VISU AID

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February 17, 2014

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser Univeristy
Burnaby, British Columbia
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Re: ENSC 440 Functional Specification for **Now I See**, a Travel Aid for the Visually Impaired

Dear Dr. Rawicz,

Please find the functional specification documentation for our travel aid for the visually impaired, **Now I See**, enclosed herein. Our device examines the frontal proximity of the user using a depth camera and informs if obstacles are present through a vibratory user interface worn on the forehead. With this device, we aim to assist our clients towards a more independent lifestyle by providing a novel way to perceive their environment and navigate it with increased safety.

This functional specification documentation establishes a list of high-level requirements for the proof-of-concept device and the production model of **Now I See**, as well as its future refinements. Functional and safety requirements for our device are examined in detail, including its hardware and software components, as well as its sustainability considerations. This document will serve as a comprehensive reference during the development phases of our device.

VisuAid is a vibrant company consisting of three enthusiastic biomedical students: Anita Kadkhodayan, Steven YM Lee, and Daria Numvar. We very much look forward to your comments on this documentation. Please feel free to contact us for any concerns or questions. You can reach us by phone at 604-763-4010 or by email at akadkhod@sfu.ca.

Sincerely,

Anita Kadkhodayan
Vice President
VisuAid

Enclosed: Functional Specification for **Now I See**, a Travel Aid for the Visually Impaired

FUNCTIONAL SPECIFICATION for **NOW I SEE**

A Travel Aid for the Visually Impaired

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February 17th, 2014

EXECUTIVE SUMMARY

The ability to live independently is a significant and desirable quality for the visually impaired; however, moving around without direct help from another individual can be a difficult feat. At **VisuAid**, we are developing **Now I See**, our new travel aid device for the visually impaired, that will provide our clients with a novel way to perceive their environment.

Through a depth camera, the user's surroundings will be examined and any obstacles (including pits) will be reported through a vibratory interface worn on the forehead. With this information, the user will be able to 'sense' the obstacles and their relative positions, thereby acknowledging and avoiding them. Also, by moving their head they will be able to estimate the size of an obstacle as the camera will detect its edges.

The development of the **Now I See** travel aid is scheduled in three phases and represented by creation of corresponding model devices, which are: a proof-of-concept model device, a marketable production model, and a refined final product. In this documentation, all functional aspects related to our new device are addressed and listed in the form of a functional specification. A list of requirements is created to carefully establish the specification details needed at each phase, to clearly define their scopes and to serve as a comprehensive reference. Each requirement is prioritized according to its functional and/or safety importance. Satisfaction of the high priority requirements constitutes the proof-of-concept device, and production model will require meeting the high and medium requirements, with the low priority requirements remaining for the refined model.

These requirements will reflect on various aspects of our device, including the core electronic hardware components, the power supply unit, the software package, the user interface module, the user manual, and its sustainability considerations. Access to this documentation will be provided to all members of **VisuAid**, and engineers are highly encouraged to refer to this documentation for during the implementation the **Now I See** travel aid.

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GLOSSARY

POC	Proof of Concept: a prototype device created to exhibit core functionalities of the **Now I See** travel aid
PM	Production Model: the final manufactured **Now I See** travel aid device
FOV	Field of View: may also refer to the artificial frontal view (since the user is visually impaired) in perspective of the user's face
UI	User Interface: unless otherwise specified, this refers to the forehead interface of the **Now I See** travel aid device
Requirement	A functional specification, a functional requirement, and/or a safety requirement that must be met for the corresponding device model
Test condition	A status or characteristic that can be verified through one or more tests; a requirement
Drop	Sudden drop in height that may cause the user to misstep; e.g. a pit or downward staircase
MTBF	Mean Time between Failures
CEHW	Core Electronic Hardware Component: refers to the following components of the **Now I See** travel aid device: depth camera, accelerometer, central processor, and micro processer
SWP	Software Package: refers to the software components of the **Now I See** travel aid device
PSU	Power Supply Unit: the module used for the **Now I See** travel aid device
Mount	Refers to device mount onto which some or all parts of the CEHW and PSU of the **Now I See** travel aid device are secured

1. INTRODUCTION

Now I See is a travel aid designed for the visually impaired to assist them towards a more independent lifestyle. **Now I See** scans and detects obstacles in the user's surroundings and alerts them through a vibratory user interface worn on the user's forehead. This document records the functional requirements of **Now I See** to serve as a comprehensive reference during creation of its proof-of-concept device (POC) and in its future development cycle.

1.1. Scope

This documentation prescribes the functional specifications and requirements that must be met by the **Now I See** travel aid. Each requirement or specification is prioritized according to functional and/or safety importance. The POC must meet all high priority requirements, while all of the high and medium priority requirements must be met for the production model (PM). Low priority requirements indicate future refinements of the device. The entirety of this list represents the current design of the **Now I See** travel aid.

1.2. Intended Audience

This documentation is intended for use by all members of **VisuAid**, and was created to serve as a reference in the development cycle of the **Now I See** travel aid. Development engineers should refer to this documentation for the implementation objectives, and testing engineers for test conditions.

1.3. Classification

In this documentation, the following convention is used to list each requirement and indicate its priority.

[R*n* - *p*] A requirement

The letter ***n*** is a number uniquely assigned to each requirement. The letter ***p*** denotes the priority of the requirement, which is classified as follows:

1 – High priority; must be met for POC and for PM

2 – Medium priority; must be met for PM

3 – Low priority; future refinements

2. SYSTEM REQUIREMENTS

2.1. System Overview

The system overview of **Now I See** travel aid is illustrated in the diagram below.

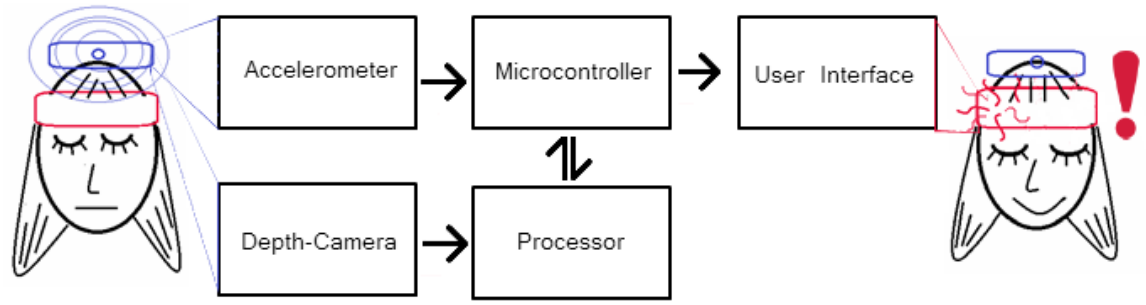

Figure 1: Now I See Travel Aid System Overview

The **Now I See** travel aid consists of a hardware device and software package. The hardware device consists of a number of electronic devices that can obtain information about the environment and a user interface module to communicate relevant aspects of the environment to the user. The software package includes image processing, decision making, and device control programs to handle data and produce suitable instructions to UI device.

The hardware device includes a depth camera, an accelerometer, a central processor, a microcontroller, a set of vibration motors, a power supply module, a wearable device mount and UI headband. The depth camera will provide the depth image of the frontal FOV, which will be examined in the processor, and appropriate alerts will be delivered to the user interface through the microcontroller. The whole device will be mounted on the user's head, including the power supply for mobility. The user interface consists of a 3x5 array of vibration motors that are implanted into a comfortable head band.

Based on the depth image and accelerometer data, the floor will be detected and the FOV will be corrected to the frontal plane (as opposed to a FOV in a declining angle). The corrected FOV is split into 15 subsections (3 horizontal, 5 vertical) and the presence of obstacles in each subsection is reported to the user at the corresponding location on the UI. Sudden drops or pits in the ground are also detected as obstacles.

2.2. General Requirements

[R1 - 1] The device must have nominal to no training time to use
[R2 - 2] The device must be aesthetically appealing or neutral
[R3 - 2] The build cost of device shall be less than $200.00 CAD
[R4 - 2] The device must be easy and simple to equip
[R5 - 2] The device must have a modular design and servicing must be possible by swapping parts
[R6 - 2] The device must be water resistant

2.3. Physical Requirements

[R7 - 1] The device must not have loose wires
[R8 - 1] The device must be balanced when equipped
[R9 - 1] The device must not be cumbersome to the user when equipped
[R10 - 2] The device must be reasonably comfortable when equipped
[R11 - 2] The device must be under 500g in total weight
[R12 - 3] The device must be under 200g in total weight
[R13 - 1] The assembly of the device must not fall apart due to the vibration and impact generated at human walking speed
[R14 - 2] The assembly of the device shall withstand impacts from collisions occurring at twice the human walking speed
[R15 - 3] The assembly of the device shall withstand a free fall from 2.0m

2.4. Electrical Requirements

[R16 - 1] The device must have and be powered from a local power source in a form of an electric battery
[R17 - 1] Said battery in [R16] must be rechargeable
[R18 - 2] Said battery in [R17] shall be chargeable using any conventional battery chargers with correct voltage and power ratings
[R19 - 2] Said voltage and power ratings in [R18] of said battery must be correctly calculated and clearly documented and displayed on the device
[R20 - 1] The device must include a recharge port for above mentioned battery in [R16]
[R21 - 2] Said recharge port in [R20] shall be in the form of conventional DC connector, commonly known as “coaxial power connector”

[R22 - 2] The device shall include a battery charger for said battery in [R16] that can be connected to said recharge port in [R20] to charge said battery

[R23 - 1] All electrical contact points must be concealed from physical interference, except above mentioned recharge point in [R20]

[R24 - 1] The device must have a power switch

[R25 - 2] Said power switch in [R24] must be reachable by the user when equipped

[R26 - 2] The device must include a protective electric fuse

[R27 - 2] The device must have a power rating no higher than 25W

[R28 - 3] The device must have a power rating no higher than 10W

2.5. Performance Requirements

[R29 - 1] The device must detect obstacles in the frontal proximity of the user

[R30 - 1] Said obstacles in [R29] must be identified and reported to the user if they are closer to the user than a predefined threshold distance

[R31 - 1] Said threshold in [R30] must be a value of at least 0.5m

[R32 - 2] The value of said threshold in [R30] shall be automatically adjusted depending on the rate of change in the displacement between the user and the obstacle

[R33 - 1] Said obstacles in [R29] must include sudden drops or pits in the ground

[R34 - 1] Said drops in [R33] must be identified and reported to the user if their magnitude is greater than a predefined threshold

[R35 - 1] Said threshold value in [R34] must be a value of at least 2cm

[R36 - 1] The device must be capable of refreshing the information about the obstacles at a rate of minimum 2 Hz

[R37 - 2] The device must be capable of refreshing the information about the obstacles at a rate of minimum 5 Hz

2.6. Standards and Safety Requirements

[R38 - 1] The device must be electrically insulated from the user

[R39 - 1] Contents of said battery in [R16] must be sealed

[R40 - 1] The device must not contain any moving parts except the vibration motors included in the UI module

[R41 - 2] The device must alert the user if the charge of said battery in [R16] is lower than 10 percent of the maximum

[R42 - 2] The device must automatically detect and alert the user if and when any malfunction is detected
[R43 - 2] The device must not create any electrical discharge or sparks
[R44 - 2] The device shall conform to IEC 61508 standards[1]
[R45 - 2] The device shall conform to CSA/UL 60950-1 standards[2]
[R46 - 2] The device shall conform to IEC 60601 standards[3]

2.7. Environmental Requirements

[R47 - 1] The device must be operable under normal indoor conditions with room temperature and humidity under 10%
[R48 - 2] The device shall be operable under ambient humidity between 10% and 60%
[R49 - 2] The device shall be operable outdoors
[R50 - 2] The device shall be operable at ambient temperatures between 0°C and 40°C
[R51 - 2] The device shall be operable at altitudes between 0m and 1000m above sea level

2.8. Reliability Requirements

[R52 - 2] The device shall be capable of minimum 4 continuous operational hours with a single full charge of said battery in [R16]
[R53 - 3] The device shall be capable of minimum 8 continuous operational hours with a single full charge of said battery in [R16]
[R54 - 2] The device must have a lifetime of minimum 5 years
[R55 - 2] The device must have an MTBF of minimum 20,000 hours

3. CORE ELECTRONIC HARDWARE REQUIREMENTS

Core Electronic Hardware (CEHW) for **Now I See** includes a depth camera, an accelerometer, a central processor, and a microcontroller. These components provide raw data for the system to work on and the hardware platform to execute its high level functions. The depth camera provides the view of surrounding, the accelerometer will be used to resolve the orientation of the camera and, therefore, that of the user's FOV, and the processor and the microcontroller process data and control UI hardware.

3.1. General Requirements

[R56 - 2] The combined cost of all CEHW must be less than $100.00 CAD
[R57 - 3] The combined cost of all CEHW must be less than $50.00 CAD

3.2. Electrical Requirements

[R58 - 1] All CEHW must operate at a voltage value of either 3.3V, 5V, or 12V
[R59 - 1] Each of CEHW must have a power rating less than 15W
[R60 - 2] Each of CEHW must have a power rating less than 10W
[R61 - 2] The combined power rating of all CEHW must be less than 25W
[R62 - 3] The combined power rating of all CEHW must be less than 10W

3.3. Physical Requirements

[R63 - 1] The depth camera and the accelerometer must be mounted on the user's head using a mounting apparatus
[R64 - 1] Said accelerometer in [R63] must be installed on said depth camera
[R65 - 2] All CEHW shall be mounted on the user's head using a mounting apparatus
[R66 - 2] All CEHW components except the depth camera must not exceed 10cm * 10cm * 5cm in size
[R67 - 2] The depth camera must not exceed 10cm * 5cm * 5cm in size
[R68 - 3] The depth camera must not exceed 7.5cm * 2.5cm * 2.5cm in size

3.4. Performance Requirements

[R69 - 1] The depth camera must meet or exceed the performance characteristics of the Microsoft Kinect sensor[4]
[R70 - 1] The accelerometer must have detection at minimum 2 axes
[R71 - 1] Said accelerometer in [R70] must have a measurement resolution of minimum 8 bits or its analog equivalent
[R72 - 1] Said accelerometer in [R70] shall have a detection range of ± 2g
[R73 - 1] The central processor must meet or exceed the performance characteristics of the Raspberry Pi model B[5]
[R74 - 1] The microprocessor must meet or exceed the performance characteristic of the Arduino Uno[6]

3.5. Standards and Safety Requirements

[R75 - 2] The depth camera must conform to IEC 60825[7]

4. DEVICE MOUNT AND USER INTERFACE REQUIREMENTS

The main advantage of **Now I See** comes from the fact that it moves with the user's head. To achieve this, a device mount is necessary to secure, most importantly, the depth camera and other components. The user interface module includes vibration motors and an apparatus that holds them in place and pushes the motors onto the skin of the user to improve perception.

4.1. General Requirements

[R76 - 1] The device mount must have a means to be secured to the user's head
[R77 - 1] The user interface module must be able to be secured to the user's forehead

4.2. Electrical Requirements

[R78 - 2] The UI module must electrically insulate the CEHW and PSU from the user
[R79 - 1] The vibration motors must be operable at 5V or less
[R80 - 2] The vibration motors must have a power rating less than 1W each

4.3. Physical Requirements

[R81 - 2] The UI module must be able to absorb moisture of a reasonable amount
[R82 - 1] The UI module shall apply a small amount of pressure on the vibration motors towards the forehead of the user
[R83 - 3] The mount shall resemble a pair of sunglasses and include all CEHW and PSU
[R84 - 1] The motors in UI module must form an array with a minimum size of 3 rows and 3 columns
[R85 - 2] Said array of motors in [R84] must be of 3 rows and 5 columns in size
[R86 - 2] Said motors in [R84] must be maintain their functional positions
[R87 - 2] Said motors in [R84] must be detachable from the holding apparatus
[R88 - 2] When detached, said motors in [R84] must maintain their positions
[R89 - 3] When detached, the holding apparatus must be machine washable

[R90 - 3] The mount shall house all of CEHW and PSU
[R91 - 3] Said mount in [R90] is water resistant

4.4. Performance Requirements

[R92 - 1] In said secure method of [R76], the user must be able to tilt his/her head at 30° angle from the vertical axis in any given direction without mount failure
[R93 - 2] In said secure method of [R76], the user must be able to tilt his/her head at 60° angle from the vertical axis in any given direction without mount failure
[R94 - 1] In said secure method of [R77], the user must be remain on at angle
[R95 - 1] Vibration alerts of different motors must be distinguishable from each other
[R96 - 1] Vibration alert of a motor must represent an obstacle in the corresponding location in the FOV
[R97 - 2] The alert for a fall shall be different from that of a regular obstacle

4.5. Safety Requirements

[R98 - 1] The mount must not inflict any physical harm to the user
[R99 - 1] The mount shall no inflict any psychological harm to the user

4.6. Usability Requirements

[R100 - 2] The mount must be reasonably comfortable
[R101 - 3] The mount shall be as comfortable to wear as a pair of sunglasses
[R102 - 2] The UI module must be reasonable comfortable

5. POWER SUPPLY REQUIREMENTS

The power supply unit (PSU) of **Now I See** holds the battery which serves as the main power source for all parts and voltage regulating circuitry to create required voltages for certain electronic components.

5.1. General Requirements

[R103 - 2] The battery of PSU must be easily replaceable

5.2. Electrical Requirements

[R104 - 1] The PSU must include said battery in [R16]
[R105 - 1] The PSU must include said fuse in [R26]
[R106 - 1] The PSU must have a voltage regulating circuitry
[R107 - 1] The PSU must have a voltage dividing circuitry to provide all required voltages by different electronic components of device

5.3. Physical Requirements

[R108 - 2] The power fuse of the PSU must be reasonably easy to access and replace
[R109 - 2] The battery of the PSU must be reasonably easy to access and replace
[R110 - 2] The PSU must include a separate power switch

5.4. Performance Requirements

[R111 - 1] The battery must be powerful enough to power all components of the device
[R112 - 2] The battery must be powerful enough to satisfy requirements listed in [R52]
[R113 - 3] The battery must be powerful enough to satisfy requirements listed in [R53]

5.5. Standard and Safety Requirements

[R114 - 2] The PSU must be physically concealed and only accessible during servicing except for said battery in [R108] and said power fuse in [R109]
[R115 - 2] The PSU must conform to IEC 61558 standards[8]

6. SOFTWARE REQUIREMENTS

The Software Package (SWP) of **Now I See** includes the image processing and decision making algorithms to be used in the central processor and the control software for the microcontroller.

6.1. General Requirements

[R116 - 2] The SWP shall not be accessible to the user
[R117 - 1] The components of SWP must be modular and easily upgradeable

6.2. Functional Requirements

[R118 - 1] The SWP must continuously, at a reasonable rate, receive depth image data from the depth camera in a reasonable data structure

[R119 - 1] The SWP must continuously, at a reasonable rate, retrieve acceleration data from the accelerometer and resolve the orientation of the depth camera

[R120 - 1] The SWP must be able to automatically detect the relative location of the ground based on said data in [R118] and [R119]

[R121 - 1] The SWP must be able to continuously, at a reasonable rate, examine the visible portion of user's proximities for obstacles and report them if said threshold in [R30] is reached

[R122 - 2] Said reasonable rate in [R121] must be no lower than 5 Hz

[R123 - 3] Said reasonable rate in [R121] must be no lower than 10 Hz

6.3. Standard and Safety Requirements

[R124 - 2] The SWP must conform to ISO/IEC 15288[9] and IEEE 12207[10] standards

[R125 - 2] The components of SWP must include fault detection methods, alert the user when faults are detected, and disable the device if the fault is critical

[R126 - 2] The SWP must automatically recalibrate upon every power-up

[R127 - 2] The SWP must include a security feature that checks the integrity of SWP upon every power-up

7. USER MANUAL REQUIREMENTS

A user manual will be included in the product package for PMs, which would be used to provide information of various aspects of the **Now I See** travel aid device, including warranty information.

7.1. General Requirements

[R128 - 2] The user manual must include warranty information

[R129 - 2] The user manual must include an introduction and a quick start guide

[R130 - 2] The user manual must explain the features of the device

[R131 - 2] The user manual must include trouble shooting guide and contact information

7.2. Usability Requirements

[R132 - 2] The user manual must include an audio version in an audio CD format
[R133 - 2] The user manual must include instructions in braille

8. SUSTAINABLITY CONSIDERATIONS

The sustainability of **Now I See** and environmental protection during its life cycle are important issues that **VisuAid** must address. Sustainability issues arise in the creation of the POC, the PM design and the usage of the battery. While a large part of the issues for the production model will be addressed in the design phase and in its corresponding documentation, some elements are addressed in this portion of current documentation.

All development engineers and designers of **VisuAid** must consider the aspects discussed in this section, perform all due diligence, and meet all requirements when applicable. The following requirements must be also met for production models.

[R134 - 2] The device must clearly label recycling information for all components where applicable
[R135 - 2] The device must clearly indicate the battery disposal information
[R136 - 2] The device must not contain any toxic chemicals

8.1. Proof of Concept Device

For the POC, many of the parts will be from previously used devices. As the POC will not require a high production quality, it was sensible to utilize used parts as much as possible, and it was also favourable in terms of the budget.

The depth camera is a used Microsoft Kinect sensor. While a unit was available to use from the ESSS parts library, it was deemed necessary to physically modify the device to achieve certain aspects of the device, so a used unit was purchased. Its functionality will not be disturbed with this modification, and will be available for reuse.

The central processor is a Raspberry PI board. This part will not be modified and will be available for other projects.

The microcontroller is a used Arduino Uno board. This unit was available from one of the members of **VisuAid**. It also will be unmodified and available for other projects.

The accelerometer is a breakout board unit which can easily be reused.

The device mount is an old bike helmet that will be slightly modified for the use of this project but will be recovered for future use.

The battery is a 12V rechargeable gel battery, which can be used for many other projects. The charger that was purchase for this battery will also be useful in the future.

The vibration motors used in the UI were purchased for this project and will be sewn onto a head band. Though the head band will no longer be usable, the motors could be salvaged for future use.

All other components involved in this project had to be purchased new and will unfortunately be significantly modified beyond salvaging. These include the electronic components that will be soldered onto a prototype board.

8.2. Production Model

In the production model, as many components as possible shall be modular and able to be swapped for servicing and upgrade. This is important to minimize waste and allow the future designs to utilize the older components as much as possible. The use of recycled and recyclable material is quite important and must be addressed in the design phase. During the development and design phases, **VisuAid** engineers must consider possible future upgrades and aim for a continuous improvement of the **Now I See** travel aid.

8.3. Battery

One of most environmentally concerning aspects of the **Now I See** travel aid is indeed the use of a battery as the power source. Unfortunately, the use of a battery or a portable power source is inevitable due to the nature of the **Now I See** travel aid. Main hardware components such as the depth camera demand high power, and heavy image processing required to handle the data from the depth camera can also consume a large amount of energy. With this in mind, usage of a rechargeable battery in **Now I See** travel aid is critical. While utilization of rechargeable batteries does reduce the environmental impact

in comparison to the disposable ones, they also have a limited life time and must be disposed of at some point. In selection of rechargeable battery type, **VisuAid** engineers must carefully examine and make a sustainable decision.

9. CONCLUSION

The functional specifications and requirements established in this documentation define the current design of the **Now I See** travel aid. Each requirement is prioritized based on its level of functional and/or safety importance in the system and our device will reflect these details at each developmental phase. With the completion of each phase and its corresponding requirements, our device will evolve from a proof-of-concept device, to a marketable production model, and to a refined final product. The development of the proof-of-concept device is well on the way, and we expect its successful completion by early April, 2014.

REFERNECES

[1] International Electrotechnical Commission. *IEC 61508 - Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems*

[2] Canadian Standards Association/ Underwriters Laboratories. *CAN/CSA-C22.2 No. 60950 (UL 60950-1) - Information Technology Equipment -- Safety*

[3] International Electrotechnical Commission. *IEC 60601 - Medical Electrical Equipment*

[4] Microsoft Kinect for Xbox 360. http://msdn.microsoft.com/en-us/library/jj131033.aspx

[5] Raspberry PI http://www.raspberrypi.org/

[6] Arduino UNO http://arduino.cc/

[7] International Electrotechnical Commission. *IEC 60825 - Safety of Laser Products*

[8] International Electrotechnical Commission. *IEC 61558 - Safety of Power Transformers, Power Supplies, Reactors and Similar Products*

[9] ISO/ International Electrotechnical Commission. *ISO/IEC 15288 – systems and Software Engineering – System Life Cycle Processes*

[10] Institute of Electrical and Electronics Engineers. *IEEE 12207 – Standard for Information Technology – Software Life Cycle processes*