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October 19, 2000

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
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Re: ENSC340 Project *Drying-Machine Auto-Stop Upgrade* Functional Specifications

Dear Dr. Rawicz:

The attached document, *Drying-Machine Auto-Stop Upgrade Functional Specification,* outlines the requirements of our ENSC340 Project. Our goal is to design and implement a device that allows consumers to save time, conserve energy and prolong fabric lifetime with their use of drying machines.

This document highlights the desired functionality of the entire system, and the specifications of the various components within the system. The functional components include the sensors, actuators, a user-defined control unit and an user interface subsystem.

EaStar Group consists of five motivated, innovative and talented fourth-year engineering students – Edward Chen, Jeffrey Chien, Eric Jen, Steven Liao, and Chris Lo. If you have any questions or concerns about this document, please feel free to contact us by phone at (604) 961-6028 or by e-mail at *ensc340-jesec@sfu.ca*.

Sincerely,

EaStar Group

Enclosure: Drying-Machine Auto-Stop Upgrade Functional Specifications

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EXECUTIVE SUMMARY

Have you ever opened your laundry dryer and found your clothes still wet and soggy? Or even worse, have you found your cloths damaged as a result of over-drying? In most circumstances, the answer to both questions is a loud "YES".

Recent advancement in technology has enabled companies like Whirlpool and Maytag to incorporate the automatic-stop functionality into their new-generation dryers. However, this technology is fairly recent and expensive. Because an average dryer has a life span of thirteen years and this technology was first introduced to the public in 1996, dryers in most households still do not have the automatic-stop function.

Our goal is to design and implement a device that will incorporate the moisture-detection automatic-stop function onto existing dryers. This device will provide consumers with an inexpensive and convenient mean of optimizing their current machine and at the same time, help protect fragile fabrics from arid conditions.

In designing and delivering this product, EaStar Group is committed to provide consumers with a convenient and inexpensive method to dry their laundry. Gone are the days of guessing when the load will be dry. EaStar Group's *Drying-Machine Auto-Stop Upgrade* is aimed to bridge the gap between older and next-generation dryers.

This document introduces the various functional components of the *Drying-Machine Auto-Stop Upgrade*, and outlines the different system requirements, evaluation methods and operational functions of the product. Systems limitations and future improvements are also discussed.

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1.INTRODUCTION

Consumers have various options when trying to determine the exact time needed to dry their clothes. They could use the wait-and-see approach and stay in the laundry room and check periodically if the load is dry. Alternatively, they could choose to over-set their dryers, making sure that the load will definitely be dry. However, both methods have their drawbacks. The wait-and-see approach will cost a consumer's valuable time and effort that could otherwise be spent on other tasks. And by over-setting the dryer, electrical power is wasted and fragile fabrics can be damaged. Many will agree that the most convenient method is a smart dryer that will sense the moisture within the dryer and stop automatically when the load inside has reached a preset moisture level.

The *Moisture-Detect Add-on Module* is a user-defined add-on device that monitors the moisture level within the dryer. The device constantly detects the moisture level with its temperature and humidity sensor. When a user-preset level has been reached, the control unit will pop open the door through the actuator, thus bring the dryer to a stop.

The purpose of this document is to describe the functional requirements of the *Drying-Machine Auto-Stop Upgrade*, and to resolve EaStar Group's December 2000 deliverables. The intended audience of this document is Dr. Andrew Rawicz, Mr. Steve Whitmore, the design engineers of EaStar Group, and various external third party design consultants.

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2.SYSTEM OVERVIEW

2.1 Overall Functionality

The *Drying Machine Auto-Stop Upgrade* module consists of four major subsystems, including **Actuators**, **Sensors**, **User Interface**, and **Control Unit**. This module is designed to be compatible with any type of dryer, regardless of the dryer operating voltage (110V or 220V), the physical size of the dryer, and the dryer model. However, one required functionality for dryer using the *Drying Machine Auto-Stop Upgrade* module is the capability to stop when dryer door is opened.

When in operation, the Sensors subsystem will constantly monitor the relative humidity and temperature inside the dryer drum. When the moisture level inside the dryer has reached the desired level set by the user, actuators will be activated to open the dryer door and this action will cause the dryer to stop.

The Actuators, User Interface, and Control Unit subsystems will be installed on the exterior of the dryer, whereas the Sensors will be placed on the inside of the dryer door. Overall, the installation of the *Drying Machine Auto-Stop Upgrade* module will be simple and easy.

Figure_1 below shows the correlation of the four major subsystems.

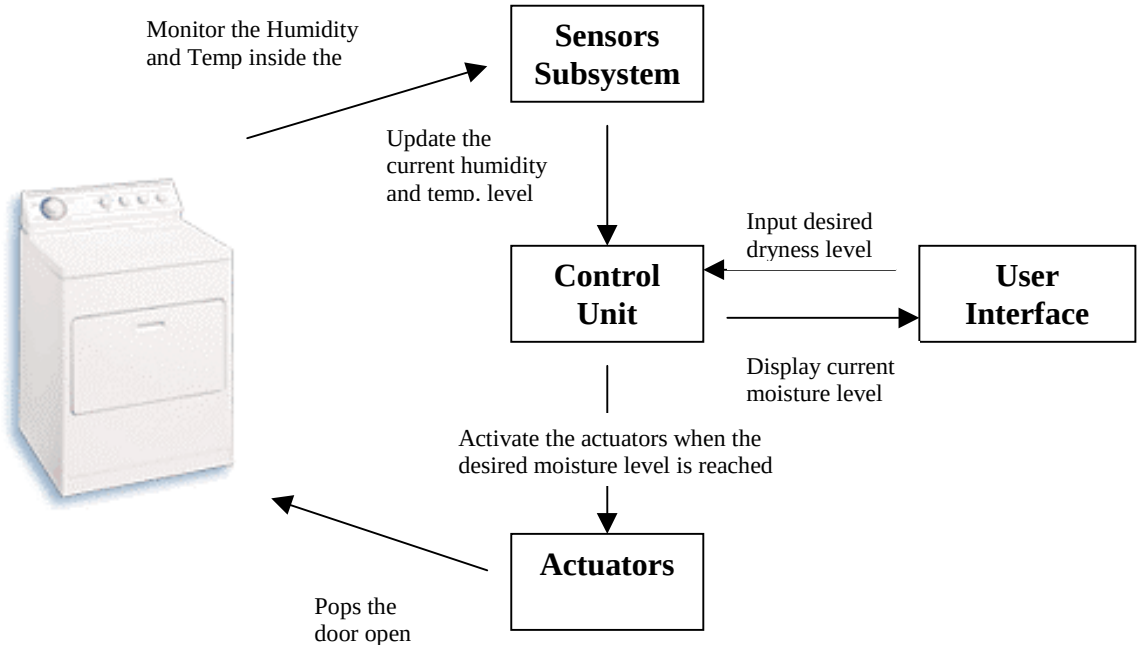

Fig_1: Correlation among Subsystems

The prototype module will demonstrate the following features:

- **Ability to detect the temperature and moisture level inside the dryer drum**
- **Ability to process the input from the user along with the current sensor status, and make a decision of whether the dryer should be stopped**
- **Ability to display the current moisture level inside the dryer drum**
- **Ability to stop the dryer when the desired dryness level is reached**
- **Ability to restore the original configuration of the module once the dryer is stopped**

The following figure shows the correlation between the three different modes of the module.

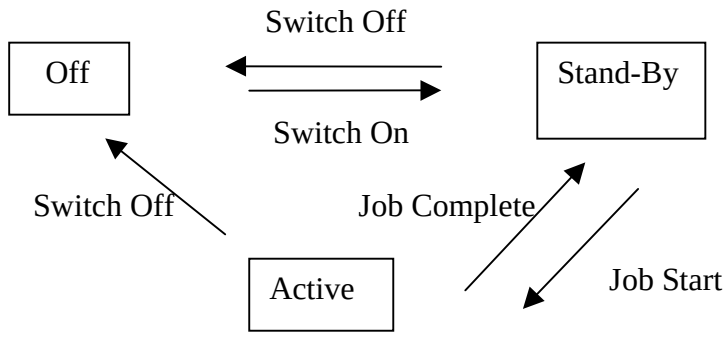

Fig_2: Correlation among basic operation modes

2.2 Actuator Subsystem

The purpose of this subsystem is to open the dryer door automatically when the desired dryness for the clothes has been reached. The Actuators are activated according to the commands sent from the Control Unit, and shall remain in the Stand-by State until such commands have arrived. Upon activation, the Actuators will open the dryer door and thus cause the dryer to stop. Once the dryer door pops open, the Actuator subsystem will return to its original stand-by mode.

2.3 Sensor Subsystem

The Sensor System consists of a relative humidity (RH) sensor, a temperature sensor, and a signal-processing module. The temperature and relative humidity data taken from the RH sensor and the temperature sensor are sent to the signal-processing module. The signal-processing module processes this information to a form that's

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appropriate for the control unit, and sends the processed relative humidity and temperature information to the control unit.

2.4 User-Interface Subsystem

The User Interface subsystem allows the user to select the preferred dryness level for clothes. This user input is sent to and processed by the Control Unit. Moreover, the User Interface subsystem provides feedback by displaying the current moisture level, or rather the relative dryness of the clothes. This subsystem will display 3 operations for *Drying-Machine Auto-Stop Upgrade*: On mode, Standby mode, and Off mode.

2.5 Control-Unit Subsystem

The Control Unit activates the Actuator Subsystem based on the relative humidity and temperature information given by the Sensor Subsystem and the desired moisture level information given by the User-Interface Subsystem. Since the determination of the relative humidity depends on the temperature at the same point of time, the Control Unit needs information from both the humidity sensor and the temperature sensor in order to calculate the correct relative humidity. This normalized relative humidity is then compared with the desired moisture level to determine whether the Control Unit Subsystem activates the Actuator Subsystem. If the normalized relative humidity matches with the desired moisture level, the Control Unit activates the Actuator Subsystem.

The flow chart shown on the next page outlines the overall flow of the Control-Unit Subsystem.

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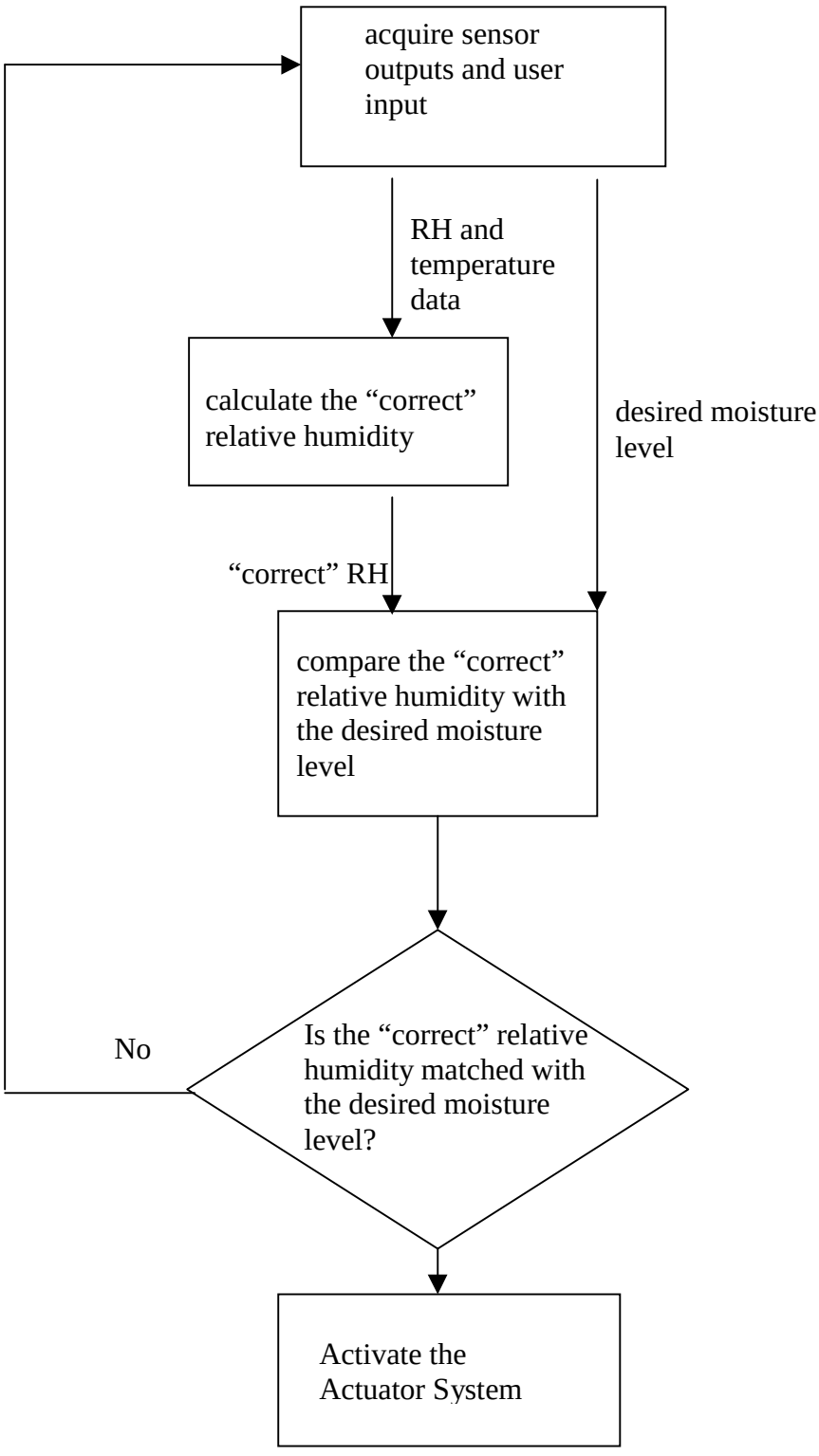

Fig_3 Flow chart representation of Control-Unit Subsystem

3.SYSTEM REQUIREMENTS

The following sections outline the physical, environmental, electrical, safety, reliability, compatibility, cost, and user training requirements for the *Dryer Auto-Stop Upgrade* module.

3.1 Physical Requirements

The Control-Unit, Sensor, Actuator Subsystems of the *Dryer Auto-Stop Upgrade* module will be enclosed in three separate rigid casings. The casings for all units will be firmly sealed to prevent damage from water leakage. The Control-Unit subsystem is to be attached to the top of the dryer so its size will be small enough to fit on most dryers. In order to pose minimal disturbance to the user, the weight of the Sensor and Actuator Subsystem will be kept to a minimum; since it will be hanging on the dryer door. These casings will conform to the specifications listed in Table_1 below.

Table_1: *Dryer Auto-Stop Upgrade* Module Physical Requirements

	Control Subsystem	Actuator Subsystem	Sensor Subsystem
Length:	30 cm max.	15 cm max.	15 cm max.
Width:	20 cm max.	10 cm max.	10 cm max.
Height:	10 cm max.	8 cm max.	5 cm max.
Weight:	1.5 kg max.	1 kg max.	0.5 kg max.

3.2 Environmental Requirements

Table_2 below specifies the range of environmental conditions that the *Dryer Auto-Stop Upgrade* module will conform to. Since the sensors of the Sensor Subsystem will be placed on the inner side of the dryer door, extended operating temperature range is required.

Table_2: *Dryer Auto-Stop Upgrade* module Physical Requirements

Operating Temperature Range:	-20^{o}C to +70^{o}C (excluding Sensor Unit)
	-20^{o}C to +110^{o}C (Sensor Unit)
Shipping Temperature Range:	-30^{o}C to +85^{o}C
Operating Humidity Range:	Full range of ATM humidity
Vibration Resistance:	Withstand a minimum vibration of 1 in. displacement, 10 cycles per second
Heat Dissipation:	Minimal

3.3 Electrical Requirements

The *Dryer Auto-Stop Upgrade* module will meet the electrical requirements listed in Table_3.

Table_3: *Dryer Auto-Stop Upgrade* module Physical Requirements

Supply Voltage:	120V AC standard wall socket
Power Consumption:	20 watts maximum

3.4 Safety Requirements

The Dryer Auto-Stop Upgrade will meet the following safety requirements.

Enclosure
The enclosure will not possess sharp corners or edges that would pose a danger to the user. The enclosure will not contain protrusions or odd extensions of any form.

Electrical Isolation
The exterior casings of the module will ensure electrical isolation from the internal circuitry. All subsystems will be shielded and protected from external static.

Emission
The *Dryer Auto-Stop Upgrade* will not emit any harmful electromagnetic radiation. Possible electromagnetic radiation from dryer and washer will not affect the operation of the Dryer Auto-Stop Upgrade.

Fire
All material contained in the module will not be flammable to at least 150°C.

3.5 Reliability Requirements

The *Dryer Auto-Stop Upgrade* will meet the following reliability requirements.

Accuracy
Moisture detection will be 5% within the actual value. The module response will be 99%, meaning that the module will perform an undesired operation only 1 out of 100 times.

Durability
The Dryer Auto-Stop Upgrade will have at least a lifetime of 5 years. The module will withstand ongoing vibrations and heat from a drying machine and being dropped from a height of 2 meters.

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3.6 Standards

The Dryer Auto-Stop Upgrade will comply with UL, CSA, and CE standards.

3.7 User-Training

The user will be required to perform a simple installation of the module. The operation of the module is automatic unless the user wishes to alter desired moisture setting. For this purpose, a simple manual will be written in order to outline instructions for installations, system functionalities, and operational procedures. This manual will be included in each product package as well as on the World Wide Web.

3.8 Compatibility

The *Dryer Auto-Stop Upgrade* module is designed to be compatible to major types of household dryers. Both compact and full-size dryers are supported.

3.9 Cost

The cost of manufacturing the *Dryer Auto-Stop Upgrade* module will be kept below 10% of the price of a new household dryer which has the Auto-Stop functionality build-in. This limit is set to ensure that our product has sufficient marketability. On average the 10% limit places us with a manufacturing cost below $50.

3.10 Potential System Limitations

The Dryer Auto-Stop Upgrade may be limited by the following factors:

- The input moisture level is for reference only, therefore, user discretion is advised.
- The system is designed for clothes dryer only, not to be used with other devices,
- The system is not designed to sustain heavy weight.

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4.SYSTEM EVALUATION

This section outlines the criteria and possible test methods for evaluating the *Dryer Auto-Stop Upgrade* module. The purpose of the system evaluation is to verify that the module meets the specification listed in Section_4.

4.1 Evaluation Criteria

The complete module will be tested against the following criteria.

Operating Temperature:
The system will be verified to be fully functional under extreme temperature environment. The testing temperature range is specified in the previous section.

Operating Humidity:
Since the sensor unit will be placed inside the dryer drum, it is necessary to verify that the system is fully functional under full ATM humidity range inside the dryer drum.

Vibration:
In order to ensure the high durability, the complete system will be tested under vibrations. A drop test will also be performed.

Accuracy:
The accuracy of moisture detection will be within 5% of the true value.

Reliability:
The system will have a minimum lifetime of 5 years. Reliability of the system will be proven by a stress test.

User Interface and Installation:
The user interface of the system will be verified for clarity and usability. The installation process and instructions will be verified to be clear and easy to follow.

4.2 Test Method

Operating Temperature:
To achieve the lower limit of the specified operating temperature range, the sensor unit, actuator unit, and control unit prototypes will be cooled down to the specified lowest operating temperature by applying cooling spray directly on the sensors, the actuator, and the control unit prototype board. Likewise, the upper limit of the specified operating temperature range will be achieved by heating up the system to the specified highest operating temperature using a hair dryer. The

system is then tested for full functionality under these two extreme environment conditions.

Operating Humidity:
The system is tested against its full functionality when the humidity level inside the drum varies from the lowest to the highest achievable value. The lowest humidity limit will be achieved by running the dryer with no load and the highest humidity limit will be achieved by running the dryer fully loaded with completely wet fabricates.

Accuracy:
The accuracy of moisture detection will be tested in two stages: the subsystem testing stage and the module testing stage. When testing the each subsystem, 10 target moisture values will be used. These values will be widely spread over the range of possible user input moisture levels. With a drying machine and a calibrated moisture detector, desired controlled moisture environment will be created for testing. Ten trials are run for each controlled value and the module has to be within 5% accuracy for nine trials in each value. When testing the completed module, ten trials should be run for all possible input moisture level values provided on the control panel. In each trial, the test will be a simulation of the true operation of the finished product. When the system stops the dryer, the moisture inside must be within 5% of the user-input value.

Reliability:
The reliability of the module is verified by a stress test. The stress test will mainly be continuous operation of the module with extra heat and vibration simulated in the test. This test may be combined with the accuracy test.

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5.CONCLUSION

This document has discussed the functional considerations of building an operational prototype for an add-on device to existing laundry dryers The *Drying-Machine Auto-Stop Upgrade* will be designed based on the functional specifications described in this document.

This device will not only provide consumers with an inexpensive and convenient way to dry their clothes, but also save on their electrical bills and the environment.

In designing and delivering this product, EaStar Group is bridging the gap between older and next-generation dryers. Gone are the days of guessing when the laundry will be dry. By constantly monitoring the status inside the dryer, temperature and moisture information is fed back into the controller, which will stop the dryer when the pre-set moisture level has been reached.