Introduction to SU^2

OpenMDAO-SU2 Joint Workshop

Stanford University
Monday, Sept. 30 2013

The Open-Source CFD Code

Prerequisites

- C++ compiler
  - GNU gcc
  - Intel icpc
- GNU Autoconf/Automake tools
  - http://www.gnu.org/software/autoconf/
  - http://www.gnu.org/software/automake/
- Git
  - http://github.com
- Numpy/Scipy

What is SU^2?

The Stanford University Unstructured (SU^2) is a software package for:

- **Fluid Simulation**
- and **Engineering Design**

SU^2 is distributed as **Open-source** software

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

http://su2.stanford.edu/

The Open-Source CFD Code

SU^2 v3.0 (Eagle) will be released on Jan 11th, 2014

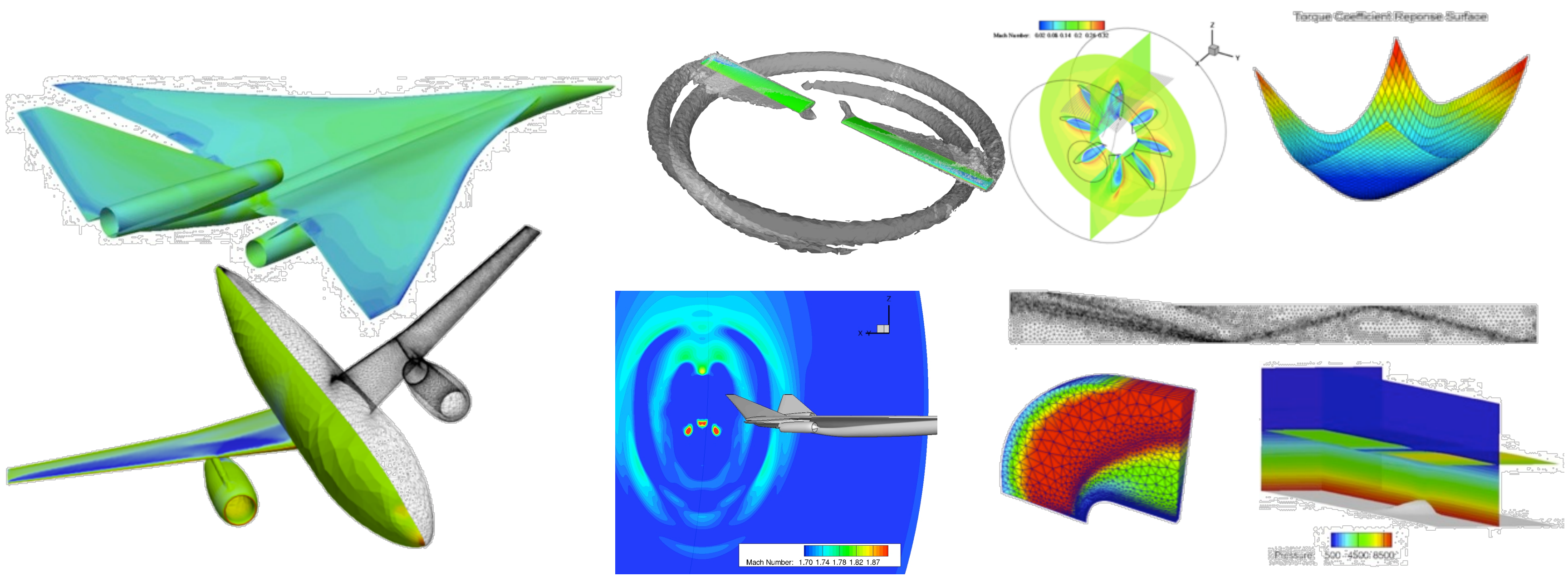
Motivation

Advanced design environment

- Enable analysis and design of complex engineering systems
- Multi-physics simulation

Leading-edge solver technology

- Tool for CFD research
- Global accessibility



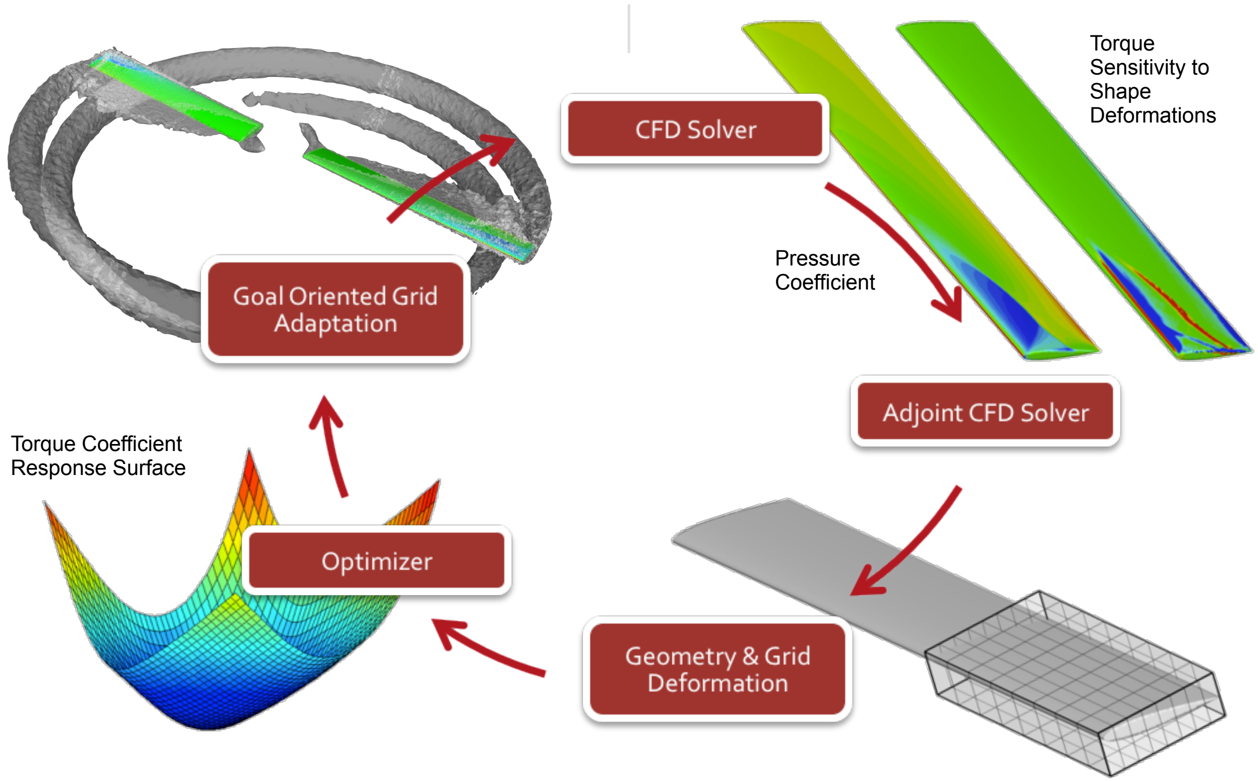
Why SU^2?

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^2 has been developed using ANSI C++ and only relies on widely-available, well-supported, open-source software.
3. **Reusability and encapsulation:** SU^2 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^2.
6. **Gradient availability:** for many applications it is important to obtain grad. of the responses computed by SU^2 to variations of design parameters.

Why SU^2?

Shape Optimization

- Self-contained optimization env.
- Gradient availability (adjoint method)
- Built-in:
  - Design var. definitions
  - Surface deformation
  - Mesh deformation



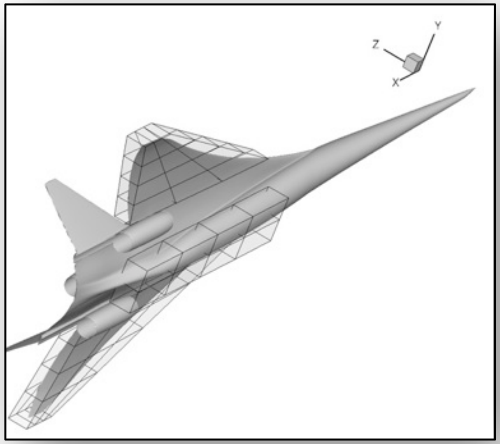
Multi-Physics Simulations

- Simultaneous analysis of different equation sets w/ tight coupling
- Aero-structural, aero-acoustic, free-surface, reacting gas mixtures, etc.

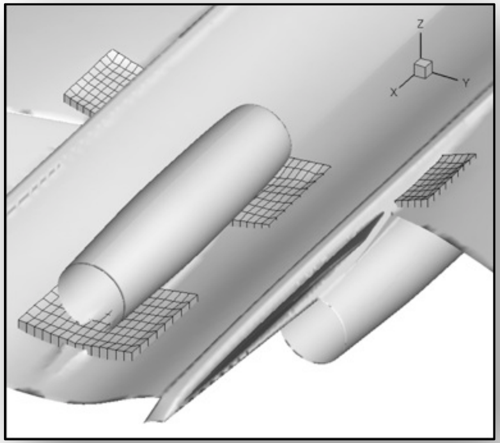
SU^2 Modules

- SU2_CFD: Computational Fluid Dynamics
- SU2_DDC: Domain Decomposition Code
- SU2_MAC: Mesh Adaptation Code
- SU2_MDC: Mesh Deformation Code
- SU2_PY: Python drivers
- SU2_SOL: Solution file processing
- + More

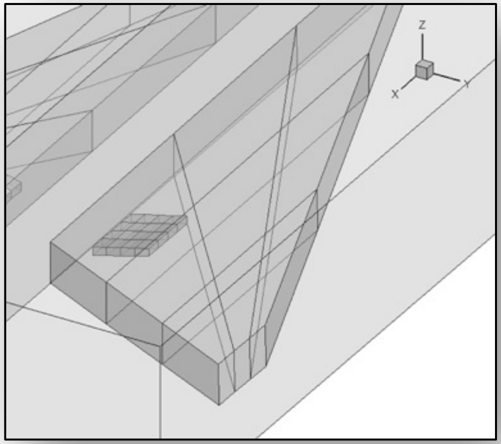
Capabilities: Geometry Deformation



Engineering-like design variables

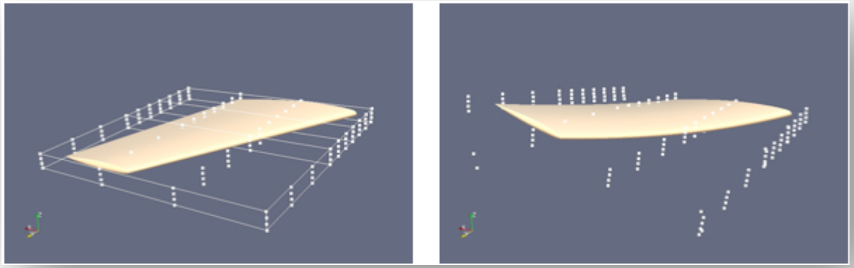


Fine control of the design surfaces



Nested FFD strategy (local and global control)

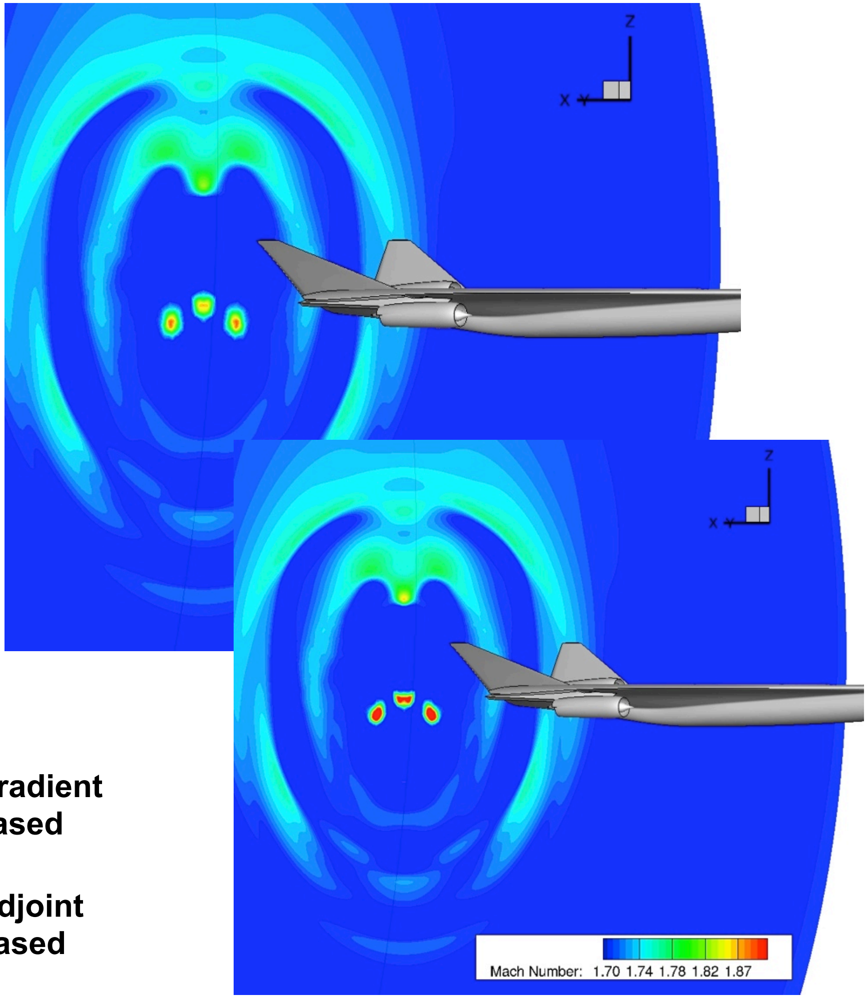
The main idea is to **embed the physical object into a 3D grid, and then modify it as a whole**. The object inherits the deformation of the auxiliary grid.

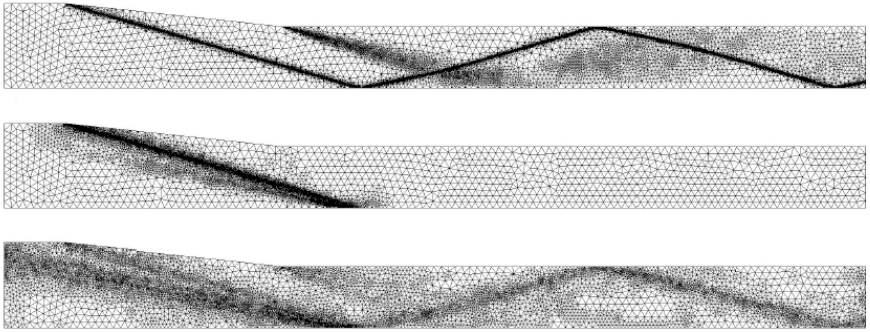


Capabilities: Mesh Adaptation

The Mesh Adaptation Code in the SU² 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.





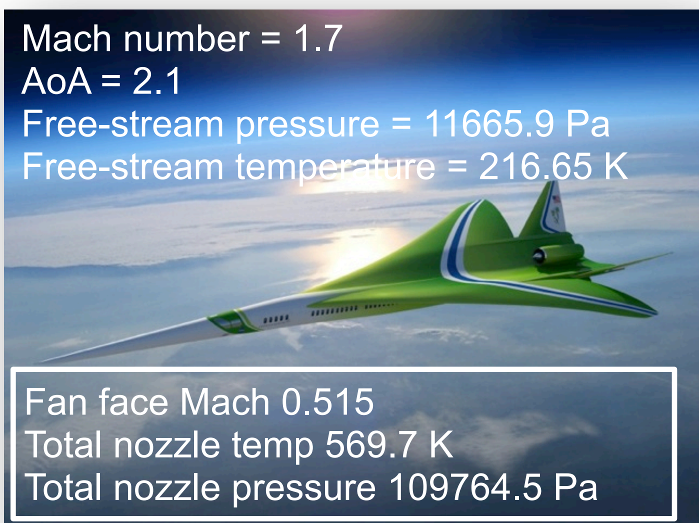
Gradient based

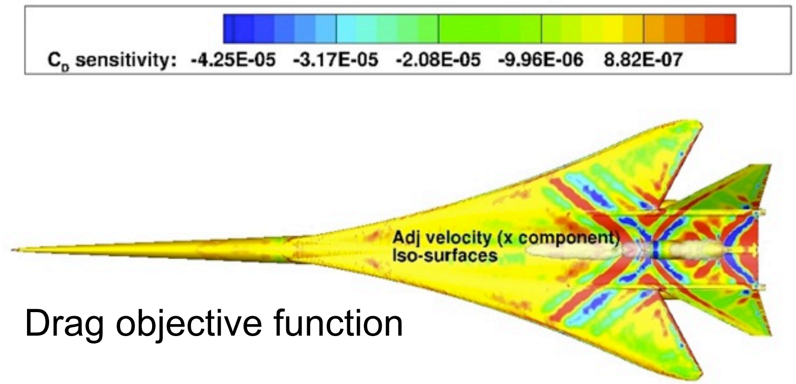
Adjoint based

Robust adaptation

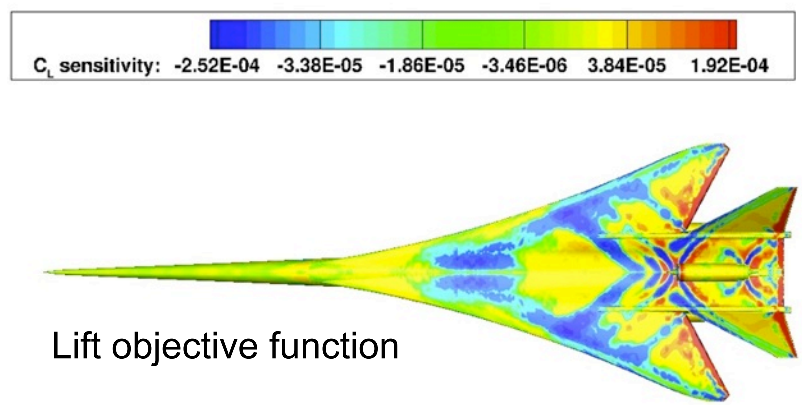
Capabilities: Optimal Shape Design

- 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.





Drag objective function

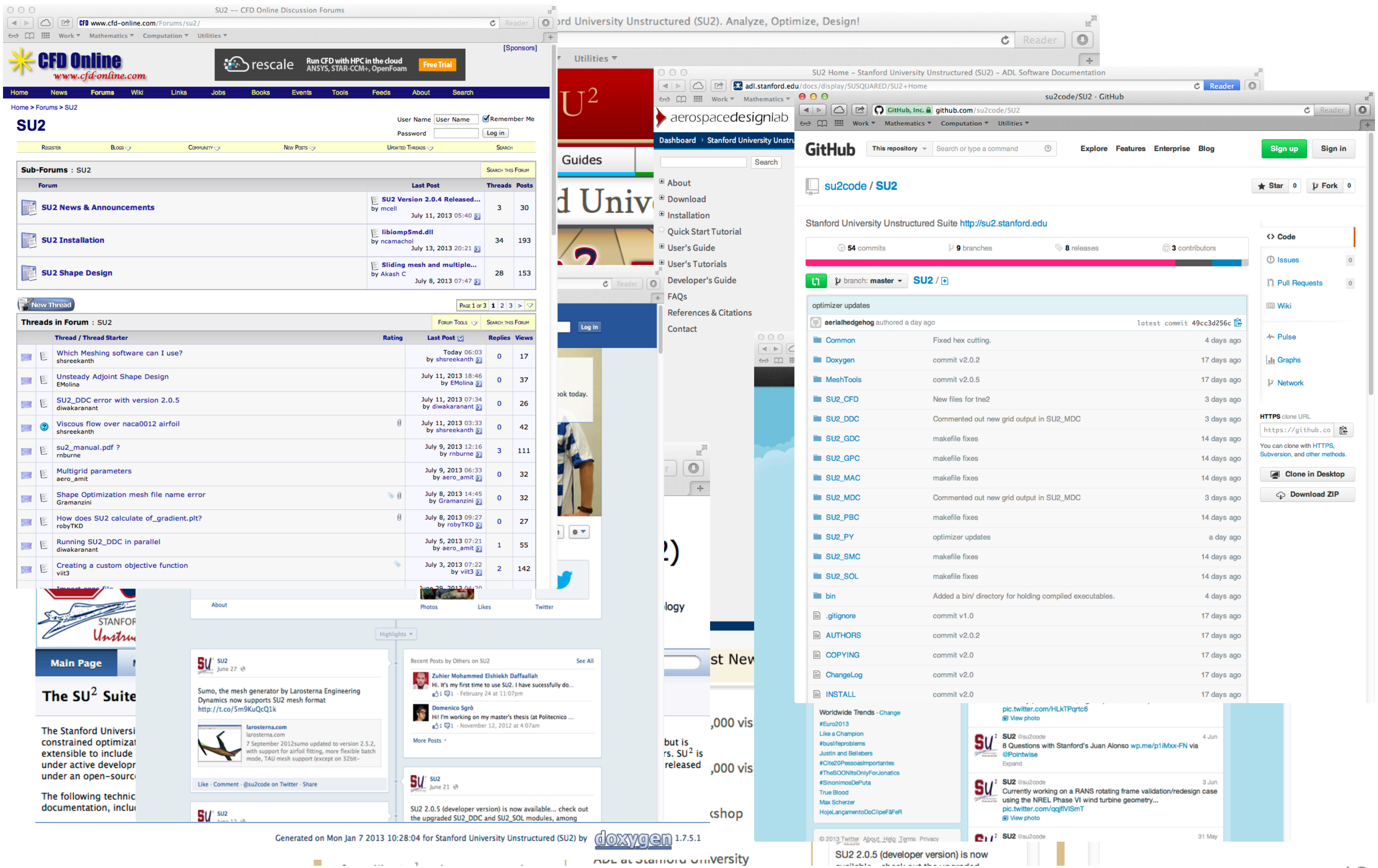


Lift objective function

SU² as an open-source project

- **Computational analysis tools have revolutionized the way we design aerospace systems**, but most established codes are proprietary, unavailable, or prohibitively expensive for many users.
- The SU² team is changing this, making computational analysis and design freely available as open-source software and involving everyone in its creation and development.
- Why?
  - Worldwide accessibility.
  - Encourage contributions from everyone.
  - Enables CFD research everywhere… the complexity of today's problems requires tools to start from in order to make a technological impact.

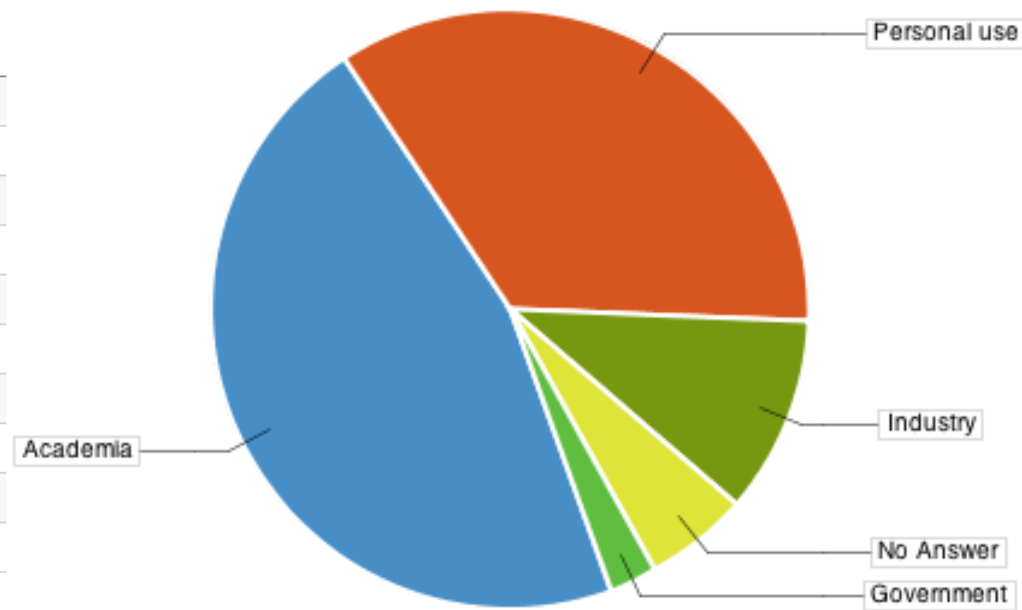
Open-source Community



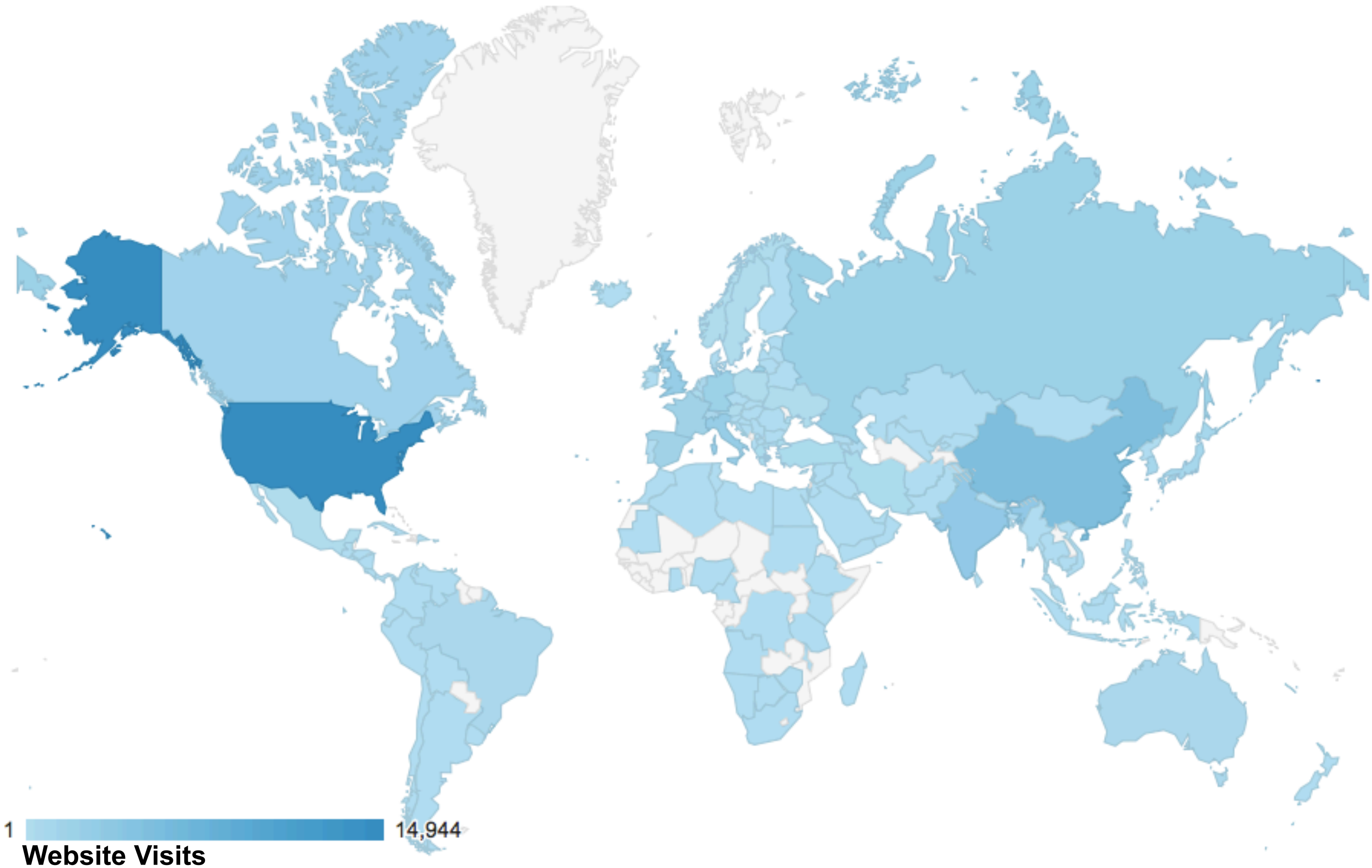
The first 20 months…

- 49,000 website visits from 136 countries
- 6,000 code downloads
- Many top universities and aerospace companies

	Country / Territory	Visits	% Visits
1.	United States	14,944	30.71%
2.	China	5,315	10.92%
3.	India	3,193	6.56%
4.	United Kingdom	2,677	5.50%
5.	Italy	2,577	5.30%
6.	Germany	2,150	4.42%
7.	Russia	1,792	3.68%
8.	France	1,636	3.36%
9.	Spain	1,631	3.35%
10.	Canada	1,411	2.90%



Global Reach



A Student-led Initiative

- “Learning through building”
- Two-way information exchange
  - Students equipped with expertise
  - Research & Industry interest

NASA

LOCKHEED MARTIN

SWISS SPACE SYSTEMS

The SU^2 Team

- Aniket C. Aranake, Alejandro Campos, Sean R. Copeland, Thomas D. Economon, Kedar R. Naik, Amrita K. Lonkar, Trent W. Lukaczyk, Santiago Padrón, Brendan D. Tracey
  - Ph.D. Candidates in the Aero/Astro department.
- Francisco Palacios
  - Engineering Research Associate in the Aero/Astro department.
  - Lead Developer.
- Michael R. Colonno
  - Engineering Research Associate in the Aero/Astro department.
- Juan J. Alonso
  - Associate Professor in the Aero/Astro department.
  - Aerospace Design Laboratory (ADL) Director.

The Open-Source CFD Code

aerospacedesignlab

STANFORD AERONAUTICS & ASTRONAUTICS

Why is SU^2 important?

- Cutting-edge research from Stanford available in real-time.
- Enables advanced Computational Fluid Dynamics research in places that don't have the resources or expertise.
- Making the state-of-the-art in computational fluid dynamics freely availability will help companies create faster and greener aircraft, cars, boats, etc.
- Perfect tool for facing some of the future challenges for aviation: achieving supersonic flight over land, and reducing fuel burn, emissions, and noise.