REQUIREMENTS AND SOLUTIONS FOR THE AUTOMATION OF TEST CELLS AND TEST FIELDS IN AUTOMOTIVE TESTING ENVIRONMENTS

Udo Oligschläger

FEV Motorentechnik GmbH, Business Unit Test Systems
Neuenhofstr. 181, 52078 Aachen, Germany
tel.+49 241 5689-606, fax: +49 241 5689-7606
e-mail: oligschlaeger@fev.de

Thomas Wagner

FEV Motorentechnik GmbH, Business Unit Test Systems
Neuenhofstr. 181, 52078 Aachen, Germany
tel.+49 241 5689-141, fax: +49 241 5689-143
e-mail: wagner_t@fev.de

Filip Chelminski

FEV Polska Sp. z o.o., Business Unit Test Systems
Ul. Lublanska 34, 31-476 Krakow
tel.+49 241 5689-141, fax: +49 241 5689-143
e-mail: chelminksi@fev.de

Abstract

Time goals, becoming shorter and shorter, and increasing demands for quality for the development of vehicles and their components ask for new methods to handle the various tasks in this area. The growing complexity of those tasks requires very good support for the users and operators by involved tools and systems. Ideally, those systems are highly integrated and build a closed, seamlessly cooperating chain of tools to support the entire development process. Besides the activities directly related to the test cell, an increasing number of administrative and overall tasks come into focus more and more. This paper introduces today's and tomorrow's requirements to a test cell and its environment combined with a discussion of appropriate solutions. The variability of a modern diesel engine, the positioning of the systems in the company overview, error indicators and problem reporting in a modern automation system such as FEV's TestCellManager, a modular approach for a test cell automation system, the general situation in a test cell based on appropriate system architecture, the systems in a test field according to functional layers, a modular approach for test field management systems, test field overview provided by the FEV's TestFieldManager are presented in the paper.

Keywords: *test cell, test field, automation, combustion engines*

1. Introduction

Looking into a test facility in the area of automotive testing one can find a lot of different processes and activities, which either perform tests directly or support the testing tasks by providing infrastructure, supervision and control, or administrative functionality to the operators.

There are two main categories, in which all this aspects can be distinguished, the test cell level and the test field level.

Emissions regulations are becoming stricter and stricter. This tendency forces the engine developers to take into account an increasing number of ways to influence the combustion process. Translated into the situation in one particular test cell (e.g. engine test cell or chassis roll) this results in an increasing number of measurement and control devices, that are applied to the device under test (e.g. engine or vehicle). Examples for these devices are listed in the following picture:

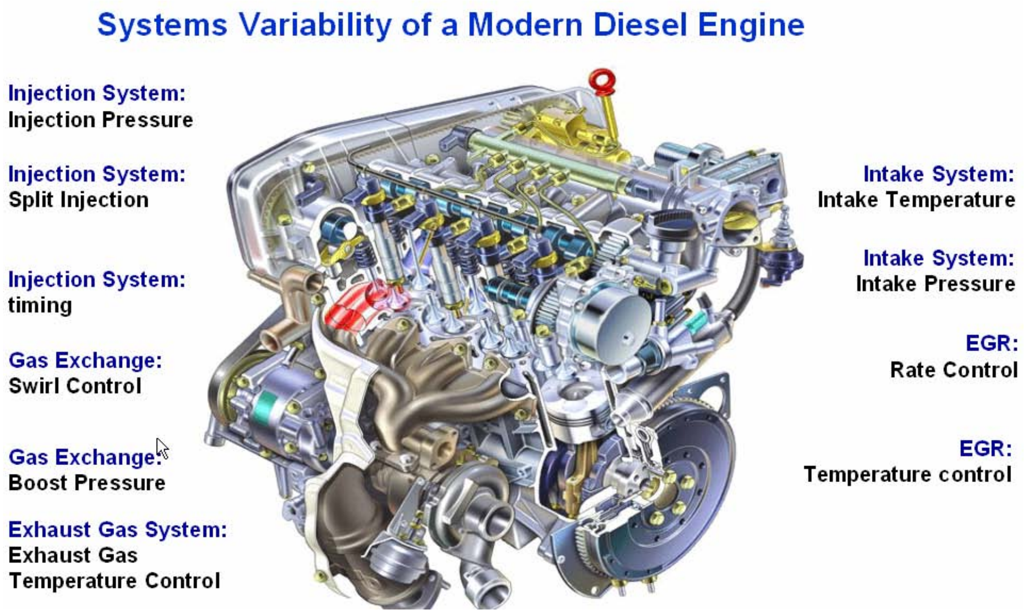

Fig. 1. The variability of a modern diesel engine

All those signals must be handled precisely in order to assure reproducible test results. This applies for the control of demand values and settings on one hand and for the acquisition and processing of measurements on the other hand.

Besides the evolution directly related to the combustion engine, the number of electronic control units in one vehicle is growing rapidly. Especially hybrid concepts need extra devices in order to control charging of the battery, to split the requested power into fractions for combustion engine and electrical motor, and so on. Of course those control units are interconnected via controller networks, which require special interfaces as well. This of course introduces the next level of complexity into the activities inside one test cell.

In the scope of a test field the situation is more characterized by an increasing number of variances of units under test, which must be handled in efficient and robust way. On top, the demands for quality assurance for the entire testing process including test preparation and post processing are indispensable as well as the efficient handling of the entire infrastructure, which is essential to run the tests. Last but not least, the flexibility to resume an interrupted test on a different test cell is an important feature of a test field, because it provides more freedom in disposition of units under test to test cells.

The following picture shows the principle situation in a test field and the position of a test field in the IT-world of a company.

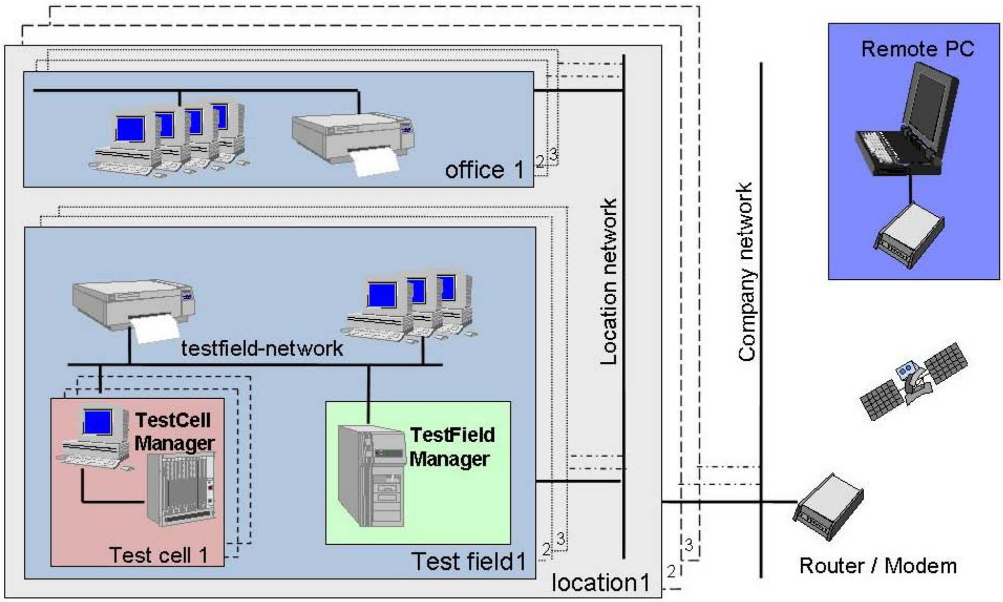

Fig. 2. The positioning of the systems in the company overview

The core part of this picture of course is the group of test cells represented by the automation system TestCellManager in this picture. The cells are connected to a host system, here called TestFieldManager, which acts as a bridge between the testing world and the other parts of the company. Besides the test fields there are offices, where typically the engine development engineers are located. They are the "customers" of the test field, because they want to have tests to be performed in the test field. As a next layer all locations of a company typically are connected. As a result this means, from the IT point of view, the infrastructure normally available in a company provides means to connect any computer in the network to any test cell in all test fields of the company.

2. General requirements

General demands, which are common to all levels of testing, are the demands for increasing efficiency, flexibility and a high level of user friendliness. These requirements directly call for highly integrated systems on all levels. Data transfer must be virtually seamless and the systems have to feature the following attributes:

- Flexibility
  - Extendibility
  - Scalability
- Openness
  - Integration platform for already existing systems
  - Interfacing to existing higher level systems
- Acceptance
  - "Migration instead of revolution".

In this context flexibility means the ability of a system to be extended by new functionality at later points in time without any impact to already existing parts of the system. E.g. the introduction of an interface to a newly installed measurement device must not result in changes of the overall test procedure. Additionally a scalable architecture must be available, which allows for tailoring the system to the current needs of the required test procedures. Again, activities, which are done in order to adapt the system to a new situation, must be performed with lowest, even better without any, impact to the existing or remaining parts of the entire system.

Openness is required to provide ways to combine the systems with other, mostly 3rd-party devices with low integration efforts. Both ways of combination must work; integration into an existing network of systems or coordination and control of subordinated systems. Key point of this requirement is, that the systems have to provide standardized interfaces, which are properly documented, well accepted and therefore widely spread among the community of system suppliers.

Last but not least the acceptance of a system is strongly based on its capability of adaptation to different ways of working, or more general, different workflows. Supposed, that these requirements are fulfilled, all processes can be optimized and refined smoothly and step by step, but always supported by the same system. Again, the goal is to reduce invest in systems and cost of training.

3. Requirements to a modern test cell

As already mentioned in the introduction, the situation inside a test cell is dominated by the increasing number of signals and interfaces to sub-systems, which overwhelms the operator in many cases. For that reason the operator needs support in the following areas:

- automatic recognition of connected hardware and devices,
- checking the incoming signals for plausibility,
- having easy, hierarchical access to status information of the entire test cell and its connected devices,
- working with configurations, which are based on libraries of well proven parts of test configurations,
- ability to operate all sub-devices via the automation system.

In day to day operation of test cells it is common practice, that equipment must be replaced by spare parts, because the part, which was used initially, is broken or needs maintenance. The replacement can also be caused by resuming an interrupted test on a test cell, which is equipped slightly different. In such a case all installation-dependent parameters of the particular device must be updated, in particular calibration parameters must be adjusted corresponding to the new instance of the same device type. This procedure is error-prone, if done manually. Therefore an automatic way to detect the connected devices and sensors is required. Having the identifier of the device available, the automation system can retrieve the needed data either from the device itself or from a central database. Of course this approach assumes that all parts of equipment, that are available in the entire test field, are registered together with all their descriptions and parameters.

Working with very high numbers of signals makes it impossible to monitor every single value of every channel manually. This calls for a functionality, which automatically checks the plausibility of the incoming signals by applying rules to the relation between the signals or the behaviour of one single signal. E.g. in most cases more than one signal, which represents engine speed, is available (ECU, brake, additional sensor mounted directly to the engine). These signals can be checked against each other to determine, if there is one signal deviating much more to the average than the others. In case of an implausible signal, the average can be temporarily used as a replacement for the faulty signal. This can be very helpful to assure a safe termination of the test run, if e.g. the signal is used as feedback for the speed control loop.

Besides the status of signals the status of more complex devices and also of the unit under test is of great interest for the operator. Ideally he should have a status indicator, which can be opened on different levels of hierarchy, where each level shows the summary of the next deeper level. If something is wrong, the operator simply can unfold the next deeper level to inspect the details.

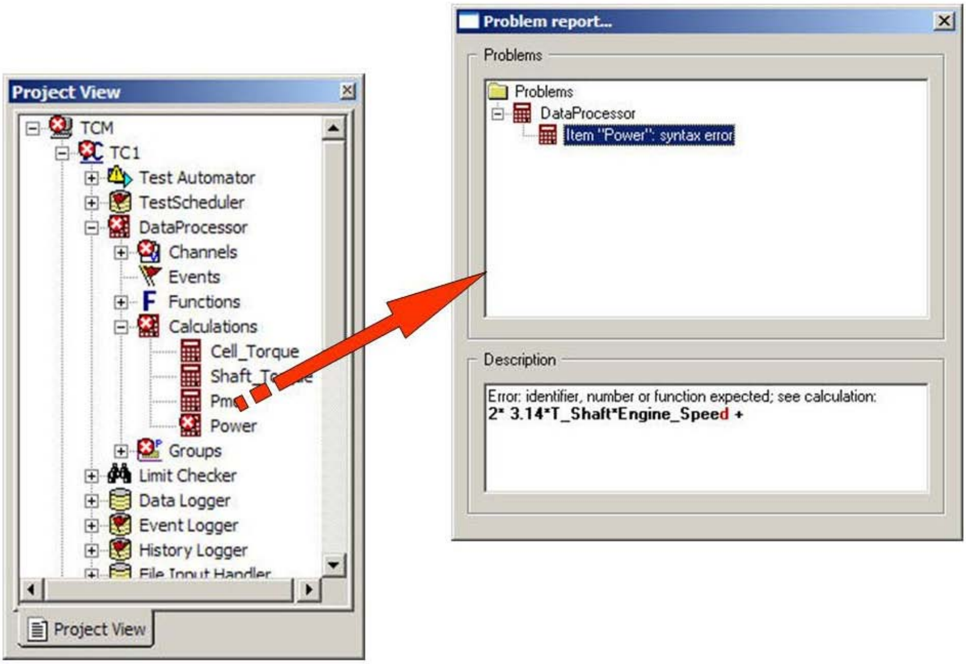

Fig. 3. Error indicators and problem reporting in a modern automation system such as FEV's TestCellManager

Since nearly all subsystems are providing an increasing number of signals, the central system (typically the automation system) needs powerful interfaces, which support transport of lots of data. E.g. the ECU provides several signals, which are part of the production engine, via software interfaces (such as ASAM-MCD). If those interfaces are used, it is not necessary anymore to apply sensors for such signals as part of the test cell setup.

4. Design of modern test cell systems

The design of a modern automation system must allow for easy extension of functionality, which was not required during introduction of the system. E.g. new interfaces to external devices, engine control units, or vehicle bus systems evolve over time, but must be available as soon as they are released by the standardization group. To assure this possibility FEV's automation system TestCellManager is based on absolute modular architecture, which is composed of a central core, providing a communication backbone and several modules, each of them providing well defined and proven functionality. This communication backbone is composed of services, which allow modules to exchange information in form of channels, events and function calls. Channels can transport any type of information such as measurement values, calculated values, manually entered values or text strings. On the other side events can be sent by a module to notify the other modules about important status changes. This can be the start of the engine in the test cell or the end of a complicated measurement procedure.

All modules can use the channels provided by the others for any purpose. This means all channels can be displayed, logged, used in calculations, monitored against limits, or used as demand values without any restriction. The only condition is matching physical dimension; this check is done automatically by TCM in order to prevent from connections, which don't make sense from the physical point of view.

The other way of communication is reacting on incoming events with appropriate activities. This can be the activation of a different operating point of the engine (e.g. "CoolDown") in case of an alarm-type event (e.g. "EngineOverheated") or the triggering of a complex script, which handles a multi-step cool down procedure after a regular full load measurement.

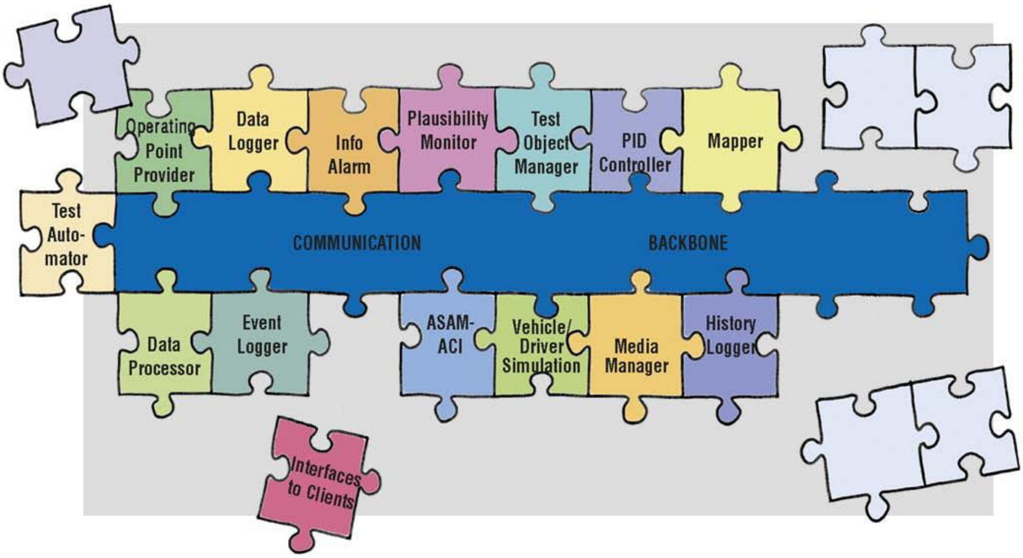

Fig. 4. A modular approach for a test cell automation system

So, a wide range of prepared functionality can be used directly without the need of programming. On top of this the module called "TestAutomator" can be used to define any procedure from simple performing a WOT test to high complex procedures and algorithms used in the area of ECU calibration.

The described concept of modularity was basis for all software based products of FEV's portfolio of test systems as well as for the other products such as conditioning units and signal terminals. It enables the user to tailor the equipment to the requirements with best possible fit and low initial cost, and openness for later extension at the same time. The following picture shows the principal set up of an engine test cell with FEV equipment.

5. Requirements to a modern test field

Talking about a test field in detail, the term must be defined first. A test field comprises multiple test cells, which either are located very close to each other, or have the same intention concerning the goals of the test procedures, that will be executed on them. Therefore, those test cells typically share required infrastructure like supply with all media. Examples are cooling water for different purposes, different types of fuel, and calibration gas for emission analyzers.

Additionally, a lot of administrative tasks can and should be done commonly for all members of a test field. The following list gives an overview:

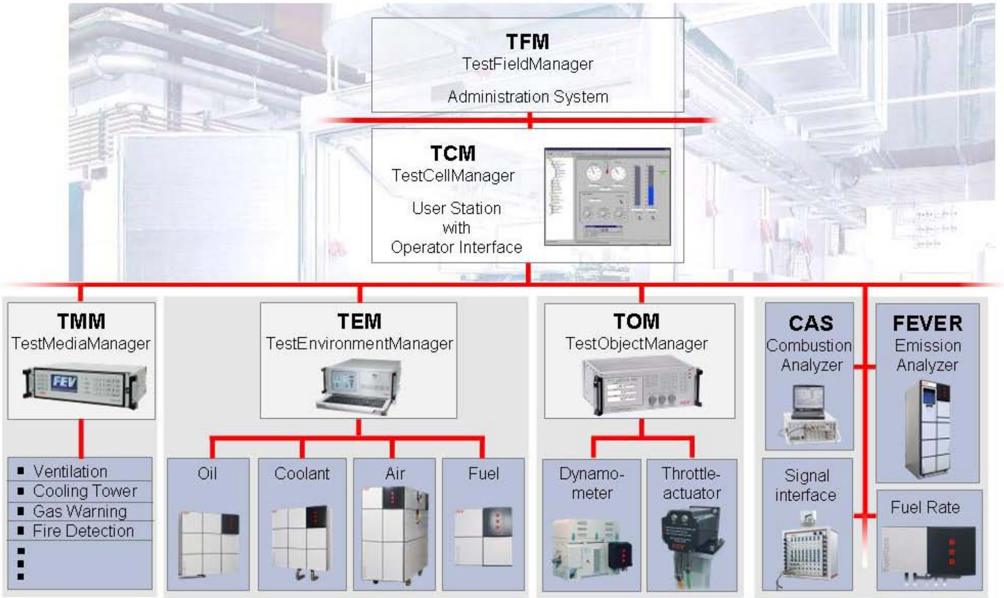

Fig. 5. The general situation in a test cell based on appropriate system architecture

- Checking feasibility of an incoming test order concerning available equipment and required timing.
- Scheduling of test orders.
- Assignment of a test order to a test cell to assure the lowest preparation effort.
- Administration of descriptive data about units under test (engines, vehicles, others).
- Administration of the entire equipment available in the test field.
- Providing information about the calibration history of equipment to support QA.
- Planning maintenance tasks.
- Monitoring of different supplies for the test cells (fuel, oil, etc.).
- Central storage and administration of measurement data.
- Distribution of information about the status of a test order to all involved people.
- Logging of utilization data in order to support cost accounting.

The overall degree of utilization of a test field must be increased as much as possible to justify the financial invest for a modern test facility. One prerequisite to achieve this goal is the possibility of disposition of test orders between test cells belonging to the test field. In the best case a test order can be processed on all test cells of a test field, but mostly it will be possible on a subset only. To enable such dispositions it must be very easy to support the migration of an already started test order to a different test cell after it has been interrupted for some reason on the initial test cell. In detail, replacement of devices, which are different between the cells, and the integrity of result data are two of the most important issues in such a case.

During the entire testing process different levels of users and operators must be able to retrieve all important data at any time from anywhere in the company. The whole bandwidth, starting from the manager of a test field, who needs to know the current backlog of test orders, including the calibration specialists, who are interested in the quality status of every piece of equipment used in the test field, up to people responsible for supply inventory of consumable material, who need to know the actual stock of e.g. fuel or calibration gas, must have an easy and consistent access to those data. Ideally all data would be accessible via standard software such as an internet explorer to avoid maintenance of special software installed on lots of computers across the entire company.

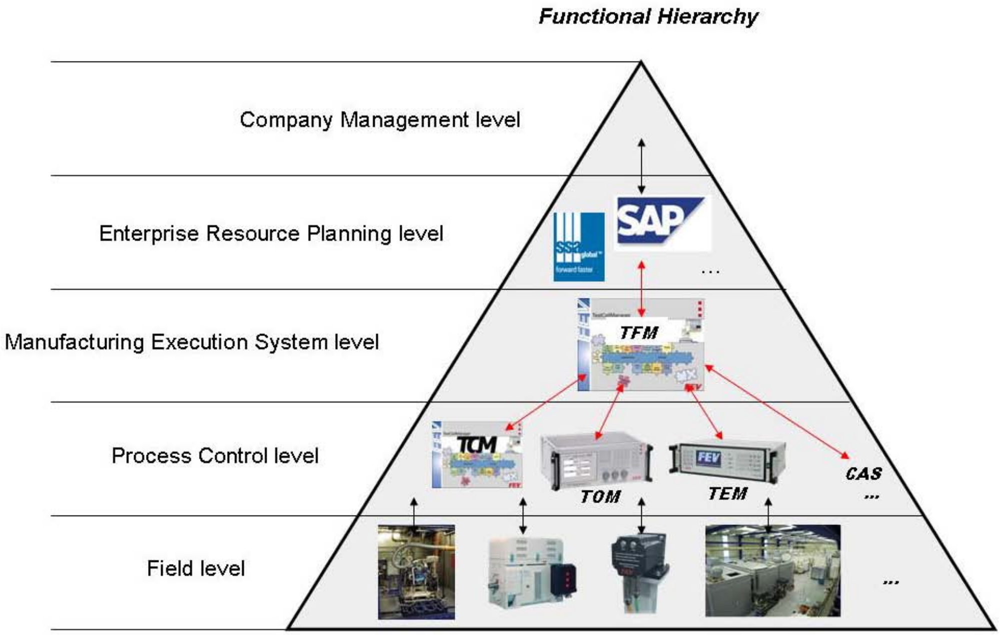

Fig. 6. The systems in a test field according to functional layers

Besides the interfaces to the human user the test field should also provide an interface to superior systems. Data transported via such an interface are occupancy of equipment, consumption of material (e.g. fuel) and man hours. They are used for accounting cost corresponding to test orders respectively projects and for further planning of invest.

Another important task of test field systems is the central storage of data. There are several categories of data, which have to be maintained on this level:

- Data, which are used during preparation of a test run: standards such as names, units and calculations.
- Data describing the units under test and the equipment, which is available in the test field: technical, calibration and utilization data.
- Data generated during preparation of a test run: configurations for the test cell systems.
- Data produced during the test run on the test cell: measurement and result data.

Since there are many resources in the whole test field, which can be disposed for test orders, a resource planning and scheduling functionality must be available. It must be used for all types of equipment starting from the test cell itself, via special equipment, which is not available on all test cells, up to human specialists, who need to be involved, when a very complicated test procedure is executed. The system must provide an overview on the current assignment and location of resources as well as support planning activities for test procedures operated in the future. At this point the access to calibration and maintenance data must be possible, because tasks related to such concurrent activities must be scheduled together with the primary tasks of the test field, the engine tests.

Another example for concurrent activities is the management of the infrastructure of a test field. All systems and devices, which deliver material or have an impact on the environment, in which test procedures are operated, must be monitored regarding their proper function and their remaining runtime. This is necessary to avoid expiration of any supply during an already started test.

6. An example for a modern test field system

The following picture shows the approach used for FEV's TestFieldManager. The architecture follows the already introduced design of the TestCellManager, based on the same central modules and services in the communication backbone. The functionality, which is special to this system level, can be found in the modules surrounding the kernel.

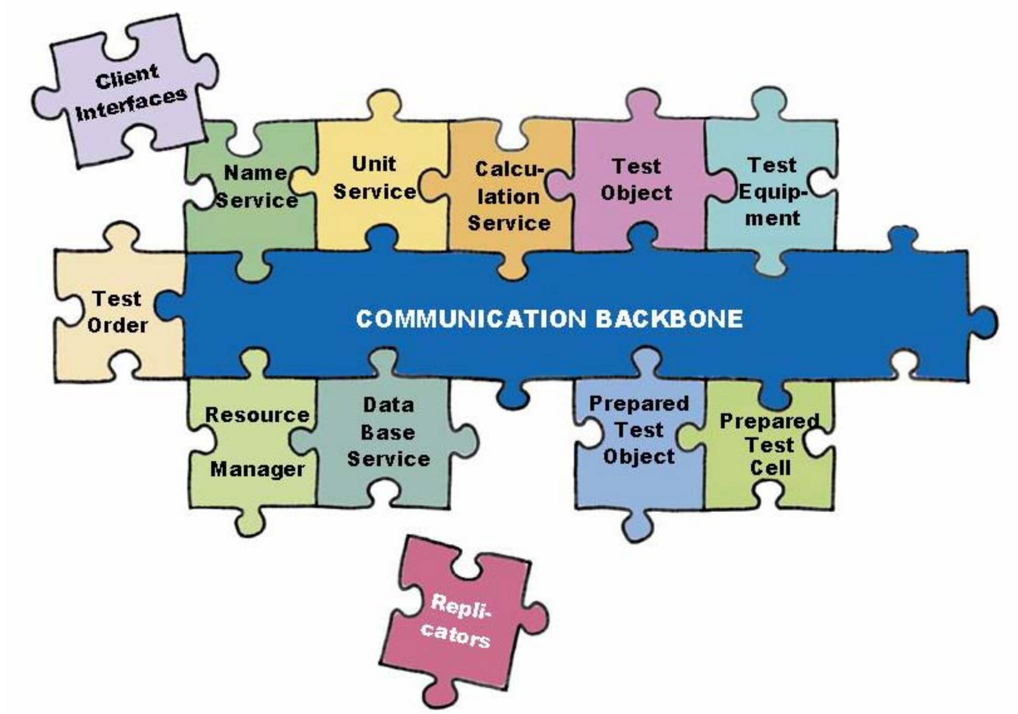

Fig. 7. A modular approach for test field management systems

The TestFieldManager comprises administrative functionality, master display (SCADA) and data management functions in one system. This means the operator does not have to switch between different tools for different tasks, but can stay in a uniform and therefore easy to learn environment. The various aspects are available via modules, which are organized in a tree view, which is well known from several standard windows applications.

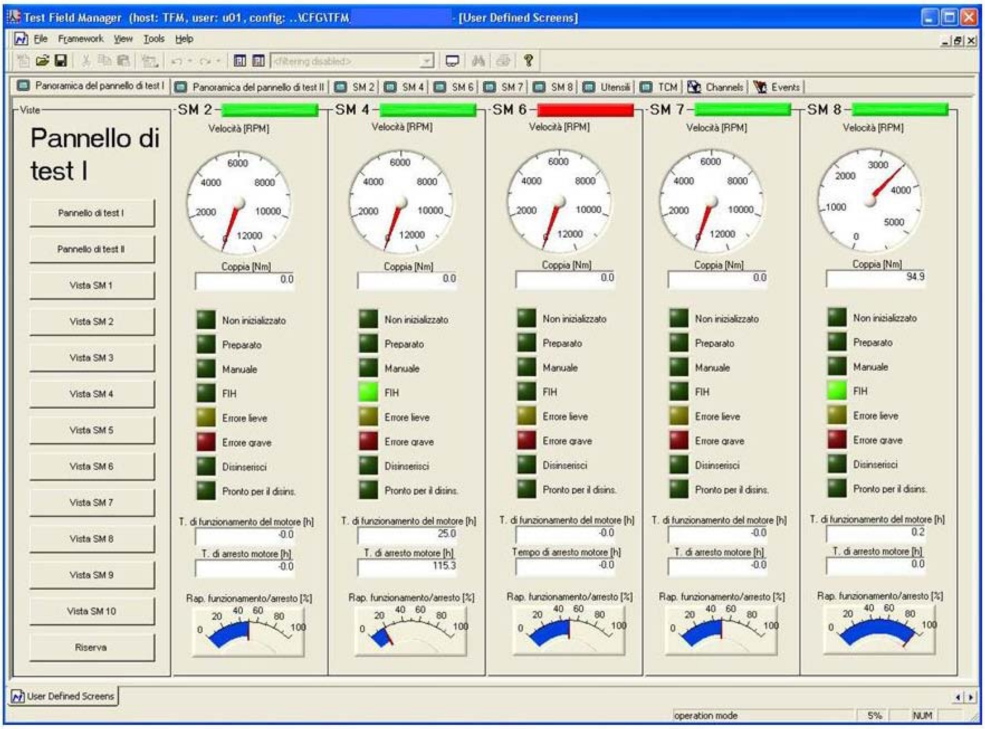

Fig. 8. Test field overview provided by the FEV's TestFieldManager

7. Conclusion and outlook

The examples of implemented systems show an approach being designed following the ideas of modularity, scalability and extendibility. All members of the presented product-line are based on the same software backbone and philosophy, and therefore come along with an integrative way of operation and a uniform look&feel. This makes usage of new modules or new systems easy and assures a fast start up, as soon as the first application is understood. The systems provide both an open system architecture and prepared functionality for day to day work. With this balancing act virtually all tasks can be performed with one basic system combined with user definable configuration packages.

Although the level of integration is already advanced in nowadays systems, an increase of interfaces, especially to higher level systems (ERP), can be expected. At the planning level all different types of tasks will be scheduled in an integrative tool, so that conflicts between e.g. maintenance of equipment and engine testing will be avoided automatically.

Last but not least the user interfaces will migrate from dedicated software installations to applications, which are just downloaded in the moment of starting via the web as part of a company intranet. This reduces maintenance of software tremendously, because the applications will be administered at a central place. Additionally the solution provides easy access for all authorized persons from anywhere in the company. Of course, the web-based interface will be only a supplement to the dedicated user interfaces coming with the particular tool.

Using the proposed solutions being implemented in FEV's product line the user can be sure to be well prepared for the current and upcoming tasks and requirements in the area of automotive testing.

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