JOINT STRIKE FIGHTER ALTERNATE MISSION EQUIPMENT TEST SET

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Overview:
Alternate Mission Equipment (AME) is the term used to describe military equipment that can be installed on, or removed from an aircraft to achieve specific mission requirements. AME covers military equipment such as aircraft Pylons, missile launchers, bomb racks, and in some cases, auxiliary fuel tanks. AME is typically handled by armament technicians and test equipment is typically developed to address all AME associated with a specific aircraft. The test equipment is used either in the field or at the hanger where the AME is being maintained (back-shop). The Joint Strike Fighter is no different and will support a wide range of AME including Pylons, launchers, and associated equipment and as a result, will require AME test equipment as well.

The Requirements:
While LM-STAR can support manufacturing and depot test requirements, it is a large 3-bay test set and cannot be used for field, back-shop, or other portable test applications. As a result, the LM-STAR could not be used, as the AME field test set and a different test set had to be developed.

The first step in the design of this test set was to select a platform, which could be based on some existing platform or could be a completely new design. The requirements of this new JSF field test set including functional, operational, and environmental aspects were all stringent and difficult to meet and had to be evaluated prior to the platform's selection.

The following aspects were evaluated, as part of the test set's platform selection:

- Portability – the test set had to be portable so that it can be easily carried by two soldiers (or war fighters) to the flight-line or from one shop to another
- Ultra-rugged construction – the test set had to be rugged not only because of the environmental conditions it has to withstand, but also because of the anticipated abuse from the users. In other words, it had to be "soldierized". The environmental requirements of this test set are provided in Table 1 below.
- COTS-based – Like LM-STAR, the new JSF AME tester had to be based on COTS technology to ensure that development costs are minimized and that it is not based on proprietary technology
- Open-architecture – the test set had to be based on an open-architecture to ensure that test instruments from different vendors could be used together and that the market could offer sufficient availability of products to prevent the need to design custom instruments
- Small footprint – other than being portable, the test set had to be small to allow placement on standard hanger benches and carts
- Cost-effective – like any other test system program, cost was a major consideration and the lower the tester's cost, the more widely used it will be, ensuring the increased readiness of JSF fleets worldwide

Table 1: Environmental Requirements

Environment	Requirement
Operating Low Temperature Range	**-40°C ±5°C (-40°F ±9°F)**
Operating High Temperature Range	**+60°C ±5°C (+140°F ±9°F)**
Storage Low Temperature Range	**-45°C ±5°C (-49°F ±9°F)**
Storage High Temperature Range	**70°C ±5°C (+158°F ±9°F)**
Maximum Relative Humidity Range	**90% to 95%**
Salt Fog	**Per MIL-STD-810 Method 509.2**
EMI	**MIL-STD-461 Class TBD**
Shock (Half-Sine)	**Per MIL-T-28800 Paragraph TBD**
Basic Transportation	**Per MIL-STD-810 Method 514.4**
Loose Cargo	**Per MIL-STD-810 Method 514.4**
Transit Drop	**Per MIL-STD-810 Method 516**
Bench Handling	**Per MIL-T-28800, Paragraph TBD**
Vibration (Sine)	**Per MIL-T-28800, Paragraph TBD**
Explosive Atmosphere	**Per MIL-STD-810 (if applicable)**
Max Operating Altitude Range	**10,000 ft ±5000 ft**
Max Storage Altitude Range	**35,000 ft ±5000 ft**

After reviewing available platforms, PXI was a natural selection as it clearly meets all six requirements. The next step was to decide if the new tester could be based on an existing rugged PXI platform or if it had to be designed from the ground up. Since the costs to design and qualify a field-capable platform would be in the millions, the availability of an off-the-shelf generic PXI platform made this choice easy and the MTS-207 (see Figure 1) was selected as the base platform for the JSF AME tester or as it is officially known: the JSF AME STE (special test equipment).

Figure 1: The MTS-207 Ultra-Rugged PXI Platform

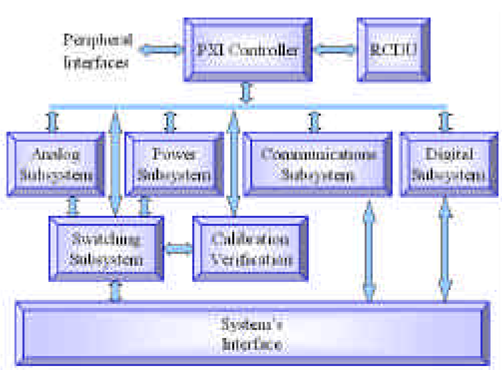
The MTS-207 is an ultra-rugged PXI platform offering a 14-slot PXI chassis with seven 6U and seven 3U slots and room for custom electronics. Of the 14 slots, slot #1 is used by the embedded single-slot PXI controller offering a Pentium 4 based 1.7GHz CPU. While this CPU is clearly NOT the latest and fastest CPU on the block, it is essential that CPU speed be reduced to reduce heat dissipation requirements. This CPU can actually operate at much higher clock speeds but then requires special cooling. The CPU also includes a built-in Flash Disk, eliminating the need for a fragile mechanical hard disk drive that would not meet the environmental requirements.

The MTS-207 has been previously used on U.S. Air Force programs including the Maverick missile system and the AC-130 Gunship. As a Maverick Field Test Set (designated as the MTS-206, see Figure 2), this ultra-rugged PXI platform has been qualified to operate at extreme environmental and EMI conditions that are more stringent than many other field testers used by our armed forces today.

Figure 2: The MTS-206 Maverick Field Test Set

Test Set Configuration:
The utilization of COTS products and in this case, PXI modules, was one of the requirements of this test set. This meant that PXI products had to be used in all cases where it was feasible. Indeed, most of the subsystems shown in Figure 3 are based on COTS PXI products with very few unique requirements dictating custom circuitry.

Figure 3: The JSF AME Tester's Block Diagram



As mentioned earlier, the PXI controller is an embedded single-slot Pentium-based PXI controller. For a portable application, the fact that the controller occupies a single-slot is an added benefit as the overall chassis solution is smaller and lighter (compared with the typical 3-slot-wide PXI controllers).

Being a portable application, the use of a keyboard and a mouse was not feasible and the selected user interface was a Remote Control and Display Unit (RCDU) which is a combination of a rugged LCD display and a touch-screen. Using intuitive menu-driven displays created by the ATEasy Test Executive, the operators have full-control over test set functions and configurations and can access test data information when needed. The controller also provides standard peripheral interfaces including USB-2 and 1000BaseT Ethernet ports. Also provided are standard PS2 keyboard and mouse interface, which are only used for development purposes.

The USB interface allows connections of peripheral devices such as printers and USB thumb drives. This is an important fact as this allows the easy download of test log files from the test set to the USB media but even more importantly, allows the upgrading of test set software in the field by shipping customers a pre-programmed USB thumb-drive. This eliminates the need to ship test sets back to the factory every time a software update is needed or alternately, sending technicians to all locations of the test set to perform the upgrade in the field. The 1000BaseT Ethernet (Gigabit Ethernet) provides for the networking of the test set when required. One of the advantages of a networked test set is the use of remote diagnostics, which enhances the built-in test, and self-test capabilities of this JSF AME Tester.

The power subsystem represented a challenge, as this test set has to support MIL-STD-1760 requirements. While mostly a straightforward specification when required by I-Level and Depot-level tester, the power required by MIL-STD-1760 represents significant weight and size for a portable test set. For this reason, the input power to the test set was selected to be a 3-phase source of 115V/400Hz. This allows the test set to switch this power rail to the Units Under Test (UUTs) without the need to internally generate this power source. However, the test set does need to generate the 28VDC and 270VDC rails required by the UUTs as well as the power supplies required by the internal PXI chassis (+5V, +3V and ±12V rails) and other internal custom circuitry (±15V and +28V). Combined, these power supplies provide a total of over 1000W of power and while custom; they are still controlled by the embedded PXI controller that can monitor power supply voltage and current via additional custom circuitry provided on e custom PCB called the Power Board. The Power Board functions as the Interface Test Adapter (ITA) typically found on I-Level and Depot-Level tester. With a portable flight-line tester, it is undesirable to have external adapters other than simple cables – hence the reason for this ITA being INSIDE the test set and not located externally. The Power Board also includes all the high-power loads required for UUT loading of signals and special stray-voltage monitoring circuitry for the squib circuits.

The power supplies were not a requirement that could have been supported by COTS PXI products and these were custom-designed for the test set. The majority of the other products however were COTS PXI modules.

The Analog Subsystem includes a 6½ digit DMM (3U PXI) and a multifunction card with A/D and D/A channels (3U PXI). There are additional analog functions provided by the Power Board.

The Communications Subsystem includes two dual-redundant MIL-STD-1553 Mux databus interface (3U PXI), a CAN bus interface (3U PXI), and a RS-422 interface (supported by the embedded PXI controller).

The Digital Subsystem includes 128 digital I/O channels that are provided by the multifunction card (part of the Analog Subsystem).

The switching subsystem includes 5 switch matrix cards (6U PXI) and one high-current switch card capable of switching up to 7.5A per channel (also 6U PXI). One of the switch matrix cards is used for internal tester functions (BIT, self-test, and housekeeping) while the others are used for UUT testing. Additional high-current switching of up to 25A per channel is provided by the custom Power Board.

Last but not least is the calibration subsystem. The Power Board includes precision references used for automatic calibration of the tester. The tester verifies its calibration status on power up and can prompt the user to run the built-in calibration in the event it is required. The only external traceability for the tester is to verify the accuracy of the internal references on a 24-month cycle.

The COTS PXI instruments are accommodated by a 14-slot 3U/6U custom PXI chassis. While this chassis had to be customized to meet the environmental requirements listed in Table 1, the 14-slot backplane is identical to that used on the GX7100 combination 3U/6U PXI chassis, thus maintaining COTS compliance. The changes made to the chassis to ensure compliance with the environmental requirements include the addition of a heater and mounting the chassis on a shock-mounted mechanical structure. Figure 4 illustrates the 14-slot chassis and the instruments selected for the JSF AME tester.

Figure 4: The JSF AME Tester's PXI Chassis

GX5315 (High-Current Switch)	Future Growth
GX6616 #5 (Switch Matrix)	Future Growth
GX6616 #4 (Switch Matrix)	Future Growth
GX6616 #3 (Switch Matrix)	Multifunction
GX6616 #2 (Switch Matrix)	CAN Bus
GX6616 #1 (Switch Matrix)	MIL-STD-1553
Embedded PXI Controller	DMM

Of the 14 available slots, all the 6U slots are in use, one by the embedded PXI controller and 6 by switching cards. The availability of the 6U slots played a major role in the switching density of the tester, providing a flexible matrix configuration up to 2x480 or 4x240 as well as 45 high-current channels. The 3U side of the chassis is partially occupied by 3 3U cards, leaving 3, 3U slots available for future growth.

The system's interface had to be customized as well, as standard mass interconnect devices commonly used by testers cannot be used in the flight-line environment. Subsequently, the system's interface consists of circular military connectors such as D38999 series III.

Test Set Maintenance:
The primary goal of each test is of course to test the Units Under Test it supports. However, a very important aspect of a test set is its ability to test and troubleshoot itself. This is even more important with field testers which are subject to continuous abuse and operated by field personnel that are typically not as experienced as those personnel operating depot-level testers.

The JSF AME tester is provided with 4 maintenance capabilities:

- Built-In Test (BIT)
- Self-Test
- Remote Diagnostics
- Calibration

The BIT is a power-up procedure that verifies the test set's subsystems are operational, the system power supplies output the correct voltages, and that the individual instruments are calibrated. It does not check any of the cables or the harnesses of the test set.

The system Self-Test is a TPS that utilizes a Self-test adapter (stored in the test set's lid). The Self-Test TPS performs a complete comprehensive parametric test of the test set and all associated cables and is capable of providing troubleshooting information to the user in case of a failure.

For those cases where UUT or test set troubleshooting needs the assistance of an experienced engineer, the test set provides the means for remote diagnostics via the Gigabit Ethernet port. This allows personnel in another location (or continent for that matter) to review parametric test data in real-time and instructs the operators of the correct action to take.

Another important aspect of test set maintenance is the calibration. The calibration philosophy of the U.S. Air Force Metrology and Calibration directorate (AFMETCAL) has changed over the years and now prefers that calibration verification be performed in lieu of calibration and that calibration be performed only if the verification fails. For this reason, the JSF AME tester, just like the Maverick field test set mentioned earlier (MTS-206) utilizes an innovative calibration approach. The test set includes a PXI card with high-precision calibration references and during the BIT, the test set's measurement instruments are checked (verified) against those references. A failure in any of these tests will prompt the execution of a calibration procedure that adjusts the test set's instruments to the required accuracy. The calibration verification card itself needs to be verified against NIST-traceable calibration equipment every 24 months. This period is based on current empirical data from other programs and will probably be extended in the future once data is available for the JSF AME Tester itself.

Summary:
The JSF AME tester program is an example where COTS products and off-the-shelf testers are used to fulfill custom test requirements, thus reducing the development and life cycle costs of the test set and the time-to-market. It is also demonstrates how innovative maintenance techniques can help reduce maintenance and life cycle costs of test sets.

References:
JSF AME Test Requirements Documents
JSF AME STE Requirements