

Altair HyperWorks 2024 新版本发布会

AI 赋能技术创新，开启仿真新篇章

2024年8月28日 | 北京



LBM +GPU: CFD 流体仿真的超级加速器

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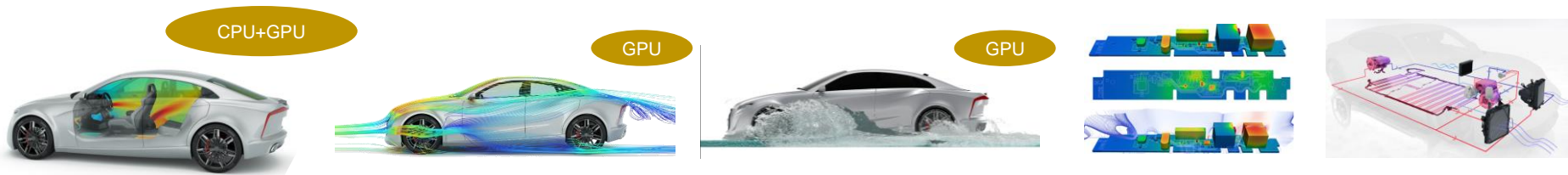
ultraFluidX

- 1 Altair CFD概述**
流体建模工具和求解器
- 2 空气动力学**
HyperMesh CFD虚拟风洞
- 3 风扇噪声**
CAA计算声学法
- 4 乘员舱噪声**
CFD耦合SEA统计能量法
- 5 GPU高性能计算**
推荐GPU类型

Altair CFD概述

适用于不同应用场景的CFD求解器

- AcuSolve: FEM算法, 通用热-流体分析
- **ultraFluidX**: LBM算法, 虚拟风洞、车辆空气动力学、气动噪声
- nanoFluidX: 前后处理SimLab集成, SPH算法, 传动系统润滑、液体晃动、涉水
- SimLab Electronics Thermal: 前后处理SimLab集成, FVM算法, PCB板级, 电子设备机箱散热仿真
- Flow Simulator: 一维流动和热网络, 系统级CFD仿真



通用热流体

空气动力学

涉水和传动系统

电子散热

一维流体系统

AcuSolve

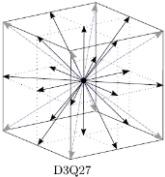
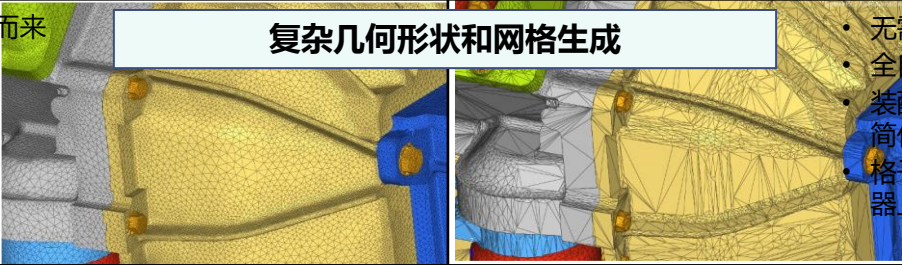
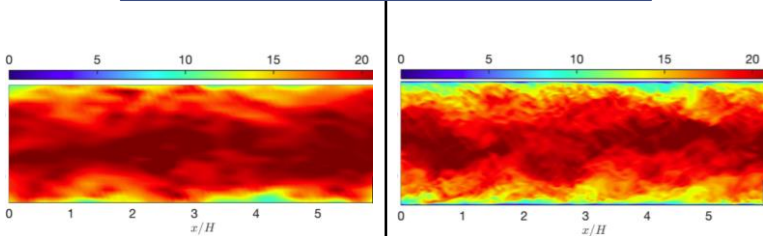
ultraFluidX

nanoFluidX

Electronics Thermal

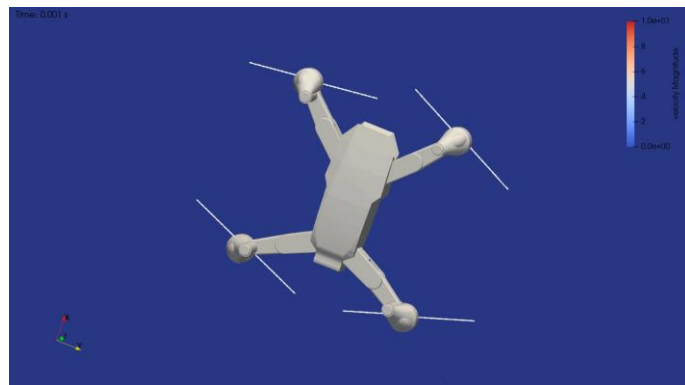
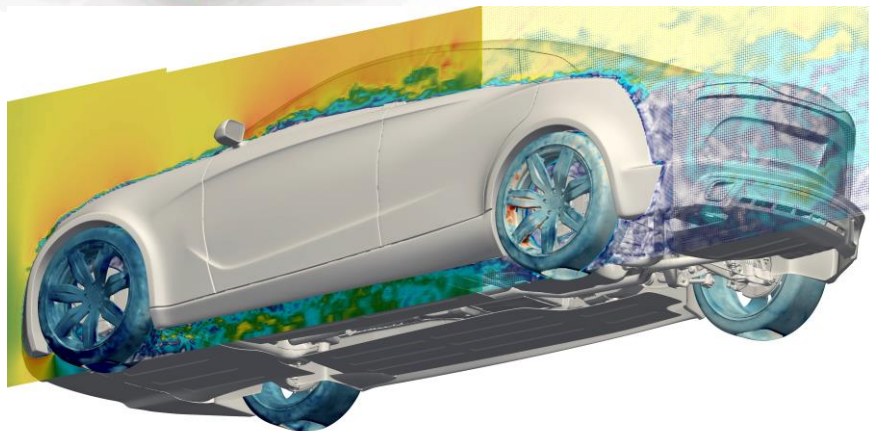
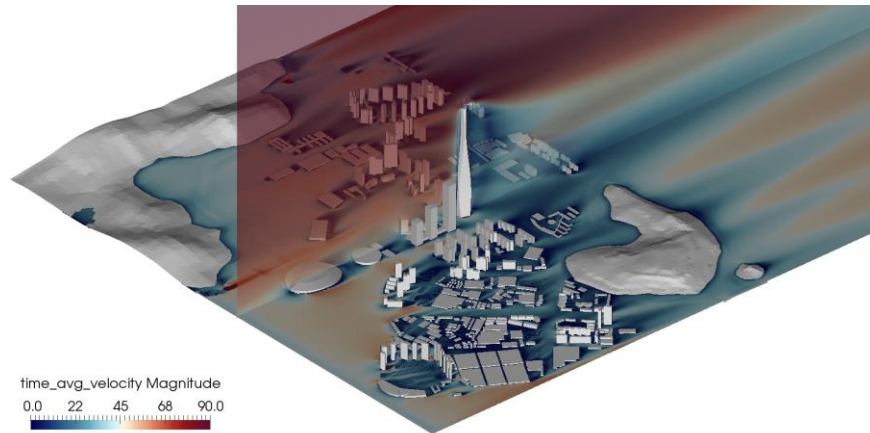
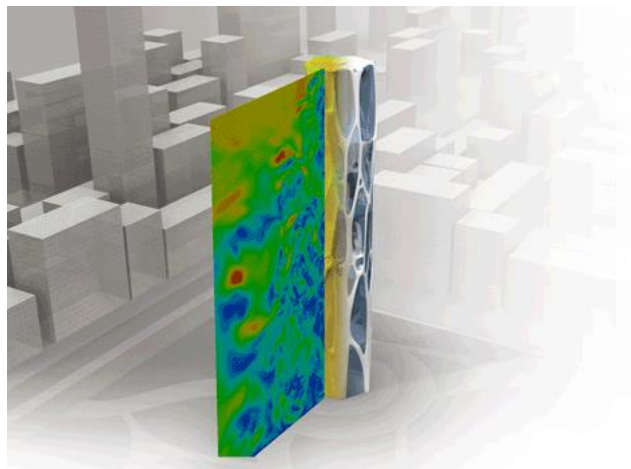
FlowSimulator

LBM算法与传统网格法CFD的优势

传统网格CFD (RANS Based)	Lattice Boltzmann
<ul style="list-style-type: none"> 被视为连续体的流体：纳维-斯托克斯方程 (PDE) 离散计算网格上偏微分方程的数值求解 $\left(\frac{\partial}{\partial t} + u_j \frac{\partial}{\partial x_j} - \nu \frac{\partial^2}{\partial x_j \partial x_j} \right) u_i = - \frac{\partial w}{\partial x_i} + g_i$	<p style="text-align: center;">数值方法</p>  <ul style="list-style-type: none"> 由在规则晶格网格上移动的离散粒子表示的流体 通过简单的粒子迁移和碰撞实现的数值解 高效的数值方案 在宏观尺度上完全恢复纳维-斯托克斯方程 $f_\alpha(t + \Delta t, \mathbf{x} + \mathbf{e}_\alpha \Delta t) = f_\alpha(t, \mathbf{x}) + \Omega_\alpha$
<ul style="list-style-type: none"> 流体体积网格从固体表面网格生长而来 必须简化复杂的几何形状 手动/半自动网格生成 	<p style="text-align: center;">复杂几何形状和网格生成</p>  <ul style="list-style-type: none"> 无需简化的 CAD 几何形状 全自动流体体网格 (格子) 生成 装配体允许穿透和干涉, 原始CAD无需简化 格子 (Voxel) 基于模板文件在GPU服务器上生成, 设计变动仅需替换STL文件
<ul style="list-style-type: none"> 模拟大多以稳态运行 非定常模拟代价较高 高质量体积网格 不保证数值收敛 	<p style="text-align: center;">瞬态计算和稳健性</p>  <ul style="list-style-type: none"> 模拟本质上是瞬态的 求解非稳态Smagorinsky LES大涡模拟模型 低数值耗散 更好的 HPC 扩展性能 稳定性强 完全基于NVIDIA GPU加速

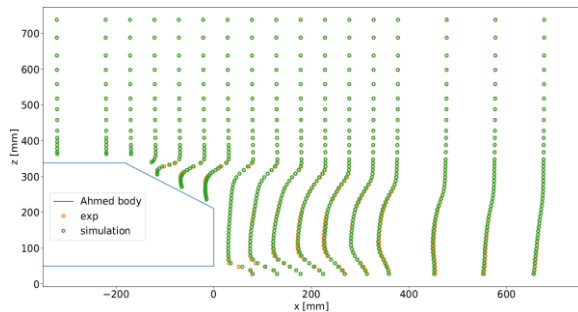
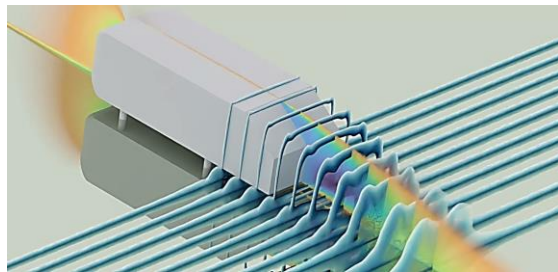
空气动力学

ultraFluidX的应用：低速空气动力学

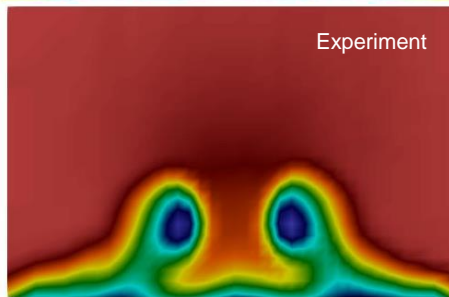
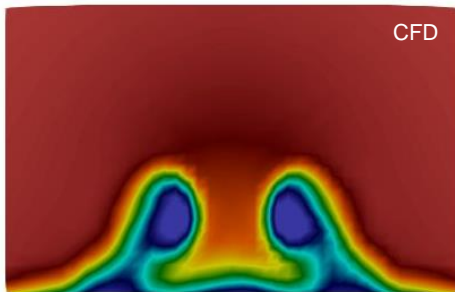


ultraFluidX的应用：低速空气动力学

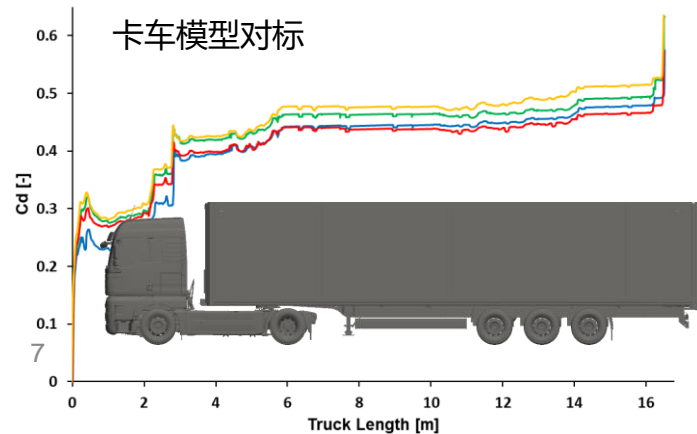
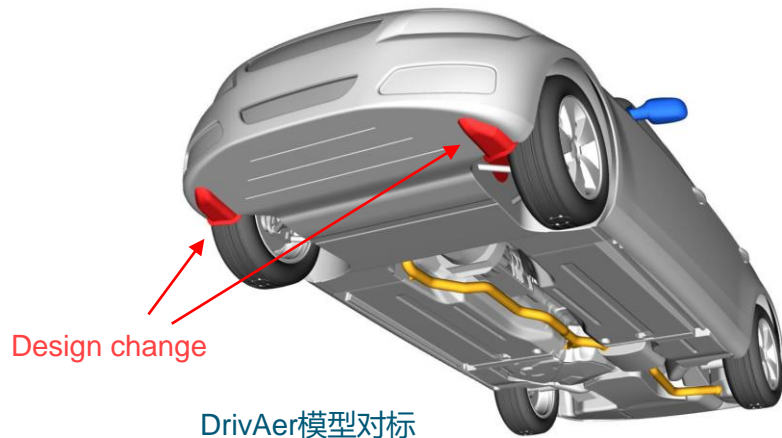
更新了湍流壁面函数



Ahmed Body对标

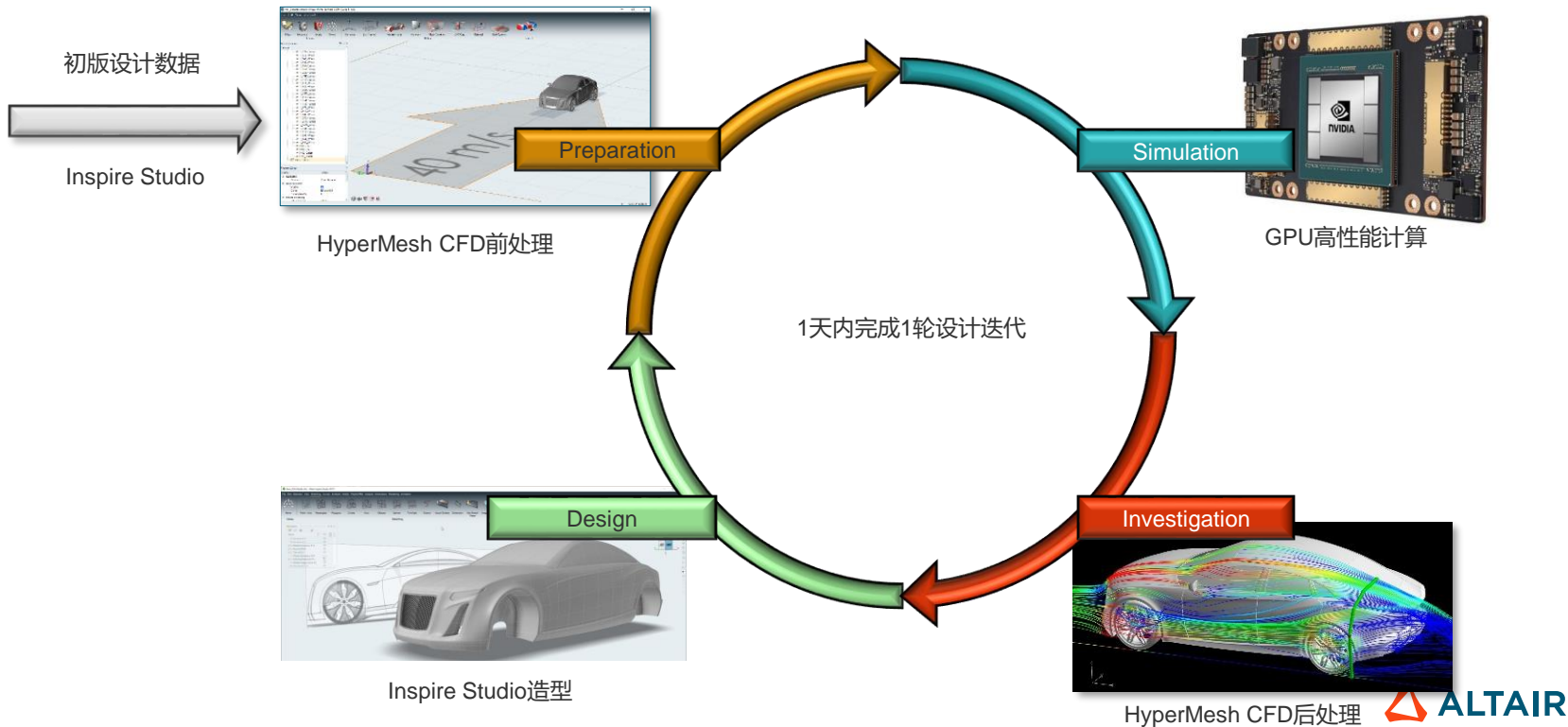


尾迹区预测

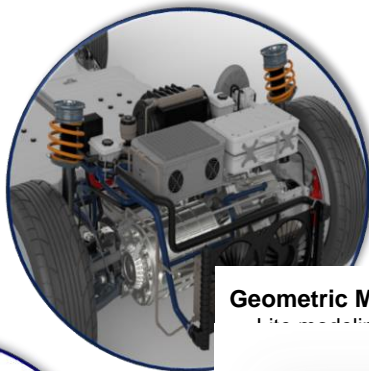


空气动力学设计优化流程

造型和仿真深度融合，借助高性能GPU计算服务器，1天以内完成1轮设计迭代

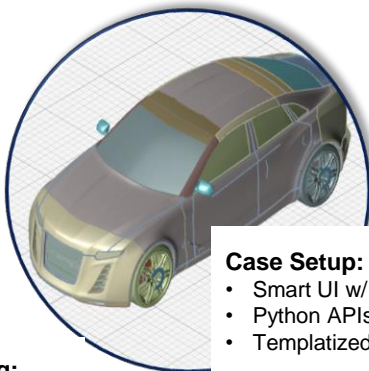


Hypermesh CFD 快速的前后处理工具



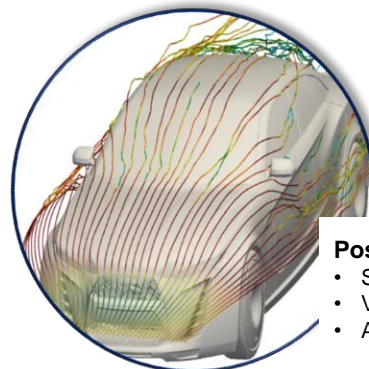
Geometric Modeling:

Mesh generation



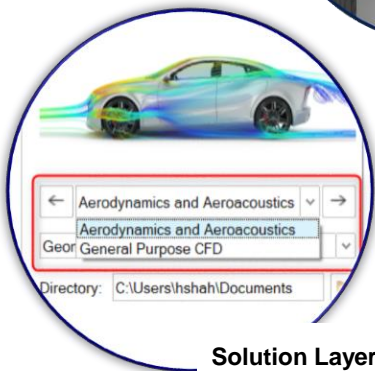
Case Setup:

- Smart UI w/ Best Practices
- Python APIs
- Templated process



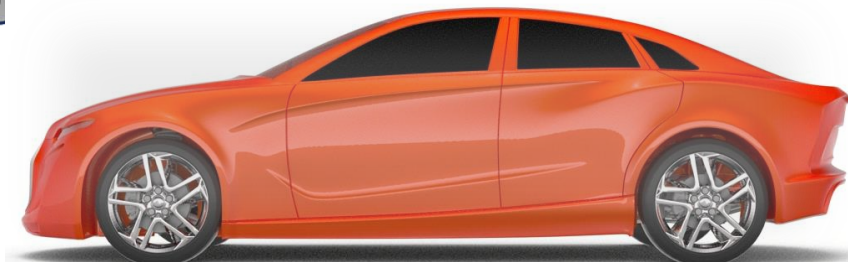
Post-processing:

- Signal processing
- Volume rendering
- Auto reporting tool



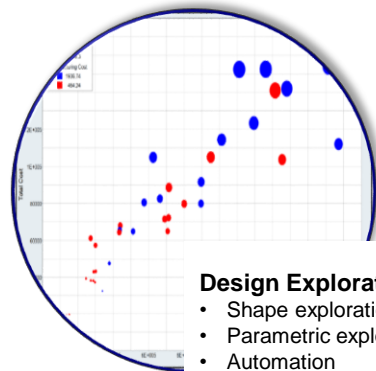
Solution Layer:

- Single UI integration
- Solution centric workflows
- Efficient Data handling



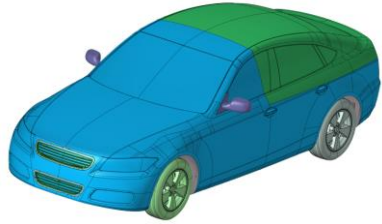
HyperMesh CFD 2024

整车建模, CFD参数设置, CFD后处理



Hypermesh CFD 前处理

STL



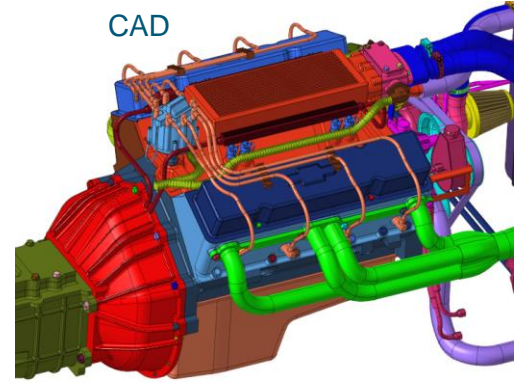
offset



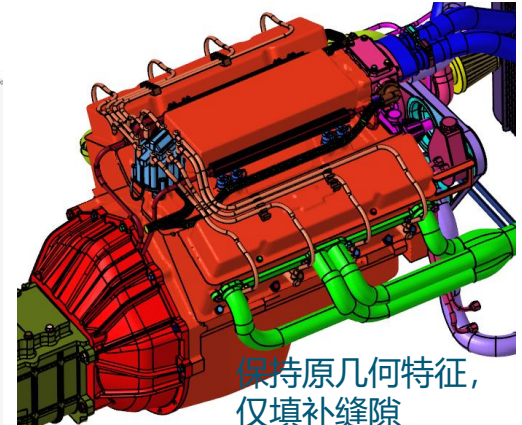
projected



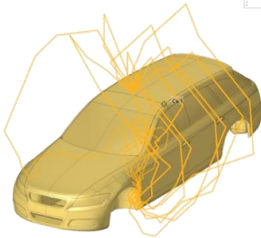
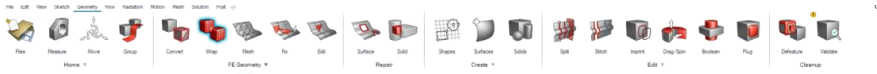
CAD



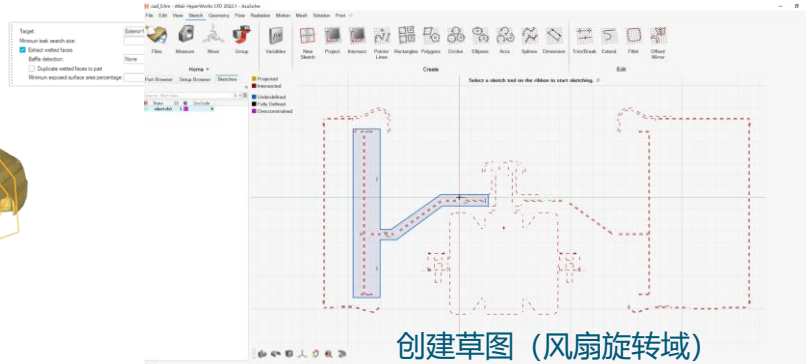
STL



保持原几何特征,
仅填补缝隙



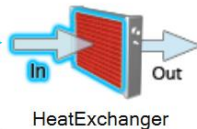
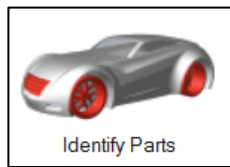
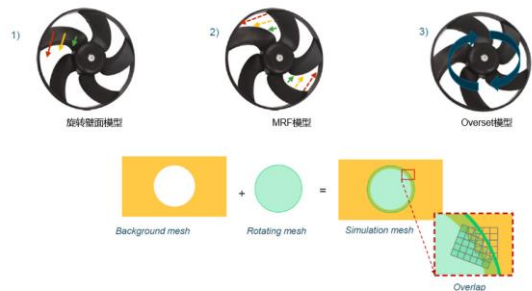
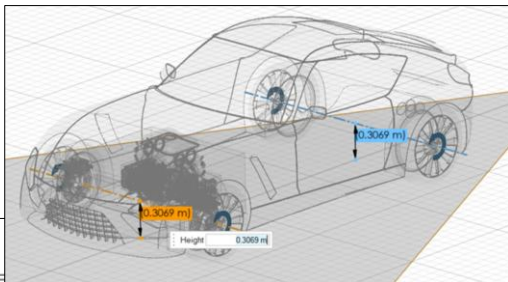
车身封闭性检查



创建草图 (风扇旋转域)

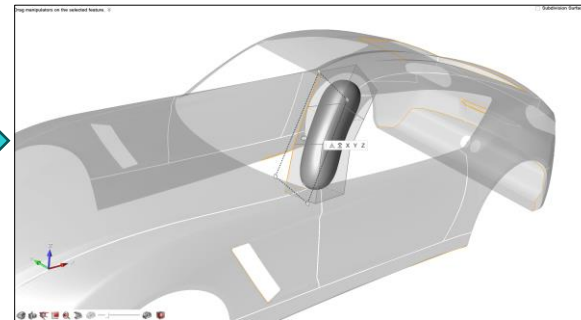
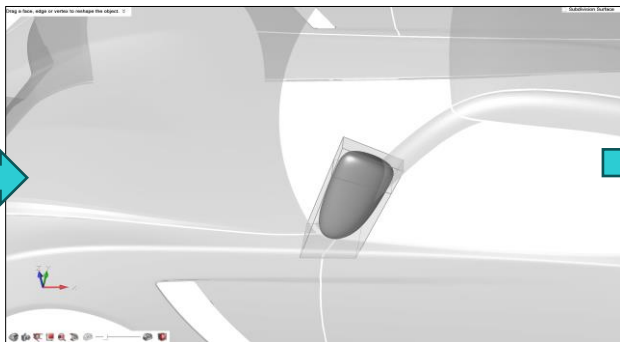
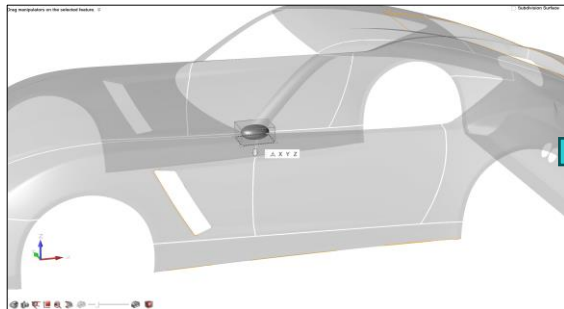
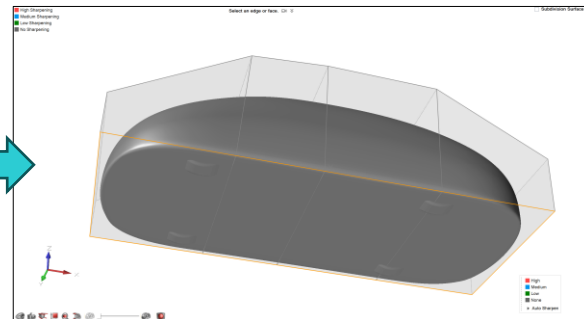
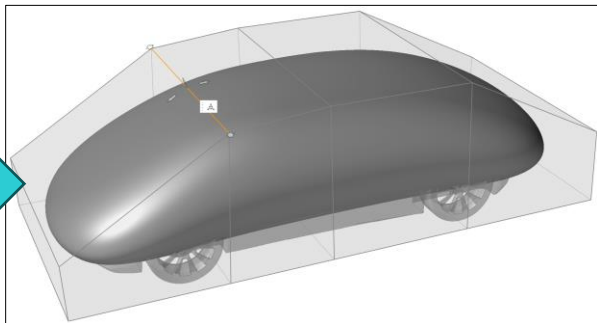
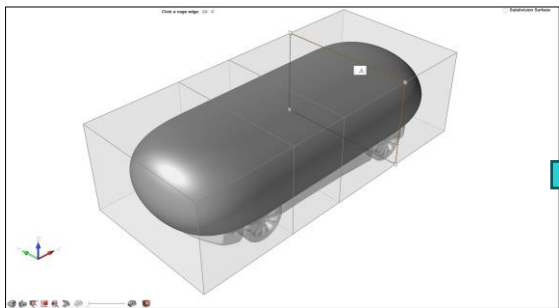
Hypermesh CFD求解设置

- 多孔介质 (换热器)
- 地面移动系统 (5带, 单带), 边界层抽吸
- 旋转体识别 (风扇, 轮胎)
- 格子加密
- 悬架高度调整
- 监测点, 监测面, 切面定义等输出选项
- 悬架高度调节



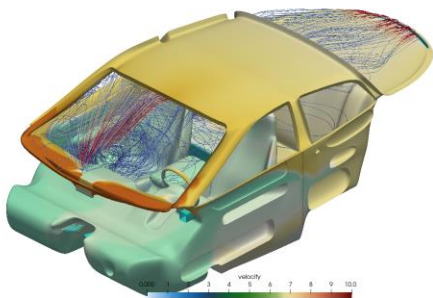
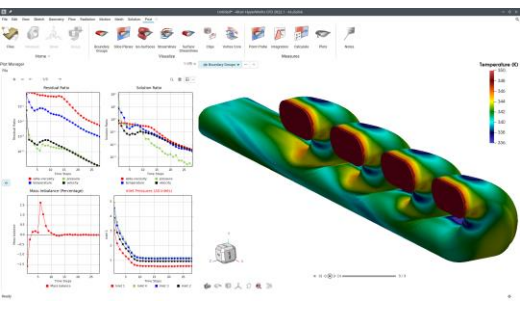
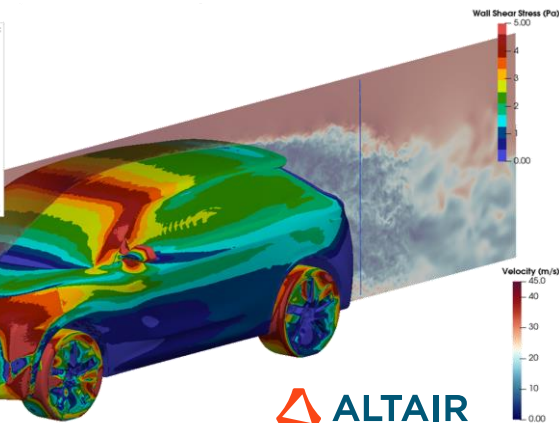
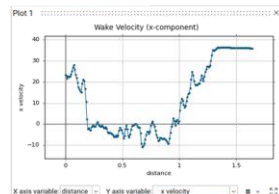
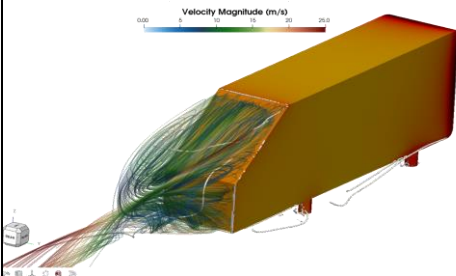
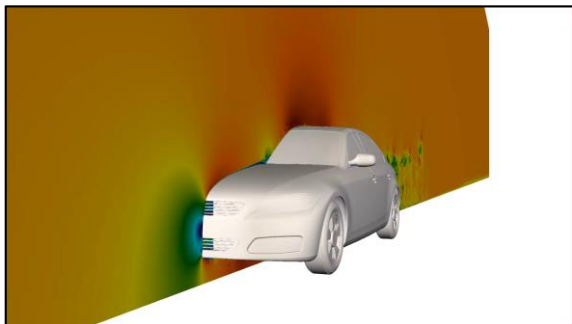
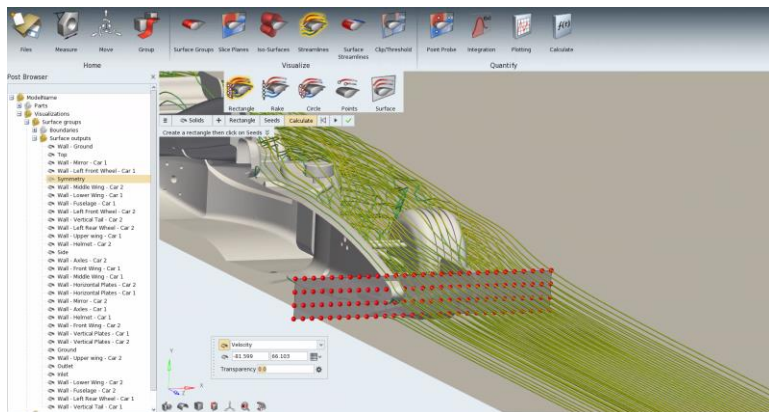
Hypermesh CFD快速造型设计

快速调整造型或加密区域形状



Hypermesh CFD后处理

- 通用CFD后处理：
 - 支持格式：LBM、传统网格法CFD结果， Enight, h3d结果
 - 云图、矢量图，动画、流线、积分、XY Plot等等



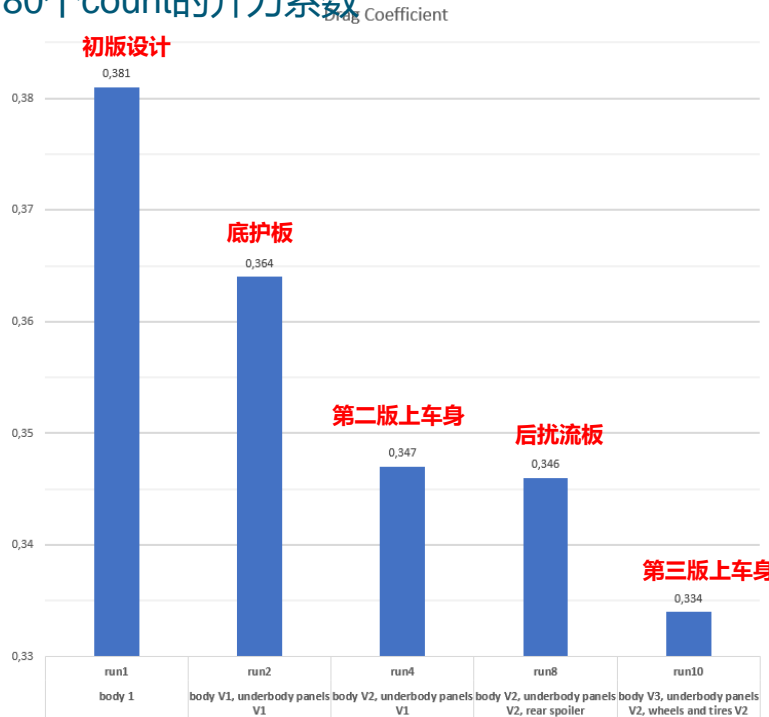
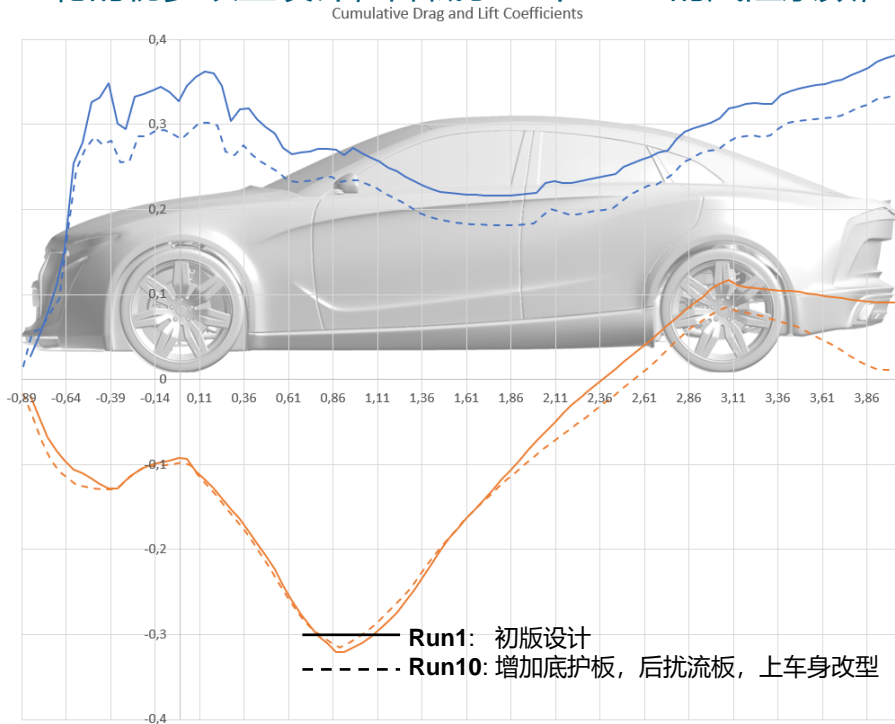
Hypermesh CFD自动出具报告

External Aerodynamics Results Report Template

HWCFD | Altair

空气动力学设计快速迭代

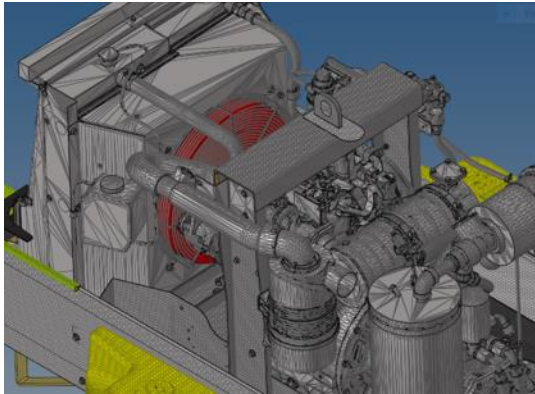
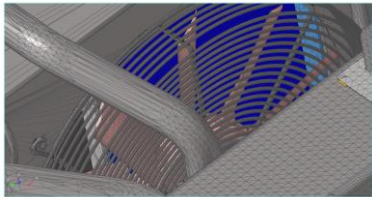
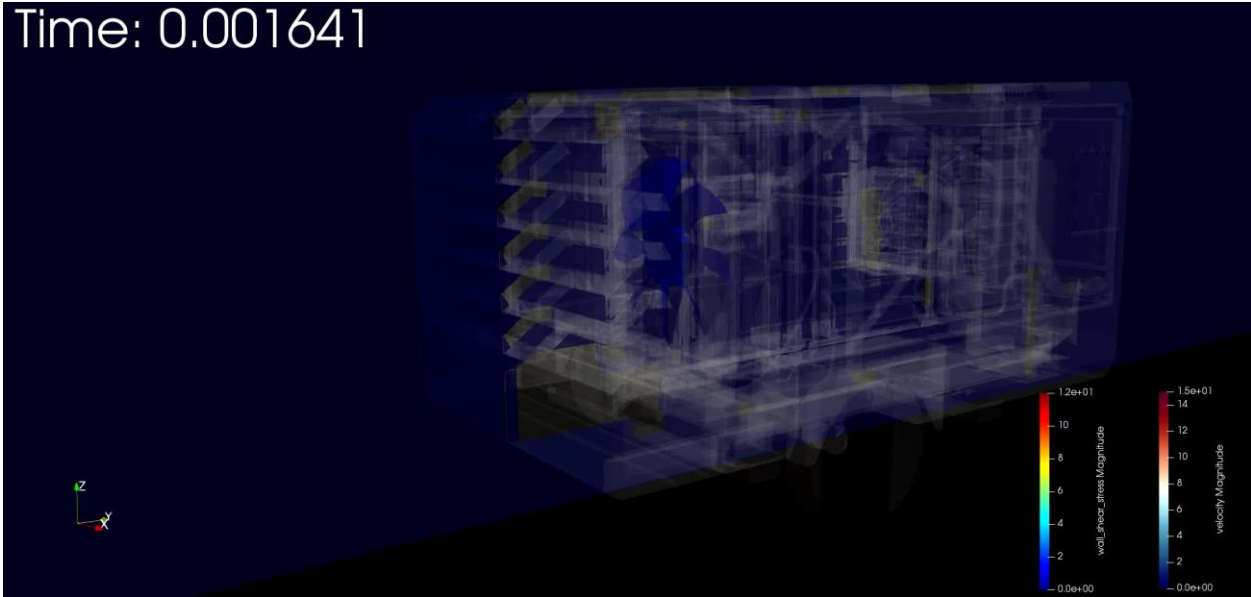
10轮的初步改型设计，降低了47个count的风阻系数，和80个count的升力系数



风扇噪声

ultraFluidX: 近场噪声

Time: 0.001641

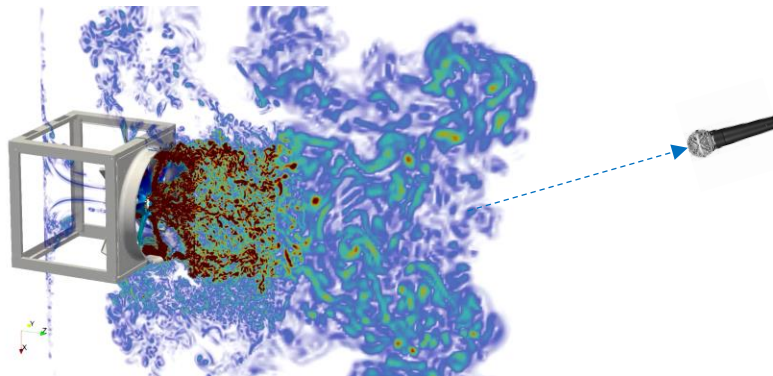


包含全细节的机舱模型，总格子数6亿
8张A100 GPU计算2天

ultraFluidX: FW-H模型

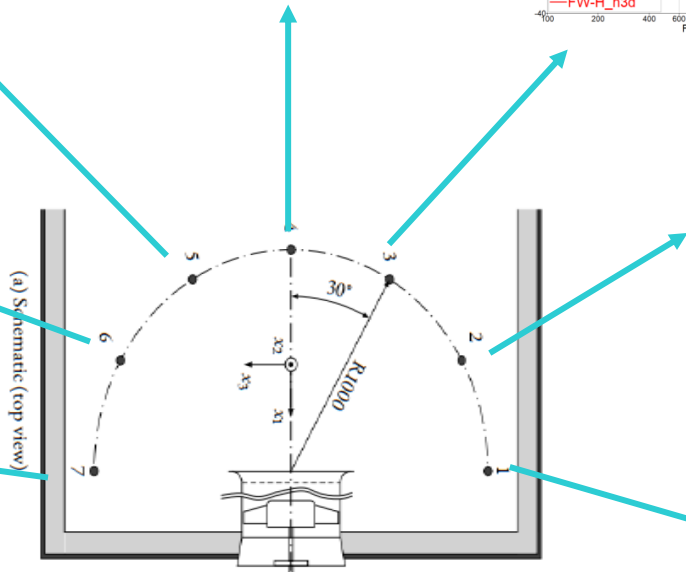
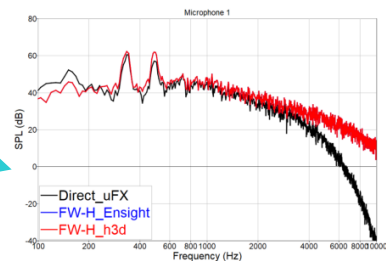
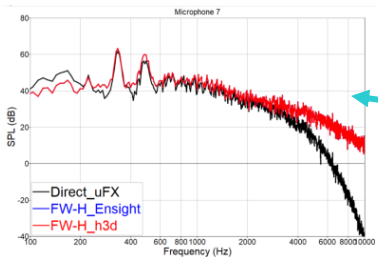
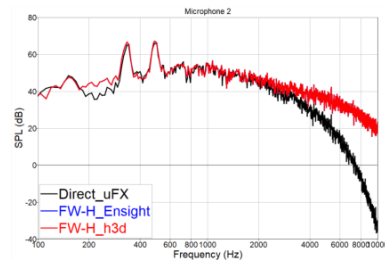
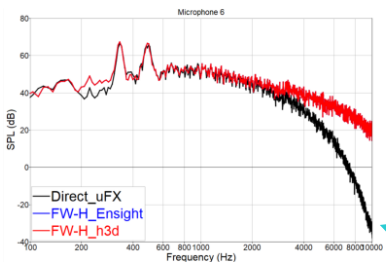
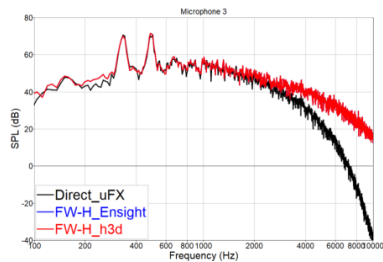
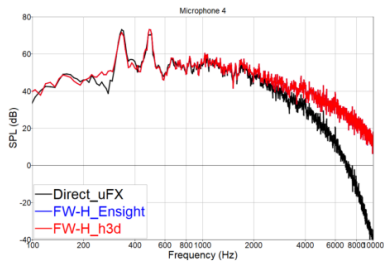
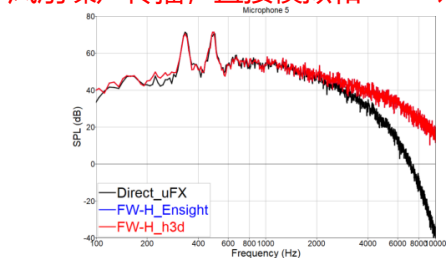
噪声远场传播

- ultraFluidX可以直接模拟从噪声源到接收端的声传播现象。如果传播距离较长，格子总数会增加
- FW-H模型基于声学类比法，单独求解波动方程模拟噪声的传播
 - 适合接收端距离声源较远的情况，减少了格子总数
 - 声波是自由传播的，可以考虑XYZ方向的反射和吸收
 - 在前处理建模中需要创建一个包裹住声源的监测面，记录监测表面上的压力脉动



ultraFluidX: FW-H模型

风扇噪声传播，直接模拟和FW-H对比



如果声波传播路径上的格子尺寸太粗，在高频部分会造成信号衰减，FW-H模型可以避免这种情况

Hypermesh NVH噪声信号处理-监测点的信号

The screenshot displays the Hypermesh NVHPost software interface. The top menu bar includes File, Edit, View, Standard NVH, NVHPre, and NVHPost. The main toolbar contains icons for Files, Job Manager, Network View, MPA/PPA, GPA, Energy, TPA, DSA, Order Analysis, Modal FRF, Correlation, Radiated Sound, Global Modes, General Signal Processing (highlighted with a red box), and Green House Noise. The interface is divided into Home, Diagnose, and Evaluate sections.

On the left, the 'Load' panel shows project settings, and the 'Probes' panel is configured for 'Element ID' with 'All Probes' selected. A red arrow points to the 'Load' button with the text '导入xxx_pressure.csv文件'. The 'Signal Processing Parameters' panel shows 'Block Size' set to 4096 and 'Time Windowing' set to 'Hanning'. A red arrow points to the 'Time Domain' option in the 'Output Request' section with the text '时域/频域'.

The main plot area, titled 'Raw Data', shows a time-domain pressure signal. The y-axis is labeled 'Pressure' and ranges from -700 to 100. The x-axis is labeled 'Time(s)' and ranges from 0.00003 to 1.09892. The plot shows a signal that starts at 0, drops sharply to approximately -600 by 0.18318 seconds, and then exhibits high-frequency noise between -400 and -600. A red arrow points to the plot with the text '时域曲线'. A red double-headed arrow at the bottom indicates a time interval from 0.36632 to 1.09892 seconds, with the text '取0.3秒后稳定时间段数据做信号处理。' (Take data from the stable time interval 0.3 seconds later for signal processing).

Legend for the plot: Probe_1(2) - Raw Data - Pressure (blue), Probe_2(3) - Raw Data - Pressure (green), Probe_3(4) - Raw Data - Pressure (red), Probe_4(5) - Raw Data - Pressure (purple), Probe_5(6) - Raw Data - Pressure (orange).

Text 'AIR' is visible in the bottom right corner.

Hypermesh NVH 噪声信号处理-监测点的信号

The image shows the HyperMesh NVH software interface with the 'NVH-Utilities' plot window open. The 'Probes' section is active, showing settings for signal processing. A red box highlights the 'General Signal Processing' icon in the top toolbar. The plot window displays a 'Sound Pressure' frequency spectrum with six data series representing different probes. The y-axis is 'Magnitude' (20 to 106) and the x-axis is 'Frequency (Hz)' (100 to 8000). A legend identifies the series as 'Probe_1(2) - Narrowband - SPL (dBA)' through 'Probe_5(6) - Narrowband - SPL (dBA)'. A text box in the bottom left of the plot provides details: 'UltraFluidX Result File: uFX_surfaceProbes_Surface_Probe_1_pressure.csv', 'Time Duration: 0.3 to 1.098920 sec', 'Sampling Freq: 37156.47 Hz', 'Cp Factor: 1.00', 'Plot Type: Narrowband', 'Frequency Range: 100 Hz to 10000 Hz', 'Bandwidth: 8 Hz', 'Overlap: 50%', and 'Time Windowing: Hanning'. Red arrows point from Chinese labels to specific settings: '采样频率' (Sampling Frequency) points to 'Saap. Freq: 37156', '采样起点时间' (Sampling Start Time) points to '0.00003 to 1.0', '采样终点时间' (Sampling End Time) points to '0.3 sec to 1.098920 sec', '样本点数量' (Number of Sample Points) points to 'No Of Steps: 29685', '数据重叠度' (Data Overlap) points to 'Overlap %: 50', '分辨率带宽' (Resolution Bandwidth) points to 'Bandwidth: 8', and '窗函数' (Window Function) points to 'Hanning'.

- 采样起点要从信号稳定段开始
- Display频率的上限是采样频率的一半
- Block size和Bandwidth二选一，分辨率越高要求样本量越大
- Export Data可以将SPL/PSD曲线转为*csv

频域曲线

窗函数

数据重叠度

分辨率带宽

样本点数量

采样起点时间

采样频率

采样终点时间

21

Hypermesh NVH 噪声信号处理-流场的FFT

The screenshot displays the Hypermesh NVH software interface, specifically the NVHPost module. The top toolbar includes icons for Files, Job Manager, Network View, MPA/PPA, GPA, Energy, TPA, DSA, Order Analysis, Modal FRF, Correlation, Radiated Sound, Global Modes, General Signal Processing (highlighted with a red box), and Green House Noise.

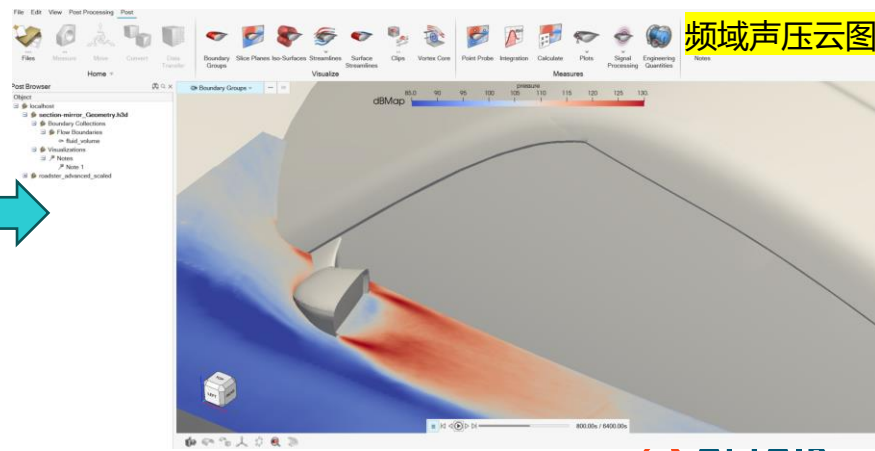
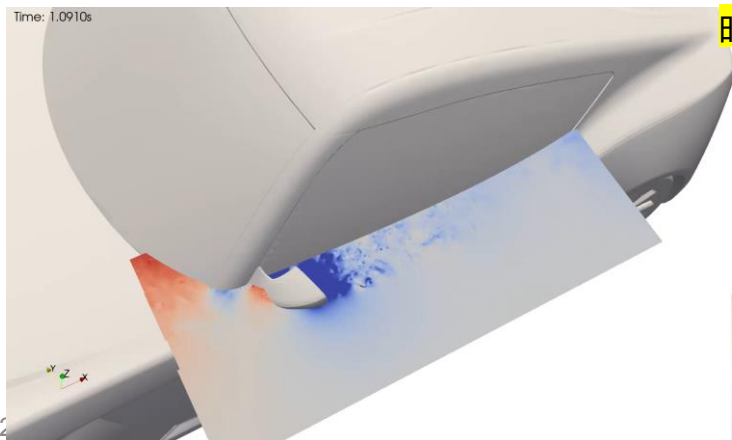
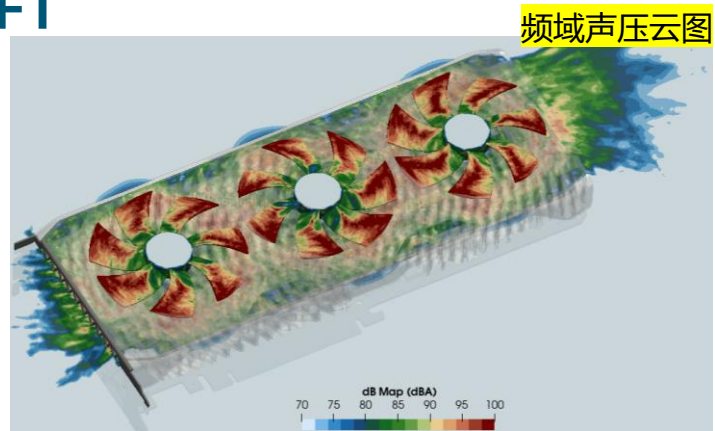
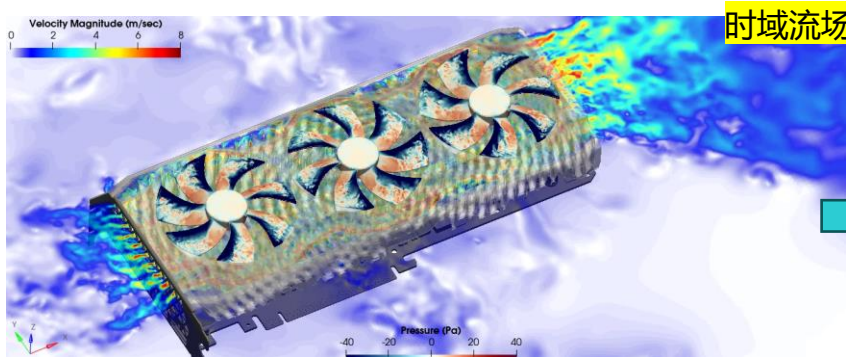
The main workspace is divided into a settings panel on the left and a visualization area on the right. The settings panel includes:

- Project Information:** Project Type (New Project), Project File, and UltraFluidX Result File.
- Probes:** Surface (highlighted with a red box).
- Input Selection:** Input Time Duration (0.29976 to 1.09892) and Samp. Freq. (18578). A red arrow points to the Samp. Freq. field with the label "样本的采样频率".
- Time Range:** Time Duration (0.299759 to 1.098920) with a red arrow pointing to the field and the label "时间范围".
- Output Request:** Band Type (1/3 Octave), Frequency Filter (50 Hz to 7500 Hz), and Signal Processing Parameters (Block Size 1161, Bandwidth 16, Overlap % 50, Time Windowing Hanning). A red arrow points to the Bandwidth field with the label "带宽".
- Result Generation:** Frequency Filtered Transient Animation (checked), dBMap (unchecked).
- Result Visualization:** Result File (section-mirror_3rdOctave), Report Generation (XY Top View), and Legend Min. (20) Max. (80). A red arrow points to the Legend Max. field with the label "选择频率范围".

The visualization area shows two contour plots:

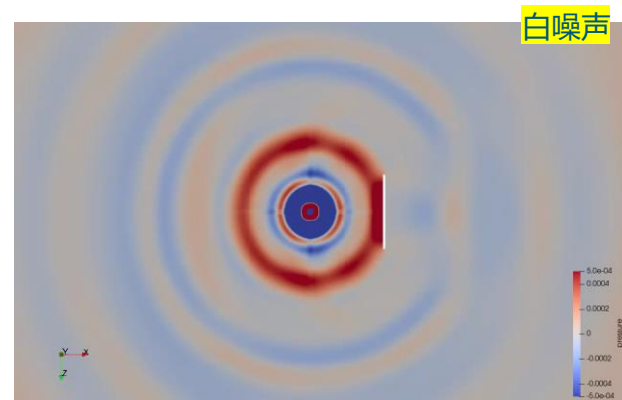
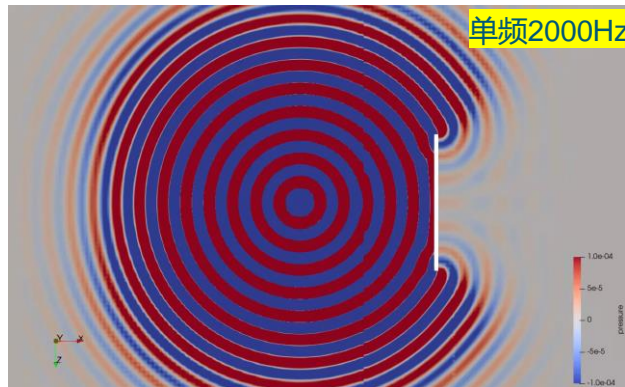
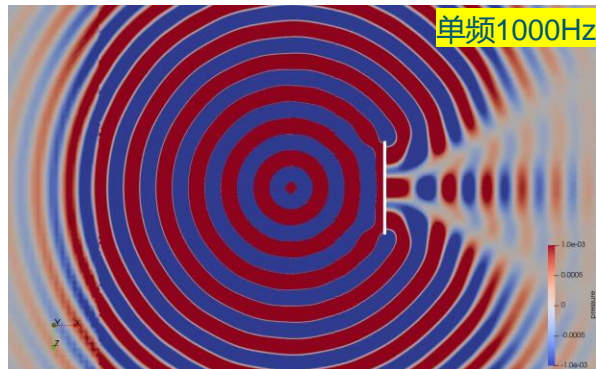
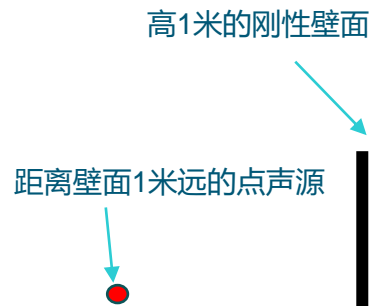
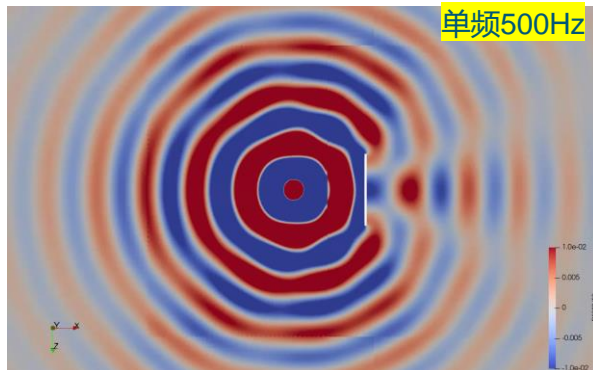
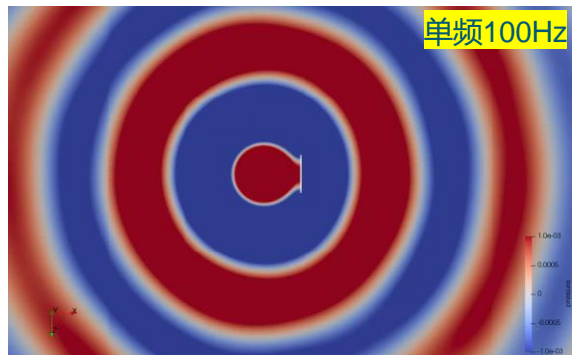
- Top Plot:** Contour Plot Pressure(Scalar value) for Frequency = 100 [89 - 89] Hz. The color scale ranges from -3.102E+01 to 2.432E+01. A red arrow points to the plot with the label "FFTA (Frequency Filtered Transient Animation)".
- Bottom Plot:** Contour Plot Pressure(Scalar value, Max) Simple Average for Frequency = 100 [89 - 112] Hz. The color scale ranges from 76 to 151. A red arrow points to the plot with the label "声压云图".

Hypermesh NVH 噪声信号处理-流场的FFT



ultraFluidX:模拟点声源

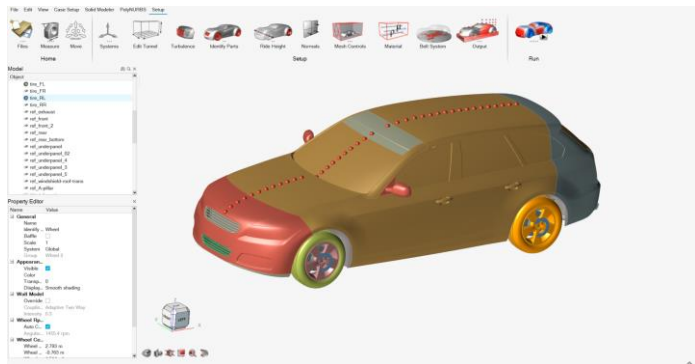
模拟声波的反射和衍射现象



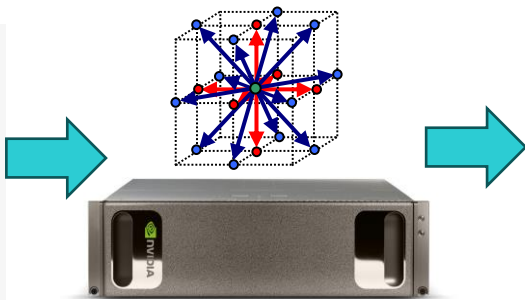
乘员舱噪声

汽车乘员舱风噪仿真流程

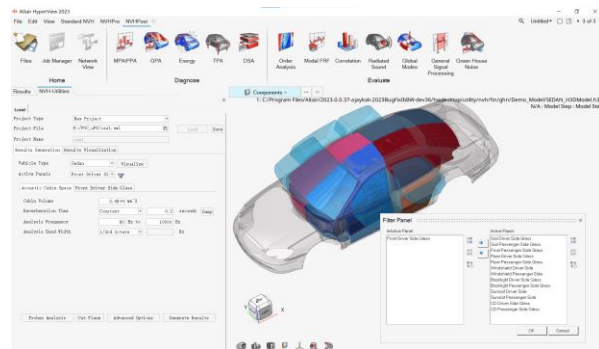
© Altair Engineering Inc. Proprietary and Confidential. All rights reserved.



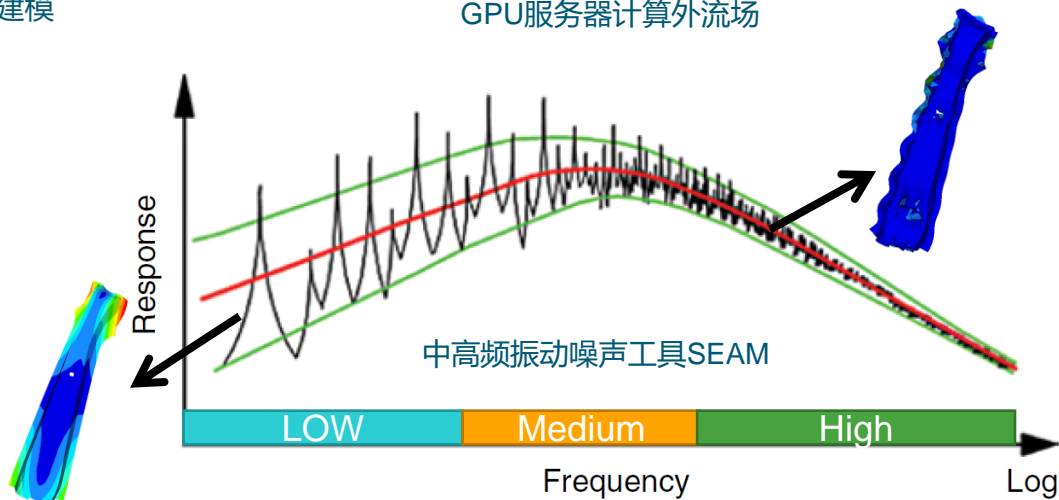
HyperMesh CFD
虚拟风洞建模



ultraFluidX
GPU服务器计算外流场

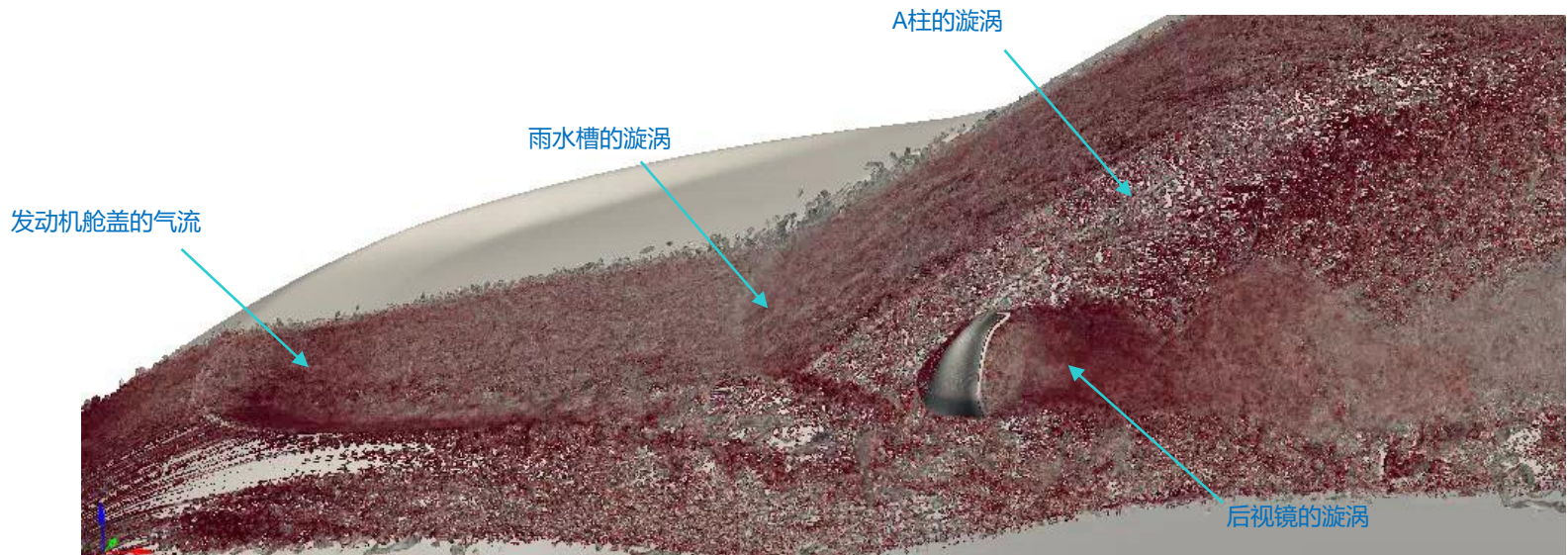


HyperMesh NVH
风噪分析专用工具



汽车乘员舱风噪仿真

- 风噪控制是细节决定成败，关键部位的微小变动都会对噪声产生显著影响，因此CFD仿真需要高保真度的瞬态解，车窗附近的分辨率约在0.5mm，信号采集频率约在20kHz，捕捉不同空间/时间尺度的精细湍流结构。
- 外流场噪声向舱内的噪声传播采用统计能量法工具SEAM计算，得到车内的声压级和语音清晰度



Hypermesh NVH 噪声信号处理

汽车乘员舱内的噪声曲线

Results Generation Results Visualization

Interior Noise Levels Plotting

Microphone Location: Front Driver Side Ear **麦克风位置**

Band Type: 1/3rd Octave

Source Type Contribution Overall **声源类型**

Panel Contribution **玻璃面板类型**

Display Options Display Export Data

dBMaps Visualization

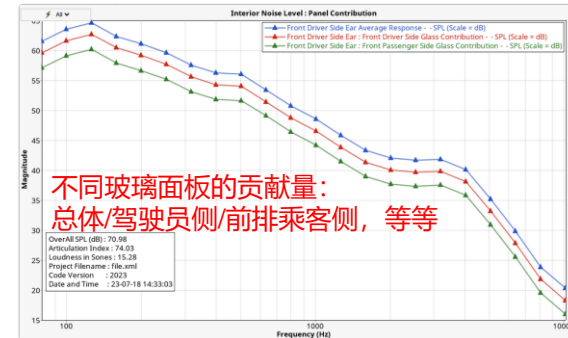
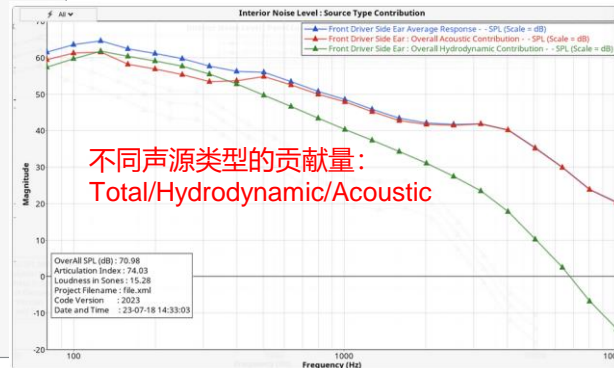
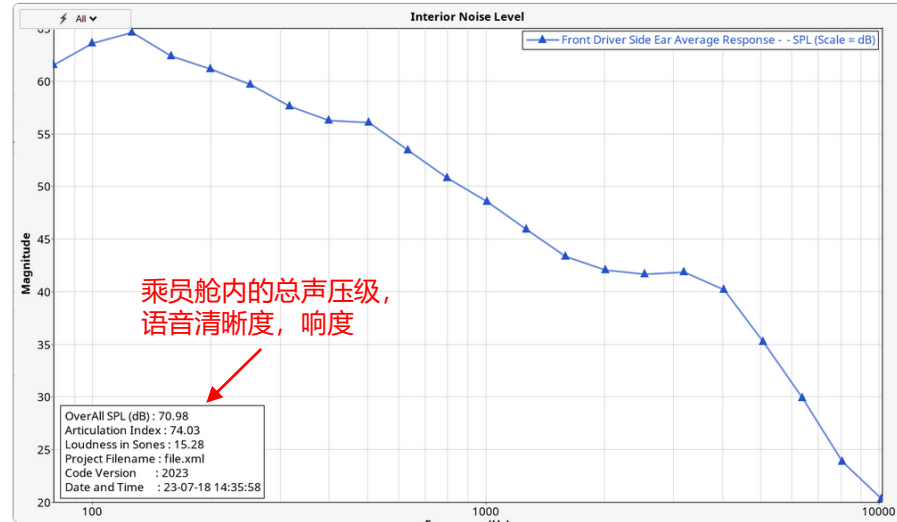
dBMap Selection: Hydrodynamic dBMap

GHN Panel: Overlay

Subcase: Octaves Result

Select Frequency Step

- Frequency = 125 [88 - 177] Hz
- Frequency = 250 [177 - 354] Hz
- Frequency = 500 [354 - 707] Hz
- Frequency = 1000 [707 - 1414] Hz
- Frequency = 2000 [1414 - 2828] Hz
- Frequency = 4000 [2828 - 5657] Hz
- Frequency = 8000 [5657 - 1131] Hz



Hypermesh NVH 噪声信号处理

车窗玻璃表面的声压云图

Results Generation Results Visualization

Interior Noise Levels Plotting

Microphone Location: Front Driver Side Ear

Band Type: 1/3rd Octave

Source Type Contribution: Overall

Panel Contribution

Display Options Display Export Data

dBMaps Visualization

dBMap Selection: Hydrodynamic dBMap

GHN Panel: Overlay

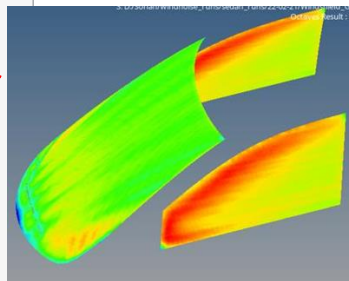
Subcase: Octaves Result

Select Frequency Step

- Frequency = 125 [88 - 177] Hz
- Frequency = 250 [177 - 354] Hz
- Frequency = 500 [354 - 707] Hz
- Frequency = 1000 [707 - 1414] Hz
- Frequency = 2000 [1414 - 2828] Hz
- Frequency = 4000 [2828 - 5657] Hz
- Frequency = 8000 [5657 - 11300] Hz

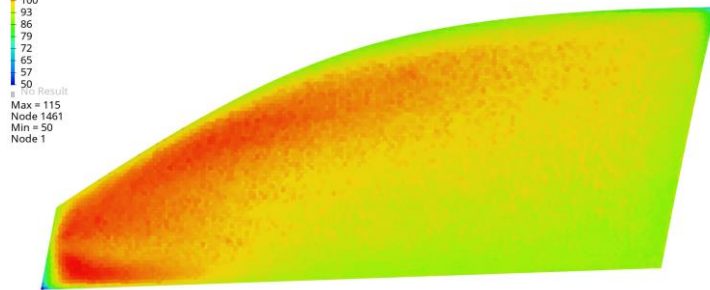
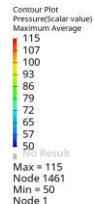
声压类型

选择频率范围

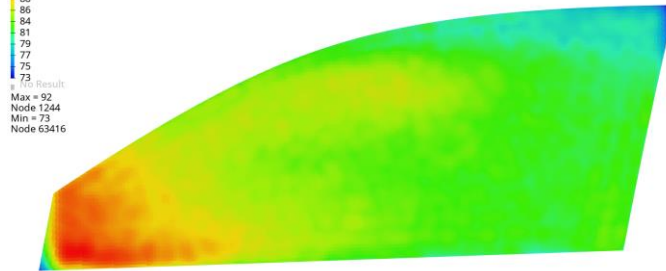
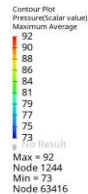


多个玻璃的单个/重叠显示

Hydrodynamic dBMap



Acoustic dBMap

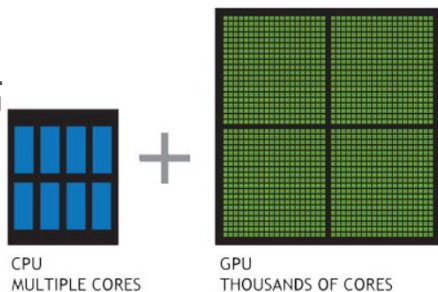


GPU高性能计算

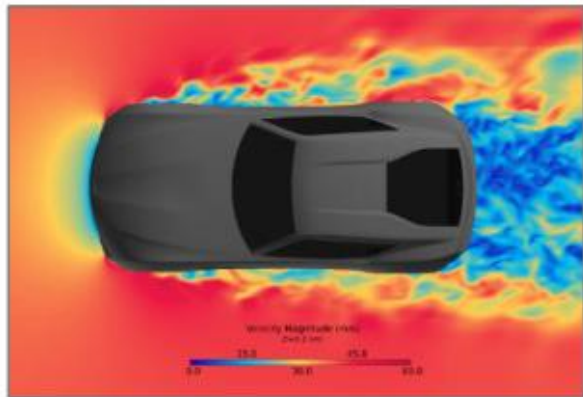
GPU高性能计算

相比传统CFD求解器，GPU求解效率极大提高

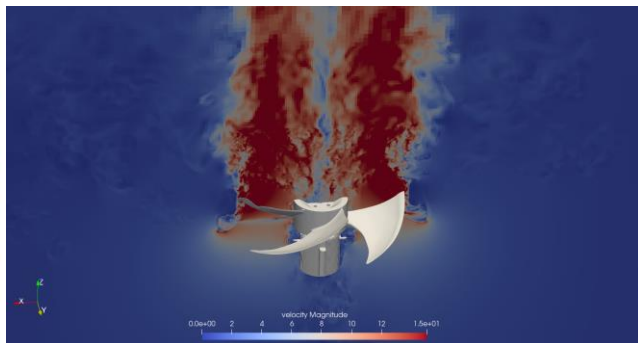
- 求解器基于NVIDIA GPU优化
- 更少的硬件投资和更短的仿真周期



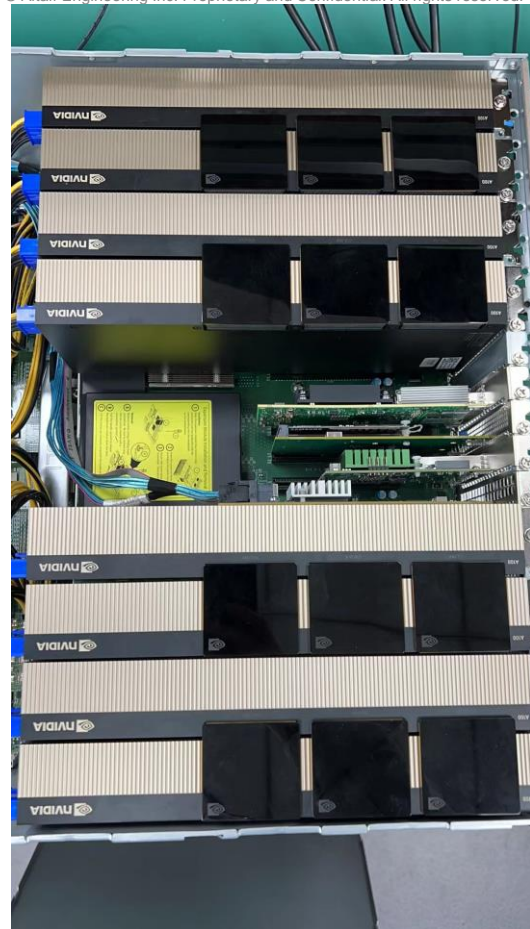
CPU与GPU架构比较



整车外流场模型
1亿4千万格子，2*A100计算7~12小时



轴流风扇噪声模型
3亿格子，2*A100计算1~2天



8*A100计算服务器

GPU高性能计算

GPU主要参数


- 显存大小：影响模型计算规模
 - NVLink/PCIE：多GPU通讯效率
 - GPU显存带宽：通讯效率
 - 浮点计算TFLOPS：解方程效率
 - CUDA核心数：解方程效率
 - 功耗：发热量和电力消耗
- ## CFD大模型推荐GPU类型
- 英伟达H100/A100/A6000/L40/L20
 - 主流计算卡显存>48G

相同的LBM模型，A100 NVLink
比PCIE快2.8倍

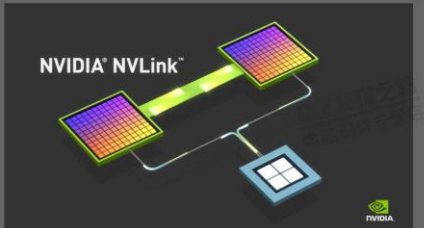
GPU Configuration	A100-PCIe-80GB	A100-SXM4-40GB
# of GPU's	02	02
# of Fluid Voxels (Mn)	104	104
Physical Time (s)	2	2
# of Coarse Iterations	1522	1522
Pre-processing Time (s)	3956	3485
Initialization Time (s)	248	227
Run & Data Export Time (s)	70722	22881
Total Wall Time (s)	74926	26593
Per GPU Performance (MNUPS)	125	375

NVLink显著提高了多
GPU并行效率

NVIDIA NVLINK
高速 GPU 互连



NVIDIA NVLink 是高速 GPU 互连技术，与传统的 PCIe 系统解决方案相比，能为多 GPU 系统提供更快速的替代方案。NVLink 技术通过连接两块 NVIDIA Quadro 显卡，能够实现显存和性能扩展¹，从而满足视觉计算工作负载的需求。



1. 使用 NVLink 扩展显存和性能是部署高性能应用的最佳选择。



THANK YOU

altair.com



#ONLYFORWARD