

To: Prof. Chang, Prof. Lasser
From: Mark Robinton, Brandon Balkind
Subject: Senior Project Proposal
Date: 12/2/2004

1. Introduction

Managing artificial aquatic environments currently requires significant human interaction and a degree of technical expertise to be successful. With increasingly available automation technology and networking capability, the need for human labor can be greatly diminished and environments more carefully controlled.

To solve this problem, a prototype "e-quarium", or digitally integrated network-controlled aquarium system, will be designed and built to demonstrate the concept and feasibility of such a device.

2. Problem Statement

It is common for inexperienced caretakers to accidentally poison, starve, overheat, or overstress aquatic life, despite efforts to the contrary. Common problems include, but are not limited to: feeding frequency/portions, adequate filtration, ammonia/nitrate buildup, water salinity/hardness, and maintaining proper heat and light cycles. All of these issues can be addressed with automated control systems via sensor feedback and scheduling. A self-sustaining aquatic environment may be difficult to achieve, but progress can be made by tightly controlling several environmental variables.

Integrating existing technology to accomplish this goal is the greatest challenge. Commercial-off-the-shelf products are available to address single-need environment quality issues, such as: thermometers, heaters, automatic feeders, and lighting systems. The goal of this project will be to incorporate such sensors and stimuli mechanisms into a digitally integrated network environment suitable for automation.

The exploration of this problem will be of particular commercial interest to companies in the pet product industry and to those who work in aquatic biology. For researchers, the issue of tight environmental control must be addressed in any serious study. For pet owners, a less labor-intensive way of caring for a home aquarium is appealing. In either case, those who are concerned with aquatic environment management will always seek to make their work easier via automation.

3. Approach to Solve Problem

3.1. Goals and Objectives

Develop a working, digitally controlled prototype. Demonstrate sustained control over an aquatic environment without significant manual interaction.

3.2. Method

The project has flexibility as to which subsystems get implemented, but the central control and integration of multiple systems remains essential to the product design.

1. Combine and alter COTS components to provide digital response/feedback. This will at the least involve overriding the control of a light source, a feeder, and an aquatic heater. At the sensor level, digital feedback will be drawn from a thermometer, and potentially a pH sensor. Additional sensor/control components are contingent on available time and budget constraints.
2. Establish common interface and communication among devices (centralized control system).
3. Develop custom automation systems on an embedded microcomputer system. This will include either an HC12 or Intel-based architecture and a running OS which will provide Ethernet connectivity to the aquatic environment's caretaker. It will also make use of an FPGA to generate control signals and operate critical subsystems. This is done with the understanding that FPGA's are more reliable than running software, which is prone to deadlock or failure.

3.3. Architecture

The prototype is divided into systems in a top-down hierarchy. The system architecture is best described by the following figures (Figure 1, Figure 2) which show the relationship between the subsystems and their characterizations.

Figure 1. System Identification and Hierarchy

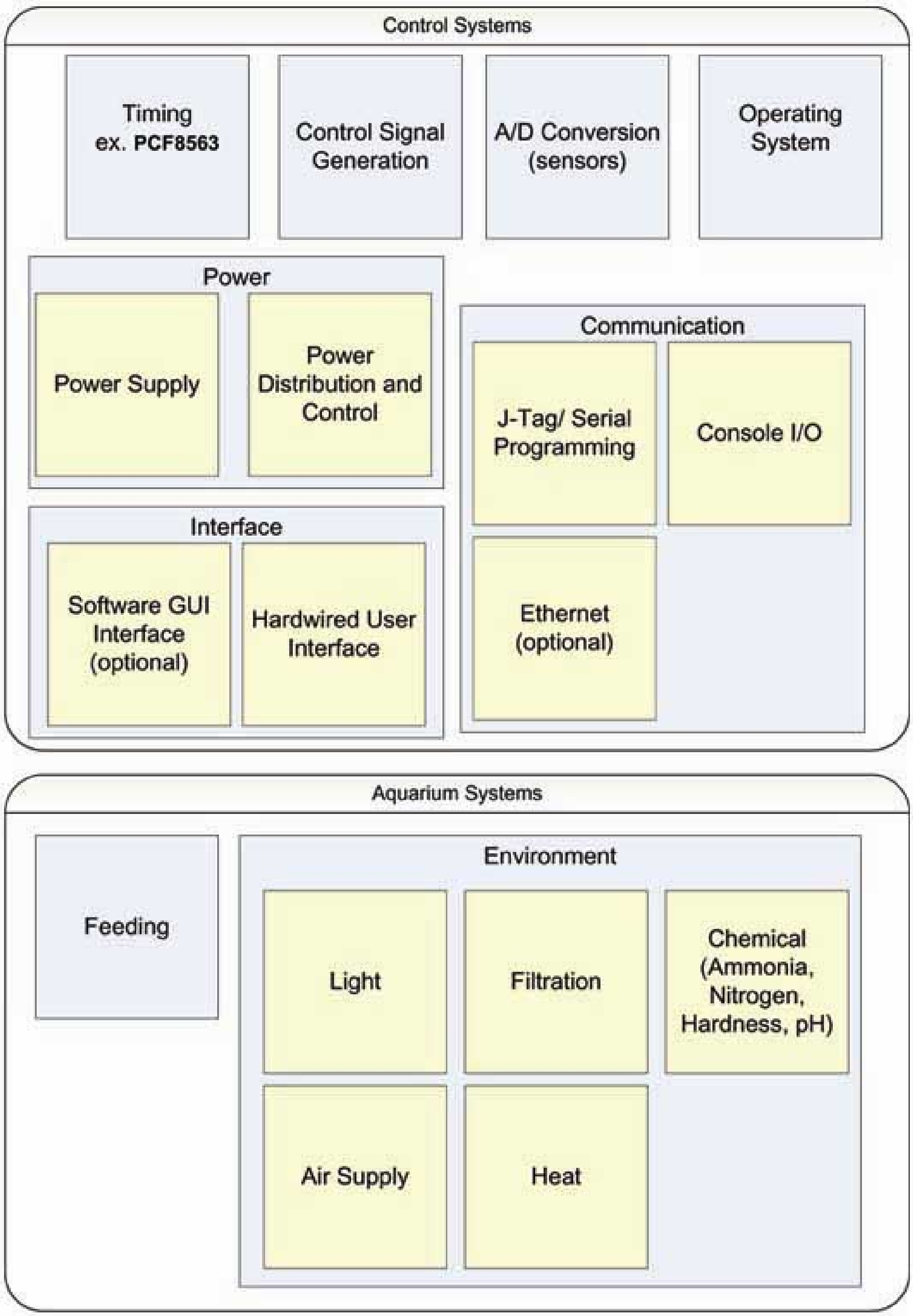
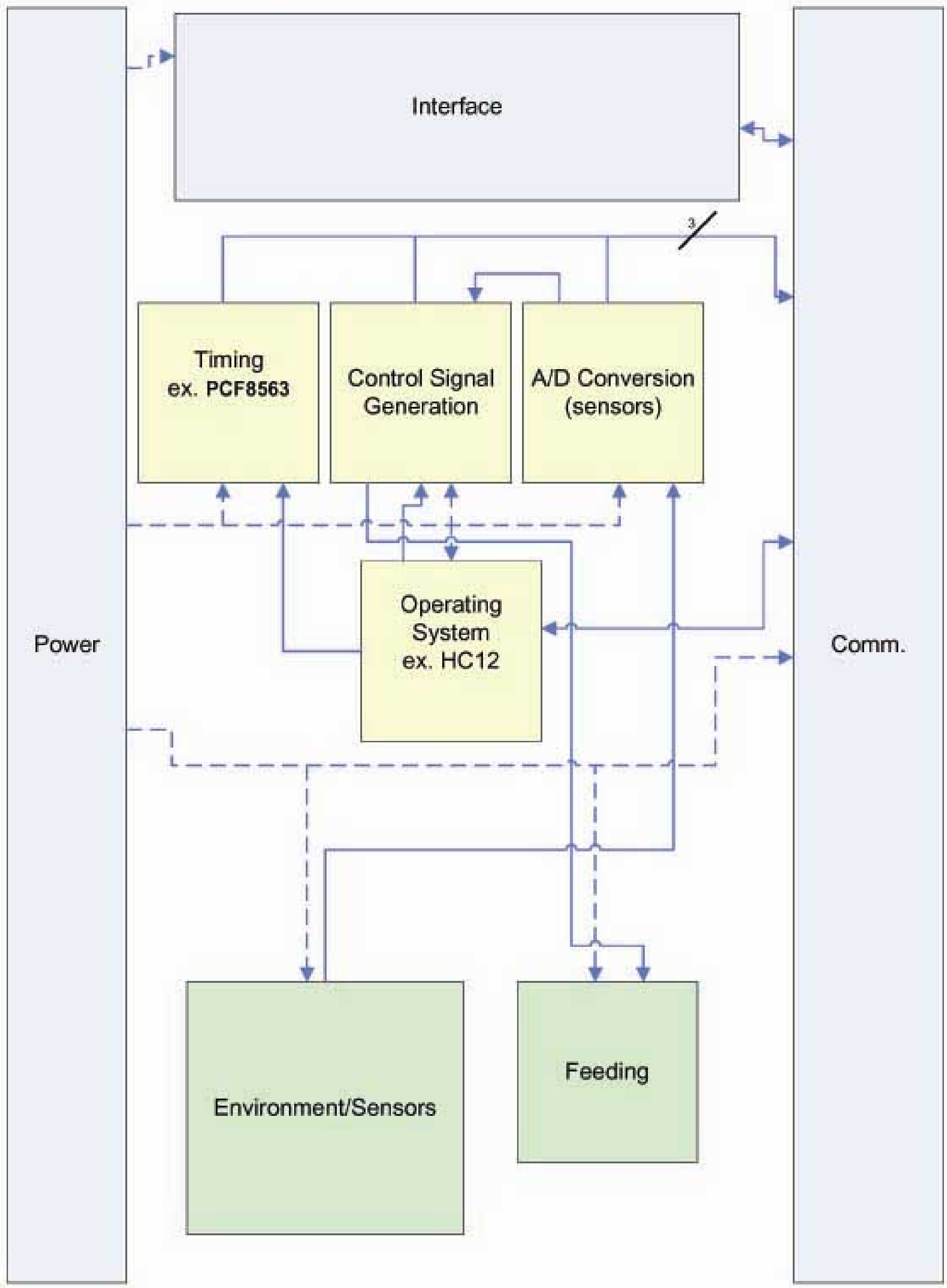


Figure 2. Control Signal Flow



3.4. Design considerations

Microcomputer Architecture

The ideal architecture for this prototype is one which is most familiar to the designers and which has a substantial code base: the Intel x86 architecture. However, price considerations have nearly eliminated this option. Few platforms with processor, memory, and proper I/O ports exist for less than $600. Instead, it is more likely that a less-expensive, less powerful/flexible architecture will be used. A significant portion of design will involve evaluation of the ARM, HC12, and SPARC architectures for their suitability in this project.

Subsystems Essential to Implementation

As dictated in the problem statement, it is the goal of this product design to eliminate the most common challenges in aquatic environment management. Feeding frequency, portion control, ambient temperature regulation, and light cycling are considered integral subsystems in this respect.

Other systems that would be valuable, but are not as practical include: pH and chemical management, water changing, filtration, and solid waste cleaning.

Communication

Ethernet is a widely documented and accepted technology for computer communication networks. For this reason, it was selected as an ideal choice for the remote management datalink of the product.

Alternatives include: Wireless (802.11 series), RS-232, or other desktop-based protocols. These are all well-documented protocols, but are less-suited to the prototype (RS-232 has limited speed, and 802.11 has high cost).

Interface

All of the systems and subsystems on of the design must interface properly with one another. To do this, there are A/D and D/A systems being constructed to convert signals from one system to another. The A/D system will be implemented by using the A/D conversion built into the microprocessor. The D/A system will be done by modulating the output of a FGPA and running it through a low-pass filter such that an average analog value is obtained. Other analog design techniques will be used where needed. A specification will be written so that all members of the group are aware of the exact interface for each component. This break down of sub-components allows a modularization of the design. Each module can then be tested and changed individually so long as it adheres to the known interface specification.

4. Risks and Contingencies

There are several risks that must be considered when attempting this project. Though they may pose problems, the risks have been considered, and contingency plans are in place to assist in coping with them.

Acquisition of Products

There are many COTS products needed for this project. A feeder, heater, thermometer, and light must be purchased, analyzed, and integrated in the system. This makes the assumption that all parts will arrive on time, that there is some feasible way to over ride the control mechanisms of parts, and none of the crucial parts are destroyed while experimenting with them. If something were to go wrong (parts never delivered, broken, too expensive, or more complicated than expected) there could be major setbacks in the development. To avoid some of these problems, the COTS pieces are being researched early so they can be ordered with enough lead time for timely delivery.

Communications

The implementation of Ethernet on a microcomputer system can be a complex task depending on what architecture is used. If limited to non-ideal architectures (by supply and cost) this portion of the project can become very difficult to realize. If able to reuse existing code for system functions, this would be less of a problem. If Ethernet proves to be impossible to implement, there are more simplistic communication methods available that can still complete the project. (RS-232 for example, which is readily available)

Environmental Considerations

In general, water and electronics do not go hand in hand. There is a risk of getting electronics inadvertently wet through spilling, splashing, and humidity. Since there is no easy way to waterproof every piece of electronics used, there is a certain degree of inherent risk, but it is mitigated by careful planning for the use of water. The best way to plan for this contingency is by allowing additional time in implementation.

5. Schedule and Milestones

The timeline for this project is divided into three main phases: research/design, implementation, and testing. Many tasks will seamlessly transition between the three phases, while eliminating queuing/dependency for other tasks. In general, the 3 phases will reach milestones as follows:

Research: 11/12/04 – 1/30/05
Implementation: Completed by 4/1/05
Testing/Report: Completed by 4/25/05

A detailed Gantt chart is attached in the Appendix, but this is a brief summary of critical tasks:

Hardware UI

Resource: Mark Robinton
Deliverable: Hardware panel to control tank, attached to tank. Knobs, buttons…
Time: MED
Importance: HIGH

A/D Conversion and Sensors

Resource: Mark Robinton
Deliverable: Sensors (temp, pH) converted to digital interface, running in aquarium.
Time: MED
Importance: MED

Control Output/Feeder
Resource: Mark Robinton
Deliverable: Automated feeder on tank, digital on/off + digital controlled heater
Time: MED
Importance: HIGH

Operating System/Microcomputer
Resource: Brandon Balkind
Deliverable: Microcomputer with OS/Mem/System software, necessary software
Time: HIGH
Importance: CRITICAL

Ethernet Communication (can be replaced with other link type)
Resource: Brandon Balkind
Deliverable: Desktop PC, (standard 802 ethernet) Datalink
Time: MED
Importance: MED

Software GUI
Resource: Brandon Balkind
Deliverable: Terminal or web-based remote control software (IP addressable?)
Time: MED
Importance: MED

Please refer to the Appendix for scheduling information.

6. Resources
Various sensors and controllers and electronics will be acquired in the initial phase of the project. The items with the largest cost are most likely to be: the FPGA test platform, the microcomputer hardware, and the digital thermometer. The aquarium test platform, interconnects, and basic aquarium equipment are all available (as provided by individual team members).

Digital test and development equipment are available in limited capacity as provided by team members. University-owned digital and analog test equipment (particularly oscilloscopes and logic analyzers) will be needed on an infrequent basis. Some design software, such as Visual Studio and Xilinx ISE may also be required, but are readily available in University computing facilities.

The greatest resource challenge in this project will be dealing with the cost constraints and lead-time of some product orders. Early acquisition and good product research will help make resources less of a worry.

The total cost of acquired components in this project should not exceed $500 dollars unless outside sponsorship is received.

7. Evaluation
The success or failure of this project will be evaluated on the resulting prototype and the design standards developed to realize it. The product, an aquarium with fish, sensors, feeder, heater and control systems attached to a computer network, will be an expensive and cumbersome model,

but the design documentation and methodology must necessarily provide an easily-reproduced method of creating aquatic management systems.

The final report will include intermediate “Interface Design Documents” which define the interfaces for: communication, sensor links, control nodes, and remote control. This will allow new elements to be added using the existing control structure. If the final report fails to define a simple, expandable control system, the project itself will be a failure.

Also of importance is the usability of the prototype. It should, beyond conveying a sense of novelty, actually make managing an aquatic environment significantly easier. This is, after all, the essence of the problem as stated.

Signature of Advisor
Professor Chang

____

Signature of Student
Brandon Balkind

____

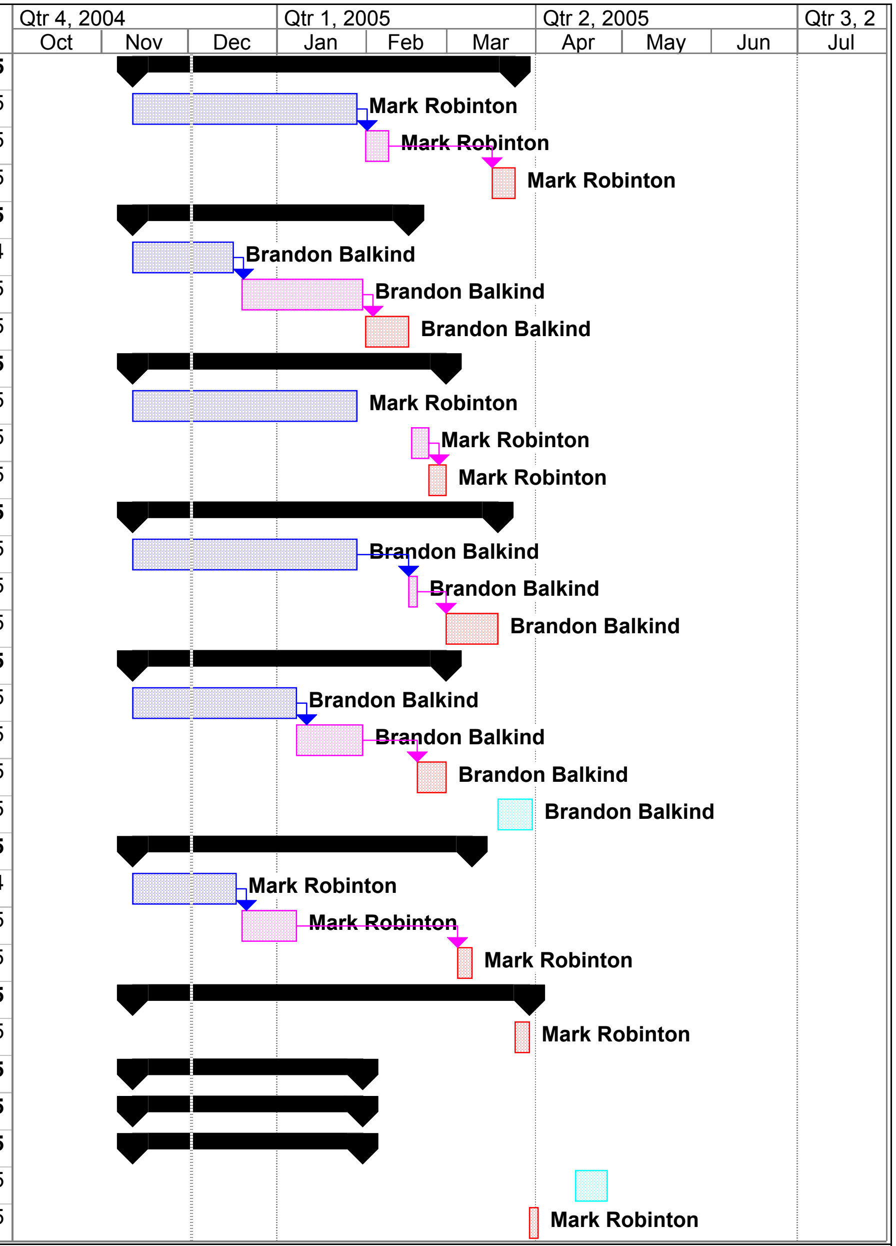
Signature of Instructor
Professor Lasser

____

Signature of Student
Mark Robinton

____

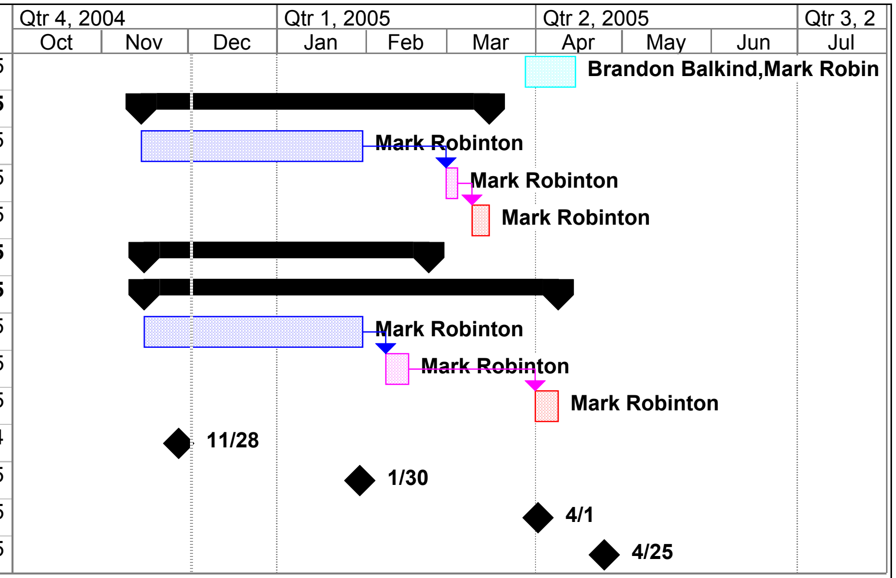
ID		Task Name	Duration	Start	Finish
8		**A/D Conversion**	**101 days?**	**Fri 11/12/04**	**Thu 3/24/05**
9		Research	57 days?	Fri 11/12/04	Fri 1/28/05
10		Design A/D interface	6 days?	Tue 2/1/05	Tue 2/8/05
11		Implement	7 days?	Thu 3/17/05	Thu 3/24/05
12		**Operating System**	**70 days?**	**Fri 11/12/04**	**Tue 2/15/05**
13		Research/Acquire	25 days?	Fri 11/12/04	Thu 12/16/04
14		Design	32 days?	Mon 12/20/04	Sun 1/30/05
15		Implement: System Software	11 days?	Tue 2/1/05	Tue 2/15/05
16		**Power: Power Distribution and Contro**	**80 days?**	**Fri 11/12/04**	**Mon 2/28/05**
19		Research	57 days?	Fri 11/12/04	Fri 1/28/05
17		Design	5 days?	Thu 2/17/05	Tue 2/22/05
18		Implement	4 days?	Wed 2/23/05	Mon 2/28/05
20		**Interface: Software GUI**	**96 days?**	**Fri 11/12/04**	**Fri 3/18/05**
21		Research	57 days?	Fri 11/12/04	Fri 1/28/05
22		Design	3 days?	Wed 2/16/05	Fri 2/18/05
23		Implement	16 days?	Tue 3/1/05	Fri 3/18/05
28		**Communication: Ethernet**	**80 days?**	**Fri 11/12/04**	**Mon 2/28/05**
29		Research	41 days?	Fri 11/12/04	Fri 1/7/05
30		Design	17 days?	Sat 1/8/05	Sun 1/30/05
31		Implement	7 days?	Sat 2/19/05	Mon 2/28/05
32		Prototype/Test Environment	9 days?	Sat 3/19/05	Wed 3/30/05
33		**Communication: Console I/O**	**88 days?**	**Fri 11/12/04**	**Wed 3/9/05**
34		Research	26 days?	Fri 11/12/04	Fri 12/17/04
35		Design	15 days?	Mon 12/20/04	Fri 1/7/05
36		Implement	4 days?	Sat 3/5/05	Wed 3/9/05
37		**Peripheral Component Integration**	**104 days?**	**Fri 11/12/04**	**Tue 3/29/05**
38		Integration with Console/FPGA	3 days?	Fri 3/25/05	Tue 3/29/05
39		**Feeding**	**58 days?**	**Fri 11/12/04**	**Sun 1/30/05**
41		**Environment: Light**	**58 days?**	**Fri 11/12/04**	**Sun 1/30/05**
43		**Environment: Heat**	**58 days?**	**Fri 11/12/04**	**Sun 1/30/05**
45		Report	7 days?	Fri 4/15/05	Mon 4/25/05
46		Large Scale Integration	3 days?	Wed 3/30/05	Fri 4/1/05



Project: Senior Design Gantt
Date: Thu 12/2/04

Task	Milestone	External Tasks
Split	Summary	External Milestone
Progress	Project Summary	Deadline

ID		Task Name	Duration	Start	Finish
47		Testing	13.5 days?	Mon 3/28/05	Thu 4/14/05
24		**Interface: Hardware User Interface**	**92 days?**	**Mon 11/15/04**	**Tue 3/15/05**
25		Research	57 days?	Mon 11/15/04	Sun 1/30/05
26		Design	4 days?	Tue 3/1/05	Fri 3/4/05
27		Implement	5 days?	Thu 3/10/05	Tue 3/15/05
1		**Timing**	**74 days?**	**Tue 11/16/04**	**Tue 2/22/05**
4		**Control Signal Generation**	**110 days?**	**Tue 11/16/04**	**Fri 4/8/05**
5		Research/Acquire	56 days?	Tue 11/16/04	Sun 1/30/05
6		Design control interface	6 days?	Tue 2/8/05	Tue 2/15/05
7		Implement	6 days?	Fri 4/1/05	Fri 4/8/05
49		Start of Project	0 days	Sun 11/28/04	Sun 11/28/04
50		Resarch Complete	0 days	Sun 1/30/05	Sun 1/30/05
51		Implementation Done	0 days	Fri 4/1/05	Fri 4/1/05
48		End of Project	0 days	Mon 4/25/05	Mon 4/25/05



Project: Senior Design Gantt
Date: Thu 12/2/04

Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline