Australian Government
Civil Aviation Safety Authority

Composite Structure Certification Lessons Learned

An Australian Perspective

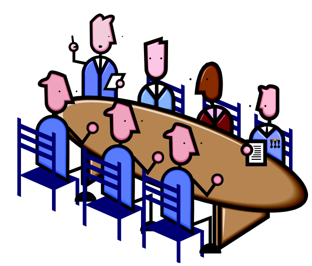
Major Composite Project Activity

Relatively recent activity;

- Composite CAR6 / Part 27 helicopter tail rotor blade. Replaces metal blade. APMA part.
- **Various "Role Equipment" composite water tanks.** Ranging from fitment to Bell 212 to Boeing BV107 (baby chinook).
- **Other More "minor" modifications. Like cabin and** rotary wing EMS.

Legacy composite certification projects;

- Jabiru (VLA)



A case study - External Water Tank – Bell 212.

- **“Role” equipment used for restricted** category firefighting operations.
- **Structure was considered “secondary” except** for main attachment points which are metal and analysed separately and considered as primary structure.
- Load conditions as per AC 29-MSG5 and FAR 29.865 as applicable to operation.

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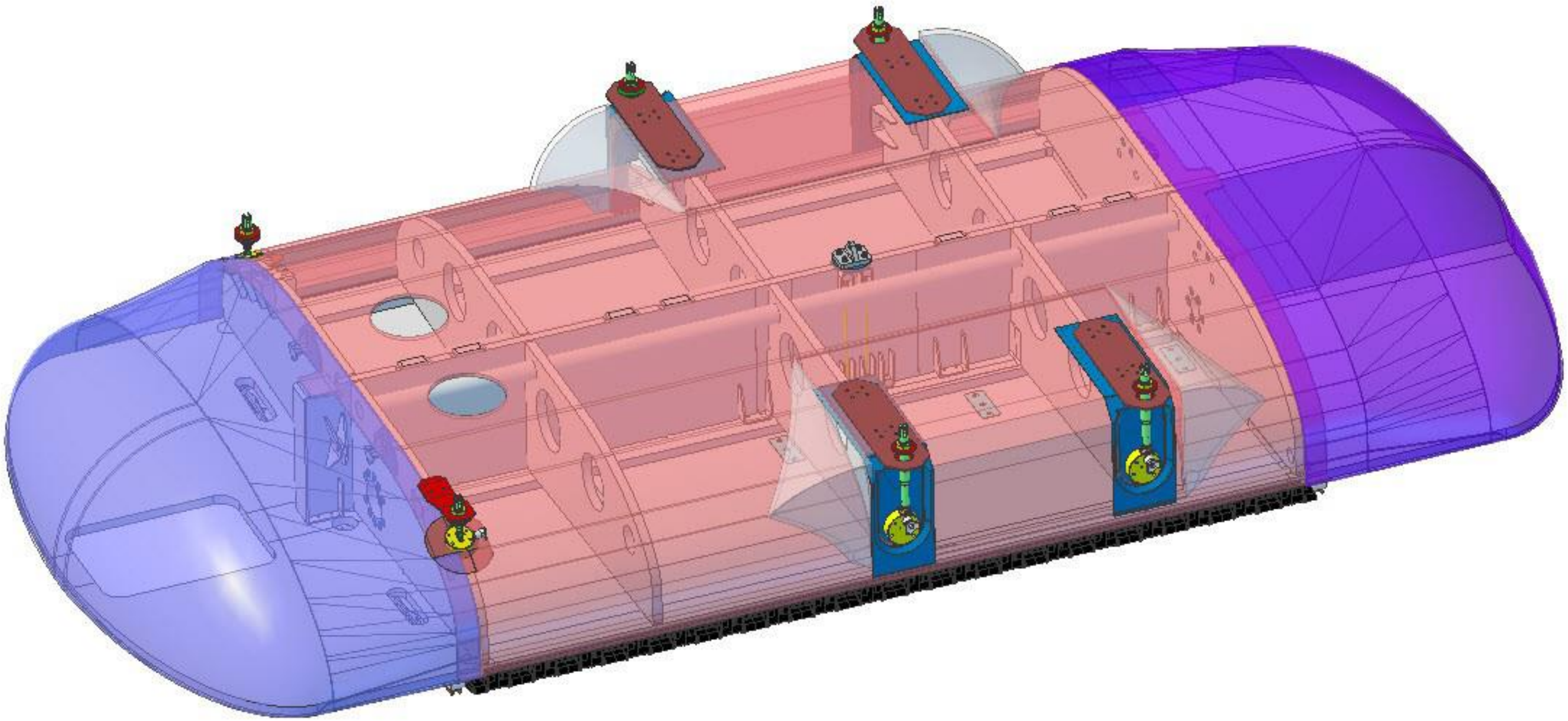
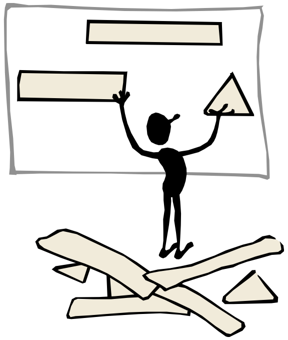
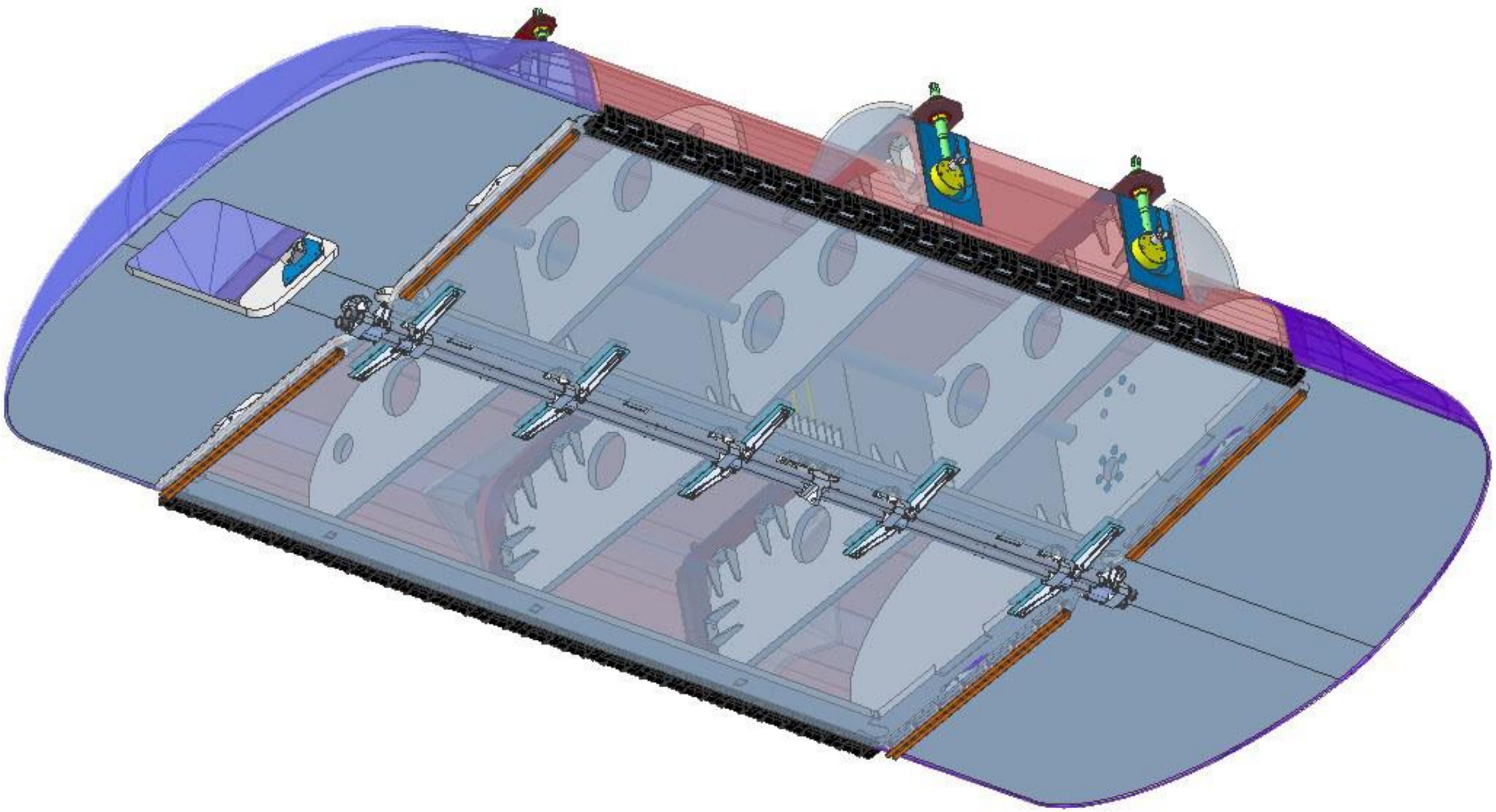
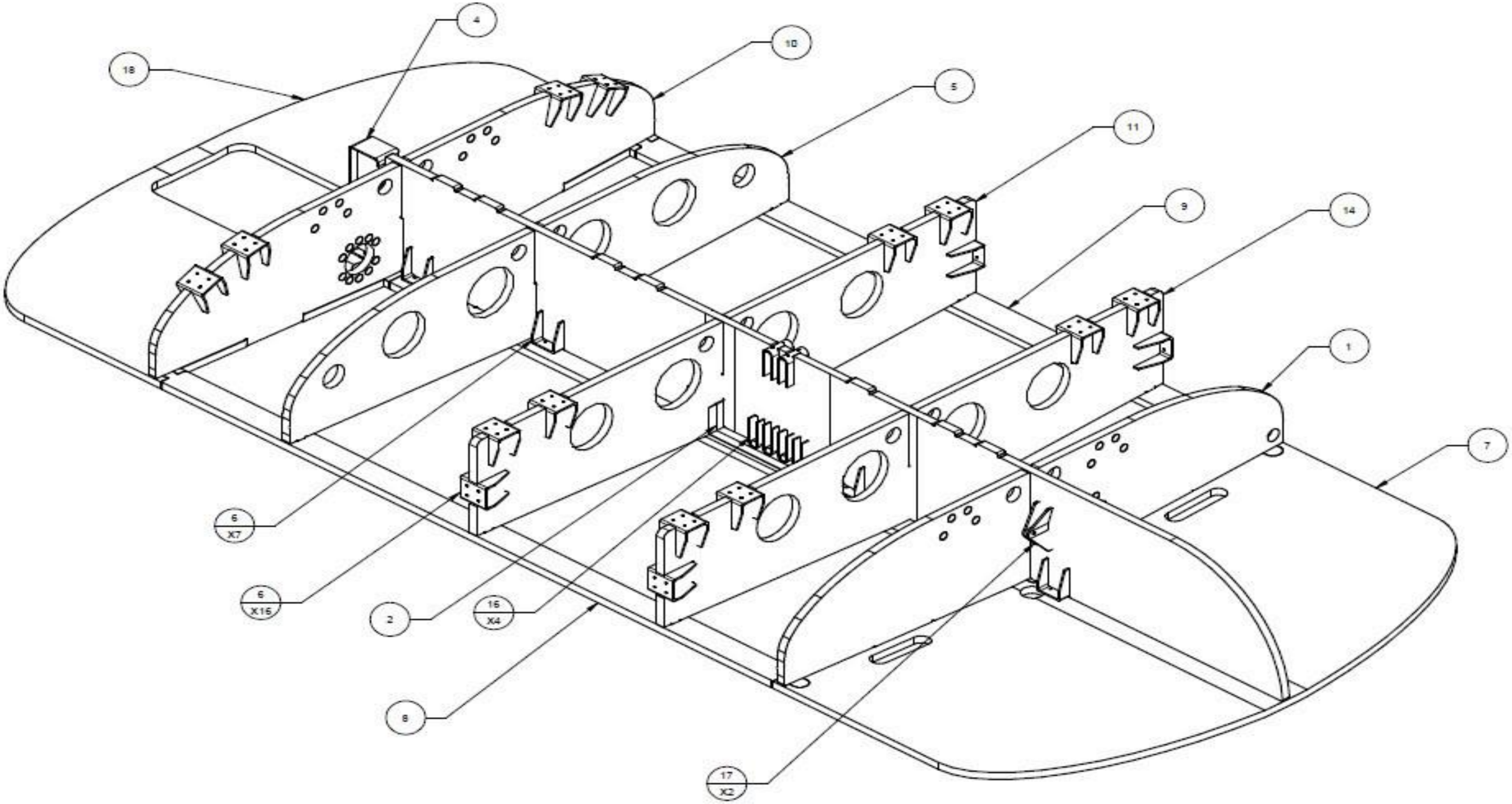


Guidance Used

- AC 20-107B – Composite Aircraft Structure
- AC 29 MSG-5 (restricted category loads)
- ASTMD648 (to determine Tg)
- CMH-17 (Material properties)
- CS-VLA AMC169 (Environmental conditioning)
- FAA Rotorcraft directorate Policy Memorandum – Secondary Composite Structure.







18
4
10
5
11
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14
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7
6
X7
6
X16
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16
X4
8
17
X2

Key features of this construction:

- Individual elements are sandwich construction
- Sandwich skins are fabricated from "pre-preg" oven cured carbon fiber materials which are bonded to the foam core.
- The Sandwich core is Divinicell Foam.
- Inserts, and local attachment points are fabricated from solid carbon fiber laminate.
- Secondary bonding operations will include both simple bonds, and bonds which are reinforced with wet laid laminates.
- The final assembly will be post cured to ensure that all features, including the wet-laid features achieve acceptable elevated temperature properties.

Items of Contention

- Glass Transition Temperature – Operating Environment
- Determination of Tg
- Lightning protection
- Full scale proof testing versus coupon level tests (allowables) then building block approach.
- Beyond the prototype – quality control. Make more of the same!

Project Assumptions

A basis of this design approval is that aircraft fitted with the Fire System:

- will operate in a Transport Category when the tank is fitted without the snorkel.
- will operate in a Restricted Category (or under FAR 133) when the tank and snorkel are fitted and the aircraft is operating in a fire-fighting role

Load conditions corresponding to this dual purpose role are understood to be as follows:

- For operations in the Standard Category loading will be in accordance with FAR 29-865
- For Operations in the Restricted Category loading will be in accordance with FAR29-MG5

Application of Special Factors

- **FAA Memorandum Dated 28 October 1998, entitled "Rotorcraft Directorate Policy, Secondary Composite Structure" discusses** the use of factors when analyzing the strength of secondary composite structures. The memorandum includes external tanks as secondary structure. Factors which are discussed deal with:
  1) Environmental Accountability
  2) Material / Manufacturing Variability
  3) Non Detectable Impact Damage

From Policy Memorandum:

ENVIRONMENTAL ACCOUNTABILITY

Environmental accountability may be approached by either testing within the environment (environmental conditioning) or using load enhancement factors. For simplicity, the load enhancement factor approach is typically preferred. It is general knowledge that moisture and temperature exposure degrade the matrix controlled mechanical properties of the composite. As a guideline for composite material system selection, the Wet-Glass Transition Temperature, Tg, should be 50° F higher than the maximum structural temperature. Unless otherwise substantiated using analysis and test from the building block method, a Hot-Wet (H-W) knockdown factor of 1.5 must be used.

Enviromental Effects

- Materials used in the construction of the tank are heat cured. Production includes a step where the entire tank assembly is post cured at 80degC. The Tg of the material after this post cure will therefore exceed 80ºC.. The FAA memorandum provides guidelines suggesting that the Tg of the material be 50ºF [27.7ºC] above the operating temperature. Under this guideline, and assuming;

- that the Tg for the material was 80 ºC then the appropriate maximum operating temperature would be 52ºC. This value exceeds all expected operating conditions that the tank is expected to operate in. Critical subcomponent tests were performed at elevated temperature to confirm DLL load capability.

- By virtue of the above discussion, load enhancement factors to account for temperature effects which are <u>other than ambient</u> will not be applied in this project

Moisture

- The basic tank structure is manufactured from heat cured materials and will therefore be in a dry condition when manufactured.
- The test articles will not have been moisture conditioned at the time of the test, therefore a load enhancement factor will be applied to allow for moisture effects.
- The value for this factor will be 1.25. Justification for this factor is as follows:
- MIL HDBK 17 Table 4.2.14(b) lists the properties for a 200 gsm plain weave carbon fiber laminate in epoxy resin, and gives compressive values for conditions at RT (dry) and RT (wet). The ratio of (wet)/((dry) compressive strength values is 86%. The applicable load enhancement factor to cover this would be a value of 1.16 (~1.2)

Material and Manufacturing Variability

- The quality assurance philosophy which the applicant nominated for this project will require each tank to be tested to a proof load condition as part of the production. This proof load will be 4g Load condition. A successful test will be one where be one the tank successfully carries the applied load without damage, or evidence of deterioration.

- This project will assume that proof loading on 100% of the production items will negate the need to apply load enhancement factors in the design qualification to account for material and manufacturing variability.

Non-Detectable Impact Damage

- The FAA policy letter provides the following advisory material with respect to No Detectable Impact Damage.

- This project accepts that the probability of impact damage on the basic tank structure will be low and;

- recognizes that the basic tank structure has been designed with distributed load paths, and;

- multiple attachments to reduce even further the probability of impact damage leading a hazardous situation.

From Policy Memorandum:

For rotorcraft secondary composite structure some judgment must be used. The probability of an impact may be considered. In general, the greatest causes of impact damage are hail, foreign object damage, and dropped tools. Engine cowlings have a higher risk than water/spray tanks for impact damage. Because of their location on the rotorcraft, impact damage on water/spray tanks is generally not considered because the probability of impact is low and the damage is detectable (thin laminate). The applicant must have an approved program to inspect for impact damage.

Lessons Learned

- More flexibility required for low production run articles which are primarily secondary structure (role equipment).
- **100% proof testing with appropriate NDT of any "critical" PSE should be** seen as appropriate in pre determined instances. (Not in every case)
- Risk based approach.
- These specials cases need to be agreed before the project commences and that all stakeholders agree (Manufacturing Inspectors, Design Approvers etc).
- Acknowledge that the creation of a design allowables data base for a secondary structural item (like an external tank operating in restricted category, state use), may not be appropriate and may be unnecessary burden.

My take on Additive Manufacturing and Fibre reinforced composites

A DEVILS ADVOCATE VIEW

Traditional Layup

- Pre-preg / Wet Layup
- Both use carbon fibre cloth
- Laid up in directional pattern 45 / 60 / 90 / 0 deg to tailor x, y directional properties. z plane is resin matrix dependent.
- Discrete laminates
- Carbon fibres created at 3000+ deg!!
- Post cure / heating / autoclave required.

Additive Manufacturing

- Can produce a matrix or mixed matrix in multiple x,y,z plane using additive process.
- But Cant produce a carbon fibre woven cloth for a laminated structure.
- Due to non-homogenous structure of a typical laminated structure, hard, if not impossible to duplicate with additive manufacturing