Autonomous Data Acquisition System for Testing Vehicles

A degree's Final Project Submitted to the Faculty of the

Escola Tècnica Superior d'Enginyeries Industrial i Aeronàutica de Terrassa

Universitat Politècnica de Catalunya

By

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Developed under labor convention at

SEAT S.A., Centro Técnico

REPORT

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To my family, to Toni
and to everyone who helped me to learn.

Abstract

Autonomous Data Acquisition System for Testing Vehicles, baptized as ADAQ by its initials, is an application developed by SEAT Technical Center company in order to improve and revolutionize data acquisition methodologies. The app uses the resources of different softwares in order to build up a self autonomous system able to deal with all steps from a data acquisition process: the acquisition, the communication from data and the analysis. Every phase follows its own parameters in order to be configured and adapted by the technician as the different acquisition projects might demand. It is an auto-controlled and robust system able to work on extreme testing tracks where the vehicle could be sent, and able to advise the pilot or the analyst in case any problem occurs during any of the phases. When a new project is requested, the technician instruments the vehicle, configures the acquisition depending on the target of the test and selects the analysis to be done during the several days the vehicle will be on track. Then, the vehicle is sent to any testing track of the World. At this point, the pilot only needs to focus on driving. After the acquisition day is completed, data is transferred until the computer on the headquarters where the analysis from the selected data is carried out, every step on an autonomous way. When the analyst/technician arrives into the office will see the report from the analysis done. In less than 24 hours it is possible to see what is the evolution from the tested vehicle and make decisions whether it is convenient. Among all possible analysis stands out the pseudo-damage analysis. This analysis let know the wear from any instrumented component of the vehicle and can be compared with other tested vehicles or with the same vehicle tested under different conditions. ADAQ offers the possibility to view the accumulated pseudo-damage report to date, which is the sum from the daily pseudo-damages values agains the total kilometers completed by the tested vehicle. ADAQ is a pioneer application on its version 0. It has been designed taking into account where the future of data acquisition is headed and has proved to be reliable and operative on the first tests done.

Resumen

La Adquisición de Datos Autónoma para Vehículos de Ensayo, bautizada como ADAQ por sus iniciales, es una aplicación desarrollada por el Centro Técnico de la compañía SEAT con el fin de mejorar y revolucionar la metodología utilizada en la adquisición de datos. La aplicación utiliza los recursos de diversos softwares con el fin de diseñar un sistema autónomo capaz de dar solución a todos los procesos implicados en una adquisición de datos: la propia adquisición, la comunicación de los datos y el análisis. Cada fase se rige por parámetros propios con tal de que el técnico pueda configurar y adaptar cada proyecto de adquisición según los requisitos específicos solicitados. Es un sistema auto-controlado y robusto capaz de acoger ensayos en pistas y condiciones extremas y avisar al piloto o analista en caso de error en cualquiera de las fases. Cuando se solicita un nuevo proyecto, el técnico instrumentará el vehículo, configurará la adquisición según el objetivo del ensayo y seleccionará el tipo de análisis a realizar durante el periodo de tiempo que el vehículo este en pista. Seguidamente el vehículo será enviado a cualquier pista de ensayo del Mundo. En este momento, el piloto solo se dedicará a conducir. Una vez completada la jornada de adquisición, los datos serán transferidos hasta un ordenador en las oficinas centrales que ejecutará el análisis de los datos seleccionados, todo ello de forma autónoma. Cuando el analista/técnico llegue a su puesto de trabajo verá el report del análisis realizado. En menos de 24 horas es posible ver cual es la evolución del vehículo ensayado y tomar decisiones si fuese conveniente. De entre todos los tipos de análisis destaca el análisis del pseudo-daño. Este análisis permite conocer cual es el desgaste sufrido de cualquier componente instrumentado en el vehículo. A su vez puede ser comparado con el de otro vehículo de prueba o con el mismo vehículo ensayado bajo otras condiciones. ADAQ ofrece la posibilidad de visualizar el pseudo-daño acumulado hasta el momento, que equivale a la suma del valor de los pseudo-daños diarios frente al total de kilómetros completados por el vehículo ensayado. ADAQ es una aplicación pionera en su versión 0. Ha sido diseñada teniendo en cuenta hacia donde va encaminado el futuro de la adquisición y a demostrado ser fiable y operativa en las primeras pruebas realizadas.

Resum

L'Adquisició de Dades Autònoma per a Vehicles d'Assaig, batejada com ADAQ per les seves inicials, és una aplicació desenvolupada pel Centre Tècnic de la companyia SEAT per tal de millorar i revolucionar la metodologia utilitzada en l'adquisició de dades. L'aplicació utilitza els recursos de diversos softwares per tal de dissenyar un sistema autònom capaç de donar solució a tots els processos implicats en una adquisició de dades: la pròpia adquisició, la comunicació de les dades i l'anàlisi. Cada fase es regeix per paràmetres propis per tal que el tècnic pugui configurar i adaptar cada projecte d'adquisició segons els requisits específics sol·licitats. És un sistema auto-controlat i robust capaç d'acollir assajos en pistes i condicions extremes i avisar al

pilot o analista en cas d'error durant qualsevol de les fases. Quan es sol·licita un nou projecte, el tècnic instrumentarà el vehicle, configurarà l'adquisició segons l'objectiu de l'assaig i seleccionarà el tipus d'anàlisi a realitzar durant el període de temps que el vehicle estigui en pista. Seguidament el vehicle serà enviat a qualsevol pista d'assaig del Món. En aquest moment, el pilot només es dedicarà a conduir. Un cop completada la jornada d'adquisició, les dades seran transferides fins a un ordinador a les oficines centrals que executarà l'anàlisi de les dades seleccionades, tot això de forma autònoma. Quan l'analista/tècnic arribi al seu lloc de treball veurà el report de l'anàlisi realitzat. En menys de 24 hores és possible veure quina és l'evolució del vehicle assajat i prendre decisions si fos convenient. D'entre tots els tipus d'anàlisi destaca l'anàlisi del pseudo-dany. Aquest anàlisi permet conèixer quin és el desgast patit per qualsevol component instrumentat en el vehicle. Alhora, pot ser comparat amb el d'un altre vehicle de prova o amb el del mateix vehicle assajat en altres condicions. ADAQ ofereix la possibilitat de visualitzar el pseudo-dany acumulat fins al moment, que equival a la suma del valor dels pseudo-danys diaris enfront del total de quilòmetres completats pel vehicle assajat. ADAQ és una aplicació pionera en la seva versió 0. Ha estat dissenyada tenint en compte cap a on va encaminat el futur de l'adquisició i ha demostrat ser fiable i operativa en les primeres proves realitzades.

Confidentiality Remark

The document exposes ideas and configurations that have been developed thanks to tools and facilities from a private company. Therefore, the document omits or hides any relevant information that could compromise the interests of the company.

Acknowledgments

ADAQ has been developed by two UPC engineering students, Daniel Martín Martínez and the author, and directed by Antonio García Rabadán from SEAT Technical Center company. Daniel Martín Martínez worked on the first part of ADAQ, from September 2015 until February 2016, while the author worked on the second part, from March 2016 until December 2016. Every step has been assisted by also SEAT worker David Aceituno, who has always been receptive for any help, as well as Salvador Amer. It has also been remarkable the help from the three SEAT school students that have been involved in the project, first Adrián, then Marta and finally Antonio. Also being thankful to the acquisition hardwares providers Juan Alsina and David Blanco from HBM company for always being in touch with the project and every step reached. The technical support center from Siemens company, the provider from the analysis software has also been helpful in order to set the autonomous parameters to the analysis.

To all these people and companies I have to say thanks, mainly to Antonio García Rabadán, he is not only the one that had this idea but also the one that has been working hard to make it possible. The most special gratitude is to my family. They have always supported me and have given me all facilities and tools for me to do what I most like. Thanks to all these participants and thanks to my university, the UPC, who taught me during these last years. Without them this could not have been possible. During my period at the Technical Center from SEAT I have learnt so much; this has been my first work as an engineer and, at the same time, the biggest project I have ever done. My biggest motivation and legacy is having done a useful work and making ADAQ an operative application for the company I have been working for.

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UNIVERSITAT POLITÈCNICA DE CATALUNYA
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List of Acronyms

ADAQ Autonomous Data AcQuisition

ARPANET Advanced Research Projects Agency Network

B2SS Box to Shared Server

BPS Bits Per Second

CAN Controller Area Network

CD Control Device

CMD Command Prompt

DAQ Data AcQuisition

DCB Driver Control Box

ETSEIAT Escola Tècnica Superior d'Enginyeries Industrial i Aeronàutica de Terrassa

GB GigaByte

GPS Global Positioning System

HBM Hottinger Baldwin Messtechnik

HW Hardware

ID Identification

IEEE Institute of Electrical and Electronics Engineers

IP Internet Protocol

IPv4 Internet Protocol version 4

KM kilometers

LabVIEW Laboratory Virtual Instrument Engineering Workbench

LAN Local Area Network

LED Light Emitting Diode

LVDT Linear Variable Differential Transformer

MANET Mobile Ad hoc Network

MB/s MegaByte per Second

MS-DOS MicroSoft-Disk Operating System

MS/s MegaSamples per Second

NL Navilock

PB Process Builder

PDF Portable Document Format

PSD Power Spectral Density

RAM Random Access Memory

RMS Root Mean Square

RPC Rich Photorealistic Content

RPM Revolutions Per Minute

SEAT Sociedad Española de Automóviles de Turismo

SG Stain Gage

SN Specific Number

SS Shared Server

SSID Service Set Identifier

SW Software

TCP Transmission Control Protocol

TFG Treball Final de Grau

TS Time Series/Time Signals

UPC Universitat Politècnica de Catalunya

USB Universal Serial Bus

VANET Vehicular Ad hoc Network

V2B Vehicle to Box

V2V Vehicle to vehicle

V2SS Vehicle to Shared Server

VB Visual Basic

VI Virtual Instrument

WANET Wireless Ad hoc Network

VW VolksWagen

WLAN Wireless Local Area Network

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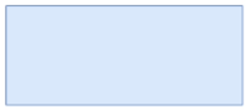
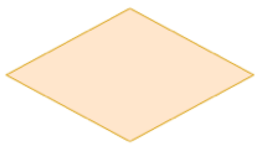
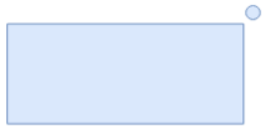
Legend for Flowcharts

Symbol	Meaning
	Start/Exit
	Action
	Decision
	Command Activation
	Reporting
	Delay
	Warning/Error
	Flow line

Context

Data Acquisition is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer. SEAT company measures the variables from their vehicles since time ago in order to improve the performance from some components, analyze and detect problems or simply control parameters between safety margins. Other times vehicle parameters are analyzed in order to reproduce track circumstances on a test bench. This is a normal practice for SEAT vehicles. In fact, every vehicle is considerer a self data acquiring and analyzer machine. Though the message-based protocol CAN bus several micro-controllers and devices on every vehicle are able to communicate to each other in real time without a host computer. Thousands of controllers are constantly talking to each other allowing any electronic function from a vehicle such as parking assist, transmission, airbags, antilock braking/ABS or cruise control. Additionally more transducers can be implemented into the vehicle in order to get more information from it, this is the action of instrumenting a vehicle. That is exactly what it is been done on this project, using CAN bus controllers and also instrumented transducers in order to get results from a vehicle and analyze them, with the novelty of completing this action on an autonomous way.

Aim

The target from ADAQ is setting an autonomous routine in order to acquire, communicate and analyze data coming from a vehicle that will be driven by a pilot in a testing track. This means building up a data infrastructure in order to host different acquisition projects and setting the commands and configurations in order to execute every action needed in this process on an autonomous way. The configuration and management of acquisition projects is through the design of an intuitive and user friendly tool. Thanks to ADAQ the technician will be able to see the results from the acquisition done every day when he/she gets into the office, since the analysis will be carried out during the night.

After having done these configurations, the second objective from ADAQ is focusing on the report from a concrete analysis in order to join the daily values obtained and set an accumulated report that will be graphed as the sum from the daily values to date. This is useful to view the evolution from the studied component of the vehicle and, eventually, compare it with a reference/objective value.

Justification

The industry, not only the automotive one, is increasingly working on autonomous processes in order to have a higher control from the whole process, to avoid workers/users from doing routine tasks and to accelerate results collection with less probability of error. When it is listened the two words autonomous and automobile, everyone thinks about a self driven vehicle. However, in order to make possible the total autonomous vehicle several controlling infrastructures must be previously implemented. This application, ADAQ, works on the line of the autonomous vehicle because it contains some of these necessary infrastructures and protocols, such as controlling vehicle's data acquisition processes by GPS or using VANETS to communicate and send information to external computers.

Nevertheless, the target of this application is not setting the autonomous vehicle but configuring the autonomous process of analyzing the desired parameters from a tested vehicle.

Scope

The author has worked on the second part from ADAQ, so only the configurations done by the author are explained on this document.

Referred to data acquisition, this document includes information of how the acquisition software has been configured (its triggers, conditions and logic functions). Referred to the electronics implemented in the vehicle, the document contains information from the general power distribution box. The document does not explain how to instrument a vehicle, how the acquisition software works or how acquisition modules and devices have been connected between them and to the vehicle.

Referred to data communication a deep information is presented about its operations. This document includes how do all computers communicate with each other, under what circumstances they communicate and which actions are carried out with data flow. The document does not explain the syntax from the implemented codes or the bases from each programing language used.

Referred to data analysis and reporting, the document explains the bases from each analysis, and why it has been decided to include it in ADAQ application. In the same way, the report from each analysis will be cited in order to identify the information provided and how to use it later. The document does not explain how to configure the different processes from the analysis or how do they work.

Referred to the application in charge of configuring a new project and assisting existing projects the document explain how it works, which are the specifications, inputs/outputs and functionality from every virtual tool that compounds the app. The document does not explain the syntax from the implemented codes or the bases from the visual graphical language used.

Author's previous knowledge

On March 1st of 2016 the author was given a big challenge and a problem to solve: making possible autonomous communication and analysis from data. Obviously, the first days where intended to identify, recognize and narrow the presented problem.

Once the situation was perfectly understood, the author presented some new ideas to the configurations done until then. Such as improving the communication of the acquisition phases to the pilot or extrapolate ADAQ system for a multiple vehicles case.

The solution presented in this document is not unique, however it is the solution thought and implemented by the author's knowledge and experiences while configuring this system. In order to reach this solution a previous programming training was requested. Some of this training was from reading manuals from the used softwares and being in touch with them. Other training, referred to the communication and its programming language, was from consulting the internet for similar problems and similar solutions and adapting them to ADAQ specifications. More training, referred to the project management app, was thanks to ADAQ's director, sir Antonio García Rabadán, who thought the author on this software.

The methodology the author has followed in order to set the right configurations to make ADAQ work on an autonomous way was, first implementing the different actions needed and recognizing all of them. Then, making them communicate with each other, so every action is activated by the previous one and, once it is completed, this one activates the following action. Once this was done, the projects management app was implemented, so the technician can create, configure and activate actions by his own on a simply, intuitive way.

1. Introduction

1.1 THE BORN OF ADAQ

The director of this project, sir Antonio García Rabadán, had the idea of setting an autonomous data acquisition system about two years ago. This idea was motivated by his day by day work where he observed how easy would it be a system able to start acquiring by its own, following specific parameters, and providing the result from the acquisition few hours later. At this point the technician would not need to do anything else than draw conclusions from the obtained results.

SEAT company provided every necessary equipment for this project, including a vehicle, acquisition modules and softwares. In September 2015 ETSEIAT UPC student Daniel Martín Martínez, started with the instrumentation from the vehicle and the configuration from the acquisition software. From March 2016 the author was in charge of continuing the work done by Daniel and setting the autonomous communication and analysis from the acquired data. Obviously the second phase from ADAQ has to understand and know how the first phase works, by its intrinsic relation.

1.2 WHY IS ADAQ THE FUTURE OF DATA ACQUISITION?

Taking a look into the evolution of data acquisition on the last decade, it has been observer a tendency from companies, from a wide range of sectors, incorporating autonomous data acquisition systems to their measurements.

For instance, talking about wind energy generating companies, windmills are being instrumented to report air pressure, temperature and any desired variable thanks to autonomous data acquisition systems. This offers the advantage of being unattended and of being able to check and control the evolution from the test from any other place. [1]

Another clear example is found on measurements in bridges an other constructions. In this case is interesting deformations measurements and structure reactions to external loads, so data acquisition systems are also working on an autonomous way.

This two examples are representative of how data acquisition will be on the next years. From SEAT company it has been decided to work on this line. Autonomous data acquisition referred to the automobile industry represent two clear challenges comparing to the mentioned applications, one is the sample rate, much bigger because of the constant change from a mobile point. And the second challenge is precisely the fact of working with a mobile reference system, the vehicle.

1.3 ENTERPRISES, HARDWARES, SOFTWARES AND ITS ROLE

SEAT S.A. company has provided for this project the following tools:

Table 1 Tools used for ADAQ prototype project.

	Tool	Type	Enterprise	Quantity/Licences
1	**SEAT León**	Vehicle	SEAT	1
2	**CX22-W**	Computer	HBM	1
3	**MX840**	Computer	HBM	2
4	**MX1615**	Computer	HBM	1
5	**Control Device**	Electronics	SEAT	1
6	**Driver Control Box**	Electronics	SEAT	1
7	**Catman**	Software	HBM	1
8	**Transducers**	Transducer	HBM/others	19
9	**Navilock NL-302U**	GPS Antenna	Navilock	1
10	**PC**	Computer	HP	1
11	**Autoit**	Freeware	Autoit	1
12	**Desktop Computer**	Computer	HP	1
13	**LMS Tecware**	Software	Siemens	1
14	**LabVIEW**	Software	National Instrument	1

1. SEAT León Ecomotive

Fig. 1 SEAT León Ecomotive.

It is a vehicle equipped with serial characteristics and totally functional.

Acquisition hardwares from HBM company:

The QuantumX family modules from HBM have been the chosen computers in order to accomplish data acquisition. They are attached to the vehicle. From the wide range of computers from the QuantumX family three of them have been chosen to implement this standard ADAQ project. They are the MX1615, the MX840 and the CX22-W (first module is optional while last two are mandatory for any ADAQ project; this ones or a previous/lately version of them).

2. CX22-W

The CX22-W is a computer with an embedded system. Its software is Windows XP. This computer rules other modules and the whole acquisition thanks to its software, Catman. It offers inputs and outputs signals that can be called from the acquisition software implemented on the same CX22-W. It offers the possibility of auto-starting modules recognition and acquisition project load at turning it on. It also has a WiFi antenna so it allows the activation of its node in order to link to other computers wirelessly. It also allows a GPS antenna to be connected and an external Memory Card. Other interfaces and specifications: [2]

- 2x Ethernet TCP/IP (LAN and WLAN)
- 2x FireWire
- 3x USB
- 2x DVI
- 3x digital inputs
- 3x digital outputs
- 1x RS232

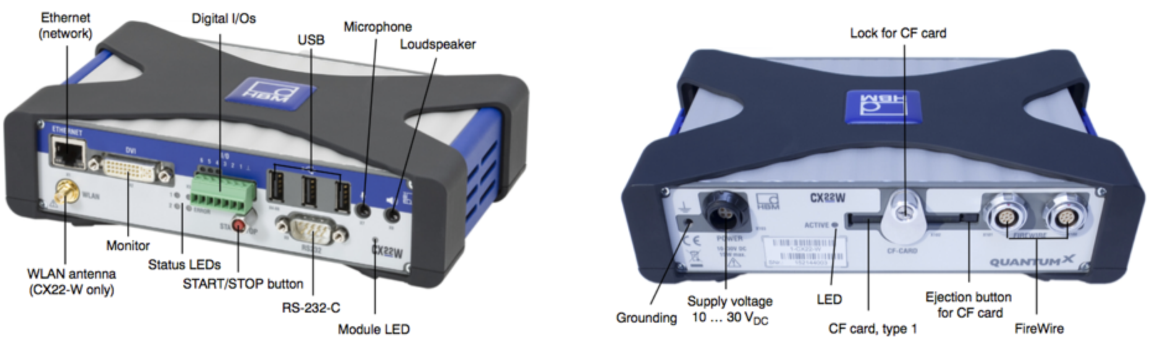


Fig. 2 CX22-W computer from HBM enterprise.

3. MX840

The MX840 is an 8 channels universal amplifier that allows the following transducers: [3]

- Complete or 1/2 Whetstone bridge SG gauges
- Complete or 1/2 Whetstone bridge inductive gauges
- Complete Whetstone bridge piezo-resistive gauges
- Resistance (5000 Ohms)
- Resistive thermocouples (PT100, PT1000)
- Thermocouples (type K,N,R,S,T,B,E,J)
- Potentiometric transducers
- LVDT
- 1 High Speed CAN
- Voltage (100mV, 10 or 60 V)
- Current (20mA)

Fig. 3 From top to bottom: CX22-W, MX1615 and 2 MX840.

4. MX1615

The MX1615 is a Whetstone bridge amplifier of 16 channels. It allows the following strain gages: [4]

- Complete, 1/2 or 1/4 Whetstone bridge SG gauges.

5. Control Device ("CDB")

A Control Device Box (CDB) has been designed to rule the implemented electronics and distribute the energy to each of the modules. Alongside the CDB, a voltage rectifier and a driver control box (DCB) have been installed. CDB functions are feeding the DCB, keep feeding the modules for few more minutes once the vehicle is turned off in order guarantee data saving and data communication, make the electronics secure thanks to a fuse and a general switch and avoid sudden supply variations at turning on the vehicle. CDB components are a timer, five relays, a fuse and two integrated boards two allow intermittent LEDs functions from the DCB.

6. Driver Control Box ("DCB")

Two LEDs on the vehicle's dashboard have been installed in order to notify the driver of each acquisition phase, in case any error occurred or a relevant circumstance on road is taking place.

Fig. 4 CDB, DCB and QuantumX modules on the vehicle.

7. Catman

Also from HBM, Catman is the acquisition software that runs on the CX22-W. Projects are configured and saved into a file, then Catman will be set to charge this file autonomously and save generated TS into the Memory Card from the CX22-W. It offers multiple formats for storage and saves data with up to 12 MS/s or 100 MB/s. [5]

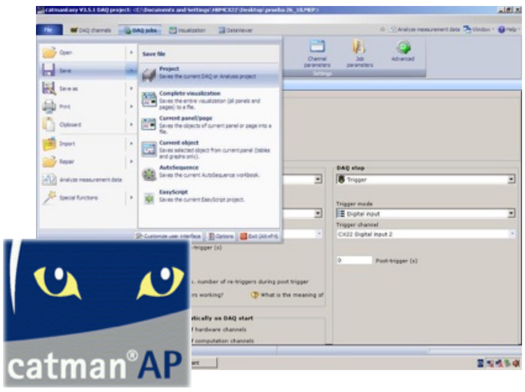


Fig. 5 Sofware Catman from HBM.

8. Transducers

The amount of physical or instrumented transducers will vary depending on the target of the project. In order to prove the polyvalence from ADAQ, different technologies of transducers have been implemented. For this prototype project the Company has decided to instrument:

- 4 Thermocouples.
- 5 Accelerometers.
- 8 SG gauges.
- 2 Displacement sensors.
- Also, 14 CAN bus channels are used.

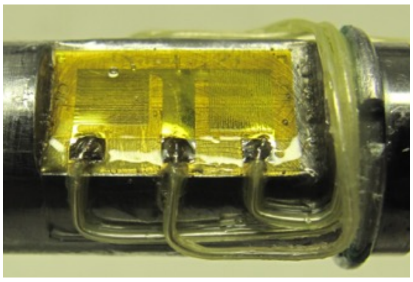


Fig. 6 Detail of an instrumented SG gauge.

9. Navilock NL-302U

This is the GPS antenna. It is located on the roof of the vehicle, united thanks to its magnet. It is connected to the CX22-W through USB connection. It works at a baud rate of 4800 bps. [6]

Fig. 7 Navilock NL-302U GPS fixed on the roof of the vehicle thanks to its magnet.

10. PC ("PC-Box")

This is the PC located on the testing track Box where the vehicle is acquiring. It is the PC in charge of receiving the acquired data and sending it into the Shared Server, so it has access to both CX22-W and Company networks. Its operative system is Windows 7. On it, different commands run in order to make TS communication possible. From now on this computer is identified as PC-Box.

Fig. 8 PC-Box.

11. Autoit

Autoit is a freeware automation language for Microsoft Windows. It is contained on the PC-Box and makes possible the remote access to CX22-W Desktop. [7]

Fig. 9 Autoit Logo.

12. Desktop Computer ("PC-Technician")

This is the computer on the Company headquarters at SEAT Centro Técnico. Its operative system is Windows 7. On it runs the analysis software, LMS Tecware and the project management app, by software LabVIEW. It has connection to the Company network, so access to the Shared Server. From now on this computer is identified as PC-Technician.

Fig. 10 PC-Tehnician.

13. LMS Tecware

It is the software from Siemens AG company in order to analyze the acquired data. It is a durability load data processor designed for testing productivity. LMS Tecware is specially good analyzing fatigue tests and allows autonomous execution functions. Its programming language is TCL. [8]

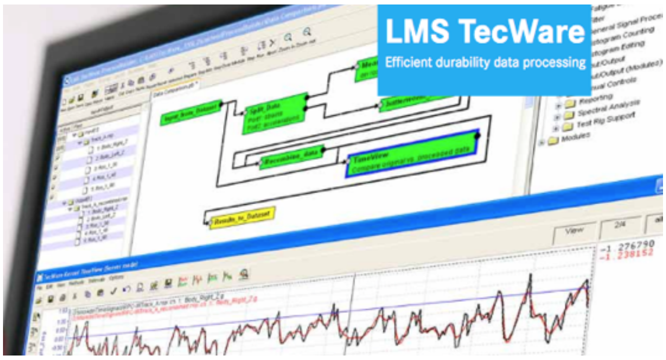


Fig. 11 LMS Tecware presentation.

14. LabVIEW

It belongs to National Instrument company. This is the software on witch the application in order to manage projects has been designed. Is a platform and development environment for designing systems, with a graphical visual programming language. It works with different VI (Virtual Instruments), each one has a particular function and together build up the application. Through this app the technician will be in touch with ADAQ projects and see its evolutions, do changes or check any parameter. By introducing few project specifications the app will automatically generate the data infrastructure and necessary commands on each of the three computers in order to start the autonomous acquisition, communication and analysis of TS. [9]

Fig. 12 LabView presentation.

1.4 PRESENT LIMITATIONS

ADAQ uses and intermediate computer identified as PC-Box. This computer receives several batches of files of acquired data during the day. There are as many batches of files as number of times the vehicle arrives into the testing track box after acquiring during for 2 or 3 hours. At specific time PC-Box transfers all of the batches at once into the company's Shared Server.

In the near future SEAT pretends to integrate the CX22-W into the company network in order PC-Box can be dispensable. This integration would mean data is directly transferred into the company's Shared Server in batches.

When this is done the technician could have the option to ask for immediate reports in order to draw conclusions from the evolution of the acquisition intraday, so it is not necessary to wait until the day after to find out whether results are expected or not.

Another important fact of this integration is that the acquisition software Catman, could be managed and configured remotely. So if any parameter from the acquisition does not work correctly, the technician from the headquarters, could decide if it does not affect to the general target of the test or if it is relevant and transcendental. At this point the technician would turn off this parameter and allow the test to proceed or stop the test to fix the problem.

ADAQ

Autonomous Data Acquisition

2. ADAQ

ADAQ application is compound by 3 different computers, each of them equipped with the necessary tools in order to correctly complete every action. The computer fixed on the vehicle is the CX22-W, the computer on the testing track box is the PC-Box and the computer at the Company's Technical Center headquarters is the PC-Technician.

ADAQ uses the resources from also 3 different softwares, Catman, LMS Tecware and LabVIEW, in order to do the acquisition, the analysis and the projects management respectively. These steps are perfectly defined. The flow that moves along this system is the data.

On the following chapters it is presented a first general view from ADAQ and its stages (chapter I). Then it is stated its data infrastructure (chapter II). After this, it is presented a more theoretical chapters, where it is shown every configuration done in the different stages (chapter III) and how works the application to make possible any technician can configure ADAQ on an easy way (chapter IV).

Finally results from using ADAQ system on the first tests are presented (chapter V) and future improvements are stated (chapter VI).

CHAPTER I
STAGES

2.1 STAGES

ADAQ, according to the TS treatment, can be divided in three different stages: the acquisition, the communication and the analysis from TS. As it is known every stage is executed autonomously and sequentially one after another.

In order to set specific parameters to each of the stages and to make them synchronize and work together a previous configuration it is required.

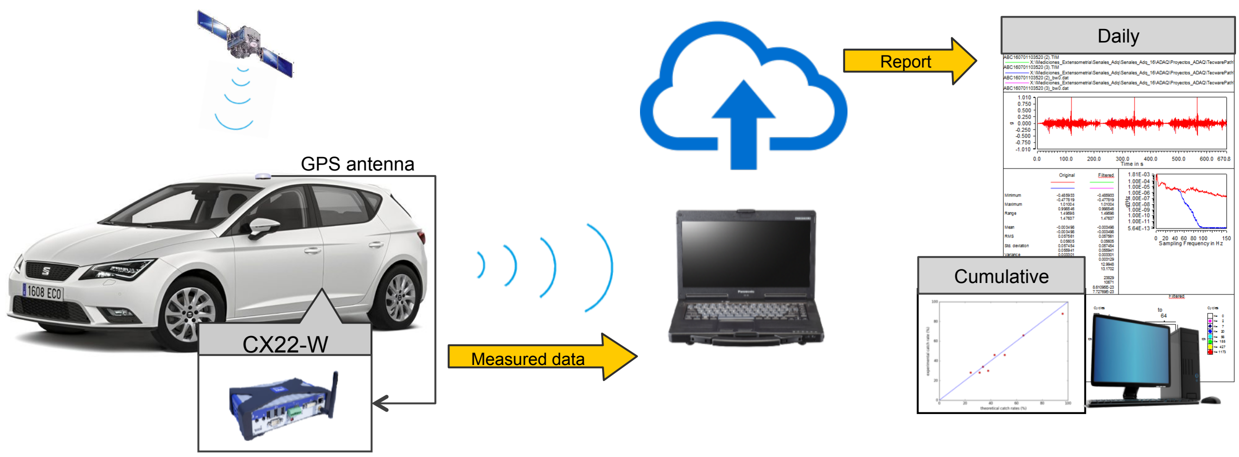


Fig. 13 Data Acquisition, Communication, Analysis and Reporting general scheme of ADAQ.

2.1.1 CONFIGURE A NEW PROJECT

Before starting an ADAQ project it is necessary to define the goals, specifications and parameters of this new test.

Configuring a new project is the action of preparing every tool, computer and software in order to make possible the autonomous data acquisition, communication an analysis of data.

In order to make this possible a qualified technician has to instrument the vehicle according to the target of the project. It is also required to implement the electronics on the vehicle that make possible to house acquisition projects.

Following the Configuration Manual (available from the Technical Sheets) and thanks to ADAQ's app the technician can configure the three computers, including the analysis software LMS Tecware, on the right way. Finally the technician also needs to configure the acquisition software Catman.

At this point ADAQ is ready to acquire, communicate and analyze data autonomously.

Fig. 14 Configuring the connections from QuantumX modules.

2.1.2 AUTONOMOUS DATA ACQUISITION

Once the project is configured, the instrumented vehicle and the PC-Box are ready to be delivered to any worldwide testing track and start the acquisition.

The autonomous TS acquisition starts since the very first moment the pilot turns on the vehicle through the key. At this point the battery feeds Quantum X modules and the CX22-W boots WinXP system. Once WinXP system is charged, the system recognizes other plugged modules (two MX840 and one MX1615 for this particular project). Then, the acquisition project is booted by software Catman. The different channels from the project are checked and if no errors occur Catman acquisition project waits for the trigger in order to start acquiring.

When this process is completed thanks to the state of the two LEDs (green and red), located on the dashboard, the pilot knows every thing is ready to start acquiring and he/she starts driving. Once the acquisition is triggered, defined by geographical coordinates and vehicle speed, modules acquire data at the configured sample rate until the DAQ stop condition is triggered.

Triggering the DAQ stop condition means vehicle is in the Box area so every TS will be saved into the Memory Card from the CX22-W and the acquisition project will be waiting again for the DAQ start trigger in order to start acquiring again. At this point, the pilote turns off the vehicle. Thanks to the timer at the vehicle's CD the battery will keep feeding the modules for a few more minutes. After this time the battery will stop feeding and the modules will be switched off until the pilote decides to turn on the vehicle again through the key on the next acquisition.

Fig. 15 Data acquisition is ongoing, intermittent green light is on.

INTERACTION WITH THE PILOT

As it has been previously introduced, two LEDs have been installed in order to notify the driver of each ADAQ phase, in case any error occurred or a relevant circumstance on road is taking place.

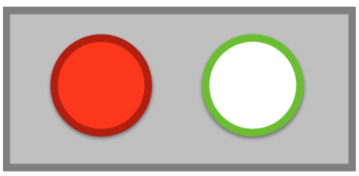
Different states are explained:

- A permanent red light is warning the driver devices are booting and Catman project is loading at switching on the vehicle. In case the red light appears while the acquisition is in progress it means an error occurred in one or more channels. At this point data acquisition will conclude and the driver must go to pit stop in order to report the problem. (1)

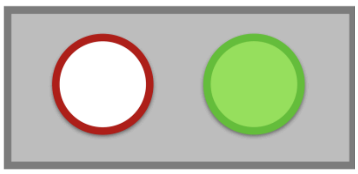
- A permanent green light means all devices are ready to start data acquisition. The project is waiting for the trigger to start the data recording. The driver can leave the Box area. (2)

- An intermittent green light informs the driver data acquisition is recording, everything is fine. (3)

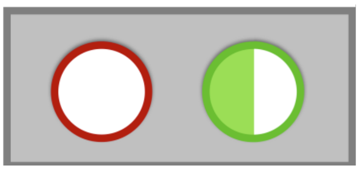
- An intermittent red light can be set for different configurable purposes. In our testing vehicle the intermittent red LED means any of the damper's temperature is too high. The driver has been previously informed what to do in this situation. (4)



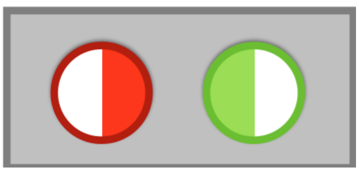
(1) Loading software/ Channel error



(2) Ready to record



(3) Recording



(4) Event happening while recording

Fig. 16 Different states from the DCB on the vehicle's dashboard.

2.1.3 AUTONOMOUS DATA COMMUNICATION

Autonomous Data Communication can be divided in to different blocks. The transference from the vehicle into the box (V2B) and the transference from the box into the company's shared server (B2SS).

V2B

When the vehicle gets into the Box, the PC-Box detects the existence from the CX22-W node thanks to its WiFi antenna. At this point the commands from the PC-Box enables the connection point to point with the CX22-W.

Once they are linked, the PC-Box activates the remote access into the CX22-W. At this point the corresponding commands on the CX22-W detect the existence from PC-Box and send all of the TS files from its Memory Card into a folder on the PC-Box. Two different settings must be correctly configured in order to make possible data transference, one is the timer on vehicle's CD, to maintain the modules fed while PC-Box "steals" data from the CX22-W. The other one is the duration of the command which activates the remotely access into the CX22-W, to guarantee the whole data is transferred.

After the transference is completed another command from the PC-Box waits until the CX22-W network is not visible. This means the vehicle is gone to acquire data again or it is turned off. At this point, the command restarts the process and looks for the CX22-W WiFi network again in order connect to the CX22-W to receive the data from the next acquisition.

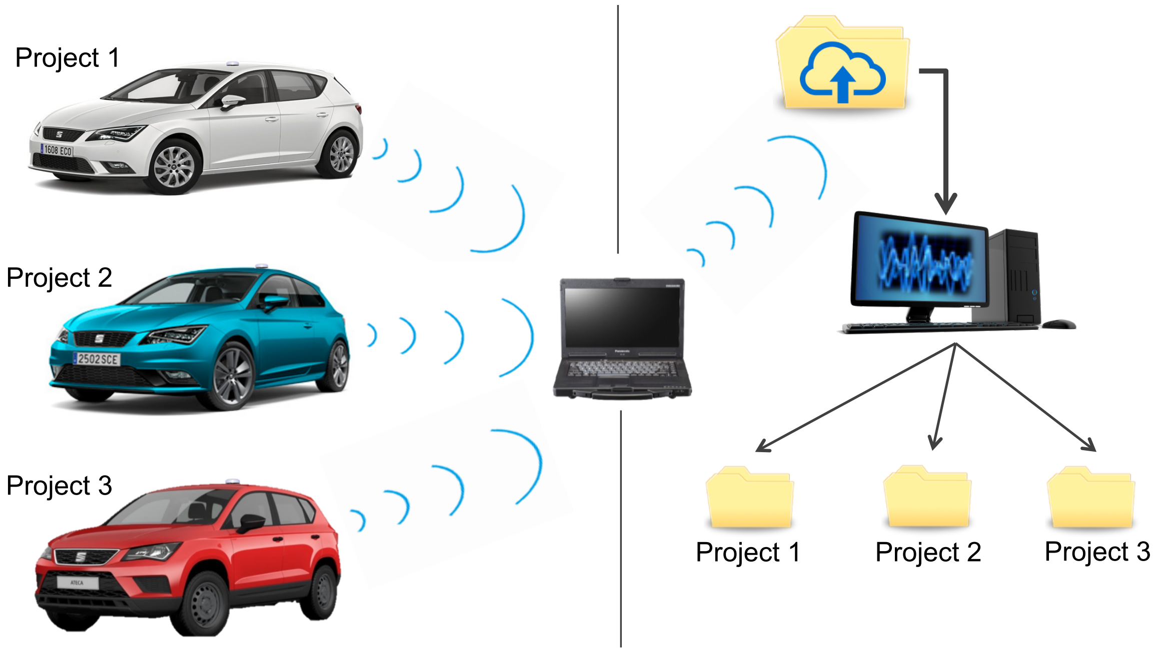


Fig. 17 Data communication general scheme.

B2SS

Once the acquisition day is finished, it is time to send every data recorded from the different acquisitions into the company's Shared Server in order the computer in charge of the analysis (PC-Technician) can have access to them.

At a specific time, a command in the PC-Box is in charge of connecting into the company's network, through Ethernet cable or WLAN. Then, every data contained in the PC-Box is sent into a specific folder from the company's Shared Server.

2.1.4 AUTONOMOUS DATA ANALYSIS

Once data is transferred into the company's shared server, at specific time the analysis is carried on. The analysis to do to each channel is decided at the configuration of a new project. It is a batch file saved on the projects information and programmed to be executed at specific time, mainly during the night.

Before the analysis start, a previous TS conditioning command is executed in order to classify and append small TS files into a larger one. TS are appended because on the CX22-W are saved in small length files so data storage is quickly and fluent. However, in order to obtain standard reports TS files must have a minimum size.

After TS append, the analysis starts. Two type of analysis are compulsory, the anomaly detection and the statistic driven KM analysis. The rest of the analysis are selectable, including a customized analysis where the technician can design another type of study.

The possible analysis are the PSD, the Pseudo-Damage, the comparative Pseudo-Damage and the Frequency-Damage. They are all very specific analysis for fatigue and durability tests.

Once the analysis has conclude the report is generated.

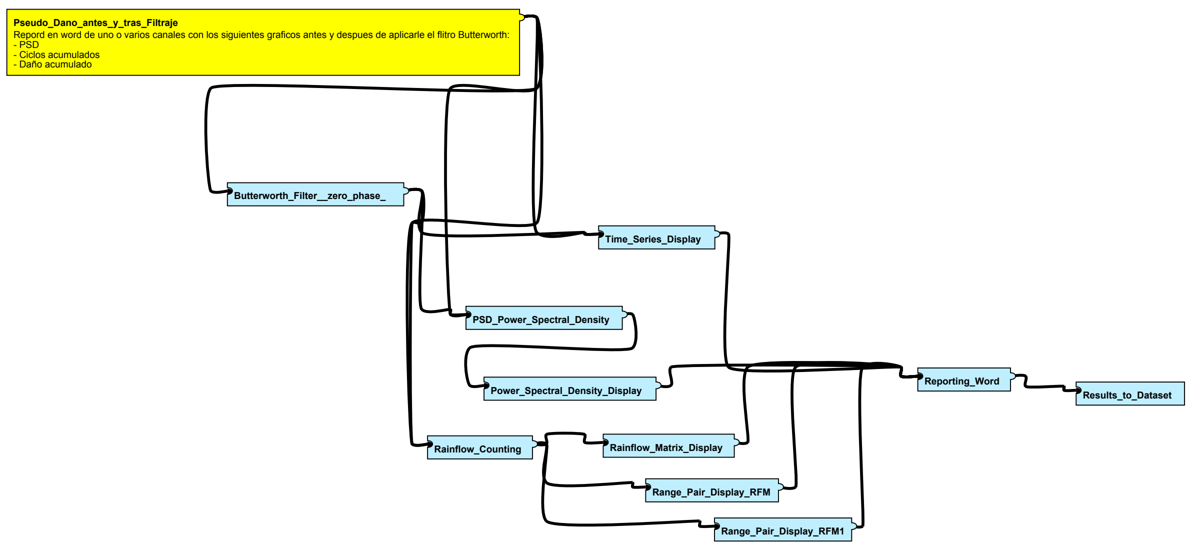


Fig. 18 Analysis routine from the Pseudo-Damage from LMS Tecware.

2.1.5 AUTONOMOUS REPORTING

When the technician gets into the office the reports from the analysis done will be available. Not only the reports but also the appended TS. At this point, the technician work is to validate the obtained results and draw conclusions from the evolution of the test. Eventually, the technician will change the parameters referred to vehicle speed or type of driving if the obtained results are not between the expected margins or defer from the test target/reference values.

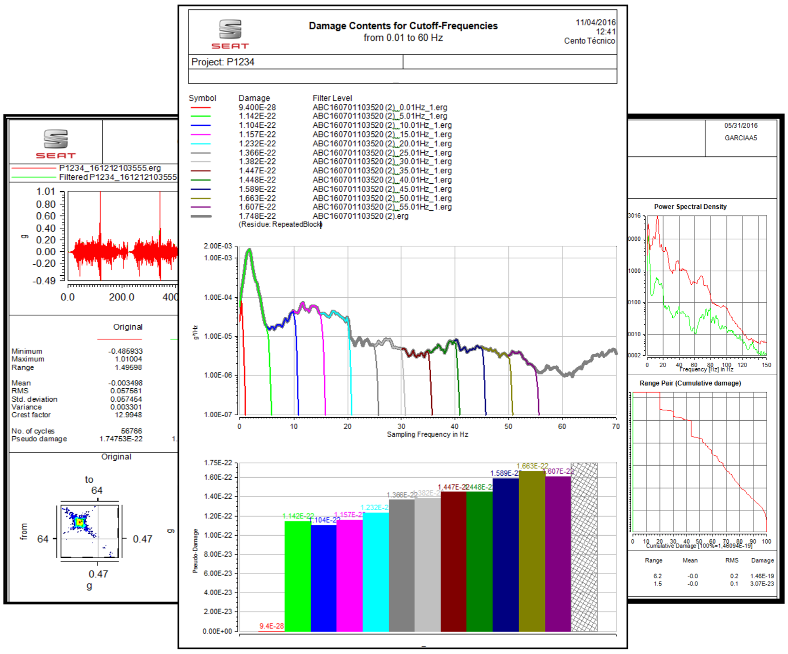


Fig. 19 Different type of daily reports offered by LMS Tecware.

CHAPTER II

DATA INFRASTRUCTURE AND STORAGE

2.2 DATA INFRASTRUCTURE AND STORAGE

In order every step from an ADAQ project is successfully completed and reported several files and folders are contained on each of the three servers, the CX22-W, the PCBox and, mainly, on the Shared Server. ADAQ data infrastructure includes different files and folders proposal. Several files make sure TS communication, pre-analysis, analysis and post-analysis is correctly completed. Other folders and files are in charge of data, reports and project information storage. More folders represent useful libraries of transducers, testing tracks or target values which help the technician during the configuration of a new ADAQ project.

2.2.1 CONTAINED IN THE CX22-W

On the CX22-W Memory Card different TS files will be saved during the acquisition. Files are saved in RPC format, there is one file per every 10min of acquisition. Files have the following name PXXXX_YYMMDDHHMMSS, being each letter digits for project identification, year, month, day, hour, minute and second.

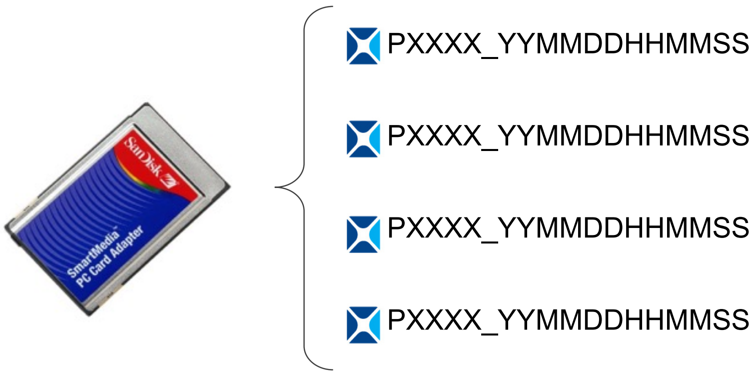


Fig. 20 Temporally data storage on the Memory Card from the CX22-W.

Also on the CX22-W are contained two batch files[1] in charge of transferring data into the the PC-Box.

Fig. 21 The two communication batch files on the CX22-W.

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[1] Batch file: In Microsoft Windows, it consists of a series of commands to be executed. They are plain text files, saved with the .BAT extension that contain an MS-DOS command set. This files are the engine for the autonomous actions of ADAQ.

2.2.2 CONTAINED IN THE PC-BOX

On the PC-Box are contained two folders with different proposals.

The first folder is 'ADAQ_Communication' and contains different subfolders for every vehicle. On every subfolder are deposited TS coming from the CX22-W's Memory Card. At specific time data from this folders is moved into the company's shared server. So this folders act as the data transmission channel between the CX22-W and the Shared Server.

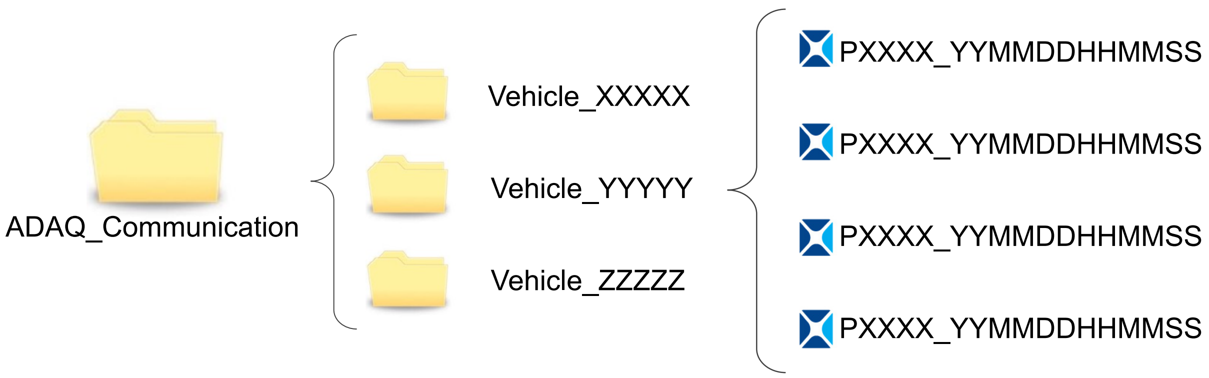

Fig. 22 Data infrastructure and temporally data storage on the PC-Box hard drive.

The second folder is 'ADAQ' and contains subfolders for each project. Each subfolders contain the necessary commands (batch files) to ensure the connection with the CX22-W and data transference into the company's shared server at specific time. So this folders rules 'ADAQ_Communication' folder.

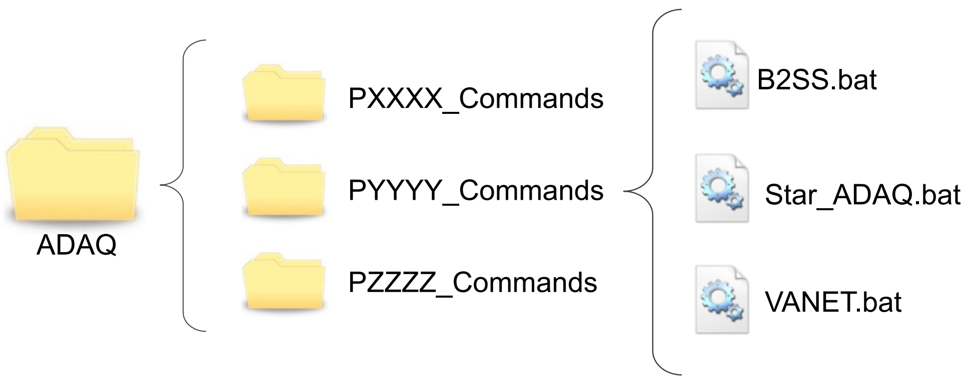

Fig. 23 Data infrastructure and batch files on the PC-Box hard drive.

2.2.3 CONTAINED ON THE SHARED SERVER

On the Shared Server is contained the whole ADAQ data infrastructure. This data is divided in 4 folders. They are the Transducers library, the testing Tracks, the Target values and the Projects container folder.

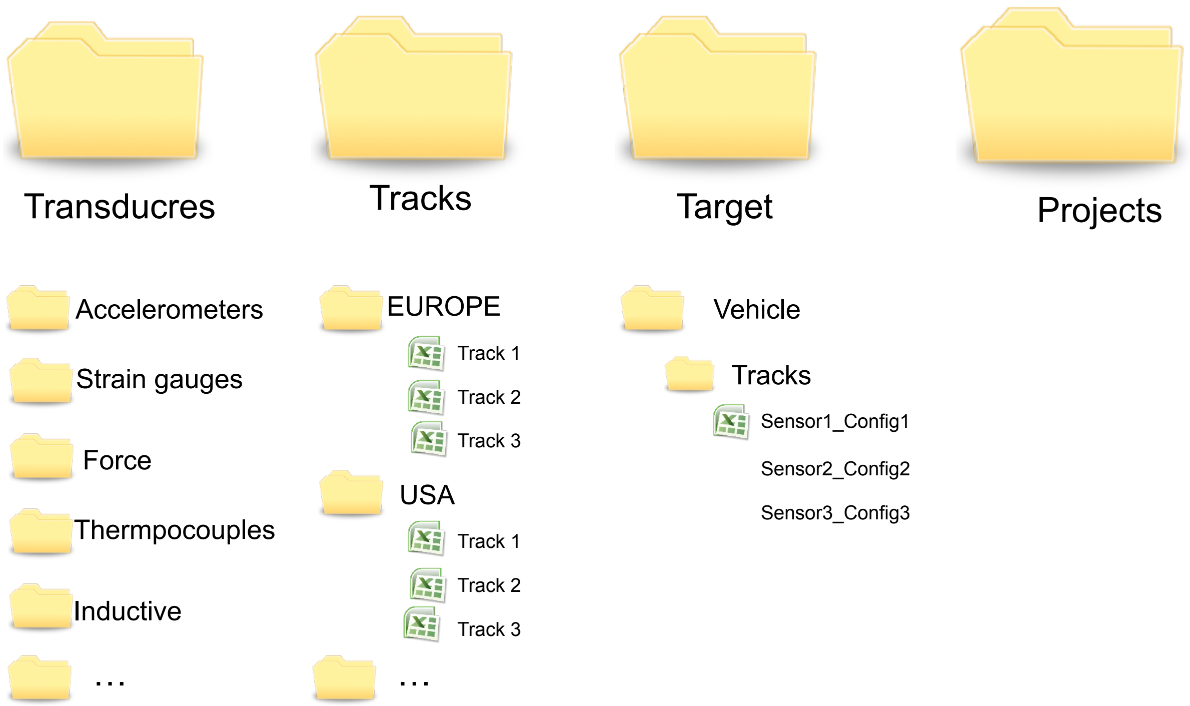

Fig. 24 Data infrastructure form ADAQ on the Shared Server.

- Transducers folder contains different subfolders according to the type of sensor. Inside each of the groups different Excel files are contained with the identification and information from the transducer. The transducer identification is the name from the Excel file.

- Testing Tracks folder contains different road circuits. The technician chooses during the configuration of a new project one of the tracks on this folder. The information contained on each of the Excel folders is: name and specifications of the circuit, GPS coordinates of the track and logic functions ready to be introduced into ADAQ management app, and later into software Catman configuration.

- Target Values folder contains the Excel files with the damage or frequency damage after doing several kilometers; this value depends on the vehicle, the testing circuit, the suspension type and the motorization. One of these files is selected by the technician at the configuration of a new ADAQ project. The information contained is basically two points from the Km vs Damage XY graphic; the point (Km=0,Damage=0) representing the starting status and the point (Km=x,Damage=y) representing the predicted damage value of the test after having driven 'x' kilometers. The damage at the last KM value represents the target for the project.

- Projects folder contains the different projects created through the projects management app. Inside every project folder different information can be found.

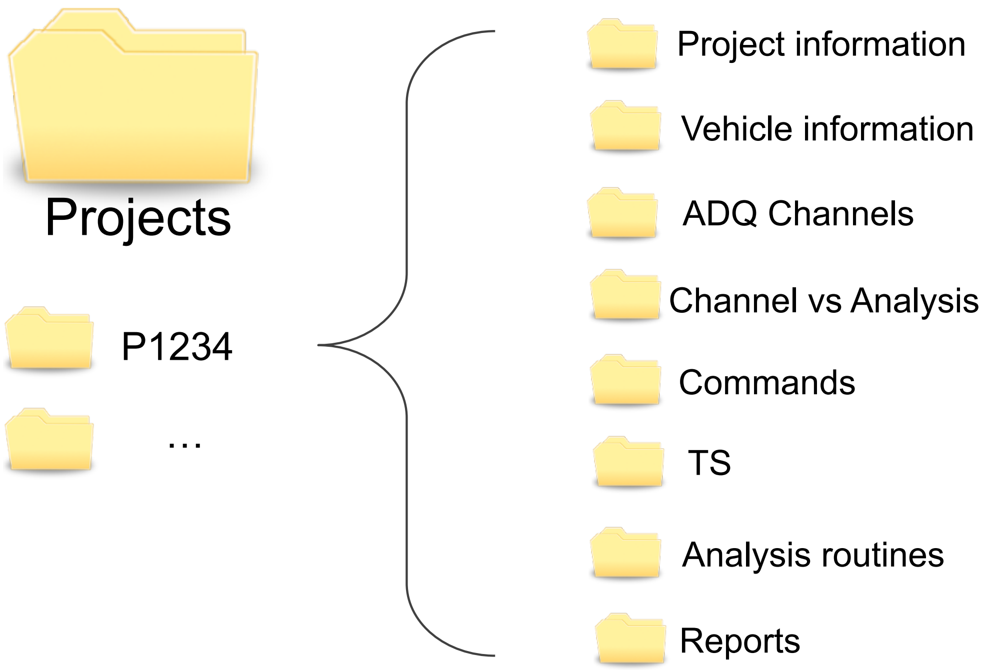

Fig. 25 Data infrastructure for every ADAQ project.

- Project information: contains information about the project, such as the testing track the vehicle is acquiring, the target damage value of the test and the time zone when the acquisition is.

- Vehicle information: contains specifications from the vehicle being used for the test.

- ADQ Channels: contains information from the different points of study of the test.

- Channels vs Analysis: contains information about what time of analysis is being done to each selected channel.

- Commands: contain every executable file in order to make autonomous data communication and analysis. A copy from executable commands on the PC-Box and CX22-W is also contained on this folder.

- TS: Contains the TS files recorded for the project up to the date. They are classified by date.

- Analysis routines: Contains several PDFs with every analysis routine used for this project, step by step.

- Reports: Contains two different folders. The daily reports and the accumulated reports. Daily reports folder contains every report generated after the daily analysis and are classified by its date. On the accumulated reports folder are two Excel files with the cumulative pseudo-damage (total completed KM up to the date vs. total pseud-damage caused) and the frequency pseudo-damage up to the date (total completed KM vs. total pseud-damage per frequency band).