Aerodynamic Testing of the A400M at ARA

by

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Aircraft Research Association
Bedford, England

- Independent non-profit distributing research and development organisation
- Set up in 1952 by 14 member companies as the wind tunnel centre for the UK aircraft industry
- Main transonic wind tunnel fully operational in 1956
- Operational range up to Mach = 1.4
- Has tested all major UK aircraft, both civil and military, and the entire Airbus family of aircraft
- Full model design & manufacture capability

Aircraft Research Association
Bedford, England

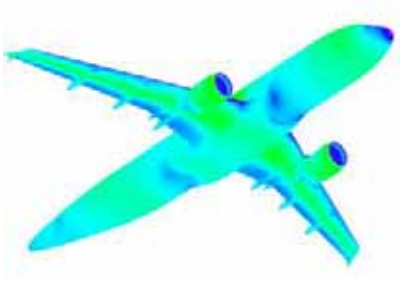
- Continuous improvement programme to enhance facilities and services
- Noise Enclosure permits 24-hour operation of TWT for tests with critical completion dates.
- Most productive transonic wind tunnel in Europe
- Large independent model design and manufacture capability
- Pioneering record in CFD code development

Experimental Facilities at ARA

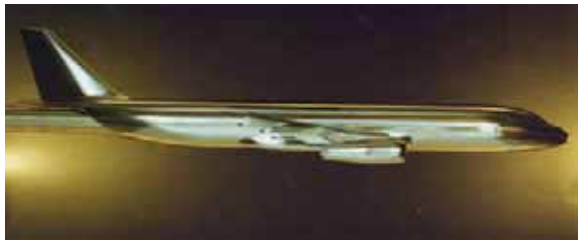
		Po (BAR)	M
Transonic Tunnel	2.74m x 2.44m (9’ x 8’)	0.8 - 1.2	0 - 1.4
Supersonic Tunnel	0.68m x 0.76m (27” x 30”)	0.4 - 1.4	1.4 - 3.0
Hypersonic Tunnels	0.30m x 0.40m (12” x 16”)	10 - 20	4 to 5
	0.30m D (12” D)	100 - 200	6, 7, 8
Two Dimensional Tunnel	0.20m x 0.45m (8” x 18”)	1.5 - 4.0	0.3 - 0.87
– Oscillatory Test Rig for helicopter rotor blades			
Z4T Small Transonic Tunnel	0.22m x 0.20m (9” x 8”)	Atmospheric 0.3 - 1.3	

- Propulsion Test House
  - Exhaust nozzle & Thrust Reverser Test Rig (LSTMR)
  - Propeller Test Cell
- Mach Simulation Tank
  - TPS & Nacelle Calibration Facility
- Specialised Rigs for Transonic Tunnel
  - CTS, Acoustic Liner, Isolated Cowl, Afterbody Twin Sting, Magnus, Propellers

A Centre of Aerodynamic Expertise



Airbus A320 SOLAR solution



Airbus A320 Cryogenic wind tunnel model
Designed and manufactured at ARA

Lockheed Martin F-35 model (pre-downselect)
Tested in the ARA Transonic Wind Tunnel

- CFD Code Development
- Application and Analysis
- Software Support

- Design and Manufacture
- Models
- Balances
- Rigs

- Transonic Wind Tunnel
- Propulsion Rigs
- Weapons Separation
- Data Analysis

A400M Military Airlifter Characteristics

- Modern supercritical wing
- High speed cruise M = 0.72 at 37,000’
- Four TP400-D6 turboprop engines each powering advanced 8-bladed propellers
- Wing span 42.4m
- Overall length 42.2m
- MTOW up to 130 tonnes
- Maximum payload 37 tonnes
- Maximum altitude 37,000 ft
- Range at max payload 1,700 nm
- Ferry range 4,900 nm
- Maiden flight due in 2008

See www.airbusmilitary.com for more information

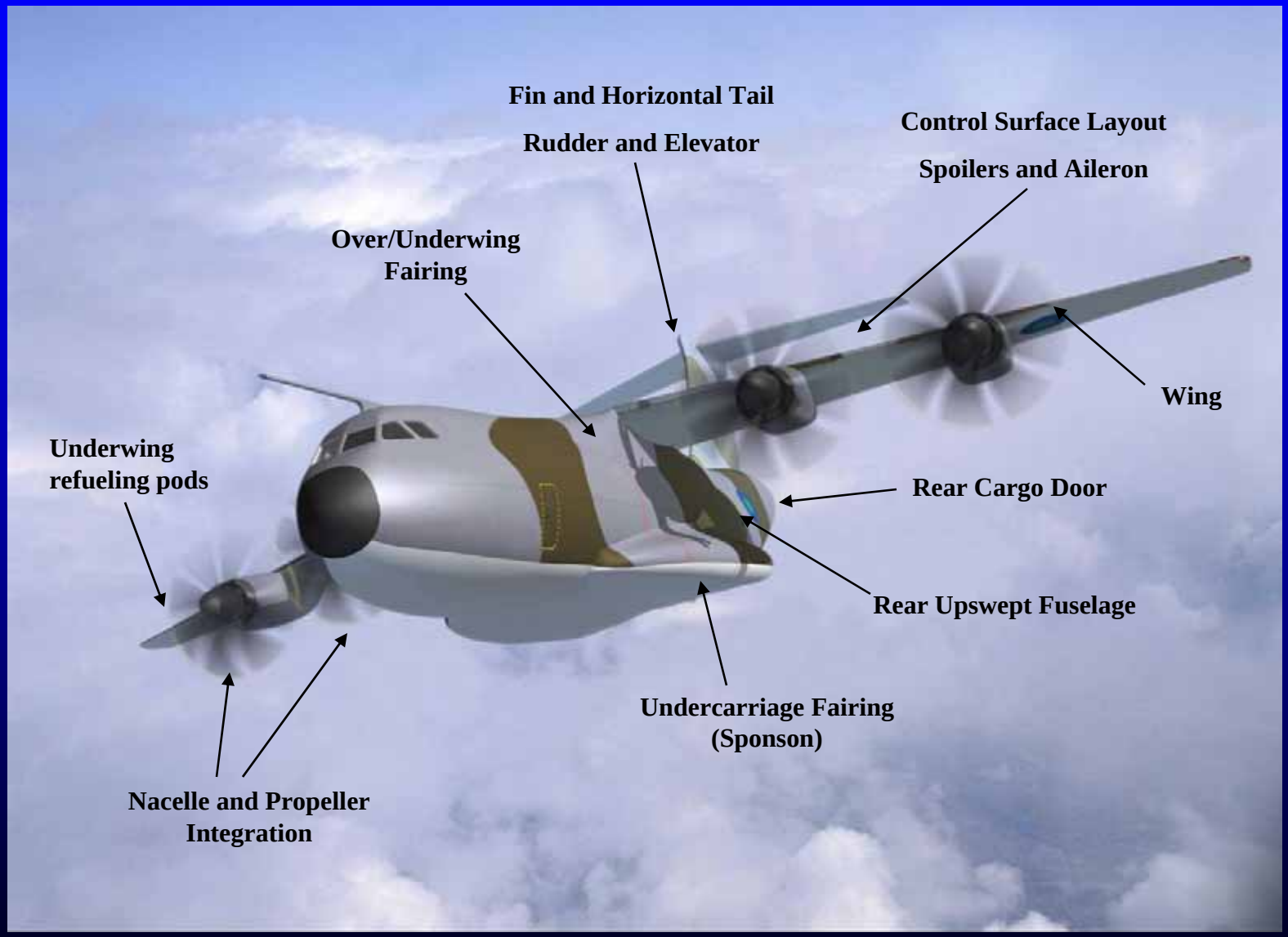
A400M Military Airlifter Roles

- **Tactical Transporter**
  - Exceptional soft/unprepared field performance
  - Less than 3,000 ft runway
  - Air delivery of paratroops and cargo
  - Accommodates all major army vehicles and helicopters
  - Very Low Level Extraction (VLLE) of single and multiple loads
- **Tanker**
  - 2 and 3 point role convertible tanker/transport
  - converts in 2 hours
  - 41 tonnes transferable fuel

A400M Airframe Strategic Workshare

- France
- Germany
- Spain
- UK
- Belgium
- Turkey

Main Aircraft Regions Studied in the ARA Transonic Wind Tunnel



Configuration Optimisation

- Full span un-powered models for efficient, highly productive testing
- First test performed at ARA on the A400M in 1993
- 28 test campaigns performed to date
- Testing scheduled to continue into 2005

Single Sting Testing

- Internal 6-component strain gauge balance on central sting
- Alternative balances available to suit test matrix
- Optimisation of wing, fuselage fairings, engine position, vertical and horizontal tail, rudder and elevator
- Multiple strain gauge balances on spoilers (up to 6) and aileron
- Definition of wing buffet onset boundary
- Surface pressure distributions for loads analysis and aerodynamic design, over 970 taps recorded simultaneously
- Typical test range
  - Mach No. = 0.2 to 0.79
  - Alpha = -4° to +16°
  - Beta = -10° to +10°

Twin Sting STSR Testing

- Twin boom mounting in place of outboard engine, no central sting
- Live rear fuselage mounted on internal 6-component balance
- Considerable M, α and β range
- Yaw capability for lateral investigations
- Rear fuselage loads up to split plane only
- For development of rear fuselage, sponson, HTP, VTP and rear door
- Extensive pressure plotting of rear fuselage, tailplane and fin
- Rear fuselage oil flow visualisation
- Used with dummy central sting to derive sting corrections to force data

Enhanced Twin Sting ETSR Testing

- Twin boom mounting in place of outboard engine, no central sting
- Each boom houses highly accurate six component strain gauged balance for measurement of overall model loads
- No split in model fuselage so no cut-off for influence of rear fuselage/tail geometry changes
- For development of rear fuselage, sponson, HTP, VTP and rear door.
- Used with dummy central sting to derive sting corrections to force data
- More specialised than STSR
- Limited α and β range

A400M STSR/ETSR Testing at ARA

ETSR Balance Calibration

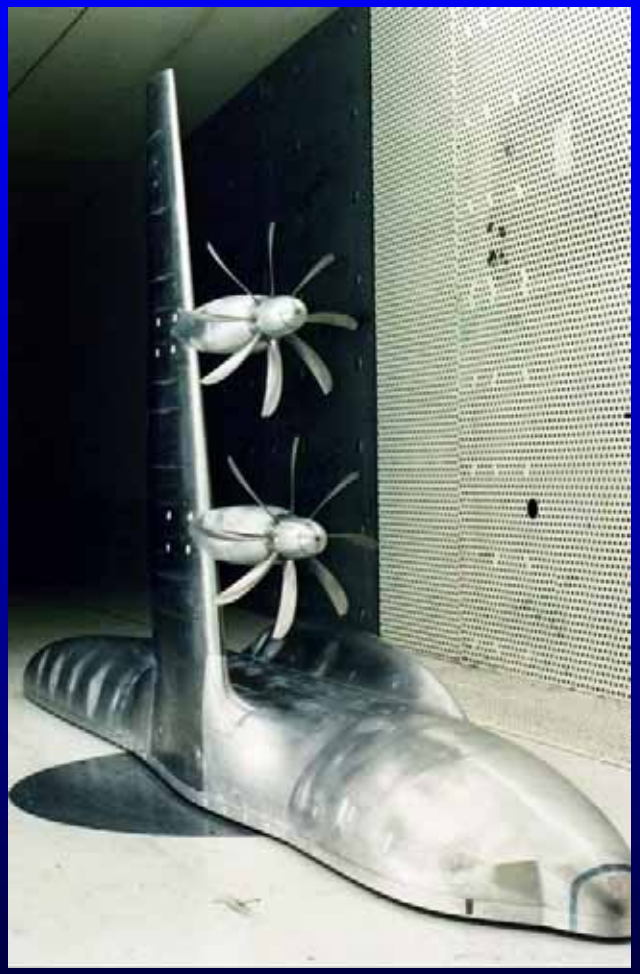
Model Instrumentation

Rear Door Testing

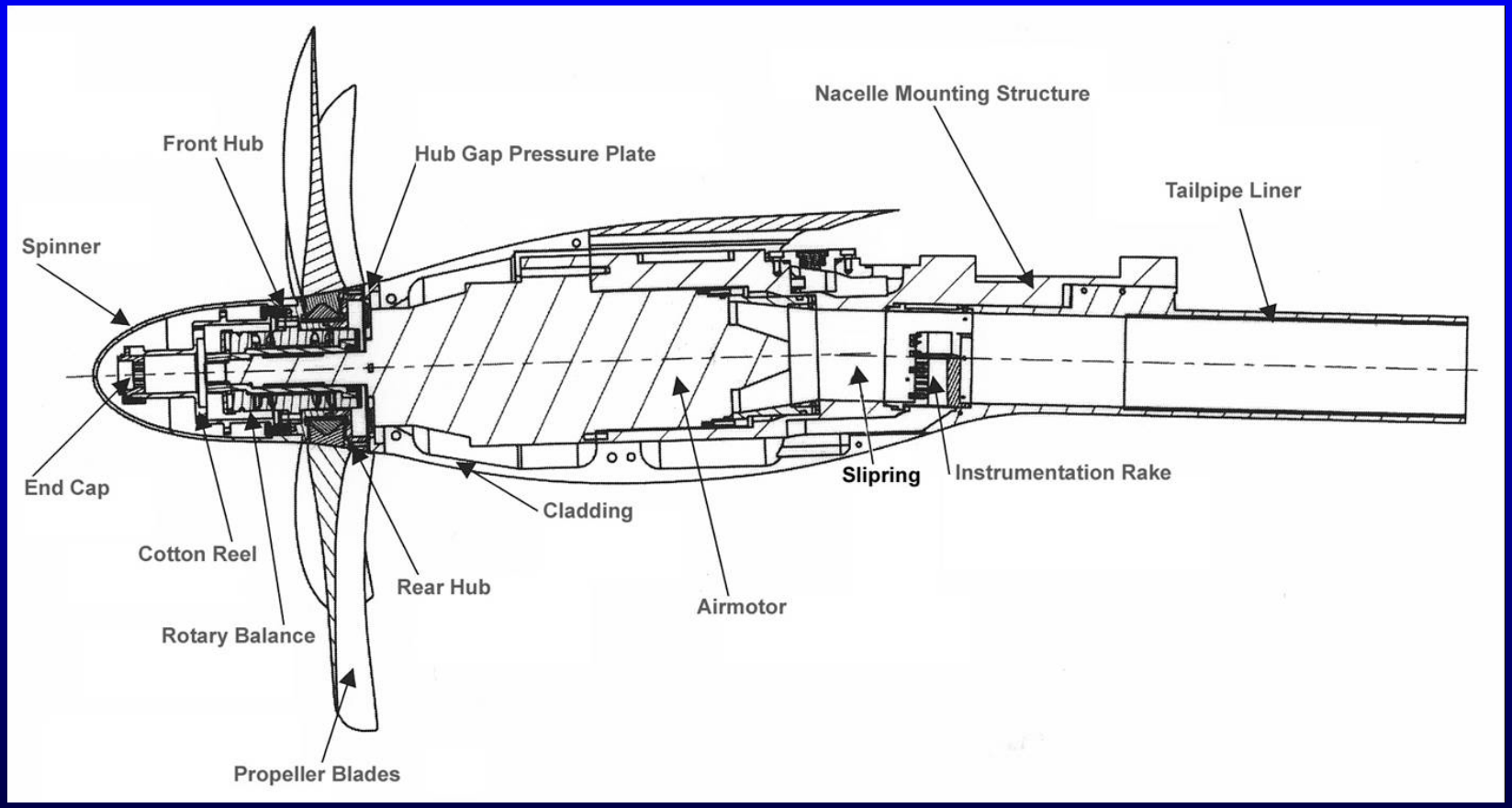
Flow Visualisation

Propeller Integration

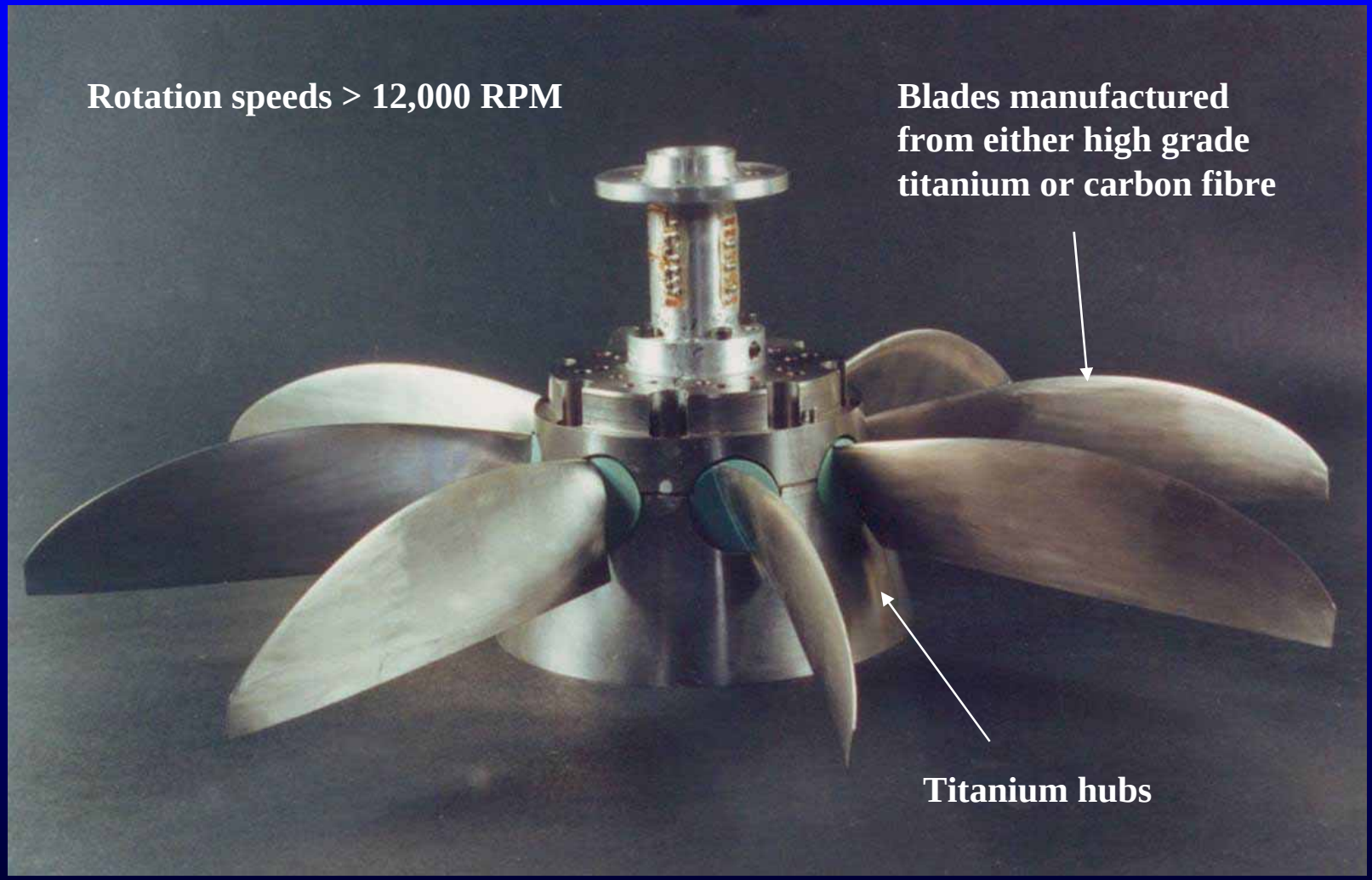
- Complex semi-span powered model to assess effects of propeller slipstreams
- Purpose made compressed air driven motors powering scaled 8-bladed propellers
- High level of instrumentation
- Designed for power-on component load measurement (e.g. spoilers, ailerons)
- First A400M powered test completed at ARA in 1997
- 4 major test campaigns performed to date
- Testing scheduled to continue into 2005
- Regarded as “high risk testing ” due to the high speed rotating components



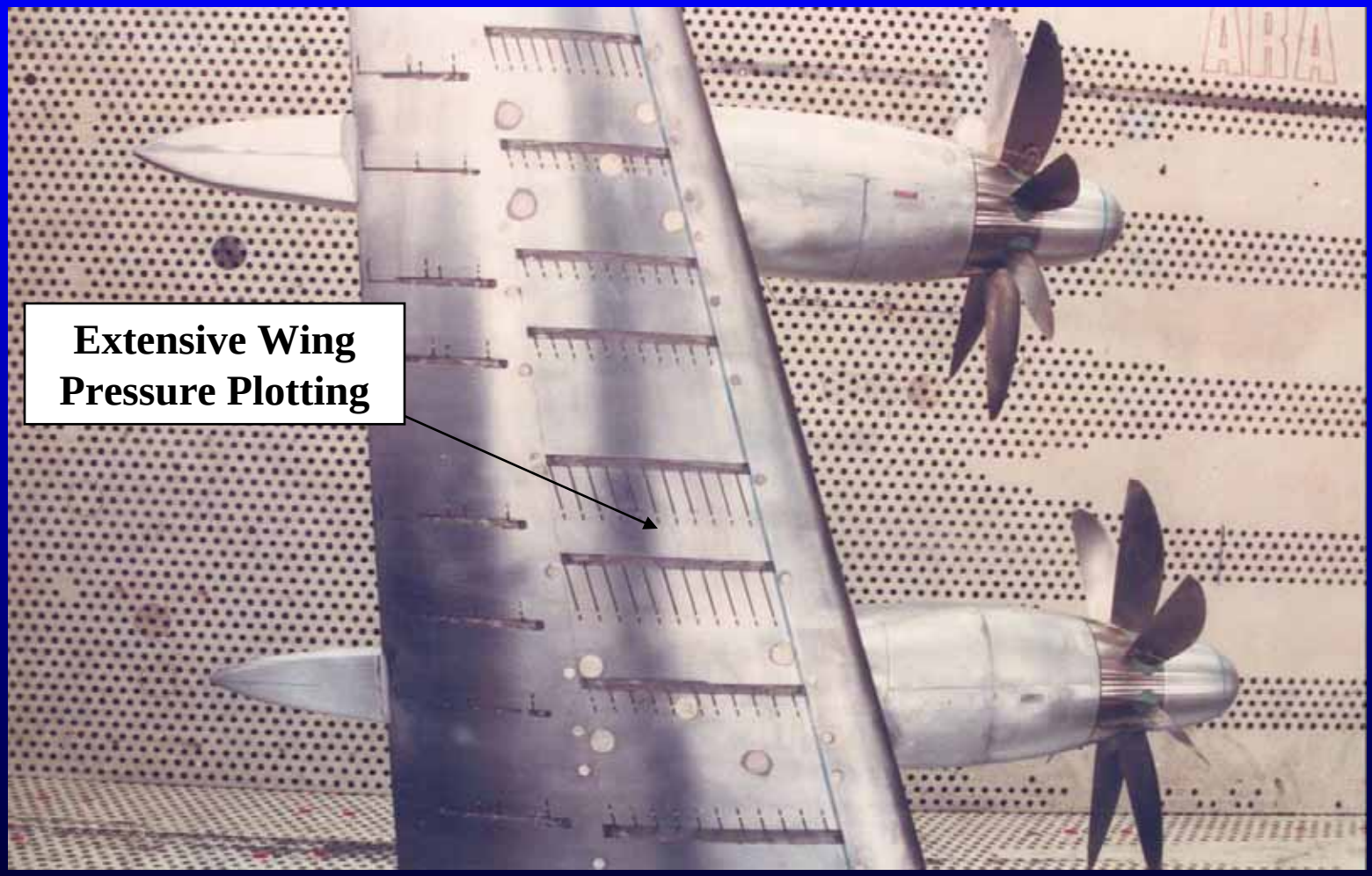
Powered Propeller Assembly



Details of A400M Model Propeller



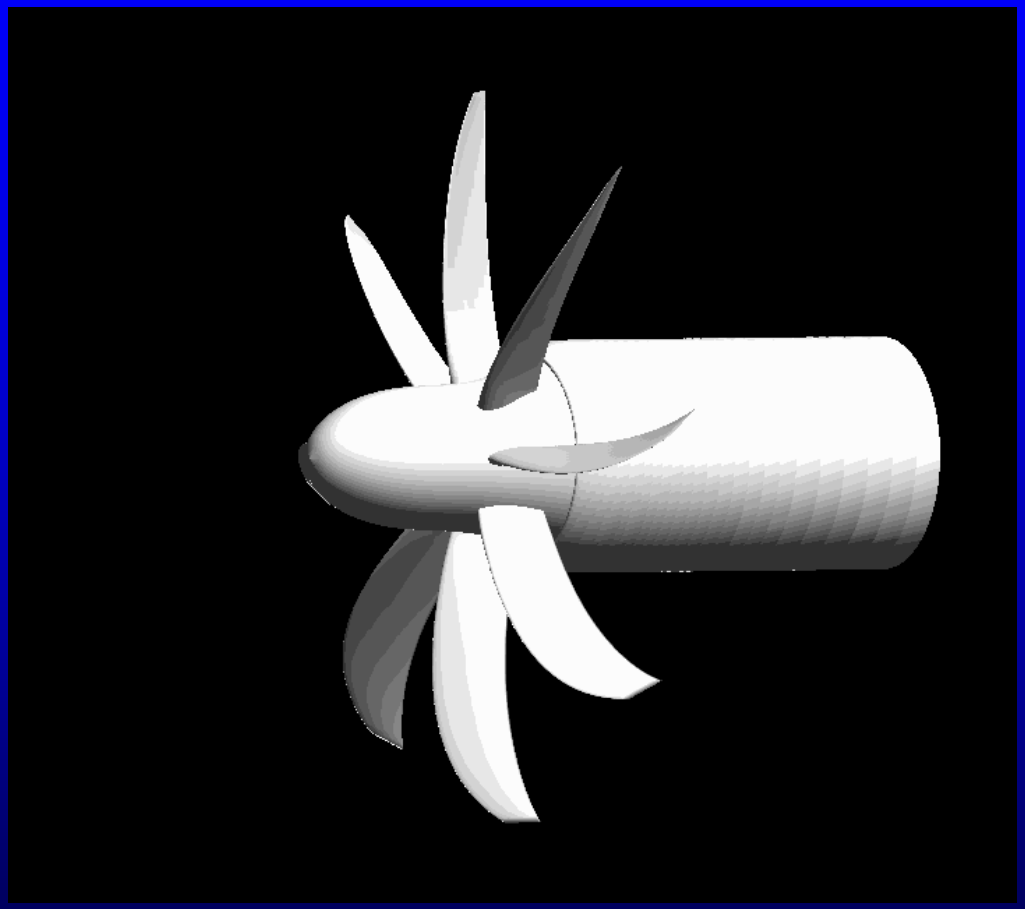
A400M Details of Wing Pressure Taps (Total for model > 600)



Powered Semi-span Model Testing

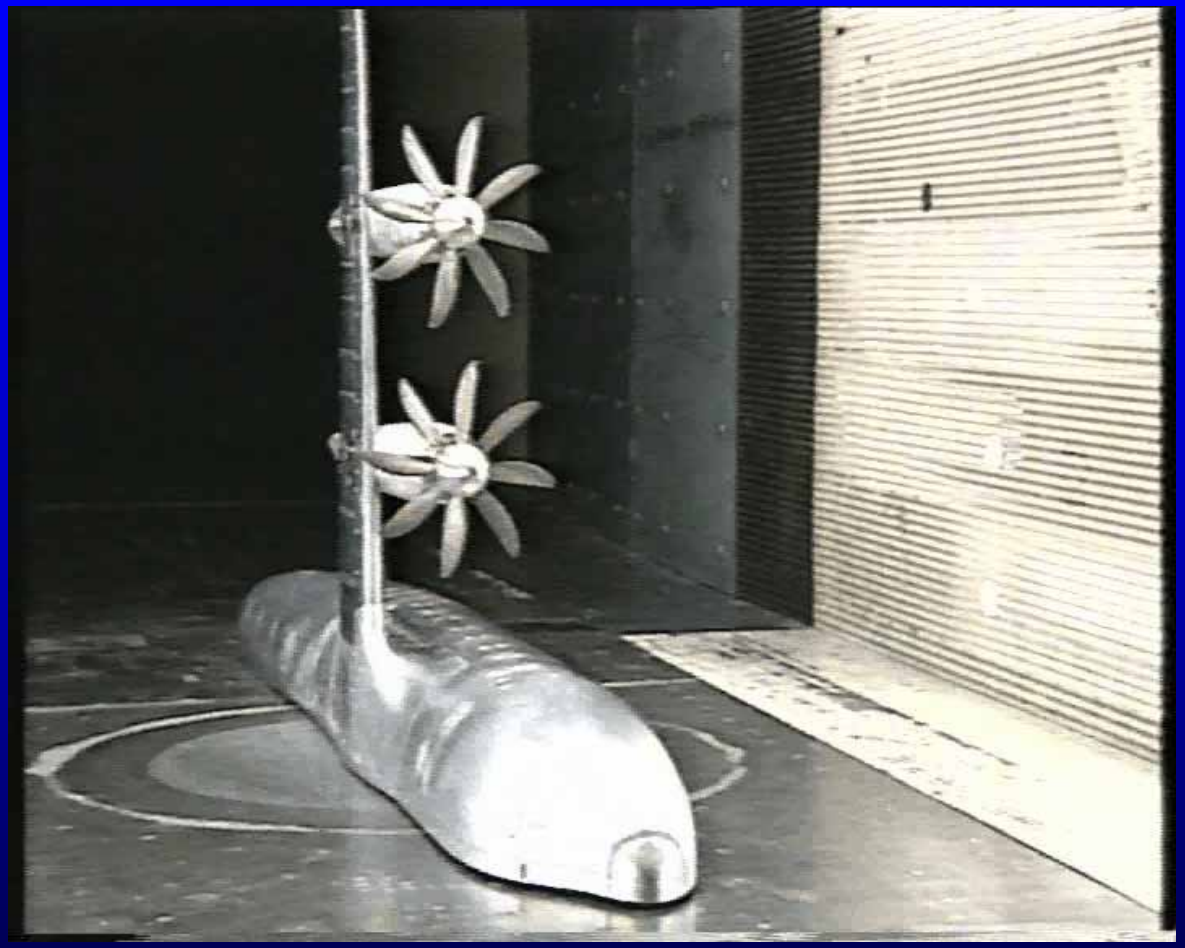
- **Assess propeller slipstream effects on:**
  - **wing aerodynamics by comparison of wing pressure distributions with those from the full-span unpowered tests.**
  - **wing control surfaces by use of balanced spoiler panels and aileron**
  - **buffet onset boundaries**
- **Study power effects by variations in thrust coefficient - achieved by combinations of blade angle and RPM**
- **Examine effect of propeller swirl direction - achieved by opposite handed airmotors and propellers**
- **Engine failure cases**
- **Loads on various under-wing pods mounted on internal force balances**
- **Flow visualisation in presence of propeller slipstream**
- **Propeller induced forces (thrust, torque, efficiency…) from rotary balance data**
- **Propeller Normal Force from 1P system using TDC lock-on**
- **Blade stressing and vibration monitoring**

Click on image to view movie



CFD generated swirl and
pressure distributions behind
A400M propeller

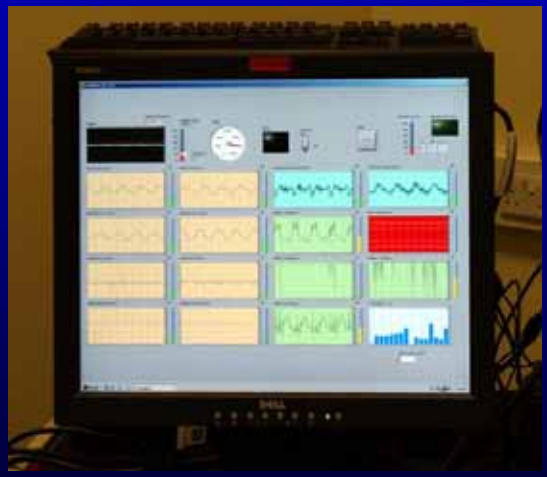
Click on image to play movie



Propeller start-up on A400M Model in ARA Transonic Wind Tunnel

SPURS Dynamic Monitoring System

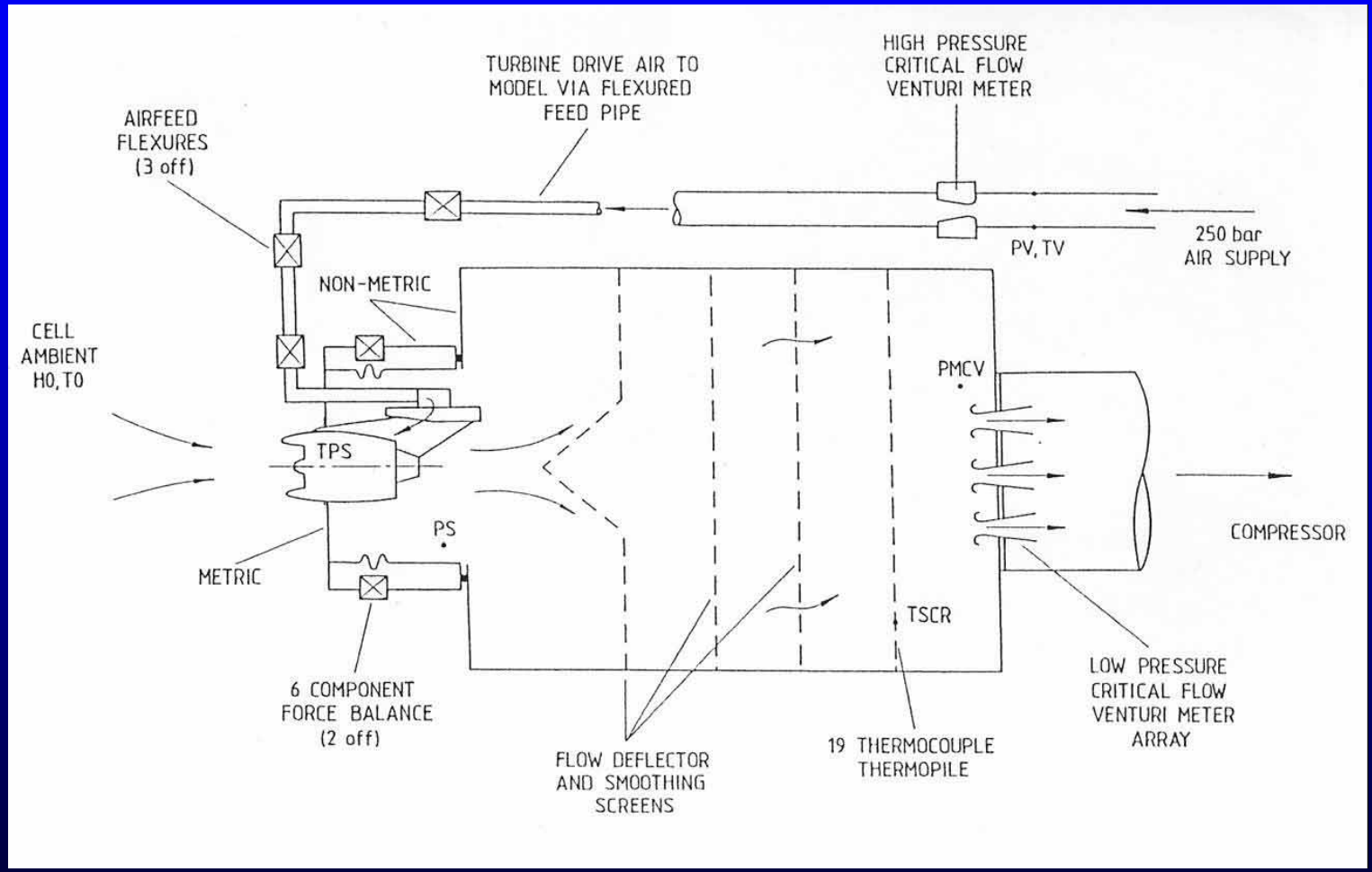
- Small Propeller Universal Recording System, developed at ARA
- Stand alone PC based system utilising LABVIEW technology
- Processes, displays, and records the dynamic signals from the model
- Rotary balance static and dynamic loads summed
- Allows monitoring of all rotary balance dynamics, blade stresses, and accelerometers
- Visual warnings when signals approach and exceed predetermined limits



A400M Model Trials in the ARA Propeller Test Cell

- Used to demonstrate reliable operation of all rotating hardware and instrumentation systems
- Propellers run up to full operating RPM (>12,000)
- Checks on dynamics of rotary balances and propeller blades
- Hub dynamic balancing confirmed
- Slipring and air-motor performance assessed
- Low cost facility
- Risk reduction exercise

ARA Mach Simulation Tank



MST Calibrations of Air-Motor Exhaust Ducts

- ARA Mach Simulation Tank used to derive thrust and discharge coefficient characteristics of air motor assemblies
- Characteristics defined as a function of the exhaust duct rake pressures and temperatures
- Calibration covered Mach number and NPR range expected in Transonic Wind Tunnel
- Applied as a thrust correction to the TWT results, based on measured exhaust duct rake pressures and temperatures

Concluding Remarks

- ARA have been heavily involved in high-speed wind tunnel testing of the A400M since 1993
- ARA have designed and manufactured most of the A400M models tested in the ARA tunnel.
- Numerous test campaigns have been performed involving a wide range of test techniques, support rigs and three ARA test facilities
- Configuration optimisation tests have used full-span models mounted on both single and twin stings. Choice of support system driven by area of model under investigation
- Propeller integration tests have used complex, highly instrumented semi-span models mounted on underfloor balance
- Powerful compressed air driven motors used to spin 8-bladed propellers (RPM > 12,000, made from titanium or carbon fibre)
- Rotating hardware requires very close monitoring of loads, stresses and vibrations. ARA have developed the SPURS system specifically for this role
- Development testing on A400M will continue in 2004 and into 2005