Novel Universal Ensemble

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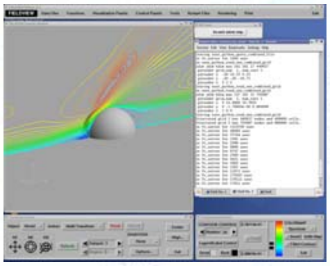
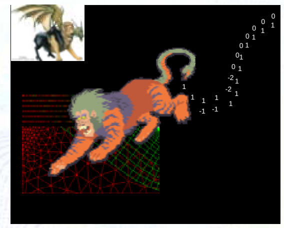


Novel Universal Ensemble - NUE

- A **Pre-Solve-Post** Integrated Environment for CFD Workflows
- **Any** Grid Type
- **Any** Flow Solver
- **In-Situ** Data Exploration
- **Automated** Parametric Studies & Reports
- All **Controlled** from FieldView GUI



Intelligent Light

NUE

Novel Universal Ensemble Capability for Overset Grids

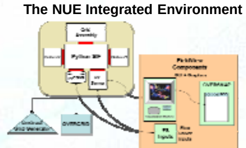
SBIR / STTR

Identification and Significance of Innovation

NASA's **OVERFLOW** code and overset grid methods supports many HEC CFD projects

HEC Users, i.e. **Fundamental Aerodynamics** SSRW and the **ESMD,** need Integrated Environment tools that automate overset grid CFD processes from CAD through report generation.

The NUE Integrated Environment



Technical Objectives and Work Plan

*- **Identify and resolve** issues in building an ensemble of overset grid tools from grid generation and assembly through flow-solver and post-processing*

*- Determine if this **Integrated Environment** can greatly improve the overset CFD workflow (e.g. OVERFLOW) on NASA's HEC resources (e.g. OVERFLOW) on NASA's HEC resources*

Phase 1 – Methods feasibility and design: Mock-Up NUE
- Architect Python Systems, Build Mock-Up
- FieldView based overset Point Search and grid Assemble
- Design Prototype system and evaluate on simple case

•**Phase 2** – Expand to robust prototype
- Implement prototype system design on HEC
- Incorporate solution-based refinement
- Optimize operation on actual HEC resources

NASA and Non-NASA Applications

- NASA
  - Fundamental Aero SSRW
  - ESMD
- Non-NASA
  - DARPA MAR
  - DoD CREATE AV

Typical Overset Workflow

Command Line Driven Workflow

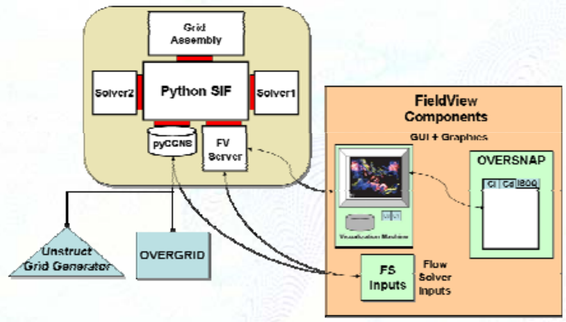
1. Launch grid generation tool and GUI
   i. Read CAD File into surface grid generator
   ii. Generate surface grids
   iii. Generate Volume Grids
2. Use sftp to **manually** transfer grid files to HEC Resource
3. **Manually** create and transfer Flow Solver input files to HEC Resource
   i. Set Flow conditions
   ii. Set Boundary Conditions and manually check if correct
   iii. Set Hole Cutting and Connectivity inputs
4. Submit job to queue (PBS), Run Flow Solver on HEC resource
   i. **Manually** check if job has finished
   ii. **Wait** for each job to finish before looking at solution
5. **Manually** transfer a copy of Flow Solver output to post-processing compute node
   i. **Wait** for large datafiles to transfer
   ii. Use an **AdHoc** method to **manually** track what files are transferred and where
6. Post-Process Data
   i. **Manually** generate reports of solution convergence
   ii. **Manually** generate reports of force and moment iteration history
   iii. **Manually** create visualizations of flow field
7. Attempt to **manually identify problems** with solution while post-processing, go back to step 2 and/or 3, repeat steps and **wait** for next set of results..

NUE Workflow

NUE Driven Automated Workflow

1. Launch grid generation tool and GUI
   a. Read CAD File into surface grid generator
   b. Generate surface grids
   c. Generate Volume Grids
2. Save files to automatically transfer grid files to HEC Resource
3. Through GUI create and **automatically** transfer Flow Solver input files to HEC Resource
   a. Set Flow conditions
   b. Set Boundary Conditions and manually check if correct
   c. Set Hole Cutting and Connectivity inputs
4. Through GUI launch job to queue (PBS), Run Flow Solver on HEC resource
   a. Request **automatic reports** to check on job **before** it has finished
   b. **View automatic reports** at end of job
5. **Remotely access** Flow Solver output from workstation
   a. **No Waiting** for large datafiles to transfer
   b. All files **automatically tracked** and archived
6. NUE system **automatically notifies user** that reports are ready to view
   a. **Review automatically** generated reports of solution convergence
   b. **Review automatically** generated reports of force and moment iteration history
   c. **Review automatically** created visualizations of flow field
7. **Review automatically** created visualizations of flow field
   a. Adjust grid regions as automatically **identify** by system
   b. Launch job

The NUE Environment

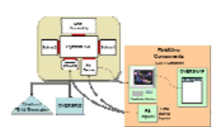


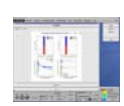
Key Components

Component	Description
1. Grid Generation	Grid generator(s) of choice built with API that enables output of NUE extended pyCGNS files.
2. pyCGNS Data Handler	Interface between external Grid Generation and FS Input GUI's. Manages the extended pyCGNS data files and exposes the information to the SIF
3. FS Inputs	A FVX-Python based GUI application that's customized to create flow solver inputs. It uses the extend pyCGNS files to store the inputs.
4. FieldView	The post-processing software with enhancements for overset grid data handling
5. FV NUE Server	The Python wrapped server application for concurrent-/post-processing with enhancements for overset grid data handling
6. Python SIF	Python Software Interface Framework similar to framework proposed by the HeLIOS development team of the CREATE A/V Program
7. Solver	Any CFD solver that is both Python wrapped and enabled to utilize overset grid methods
8. Grid Assembly	Largely upon the search methods in FieldView which allows for the use of different grid types, outputs assembly information to the extended-pyCGNS data handler
9. *OVERSnap*	OVERSMART, SnapShot and pyQT based tool that automatically generates a browsable report of force, moment and solution residual reports and automatically generated visualizations and post-processed numerical tables.

Usage Model

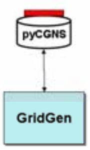
- How are these component tools used together ?
- From Grid to Reports
- NUE used to manage the workflow
- Facilitate Parametric Studies





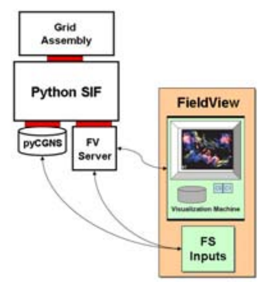
Grid Generation

- Generate overset grids using grid generator(s) of choice which is either python wrapped or uses NUE API



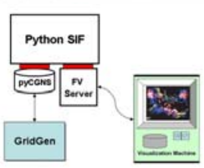
Grid Assembly

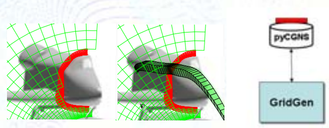
- Execute the *Grid Assembly* and view the resulting overset grid system in FieldView.
- FieldView automatically detects and highlights overset flaws such as orphans, and overlap quality



FieldView Feedback for Grids

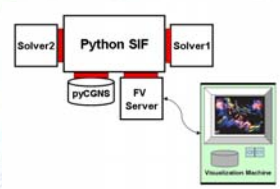
- FieldView outputs grid generation inputs for use in directing grid repair and use in Grid Generator
- Grid Generators use FieldView output to regenerate grid

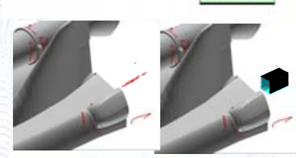




In-Situ Monitor and Steer Solution

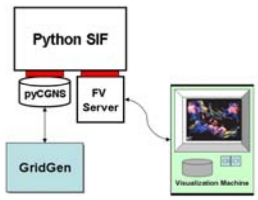
- Using FieldView server, user interrogates solution as it progresses
- FieldView outputs grid generation inputs
  - Feature detection automatically flags regions for refinement
  - User uses visualization tools to detect high gradient regions requiring refinement and manually directs
- Overset grid quality flaws automatically detected (i.e. bodies moving into regions of poor resolution)





Regrid and restart

- Grid Generators use FieldView output to regenerate grid
- FieldView interpolates previous solutions to new grid system
- Solution restarts

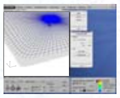


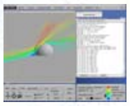
Automated Reporting for Parametric Studies

- User uses wizard to setup Parametric Studies and report requests
- Browser reports of Solution residuals, force moment time histories, automated image generation
- Send notification to user if problems occur in the computations

Phase 1 Work Effort

- **Technical Objective**
  - Identify and resolve issues in building an ensemble
  - Determine if this Integrated Environment can greatly improve the Overset CFD Workflow
- **Work Plan Goals**
  - Create a Mock-Up system
  - Determine how to efficiently utilize FieldView's capabilities
- **Accomplishments**
  - Architected Python Systems & Built Mock-Up
  - Created FieldView based overset Point Search and grid Assembly
  - Designed Prototype system and evaluated on simple case





NUE Automated Workflow

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Phase 1 Workflow Efforts

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- Through GUI create and **automatically** transfer Flow Solver input files to HEC Resource
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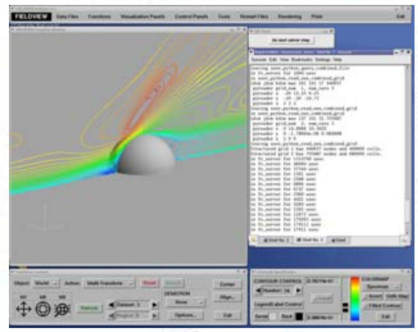
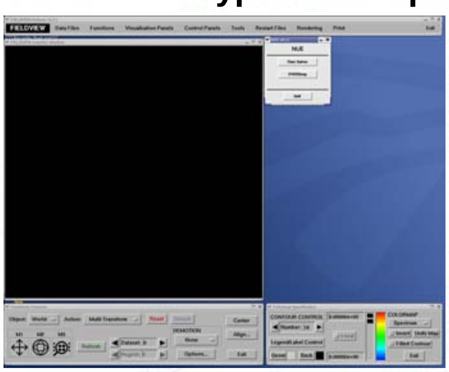
- NUE system **automatically notifies user** that reports are ready to view
- **Review automatically** created visualizations of flow field

- Five (5) automated workflow steps addressed
- Proof of Concept developed

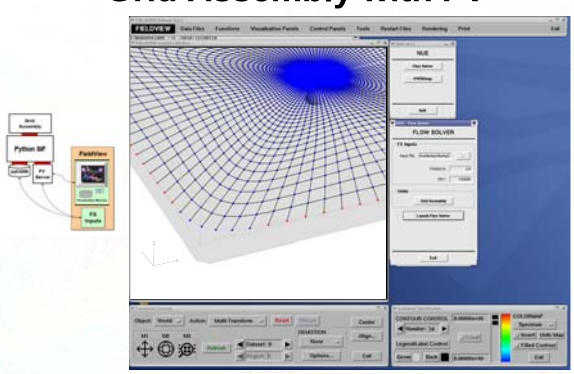
NUE Mock-up

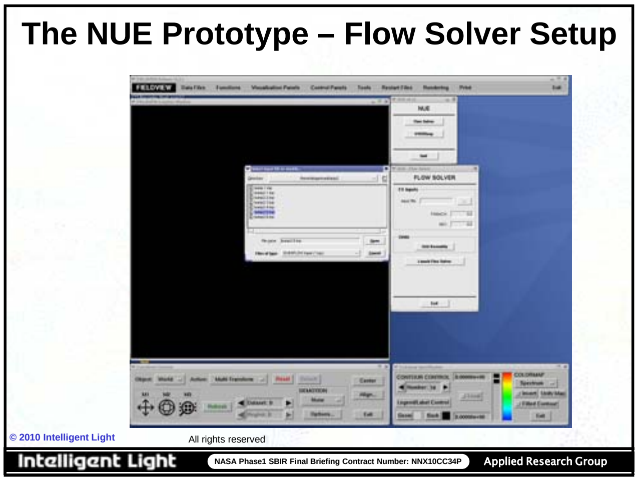


The NUE Prototype - Startup



Grid Assembly with FV




The NUE Prototype – Flow Solver Setup
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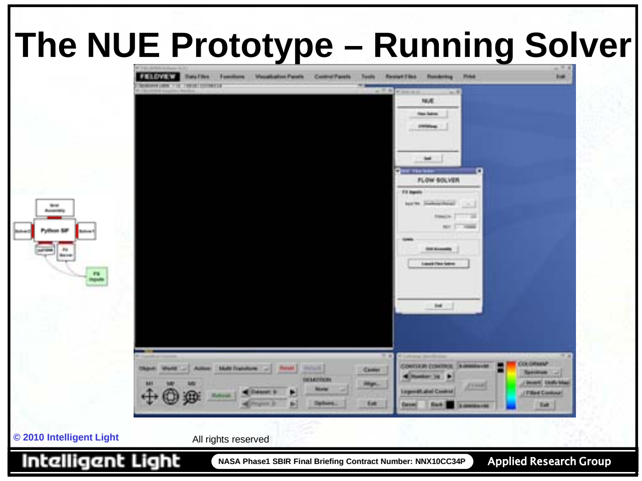
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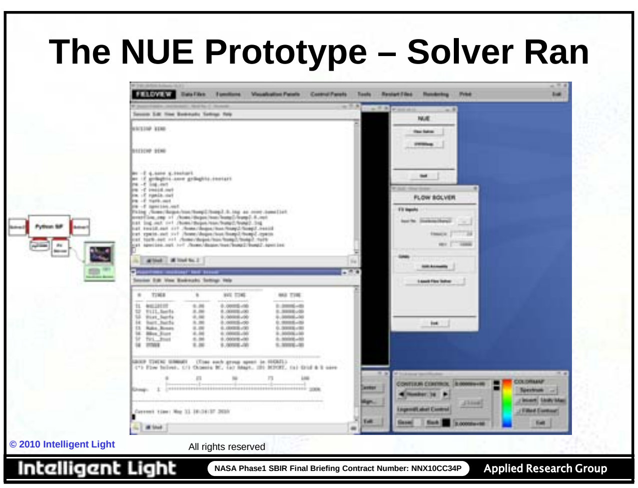
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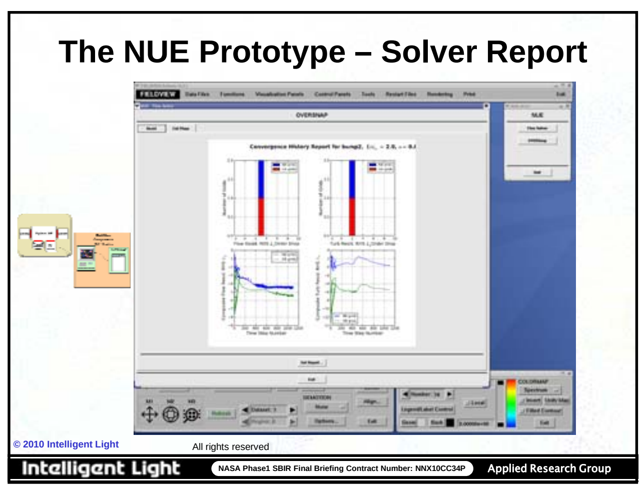
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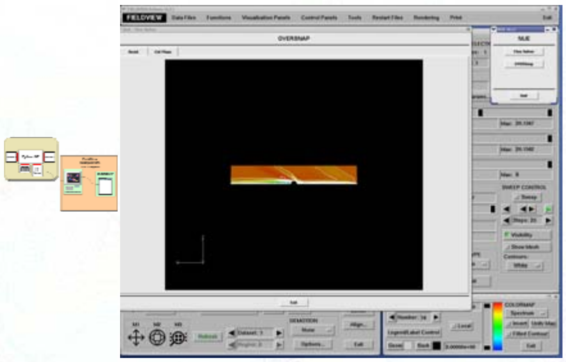
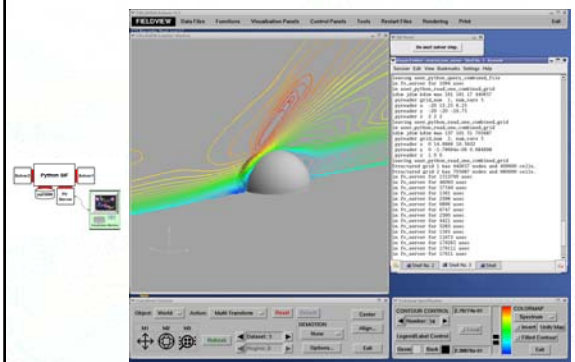
The NUE Prototype – FV Report

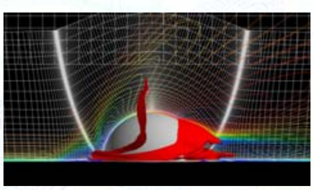


Maintains Interactivity



Phase 1 Lessons Learned

- Able to control python wrapped components via FieldView Python GUI
- Grid Assembly
  - FieldView Component Point Probing needs improvement
  - Visualization of Sphere elements needs improvement
- pyCGNS
  - I/O Speed a concern
  - CGNS support uncertain

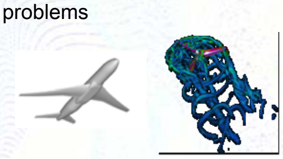


Proposed Phase 2 Workflow Efforts

Expand to robust prototype

- Launch grid generation tool and GUI
- Save files to automatically transfer grid files to HEC Resource
- Through GUI create and **automatically** transfer Flow Solver input files to HEC Resource
- **Automated** Setup and Manage Parametric Study
- Through GUI launch job to queue (PBS), Run Flow Solver on HEC resource
- **Remotely access** Flow Solver output from workstation
- NUE system **automatically notifies user** that reports are ready to view
- **Automated** Reports for Parametric Study
- **Review automatically** created visualizations of flow field

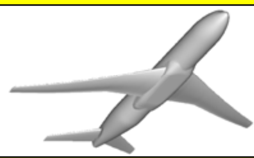
•**Implement** prototype system design on HEC
• **Incorporate** solution-based refinement
• **Optimize** operation on actual HEC resources
• Use on relevant NASA FA problems



Utilize a Drag Prediction Workshop Study as Prototype Demo Problem

- Use NUE to manage a Grid Convergence Study
- Parametric Study of Multiple Grid Resolutions
- Automated Grid Convergence Criteria Reports
- Structured & Unstructured Grid Study
- Needs HEC access

Automated Setup and Manage Parametric Study

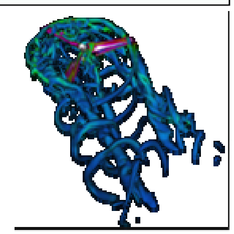


Automated Reports for Parametric Study

SubSonic Rotor Wing

- Use NUE to execute and monitor large unsteady runs
- Automatically identify features
- Create reports of relevant rotor performance information
- Would need HEC access

Remotely access Flow Solver output from workstation



Review automatically created visualizations of flow field

Proposed Phase 2 Activities

- Fully enable pyCGNS
- Enable Interaction with Grid Generators
  - GridGen
  - OVERGRID
- Fully enable In-situ Capability
  - Wrap Solvers
    - OVERFLOW
    - FUN3D or USM3D
    - Commercial Solvers
  - Grid Assembly
    - FieldView improved search components
    - Incorporate SUGGAR
- Fully enable solver controls w/ parametric study
- Database system
  - Solver metadata
  - Solution metadata
  - Post-Processed Results
- Improved Overset Grid Handling
  - Overset boundary handling for visualization (i.e. contours)
  - Overset boundary integration (USURP or MIXSUR or Both ?)

Summary

- Built a prototype NUE system
- Demonstrated ability to integrate the ensemble of tools
  - Assembly
  - Solver inputs
  - Report generation
- Gained experience to plan for more complete prototype