Telemetric Data Visualization of Vehicle's Crew in Geographic Context

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***Abstract* - The work is focused on information systems and design of web applications that visualize telemetric data and track of vehicle in geographic context. All the measured values and actual location are shown on maps provided by Google. For this purpose, a web application was designed and implemented. This application is able to show data of vital functions in real-time (electrocardiography, heart rate, respiration, oxymetry, etc., as an example of future needs) and basic information about the vehicle, such as location of the vehicle, temperature of interior, acceleration, etc. Collection of data in database with appropriate tools for its acquisition and indication is the aim of the work described in this article. This is starting point for post-processing and data analysis for specialists and experts.**

Keywords - Biological signal; Telemonitoring, GPS; GIS; ASP.NET; MySQL.

I. INTRODUCTION

If we talk about the means of transport, everyone would agree that the most important value is the vehicle's location in this particular context. It would be useful if the geographical coordination was drawn into map on computer and thanks to this you will obtain some important information, such as driver's vital signs, and crucial data about the vehicle itself.

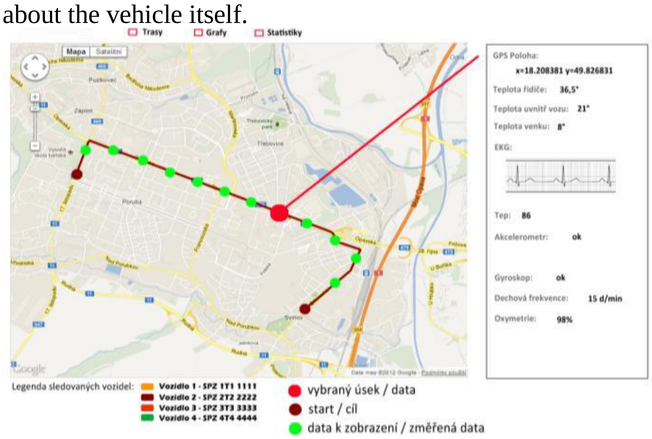

Figure 1. Concept of designed application.

Let us consider an information system that allows us vehicle tracing in real-time, to show current biological data of driver and important data about the vehicle itself for each particular time interval. In the other words, for the current vehicle's position on the map, there will be shown following measured health-status values, such as breath rate, heart rate, temperature or ECG curve, in the system. Of course, for somebody, these details could be insignificant, but for doctors, paramedics, or similarly educated people it could represent very important information. In addition to this, other information obtained from accelerometer and gyroscope could be provided. This information should be indicative of the fact that, for example, particular vehicle had an accident. The usage of such information system is quite extensive, both for fire-fighters, racing drivers, professional drivers, etc., and moreover, it is not necessary to use the system in cars only.

Section II reports the state of the art, following by three sections covering theory of the data sources (biological signals in Section III, geographic informations in section IV, vehicle and its parts usage technological data in section V). In the VI section there is described application design. Then there is measurement and data collecting chain description section. Software solution is presented in section VIII where are used components described. Section IX shows working user interface with a few examples. The last section of this article contains list of used technologies with appropriate description.

II. STATE OF THE ART

Nowadays, it is possible to buy interesting Global Positioning System (GPS) trackers that are able to record position and work with these data offline or online. Real-time behaviour, integrated into a single embedded system and openness of these solutions might be a problem. Another problem could also occur with operating parameters of monitored cars that are often very specialized and manufacture-oriented. Currently, there is a lot of work on current status of the driver [2], [3], who has major impact on the road traffic.

The aim of this work is to present an embedded platform that would enable collecting data from the heterogeneous resources and make the real-time visualization of data. The department of cybernetics and biomedical engineering created several prototypes (Kaipan Voltage) of electric cars in 2009-2012 with industry partners from the Czech Republic (see Fig. 8).

The next step was to implement an experimental system for above mentioned problematic areas.

We prepared solutions for all the data collection and processing that provide interesting results in improving safety of car driving with crew's interaction, looking for driver's stress factor and dynamics of load during driving. It is open source solution in a strong experimental phase where the driver is depersonalized at that time. It means that the work is oriented on data measurement, transmission and processing.

In [4], an embedded sensor system that collects physiological data, such as electrical activity of heart muscle, heart rate, breath rate, temperature and mechanical data as acceleration with built-in sensors, was designed. The acquired data are transmitted to the vehicle via Bluetooth communication interface. The data visualization is designed for Personal Digital Assistant (PDA). This application is usable for both, for displaying sensor data in real-time and for recording measured data to internal memory of PDA or to some other data medium.

Application for PDA was designed in [7]. The PDA is used for displaying actual values of process variables – actual speed, average speed, distance, battery's voltage and current, hydrogen fuel cells voltage and electrical motor current. It is also connected to programmable controller by serial communication link.

On the other hand, our work can indicate the vehicle location on the map, together with driver's biological signals in real-time. This is the advantage because we are able to see where the vehicle is at any given time and what the driver's vital signs are, at the same time. The acquired data are transmitted to database via GSM (originally Group Spécial Mobile) network.

III. BIOLOGICAL SIGNALS

Biological signal (biosignal) is a signal that is used in biology and medicine to represent information about the observed biological system (human body). These signals may be courses of electrical voltage, variable magnetic fields, changes in chemical concentration, mechanical motions, sounds, temperature changes, etc. We can record those signals as results of spontaneous activity of biological system (native signals), or as results of any intentional stimuli (evoked signals, provocation, etc.) [1, 2, 4]. The most often measured biosignals are:

- ECG
- Blood pressure (invasive or non-invasive measuring method)
- SaO2 / plethysmography
- Parameters related to breathing
- Temperature
- Analysis of anesthetic gases

A. Electrocardiography (ECG)

ECG is diagnostic method used to capture and record electrical activity of heart. It is basic method for examination in cardiology. It allows us to detect any abnormal heart rhythms (called arrhythmias), ischemic changes in myocardium, check effectiveness of cardio drugs, etc. The entire activity of heart is accompanied by emergence of an electrical signal. The graphic record is called electrocardiogram (ECG). Signals are sensed by electrodes placed on patient's skin. Any disorder of production or distribution of nerve impulses can affect not only the mechanical activity of heart, but also the shape of electrical signal. [3]

B. Heart Rate

Heart rate is one of basic and most frequently monitored physiological data, especially in clinical medicine, work and sports medicine. It is an accurate indicator of activity and performance of heart. Heart decreasing below certain limit or increasing above certain limit, or even irregular changes might indicate serious disturbance in the activity of heart, so called arrhythmia.

Pulse is a pressure wave which is caused by expulsion of blood from the left ventricle into aorta, from where it spreads to other arteries throughout the entire body. In medicine, series of these waves correspond to cardiac rhythm and heart rate. The heart rate indicates the number of beats of heart within one minute.

C. Respiratory

Respiration is a process of gas exchange between an organism and environment. During normal calm breathing an average adult breathes 6-7 litres of air per minute and the respiration rate is 12-14 breaths per minute. The respiration rate is evaluated mainly on the basis of other measured biological signals. For example, it can be evaluated from electrocardiogram that is modulated in the rhythm of breathing. Respiration is affecting and closely related to ECG records, e.g., it affects the change of amplitude of ECG.

D. Body Temperature

Measurement of body temperature is one of the oldest methods in medical diagnostics. We differentiate between contact and contactless temperature measurement of human body. In contact methods, the measuring device is (thermometer or only its sensor) directly touching the tissue whose temperature is measured. The heat is transferred from the tissue to the thermometer, directly by this contact. The opposite way is the contactless method where heat transmission from the tissue to the thermometer passes through the surrounding environment.

The body temperature of each individual person varies over the day, and it is usually higher in the evening. The temperature can be increased due to physical activity, mental effort, after a meal or, using certain drugs, and the height of temperature (even humidity of the surrounding environment) can impact.

E. Oxymetry

There are two ways of blood oxygen saturation measurement – invasive and non-invasive. Oxygen is transferred physically into the blood, dissolved in blood plasma, and chemically bound to blood pigment haemoglobin. Four oxygen molecules can bind themselves into one haemoglobin molecule. This creates oxy-haemoglobin, the reaction is reversible and repeatable. Within the chemical bond 70-times more oxygen is

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transferred than in physical dissolution. Oxygen is transported primarily by chemical bonds.

The amount of oxygen transferred by chemical bonds is expressed by blood oxygen saturation SaO2 (in arterial blood) and SvO2 (for venous blood). Their units are given in %.

IV. GEOGRAPHIC INFORMATION SYSTEM

The concept of Geographic Information System (GIS) is commonly used to refer to computer-based systems for processing geographic data, presented mainly in the form of various maps. The advantage of GIS in comparison to common maps is that it consistently separates functions of the maps, the storage of geographic data and their presentation, and adds even more options, such as spatial data analysis. Then the same data can be easily updated, analyzed and represented in different ways, so it can satisfy different user requirements at much lower need for compromise.

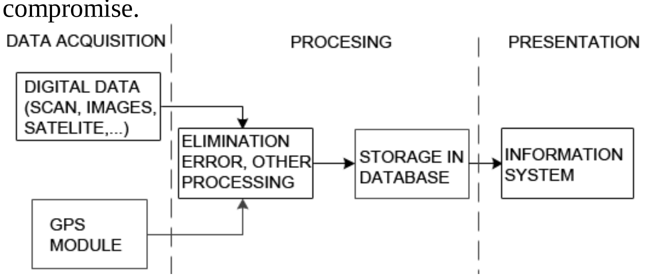

Figure 2. Flowchart GIS.

V. VEHICLE DATA

As well as human biosignals determine their health status, information about vehicle can also determine its characteristics and its condition. The overview of health status of vehicle's driver together with the characteristics and location of vehicle displayed on the map at the same time allow us to track these important parameters and to take actions if it is necessary.

A. *Location of the Vehicle*

The most important information about vehicle is definitely its location [5, 8]. The latitude and longitude of vehicle can be determined by using GPS coordinates. This information is obtained from the GPS module installed in the vehicle.

B. *Temperature of Interior*

Another important variable is the interior ambient temperature since changes occurring in the environment temperature are affecting thermoregulation of human body. The change of ambient temperature has high serious impact on human body and it can result even in overheating or hypothermia.

People belong to warm-blooded animals in which the core temperature of inner body is kept at 37° at normal conditions. Maintaining of temperature is possible only if the heat production in equilibrium dispense. This is done by system that is able to control body temperature by various thermo regulation mechanisms – (thermoregulation). Body temperature depends on the generation of heat and on other the external and internal factors.

C. *Accelerometry*

Accelerometry is a method of sensing acceleration using accelerometer's sensors. Accelerometers are used to measure acceleration. Generally, acceleration characterizes the rate of velocity change of mass point or the entire system of mass points in time.

D. *Gyroscope*

Usage of gyroscope is another way how to measure movement in space, change of position and angle or rotation. Gyroscopes are well known and used for measuring and determining the change in position or rotation in a perspective of any object to which they are attached. The gyroscope is a device for navigation and direction. Actually, it is the flywheel; heavy wheel rotating on bearings with little friction. The rotating flywheel has momentum, so that its axis without external forces is kept in the same direction. It means that it is a device that can determine its orientation in space (flywheel never changes its position during the rotation and thus gives information about the orientation of the vehicle in space). Gyroscopes are widely used for measuring angular velocity in units of degrees per second (° / sec), for example, to see how quickly the measured object is rotated.

VI. APPLICATION DESIGN

The application will display biosignals that are gathered by the sensor systems. Signals will indicate the driver's health and the current load of his organism together with the signals reporting the status of the vehicle. These signals are quite important since we know where the vehicle is, how the driver's body reacts in different situations, and in the case of health problems an immediate assistance can be provided. It should be noted down that all these values are gained from devices that are placed on-board of the vehicle.

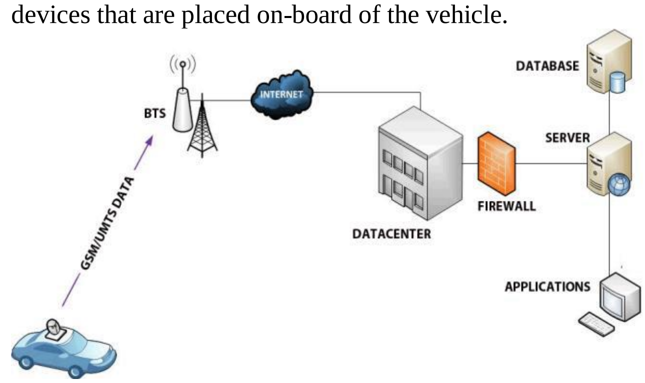

Figure 3. Data procesing.

First of all, the process of acquiring and processing data in general is described there. Then data processing will be particularly described in the application.

In Figure 3, there can be seen the whole process of communication. Data obtained from the modules located in the vehicle using GSM (or Universal Mobile

Telecommunication System) are transmitted via internet to central location (data-centre). In data-centre, servers and applications are located. Then, on these servers data are processed and stored in database. The application is finally accessing those processed records and performs and offer further necessary operations (calculations, visualization, etc.).

VII. MEASUREMENT CHAIN

Measurement chain consists of three basic blocks, namely, remote devices, server, and the client. These individual blocks communicate with one another via Internet network.

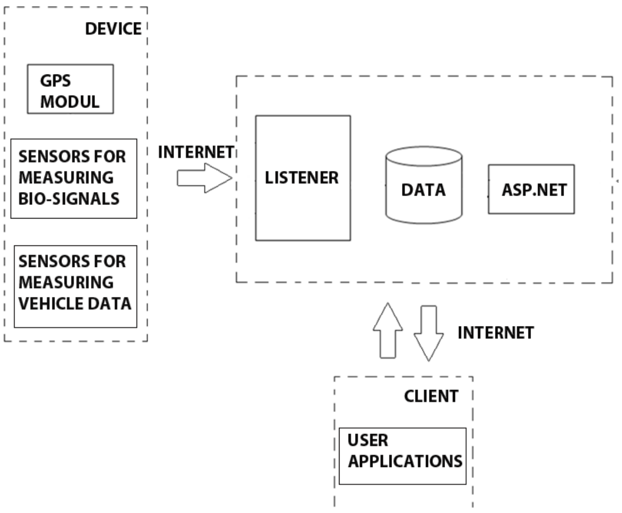

Figure 4. Measuring chain for the acquisition, processing and displaying data.

A. Remote Devices Block

This block contains modules for data measurement. In our case it will include GPS module that allows us to get information about where the vehicle is located. We could use Smartphone for localization and some other information, such as acceleration, but free applications did not meet our requirements. It is necessary that the data string contained to have a unique identification key.

Then sensors for measuring biological signals by which data indicating the driver's vital signs are obtained. Finally, sensors for measuring vehicle's data are needed. These sensors can be selected according to the purpose (temperature inside, temperature outside, tire pressure etc.). There is an attempt to make the application universal as much as possible for different usages so that it is necessary to choose the measured data (sensors).

It is possible to use it generally, but this work was focused on the vehicle Kaipan Voltage.

B. Server block

This block contains a service called "Listener", then relational database and robust applications implemented using ASP .NET framework [6].

Listener service allows us to listen to the particular server port and to have connection handling of one or more clients. The purpose of this is to receive pre-process data- streams. This means that data is not only received and stored into selected database "telemetriedb" but there is parsing of data performed to the individual data segments on beforehand. With such prepared records, we can then proceed with further processing and examine these in the application.

Data are stored in the standard MySQL database called telemetriedb. The database uses standard web interface phpMyAdmin for access to database. Communication with the DB is using the SQL query language.

Both blocks, the remote devices and the server, are communicating as client-server. The remote devices represent the client in the meaning of the network architecture and the server block is obviously the server.

Protection of personal data is not necessary because we do not indicate sensitive information. That would point out on a concrete user. Database is secured with password.

C. Client Block

The final block is the client. It is representing user application (user interface) and it is the only thing from the whole solution that the user will be able to see and work with. The goal was to create application's user interface as much clear and intuitive as possible, and in the way to have good view of the current health status of driver. On the welcome page, there is user guidance what applications you are allowed to see and what operations can be performed there.

VIII. SOFTWARE SOLUTIONAPPLICATION DESIGN

A. Listener Service

Service "Listener" is used for receiving and parsing data strings that come from each device. After Listener service starts, first it initializes required data and begins to run an infinite loop that waits for a client connection. The algorithm flowchart is shown in Figure 5.

When the device or client connects to the server (Listener service), a new thread is created. This thread is handling the processing, the requirements of any particular client. The thread is waiting for receiving data from the client. When the data are received, it converts them from a stream to a text format, the received data "received telegram" starts to process. Then, the data are stored in database. After that based on IMEI identifies the device type (which type of device was sent). Based on the type, it begins with parsing of the data. Once data are parsed to an object, then the object is stored into database.

B. Data Sending

Due to the unavailability of functional devices that could send real data directly to the server, we were forced to simulate this data. The concept of simulated data is very simple.

For the data that describes biological functions of driver and vehicle data (NOT its position) a simple simulation tool based on limited random values that create artificial data strings (received telegrams) was created. Those data strings are sent to the service Listener.

To be able to display the vehicle's path, it was needed to simulate the whole track. The values of its trajectory are gradually stored in data string (received telegram) as well. This is sent towards the server, as well.

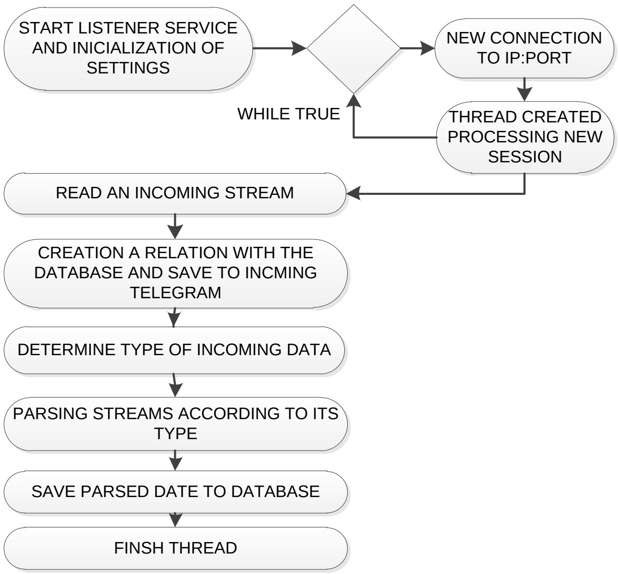

Figure 5. Flowchart Listener service.

C. *Loading Map*

Maps are implemented by busing the Google Maps API that allows us to load the maps into the web application using JavaScript. In this work, we use the Google Maps API v3, that is free and available for non-commercial purposes.

IX. USER INTERFACE

Here, one can see how the application looks like and what its functions are. In Figure 6, we can see a part of the application that could be interesting for the end-users. Tabs Car, Car type, Contact persons and Equipment are used for user's communication with the database. It is a user-friendly interface for users who are not aware of SQL query language since the data can be inserted, edited or deleted directly in the web application by simple mouse clicking.

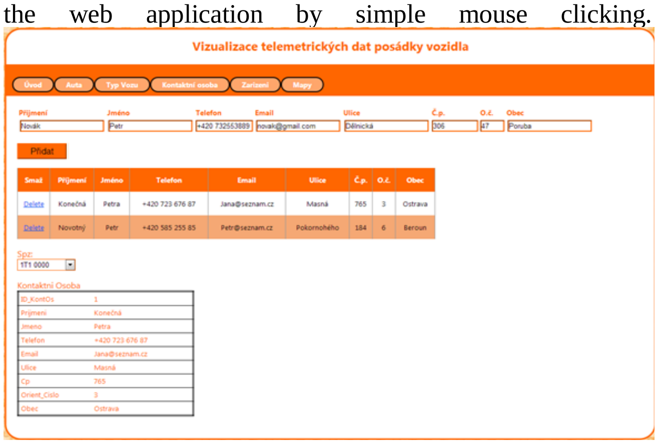

Figure 6. Edited data from the database in application.

For example, in Figure 6, there is shown contact person tab where you can add or delete a new contact person. There is also a selection box for the license plate that can help the user find contact persons related to the particular registered vehicle. Other tabs are designed in very similar way, everything straight and easy for the end users.

The most important part of the application is shown, if you open the Maps tab. It is practically the main part of the application that allows the user to view vehicle on the map, and displays all the driver's important biosignals and the current information about the vehicle.

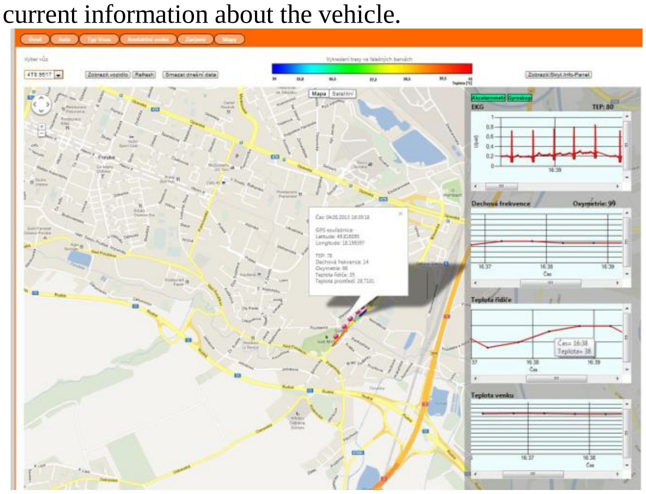

Figure 7. Edited data from the database in application.

X. SYSTEM IMPLEMENTATION

One of the main parts and the most essential task of this work was to design and create database that stores all data and is able to process them later. For this purpose, MySQL database was used because its function adequately covers the requirements of the problem. When using an application together with using all the client devices huge amounts of data that limit the processing speed and could clogging up the database are stored. Therefore, it was necessary to solve automatic or manual data clean-up that are no longer required, and solved by the application itself. To redeem the adequate processing speed of the application, the individual procedures were highly optimized within the database (creating additional indexes for parameters that could be searched out of the data).

Once this important task was resolved, it was decided what data are needed to be registered (in what format they should be obtained), it was necessary to design and create a service called "Listener". This service was created by using the Microsoft .NET Framework as a service for Windows OS (the server). Its main task is to listen to a specific IP address and port. These parameters can be easily changed because it is possible to use the service in any network, on any server where software tools (Microsoft Framework & IIS) are available. Service can receive and handle multiple concurrent connections (called threads) simultaneously. Unfortunately, there is fixed International Mobile Equipment Identity (IMEI) parameter set up that is used to differentiate the device type, the service that should react appropriately

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and find out the type of communication. In practice, this means that the distinction between the types of devices is made on the basis of fixed IMEI. In other words, according to the IMEI chain the service will recognize that it is, e.g., GPS module and for that purpose there is set particular parsing routine. However, this can be removed by expanding data structure that would allow detecting the type of device based on IMEI automatically.

For the visualization of map data, the GIS system from Google, available for free, was used. More specifically, the "Google Maps API v3" were used where the application is written in ASP .NET with JavaScript and C# programming language. For the visualization elements, "chart.components" were used. We have chosen the type of graphs that can display static charts only. The application allows users to view route of one selected vehicle (however it is possible to switch among vehicles). Route is drawn in false-colours according to driver's body temperature.

It is possible to view the measured data in the given time points, for both the car and the driver, and also in every point of measurement along the route. It is also possible to display the information panel where graphs of the measured values related to time are.

The application can be further improved and expanded. First of all, the expansion of visualization with providing of information about other parameters (e.g., engine temperature, vehicle speed, etc.) could be. Then, there can be implemented feedback between the vehicle and the visualization part which would enable automatic detection and response to changes in essential signal characteristics. It might be needed to use dynamic graphs that could display the transparent visualization of biological data, as well. Another important improvement could be auto-call, the pre-defined contact person in case of sudden changes in vital signs or during an accident. To react on the current world trends, creating of suitable application for mobile phones with the Android OS or Apple iOS, which could allow drivers to check their vital signs and conditions of their cars directly in their vehicle, would be useful.

XI. CONCLUSION

The main goal of this work was to create an application for displaying Telemetric Data of vehicle's crew at map background. Since we did not have any devices that would generate real data and send them to the database server, the data were simulated.

This work follows [4] and is extending it by the amount of captured data. Not only information about drivers are captured, but also vehicle's data. All the values are displayed on the map then.

The system was created to show biometric and operating data on the map. For testing purpose, the system was designed for electric Kaipan. It shows information about crew's health status during vehicle testing. System is used for ergonometric measurements of vehicle's prototype during driving tests. The system is able to interconnect telemetric data and crew's biometric data together for prototype of electric vehicle Kaipan Voltage and shows joined data in geographic context. The result is that driver's subjective feelings are extended by objective measurement data.

Figure 8. Kaipan Voltage prototype.

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