Publishable summary

The T-REX project (http://t-rex-fp7.eu/) is funded by the European Union and addresses the **development of usage-oriented business models** in the domains of Machinery, Automation and Transportation. In these business models the sales of the product is substituted by the sales of its usage (e.g. renting, pay-per-use) or its performance or outcomes (e.g. pay-per-performance). This new trend is fuelled by an increased emphasis on the service business in capital goods industries.

Consequently, the T-REX project will promote the development of **integrated Product-Service Systems (PSS) and business solutions**: a shift from value in exchange to value in use to satisfy customer needs. Companies and supply chains should focus on reducing the Total Cost of Ownership of the PSS and extending their lifecycle in order to maximize profits, but also to increase customer utility and the lifecycle value of their offerings.

The objective of T-REX is then to develop and implement, through three industrial application cases, **a business platform for the offering of capital goods** whose main elements are:

- A new **Service-Oriented Business Models** (SOBM) reference framework.
- An improved design of the products by the adoption of the **Design for X** (DfX) approach.
- The re-engineering of traditional support services by using **Service Engineering** (SE) techniques.
- The increasing of product availability and the reducing of the Total Cost of Ownership by developing **Condition based Maintenance** technologies and a **Fleet Management** platform (CbM & FM).

Three practical demonstrators in the transportation (forklift trucks), machine tools and robotic systems domains are being developed to be experimented. Demonstrators will show through the new business platform that it is possible to create new business models that can achieve up to 70% of component re-use, a lifecycle extension in the range of 25-30%, and a reduction of maintenance service costs by 15-30%, which can be translated into 25 to 30% of savings on Total Cost of Ownership.

Likewise, main project results have been characterized from a holistic approach taking advantages of the synergies between technological and industrial partners to set up **five Global Key Exploitable Results** named KER G1 to G5.

KER G1: Service-Oriented Business Modelling process and toolset

This result concerns to the new Business Model (BM), and in particular to the new Service-Oriented Business Models (SOBM) reference framework deployment. It offers **a methodology to support companies at developing SOBM for new Product-Service Systems (PSS)** implementation by using sequential steps, guidelines and practical tools (see Figure 1).

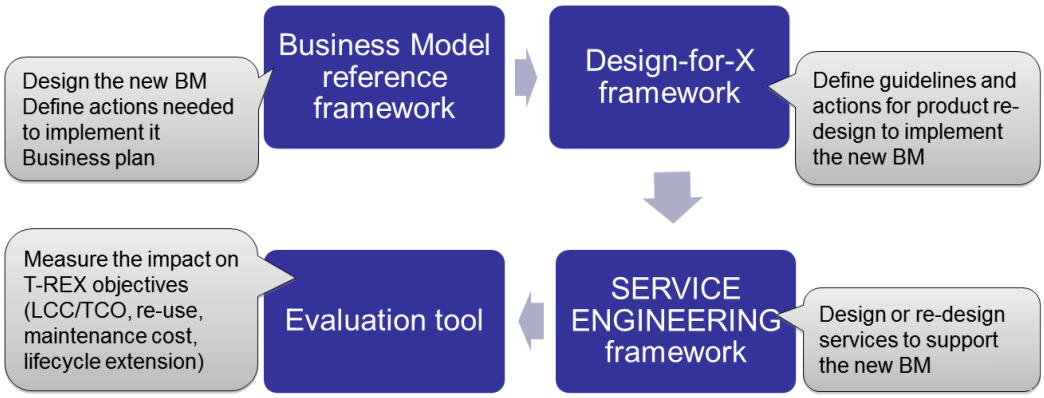

Figure 1: Service-Oriented Business Modelling process and toolset

The KER G1 includes the T-REX SOBM reference framework, which is based on three levels:

- LEVEL 1: a description of five archetypes of Business Models that reflects different degrees of service orientation (**5 Business Model Typologies**, see Figure 2).

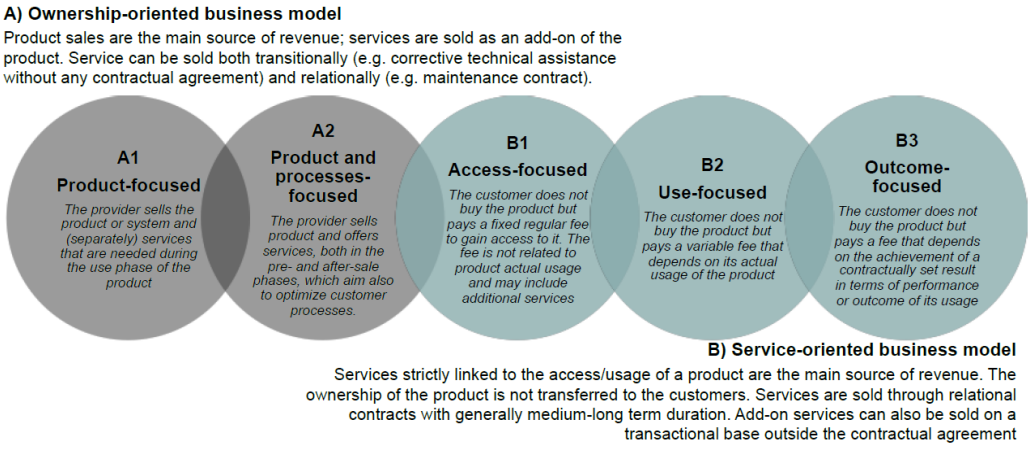

Figure 2: the five Business Model Typologies (service orientation)

- LEVEL 2: a process model that points out the steps to be followed by a company in order to define and plan the new Business Model (**Business Model Innovation Process**).
- LEVEL 3: some tools that can guide companies through the steps of the Business Model innovation process, towards the implementation of the new Business Model (**Innovation Methods & Tools**).

This result includes complementary reference frameworks named **Design-for-X (DfX)** and **Service Engineering (SE)** to describe the typologies, innovation processes and related methods and tools needed to improve products and services associated to the existing business models when facing a comprehensive SOBM transition.

Four selected DfX typologies (Reliability, Serviceability, End-of-life and Life-cycle), as well as four scenarios for the (re-)engineering of services (redesigned services for existing markets, redesigned services for new markets, new services for existing markets, new services for new markets) will be the basis to reach the four goals of T-REX project (extend product life-cycle, increase reuse, decrease maintenance costs, and consequently improve the Total Cost of Ownership).

All these steps towards a successful transition to new SOBM will be assessed through the use of a novel **Evaluation Tool**, specifically developed for a quick preliminary evaluation of the concepts and a comprehensive final validation of a whole Service-Oriented Business Model transition.

KER G2: Platform for an easy to deploy Predictive Maintenance (PdM) solution for Fleet-Wide Asset Health Management (FW-AHM)

This platform offers, as a key innovation point, **a methodology that allows identifying the best maintenance strategy** to be applied according to customer objectives, constraints and preferences, which leads to a **fast deployment of Predictive Maintenance (PdM) solutions** integrated in the FW-AHM platform. The methodology links the business perspectives (e.g. financial, reusability, maintenance) with technical objectives (usage, condition, performance) and specific indicators and variables linked to the use case, at the same time that facilitates the choice of appropriate hardware to support the local condition monitoring.

The **Fleet-Wide Asset Health Management (FW-AHM) platform** is supported by Condition based Maintenance (CbM) technologies, including Condition Monitoring (CM), and the Fleet Management (FM) software KASEM® (see Figure 3).

To support the deployment of the PdM solutions a distributed architecture (based on easy to deploy low cost devices) has been defined and tested, which includes standard local monitoring algorithms & software to be embedded in different hardware solutions depending on the range of complexity and performance requested.

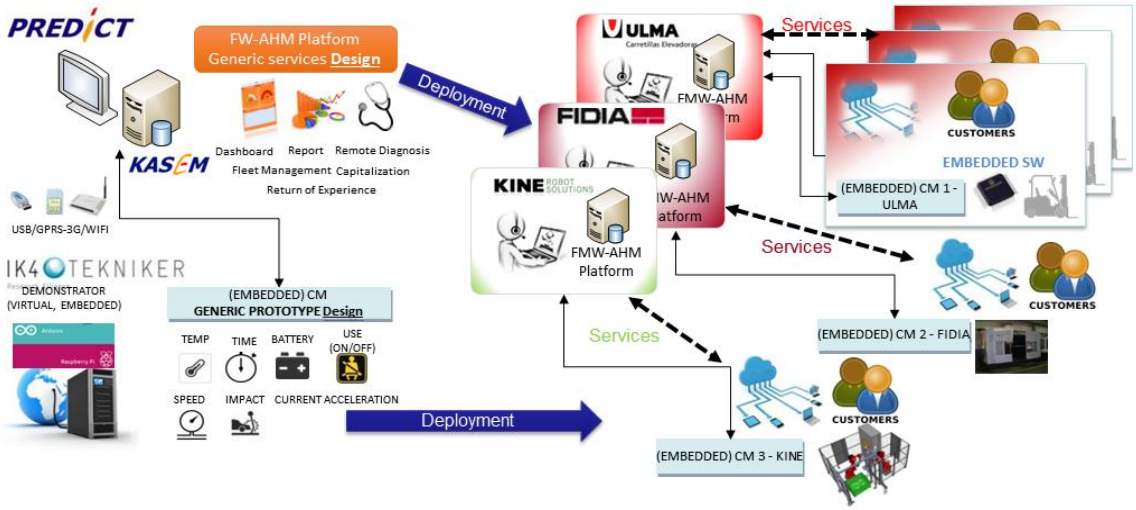

Figure 3: Fleet-Wide Asset Health Management (FW-AHM) platform distributed architecture

Individual **local CbM modules** are then connected to a remote **Fleet Management module KASEM®** with enhanced features (data collection, storage, usage, performance, health assessment and remote diagnostic). The FW-AHM platform support innovative features and technology to provide fleet-wide monitoring, diagnostic and health management services, to deliver the required data and information for the operational and related maintenance strategy optimization services.

KER G3: Service solution offering an integrated platform for Condition based Maintenance (CbM) and Fleet Management (FM)

This result offers to customers a service package made of an **embedded hardware** that collects essential data from forklift trucks, and other equipments in transport sector, for the **Condition based Maintenance (CbM) service**. The input data is comprised of several signals and comes from sensors over the whole vehicle and from certain components like battery that have been enabled, for example, to monitor its level of charge or temperature. The monitoring device is composed of several embedded modules monitoring, decision taking (health assessment) and communication with external devices, including the integration with other components dataloggers.

The package is also made of a **software platform** where this information is displayed and exploited at manufacturer / dealer / end user level, i.e. the Fleet-Wide Asset Health Management (FW-AHM) platform by means of KASEM® software (see Figure 4), which also provides integration capabilities with the Enterprise Resource Planning (ERP) software at the company to gather the maximum possible information for the **Fleet Management (FM)**.

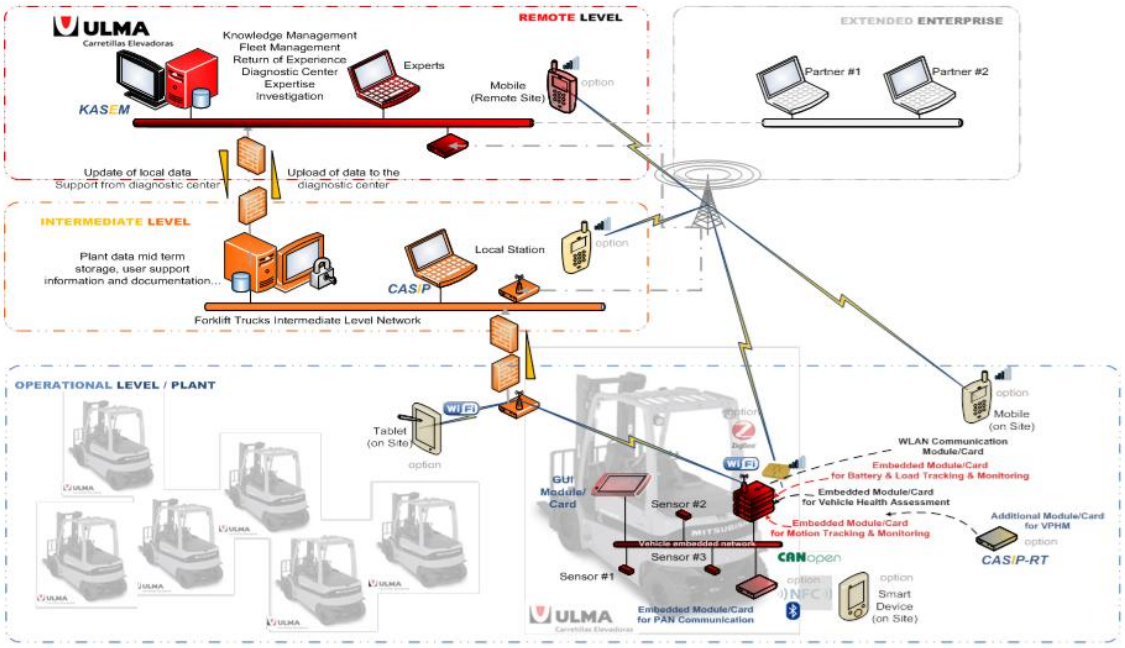

Figure 4: Condition based Maintenance (CbM) and Fleet Management (FM) architecture

As differential factor, both CbM embedded hardware and the Fleet Management software include some "knowledge algorithms" to provide **predictive functionalities**. No other commercial monitoring systems have this feature that allows a fast local actuation over the vehicle (e.g. stop the forklift truck after a strong collision or when possible danger for the engine), and experience capitalization and knowledge management at fleet level to support remote diagnosis and health assessment.

KER G4: Service solution of Condition based Maintenance (CbM) for new generation machine tool electro-spindles

The overall solution proposed exploits the features of **a new electro-spindle** that has been re-designed from a reliability driven approach and for condition monitoring in practical applications. The new electro-spindle has been equipped with a set of new sensors that allow the machine tool builder to retrieve essential data about the working and operating conditions of the component.

The solution has been supplemented with the development of a new software application that allows a machine tool to perform some automatic tests at the same time that collects data from the field operation and transmit it via FTP to a remote server managed by KASEM® software. This software application enables the company to offer its customers **a new Condition based Maintenance (CbM) service** (see Figure 5).

Predictive capabilities provided by this new service improve machine tool productivity avoiding sudden interruptions in machining of workpieces due to unexpected breakdowns, which in turn increases machine tool availability and lowers Total Cost of Ownership (TCO) for customers.

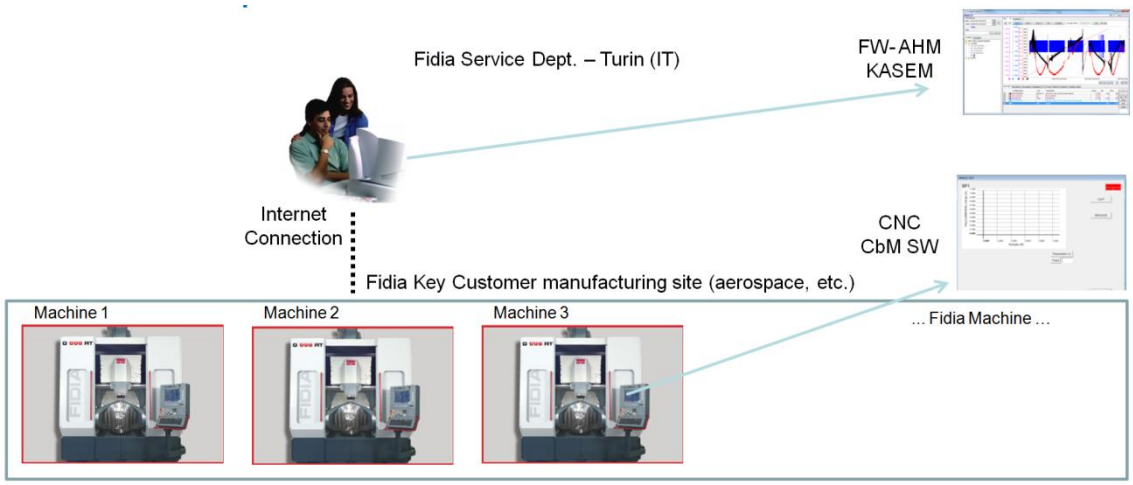

Figure 5: Condition based Maintenance (CbM) solution for Machine-Tools

KER G5: Condition Based Maintenance (CbM) solution for custom robot systems

A **new datalogger hardware & software** solution developed for gathering data from virtually any electronically controlled device or system. This is the main component for a **new Condition based Maintenance (CbM) solution** for complex robotic systems (see Figure 6). The modular and easily customizable datalogger device will decrease systems downtime by applying CbM instead of the traditional scheduled preventive maintenance.

Operation and productive data is transferred to KASEM® software and can be accessed remotely to be analysed and built in with manufacturer's know-how in order to raise critical components and other maintenance factors that will cut down maintenance costs for both manufacturer and clients.

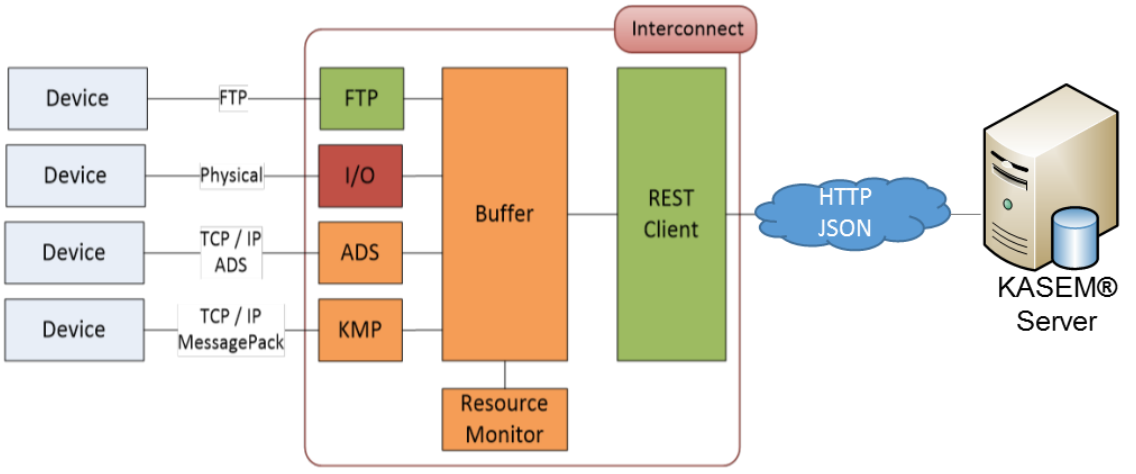

Figure 6: Condition based Monitoring (CbM) architecture for datalogger HW/SW

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T-REX INNOVATIVE STRATEGIES FOR RENOVATION AND REPAIR IN MANUFACTURING SYSTEMS

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