Supporting file to the Designer Bonus Registration Form

by Philip Avonds

Fouga Magister CM170

My motivation:

I was inspired to do the Fouga Magister for many reasons. First of all, it was the very first jet I have ever flown. Actually, as I write this, I realise it's already 33 years ago. My first flight on the Fouga Magister was made on February 3rd, 1978 and my first solo on the Fouga was done a few weeks later: February 28th, 1978 (I was just 19 years old…).

I have always been in love with the gracious lines of the Fouga and loved watching the national aerobatic team, the Red Devils perform their formation and solo routines at airshows in their beautiful red Fouga Magisters. The butterfly tail is so typical and contributes to the elegance of the design.

Fouga in Red Devils colours

I'm also in love with the technical design of the Fouga. The designers, Castello and Mauboussin (hence the CM designation), were renown glider designers and when they were contracted to design a pure jet trainer, they used a lot of their glider design experience in the Fouga Magister. This is evident from the very clean lines. An example: the flaps are fowler flaps but instead of having offset hinges which create drag, they chose a more difficult approach of letting the flaps run on ball bearings in tracks so as not to compromise the aerodynamic clean lines. These are some of the technical challenges I wanted to replicate in the model.

Another motivation are the superb flying qualities of the Fouga Magister, both as a full size jet and as a model jet.

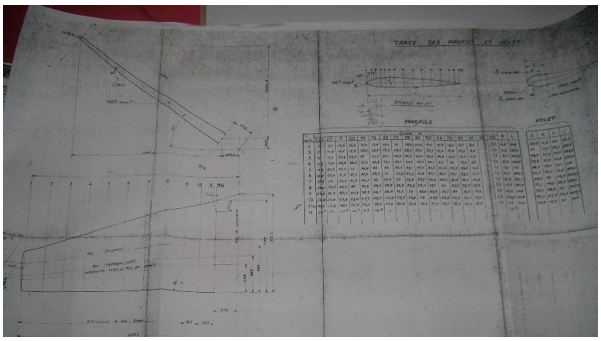
Last motivation is the fact that no serious precision scale model is available of this jet and I wanted to make the ultimate Fouga to compete at the IJMC Jet World Masters.

Gathering of information:

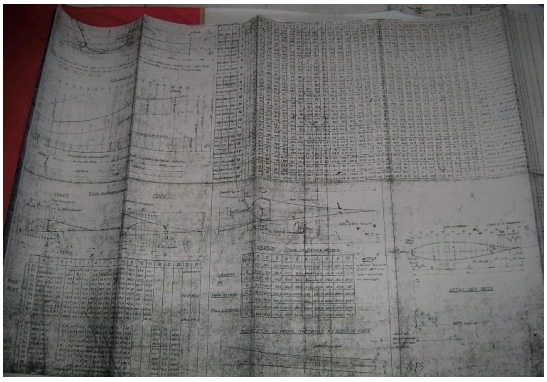
1. Original drawings by the original aircraft manufacturer, obtained through various sources of which the most important are:

- EADS who possess all the archives of the original Fouga Magister (through Jean Cosme Rivière)
- Flug Werk GmbH who restored a Fouga Magister (through the president, Claus Colling)
- Philippe Goulard (who made the master of the Heller Fouga Magister plastic kit to scale 1/72)
- José Vrancken (who made the master of the Aviation Design Fouga Magister to scale ¼)

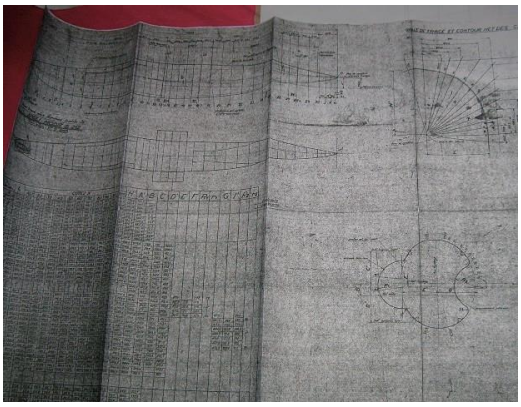
plans of fuselage cross sections



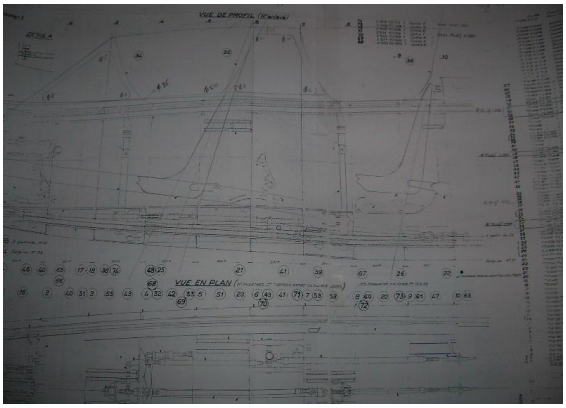
plans of V-tail



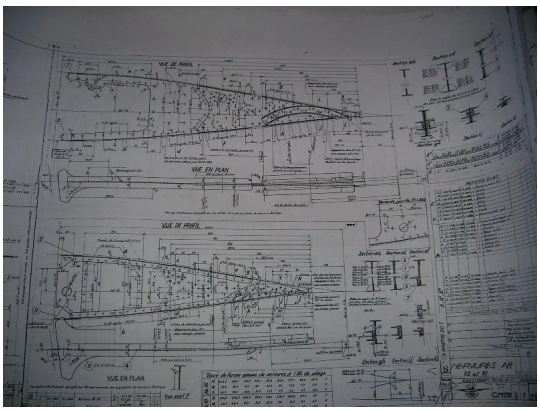
plans of wings and flaps



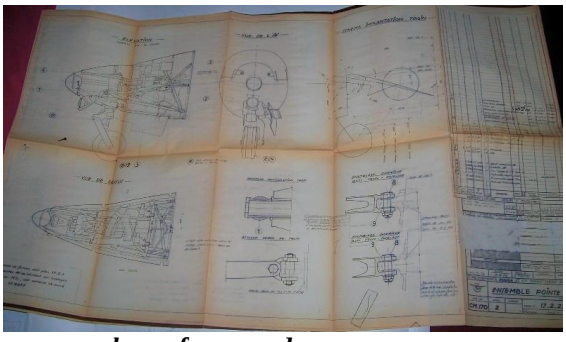
plans of fuselage



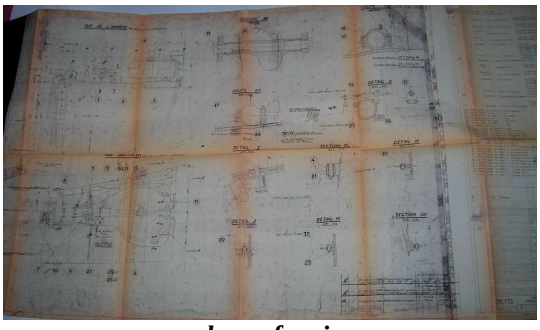
plans of cockpit



plans of flap rails



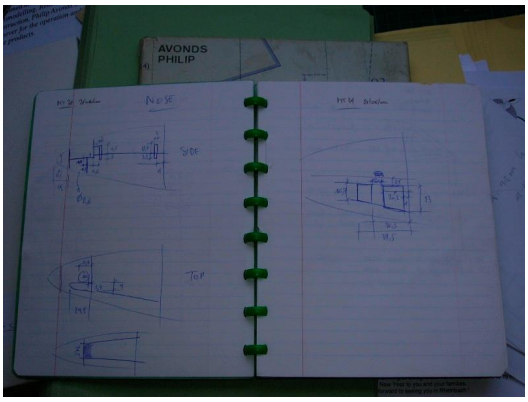
plans of nose and nose gear



plans of main gear

To complement the full size drawings, I made a lot of photographs and tape measured the complete aircraft. I did not do all this in one day, but divided over many days. Not only because it is not feasible to do it in one day but also because you do the general sizes the first time and it is only later that you realise you have forgotten things…I also made a "slide rule" in 2003 to simplify the task of taking measurements, see photo at museum.

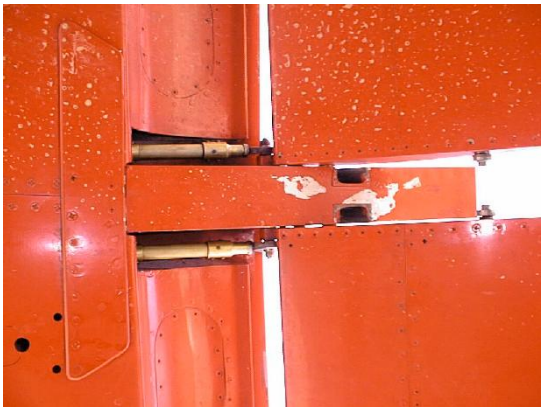
2. Own measurements and photographs taken at the Beauvechain airbase (Belgian Air Force) on 21/06/00 on aircraft number MT34:



own measurements noted in a booklet

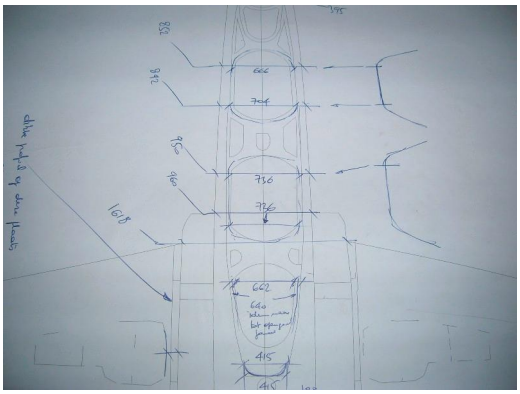
photo used as additional reference for canopy shape

3. Own measurements and photographs taken at the Koksijde airbase (Belgian Air Force) on 16/05/03 on aircraft number MT48 flown in by the display pilot Paul Rorive, a good friend and also an RC model flier! On this occasion, I asked him to let the flaps down in the landing position so I could take measurements and photographs of the flaps in detail.



detail photographs of lowered flaps, flap rails, flap actuators and wing structure

4. Own measurements and photographs taken at the Beauvechain airbase (Belgian Air Force) on 23/05/03



own measurements noted onto 3-view drawing

yardstick taped to the fuselage for size reference

5. Own measurements and photographs taken at the Brussels Air Museum on 09/11/08

the arrow points at my self made "slide rule"

working at the museum, plans on the ground

again using a yardstick for size reference

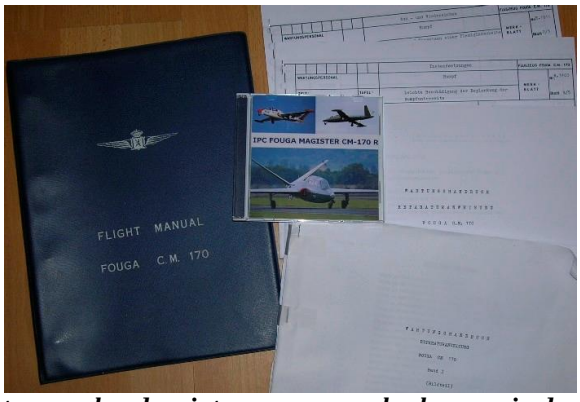
6. Various publications of which the most important are the following books:

Le FOUGA sous toutes les couleurs ISBN 2-907341-11-1
Fouga "Magister" by Jean-Pierre Tedesco (éditions Ouest-France)
Fouga C.M. 170 R Magister by Michael Riedesser (F-40 Flugzeuge der Bundeswehr)
Butterflies in the Skies, Fouga Magister (Synergic sc, Belgium)
Les Diables Rouges by JP Scruel (who was my flying instructor on Fouga Magister!)
Fouga Magister, Whistling Turtles in Belgian Skies by Serge Van Heertum and Marc Arys (Flash Aviation)

various books as listed above

other publications: magazines, solo display folders etc.

7. Flight and Maintenance Manuals Belgian Air Force



flight manual and maintenance manuals also acquired on CD

8. Detail underside photographs taken from MT03 located on a roundabout near Sint-Truiden (B) on my return way from the November 2008 IJMC Board Meeting.

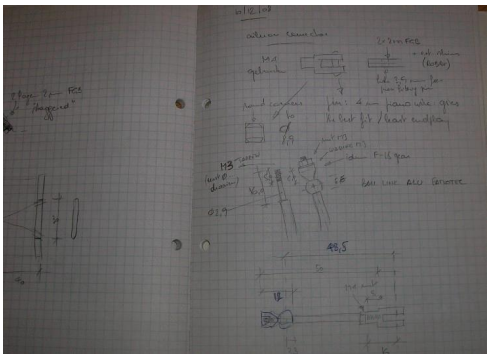
one of the photographs of wing underside for panel line reference

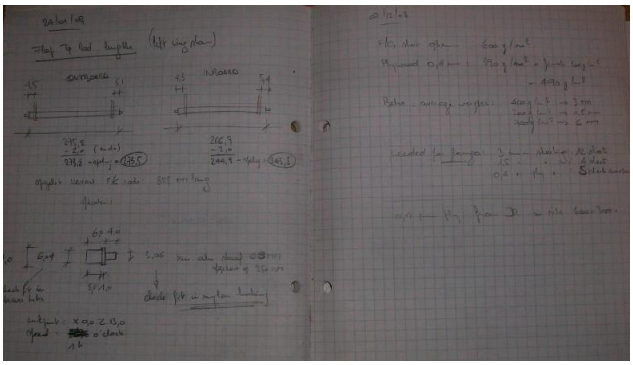
9. Detail underside photographs taken from MT30 located on a roundabout at the industrial park Hauts-Sarts (B) on my return way from the January 2009 IJMC AGM.

one of the photographs of the fuselage underside for panel line reference

Design drawings:

I made both **manual and computer** drawings, based on all the info gathered above. The manual drawings are mostly sketches drawn in a drafting booklet (I even take this booklet with me on holidays to take notes and make sketches…)

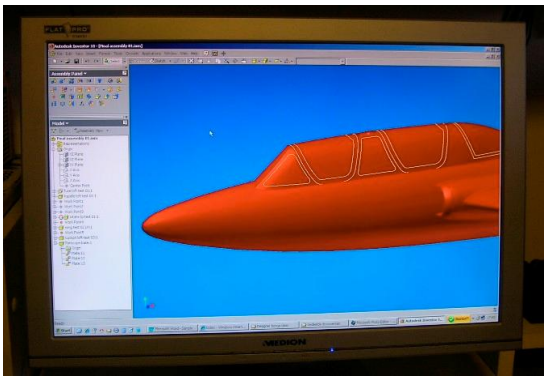




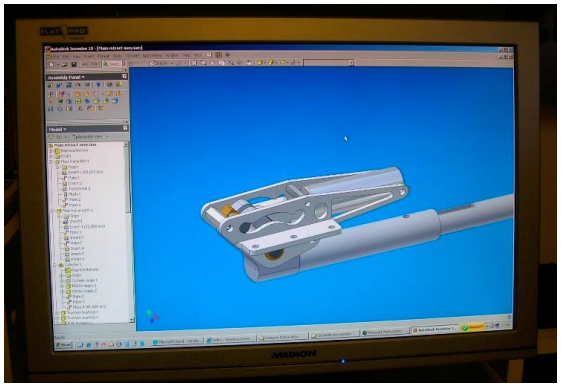
my sketchbook with examples of technical solutions for aileron linkages and flap linkages

The CAD computer software used is:

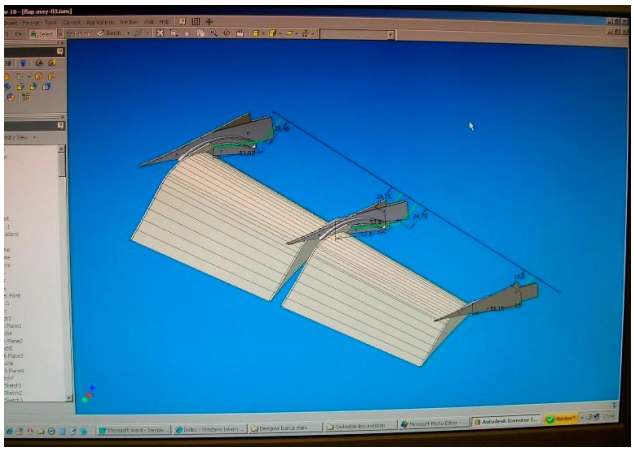
- **Autodesk Inventor** for all 3D work like the overall shapes of fuselage, wings, stabs, cockpit and engine nacelles. It is also used for mechanical parts like landing gear, struts, wheels, airbrakes, flaps etc.



half of fuselage, cockpit, engine nacelle and wing root



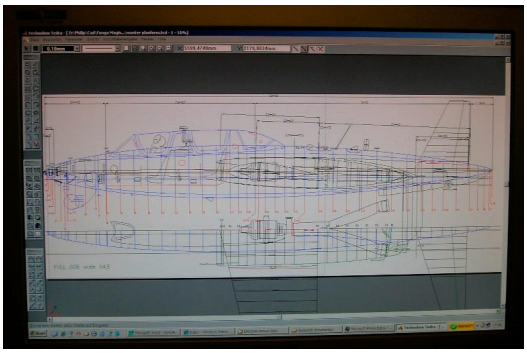
main gear mechanism with main strut



flap assembly on rails

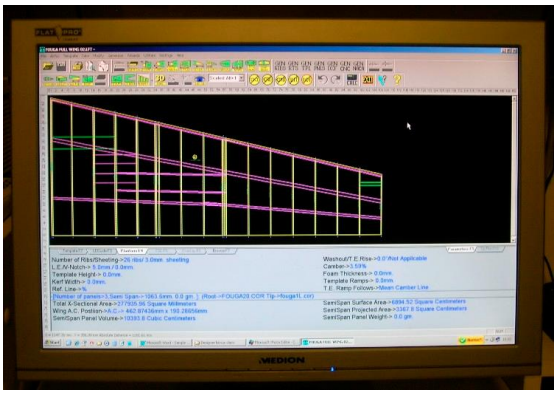
- **Technobox Tedra** for all 2D work: building drawings for wings, stabs and for working out geometry of flaps, airbrakes, landing gear, struts, wheels, gear doors etc.

overall view of my workstation in my "design room"



fuselage 2D drawing

- **CompuFoil**: for lofting wing and stab ribs



wing layout in CompuFoil

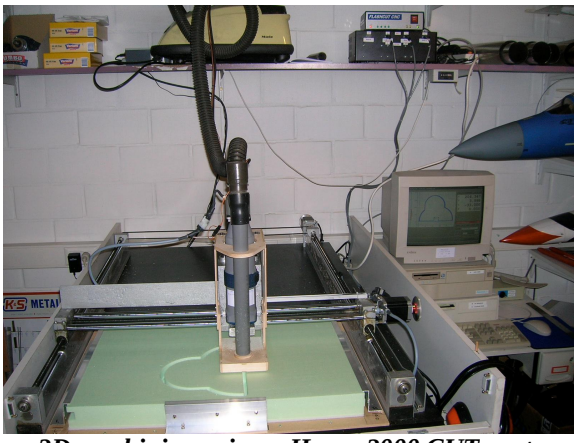
Build of the model:

I build the model with a fibreglass fuselage and with wings and stabs of conventional structure. Here is a detailed account of how all components were designed and made, which software and which machine tools was used for the computer design and manufacturing work.

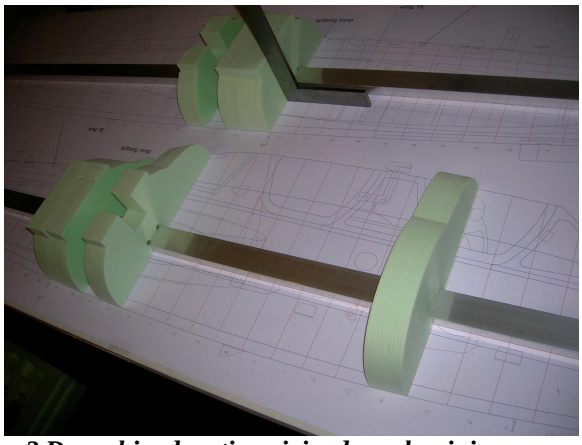
Fuselage: the masters for the fuselage were first created in 3D on the computer with the help of **Autodesk Inventor** software using the co-ordinates (thousands of them) of the full size plans and in some areas where these were not available, from working with photographs and working from own measurements taken. The 3D drawing was then exported as an STL file and imported in a CAM software program called **MeshCam** to make it suitable for 3D machining using a **Haase 2000 CUT** router and **FlashCutCNC** hard- and software. The sections were cut from medium density extruded green foam and assembled. Some parts were also made on my **Roland Modela 3D Plotter** (smaller parts like intake lip, scale details like grilles, the masters for scale details like scoops, antennae etc.). The assembly is then finished with a few layers of fibreglass and epoxy resin to form a durable skin for the primer. The primer is applied and all scale surface detailing is added before the epoxy glass negative moulds can be made. Everything done in house, see following photographs..

Roland Modela 3D plotter suitable for small parts only

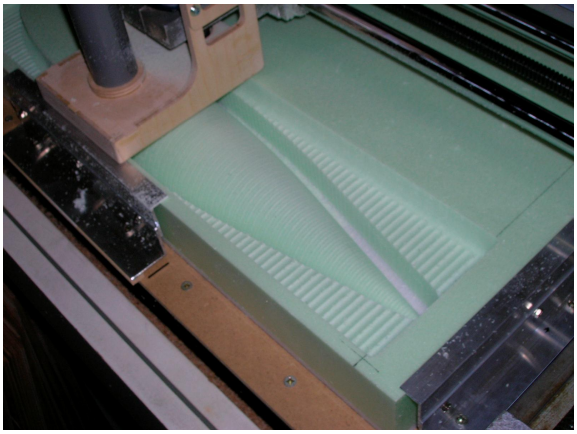
intake lips made on the Roland Modela



3D machining using a Haase 2000 CUT router (fuselage section)



3 D machined sections joined on aluminium spar



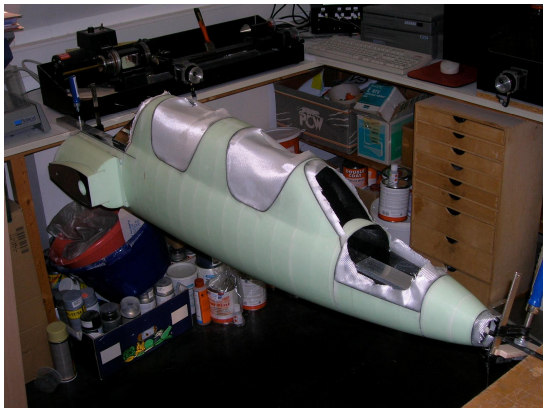
3D machining using a Haase 2000 CUT router (tip tank section)

3 D machined sections joined on aluminium spar

fuselage sections joined, canopy frames cut

fibreglassing the foam parts

fibreglassing the foam parts



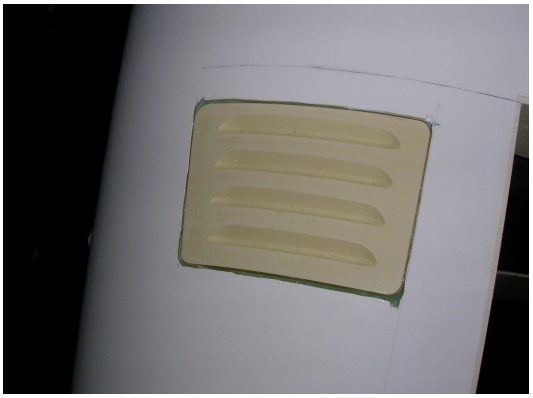
fibreglassing the foam parts

sanding the fuselage before the spray filler

fuselage spray filled

other parts spray filled

fuselage all primed and filled



separately milled grille detail let in fuselage

preparing fuselage master in parting board

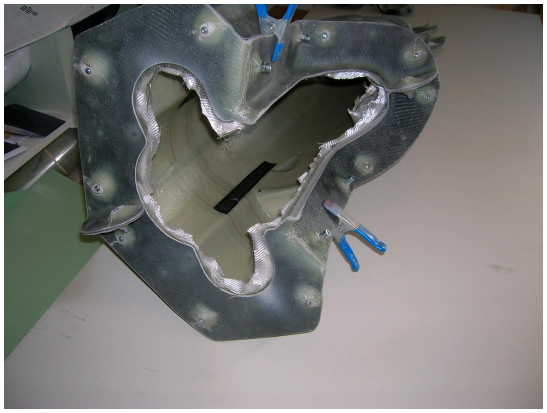
laying up the moulds of the fuselage…

… and of the other parts

finishing off the moulds

view of all the moulds

primer sprayed into the moulds



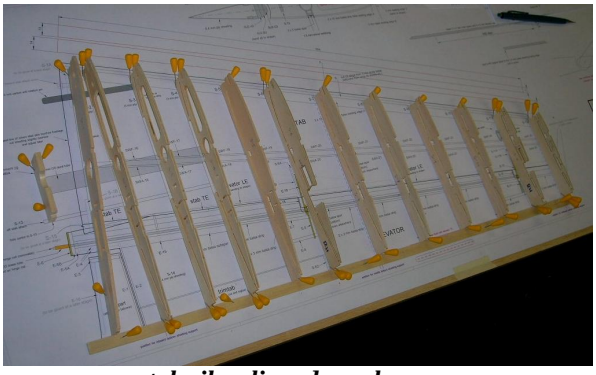
prototype fuselage laid up in moulds

prototype fuselage fresh out of the moulds

prototype fuselage fresh out of the moulds

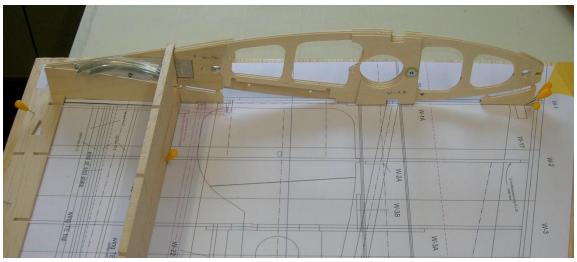
Wings and stabs: the flying surfaces were mostly created with **Technobox Tedra** 2D CAD software and **CompuFoil** for lofting the wing and stab ribs. I also made some use of **Autodesk Inventor** to solve challenging technical problems in the area of flaps, airbrakes, landing gear and wheel doors. Once the parts were all drawn, they were exported as HPGL files to be cut on the same **Haase 2000 CUT** router as above but using 2D cutting software: **CncProfi**. Everything done in house.

Haase 2000 CUT router to cut all 2D parts

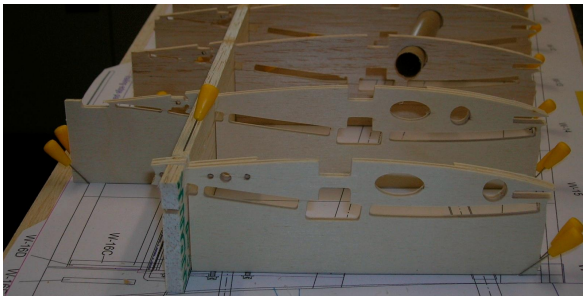


stab ribs aligned on plan

stab internal structure

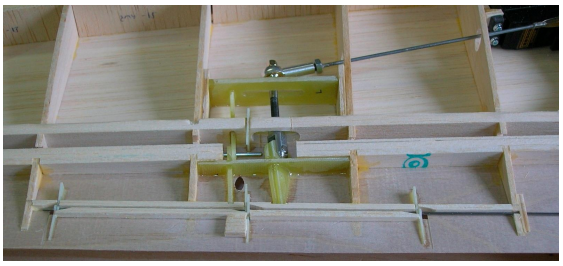


start of wing build with aluminium flap rail visible



wing tip internal structure

airbrake and flap servo installation

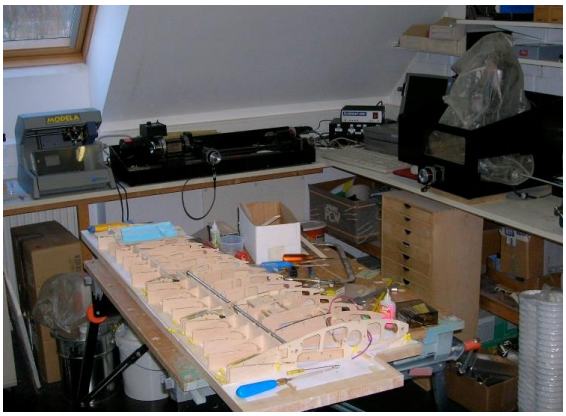


internal aileron linkage

flap structure detail

complete wing structure before sheeting bottom

Landing gear: I made the landing gear parts, the **flap rails** and the **airbrakes** on my metal cutting machines, a **Sherline CNC lathe and a Sherline CNC mill**, both CNC controlled through the **FlashCutCNC** hard- and software. Everything done in house.

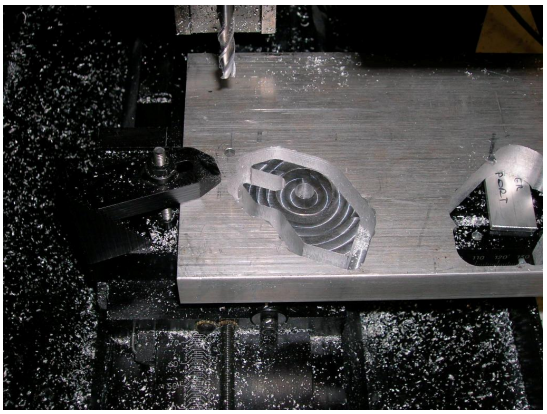


wing structure on foreground, CNC machines from left to right: a Roland Modela, a Sherline CNC lathe and a Sherline CNC mill

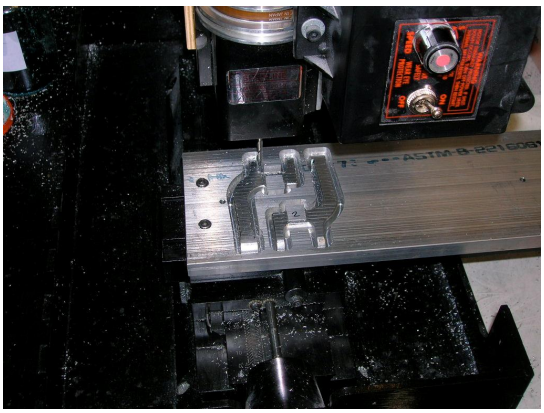
milling the flap rails on the Sherline CNC mill

milling the main gear retract frames

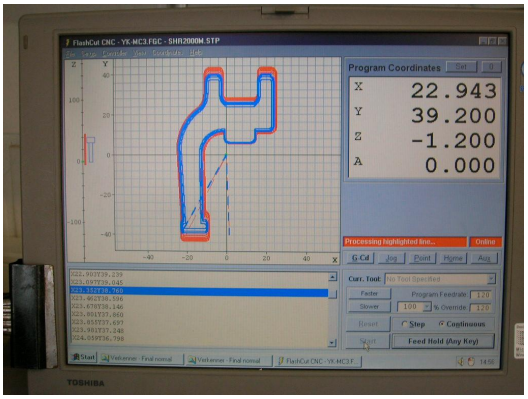
milling a nose retract frame



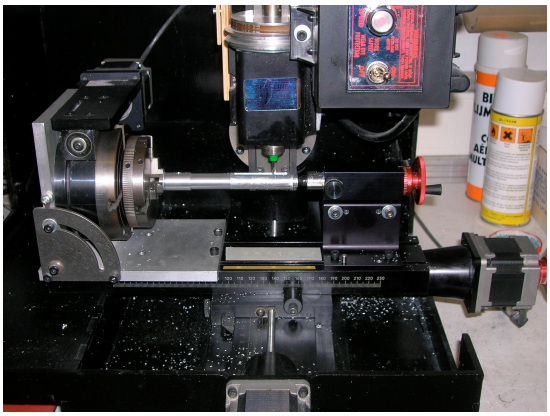
milling a nose retract pivot block



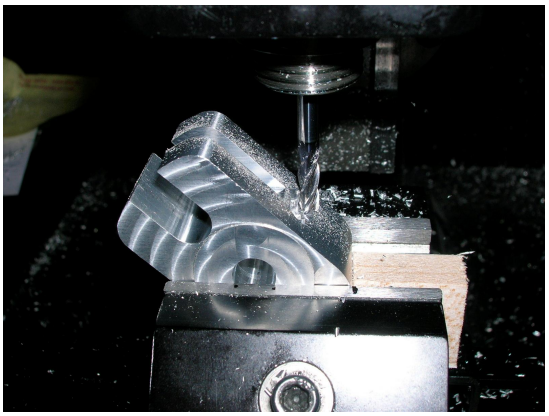
milling the nose leg half fork…



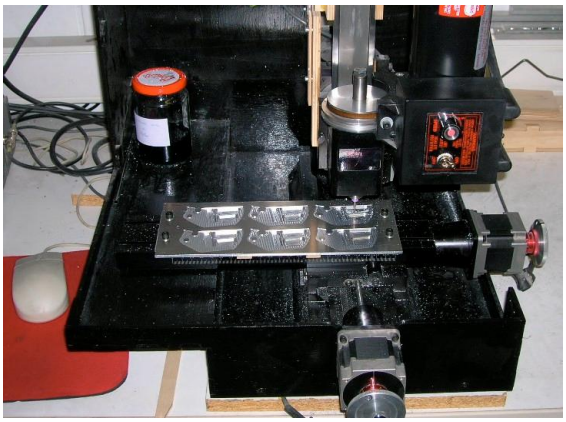
… from the computer with FlashCutCNC software



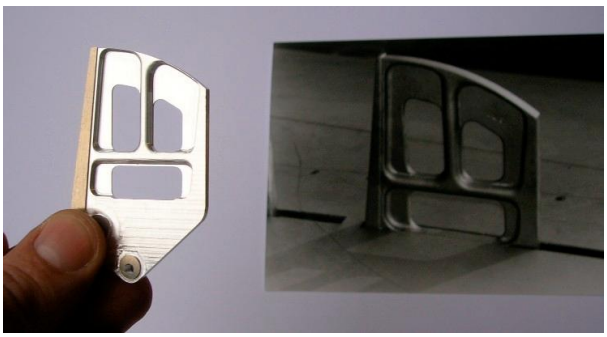
machining the anti rotation slot in the main strut



machining work on the main retract pivot block



milling the airbrakes…



…and finished airbrake next to photograph

prototype of completed nose gear

Scale details: I designed them on the **Autodesk Inventor** 3D software, postprocessed them with **MeshCam** and machined the masters in blue hard wax on my **Roland Modela 3D plotter**. From these, silicone moulds were made and epoxy resin moulds were cast. These moulds were used to vacuum form all the air scoops, antennae etc. All done in house with my own design vacuum forming machine.

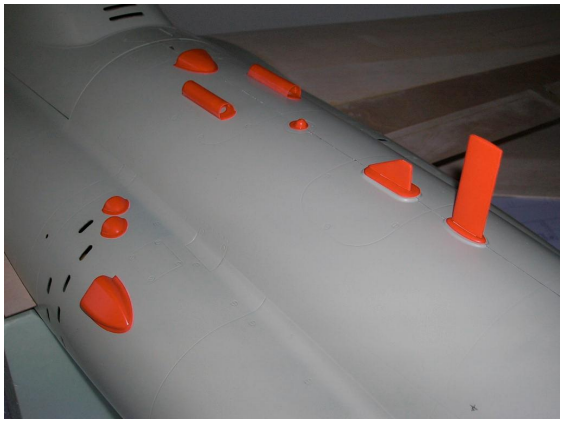
master for periscope, antenna base and scoops

master for pitot tubes, windshield de-icer etc.

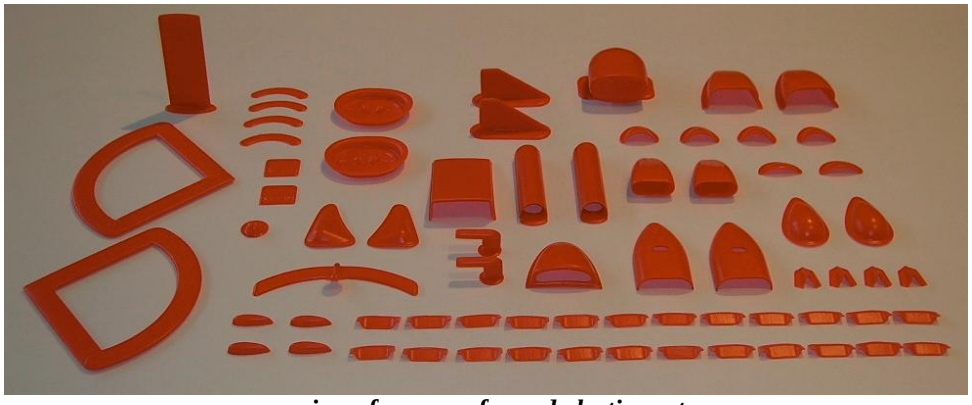
vacuum formed detail sheet 1

vacuum formed detail sheet 2

inside of engine nacelle with outlet scoops



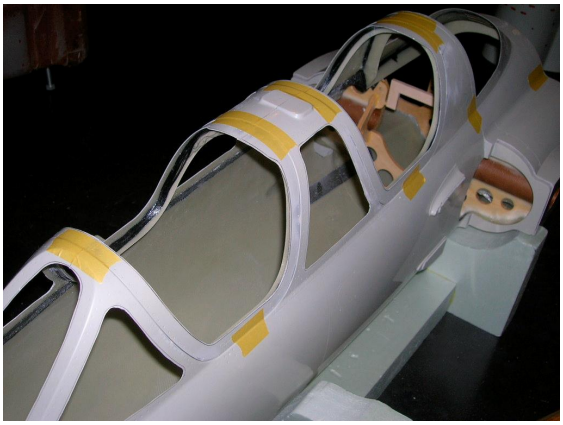
antennae and scoops on fuselage



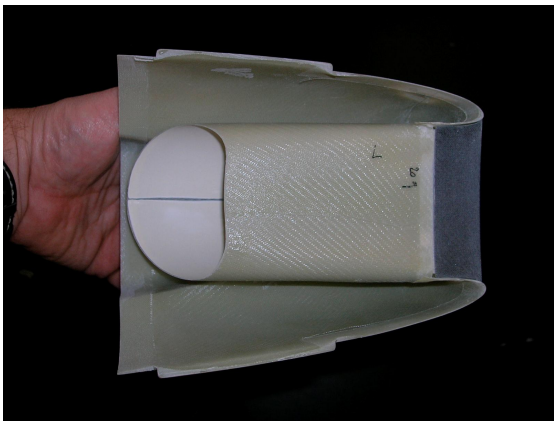
overview of vacuum formed plastic parts

Also the clear canopy sections and the clear lenses on the nose and the tip tanks were vacuum formed in house.

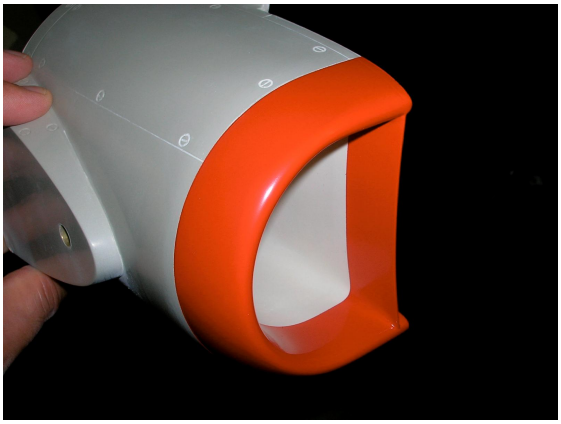
Some more photographs on the build of the model:



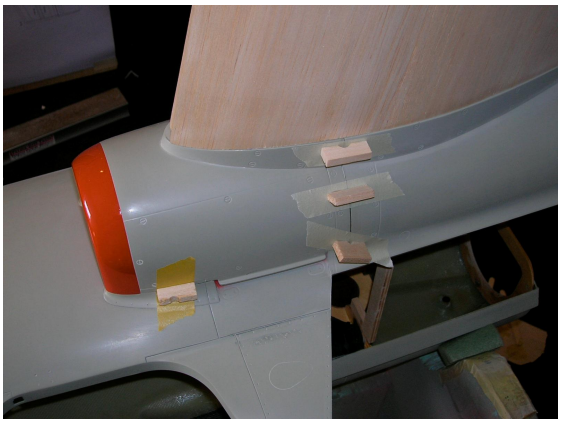
work on canopy frames



inlet ducting and splitter plate installed



intake lip, splitter plate and ducting painted…

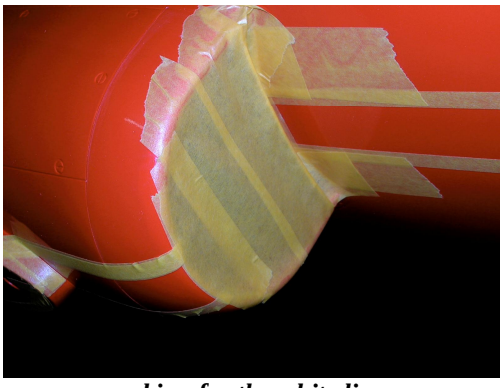


… before installation on fuselage

priming the fuselage and parts out of doors

the fuselage ready to be painted

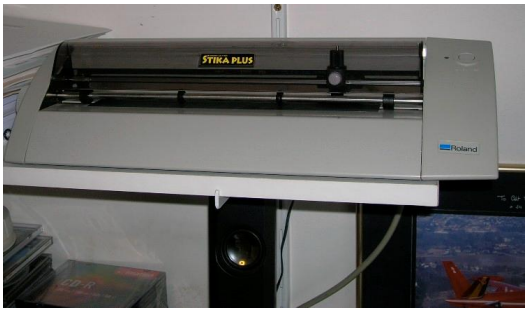
the fuselage painted in red under a shelter



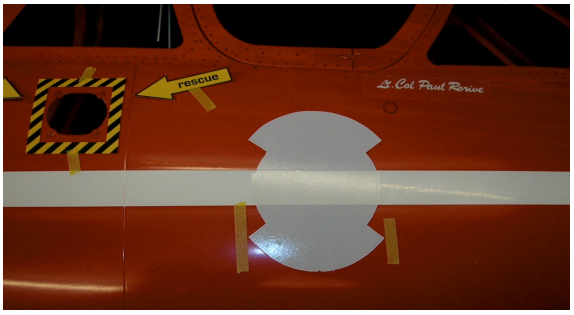
masking for the white line

Graphics: I designed all graphics on **Technobox Tedra**. The decals are printed on a **QMS Minolta Magicolor 2** laser printer and the self adhesive graphics (stickers) are done on a **Roland Stika STX** vinyl cutter. Everything done in house.

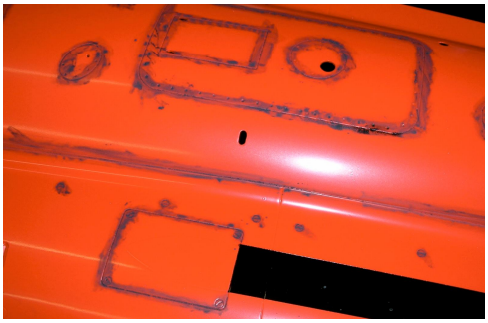
QMS Minolta Magicolor 2 laser printer on which I printed these decals



Roland Stika STX vinyl cutter on which I cut the above graphics

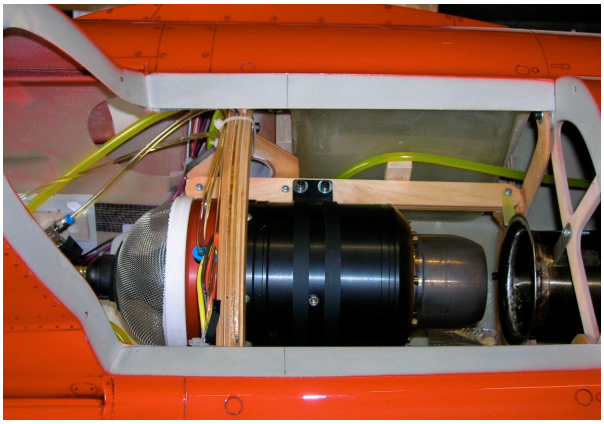


aligning the decals



applying a wash on the panel lines

all parts drying in garage after clear coating



G-Booster 80+ turbine installed

weight and balance checks

Help of others:

All the design work, **and I mean 100% of the design work and the development work was done by myself.** All the work to prepare the parts for CNC cutting and all the actual CNC cutting was done by myself, again 100%. All the landing gear parts are done by myself. Only exceptions where I got help from others:

Marc Thienpont (Belgium) made the tailpipe from stainless steel (based on my design drawings)
Igor Zhydanov (Ukraine) made the rubber tyres (based on my design drawings)

Development into a kit:

The model is now available as a kit although the model was developed without any constraints of commercialising. This was because I didn't want to compromise, I wanted the model to be as scale as possible. The tools and machines I have available at home and already described above helped to achieve this goal.

Funding:

All funding is 100% own funding, no outside sponsoring is involved

Use of commercial components:

Raw materials: balsa wood, plywood, extruded foam, glass cloth, epoxy, dural, piano wire, transparent plastic etc.

Commercial mechanical parts: all screws, bolts and nuts, mostly from RS Components
Gear doors: air cylinders from Bob Violett Models (BVM)
Air valves: Robart and Ultra Precision
Pneumatic lines and connectors: Robart
Wheel axles and wheel brakes from BVM
Landing gear: air cylinders from Robart
Springs for struts: RS Components
Hardware for servo connections etc. mostly from Du-Bro, but also some Graupner and RS Components
Ball bearings from a Chinese ball bearing manufacturer

early test flight on prototype model

early test flight on prototype model

Last name:	Avonds
First name:	Philip
Country:	Belgium
Type of model:	Fouga Magister
Scale:	1 / 4,5
Date:	May 1st, 2011