



# *Welcome and introduction to SU<sup>2</sup>*

**SU<sup>2</sup> Release Version 2.0 Workshop**

*Stanford University*

*Tuesday, January 15<sup>th</sup>, 2013*

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# Outline

- Motivation
- Why SU<sup>2</sup>?
- Current capabilities
- Conclusions



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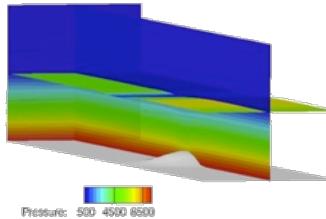
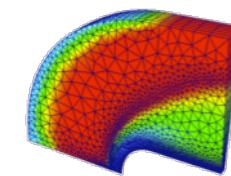
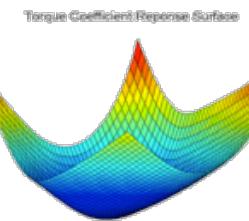
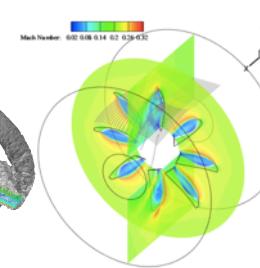
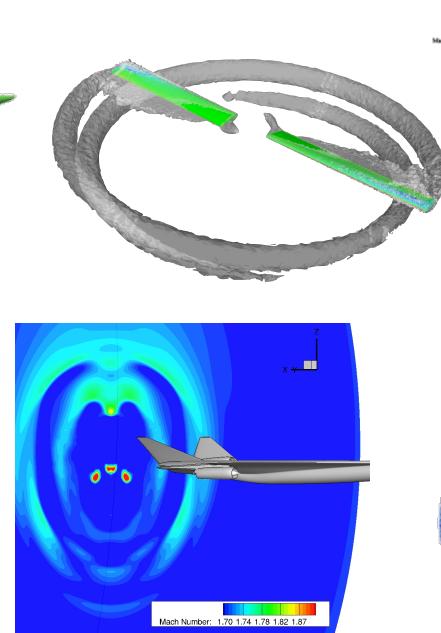
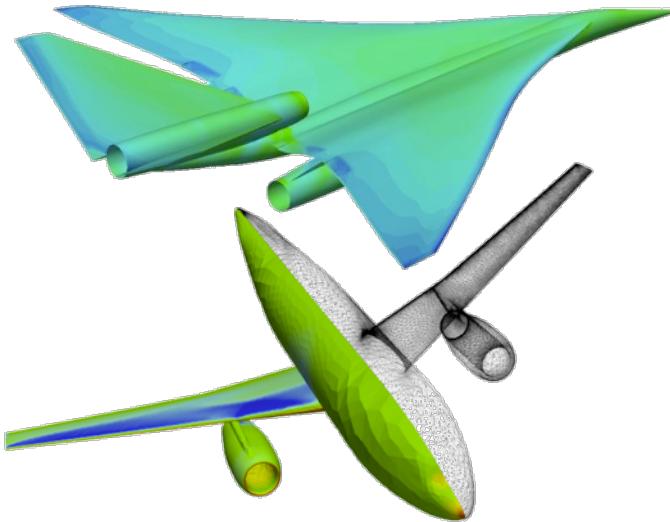


# Motivation

## Our objective

Develop advanced design environments to enable systems that **address the challenge of meeting the demand while minimizing the impact on the environment.**

Develop a **leading solver in the unstructured CFD community**





# Motivation

## Multi-Disciplinary Shape Design Optimization

Optimization techniques are the **final goal of all practical design project** but they are not used everywhere because:

1. The optimization of a **complete aircraft configuration** implies the interaction of a lot of different SW modules.
2. It is not easy to parameterize appropriately the **geometry modifications** (intersections and geometric constraints).
3. An optimizer is **limited to considering those designs that are described by the selected parameterization**.
4. Important **mathematical difficulties** in the gradients evaluation.
5. Great **time and personnel resources** are typically needed.

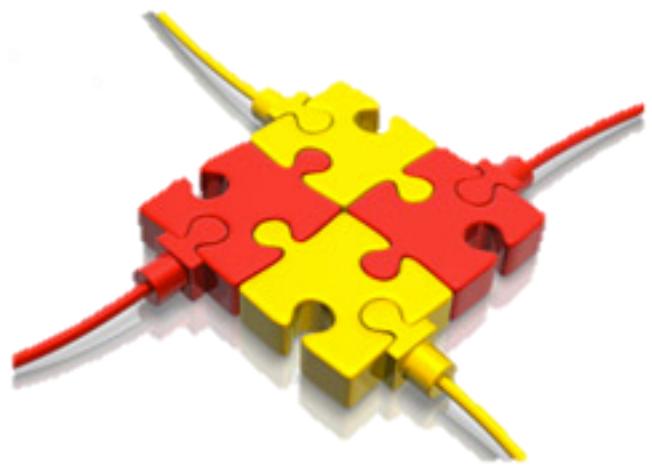
# Motivation

## Software integration in shape design

To integrate the existing SW packages into coupled multi-physics analysis and design optimization solvers is a challenge.

The variety of approaches chosen for the independent components of the overall problem make it difficult to:

- **Expand the range of applicability** to situations not originally envisioned.
- Reduce the overall burden of creating **integrated applications**.
- Exploit **fully coupled approaches**.



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# Why SU<sup>2</sup>?

## Stanford University Unstructured (SU<sup>2</sup>) suite

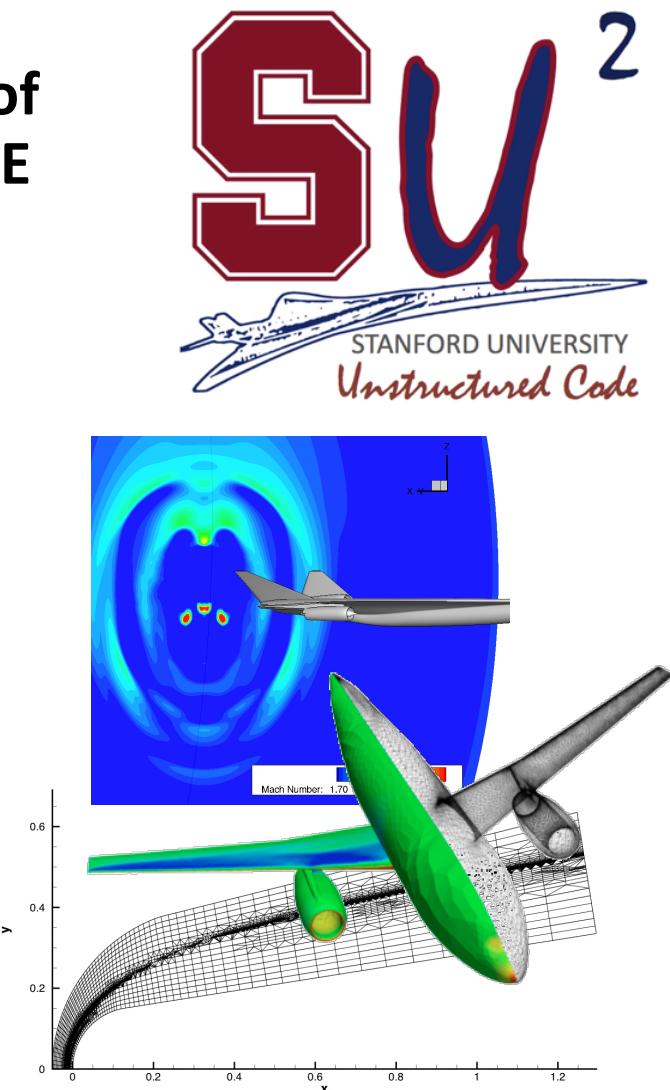


The Stanford University Unstructured (SU<sup>2</sup>) suite is an open-source collection of C++ based software tools to perform PDE analysis and solve PDE-constrained optimization problems.

SU<sup>2</sup> is under active development at Stanford University in the Aerospace Design Lab (ADL) of the Department of Aeronautics and Astronautics.

More than 24,000 visits and 3,150 downloads since January 19, 2012

<http://su2.stanford.edu/>



# Why SU<sup>2</sup>?

## Lasting infrastructure for future efforts

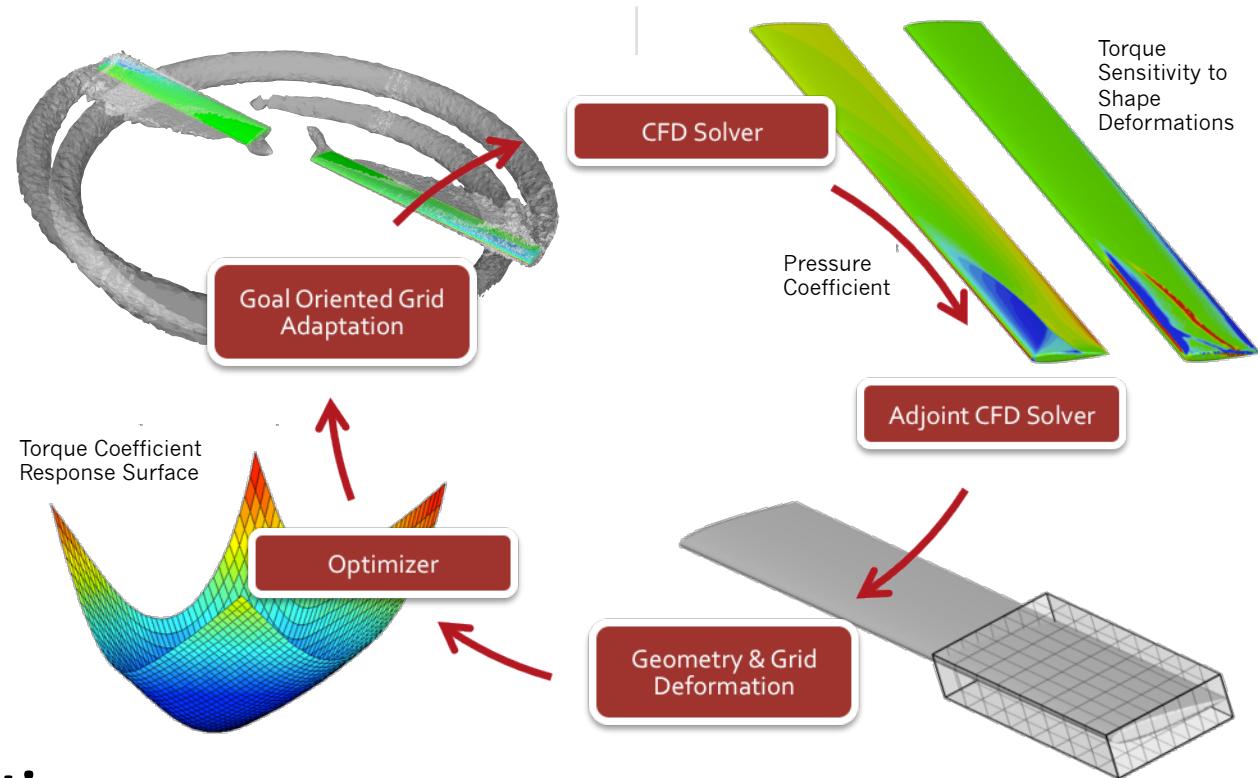
1. **An open-source model:** basic formulation with a reasonable set of initial capabilities, we would like to see contributions from the community!
2. **Portability:** SU<sup>2</sup> has been developed using ANSI C++ and only relies on widely-available, well-supported, open-source software.
3. **Reusability and encapsulation:** SU<sup>2</sup> is built so that the main concepts (geometry, sol. algorithms, num. algorithms, etc) are abstracted to a very high-level. This abstraction promotes reusability of the code and enables modifications without incorrectly affecting other portions of the suite.
4. **Flexibility** required to re-purpose existing software for new and different uses. Enabling a common interface for all the necessary components.
5. **Performance:** we have attempted to develop numerical solution algorithms that result in high-performance convergence of the solver in SU<sup>2</sup>.
6. **Gradient availability:** for many applications it is important to obtain grad. of the responses computed by SU<sup>2</sup> to variations of design parameters.

# Why SU<sup>2</sup>?

## Multi-physics shape optimization.

### Shape Optimization

- Self-contained optimization env.
- Gradient computation using adjoint approach.
- 3D design variable definition and built-in geometry and mesh deformation.



### Multi-Physics Simulations

- Simultaneous analysis of different equation sets with tight coupling.
- Free surface simulations, noise, fluid structure, etc.
- Multi-species plasma solver for simulating ionized flows.

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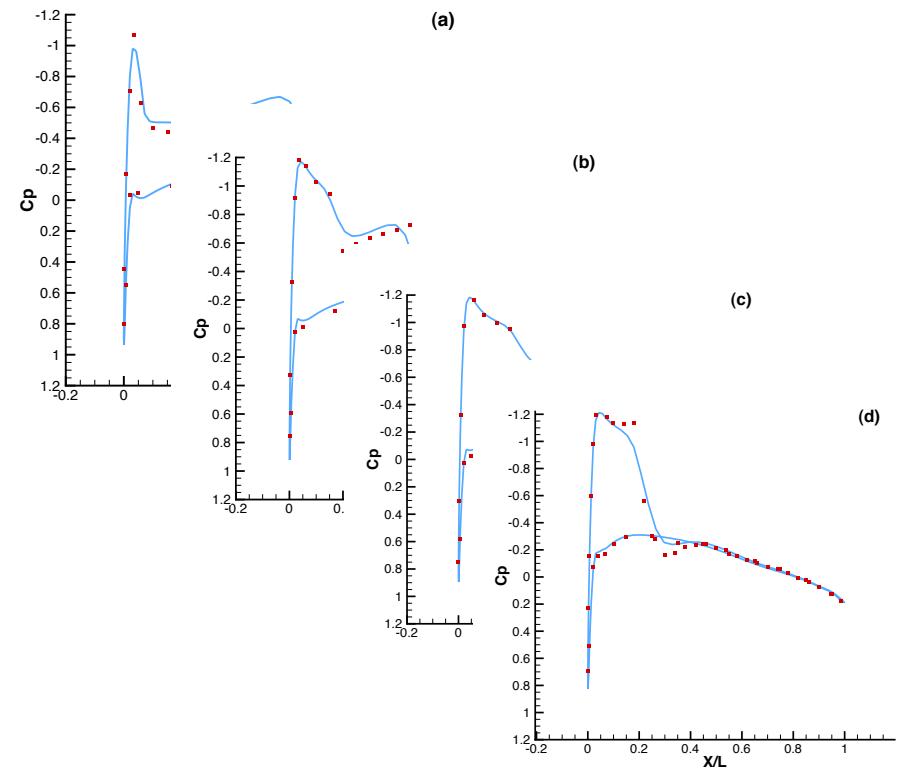
# Current capabilities

## High fidelity analysis (I/II)

**Verification and Validation** is critical.

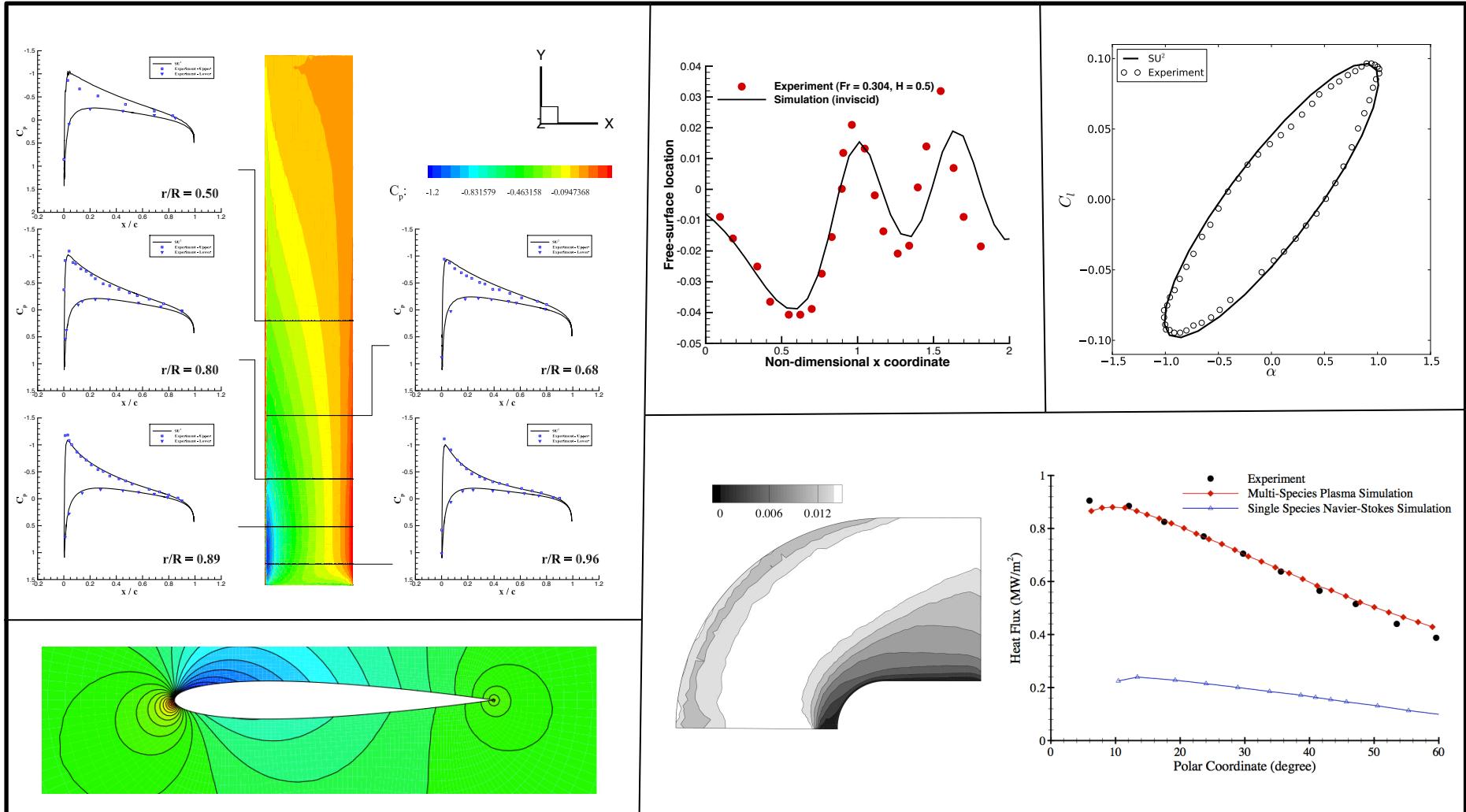
It should address **the consistency of the numerical methods**, the **accuracy assessment** for different critical application cases, and **sensitivity studies** with respect to parameters.

1. Compressible RANS simulation.
2. Rotating frame simulations.
3. Supersonic simulations.
4. Low-Mach simulations.
5. Time-accurate, unsteady simulation.
6. Free-surface simulation.
7. Plasma simulation.



# Current capabilities

## High fidelity analysis (II/II)

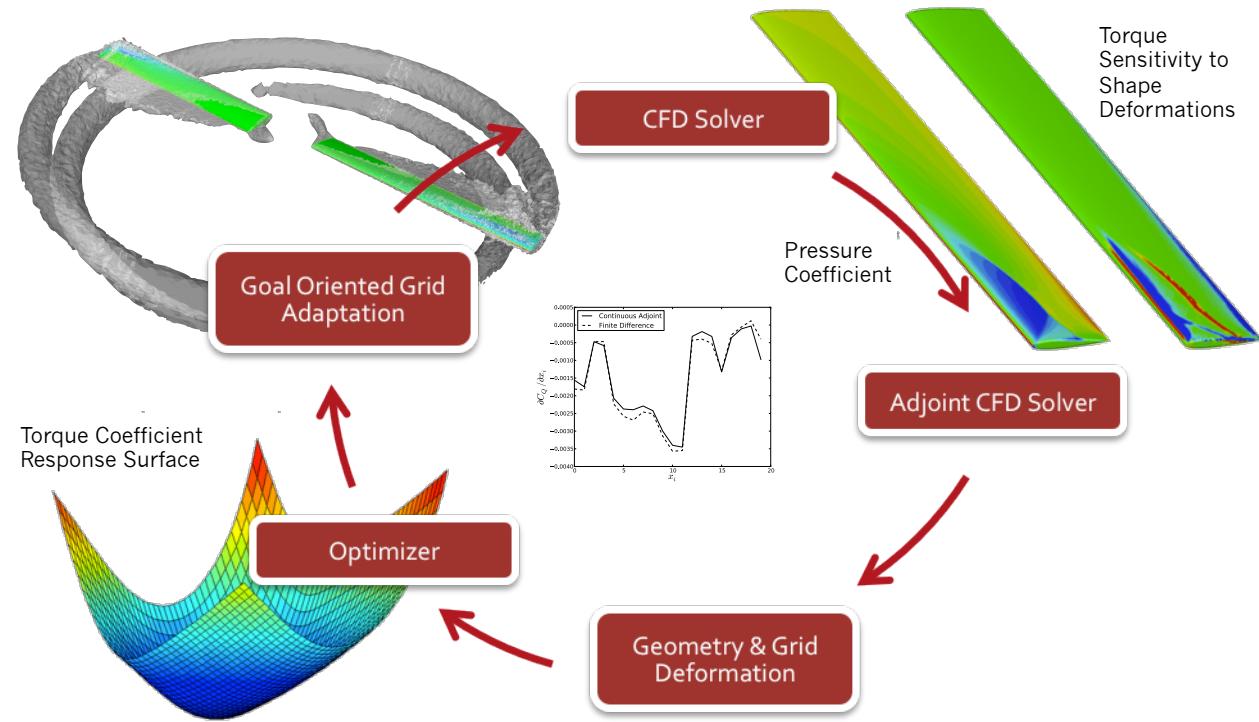


# Current capabilities

## Optimal shape design and optimization (I/II)

The design optimization of PDE constrained systems is a primary function of SU<sup>2</sup>.

The built-in adjoint solver in the CFD module, in conjunction with GPC, and MDC deliver objective function gradients.

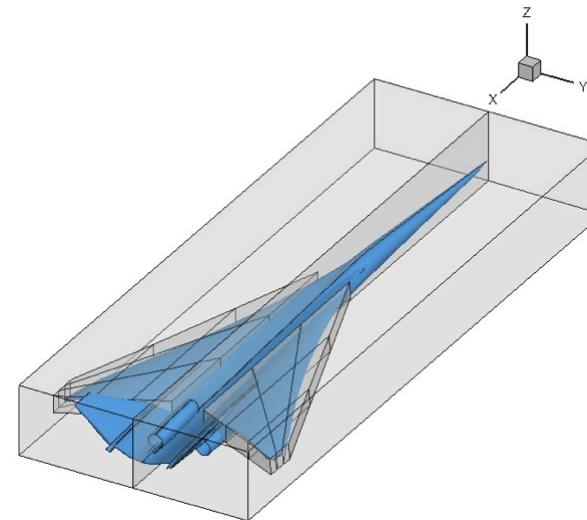
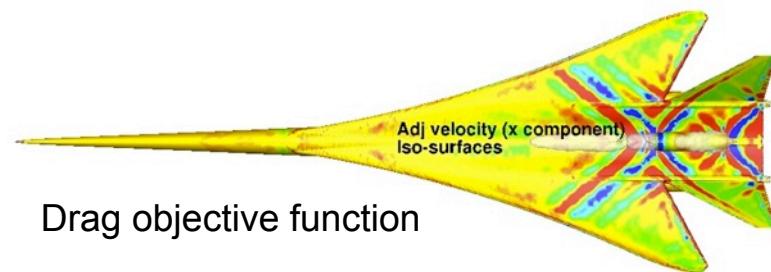
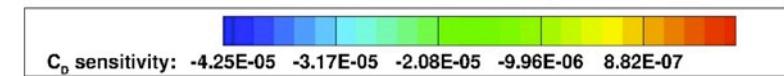


1. Supersonic aircraft design.
2. Airfoil and fixed wing optimization.
3. Viscous (RANS) design.
4. Unsteady design.
5. Nested Free-Form Deformation boxes.

# Current capabilities

## Optimal shape design and optimization (II/II)

- Magnitude of surface sensitivity is related to changes in cost function caused by changes in geometry.
- Designers can use this sensitivity information to determine appropriate parameterizations of the configuration prior to optimization.

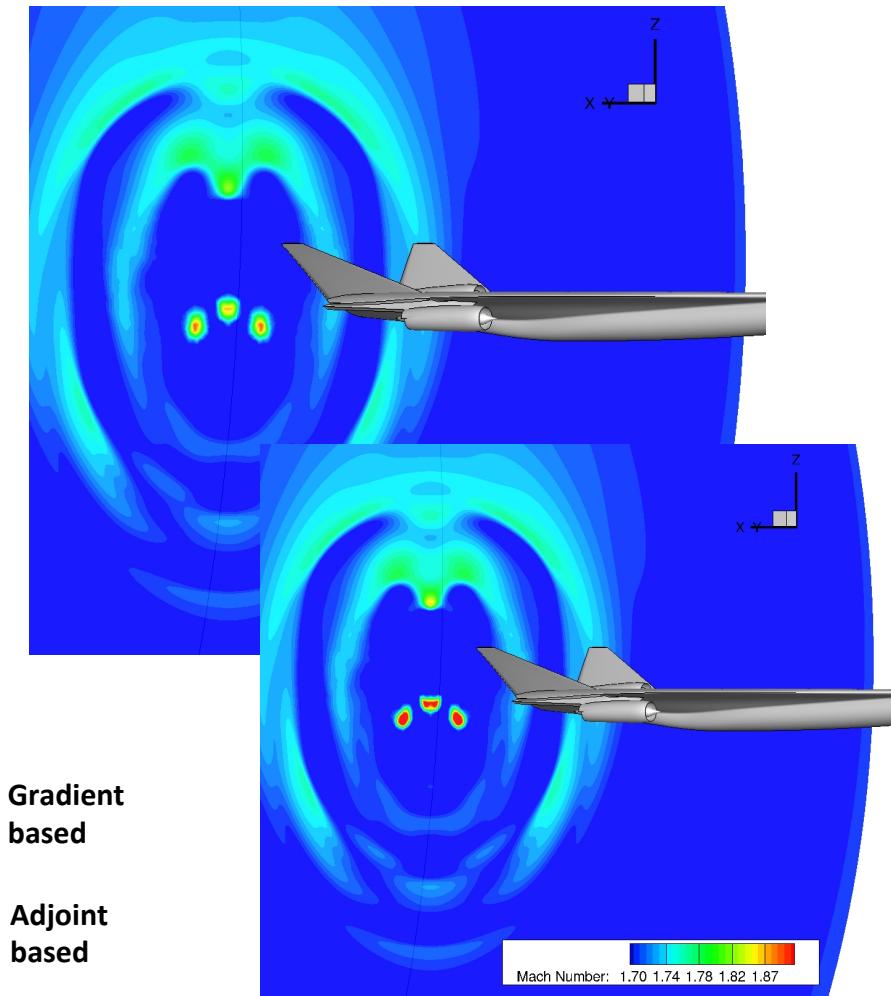
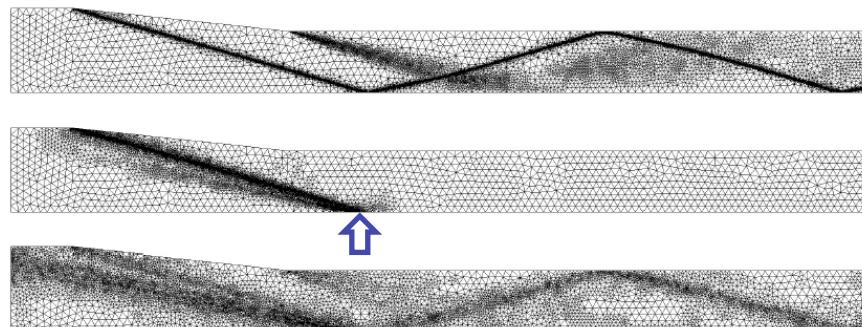


# Current capabilities

## Adaptive mesh refinement (I/II)

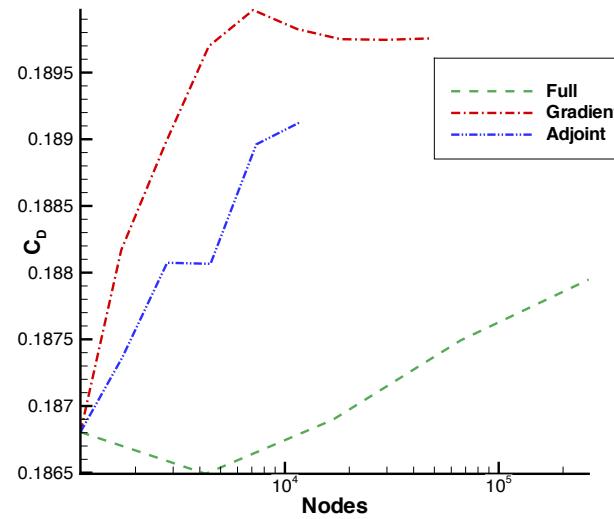
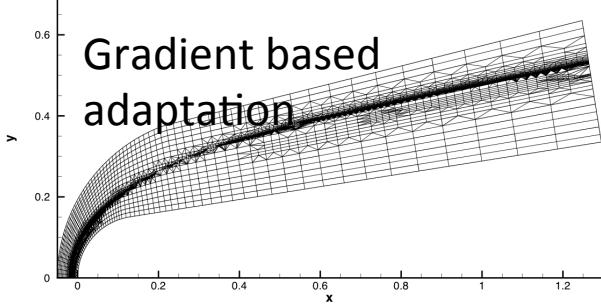
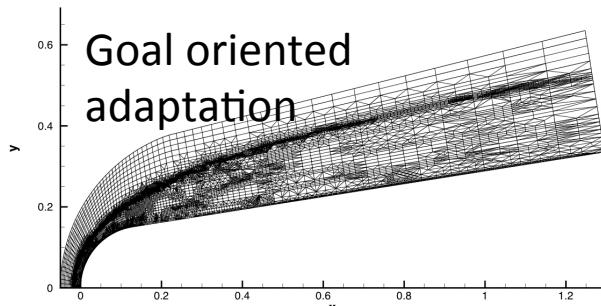
The Mesh Adaptation Code in the SU<sup>2</sup> suite facilitates **strategic mesh adaptation based on several common schemes**, including gradient and goal-oriented methods.

1. Goal-oriented mesh adaptation.
2. Engine propulsion effect adaptation.
3. Plasma adaptation.



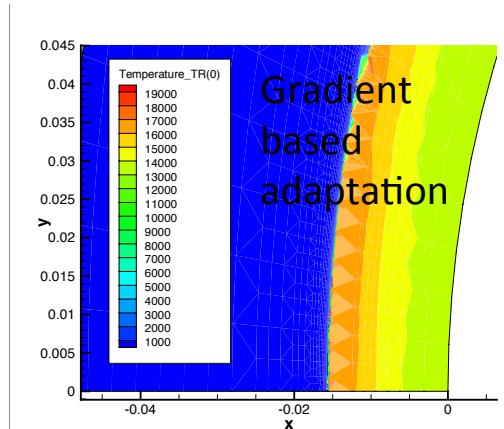
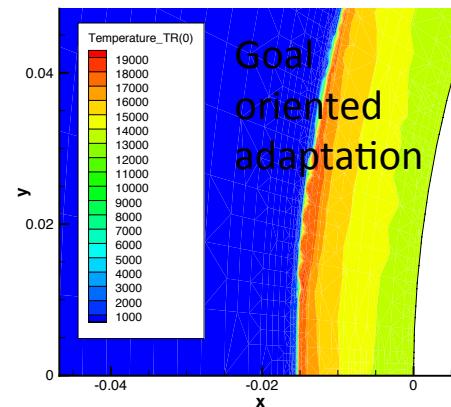
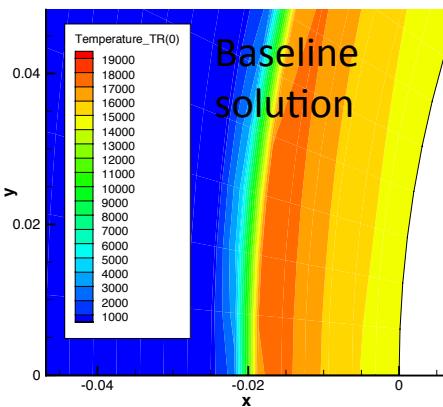
# Current capabilities

## Adaptive mesh refinement (II/II)



Grid adaptation  
Plasma equations

Two-species Nitrogen  
gas chemistry model  
( $M = 25.9$ ,  $H = 71\text{km}$ ,  
 $T = 216\text{K}$ , and  
 $\text{Re} = 6280$ )



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- Code structure
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- Conclusions



# Conclusions and future work

Analyze, optimize, design!

- ✓ Thanks to its **data structure**, SU<sup>2</sup> is an **ideal vehicle for performing multi-physics simulations**, including multi-species thermochemical non-equilibrium flow analysis, combustion modeling, two-phase flow simulations, magneto-hydrodynamics simulations, etc.
- ✓ The **optimization of PDE constrained systems** is a primary function of the **SU<sup>2</sup>** suite.
- ✓ SU<sup>2</sup> has been **released under an open-source license** and it is freely available to the community. Developers around the world can contribute to and improve the suite.
- ✓ Significant efforts were directed at the **development of documentation** so that prospective users could get up to speed with a minimum effort.

# Conclusions and future work

## Workshop agenda

### SU<sup>2</sup> Release Version 2.0 Workshop

Tuesday, January 15<sup>th</sup>, 2013

William F. Durand Building, Rm. 450  
496 Lomita Mall  
Stanford, CA 94305



The New Open-Source CFD Code

11.00 – 11.20: Welcome and Introduction to SU<sup>2</sup> (Dr. Francisco Palacios & Prof. Juan Alonso)

11.20 – 11.30: Quick Overview of SU<sup>2</sup> Installation (Dr. Mike Colombo & Aniket Aranake)

*Please come to the workshop with the software downloaded and installed. If you have any problems, we will provide individual support around the room.*

11.30 – 12.00: Introduction to the SU<sup>2</sup> Code Structure (Amrita Lonkar)

*Have a unique application in mind? Learn the structure of the code so you can expand its capabilities to suit your needs!*

12.00 – 12.30: Running SU<sup>2</sup> (Sean Copeland & Tom Taylor)

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12.30 – 12.45: Break (food provided)

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12.45 – 13.15: Problem Workshop I: SU<sup>2</sup> as a High-fidelity Analysis Tool (Thomas Economou)

*SU2 has a multitude of capabilities for performing high-fidelity analysis of complex geometries. Learn about them here.*

13.15 – 13.45: Problem Workshop II: Design and Opt. Using SU<sup>2</sup> (Dr. Francisco Palacios)

*Learn why SU<sup>2</sup> is uniquely suited for performing design and optimization of complex aerospace systems.*

13.45 – 14.15: Problem Workshop III: Task-Based Design Eval. with SU<sup>2</sup> (Trent Lukaczyk)

*Explore the design space with our task-based framework.*

14.45 – 15.00: Adjourn

Thanks for attending, and note that all stated times are Pacific Time (PST).

Please join our community!

SU2 Homepage:

<http://su2.stanford.edu/>

CFD Online Forum:

<http://www.cfd-online.com/Forums/su2/>

Follow us on Twitter:

<https://twitter.com/su2code>

Like us in Facebook:

<http://www.facebook.com/pages/SU2/266488403453493>

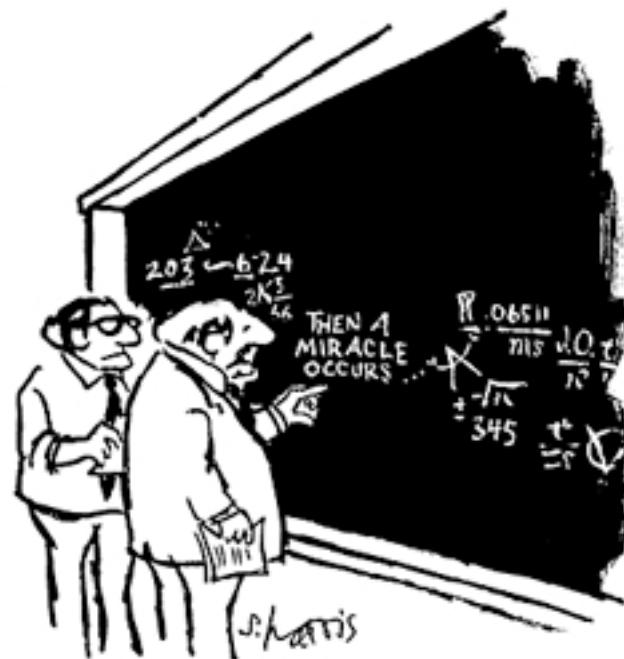
# Thank you for your attention!

## Your feedback is very important for us!

<http://www.cfd-online.com/Forums/su2/>

## Questions?

[su2.stanford.edu](http://su2.stanford.edu)



"I think you should be more explicit here in step two."