AP Labs

Deploying Ruggedized Systems in Unmanned Military Vehicles for Advanced Air-Sea-Land Applications

Part 1

An Overview of the Challenges, Constraints & Opportunities
In the Military's Most Demanding Environments

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Part 2

(to be available December 2009)

Implementation Methods & Key Factors for Success:
Designing, Integrating and Deploying COTS/Custom Computing Platforms

Overview

Over the past decade, military platforms of all types and sizes have seen a dramatic increase in the use of sophisticated on-board electronic systems. This growing reliance on small embedded, rugged computers and complex high-speed I/O requirements for "mission computing" provides a wide range of real-time applications to support both reconnaissance and war-fighting activities on land, in the air and at sea. These high performance mobile systems offer significant advantages to protect troops on the battlefield and enhance their combat capabilities, as well as improving inter-unit communication and coordination at both tactical and strategic levels.

One of the key arenas in which advanced on-board electronics have proven to be a fundamentally game-changing factor is the evolution of Unmanned Vehicles that can operate remotely to provide critical intelligence and/or attack capabilities. In addition to providing some of the greatest opportunities, these unmanned vehicles also present some of the most difficult design challenges. This is because of the need to package a high level of computing power and data collection/distribution elements within minimal size, weight and power constraints, while assuring the ruggedized capabilities to survive and perform in very demanding operational environments.

This first whitepaper provides an overview of the factors that are driving unmanned vehicle applications and the key design requirements for successful deployments. While most of the discussion will focus on unmanned aerial platforms, many of the same concepts are being incorporated into advanced ground vehicles that support warfighting and defensive functions for all the armed services. Part 2 in this series of whitepapers will provide a discussion of the specific issues that must be addressed to optimize ruggedized system platforms to handle these requirements. The follow-on paper will also describe a number of real-world COTS solutions that can be readily adapted and customized to address the demanding challenges of remote platforms operating in unmanned vehicles.

War Strategies Are Shifting Toward Unmanned Vehicles

An unmanned aerial vehicle (UAV) can generally be defined as a reusable, non-crewed vehicle that is capable of controlled, sustained, level flight. This distinguishes UAVs from guided missiles and other such vehicles that are typically designed for a single-use one-way delivery of a ballistic payload.

In recent years, the UAV category has moved dramatically beyond the traditional focus on "drones" designed to fly relatively simple missions that were either entirely controlled by a human operator or were pre-programmed to follow fairly rigid mission parameters. Because of these limitations, most early generation UAVs were essentially local assets, controlled entirely from within the specific theater of operations. In contrast, many of today's UAVs are capable of highly-autonomous flight, in which the vehicle itself has the on-board intelligence to make real-time adjustments to the mission parameters, based on new information and/or changing conditions. Also, the increased computing and communications capabilities enable much more sophisticated operational control; with some unmanned vehicles now capable of being controlled in real-time by ground-based operators on the other side of the globe. Generally today's UAVs fit into two categories: 1) those that entirely controlled from an in-theater location, and 2) those that can operate autonomously using more complex dynamic automation systems in combination with pre-programmed flight plans and remote operator control.

UAS, or unmanned aircraft system, is the official U.S. Department of Defense term for an unmanned aerial vehicle. Initially coined by the Navy, UAS better reflects the fact that these are comprehensive, complex systems that include ground stations and other elements besides the actual aircraft. The term UAS was first officially used in the DoD 2005 Unmanned Aircraft System Roadmap 2005–2030. However, the official acronym 'UAS' is not widely used outside military circles, as popular usage and media coverage have already made the term UAV a fairly common part of the modern lexicon.

Reconnaissance & Data Acquisition

Because unmanned vehicles are not burdened with the physiological limitations of human pilots, they can be designed for extended missions that allow for maximized on-station times and enable continuous monitoring of targets.

For reconnaissance purposes, UAS remote sensing functions can include vision systems, heat-sensors, electromagnetic spectrum sensors, biological sensors, and chemical sensors. A UAS's electromagnetic sensors typically include visual spectrum, infrared, or near infrared cameras as well as radar systems. Biological sensors are capable of detecting the airborne presence of various microorganisms and other biological factors. Chemical sensors use laser spectroscopy to analyze the concentrations of each element in the air. Hyperspectral imaging processes information from across the electromagnetic spectrum, enabling scanners to read various spectral signatures like "fingerprints" in order to identify the materials that make up a scanned object.

As will be discussed later, the huge and ever-increasing amount of sensor data that can now be collected and analyzed is constantly driving the need for greater on-board computational functionality and more storage capacity. In addition, these increased data loads, along with 24/7 reconnaissance requirements, are driving the need for quick-swap Line Replaceable Module (LRM) storage options in order to optimize end-of-mission turnaround times and faster mission de-briefs.

Remote War-fighting Capabilities

While intelligence, reconnaissance and surveillance missions continue to be the predominant focus, the role of UAS has also expanded into proactive war-fighting functions. These often include electronic attack, strike missions, suppression or destruction of enemy air defense, combat search and rescue, and derivations of these themes. Unmanned vehicles such as the Predator (shown at right) can stay on station for extended periods of time, controlled by operators beyond the local theater, until they have acquired, identified and then destroyed the targeted enemy combatants and/or assets.

The military role of unmanned aircraft systems continues to grow at unprecedented rates. Through 2005, tactical and theater-level unmanned aircraft alone had flown over 100,000 flight hours in support of Operation Enduring Freedom in Afghanistan and Operation Iraqi Freedom. Rapid advances in technology are enabling more and more capability to be placed on smaller airframes which is spurring a large increase in the number of Small Unmanned Aircraft Systems (SUAS) being deployed on the battlefield. The use of SUAS in combat is so new that no formal DoD wide reporting procedures have been established to track SUAS flight hours.

Current UAS vehicles can range in cost from a few thousand dollars to tens of millions of dollars, with aircraft ranging from just a few pounds to over 40,000 pounds. In addition, the on-going success of UAS programs at improving combat outcomes and minimizing risk to military personnel, is spurring the development of new capabilities and systems, with new research and development leading to further advances in on-board functions as well as overall mission control and support systems.

Battlefield Integration Applications

The increasing availability of real-time data at both tactical and strategic levels, along with highly interoperable standards-based communications systems, is also driving new innovations and development of advanced battlefield integration applications. This convergence of capabilities will enable UAS missions to be tightly integrated with other land-sea-air assets and frontline combatants, as well as unmanned ground vehicles, to maximize achievement of unified objectives while also minimizing risks to personnel.

Key Requirements for Unmanned Mobile Systems

Although the specific requirements for each project will vary with the unique operational objectives, there are a number of key factors that are critical to success for the electronic systems deployed within virtually any unmanned vehicle program.

Survivability & Reliability in Harsh Environments

Survivability must be the core design objective for any mobile electronics system used in military applications. If the system is not able to operate continuously and reliably within the target environment, no amount of sophisticated features can be of any practical benefit for the mission.

The design approach that has proven most effective over time is to implement all of the required system functionality in a chassis that has already been certified for ruggedized operation and is not simply listed as “designed to meet”.. For example, selecting a chassis that is manufactured to meet the requirements of MIL-E-5400 Class 1 thermal performance, MIL-901D shock, MIL-167-1 vibration, etc. assures the designer that it can withstand specified extremes of temperature, vibration, shock, salt spray, sand and chemical exposure, while maintaining a sealed and temperature controlled environment for the computing elements and electronics inside.

Depending on the mission requirements, the chassis may need to be cooled and mounted in a variety of different ways; therefore project engineers find it useful to standardize on a proven family of COTS chassis that can be adapted to meet a wide range of requirements. In addition to being able to mount systems within standard racks or into ARINC style equipment trays, it is useful to have options for custom hard mounting or shock mounting within the mobile platform. From a cooling standpoint, some applications can use forced air, sometimes called forced convection (using internal or external fans) but because of space, weight and environmental constraints, many UAV applications need to use conduction cooling methodologies (with or without fan assist). Therefore it is helpful for designers to be able to choose between a variety of cooling and mounting options at the outset and then build the optimized system upon a proven foundation.

As will be explored more in subsequent sections, the approach of leveraging pre-qualified MIL-E-5400 COTS platforms that are also designed for optimal customization allows for creation of on-board electronics systems that can be tailored to fit virtually any set of program-specific requirements, while assuring the survivability that is critical to the success in such demanding environments.

Support for Streaming Video & Large Data Storage

Another key element that is essential in most unmanned system applications is the ability to support real-time video streaming and the on-board storage of very large amounts of digital and sometimes analog data. The fundamental nature of unmanned mobile applications requires the on-board system to act as the “forward-edge eyes” for the remote operators.

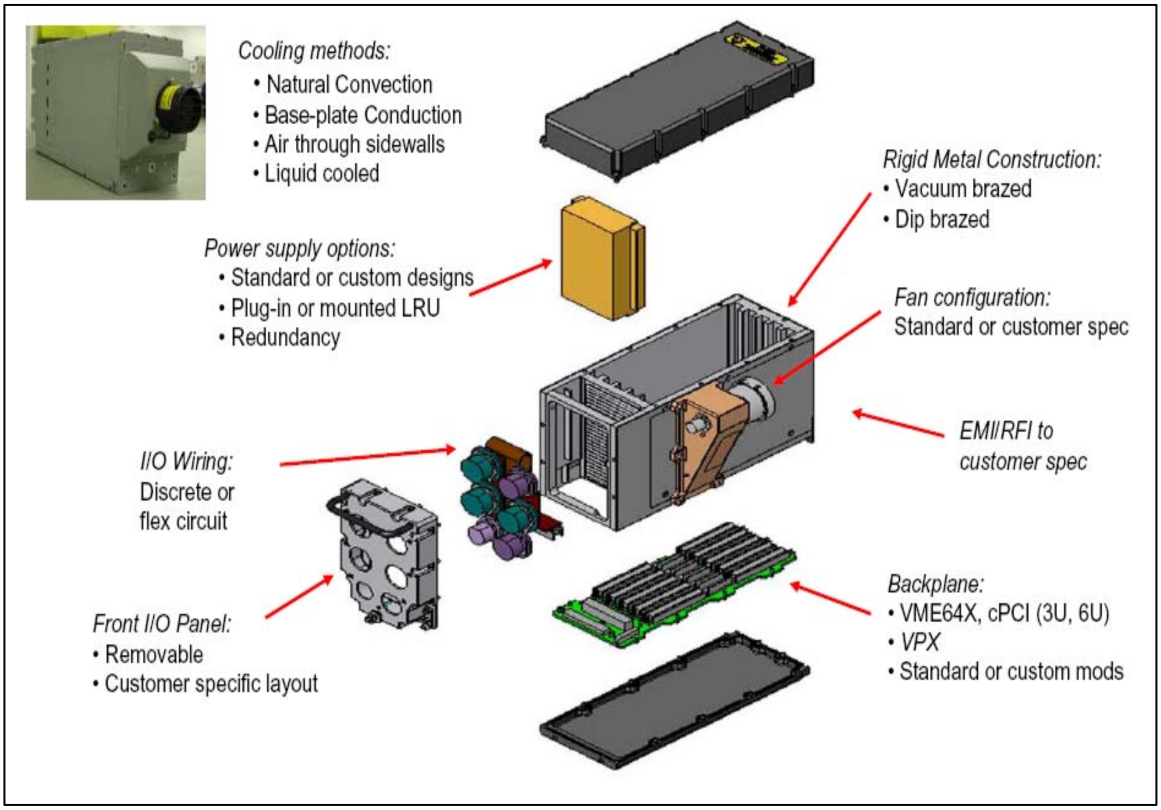
The sheer amounts of visual content and other data that are routinely collected by UAVs would have been unthinkable just a few years ago. However, today’s on-board systems must be able to not only process multiple streams of incoming video and other data; they also need the local storage capacity to retain information collected throughout the entire mission. This challenge will only get larger as UAV capabilities allow for even more extended time-on-station reconnaissance and improved sensors continue to expand the amount of data that can be collected. The recent significant cost reductions in flash memory have resulted in the viable replacement of rotating media (disk drives) with solid state drives. These drives are generally more robust environmentally, more reliable and provide noticeable improvements in access and data retrieval times.

In addition, the evolution of real-time remote monitoring as well as the integration of “look-and-shoot” attack capabilities into unmanned platforms also is requiring a much higher level of computational performance from the on-board electronics. Besides collecting and storing the acquired data, the on-board systems must be able to stream visual information to the remote operator in real time. The system also needs to respond quickly to remote commands for repositioning, additional data collection and/or initiation of attack modes. From a chassis design standpoint, these application requirements drive the need for advanced backplane architectures with high-speed signaling capabilities as well as modular data storage sub-systems that can handle large amounts of data and support quick-swap exchanges for rapid mission debriefing and/or mission turnaround.

Designing the Optimal Rugged Platform

It has become clear that there will never be a "one-size-fits-all" approach that can accommodate the diverse and demanding requirements of on-board electronic systems used in unmanned system applications. However, as previously described, one can come close to this goal by addressing all of the key fundamental challenges within configurable families of COTS platforms, while building-in the ability to readily customize as required for specific program requirements.

As illustrated in the example below, this approach can give project engineers and program managers a wide range of latitude to consider different cooling methods, power supply loads/designs, backplane architectures, I/O configurations and EMI/RFI specs. The result is a cost-effective platform tailored to fit the overall design requirements, rather than either a rigid platform that forces compromises or a full-custom approach that forces both high-cost and extended development timeframes.



PART 2:
Implementation Methods & Key Factors for Success

The second part in this whitepaper series will discuss a series of specific implementation methodologies and issues that must be addressed in order to create optimal COTS/custom systems to meet the needs of these ultra-demanding unmanned vehicle applications.

The following specific topics will be covered in detail in Part 2:

- SWaP – Size, Weight and Power
- Advanced Cooling Methodologies
- Backplane & Bus Fundamentals: High-speed Signaling
- Storage Subsystems: High-Capacity & Quick-swap Options
- Leveraging Standards-Based Communications
- Optimizing Performance, Reliability and Cost
- Design for Field Maintainability
- Real-world Configuration Examples