



AW609 TiltRotor Flight Test Program Overview



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AW609



- Effective November 15th 2011 AgustaWestland is the sole owner of 609 Program
- AW is pursueing FAA Type-Certification and the aircraft model is now identified AW609 and it is part of AW product line









Powered Lift Evolution



















- Powered lift evolution since Fifties recognized as a market need
- Operating Conditions: avoid runways for military operations during Cold War; fly with "flexibility" point-to-point within "overcrowded" area today
- Technology as a Critical Factor: several key improvements paved the way to modern VTOLs
- Challenging Evolution: several configurations explored; few concepts proved to be valid

Manufactures' strategies comparison



Expanding Rotorcraft Performance

Bell–Boeing (USA)

Tilt Rotor



In service

AgustaWestland (EU/USA)

Tilt Rotor



Production prototype

Sikorsky (USA)

Hybrid helicopter



Technology demonstrator

Eurocopter (EU)

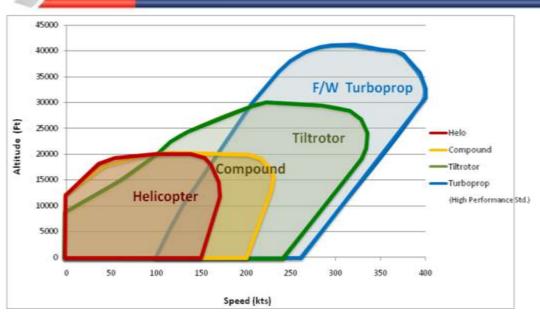
Hybrid helicopter



Technology demonstrator

AgustaWestland Tiltrotor vision



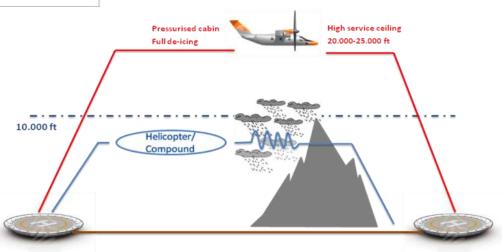




AW609
675 nmi
3 hours
TYPICAL
HELICOPTER
350 nmi
3 hours

Tiltrotor as complementary helicopter solution to answer additional market demands:

- FASTER
 - FARTHER
 - W/OUT RUNWAY



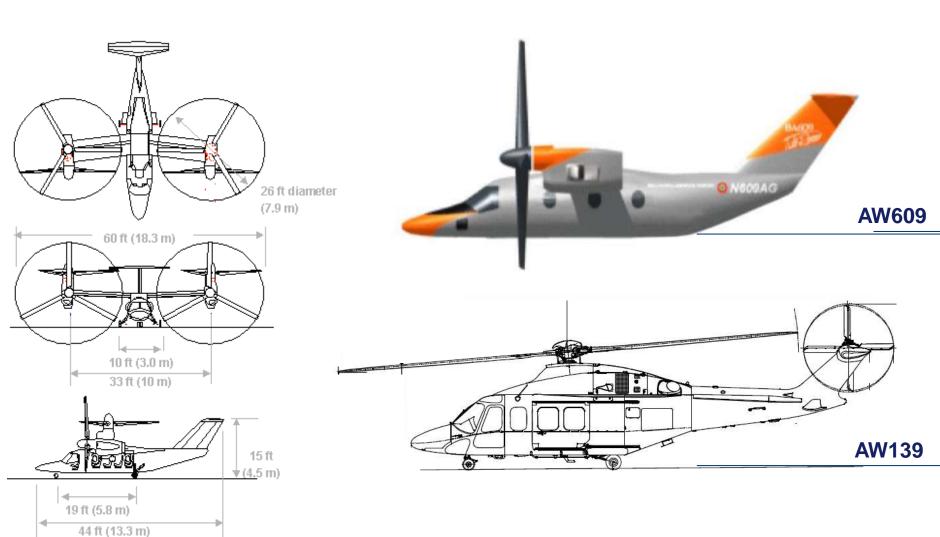
AW609 Specifications





Dimensions & Size Comparison





Design Features



Hydraulic & Electrical

- •Triplex 3000 psi Hyd Sys
- •3 DC GENS + 28AhBatt
- •2 PMG's + 2 FCC BATT's
- •2 AC GENS

Power Plant

- PWC PT6C-67A engines
- AEO Power Ratings: Takeoff (1940 shp), MCP
- OEI Power Ratings: 30 sec (2492 shp), 2 & 30 min, Continuous

2480 lb capacity

Fuel System

•10 crashworthy fuel cells

Rotors / Drive

26 ft. dia. Proprotors
 w/mechanical interconnect



Conversion System

 Via dual telescopic ball screws w/mechanical interconnect

Ice Protection

- Rotor Anti-ice / De-ice
- Wing De-ice Boots
- Engine Inlet
- Windshield Heated

Airframe

- Largely Composite Fuselage
- Pressurized Cabin
- Vapor Cycle Air Conditioning
- Full Composite Wing
- Rudderless

Flight Controls/Avionics

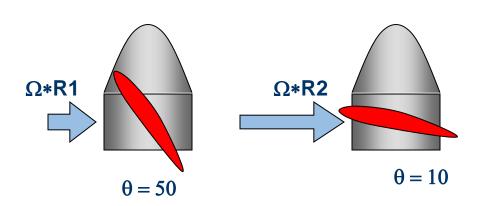
- FCS Triplex Digital Full Authority FBW
- Collins State-of-the-art Avionics suite

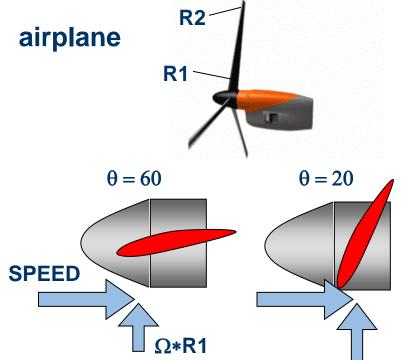
The Proprotor



Ω*R2



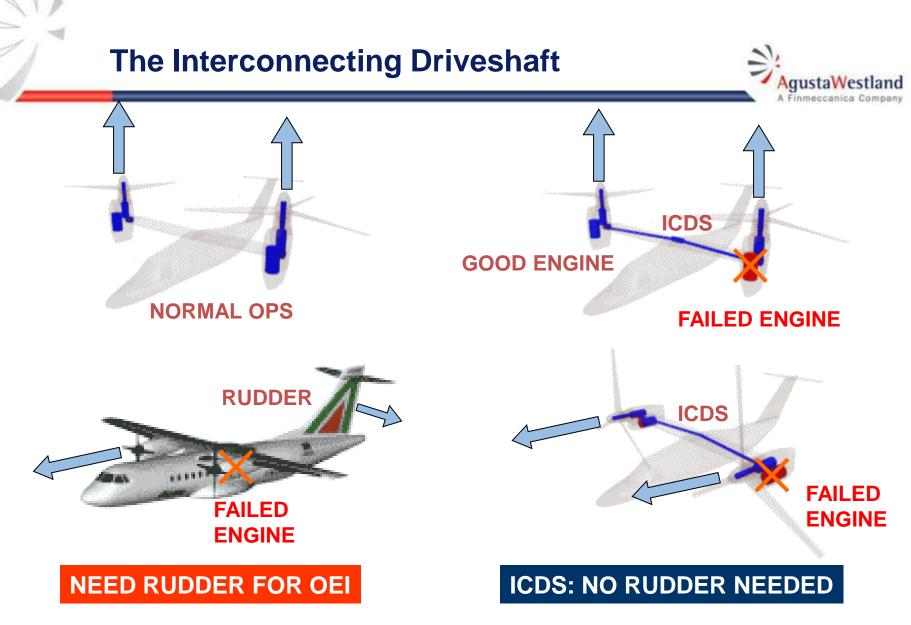




- HELICOPTER: LOW COLLECTIVE
- AIRPLANE: HIGH COLL. & FLOW VARIATION WITH R



- BLADE TWIST (~40 DEG)
- BIG COLL. EXCURSION (0-60 DEG)



Safety requirement turned into an opportunity

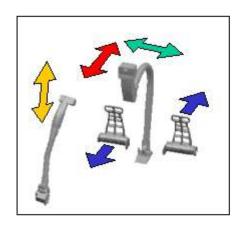
"INTUITIVE" Flight Controls



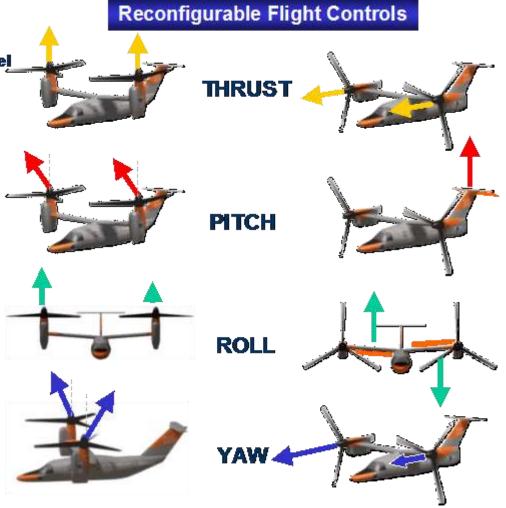
Conventional Helo Cockpit Controls:

- Center Stick and Pedals
- Collective/Power Lever (has Thumbwheel for RPM & Nacelle Tilt Commands)

creating typical aircraft behaviors by different aeromechanic means



Flight Controls from VTOL/Conversion to A/P mode are transparent phased with nacelle tilt angle



The Conversion



- Control phasing
- FCS augmentation
- Conversion protection

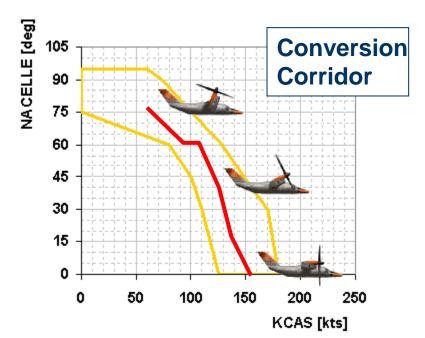


- Low workload
- Constant altitude



160 knots

80 knots



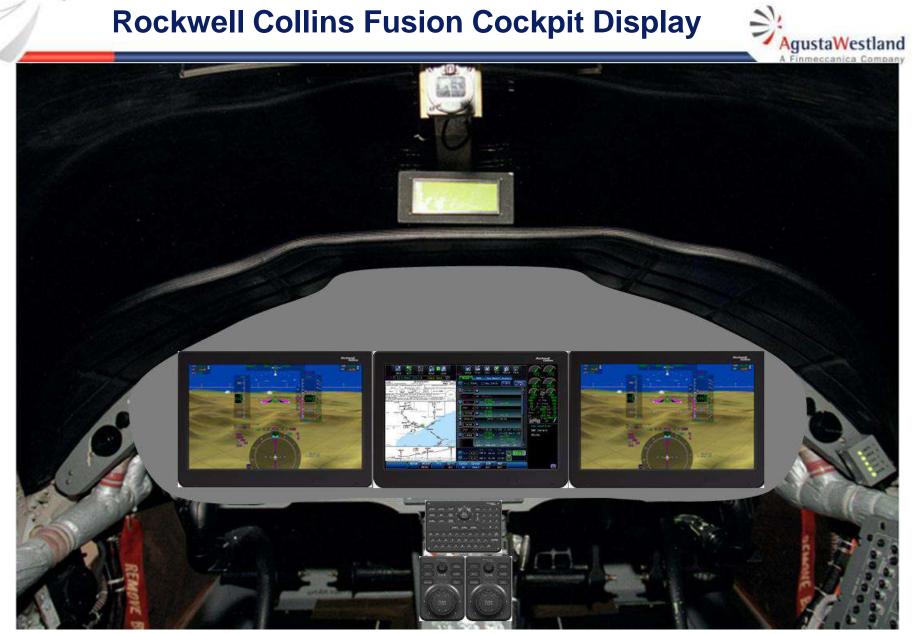


Transition to APLN





Rockwell Collins Fusion Cockpit Display



Rockwell Collins Touch Screens





217 Pilot Training Tasks



Common Tasks
 (Can be Trained in any Aircraft)

Helicopter Maneuvers

- Hover/Slow Flight
- Autorotations

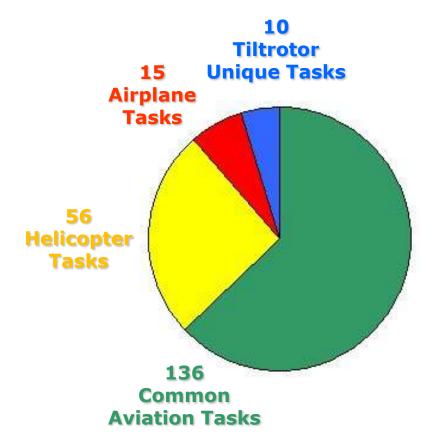
Airplane Maneuvers

- High Speed/High Altitude
- Stalls

Tiltrotor Unique Maneuvers

- Use of Nacelles
 - Attitude Control (Center of Gravity)
 - Thrust Vector Control (Airspeed)

Less Than 5% New Tasks

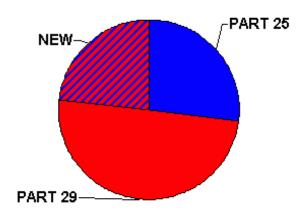


Certification Basis



- AW609 Certification Basis <u>established</u> by FAA under the provisions of Part 21.17(b) for "Special Class Aircraft" with portion of Part 25, 29 and new specifics TR
- Certification Basis managed through Issue Paper G1
 between FAA and Applicant iaw FAA rules
- All AW609 activities (testing, analytical substantiation, conformity, compliance findings, ..) are performed in accordance with the Certification Plan accepted by the Certification Authority, and identified within Applicant Project Specific Certification Plan and several System Specific Certification Plans

Powered Lift Category Tiltrotor Class Aircraft



Certification Basis

Mostly: FAR25 + FAR29 + TILTROTOR

Flight Prototypes Plan





A/C 1



- Envelope Expansion
- Ice Shapes (risk mitigation)
- FCS & Handling Quality

- External Noise
- Performance
- HV/Autorotation



A/C 2

- Envelope Expansion
- Load Level, Vibration Survey
- Stall & Buffet demo

- Avionics Development
- Kits
- Drive System Endurance Test



A/C 3



- Icing Trials (HISS + Nat. Icing)
- **Cold Weather demo**
- **Propulsion**

- Cooling Hot Weather, Hot Fuel & Hyd. test
- Cabin Pressurization
- Mini Load Level Survey



A/C 4



- HIRF, Lightning, EMC
- Electrical & Weather Radar demo · Avionics
- **Lighting, ECS, Night Flight**
- **Internal Noise**

- **Equipment Temperature Survey**
- Functional & Reliability, Maintenance flights, Customer demos

Air Vehicle Testing Overview







Accomplishments

- ✓ About 800 Flight Hours + 300 Ground Run
- ✓ Envelope expansion in 3 flight regimes
 - 25,000 feet press alt
 - 293 KEAS
 - +3.1, -1.0 g
 - GW / cg to limits
- ✓ Flutter clearance
- ✓ High Rate of Descent testing
- ✓ Category A performance testing
- Autorotation
- ✓ Flight control law software / hardware improvements

High Rate-of-Descent Testing



- AW609 will have a sink rate warning system
- Goal is to maximize allowable descent rates at slow speed while providing safety margin
- Used the simulator for recovery technique and practice
- Simple recovery technique



- Developed vortex ring state (VRS) predictions based on V-22 data
- Used a Laser Optical Air Data Sensor for airspeed measurement

Optical Air Data Sensor

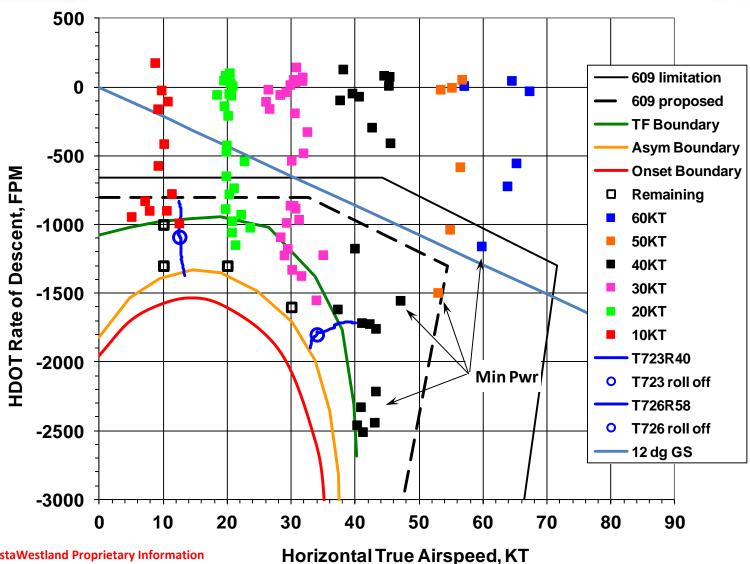


- Needed an accurate way to measure very low airspeed at high altitude
- Triple laser system was developed to provide airspeed cueing on helicopters in brown-out conditions
- Adapted it to the 609 for HROD testing
- System required calibration, filtering before it was usable
- Calibrated it with a pace truck going up and down the runway
- Filtered it within our existing instrumentation display



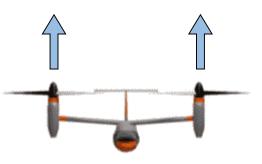
High Rate-of-Descent Data Points

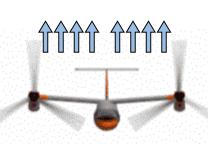




WINGS' FEATURES – Why such emphasis on aeroelastics

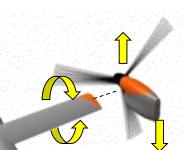




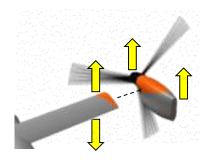


Tiltrotor Loads: Rotor & wing loads; Helo. vs. Airplane mode

Wing torsion



Wing bending



Big nacelle mass & whirl flutter: minimize pylon oscillations Wing stiffness, 23% airfoil, downstop, FCS margins

Aeroservoelastic Testing



- Inputs accomplished through an FTIP panel on center console of cockpit
- Symmetrical and asymmetrical (differential) collective pitch
- Symmetrical and asymmetrical (differential) longitudinal cyclic
- Asymmetrical flaperon inputs

Bending moments created:

Wings fore and aft
Wings up and down
Wing torsion

All at 90, 60, 30, 5 and 0 deg In



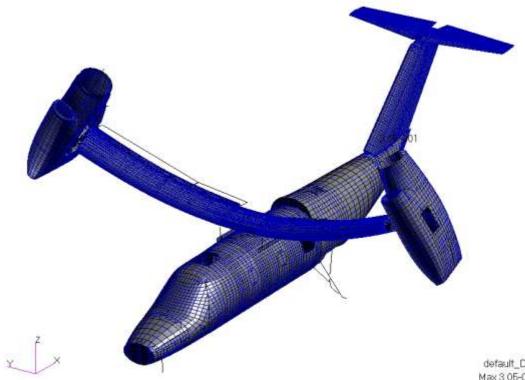


Wing Bending Using Symmetrical Collective Inputs



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Deform: SC1:75-2108-LB WING FUEL-L/G RETRACTED-STIFF NAC MTG, A1:Mode 7 : Freq. = 3:0073, Eigenvectors, Translational,



default_Deformation : Max 3.05-001 @Nd 1301

Frame: 1 Scale = 1.00+000

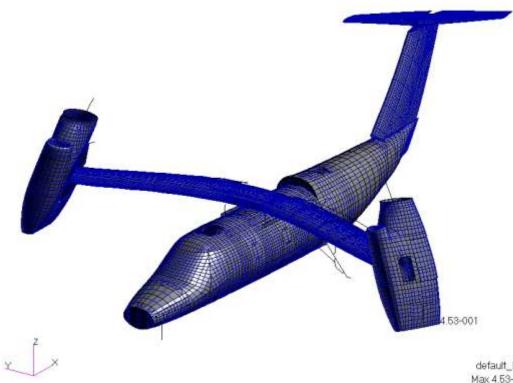


Wing Chord Bending Using Symmetrical Longitudinal Cyclic



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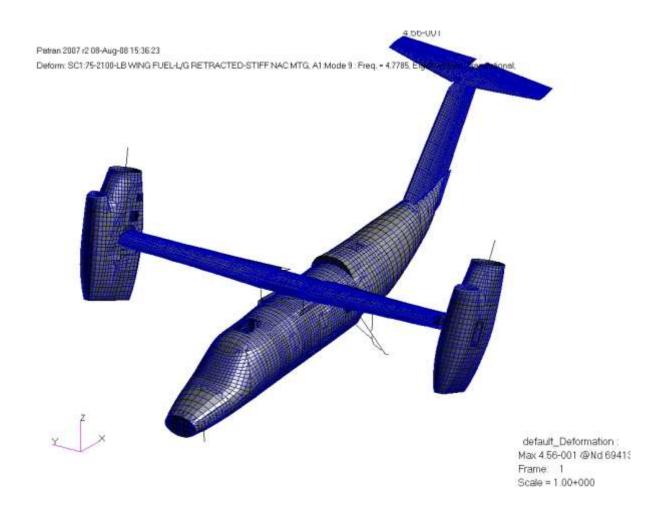


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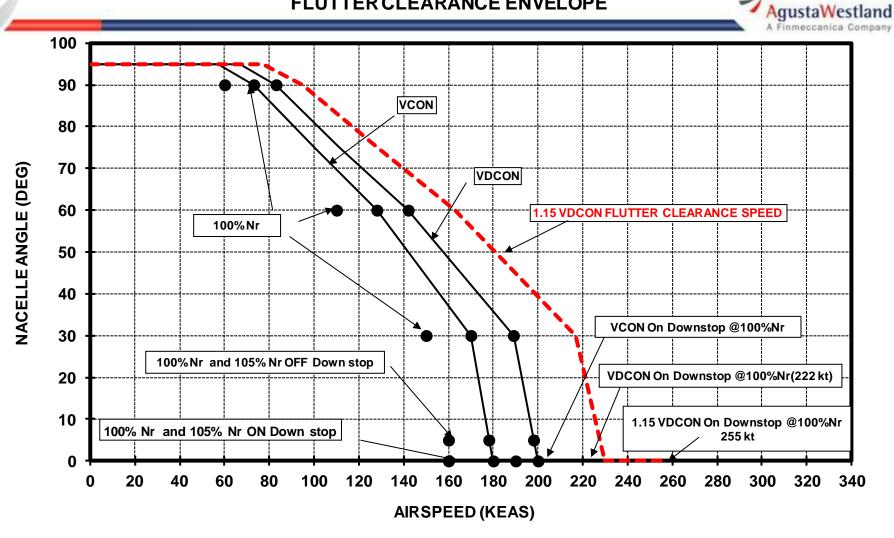
Scale = 1.00+000

Wing Torsion Using Longitudinal Cyclic





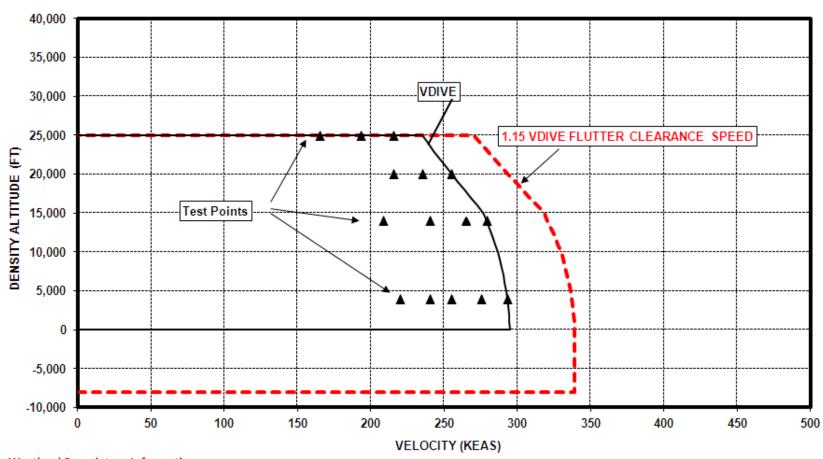
AW609 AIRSPEED vs. NAC ANGLE: POWER ON ENVELOPE EXPANSION VTOL/CONVERSION MODE TEST POINTS ON FLUTTER CLEARANCE ENVELOPE



APLN Mode Flutter Testing



AW609:POWER ON:AIRPLANE MODE/84% NR ENVELOPE EXPANSION TEST POINTS ON ALT VS VELOCITY FLUTTER CLEARANCE ENVELOPE



Category A Testing (On-going)



- Will use OEI training mode for testing with minimal actual OEI validation points
- Validated OEI training mode with run-stand engine failures at maximum power
- Takeoff and landing profiles developed in AW609 simulator
- First cut at TDP / LDP heights determined on simulator

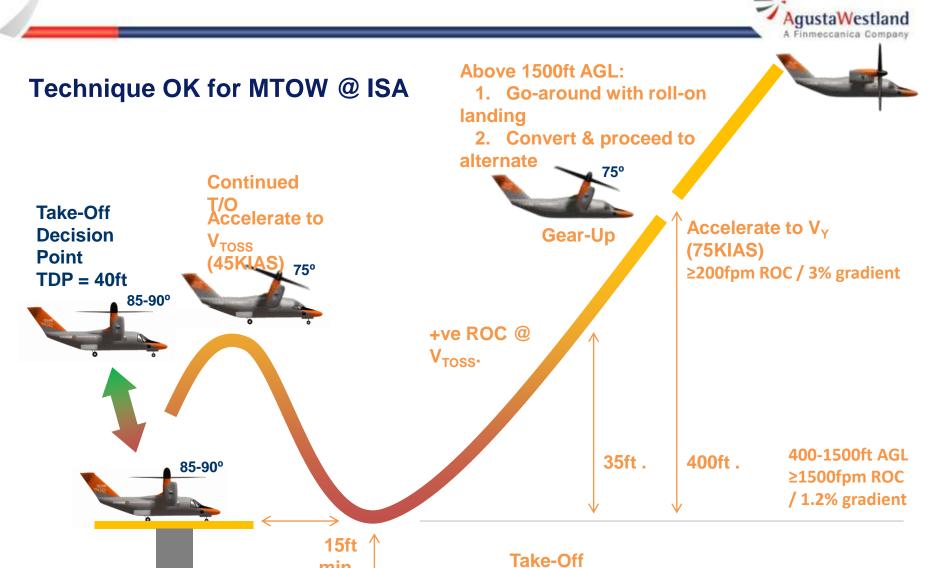
AW609 OEI performance is enhanced by:

Moving softstop
Optimal rotor RPM
Super droop

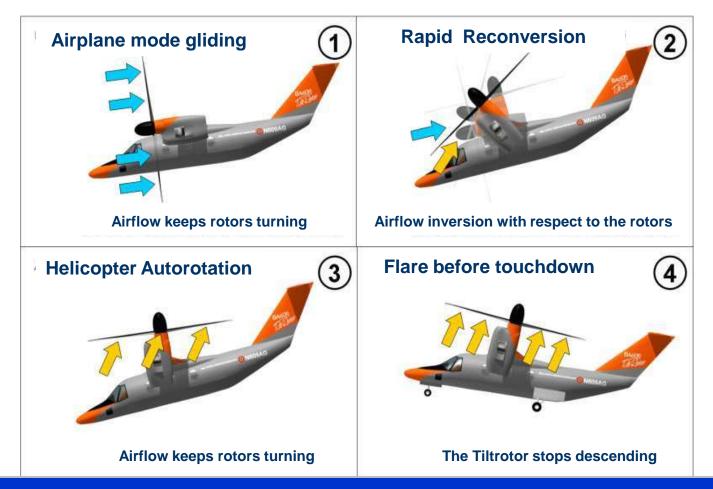


Takeoff Profiles developed in Simulator

min.



All Engine Inoperative – P/Off Entry Into Autorotation



Tiltrotor capability to safely handle a dual-engine failure emergency in normal cruise Demonstrated in flight May, 15th 2009

Autorotation Testing (November 2013)



- First stage will review previous testing (2009)
- Second stage will evaluate steady-state conditions of windmilling in APLN mode and autorotation in VTOL mode
- Third stage will look at transitioning to 95 degrees nacelle angle from 75 and from APLN at various GW, CG combinations

CONCLUSIONS"A New Way to Fly"



- AgustaWestland is committed to the continuous improvement of the performances and the comfort of its helicopters at a reduced operating cost.
- The Tiltrotor solution is developed in parallel and as a complementary solution, not substitutive or competitive with future improved helicopters
- The Tiltrotor provides fundamental operational step-changes and answers to the rotorcraft market demand: FASTER, FARTHER, WITHOUT RUNWAY
- FAA Type Certification process with concurrent EASA Validation is ongoing with
 Type Certification Basis established since "day one" for AW609 design/safety/testing
- System testing and Flight Testing are successfully proceeding in line with the Certification Plans.

AW609 is progressing towards the Type Certification

AW609 is ready to pave the way to "A new way to fly"



Backup Slides





THE TILTROTOR

THE AW609 OVERVIEW

PROGRAM HIGHLIGHTS

CONCLUSIONS



The pursuit of High Speed VTOL solution



Taken from AIAA.ORG, American Institute of **Aeronautics and Astronautics**

Created by Analytical Services Inc., www.anser.org

V/STOL Aircraft and Propulsion Concepts Shaft Rotor Rotor Augmented Power Plant for Hover Same Yakovlev Canadair Propulsion Combined System for Yakovlev **Power Plant** Hover and Boll XV-15 Yak-38 for Hover Forward Rotor Bell Boeing Lift/Cruise Flight VAK 1918 Deflected Slipstream Lift + Cruise Vectored Sitters

45 aircraft have flown over 45 years in an attempt to go fast without the need for runways

A NOT-FOR-PROFIT PUBLIC SERVICE RESEARCH INSTITUTE http://www.anser.org

Includes only

and flown with

intent to enter

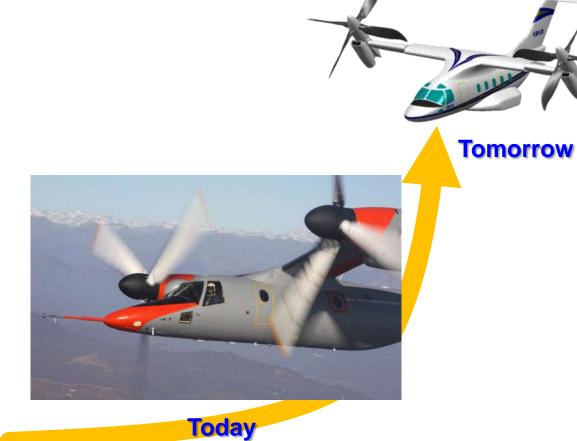
production.

aircraft built

Tiltrotor: a Proven Solution







Yesterday

Demonstrated Technology, Flying Reality and Achieved Operational Capability

Tiltrotor: the solution





Formula simplicity: same elements to produce lift in hover and thrust in forward flight

Architecture clearance: rotor is far from ground in VTOL operations

Ride quality: nacelles and engines far from cabin

Scalability: formula proven on a range of applications, from 1 ton UAV (Eagle Eye) to 30 ton tiltrotor (V 22)

Open performance potential: no immediate hard limits imposed by physics



THE TILTROTOR

THE AW609 OVERVIEW

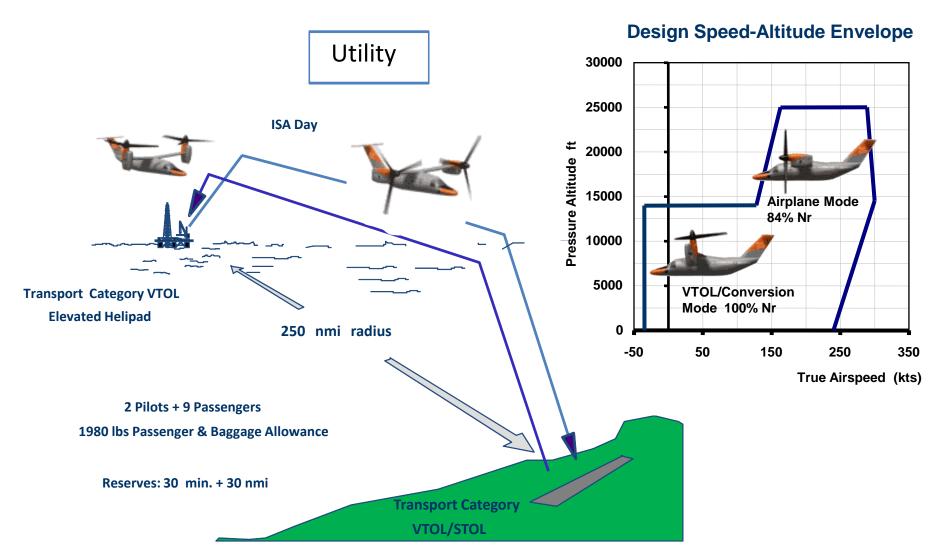
PROGRAM HIGHLIGHTS

CONCLUSIONS



Performances and Missions







THE TILTROTOR

THE AW609 OVERVIEW

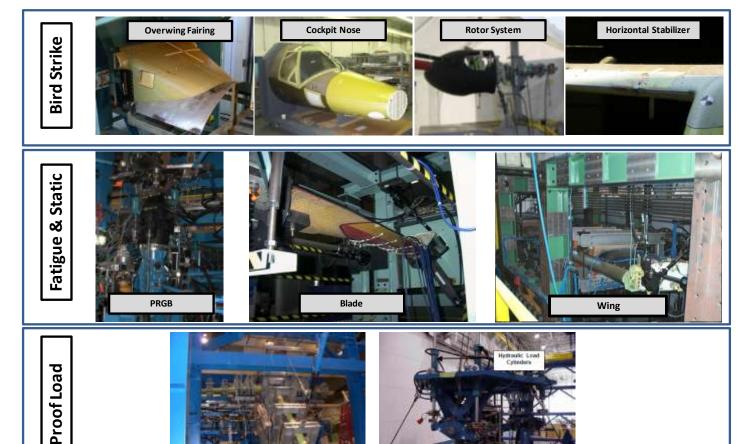
PROGRAM HIGHLIGHTS

CONCLUSIONS



Program Highlights Certification Testing





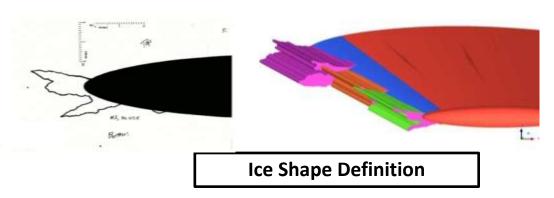
Several Structural tests in progress or completed All in accordance with Test Plans agreed with Civil Authority

Rotor System

Program Highlights Ice Protection System





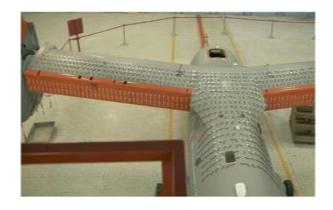




Horizontal Stabilizer - Ice Shape flight risk reduction testing

Program Highlights Lift Enhancement





Stall: new task for rotorcrafts, common for fixed wing

Stall has important implications on take-off and landing for fixed wing; it affects only airplane mode envelope for tiltrotor



Thick wing design, resulting from dynamics requirements, produces benign stall behaviour

Envelope expansion tests to define stall speeds and to introduce lift enhancements

Program Highlights Carefree Maneuvering through FCS





Low Speed Regime SEMI - ACTIVE

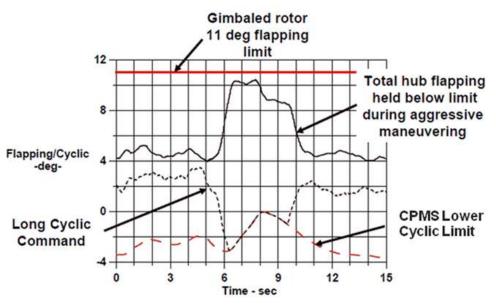
CPMS limits control to reduce flapping

High Speed Regime ACTIVE CYCLIC

Cyclic input to reduce flapping with high roll rate



CPMS - Control Power Management System

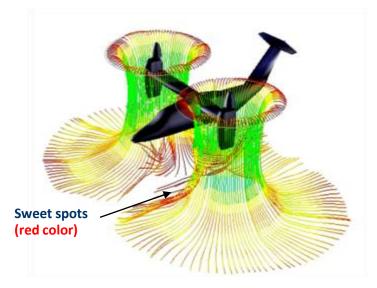


Carefree maneuvering activation at Low Speed Regime

CPMS system tuning verified in flight

Program Highlights Downwash





Downwash is a relevant topic to be considered for VTOL operations.

With respect to helicopter higher disk loading causes higher induced velocity.

However simmetrical rotors plus the wing produce sweet spots useful for rescue operations.



Analytical and experimental tests performed to assess SAR operations.

Operating results are comparable with higher class helicopters



THE TILTROTOR

THE AW609 OVERVIEW

PROGRAM HIGHLIGHTS

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