ALENIA EXPERIENCE IN METAL BONDING

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ATR 72 METAL BONDED STRUCTURES

The ATR Family: Unmatched Versatility

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ATR Family

ATR 42
46-50 seats

The only true family in the 40-70 seats turboprop market segment

ATR 72
64-74 seats

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Metal-to-Metal Bonding vs Mechanical Fastening in ATR A/C's

- More durable structure
  - No fastener hole acting as cracking sources
  - Better behaviour in case of accidentally damaged skins
- More efficient manufacturing sequence
- Aerodynamic improvement
- Appearance improvement

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Design Concepts

- Application limited to
  - Section 13 Upper side panels
  - Section 13/15 Crown panels
- Metal bonding to skins of
  - Stringers, doublers, straps
- Reduced numbers of skin-stringer configurations
- No joggle provided for stringers to be bonded
  - Extra layers of adhesive films at stepover
- No bonding under the floor
- Installation of fasteners through the bondline quite limited
  - Wet installation where necessary to

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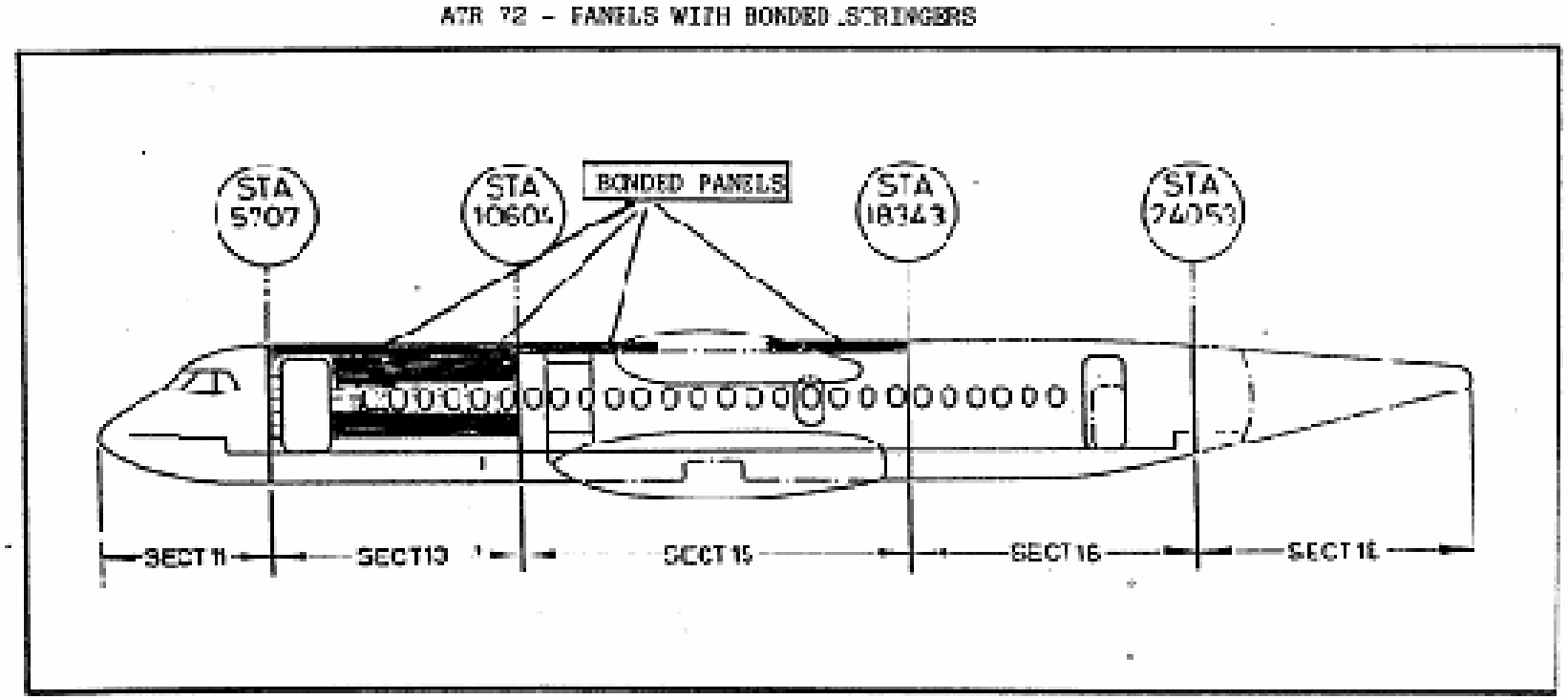
M-M Bonding in ATR 72 vs ATR 42



CROWN PANEL SECT. 13

CROWN PANELS AFT & FWD SECT 15

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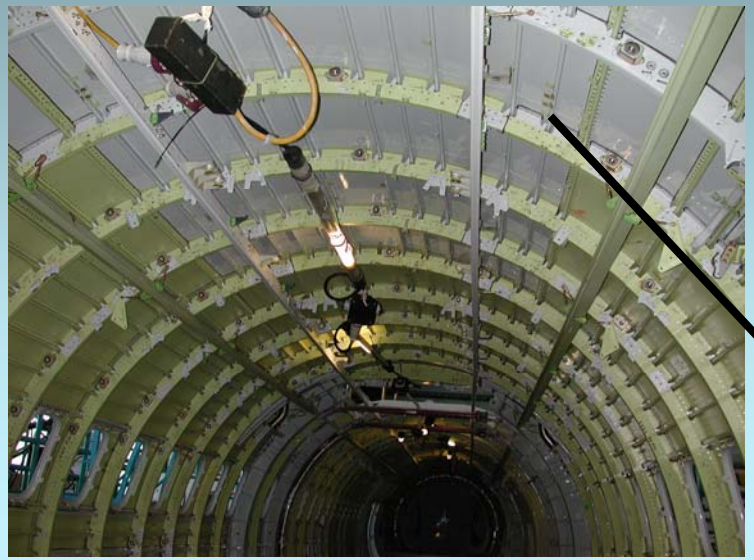

View of Clip, Bonded Stringer & Frame - Typical

Materials

Adherends

- Skin, Straps and Doublers - Clad 2024-T3 Aluminium Alloy per QQ-A-250/5
- Stringers - Bare 7075-T62 Aluminium Alloy per QQ-A-250/12

Adhesive film

- AF163-3M Grade5/Grade10 per NTA 65252
  - Grade 5 used for doubler, strap bonding
  - Grade 10 used for stringer bonding
- Superior properties to other systems
  - Resistance to ageing
  - Mechanical strength
  - Good behaviour during processing

Primer

- Corrosion Inhibiting Adhesive Primer
  - BR127 or EC3960 per NTA 65253

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Processes

- Adherends surface preparation
  - Phosphoric Anodization per NTA 72267
- Primer Application
  - Spray coating
  - Air Dry
  - Oven Cure at 121°C per 90 minutes
  - Baked film thickness : 3 – 10 μm
- Bond Assy
  - Vacuum Bagging and Autoclave curing
    - Cure Temperature : 121°C per 90 minutes
    - Cure pressure : 3.2 daN/cm^2

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Manufacturing Flow sequence

Phase A	Phase B	Phase C
Metal parts check &	BAJ – Bonding tool preparation	NDI Control
Straightness & Waviness Checks	Skin positioning	Visual &d imensional checks
Dimensional Controls	Adhesive cut for straps & doublers	Fokker US Inspection
Phosphoric Anodization	Omega tool positioning	
	Stringer positioning	
Primer application and curing	Adhesive laying	
	Extra adhesive laying in joggled areas	
	Vacuum bag preparation	
	Autoclave curing	

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PHASE A-

- All metallic components are checked to ensure a satisfactory fit up during bonding assembly.

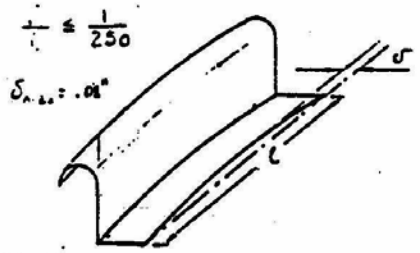
- The tolerances are defined in terms of max lateral and longitudinal deflections

- Max web-to-flange angle and twist angle are controlled for stringers

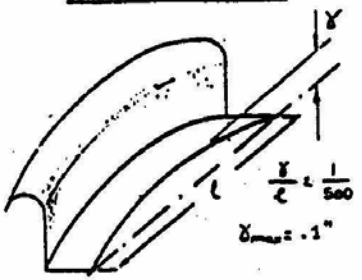
STRINGER QUALITY REQUIREMENTS

THE IN HOUSE ROLLED STRINGERS MUST HAVE THE FOLLOWING ACCEPTANCE LIMITS WHEN MEASURED TAPED TO A FLAT SURFACE:

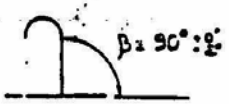
* LATERAL INFLECTION



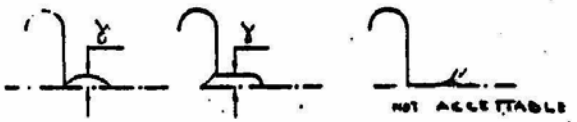
* LONGITUDINAL INFLECTION



* WEB-FLANGE ANGLES



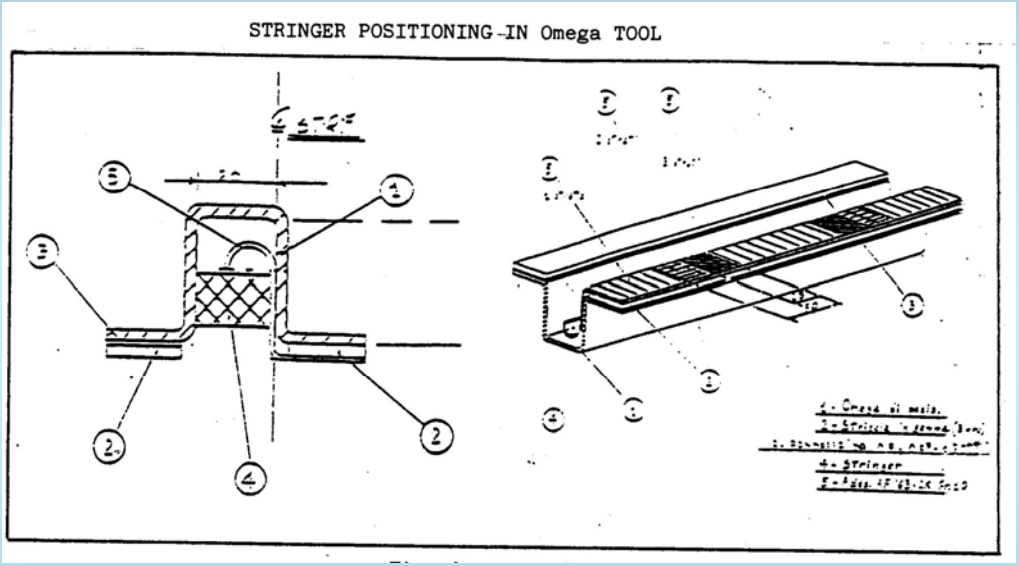
* FLANGE FLATNESS



* NO WRINKLES OR JOGGLING OF THE FLANGE IS ALLOWED IF GREATER THAN .005" IN DEPTH.

PHASE B-

- Omega shaped tools used as stringer positioners
  - Improved dimensional quality due to their acting as pressure distributor



- Joggles (Stringers/Straps & Stringer/Doubler)
  - 2 extra adhesive film layers applied over .35 mm
  - 3 extra adhesive film layers applied between .35 and .60 mm

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PHASE C

- The bonded panel is visually inspected
- The presence of properly adhesive squeeze out all along the bonded edges is of primary significance for the bonding goodness and acceptance.
- The adhesive fillet ensures edge sealing. Only excess fillet is removed
- After visual checks, all bondlines are inspected by a Fokker bondtester- ultrasonic resonance technique.

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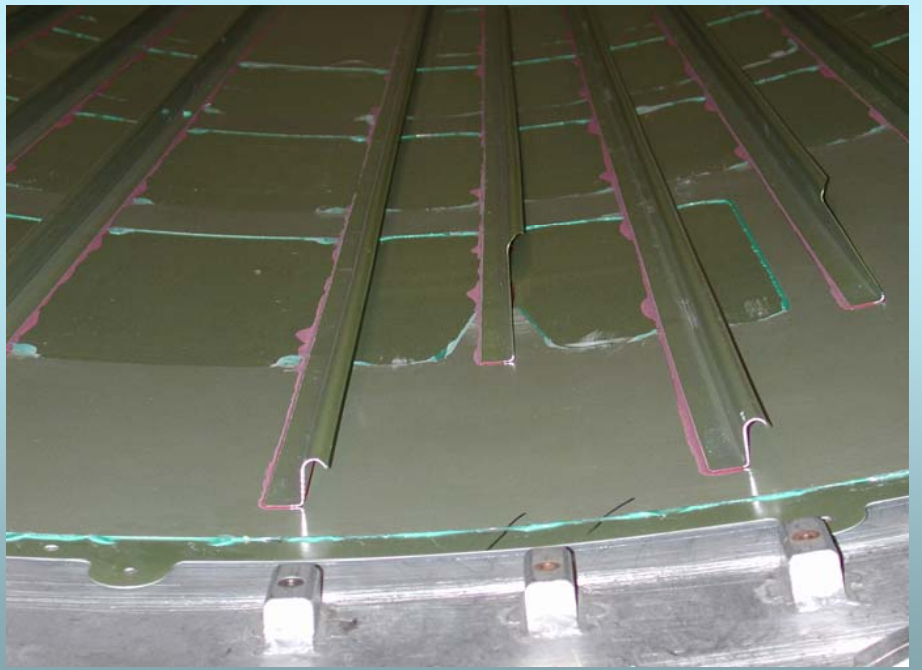
Bond Assy and BAJ (Curing Tool)

View of Bonded stringers



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Structural Analysis Approach

- **Post-buckling design of bonded stringer reinforced skins**
- **Design provisions to improve the assy strength**
  - **Stringer stopped on doublers, at highest thickness**
  - **Adequate run out shape at stringer end**
- **Adhesive must have the capability to:**
  - **Transfer shear loads from skin to stringer, avoiding peeling stress**
  - **Withstand the pulling load originated by diagonal tension field at buckling**

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Durability

- All the fatigue critical details in ATR 72 have been verified
  - Hardpoints
  - Stringer –to-frame attachments
  - Stringer runouts

Hardpoints

- Fatigue tests have been carried on hardpoint specimen.
- Typical " hardpoint" (bonded flange for hoop stress) have .8 – 1.27 mm strap.
- The strap thickness seems almost not influencing the fatigue strength up to 100000 cycle life.
- The failure origin occurred regularly at the strap edge that act as stress concentration points
- A comparison with tests on similar riveted details evidenced comparable results, despite the presence of a secondary bending in bonded details

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Stringer runouts

- Different geometries have been considered for the stringer end bevel.

- Fatigue tests have been carried out at constant mean stress Sm = 50 MPa, this one referred to the total stiffened panel area (stringer + skin).

- A secondary bending factor has been evaluated , but increasing stiffness of skin/ end stringer ratio results in stress concentration as well as in secondary bending decrease.

Stringer-to-frame attachments

- **"Pull Up" detail –Test performed with a 50 daN load corresponding to the pressure induced load on shear clip at 5 PSI for the larger stringer spacing.**

- **All the tests have been continued until to 300000 cycles, without any failure in the adhesive.**

- **A fatigue test performed on a bonded fuselage barrel proven the capability of this bonded detail to sustain pressure loads by not less than 200000 cycles**

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Corrosion

- Corrosion behaviour evaluated through exposure of metal bonded parts in salt solution
- Mechanical properties decay verified on standards “Lap Joints“ specimens
- The same materials and processes of ATR 72 used for specimens manufacturing.
- Each specimen exposed in salt solution per ASTM B-117 for 1000 Hours.
- “Cohesive” type of failure found on bonded surfaces. Absence of degradation and corrosion of bonded surfaces.
- Fatigue tests performed aft environmental conditioning. The tests performed at “pull up” after exposure at 100% R.U. and 55°C for 42 days, under cyclic “ pressure equivalent load “ (50 daN)
- No evidence of problems in bondlines. after 242.000 cycles when testing was stopped

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Service Experience

- Near 11.900.000 Flight Hours cumulated by the whole fleet
- 1.370.000 F Number of Flights cumulated by the whole fleet
- No major inconvenience reported for bonded structures
- No corrosion problem ever reported
- No repair embodied during the whole service

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DEVELOPMENTAL ACTIVITIES ON METAL BONDED STRUCTURES

TANGO Metallic Fuselage ALA deliverables

Technology Application to the Near-Term Business Goals and Objectives

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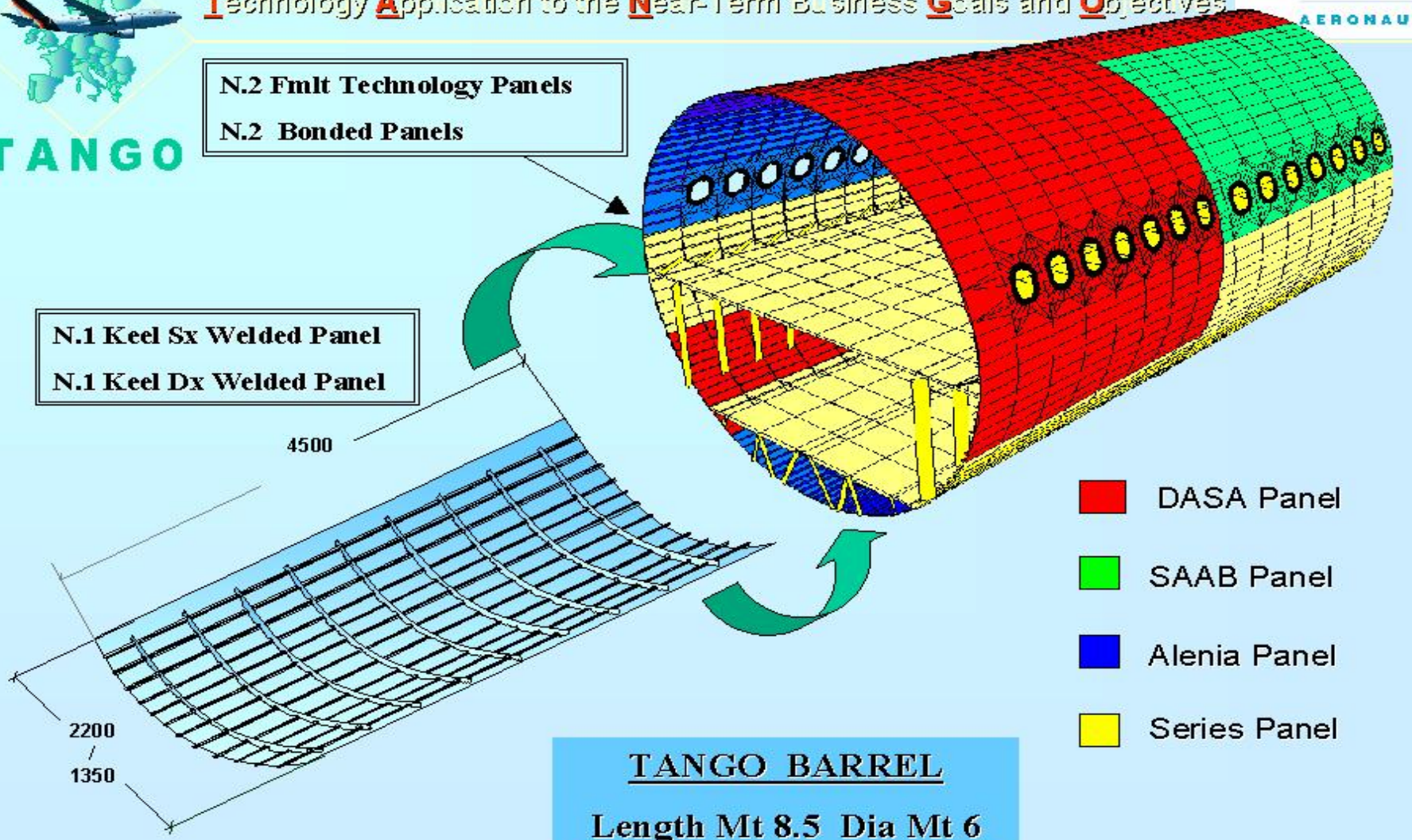
N.2 Fmlt Technology Panels

N.2 Bonded Panels

N.1 Keel Sx Welded Panel

N.1 Keel Dx Welded Panel



TANGO BARREL

Length Mt 8.5 Dia Mt 6

Multi-layer Concept

- Structural configuration based on a basic thickness with additional doublers added where needed
- Substitute chem-milling operation for thickness variation in the skin
- Improvement of damage tolerance behaviour
- Accomplishment of significant weight saving

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Multi-layer Metal bonding Technology

- Materials and processes selection
- Multi-layer adhesive bonded flat Panel
- Flat panels with co-bonded window frames
- Metal to Metal Bonding Full scale TANGO panels

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Testing objectives

- To acquire more knowledge about static, fatigue and damage tolerance behaviour of fuselage panels manufactured using Alenia Metal Bonding technologies
- To verify methods used for the analysis
- To substantiate the capability of Alenia full-scale panels to sustain static and fatigue loads according to Tango Barrel F.E. model results

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Activities performed

A representative multi-layer adhesive bonded flat panel, with circumferential splices of 0.3 mm Al lamina was designed and manufactured

Panel was inspected with ultrasonic control

A destructive inspection was performed in order to characterize natural defect and establish a correspondence with ultrasonic map

Specimens were manufactured with coupons cut from the flat panel

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Testing on specimens

- Tensile
- Compression
- Bearing (e/D=1.5 and e/D=2.0)
- Impact
- Fatigue
- Crack Growth

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Achievements

- Material selection (aluminium alloy, adhesive, primer)
- Configurations definition (minimum/maximum thickness)
- Bonding requirements definition within an ALA internal specification
- Process parameters optimisation (surface treating, autoclave pressure, temperature profile, etc.)
- Testing of specimens and details for material basic properties data base implementation

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METAL BONDED SUBCOMPONENTS

ID	TEST TYPE	LOADING	T.A. CONFIGURATION	T.A. SIZE
MB #1	Static	Shear	Flat skin panel with a machined window frame	600mm x 800mm
MB #2	Fatigue	Shear	Flat skin panel with a machined window frame	600mm x 800mm
MB #3	Static	Hoop Tension	Flat skin panel with a machined window frame	600mm x 800mm
MB #4	Fatigue	Hoop Tension	Flat skin panel with a machined window frame	600mm x 800mm

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MB #1
test article
instrumentation

Outside view

Inside view

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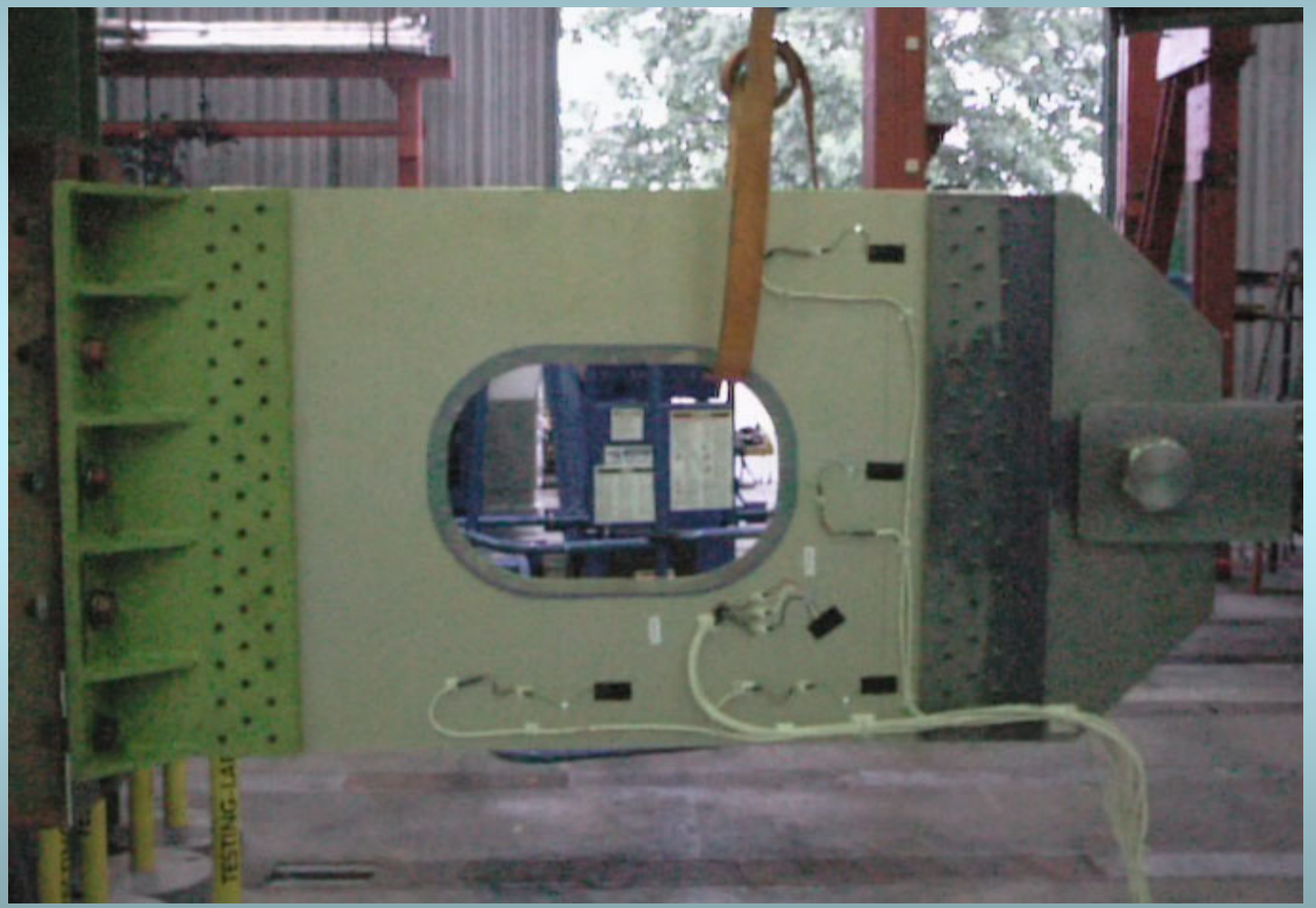
MB #1

Set-Up



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Metal Bonded Subcomponents Test Results

- Very good static (loading failure higher than 180% of Limit Loads) and fatigue behaviour (no failure up to 100,000 cycles) of the bonded panel (window frame bonded to a metal to metal bonded multi-layers skin) under hoop tension and shear loading (separately)

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METAL BONDED

FULL SCALE PANELS

TANGO TX 9 / TX 10 PANELS

- **Technology: Metal to Metal Bonding (one shot bonding)**
- **Skin**
  - **Basic : 2524-T3 Al Alloy t=1.8mm**
  - **Reinforcement: 2024-T3 Al Alloy t=0.3/0.4mm**
- **Max Skin Thk: 2.8mm**
- **Stringers: 2024-T3 Al Alloy (Series)**
- **Window Frame: 7050-T7451 Al Alloy Prec. Forg. (Series)**
- **Stringers, Doublers and Window Frames bonded to Skin in one shot.**

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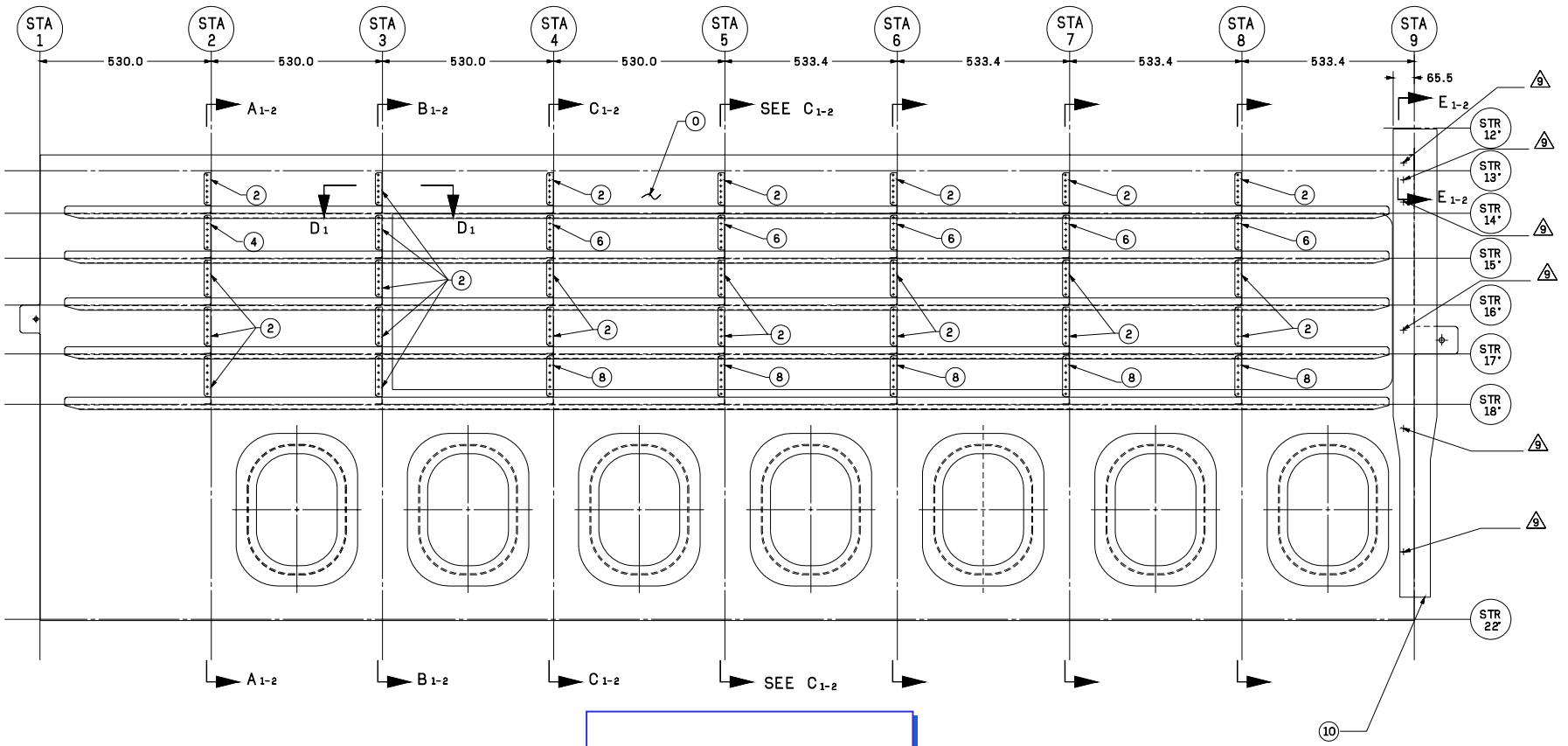
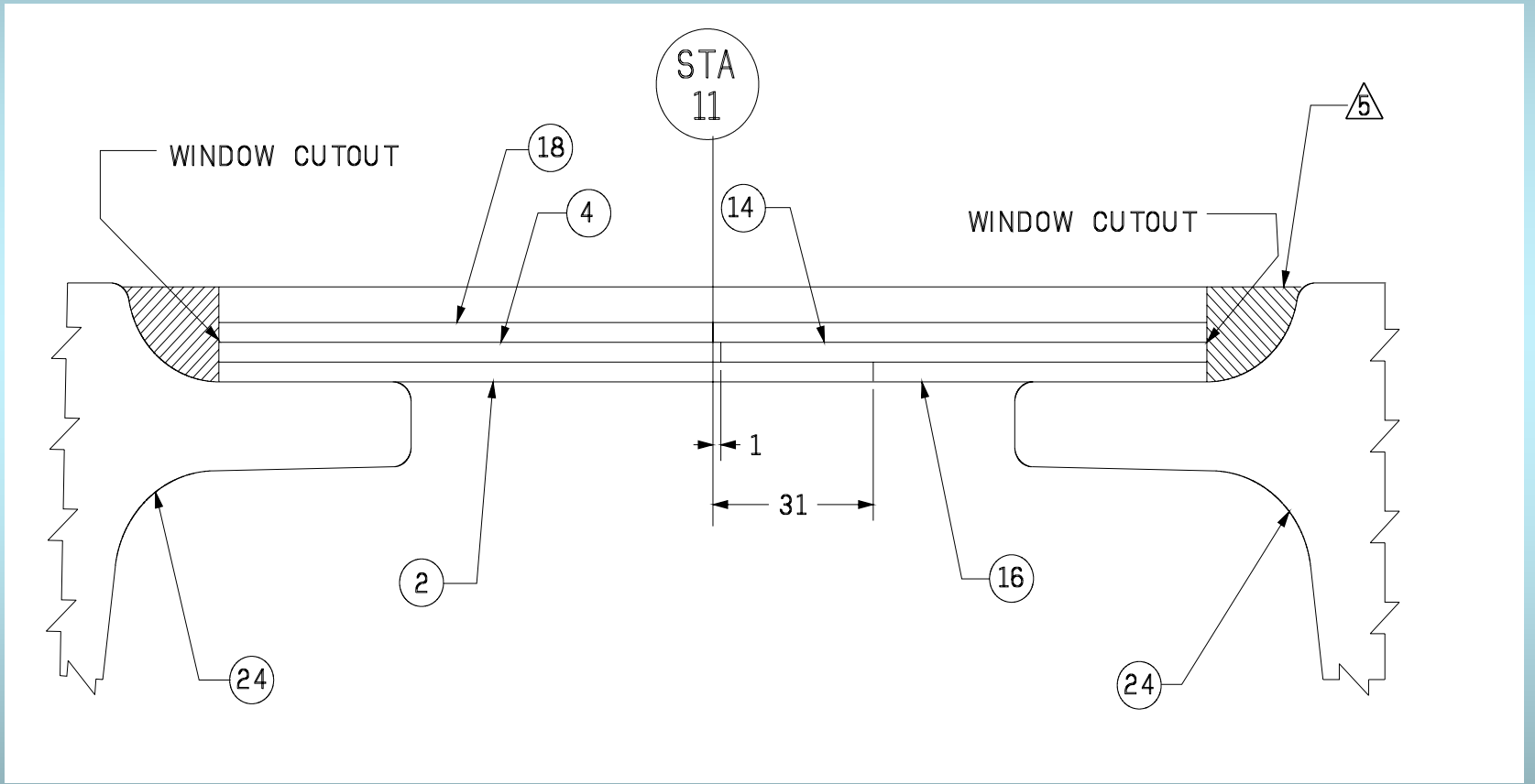

STA 1
STA 2
STA 3
STA 4
STA 5
STA 6
STA 7
STA 8
STA 9
530.0
530.0
530.0
530.0
533.4
533.4
533.4
533.4
65.5
A 1-2
B 1-2
C 1-2
SEE C 1-2
D 1
D 1
E 1-2
E 1-2
STR 12°
STR 13°
STR 14°
STR 15°
STR 16°
STR 17°
STR 18°
STR 22°
A 1-2
B 1-2
C 1-2
SEE C 1-2

TX 9 PANEL

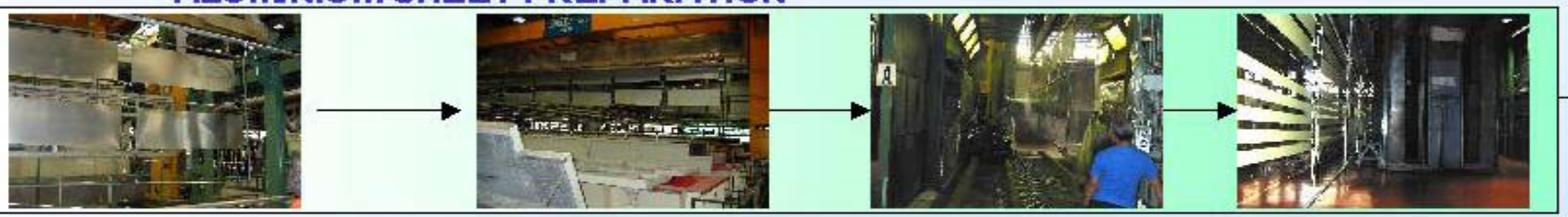
TX 9 / TX 10 PANELS DESIGN DETAIL



Multi-layers skin and bonded window frame

METAL TO METAL MFG FLOW

ALUMNIUM SHEET PREPARATION



LAYERS LAY - UP (METAL SHEET &

ASSY SKIN/STRINGER/WINDOW FRAME

BAGGING

ONE SHOT AUTOCLAVE CYCLE FOR SKIN CURING

AND STRINGER / WINDOW FRAME BONDING

1. FLAT PANEL METAL TO METAL BONDING DEMONSTRATOR (1200 X 3000 mm)

= 2024 -T3 /THICKNESS 0,3 mm

= 1 ADHESIVE /THICKNESS 0.1 mm

= 2024 -T3 /THICKNESS 1,6 mm

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2. SINGLE STEP BONDED STRINGER & SHEAR TIES FLAT PANEL *DEMONSTRATOR* *1700 X 1000 mm*

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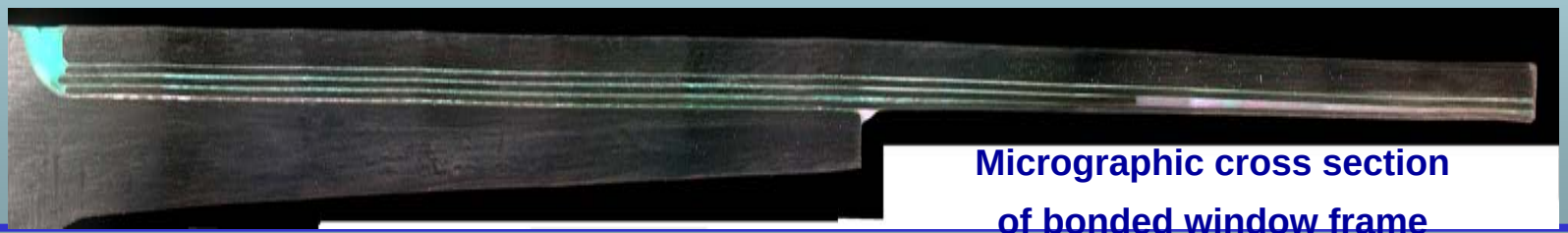
METAL TO METAL SUB COMPONENT

Multilayer Adhesive Bonded Skin and Window Frame -One Step-cure cycle



Micrographic cross section of bonded window frame

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TANGO Metallic Fuselage ALA deliverables

Technology Application to the Near-Term Business Goals and Objectives

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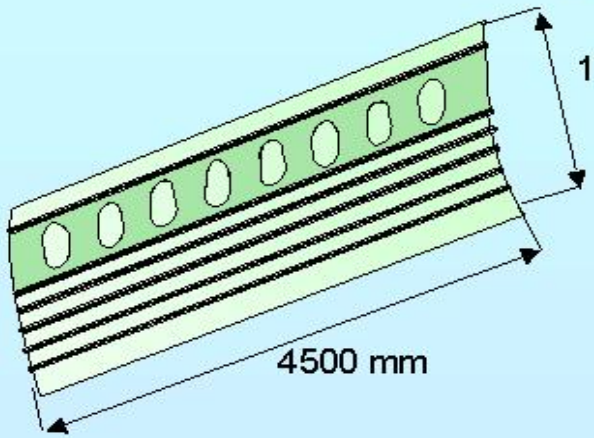
July 23 /2002

METAL TO METAL BONDING MULTILAYER TECHNOLOGY

FULL-SCALE PANELS TX 9 PANEL
TX 10 PANEL

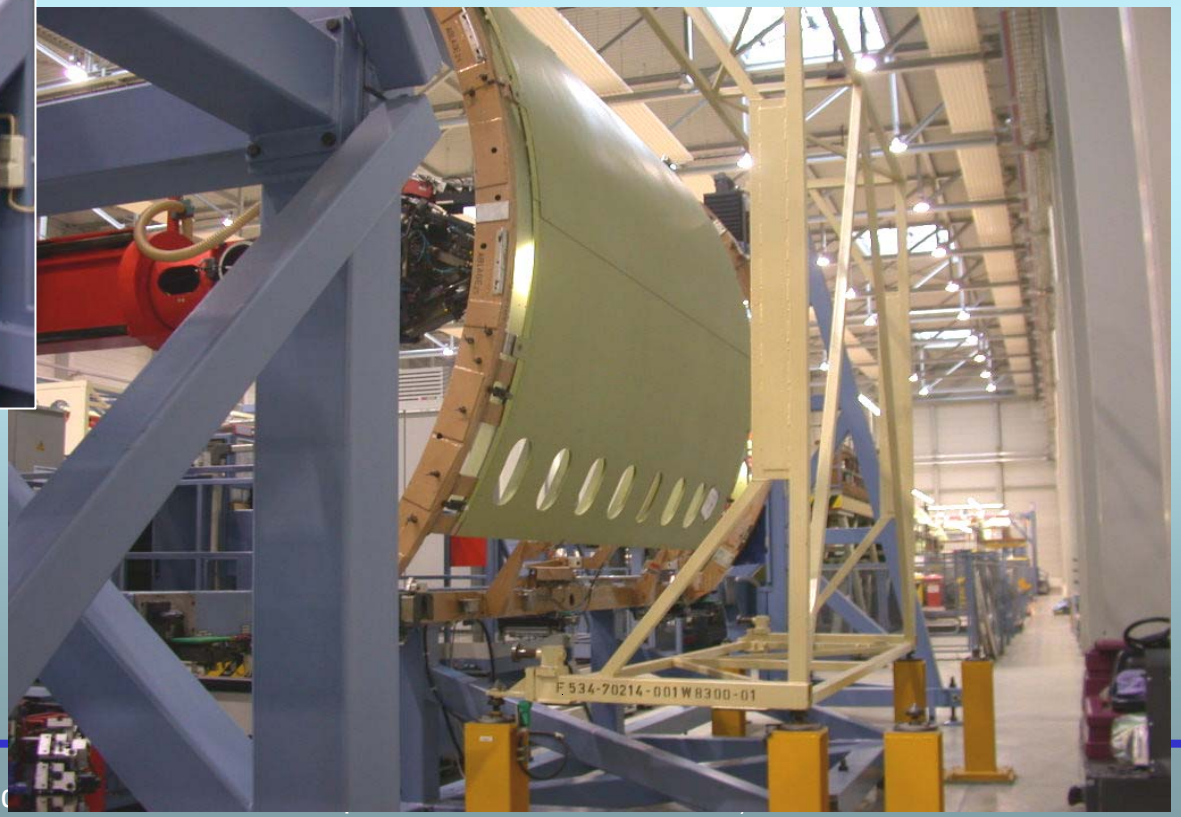


Skin: Multilayer Adhesive Bonded
(2524 & 2024 Al sheets)

Co-Bonded Window Frame

Bonded Stringer (extruded 2024)

TANGO Metallic Fuselage - Barrel assy



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TANGO Metallic Fuselage - Barrel assy

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