FocalPoint The Newsletter for Pointwise® Users

Tel. Volume 15 Issue 1 Spring 20

Store Separations for F-35s Analyzed Using Grids Made With Gridgen

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F-35 pilots need the ability to jettison stores in the event of emergencies during takeoff (such as a cold catapult stroke or power plant problems), and emergencies in landing configuration (such as during Short Take-Off and Vertical Landing - STOVL mode approach). No wind tunnel data have been obtained for store separation in the STOVL mode, with landing gear extended and vectored thrust from the lift fan propulsion system, as shown in Figure 1. A collaborative team consisting of Naval Air Systems Command (NAVAIR), Air Force Seek Eagle Office (AFSEO), and Lockheed Martin store separation engineers was formed to conduct computational fluid dynamics (CFD)-based trajectory analyses to support issuance of flight clearance limits related to F-35 emergency jettison in those flight conditions. This article, taken from AIAA paper 2010-510 "Store Separations in Jet Flow Environments," describes challenging aspects and results of CFD-based trajectory analyses for stores separating in jet flow environments.

Figure 1: F-35B in STOVL Mode

The Beggar CFD code was selected for this task because the code has been tailored exclusively for store separation applications and validated against flight test data for more than 20 years. The philosophy behind Beggar is to use a Chimera, or overlapped, grid system so that the components of a problem may be gridded independently of each other and then assembled to form the complete system of computational grids. By automating the Chimera assembly process and incorporating an algorithm to solve the rigid-body equations of motion, the code has become a user-friendly platform ideal for store separation calculations.

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USAF Academy Students Create CFD Grids With Pointwise

In 2004, the USAF Academy was one of the first universities in the nation to establish an undergraduate computational aerodynamics class. This class is taught to all USAFA aeronautical engineering majors during their junior year. The goal of this course is to help students become "intelligent users" of computational fluid dynamics (CFD) as they analyze real-world flows of interest to the Air Force and guide them through the

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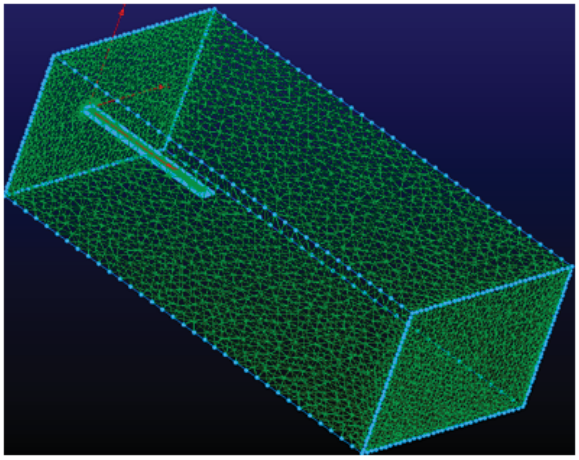

Figure 1: Complete 3-D unstructured wing grid created using Pointwise

Store Separations for F-35s Analyzed Using Grids Made With Gridgen

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Gridgen was used to generate CFD grids for configurations of interest. The NAVAIR, AFSEO, and Lockheed Martin engineers were well aware of the challenging complexities associated with STOVL aircraft configuration/control.

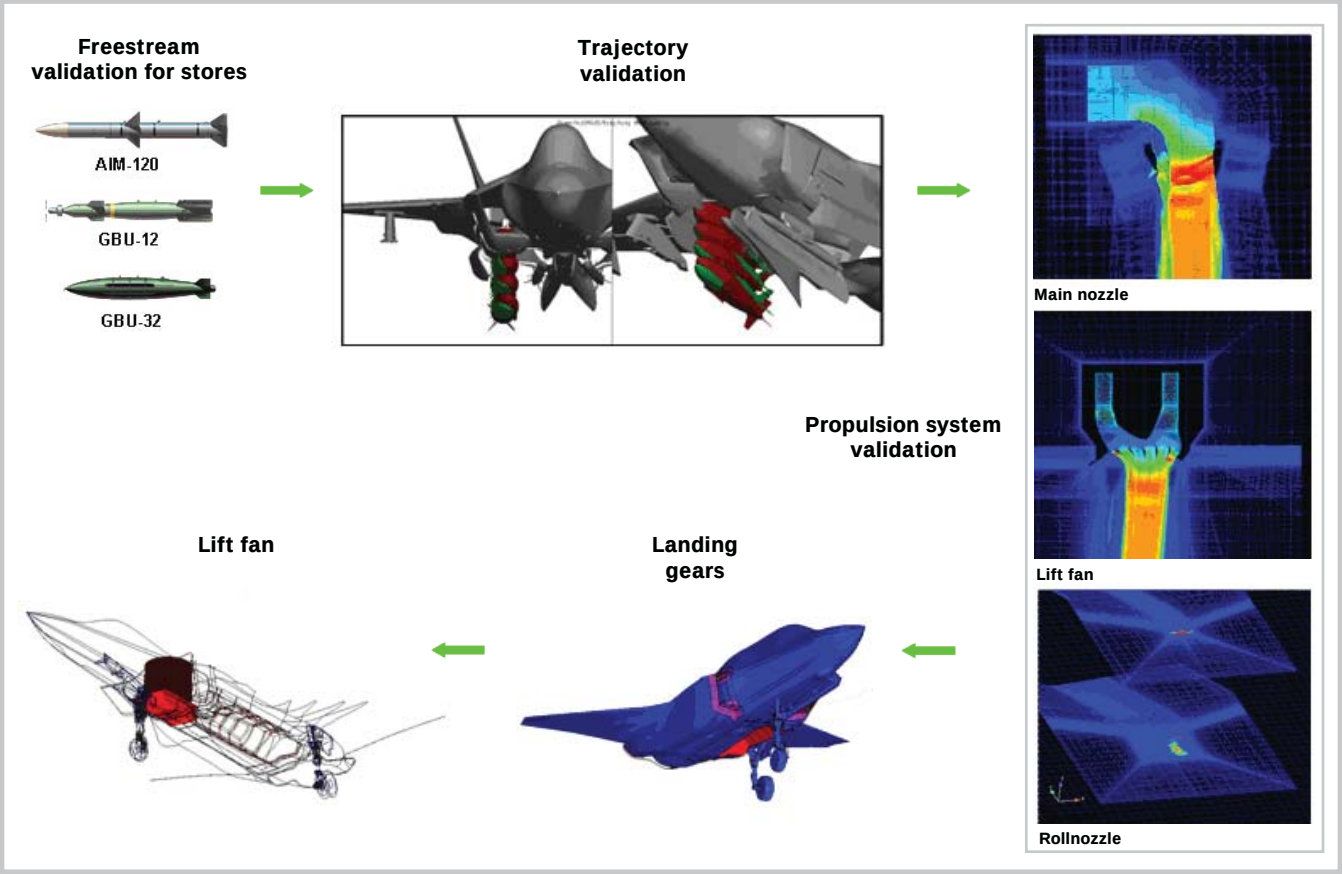
When this project was started a year ago, a Lockheed Martin CFD engineer already had worked on CFD validation of the F-35B propulsion system (main nozzle, roll nozzle, and lift fan). High resolution grids for the propulsion system had been built to capture jet flow characteristics better and Lockheed Martin had already validated their solutions against a thrust-based criterion. The computed thrust had 99 percent accuracy against measured wind tunnel test data. The CFD grids for the propulsion system were transferred to NAVAIR and converted to a Beggar format.

The CFD grids for geometrically complex nose and main landing gear were built by AFSEO CFD engineers using Gridgen and had 30 million grid points, the weapon bay itself had 30 million grid points to have a direct eddy simulation (DES) quality grid. NAVAIR engineers integrated the CFD grids from different sources to attain the desired configurations, set up input files for Beggar runs, and transferred both integrated CFD grids and Beggar input files to the AFSEO CFD team to use their computing resources.

All of these grids, plus grids for any stores to be carried are assembled in a build-up procedure highlighted in Figure 2. Grid quality for the individual components was validated through comparisons with data to provide confidence in the results from the integrated system grids. Results from CFD computations on the complete configuration compare favorably to wind tunnel tests of store trajectories.

The joint team consisting of NAVAIR, AFSEO, and Lockheed Martin engineers has worked together successfully to take a CFD approach to support issuance of flight clearances that provides for STOVL emergency jettison of stores. The CFD models were validated and applied to a couple of STOVL conditions. The CFD analyses showed that STOVL emergency store ejection looks safe and benign for configurations and conditions investigated. ■

Figure 2: Build-up and validation processes



USAF Academy Students Create CFD Grids Using Pointwise

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four-step CFD process of geometry generation, grid generation, flow solution and post-processing.

The students start by learning the fundamentals of computational methods, including stability, accuracy, turbulence modeling, grid generation techniques and parallel computing. They participate in several smaller projects covering each of these topics, then are introduced to state of the art computational tools that they use to follow the four-step CFD process.

For the grid generation step, students are introduced to Pointwise, which they use to create multiple two- and three-dimensional grids for both viscous and inviscid simulations. As part of one project, teams create a three-dimensional grid around a wing design that they use to solve their design's aerodynamic properties. An example of the complete grid is shown in Figure 1, with a close-up of the wing in Figure 2. The characteristics of each of these wings are then compared with the other teams' designs and analyzed.

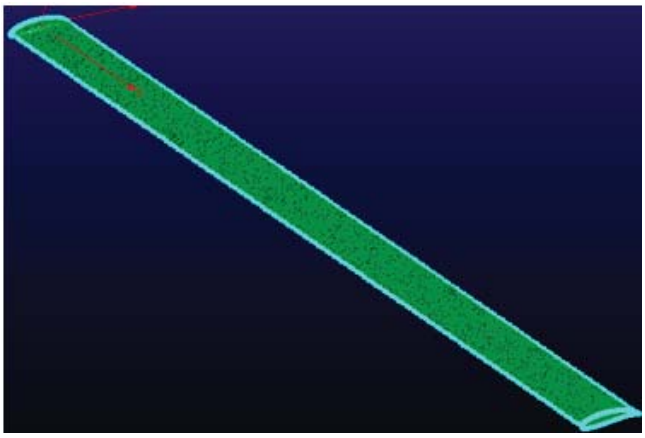


Figure 2: Close-up of 3-D wing grid created using Pointwise

The final project of the computational aerodynamics course is to develop a two-dimensional viscous grid to analyze several different airfoil types. Each team selects a unique airfoil design, creates a grid compatible with viscous solutions, conducts a grid-sensitivity study with varying degrees of coarseness, and then uses the selected grid to analyze the characteristics of that airfoil at several angles of attack. Both steady-state and time-sensitive simulations are conducted using this grid and the results are analyzed, compared with the other airfoils, and other post-processing is done to include a movie of the airfoil at a high, post-stall angle of attack. An example of this is shown in Figure 3, with a close-up of the airfoil in Figure 4.

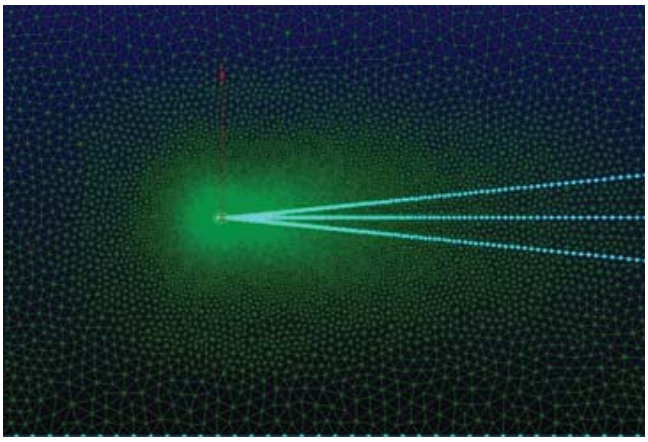


Figure 3: 2-D viscous airfoil grid (hybrid) created using Pointwise

Although the purpose of this course is not to create CFD experts, approximately 10-12 students annually continue in the USAFA's advanced computational aerodynamics class, participate in a computationally-based Cadet Summer Research Program and/or perform independent study (Aero 499). These students use computational tools and learned skills to perform research jointly with USAFA faculty and Air Force engineers. All these computational research projects are funded by outside sources and the data these students present is used to advance Department of Defense and industry projects.

USAFA has used Pointwise as its grid generation tool with great success in all of these courses. Students are introduced to Pointwise in their junior year and nearly all of them use it again when the need arises for grid generation in their higher-level classes. They have used Pointwise to create grids to analyze the aerodynamics of such diverse geometries as a backward facing step, the wake of the NASA Crew Exploration Vehicle, and blended wing designs. ■

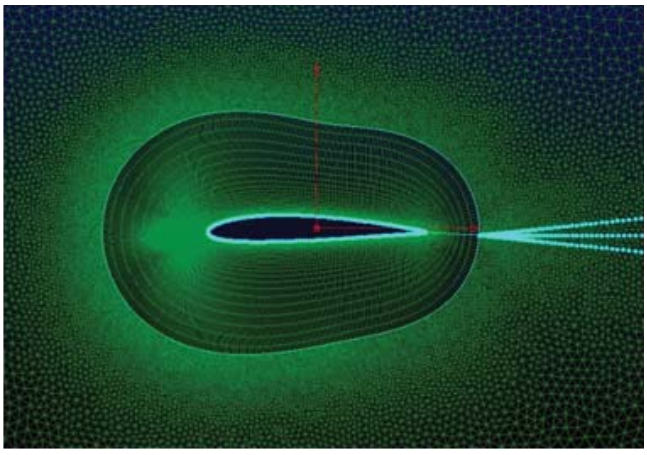
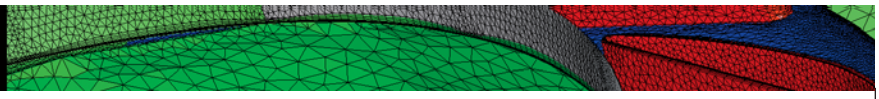


Figure 4: Close-up of 2-D hybrid airfoil grid created using Pointwise

Partner Highlight



This year marks the 15th anniversary of Pointwise's partnership with Visual Integration and Numerical Analysis Systems (VINAS) in Japan. Founded in 1996, VINAS provides leading edge numerical analysis systems and services to companies in a wide range of fields, such as aerospace, heavy industry, automotive, maritime, atomic, electronics, medical and construction.

One of VINAS's largest customers, the Japan Aerospace Exploration Agency (JAXA), has been using Gridgen for many years and finds it to be a valuable tool. Gridgen is used by JAXA for design and analysis in development of next-generation liquid rocket engines.

Dr. Nobuhiro Yamanishi, team leader at JAXA's Engineering Digital Innovation Center, said, "Specs required in development of liquid rocket engines are more and more harsh. Compared to our current rocket engine, LE-7A, we have been trying to double the reliability, and reduce the development time and cost in half. To fulfill this condition, we have used Gridgen to generate large-scale models to accurately understand the devices' reliability and flow phenomena and mechanisms related to their durability. The model shows the part of the inducer mesh.

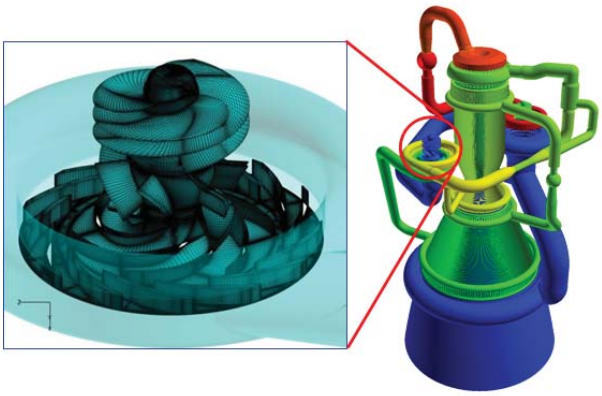


Figure1: Pump side model of liquid oxygen turbo pump. Image provided by JAXA.

"High-precision calculations became possible by using Gridgen's hexhedral mesh capabilities. We have been running trials for Pointwise for application to practical development since last year. In addition in 2010, we completed the world's first full model analysis of a rocket engine including turbo pump, regenerative cooling system and combustion. Thanks to Pointwise's high-precision meshing tools and support from VINAS engineers, we have completed vast numbers of high-quality meshes and have gained various perceptions."

By providing support to increase the efficiency in development of the next liquid rocket engines at JAXA, VINAS has contributed to the accomplishment of high-fidelity simulation with large-scale, high-quality mesh generation.

Pointwise Training Will Fast-Start Your Projects

Are you a long-time Gridgen user who finally is ready to give Pointwise a try? Want to see how Pointwise can make you a more efficient mesher?

Try one of our Pointwise training courses. You can attend a course in Fort Worth, regionally or even have one at your own site.

Our Pointwise Standard Course will teach you the most effective ways to use Pointwise to deal with dirty CAD and create structured, unstructured, and hybrid meshes. Throughout the course, our experienced instructors will be sure that you get the one-on-one attention you need to hit the ground running with your own work projects in Pointwise.

Training Dates

Pointwise Standard Course	21-23 June	Independence, OH
Gridgen Advanced Course	12-14 July	Fort Worth, TX
Pointwise Standard Course	13-15 September	Fort Worth, TX
Pointwise Standard Course	11-13 October	West Coast

For more information, contact our training department at training@pointwise.com.

Product News

New Features Coming in Pointwise

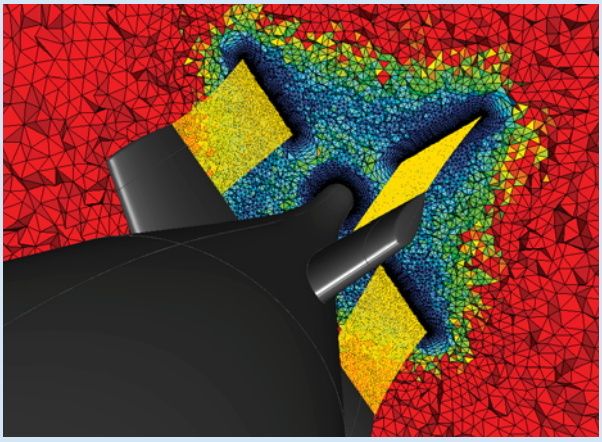
It is interesting to note that during Pointwise's 17th year of operation, we will be delivering Pointwise Version 17, the culmination of a multi-year effort to create a new platform for mesh generation. Here is what that means to you.

In V17 you will have access to the full T-Rex (anisotropic tetrahedral extrusion) volume meshing technique but with a twist relative to Gridgen. T-Rex in Pointwise includes inheritance by which the volume mesh's attributes are inherited automatically by its bounding surface and curve meshes. Not only does this ensure consistent meshes at all levels, but it eliminates the manual work you have had to do in Gridgen.

Native CAD reading capability – the ability to read native CAD formats like Pro/E, SolidWorks and six others is on the verge of completion. Although this feature is not yet complete (and therefore we cannot commit to anything in particular), the plan is to bundle readers for all eight formats with every Pointwise license. When coupled with Pointwise's built-in IGES reader, odds are that you will be able to import most CAD files you are given.

Completing Pointwise's Feature Set

What also makes Pointwise Version 17 a notable milestone is that it represents functional parity with Gridgen – you will be able to make any grid in Pointwise than you can make in Gridgen, from core meshing techniques to utility commands. Combine that with the fact that everything is easier to do in Pointwise and that Pointwise can do things Gridgen will not ever do (for example, floating block boundaries in the elliptic PDE solver, intersecting faceted geometry) and you have a powerful new tool at your disposal.



By using baffles (shown in yellow) with the T-Rex hybrid meshing technique, you can cluster cells around thin surfaces or flow features. Shown above is wake clustering behind the tailplanes of the SUBOFF benchmark submarine geometry.

Rounding out Pointwise's feature set are the ability to select all entities in a layer, double precision graphics, an isoparametric (u,v) highlighter for NURBS surfaces, and the addition of spacing constraints to the list panel for tabular selection, sorting, and setting, groups, re-extrusion, and structured subgrids.

Baffles for Gridgen's T-Rex

Recently we delivered new features for Gridgen, including the addition of baffle support in T-Rex meshes in Version 15.17. Baffles are surface meshes inserted into the middle of a volume mesh to resolve a thin surface or flow feature. With T-Rex support, you will get extruded layers of tets off the baffle, thereby providing a fine mesh for accurately resolving the flow feature.

Going forward, you are going to continue to have access to Gridgen to use as you see fit and we will maintain and update it as necessary and with your guidance. Yes, Pointwise will be the basis of our new advancements but, as we have said before, "Just because there's a new horse in the barn doesn't mean we're sending Old Reliable out to pasture."

Beyond Version 17

One final consequence of the upcoming V17 release is that we will be turning our complete attention to advancements in CFD preprocessing without having to migrate functionality simultaneously. Conversations with our customers and partners have helped define paths for moving forward. Some of those paths are massive grids (billions of cells), the complexity of geometry (both analytic and faceted), and mesh algorithms (and types of meshes). We will be expanding those paths, seeking feedback, and showing some early concepts at the Pointwise User Group Meeting 2011 on 8-9 November 2011 in Fort Worth. We invite you to join us, see the current state of the art in meshing, and help us plan the future.

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FocalPoint is a publication of Pointwise, Inc. It is for Gridgen and Pointwise users and people interested in learning more about numerical grid generation. It includes information about the software, latest releases, future development plans, and tips on how to get the most out of Gridgen and Pointwise while saving time in grid generation.

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Volume 15 Issue 1 Spring 2011

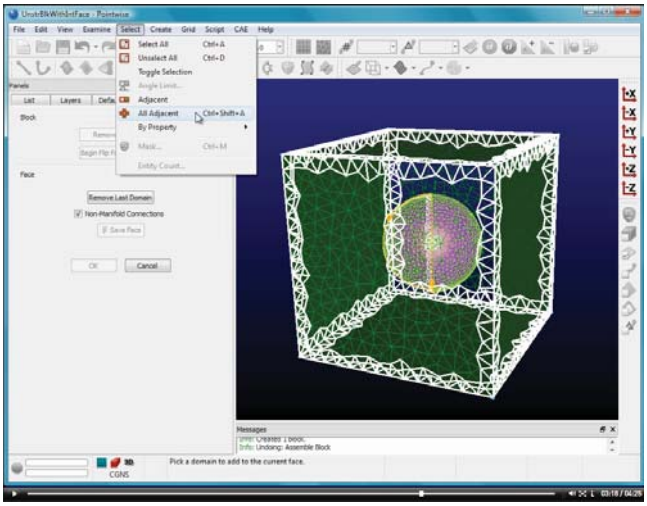
DIY Video Makes Unstructured Block With Interior Faces Fast, Easy

Make short work of an unstructured block with interior faces after watching the Do-It-Yourself (DIY) video at www.pointwise.com/DIY/. It only takes a few minutes to learn how it's done.

Interior faces are used when there is a portion of the volume inside a block in which you do not want to put grid points. The video "Creating an Unstructured Block With an Interior Face" describes how to build the outer face of the block using Pointwise's Select Adjacent command to speed the selection process. The video then steps you through how to be sure the face is properly oriented and how to add an interior face for the sphere.

Online video training helps you enhance your skills while accommodating your schedule and professional needs. There are three types of videos available:

- High level feature demos – Learn how to use high level features in Pointwise to impact common meshing problems at www.pointwise.com/videos/.
- Webinars – Explore the details of important feature sets in our webinar library at www.pointwise.com/webinar/.
- Do-It-Yourself Training – Get information quickly with short and simple training at www.pointwise.com/DIY/.



This DIY video shows how to add an interior face to an unstructured block.

Another Fine Mesh Blog

Another Fine Mesh, Pointwise's blog, is a forum for computer aided engineering, where we and our guests share ideas and opinions about hardware, software, the industry and personalities.

Join the conversation: www.pointwise.com/follow