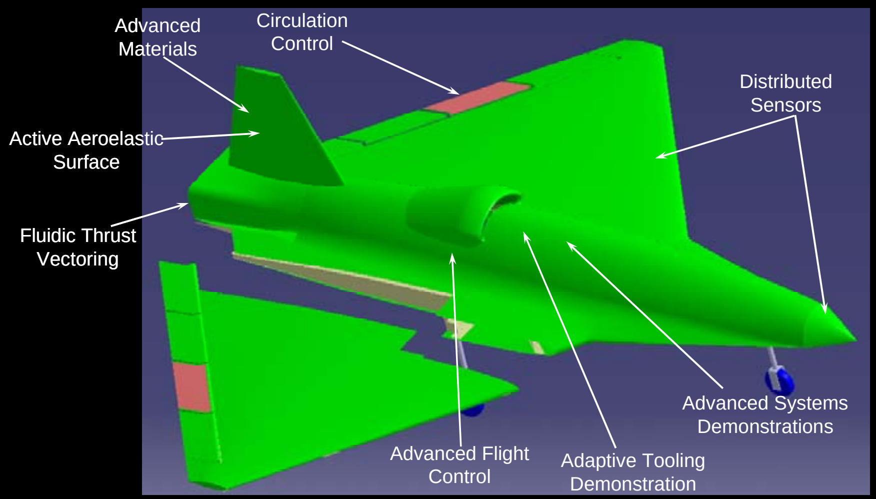
FLAVIIR

Integrated UAV Research Programme



Presentation to ICAS Workshop Sept 24th 2007

Academic Technical Director: Prof. Phil John (Cranfield University)
Project Manager: Dr Clyde Warsop (BAE Systems ATC)

Industrial Need:
To be Prepared for Future Markets

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INNOVATION THROUGH PARTNERSHIP

Assembling the best university skills as the *market changes*

Research

Staff Education and Training

Skilled Recruitment Pool Creation

Competitive Products, Processes and Capabilities

For

Future Markets

<u>The Challenge: Large scale coordination and alignment</u>

- To align cross-company requirements
- To align the best university skills
- To involve ALL stakeholders
- To assemble sufficient funding

BAE SYSTEMS' Objectives

- **Maintain and develop a capability in autonomous, unmanned air vehicle systems.**

- **Provide credible technology options for the next generation defence systems.**

- **Maintain and develop aeronautical engineering capability.**

FLAVIIR Strategic UAV Programme

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INNOVATION THROUGH PARTNERSHIP

Cranfield — *Imperial* — *Leicester* — *Liverpool* — *Manchester*

Breadth + Depth of Academic Capabilities

York — *Warwick* — *Swansea* — *Southampton* — *Nottingham*

⇩

Today's Integrated Research: Flapless, maintenance-free

Control Systems — **Manufacturing** — **Numerical Simulation**

Integration and Concept Demonstration
Cranfield University

Electromagnetics — **Aerodynamics** — **Structures & Materials**

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Tomorrow's Engineering Capabilities

FLAVIIR “Grand Challenges”

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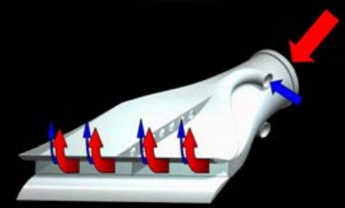
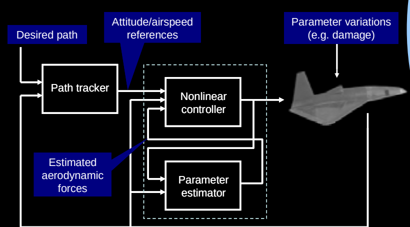
INNOVATION THROUGH PARTNERSHIP

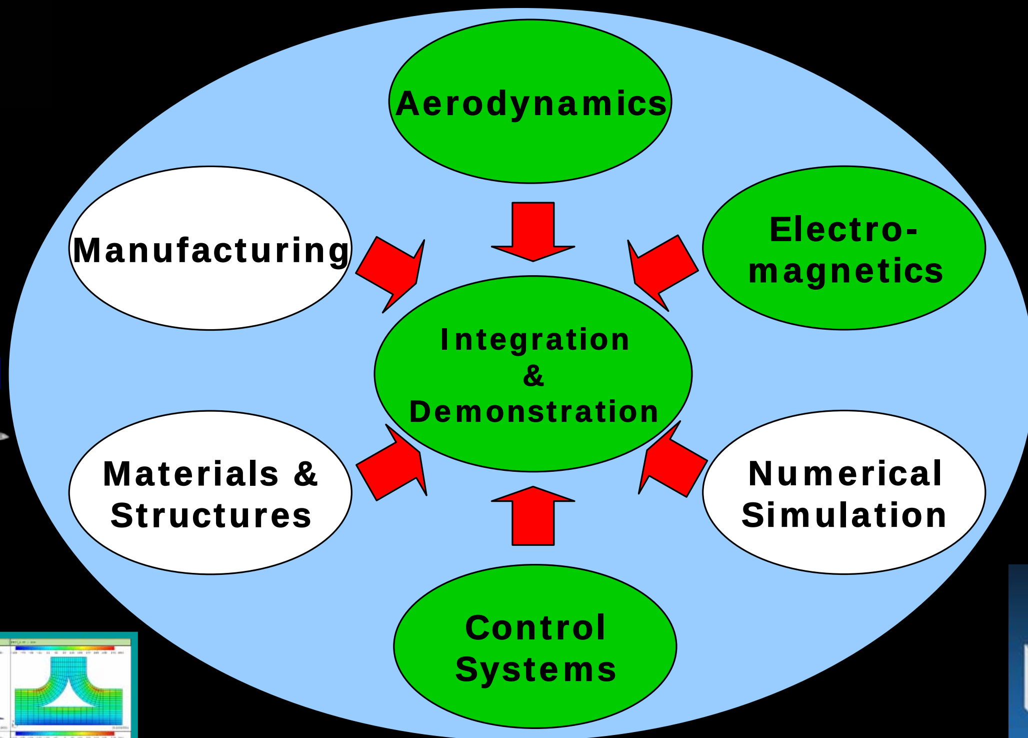
Clear simple challenges:

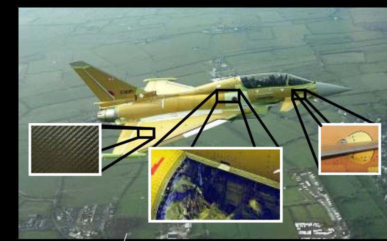
- “A maintenance-free UCAV without conventional control surfaces and no cost or performance penalties”
- “Significant research impact through effective academic/industry management and exploitation of large-scale, integrated academic research”

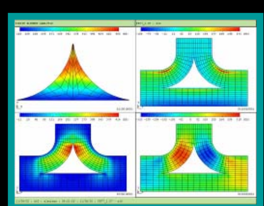
Research Scope

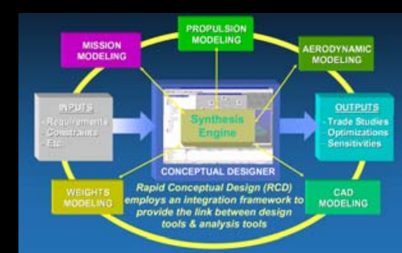






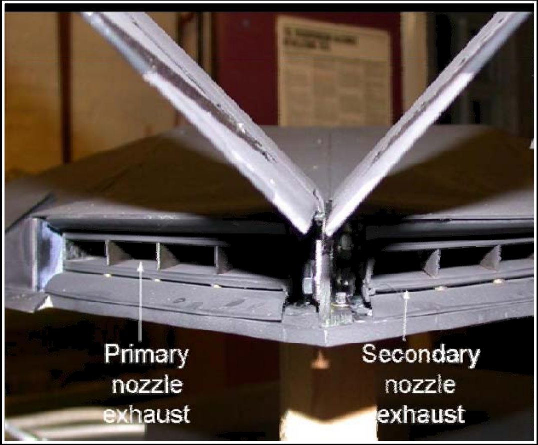


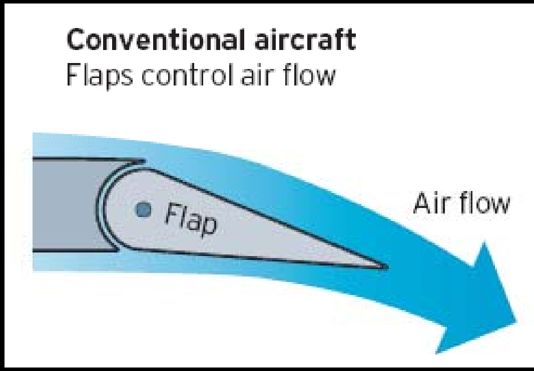




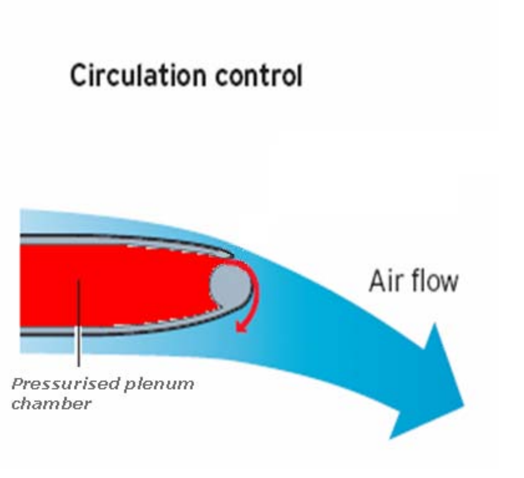
Addressing high-risk technologies with potential for significant advancements in capability and future business growth

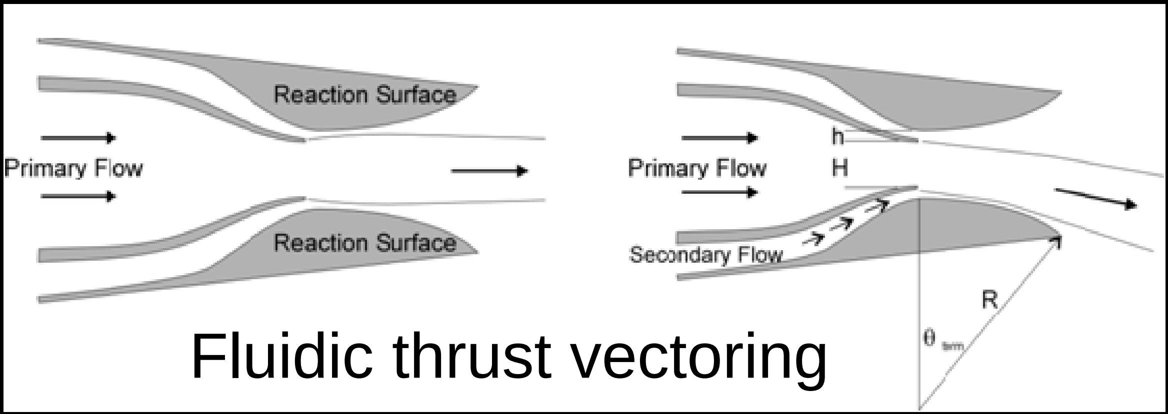
Fluidic Flight Control



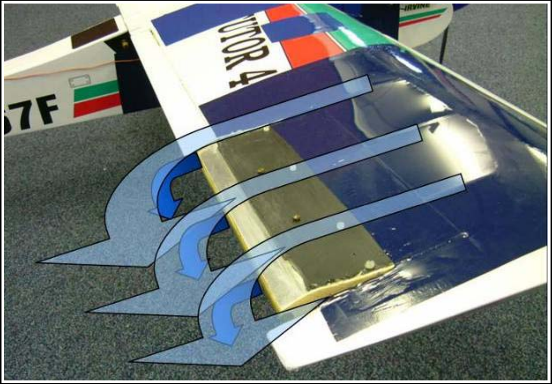


Circulation control



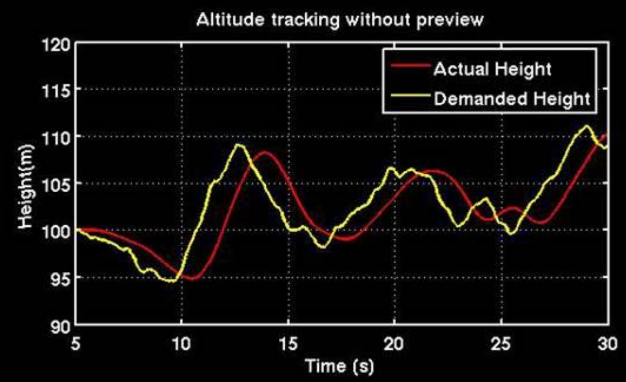


Fluidic thrust vectoring

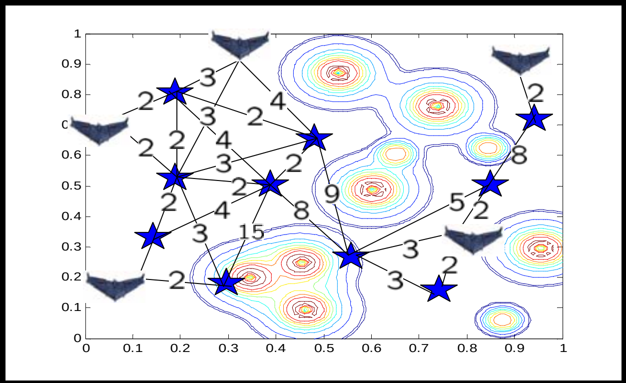


Technology (Control Systems)

- Preview Control
  - Tighter flight path following less control input.



- Non-linear adaptive control
  - Robust to change in vehicle characteristics (damage, wear or design/manufacturing tolerance.
- Real-time path planning
  - Adaptive real-time navigation



- Low-cost flight dynamics parameter identification process.

Technology (Electromagnetics)

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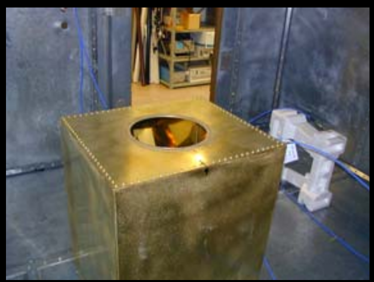
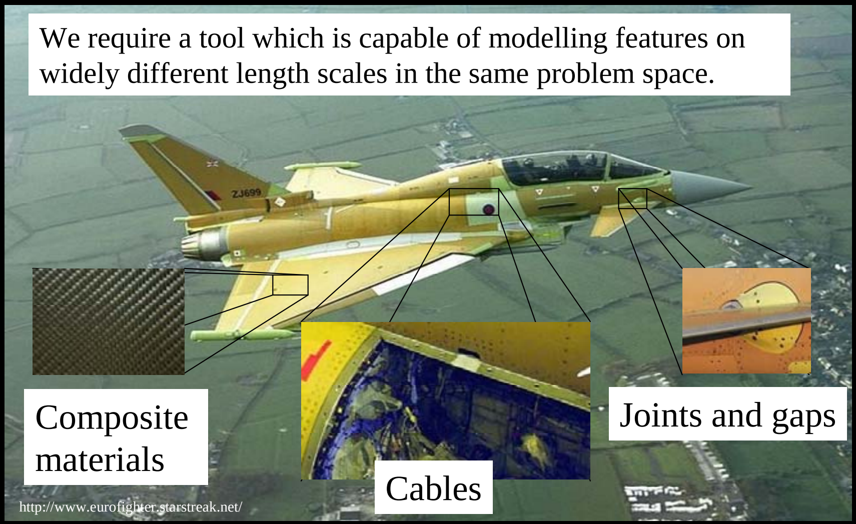
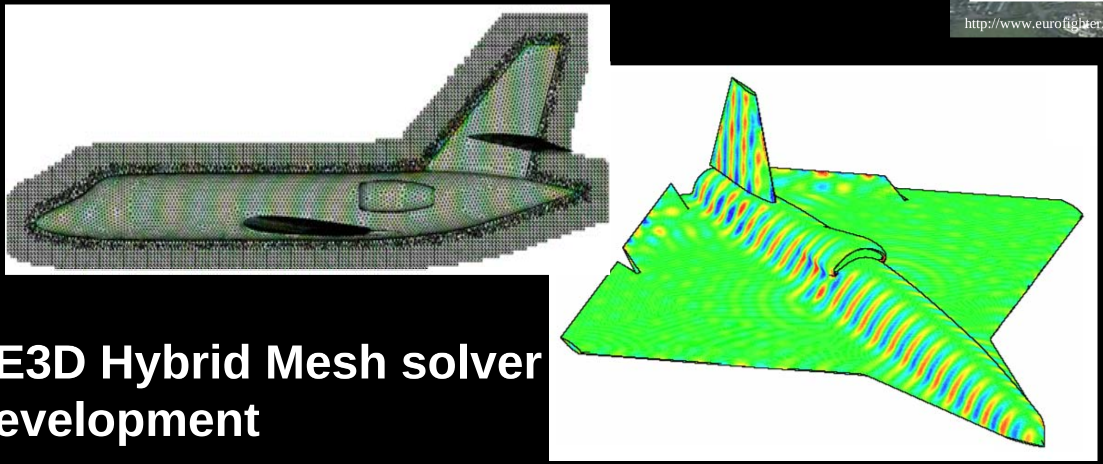


EM nested reverberation test facilities and evaluation



cable modelling for EM compatibility simulation



FE3D Hybrid Mesh solver development

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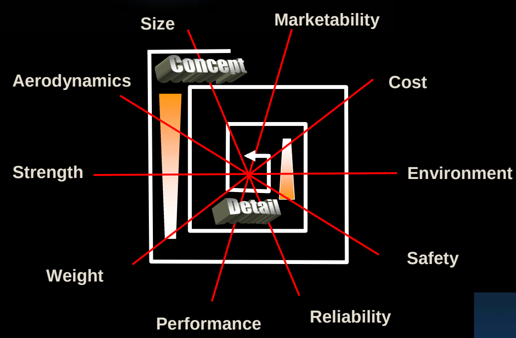
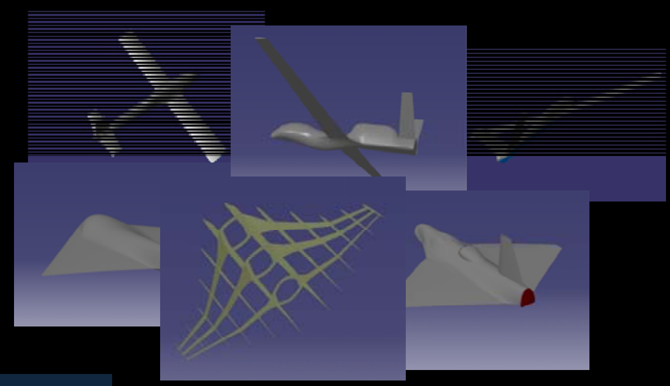
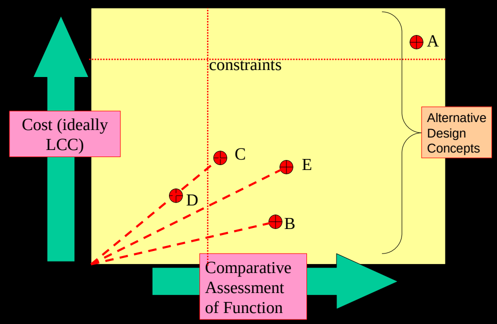
Technology (Design Tools)

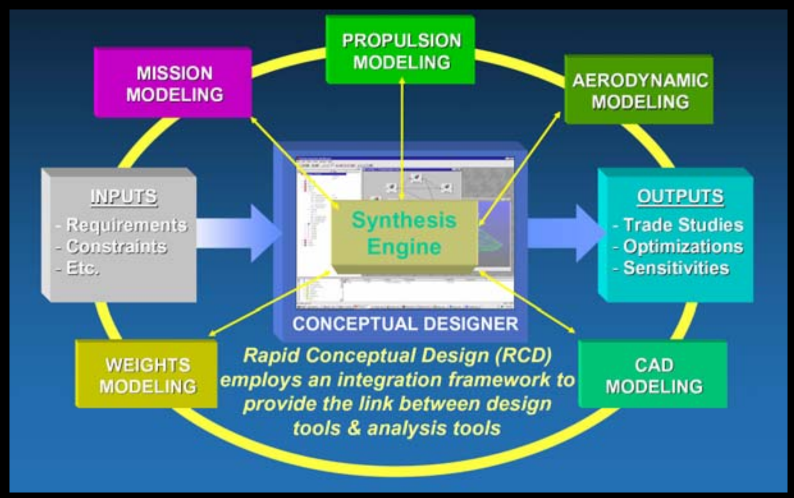


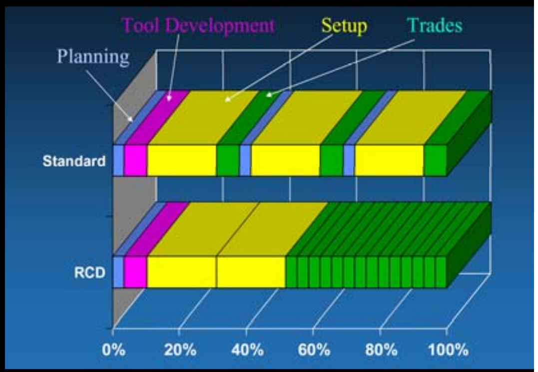
Parametric CAD for shape and structure "morphing"





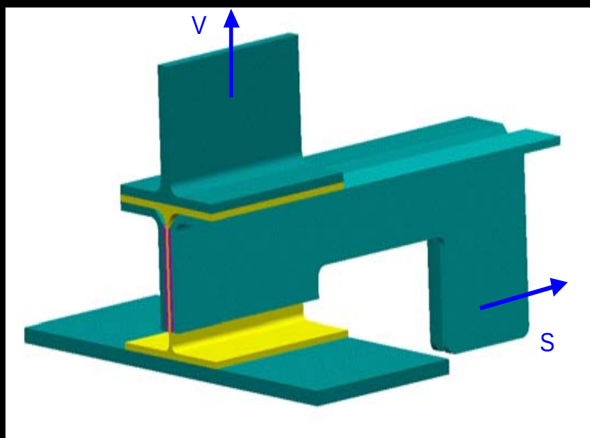
Cost Modelling

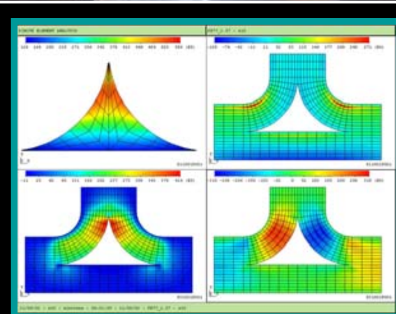


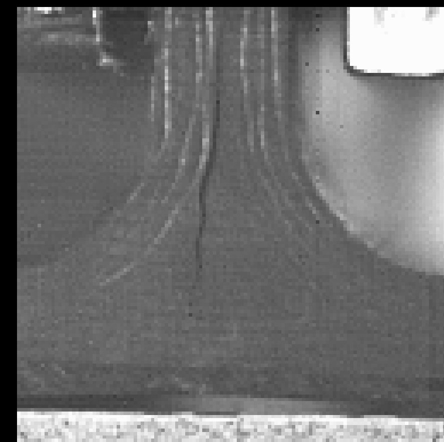


Integrated, rapid design simulation and optimisation tools

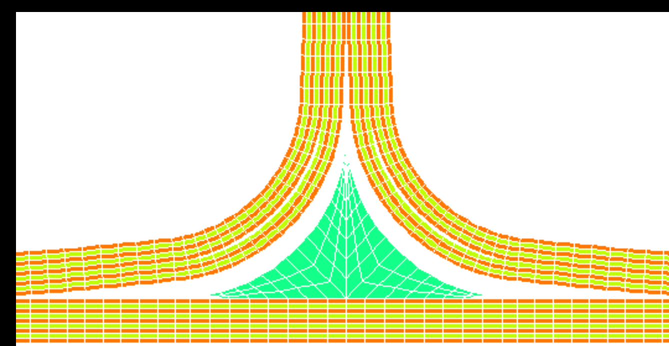
Technology (Materials)







Test

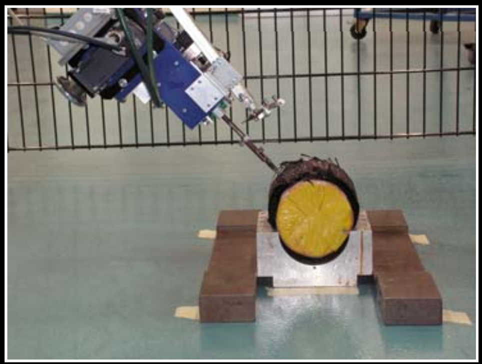


Simulation

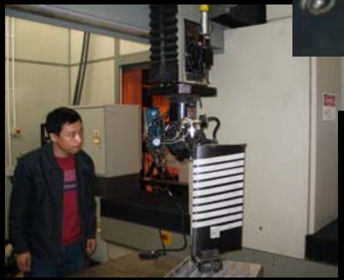
Virtual testing of composite structure failure by numerical simulation:

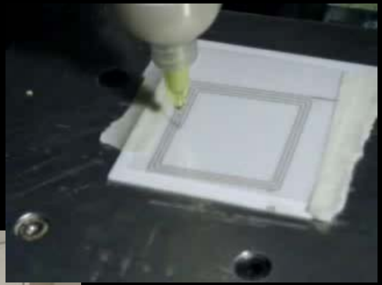
Reduces cost and time for testing

Technology (Manufacturing)



Robotic tufting of preformed dry composite lay-ups for increased through-thickness strength





“Direct Write” Technologies

Resin infusion moulding

Reconfigurable tooling

Rapid Low Cost Composite Manufacture

Reduces cost and time

Research/Development Process

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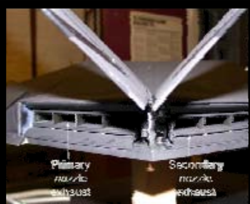
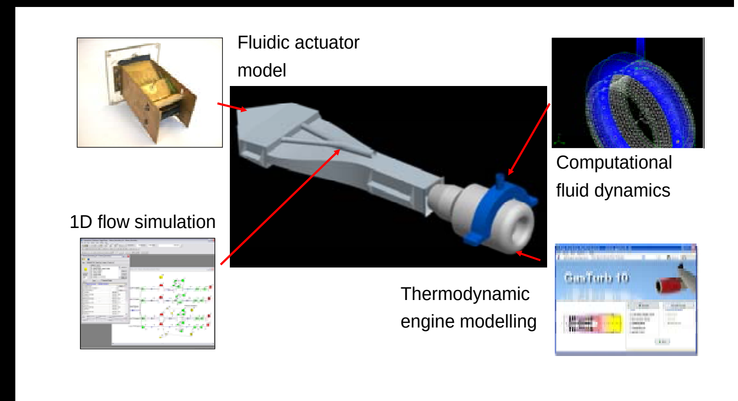
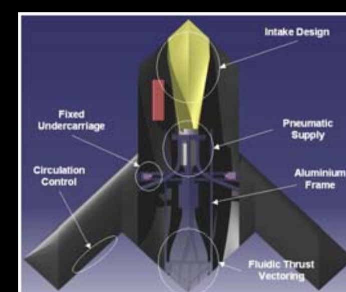


Understand physics

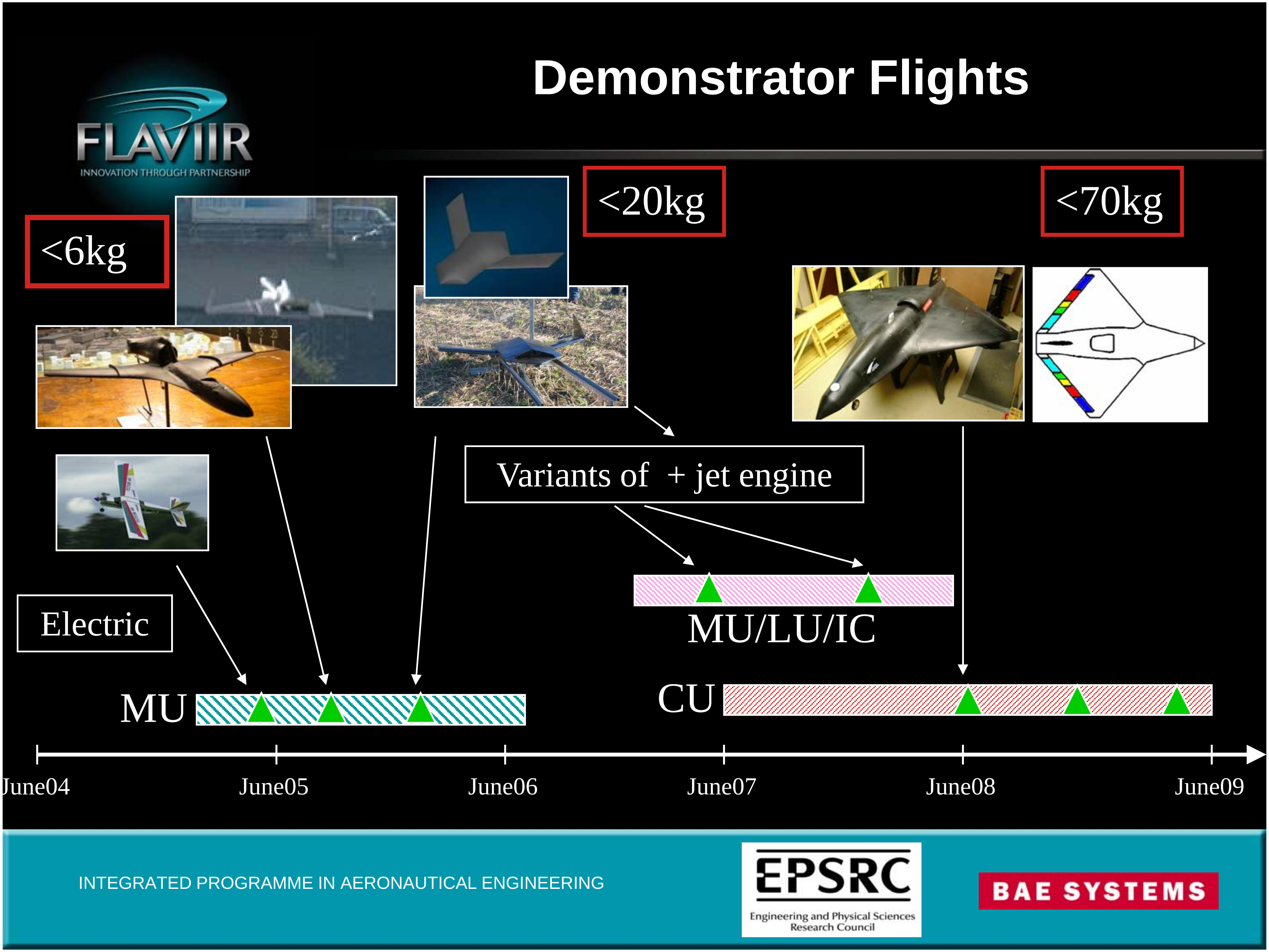
Ground Test Demo



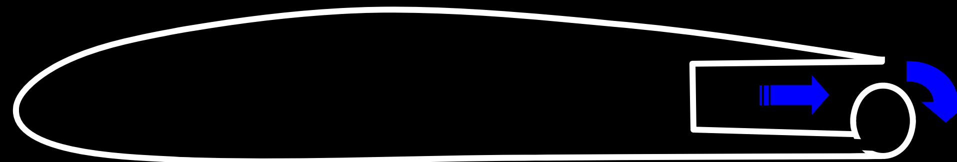
Develop/validate system model

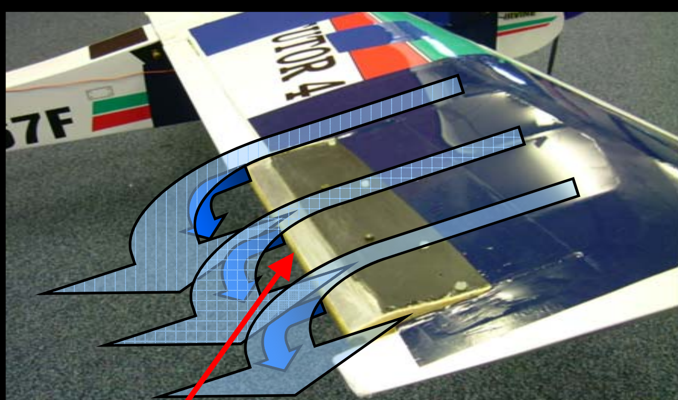


Demonstrate on increasing complexity of flight vehicle


Demonstrator Flights
FLAVIIR
INNOVATION THROUGH PARTNERSHIP
<6kg
<20kg
<70kg
Variants of + jet engine
Electric
MU/LU/IC
MU
CU
June04
June05
June06
June07
June08
June09
INTEGRATED PROGRAMME IN AERONAUTICAL ENGINEERING
EPSRC
Engineering and Physical Sciences Research Council
BAE SYSTEMS

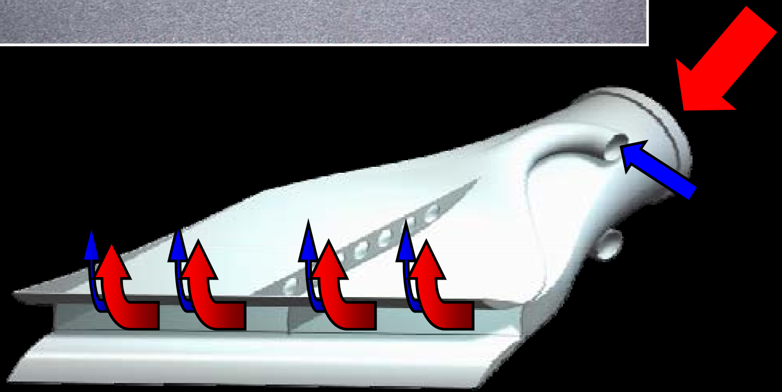
Flying Without Ailerons





Trailing edge slot

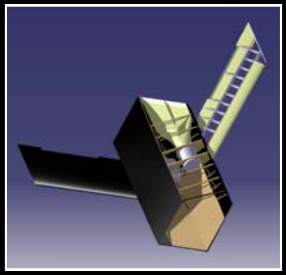
Flying With Fluidic Thrust Vectoring



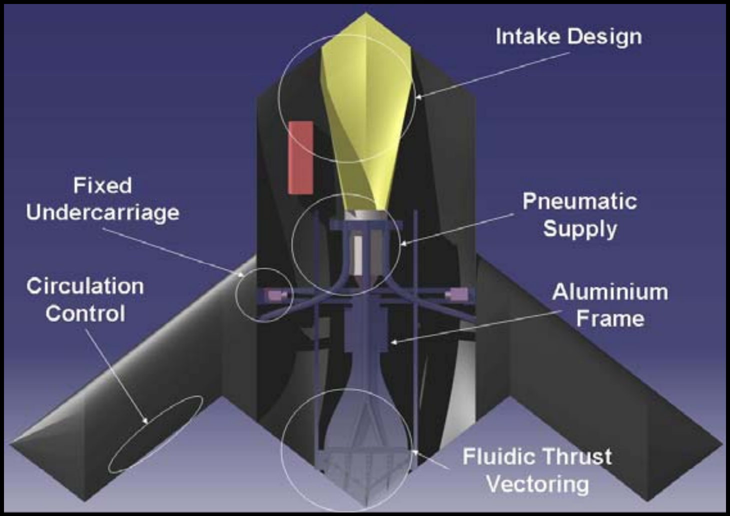
Thrust Vectoring Nozzle

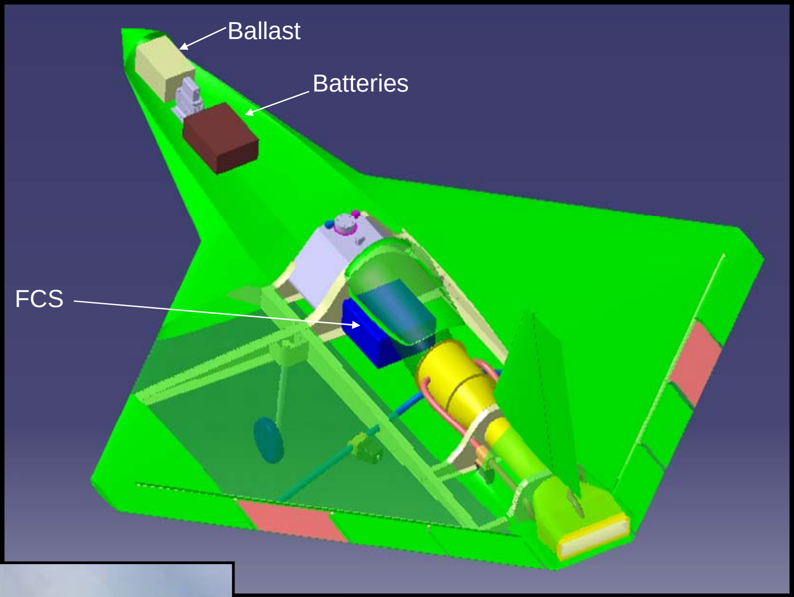
Integrated Demonstrators

- All Electric Powered
- 4 Min. Endurance
- Weight: 7Kg.
- Speed: 30m/s
- Fluidic manoeuvre effectors as the sole flight controls



Gas-Turbine Demonstrators





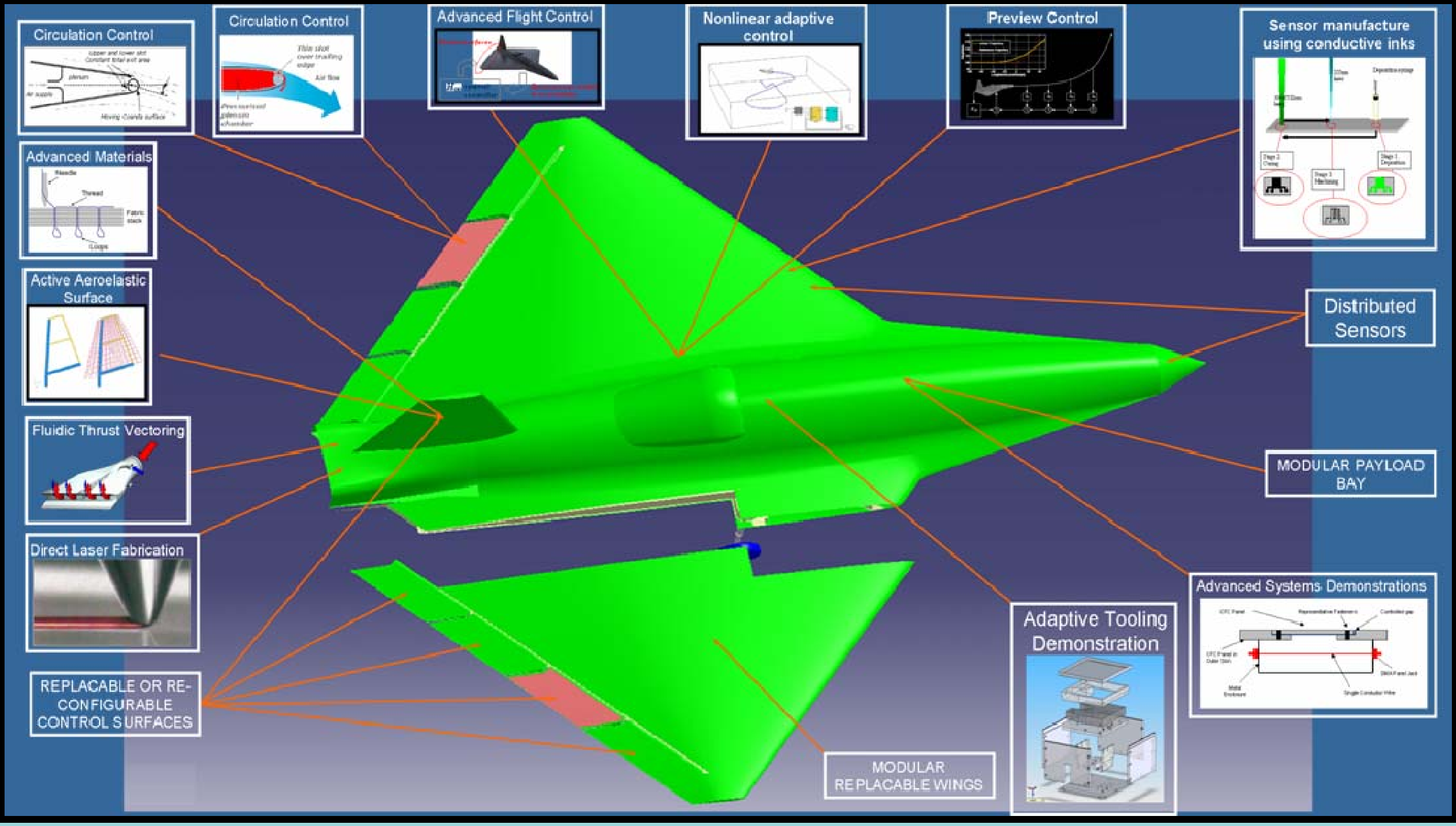
JAVA
15Kg
fluidic flight control
shakedown test platform

DEMON
70Kg
multi-technology
demonstrator

Technologies (Integration)

- **Large-Scale Flying Demonstrations**
  - Higher Technology Readiness Levels
  - Integration into a working system
  - Pursue industrial exploitation
  - To learn how technologies interact & affect air vehicle configuration and operation

Technology Integration / Demonstration



Demonstrator Development

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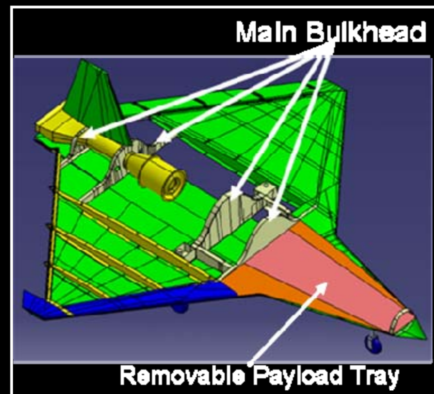
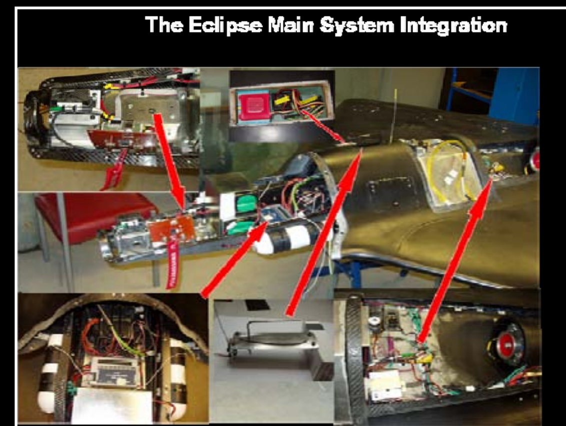
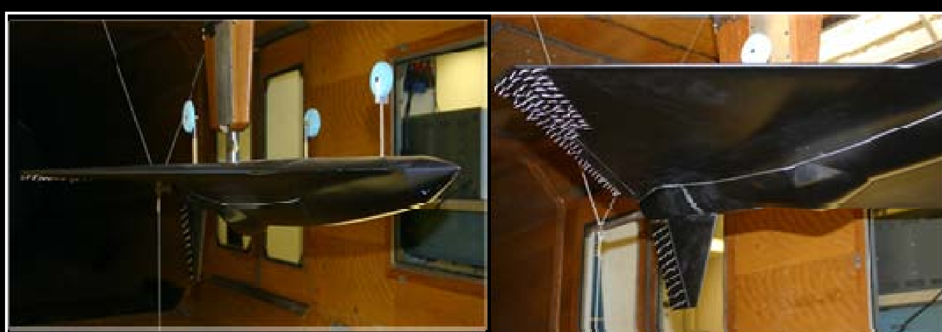


Structural/system design





System development & integration

Aerodynamic testing

Conclusions

- FLAVIR: an experiment in collaborative academic research
  - fundamental research, integration and demonstration
- Many challenges involved in this type of project
  - Collaboration between academics/industry
  - Increased TRL from universities
  - Achieving flexibility to meet industry needs
- New technologies pose serious questions for clearance and certification
  - Coupled propulsion/fluidic flight control
  - Adaptive flight control algorithms

Questions?

INTEGRATED PROGRAMME IN AERONAUTICAL ENGINEERING

EPSRC Engineering and Physical Sciences Research Council

BAE SYSTEMS

FLAVIIR
INNOVATION THROUGH PARTNERSHIP

Scope

- Aeronautical Engineering
  - Technologies integral to the design, development and through life support of an air platform and those that enable a vehicle to fly.
  - Heavily reliant upon integration of disciplines, knowledge and data transfer and maintenance.
- FLAVIIR Aim
  - To research and demonstrate integrated technologies leading to dramatically increased business opportunities in the area of UAVs.
- Statistics
  - £6.5M, 10 Universities, 35+ researchers, Sept 2004-Sept 2009.

FLAVIIR Research Process

- **Flexible, demonstrator led programmes**
- **Emphasis on "Blue Skies" and higher TRL (2015-2020)**
- **High BAE Systems involvement**
  - **Key technical representation in management**
  - **Fully involved in reviews and programme setting**
- **Emphasis on leverage**
  - **DTA, JGS, EPSRC, DTI & SME involvement**

Technology (Aerodynamics)

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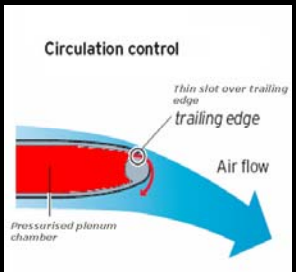
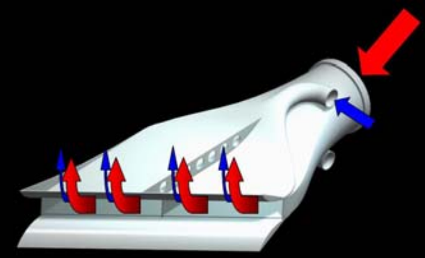
Fluidic Control for Manoeuvre

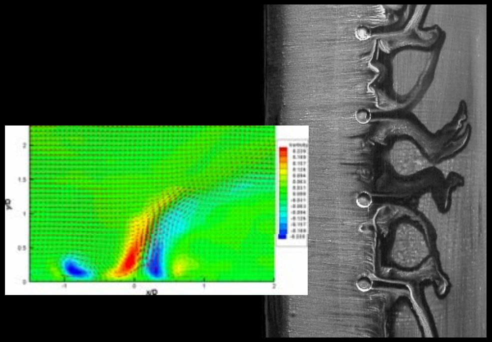


Circulation control

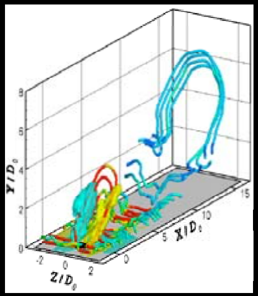


Fluidic Thrust Vectoring

Boundary Layer Control



Dynamic Dimples



Simulation of Flow actuators

Dynamic Test Facilities

Boundary Layer Control

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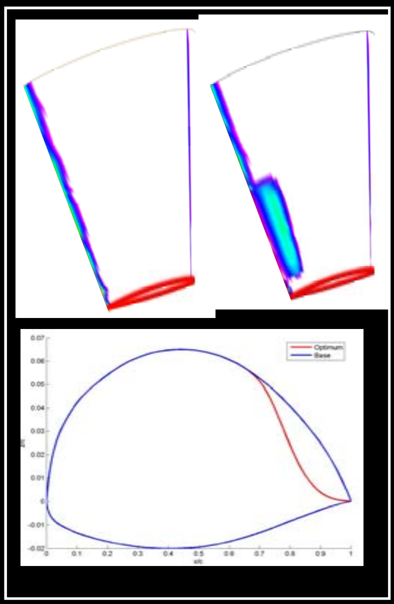
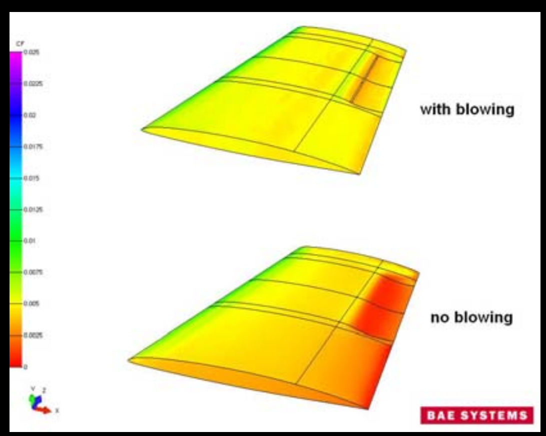
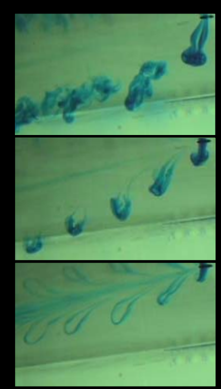


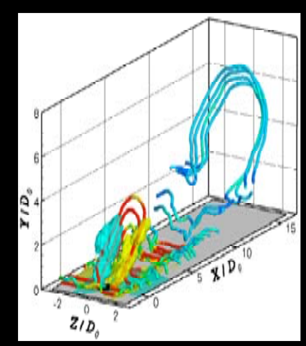
Objective: Control Flow Separation

- Enabler for Increased high-lift capability
- Enabler for “receptive aerodynamics” flight control
- Fundamental experimental/numerical (LES) studies

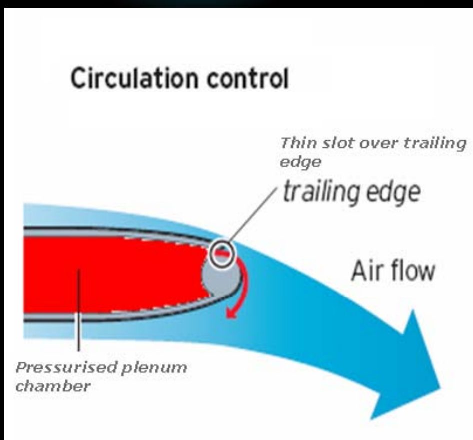
- Simplified methods in RANS for engineering design
- Understanding of basic fluid physics

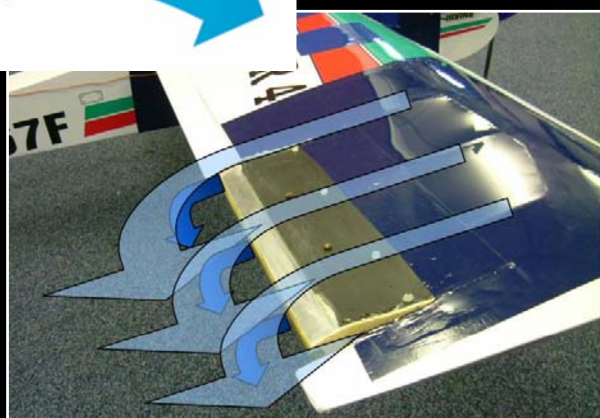






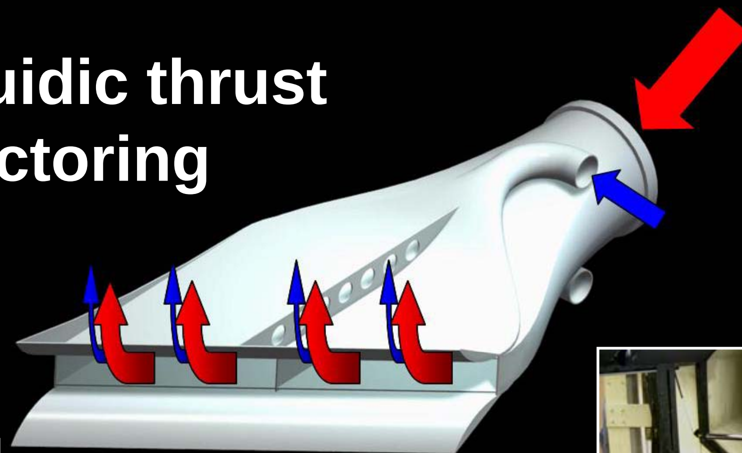
Technology (Aerodynamics)

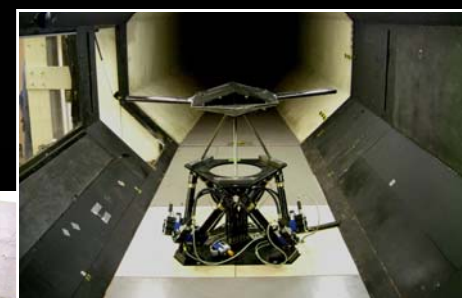




Circulation control

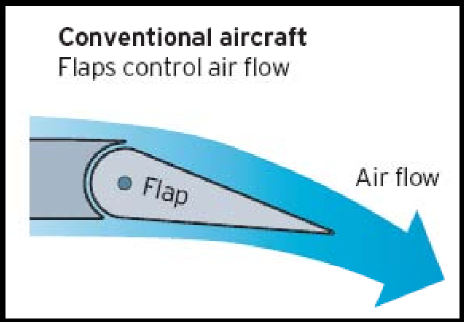
Fluidic thrust vectoring

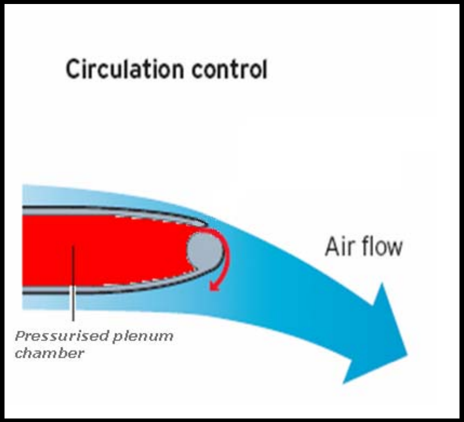


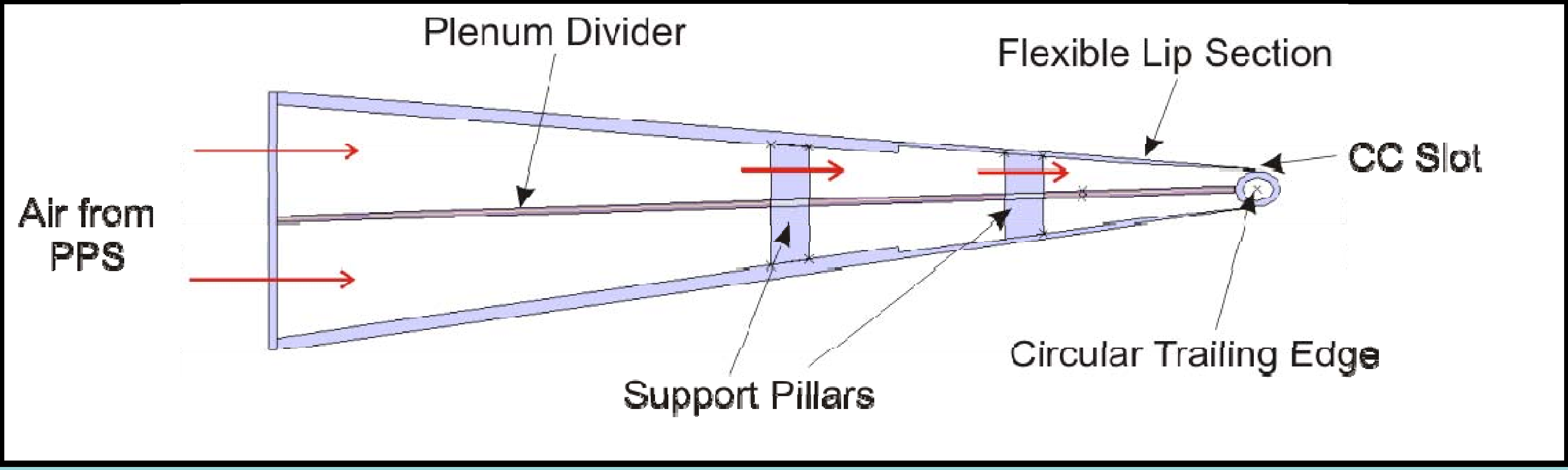


Dynamic test facility

Fluidic Flight Control







Dynamic Test Facility

Stuart Platform in AVRO tunnel

- Computer driven motion platform (6DOF)
- Integral force balance & position feedback
- Static/dynamic derivatives
- Force/motion feedback gives “captive flight” capability

- Low-cost, transferable system
- Inertial scaling of model not required
- Arbitrary motions can be defined