Integrating CFD and Experiments

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University of Glasgow

Experimentalist's requirements for a safe methodology in CFD code validation

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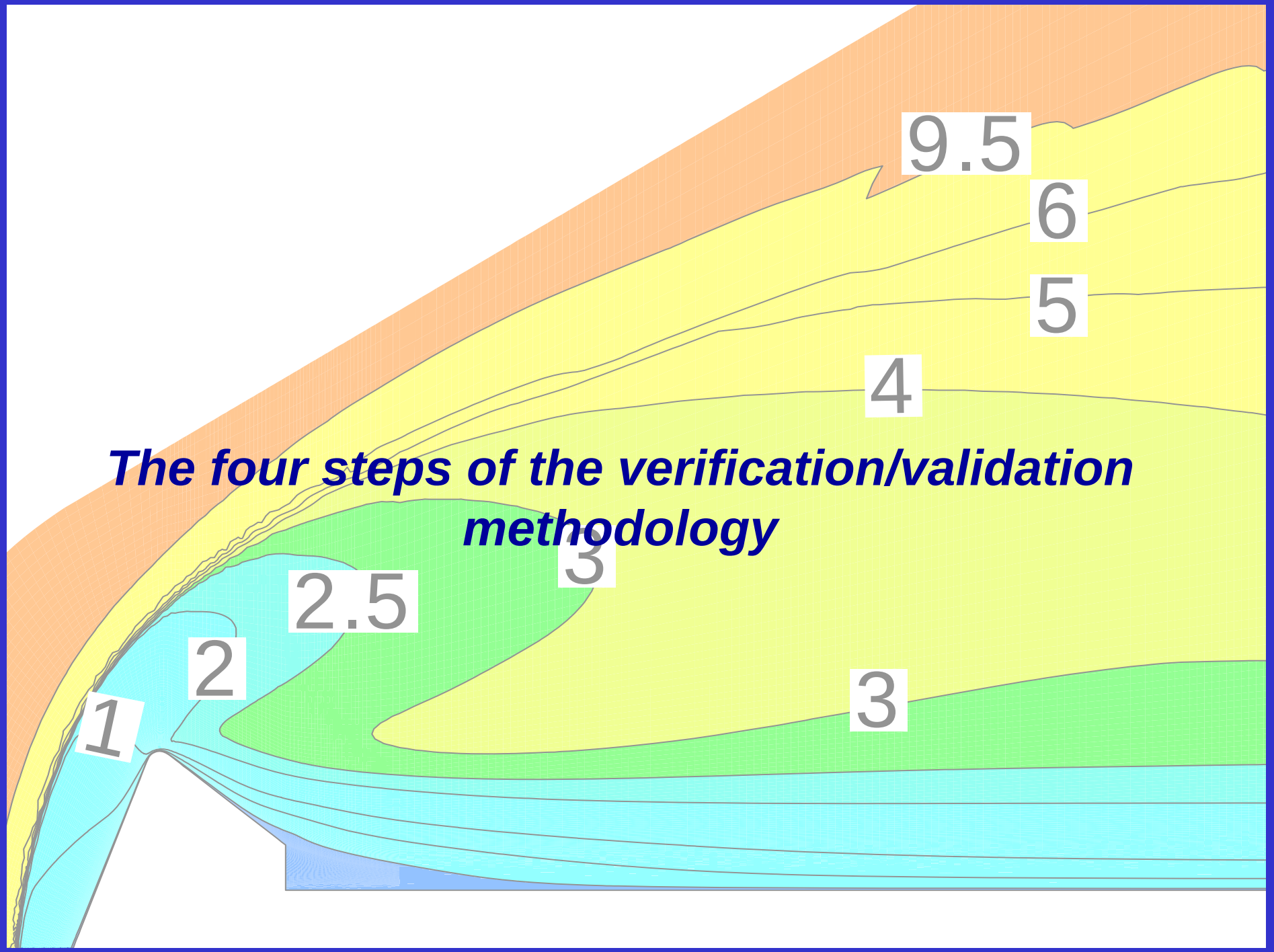
The parts of the paper

- ***The four steps of the verification/validation methodology***
- ***Requirements for sound and useful experimental results***
- ***Methodology for a thorough experimental flow qualification***
- ***Data bank constitution and management***



The four steps of the verification/validation methodology

The four steps of the verification/validation methodology

1. First step: **assessment of the code numerical accuracy and reliability is a prerequisite to any further validation step**

➡ **how do do it?**

- ***comparison with exact analytical solutions (such solutions are scarce)***
- ***confrontation with other codes or cross-validation (are the other codes better?)***
- ***comparison with good experimental results***

basic rule ➡ **avoid the mixing of numerical techniques, meshing difficulties and modelling uncertainties**

The four steps of the verification/validation methodology

2. Second step: **validation of the physics implemented in the code on simplified configurations emphasising hard points**

For this step building block experiments must be used (if available)

- ***the flat plate boundary layer***
- ***typical separated flows***
- ***vortex formation and development***
- ***shock interference patterns***
- ***shock wave/boundary layer interactions***
- ***.....***

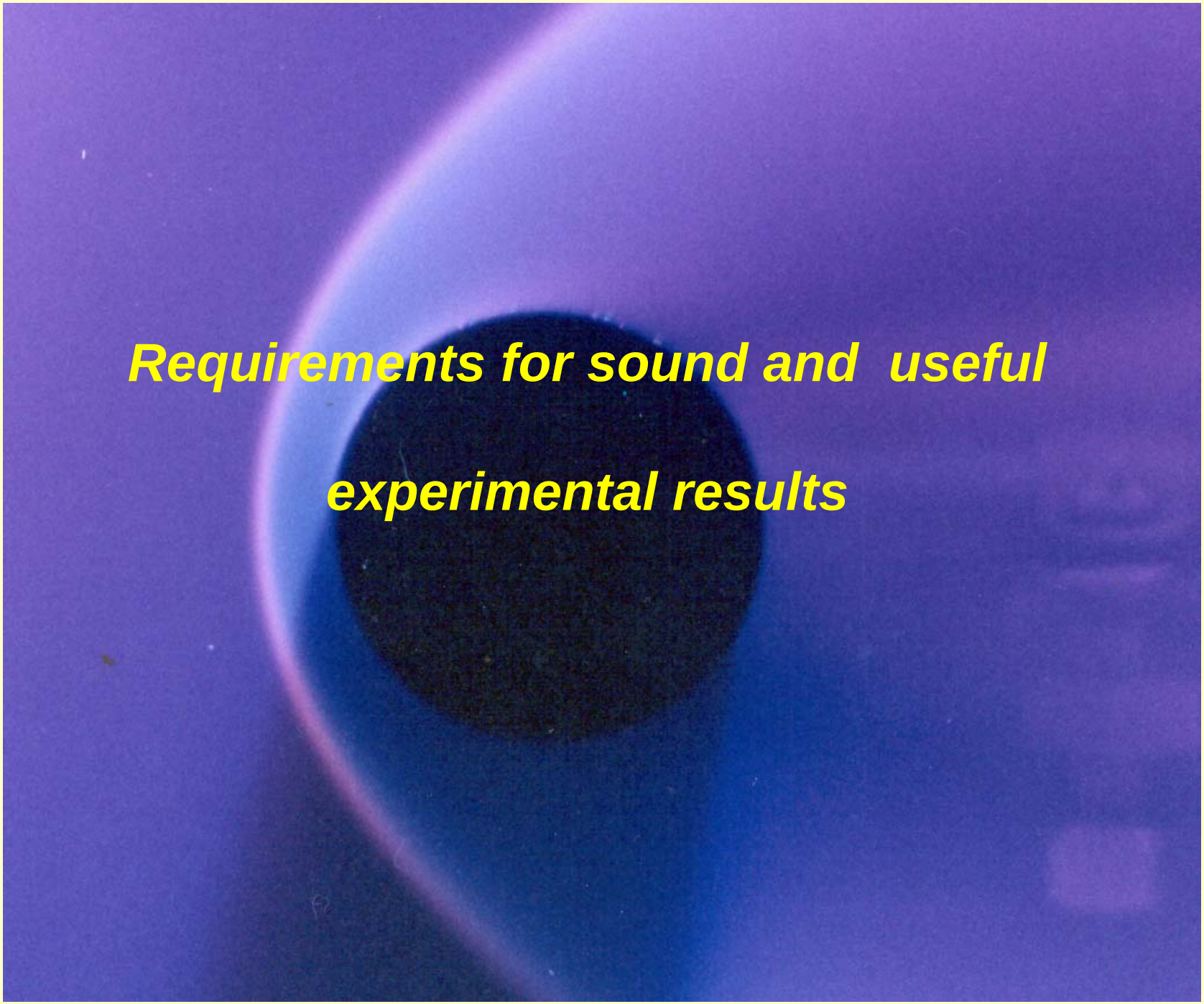
The four steps of the verification/validation methodology

3. Third step: **validation on sub - systems**

- *wing*
- *fuselage*
- *nacelle*
- *air-intake*
- *nozzle - afterbody*
- *engine component*
- *.....*

4. Fourth step: **validation on a complete object**

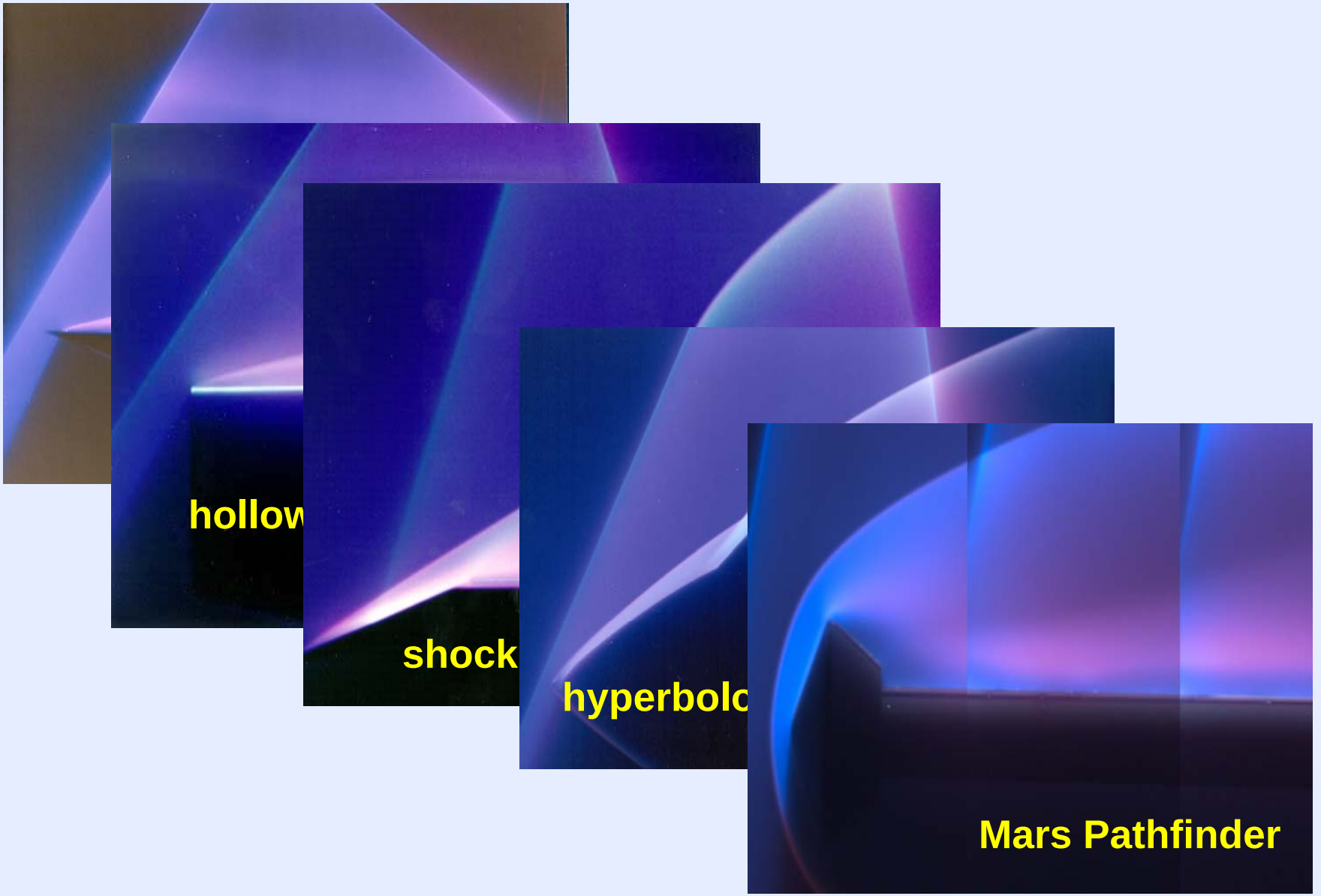
- *aircraft*
- *space launchers*
- *helicopter*
- *any vehicle ...*
- *.....*


Requirements for sound and useful
experimental results

Requirements for sound and useful experimental results

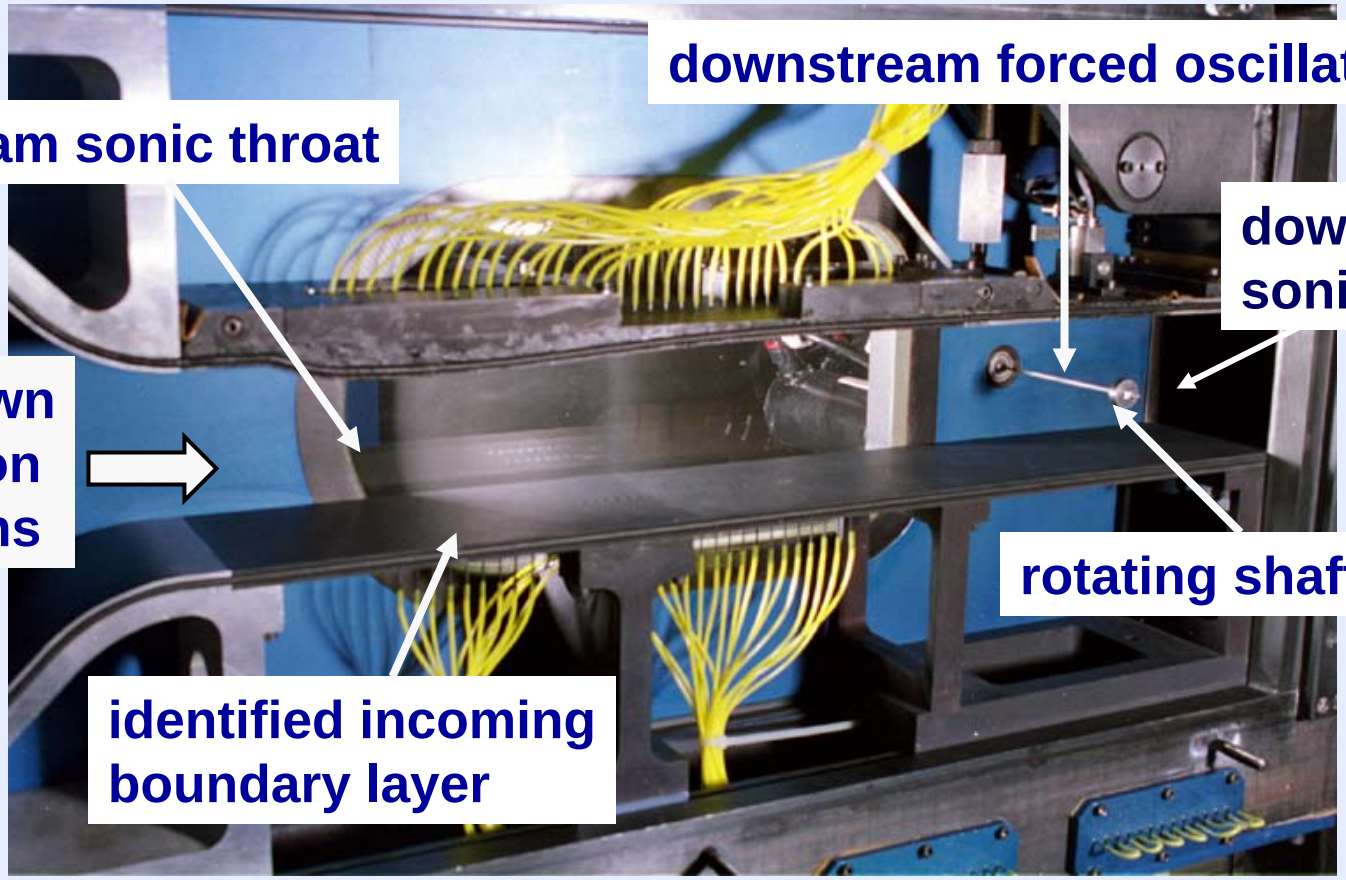
The geometry of the configuration must be precisely defined and well known and, if possible, simple to avoid too hard meshing difficulties

Laminar high - Mach number test cases from the R5Ch wind-tunnel



Requirements for sound and useful experimental results

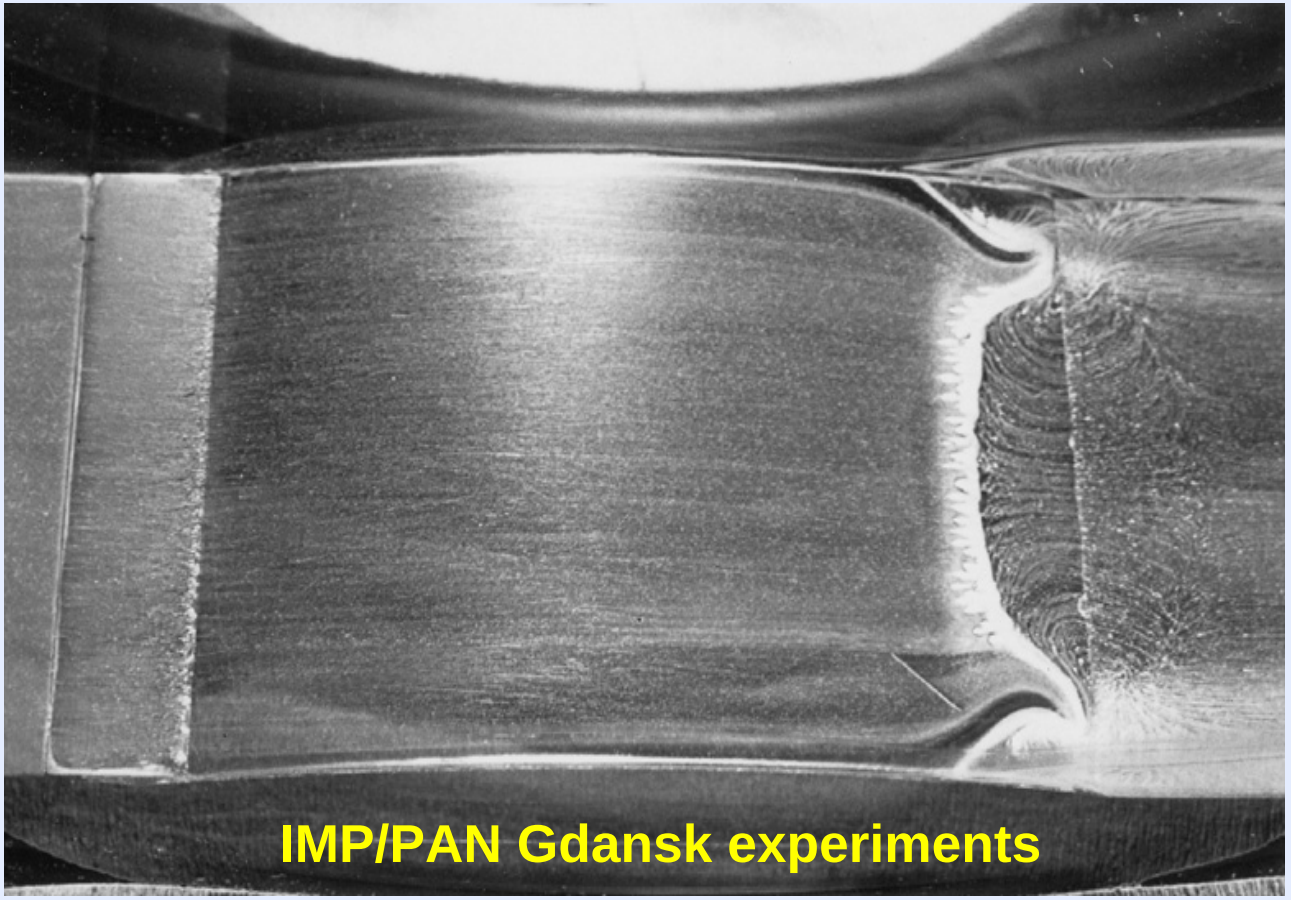
The boundary conditions must be clean and well identified



transonic channel for unsteady shock /boundary layer interaction

Requirements for sound and useful experimental results

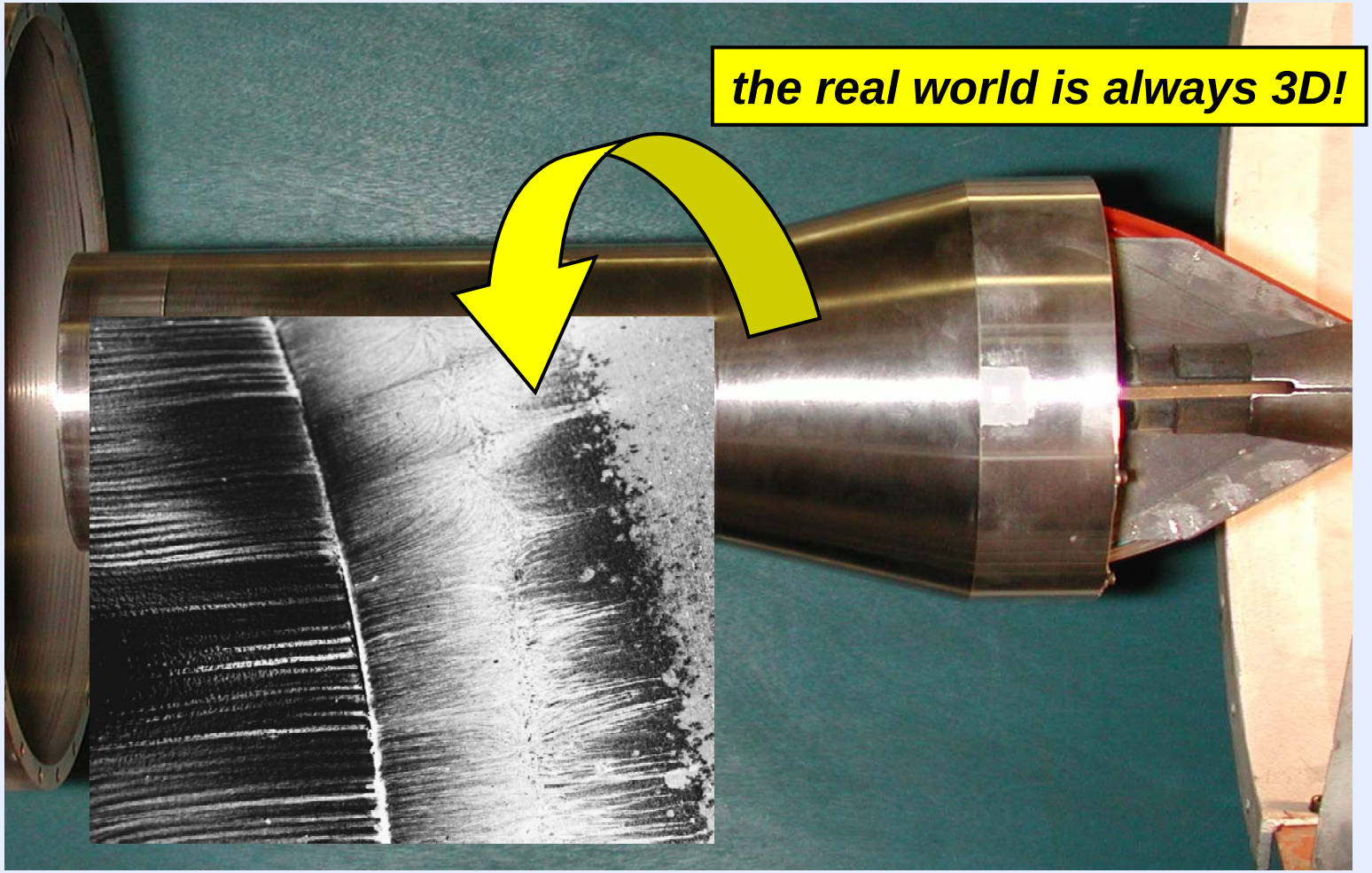
Side effects or perturbations must be avoided if they cannot be accounted for in the calculation



side effects in a 2D planar transonic channel

Requirements for sound and useful experimental results

For 2D calculations choose an axisymmetric configuration

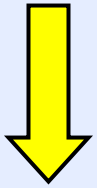


hollow cylinder for shock/boundary layer interaction

Requirements for sound and useful experimental results

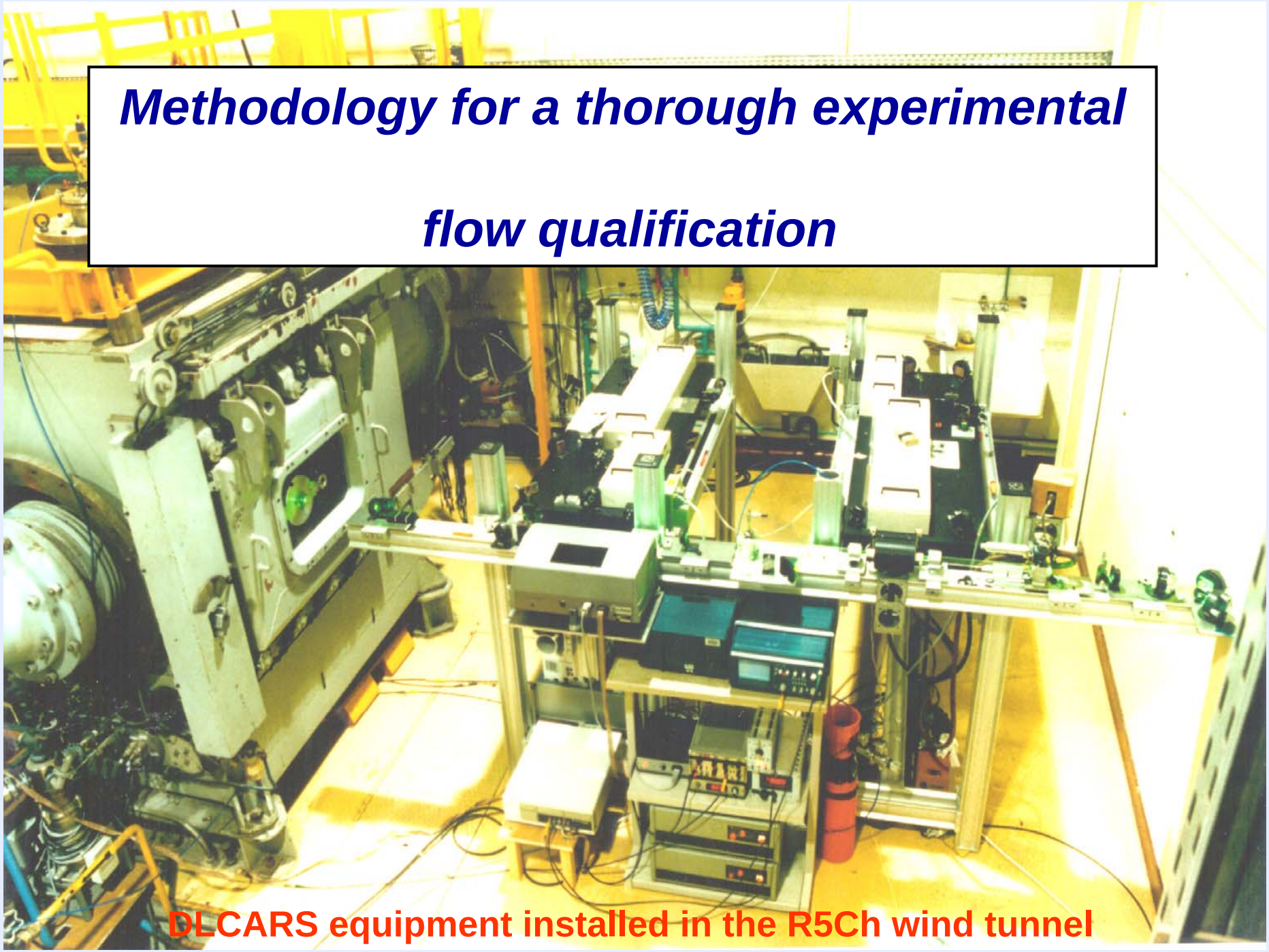
All the uspstream flow conditions must be precisely known

The flow description must be as complete as possible



develop and use an adequate instrumentation

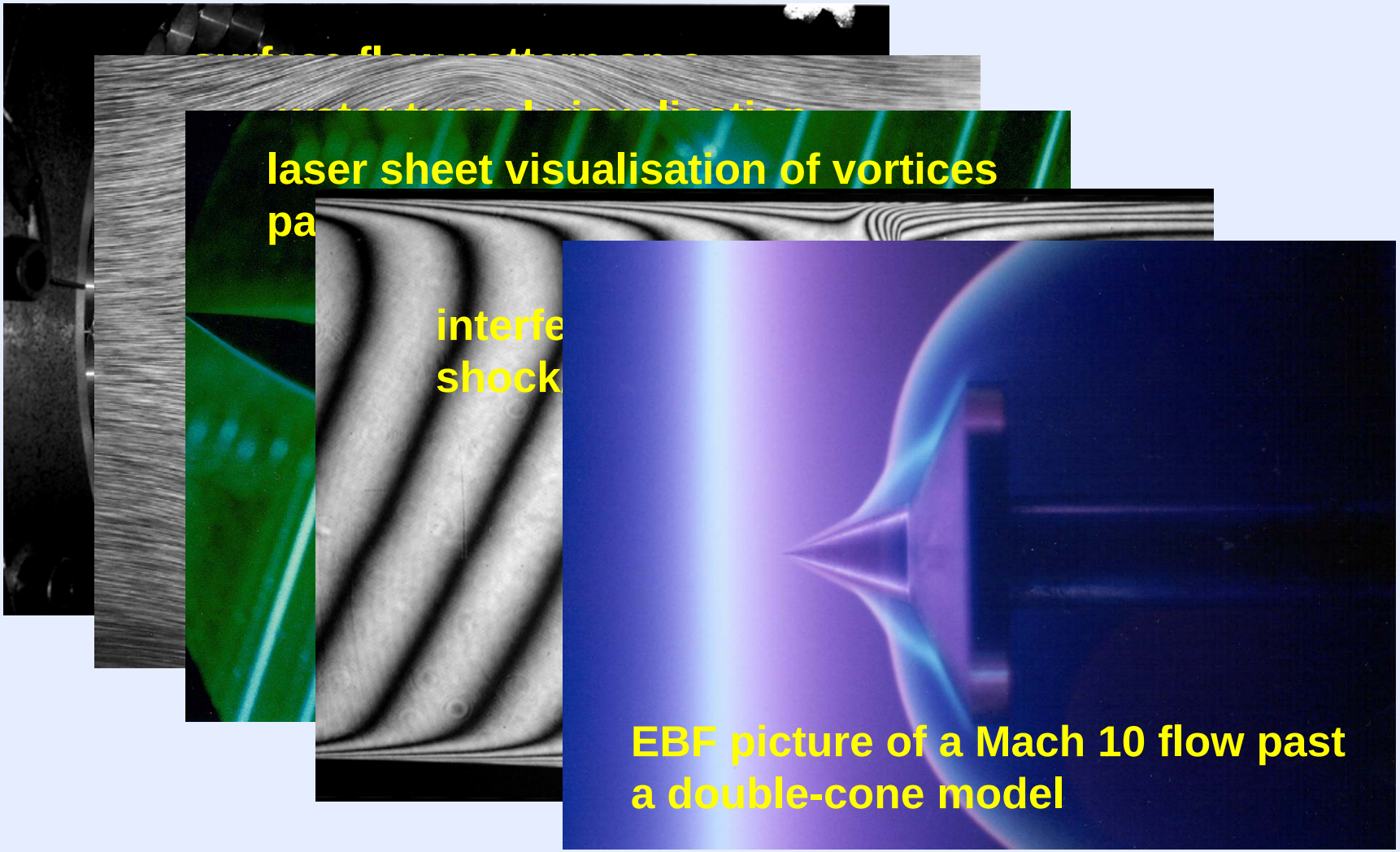
Methodology for a thorough experimental flow qualification



DLCARS equipment installed in the R5Ch wind tunnel

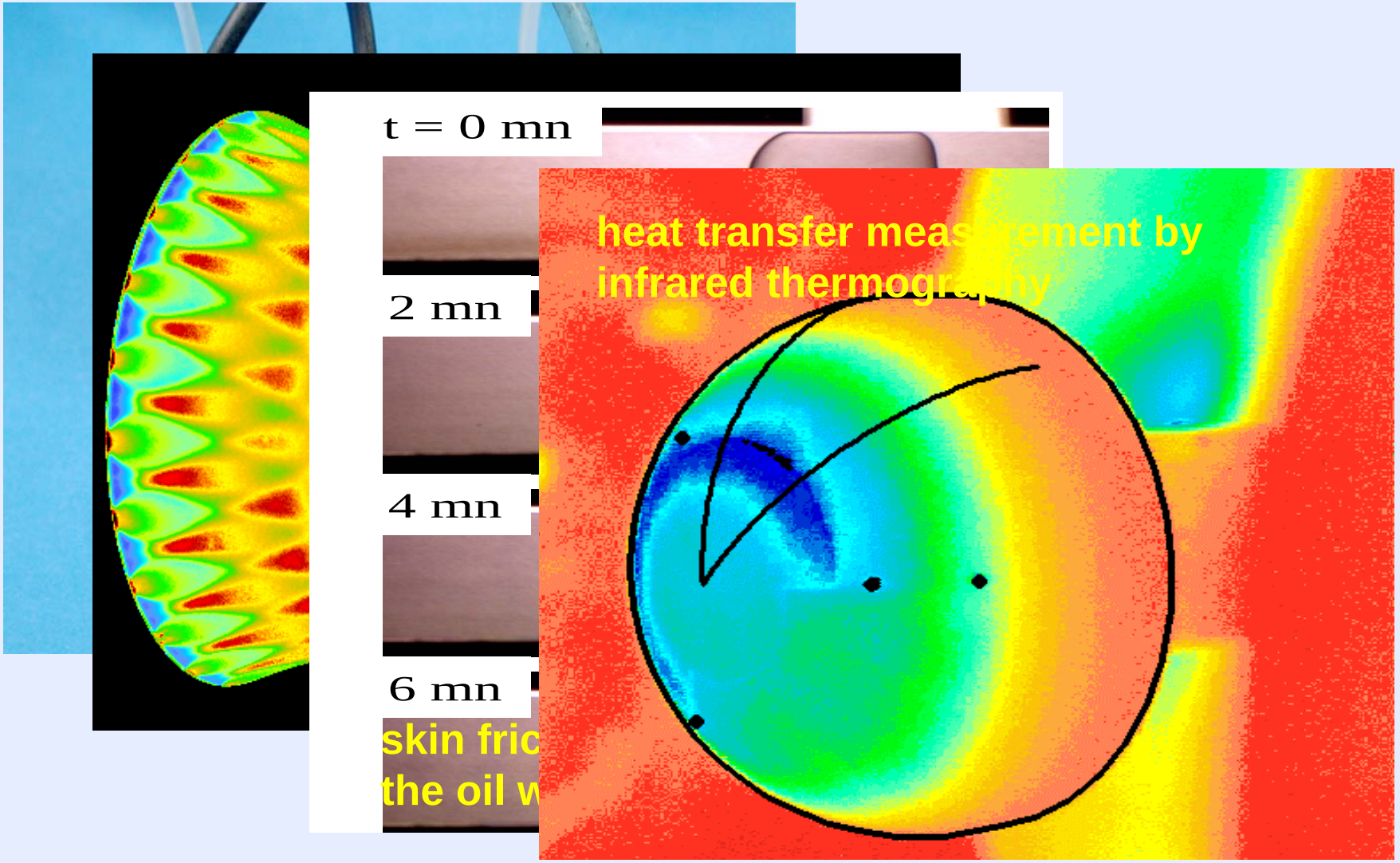
Methodology for a thorough experimental flow qualification

Flow overall organisation and topology ➡ **surface flow definition (skin friction line pattern), flow field visualisation (localisation of vortices, main features)**



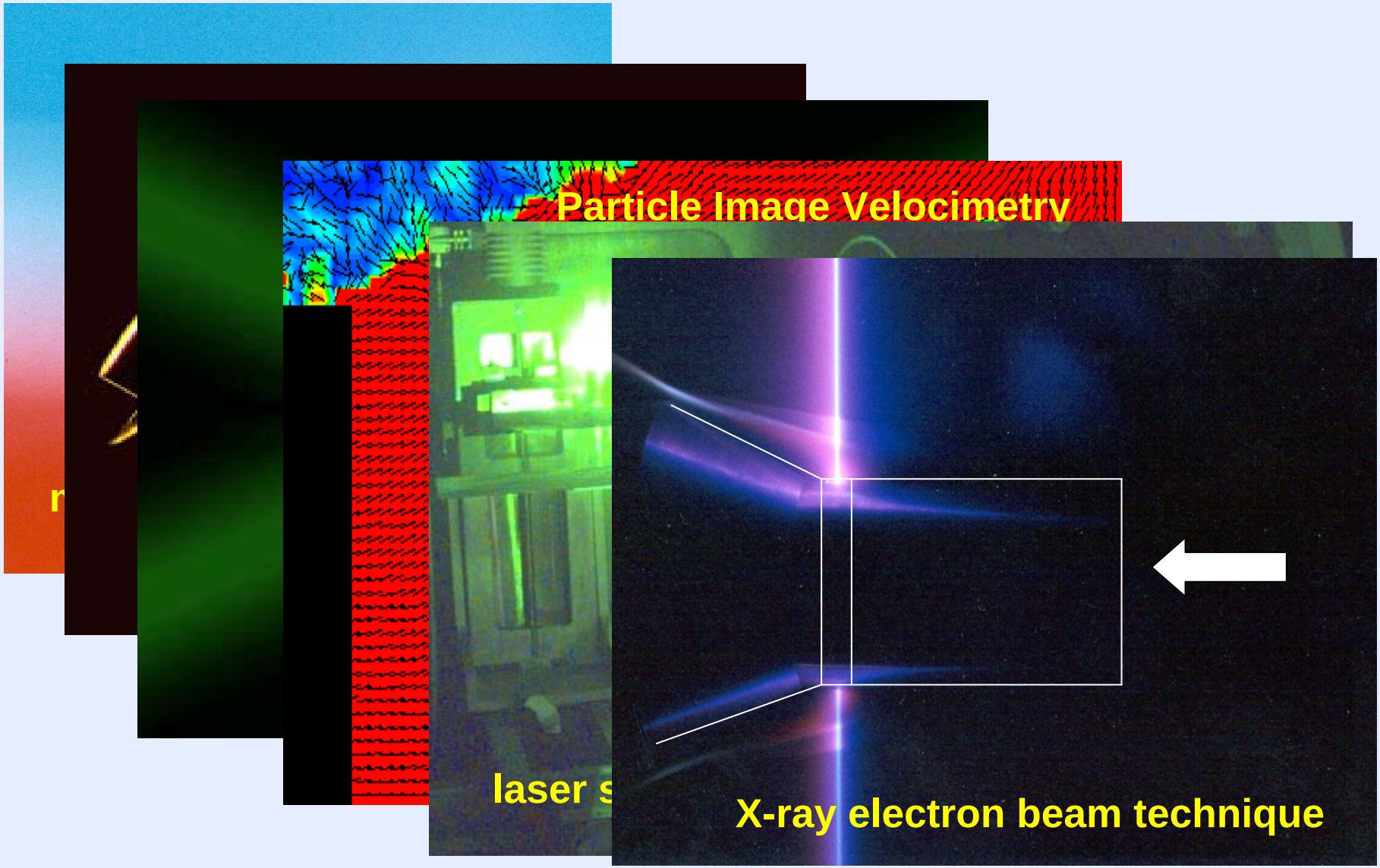
Methodology for a thorough experimental flow qualification

Wall quantities determination ⇨ **pressure (easy), skin friction (difficult), heat transfer (moderately difficult)**



Methodology for a thorough experimental flow qualification

Determination of field quantities ⇨ **velocity, pressure, temperature, density, species concentration, turbulence (Reynolds stress tensor)**



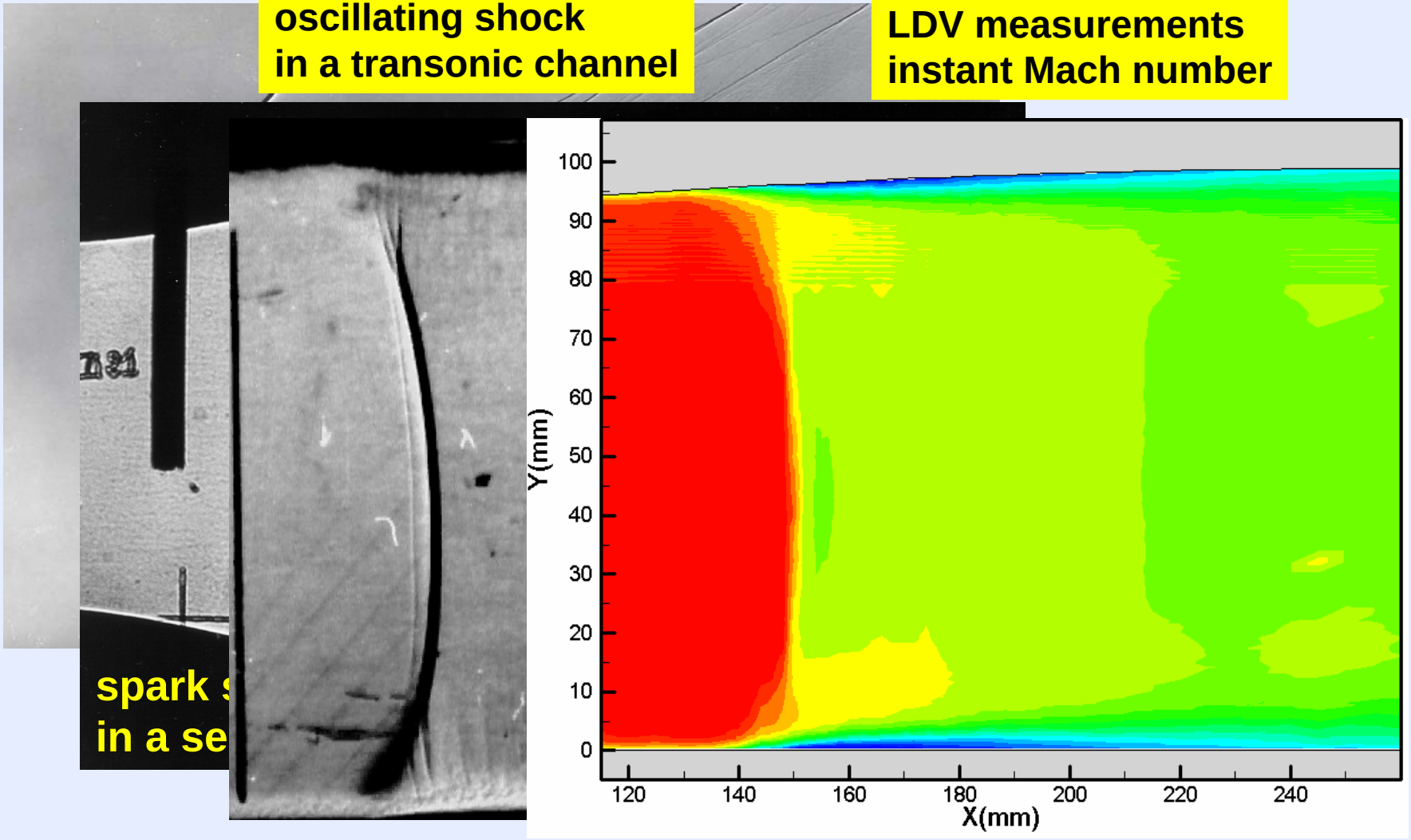
Methodology for a thorough experimental flow qualification

Unsteady measurements ➡ ***flow in space and time*** ➡

instant schlieren/shadowgraph, high speed cinematography, unsteady measurements, conditional sampling

oscillating shock in a transonic channel

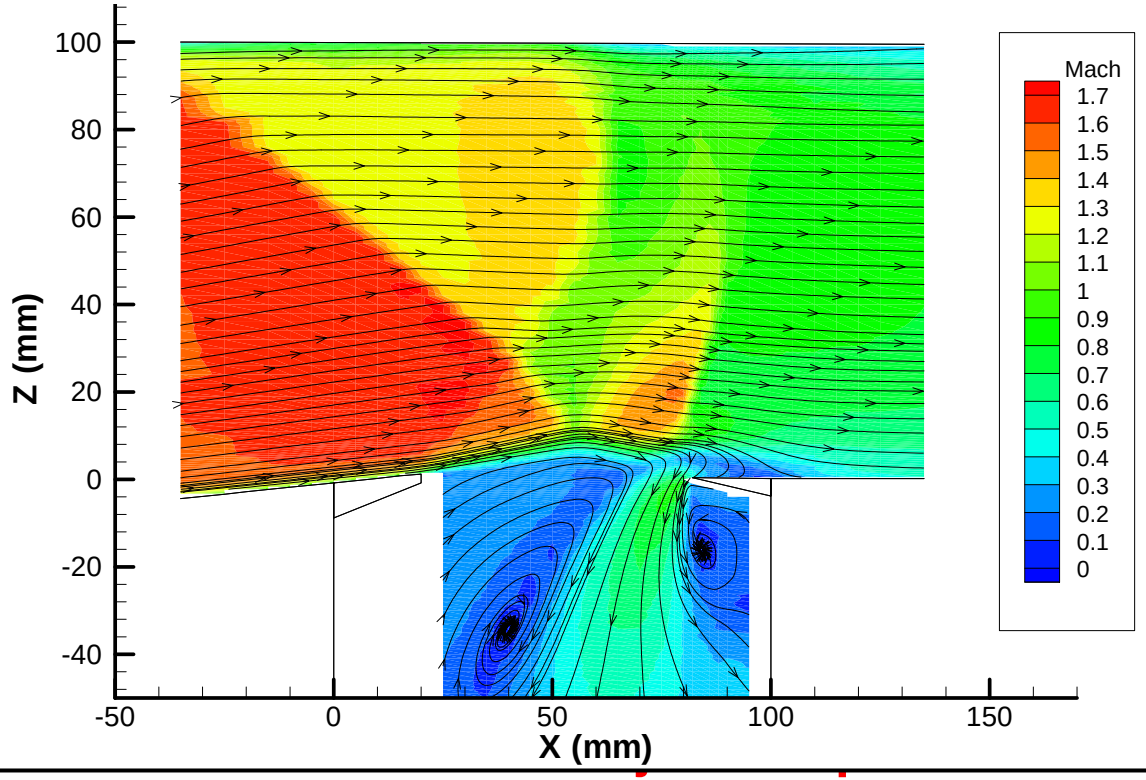
LDV measurements instant Mach number



Requirement for useful experimental results

- measurements must be **reliable and safe**: comparison with calculation can validate a new measurement technique !

flow in a supersonic air intake bleed system



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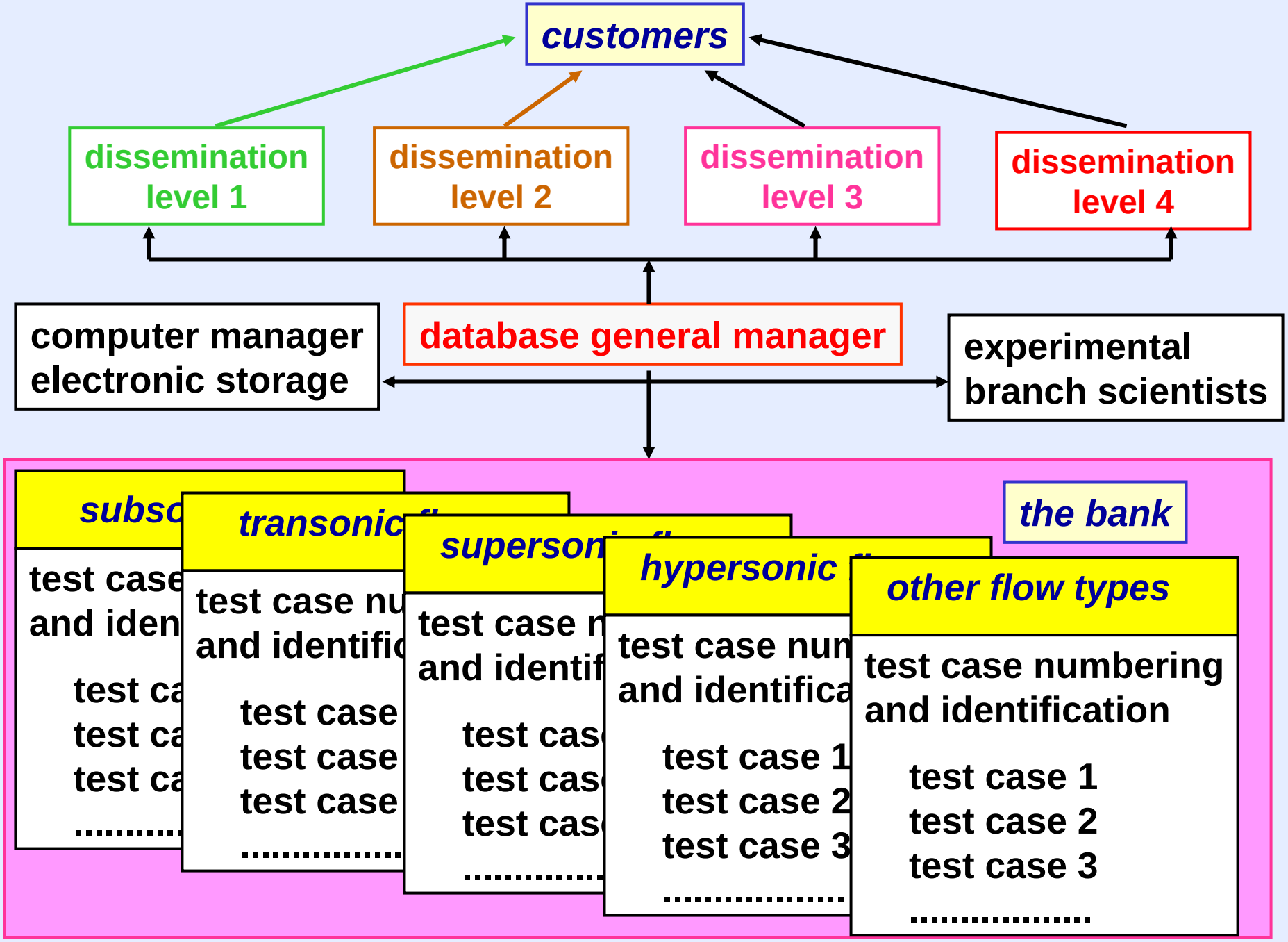
- **all** … **and**
  ana … **w**
- **do** … **ning**

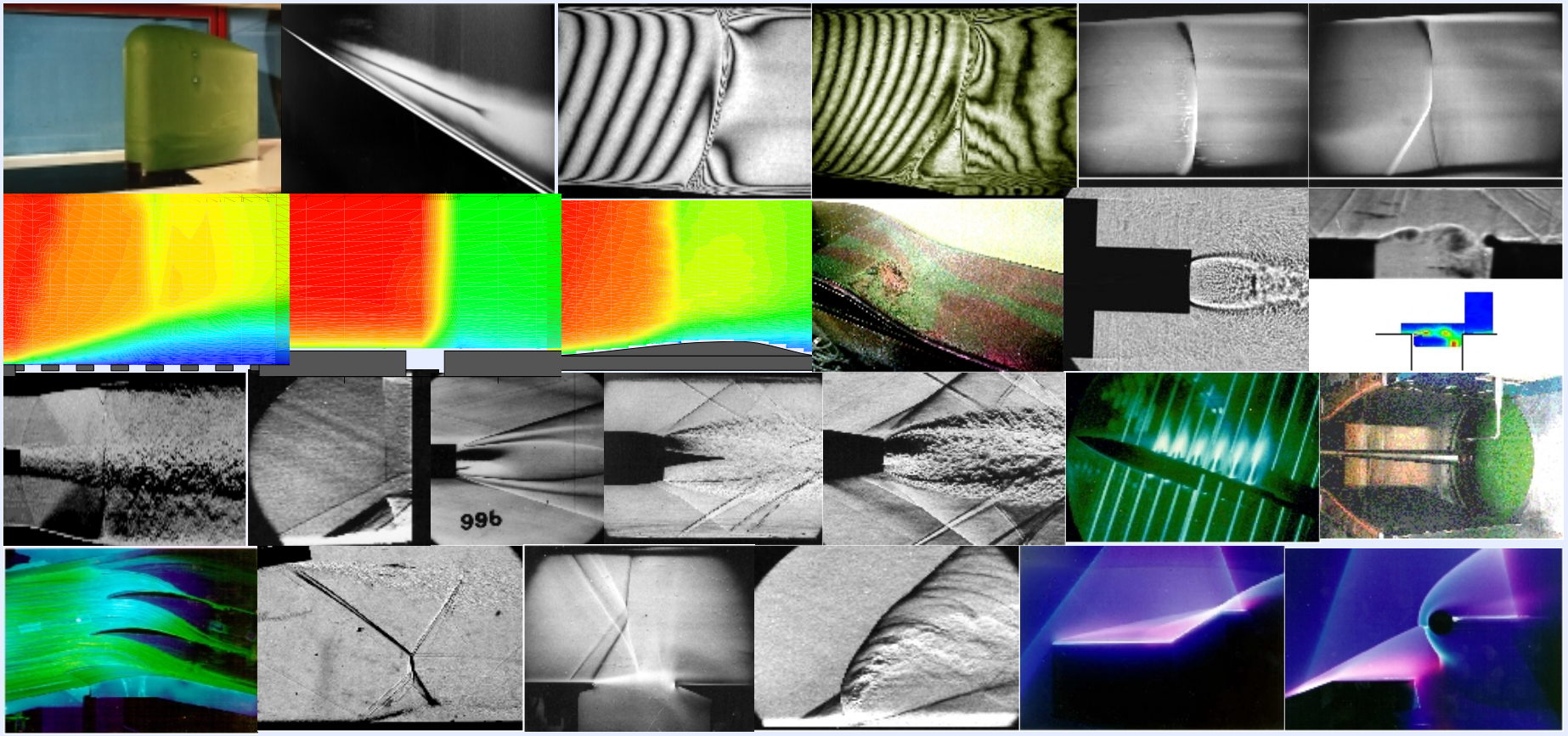
is more expensive that a useless experiment !

The database constitution and management

- **the database must contain all the information necessary to perform a calculation: geometry, flow general conditions, boundary conditions....**
- **results must be stored in a convenient format on an appropriate and safe electronic support**
- **define a precise protocol for data transmission**
- **establish well defined dissemination rules: experiments are expensive, good experimentalists tend to be rare!**

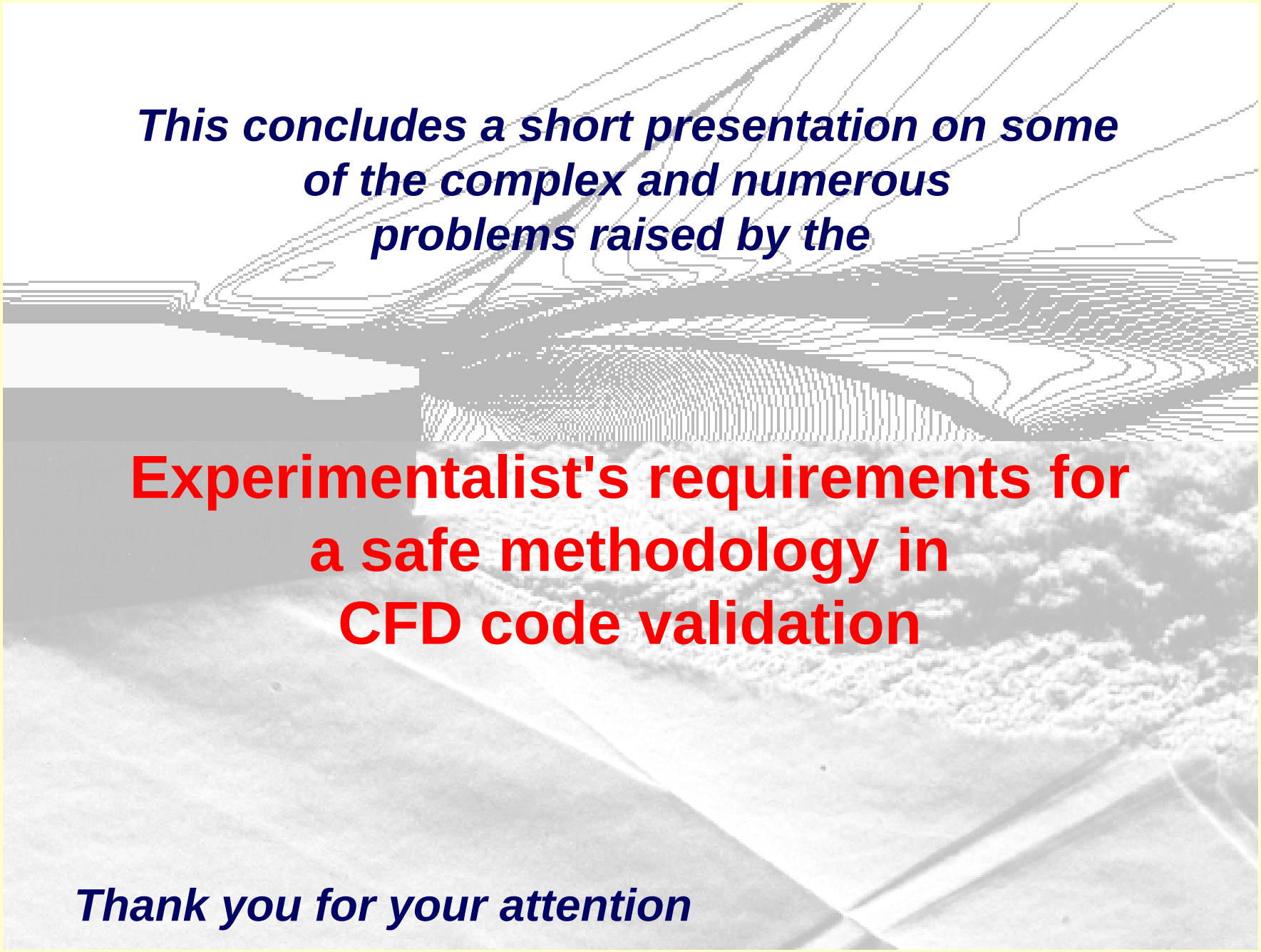

customers
dissemination level 1
dissemination level 2
dissemination level 3
dissemination level 4
computer manager electronic storage
database general manager
experimental branch scientists
the bank
test case numbering and identification
test case 1
test case 2
test case 3
other flow types

To-day deposit in the Onera - DAFE database!



the *ERCOFTAC* database stored at the University of Surrey

the *FLOWNET* database stored at INRIA/Sophia Antipolis



This concludes a short presentation on some of the complex and numerous problems raised by the

Experimentalist's requirements for a safe methodology in CFD code validation

Thank you for your attention