ELECTRONICS & DEFENSE

ULTRA-COMPACT AVIONICS

Elevating eVTOL operations with proven avionics technologies

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OUTLINE

1. **AVIONICS & FLIGHT CONTROLS IN TRADITIONAL AVIATION & eVTOLs**

2. **CURRENT TECHNOLOGIES & BENEFITS**

3. **TRENDS FOR THE FUTURE :**
   1. **FULL INTEGRATION OF AVIONICS & FLIGHT CONTROLS & POSITIONING**
   2. **RESILIENT POSITION, NAVIGATION & TIMING**

This presentation is based on eVTOL market trends put in perspective with general & commercial aviation as well as helicopter technology. No aim of completeness.

Avionics & Flight Controls in traditional aviation & eVTOLs

SAFRAN

Avionics & Flight Controls Requirements (for piloted A/C)

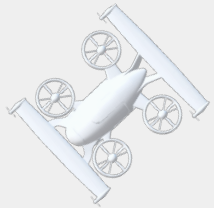
FLY PAX SAFELY TO DESTINATION
KNOW FOR SURE WHERE YOU ARE
CERTIFY AIRCRAFT AND OPERATIONS

TRADITIONAL AIRPLANES & HELICOPTERS

- 1 TO 500 PAX
- UP TO 15,000 KM
- SMALL SET OF AERODYNAMIC ARCHITECTURES (USUALLY STABLE)
- LARGE A/C CAN AFFORD MULTIPLE BOXES

eVTOL

- 1 TO 7 PAX
- 20 TO 500 KM
- INNOVATIVE AERODYNAMIC ARCHITECTURES (OFTEN UNSTABLE)
- FEWER, MORE LIGHTWEIGHT BOXES DESIRED BETTER FOR ENERGY CONSUMPTION



Avionics & Flight Controls Implementation

TRADITIONAL AIRPLANES & HELICOPTERS

- FBW OR CONVENTIONAL (DIRECT COUPLING)
- AUTOPILOT ≠ FLIGHT CONTROL ≠ PROPULSION
- HYDRAULICS USUALLY IN PRIMARY FLIGHT CONTROL ACTUATION

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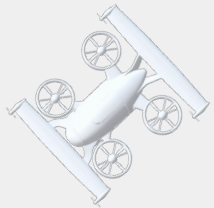
- FBW ONLY –> MORE COMPLEX MODING & CONTROL LAWS
- MERGE [PROPULSION + FLIGHT CONTROL + AUTOPILOT]
- ALL-ELECTRIC FLIGHT CONTROL ACTUATION

- AVIONICS AND FLIGHT CONTROL COMPUTERS OFTEN SEGREGATED



Current technologies & benefits

Current technology benefits - Computing

1990s

EXAMPLE: FCC NH90 H/C

- TWO REDUNDANT DIGITAL AND ANALOG CONTROLS
- 14 LITERS / KG
- 600 DMIPS X 1 CORE
- 2 COMPUTING LANES (COM/MON) ON DIGITAL CONTROL
- MANUAL CODE GENERATION IN LOW-LEVEL LANGUAGE FOR APPLICATIVE (FLIGHT CONTROL) SOFTWARE
- EMBEDDED INERTIAL MEASUREMENT UNIT (BACKUP)

TODAY

ULTRA COMPACT AVIONICS PLATFORM

- ONE FULL DIGITAL CONTROL
- 1.6 LITERS / KG
- 2400 DMIPS X 4 CORES
- 2 COMPUTING LANES (COM/MON)
- TIME-TRIGGERED RTOS SAFE & CERTIFIABLE BY CONSTRUCTION
- AUTOMATIC CODE GENERATION AND VALIDATION FOR APPLICATIVE SOFTWARE

Current technology benefits – Positioning

TRADITIONAL AIRPLANES & HELICOPTERS

- **HYBRIDIZATION OF MULTIPLE SOURCES:**
  - Air data
  - Earth magnetic field
  - GPS
  - Radars (incl. DVR)
  - Radio signals (beacons…)
  - Inertia of different technologies and performances
  - Ground altimeters
  - Etc.
- **LONG MISSIONS/RANGES BUT LIMITED ACCURACY**

DOMINANT GYRO TECHNOLOGY:
RLG, RING-LASER GYRO

eVTOL

- **GNSS + AIR DATA = PRIMARY SOURCE OF POSITIONING**
  - Multi-constellation (GPS, Galileo, Glonass, Beidou)
  - Augmentation systems, special antennas,…
  - etc.
- **INERTIA COMPLEMENTS ATTITUDE & HEADING AND BACKS UP GNSS**
- **MEMS (LOW TO MID GRADE) AND HRG (HIGHER-GRADE) GYROSCOPES: ENABLERS FOR SMALLER AND RELIABLE INERTIAL SENSOR SYSTEMS**
- **SHORT MISSIONS/RANGES → SIMPLER, BUT INCREASED ACCURACY**

FUTURE: USE OF CERTIFIED VISION-BASED NAVIGATION

SUITABLE GYRO TECHNOLOGY:
HRG: HEMISPHERICAL RESONATOR GYRO

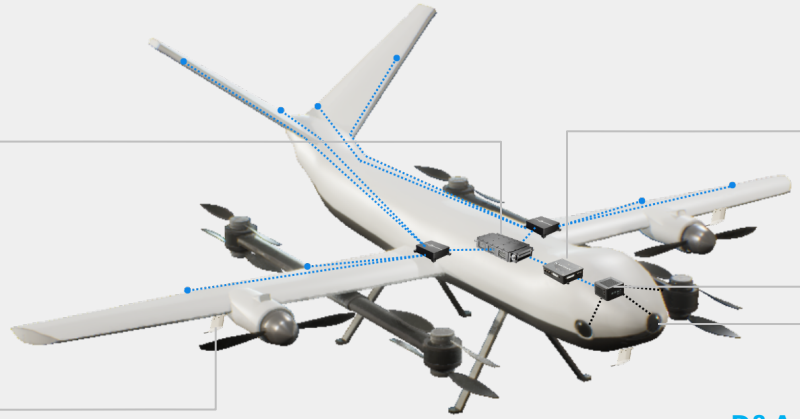
AT LEAST 4 TIMES SMALLER THAN RLG AT SAME PERF

Trends for the future

1- Technology demonstrator: Full integration of [avionics + flight controls + positioning]

EXAMPLE: 100 KG CLASS UAV TO SAFELY OVERFLY POPULATED AREAS (CAT: 10^{-7}/FH – SAIL VI)

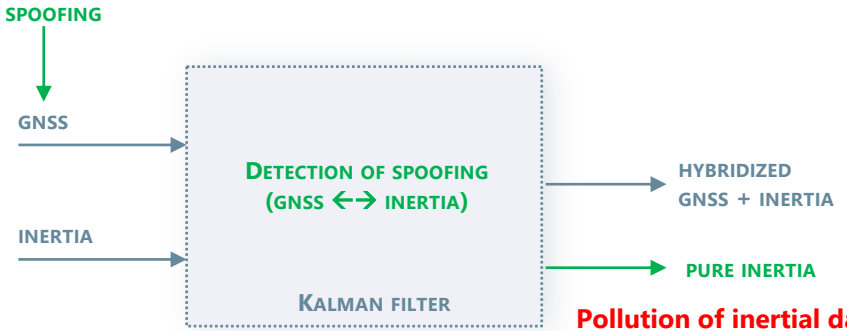
- SLIGHTLY DIFFERENT APPROACH TO AIR TAXI eVTOL, LOWER SAFETY ACCEPTABLE (NO PAX ON BOARD)
- SMALLER, LIGHTER, MORE INTEGRATED ARCHITECTURE: 2.5 KG FOR THE MODULES DESCRIBED IN THE PICTURE BELOW



2- Resilient Position, Navigation & Timing (GNSS & inertia)

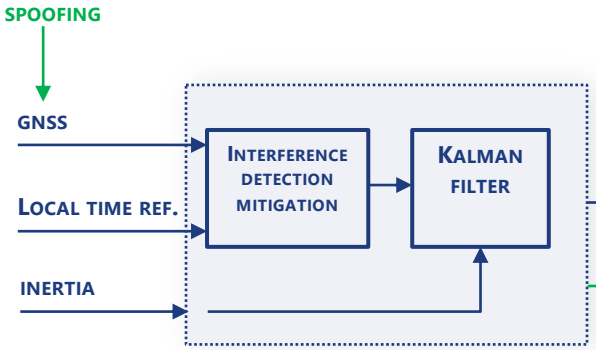
INCREASE THE INTEGRITY OF POSITIONING & ADHERENCE TO DEFINED TRAJECTORY

TODAY



Pollution of inertial data by erroneous GNSS between start of spoofing & detection of spoofing.

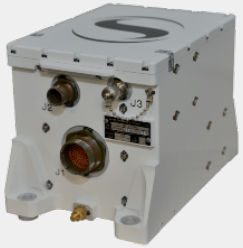
FUTURE



Immediate spoofing detection:
No pollution of inertial data.

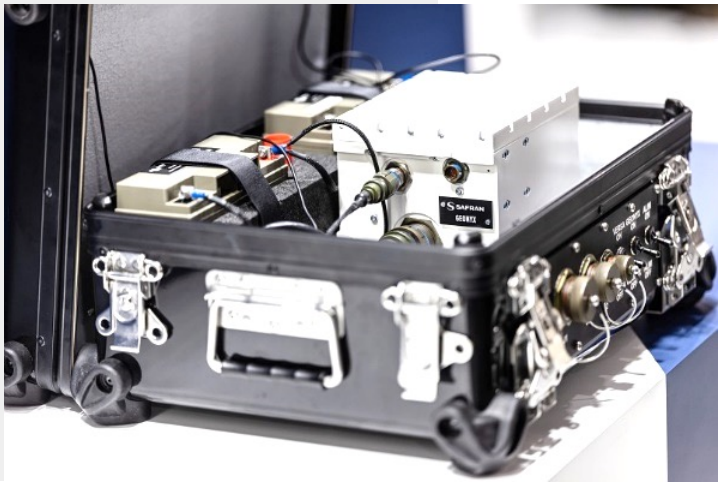
2- Concept implementation and operational validation for military naval application (non-certified)

NAVKITE: COUPLING OF AN INERTIAL NAVIGATION SYSTEM WITH A TIME REFERENCE, INTERFERENCE, DETECTION & MITIGATION



GEONYX™ M INERTIAL NAVIGATION SYSTEM

VERSASYNC® LOCAL TIME REFERENCE AND INTERFERENCE, DETECTION & MITIGATION



NAVKITE: development by Safran with the French Navy's commandos.

Conclusion

Conclusion

PERSISTING	TODAY	FUTURE
➲ Safety – Certification (and associated development effort)	➲ Integration (equipment & function) ➲ Miniaturization ➲ Move to all-electric	➲ Resilient PNT ➲ Single set of critical computers in aircraft ?

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