

# Rapid Development of Aerodynamic Models for UCAV Flight Dynamics & Control Studies

Dr Doug Greenwell

*Department of Aerospace Engineering  
University of Bristol*



# Report Documentation Page

*Form Approved*  
*OMB No. 0704-0188*

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE <b>26 JUL 2004</b>	2. REPORT TYPE <b>N/A</b>	3. DATES COVERED <b>-</b>	
4. TITLE AND SUBTITLE <b>Rapid Development of Aerodynamic Models for UCAV Flight Dynamics &amp; Control Studies</b>		5a. CONTRACT NUMBER	
		5b. GRANT NUMBER	
		5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)		5d. PROJECT NUMBER	
		5e. TASK NUMBER	
		5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Department of Aerospace Engineering University of Bristol</b>		8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)	
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release, distribution unlimited</b>			
13. SUPPLEMENTARY NOTES <b>See also ADM001685, CSP 02-5078, Proceedings for Aerodynamic Issues of Unmanned Air Vehicles (UAV)., The original document contains color images.</b>			
14. ABSTRACT			
15. SUBJECT TERMS			
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>	<b>UU</b>
			18. NUMBER OF PAGES <b>9</b>
			19a. NAME OF RESPONSIBLE PERSON

# Are we getting the most out of the UCAV concept?

- unmanned = loss of flexibility
  - mission planning – restricted operational areas & times
  - autonomy – dealing with the unexpected!
- so what are the advantages?
  - cost
  - expendability – D<sup>3</sup> missions
- but are these being achieved?
- UCAVs still designed as '*unmanned manned aircraft*'
  - large, complex & expensive
  - long development times & protracted in-service life
  - definitely *not* expendable!



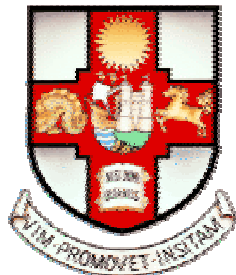
# Instead, design for short service life ...

- accept the inevitability of high attrition rate in service
  - ‘wooden round’ concept unworkable
  - launch & recovery accidents etc
  - operating in harms way
- design for short term flexibility
  - high-cost systems transported in low-cost airframe
  - modular ‘plug & play’ architecture – not integrated!
- plan for long term flexibility
  - rapid response to changes in concepts of use
  - take advantage of advances in airframe technology
- design for expendability
  - cost, numbers, replacement time
  - operators *must* be prepared to lose platforms



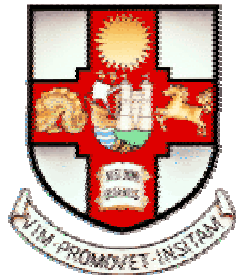
# How are we going to do this?

- key factors
  - cost – development & manufacture
  - development time
  - platform flexibility
- look for common element ...
  - the flight control system
    - *design*
    - *development*
    - *clearance*
- what's the problem with current FCS design process?
  - linear process
  - protracted & costly!



# Conventional linear FCS design process

- FCS designed & implemented before 1<sup>st</sup> flight
  - complex, highly integrated systems
  - financial & political implications of accidents in flight test
- FCS design largely simulation based
  - therefore needs high quality aerodynamic S&C model
- extensive platform characterisation required
  - 1000's of hours of wind tunnel testing
  - specialist test facility needs for S&C
- *but* FCS problems still common in early flight test
  - F-16, F-22, Gripen, Dark Star etc ...
- FCS development & clearance now the major element of a flight test programme



# An alternative approach?

- do we really need a high level of integration?
    - are performance benefits worthwhile for low-cost UCAV?
  - multiple losses in flight test acceptable for UCAVs
    - basic airframes are cheap, electronics are robust
  - opportunities offered by modern FCS design tools
    - Nonlinear Dynamic Inversion (NDI)
    - *full (or accurate!) aero model not required for basic control*
- coupled with availability of
- low-cost, high-performance computing hardware
  - improved data analysis techniques
  - low-cost, rapid airframe manufacturing methods
  - COTS airframe components



# Iterative UCAV FCS development

- combine

- aerodynamic characterisation
- FCS design & development
- platform optimisation
- flight test

in a single integrated, *iterative* process

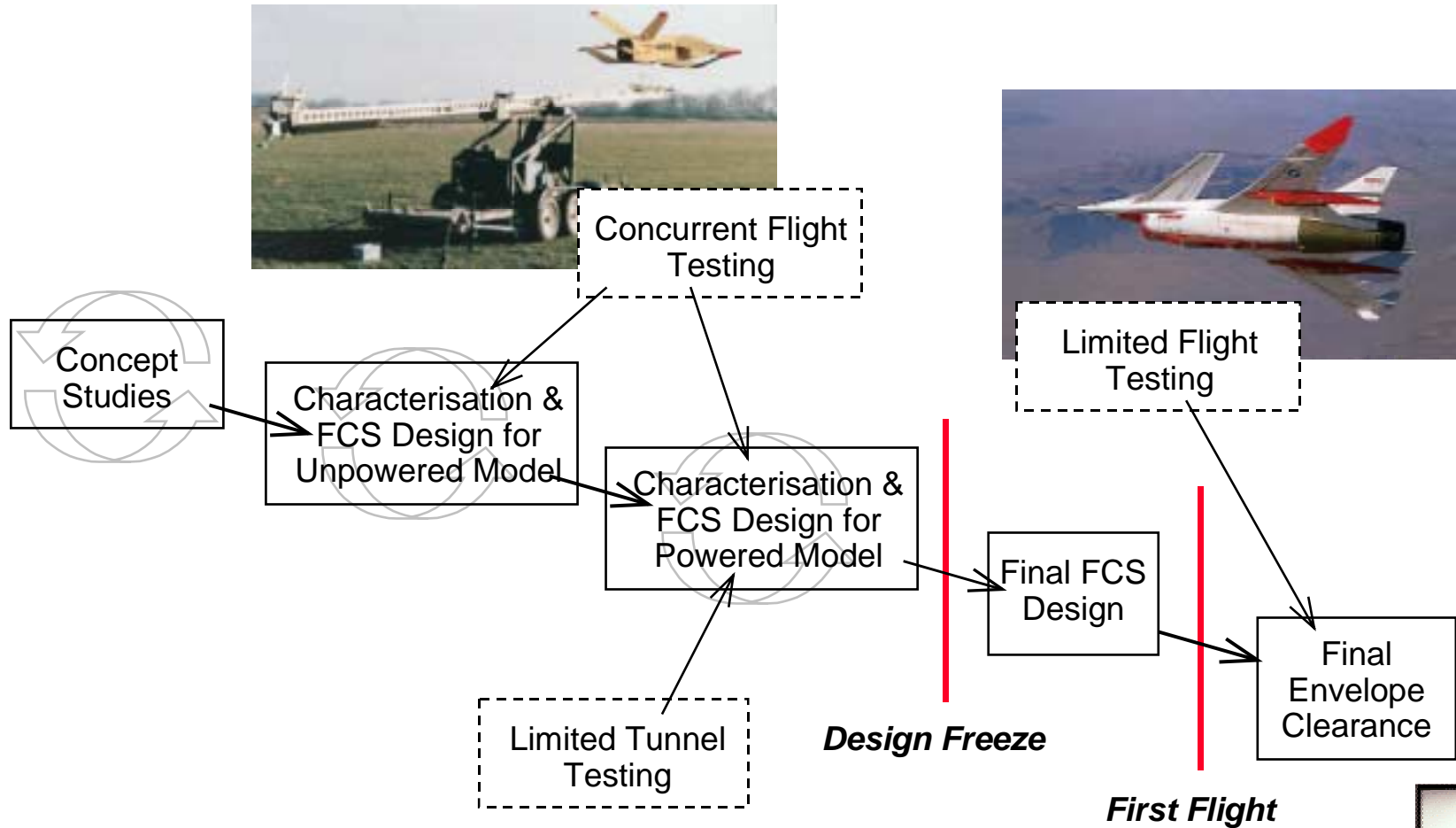
- aerodynamic model and flight control laws developed in *parallel*

- NDI (or similar) coupled with advanced non-linear parameter ID
- recast aero model in control system form – eg aerodynamic transfer function

- final aero model ‘only as good as it needs to be’



# A possible iterative UCAV design process



# Aspects of an iterative approach

- use industry-standard control system design tools
  - PC-based FCS – maximum use of COTS components
  - desktop design & development environment
  - VAAC Harrier demonstrates potential of this approach
- an alternative 2-stage approach to clearance
  - control system architecture **validated** at sub-scale
  - **verification** of final (auto-coded) implementation
- flexible development process
  - technology insertion opportunities
- continuous risk reduction exercise
- shorter timescales & reduced cost
- ‘fit for purpose’ FCS

