MIL-STD-1553B: The Past and Future Data Bus

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As the avionics systems in military aircraft and other platforms increase in performance, the need for MIL-STD-1553B may decrease, and some industry pundits project it may soon be relegated to the annals of history. However, such projections have been made for years, and MIL-STD-1553B hasn't just survived for more than four decades--it's prospered--delivering an unbeatable combination of relative simplicity, modularity, redundancy, and bulletproof reliability. So, there's ample reason to believe that even with challenges from Gigabit Ethernet, Fiber Channel, and other higher-performance networks, it will continue to be the "go-to" choice for some defense and aerospace platforms for many years.

First, although exact numbers are scarce, MIL-STD-1553B has at least 100 million hours in service on ground, sea, air, and space platforms, in countries throughout the world. It also boasts a robust vendor base, universal recognition in the defense and aerospace community, and is well understood by huge numbers of technicians and engineers.

Second, once placed in service most defense platforms remain there for decades, so current systems using MIL-STD-1553 (Figure 1) are likely to be around many years and spares will be always be needed. Wholesale replacement of MIL-STD-1553 with an alternative in these platforms would require new electronics connected to the bus, an expensive proposition. Third, even though its 1-Mb/s data rate is orders of magnitude slower than more "modern" contemporaries, some platforms simply do not require higher speeds (although admittedly, their numbers are declining).
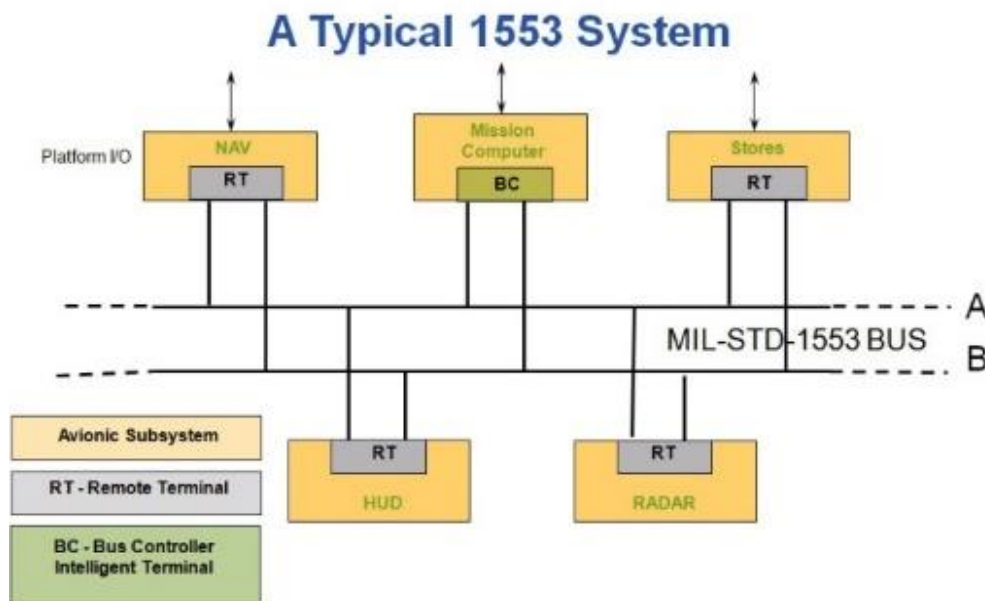
Figure 1 A typical MIL-STD-1553B system including remote terminals and bus controllers serving various portions of an aircraft.

That said, to retain its relevance in the future MIL-STD-1553B will need to adapt to the modern world. Specifically, this means it's potential must be more fully exploited to deliver data rates in the hundreds of megabits per second. There have been significant efforts to achieve this over the years, principally by Data Device Corp. (DDC) and Edgewater Computer Systems beginning in the early 2000s. Unfortunately, this story doesn't have a very happy ending, even though both companies developed and demonstrated not only that MIL-STD-1553B could be enhanced but was achievable without significantly modifying the standards underpinnings.

DDC began its efforts with an approach it called Turbo 1553 that increased MIL-STD-1553's data rate without modifying its fundamental features such as its modulation technique, line code, or coupling methods. Turbo 1553 was shown capable of reliably delivering 5 Mb/s on standard MIL-STD-1553 terminals over 430 ft. with 10 stub connections to three remote terminals. The second, called "High Performance 1553" or "Hyper 1553" uses frequency-division multiplexing and other techniques to allow higher speed data to be simultaneously carried along with standard 1-Mb/s MIL-STD-1553 data on the same bus cable. It was also envisioned to implement a multi-drop bus, which eliminates the need for active hubs or switches.

In Hyper 1553, the 1-Mb/s signals are limited to lower frequencies while the higher speed signals occupy higher ones. DDC's experiments using this approach demonstrated that MIL-STD-1553 has enough bandwidth to allow the concurrent signals to be reliably transferred at higher speeds, depending on the length of the bus and number of stubs.

DDC demonstrated HyPer 1553 in a 2-hr. flight on an Air Force F15-E1 Strike Eagle fighter in 2005, where was used to transfer imagery between a computer in the forward avionics bay and a smart bomb mounted on wing pylon. The imagery data was transferred without errors at 40 Mb/s over existing cabling along with 1-Mb/s traffic. DDC still includes Hyper-1553 capability in its catalog, presumably as custom boards.

Edgewater was also instrumental in delivering essentially the same result, but it had the benefit of being under contract to the DoD to develop its technology, called Extended 1553 (E1553). Edgewater along with researchers from the Air Force and Navy worked on the project for several years, and the technology was flight tested in an Air Force F-16 and Navy F/A-18.

The results were very promising but as the program didn't have the visibility and priority of others, the Air Force cancelled it after spending tens of millions of dollars. It had delivered the desired 200 Mb/s data rate, without the need for huge changes, and allowed legacy MIL-STD-1553 data at 1 Mb/s to be carried simultaneously. The company believed it had the potential to reach 500 Mb/s. As Military & Aerospace Technology Editor John Keller pointed out in 2012, not only had government wasted considerable time and money, it also lost the opportunity to make MIL-STD-1553B a more viable data bus technology for years to come.

Fortunately, all was not lost as after the Air Force turned off its funding for E1553, the Assistant Secretary of Defense for Research and Engineering and a consortium from Canada, the U.K., Germany, and others indicated they wanted to complete the development of E1553. It was tested on several fixed-and rotary-wing aircraft, and the NATO Avionics System Panel (AVSP), chaired by the U.S. Navy, sponsored standardization efforts within NATO began the ratification process in 2010.

The result was a NATO Standardization Agreement (STANAG 7221) and in 2015 the "Broadband Real-Time Data Bus Standard" was unanimously ratified by NATO. Unfortunately, 7221 is restricted to a NATO server so government sponsorship is required to use it, but even with this limitation it is being mandated on various programs, including fifth-generation aircraft like the F-35 Joint Strike Fighter. Edgewater has subsequently begun offering PCI and PCIe mezzanine network interface cards that comply with both MIL-STD-1553B and STANAG 7221. Considering its restrictions, there is little chance this enhanced MIL-STD-1553B technology will make its way into the broad market.

While 200 Mb/s and even 500 Mb/s isn't terribly impressive today, it's important to remember that it was achieved on a bus that already serves dozens of different platforms and thousands of individual vehicles, so making the upgrade "should" have been an obvious solution. At 200 Mb/s (two hundred times faster than standard MIL-STD-1553B), it could serve not just its traditional command and control functions but also perform as a "mid-level" solution for transferring the large amounts of data produced by sensors.

The upper-layer protocol of MIL-STD-1553B are also used in other standard, such as FC-AE-1553 and High-Speed 1760. FC-AE-1553 uses the MIL-STD-1553B command/response protocol and supports all its core elements including command and status, sub addresses, mode codes, transfers between remote terminal, error checking, and broadcast. As a result, it allows the reuse of MIL-STD-1553 and MIL-STD-1760 commands and legacy software. In addition, FC-AE-1553 includes extensions and optimizations supporting RDMA to provide direct memory access of remote systems over Fibre Channel.

MIL-STD-1760 is typically used for interfacing weapon stores to an aircraft's control systems but an enhanced version called High-Speed 1760 (SAE standard AS6653) has a high-speed interface based on Fibre Channel that can deliver data rates up to 1 Gb/s over two 75-ohm coaxial cables. The Fibre Channel upper layer protocols are based on FC-AE-1553, MIL-STD-1553B for command and control messaging and FC-AV for transferring images, video, and audio files.

The Path from Here

Few data buses have withstood the test of time better than MIL-STD-1553 (Figure 2). One obvious reason for this is that the Department of Defense is its primary beneficiary, in which change takes place over decades rather than months or years. However, it would never have remained relevant for this long if it weren't for its inherent, time-tested capabilities. Nevertheless, emerging avionics, weapon systems, and other subsystems bear little resemblance to their predecessors, as they are required to transfer gigabytes or even terabytes of data over relatively short periods of time. This data will come from more sophisticated and higher resolution sensors that are becoming more formidable every year.
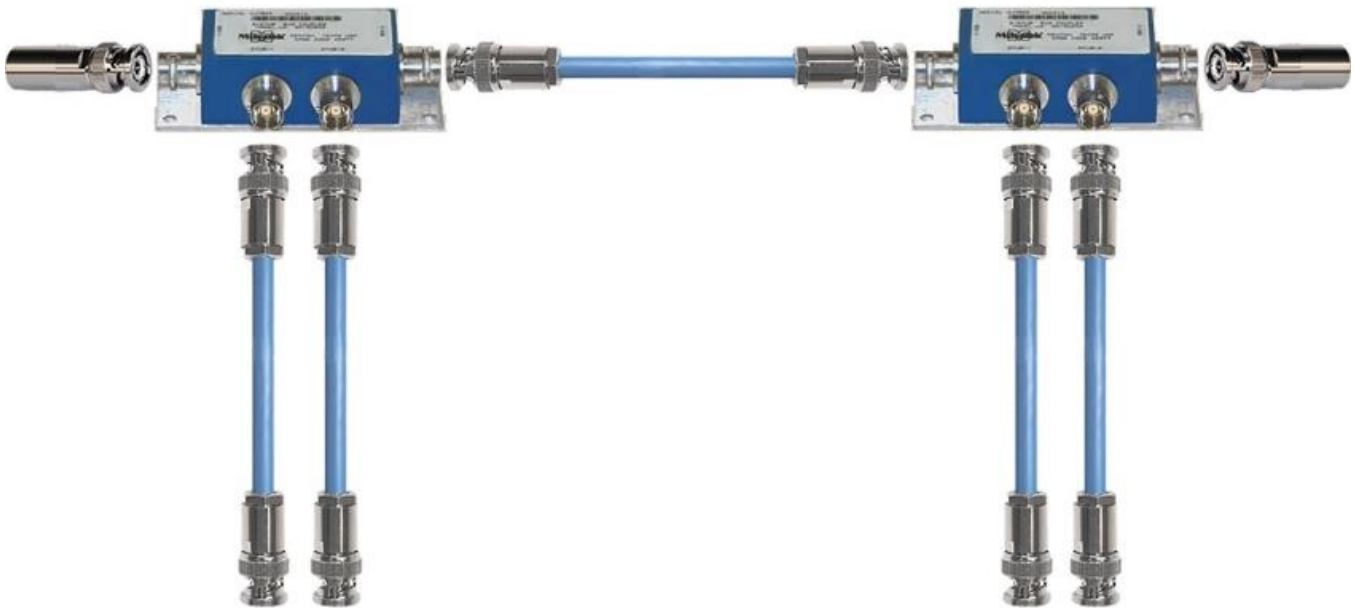
Figure 2 MilesTek's TK-1038 is a four-terminal bus kit that includes couplers, terminators, and cable assemblies, and has been a staple for users of MIL-STD-1553B for many years.

With this as a backdrop, it seems obvious that the heyday of MIL-STD-1553B is over and perhaps it is. However, this does not mean a data bus like MIL-STD-1553 will not be needed throughout the next decade and perhaps longer, especially as the enhancements within STANAG 7221 have only been available for about two years. In addition, even if MIL-STD-1553B itself declines in significance, its basic structure is included in other standards such as MIL-STD-1760 and FC-AE-1553, so it will live on invisibly within them for decades or more.

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