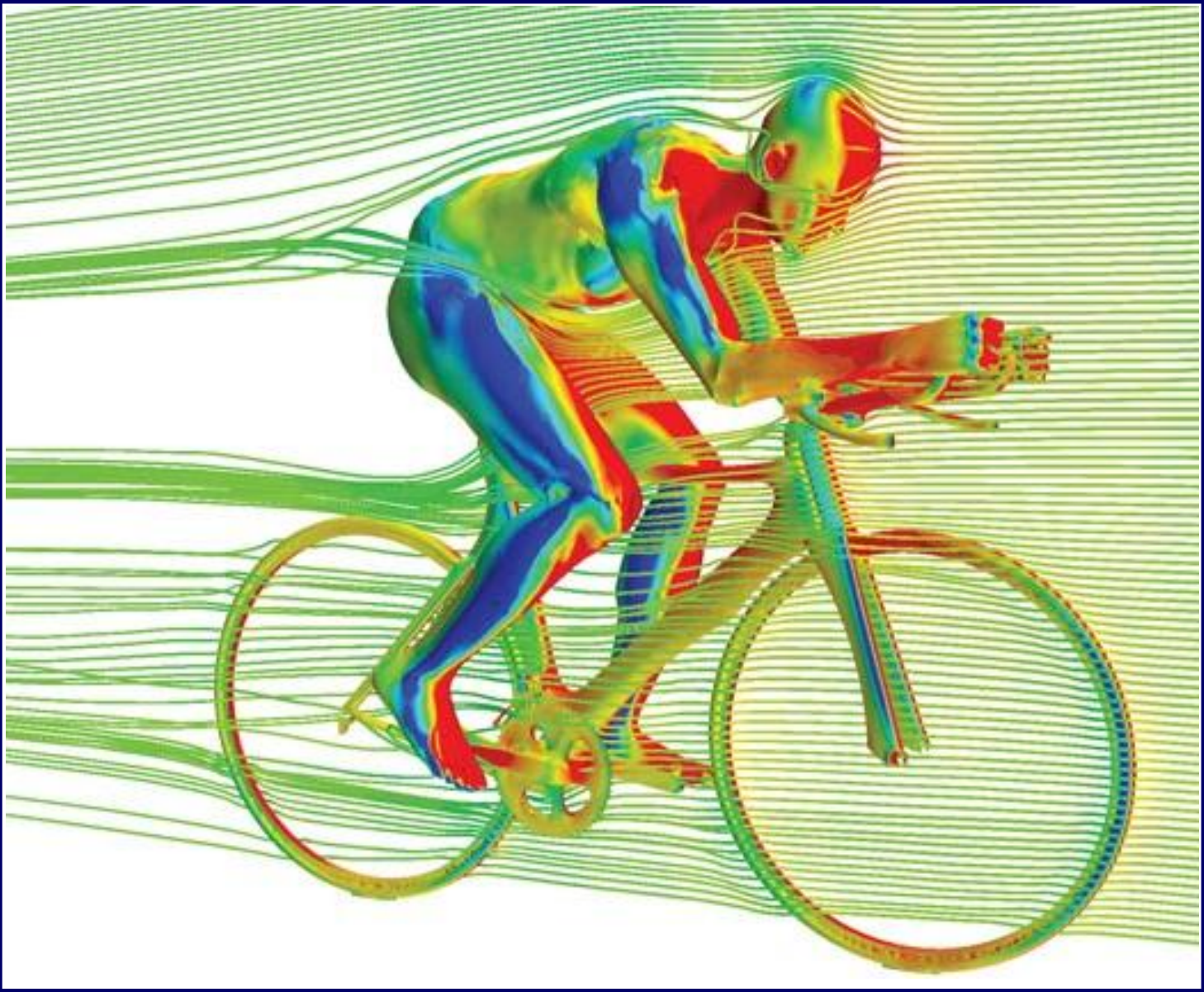
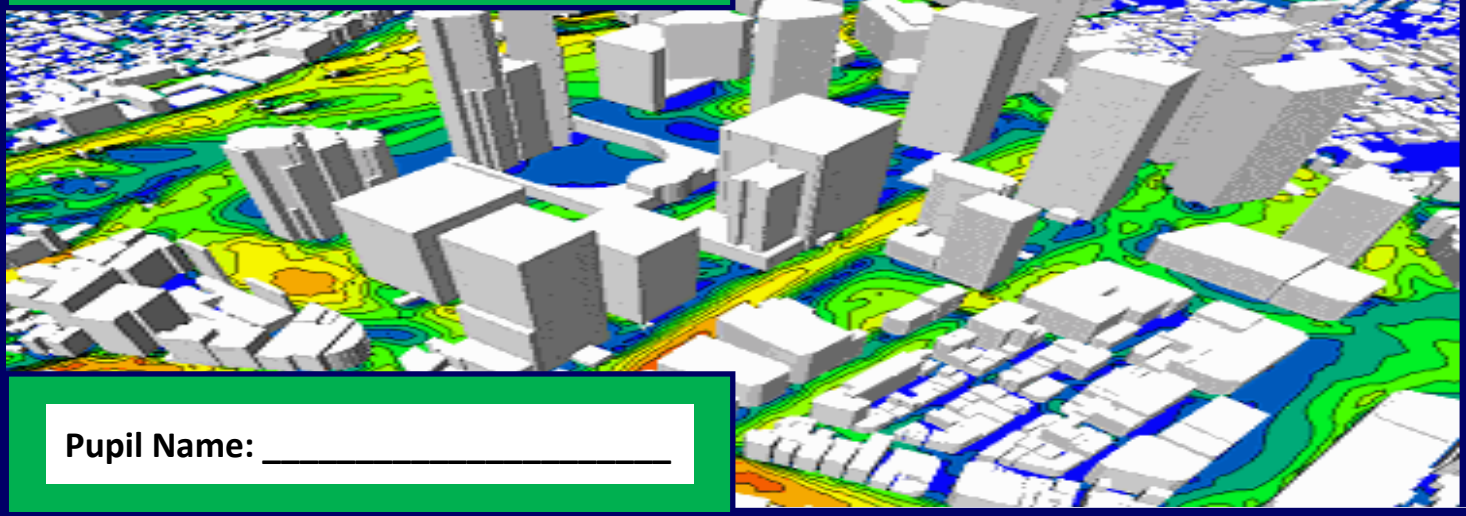


The **Scholars** Programme

From Bikes to Buildings: Testing Modern Designs Using Computational Fluid Dynamics

Tutor Name: Dr. Di Salvo



Pupil Name: _____

The Scholars Programme – Pupil Feedback Report

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at first year undergraduate level
2:1	60-69	Performing to a good standard at first year undergraduate level
2:2	50-59	Performing to an excellent standard at GCSE level
3rd	40-49	Performing to a good standard at GCSE level
Workings towards a pass	0-39	Workings towards a pass
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Name of PhD Tutor			
Title of Assignment			
Name of Pupil			
Name of School			
ORIGINAL MARK / 100		**FINAL MARK / 100**	
DEDUCTED MARKS		**FINAL GRADE**	

If marks have been deducted (e.g. late submission, plagiarism) the PhD tutor should give an explanation in this section:

Learning Feedback Comment 1	
What you did in relation to this Key Learning Priority	**How you could improve in the future**

Learning Feedback Comment 2	
What you did in relation to this Key Learning Priority	**How you could improve in the future**

Learning Feedback Comment 3	
What you did in relation to this Key Learning Priority	**How you could improve in the future**

Resilience Comment	
How you showed learning resilience during the course	**How you could build learning resilience in the future**

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Course Rationale

How does a Formula One team improve on the design of their car in such a short space of time? How does Airbus test out hundreds of aircraft designs without having to build a prototype each time? How does a pharmaceutical company test out the efficiency of a new asthma inhaler without having to manufacture it first?

The answer is by using a method called Computational Fluid Dynamics (CFD), where real world situations are simulated using a specialist computer program, enabling companies to test out new ideas digitally before spending millions of pounds physically making the products. CFD is a cutting-edge branch of engineering where research is continuously being conducted in order to improve upon the current techniques, along with new advances in computing making everything faster, cheaper and more accurate than ever before.

This course will suit a vast range of students with an interest in aerospace and automotive design through to architecture and medicine. The tutorials will guide students through the principles behind this exciting field of engineering, as well as introducing the theory and equations used in CFD simulations, namely the conservation of mass, momentum and energy. The students will be guided through two-dimensional problems before discussing the different techniques available for solving more complex three-dimensional cases. The students will be asked to choose a real world example as a case study and write a report as if they were a CFD engineer working on the design.

Mark Scheme

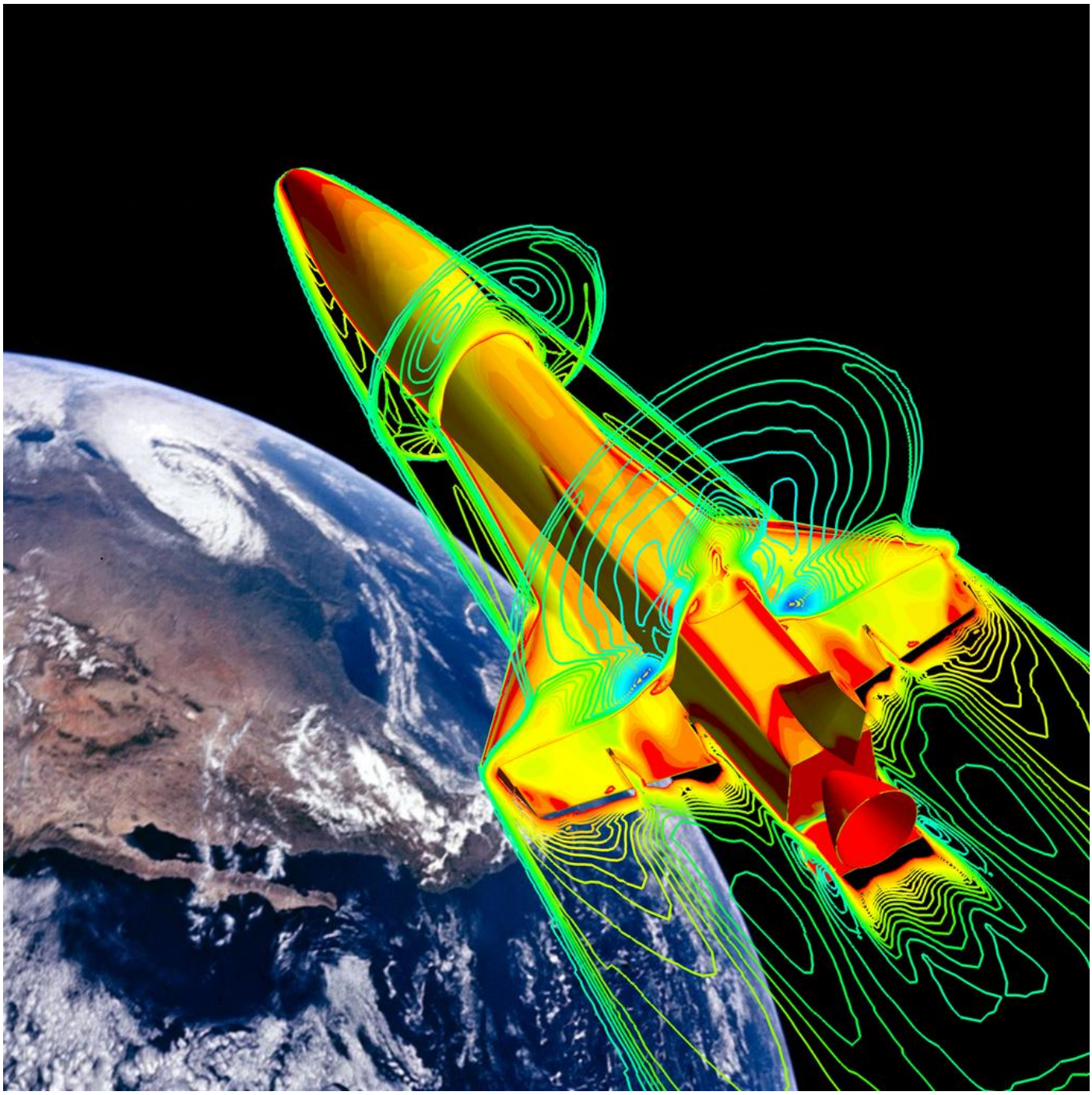
Key Skill	1st	2.2
Language	☐ Uses appropriate new and scientific vocabulary correctly and effectively when discussing the key stages of a CFD simulation. ☐ Specific terminology is consistently used correctly.	☐ Uses simple new vocabulary effectively but struggles with new vocabulary that is more challenging. ☐ Specific terminology may be used incorrectly at times.
Research skills	☐ Uses a wide range of resources (for example: website pages, journal articles, all of which are correctly referenced. ☐ Comprehensive research is evidenced.	☐ A narrow range of sources has been used and are not always referenced correctly.
Contextualising	☐ The course concepts previously applied to specific case studies are applied successfully and confidently to new case studies.	☐ An application of the course concepts to new case studies has been attempted and is mostly successful.
Critical thinking and Evaluation	☐ Validity of all CFD results is discussed without the need to be prompted to do so. ☐ Critical evaluation of the CFD process, including its limitations, is clear and well-argued.	☐ Validity of some of the data used is discussed. ☐ Some critical evaluation is attempted.

Glossary of Keywords

Make a note of the key terminology from the course here, to be filled in as the course progresses.

Term	Definition	Symbol	Units
Density			
Velocity			
Pressure			
Viscosity			
Energy			
Fluid			
Gas			
Liquid			
Temperature			
Volume			
Mass			
Flow			
Time		t	s
Distance		x	m

Tutorial 1 – What is CFD?



What is the Purpose of Tutorial 1?

- To introduce the tutor and the course
- To familiarise the students with key fluid flow terms
- To introduce CFD
- To introduce the stages of a CFD simulation

What is fluid flow?

Give examples of fluid flow from the picture below:

Give some examples of fluid flow found in everyday life:

Why is it important to study fluid flow?

What is CFD?

What are the 6 key stages of a CFD simulation?

1	
2	
3	
4	
5	
6	

Tutorial 1 – Baseline Test

The homework assignment for the first tutorial is a baseline test to see your initial level of attainment in this subject area. Do not worry too much about doing 'well' or 'badly' on the baseline test, it takes into account the fact that you may not be familiar with the subject area. It is designed to help you and your PhD tutor identify where you are at the start of the programme and to help you measure your progress along the way.

Find the derivative of the following functions:

$$x^2$$
$$3x^3$$
$$4x^2 + x^5$$

Find the partial derivatives with respect to x:

$$xy^2$$
$$4x^3 + y^3$$
$$y^2z^2x$$

In your own words, describe the meaning of:

- Conservation of mass

- Conservation of momentum

- Conservation of energy

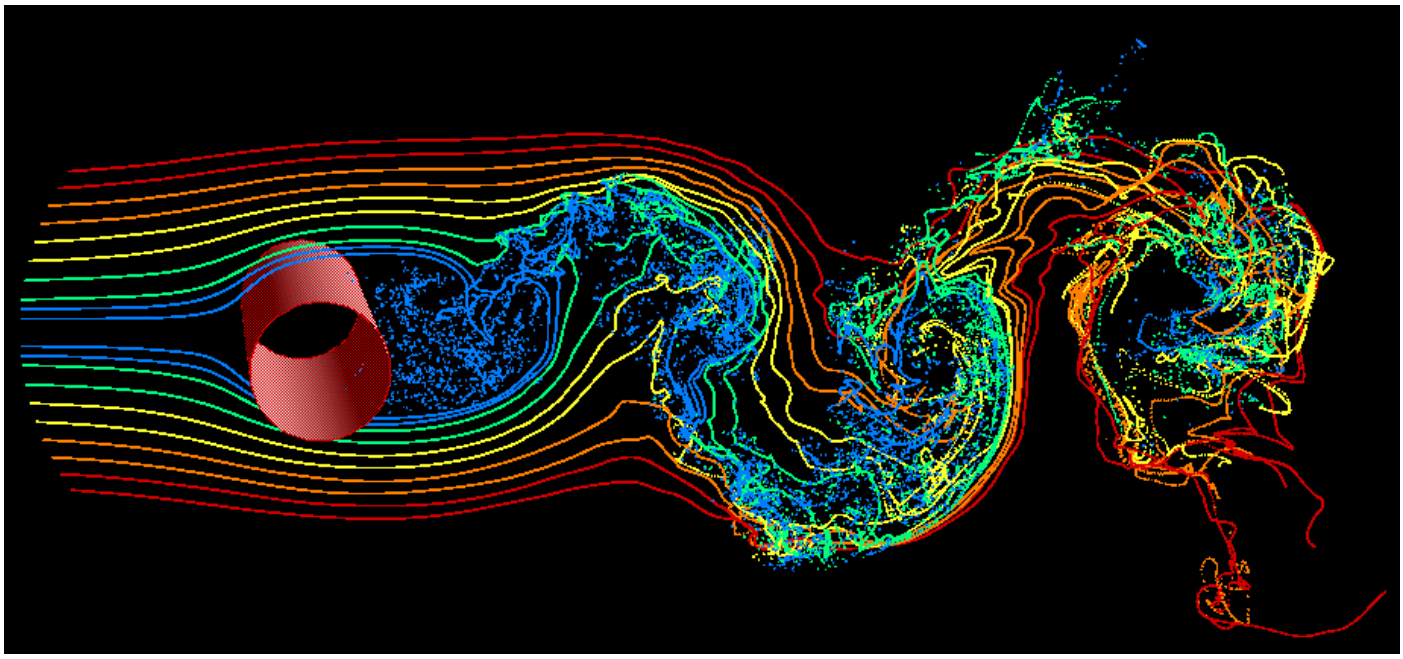
Give three real world examples of where you would expect to find turbulent fluid flow.

1.

2.

3.

Tutorial 2 – Turbulence and the Governing Equations



What is the Purpose of Tutorial 2?

- To introduce the key concepts behind CFD
- To understand the principles and equations used
- To introduce the control volume
- To explain the general transport equation
- To introduce turbulence and its modelling

Write down the three physical principles of CFD and the governing mathematical equations associated with them:

	Physical principles	Mathematical equations
1		
2		
3		

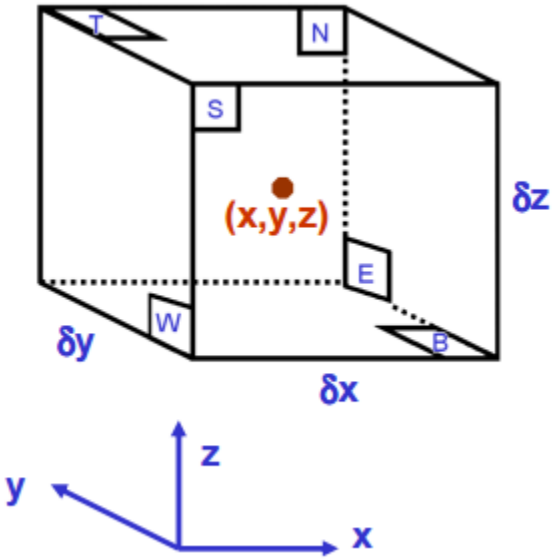
You will be given a principle to research in class, make notes as each group presents their findings:

1.

2.

3.

Consider a volume in space. How do these conservation principles relate to this volume?



Annotate the general transport equation:

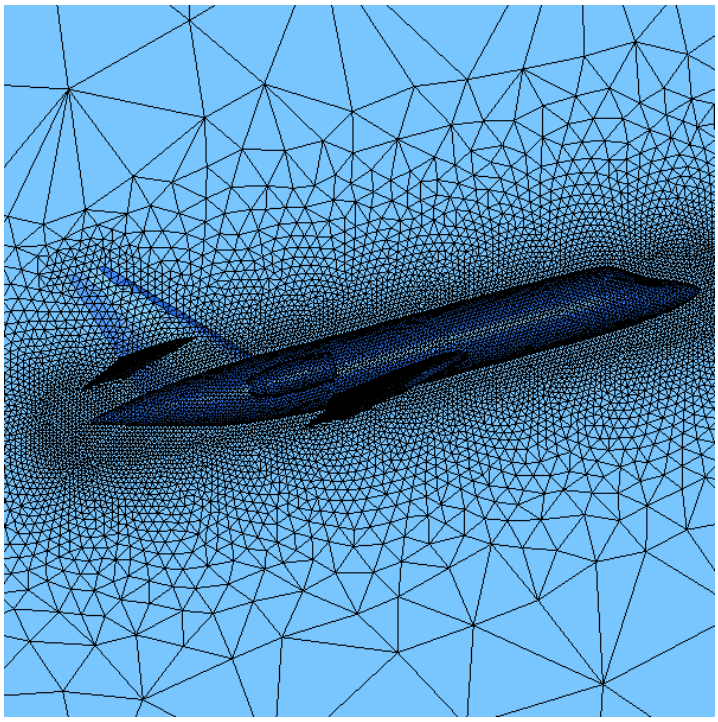
$$\frac{\partial(\rho\phi)}{\partial t} + div(\rho\phi\,\mathbf{u}) = div(\Gamma\, grad\,\phi) + S_\phi$$

_____ + _____ = _____ + _____

What are the other sources?

What is a turbulent fluid flow?

Tutorial 3 – The Choices You Make



What is the Purpose of Tutorial 3?

- To understand what choices an Engineer has when setting up a CFD simulation, and what effect these choices have on the results
- To introduce the concept of the mesh and mesh refinement
- To understand the meaning of specific grid generation terminology
- To be able to make an informed decision on the grid based on expected the expected flow

What is a mesh and why is it needed?

What is mesh refinement?

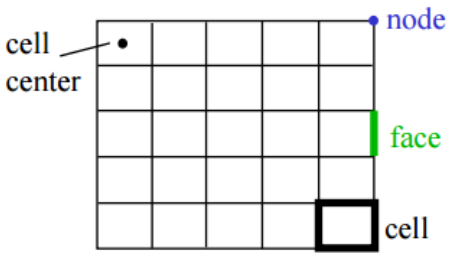
In what ways does it affect the simulation?

What are the advantages and disadvantages of using a fine mesh compared to a coarse mesh?

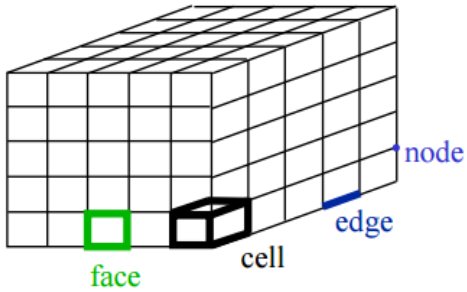
What compromise is available?

Define the following terms:

Cell	
Node	
Cell centre	
Edge	
Face	
Zone	
Domain	



2D computational grid

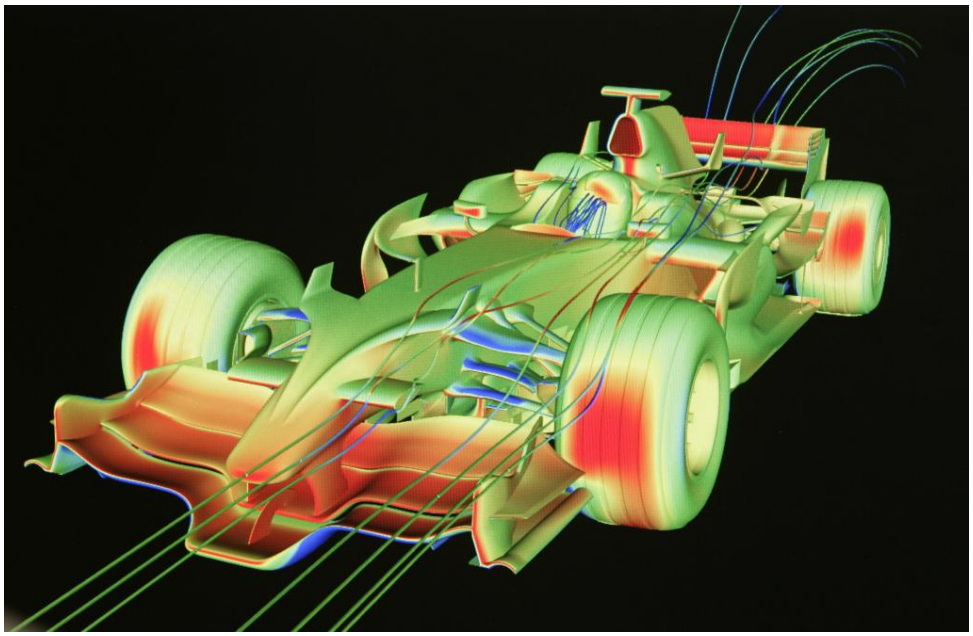


3D computational grid

Structured or unstructured mesh? Make notes and draw examples during the tutorial:

Summarise the choices you have control over when preparing a CFD simulation:

Tutorial 4 – Formula One Car Case Study

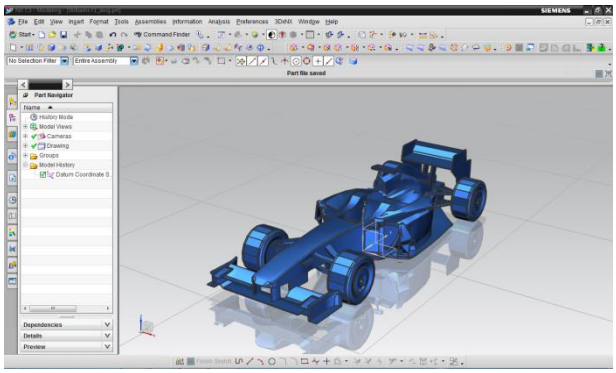


What is the Purpose of Tutorial 4?

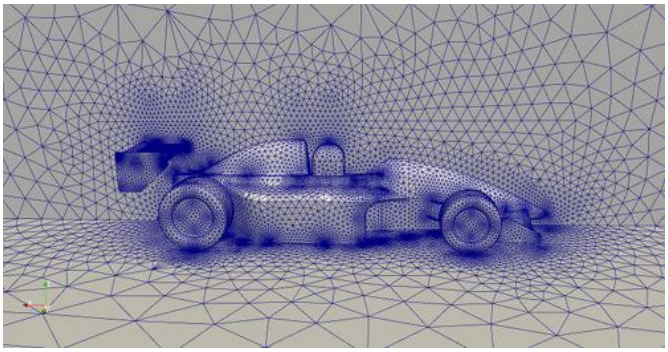
- To go through the stages of a CFD simulation, using a Formula One car as a case study
- To highlight the key results available to the user after completing a simulation

Make notes on the 6 stages of a CFD simulation during the tutorial:

1. CAD model



2. Grid



3. Algorithm

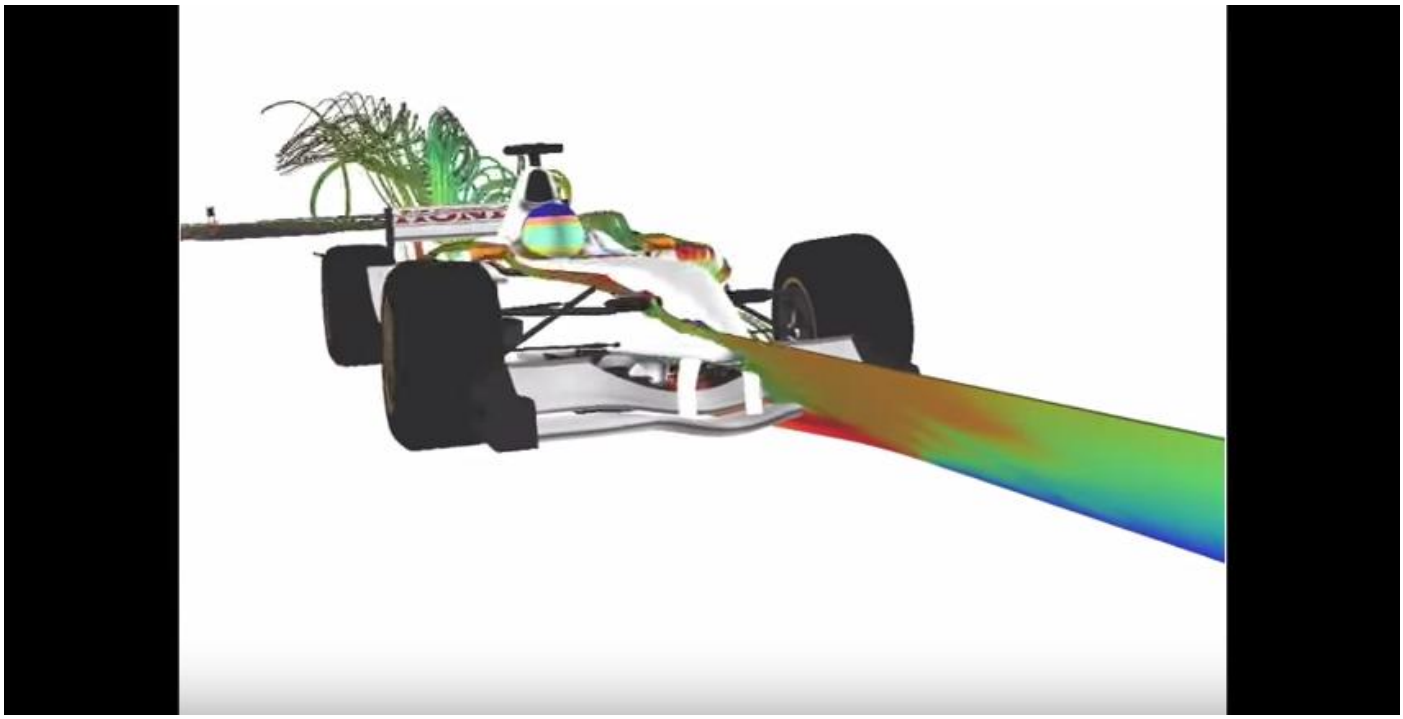
4. Simulation

5. Verifying results

6. Post-processing

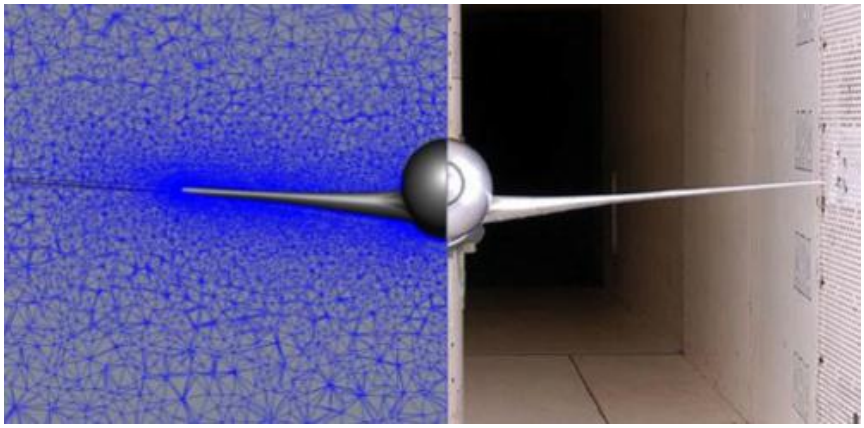
What results would you be interested in when analysing a Formula One CFD simulation?

Make notes on the different results highlighted in the video shown in class:



Tutorial 4 – Homework: Draft Assignment

Tutorial 5 – Critical Thinking



What is the Purpose of Tutorial 5?

- To allow the students to think critically
- To consider the questions to ask when verifying CFD results
- To explain whether they would use experimental or computational techniques for different situations
- To discuss the advantages and limitations of CFD

How you would verify the validity of CFD results:

What are the advantages of using CFD?

What are the limitations of CFD?

Tutorial 5 – Homework: Final Assignment

Comparing against the Formula One case study in the Tutorial 4, discuss and analyse why CFD would be used to improve the design of a real world case study of your choice.

For the final assignment you will pick a case study of your choice based on your own interests. You will produce a report as though you are a part of the initial design team at an Engineering company, looking at the kind of issues you would expect from a computational fluid dynamics point of view. Case studies can be chosen from:

- Aerospace engineering: Airbus A380
- Biomedical engineering: Asthma Inhaler
- Civil engineering: "The Gherkin" building, London
- Sports engineering: 2012 British Olympic Cycling Track Bicycle
- Turbomachinery: Rolls Royce Trent 900 Jet Engine
- Any other case study of your choice, with prior approval from the tutor.

You will produce a report which looks at different designs, potential problems, as well as researching and critically assessing different techniques available as a CFD engineer to come up with what methods you think will suit your case study. You will compare the issues found in the Formula One test case with the issues you anticipate with your chosen case study. It is designed to get you thinking about both research and industry, and how the two come together in Engineering.

It will assess your abilities to write a report supporting your choices. You will have a basic understanding of the numerical methods involved in CFD. You should show awareness of the latest research developments in CFD.

You should go through the six key steps of a CFD simulation and show an awareness of any problems and ideas you have during each stage, and how to deal with them. Your own independent research is expected. Your report should address the questions:

- What are the benefits of using CFD over experiments for your case study?
- What kind of problems would you expect when running these simulations?
- What techniques would you use in your simulations? Think about the kind of grid used, the speed of the simulations. For example, how big a grid and computational power would you need for an asthma inhaler compared to a Formula One car? How much detail do you want in certain regions?
- What range of tests would you investigate?
- Do you need to consider internal or external fluid flow, or both?
- What results are you looking for from your simulations?
- How would you measure these results?
- How would you display your results?
- How would you validate your code?
- What problems would you envisage in your case study that wasn't an issue in the Formula One car?

Tutorial 6 – Feedback

What is the Purpose of Tutorial 6?

- Reflect on skills learned on the programme with a view to encouraging resilience
- Receive feedback on final assignment

What are the key questions?

- What strengths have I demonstrated in my work and what areas of development are there left for me to address?
- What steps do I need to take to improve my academic output?

Activity 2 – Marking your own

Using the mark scheme, identify three things you did well and three things you could improve.

What went well?

1.

2.

3.

What could be improved?

1.

2.

3.

Activity 3 – Responding to feedback

Read through your feedback sheet and highlight on your assignment where you received positive feedback (one colour) and areas for improvement (different colour). You might find it helpful to annotate this with a brief comment or two.

(Acknowledgement: The structure and the activities in this feedback tutorial were first designed by Hannah Manktelow in January 2015. We have repeated them here as they demonstrate thoughtful and excellent planning, and can be used by all tutors to ensure a successful and productive feedback tutorial.)

University Applications Guidance

For course choices and careers information: www.brightknowledge.org.uk

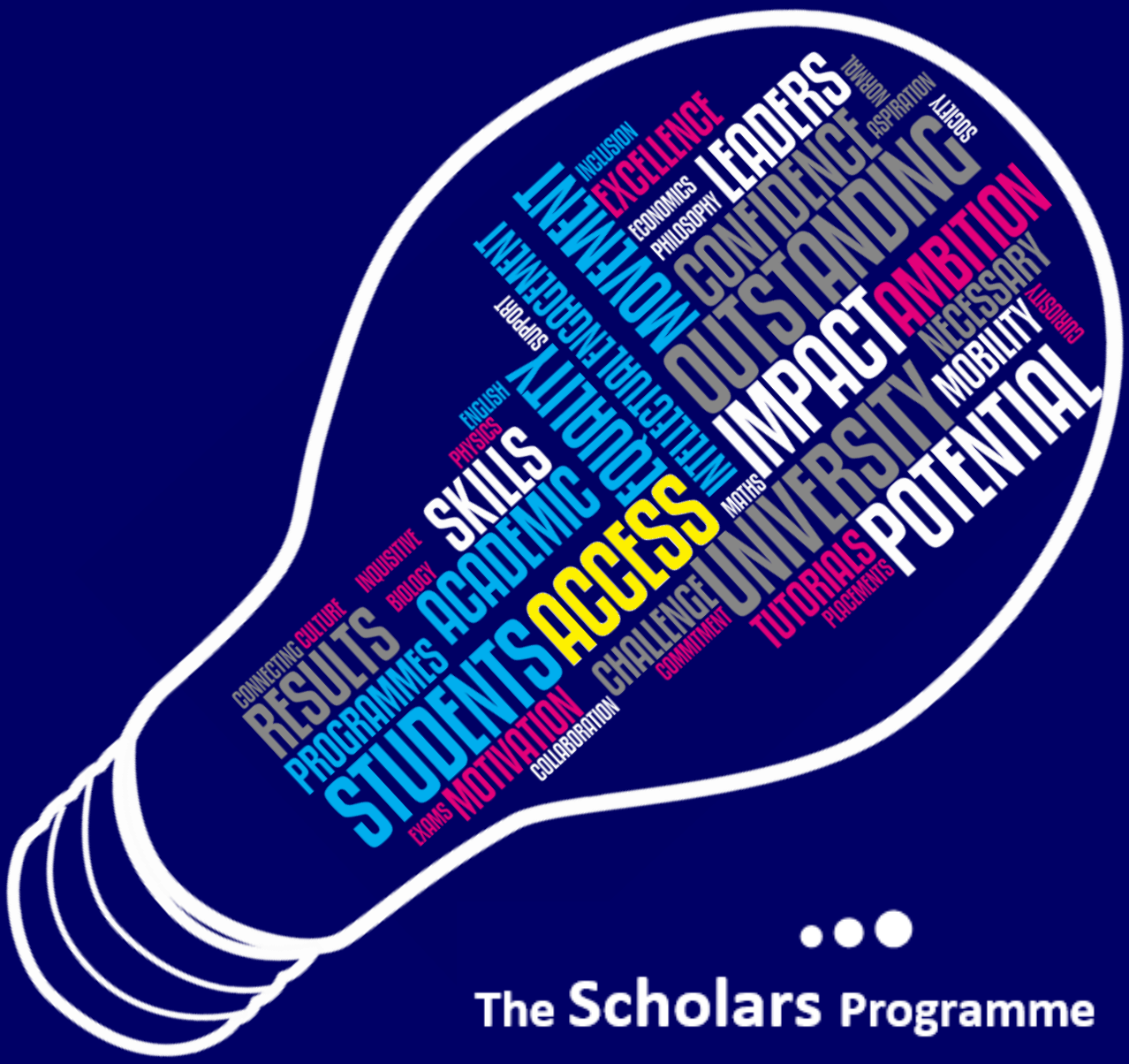
For information and statistics on universities and course: www.unistats.direct.gov.uk

For comprehensive information on universities, including rankings: www.thecompleteuniversityguide.co.uk

PLEASE NOTE – The Scholars Programme is designed to support the university applications process at your school. The work you complete for the programme should add to your schoolwork rather than detract from it. Please be aware of deadlines and try to manage your workload appropriately. If you are worried about the Scholars Programme interfering with your schoolwork then please speak to your teacher.

Subject Specific Top Tips for Strengthening your application

What could you read around the subject?
Suggestions of podcasts/videos that can be found online? Are there any age-appropriate, good films on this topic?
What cheap or free events and talks would it be good to attend?



The Scholars Programme