ME218c Smart Product Design

ME 218c Spring 2010 Project
An Even Deadlier Catch

Project Preview on May 20, 2010 6-10 PM in SPDL.
Grading Session on May 26, 2010 9 AM-12 PM in Terman Pond.
Project Presentations on May 27, 2010 in Terman Pond starting at 5:00 PM.

Goal:

The goal of this project is to provide a framework in which you can apply your knowledge of microcontrollers and multi-processor communications to a task that will provide an enjoyable experience for the users and the observers.

Purpose:

The underlying purpose of this project is to provide you with an opportunity to gain experience in integrating all that you have learned in the ME218 course sequence, with an emphasis on the new material in ME218c.

The Task:

Design and build a tele-operated Deadlier Catch Harvester (DCH) and a companion Harvester Controller (HC). Groups of DCHs will operate in Terman Pond and cooperatively strive to harvest a crop of virtual crab during a series of crabbing "seasons".

Specifications

General:

- ☐ Each team will construct a DCH and an HC.
- ☐ The DCHs are devices capable of navigating in Terman Pond while it is filled with water, moving between the crab pots and communicating with Neptune, God of the Seas, to ascertain the state of the crab pots that they are visiting.
- ☐ The HCs are the remote controllers for the DCHs.

Game Play:

- ☐ A crabbing season (AKA game round) will be a competition between two fleets, each composed of three DCH/HC pairs. The makeup of the fleets will vary for each season.
- ☐ Each season will begin with the fleets in the harbor. The crab pots will be in fixed positions in Terman Pond, but their contents and rate of crab accumulation will vary from season to season.
- ☐ The goal of the game is to visit the crab pots, harvest as much crab as possible and return them to the unloading docks within a 5-minute season.
- ☐ If a DCH becomes water-logged, it must jettison its current crab harvest and return to the dry-dock for repair before it can harvest any more crab.
- ☐ The season will be opened with a broadcast message from Neptune with a data packet consisting of: 0x47,0x6F,0x21
- ☐ The winning fleet is the one that has delivered the most crab to the unloading docks by the end of the season.

The Field:

- ☐ The Field is comprised of a portion of the soon-to-be-defunct Terman Pond, initially measuring approximately 26 ft. wide by 30 ft. long (see Figure 1). One fountain spout will be located at the approximate center of the Field. Every effort will be made to ensure that the fountain will be off during grading sessions and public presentations.
- ☐ The absolute boundaries of the Field are formed by the cement border to the pond.
- ☐ All DCHs will be placed in the regions around the unloading docks (AKA the "harbor") at the beginning of each season.

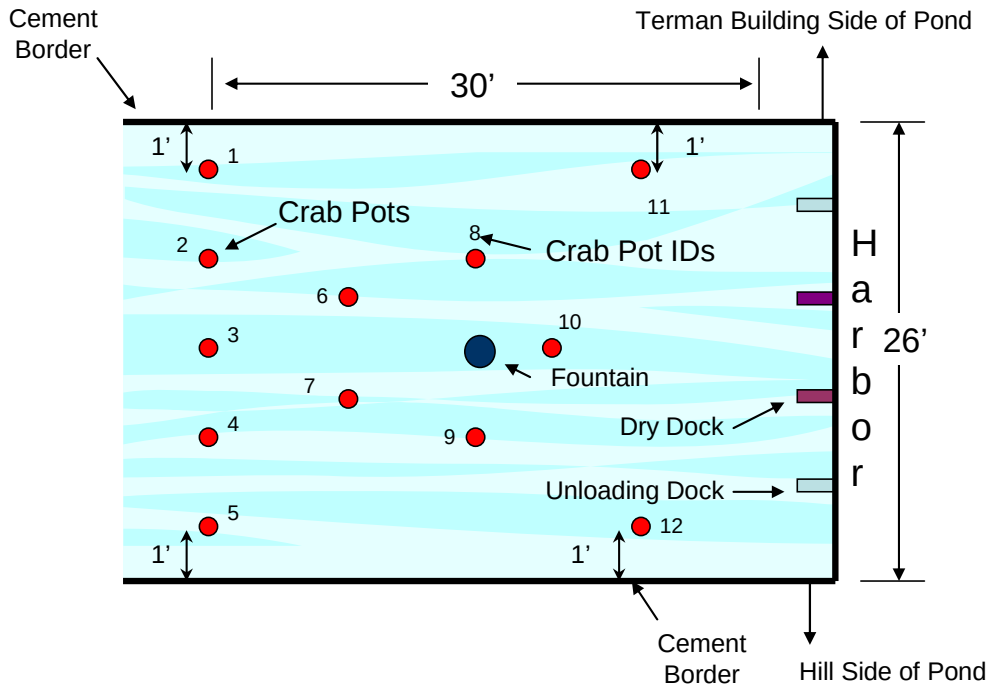


Figure 1: Field layout and dimensions

The Crab Pots:

- ☐ The crab pots will be floating on the surface, tethered to the bottom of the pond, at the approximate positions shown in Fig. 1.
- ☐ Each crab pot will consist of a 6" square of closed cell foam on which is mounted an RFID card. Each RFID card will have a unique serial number to identify that particular crab pot.
- ☐ Crab pot RFID cards are mounted parallel to the surface of the water.

The DCHs:

- ☐ Each DCH must be capable of moving under its own power within Terman Pond. Terman Pond will be filled with water (its normal state) at the time of the grading and the public presentation. Every effort will be made to ensure that the fountains are off during the events.
- ☐ DCHs must be battery powered and operate without a tether.
- ☐ Control of DCH functions must be achieved via an HC using the provided RF hardware.
- ☐ The DCH must detect the presence of a crab pot using the RFID tag on each pot (RFID readers (RDM630) will be supplied). The crab pot's serial number will be used to communicate with Neptune (over the RF data link) to determine the current catch in the pot and the rate at which crabs are accumulating in that pot.
- ☐ Each DCH must provide a clearly visible mounting for the Fleet Colors. One 3"x5" Fleet Color card will be mounted horizontally and one will be mounted vertically. Fleet color cards will be supplied.
- ☐ Each DCH may carry a maximum of 300 units of crab.
- ☐ Each DCH must carry a highly visible electro-mechanical indicator of the percentage of its maximum crab capacity it is currently carrying. This indicator must be under software control and clearly visible in sunlight at a distance of 20'. The minimum capacity resolution for this indicator is 20% of total.
- ☐ DCHs must incorporate an easily accessible switch that disables all propulsion systems.

- ☐ The perimeter of the largest projection into the plane of the water surface of the DCH must not exceed 72". Height is not restricted.
- ☐ Each DCH will be assigned to either the RED or GREEN fleet at the beginning of a season by presenting the RFID reader with one of two special RFID tags. The unique serial numbers of these tags must be detected and used to associate the DCH with a fleet.
- ☐ Each DCH must carry an SPDL supplied water-logged sensor (a funnel) and its associated security controller. The sensor must be mounted upright and in a manner such that the entrance to the sensor is unobstructed.
- ☐ The supplied water-logged sensor becomes activated when water enters the funnel at a rate faster than can be drained. At this point, the supplied security controller chip will raise a digital output to +5V and hold it high until the DCH visits a dry-dock.
- ☐ Each DCH must have an indicator that shall be activated when the DCH becomes waterlogged. This indicator must be visible from 20' in direct sunlight.
- ☐ The DCH will interface with the supplied security controller to obtain a unique key that it will use in every transmission to Neptune.
- ☐ DCHs must incorporate a class standard foam bumper around their perimeter, and must be tolerant of moderate bumping from other DCHs. The bottom edge of the foam bumper must be at a height between 0" (the water line) and 1.5" above the water line of the DCH. The bumper must follow the same perimeter that is measured to fit the 72" requirement.
- ☐ The DCH may issue messages to Neptune at a rate no greater than 5 Hz.
- ☐ When a DCH visits a crab pot, it must report the rate of crab accumulation for that pot to the other members of its fleet.

The HC:

- ☐ Each team will design and construct an HC (remote controller) that will relay commands from a human operator to a DCH, and receive and display status information from the DCH.
- ☐ The HC must be capable of displaying to the operator the crab pot ID and accumulation rate of at least the crab pot most recently visited by any member of its fleet.
- ☐ HCs will provide bi-directional communications between itself and the DCH that it is controlling.
- ☐ HCs must be battery powered, and shall have sufficient battery capacity for at least 8 hours of continuous operation. The report should show documentation and calculations to support meeting this requirement.
- ☐ HCs must be untethered and portable by one person.
- ☐ Input to the HC should involve at least 3 sensing modalities (e.g. position, force, audio, acceleration, etc.). Use of unusual interface methods is encouraged.
- ☐ The actions required by the user of the HC to issue commands to the DCH should be inventive and interesting for the audience to watch. Use of actions that make the operator look and feel foolish is encouraged.
- ☐ The HC may issue commands to a DCH at a rate no greater than 5 Hz.
- ☐ HCs should be intuitive to operate, and/or have sufficient visual instructions that a typical spectator (even a non-engineer) would be able to learn its controls within the time span of a single season.

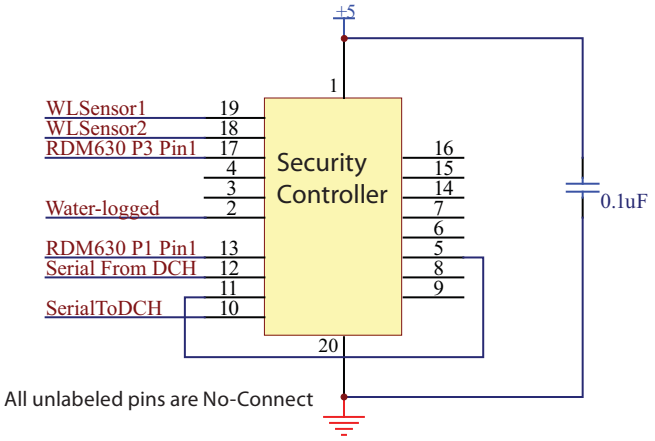
Neptune:

- ☐ Neptune, as the Roman God of the Seas, knows everything about the state of the subsurface world. To determine the contents of a crab pot and the rate at which crabs are accumulating in the pot, your DCH must communicate with Neptune.

- ☐ Neptune is up on the current state of communications and is constantly monitoring 802.15.4 communications sent to address 0x7777.
- ☐ Neptune expects that the data field of packets addressed to 0x7777 will be formatted as follows: RQ,S1,S2,S3,S4,S5,SK1,SK2,SK3. RQ is the Request byte (0x66), S1-S5 are the serial number bytes from the RFID tag of the crab pot, dry-dock, or unloading dock, and SK1 through SK3 are the security key values from the security controller supplied to each team. A new security key must be obtained for every transmission to Neptune.
- ☐ Neptune will respond to messages addressed to 0x7777 with a packet with a data field composed of four bytes: Byte 1 will be the amount of crab (in units of crab) transferred to your DCH, Byte 2 will be the complement of byte 1, Byte 3 will be the rate at which crab is accumulating in this pot (in units of crab/min.) and Byte 4 will be the complement of byte 3.

The Security Controller:

- ☐ The security Controller must be wired to the Water-Logged Sensor and a processor on your DCH according to the schematic shown below:



- ☐ A new security key is requested by sending a packet (9600,N,8,1) to the security controller formatted as: 0x04,S1,S2,S3,S4,S5,0x08, where S1-S5 are the 5 bytes of the serial number received from the RFID reader (RDS630).
- ☐ The security controller will respond with a packet of the form: SK1,SK1N,SK2,SK2N,SK3,SK3N where SK1 is security key byte 1, SK1N is the complement of security key byte 1, SK2 is security key byte 2, SK2N is the complement of security key byte 2, SK3 is security key byte 3, and SK3N is the complement of security key byte 3.
- ☐

Communications:

- ☐ Communications between the DCHs, HCs, and Neptune will take place over an SPDL-supplied 802.15.4 radio (Xbee24) using the Non-Beacon API mode of operation.
- ☐ Once a season begins, communication will take the form of bi-directional communications between a DCH and its designated HC as well as bi-directional communications between the DCH and Neptune.
- ☐ Each DCH and HC will be assigned a unique ID in the form of the source address of each SPDL-supplied radio. Neptune will also have a unique address of 0x7777.
- ☐ Communications within a fleet will take place using the broadcast mode of RF transmission. To limit the use of the information to only the members of a given fleet, broadcast mode communications will be encrypted using an XOR cipher and a key that is shared among the fleet members at the beginning of each season.

- ☐ The details of the communications protocol will be defined and specified by a Communications Committee, which will consist of one member from each project team. The specification must be in a written form and with sufficient detail that someone sufficiently skilled in ME218 material could implement it. The broadcast communication must be compatible with all other specified communication, i.e. it must not overlap with the special messages already defined in this document.
- ☐ In order to better balance the workload and learning among team members, each of the following tasks must be completed by a different member of the team: serve on the communications committee, implement communications on the DCH, implement communications on the HC.
- ☐ The class communications protocol must include a procedure for fleet-wide validation of communication that will take place before the start of each season. The HCs must provide a visual indication of when the fleet-wide validation messages are received.

General Requirements:

- ☐ At a minimum, either the HC or the DCH must contain two actively communicating processors. There is no class imposed upper limit on the number of processors employed. The only processors permitted on the DCH are PIC microcontrollers.
- ☐ The microcontroller that interfaces with the RFID reader must be programmed entirely in assembly language.
- ☐ You are limited to an expenditure of **$150.00/ team** for all materials and parts used in the construction of your project. Materials from the lab kit or the Cabinet Of Freedom do not count against the limit. All other items count at their fair market value.
- ☐ A project logbook must be maintained for each group. An on-line blog is appropriate to meet this requirement as long as it is made available to the teaching staff for review. This book should reflect the current state of the project, planning for the future, results of meetings, designs as they evolve etc. The project logbook will be collected at irregular intervals for evaluation.
- ☐ A report describing the technical details of the system will be required. The report should be of sufficient detail that a person skilled at the level of ME218c could understand, reproduce, and modify the design. The report must be in website format, and be suitable for posting on the SPDL site.
- ☐ DCHs based substantially on purchased vehicle platforms are not allowed.
- ☐ All projects must respect the spirit of the rules. If your team is considering something that **may** violate the spirit of the rules, you must consult a member of the teaching staff.

Safety:

- ☐ Both the DCHs and the HCs should be safe, both to the user and the spectators.
- ☐ Intentionally disabling or damaging other DCHs is not allowed. Prohibited actions include, but are not limited to, the following: ramming at excessive speed (as determined solely at the discretion of the teaching staff), swamping and/or sinking.
- ☐ DCHs will be exposed frequently to lots of water. Electronics, actuators and energy storage devices (e.g. batteries) do not typically fare well in the presence of water. Plan on it. Design accordingly.
- ☐ The teaching staff reserves the right to disqualify any device considered unsafe.

Check-Points

Design Review:

During class-time on **05/04/10** we will conduct a design review. Each group should prepare a few slides (scans of sheets of paper are fine) showing your proposed designs for both the DCH and the HC. At this time, initial calculations are required for estimating the mass of your proposed DCH as well as any water displacement calculations relevant to your design. You will present these in 550-200 (our usual classroom) to the class, members of the teaching staff and coaches who will provide feedback.

First Draft of Communications Standard:

Due by 5:00 pm on **05/04/10**. Ed will meet with the communications committee on the evening of 05/05/10 to provide feedback on the specification.

Communications Standard:

Due by 5:00 pm on **05/07/10**. This is the working draft of the communications standard.

First Check-Point:

On **05/11/10**, you must demonstrate
1) The ability of the DCH to receive and correctly decode and respond to commands from the HC (simulated inputs are acceptable at this time).

2) Your team's DCH. At this check-point, you will demonstrate that your DCH platform has been built, and is capable of bearing the approximate weight of all the necessary components it will carry when complete. It is encouraged, but not required, to demonstrate working propulsion and steering subsystems.

3) The ability to read and report the serial number from an RFID card.

The final working version of the communications standard is due. No further changes are allowed to the standard. This protocol will be evaluated with respect to its completeness and suitability for the proposed system. **Note:** this is a functional evaluation only. The focus should be on demonstrating **functional** hardware and software.

Second Check-Point:

On **05/18/10**, you must demonstrate the ability to communicate all required functionality between your DCH and HC. This will include commands from the HC to the DCH, all status messages from the DCH to the HC. You must also demonstrate the ability to bidirectionally communicate with Neptune, and to correctly respond to the waterlogged sensor.

Project Preview:

At the Project Preview on **05/20/10**, each team must demonstrate (in addition to the 1st & 2nd check-point functionality)
1) The ability to successfully send and execute the drive and steering commands (including the actuation of all electromechanical outputs) from an operator of the HC to the DCH.
2) The ability to fill and empty the DCH crab storage through successive application of crab pot and unloading dock RFID cards, and the requisite communication with Neptune.

Grading Session:

During the Grading Session on **05/26/10**, each team will be required to demonstrate the ability to successfully participate in a crabbing season. This will include
1) Navigating a DCH from the harbor and successfully fishing crab from multiple pots.

2) Navigating to the unloading dock to unload crab from a DCH.

3) Response to a waterlogged sensor, and the subsequent navigation to the dry-dock for repair.

Public Presentation:

This will take place on **05/27/10** starting at 5:00 pm in Terman Pond. At this event, members of the public will be allowed to act as operators of the HCs.

Report:

Draft due on **05/31/10** by 4:00 pm. The final version (with revisions incorporated) is due by 5:00 pm on **06/04/10**.

Evaluation

Performance Testing Procedures:

One or more of the team members will demonstrate the DCH and HC during the first & second check points and project preview. Members of the teaching team will operate the DCH and HC during the grading session.

Grading Criteria:

- ☐ **Concept (15%)** This will be based on the technical merit of the design and coding for the machine. Included in this grade will be evaluation of the appropriateness of the solution, as well as innovative hardware, software and use of physical principles in the solution.

- ☐ **Implementation (15%)** This will be based on the prototype displayed at the evaluation session. Included in this grade will be evaluation of the physical appearance of the prototype and quality of construction. We will not presume to judge true aesthetics, but will concentrate on craftsmanship and finished appearance.
- ☐ **First Check Point (10%)** Based on the results of the performance demonstrated on 05/11/10**.**
- ☐ **Second Check Point (10%)** Based on the results of the performance demonstrated on 05/18/10**.**
- ☐ **Preliminary Performance (10%)** Based on the results of the performance demonstrated during the Project Preview.
- ☐ **Performance (15%)** Based on the results of the performance testing during the Grading Session.
- ☐ **Report (10%)** This will be based on an evaluation of the report. It will be judged on clarity of explanations, completeness and appropriateness of the documentation.
- ☐ **Report Review (5%)** These points will be awarded based on the thoroughness of your review of your partner team's report. Read the explanations, do they make sense? Review the circuits, do they look like they should work?
- ☐ **Log Book (5%)** This will be evaluated by the evidence of consistent maintenance as well as the quality and relevance of the material in the log book.
- ☐ **Housekeeping (5%)** Based on the timely return of SPDL components, cleanliness of group workstations as well as the overall cleanliness of the lab. No grades will be recorded for teams who have not returned all loaned materials.

Gems of Wisdom from Prior Generations

- Get the radio working with the 'E128 first.
- Do not continue working until the wee hours of the morning unless you absolutely have to because errors propagate when tired. A fresh look at things in the morning will save you a lot of pain at night. Sleep is not a crutch, it is a necessity.
- Put some time into your first prototype. You might be surprised how many things you throw together for testing purposes make it into your final project.
- Label or color-code your connectors so that it's easy to plug them into the right place. Connectors that can only be hooked up one way (such as Molex) prevent undesirable incidents like reversing the voltage and ground connections and frying components in the process.
- When building networks, add nodes one at a time to better track down "bad nodes".
- Debugging LEDs are useful for getting feedback on the operational state of PICs.
- A "power central" board is a good thing to have, particularly if you're dealing with multiple supply voltages. This makes the circuitry cleaner, and can save you from supplying your PIC with 37 volts.

- Think twice before planning to provide PWM for motors with PICs (at least the one with 20 pins). You will need to take care of output compares and timers also.
- You will need to leave some pins on PICs (especially those with only 20 pins) open for debugging.
- Don't hesitate to add another PIC and SPI communication. It's really easy.
- Using shift registers for debugging can also be a helpful trick to obtain more information, but it is not good for timing issues.
- Try working during the day (seriously!). Debugging is way easier with a clear head.

- The radio boards runs on 3.3V not 5V. The iButton reader runs on 5V not 3.3V. Design your circuits accordingly and be ready to convert between the two voltages.
- Jameco is NOT OPEN on weekends. Don't postpone your trip until Saturday – you will be sorely disappointed.
- Don't be dead set on a theme at the beginning of the project. Let the project theme develop as you move through the project. You'll be surprised how many great ideas pop up as you go along.
- Hot glue down all soldered wire connections. You'll lose a lot of time tracking down an error that may end up being a loose/broken wire.
- Write all functions as non-blocking code – no matter where they fit into the flow of the program.
- Just because two points on a circuit look like ground when probed doesn't mean they are connected.

- Test circuit as it will be implemented in final form, as well as fully integrated.
- Test in environment in which hardware will be used (radios outside, with appropriate distant in between).
- Testing our radio pair in the presence of other active radio pairs revealed problems that didn't exist when we test alone.
- It's easy to make a design with bad ergonomics which make it impossible for the user to perform the task. Prototype/try out the user scenario yourself as early as possible.
- Keep circuit diagrams up to date as you make them.
- Use lab notebook so that all information is at one place and teammates can have easy access to it.
- Take a lot of pictures as you go.
- Remember to HAVE FUN.

- If you are having intermittent problems (e.g. it works only some of the time) check your connections – especially those connecting your various circuits to a common ground.
- Modularize as much as possible – test all of the components separately before integrating
- Build and test all of your circuits and sensors on breadboard before you make them hard mounted on perfboard.
- When moving your circuits from breadboard to perfboard, rather than dismantling your breadboards, leave your working breadboards intact and buy new components and build entirely new circuits on the perfboard. That way, if something goes wrong once everything is built, you will always have a backup copy of your circuits on the breadboard that you know worked before you integrated everything.
- Isolate your circuits onto individual perf-boards (rather than having a giant perf-board with all of your circuits). Makes it much easier to take them out to debug them.
- A nice pair of wire snips (flush cutters) and wire strippers makes wirewrapping and circuit building in general much easier.
- Do your circuit calculations to make sure you have enough/not too much voltage/current/power
- Have plenty of spare parts ready to go in case something blows at the last minute
- Always take the time to test on the actual competition field at the actual competition location
- Make sure at least two people of the group understand or at least have an idea of each component – mechanical, electrical, software. Doesn't have to be the same two people, but it insures that if someone's missing, that the group isn't stuck.
- Be friendly with other teams – you never know when you're going to need help.

- Test your wireless communication outside and at range!
- Test your components for interoperability with everyone else's before game day.
- Source an off-the-shelf housing/controller and gut it. That way you can focus on the electronics and not the mechanical design.
- If you can avoid having to spend time building something by buying an equivalent part, do it!
- Remember your banksel commands and save yourself hours of debugging.
- Make things accessible (i.e. batteries, boards, DIP sockets, etc.) so you don't have to unscrew things when you need to test, power cycle, or reset things.
- Learn to use assembler macros. They clean up your code visually.

- Don't use macros when you can use a function-type subroutine!
- Size does matter. The bigger or larger the motions involved in your controller, the more entertaining it will be to watch.
- Do not bury your wireless antenna in a box. Try to keep it out in the open.
- Buy a good pair of wire strippers, preferably ones that can strip 30AWG wire. Your fingers will thank you.
- Try to avoid having to scramble together parts or code for a check-off. This means keeping on top of the project schedule. If you don't, you will end up throwing away a lot of hours on setups that will not make it to your final design.
- PICs are notoriously difficult to debug. Either source an MPLAB ICD2 (or equivalent), or finish your circuitry early, before writing the bulk of your code. You will find that changing even small things in assembler can cost you hours.

- If a change causes things not to work the first thing you should check is if the code is in the correct bank. It is always a good idea to use a bank select command at the start of every routine rather than assume you'll know where it is.
- Build and test the code in small manageable pieces. If a lot of changes are made at once and the new program doesn't work, it is very hard to isolate the problem without a lot of work.
- Use the debugger. Running routines through the debugger to see what will happen will save lots of time and effort. Getting a routine to work in the debugger usually allows you to assume problems that come up in actual testing are hardware rather than software related.
- When you're tired and everything starts to fail don't forget to check the batteries.
- If you're tired and everything starts to fail and it's not the battery consider going home and looking at it again the next morning rather than changing a lot of code. Often it is some small little change you overlooked and are too tired to notice.
- Make sure all data tables are in the correct location.
- Make use of calls and macros whenever possible to keep the code clean. This also makes repetitive actions easier to code and change.
- Make use of #defines for labeling pins and value as much as possible. This makes it very easy to see what pins are connected to what and allows for the easiest changes. Rather than searching for a specific port and pin throughout the code you only have to change one #define value.

- Don't believe anyone that tells you that the 218C project is less time consuming than the 218b project. It's not.
- Pick your battles early. Learning to program the PIC's and the Zigbees is a lot of work on its own. Trying to add other challenges can be tough.
- Move to solder boards or wire wrap boards as soon as you can. If you are developing simple hardware that you understand well, don't be afraid to solder it on a board. Troubleshooting bad connections on a breadboard is a waste of your time.
- Allocate your pins and subsystems early. A spreadsheet that shows all of your pins is very handy.
- Practice on the course as soon as possible to test your operable range.

- PICs are apparently not designed to be inserted backwards. We recommend against doing this.
- Don't spend more than a few hours debugging SPI code before debugging all of the related hardware.
- Start by making a schedule for the project and include any outside events like vacations, graduations, etc. to avoid surprises later on.
- Black objects left in the sun tend to melt any hot glue that is exposed. This is detrimental to the project's structural integrity. It is therefore wise to a) avoid hotglue or more realistically, b) avoid leaving black hotglued objects in the full sun for extended periods of time.

- Although checkpoints are important, the key is to continue working on the final product, so at all times try to write code/build hardware that you will be able to use in the final product. Try to minimize writing special "check-off code" and building "check-off hardware" that you won't use later.
- Thinking very carefully about your electrical design/layout will save you lots of soldering time. By designing carefully, you'll optimize locations of every components, and you'll end up making a lot less solder joints/connectors/electrical boards, fewer corrections.
- Use Debugging Leds if using PICs. Reserve a few outputs so you can toggle the bits and see if you get into loops or states. This was really helpful when we were trying to figure out what was wrong with our code. Also, since we already used the SSP and Asynchronous communications outputs, we could not use printfs to the terminal.
- Check your #defines and labels. With PIC programming, you tend to have a lot of GOTOs and CALLs which means you need a lot of labels. Try to have a good system for labeling things and creating your constants and variables. We used CAP_UNDERSCORE for # defines and FirstCapitalLetter with no spaces for variables. Where we went wrong was creating "FORWARD" and "FORWARD_CMD" which we misinterpreted and messed us up for a long time.
- Talk to other people about the communication protocols and how they implement their code. It's hard to figure out the datasheets by yourself with no help from anyone.
- Debug code extensively prior to integration with other software/hardware elements.
- Utilize 7-segment display or LCD display for real-time debugging.

- Modularize mechanical systems so that simpler parts can be made earlier and used from the beginning of development.
- Develop a clear understanding of the communications protocol from the beginning of code development.
- Communicate well within your team so that some tasks are not overlooked, while others are duplicated.
- Learn some of the common problems with writing PIC code (such as dividing your long code into small sections using the "Maincode code" command).
- Bathe as frequently as possible; encourage others to do so as well.