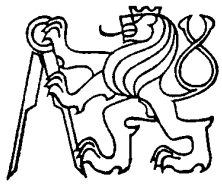

Joint Laboratory of System Reliability

Czech Technical University, Prague
Faculty of Transportation Sciences
Department of Control Engineering and Telematics
Konviktská 20, Prague 1, 11000
Czech Republic
phone:004202 2435 9548, 004202 2435 9546 (fax)
e-mail.: mirko@fd.cvut.cz

Institute of Computer Science
Academy of Sciences of the Czech Republic
Pod vodárenskou věží 2, Prague 8, 18207
Czech Republic
phone:004202 6605 2080, 004202 821630 (fax),
e-mail: mirko@uivt.cas.cz

Project of Micro-Sleep Base

Research Report No. LSS 112/01

Authors:

Prof. Dr. Mirko Novák,
Prof. MUDr. Josef Faber,
Ing. Tomáš Tichý
Tomáš Kolda

Prague, November 2001

Abstract:

In this report the project of the information based is presented, the aim of which is to store the necessary data and information for detection, analysis, classification and prediction of human subject attention decrease in the course of his/her artificial (namely technical) system operation and/or use (the Micro-Sleep Base – MSB). The respective data are obtained from various measurements on human subject not only in the laboratory, but also in the course of human system operator real service. These data are stored in the so-called primary data bank of MSB. From them the necessary information on human subject ability to operate or use the system well is derived. Therefore, besides the parts serving for sophisticated storing of various primary data types the structure of MSB involves also the bank of so-called secondary data and information, where the knowledge, reached by special data-mining approaches from the primary data bank is accumulated. This serves as the background for attention decrease and micro-sleep advent classifiers and predictors, which can eventually stimulate the necessary warning system.

The MSB is proposed so that it can be applied as one of the building blocks of the international brain-science oriented information base (the NeuroBase), developed in the range of the OECD Global Science Forum project Neuroinformatics. It will be realized on the computer network of the Laboratory of System Reliability (LSR) of the Department of Control Engineering and Telematics of the Faculty of Transportation Sciences, Czech Technical University, Prague.

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Content:

1. Introduction

Almost all artificial systems, namely that, which are of the technical nature, require for their proper operation the interaction with the human subject. This concerns especially all the transportation systems. Human subjects can be in the role of system operators (drivers, pilots, navigators, dispatchers etc.) or in the role of their users. In all these cases the natural limitation and eventual decrease of their vigilance and attention can be the source of extraordinary danger. There is well known that no human subject, without the level of his/her training is able to interact with artificial system for long time without breaks and necessary relaxation. However, the operation and exploitation of many modern systems requires very high human subject attention for considerably long time. Naturally, his/her attention must decrease.

2. Concept of Micro-Sleep Base as one of functional blocks of the international NeuroBase

The NeuroBase is in principal considered as open heterogeneous information system, consisting of many partial functional blocks, represented by regional, national and specialized databases. Such system needs for its proper function very reliable and safe exchange of information and data among interacting functional blocks. These exchanges will be realized by specialized interfaces in which the necessary translation functions will be performed. The functional coordination of the whole system, including all the functional blocks and interfaces will be done by the international Neuro Portal.

Individual functional blocks of the NeuroBase will operate at various functional levels. Some parts of them will concern the internal operation of particular block, but othesr, which can be considered to be of the higher level, will be based on mutual cooperation of more blocks, dominantly through the Neuro Portal. Therefore also the

MSB must be able at the top level of its activity to communicate with this international portal.

Of course, also the MSB represents in principal of the information subsystem of the heterogeneous nature. Therefore in its structure the internal portal must be included, which ensures the proper coordination and data and information exchange among all its partial functional blocks.

3. The Basic structure of MSB

The Micro-Sleep Base itself represents therefore a considerably complicated heterogeneous specialized information system. It consists of 6 specialized basic functional blocks, realizing their specific system functions. Among all of them mutual interactions exist. Because individual blocks operate with data and information expressed in their own alphabets and grammars, the translation of them in the proper form understandable for the particular partner block is necessary. These translations are realized by specific interfaces (not shown in the Fig. 1, where the basic structure of MSB is presented).

Because the MSB is proposed (as was already mentioned in section 2) to act as a part of the international neuroinformatic base (NeuroBase), it must be able to communicate with the respective international NeuroBase portal (NI Portal). The proper interaction between MSB and NI Portal a specific interface ensures (also not shown in Fig. 1).

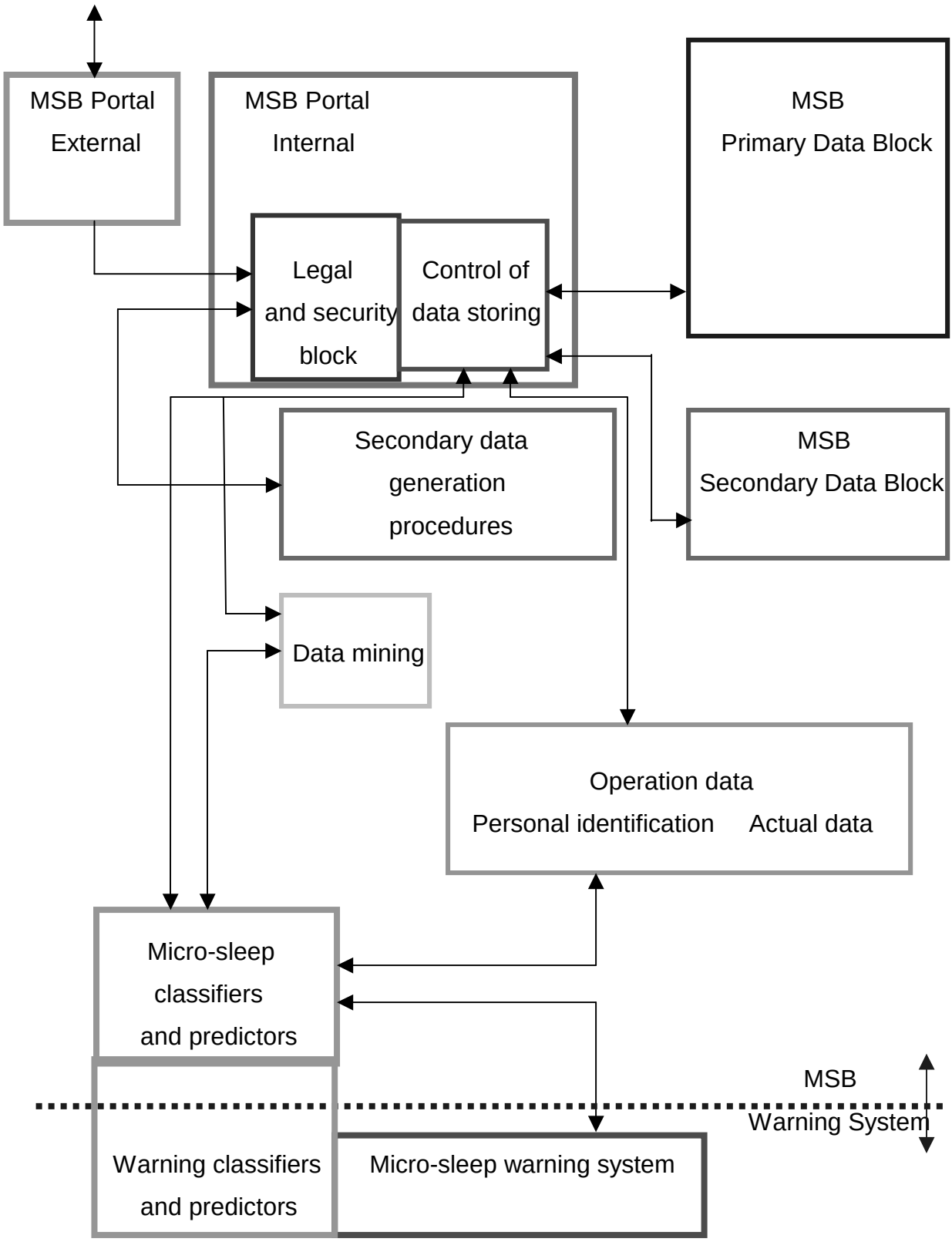

Fig. 1: The basic structure of MSB (interfaces are not presented). The blue dotted line represents the boundary between the MSB and the Micro-sleep Warning System. Some of the warning classifiers and predictors will be realized by special hardware.

The detail structure of the two MSB data blocks is shown in Fig. 2.

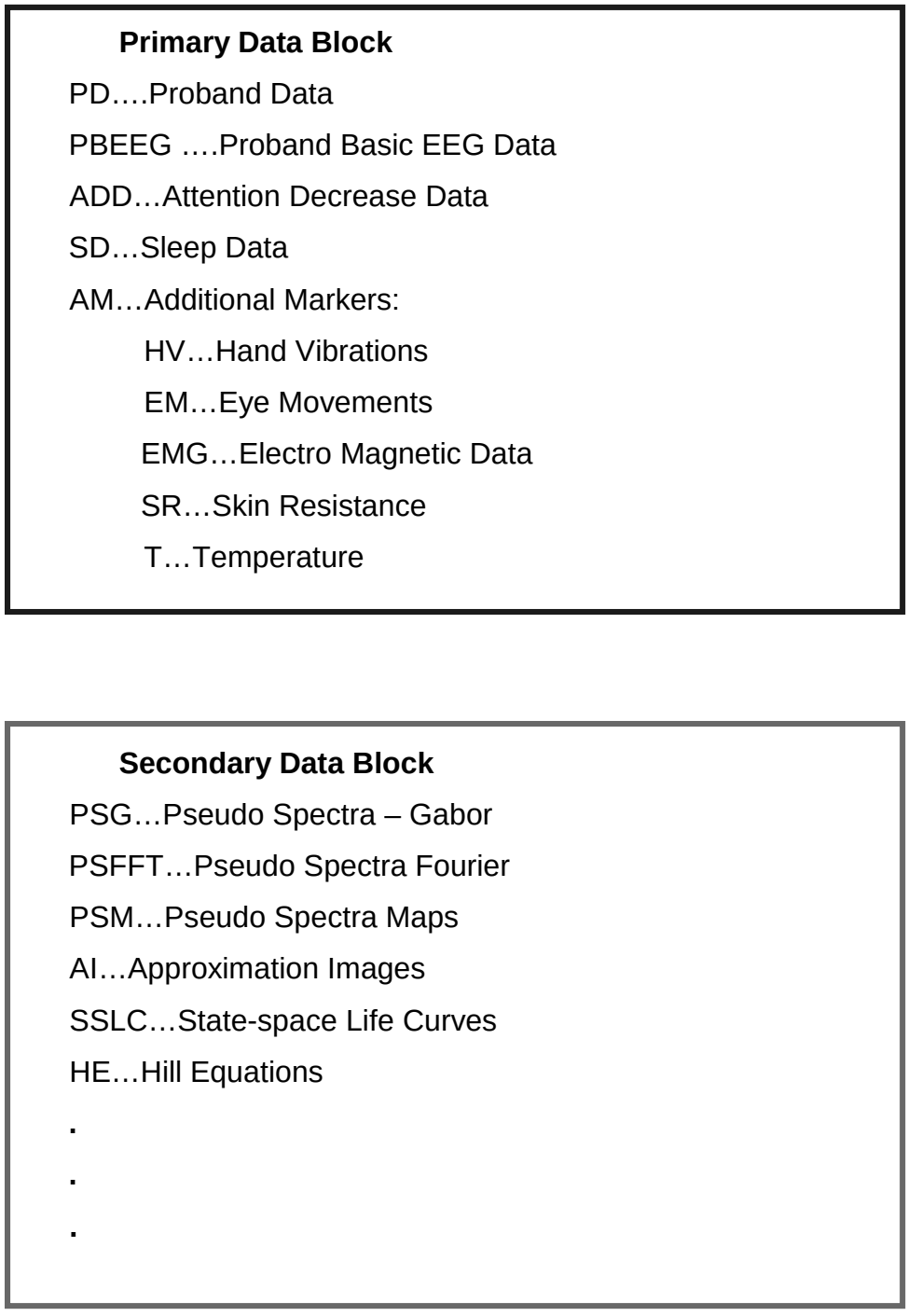

Fig. 2: Proposal of the content of the MSB primary and secondary data blocks.

In the course of the research on detection, analysis, classification and prediction of human subject attention decrease and micro-sleep advent the extension of the content of the secondary data block is expected. This concerns especially the eventual results of new methods for analysis and classification of quasi-periodical and quasi-stationary time series.

The MSB will operate in several operation phases. The following are expected now, however more can be found to be useful after some practical experience.
At present expected operation phases of MSB:

a) Laboratory measurements
b) Data mining
c) Secondary data generation
d) Operation measuremets
e) Attention decrease and micro-sleep classification and prediction
f) Warning.

4. The MSB Portal

The control of all the MSB activities will be done in the MSB portal. It consists of two parts:
The External MSB Portal and
The Internal MSB Portal.
The role of the External MSB Portal was already mentioned in section 2 of this report. Its development is realized under the supervision of the OECG GSF Workgroup “Neuroinformatics” and is not in the focus of interest of this report. However, the necessary interface on the side of MSB must follow the respective NeuroBase standards, after they will be finished. Because the development of MSB will be done almost in parallel with the works on NeuroBase Portal, the respective interface between the External and Internal parts of MSB Portal needs to be constructed flexible.

All the internal supervision of the MSB function will be realized through the Internal MSB Portal (shown schematically in the left upper corner of Fig.1). It interacts straight with the block for legal and security activities, in which the approbation of the rights to exploit the MSB from other users will be realized. This block interacts straight with the block for data storing control.

The functions of Internal MSB Portal will be realized on special server of the computer network of LSR.

5. The primary data-bank of MSB

The basic structure of this block is shown in the upper patr of Fig.2. Its hardware basis will be the server OLAF of the computer network of LSR. The respective supervision software is written in JAVA. In this block the measured data are stored, namely:

- the Proband Data (PD), which involves the necessary characteristic of the respective proband (his/her name, sex, age, address, profession, basic medical anamnesis) – these data are of the alpha-numerical type,
- the data concerning the measurement of his/her EEG signals – Proband Basic EEG Data (PBEEG). Such data represent the group of time series (measured at present with sampling rate 128 samples per second), corresponding to certain specified placement of measuring electrodes on the probands head surface. The location of electrodes is done according to the international standard “10-20” (see Fig. 3). Various number of electrodes will be used for different probands, however certain minimal pattern of their location, shown in Fig. 4, is proposed to be used in any case as standard.

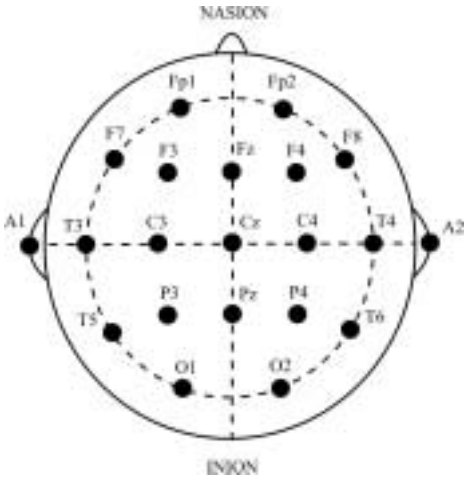

Fig. 3: International standard “10-20” for EEG electrode location on the surface of probands head.

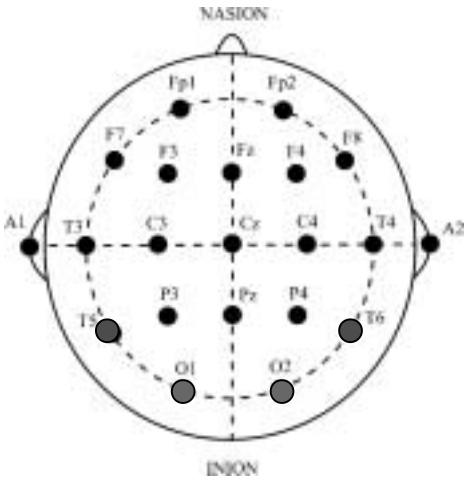

Fig. 4: Minimal recommended location of EEG electrodes on the surface of probands head (red spot – primary recommendation, blue spot – alternative recommendation).

The length of the stored time-series differs upon the actual condition of the particular measuring experiment, however at least 20 minutes is recommended. In the course of measurement the proband observes the screen on which the record of actual system control scene is projected (the view, which the car driver or rail-road driver sees from cock-pit, etc.). These records are recommended to be standardized for all the laboratories, participating on the MSB project.

- For the purpose of micro-sleep classification and prediction, additional data concerning the decrease of probands vigilance and attention in the course of measuring experiment are recorded. These data are stored in the Attention Decrease Data base (ADD). For representation of vigilance and attention level the probands reaction time (RT) on suddenly appearing random stimulus is measured and stored, coordinated with the respective EEG signals. At least two basic kinds of stimulating signals for RT testing are recommended:
    a. Sound signals, high and low tone of the frequency about 1000 Hz and 400 Hz, of the level about 50 dB.
    b. Visual signals, the red and green spots, of the diameter about 10 mm projected randomly on the screen, which proband observed in the course of measurement.

For the purpose of the detection of probands reaction instant the simple manual bi-positional handle is recommended. Each position of this handle corresponds to correct reaction on certain stimulus, preferably back move from

central position to high tone or read spot, front move from central position to low tone or green spot.

As standard, the right hand control of this handle is preferred. The records of probands, operating preferably with left hand must be stored in separate part of this data-base.

Besides the length of reaction time RT also the correctness of the probans reaction is recorded and statistically evaluated.

- Similar character as PBEEG has the basis of so called Sleep Data (SD), where the records of time-series of EEG signals during the whole period of his/her night sleep is stored. Of course, here the RT is not investigated.
- Because besides the EEG signals also some other kinds of human subject signals are important for estimation of particular proband vigilance and attention level, also several Additional Markers (AM) are recommended to be measured and stored, namely:

Hand Vibrations (HV),
Eye Movements (EM),
Electro Magnetic Data (EMG),
Skin Resistance (SR),
Temperature (T).

The recommendation for the measurement and storing of these kinds of primary data will be formulated in separate reports.

6. The secondary data-bank of MSB

In the secondary data bank of MSB are stored the data derived from the primary data by the use of some of the mathematical procedures, involved in the respective block of MSB. Evidently, not all these procedures are applicable for any kind of primary data. Besides the procedures of statistical nature, almost all other are focused on the EEG (or eventually EMG) signals.

7. The procedures for secondary data generation

Because the main part of the primary data consists of time-series, representing the EEG (or eventually also EMG signals), the mathematical procedures generating the secondary data are focused on their processing before all. However, these time-series are of the quasi-periodical and quasi-stationary nature. This causes, that the

conventional methods and tools for spectral analysis, based on certain modification of Fourier transform can be applied here only incorrectly. Therefore, dealing with results of such analyses, one has to speak about pseudo-spectra instead of spectra. Nevertheless, almost all up to now known analyses were made on the base of this approach. The respective pseudo-spectra are stored in a special part of the secondary data-block of MSB (Pseudo Spectra Fourier – PSFFT). The considerably good results obtained by several authors can be explained by their high knowledge, intuition and long experience and skill in EEG time-series analysis.

From the pseudo-spectral lines the maps of their distribution on the probands head surface can be derived (Pseudo Spectra Maps, PSM).

For to prevent the problems arising from the low comparability of the results obtained by various modifications of Fourier transform, a special type of Gabor filtration was developed. This is recommended to use as a standard one. The respective pseudo-spectra obtained by the use of this method are stored in special part of the secondary data block of MSB.

Because of the problems with the spectral analysis of quasi-periodical and quasi stationary time-series, several other approaches how to find the set of representative significant parameters (markers), characterizing with satisfactory accuracy the specific kind of such time-series corresponding to the proband particular stage and his/her level of ability to control or use respective artificial system needs to be developed. The research in this respect is in its beginning. Among the promising approaches the use of approximation of selected parts of these time-series and the investigation of the pole-zero location of the respective Z-transform images (Approximation Images, AI), the investigation of the shape of state-space life curves (SSLC) and the investigation of the coefficients of the Hill´s differential equations (Hill´s equations, HE) are to be mentioned.

8. Data-mining

In the various data, stored in MSB various information and knowledge will be involved, concerning the hidden interrelations especially. For the purpose of the necessary mining of the knowledge, a set of respective data-mining methods will be involved in the special block of MSB. Among them the approaches and tools on the base of the GUHA (General Unary Hypotheses Automaton) methodology is to be mentioned before all.

9. Warning system

The interaction between the MSB and the warning system, which will realize the eventual generation of the information, that the particular system operator (driver, pilot, dispatcher etc.) is on the way to loose his/her ability of safe and reliable control of the respective system is presented in Fig. 1 by the blue dotted line. Actually, this system can be considered as the extension of MSB useful for practical applications. In the case, that MSB is used for research purpose the activity of warning system is not necessary, of course.

The first part of this system involves the warning classifiers and predictors, Some of them can be realized by the use of micro-sleep classifiers and predictors, involved in the respective block of MSB. For mobile applications, some of these warning classifiers and predictors can be realized by special hardware.

The second part of warning system consists of the micro-sleep warning devices, realizing the transmission of suitable warning signal either to the system operator, or to system operation supervisor or to both. As concerns the signals for operator warning, the acoustic signals in the form of artificial voice are preferred (the intensity and aggressive tuning of this voice warning can be subsequently graduated).

Detail structure of the warning system itself will be proposed in special research report.

10. MSB operation phases

The MSB can be operated in several operation phases. The dominant of them are:

a) the phase of primary data storing,
b) the phase of secondary data generation and storing,
c) the phase of data mining,
d) the phase of proband attention or vigilance analysis,
e) the phase of system operator warning against danger of decrease of his/her attention and vigilance,
f) the phase of MSB content exploitation for other research purposes.

The operation flow of the phase a) is schematically shown in Fig. 5.

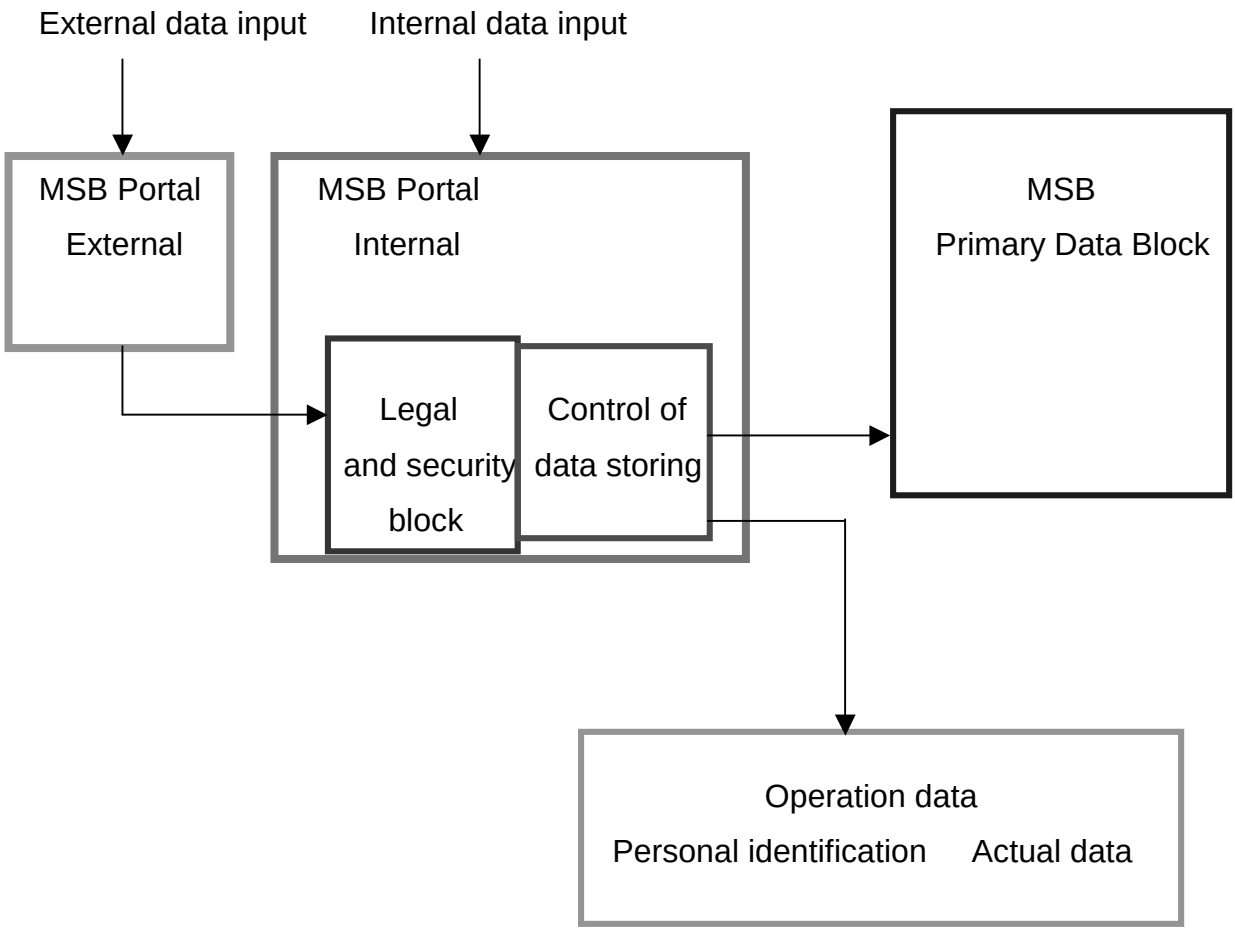

Fig. 5: The basic structure of MSB operation flow for the phase of primary data storing.

The legal and security block is expected to be active also in this phase because of the necessity to prevent inputs of incorrect primary data from not authorized sources.

The operation flow of the phase b) is schematically shown in Fig. 6.

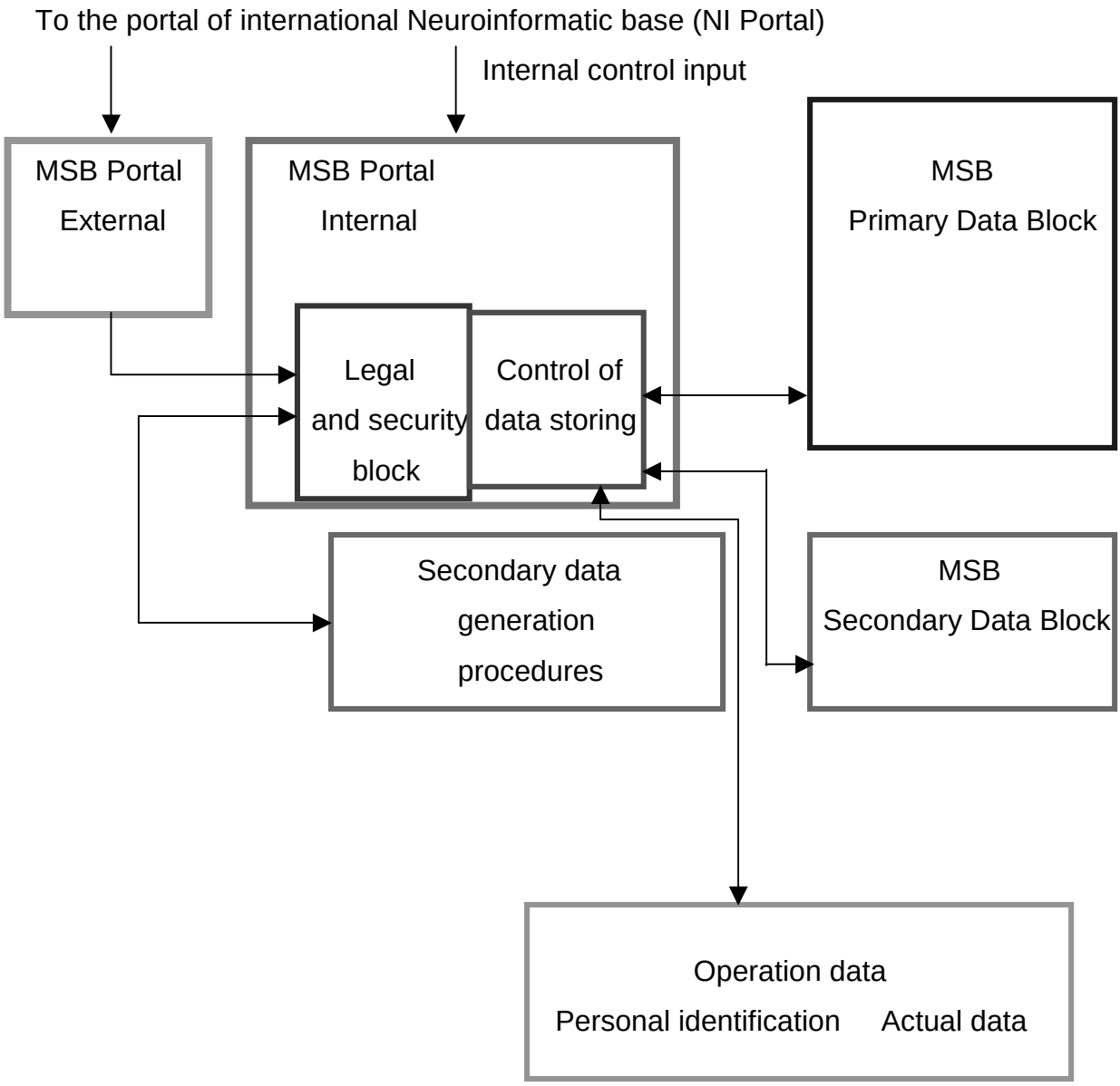

Fig. 6: The basic structure of MSB operation flow for the phase of secondary data generation and storing.

The instructions to secondary data generation i.e. the selection of the respective primary data on which certain secondary data procedure has to be applied, the supervision of calculated secondary data and instructions to their eventual storing in Secondary Data Block can be given either to the MSB Internal Portal through internal control input or also from outside to the MSB External Portal. In such case the verification of the access authorization through the Legal and Security Block is necessary.

The operation flow of the phase c) is schematically shown in Fig. 7.

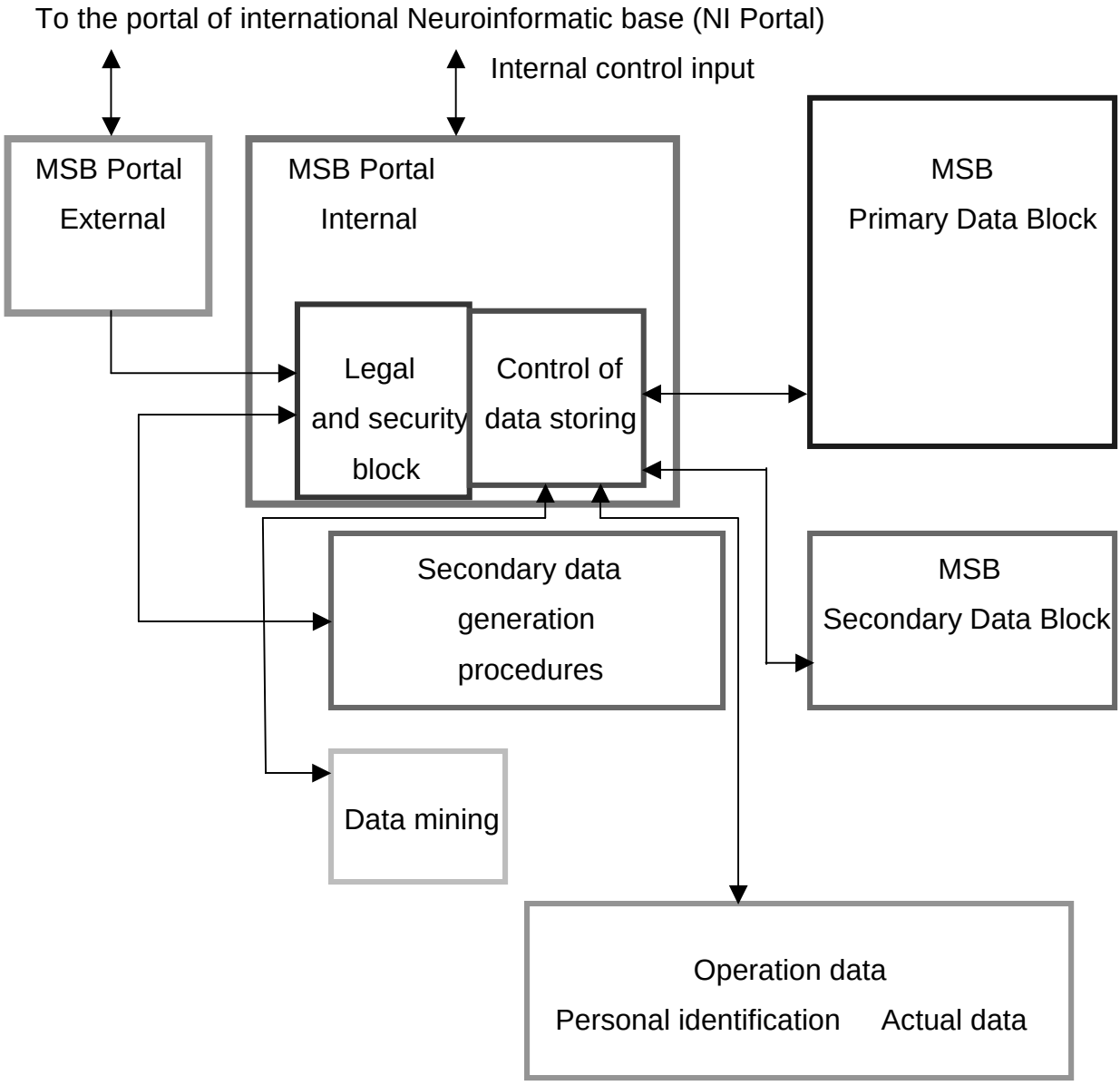

Fig. 7: The basic structure of MSB operation flow for the phase of data mining.

Also in this operation phase the instruction for data-mining can be done either through the internal or through the external input. If external input is used, the verification of input authorization is necessary.

The operation flow of the phase d) is schematically shown in Fig. 8.

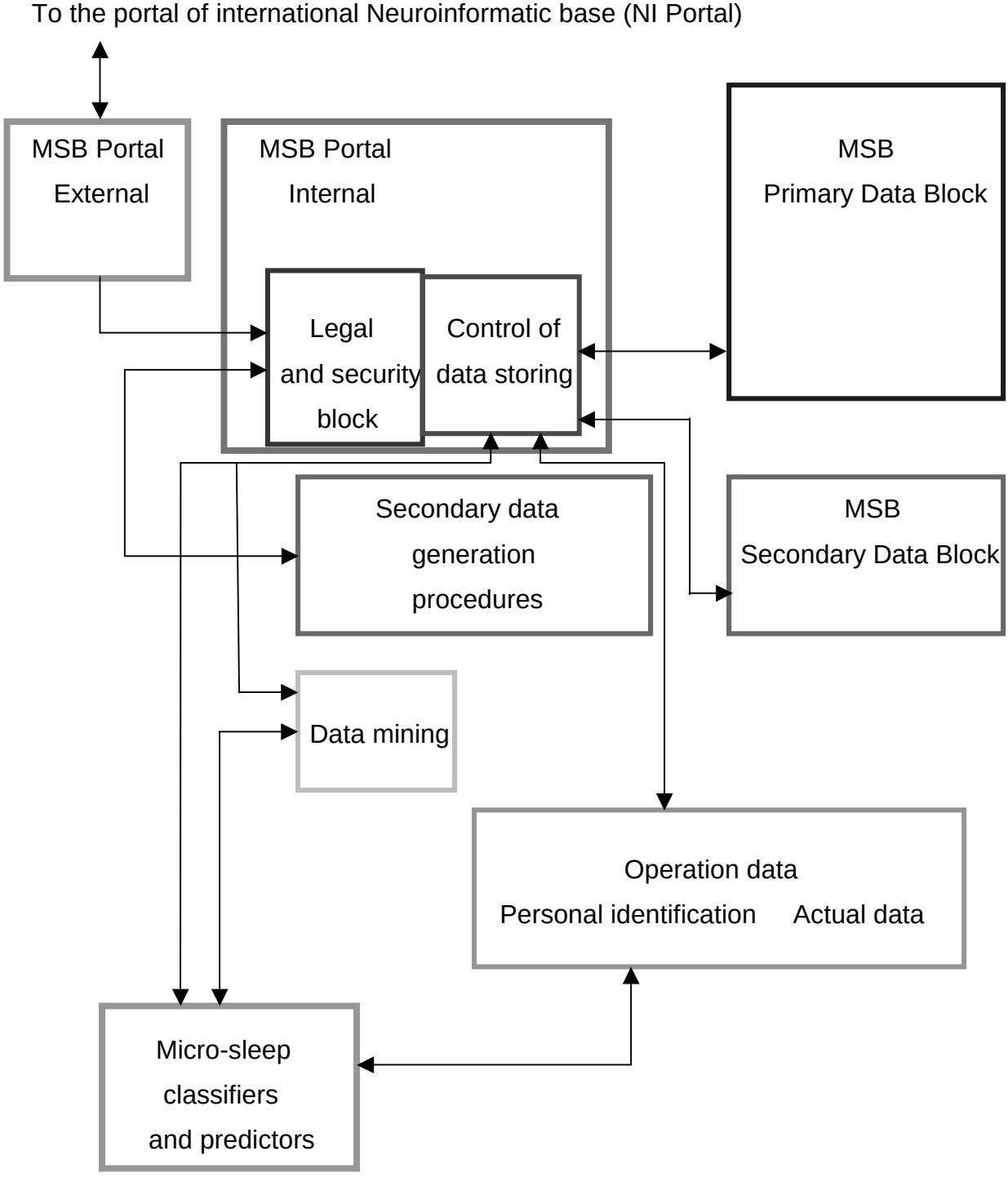

Fig. 8: The basic structure of MSB operation flow for the phase of attention and vigilance analysis.

The operation flow of the phase e) is schematically shown in Fig. 9.

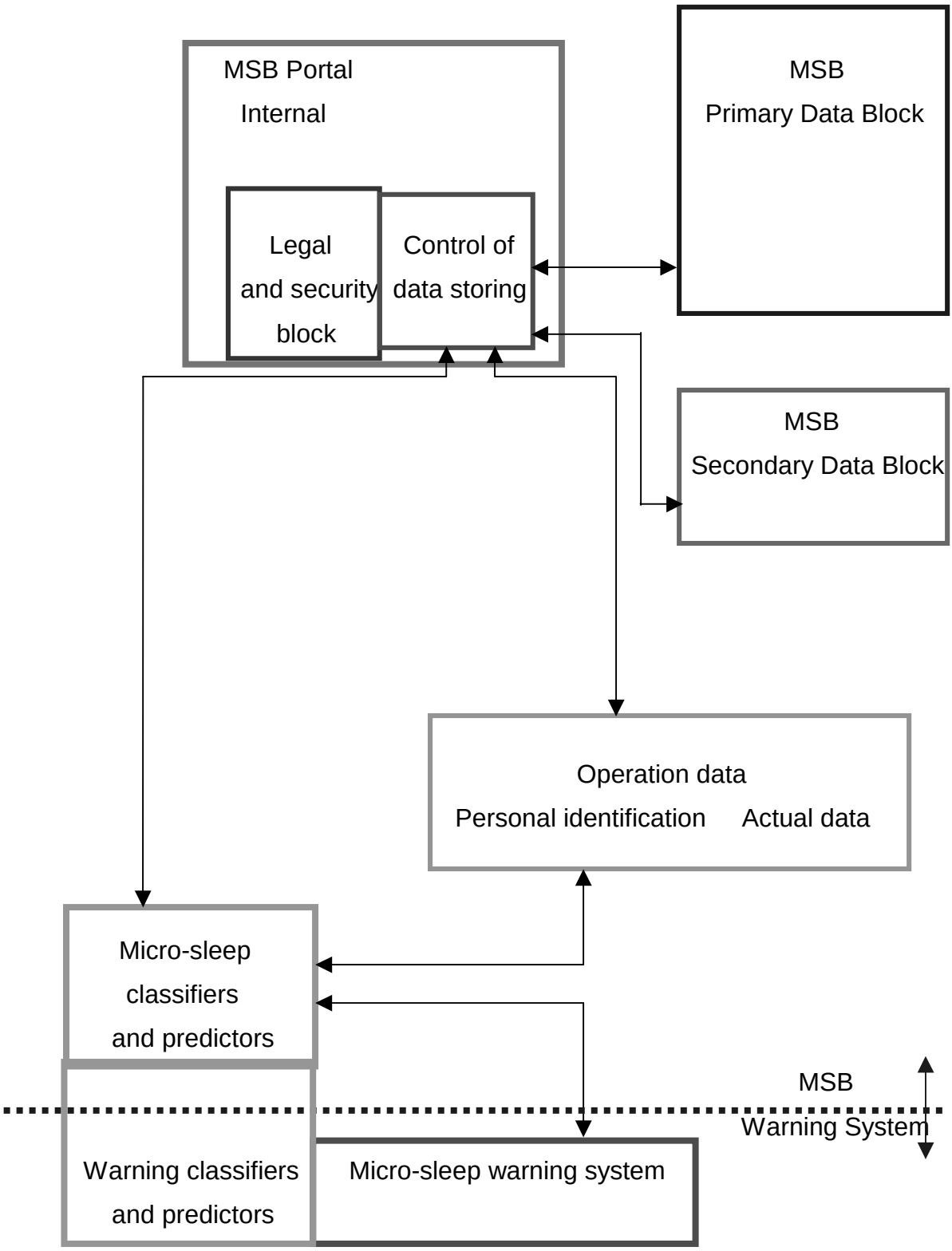

Fig. 9: The basic structure of MSB operation flow for the phase of system operator warning

g) the phase of MSB content exploitation for other research purposes.

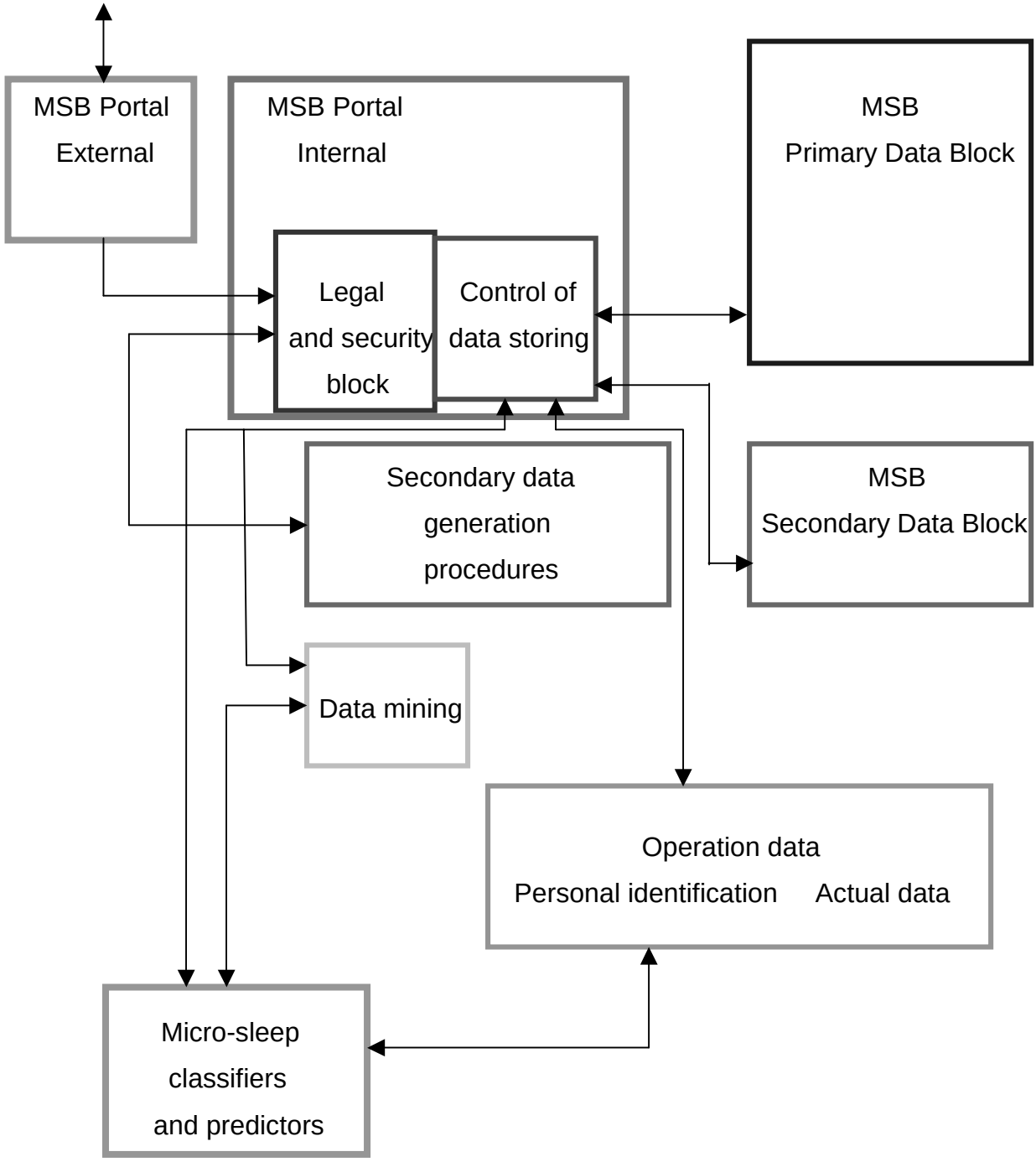

Fig. 10: The basic structure of MSB operation flow for the phase of system MSB content exploitation for other research purposes.

In such type of MSB operation either the internal or the external input gate serves for user communication with the whole MSB except its warning parts.

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