we must define and standardize the **Common Denominator Geometry (CDG)** of these hyperobjects. Originating in aerospace engineering to solve complex lofting problems for aircraft wings [8], CDG provides the mathematical "truth" that ensures interoperability between disparate systems. In the context of the open commons, CDG represents the standardized interfaces—the rails, grids, threads, and sockets—that allow a globally distributed community to build compatible infrastructure without centralized coordination.[10]

The societal benefit of defining these objects in an open "commons" data pool is profound. It enables a circular economy where waste plastic is recycled into useful infrastructure [11]; it empowers a "right to repair" culture that extends the lifespan of consumer goods [12]; and it provides disaster resilience by allowing communities to manufacture essential medical and shelter infrastructure independent of fragile global supply chains.[13] This report identifies the specific hyperobjects that constitute the highest-value targets for this open standardization.

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2. Theoretical Framework: Common Denominator

Geometry (CDG)

2.1 Origins in Aerospace and Translation to Additive Manufacturing

The concept of Common Denominator Geometry was originally formalized in the domain of computational fluid dynamics (CFD) and aircraft design by researchers such as Rizzi and Oppelstrup.[8] In high-fidelity aircraft design, engineers faced a persistent problem: the geometric data required for aerodynamic analysis (CFD), structural analysis (FEM), and manufacturing (CAD) were often incompatible. The "lofting" of a wing—defining the complex curves of the airfoil—required a single, mathematically rigorous definition that could serve as the "common denominator" for all downstream applications.[15]

In the context of the Additive Manufacturing Commons, we face an identical problem. A 3D model of a bracket might be designed in Blender (a mesh-based artistic tool) or SolidWorks (a parametric engineering tool). When shared as a static STL file, the "intelligence" of the design is lost. The recipient cannot easily adjust the screw hole diameter to match a local metric bolt, nor can they thicken the wall to account for a weaker recycled material. The object has lost its CDG; it is merely a "dumb" shell.

To manifest high-utility hyperobjects, we must translate the aerospace concept of CDG into the realm of distributed manufacturing. Here, CDG refers to the **invariant geometric interfaces** and **parametric logic** that define the object's function. For a modular drawer system, the CDG is not the drawer itself, but the specific profile of the interlocking lip and the grid spacing.[17] For a prosthetic arm, the CDG is the bolt pattern of the wrist connection.[18] By standardizing these denominators in an open data pool, we create a platform for innovation where the "edges" of the design are fixed standards, but the "center" involves infinite creative variation.

2.2 The Bounded 4D Hyperobject Defined

A Bounded 4D Hyperobject is distinct from a traditional CAD file in three critical ways:

1. **Parametricity (The 4th Dimension):** The object is defined by variables (dimensions, material properties, functional requirements) rather than fixed coordinates. The "object" is the script, which contains infinite potential physical manifestations.[19]
2. **Bounded Constraints:** The code enforces logical limits. A hyperobject for a "Load-Bearing Bracket" might allow the user to change the length, but the code effectively "bounds" the design by preventing the wall thickness from dropping below a structurally safe threshold for the selected material.[20]
3. **Manifestation Awareness:** The hyperobject is "aware" of the manufacturing process. It includes logic to adjust tolerances based on the specific printer's accuracy or the material's shrinkage (e.g., scaling up 2% for ABS).[21]

Table 1: Evolution of Digital Artifacts in Manufacturing

Artifact Type	Definition	Modifiability	Interoperability	Commons Utility
Static Mesh (STL)	Fixed set of triangles defining a surface.	Low (requires mesh editing).	Low (brittle interfaces).	**Low**: Good for replication, poor for adaptation.
Parametric CAD (STEP)	Solid model history tree.	Medium (requires specific CAD software).	Medium (standard formats exist).	**Medium**: Editable, but often locked in proprietary tools.
4D Hyperobject (SCAD)	Script-based geometric definition.[4]	High (text-based, universal).	High (math-driven interfaces).	**High**: The foundation of a resilient commons.

2.3 The Infrastructure of the Commons: Geometry as Data

The realization of this theoretical framework requires a specific technological substrate. The open-source tool **OpenSCAD** has emerged as the *lingua franca* of the AM commons because it treats geometry as code.[23] Recent developments, specifically the **OpenSCAD Enhancement Proposal 8 (OEP8)**, promote the concept of "Geometry as Data".[4]

Under OEP8, geometry is not just a visual output; it is a variable that can be passed into functions, measured, and manipulated. This allows for "Introspective Design"—a script can take an imported geometry (e.g., a 3D scan of a patient's limb) and mathematically analyze its bounding box or surface curvature to generate a perfectly fitted interface.[4] This capability is the bedrock of the "Hybrid" hyperobjects discussed in this report, particularly in the medical field where standard components must interface with organic, variable human anatomy.[25]

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3. The Domestic Commons: Organizing and Sustaining the Living Space

The household is the primary deployment zone for distributed manufacturing. While often dismissed as the domain of "trinkets," the domestic sphere is actually a complex logistical environment requiring sophisticated organization, maintenance, and infrastructure. The most sought-after hyperobjects in this sector are those that reduce cognitive load (organization) and increase self-sufficiency (repair and sustenance).

3.1 The Gridfinity Hyperobject: A Case Study in Bottom-Up Standardization

The single most impactful household hyperobject to emerge in recent years is the **Gridfinity** system. It serves as the quintessential example of a "Common Denominator Geometry" applied to domestic organization.[17] Developed initially by Zack Freedman and released into the commons, it has evolved into a massive ecosystem of interoperable parts.

3.1.1 The Geometric Standard

The Gridfinity hyperobject is defined by a rigorous set of geometric constraints that ensure modularity:

- **The 42mm Module:** The fundamental unit of the grid is a 42mm x 42mm square. This dimension was likely chosen as a compromise between holding substantial items (like hardware fasteners or batteries) and fitting efficiently onto the print beds of standard hobbyist machines (a 235mm Ender 3 bed accommodates a 5x5 grid perfectly).[27]
- **The Vertical Unit (7mm):** Vertical modularity is established through a 7mm unit height. This allows bins of different heights to align perfectly when stacked, facilitating the creation of complex, multi-level storage drawers. A "3-unit" bin stacked on a "3-unit" bin equals a "6-unit" bin, minimizing wasted vertical space.[17]
- **The Interface Profile:** The most critical CDG feature is the mating profile between the bin and the baseplate. It utilizes a specific chamfered lip and a weighted base design. This geometry is "bounded" to allow for significant printer tolerance (slop). Unlike a tight friction fit, the tapered profile allows gravity to center the bin, making the system robust against the variable calibration of consumer printers.[28]

3.1.2 Societal Utility and the Commons Data Pool

The societal benefit of defining Gridfinity in the open commons lies in the reduction of waste and the promotion of a "culture of repair." Traditional storage solutions are monolithic; if a plastic organizer tray cracks or doesn't fit a new tool, the entire unit is discarded. With Gridfinity, the storage infrastructure is fluid. Users print only what they need.

The "Commons Data Pool" for Gridfinity has transitioned from a repository of static files to a library of parametric generators. Online tools and OpenSCAD scripts now allow users to specify arbitrary grid dimensions (e.g., "3x2"), features (e.g., "SD card slots"), and label styles, instantly generating the required hyperobject.[17] This shifts the value from the *object* to the *interface*—as long as the 42mm base profile is preserved, the function of the bin is infinite.

3.2 The Parametric Connector: Decentralized Infrastructure

If Gridfinity organizes the contents of the home, the **Parametric Connector** organizes the structure of the home itself. This hyperobject is critical for disaster relief, gardening, and temporary structures.[30]

3.2.1 The "PVC/Bamboo" Hyperobject

Standard building materials (lumber, steel beams) are heavy and difficult to transport. However, cylindrical commodities—PVC pipe, bamboo, and wooden dowels—are ubiquitous globally. The challenge is that their dimensions vary significantly by region and source. A 3/4-inch pipe in the US is not compatible with a 20mm conduit in Europe, and bamboo varies naturally along its length.[31]

The Parametric Connector hyperobject solves this by treating the **connection node** as the variable geometry.

- **Input Parameters:** The script accepts the *exact* measured diameter of the local material (e.g., "21.5mm bamboo culm").
- **Topology:** The user defines the connectivity (3-way corner, 4-way cross, variable angle for geodesic domes).
- **Structural Optimization:** The code generates the optimal wall thickness and internal ribs based on the intended load (e.g., "Heavy Load" for a shelter vs. "Light Load" for a trellis).[32]

3.2.2 Disaster Relief and Shelter

In humanitarian crises, the ability to manufacture infrastructure on-site is transformative. Organizations like "Field Ready" have demonstrated the efficacy of printing critical connectors in disaster zones.[33] By defining these connectors as open hyperobjects, relief workers can utilize local debris or scavenged materials to build emergency shelters. The snippet [52] highlights the use of mobile 3D printers to create temporary shelters in crisis zones. The CDG here allows for a "hybrid" construction model: the high-complexity nodes are printed (digital), while the high-volume struts are scavenged (analog). This leverages the best of both worlds—the precision of AM and the availability of local biomass or waste.

3.3 Water Sovereignty: The Open Filtration Ecosystem

Access to clean water is perhaps the most critical "household" need. The **Faircap** project and similar initiatives represent a vital class of hyperobjects: open-source water filtration hardware.[34]

3.3.1 The Filtration Interface Standard

The CDG for water filtration is defined by two interfaces:

1. **The Input Interface:** The standard thread of global waste containers. The most common is the **PCO 1881** thread found on PET soda bottles. By standardizing this geometry, the hyperobject allows any discarded soda bottle to become part of a sanitation system.[34]
2. **The Output/Filter Interface:** The housing dimensions for the filtration medium (e.g., hollow fiber membranes, activated charcoal discs, or ceramic disks).

3.3.2 Parametric Optimization and Circular Economy

Research cited in snippet [11] and [11] demonstrates that 3D printed pipe fittings and filter housings can be manufactured for a fraction of the commercial cost (3 to 17 times cheaper). Furthermore, these components can be printed from recycled PET (rPET) derived from the very bottles they connect to, closing the loop on plastic waste. The "Parametric Pipe Fitting" hyperobject described in [11] utilizes OpenSCAD to generate couplings that can withstand hydrostatic pressures up to 4.5 MPa (using PETG), far exceeding residential requirements. Defining these geometries in the open commons effectively grants communities "Water Sovereignty"—the ability to maintain and expand their own water infrastructure without reliance on imported, proprietary hardware.[14]

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4. The Industrial Commons: Re-shoring and Bridge Manufacturing

The industrial application of additive manufacturing is shifting from prototyping to "bridge manufacturing"—the production of functional end-use parts that "bridge" the gap between prototyping and mass production. In this sector, the most sought-after hyperobjects are those that interface with existing global industrial standards.

4.1 The Linear Hyperobject: DIN Rails (TS35/TS15)

The **DIN Rail** (Deutsches Institut für Normung) is the spinal cord of industrial automation. It mounts circuit breakers, relays, Power Supply Units (PSUs), and Programmable Logic Controllers (PLCs). It is a perfect candidate for a hyperobject because its utility is entirely derived from its geometric compliance.[35]

4.1.1 The CDG of Control Infrastructure

- **TS35 Standard:** The 35mm wide "top hat" rail is the global standard.[36] The CDG is defined by the 35mm width and the 7.5mm or 15mm depth.
- **TS15 Standard:** A 15mm wide miniature rail used for smaller terminal blocks.[36]

4.1.2 The Parametric Clip Challenge

Designing a 3D printable DIN clip is a non-trivial engineering challenge due to the material properties of FDM polymers. Unlike injection-molded Nylon or stamped steel, printed PLA and

PETG are susceptible to **creep** (deformation under constant load) and **fatigue**. A static STL of a DIN clip often fails after a few months of tension. The **Parametric DIN Clip Hyperobject** solves this through algorithmic design.[37]

- **Compliant Mechanisms:** Instead of relying on the material's inherent flex, the hyperobject utilizes geometric springs—folded, wavy structures that distribute stress over a longer path length.
- **Variable Tension:** The user inputs the expected load (weight of the device) and the material (e.g., "PETG"), and the script calculates the necessary thickness of the spring element to maintain grip without inducing plastic deformation.[29]
- **Hybridization:** The integration of "Gridfinity" bins onto DIN rails [37] represents a powerful crossover, bringing the modularity of the maker's desk into the industrial control cabinet.

4.2 The Structural Frame: 80/20 Aluminum Extrusion

T-slot aluminum framing (often referred to by the brand name "80/20") is the "industrial LEGO" used to build machine frames, workstations, and assembly lines.[38] The profile itself is a global CDG.

4.2.1 Profile Families and Standardization

- **Metric Series:** 2020 (20mm x 20mm), 3030, 4040.
- **Imperial Series:** 1010 (1 inch), 1515.
- **Geometry:** The critical CDG dimensions are the slot width (usually 6mm, 8mm, or 10mm), the slot depth, and the core bore diameter.[39]

4.2.2 The Accessory Hyperobject Ecosystem

The open commons is currently revolutionizing the ecosystem of T-slot accessories. Commercial T-nuts, hinges, and brackets are expensive and subject to shipping delays. Parametric hyperobjects allow for the on-demand production of these components.[40]

- **Cable Management:** Twist-in clips that lock into the slot to manage pneumatic lines and sensor wires.[41]
- **Sensor Mounts:** Parametric brackets that interface a specific sensor (e.g., an inductive proximity switch) to a specific rail (e.g., 2020). The script ensures the sensor is held at the correct distance from the target.
- **Linear Motion:** V-slot variants allow 3D printed wheels to roll *inside* the slot, converting the structural frame into a linear motion guide for robotics.[38]

4.3 Manufacturing Aids: Jigs, Fixtures, and Soft Jaws

Perhaps the most immediate "high value" application of industrial AM is the production of manufacturing aids—tools that help make other products.

4.3.1 The Soft Jaw Hyperobject

In CNC machining, holding a complex, organic part in a rigid steel vise is difficult. **Soft jaws** are custom inserts machined or printed to match the negative geometry of the part.[21]

- **The Boolean Operation:** The hyperobject is defined by a Boolean subtraction: Jaw_Geometry = Base_Jaw - Target_Part.
- **CDG:** The "Base Jaw" geometry is standardized to fit common industrial vises (e.g., Kurt, roughly 6 inches wide with specific bolt spacing).[21]
- **Impact:** [53] and [54] highlight that 3D printed jigs reduce lead times from weeks to hours. By defining standard vise geometries in the commons, any machine shop can download the "Master Jaw Script," import their part file, and print a fixture that perfectly cradles their component, protecting surface finish and ensuring precise alignment.

4.3.2 Drill Guides and Go/No-Go Gauges

Parametric scripts can also generate drill guides (bushings) and inspection gauges. [53] notes that for drill guides, the script must account for the *tolerance* of the press-fit bushing. A 5mm steel bushing requires a 5.1mm printed hole (depending on printer calibration). The hyperobject encapsulates this "manufacturing knowledge" into the code, asking the user "What is your printer's hole shrinkage?" and adjusting the geometry accordingly.

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5. The Commercial & Medical Commons: Hybrid Hyperobjects and Equity

This sector encompasses high-value, high-complexity objects where the commons model addresses issues of equity, accessibility, and the "Right to Repair."

5.1 The Prosthetic Commons: Solving the Interface Crisis

Open-source prosthetics, pioneered by groups like **e-NABLE**, have democratized access to assistive devices. However, the ecosystem suffers from fragmentation. A "hand" designed by one group often cannot connect to a "socket" designed by another.

5.1.1 The Socket Hyperobject: Parametric Anatomy

The socket—the interface between the device and the user's residual limb—is the most critical and difficult component. It must be custom-fitted.

- **The CDG Solution:** The hyperobject here is a script that generates a socket based on input measurements or a 3D scan.[25]
- **Material Science:** [22] emphasizes that geometry alone is insufficient. The data pool must specify material parameters. Sockets require flexible, biocompatible materials like **TPE** (Thermoplastic Elastomer) or **TPU**. The script should generate "breathable" geometries

(e.g., Voronoi patterns) to manage thermal comfort, with density varying based on structural load maps.
- **Printing Parameters:** The hyperobject must include metadata for printing TPE (e.g., slow print speeds, 235°C extrusion), as these materials are notoriously difficult to print.[22]

5.1.2 The Distal Interface Standard

To enable modularity, the commons must define a **CDG for the Wrist and Ankle**.

- **e-NABLE Standards:** The "Phoenix" hand utilizes a specific tensioner pin system (whippletree).[19] Standardizing this cabling geometry allows users to swap terminal devices (e.g., a gripper vs. a violin bow holder) without refitting the entire arm.[43]
- **Open Source Leg (OSL):** This project focuses on the lower limb, utilizing a high-torque motor interface. The CDG here is the bolt pattern and spline geometry connecting the knee actuator to the pylon.[18] By publishing this interface under open licenses (LGPL), OSL enables third parties to develop specialized foot attachments (e.g., for running or hiking) that are compatible with the core robotic unit.

5.2 The Diagnostic Hyperobject: Glia and Medical Independence

The **Glia** project represents the pinnacle of "medical independence"—the ability for a hospital to manufacture its own diagnostic tools.

5.2.1 The Stethoscope and Otoscope

- **Cost Disparity:** A commercial otoscope costs hundreds of dollars; a Glia otoscope costs roughly $5 to produce.[44]
- **CDG:** The critical geometries are the **speculum interface** (the disposable cone that enters the ear) and the **diaphragm housing** (for the stethoscope). These must match standard medical consumables.
- **The Software Shift:** [44] notes that Glia is transitioning from TinkerCAD (non-parametric) to OpenSCAD/FreeCAD. This is a crucial evolution. An OpenSCAD stethoscope script allows a user to adjust the spring tension of the headset (by changing the printing curve radius) to fit different head sizes, or to modify the tubing barbs to fit locally available silicone hose diameters. This adaptability is the core value of the hyperobject.

5.3 The "Right to Repair" Commons: A Library of Kinematics

Society generates millions of tons of e-waste annually, often due to the failure of a single small plastic gear or clip. Manufacturers rarely sell these individual components. A **Parametric Spare Parts Library** is a highly sought-after commercial hyperobject.[12]

5.3.1 The Universal Gear and Knob

Instead of 3D scanning every broken gear in existence, the commons needs a library of

Kinematic Hyperobjects.

- **Gears:** An involute gear generator (defined by module, pressure angle, tooth count) allows a user to replicate *any* spur gear.[6]
- **Knobs and Levers:** A script that generates a knob with a D-shaft interface. The user measures the metal shaft of their broken washing machine, inputs the diameter, and the script generates a replacement knob.[26]
- **Material Implications:** [55] and [12] discuss the legal and safety implications. The commons must include data on material substitution—e.g., advising that a replacement gear for a food mixer must be printed in Nylon or PETG, not PLA, due to heat and fatigue requirements.

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6. Digital Infrastructure: Implementing the Commons

Defining these objects is futile without a digital infrastructure capable of managing them. We must move beyond the "File Repository" (Thingiverse) to the "Computational Engine."

6.1 OpenSCAD and OEP8: The Engine of the Commons

OpenSCAD is the de facto language of the AM commons because it is text-based, lightweight, and version-controllable (Git-friendly). The recent **OpenSCAD Enhancement Proposal 8 (OEP8)** represents a watershed moment for the "Hyperobject" concept.[4]

6.1.1 Geometry as Data

Prior to OEP8, OpenSCAD could only "draw" shapes. It could not "know" anything about them. OEP8 introduces the ability to treat geometry as a data type.

- **Introspective Design:** A script can now import an STL file (e.g., a scan of a broken part), measure its bounding box, find its center of mass, and then generate a new geometry relative to those features.
- **Example - The Universal Case:** A "Case Generator" hyperobject can take *any* 3D object as an input variable. It calculates the object's extents, adds a specified clearance, generates walls, and places reinforcing ribs automatically. This transforms the design process from manual drawing to automated logic.[4]
- **Object-Oriented Logic:** OEP8 introduces dictionaries/structs (object()), allowing for complex data structures to pass parameters (e.g., a material object containing properties like shrinkage_factor and print_temp).[4]

6.2 BOSL2: The Standard Library

The **Belfry OpenSCAD Library v2 (BOSL2)** is effectively the "Standard Library" of the AM commons.[46] It solves the CDG problem at the code level.

- **Attachments:** BOSL2 standardizes how objects connect. Instead of translating a cylinder to [1, 2, 3], a user attaches it to the TOP anchor of a cube. This semantic geometry ensures that if the cube changes size, the cylinder stays attached to the top face automatically.[47]
- **Standard Parts:** The library includes pre-defined hyperobjects for screws, nuts, bearings, and linear rails, ensuring that all designers using the library are pulling from the same geometric truth.[46]

6.3 Metadata and Licensing

For the commons to be functional, hyperobjects must be searchable and legally clear.

- **Licensing:** The **CERN Open Hardware License (CERN OHL)** is the gold standard for physical objects, covering both the design documentation and the physical realization.[48] Creative Commons (CC-BY-SA) is widely used for the "artistic" side (Gridfinity).[49]
- **Metadata:** The "Data Pool" must index objects not just by name ("Cup Holder") but by geometric compatibility ("Gridfinity Compatible," "2020 Rail Compatible").

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7. Strategic Recommendations and Conclusion

To maximize the societal ROI of the Open Commons Data Pool, development should focus on the following high-leverage areas:

7.1 Priority 1: The "Universal Interface" Strategy

The community should stop focusing on designing "products" and start focusing on "interfaces."

- **Standardize the Connection:** Defining the **Gridfinity Base**, the **DIN Clip**, the **VESA Plate**, and the **Bottle Thread** as immutable, high-quality hyperobjects is more valuable than designing 1,000 different cup holders. Once the interface is perfect, the community will build the rest.

7.2 Priority 2: Resilience Through Hybridization

Develop hyperobjects that bridge the gap between "scavenged" and "manufactured."

- **Disaster Relief:** The **Parametric Pipe Connector** is the ultimate hybrid object. It turns trash (rubble/pipes) into infrastructure.
- **Medical:** The **Parametric Socket** turns a biological variable (the limb) into a standard mechanical interface.

7.3 Priority 3: Material-Aware Code

The commons must integrate materials science into the code.

- **Recycling Loop:** Generators should include "Recycled Material" toggles that automatically adjust tolerances and wall thicknesses to account for the inferior mechanical properties of rPET or recycled PLA.[11] This is essential for a true Circular Economy.

Conclusion

The "most sought after" hyperobjects are not specific gadgets; they are the **connectors, adapters, and organizers** that allow the physical world to be reconfigured. By defining these objects through **Common Denominator Geometry**—the rigorous mathematics of fit and function—and encoding them in **Bounded 4D Hyperobjects** (OpenSCAD/OEP8), we create a resilient, distributed manufacturing capacity.

This "Commons Data Pool" is not merely a library of files; it is a distributed industrial infrastructure. It allows a hospital in Gaza to print a stethoscope [50], a farmer in Idaho to print a tractor repair gear [51], and a disaster relief team in Nepal to print shelter connectors.[33] The transition from the static .stl to the dynamic .scad is the mechanism by which we secure a sustainable, self-sufficient physical future.

Table 2: Summary of Key Hyperobjects and CDG Definitions

Domain	Hyperobject	CDG (Common Denominator)	Societal Benefit
Household	**Gridfinity**	42mm Module, 7mm Z-Unit, Lip Profile	Org. efficiency, waste reduction, modularity.
Household	**Parametric Connector**	Pipe ID/OD, Connectivity Topology	Disaster shelter, local material use, agriculture.
Household	**Faircap Filter**	PCO 1881 Thread, Membrane Housing	Water sovereignty, plastic upcycling.
Industrial	**DIN Rail Clip**	TS35 Rail Profile, Spring Geometry	Democratized automation, repair of industrial controls.
Industrial	**Soft Jaw / Jig**	Vise Bolt Pattern,	Supply chain

		Negative Volume	speed, bridge manufacturing.
Medical	**Prosthetic Socket**	Limb Scan Data, Voronoi Density	Custom fit, accessible healthcare.
Medical	**Glia Diagnostic**	Speculum Geometry, Diaphragm Housing	Medical independence, cost reduction (99%).
Commercial	**Kinematic Spare**	Gear Module, Shaft D-Profile	Right to Repair, circular economy, e-waste reduction.

(Citations referenced inline via `` format based on provided research snippets.)

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