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Achieving air superiority

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Paul Parkinson, senior systems architect, Wind River - 11/29/2006

In recent years, as military aircraft have become more and more sophisticated, with advances in flight control systems, radar systems, weapons and countermeasures, etc, the complexity of the underlying systems has increased dramatically.

In today's uncertain world, governments are striving to deal with new emerging threats to their countries and are demanding that their armed forces change rapidly in order to defend against these threats.

The changing threat

During the Cold War era, the requirements for a country's armed forces in order to repel a threat were clear, and changes to the nature of the threat and an enemy's capability could be predicted. The development of new military aircraft to fulfil a specific role could be planned and executed with reasonable expectation that the threat would not change substantially during the development phase. Since the end of the Cold War, although there is no longer a stand-off between the superpowers, instability has emerged in other areas of the world, and governments are now asking their armed forces to operate in theatres that had not been a primary consideration in the development of their defence systems.

In addition, as a result of the perceived reduction in threat in recent years, many western governments have been under political pressure to reduce defence spending and to divert funding into other areas. This has placed defence spending under even greater public scrutiny, with several results. Firstly, governments have had to strive hard to justify the procurement of next generation aircraft, illustrated by the political debate that occurred in Austria over the purchase of 18 Eurofighter Typhoons at a cost of nearly 2 bn Euros[1]. Secondly, that governments have had to optimise their defence spending to include the enhancement, capability and extending the in-service lifetimes of existing military aircraft, illustrated by the B-52 bomber, which is now expected to have an in-service lifetime of over 90 years[2].

The changing response

There is a need to be able to rapidly change aircraft capabilities to enable the war-fighter to use them in new operation roles to tackle new emerging threats. However, this requirement is at odds with the development timescales of new military aircraft (and defence systems generally) that are now being undertaken in timescales longer than a decade, rather than a few years. As a result, governments are having to seek new ways to adapt their existing squadrons so that they can be deployed for new operational roles. For example, the development of the Eurofighter was instigated to produce a state-of-the-art air-superiority fighter to address a Cold War threat. However, as that threat has receded, the Eurofighter Typhoon is being considered for other roles as it enters service with NATO Forces, these potentially including a ground attack role for possible future conflicts that were not anticipated at the time of the Cold War.

The role of software

In recent years, as military aircraft have become more and more sophisticated, with advances in flight control systems, radar systems, weapons and countermeasures, etc, the complexity of the underlying systems has increased dramatically. This is particularly evident in relation to software, which, in earlier generations of fighter aircraft, could be measured in tens of thousands of source lines of code (SLOC), and for current programs, is measured in millions of SLOC.

One of the underlying reasons for the increasing software content is that software provides the ability to deploy flexible multifunction systems that could not easily be achieved though hardware alone. This can provide benefits in terms of a reduction in the number of dedicated systems. For example, in airborne radar systems, software configuration can be used to exploit the fundamental capabilities of the radar for different modes of operation. These include modes for tracking airborne targets, and also a synthetic aperture radar (SAR) mode for a number of different purposes, including terrain mapping and collision avoidance. In very advanced radar systems, this could also include an inverse SAR mode for non co-operative target recognition (NCTR).

Software is being used to manage the increasing complexity of aircraft systems; this can reduce the burden on the crew, for example, the vectored-thrust aircraft advanced flight control (VAAC)[3], which was developed for the Harrier short take off, vertical landing (STOVL) aircraft, used by the Royal Navy and Royal Air Force and US Marine Corps. This revolutionary 'fly-by-wire' system eliminates the need for the 'third lever' for the thrust nozzle control, by taking control of many of the Harrier's flight characteristics, making their aircraft easier to manoeuvre, and so reducing the risk of pilot error and improving safety.

In addition, it is also being used to manage complex systems to provide fighter pilots with a key tactical advantage in combat engagements. This is illustrated by the Eurofighter Typhoon employing aerodynamically unstable design in order to provide extremely high levels of agility; however, this instability needs to use a computerised fly-by-wire system for the pilot to be able to fly the aircraft[4].

Software is also being used to improve situational awareness in the area of sensor fusion. Data from different sensor inputs is processed, integrated and presented to the pilot in a coherent manner to enable them to make rapid decisions about their next actions. The implementations of many such systems are classified due to their sensitive nature; however, one instance that is in the public domain is the Tornado advanced radar display information system (TARDIS), which performs data fusion of radar data and digital moving map display data to provide advanced enhanced situational awareness for low level terrain navigation and avoidance capabilities. This provides a critical tactical advantage during flight[5]. In another example of sensor fusion, it is understood that, in a mock combat engagement, Israeli Air Force (IAF) fighters prevailed over US Marine Corps F/A-18s in 220 out of 240 engagements[6], the Israelis having a tactical advantage of state-of-the-art helmets, which enables pilots to aim their weapons simply by looking at the target; such systems utilise advanced software and sensors.

Designing software for the future

The digitisation of the battlespace continues to gather pace and even more advanced capabilities are being considered, including realtime information flow for situational awareness and tasking of aircraft. These operational requirements will continue to have an impact on the design of aircraft systems and the software that they will contain.

Experience gained in avionics software development and deployment over many years has been used to define a new software architecture known as integrated modular avionics (IMA). This uses a common computing platform to host multiple avionics applications, which reduces the dependency on specific hardware architectures and reduces the number of distinct subsystems used in an aircraft, which, in turn, reduces the burden of planning for obsolescence and technology insertions.

IMA can be used in conjunction with software standards such as ARINC 653[7], which enables the development of portable avionics applications, and also provides a software framework for implementation of in-service upgrades for both safety-critical and non-critical systems from the programme outset. This software architecture can also be used as the basis for secure aircraft systems requiring multiple independent levels of security (MILS), which is required for systems that contain top secret and mission data, and need to interface with unclassified systems.

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About the author

Paul Parkinson, BSc CEng MBCS MIEE, is a senior systems architect with Wind River in the UK, working with customers in the aerospace and defence sectors. His professional interests include integrated modular avionics (IMA) and intelligence surveillance target acquisition reconnaissance (ISTAR) systems.

For more information contact Andrew Palmer, Embedded Industrial Solutions, +27 (0) 12 547 6071, palmer@eisol.co.za