

## 2. Design Constraints

The goal of this project is to design and implement an autonomous robot to compete in the 2006 SECon hardware competition. The rules provided by the competition dictate a variety of restrictions and necessary capabilities of the robot. Complying with these constraints will give the robot an optimal chance of completing the task successfully each round.

### 2.1 Technical Design Constraints

There are several constraints for the robot design that were developed from the SECon competition rules and other technical requirements of the robot. These technical design constraints are listed below in Table 2.1.

**Table 2.1 – Technical Design Constraints**

Name	Description
Dimensions	The robot must be able to store all twelve packages along with its internal mechanisms within a starting size of 7.75" x 7.75" x 11.875."
Navigation	The robot must efficiently navigate the board.
Speed	The robot must travel at a minimum speed of 1.1 inches per second.
Package Identification and Manipulation	The robot must be able to correctly identify and transport each of the 12 packages to their corresponding destination.
Weight	The robot must weigh less than 20 lbs with all packages on board.
Power	The robot needs a power system capable of supplying 30W of power during a 5-minute time interval.

#### 2.1.1 Dimensions

Compliance with mandated size requirements will be verified at the competition by placing a hollow box over the robot. Because the box may be slightly warped and the robot may be damaged if the box scrapes against its side, a buffer zone of 1/8" will be left around all outer surfaces. This reduces the starting size requirements to 7.75" wide by 7.75" long by 11.875" high.

While SECon rules allow the robot to expand to 14" wide by 14" long by 20" high, the design will not employ any expansion past the starting size requirements except that required by the mechanism to retrieve packages from the vertical chute [1]. Eliminating extra expansion reduces overall complexity and saves time that would be needed for initial unfolding and retraction at the end of the round when the robot must return to its starting size.

#### 2.1.2 Navigation

Determining an efficient and effective route to traverse the playing field is a vital design issue. During the competition, the robot will be required to leave the starting square and travel to four preset destinations to accomplish the given task. To be competitive, the robot will need to travel the shortest and quickest routes possible. To accomplish this, the robot must have an accurate navigation system which places the robot within a quarter inch of its desired position. The robot will also use sensors to verify its position throughout the competition and detect obstacles as near as half an inch away and as far as two feet away. These measures ensure that the robot avoids collisions with objects on the playing field and positions itself effectively for the loading and unloading of packages.

### **2.1.3 Speed**

The speed the robot can travel at is as important, if not more so, than the route the robot takes. The robot must travel a total distance of 5.5 feet as it drives from the starting square to the package chute and then from the package chute to the first plane. Designating a maximum of two minutes (10 seconds per package) for loading and sorting leaves only 60 seconds for the robot to travel this distance if it is to stay within the 3-minute time restriction for the first delivery. In order to go 5.5 feet in 60 seconds, the robot must travel at an average speed of 1.1 inches per second.

### **2.1.4 Package Identification and Manipulation**

The robot must be able to correctly identify each package by scanning a Codabar-formatted barcode. After scanning, each package will be stored in one of three partitions on the robot. Storing all packages on the robot before delivery will decrease the time required to complete the task since only one trip will be made to deliver all packages to each plane.

After loading all 12 packages, the robot must travel to each of the three planes and deposit the corresponding packages before the plane leaves. The average speed of 1.1 inches per second derived in Section 2.1.3 is sufficient to carry out this task as long as the loading process lasts a maximum of 10 seconds per package.

### **2.1.5 Weight**

There is no weight requirement stipulated by the SECon competition rules; however, the weight of the robot has important repercussions for other design elements. A heavier robot will require larger stepper motors with higher torque ratings for locomotion. More powerful motors will also draw more current and require more batteries, which take up more space on the robot and add additional weight themselves. To avoid adding large, heavy components to compensate for weight, the robot is designed to weigh no more than 20 lbs when fully loaded. This weight limit allows moderately sized (2" x 2" x 2") stepper motors to propel the robot at the speeds discussed in Section 2.1.3.

### **2.1.6 Power**

The robot will operate many stepper motors and servos to achieve the motions needed to load packages, maneuver around the playing field, and unload packages. The robot power source must be able to supply all these motors in addition to the onboard barcode scanner, sensors, microcontroller, and other control circuitry that will be required to carry out the task. All of these devices can be run with a 5V supply, but a supply voltage of 6V will produce better performance for some stepper motors and servos. Because of this, the robot power supply will be required to provide both 5V and 6V.

The power consumption of the robot will be set at a maximum of 30W. This allows sensors, locomotion stepper motors, and microcontroller circuitry to run continuously at the same time while the robot is driving around the playing field. The 30W allowance can also be distributed to run a barcode scanner, a microcontroller, and several servos or linear motion stepper motors, which would all be needed while loading and unloading packages. The maximum power allotted to each type of device during both phases of operation is broken down in Table 2.2.

**Table 2.2 – Maximum Power Allotments**

Device	Voltage	While Driving		While Loading/Unloading	
		Current Draw	Power	Current Draw	Power
Stepper Motors (Wheels)	6V	3.5A	21W	-	-
Barcode Scanner	5V	-	-	.2A	1W
Microcontroller and Control ICs	5V	1A	5W	1A	5W
Sensors	5V	.2A	1W	-	-
Servos and Stepper Motors (Linear Motion)	6V	-	-	3.5A	21W
		<b>Total</b>	27W	<b>Total</b>	27W

SECon rules require the robot to be completely autonomous, so all power must come from onboard batteries. These batteries must be able to provide the required 30W of power for at least 5 minutes, the maximum length of each round of the competition.

## 2.2 Practical Constraints

Some design constraints are derived not from SECon rules, but from practicality. These practical design constraints are listed below in Table 2.3.

**Table 2.3 – Practical Design Constraints**

Type	Name	Description
Economical	Cost	Costs for the robot will remain reasonable in relation to the associated benefit the cost represents.
Health and Safety	Safety	The robot will not harm spectators, packages, planes, or the playing field.
Ethical	Playing Rules	The robot will comply with all rules and regulations as posted by the competition committee.
Sustainability	Reliability	The robot will be able to complete the task successfully multiple times.
	Repeatability	The robot will be designed with a modular approach to ease testing and repair.
Environmental	Pollution	The robot will use rechargeable batteries that do not contain cadmium.

### 2.2.1 Cost

All parts chosen for the robot will be practical and economical. Parts will be justified by a balance of cost and performance. Also, the team will refrain from using discontinued or out of production parts wherever possible, as they tend to be more expensive and harder to obtain in large amounts.

### 2.2.2 Health and Safety

To prevent harm to team members, competition spectators, and officials no toxic chemicals or combustible materials will be used in the robot design. Also, the robot will not launch any kind of projectile that could injure people standing nearby.

### **2.2.3 Ethical**

The robot will obey all rules established by the SECon 2006 hardware competition committee. Because competitors' robots are not present on the playing field during rounds of the competition, the robot will not interfere with their operation in any way. Also, the robot will not damage, deform, or mark the playing field or packages during its run.

### **2.2.4 Reliability and Repeatability**

To guarantee the reliability of the robot, it must be able to complete the task in several consecutive runs. This will allow the robot to complete several practice rounds and all competition rounds free of error. If the robot can reliably complete the task, then victory will be determined by efficiency.

To increase repeatability, the robot will utilize a modular design. This allows each module to be thoroughly tested and proven before its addition to the robot. Having a robot composed of modules also speeds repair. Should a part fail, the entire module can be replaced without the need to trace the exact source of the problem through complicated debugging. Likewise, the microcontroller code will be constructed with a modular approach to allow each portion to be debugged individually. While a modular design does not always yield the most efficient code, it will generate the most reliable programming. Furthermore, with the speed of current microprocessors, any extra processing time due to the modular nature of the code will be negligible.

### **2.2.5 Environmental**

Some types of rechargeable batteries, particularly those containing cadmium and other heavy metals, are a source of environmental pollution when disposed of improperly. The EPA warns that such batteries "can cause serious harm to human health and the environment if they are discarded with ordinary household or workplace waste" [2]. To avoid the possibility of releasing such toxic chemicals into the environment, the robot design will employ only disposable Nickel Metal-Hydrate (NiMH) batteries, which do not produce any hazardous waste [3].

**References:**

- [1] "SoutheastCon 2006 Hardware Competition Description," SECon Hardware Competition Rules, 28 August 2005. [Online]. Available: <http://ewh.ieee.org/reg/3/secon/06/hardwarerules080805.PDF>
- [2] V. Bueno, "The 'Battery Act'," March 2002, (Vol 5 Num 2). [Online]. Available: <http://www.rbrc.org/graphics/PDF/BatteryAlert.pdf>
- [3] "Disposal of Energizer Nickel Metal Hydride Batteries," January 2002. [Online]. Available: [http://data.energizer.com/PDFs/NiMH\\_disp.pdf](http://data.energizer.com/PDFs/NiMH_disp.pdf)