ME218c Smart Product Design

ME 218c Spring 2011 Project
King of the Atoll

Project Preview on May 19, 2011 6-10 PM in SPDL.
Grading Session on May 25, 2011 9 AM-12 PM in Hoop Fountain.
Project Presentations on May 26, 2011 in Hoop Fountain starting at 4:00 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 Atoll Capture Vehicle (ACV) and a companion Capture Vehicle Controller (CVC). Groups of ACVs will operate in Hoop Fountain and cooperatively strive to take control of the maximum number of Atolls during rounds of the game.

Specifications

General:

☐ Each team will construct a ACV and an CVC.

☐ The ACVs are devices capable of navigating in Hoop Fountain while it is filled with water, moving between and communicating with the Atolls, to take control of the Atolls and communicating with the other members of their fleet,.

☐ The CVCs are the remote controllers for the ACVs.

Game Play:

☐ A campaign (AKA game round) will be a competition between two fleets, each composed of two ACV/CVC pairs. The makeup of the fleets will vary for each campaign.

☐ Each campaign will begin with the fleets positioned as shown in Figure 1. The Atolls will be in fixed positions in Hoop Fountain, as shown in Figure 1.

☐ The goal of the game is to visit the Atolls, read their RFID cards (see below) and communicate with the Atolls to take control of the maximum number of Atolls within a 255 second campaign.

☐ The campaign will be opened and closed with a blast from an air horn.

☐ The winning fleet is the one that is in control of the most Atolls at the end of the campaign.

The Field:

☐ The Field is comprised of Hoop Fountain and a small region around the fountain perimeter (Figure 1). Every effort will be made to ensure that the fountain will be **ON** during grading sessions and public presentations.

☐ The absolute boundaries of the Field are formed by an imaginary perimeter drawn 2' outside the water-filled pool of the fountain.

☐ All ACVs will be placed in the starting boxes as shown in Figure 1 at the beginning of each campaign.

☐ The depth of the fountain is approximately 5.5" in the gray region and 17.5" in the white region. The region directly under The Hoop contains lighting canisters that reduce the depth in that region.

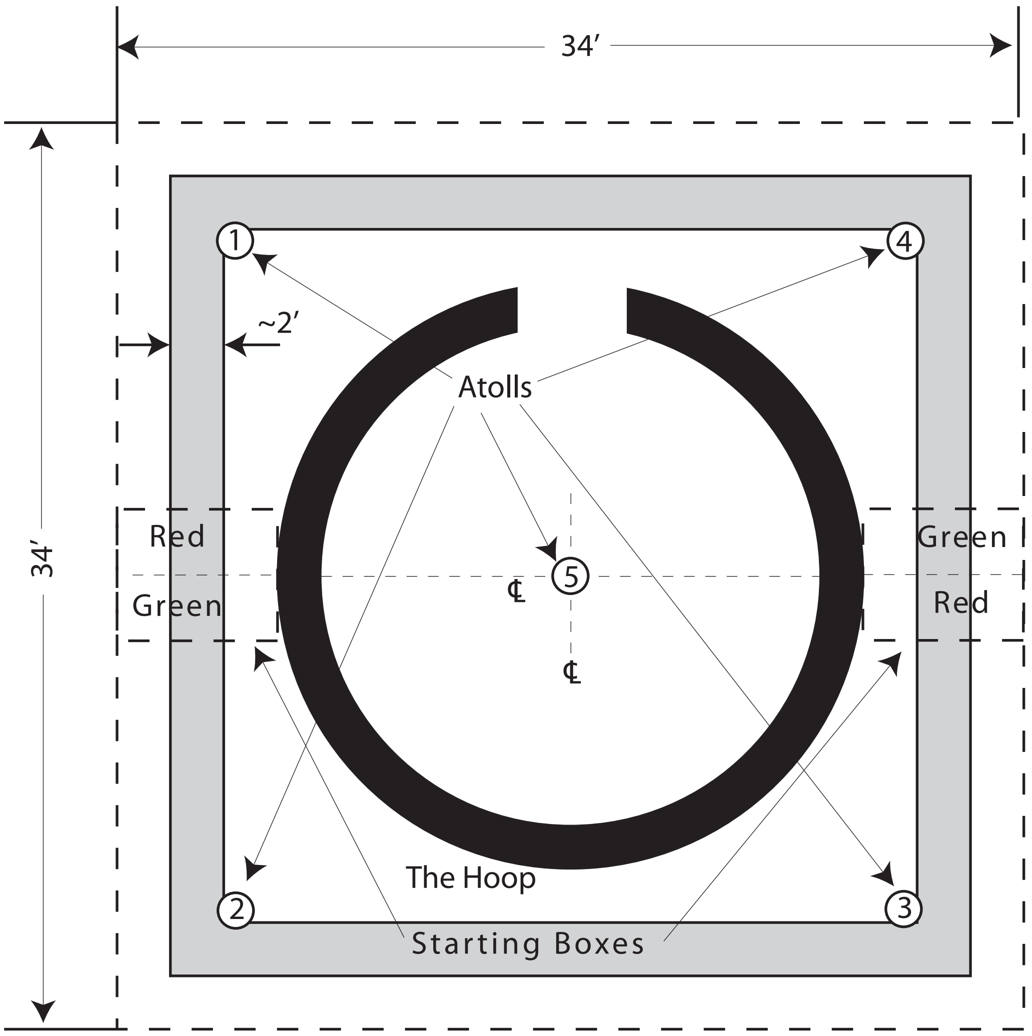


Figure 1: Field layout and dimensions

The Atolls:

- ☐ Each Atoll will consist of an approximately 16” diameter foam disk on which are mounted two RFID cards. Each RFID card will have a unique serial number that is used to identify that particular Atoll.
- ☐ The RFID cards will be mounted at the outer perimeter of the Atolls, at opposite sides along a diameter line and oriented relative to the field so that they lie along the diagonals of the pond.
- ☐ Atoll RFID cards are mounted vertically (perpendicular to the surface of the water).
- ☐ The Atolls will be rigidly supported from the bottom of the pond, with their lower edges approximately at the water line, in the approximate positions shown in Figure 1.
- ☐ Each Atoll will constantly monitor 802.15.4 communications broadcast on the network.
- ☐ In order to take control of an Atoll, the ACV should broadcast a packet with the data field formatted as follows: RQ,AN,S1,S2,S3,SK1,SK2,SK3. Where RQ is the Request Capture byte (0x66), AN is the Atoll number, S1-S3 are the serial number bytes from the RFID tag read from the Atoll, and SK1 through SK3 are the security key values from the security controller supplied to each team. S1 and SK1 are the most significant bytes (received first) and S3 and SK3 are the least significant. A new security key must be obtained for every transmission to an Atoll.
- ☐ Attempts to take over an Atoll will only succeed if a received packet matches one of its serial numbers **and** the security key is valid.

- ☐ The Atoll will respond to messages that contain its Atoll number with a targeted message to the ACV attempting capture. This response will be a packet formatted as follows: RP,AN,SF,NO, where RP is the Reply byte (0x67), AN is the Atoll number,.SF is the Success/Failure indicator (0xFF = Success, 0x00 = Failure), and NO is the New Owner (Red = 0xFE, Green = 0x01, unoccupied = 0x88).

The ACVs:

- ☐ Each ACV must be capable of moving under its own power within the field (described above). Hoop Fountain 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 **ON** during the events.
- ☐ ACVs must be battery powered and operate without a tether.
- ☐ Control of ACV functions must be achieved via a CVC using the provided RF hardware (XBee24 modules).
- ☐ The ACV must detect the presence of an Atoll using the RFID tag on each Atoll (RFID readers (RDM630) will be supplied). The Atoll's serial number will be used to communicate with the Atoll (over the RF data link) to take control of that Atoll.
- ☐ Each ACV must carry a highly visible electro-mechanical indicator of the fleet to which it belongs. This indicator must be under software control and clearly visible in sunlight at a distance of 20'.
- ☐ ACVs must incorporate an easily accessible switch that disables all propulsion systems.
- ☐ The perimeter of the largest normal projection into the plane of the water surface of the ACV must not exceed 72". Height is not restricted.
- ☐ Each ACV will be assigned to either the RED or GREEN fleet at the beginning of a campaign 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 ACV with a fleet.
- ☐ After being presented with either of the two special RFID tags, the ACV will follow the class-defined protocol to validate communications within its fleet.
- ☐ The ACV should respond to the successful validation of fleet-wide communications by "hoisting" the appropriate fleet color indicator.
- ☐ The ACV will interface with the supplied security controller to obtain a unique key that it will use in every transmission to an Atoll.
- ☐ ACVs must incorporate a class standard foam bumper around their perimeter, and must be tolerant of moderate bumping from other ACVs. 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 ACV. The bumper must follow the same perimeter that is measured to fit the 72" requirement.
- ☐ The ACV may issue messages at a rate no greater than 5 Hz.
- ☐ When a ACV takes control of an Atoll, it must report the new ownership to the other members of its fleet using broadcast messages.

The CVC:

- ☐ Each team will design and construct a CVC (remote controller) that will relay commands from a human operator to an ACV, and receive and display status information from the ACV.
- ☐ The CVC must be capable of displaying to the operator the current ownership of all of the Atolls.
- ☐ CVCs will provide bi-directional communications between itself and the ACV that it is controlling.
- ☐ CVCs 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.

☐ CVCs must be untethered and portable by one person.

☐ Input to the CVC should involve at least 3 sensing modalities (e.g. position, force, audio, acceleration, etc.). Use of unusual interface methods is encouraged.

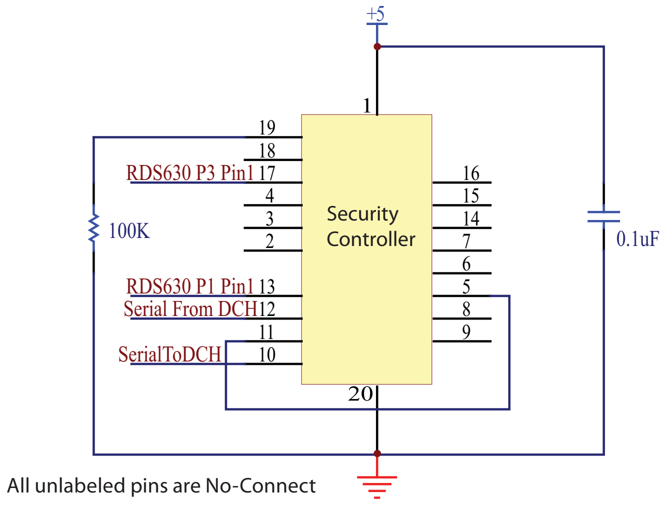
☐ The actions required by the user of the CVC to issue commands to the ACV should be inventive and interesting for the audience to watch. Use of actions that make the operator look and feel foolish is encouraged.

☐ The CVC may issue commands to an ACV at a rate no greater than 5 Hz.

☐ CVCs 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 game round.

The Security Controller:

☐ The security Controller must be wired to the RFID reader and a processor on your ACV 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,S3,0x08, where S1-S3 are the 3 bytes of the serial number received from the RFID reader (RDS630). S1 is the most significant of the 3 bytes, S3 is the least significant.

☐ 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 ACVs, CVCs, and Atolls will take place over an SPDL-supplied 802.15.4 radio (Xbee24) using the Non-Beacon API mode of operation.

☐ Once a campaign begins, communication will take the form of bi-directional communications between an ACV and its designated CVC as well as bi-directional communications between the ACV and Atolls.

☐ Each ACV and CVC will be assigned a unique ID in the form of the source address of each SPDL-supplied radio. All Atolls will monitor messages broadcast to the entire network.

☐ Communications within a fleet will take place using the broadcast mode of RF transmission.

- ☐ 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 ACV, implement communications on the CVC.
- ☐ The class communications protocol must include a procedure for fleet-wide validation of communication that will take place before the start of each campaign. The CVCs must provide a visual indication of when the fleet-wide validation messages are received.

General Requirements:

- ☐ At a minimum, either the CVC or the ACV 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 ACV 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.
- ☐ ACVs 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 ACVs and the CVCs should be safe, both to the user and the spectators.
- ☐ Intentionally disabling or damaging other ACVs 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.
- ☐ ACVs 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 **05/03/11** 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 ACV and the CVC. These should be scanned into a no-frills powerpoint file (landscape, 4:3 format, .ppt, not .pptx) for projection in our classroom. You will have 5 minutes to walk us through your ideas. The focus should be on system level concepts, not detailed hardware or software. The other members of the class, the teaching staff and coaches will be on hand to hear about your ideas and provide feedback and advice. At this time, initial calculations are required for estimating the mass of your proposed ACV 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 **05/03/11**. Ed will meet with the communications committee on the evening of 05/04/11 to provide feedback on the specification.

Communications Standard:

Due by 5:00 pm on **05/06/11**. This is the working draft of the communications standard.

First Check-Point:

On **05/10/11**, you must demonstrate

1) The ability of the ACV to receive and correctly decode and respond to commands from the CVC (simulated inputs are acceptable at this time).

2) That your ACV 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 **05/17/11**, you must demonstrate the ability to communicate all required functionality between your ACV and CVC. This will include commands from the CVC to the ACV, all status messages from the ACV to the CVC. You must also demonstrate the ability to bidirectionally communicate with an Atoll.

Project Preview:

At the Project Preview on **05/19/11**, 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 CVC to the ACV.

2) The ability to recognize Atoll RFID cards, and the requisite communication with the Atoll.

Grading Session:

During the Grading Session on **05/25/11**, each team will be required to demonstrate the ability to successfully participate in a campaign. This will include

1) Navigating an ACV from the starting box and successfully taking control of multiple Atolls.

2) Displaying on the CVC the correct states of each Atoll.

Public Presentation:

This will take place on **05/26/11** starting at 4:00 pm in Hoop Fountain. At this event, members of the public will be allowed to act as operators of the CVCs.

Report:

Draft due on **05/30/11** by 4:00 pm. The final version (with revisions incorporated) is due by 5:00 pm on **06/03/11**.

Evaluation

Performance Testing Procedures:

One or more of the team members will demonstrate the ACV and CVC during the first & second check points and project preview. Members of the teaching team will operate the ACV and CVC 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 05/10/11**.**
- ☐ **Second Check Point (10%)** Based on the results of the performance demonstrated on 05/17/11**.**
- ☐ **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.