THE GPATE SYSTEM

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Abstract - The GPATE System is the maintenance solution at level two (ML2) for the avionics units of Eurofighter Typhoon aircraft.
GPATE program main target is the development and production of a General Purpose ATE (GPATE CORE) and a collection of TPS whose outstanding features are its reduced footprint, portability, rapid deployment capability and obsolescence mitigation design.
The paper outlines the most challenging requirements of the program and describes the design approaches that addressed them during the development phase. It describes also the GPATE CORE ATE as an innovative solution in the field of transportable general purpose ATEs.
The paper shows how the technical issues were solved and tested, and the problems encountered.
Finally it outlines the present status of GPATE program, with nine COREs and 48 TPS in production, and the next future applications forecasted.

INTRODUCTION

GPATE is a multinational program sponsored by Spain, UK, and Italy, where INDRA is the prime contractor for the consortium in charge of the development, being SELEX Sensors & Airborne Systems and Galileo Avionica the other partners.

The purpose of GPATE System is to provide a comprehensive maintenance level 2 solutions for the avionics of Eurofighter Typhoon Aircraft. The 48 TPS under contract encompass technologies that go from digital buses to radio communications and navigation aids. GPATE System (Figure 1) is designed under severe deployability requirements. In transportation order, all the HW items are packaged in rugged cases, including the CORE tester, the interface adapters and all the accessories. The system can be deployed to a forward operating base with a minimum of installation requirements to work in a controlled environment. The GPATE can be also operated within a military shelter.

The GPATE tester (called the CORE) is a General Purpose ATE entirely designed and produced by INDRA. It is based on Commercial of the Shelf (COTS) instruments, allocated in rugged cases, most of which are around 40 Kg weight. Designed for use in the field, it is composed by 11 operational boxes made of carbon fibre, strong enough to meet the environmental requirements while minimising weight. The cases include either rugged chassis to hold either VXI cards or 19” standard instrumentation.

Fig. 1. GPATE System in Operation Mode

The CORE has been designed to be easily set-up and dismantled by two people. A standard Allen-key is the only tool required to assemble the CORE. An inter-cases connection system based on blind mate connector philosophy is used, avoiding the need for external cables or connector blocks to provide the signal paths. This solution makes the GPATE CORE very unique in the field of transportable testers.

The System SW is based on the latest technologies: Component Based Development (CBD), Object Oriented (UML1.1), and Development Standards based on ISO/IEC 12207 and MIL-STD-498 are some of its features. The System SW provides multiple services: execution support for the TPS, test reports management, statistics, station utilities and many others.

GPATE CORE REQUIREMENTS

This section describes the most challenging requirements that led the CORE design to the present configuration.

Functional Performances

The CORE is a general purpose ATE that embraces different technologies: analog, digital, communication buses and RF, among others. It is based on COTS instruments, being the VXI standard the preferred one, although other commercial standards like GPIB are allowed.
A spread range of instrumentation is specified, as described below.

Low frequency measurement

Apart from the most common equipment (Digital Millimeter, Counter) a powerful 4 channel 500 MHz bandwidth digital oscilloscope was required.
Audio signals analysis capability is also specified.

Low frequency stimulus

The low frequency collection of requirements is very wide, comprising 2 Arbitrary Waveform Generators up to 50 MHz, 1 Pulse Generator up to 300 MHz, 32 channels of 16 bit D/A converters and 16 channels of A/D converters. The stimulus resources group is completed with a Universal Video Pattern Generator.

Communication buses

The CORE is comprehensive in digital buses, providing the MIL-STD-1553 /STANAG 3838 and STANAG 3910.It also provides ARINC 429, Serial RS232 /422/485, IEEE 802.3 (ETHERNET), IEEE-488 (GPIB), and CANBUS (optional).

Power supplies

The CORE is required to have an extensive set of programmable DC sources. Up to 9 low power and two high power DC power supplies are specified. The AC power supply is a three-phase programmable up to 125 VAC.

Radio-frequency

In the field of radio-frequency the CORE has to provide a basic set of resources like Synthesizer, Spectrum Analyzer, Power Meter and RF switching matrix, among others.

Other functional requirements

- The CORE has an Air cooling Unit for UUT cooling purposes.

- The CORE has to operate either from a 220 VAC / 60 Hz three-phase supply or from 115 VAC / 400 Hz three-phase supply.

Environmental Conditions

The CORE is designed in accordance with MIL-PRF-28800 for environmental conditions, and to meet EN5502 and EN61000-3/4 regarding the EMI/EMC conditions.

Deployability

Deployability is understood as the ability of the system to be deployed in a quick time using limited resources. In that sense the main requirements for the CORE are:

- Can be set-up by two people in less then 4 hours, including self-verification of its operational status.

- Can be broken down into individual units each of which weights less than 60Kg, being the target 40 Kg per unit.

- Air transportable.

- Can be operated in an APAWS (Air Portable Work Shop)

Maintainability & Testability

The CORE maintenance policy is based on the removal and replacement of modules without the need for special tools, soldering or wrapping. Scheduled maintenance is kept to a minimum.

The CORE has comprehensive Self-Verification utilities able to detect and isolate failures at replaceable module level, and to perform adjustment and calibration routines in order to avoid, at the maximum extent possible, instruments removal for calibration purposes.

Regarding accessibility, it is possible to perform almost all maintenance and repair work from the front of the test equipment, being the target to achieve a MTTR not higher than 100 minutes.

Obsolescence

The GPATE is designed to have an operating and supporting life of 25 years when it is maintained in accordance with approved maintenance procedures which may include the replacement of components.

System SW

The set of System SW requirements addresses many concepts like portability, expandability, diagnostics, usability, fault recovery, etc. The quality requirements are based on the most advanced standards, like MIL-STD-498.

GPATE CORE SOLUTIONS

This section describes how the CORE design addresses the most relevant challenges inherent to the requirements detailed above.

Functional performances

Stimulus & Measurement

The GPATE is a good example of "how to build a rugged system based on COTS". Instruments selection for the CORE was a really complex task because, in addition to the very demanding technical performances , COTS had to meet a set of environmental requirements like operation & storage temperature ranges, and physical conditions (dimensions, weight, mechanical strength, etc).In some cases the number of choices for a given instrument selection was very low. Nevertheless we can state that GPATE CORE is running a set of purely commercial instruments.

VXI is the basic standard used. Six of the eleven operational cases (named A1 to A11) incorporate a VXI mainframe (Figure 2), each one holding the PC controller, the instrumentation and the mainframe VXI plug-in power supply that is an INDRA design.

More in detail the VXI cases resources are:

- A1: Communications buses (MIL-STD-1553/STANAG 3838, STANAG 3910, RS-232/422/485, ARINC-429)
- A2: Low frequency stim. &meas (Counter, Pulse generator, Audio Analyzer, System Trigger).
- A3: Radio Frequency 2 (Synthesizer & Waveform Modulators).
- A4: CPU (DMM, Oscilloscope, Ethernet HUB).
- A5: GPI (Switching cards in CASS configuration and Digital I/O).
- A6: Radio Frequency 1 (Power Meter, AWG, RF Switching Matrix, Resistor Ladder).

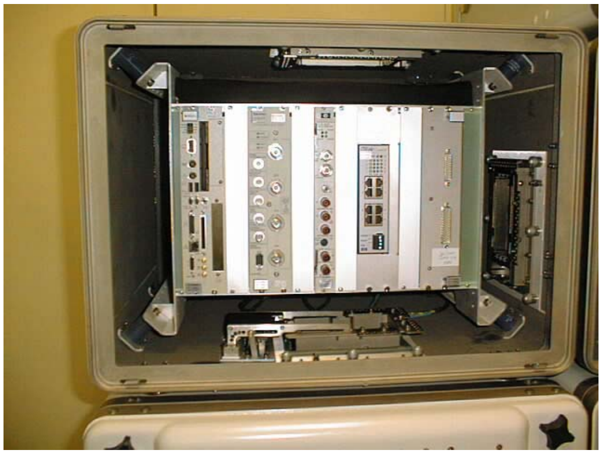

Fig. 2. CORE Case A4 with VXI Mainframe

The stimulus resources not available in VXI format are implemented using "rack & stack" instruments. This is the case for DC & AC Power Supplies, High Power Loads, Spectrum Analyzer and Rubidium Clock and Video Pattern Generator.

DC Power Supplies system is implemented using lightweight, compact, multiple output modules controlled via RS-485, allocated in A10 & A11 cases. Its features include reverse polarity switch and output isolation. There are 6 modules 0-65 V @ 30 A max; 3 modules 0-120 V @ 15 A max;

and two high power modules with ranges 0-30 and 0-40 V respectively.
DC Power System is completed by one High Power Load up to 500 V & 500 W dissipation.

For the AC PSU, allocated in A9, a lightened version of a commercial three phase 1-135 V @ 5 A per phase model was used. Weight reductions were made by changing mechanical parts and the output transformers size.

The Spectrum Analyzer selected was a consolidated commercial model from 100 MHz to 22 GHz installed in a floating chassis within the case A7.

A Rubidium Clock Generator , allocated in A8 provides base clock signals for every instrument in the CORE. A universal Video Pattern Generator is also allocated in A8.

Switching Matrix & GPI

The CORE Switching Matrix is based on VXI cards, allocated in A5 and wired to the GPI.Both items (Switching Matrix and GPI) are fully CASS compatible. The design of A5 was one of the biggest challenges. It had to allocate the relay cards, route their inputs & outputs to the GPI and, at the same time, route the rest of the ATE signals to the GPI, with the exception of RF & communications that went to a dedicated panel. The amount of wiring within A5 was huge, taking into account the service loops required for maintenance. The solution was a unique lightened GPI whose modules can be removed from the front, avoiding the need for service loops. The design features of CORE A5 allowed having a CASS-like GPI & switching matrix within a box weighting less than 60 Kg.

Power distribution & environmental monitoring

GPATE CORE has a set of specific features related to the power control and distribution. These functions, together with other ones, are managed by the Environmental Control System (ECS), which main purpose is to protect the CORE and the UUT from any damage or malfunction due to external or internal potential dangerous conditions like: Input voltage out of range or out of phase, over current, earth leaking, etc.

Temperature is monitored at the air intakes & exhausts and inside the VXI power supplies.
All VXI backplane voltages are also monitored.

When the cases are assembled, the ECS verifies their connection to ensure that they can be powered up in a sequential way. The ECS also sequences the system shut-down to avoid power line spikes.

The VXI Power Supplies are fed with VDC coming from AC-DC converters located in A8, where the power distribution for the system comes from. The stand-alone instruments are fed with one phase AC power.

In summary, the ECS controls all the parameters related to the system health and is able to prevent undesirable conditions, keeping record of every anomaly to allow subsequent investigations.

Environmental Conditions

The GPATE CORE is a rugged system built using COTS instruments. Therefore it is necessary to protect COTS in many ways (EMC, shock, etc). This protection is provided by cases in different ways.

Electromagnetic Compatibility

Silver lining screens embedded within the cases structure provide a very high attenuation in a extremely light format for electromagnetic shielding. The remaining of shielding is achieved by the use of conductive gaskets in the system connectors. Shielding of external cables and the use of rugged peripherals (printer, display & keyboard) which are self-protected completes the set of protection features.

So far the CORE has been successfully tested in accordance with the EN5502 for radiated and conducted emissions and EN61000 for radiated and conducted susceptibility (Figure 3).

Shock & Vibration

GPATE CORE enclosures are made of carbon fiber reinforced in the corners. Their internal structure is an aluminum chassis tied to the skin by rubber shock absorbers. This chassis can be either a VXI mainframe or a 19” rack, depending on the instruments allocated inside the case.

Mechanical strength of the cases has been tested by placing up to 400 Kg on top of them. This is a challenging figure considering that a case without instruments weights only 26 Kg.

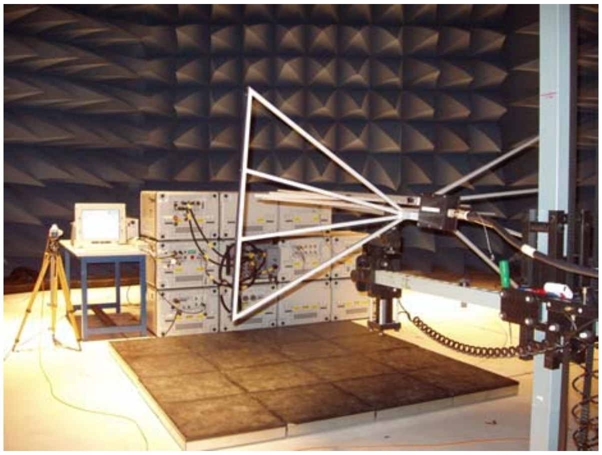

Fig. 3. GPATE CORE Susceptibility Testing

Transit drop and random vibration testing has been performed in accordance with MIL-PRF-28800. Test results show that the structures are able to protect instruments against the effects of shocks and vibrations.

Temperature & altitude

By requirement GPATE CORE has to operate from 10 to 30 ºC. Testing performed has shown that the system could operate beyond this range. CORE cooling forces air to circulate from the front to the rear of cases, passing through the instruments.
Regarding storage & transport, the system has been tested from -40 to 70 ºC.
One of the outstanding CORE characteristics is the ability to support an emergency decompression while being air carried.
Finally, the CORE has been tested to work 3,048 m of altitude.

Deployability

Defined as the ability of the system to be deployed in a quick time using limited resources, the main drivers for the design were:

- Lightweight cases: A maximum of 60 Kg, being the target 40 Kg per case.

- Inter-cases connections: A quick, safe, reliable and easy to operate inter-cases mechanical and electrical connection was the key to achieve a system set-up an tear-down operations which could be performed by two people in less than 4 hours, including CORE self-test end-to-end execution.

Lightweight cases

Taking 40 Kg as a target ,the available weight for a given case structure and wiring, after discounting the contribution of COTS instruments, was around 26 Kg. Considering that connectors and wiring were a significant part of the total weight, it was clear that the mechanical design approach had to be a non-conventional one. Neither the aluminum nor glass fiber was light and strong enough for the purpose. Then a carbon fiber envelope was selected. A silver lining was embedded to provide electromagnetic shielding.

Internal chassis, customized to allocate COTS instruments are built in aluminum. The trade-off between chassis lightness and robustness to hold shock & vibrations was difficult to achieve, and the last adjustments required some real mechanical testing done with prototype boxes.

Inter-case connections

The concept used was the blind mate connector (Figure 4).Each blind mate is like a down sized CASS GPI .There are two types of blind-mate :

- Receivers: Fixed connectors with female pins. They hold the locking mechanism which is very similar to the CASS GPI. The lever that operates has been replaced by an Allen key that is inserted from the front.

- Floating: Connectors with male pins. They have a mechanism that projects them around 3 cm beyond the box surface until they get in contact with the receivers. The approaching mechanism is operated using the same tool used for the receiver engagement.

The blind mates are configured in accordance with the number and type of signals that they have to pass between adjacent boxes. Each one can allocate up to 256 signal pins, 76 power pins or 76 coax pins. Each case can mount up to 4 blind mates, located on the top, bottom, right and left sides respectively. However, the number of blind mate used is optimized, being the GPI box (A5) the only one with 4 blind mate mounted.

The blind mate provides electrical connection and mechanical link between the cases but needs a good physical alignment for a proper engagement. For that purpose the cases incorporate a set of mechanical pins (males & females) located on the sides that need to be engaged to assemble the boxes (Figure 5). This engagement is made by cases gravity, not requiring the use of tools.

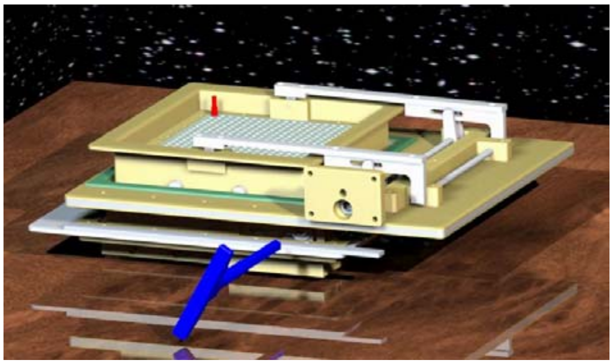

Fig. 4. Blind Mate Engaging Mechanism

Fig. 5 . Example of Case Side with Floating Blind Mate and Alignment Pins (Female Type).

When the cases are mounted, the blind mate connectors are engaged one by one. Any missing engagement is detected and identified by ECS at system start-up. Power will be never applied to the system if there is any missing connection.

The blind mate connection system is one of the key features of GPATE CORE, having the following advantages:

- Avoids need for external inter-case connection cables.

- Is reliable, because is based on the CASS GPI standards.

- Reduces signal paths length and system footprint.

- Standardizes the number & type of system connectors.

Maintainability & Testability

GPATE CORE maintenance philosophy is based on the replacement of COTS instruments. In terms of testability, the emphasis is put in detecting and isolating the faulty instruments.

Self-Verification utilities

There are three levels of testing:

- Instrument self-test: Performed at power-up or requested by the operator, is a confidence test that exercises the internal instruments BIT. External adapters or cables are not required.

- Operational Testing: Is the main maintenance tool of GPATE CORE. Its main purpose is to ensure that instrument functionalities are available at GPI level. Operational needs the connection of an interface device, the OPID, and runs a modular ATLAS program that tests every instrument and its associated wiring.

- Performance Testing: Its main purpose is to ensure that instrument parameters are within their specifications at the GPI level. The second purpose is to avoid instrument removal for periodic calibrations. Assuming the principle that a given instrument doesn't need to be externally calibrated unless its parameters are out of tolerance, the performance test verifies all the instrument functional parameters and jumps to self-alignment routines wherever possible. The adapter used with the Performance is the OPID, complemented with some special cables, adapters and load-box.

Maintenance

Replacement of an instrument is an easy task, only requiring the use of standard tools. Cases front covers are fixed with locking screws that are manually operated. Once the front cover is removed we gain access to the instruments and their connectors. All instruments are removed from the front, including the VXI mainframe power supplies. Rack & stack instruments are equipped with slides to facilitate its replacement.

The only maintenance task requiring access to the rear of the boxes is the replacement of the air cooling fans.

System SW

GPATE CORE is controlled by a SW package named SAMe SW. This package is an INDRA product that is currently used in several programs and provides the typical functionalities of an ATE, like instruments control, man-machine interface, run-time systems, and utilities (test reports, maintenance utilities, etc).SAMe SW has been extensively debugged along these programs and is in a mature state. Among its features we can emphasize the following:

- Runs test programs from different development environments, including legacy TPS. SAMe SW is able to run, for instance, TPS in ATLAS, BASIC or C++.

- HW independency: The use of IVI-like drivers and virtual instrumentation techniques allows to isolate SW from HW in such a way that replacement of obsolete instruments is not traumatic. The independency from HW is the best way to prevent obsolescence in a system like GPATE.

- Access to Expert Systems: A SAMe SW module called TPCS (Test Program Control SW) allows the CORE to control TPS execution. The test sequence is allocated in an independent database allowing the execution sequence to be optimized without any impact on the TPS itself. To enable this feature the tests have to be encapsulated following certain rules. TPS can benefit from this feature when the field data from TPS become available.

- CASS compatibility: SAMe SW is running In other ATEs with a high degree of CASS compatibility.

Obsolescence

The CORE is designed for a service life of 25 years. In a system like this, the obsolescence of COTS is unavoidable. The best way to prevent system obsolescence is making SW independent from HW. Obsolescence survey is made by the INDRA Obsolescence Management Group that issues periodic Obsolescence Reports containing forecasts and recommendations. GPATE program has not yet suffered any replacement due to obsolescence, but other programs using SAMe SW suffered changes with a minimum impact on TPS.

GPATE PROGRAM TODAY

GPATE CORE is one piece of GPATE SYSTEM, which comprises 48 TPS for the Eurofighter Typhoon Aircraft.

Nine CORE have been produced for TPS development & integration, that is taking place at three sites: INDRA (Madrid, SP), SELEX Sensors & Airborne Systems (Edinburgh, UK) and Galileo Avionica (Torino,IT).

The 48 TPS are grouped in 3 OTPSs, sharing the basic ID design. Interface customizations are implemented in the holding fixtures (Figure 6).

GPATE TPS embrace many technologies, including computers, displays, communications, navigation (MLS RNAV, DME, etc) and others. First delivery of 3 GPATE Systems to the three participant nations (UK, SP & IT) is scheduled for May 2006.

Fig. 6. GPATE TPS: UUT & Holding Fixture