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The Blessing University

COMPOSITE IN AEROSPACE MANUFACTURING INDUSTRY

"Mini Project during PhD"
at Universiti Putra Malaysia,

Studi Banding di:
Composites Technology Research Malaysia

Dr. M. Sayuti, ST.,M.Sc

JURUSAN TEKNIK INDUSTRI
FAKULTAS TEKNIK – UNIVERSITAS MALIKUSSALEH

2016

By *Dr. M. Sayuti, ST.,M.Sc*

CONTENTS

- Objectives
- Introduction:
  - A. History & Development of aircrafts
  - B. Aircraft structure & assembly
  - C. Aircraft materials & processes
- Background of Malaysia Aerospace industry
- Aerospace companies in Malaysia
- CTRM
- CTRM production flow
- Conclusion

OBJECTIVES

1. To discuss the general process, parts and components of aircraft production.
2. To discuss about the Malaysian aircraft industry and introduce about the CTRM process
3. To elaborate on the aircraft composite production process

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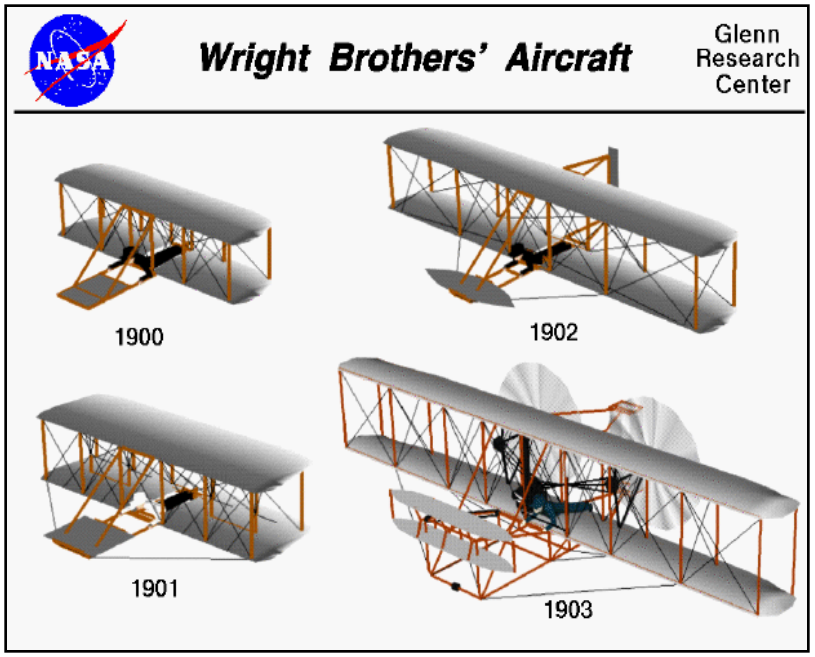
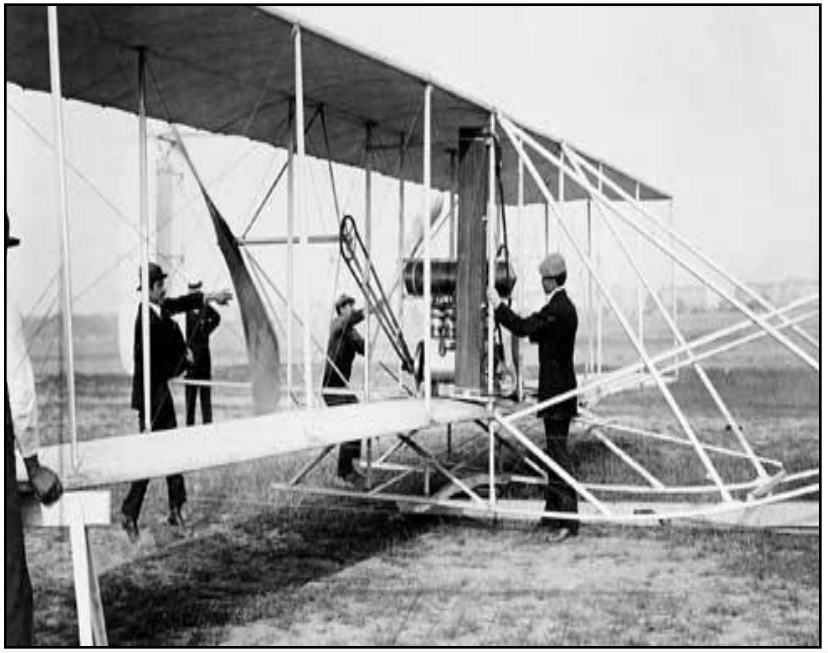
HISTORY OF AIRCRAFTS

First Aero plane to fly successfully was invented by Orville and Wilbur Wright in December 17th 1903 after 2 earlier unsuccessful attempts.





[Source: History of Aeroplane (Anon, 2006)]

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T O D A Y

MILITARY AIRCRAFT

COMMERCIAL AIRCRAFT

FIGHTER JETS

COMMERCIAL AIRCRAFT

IMPORTANCE OF AIRCRAFTS:

- One of the fastest transportation method
- Facilitate international trade
- Provision of security & for distributing supplies during
- Aviation industry provides more job opportunities
- Facilitate rescue missions.

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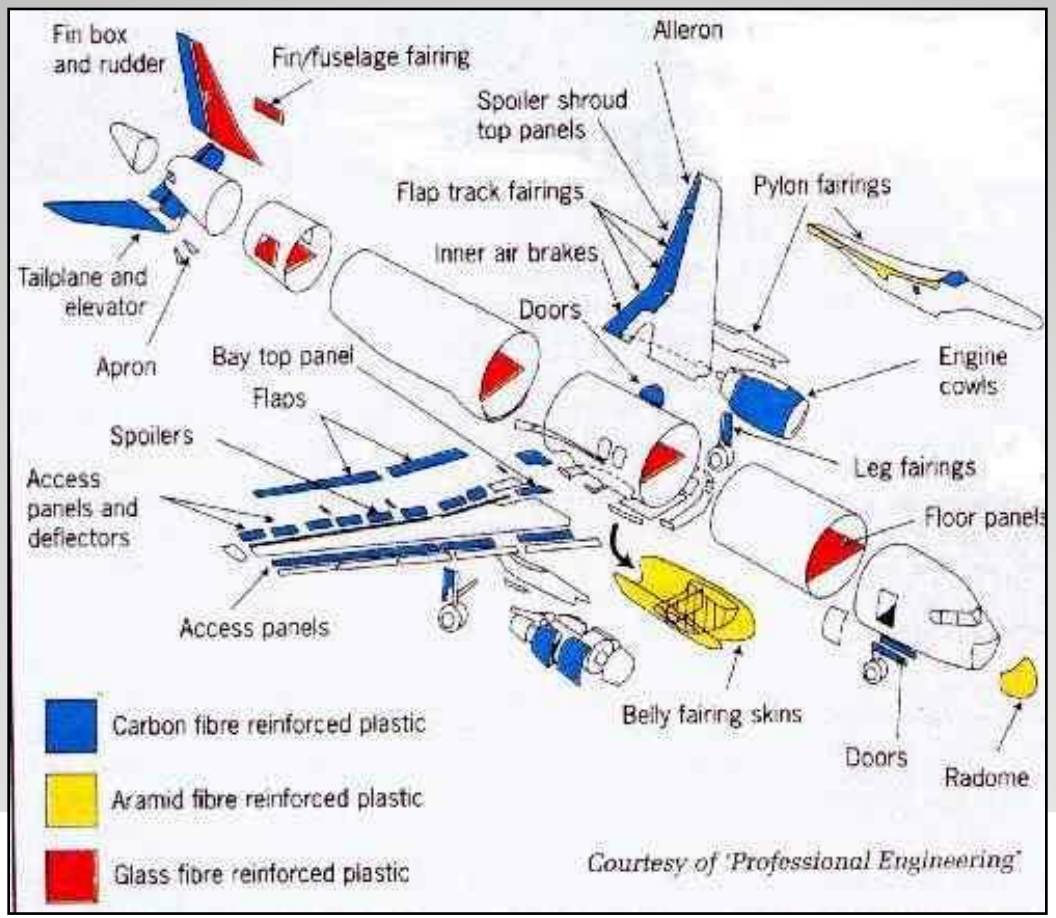
AIRCRAFT SECTIONS



[Source: Boeing presentation(Anon, 2006)]

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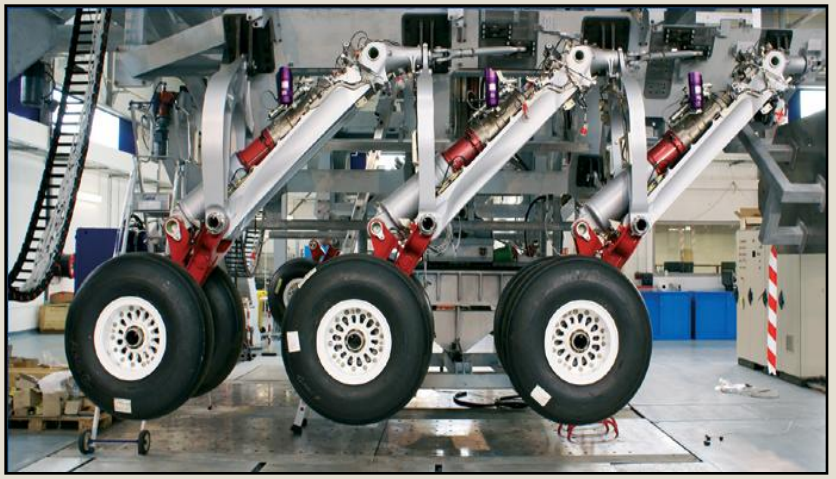
MAIN ASSEMBLY SECTIONS

FUSELAGE SECTION



LANDING GEARS

WINGS

ENGINES

TAIL SECTION

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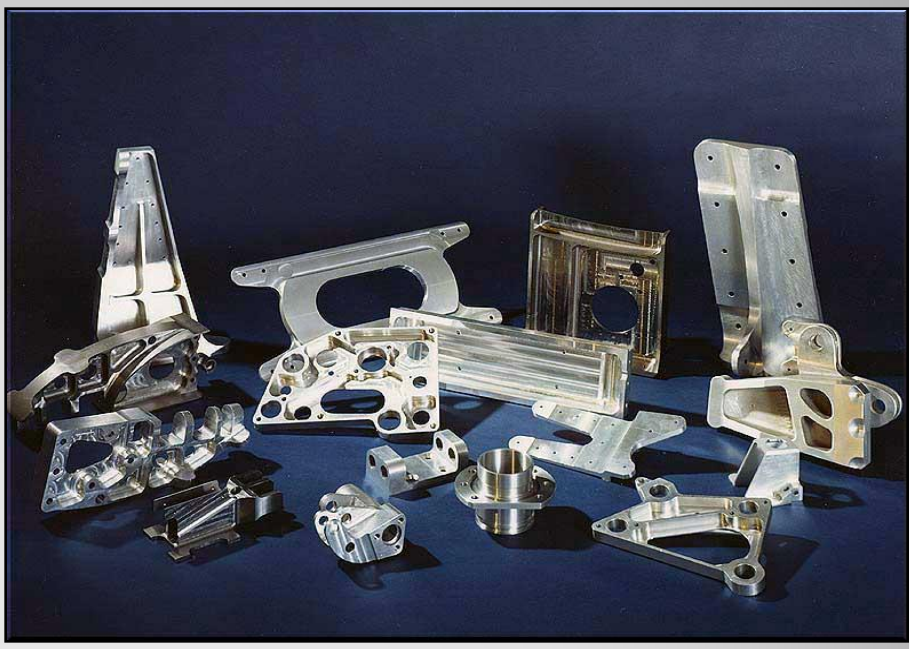
AIRCRAFT COMPONENTS



Aircraft components such a engine parts, fly wheels etc are produced via Advanced manufacturing processes such as casting, powder metallurgy, Drilling, machining. This components can be produced by highly specialized Producers in order to obtain high level of quality. For example, Boeing aircrafts got its parts or components from countries such As Japan and Italy. However the final assembly is done in US.

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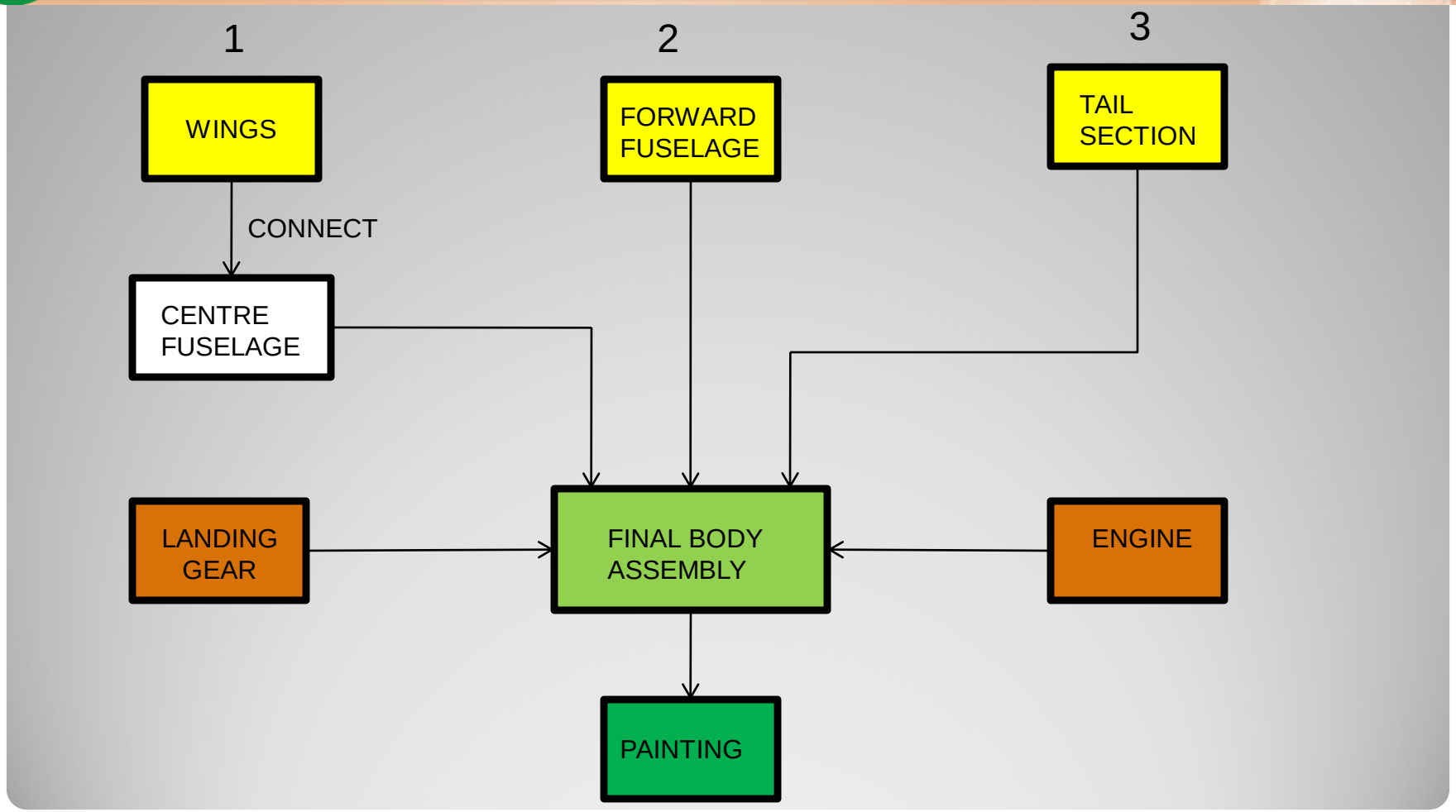

AIRCRAFT FINAL ASSEMBLY PROCESS

EXAMPLE

Boeing 777 commercial aircraft assembly process in progress.

[Source: Boeing presentation(Anon, 2006)]

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AIRCRAFT MATERIALS

1. Aluminium alloys
2. Steel alloys
3. Titanium alloys
4. Composites
5. Plastics
6. Glass

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ALUMINIUM ALLOYS

APPLICATION

- Airframes
- Skins
- Stressed components
- Fuselage structure

FACTORS CONSIDERED

- Strength
- Ductility
- Ease of manufacture e.g. extrusion and forging.
- Resistance to corrosion
- Fatigue strength
- Freedom from sudden crack

	Alloy	Advantage	Disadvantage	Process
1	Aluminum-Zinc-magnesium	High static strength	Sudden crack in unloading condition. Reason **forging** and **heat treatment** (retention of internal stress.)	Forging Extrusion
2	Aluminum-copper(4%)	High strength, good fatigue, crack growth resistance, toughness	Slightly high cost	Casting Machining
3	Aluminium-magnesium-silicon	Cheaper than (2), Weldable, high fracture toughness Resistance to crack	Ductility decreases as result of heat treatment (segregation of Si at grain boundary) Solution add chromium	Casting Machining
4	Aluminium-Lithium alloys	Increase fatigue life Reduction in weight	Reduced ductility and fracture toughness in short transverse direction.	-

ALUMINIUM ALLOY

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STEEL ALLOYS

- APPLICATION
- Under carriage pivot brackets
- Wing root attachments
- Fasteners and tracks
- Aircraft arrester hooks
- Rocket motor cases
- Gears
- Ejector seats
- Other structural components

CONSIDERED FACTORS

- High tensile strength
- High stiffness
- High resistance to wear

STEEL ALLOYS CONT'D

Type of steel	Advantage	Disadvantage	Process
Conventional steel	Low cost	High carbon thus brittle & distort(Machining , cold forming, welding difficulty	Machining Casting
Maraging steels (1961)	High fracture toughness, notched strength, simpler heat treatment, simple to weld, easier to machine, better resistance to corrosion	Cost is 3 times the cost involved in conventional steel	Machining

- Usage increases in 1980s to 1990s and are common in Combat aircrafts

PROPERTIES

- Good Fatigue/ tensile strength ratio
- Retain considerable strength at 400 to 500 degrees Celsius
- Good Resistance to corrosion

APPLICATIONS

- Airframe
- Engine
- Wing Part
- Tail assembly
- Flap & slat tracks
- Undercarriage parts
- Access doors

PROCESS INVOLVED

Forging are common

TITANIUM ALLOYS

TITANIUM ALLOYS

PROBLEMS

- Properties are adversely affected by exposure to temperature & stress in salty environment e.g. aircraft carriers
- Relatively high densities(weight)
- High fabrication cost (7x more than AL & steel alloys)

SOLUTION

- New fabrication process e.g. super plastic forming combined with diffusion bonding which allows large & complex components to be produced.
- Typical savings: 30% red in man hrs; 50% red in cost

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PLASTICS & GLASS

PLASTICS

- Material is heavier than wood but much lighter than AL-alloys

Applications

- Windows
- Lightly stressed parts
- Electrical insulators

GLASS

- Material are normally heat strengthened for aircraft applications

Applications

- Windscreens
- windows

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COMPOSITE MATERIAL

Composite materials consist of strong fibre such as glass or carbon set in a matrix of plastic or epoxy resin, which is mechanically and chemically protective.

	Material & Development	Advantage	Disadvantage
1	Glass Reinforce Plastic (GRP)	Strength	Low stiffness
2	Kelva (1960)	Strength, Stiffness	Low Elasticity
3	Boron fibre composite	Strength, Stiffness, Elasticity	High Cost
4	Carbon Fibre Reinforced Plastic(CFRP)	Strength, Stiffness, Low cost	Brittle, not elastic to high stress area
5	Composite(fibre glass & aluminum)	Used in main aircraft structures	

Application:

- Helicopter Blades
- Wings
- Tail plane
- Forward fuselage
- Panels
- Galley partitions
- Beam structure

[Source: (Megson, 1999)]

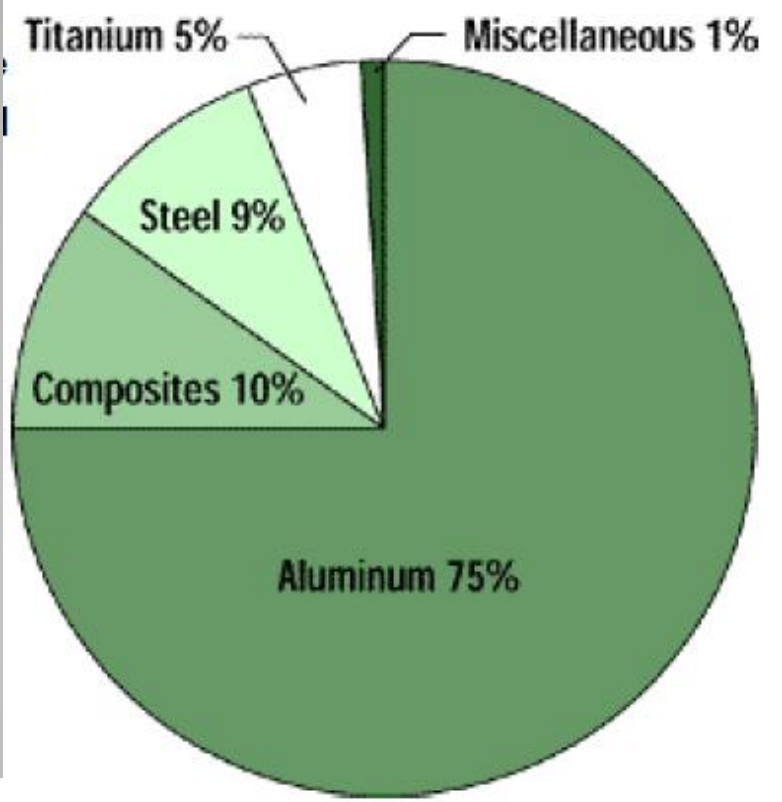
Problems

- Main material which is epoxy resin absorbs Moisture which degrades its mechanical Properties. Polyetheretherketone absorbs less moisture thus is new research area in composite materials for aircraft
- Cost of composite structures are high due to labor intensive production Thus max use so far is 15% composite.

COMPOSITE MATERIALS

AIRCRAFT MATERIAL

TYPICAL EXAMPLE OF BOEING AIRCRAFTS



- Aluminum (2024T3)used in fuselage skin and aircraft structures
- Composites used on fuselage fairings, wings and panels
- Steel (AISI301) used on aircraft components
- Titanium (AMS4901) used on pylon & engines
- Miscellaneous used on minor areas

[Source: Boeing presentation(Anon, 2006)]

Prepreg

- specially formulated resin matrix systems
- reinforced with man-made fibers such as carbon, glass and aramid
- when cured at elevated temperatures and under pressure, the themoset resin undergoes a chemical reaction that transforms the prepreg into a solid structural material
- the solid structural is highly durable, temperature resistant, exceptionally stiff and lightweight
- roll form, to be stored frozen and defrosted before use
- golf clubs, satellite arrays, wind turbine rotor blades and others

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Direct Materials

Aerospace Industry

Introduction

New aerospace industry in Malaysia, it offers opportunities of advanced technology transfer in engineering field, electric, electronic and composite materials and manufacturing and system integration

Aerospace manufacturing is a high technology industry that produces "aircraft, guided missiles, space vehicles, aircraft engines, propulsion units, and related parts

The aerospace industry and manufacturers' unrelenting passion to enhance the performance of commercial and military aircraft is constantly driving the development of improved high performance structural materials.

Composite materials are one such class of materials that play a significant role in current and future aerospace components. Composite materials are particularly attractive to aviation and aerospace applications because of their exceptional strength and stiffness-to-density ratios and superior physical properties.

Introduction

Malaysia's aerospace industry categorized to four subsector:

Light aircraft installation	**Part and component manufacturing**
Maintenance / repair / reshuffle treat (MRO)	**Design and development**

Introduction

- Currently, in Malaysia have two assembler company light aircraft, six parts produce and component, 30 company labour in MRO's activity and four companies involved in design and development field.
- Aerospace industry contribute 3.6 percent economy to country and near to 2015 will increased to 5-8 percent.

Company involve in Aerospace, Composites and Engineering at Malaysia

1. Composites Technology Research Malaysia Sdn Bhd (CTRM) at Batu Berendam, Melaka.

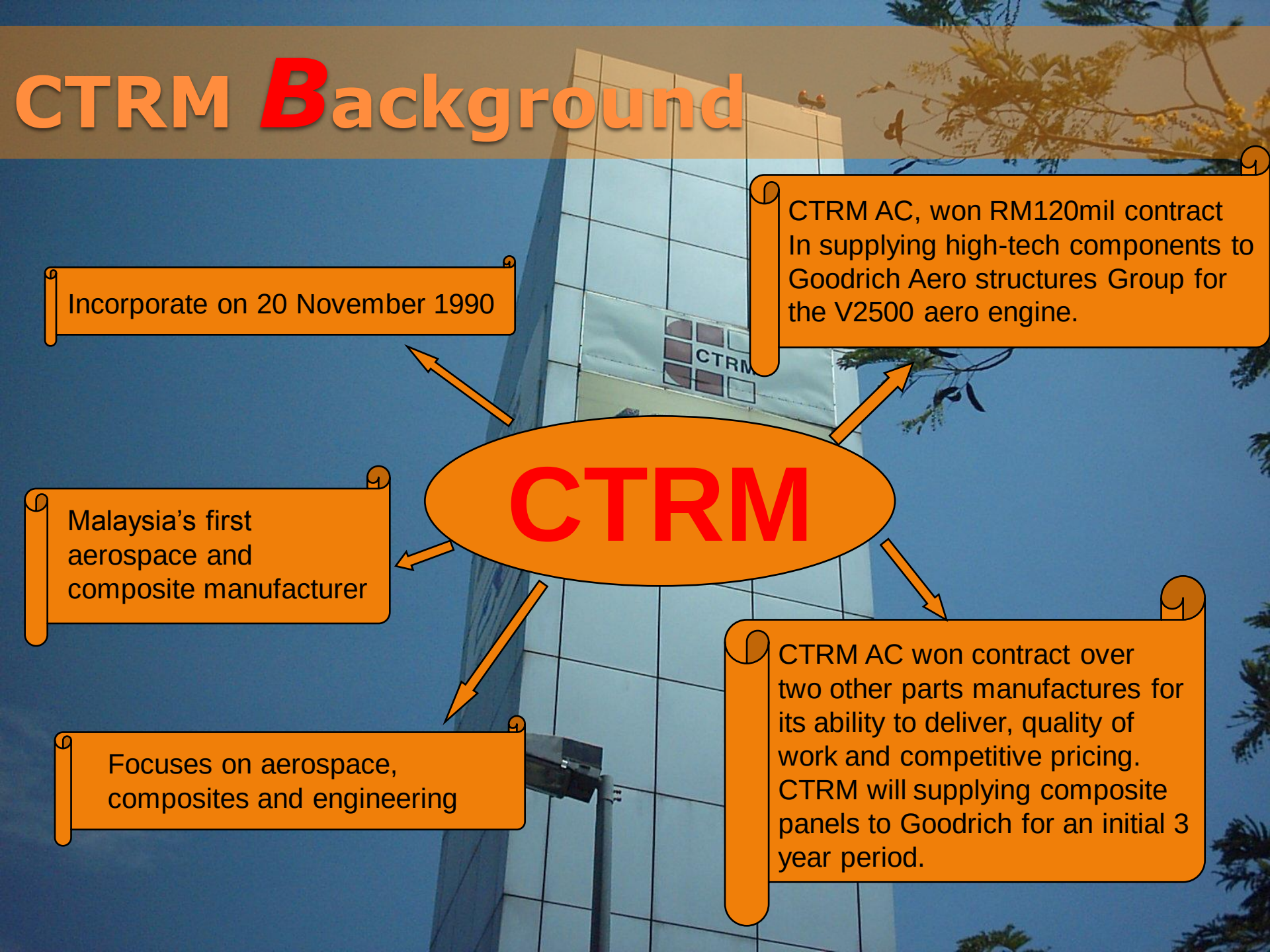
   CTRM supply chain composites aero structures for major commercial and military aircraft manufacturers in the world.

2. Asian Composites Manufacturing Sdn Bhd (ACM) at Bukit Kayu Hitam, Kedah, Malaysia.

   The primary business is the manufacture of composites material components and sub-assemblies for aircraft application.

CTRM
Composites
Technology Research
Malaysia

CTRM Background



Incorporate on 20 November 1990

CTRM AC, won RM120mil contract In supplying high-tech components to Goodrich Aero structures Group for the V2500 aero engine.

CTRM

Malaysia's first aerospace and composite manufacturer

Focuses on aerospace, composites and engineering

CTRM AC won contract over two other parts manufactures for its ability to deliver, quality of work and competitive pricing. CTRM will supplying composite panels to Goodrich for an initial 3 year period.

CTRM Project

Airbus A380

Design and manufacturing support for the Forward Leading Edge Access Panels. A total of 66 panels per aircraft that consists of both composites and metallic structures.

Nimrod Floor Panels

Complete composite floor panel design from cockpit to rear pressure bulkhead including structural support for panels.

Scottish Aviation Bulldog Military Trainer Aircraft

Development of the wing spar strengthening modification kit.

A400M

Design works packages on the A400M military airlifter.

Eagle Reconnaissance Vehicle

Responsible for the aircraft modification, system integration, ground vehicle integration, flight testing and joint system development with BAE SYSTEMS.

Customer	Program	Contract Period	Value (RM)
Spirit Aerosystem	A300 FTE	2000-2010	20M
Spirit Aerosystem	A320 LTEP	2000-2010	78M
Spirit Aerosystem	A320 Ph I & II	2000-2010	773M
Spirit Aerosystem	A380 IOFLE	2002-2012	145M
Airbus AUK	A380 FLELP	2002-2019	800M
Goodrich	V2500	2004-2007	101M
BAE Land System	LRAC	2000-2006	9M
GKN	A400M WTE	2005-2015	]
Airbus UK	A400M NEF	2005-2015	] 417M
Airbus UK	A400M FPF	2006-2015	]
CASA EADS	A400M VTP	2005-2015	] 356M
CASA EADS	A400M HTP	2005-2015	]
SONACA	A400M MLGD	2006-2015	61M

Composites Engineering

Composites Manufacturing and Assemblies

- Structural Carbon Fibre Composites Assemblies
- Major Structural Assemblies – Composites and Metallic
- Structural Carbon Fibre Bonding
- Non-Destructive Testing for Composites Components
- Machining Capabilities For Composites Components
- Manufacturing and Assemblies of Composites Components for Aerospace, Non-Aerospace and Defence Industries

Composites Engineering and Designs

- Structural Designs
- Structural Stress Analysis
- Weights Engineering
- Structural and Material Testing
- CTRM and its Group of Companies also possess CAD/CAM/CAE Capabilities:
- CATIA 4.2.2, CATIA V5R14, Solid Works
- MSC Nastran/Patran
- Laminate Analysis Programme (LAP)

Composites Engineering

Composites Research & Development

CTRM also conducts Composites R&D Programme:

- 2D Honeycomb Chamfering Process Development
- Out of Autoclave (OOA) Prepreg Processing
- Resin Infusion
- Resin Transfer Moulding (RTM)

Aircraft Services

CTRM through CTRM Aviation provides Aircraft Services for General Aviation Industry:

- Aircraft Leasing Services
- Aircraft Schedule and Unscheduled Maintenance
- Aircraft Avionics Upgrade and Modifications
- Aircraft Structural Modifications Handling and Hangar Services
- Aircraft Maintenance, Repair & Overhaul Services

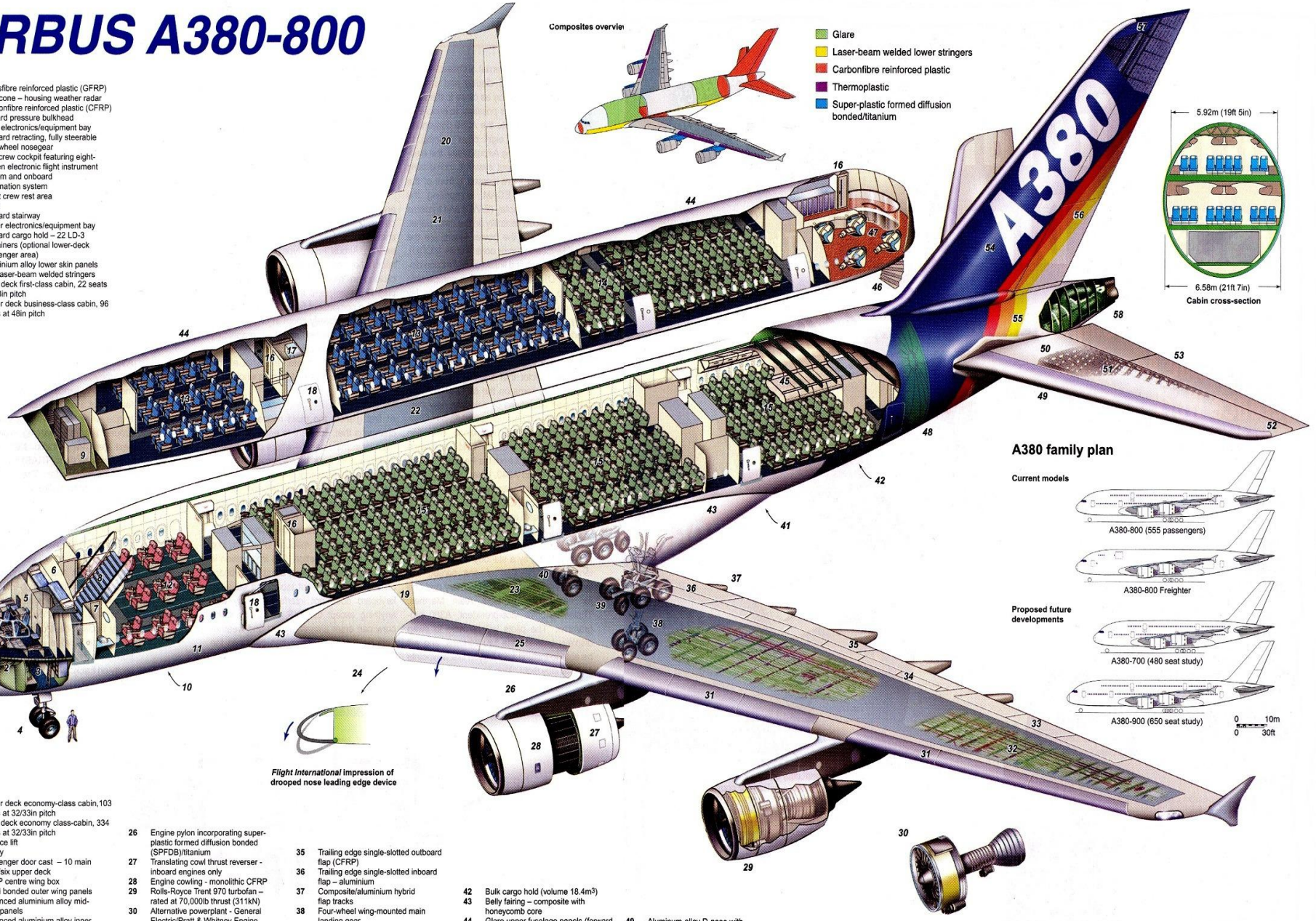
AIRBUS A380-800

1 Glassfibre reinforced plastic (GFRP) nosecone – housing weather radar
2 Carbonfibre reinforced plastic (CFRP) forward pressure bulkhead
3 Main electronics/equipment bay
4 Forward retracting, fully steerable twin-wheel nosegear
5 Two-crew cockpit featuring eight-screen electronic flight instrument system and onboard information system
6 Flight crew rest area
7 Toilet
8 Forward stairway
9 Upper electronics/equipment bay
10 Forward cargo hold – 22 LD-3 containers (optional lower-deck passenger area)
11 Aluminium alloy lower skin panels with laser-beam welded stringers
12 Main deck first-class cabin, 22 seats at 68in pitch
13 Upper deck business-class cabin, 96 seats at 48in pitch

Composites overview

- Glare
- Laser-beam welded lower stringers
- Carbonfibre reinforced plastic
- Thermoplastic
- Super-plastic formed diffusion bonded/titanium

Cabin cross-section



Flight International impression of drooped nose leading edge device

A380 family plan

Current models

A380-800 (555 passengers)

A380-800 Freighter

Proposed future developments

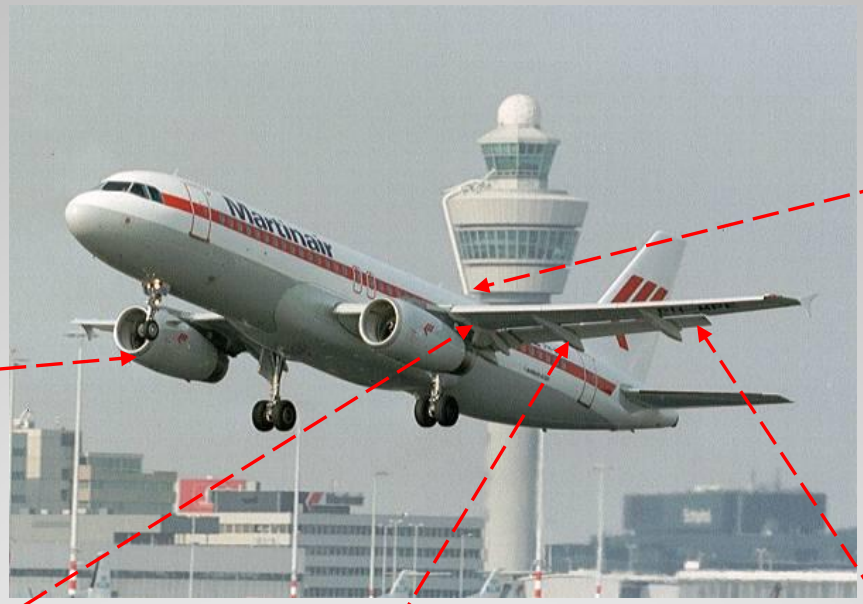
A380-700 (480 seat study)

A380-900 (650 seat study)

0 10m
0 30ft

14 Upper deck economy-class cabin,103 seats at 32/33in pitch
15 Main deck economy class-cabin, 334 seats at 32/33in pitch
16 Service lift
17 Galley
18 Passenger door cast – 10 main deck/six upper deck
19 CFRP centre wing box
20 Metal bonded outer wing panels
21 Advanced aluminium alloy mid-wing panels
22 Advanced aluminium alloy inner wing panels
23 Main fuel tanks – total fuel capacity 310,000 litres
24 Variable position drooped nose leading edge high lift device
25 Thermoplastic (fixed) wing leading edge – J-nose
26 Engine pylon incorporating super-plastic formed diffusion bonded (SPFDB)/titanium
27 Translating cowl thrust reverser - inboard engines only
28 Engine cowling - monolithic CFRP
29 Rolls-Royce Trent 970 turbofan – rated at 70,000lb thrust (311kN)
30 Alternative powerplant - General Electric/Pratt & Whitney Engine Alliance GP7270 – rated at 70,000lb thrust
31 Leading edge slat
32 CFRP outer wing ribs
33 Three part ailerons - CFRP
34 CFRP spoilers – eight spoilers per wing
35 Trailing edge single-slotted outboard flap (CFRP)
36 Trailing edge single-slotted inboard flap – aluminium
37 Composite/aluminium hybrid flap tracks
38 Four-wheel wing-mounted main landing gear
39 Six-wheel body-mounted main landing gear with rear-axle steering
40 Proposed additional twin-wheel centre main landing gear for high gross weight/stretch variants
41 Aft cargo hold – 16 LD-3 containers (Optional lower deck crew rest area)
42 Bulk cargo hold (volume 18.4m³)
43 Belly fairing – composite with honeycomb core
44 Glare upper fuselage panels (forward and aft)
45 CFRP composite upper-deck floor beams
46 Aft spiral stairway
47 Galley area with optional passenger facility illustrated
48 CFRP rear pressure bulkhead
49 Aluminum-alloy D-nose with CFRP/honeycomb side panels
50 CFRP monolithic tailplane box
51 Tailplane – trimming fuel tank
52 Aluminium-alloy tailplane tip
53 CFRP monolithic elevators
54 Fin with aramid-fibre reinforced plastic/CFRP box – monolithic design
55 CFRP aft fuselage – section 19
56 CFRP monolithic split rudders
57 GFRP/honeycomb fin tip
58 Pratt & Whitney Canada PW980 auxiliary power unit – rated at 1,270kW (1,700shp)

Airbus A320 Series



Products and Services

Aerospace

Airbus 320 series

moveable fairing

over wing panels

a320 spoilers

spoiler

under wing

falsework

a320 fix fairing

a321 fix fairing

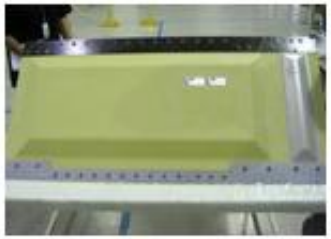
Products and Services

Aerospace

Airbus 380

inboard outward fixed leading edge

fixed leading edge lower panel


flelp (ip)

upper panel 2

flelp (mp)

flelp (op)

upper panels

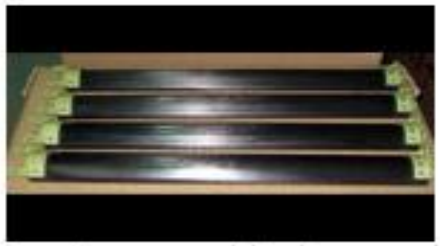
seal panel - 4LH

seal panel - 3RH

Products and Services

Aerospace

V2500 Engine Nacelle



actuator cover blank cascade

blank cascade

cone torque box

torque ring fairing

outer panel

cone torque & torque ring

Products and Services

Non-Aerospace

Lotus Europa S body shell

RADOME

Western Hill RADOME

Bukit Kubong RADOME

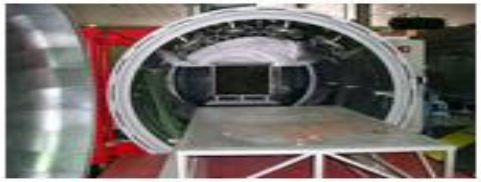
RADOME

Alvis Bridging

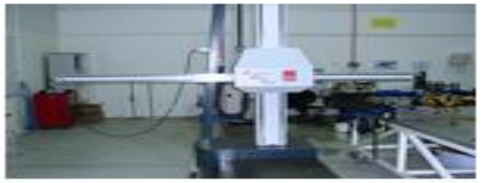
Products and Services

Autoclave 1

Autoclave 2


Autoclave 3

Autoclave Burner


CMM Machine

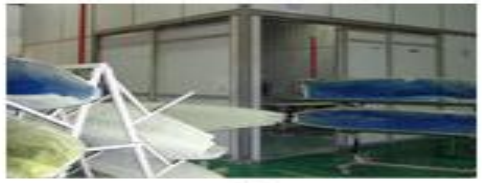
CMM Machine 2

CMM Controller

ControlPanel & Chart Recorder for Core Oven

Core Drying Oven

Drilling Machine


Dry Sanding Area

FPF Mould 1

Capabilities

Products and Services

FPF Mould 2

Gantry Crane

Gantry Crane Side View

Fuselage Mould

Fume Hood

Gerber1 Digitizer

Gerber1 Data Entry Machine

Gerber1 Plotter

Gerber Cutter1a

Gerber Cutter1b

Gerber Cutter1c

Gerber Cutter2

Products and Services

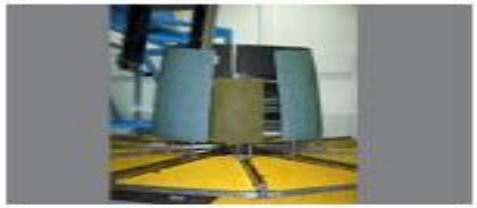
Gerber Cutter2b

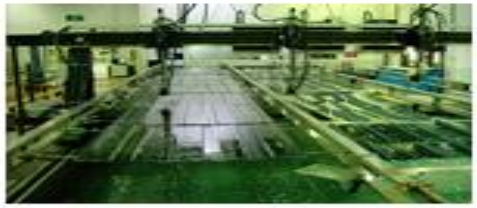
Lab Refrigerator

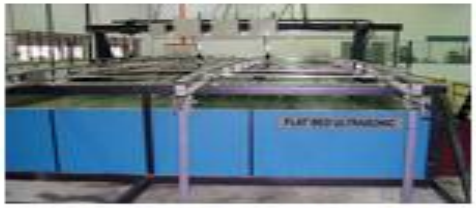
Lathe Machine

Milling Machine

Mould Release Oven


NDT 2


NDT 3


NDT FlatBed

NDT FlatBed1

NDT Vertical (Multi Axis1)

NDT Vertical (Multi Axis)

New Paint Shop

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Production Flow

- Warehouse (Raw Material) @ Freezer
- Thawing Room
- Kitting Department
- Clean Room (Layered Process)
- Demould
- Cure Process
- Painting Department
- Inspection

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Warehouse (Raw Material)

Freezer

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Thawing Room

Kitting Department

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Kitting Department

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Clean Room (Layered Process)

Demould

Demould

Cure Process

PROCESS FLOW

Receiving

Storage

Cutting

Lay-up

Bagging

Curing

Trimming

Mechanical Assembly

Painting

Packaging

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Storage

General
Storage area : 11,395 sq.ft
FIFO system
3 freezers for cold storage
Walk in industrial freezer

Dry
Material:
Breather cloth
Honeycomb core
Peel Ply cloth
Carbon cloth
Glass cloth
Perforated sheet
Bagging sheet
Kevlar cloth

Cold

Freezer capability:

- Min. temperature : minus 25°C (-12.6°F)
- Size freezer 1& 2: 36 ft x 36 ft x 10 ft
- Size freezer 3: 42’9”x31’10”x10’
- Temp chart recorder
- Automatic restart – Zero interruption generator back-up
- Alarm system (when temp. drop at below set temp)

Material:

- Glass Prepreg
- Carbon Prepreg
- Uni-carbon Prepreg
- Lightning Mesh (Al) Prepreg
- Film Adhesive
- Core splice

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Thawing Room

- the material been kept for several hours to warm up the material until it reach room temperature before proceed to next process.

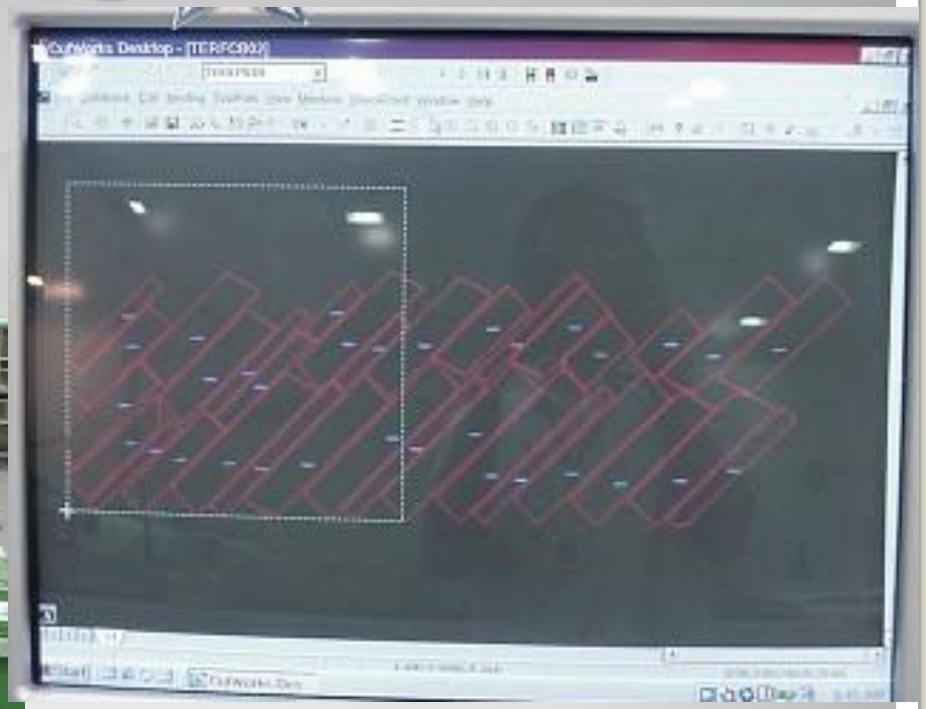
Cutting Process

- CNC Gerber Cutter
  - Cut material
    - Carbon cloth
    - Glass cloth
    - Kevlar cloth
    - Glass prepreg
    - Carbon prepreg
    - Kevlar phenolic prepreg
- Operation
  - Blade speed between 210 to 4300 rpm
  - Axis speed between 1 to 15 (Selected type)
    Min Speed: 2600/min
    Max Speed: 3800/min
  - Table size 36 ft x 6 ft
  - Max. turning angle 45°
  - 2 tables to support continuous cutting
  - Automatic & manual pattern nesting program to achieve optimum material utilization
  - Use Accumark Software for digitizing
- Manual
  Glass Prepreg/ dry
  Carbon Prepreg/ dry

By *Dr. M. Sayuti, ST.,M.Sc*

From Programming to Gerber Cutter

The nesting design are upload to the machine



The nesting design

Max 7 plies

Material is hold to its position on table by vacuum suction from under the cutting bed

By *Dr. M. Sayuti, ST.,M.Sc*

Before & after segregation kit

After cutting before segregate

Segregate by set

Packing the kit prepreg

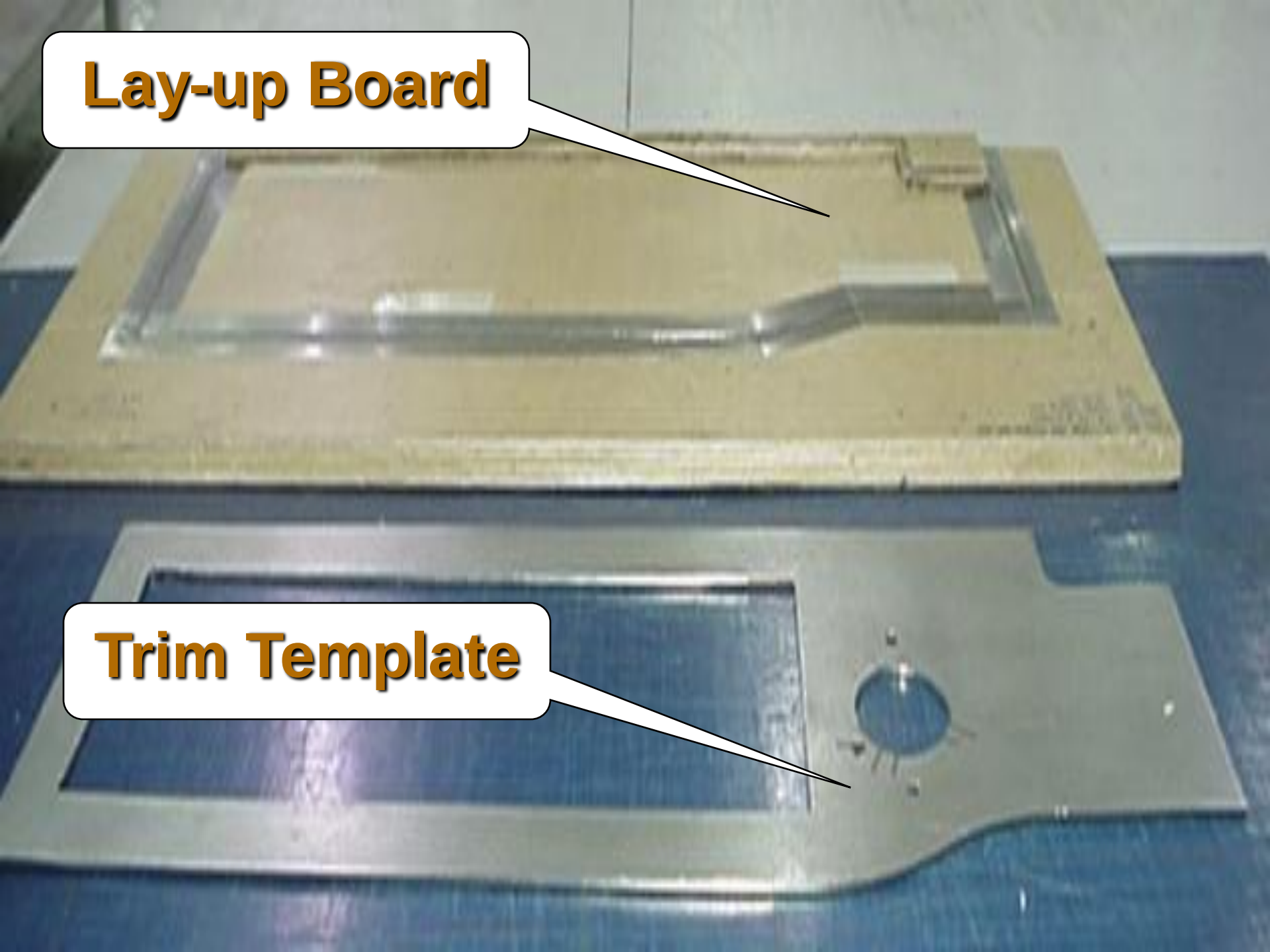
Ready kit

By *Dr. M. Sayuti, ST.,M.Sc*

Lay-Up Process

- The prepreg that had been cut are lay-up one by one according to the requirement
- Debulk process is required to consolidate the lay up of prepreg and to remove entrapped air
- Trim excess plies using knife
- Monolithic panel only contain prepreg but sandwich panel contain honeycomb and pepreg

Clean Room


Lay-up Board
Trim Template

By *Dr. M. Sayuti, ST.,M.Sc*

Lay-up Manual Consolidate

Push the air out of the layers by using spatula with specific direction (0 degree, 45 degrees)

Indirect Materials

- Breather cloth
- Honeycomb core
- Peel Ply cloth
- Carbon cloth
- Glass cloth
- Perforated sheet
- Bagging sheet
- Kevlar cloth

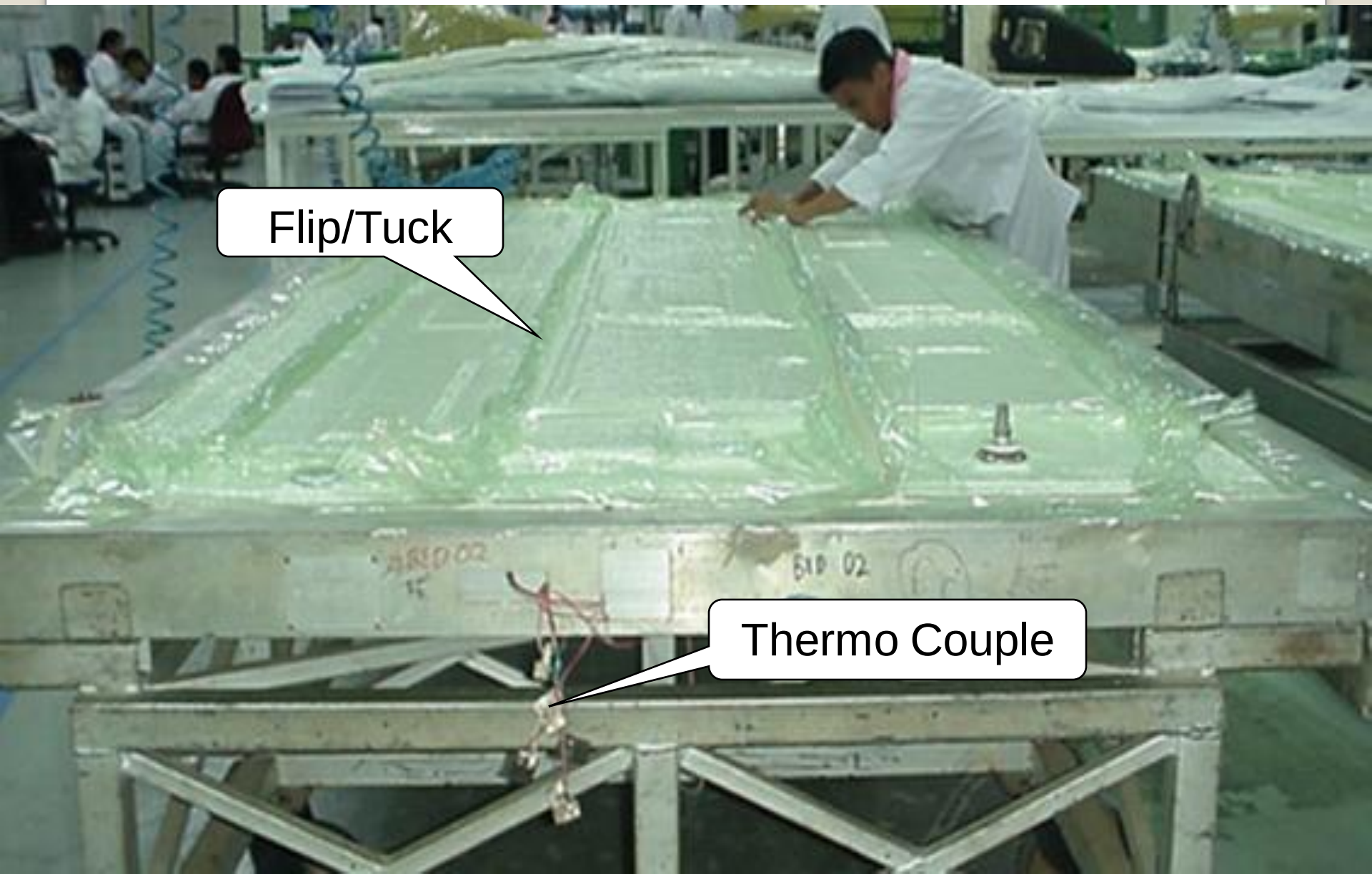
Indirect materials Regulator

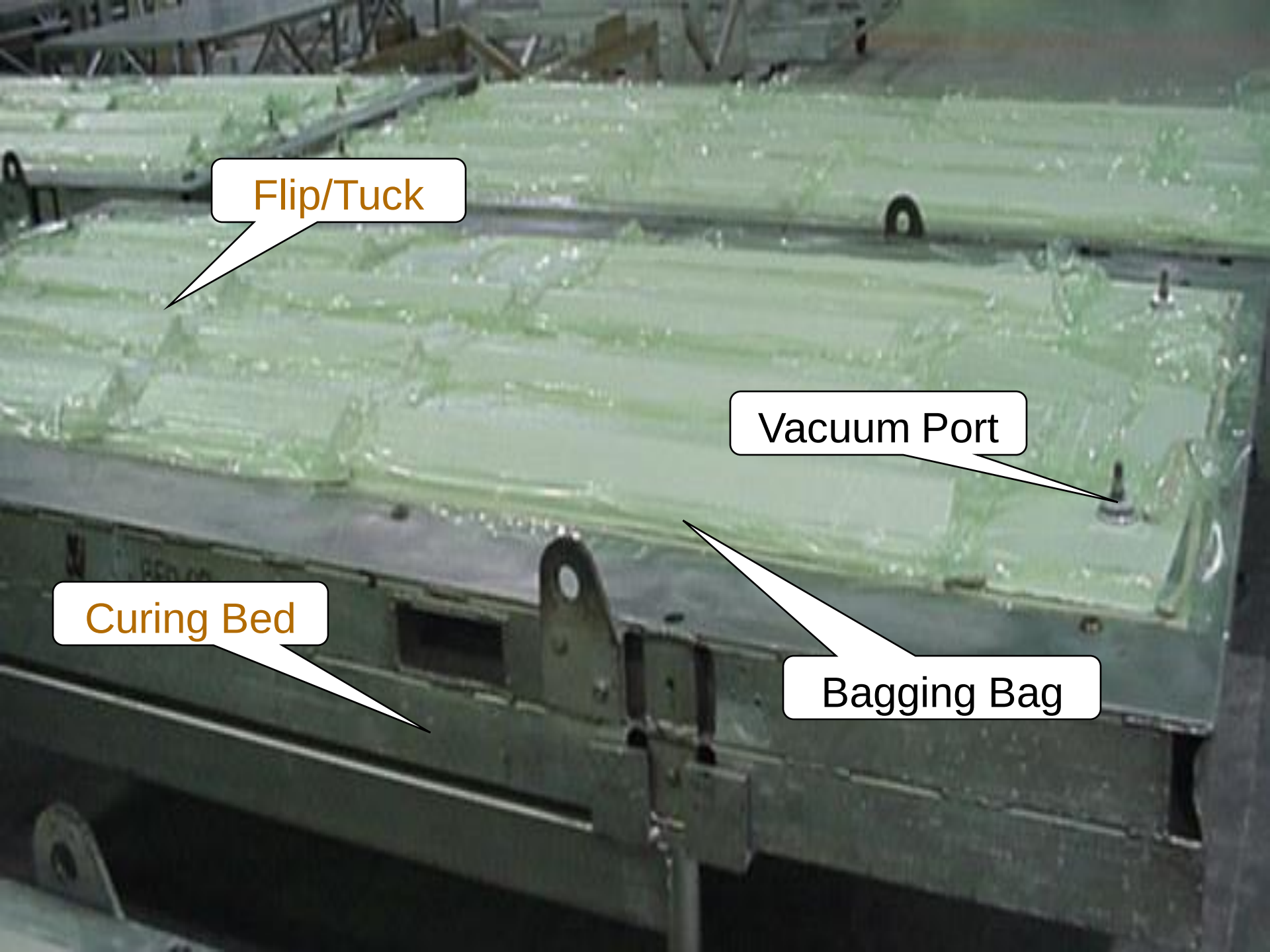
Debulking Process

Debulking Process

Air Pressure Monitoring

Final Bagging Process



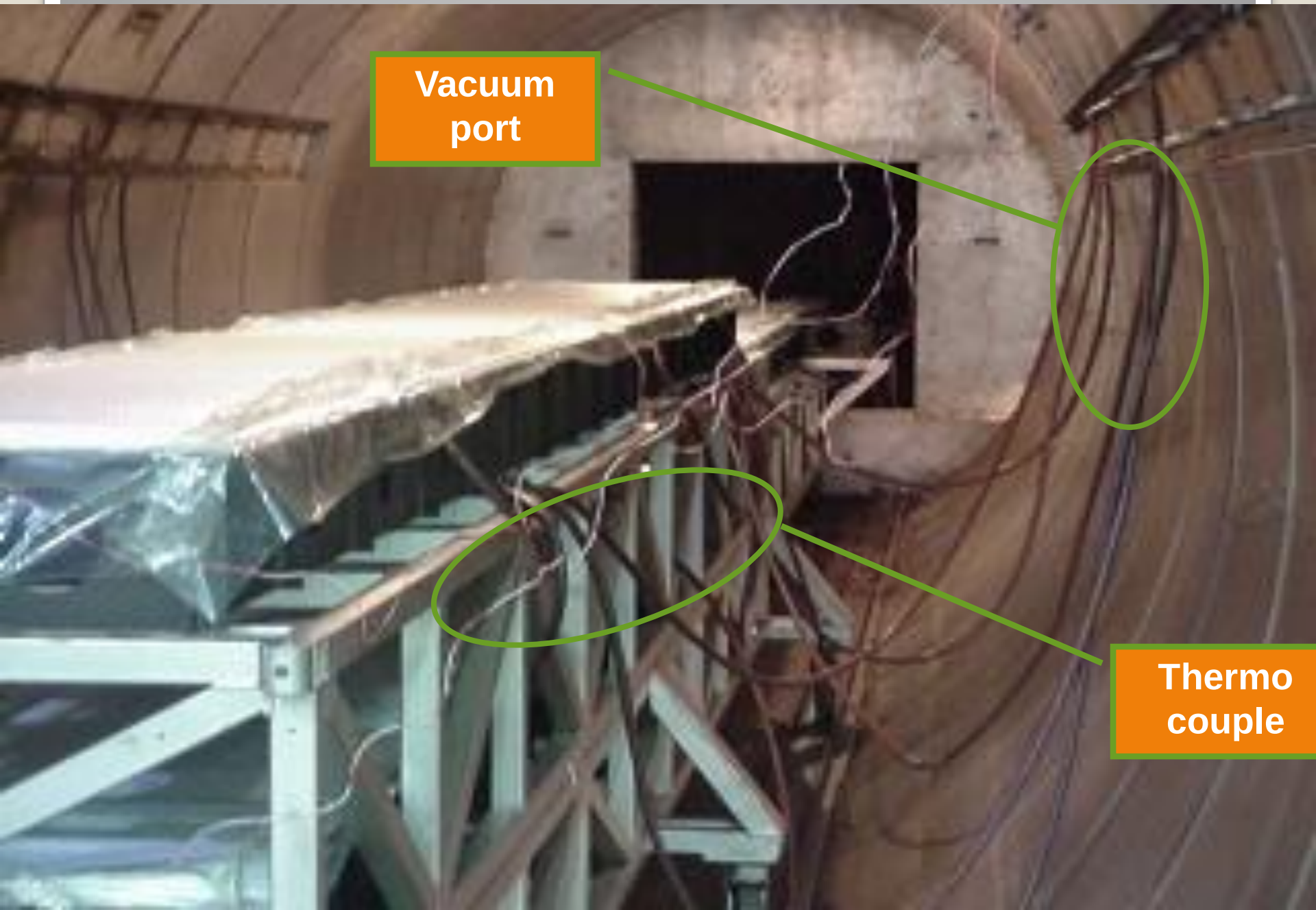

Flip/Tuck
Vacuum Port
Curing Bed
Bagging Bag

By *Dr. M. Sayuti, ST.,M.Sc*

Curing Process

- The panel are cure according to types of materials and panel thickness.
- The important factor in curing is the air temperature, pressure and the time duration
- Normally one panel would take around 8-10 hours to cure

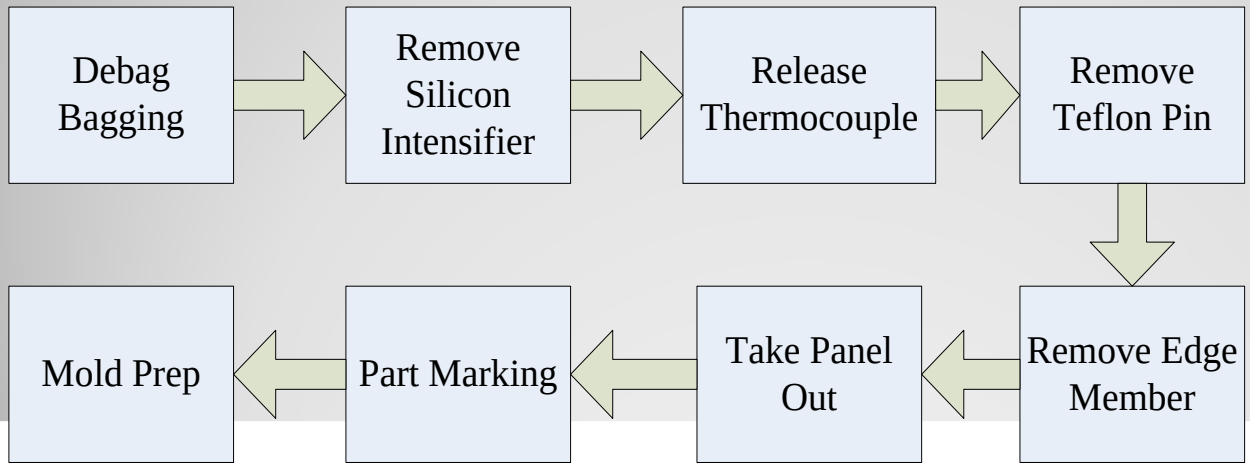
Autoclave



Mould Staging In Autoclave

Demould Process

- remove out the indirect material at the panels and separate it from mould



Demould Process

Remove the panel from the mould and the mold are clean with solvent for next process

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Mechanical Assembly

Trimming Process

Countersunk Drill

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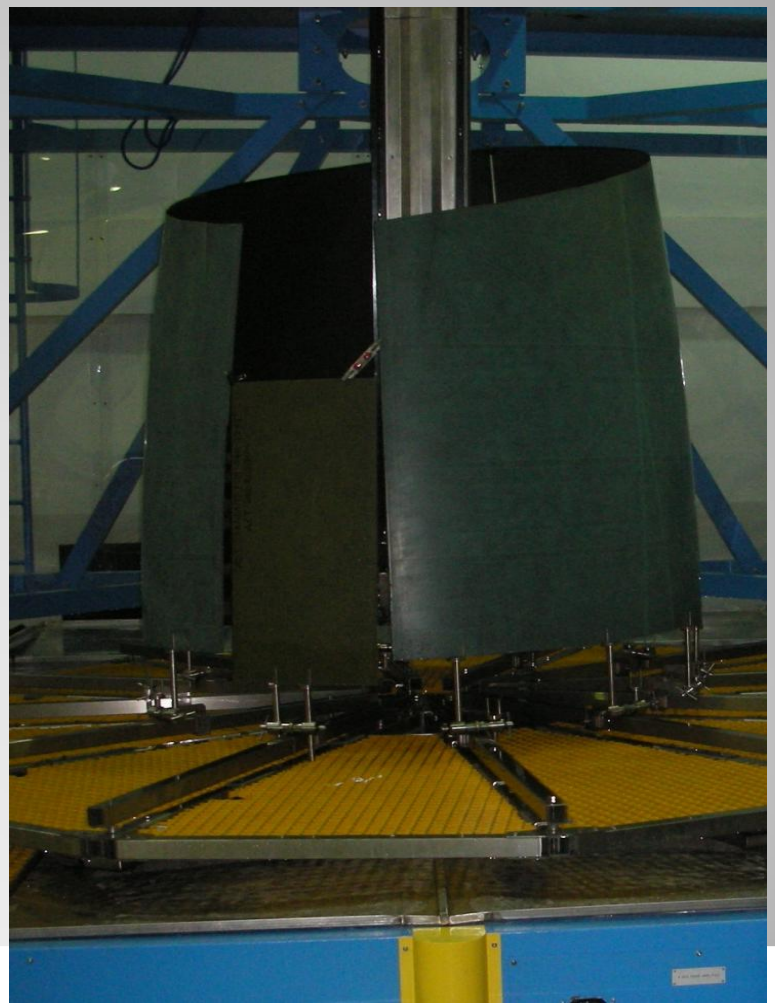
NDT Station

- The Non Destructive Test (NDT) is for inspection process
- To detect defect such as delaminating and dis bond on the panels by using Ultrasonic Test where water is used as a medium.
- using ultrasonic pulse-waves with frequency of 1MHz or 2.5 MHz



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NDT Main Machine

C-scan 7 axis

Horizontal C-scan 3 axis

NDT Main Machine

A and B-Scan

A-Scan Bond Tester

Painting Process

- "undercoat spray" to all panels
- There are 2 stages, light coat and primer
- In between the stages , the panels must be dry out by using oven
- Normally the time taken is 4 hours for the whole process

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Painting Process

Dry sanding process

Painting process in progress

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Set before & after painting

Before painting

After Painting

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Packaging

Conclusion

Composite technology are developed rapidly form day to day, we had to learn about the technology if don't want to be left behind

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