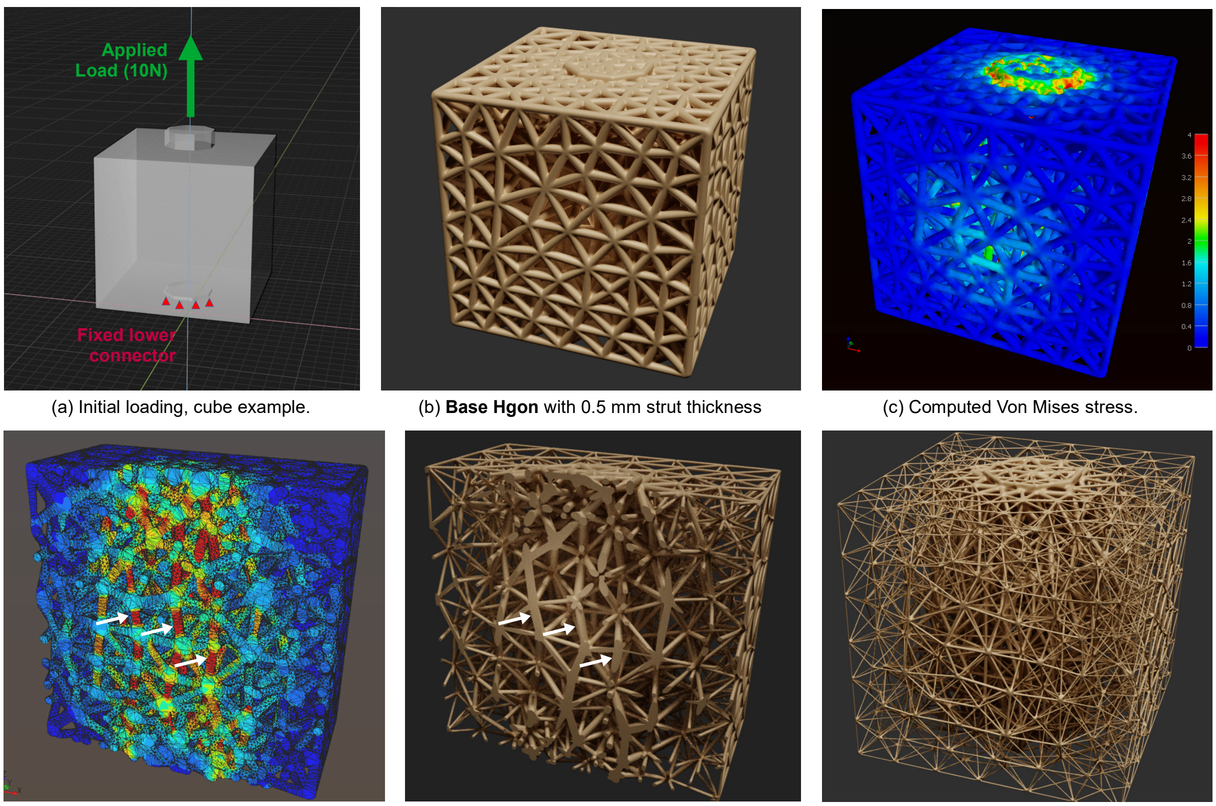
Introducing Hyper-structures for Additive Manufacturing and Generative Design of *ultra*-lightweight, high strength-to-weight ratio, vibration controlling components

- View the new for Jan 2020, Tech Reel #4 (2 min): https://youtu.be/k-0MyWpFrio

Additive manufacturing (AM, e.g. 3D printing) technologies has enabled the design and production of novel structures that are impossible to produce using standard manufacturing processes. ABĒMIS Hyper-structures (Hgons) introduce a completely new class of multi-scalar structure with unprecedented strength-to-weight ratios, unique micro-macro *conforming* topologies, and field-adaptive optimization capabilities. Although an obvious and primary goal is 'light-weighting' for components with complex shapes and boundary condition requirements – Hgons also have unique *vibration*, impact resistance, and fatigue resistance properties due to the ability to combine both isotropic and anisotropic multi-scale structures in ways never before possible. Stress, strain-energy and related field adaptive optimization can be done for wide ranging applications, including electromagnetic and fluid-solid (heat transfer) interactions, cushioning, impact, and related. Multiple materials can be used. Various novel generative and optimization strategies have been implemented *in-house* with fast, GPU enabled and parallel-capable computational approaches in Python and C++.

As an introduction, below is a simplest example of (a) 'default cube' in tension, (b) the generated base isotropic hyper-structure, and two successive stress-adaptive optimizations L1 (e) and L2 (f):



(a) Initial loading, cube example. (b) **Base Hgon** with 0.5 mm strut thickness (c) Computed Von Mises stress.

(d) Cutaway showing internal stresses. (e) Cutaway, **L1** stress optimized H-structure. (f) **L2** stress optimized Hyper-structure

Figure 1. This 'default cube' example Hgon is optimized for tensile load in both topological density and strut thickness, in this case via von Mises stress computed using nonlinear Finite Element Analysis (FEA). Arrows (d, e) indicate 'thickened' struts in high stress regions. The resulting 'hypercube' (f) is 25% *stronger* than the base cube, and *55% lighter*, with just 2 optimization steps. This is a fully manifold, 3D printable structure. *To our knowledge, the first of its kind (p-pend 2020).*

Hyper-structure conversion can be done with much more complex components than this simple cube. Our process can convert most any STL or STEP (CAD) solid to a parametric hyper-structure. To illustrate, Figure 2 (next page) shows a single leaf of a prototype electric motor stator frame component, with optimized shape to enable shaft off-axis tilt control. The shape has highly complex, multi-connected topology, with both curved and very sharp features.

We have developed a comprehensive workflow enabling non-linear FE analysis of hyper-structures, currently using FEBio (for bioengineering applications), ELMER (for electromechanical and electromagnetic designs), and Tochnog for geophysical and architectural/civil engineering applications. Integration with ABAQUS, ANSYS, and other commercial FE software is under development. Structures can be optimized for impact, vibration, fatigue resistance and many other factors. Current projects and applications include cushioning, footwear, aerospace, automotive, nuclear, antennae, advanced physics experiments (Z machine), advanced motors, active sensing structures, impact-ballistics, and others. Selected case studies, further introductory info, and a gallery are shown on our website (http://Abemis.com).

ABĒMIS is now offering free consultation on optimal conversion of your component to a parametric hyper-structure (Contact, techdemo@abemis.com). We provide comprehensive design, conversion, and optimization services which are *not cloud based* and thus fully secure, with all in-house systems that are not internet connected (unless desired). Conversion to a hyper-structure is not a trivial 'point-and-click' task. We have developed an expert system (PyTorch ML based) and workflow that computes custom parameters that are highly component and application specific. At ABĒMIS we are constantly improving our training database and parametric Hgon computation routines for many applications; with services providing both your generated Hgon model (single or parametric array) and if desired fully printed products in metals, nylon, and many other materials. Our experts help to guide the selection of 3D printer (low, medium, and high volume) and material that is best suited to your application.

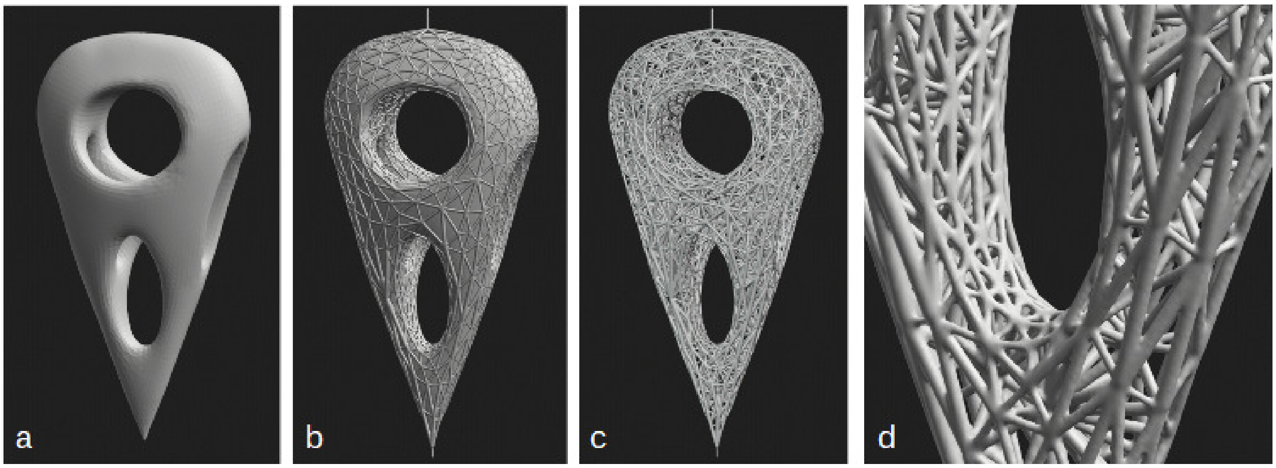


Figure 2. One lobe of an advanced bi-axis motor/generator stator (a) and fully conforming Hgon hyper-structure (b-d). Note the near-perfect conformity (b) to this highly complex shape and adaptive strut sizing (d). This cannot be done with lattices.

It is important to note that Hgon hyper-structures are NOT simple lattices. Hgons expand and computationally extend the concept (p-pend 2020) – i.e. Hgons *can* be lattices, but lattices can *never* be fully isotropic and *conforming* Hgons, particularly for highly complex topologies such as shown in Fig. 2.

Hgons are now optimizable and analyzable using latest GPU-enabled FEA methods (all done in-house), facilitating a Generative Design workflow. Figure 3 below shows an example tri-connected bracket optimization for an ultralight, vibration dampening antenna mount (microsat). The process involves computing the overall stress field of the part, and then subsequent iterative stress fields of the parametrically generated Hgon hyper-structure; reparametrizing and repeat.

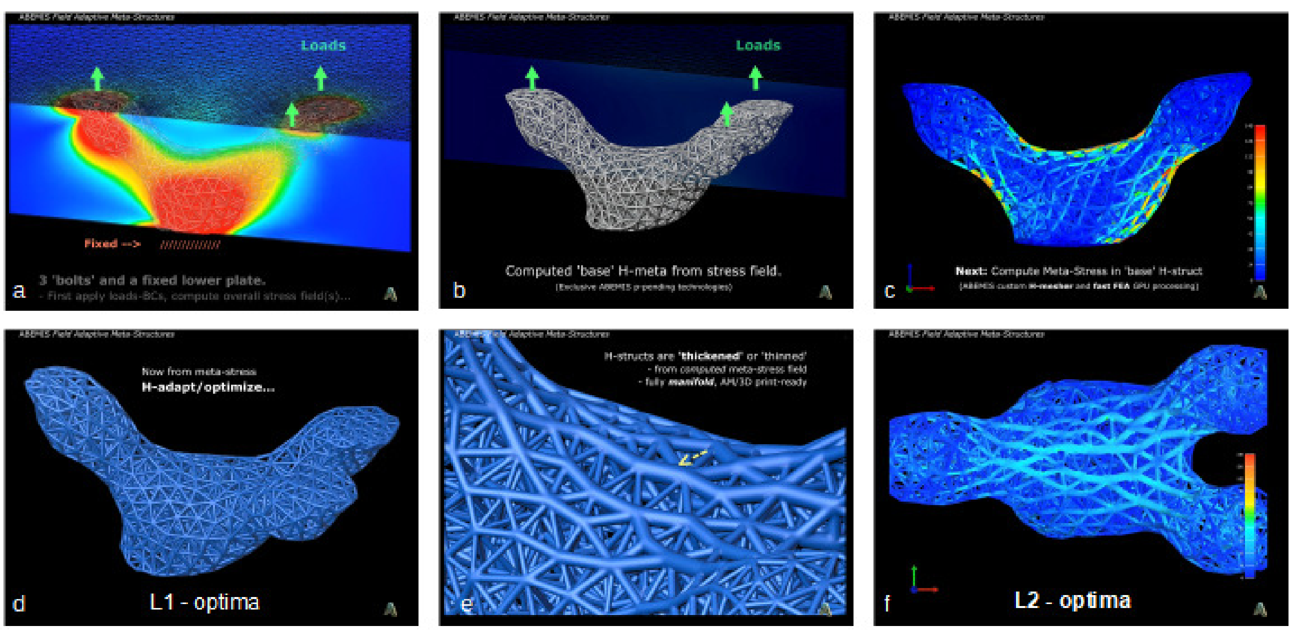
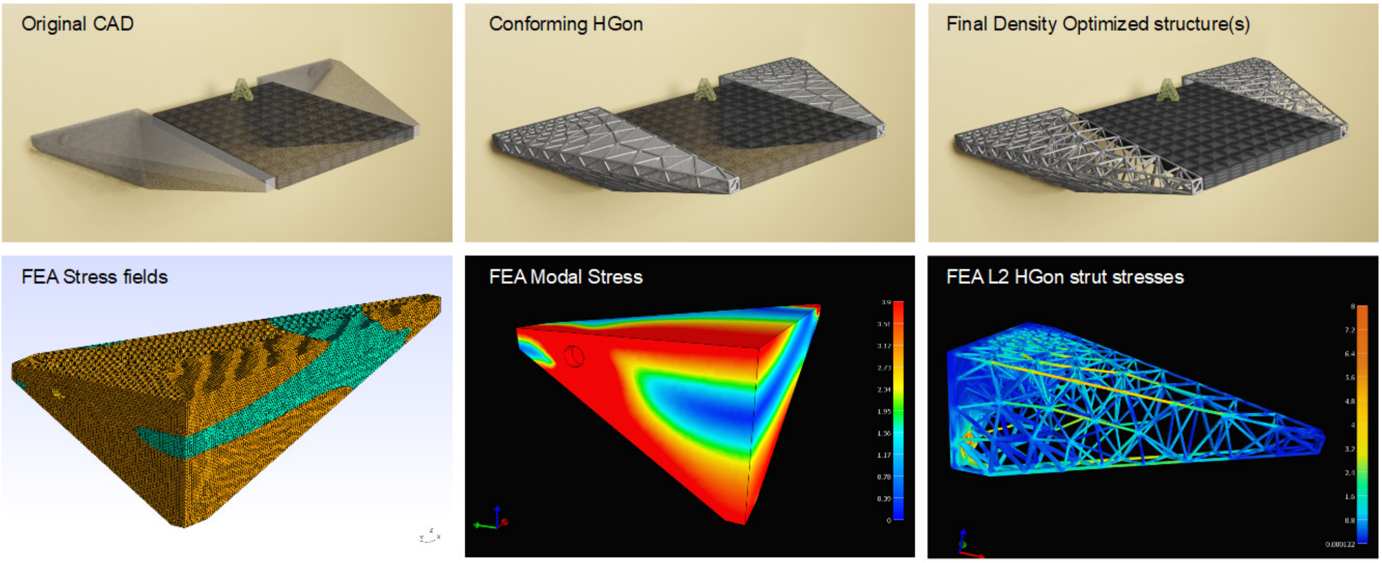


Figure 3. An optimized bracket support (microsat) generated (a) from defined loads and boundary conditions (von Mises stress), (b) the computed Hgon hyper-structure with (c) 1st level FE stress calculation, and (d,e,f) the 2nd level strut thickness optimization. Struts are thickened or thinned according to computed stresses. The resulting stresses in the structure are reduced by 70%+, while the overall structure is 20% lighter, and still **200% stronger**. This process can be repeated as desired to achieve optimal ultra-lightweighting, and other design criteria. To our knowledge *only* ABĒMIS H-structures enable *both* macro and micro-scale optimization.

Many different approaches can be used for macro-micro optimization. Figure 4 below shows a different approach for a vibration isolating bracket support. In this case the outer wedge shape is proscribed (from client's CAD STL file) and an initial FEA is performed to compute stresses in the structure. The base conforming Hgon hyper-structure is computed with mesh *density* (tetrahedra) controlled by the stress field. Then subsequent micro (strut) optimization is done to generate the optimized Hgon – for stress and in this case modal vibration optimizing (damping) ultralight bracket structure. More details of this work can be found online in our 'case studies' section (abemis.com).



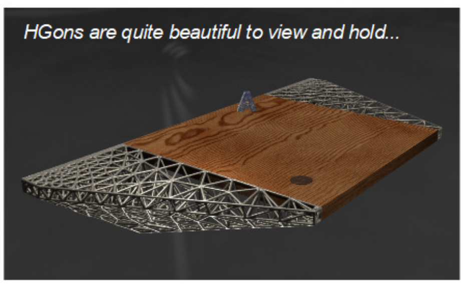


Figure 4. A vibration dampening bracket prototype. Shown is the original CAD, and generated HGon optimized for density, stresses (z-y loads) and dampen vibrations in the 200-2000 Hz range. This uses both a macro (whole component) and micro (L1 strut level) dual optimization approach. Further optimizations with many other criteria can be done. Also note that HGon structures are quite beautiful, sculptural, and architectural (left). They also 'feel' very interesting due to the ultra-lightweight and ultra high stiffness characteristics. People often describe them as... "Astonishing!"

ABĒMIS HGon hyper-structures (p-pending 2020) offer an entirely new way to design and generate optimized, ultra-light and ultra-strong components. Applications are vast, including Aerospace, Automotive, Bioengineering, Impact/Ballistics, Electro-magnetics (e.g. low and high energy physics), Footwear (sport *and* fashion), Architecture, and Artistic sculptural designs (e.g. atriums, lighting fixtures, large scale frame structures, sculptural, etc.) just to name a few.

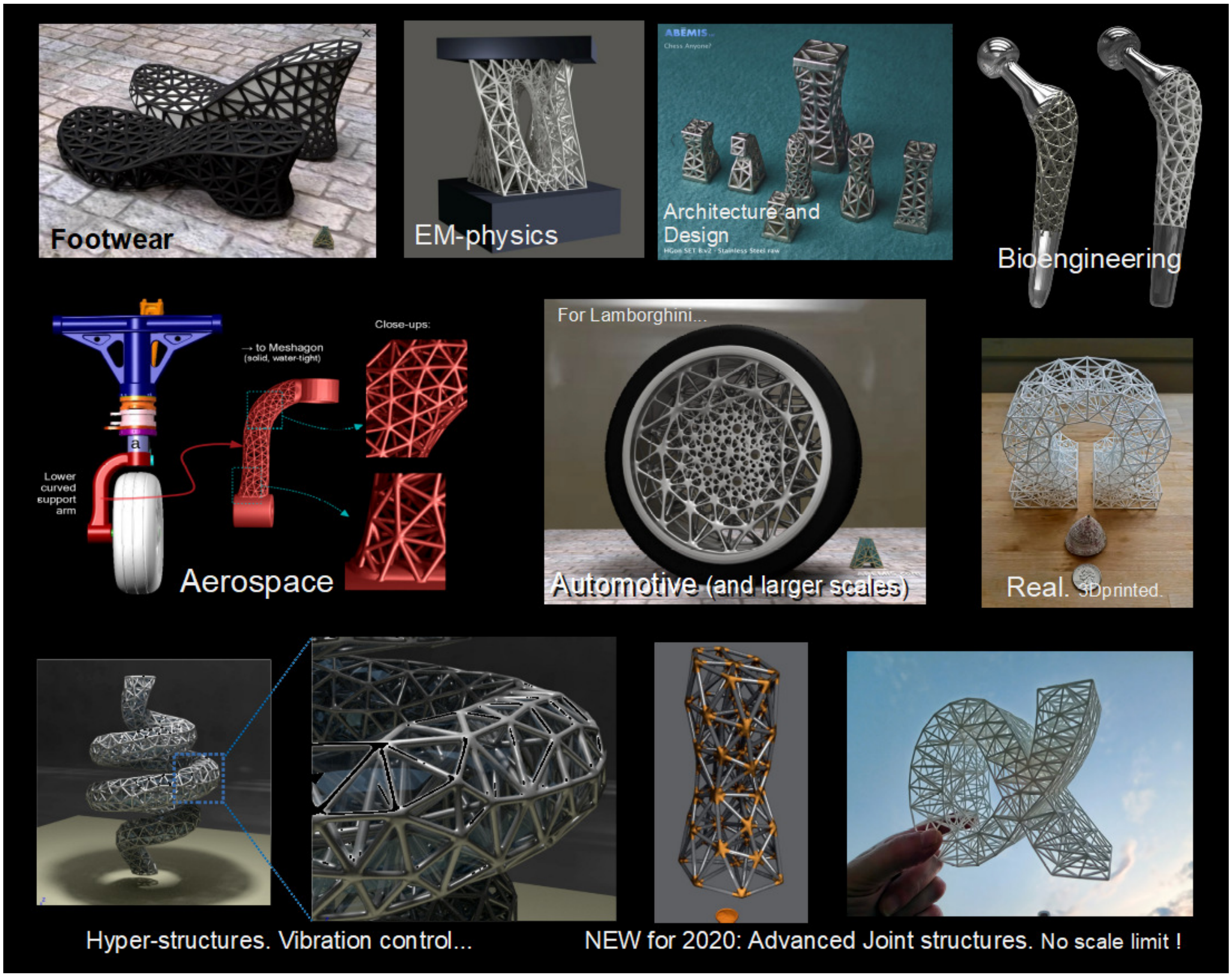
We are now offering full design services, consulting, and product development/manufacturing support. Current clients include Philips Respironics (CPAP cushion), ADDITEC Inc (nuclear fuel rod cassette), Bosch (Hyper-fuel pump), and several others in research/academia (Sandia Nat. Labs Z-machine, U. Akron, TAMU, Marquette U. and others).

After 10+ years of development, ABĒMIS is now ready for investor inquires, with a *provable* system, patent and IP coverage, developed clients and products that have the potential to revolutionize ultra-high performance component design and manufacture for Additive Manufacturing – a rapidly advancing, projected $1.2T+ industry (viz Business Insider). We emphasize that to our knowledge, no other company or group, worldwide, has any equivalent technology. These are not lattices. HGons have much greater capabilities. The generation of these structures has been a technical challenge. It is not a 'regular' structure. We have developed a completely novel and unique method (p-pend 2020).

Please contact us at techdemo@abemis.com for a free consultation and/or live demonstration of our systems and capabilities. We are now offering both single part conversion services, parametric part arrays, and full turnkey (hardware GPU, software) systems. For investors, we have a comprehensive business plan, financial info and valuation, company portfolio, and are open to equity investment or other agreements. All of our theory/math, software (Python and C++ based) and hardware systems have been developed in house.

The possibilities, are endless…

… and the Applications are endless:



Note: The best way to experience our HGon technologies and hyper-structures is via 3D viewing and video.
Many 3D views of HGon generated structures can be found on our Sketchfab website: https://sketchfab.com/tcdoeh/models
– Latest tech demo reel for January 2020: https://youtu.be/k-0MyWpFrio

We have also made a number of video technical introductions and demonstrations which present info and examples.
Please visit these links for more information, technical demonstrations, and example product designs:

1. Basic video technical introduction (2 min, with audio): https://youtu.be/pU_4_fPelJ4
2. Short intro example of L1 and L2 HGon generation (under 1 min): https://youtu.be/unLOuyc9pa8
3. ABĒMIS tech demo reel (2min, no audio, https://youtu.be/a7L0LXZ9bdo) This shows a number of our newest technologies and examples of vibration control, impact/ballistics, **multi-domain** structures, and prototype designs for current clients, and new Finite Element based analysis capabilities (fast GPU).
4. New hyper-flex, anti-vibration bracket. A true meta-structure (30 sec, no audio): https://drive.google.com/file/d/1tSyjsK-fyO638dyLvoCv69v9VnpgQ8MV/view
5. The Alcoa Challenge bracket, with related info (1min, no audio): https://youtu.be/zviRK9H2OJc
6. The “Starfish Project”: an example of HGon advanced simulation (1min, no audio): https://youtu.be/9z1YuoVNexY
7. Mgon Hyper-Structures brief 1min (tech demo #1b, no audio): https://youtu.be/_PhrFycIM7I

Case studies are being constantly updated on our website: https://www.abemis.com/
Also, we are now developing new systems for *physical testing* of HGon (or any) structures, with tensile, multi-axis, fatigue testing, more. New hyper-structure testing system (HSTS): PDF (2 page)

Thank you for reading, and contact us for any further information: techdemo@abemis.com. Todd Doehring, Ph.D., CEO: tcd@abemis.com