2nd Brazilian Swedish Workshop in Aeronautics and Defence

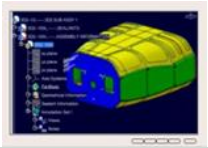
FADEMO - Research Collaboration for Future Capabilities

Petter Krus

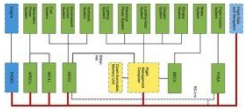
Swedish *at ITA*

WHAT DOES AERONAUTICS CONTAIN ?

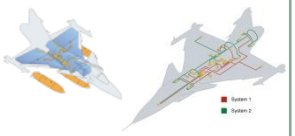
Aeronautical Engineering



Computer Systems



Vehicle Systems



Human-Machine Interaction

Autonomy & Decision Support

Maintenance Systems

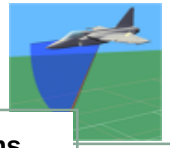
Systems Integration

- Systems of Systems Integration
- Decision support
- Operational Analysis
- Concept Design
- Overall Design and Architecture
- Survivability
- Safety & Reliability
- ILS, Availability and Maintainability

Tactical System

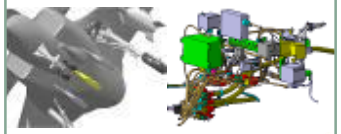
Weapons Integration

Flight Test and Verification



Structural Technology

Airframe Design

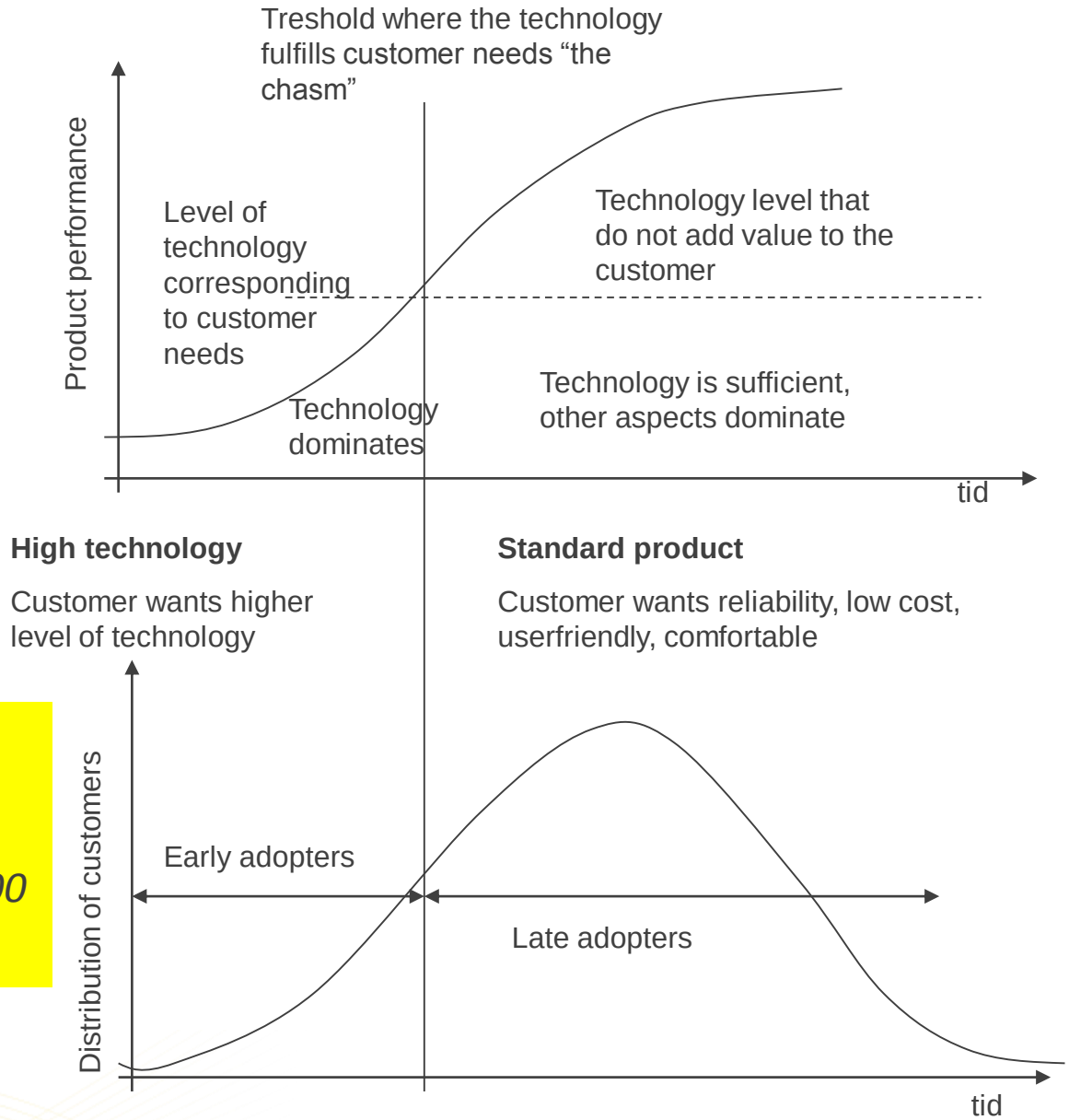


Production Systems

Support Systems and Simulators

Engineering Methods & Tools

Development phases



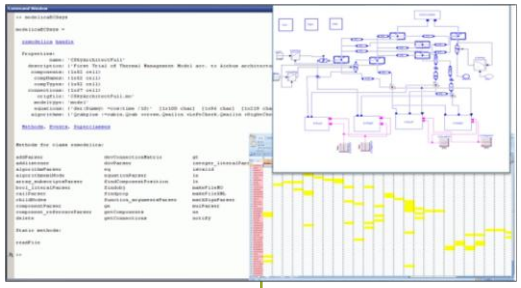
- *A car costs ca 10 $/kg*
  - *(Like a hamburger)*
- *A military aircrat costs 100-1000 times more*

Conceptual Aircraft Design (LiU/Saab)

SIZING AND AERODYNAMICS

Matlab

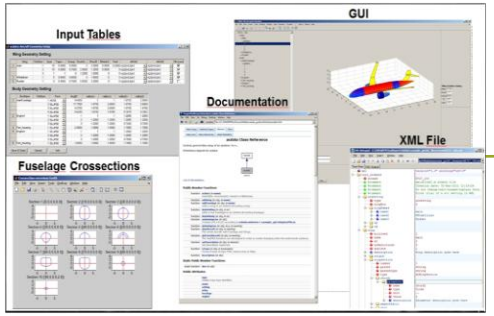
- **Tango -** Aircraft sizing
- **Tornado**- Aerodynamics



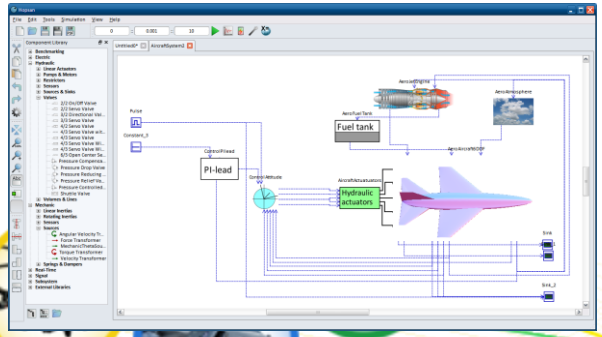
Modelica (Dymola)

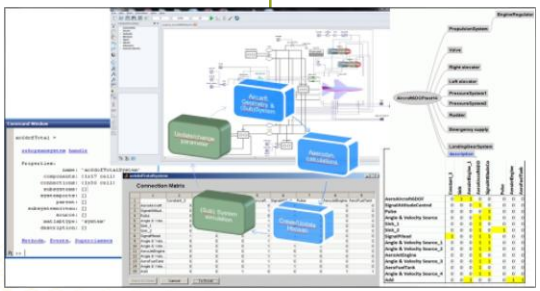
CATIA

RAPID

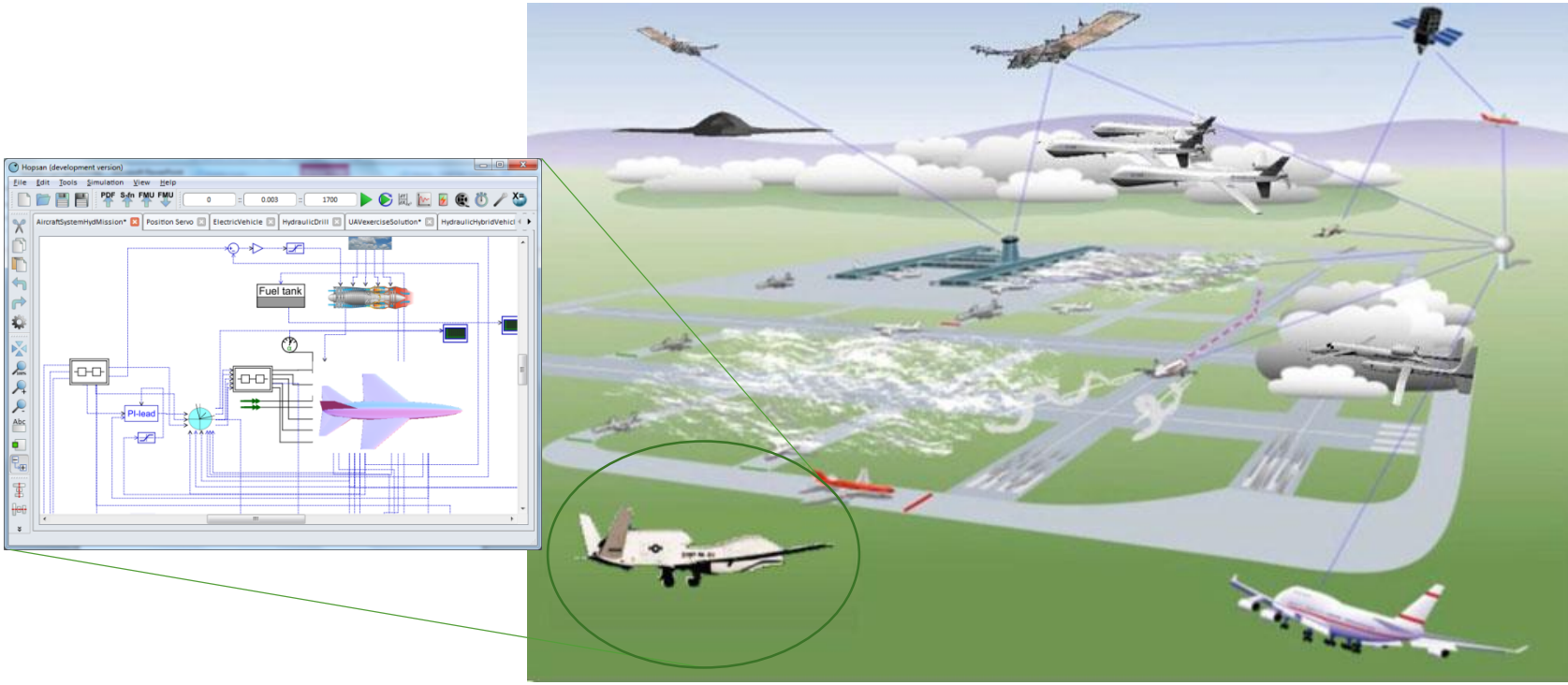


Hopsan





System of systems



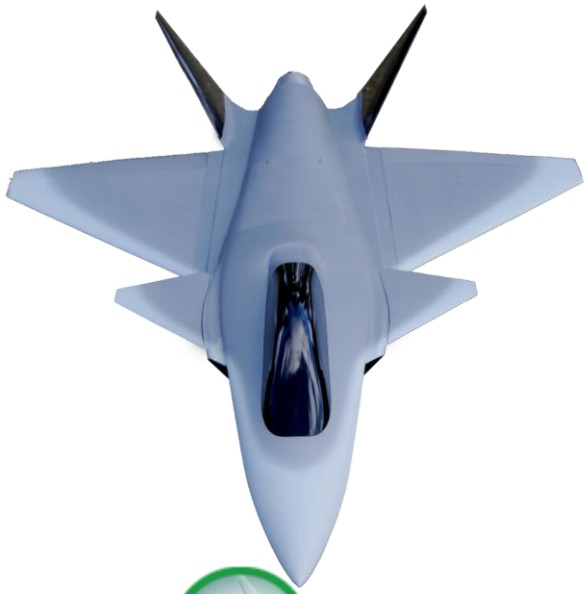
Simulation for operational analysis
and subsystem verification

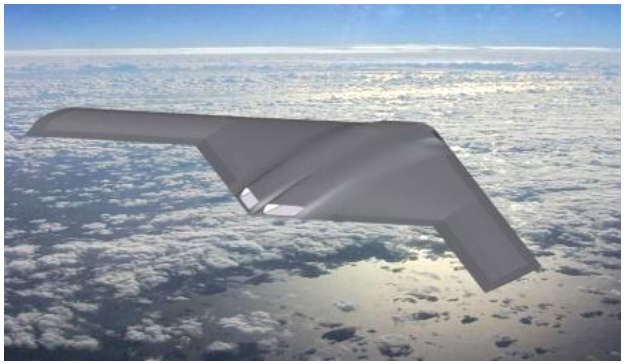
Bilateral Research Project

- FADEMO - Future Combat Aircraft Design Study and Demonstration
  - MSDEMO- Methods for Scaled Demonstrator Development
    - Swedish subset (Innovair)

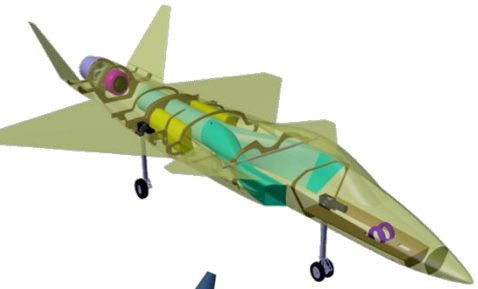
New Project: Future Combat Aircraft Design Study and Demonstration, FADEMO

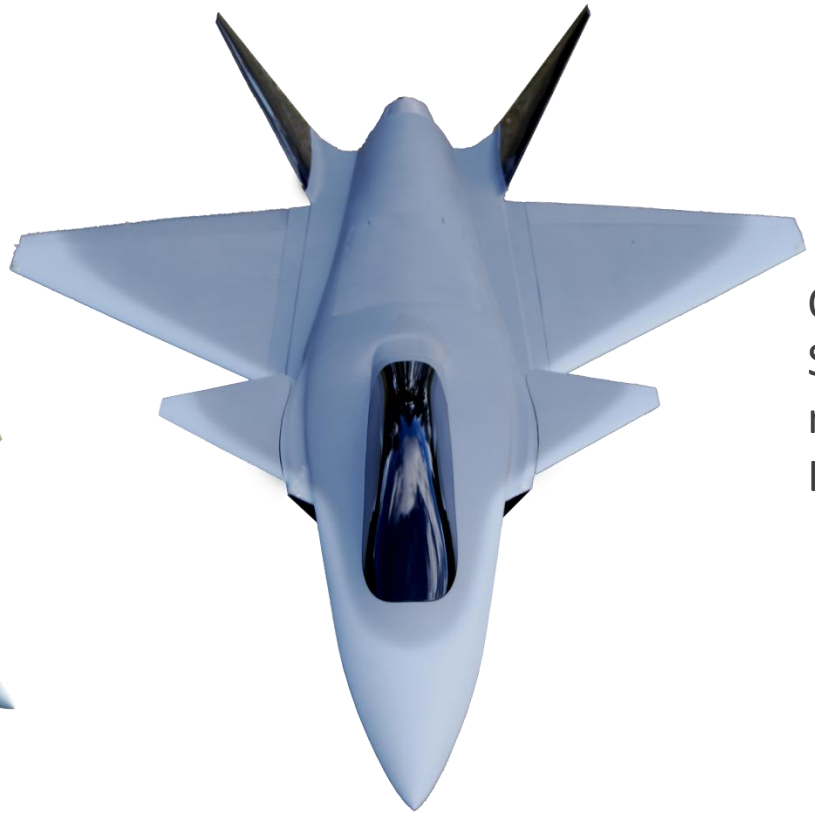
- Subscale flight testing for early evaluation of new concepts





Generic Future Fighter (GFF) Subscale Demonstrator





Concept developed by Saab
Subscale demonstrator build on request from FMV and Saab at Linköping University

Real Jet Engine with
170 N thrust a
Length 2.4 m
Span 1.5 m
Weight 15 kg
13% scale

FADEMO - Future Combat Aircraft Design Study and Demonstration

- Development of a scaled fighter that will serve to test different technologies for the future combat aircraft design.
- Subscale prototyping and flight test capability proposed platform LiU - GFF (Generic Future Fighter) for a subscale flight test mission.
- Accomplished result: definition of a larger project that would continue to the end of 2016, the GFF2, considering additionally:
  - (i) Dynamic scaling;
  - (ii) Prototype with variable (relaxed) static margin;
  - (iii) Control system implementation to fly in a relaxed stability/instable configuration;
  - (iv) Model identification on the basis of flight test data

FADEMO and - Future Combat Aircraft Design Study Demonstration

- Scaling can be done in many aspects:
  - Aerodynamic scaling for investigation of aerodynamic phenomenon
  - Dynamic scaling in order to investigate the behaviour of a concept
- Typical areas of application for military concept would be:
  - Dynamic stability and control
  - Flight at high angles of attack
  - Spinning and recovery
  - Associated aerodynamic tests
  - Control law testing

- Opportunity to present common research results from BR and SWE universities, showing the value of collaboration abroad boarders.
- Tangible results obtained from the collaboration will be:
  - A scaled demonstrator with flight test instrumentation allowing testing of control laws
  - **A unique aerodynamic data set based on CFD, wind tunnel data and flight test data that will be make available to the entire aerospace community. This data set provides opportunity to publication with high citations potential and good exposure of a unique collaboration.**

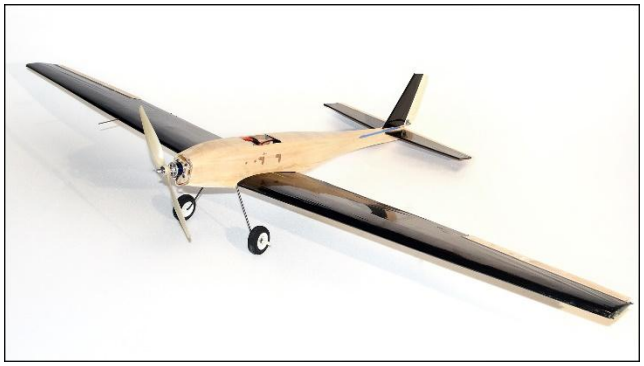
Master thesis project

Alejandro Sobrón Rueda

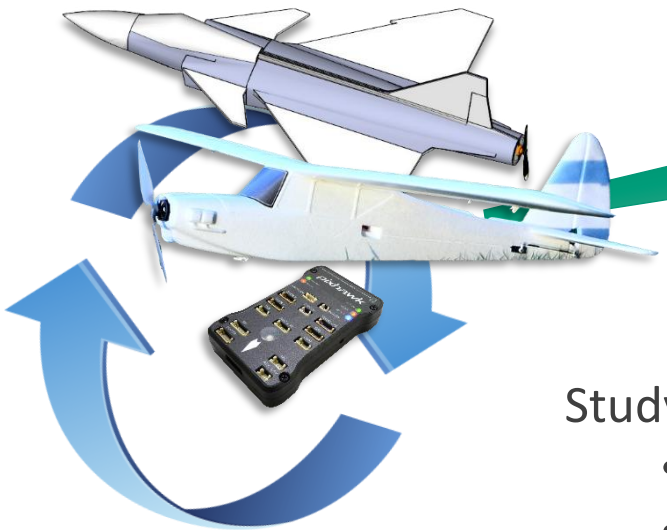
- Final project work for the degree of MSc Aeronautical Eng.
- Carried out between January-June 2015
- Full length report openly published by Linköping University Electronic Press
- Pre-study for some of the MSDEMO project goals
- Awarded Third Place in the European Young Researcher Competition at Aerodays 2015 (Royal Aeronautical Society, London)

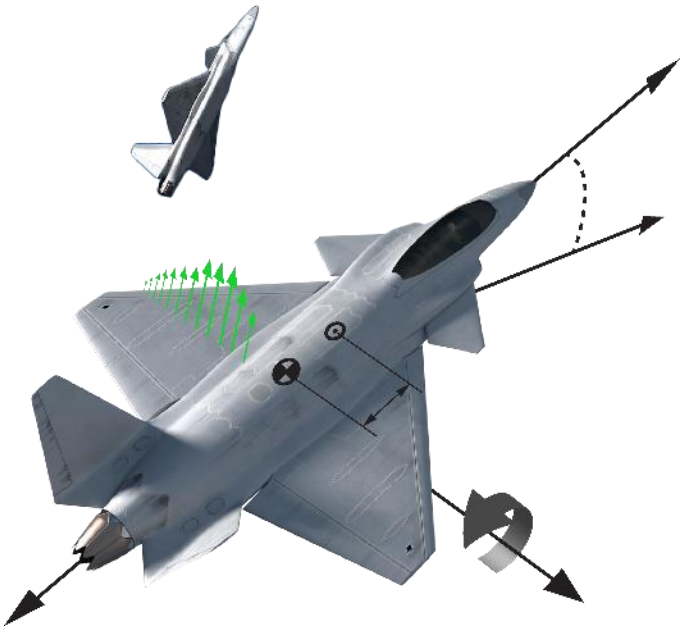
Subscale testing – test aircraft at LiU

Subscale testing – model aircraft used in initial phase



Project aim

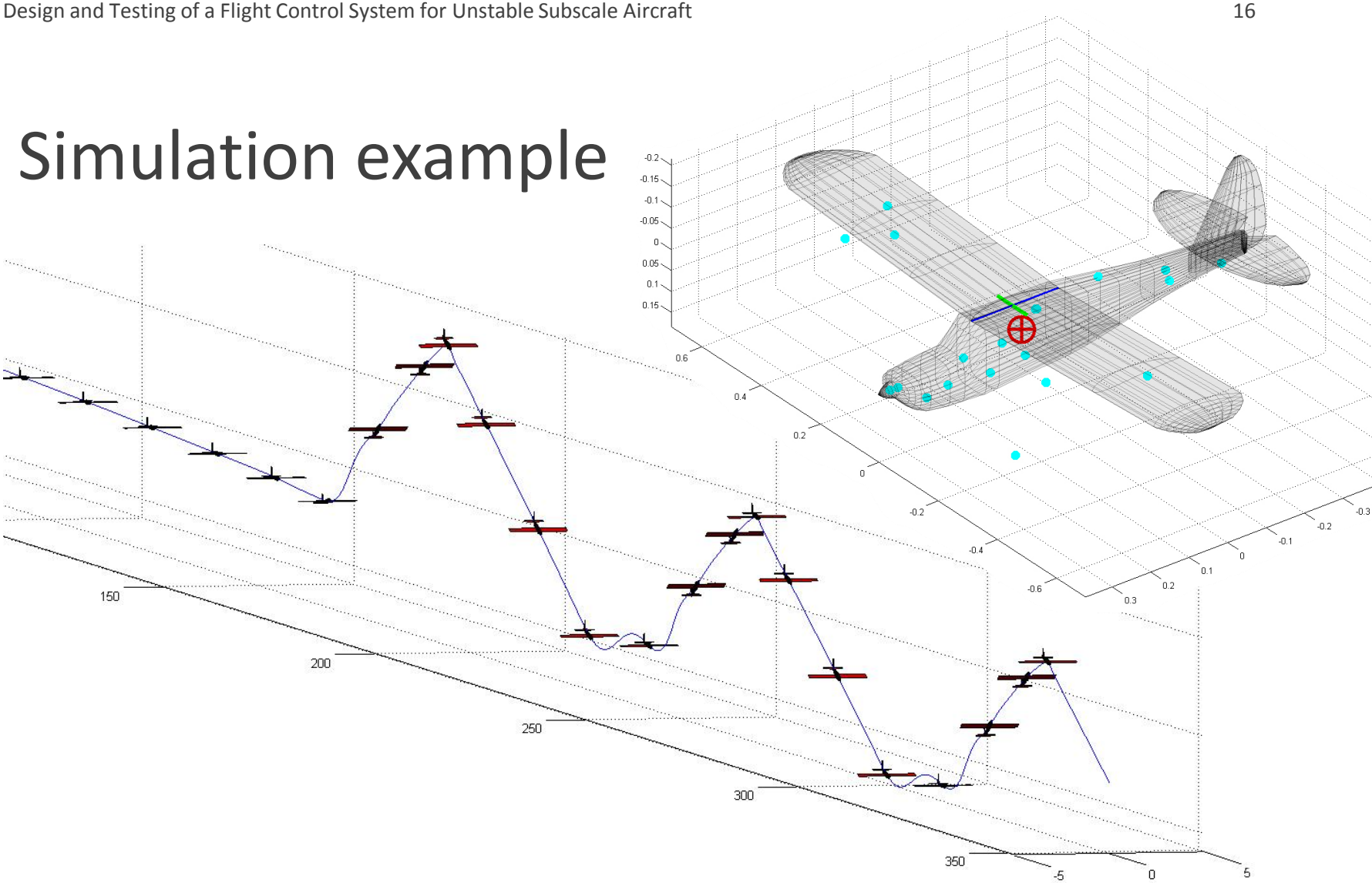


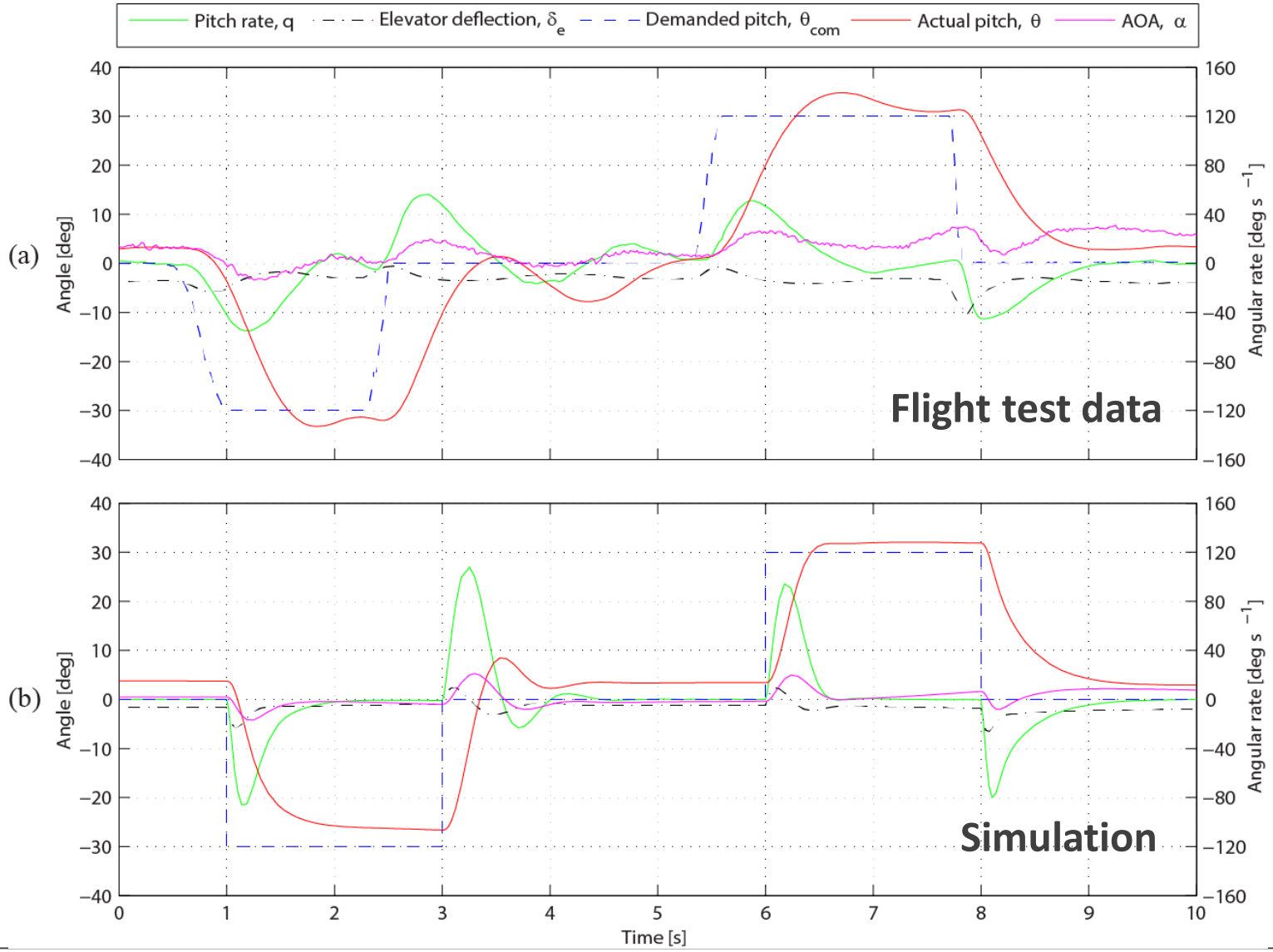


Study implementation of a **low-cost FCS**, allowing:

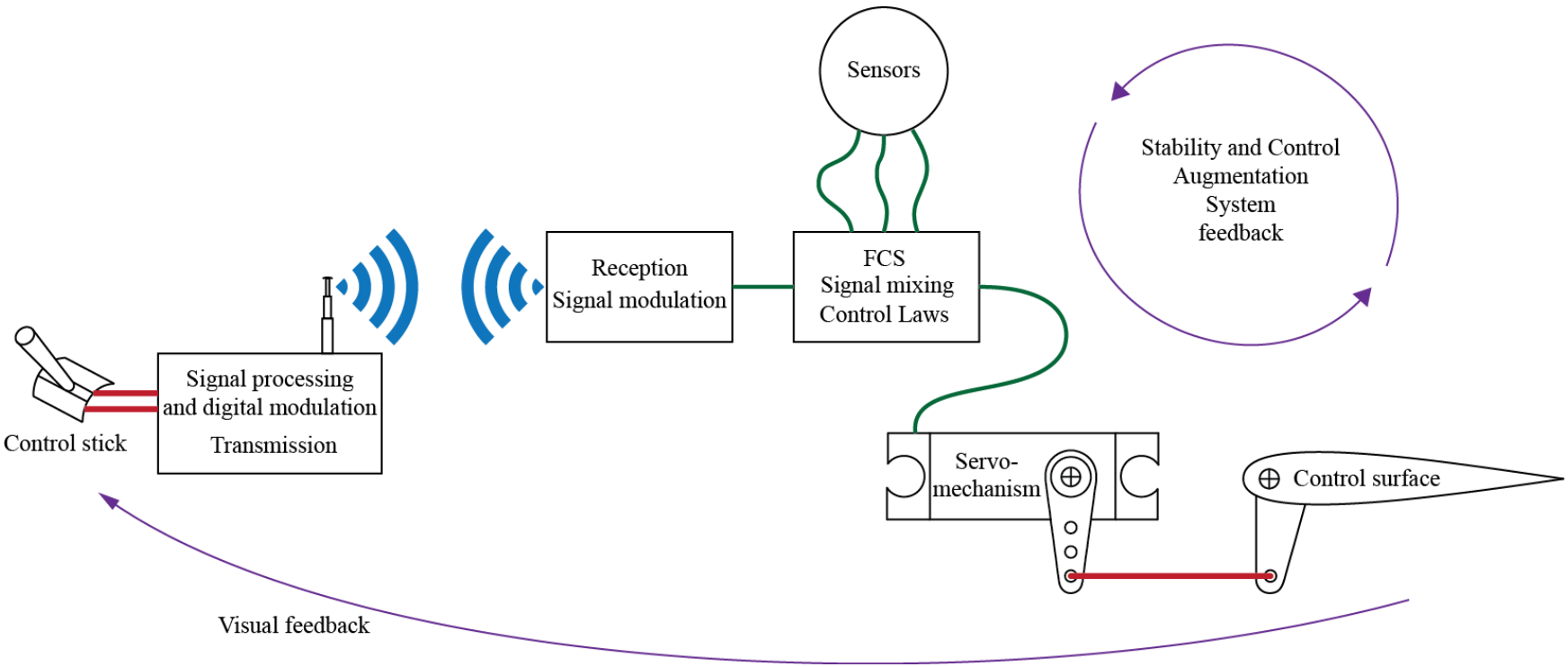
- Flight test **unstable** configurations
- Explore different **control laws**
- Take advantage of **augmented control** to ease aerodynamic tests, reduce pilot workload and improve flight test safety

Simulation example




Pitch rate, q
Elevator deflection, δ_e
Demanded pitch, θ_{com}
Actual pitch, θ
AOA, α
(a)
(b)
Angle [deg]
Angular rate [deg s^{-1}]
Flight test data
Simulation
Time [s]

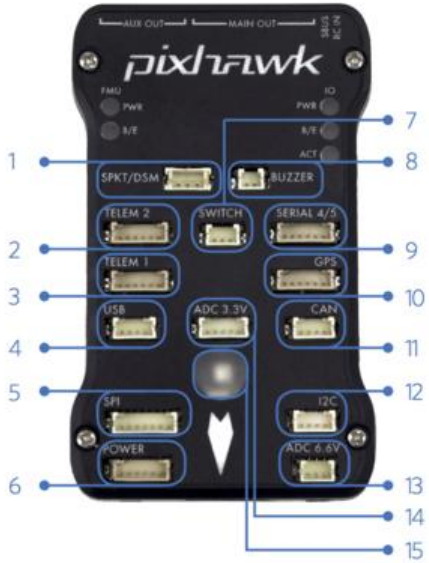
Flight Control System - overview



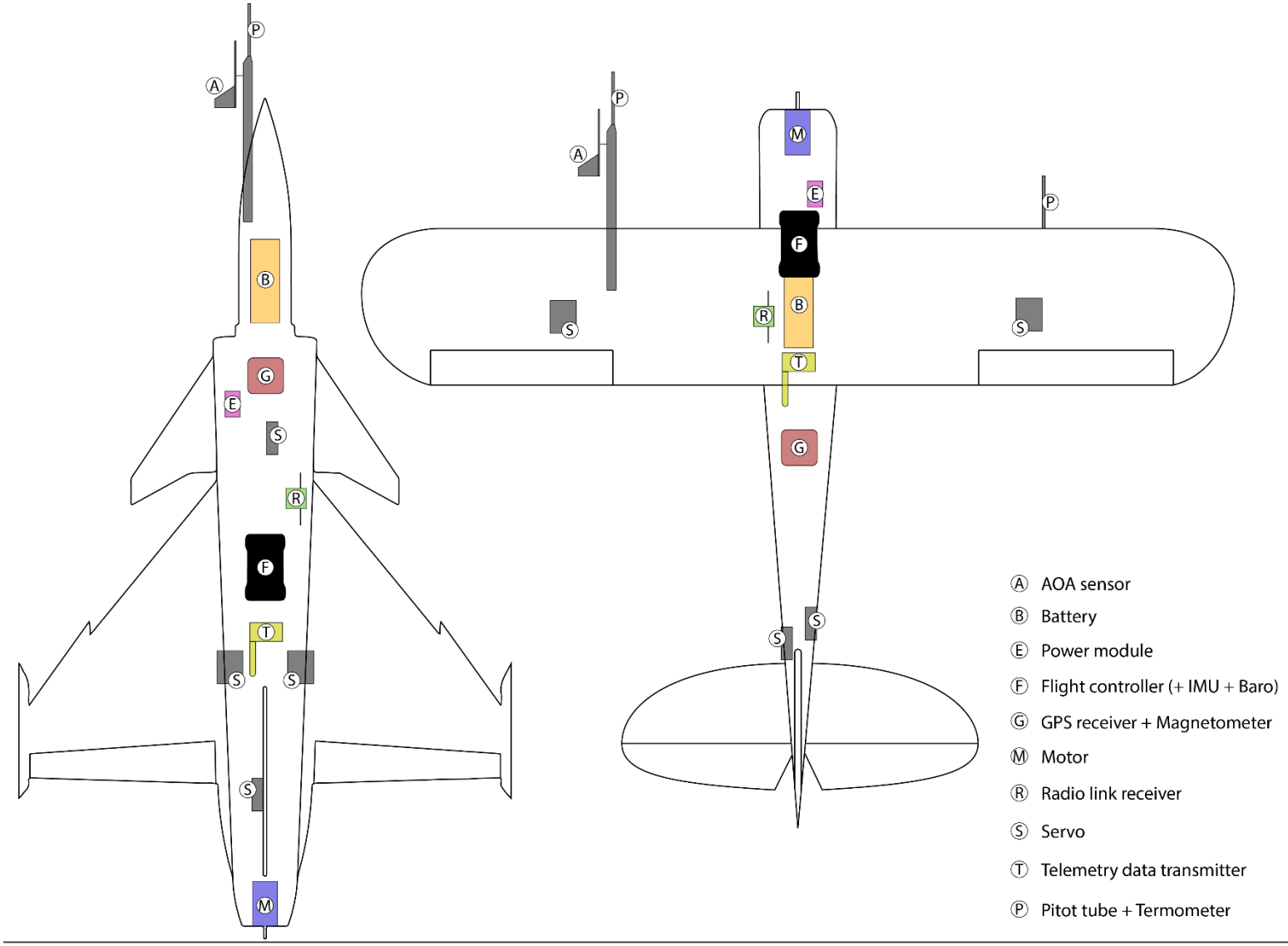
Flight Control System - onboard

- CAS based on 3D IMU and multiple sensors
- PX4/Pixhawk hardware and APM:Plane autopilot firmware

open source



1 Spektrum DSM receiver
2 Telemetry (radio telemetry)
3 Telemetry (on-screen display)
4 USB
5 SPI (serial peripheral interface) bus
6 Power module
7 Safety switch button
8 Buzzer
9 Serial
10 GPS module
11 CAN (controller area network) bus
12 I²C splitter or compass module
13 Analog to digital converter 6.6 V
14 Analog to digital converter 3.3 V
15 LED indicator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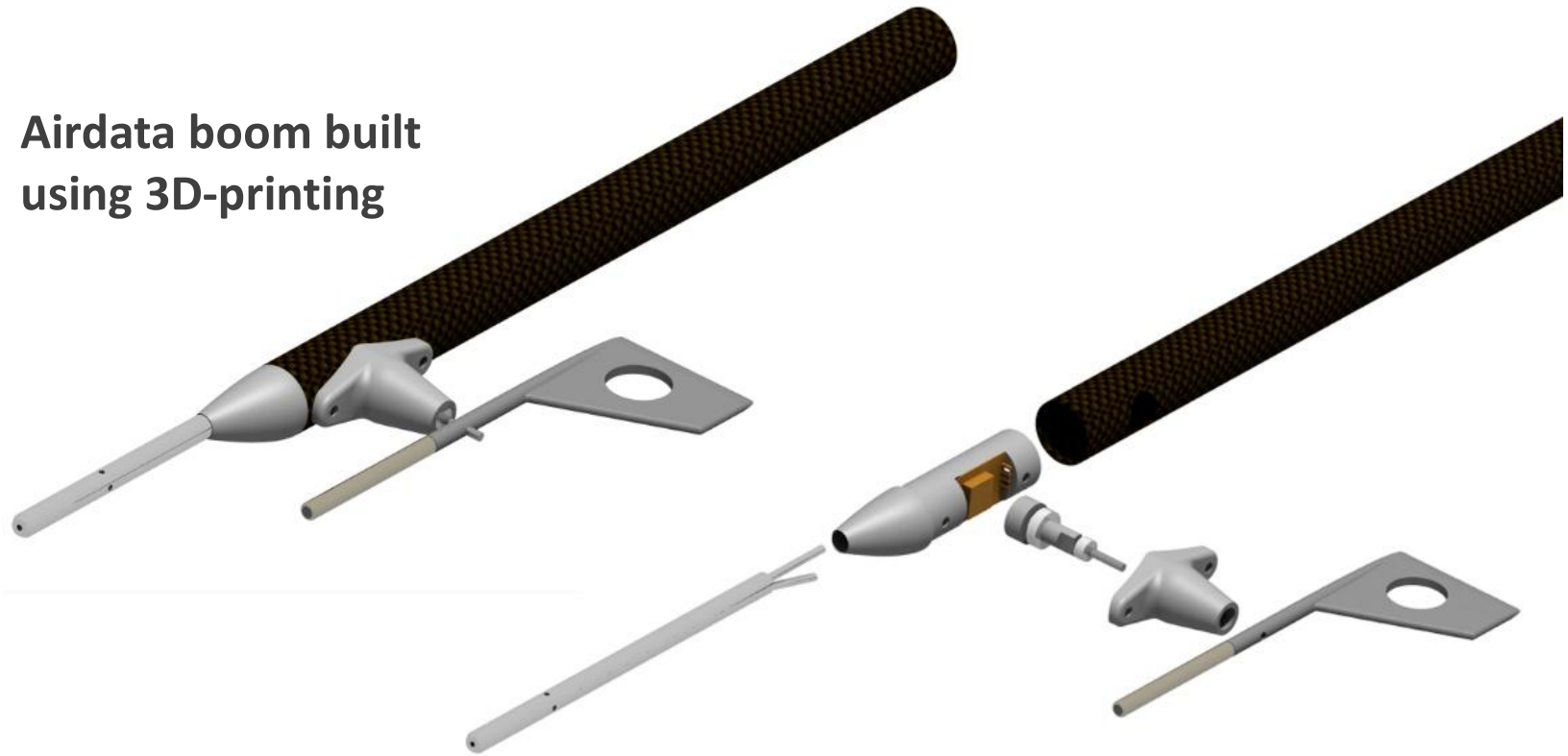
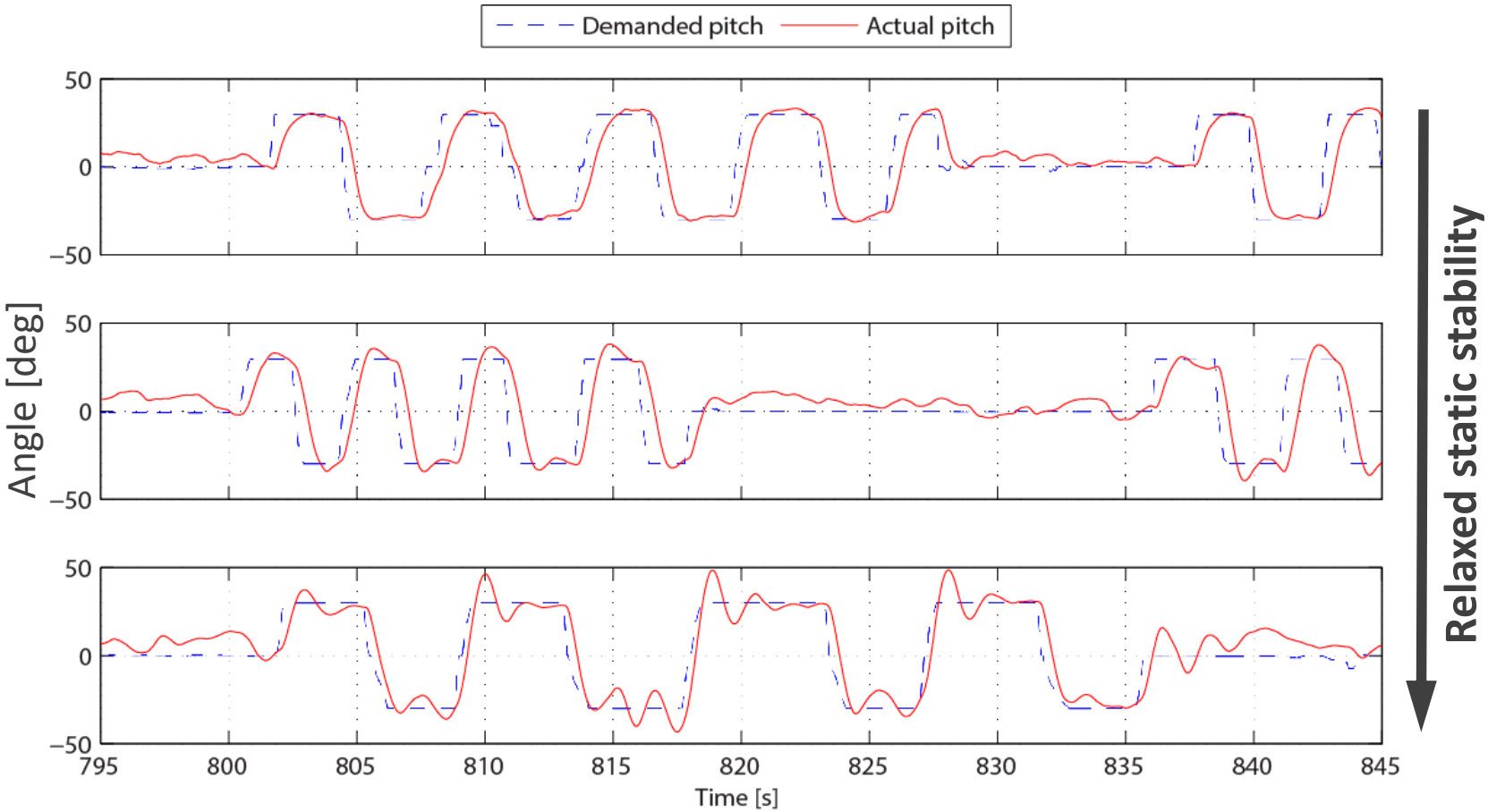
S
S
T
G
S
S
Ⓐ AOA sensor
Ⓑ Battery
Ⓔ Power module
Ⓕ Flight controller (+ IMU + Baro)
Ⓖ GPS receiver + Magnetometer
Ⓜ Motor
Ⓡ Radio link receiver
Ⓢ Servo
Ⓣ Telemetry data transmitter
Ⓟ Pitot tube + Termometer

Flight Control System: custom instruments

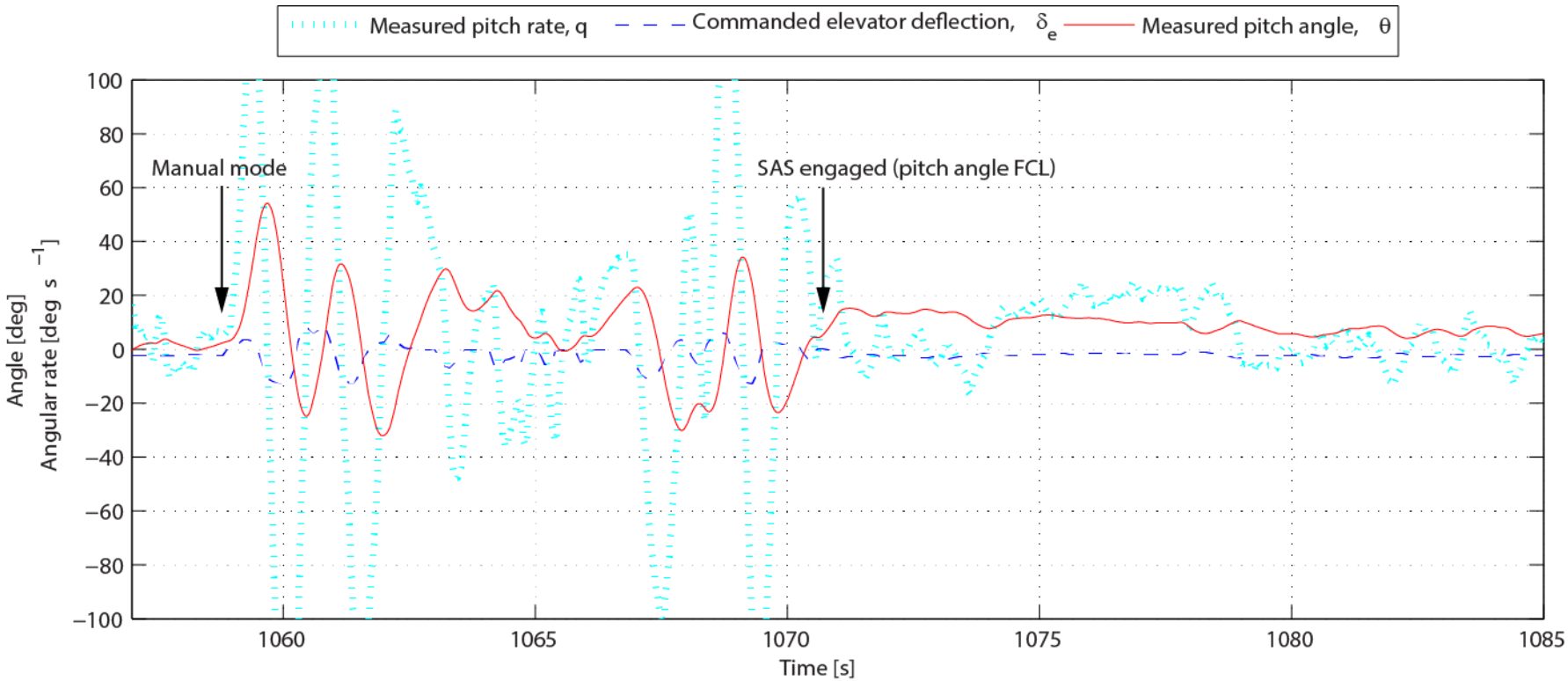
Airdata boom built using 3D-printing



Evaluation – effects of relaxed stability



Evaluation – limits of manual control



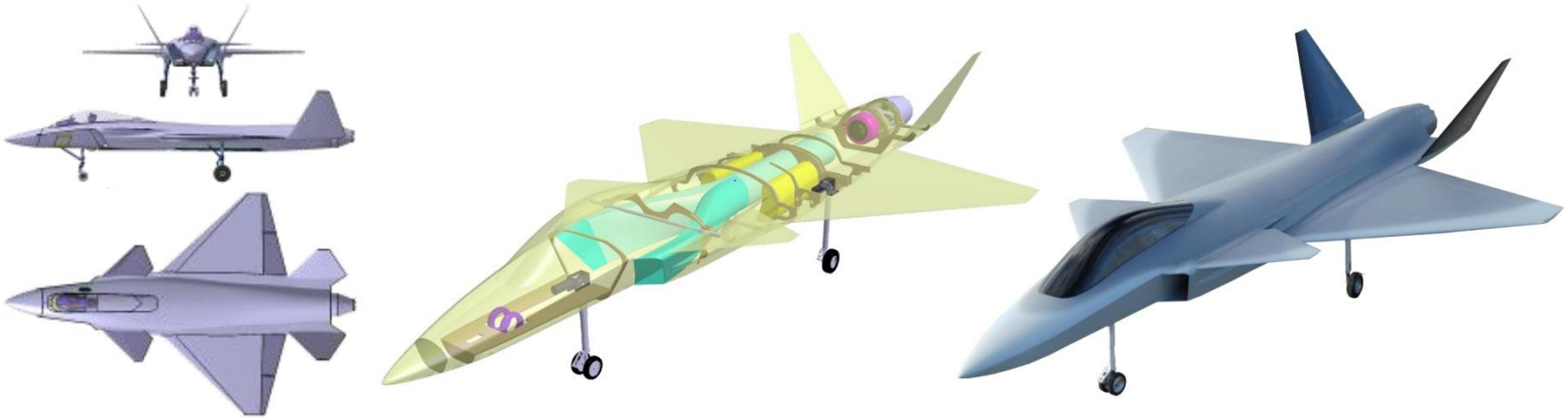
Achievements

- Within a simple, low-budget project, it was possible to set up a relatively advanced multi-sensor system with tremendous capabilities for research and education.
- It was proved that inexpensive electronics can be used to control highly unstable small aircraft.
- Different flight control laws were successfully tested.
- Work continues towards a practical control-law test-bed.

Achievements

Parameter identification from flight tests used for improving the theoretical models and simulations.

Achievements



Work continues towards the implementation of a similar system into the GFF subscale demonstrator with multi-surface configuration and thrust vector control.

FADEMO/MSDEMO Near Term Plan 2015

- Initial open data set of the GFF established
- Initial flight testing of GFF-Subscale
- Modelling of GFF in both fullscale and subscale in different tools at ITA using open data.
- Reiteration for Brazilian prototype

GFF data

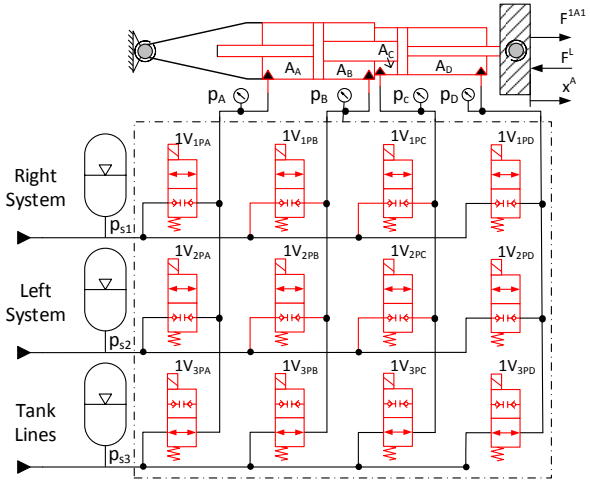
		Subscale		Full scale		Scalefactor
		Summary		Summary		7.692307692
Operating empty weight, OEW	kg	14.95	1%	10300	0%	
internal fuel weight	kg	2.9	5%	6200	0%	
Max cargo weight		2.15	10%	7300	10%	
Loaded weight	kg	17.95	10%	15400	10%	
Max takeoff weight, MTOW	kg	20	0%	21500	0%	
design weight,DRW	kg			0		
fuselage length	m	2.6	9%	18.862	9%	
Reference CG	m	1.185	2%	9.115	11%	
engine nozzle position	m	2.400	5%	18.462	5%	
Reference wing area S	m2	0.747	0%	44.215	0	
Reference wing 1 + body area S	m2	0.622	0%	36.215	0	
wetted area	m2	NA	0% NA		0	
Reference wing 1 span b	m	1.365	0%	10.5	0%	
Mean aerodynamic chord MAC	m	0.645	5%	4.960	5%	
Aerodynamic reference point from nose tip		1.185	2%	15.196	0%	
Reference condition						
air density	kg/(m^3		0%	1.225	0%	
Airspeed	m/s		0%	100	0%	
Angle of attack	rad		0%	0.142864	0%	
CL			0%	0.295105	0%	
CdS			0%	0.010471	0%	
Cm			0%	-0.043091	0%	
Cd0		0.010	15%	0.010169	15%	
Aerodynamic derivatives						
CL_alpha		3.137	15%	3.137226	15%	
CD_alpha		0.173	15%	0.17326	15%	
Cm_alpha		-0.083	15%	-0.082963	15%	
Cy_beta		-0.351	15%	-0.350564	15%	
Cl_beta		0.066	15%	0.066405	15%	
Cl_P		-0.215	15%	-0.21468	15%	
Cy_P		-0.066	15%	-0.066385	15%	
Cl_P		-0.215	15%	-0.21468	15%	
Cn_P		-0.035	15%	-0.034899	15%	
Cy_R		-0.607	15%	-0.607554	15%	
Cl_R		0.063	15%	0.062766	15%	
Cn_R		-0.259	15%	-0.259316	15%	
Flap						
CL_d		0.522	15%	0.522473	15%	
CD_d		0.031	15%	0.031044	15%	
Cy_d		0.000	15%	0	15%	
Cl_d		0.000	15%	0	15%	
Cm_d		-0.231	15%	-0.231036	15%	
Cn_d		0.000	15%	0	15%	
Ailerons						
CL_d		0.000	15%	0	15%	
Cy_d		0.069	15%	0.069001	15%	
Cl_d		0.111	15%	0.11052	15%	
Cm_d		0.005	15%	5	15%	
Cn_d		0.037	15%	0.037079	15%	
Canard						
CL_d		0.000	15%	0	15%	
Cy_d		0.000	15%	0	15%	
Cl_d		0.000	15%	0	15%	
Cm_d		-0.456	15%	-0.456	15%	
Cn_d		0.000	15%	0	15%	
Cd0 (subsonic)		0.010	15%	0.010169	15%	
Cdbase (Mach 1.2)		0.025	50%	0.025	50%	
roll moment of inertia Ix	kg m2	0.56	2%	22160.612	2%	
pitch moment of inertia Iy	kg m2	5.26	2%	208980.426	2%	
yaw moment of inertia Iz	kg m2	5.56	2%	220592.932	2%	
product moment of inertia Ixz	kg m2	0	2%	0.000	2%	
product moment of inertia Ixy	kg m2	0	2%	0.000	2%	
product moment of inertia Iyz	kg m2	0	2%	0.000	2%	
reference c.g. location Xcg	m	1.185	2%	9.115	2%	
reference c.g. location Ycg	m	0	2%	0.000	2%	
reference c.g. location Zcg	m	0.024	2%	0.185	2%	
dry thrust	N	200.000	20%	92000.000	20%	
wet thrust	N	NA	0%	170000.000	0%	
Questions for HOPLAN model						
wing 1 + body MAC quarter cord position (xprow neutral point without canard)	m	NA	0%			
wing2 area S2 (canard/tailplane)	m2	0.135	20%	8	20%	
wing2 span b	m	0.600	15%	5	15%	
wing 2 MAC quarter cord position	m	NA	0%	0		
wing area S of fin	m2	NA	0%	0		
CL_alpha2 (wing 2)		NA	0%	0		
Cl_alpha (Wing 1 + body)		NA	0%	0		
Derived quantities						
Aspect ratio		2.6935	0%	2.6935		
Aspect ratio wing 1		3.0463	0%	3.0463		
aspect ratio wing 2		3.1250	0%	3.1250		
stretched mean cord SMC	m	0.4954	0%	0.4954		
cord ratio (MAC/SMC)		1.3016	0%	1.3016		
Dimensionless wing area S2		0.2209	0%	0.2209		
reference c.g. location Xcg (in MAC)		1.8377	0%	1.8377		
engine nozzle position Xeng (in MAC)		3.7229	0%	3.7229		
roll moment of inertia Ix0 (Ix/(mas*b^2)		0.0201	0%	0.0201		
pitch moment of inertia Iy0 (Iy/(mas*MAC^2)		0.8494	0%	0.8494		
yaw moment of inertia Iz0 (Iz/(mas*MAC^2)		0.8944	0%	0.8944		
product moment of inertia Ixz0 (Ixz/(mas*MAC^2)		0	0%	0		
product moment of inertia Ixy0		0	0%	0		
product moment of inertia Iyz0		0	0%	0		

FADEMO as a Vehicle for Collaboration

- FADEMO could be an application and thematic area for other projects in aeronautics.
- By having a common target aircraft research projects will be more aligned, and a greater sense of community can be obtained.
- A open dataset based on open information for the GFF has been created, that can be shared among researchers and students and that can be used for various projects.

Future Aircraft Actuation Systems at UFSC

- This project has been going on through two successive PhD students who have come on CISB-grant to work at LiU with Saab. The partner at USFS is Prof Victor de Negri at LASHIP (Hydraulics and pneumatics laboratory), working with Birgitta Lantto at Saab.
- They are in the process of producing a prototype cylinder. The technology developed in this project can possibly be seen as an example with potential spill over effects outside aerospace industry.



Thanks!