The Use of UAV technology for Rapid Prototyping

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Rapid Prototyping

In aircraft design and development program, it is often the case that:

- Many problems causing program time & cost **overrun** are introduced in the **early** stages of a project.
- Early **identification** of issues provides considerable program **de-risking**.
- **Flight test** is the only truly satisfactory way to **demonstrate** concepts
- Early **demonstration** is a powerful way to generate customer confidence

Rapid Prototyping –UAV Systems

Designing UAVs using the traditional manned aircraft process introduces a number of problems. How do we resolve?

- **Compress the design process into a shorter time period.**
- **Create and maintain small design teams w. appropriate level of skill and experience – *need small number of people with total system experience.***
- **Manage the increased technical risks in critical areas *e.g. aerodynamic prediction and flight control system design*.**
- **Attempt to match the design cost to vehicle value.**

Shortcomings of the traditional process

- Heavily dependent upon simulation
  - **CFD is slow expensive & often inaccurate due to poor physical modelling**
  - **Wind tunnel testing slow & expensive. Limited & often physically unrepresentative**
  - **Certain important information can't be obtained with any degree of accuracy *e.g. damping derivatives for use in flight control law design, non-linear aero. characteristics, unsteady aero. characteristics***
- Flight control laws are designed (initially) with incomplete data
- Early results from simulation often misleading
- There is little experience of systems integration before hardware is available
- Once system integrated very costly to rectify fundamental errors

Benefits - Rapid Prototyping

- **Full aerodynamic definition - including all non-linear effects, control effects, derivatives and damping.**
- **Accurate flight dynamics data by correct scaling of outer geometry, moments of inertia and aero. characteristics**
- **An early validation of the flight control system design and flight control laws – *a critical component and a major programme risk item.***
- **Hard data for design, tool and process validation.**

Benefits - Rapid Prototyping

- **Provides early appreciation of total system integration issues - *especially critical components e.g. novel control systems or novel propulsion concepts.***
- **A data base for tool validation**
- **A realistic initial exercise for the design team – *exposes strengths & weaknesses before main phase***
- **Early modelling of production and engagement of the supply chain members**

How is it done?

- **Initial design *(sub-scale or full scale)***
- **A limited CFD and/or wind tunnel programme to establish data for the minimum number of parameters required to give safe first flight.**
- **Design of initial flight control laws *(robust control theory can be used because vehicle is unmanned)***
- **Simulation to determine conditions for safe *(very limited envelope)* first flight**

How is it done?

- **First flight *(on military range treated as munition)***
- **Data from flight analysed and aerodynamic characteristics determined**
- **Flight control laws modified**
- **Simulation to determine expanded envelope for second flight**
- **Second flight**
- **Repeat process**
- **Learn lessons**
- **Refine design**
- **Gather data**

Post Flight Analysis

- On board avionics send full air-data, control surface setting angles & vehicle response data to ground station
- Recorded data is analysed by comparing pre-flight simulation model with actual vehicle characteristics
- Model is refined until simulation and flight data are in full agreement
- Flight envelope is extended based on new model
- More flight data gathered
- Process repeated until all data have been obtained
- Sophisticated flight testing methods can be used e.g. parameter identification techniques.

Cranfield's Capabilities

- Over 20 years of hands on experience
- Substantial and successful track record
- Total system view
- A high level intellectual approach to problem solving combined with practical skills and unique 'Concept to Flight' experience
- Flight test and analysis capability and experience
- Civil and military design, manufacture and maintenance approvals
- A highly evolved FCS that is
  - ***Miniaturised***
  - ***Light weight (air borne element < 0.36 kgs)***
  - ***Totally generic (unstable about all three axes)***
  - ***Fully autonomous***
  - ***Flight validated***
  - ***Certifiable system***

UAV Systems – the evolution of capability

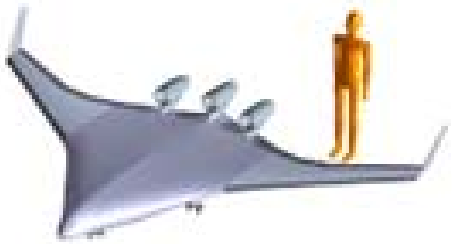
1977









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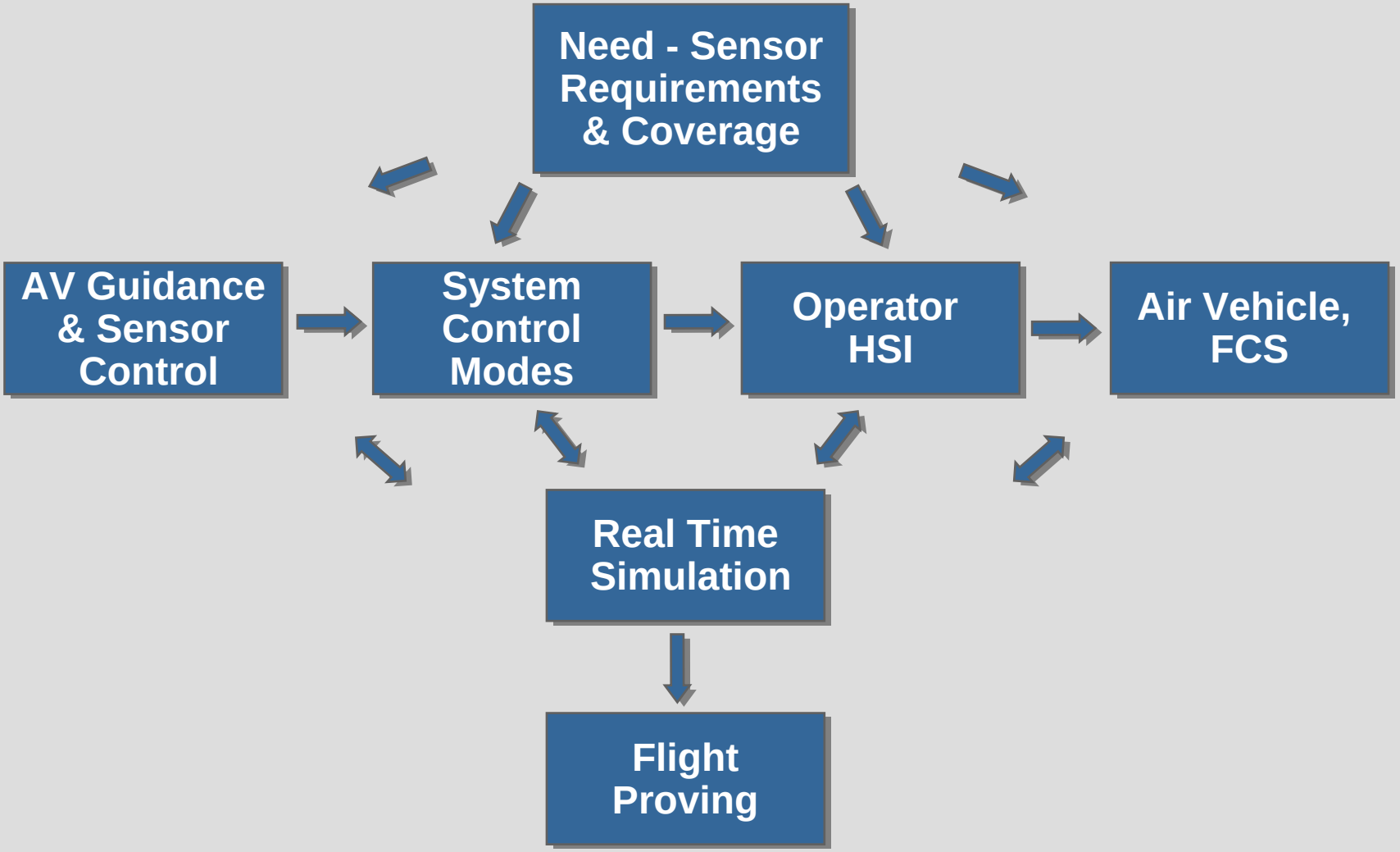
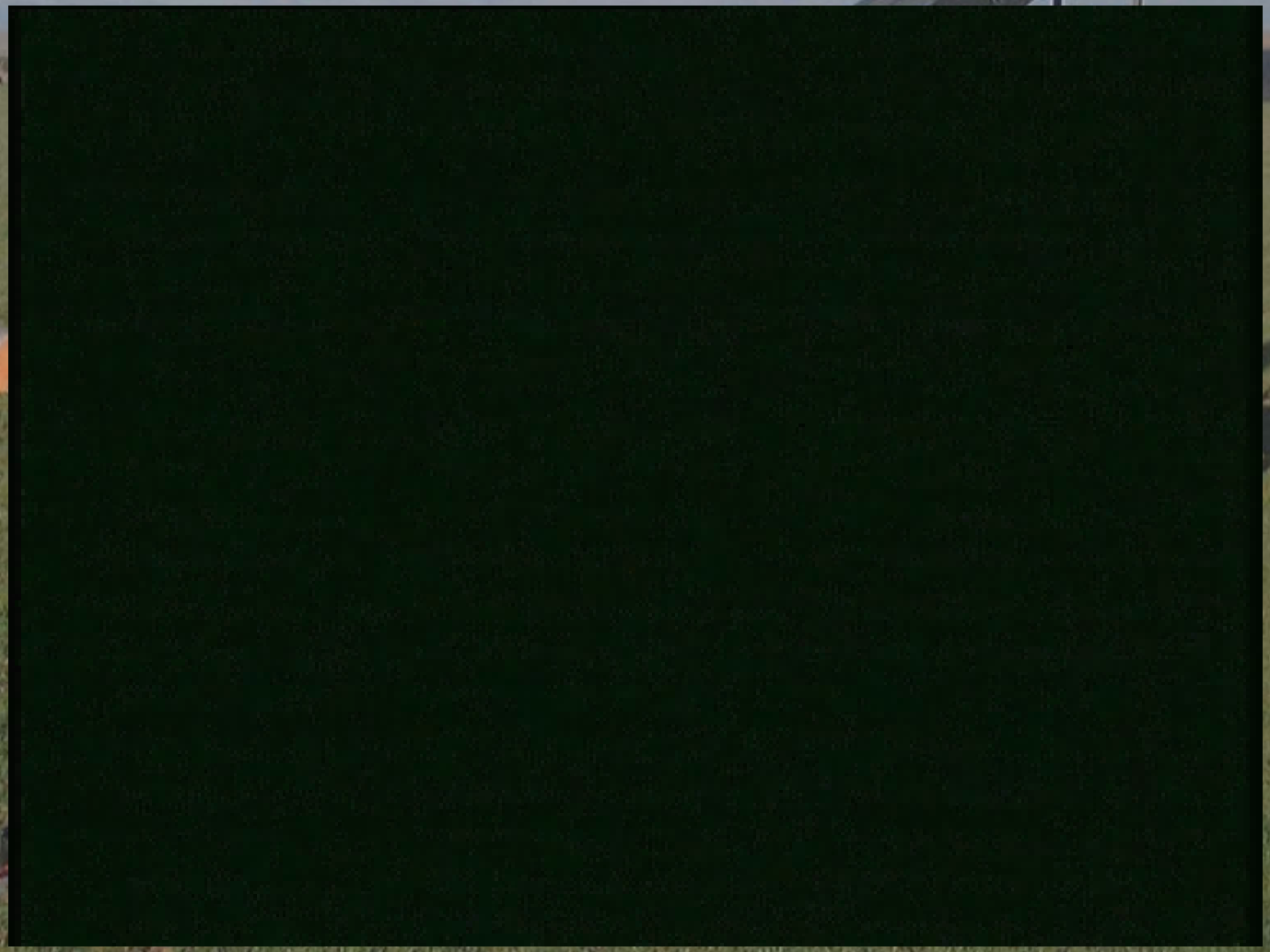
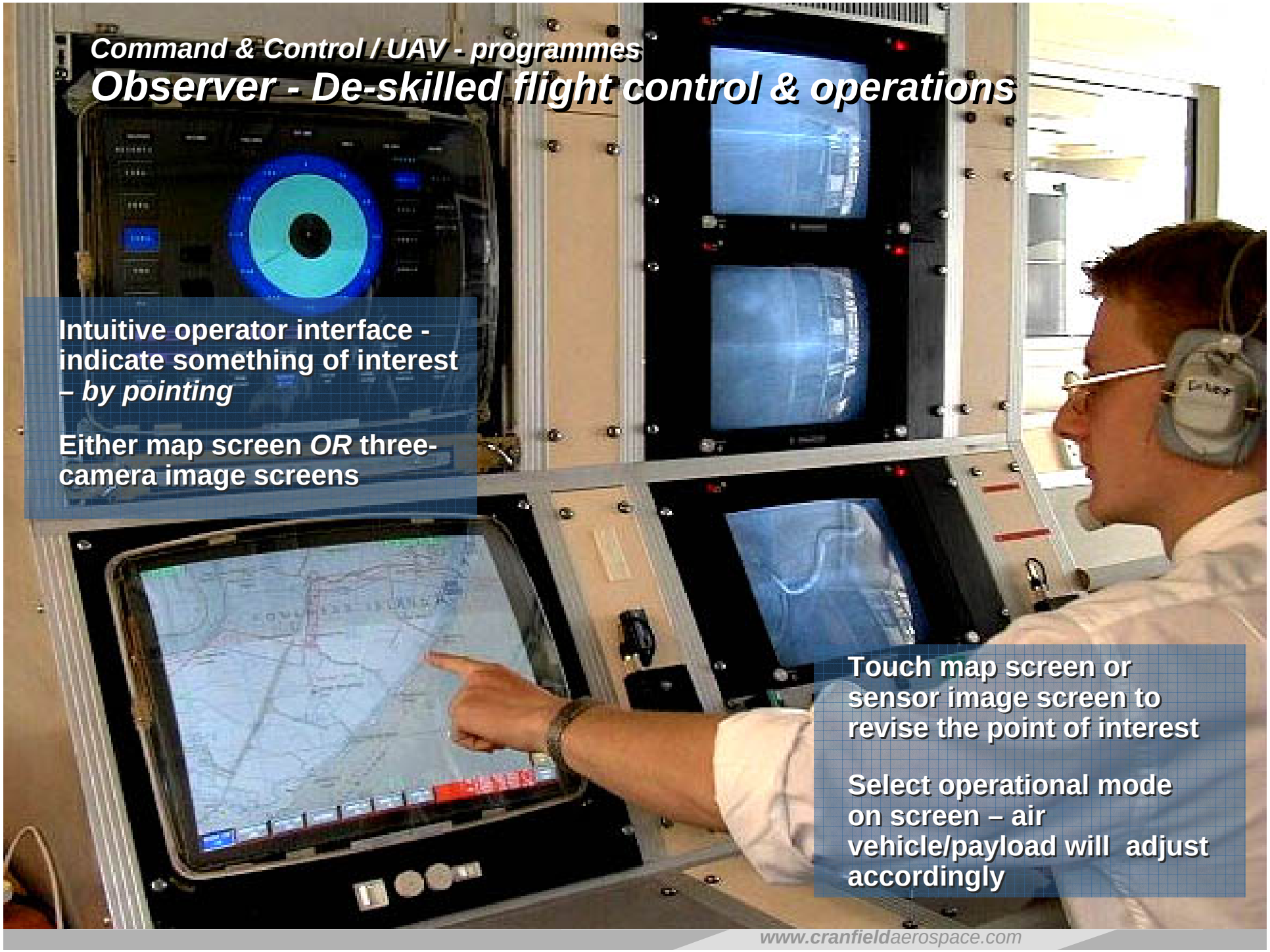
Concept to Flight - the Systems Approach



Observer UAV system demonstrator





Command & Control / UAV - programmes

Observer - De-skilled flight control & operations

Intuitive operator interface - indicate something of interest *– by pointing*

Either map screen *OR* three-camera image screens

Touch map screen or sensor image screen to revise the point of interest

Select operational mode on screen – air vehicle/payload will adjust accordingly

Command & Control / UAV - programmes

MinO

- **Gust insensitive airframe**
- **Clean parachute deployment, from underside**
- **Robust - inverted landing**

- ***Span 1.4m***
- ***Wing area 0.548 sq m***
- ***Launch Weight 11Kg***
- ***Vstall 20m/s***
- ***Vcruise 30m/s***
- ***Vmax 45m/s @ ISA+15, 1000m***

Cranfield's 'Total System'

- **Air vehicle design capability**
- **CFD/Windtunnel facilities**
- **Simulation programmes**
- **Miniature FCS capable of fully autonomous control for a vehicle that is unstable about all three axes**
- **Ground control station**
- **Flight test programme design and management**
- **Post flight data analysis**