

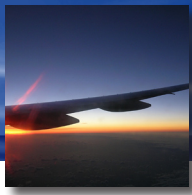
Design on the Lighter Side



HyperSizer[®]
Structural Sizing Software

Professional
Pro[™] Software Product Guide





HyperSizer® Pro

For over a decade, **HyperSizer®** has significantly reduced weight on major aerospace programs with rapid analysis and composite optimization. Originally developed at NASA, it's now greatly enhanced and supported as a commercial product worldwide. **HyperSizer** is not CAD and is not finite element analysis (FEA).

HyperSizer is something different and is described next as three separate products that all share and build upon the same integrated and internal database. Starting with a user friendly software interface, it's both easy to use and powerful.

HyperSizer Pro® includes all the functionality of **HyperSizer Basic®**, plus couples with FEA for system level analysis and automatic finite element model resizing. Maintain and report results of a complete vehicle detail

design. Perform advanced statistical optimization and find multiple robust optimum solutions for manufacturing producibility review. Plug-in your own analysis software to supplement **HyperSizer's** methods and have their results integrated with and graphically displayed in the interface.

Save time and weight and then document your methods, analyses, and designs automatically with HTML documenter. **HyperSizer designs on the fly!**

"It would be impossible to do my vehicle design optimization any other way. No other software does as many failure analyses as HyperSizer does."

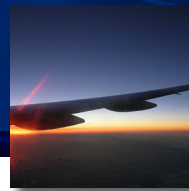
Lloyd Eldred, Phd, Reusable Launch Vehicle structural analyst

The screenshot shows the HyperSizer Pro software interface for a project named "App Ap2 SpacePlane". The main window displays a 3D model of a fuselage section with a color-coded stress distribution. The interface is divided into several panels:

- Group:** Corrugated Stiffened Panel Family, Group #2 "Fuselage Top, with fuel pressure"
- Components in Group:** Component #64 "Component 64", Hat stiffened panel adjacent to the Payload bay door
- Group Bounds:** Combinations: 4137, Avg Weight: 2.186279, Min Weight: 1.168297, Max Weight: 3.73473
- Component Results:** Selected Combination: 1727, Unit Weight: 1.973862, Workable Combinations: 1, Weight: 20.51089
- Section:** Panel Width (30.0), Exaggeration Factor (1.0), Show Cross Section button
- Component Display:** Default, Show stress gradients, Show margin of safety gradients, Show Optimal Cross Section button
- Finite Element Model:** Export FEM, Export Data, Plot Current Family Only, Value: Optimum Unit Weight, Variable: Height, Material: Top Face - material, Min Value: 0.5, Max Value: 2.8, Levels: 0, Component, Group, On Assembly, On Full Model, Bars, Triangles, Quads, Legend, Show BB, Mirror, X Axis, Y Axis, Z Axis

At the bottom of the window, there are controls for rotation (Rotx, Roty) and zoom (Zoom, 45.0, Dolly).

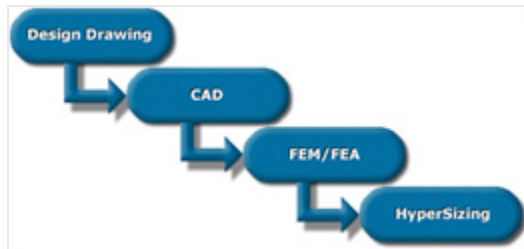
Free Body Diagram



Finite Element Models

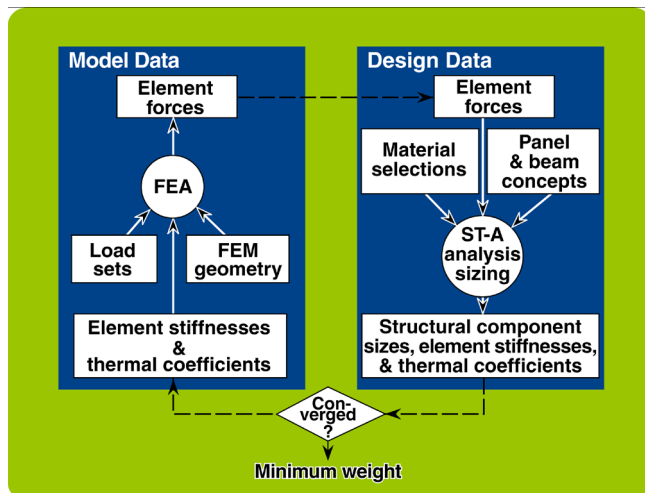
Using panel, beam, and laminate analyses from the **HyperSizer Basic** and **Material Manager®** products, **HyperSizer Pro** provides a complete and detailed analysis of entire systems such as airframes, rocket engines, ship hulls, and train bodies. Complete margin-of-safety (MS) summaries of all potential structural failure modes are reported.

In contrast to the **HyperSizer Basic** which uses manual input of loads, **HyperSizer Pro** uses FEA computed internal loads. This permits the automation of the complete design, analysis, and build process.



Applied Loadings

The general FBD loading approach used by **HyperSizer Basic** still consistently applies to the **Pro** process. The FBD GUI of **Basic** allows general loadings, enforced deformation, or boundary constraints at each panel/beam edge. With **Pro**, the FEM is used to resolve the general boundary conditions and applied external loadings into resulting internal loads. **HyperSizer Pro** retrieves these internal loads from the FEA, uses them to size the panels and beams, and then creates generalized thermoelastic stiffness terms to send back to the FEM for another iteration of computed internal load paths.

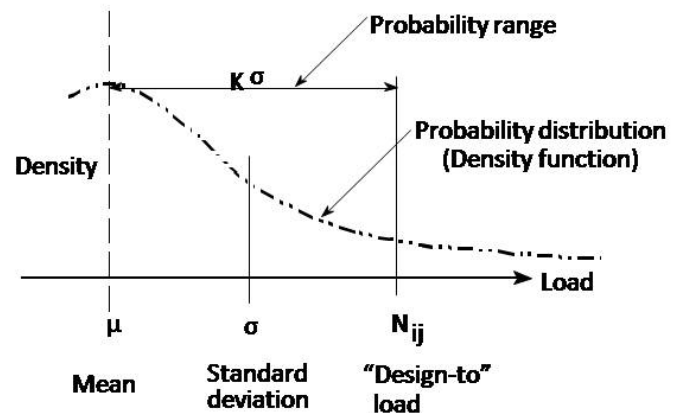


Design Structural Components

The **HyperSizer** process analyzes and optimizes using structural components, which are manufacturable pieces of panels and beams, rather than finite elements. Usually many finite elements are used to model a structural component and as such, this presents a ‘pulling-loads’ problem. Designing to the maximum element load could be far too conservative and result in overweight designs. This is especially true if the modeled panel has substantial load variation from midspan to edge, or from one edge to another edge. Buckling is dependent on an integrated, compressive type load rather than an element peak load that may be located at the panel’s corner.

Statistical “Design-to” Loads

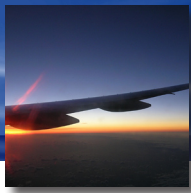
$$\text{“Design-to” loading} = \mu + K \sigma$$



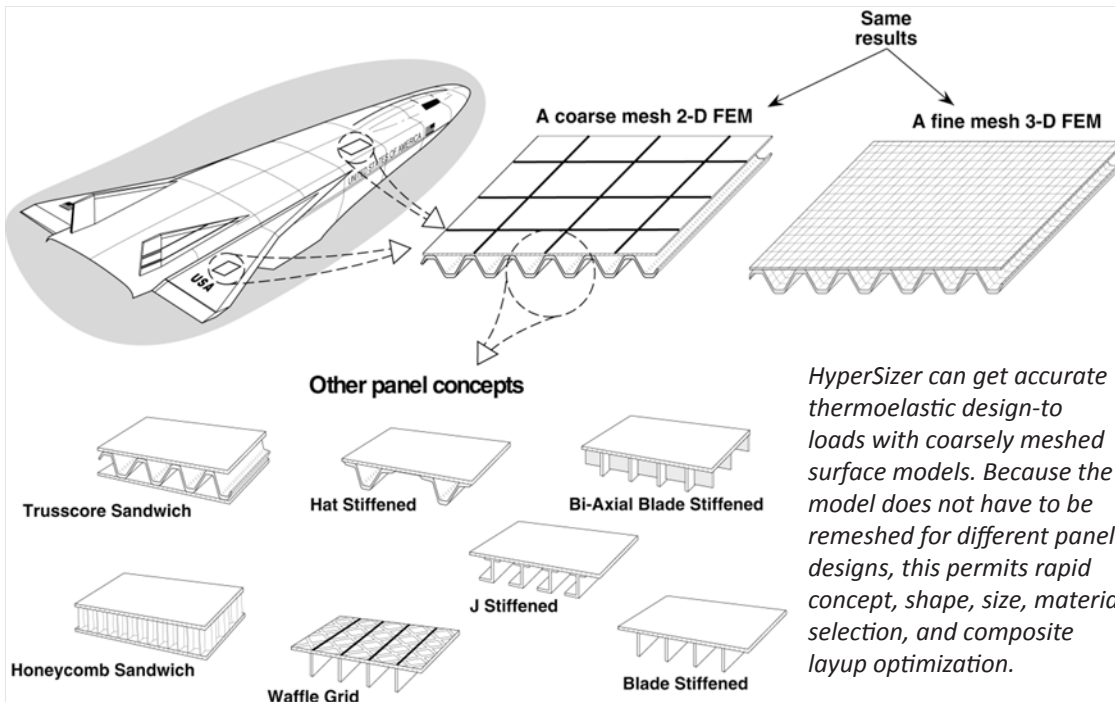
HyperSizer uses statistical methods to determine the appropriate design-to load. A **HyperSizer** user can select the ‘K’ standard deviation factor for determining the design-to loads for strength analysis. The higher the K standard deviation (σ), the higher the confidence limit is for capturing peak loads (more conservative).

For instability, **HyperSizer** uses a different statistical approach. A key aspect of this approach is to statistically determine the percentage of the component’s area that is in the compressive, buckling zone and integrate the compressive magnitude over that area.

| Factors | |
|--------------------------------|---|
| Required MOS | <input type="text" value="0"/> |
| Mechanical Limit | <input type="text" value="1.1"/> |
| Mechanical Ultimate | <input type="text" value="1.5"/> |
| Thermal Hurt | <input type="text" value="1"/> |
| Thermal Help | <input type="text" value="0.8"/> |
| Biaxial Buckling Tension | <input type="text" value="1"/> |
| Field Stiffening | <input type="text" value="1"/> |
| Tensile | <input type="text" value="1"/> |
| Compressive | <input type="text" value="1"/> |
| FEA Statistical Loading Method | <input type="text" value="2-Sigma"/> <input checked="" type="checkbox"/> 2-Sigma <input type="checkbox"/> 3-Sigma <input type="checkbox"/> 1-Sigma <input type="checkbox"/> 0-Sigma (Avg) <input type="checkbox"/> Max/Min |



HyperSizer[®] Pro



as shell elements (2-D surfaces). A highly accurate equivalent plate stiffness formulation permits modeling of any general 3-D cross section with a coarsely meshed 2-D FEM. This is accomplished by including longitudinal, transverse, and in-plane shear; membrane, bending, membrane-bending coupling, twist, and bending-twisting coupling stiffness terms and thermal coefficients.

The reference plane used for all panel

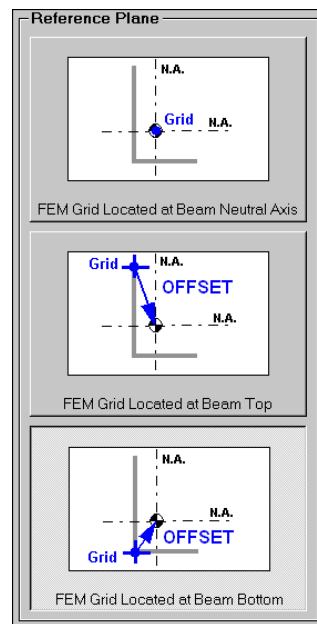
In summary, FEA computed internal loads are statistically processed for each structural component's mesh density. Based on the user's selection of FEA statistical σ (sigma) loading method, mechanical limit and ultimate load factors, and thermal hurt and help factors, each structural component's design-to loads are obtained for each loading condition.

One last loading issue to consider is conceptual and preliminary coarse meshed FEMs that do not have enough elements to represent panel spans accurately. This happens, for instance, with airframe fuselage panels that support fuel pressures across ring frames, or propulsion system combustion chamber panels that contain flowpaths pressures. For these applications, **HyperSizer** can analytically compute these lateral pressure effects and supplement them with FEA loads from coarse FEMs.

FEM Updates

Once the optimum panel and beam shapes, sizes, materials, and layups are determined, then the FEM is updated.

Panels are represented in the FEM



properties is the facesheet. This allows the FEM grids to be located on the Outer Mold Line (OML).

Beam stiffness formulations permit modeling any standard cross section using 1-D line elements. This is accomplished by including moments of inertia, product of inertia, principal moments of area, torsional constant, effective elastic moduli, EA, EI, GJ.

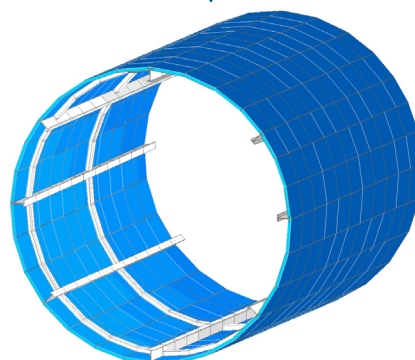
HyperSizer generates FEM beam offset vectors in 3D space to account for beam neutral axis shifts caused by cross section shape changes or sizes during sizing.

HyperSizer takes care of coupling to FEA such as reading computed element forces and writing generalized stiffness terms, including

the difficult part of having to consider complexities in how each specific solver uses properties to formulate their thermoelastic element stiffnesses, handling shell material coordinate systems, and beam element coordinate systems.

FEA Solver and FEM Modeler Integration

HyperSizer supports MSC/NASTRAN,



HyperSizer® Pro



I-DEAS, FEMAP, with plans for PATRAN, ANSYS, etc. Automatic coupling is provided to these software packages, including data transfer of generalized thermoelastic stiffness terms and thermal coefficients, computed element/grid forces, and results display.

The bottom center figure shows three options the user has for locating the FEM beam neutral axis. In this example, the beams are offset inside the cylinder with the beams cross sectional shape data automatically generated by **HyperSizer** for modeler display.

HyperSizer can update the model in whole or in part by component, group, assembly, or entire project.

System Level Design Optimization

Speed

Very large FEMs can be optimized such as complete aircraft systems. One million degree-of-freedom models have easily been handled.

Optimization Run Times

(40,000 design variables for vehicle)

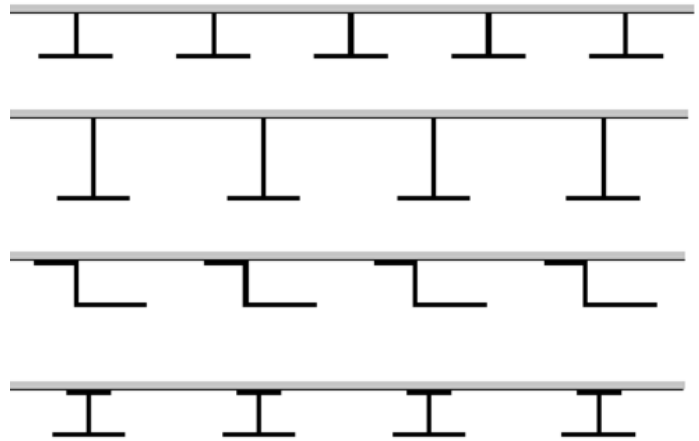
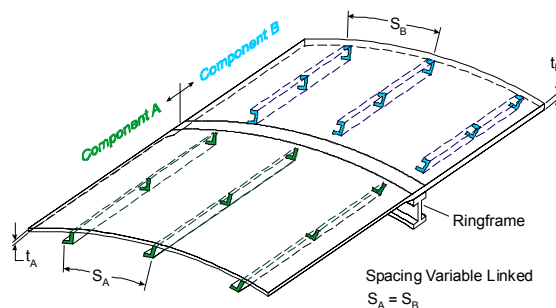
| FEM DOF's | Entire FEM | Component |
|-----------|--------------|-----------|
| ¼ million | 1 min 18 sec | 2.9 sec |
| 1 million | 1 min 21 sec | 3.4 sec |

These run times do not include FEA solutions. They are times for reading FEA internal loads, performing a minimal optimization, and updating the FEM. The times indicate **HyperSizer's** rapid processing of large data sets.

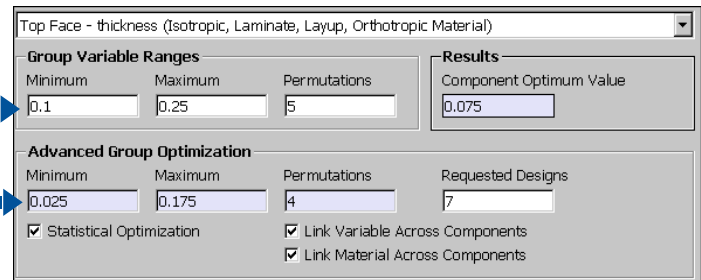
Advanced Optimization

HyperSizer Basic performs optimization using many structural integrity analyses such as strength, stability, stiffness, deformation, and frequency. **Basic** is also able to link variables within its structural component cross section, such as the materials and layups of top and bottom facesheets.

HyperSizer Pro is able to **link** any number of cross sectional dimensions across adjoining structural components. An example is panel stiffener spacing across ringframes of an aircraft fuselage. The user may also link materials and layups across adjacent surfaces.



Another advanced feature of **Pro** is **robust optimization** that finds multiple light weight designs that can be reviewed for manufacturing producibility. The four different panel designs shown above were optimized concurrently to weigh the same amount and be able to support the same design loads.

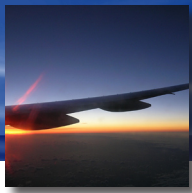


Use **HyperSizer's** advanced statistical optimization capabilities to shift, expand, and refine variable ranges and the number of variable permutations to automatically reduce more weight. By toggling on this capability, **HyperSizer** will perform statistical analysis on design variables from the sample of workable solutions and quickly rerun the optimization. This new technique has demonstrated an average additional weight savings of 12%, over solutions where the capability was turned off.

Project Data Management

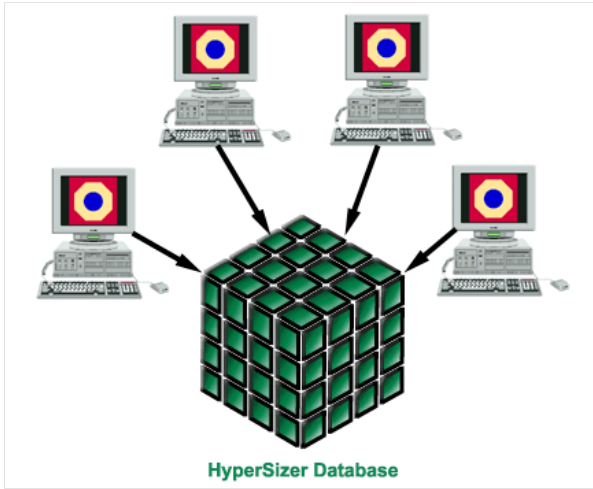
Relational Database

All data is contained in a true relational database management system providing use by a multi-user design team. A single or multiple user team

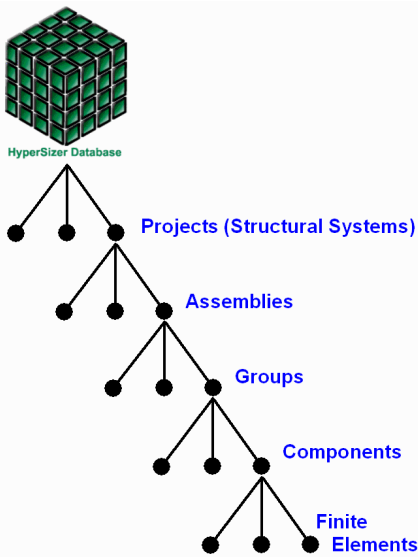


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can access the same database as indicated below. Administrator, user, and guest levels of security are supplied. Passwords can be assigned to single users and to groups.



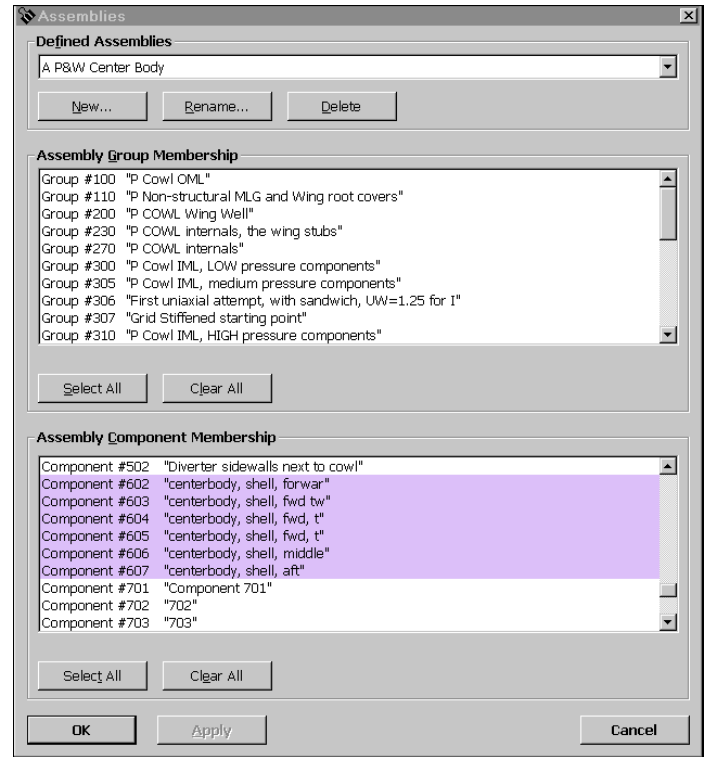
The database provides full integration of all material data with material filtering and searching capability. Many projects can exist in one database. Projects can be deleted, copied, and renamed. While doing trade studies, it is useful to be able to conveniently go back and forth between versions of the same design.



A Data Hierarchy provides organization and integrity to the task of managing the large amount of data associated to a project. The following levels of hierarchy are identified. As indicated by the tree nodes, there can be several projects contained in a database, several assemblies to

a project, several groups to an assembly, etc. Within **HyperSizer**, the user can interactively define and redefine assemblies and groups from structural components.

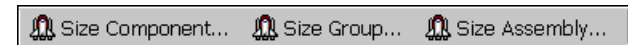
In addition to optimizing a complete FEM project, the



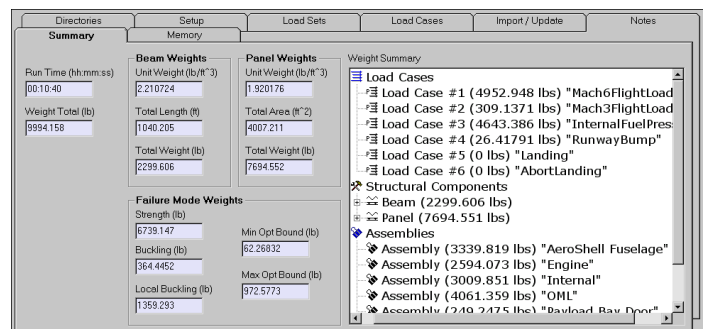
user can conveniently analyze and optimize in seconds any component, group, or assembly.

Weight Reports

Many years ago, **HyperSizer** was developed with the

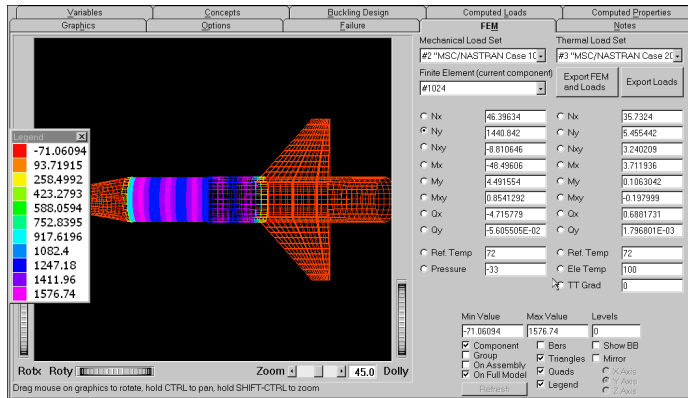


original purpose of analytically predicting achievable weights for new designs. This is in contrast to methods usually implemented with spreadsheets that interpolate from historical data. In performance trade studies, all new conceptual design's weight statements should be proven analytically. **HyperSizer** finds the lightest weight structure for designs, and ensures they support service loads without failure. While doing this, **HyperSizer** reports weights using many different categories, such as assemblies, groups, structural components, panels,





beams, loadcases, and controlling failure modes. Weights are calculated based on material densities, adhesive bond weights, fastener weights and counts, and user specified non-optimum penalties.

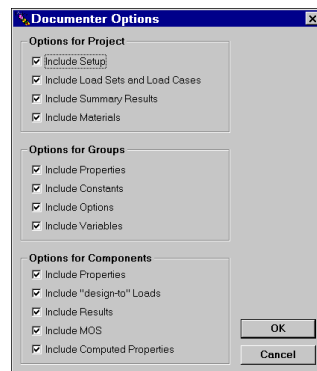


Graphical User Interface

HyperSizer interactively plots many types of results on the FEM to indicate areas that fail structural integrity requirements, or identifies over-designed areas which can be made lighter. Interactive 3-D graphics provide visual inspection of structural component layouts, optimization groups, and manufacturing assemblies along with their corresponding drawn to scale optimum panel and beam cross sections. These features quickly identify design differences throughout the entire structural system. You may also plot, within **HyperSizer**, FEA computed internal loads (stress resultants) transformed in the material axis as shown on the fuselage.

Stress Reports

Stress reports are generated for all aspects of your project, including margins-of-safety, material properties, design-to loads, optimum design dimensions, etc. The user may select what type of data to be included using the Documenter, and choose an HTML format or a Microsoft® Word format to display the data. For HTML reports, a directory is created and the entire report can easily be posted on an internet site for collaboration. For Word reports, a file is created that is easily accessed and shared with project team

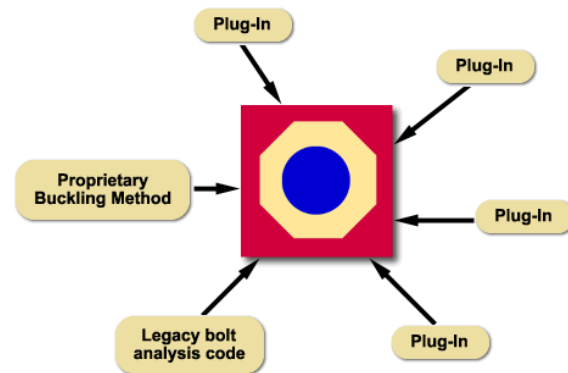


members.

Analysis Plug-ins

HyperSizer Pro® offers developers a way to plug-in their own user defined analysis methods. By compiling your Fortran, C, or C++ analysis routine into a dynamic link library (DLL) you will be able to integrate your own software with **HyperSizer**. This coupling is possible with no performance degradation to your codes, and with no intermediate ASCII files required. Your software will compute as efficiently as **HyperSizer's** built-in analyses. This plug-in capability offers users three benefits.

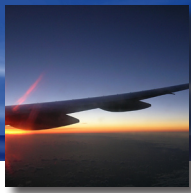
You can plug-in your own best-in-class legacy and proprietary computer codes into the data flow stream of **HyperSizer's** well integrated design and analysis process.



The first benefit is the ability to incorporate legacy, standalone codes into a ready made GUI that brings new life into them. The GUI provides productivity and **HyperSizer's** relational database provides data integrity. Your analysis automatically shares all material and composite data, is included in all of the FEA multiple design-to load cases, is performed for all structural assemblies, groups, and components, is an innate part of the optimization, is maintained in the database with all other project data, can be plotted graphically, and shows up in the stress reports.

The second benefit is the ability to secure **proprietary source code**. You can couple your software with **HyperSizer** on your own, by using the published interface protocols for each analysis type. You maintain your codes interactively with **HyperSizer** and protect the competitive edge they provide your company.

The third benefit is using **HyperSizer** as an environment for writing code, compiling, and testing/debugging. By piggy backing off of **HyperSizer's** infrastructure for controlling



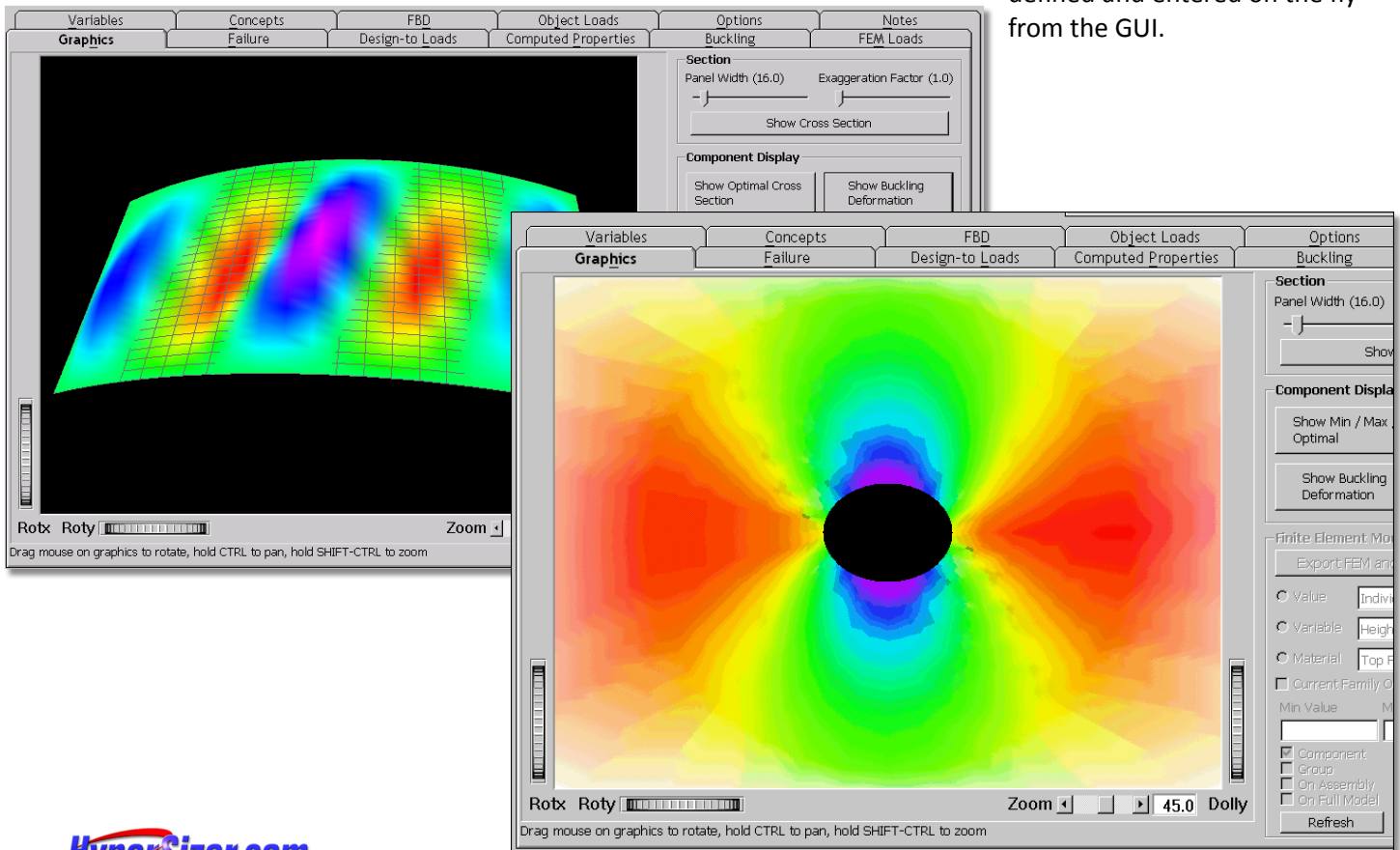
HyperSizer® Pro

data flow, researchers can focus efforts on their methods development. In this way it becomes an ideal tool for university research.

Test data validation and years of use make standalone legacy codes invaluable to industry. As such, they are necessary building blocks for design synthesis. For this reason, an objective at **Collier Research** is to provide them as an innate part of our software where possible. However, regardless of whether the legacy capability

is delivered with **HyperSizer** or implemented by your company, the efficiency and use of legacy software is the same. Consistent implementation is ensured in both cases. This interchangeability is achieved by defining standard input/output protocols for each failure analysis category (beam buckling, crippling,....)

For the case where you would like to define unique data not part of the established standard interface protocol, **HyperSizer Pro** allows additional variable input to be defined and entered on the fly from the GUI.



[HyperSizer.com](http://www.hypersizer.com)

For more information,
visit us online at www.hypersizer.com
or contact us directly at:

Collier Research Corporation
Phone: (757) 825-0000
Fax: (757) 825-9988
<http://www.hypersizer.com>
email: sales@hypersizer.com

HyperSizer standard interface protocols include graphic information. Analysis results from your own plugged-in software can be shown real time. This figure shows by color gradient, within HyperSizer, the displacement fields predicted by the BJSFM bolted composite program including the effects of far field stress resultant on the loaded hole,(bottom) and the buckling mode shape of a Raleigh Ritz cylindrical panel buckling energy solution (top). In both cases, these analyses were implemented as customer legacy codes and automatically became part of the design optimization process.

[HyperSizer.com](http://www.hypersizer.com)