Small Aircraft Future Avionics Architecture

How to learn from Automotive Industry

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CONTENT

- VISION PERSONAL AIR TRANSPORT
- LEARNING FROM AUTOMOTIVE

- SAFAR APPROACH
  - FBW
  - FLIGHT CONTROL
  - NAVIGATION
  - ATC / ATM INTEGRATION

- CONCLUSIONS
The ability of personalize air travel through the use of an on-demand, highly distributed air transportation.

AUTOMATED AIRSPACE
SELF-OPERATED AIRCRAFT

- SAFE
- COST EFFICIENT
- FLEXIBLE
- CAPABLE

* SATS, Nasa 2004
PERSONAL AIR TRANSPORT - Requirements

- **FLEXIBILITY**
  1. Weather independent operations
  2. Operations during day and night
  3. File and fly
  4. Easy flight plan change

- **DISTANCE & SPEED**
  5. At least 600 km non-stop flight distance
  6. Time saving for supplementary transportation between 200-600 km
  7. Road independent supplementary individual transportation means

- **COST & CAPACITY**
  8. Lower costs for distances between 200 - 600 km than for exclusive use of cars
  9. Comparable transport capacity to cars providing 4-7 seats on average

- **SAFETY**
  10. Reduction of traffic deaths by 50 % based on their share on individual transportation.

- **ENVIRONMENT**
  11. The average CO2-emission shall be restricted to 120 g/km.
  12. The individual means of transportation shall reduce the noise level along main roads.
PERSONAL AIR TRANSPORT – Growth in Business Aviation*

- Crisis 2009 seems to be overcome
- Expected steady growth of minimum 3 % per year

* EUROCONTROL STATFOR 2010
AUTOMOTIVE VS AVIATION - Safety

COMPARISON AUTOMOTIVE VS AVIATION SAFETY

- CS25
  - \( P_{\text{VEHICLE}} \{\text{CAT}\} < 10^{-6} \)
  - \( P_{\text{CONTROL}} \{\text{CAT}\} < 10^{-9} \)
- CS23 / Class 1
  - \( P_{\text{VEHICLE}} \{\text{CAT}\} < 10^{-4} \)
  - \( P_{\text{CONTROL}} \{\text{CAT}\} < 10^{-6} \)
- Automotive
  - \( P_{\text{VEHICLE}} \{\text{CAT}\} \approx 5 \times 10^{-6} \)
  - \( P_{\text{CONTROL}} \{\text{CAT}\} < 10^{-7(8)} \)

DIFFERENCES AUTOMOTIVE VS AVIATION

- AUTOMOTIVE
  - Safety (Integrity)
  - Reliability
  - Very High
  - Fail / Operational 10min
- AVIATION
  - Safety (Integrity)
  - Reliability
  - Very High
  - Very High

SAFAR OBJECTIVES

- CS23 / Class 2
  - Scalable to
  - CS25
  - \( P_{\text{VEHICLE}} \{\text{CAT}\} < 10^{-5} \)
  - \( P_{\text{CONTROL}} \{\text{CAT}\} < 10^{-7} \)
  - \( P_{\text{VEHICLE}} \{\text{CAT}\} < 10^{-6} \)
  - \( P_{\text{CONTROL}} \{\text{CAT}\} < 10^{-9} \)
AUTOMOTIVE – X-by-Wire SPARC Platform (EU Research)

- **Driver**
  - Objective: Wish Control Vector

- **Auto Pilot**
  - Objective: Redundant Auto Control Vector

- **Decision Level**
  - Objective: Safe Control Vector
  - Objective: Redundant Auto Control Vector

- **Execution Level**
  - Objective: Control Signals to Aggregates
  - Objective: Safe Decision Control
  - Objective: Driver Monitor
  - Objective: Vehicle Monitor
  - Objective: Safe Decision Control
  - Objective: Electric Power
  - Objective: Steer-by-Wire
  - Objective: Brake-by-Wire
  - Objective: Power Train Control

- **World Wide First Absolute Safety Critical FleyRay Platform**

- **16 Complex Applications**
SAFAR – FBW Platform Concept 1/4

Platform includes
- Platform management
  incl. redundancy management (RM)
- All relevant applications

RESULT: Fulfillment of Safety Target
EFFICIENT PLATFORM STRUCTURE WITH MODULE BASED REDUNDANCY MANAGED GRANULATES

- Reuse of HW / Common modules
- Reuse of SW / Common platform management (ROS)
- Virtual simplex implementations for applications

RESULT: Cost efficient platform structure, bus application, granulates for RM
RECONFIGURATION STRATEGY WITH RESPECT TO “NO DEGRADATION PHILOSOPHY”

ROS: Layer characterizes structure
- Each core module has access to all aggregates (sensors, actuators)
- Efficient use of hardware resources by dynamic MAP-reallocation

Appli(1)  Appli(2)  Appli(N)
AppMa(1)  AppMa(2)  AppMa(N)

PlaMa incl. dyn. Reconfiguration

Signal based (Agg. Level)

Integrity Frame based / (X-Module)

Integrity / Frame based (Modul)

Communication

OS incl. Partitioning & Driver

Laws, High Level Filtering

System-Management

Platform Management

IAC, Integrity, Synchronism

Platform Routing

OS-Kernel with Partition Management
SAFAR – FBW Integration 1 /

COMPUTING & NAVIGATION
Centre Fuselage

ADC computers

GNSS receivers

IMUs

PSB

Core Modules
SAFAR – FBW Integration 2 /

ACTUATORS linked to the control linkage
Centre Fuselage

- Elevator Actuators
- Rudder Actuators
- Aileron Actuators
SAFAR – FBW Integration 3 /

HUMAN MACHINE INTERFACE
Cockpit

Safety
FBW

Status panel
Switch panel
Emergency disconnect

Display
Speed-Lever
Side-Stick
SAFAR – FBW Integration 4 /
CS23 Operations

Handling
- Coupling of aircraft states, such as altitude and speed
- Manually (and mentally) closing multiple control loops
- Counteracting disturbances (turbulence, wind effects)

Operation
- Simultaneous execution of several navigation and communication tasks
- Requires much training and experience/expertise

Safety
- Adverse weather conditions
- Human error (decision-making, aircraft handling)
- System failures
SAFAR – Easy Handling Characteristics

Fly-by-Wire technology (handling)
- Decoupling of aircraft states (vertical and lateral)
- Automatic closing of inner and outer control loops
- Automatic disturbance rejection

Human-Machine Interfaces (operation)
- Enhanced pilot situation awareness (improve decision-making, mitigate human error)
- Supporting several navigation and communication tasks

Flight envelope protection (safety)
- Keep aircraft within safe regions of the flight regime
- Control allocation with system health monitoring
SAFAR - Control law design

Flight trials

Flight control laws

Aircraft dynamical model
SAFAR - Primary Flight Display

DIFFERENT FLIGHT MODES

- ATTITUDE HOLD
- AUTONOMOUS (4D)
- DIRECT (only for Tests)

ENHANCED SITUATION AWARENESS

- Surrounding Terrain
- Flight Trajectory
- Flight Envelope Limits

Synthetic Vision Display
ATT/NAV PHILOSOPHY

- Two independent full navigation chains
- Three FDE modules to filter wrong data
- Inertial Measurement FDE
- GNSS Measurement FDE + Integrity
- NAV solution FDE
- Sensor redundancy
SAFAR – Extensive Navigation Flight Trial

- GNSS receiver compute attitude to the local East-North-Up referencial by using high accuracy phase measurements of GNSS signals received at multiple antennas.

- The GNSS measurements are to be integrated with the IMU measurements so that the drift inherent to lower cost IMU can be compensated for.

- The GNSS-IMU combination provides a minimal cost navigation grade solution.
SAFAR – Integration in ATM SESAR 2020+

SMOOTH INTEGRATION OF SAFAR AIRCRAFT WITHIN SESAR

- New Airspace Structure (managed and unmanaged airspace)
- Flexible use of airspace
- 4D Trajectory based operation
- System Wide Information Management (SWIM)
- Datalink
SAFAR – Ongoing Work (until Dec. 2011)

- **IRON BIRD**
  Stress Tests, Burn-in Tests

- **AIRCRAFT**
  Ground Tests

- **AIRCRAFT**
  Flight Tests

- **6DOF SIMULATOR**
  Handling, Training of Test Pilots
CONCLUSIONS

- **STABLE TECHNOLOGY PLATFORM**
  Time is ready to realize full authority fly-by-wire avionics on small aircraft based on experience in the automotive industry.

- **ATC/ATM INTEGRATION**
  Based on SAFAR fly-by-wire avionics architecture main SESAR functionality will be available for Small Aircraft as well, at least the infrastructures precision navigation and information services.

- **SMALL AIRCRAFT**
  A lot of aircraft with modern design and low lifecycle costs exist which are potential candidates for such a fly-by-wire avionics.
THANK YOU FOR YOUR INTEREST!