Development of an Experimental tilt-wing VTOL Unmanned Aerial Vehicle

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Thesis Presentation

Overview

- Introduction
- Project Goals
- Flight System Development
- Simulink Simulation
- Control Demonstration
- Results & Conclusions
- Acknowledgements

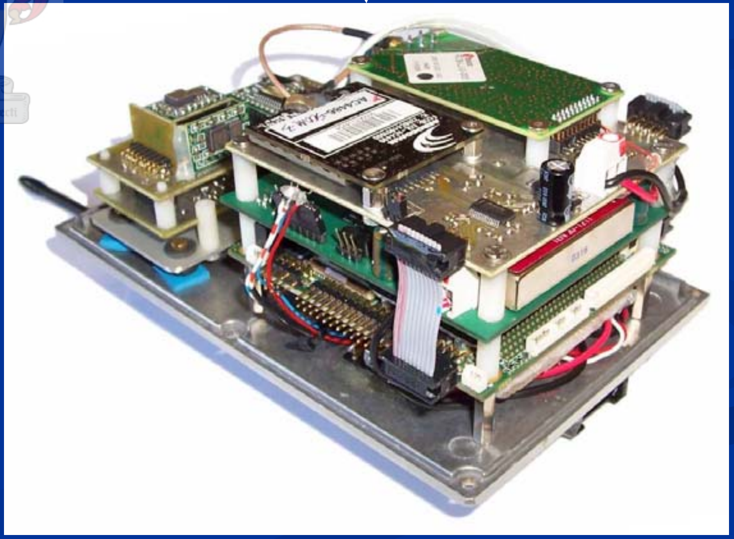
Introduction

- Started in 1980's in SA
  - Seeker (bottom)
  - Vulture (top)
- Started in ESL in 2001
  - Small Electric Helicopter
  - Fixed Wing Airplane
  - Methanol-powered Helicopter
  - Experimental VTOL
  - Takeoff/Landing
  - Acrobatic flight

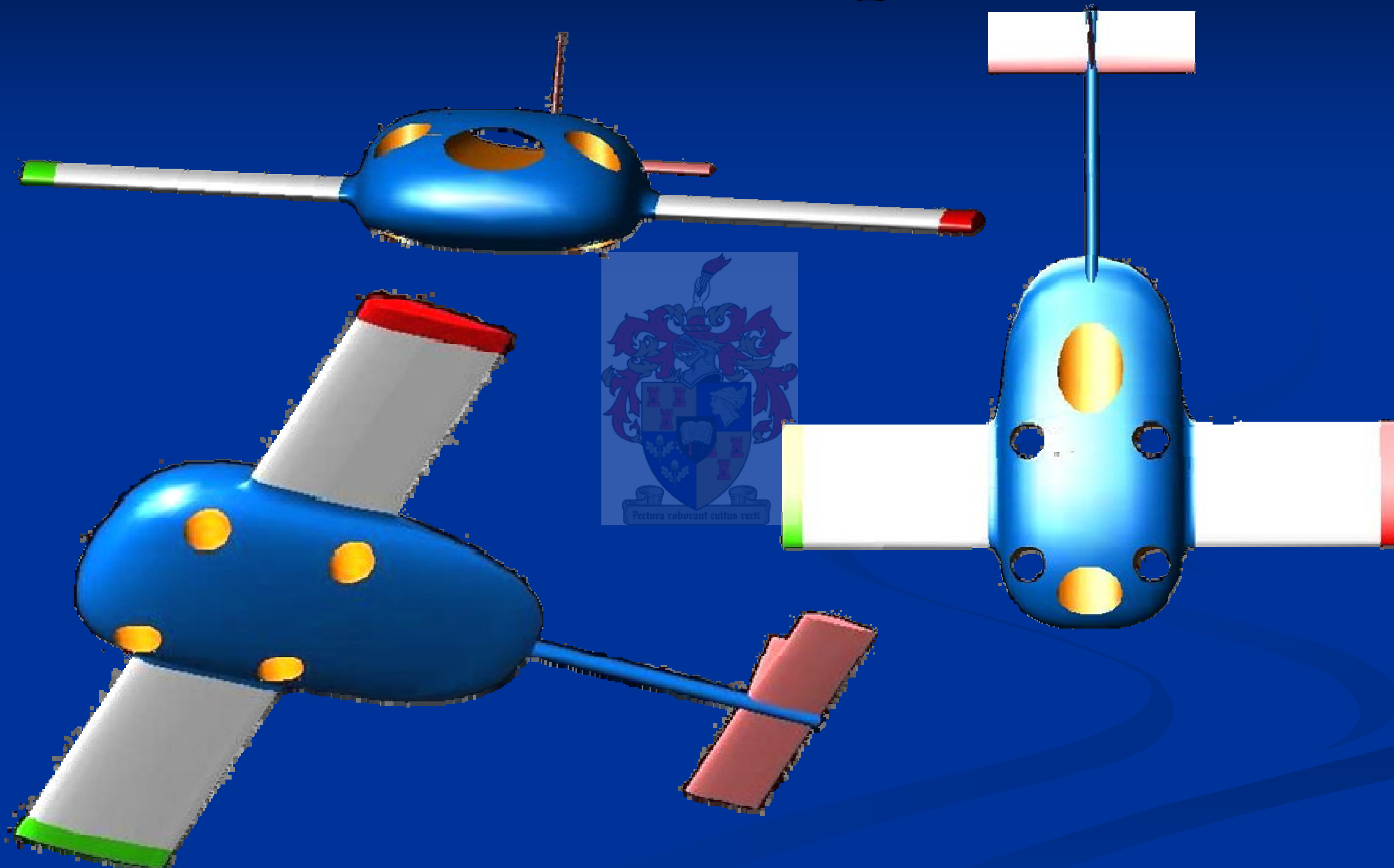
Project Goals

- To develop an airframe
- To develop sensors and avionics
- To model this airframe and simulate it
- To control this airframe using the developed avionics
- To provide a solid basis for similar future projects

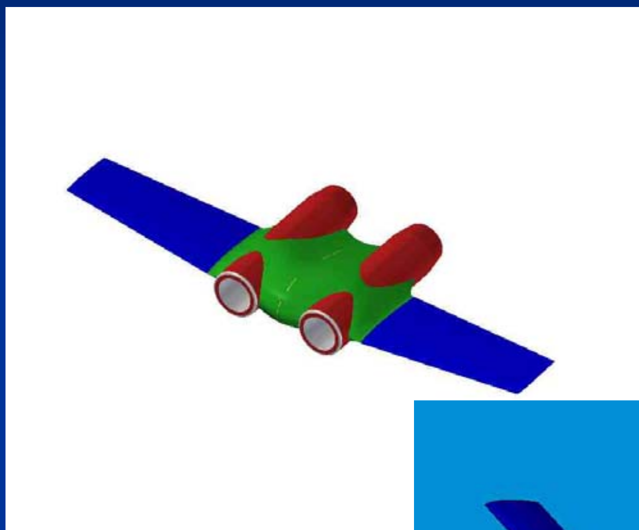
Flight System Development

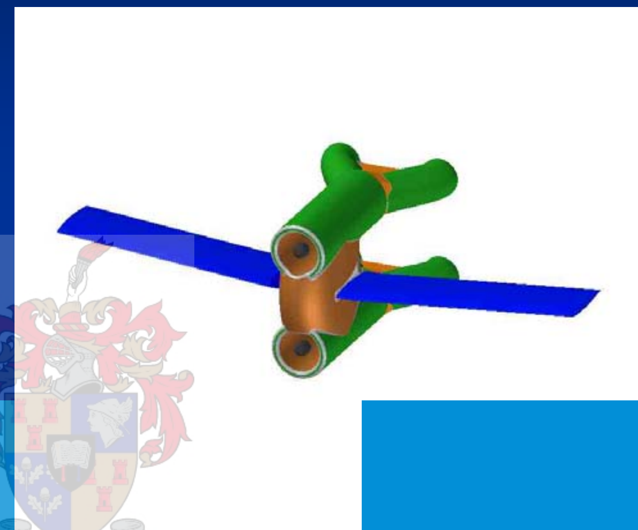


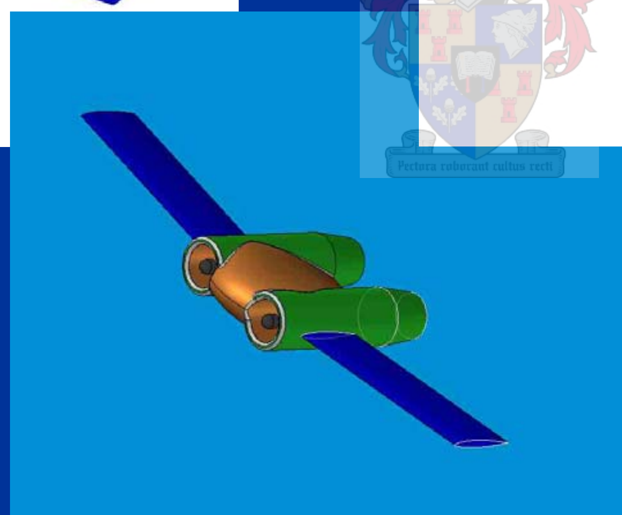
Airframe Development…

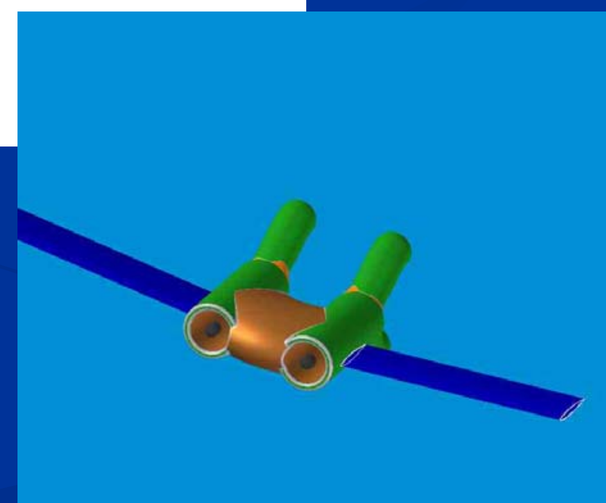


…Airframe Development…





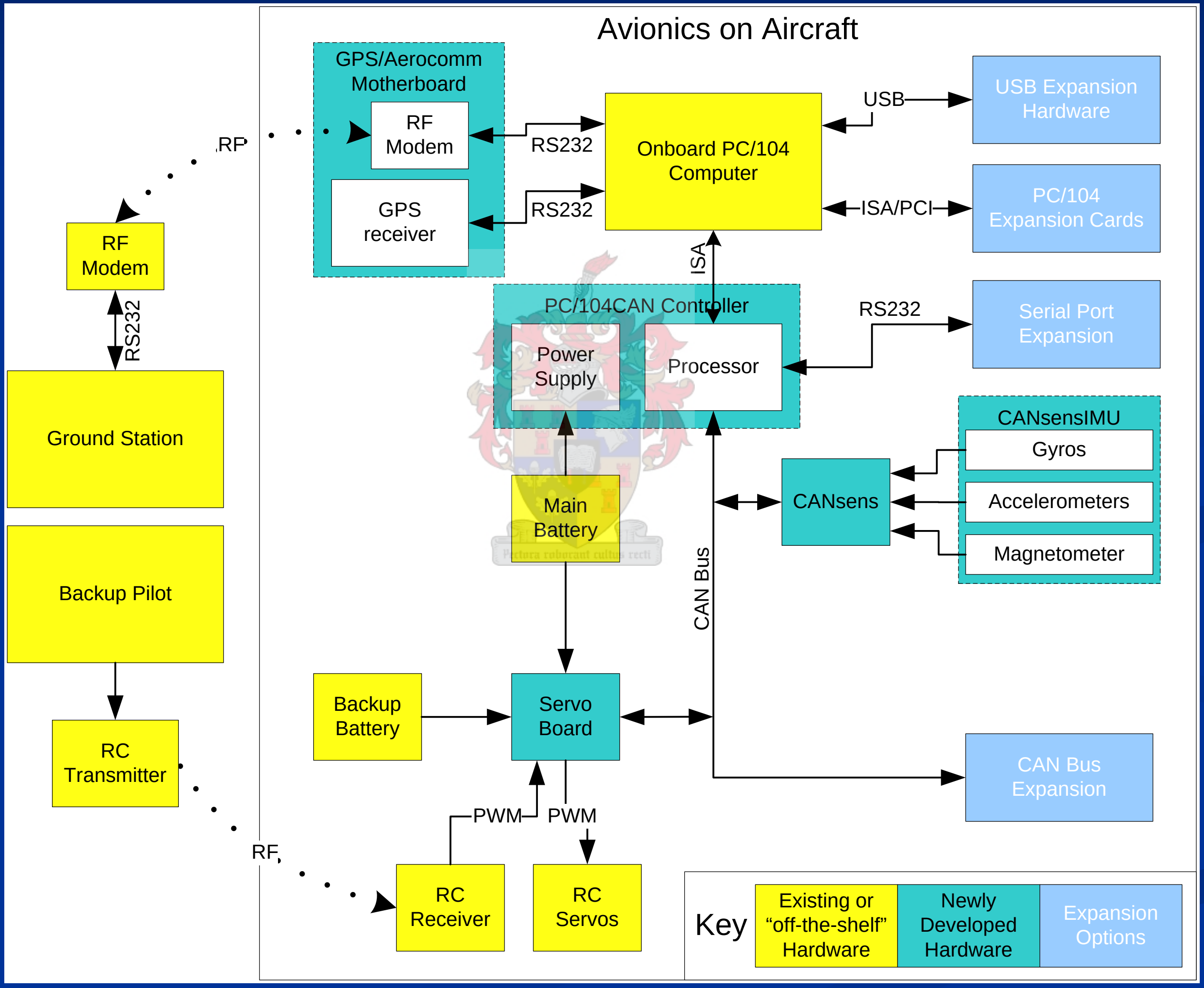




…Airframe Development

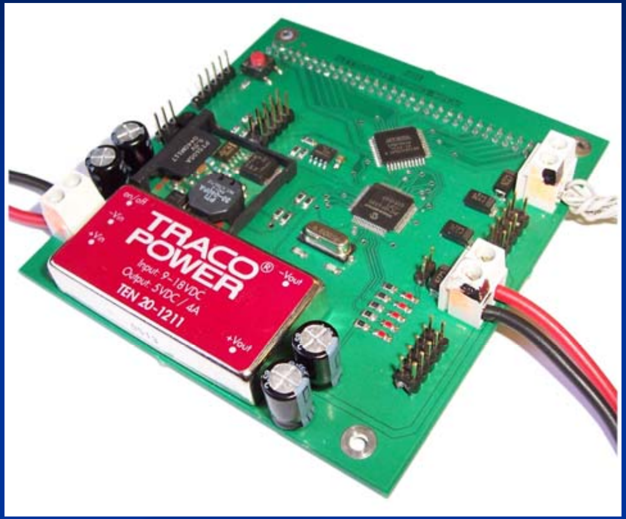
- Thrust: 11.5kg
- Weight: 8.25kg
- Power source:
  - 1×11.1V LiPo Battery
  - 1×4.8V NiCad Battery
  - 2×36V LiPo Battery
- Flight Time: 5 minutes
- Total Servos: 8

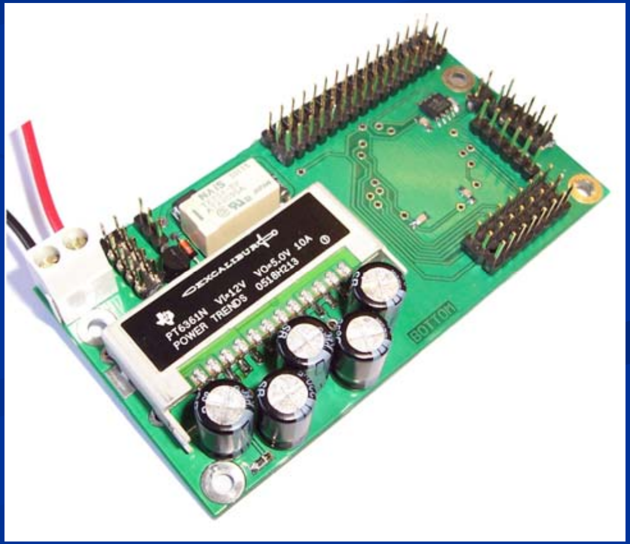
Avionics Development…



…Avionics Development…

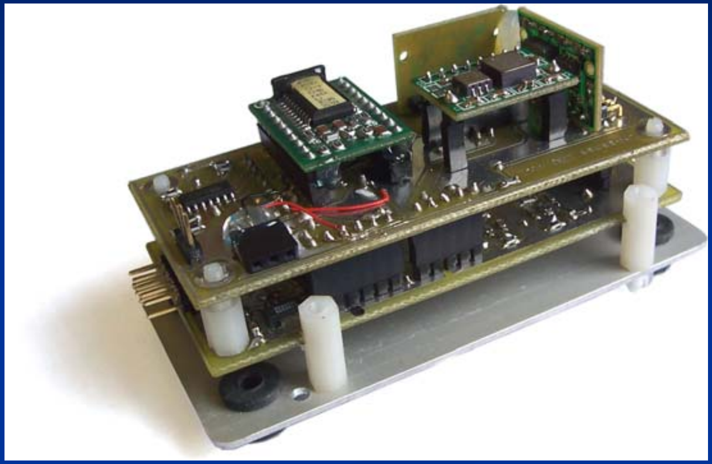
- PC104CAN Board
  - CAN Communication
  - Timing
- Servo Board
  - Backup Battery
  - Drive Servos
  - Backup Pilot Interface





…Avionics Development…

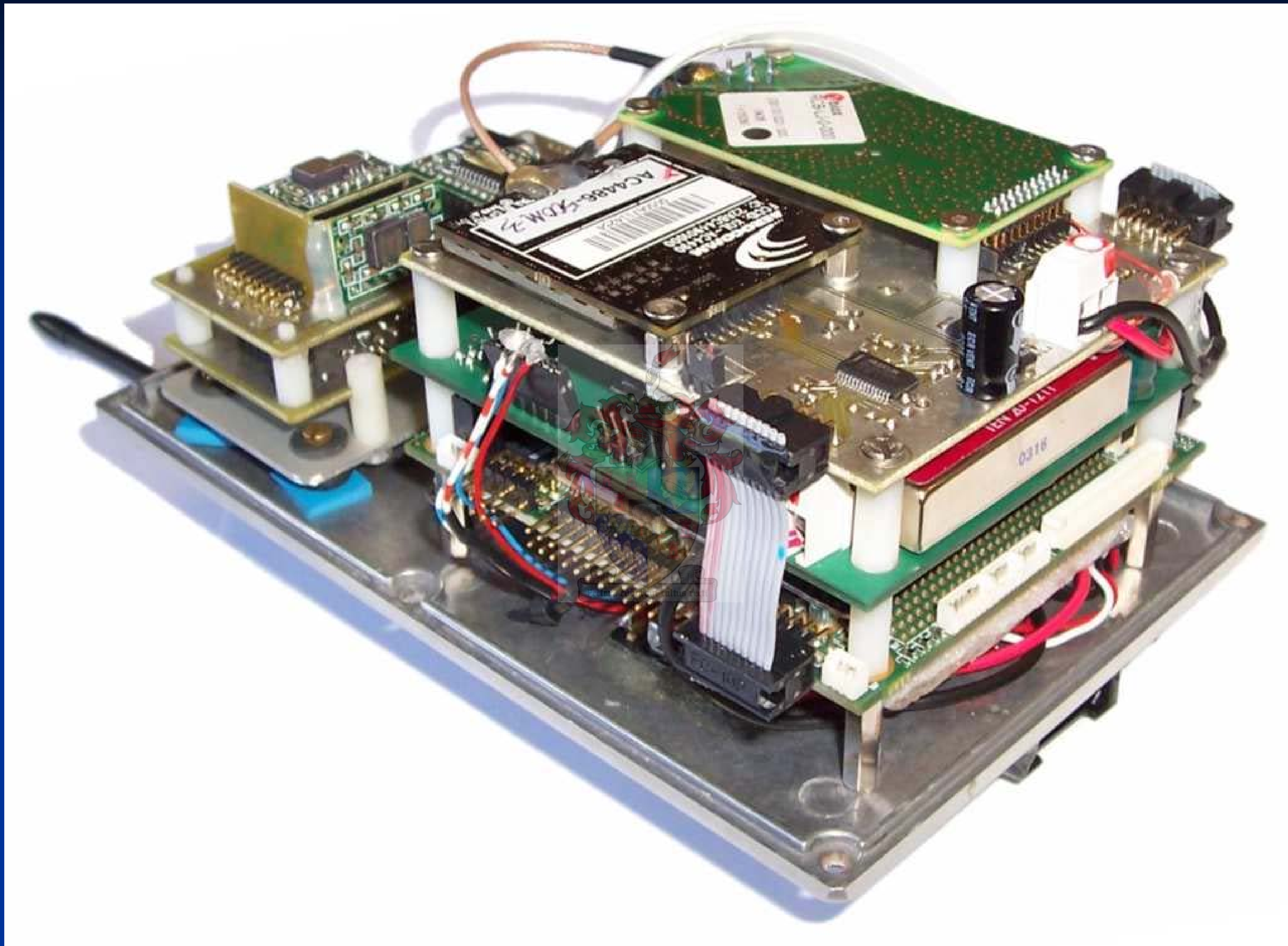
- IMU
  - Inertial (Rotation and Lateral) Measurement Unit
  - Developed by Fanus Groenewald and Johan Bijker



- GPS/Aerocomm Board
  - Houses GPS receiver and radio Modem
  - Developed by Fanus Groenewald

…Avionics Development

- Main Processor
  - Fanless Intel® PIII Celeron® 300MHz CPU
  - 2xRS232 Serial Ports
  - 2xUSB Controllers
  - 64MByte RAM
- 32MByte Solid-state IDE HDD
- All RC equipment standardized on JR ("Japan Radio")



Modelling…

- Forces & Moments calculated as a function of Total Thrust and Paddle Angles
- Airframe Moment of Inertia calculated using the Torsion Pendulum
- Total Expected Weight Calculated
- 6 Degrees of Freedom Dynamic Equations
- No aerodynamics

…Modelling

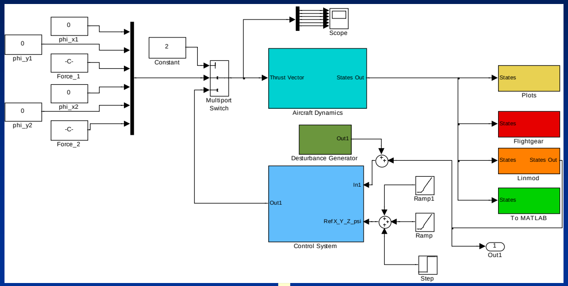
All measurements is with aircraft in VTOL configuration														
	l	**d**	**T**	**m**	**g**	**Total Time**	**Total Osc**	**J**	**Dist From CG**	**J around CG**	**CG**	(0;0;0) is middle of rod		
Roll Inertia	3.1	0.5	2.9	1.474	9.8	47.1	16.0	0.2	0.0	0.2	X	0.0	**Wing**	
Pitch Inertia	1.4	0.2	1.5	1.474	9.8	46.3	30.0	0.0	0.0	0.0	Y	0.0		
Yaw Inertia	3.1	0.5	3.3	1.474	9.8	42.6	13.0	0.3	0.0	0.3	Z	0.0		
Roll Inertia				1.054				0.0	0.3	0.1	X	0.0	**Mot&Mnt**	**Starboard**
Pitch Inertia				1.054				0.0	0.1	0.0	Y	0.3		
Yaw Inertia				1.054				0.0	0.3	0.1	Z	-0.1		
Roll Inertia				1.054				0.0	0.3	0.1	X	0.0		**Port**
Pitch Inertia				1.054				0.0	0.1	0.0	Y	-0.3		
Yaw Inertia				1.054				0.0	0.3	0.1	Z	-0.1		
Roll Inertia				1.141				0.0	0.2	0.1	X	0.0	**Battery**	**Starboard**
Pitch Inertia				1.141				0.0	0.1	0.0	Y	0.2		
Yaw Inertia				1.141				0.0	0.2	0.1	Z	0.1		
Roll Inertia				1.141				0.0	0.2	0.1	X	0.0		**Port**
Pitch Inertia				1.141				0.0	0.1	0.0	Y	-0.2		
Yaw Inertia				1.141				0.0	0.2	0.1	Z	0.1		
Roll Inertia	2.2	0.3	1.5	1.385	9.8	44.6	30.0	0.0	0.1	0.0	X	-0.2	**Fuselage**	
Pitch Inertia	2.3	0.4	2.7	1.385	9.8	53.3	20.0	0.2	0.2	0.2	Y	0.0		
Yaw Inertia	2.3	0.4	2.7	1.385	9.8	63.8	24.0	0.2	0.1	0.2	Z	0.1		

Total Aircraft Moment of Inertia about CG					
	Wing	Motor	Battery	Fuselage	**Total**
Roll Inertia	0.21	0.23	0.11	0.034	**0.5781**
Pitch Inertia	0.02	0.03	0.01	0.208	**0.2597**
Yaw Inertia	0.26	0.20	0.11	0.194	**0.7600**

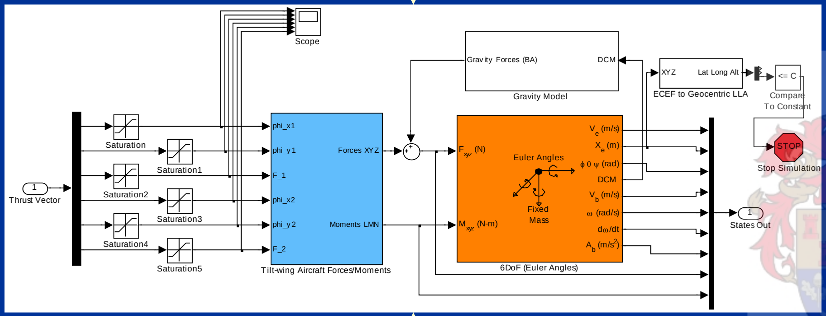
Total Aircraft Weight
7.249

Aircraft CG	
X	-0.0305
Y	0.0000
Z	0.0433

Simulink Simulation



Dynamics

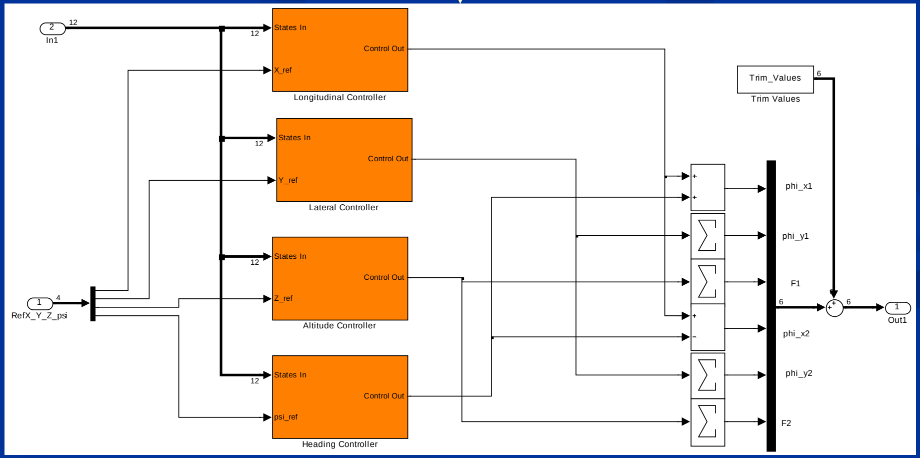


$$F_x = \frac{F \tan \phi_x}{\sqrt{1 + (\tan \phi_x)^2 + (\tan \phi_y)^2}}$$

$$F_y = \frac{F \tan \phi_y}{\sqrt{1 + (\tan \phi_x)^2 + (\tan \phi_y)^2}}$$

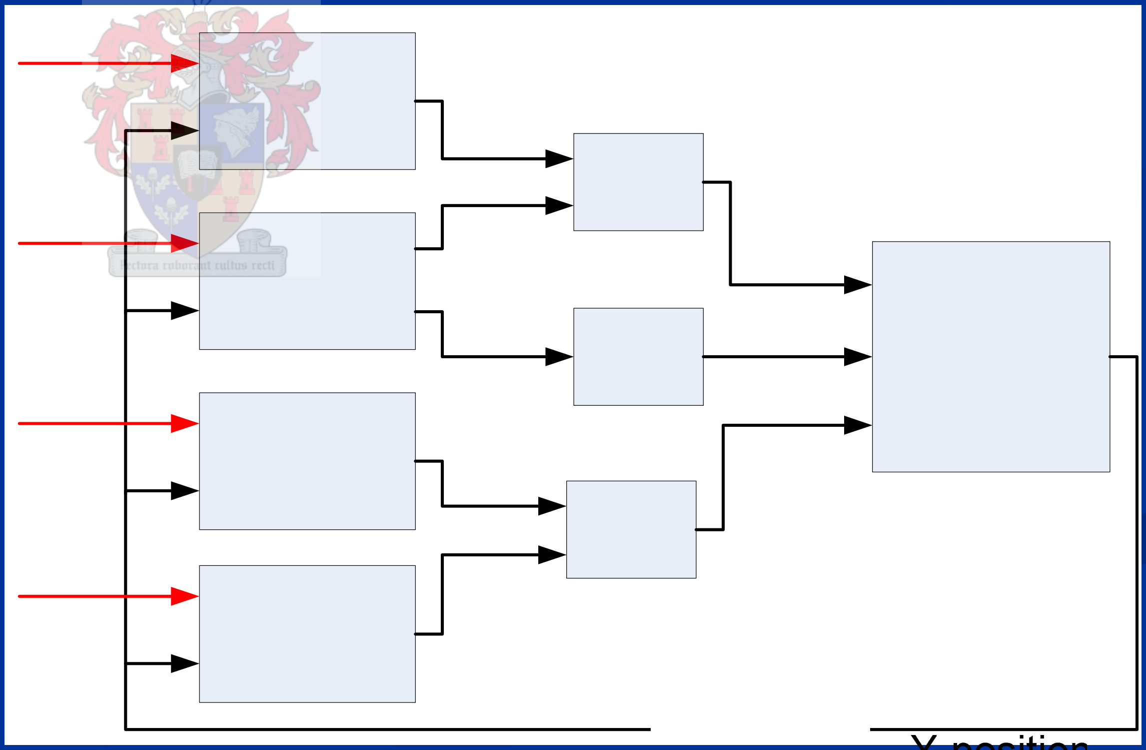
$$F_z = \frac{F}{\sqrt{1 + (\tan \phi_x)^2 + (\tan \phi_y)^2}}$$

Controllers



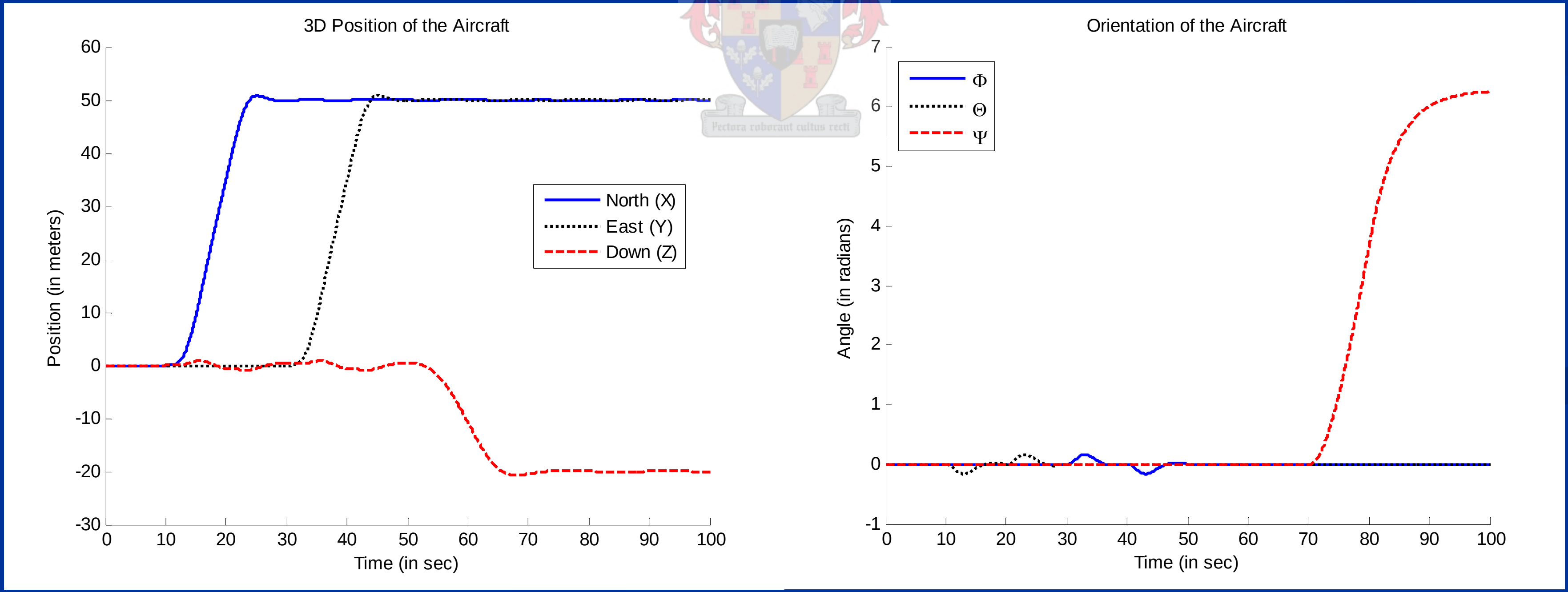
Control Demonstration…

- Controller split into four smaller Controllers (models acquired with decoupling):
  - Lateral (Y)
  - Longitudinal (X)
  - Altitude (Z)
  - Heading (Ψ)
- LQR



…Control Demonstration

- 20m step command ($2m.s^{-1}$ ramp) on X, Y and Z after 20, 40 and 60 seconds respectively
- 360° heading step command (18°/s ramp)



Results & Conclusions

- Results:
  - Useful Modular Avionics was developed
  - A new experimental airframe was built
  - Acceptable control results were obtained
  - Simulink model can easily be augmented with aerodynamics, etc.
- Conclusions:
  - Provides a foundation for future projects
  - Simulation suggests control is possible

Acknowledgements

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- Thomas Jones
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- Johan Bijker
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THE END