Development of a Subscale Flight Testing Platform for a Generic Future Fighter

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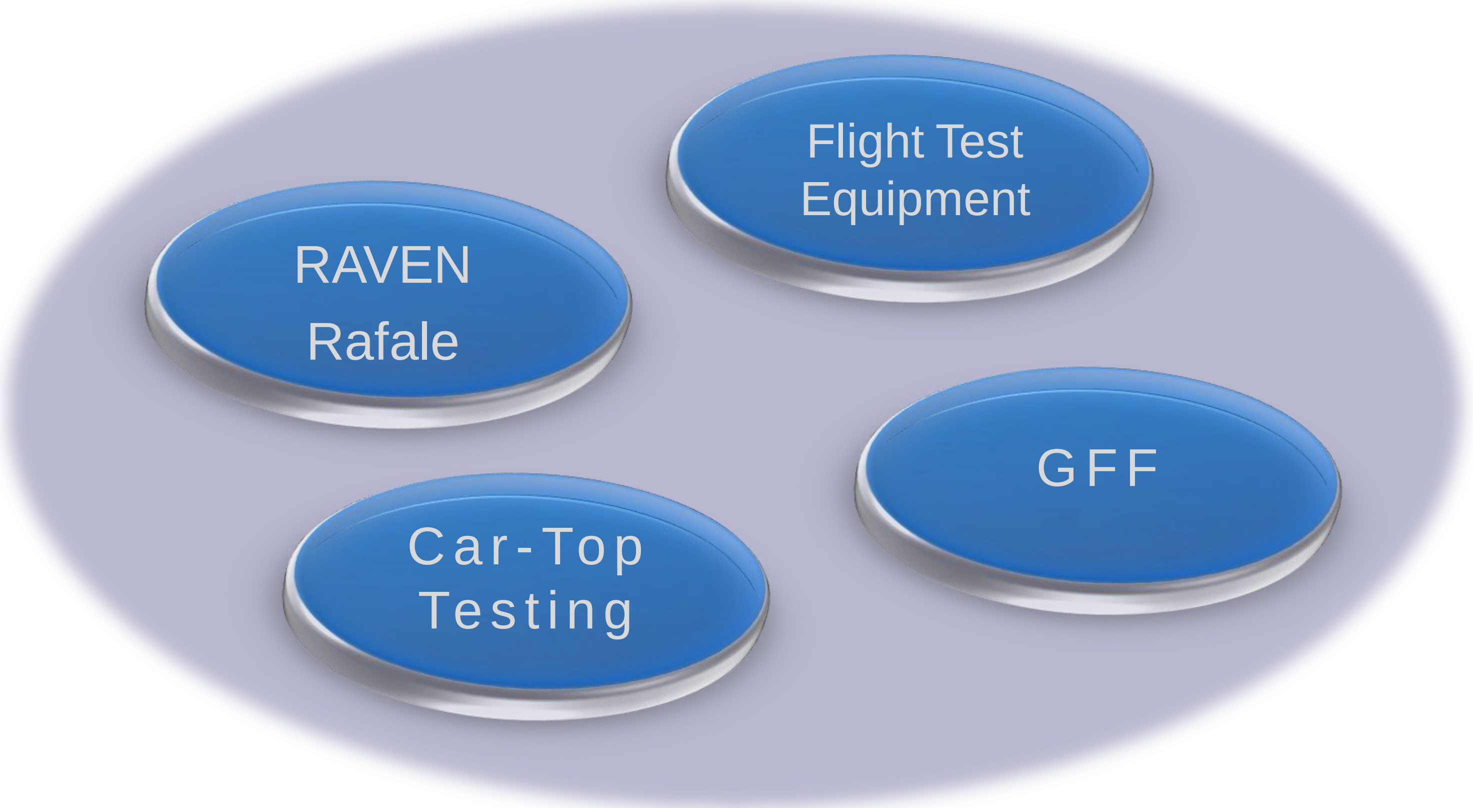
CONCEPT REALISATION LABORATORY

Subscale Demonstrators at Linköping University



Plattforms at LiU/FluMeS

- Business Jet “Raven”
- In-house design and fabrication

•scale	~1:7
•Length	1.76 m
•wingspan	2.00 m
•TOW	13.0 kg
•propulsion:	2x70 N

- Forward swept wing
- Dynamically scaled
- High wing load for remote controlled aircraft

- Dassault Aviation Rafale
- Commercial Kit

•scale	1:6
•length	2.05 m
•wingspan	1.44 m
•TOW	~14 kg
•propulsion	1x120 N

- Used for high angle of attack testing
- Serves as a flying test bench

- Generic Future Fighter (GFF)
- Design: Saab
- In-house fabrication

•scale	~ 1:7.5
•length	2.4 m
•wingspan	1.5 m
•TOW	~17 kg
•Propulsion	1x160 N

- Model of a fictive fighter of the 5th generation
- Thrust vector nozzle

Background:
The Research Project

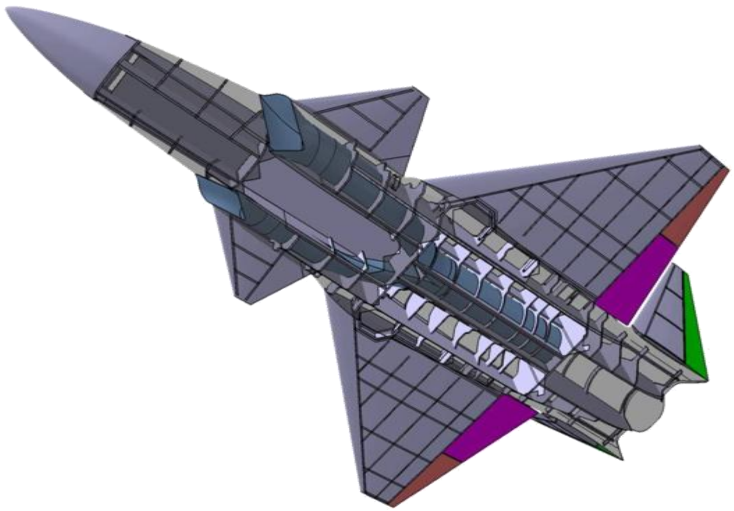
- Research study from the Swedish Material Board (FMV) initiated in 2006.
- Aeronautical design and integration of a Generic Future Fighter (GFF) with stealth capabilities, super-cruise and long range.
- Parties involved:
  - Saab AB
  - Swedish Defense Research Agency (FOI)
  - Volvo Aero
  - Linköping University (LiU)
  - Royal Institute of Technology (KTH)

Background: Specifications

- The specification of the GFF asked for:
  - Multirole
  - Stealth
  - Internal payload bays
  - Super-cruise
  - Integration of future sensors and system architecture
  - Studies of a new engine
  - Scaled demonstrator

Background:
The GFF Concept

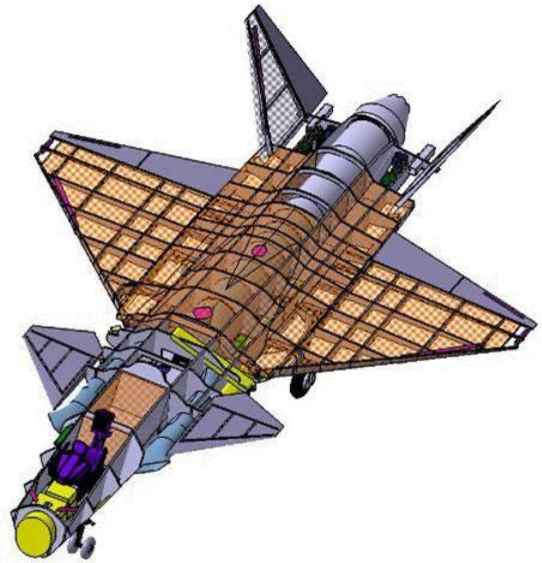
- Three internal payload bays in the fuselage
- Canard configuration (i.e. a stealthy development of the Gripen system)
- Canted fixed fins by stealth reasons
- All moveable canards

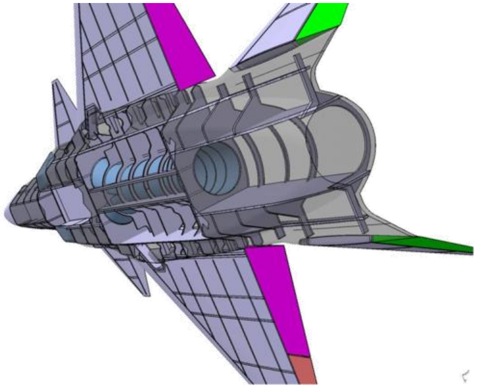


Background:
The GFF Concept

- Main characteristics:

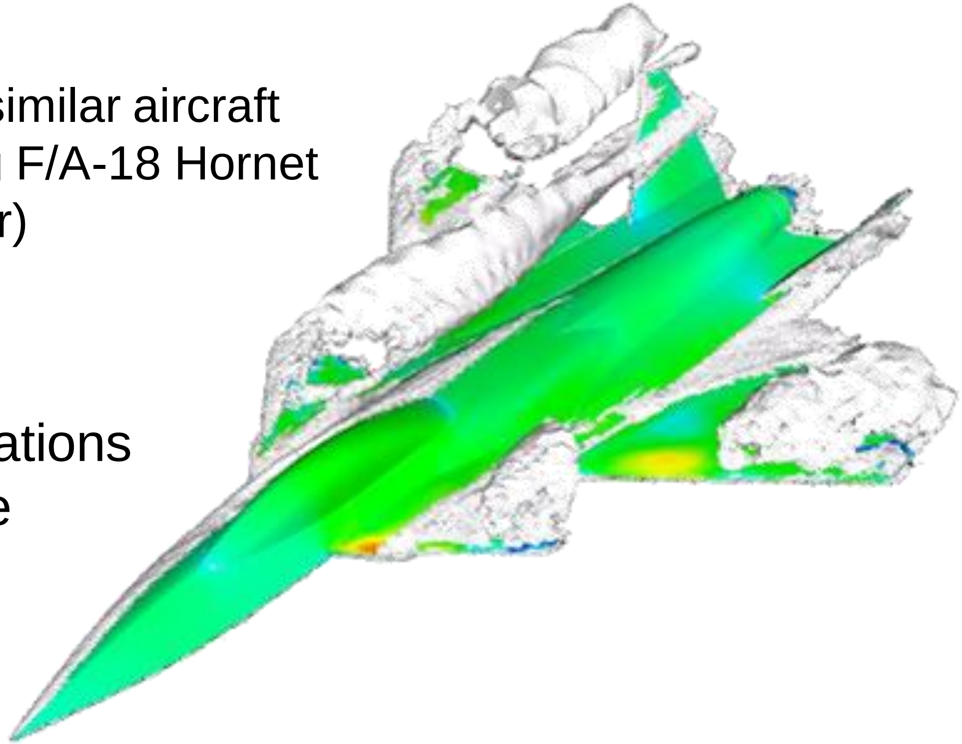
Length	[m]	17
Height	[m]	4
Span	[m]	10,5
Wing Area	[m^2]	47
OEW	[kg]	10000
Design Weight	[kg]	15400
Internal Fuel	[kg]	6200
MTOW	[kg]	23500
New Engine with AB	[kN]	170





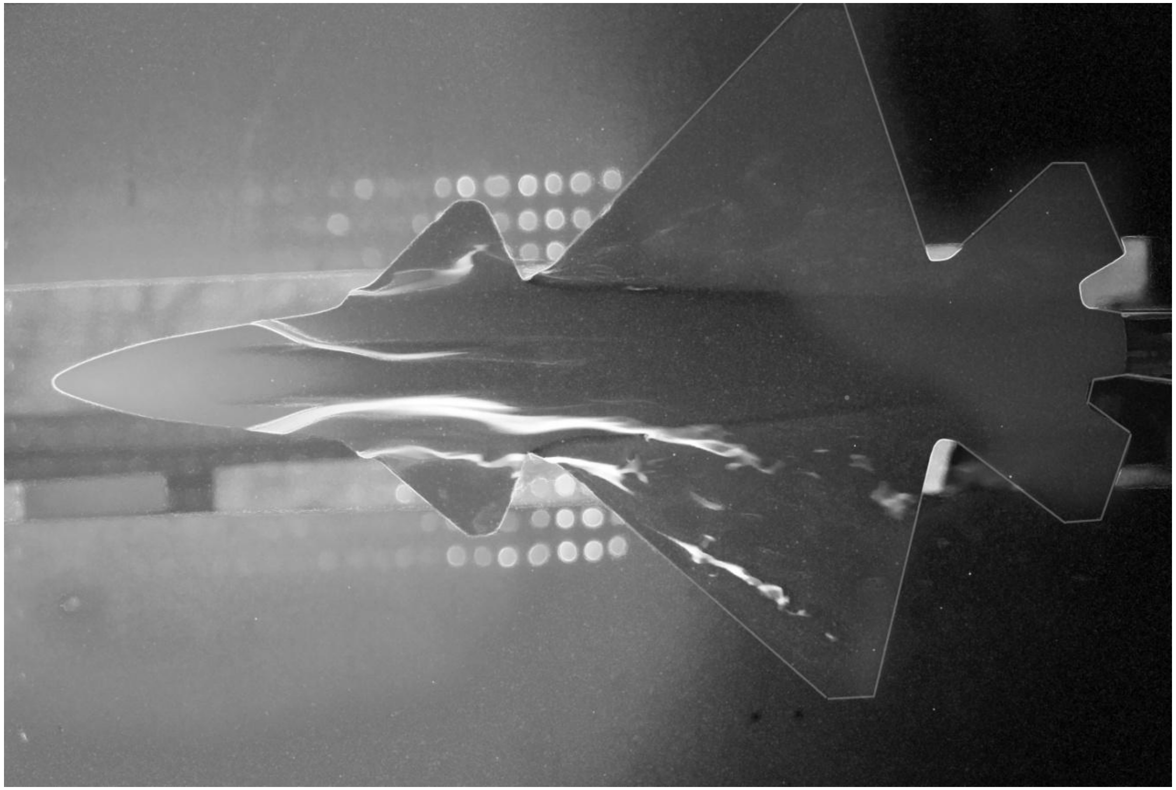
Background: Challenges

- FOI investigations confirmed interactions between vortices and fins:
  - vortices created by the sharp edges of the forebody and/or canard at high angles of attack
  - major problem in the past on similar aircraft configurations (like the Boeing F/A-18 Hornet and the Lockheed F-22 Raptor)
  - potential flutter and/or fatigue problems
- May require structural modifications and hence a heavier structure



Background
Water Tunnel Testing

- The tunnel is being used to investigate the vortex breakdown behavior and its relative location to the fin



Introduction:
Subscale Flight Testing

- Allows to evaluate the flight characteristics prior to building a full-scale prototype
- Investigate extreme, high-risk portions of the flight envelope without risking expensive prototype air vehicles
- Evaluate, demonstrate and compare high-risk platforms and technologies without the prohibitive expense of a full-scale vehicle
- Subscale flight testing is not new: several examples are available (MDD X-36, Rockwell HiMAT, Saab UCAV, NASA X-43A-LS and Gulfstream Quiet Supersonic Jet)




Flight Testing: Airfield & Test Procedures

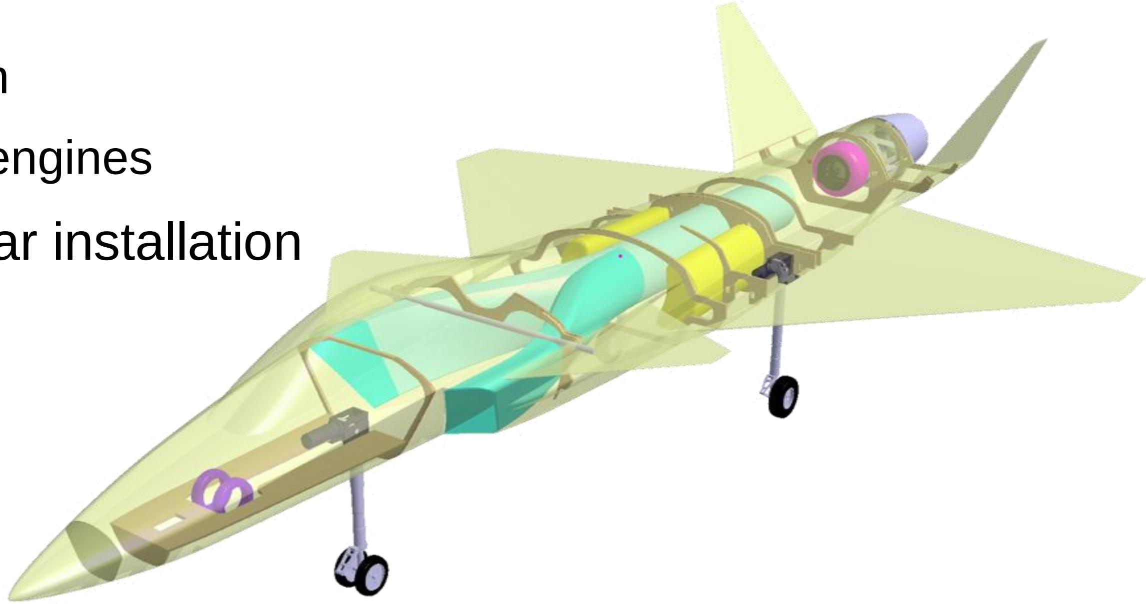
- Test site:
  - Closed military airfield
- Test procedure:
  - Pilot + one observer/system controller
  - Flight only within visual range
    no usage of autopilot
  - Flight manoeuvre / segment marking by setting timestamp flag

Available Scaling Methods

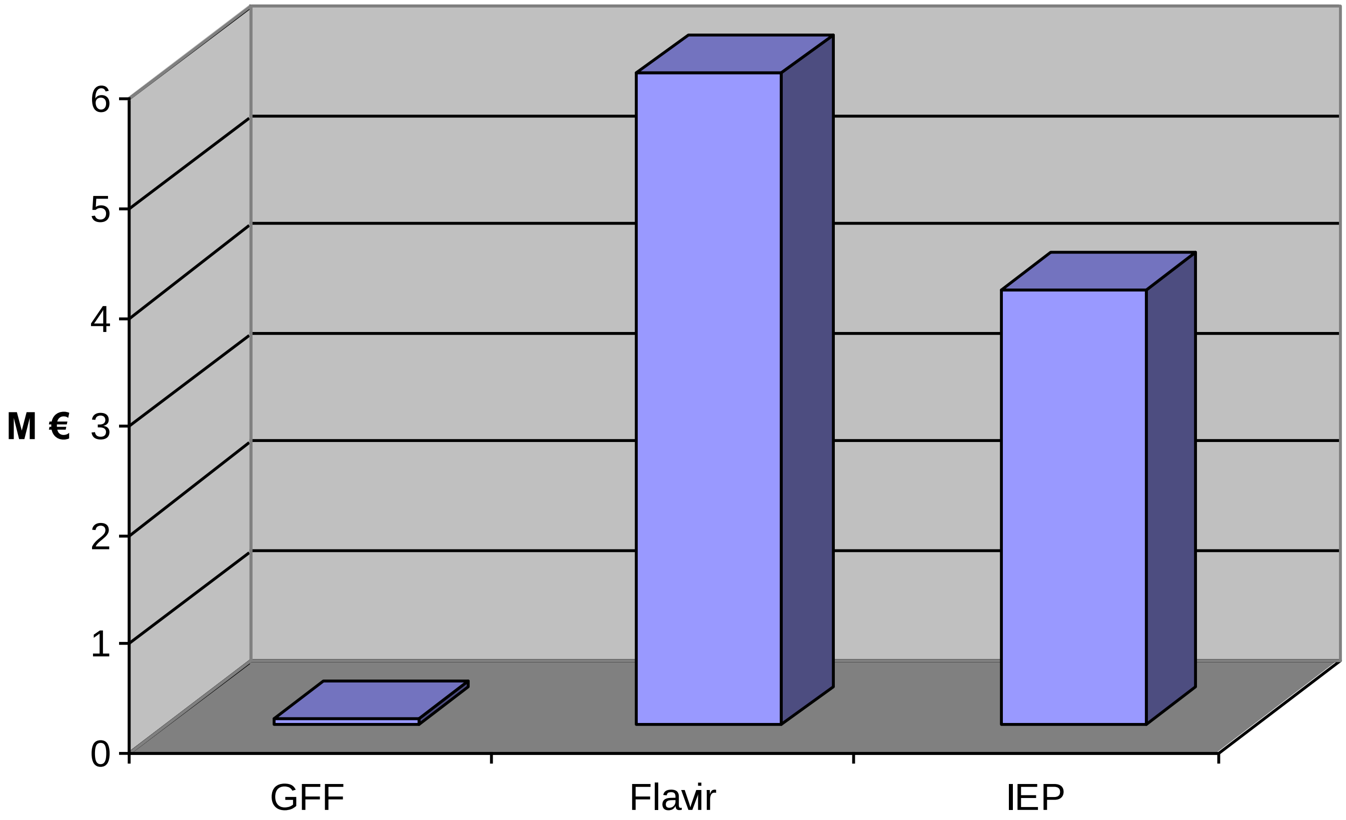
- Different scaling methods can be employed. Key scaling similarity conditions that must be met in order to achieve full similarity are:
  - Geometric similarity
  - Aerodynamics
  - Reynolds number (inertia-to-viscous forces ratio)
  - Mach number (inertia-to-pressure force ratio)
  - Inertial scaling
  - Froude scaling

Scaled Model

- 13% down-scaled demonstrator
- Main influencing factors:
  - Handling
  - Transportability
  - Weight estimation
  - Availability of jet engines
- Careful landing gear installation

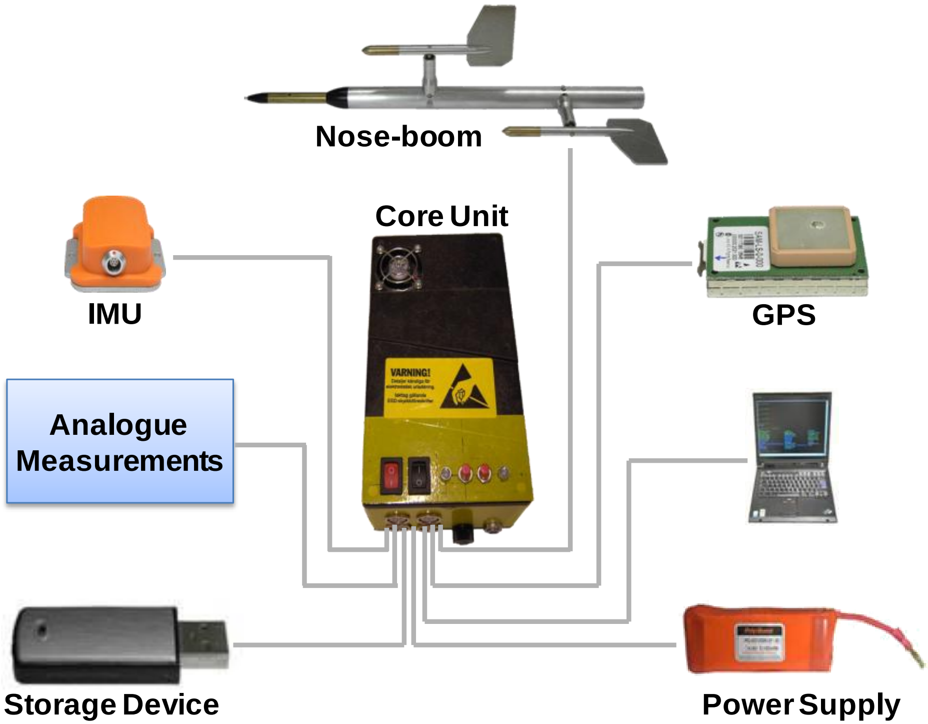


Scaled Model Cost



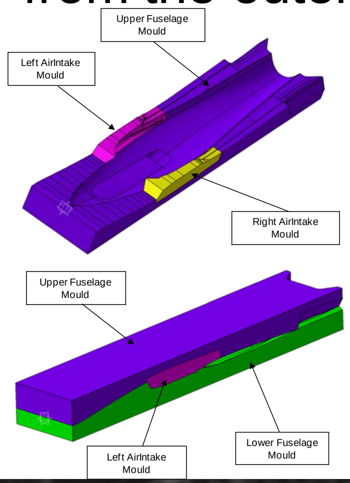
Flight Test Equipment

- The objective:
  to construct an instrumentation package consisting of both the ground and airborne package.



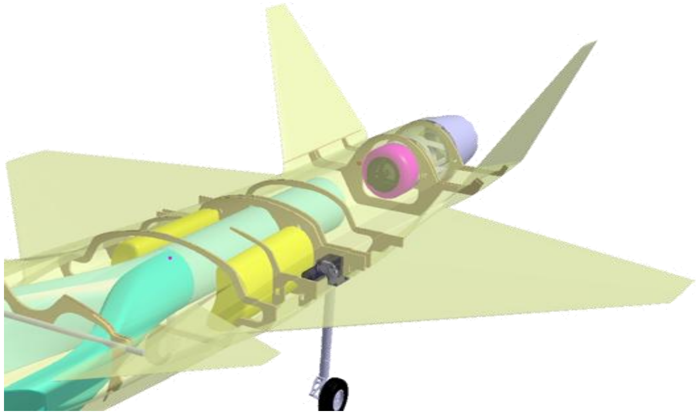
Manufacturing: General Considerations

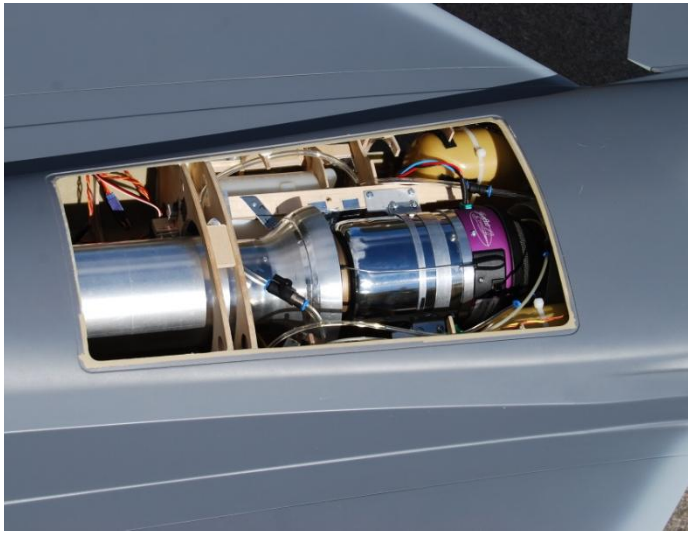
- The demonstrator is realized in composite materials with the internal structural elements of the fuselage made of plywood and carbon-fiber.
- Fuselage: sandwich of two glass-fiber layers and one Herex^{TM} sheet, cured in vacuum bags.
- The moulds were milled from RenShape^{TM} 5460 blocks directly from the outer mould-line of the aircraft defined in CATIA V5.



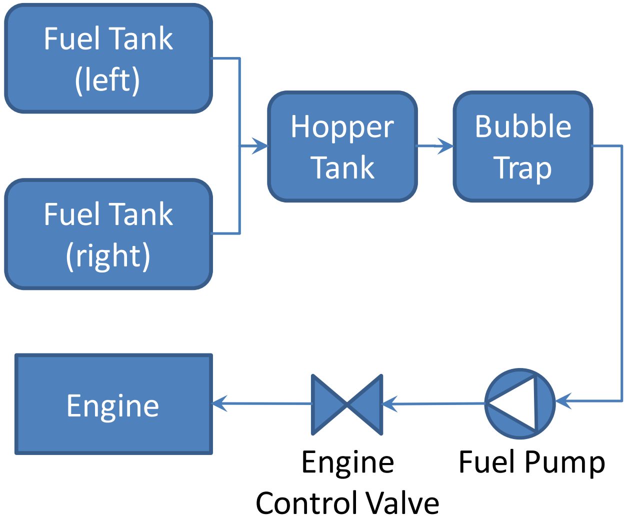
Manufacturing: Engine Installation & Fuel System

- Engine: JetCat P160
- Thrust-vectoring exhaust pipe
- Engine placement?

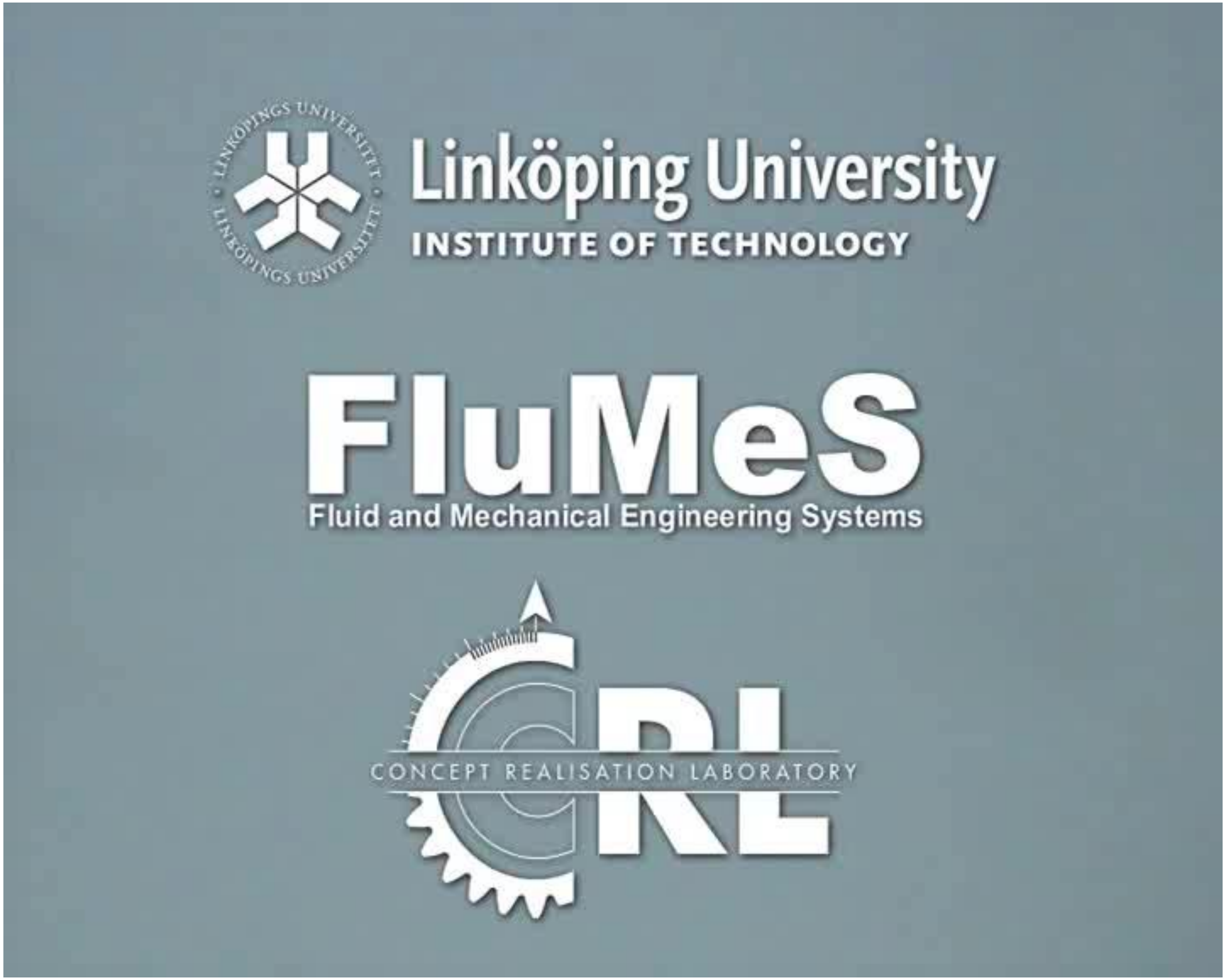




- Fuel system with 2 tanks:



Maiden Flight



Conclusions and Future Work

- GFF: the latest subscale demonstrator that has been designed and manufactured at Linköping University for a very low cost 50 k€
- Incorporates the results from a research initiated by the Swedish Material Board (FMV) in 2006
- After a successful maiden flight, the flight testing will continue during summer 2011
- Water tunnel and CFD analyses are/have been carried out and indicate that vortex brake-down at higher angles of attack seem to interact with the fins
- The demonstrator will be flown to specifically explore the effects of the vortices on the fins and the risk for potential problems

Thank you!

From left to right:

K. Amadori, D. Lundström, P. Berry, C. Jouannet, P. Krus, I. Staack
(T. Melin missing on the picture)

Scaling Method: Froude Scaling

- In this project Froude scaling is used, originating from the similarity parameter Froude number N_{Fr}:

$$N_{Fr} = \frac{V^2}{\ell \cdot g}$$

- The method compensates for inertial and gravitational effects, assuming that two objects flying at different speed, altitude, etc. have the same Froude number.
- From the conversion factor n, a wide spectrum of quantities can be derived, i.e.:

$$\frac{\ell_{\mathrm{M}}}{\ell_{\mathrm{A}}} = \mathrm{N}_{Fr} \quad \rightarrow \ell_{\mathrm{M}} = \mathrm{N}_{Fr} \cdot \ell_{\mathrm{A}}$$

Scaling Method: Froude Scaling

Scale	Size [mm]	Wing Span [mm]	Weight [kg]	Design Weight [kg]
1,00	17000	10500	23500	15400
0,17	2890	1785	115,456	75,660
0,16	2720	1680	96,256	63,078
0,15	2550	1575	79,313	51,975
0,14	2380	1470	64,484	42,258
0,13	2210	1365	51,630	33,834
0,12	2040	1260	40,608	26,611
0,11	1870	1155	31,279	20,497
0,10	1700	1050	23,500	15,400

Europeen Student project

- Goals
  - Run a common aircraft design project at different university
  - Work shearing
  - Usage of common tools
  - From concept to flying prototype (scaled or not)
  - Run as a “mini company” with a steering board
  - Enable student to work within a “real project” during education
- Spread design teams