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DAL-A Certifiable Auto Pilot and Mission Computer LRU for Airborne Applications

Introduction

The Defense industry is witnessing an unprecedented growth in the use of Airborne Platforms for combat and ISTAR missions. This has resulted in an increasing demand for efficient SWaP optimized DO-178C Safety Certifiable airborne systems that assure hassle-free future system upgrades, using LRU designs. Auto Pilot and Mission Computers are critical components of both manned and unmanned airborne platforms. These systems allow Airborne Platforms to perform entire missions autonomously, with minimal involvement of an operator.

Auto Pilot system receives data from an array of sensors including Gyros, Magnetometers, Accelerometers, Radars, Navigation Systems, Engines and other peripherals. The received data is processed to capture, record and send out critical flight information on altitude, velocity, position and direction of the platform to the flight control actuators and other systems to assist autonomous operations.

This case study outlines Mistral's expertise in design and development of a DAL-A Certifiable Auto Pilot and Mission Computer LRU which is critical to carry out flight operations such as take-offs, flight manoeuvres, landing and user defined autonomous missions, in addition to receive, process and store ultra-high-definition images captured by the Airborne Platform.

The Customer

A leading Aerospace and Defense Organization.

The Requirement

The customer approached Mistral to build an advanced LRU-based Auto Pilot and Mission Computer system for their ongoing Project. The customer was keen on a small form-factor, SWaP optimized LRU to ensure maximum flight efficiency and hassle-free upgradation in future. The Auto Pilot and Mission Computer LRU had to be a DO-178C and DO-254 Level A Safety Certifiable system.

Solution Provided

Mistral and the customer jointly conducted a thorough requirement analysis and agreed on the system specifications including COTS modules, software and dimensions for Auto Pilot and Mission Computer.

Considering the key requirements of a SWaP optimized LRU that meets DAL-A safety parameters, Mistral designed a rugged 3U ¾ ATR Chassis with a VPX backplane, which can house multiple COTS SBC Modules, I/O Cards, GPU Cards, Switch, SATA Storage cards, load sharing power supply and mating I/O Connectors.

The LRU was designed based on Integrated Modular Avionics (IMA) Architecture using VxWorks 653, as the system handles multiple avionics functions of different criticalities. The use of VxWorks 653 enabled multiple applications running concurrently on multiple partitions in the system.

Hardware

The Hardware of Auto Pilot and Mission Computer LRU was realized using COTS modules from Curtiss-Wright and custom designed SATA Cards, I/O panel, power supplies and multi-slot backplane.

Auto Pilot and Mission Computer LRU

The Auto Pilot and Mission Computer LRU was built into a ¾ ATR Chassis designed by Mistral, with a dual redundant system to ensure operational continuity of the platform in the event of a system failure. The system includes DO-254 DAL Certifiable I/O cards, SBCs, custom designed SATA Card and dual redundant power supplies. The I/O panel, custom designed with MIL-38999 standard circular connectors, brings out the I/O lines from the LRU.

The heart of the LRU is a 3U VPX Conduction Cooled T2080 Processor Card. It includes,

- 3U VPX Conduction Cooled I/O Card with MIL1553, A429, RS-232, RS-422/485 Serial I/O, Analog Interfaces
- DO-254 and DO-178C Safety Certifiable 3U VPX AMD E8860 Graphics and Video Capture Module
- 3U VPX Conduction Cooled 20 Port Ethernet Switch
- Custom-built 1TB SSD SATA Card
- Custom-built I/O Panel with MIL-38999 Circular Connectors
- Custom-built ¾ ATR Conduction Cooled Chassis with 6-slot 3U VPX backplane
- Custom-built Dual Redundant Power Supplies
- DAL-A Certifiable VxWorks 653 RTOS on SBC, BSP and Drivers

3U VPX Backplane Design

The backplane was designed to meet the dual redundancy requirement of the system. The main highlight of the backplane design is the conversion of RS-232 from I/O Card to RS-485 and RS-422 and the bi-directional communication circuitry between the Auto Pilot LRU and the flight actuators, over these interfaces.

SATA Storage Design

Mistral designed and integrated solid-state SATA Storage cards for Auto Pilot and Mission Computer LRU. The storage units provide 1TB of storage with SATA Gen3 interface (6.0Gb/s). The unit stores logs from various peripherals and engine of the Airborne Platform.

Power Supply Design

A dual redundant power supply is designed and built into Auto Pilot and Mission Computer LRU. The load sharing power supplies cater 250W power with input supply voltage of 18 V to 36 V.

The power supplies are built with fully protected output in addition to input overload and reverse current protection. Mistral has also implemented a health monitoring mechanism that helps to continuously check and monitor the health status of the power supply over the serial port.

Software

The Auto Pilot and Mission Computer LRU runs VxWorks 653 RTOS, an Integrated Modular Avionics (IMA) DAL-A certifiable platform. Mistral integrated BSPs and Drivers which are certifiable to DAL-A levels on the LRU. This was in line with the hardware modules used. In addition to fully integrated units, Mistral also provided the Wind River VxWorks 653 Development Environment on customer provided computers.

The BSPs and Drivers integrated by Mistral includes:

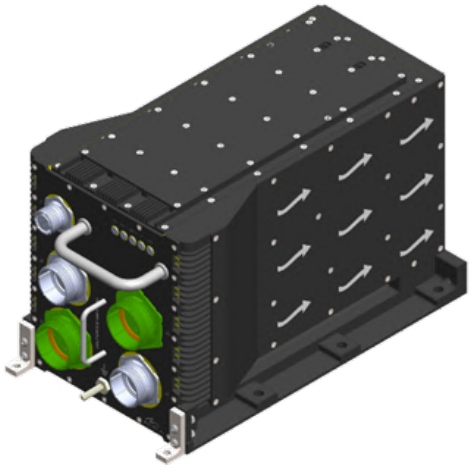
- DAL-A Certifiable VxWorks 653 BSP for T2080 based SBC
- DAL-A Certifiable VxWorks 653 v3.x Device Drivers for 3U VPX Graphics and Video Capture Card
- DAL-A Certifiable VxWorks 653 v3.x Device Drivers for I/O Card

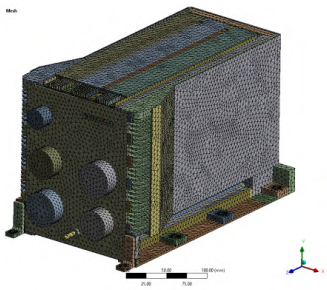
Application Framework for I/O Card

Mistral designed and developed an application framework using VxWorks 653 v3.x to test all the functionalities of the I/O card.

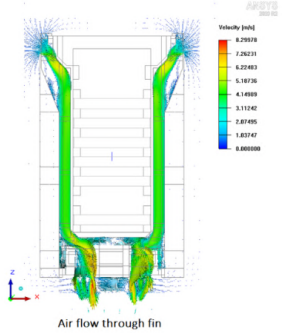
Mechanical Design

The LRU is integrated into a custom designed ¾ ATR Forced Conduction Cooled Chassis with 3U VPX backplane. The Chassis is built with aero grade Aluminum 6082 alloy using milled block construction and complies with ARINC 404A - Air Transport Equipment Cases and Racking Standard. The Chassis also meets the stringent requirements of DO-160G, MIL-810, MIL-461E standards for environmental and EMI compliances.





Meshed Model

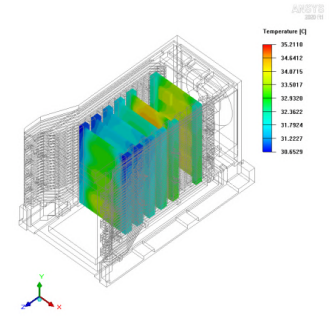


Air flow through fin

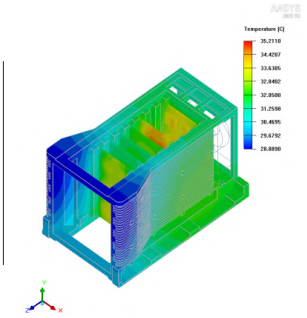
Mistral optimized the design of Chassis Fins to obtain maximum thermal efficiency and avoid over heating conditions that can significantly affect the performance and durability of electronic devices. The custom-built I/O panel integrated into the Chassis is provided with MIL-C-38999 type Connectors for power and I/O Signals.

Thermal and Structural Analysis

Mistral conducted Thermal and Structural Analysis of the 3D Model to ensure that the system meets demanding needs of high temperature, vibration, shock and altitude among others in harsh operational environment. Thermal analysis was done with respect to forced air convection mode with steady simulation for an ambient Temperature of 25^{0}C and 65^{0}C. The Chassis was designed in such a way that power dissipation is spread equally over the card at primary side of the backplane without heat sink.

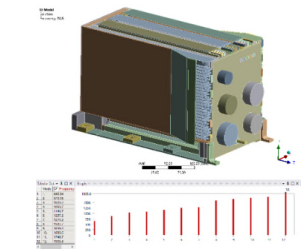


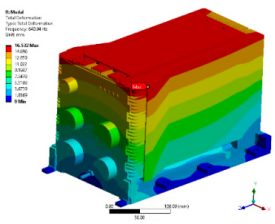
Temperature plots for the SRUs



Temperature plot for the chassis

Mistral conducted Modal Analysis, Random Analysis, Transient Structural (Shock) and Static Structural Analysis and Deformation and stress for the LRU to validate structural compliance.





Electrical CAD

Mistral also conducted Signal Integrity and Power Integrity analysis of the design at various levels to ensure compliance with electrical specifications as per standards. Mistral also calculated and provided MTBF (Mean-time Between Failures) and FMEA (Failure Mode Effect Analysis) reports to the customer as per MIL-STD-1629 for each component in the system.

DO-254 and DO-178C Safety Compliance

Mistral assured that DO-254 Compliance evidence can be made available for all the hardware components during the process of certification. The entire system software supplied by Mistral qualifies to DO-178C Level-A Safety Level. Mistral also ensured the availability of artifacts for individual BSPs, Drivers and RTOS for DO-178B compliance from respective OEM's, to meet certification requirements.

Mistral provided Hardware and Software manuals, various reports including Thermal and Structural Analysis, Software Programming Manuals, Backplane Interconnect Details, I/O Connector ICD etc along with the System.

Environmental Standards

Mistral supported the customer for the Environmental Qualification activities of the System. The chassis & cards of the Auto Pilot and Mission Computer were designed to adhere to following Environmental Standards.

MIL-810 | DO-160G | MIL-461E

Challenges

Engine Data and Feedback

The DAL-A Certifiable I/O Card used in the LRU does not provide a CAN interface to gather engine data and RS-422/RS-485 to send commands or receive feedback from flight actuators or control systems. This was a major challenge in the design as Auto Pilot had to have a bidirectional communication system with flight actuators and Engine that enable the platform to fly autonomously. Mistral implemented a Direction Control (bidirectional data transfer) mechanism over the custom VPX backplane by making use of the RS-232 interface on the I/O card. The RS-232 interface is brought out and converted into RS-422 and RS-485 by implementing an inbuilt circuitry on the backplane. Mistral also maintained all documentation / artifacts necessary for DAL-A Safety Certification.

Size and Weight

Confining the system with multiple COTS modules and dual redundant power supplies within a small chassis was a challenge. This was addressed by careful real-estate planning and integrating redundant units (two SATA Cards and two PSUs) into the same mechanical slots.

Achievements

- First multicore DAL-A Certifiable system designed and built in India using VxWorks 653 RTOS
- Mistral designed and offered a system that is certifiable to DAL-A level. Mistral ensured the availability of all necessary artifacts for DAL-A certification of the LRU including the custom designed modules.

Customer Benefits

- Mistral's partnership with Global COTS solution providers and unparalleled competence in custom hardware and software design, enabled us easily design, source, develop and supply the systems in a shorter time period
- Single vendor design, development and integration of the ATR LRU.

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Mistral Solutions Pvt. Ltd.,
No.60, 'Adarsh Regent',
100 Feet Ring Road,
Domlur Extension, Bangalore - 560 071
Tel: +91-80-4562-1100
Fax: +91-80-2535-6444
E-mail: info@mistralsolutions.com

Mistral Solutions Inc.,
43092 Christy Street
Fremont, CA 94538
USA
Tel: +1-408-705-2240
E-mail: usa@mistralsolutions.com

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