Rebel Alliance Intelligence Report

##-03xP-AAL-S009642

Security Clearance: **TOP SECRET**

Subject Keywords: Integrated Design Challenge

IDC17F: *STAR WARS*

In this Integrated Design Challenge (IDC), you and your fellow lab section members will create robots that must work together to complete a complex, multi-stage problem. To solve this problem, you will need to determine special code numbers by extracting information from the environment and use these code numbers to coordinate the movement of the team's robots. **Repeatability, Reliability and Robustness are critical to your success!**

Your challenge: Stop the evil Galactic Empire and destroy the Death Star

In the last episode of our saga, the Rebel forces were able to defeat the plot of the evil Galactic Empire and destroy the first death star. Now, however, the Empire has set about to build a second, more powerful Death Star battle station. You, the engineers of the Rebel Alliance, have been selected to produce elite autonomous robots using the latest technology to once again turn the tides of the galactic civil war. Your task will be to engineer Arduino BOE-Bots to perform the critical task of destroying the nearly completed second Empirial Death Star.

This task will be challenging and will require you to integrate all you know about sensing and information processing. Your team will be divided into five squadrons, each of which will be responsible for obtaining information critical for a successful assault on the Death Star. These tasks include:

- **YELLOW SQUADRON** - Determine which defensive turrets are activated
- **BLUE SQUADRON** - Determine the location of the Death Star
- **ORANGE SQUADRON** - Obtain the shuttle access code
- **RED SQUADRON** - Determine the number of TIE fighters and non-threatening ships
- **GREEN SQUARDON** - Determine the distance available for maneuvering

Each squadron will be deployed to its starting position and will wait for the "go" signal to begin recognizance operations. After obtaining the necessary information, each squadron will need to **persistently display their code number visibly (1-5)** (i.e. display your number and keep it on.)

Completing the above successfully will earn the team up to 93 (out of 100) points in the final demonstration. To earn up to an additional 7 points, all 5 robots on the team must **proceed in the proper order down the U-shaped ventilation shaft into the core of the Death Star and locate their crafts in order, based on the intelligence obtained from their phase!** Only the proper ordering of 'bots will defeat the Dark Side. This will require **successful communication between**

robots.

Creativity and practicality are encouraged in showing that all squadrons have completed their missions, are present, and can proceed in order and controllably stop on the appropriate hash mark at the end of the challenge board. Other creative performances to show successful communication and mission completion are encouraged! Any deviations from this plan will result in failure of the rebel mission and another gain for the evil Empire in the war for galactic freedom.

For success, this mission requires both **individual excellence and teamwork**. As the Rebel Alliance is experiencing a shortage of advanced sensors, individual squadrons must devise a solution to their task using basic components and sensors (e.g., photodetector, LEDs, IR, …). Navigation and communication, however, can be accomplished using basic components and/or available sensor modules (see list in Part Pricing List, available on Sakai). The team is encouraged to be creative and explore novel and innovative solutions. Remember, however, the Alliance is depending on each and every squadron to be reliable and robust. **Don't forget to have a backup plan in the unfortunate event that a squadron fails to complete its individual mission and report to the Death Star rendezvous point!**

Huettel 03.16.06
Huettel, Coonley, Ybarra 03.21.07
Coonley 10.22.09, 03.02.14, 09.30.15, 09.28.17

Rebel Alliance Intelligence Report

YELLOW SQUADRON

Security Clearance: A-1

Subject Keywords: Defensive Turret Activation Pattern

"Stay away from those turrets!"

A sequence of defensive turrets blocks our way! In the defensive perimeter of the Death Star are multiple ion cannons. In order to attack the vulnerable thermal pipe on the Death Star, we must determine which ion cannons have been activated in the perimeter. Because the Death Star has not yet been completed, not all cannons are operational. The incomplete superstructure of the Death Star has left certain plasma lines to the ion cannon accessible from the outside of the Death Star. Intelligence has provided a birds-eye view of the superstructure and a perspective view of an individual plasma line (below).

We have discovered that the activation of the defensive turrets can be detected through thermal and visual electromagnetic radiation emanating from these plasma lines. Your goal is to follow Rebel Intelligence's pre-calculated path and reconnoiter the plasma lines and detect the hot and glowing plasma lines! Between 1 and 5 plasma lines will be energized at any given time. The overall pattern of activation can be determined as the sum of the active lights (1-5). Once successfully determined, this integer code must be clearly displayed. At the end of this phase, your next task is to await the arrival of your fellow Rebel squadrons in order to proceed down the Death star ventilation shaft in the proper order. Remember that your integer number must be kept on for the remainder of the mission; it must be kept on and displayed in the Death Star ventilation shaft when all team members are lined up. Only through proper Bot ordering will the Empirial code be broken and balance be restored to the Force.

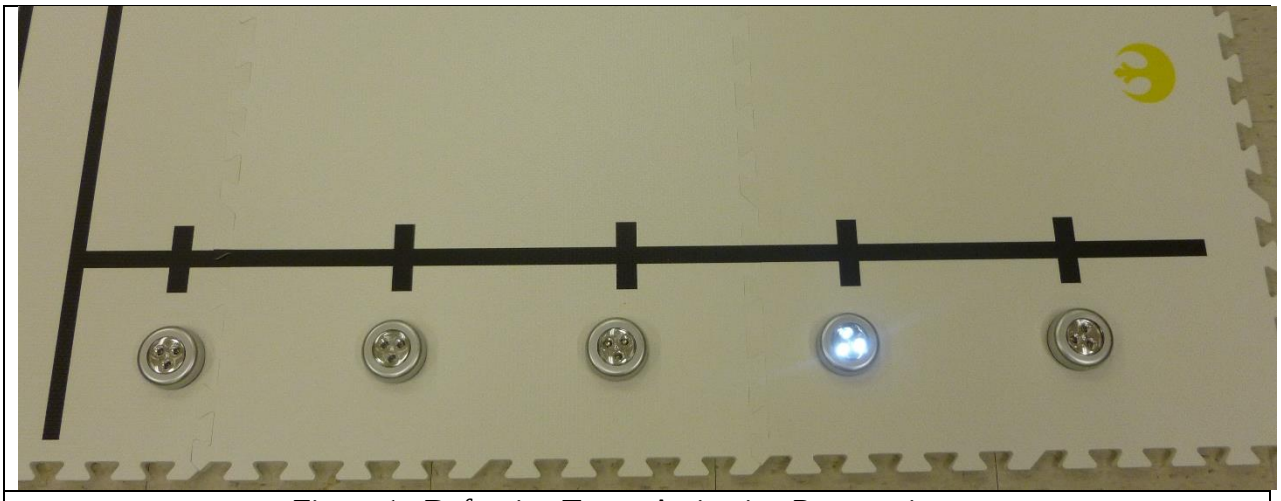

Figure 1. Defensive Turret Activation Pattern picture

Rebel Alliance Intelligence Report

BLUE SQUADRON

Security Clearance: A-2

Subject Keywords: Death Star Location

"That's no moon… it's a space station"

The empire's new version of the Death Star has been determined to be located in orbit of the planet Endor. It is almost as large as the other moons of Endor, and we need to know its precise location so that we can launch an assault. While we have detected five large moons in its probable location, we need you to do a fly-by and figure out which one is the Death Star. We've marked the location of each moon on your navigation computer, along with a path that will take you past each moon close enough for visual or sensory identification.

The Death Star is a hulking mass of high-tech equipment, and should be identifiable from its magnetic field strength, mechanical appearance, and orbital location. We do not at this time have an intended protocol for detecting the Death Star. We trust that you will find all the equipment you need to outfit your Rebel starfighter for this mission. Once you have determined which moon is the empire's ultimate weapon, you must proceed immediately to the Bot rendezvous point at the end of your phase and report its location by clearly displaying the acquired number, 1–5 (the closest location to the starting point being 1 and the furthest, 5). At the end of this phase, your next task is to await the arrival of your fellow Rebel squadrons in order to proceed down the Death star ventilation shaft in the proper order. Remember that your integer number must be kept on for the remainder of the mission; it must be kept on and displayed in the Death Star ventilation shaft when all team members are lined up. Only through proper Bot ordering will the Imperial code be broken and balance be restored to the Force. Help us young Jedi, you are our only hope!

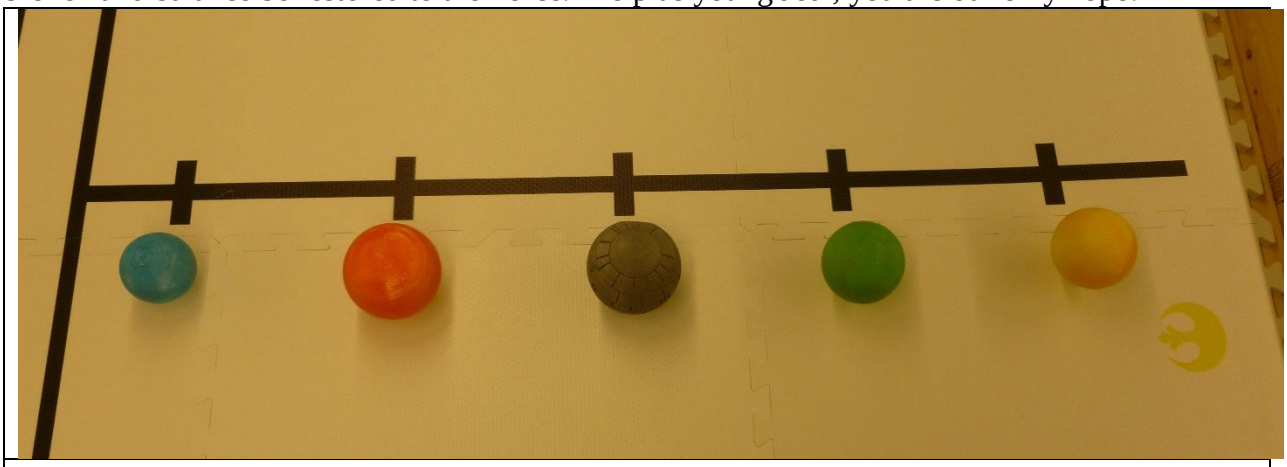

Figure 2. Death Star Location

Rebel Alliance Intelligence Report

ORANGE SQUADRON

Security Clearance: A-3

Subject Keywords: Shuttle Access Code

"Do they have code clearance?"

There is a shield generator stationed on one of Endor's moons. In order to gain access to the shield generator, we will infiltrate the facility and deactivate the shield generator.

Our intelligence tells us that the relay station broadcasts the oft-changing code to the imperial fleet from each of 5 radio-frequency identification tags (RFID). Each tag emits a unique serial signature. The current code to the facility can be derived by adding the 5 unique signatures together. The Empire changes the ordering of specific tag combinations frequently, so beware. The resulting code, 1–5 will represent your number in the final assault. At the end of this phase, your next task is to await the arrival of your fellow Rebel squadrons in order to proceed down the Death star ventilation shaft in the proper order. Remember that your integer number must be kept on for the remainder of the mission; it must be kept on and displayed in the Death Star ventilation shaft when all team members are lined up. Only through proper Bot ordering will the Empirial code be broken and balance be restored to the Force.

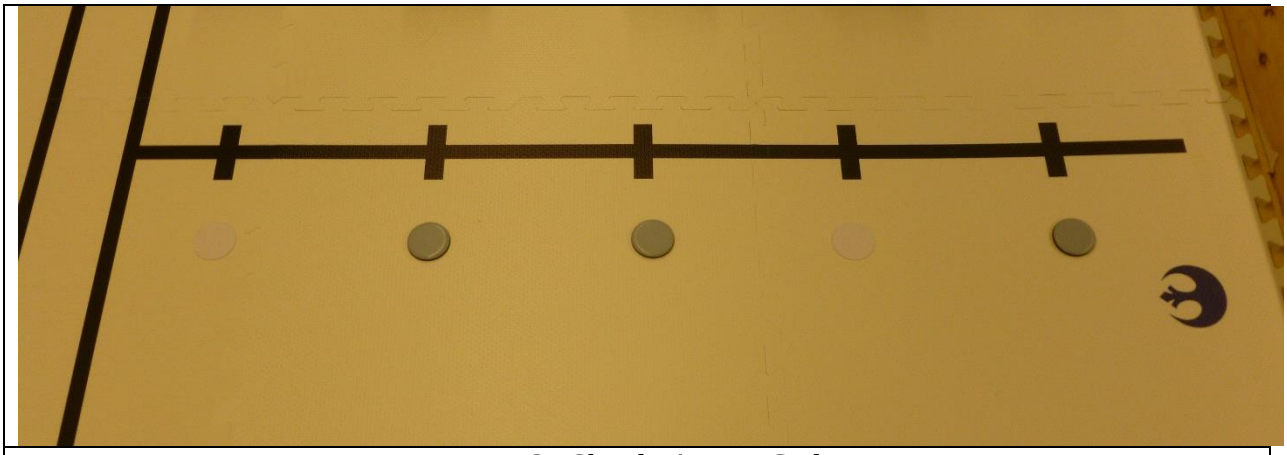

Figure 3. Shuttle Access Code

Rebel Alliance Intelligence Report

RED SQUADRON

Security Clearance: A-4

Subject Keywords: Star Fighter Reconnaissance

"Try and get some of those TIE Fighters to follow you!"

Major factors in the successful demolition of the Death Star are the X-Wing and Y-Wing squadrons that will fight in the assault. In order to allocate an adequate number of fighters, we must know the number of TIE fighters the empire has available. Given the recent massive construction shipments and number of Imperial Star Destroyers that have passed near the proposed attack site, the amount of starfighter power the Empire will have on hand is uncertain.

Your mission is to equip a BOE-class unmanned recon' vehicle with appropriate sensors capable of detecting the number of TIE fighter and TIE avenger squadrons present near the Death Star. However, there are also aero-spacecraft, such as the Lambda-class shuttle that do not pose a threat to our attack squadrons.

Rebel Intelligence was able to recover classified information regarding the potential locations of starfighter squadrons (see Figure below). The black line represents the recommended flight path. The dotted outlines represent the possible TIE squadron locations. You must tally the number of squadrons facing the recommended flight path–that of TIE fighters (white) and non-threatening ships (black). The **difference** (absolute value) between these numbers (an integer from 1 to 5) represents your code number in the final assault to be displayed prominently on your robot. At the end of this phase, your next task is to await the arrival of your fellow Rebel squadrons in order to proceed down the Death star ventilation shaft in the proper order. Remember that your integer number must be kept on for the remainder of the mission; it must be kept on and displayed in the Death Star ventilation shaft when all team members are lined up. Only through proper Bot ordering will the Emperial code be broken and balance be restored to the Force.

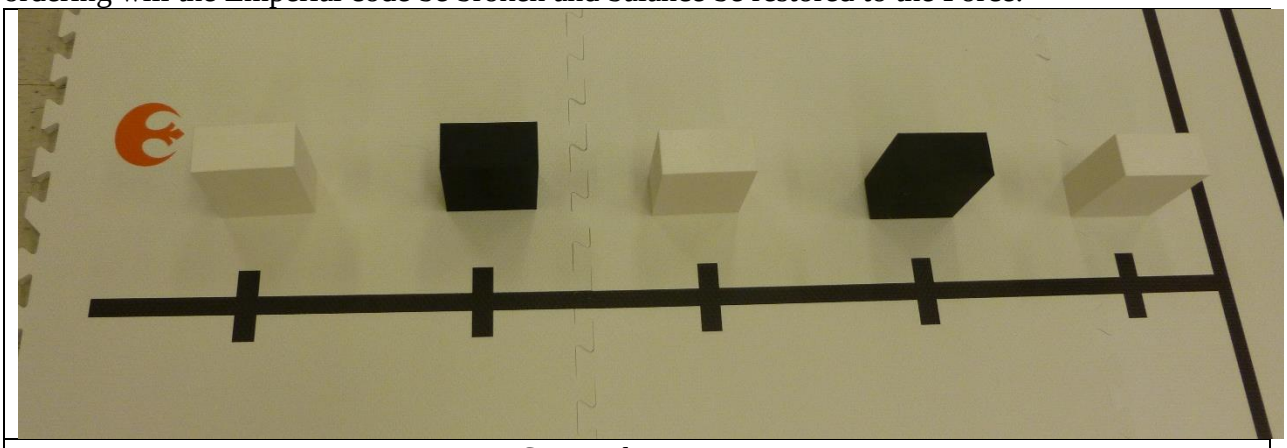

Figure 4. Star Fighter Reconnaissance

Rebel Alliance Intelligence Report

GREEN SQUADRON

Security Clearance: A-5

Subject Keywords: Reactor Core and Shaft Locations

"Only a precise hit will set off a chain reaction"

The Green Squadron holds the key to the entire team's success! It is your job to determine the location of the entrance to the reactor shaft and the optimal location for the final attack relative to the entry point. Intelligence has determined that there are 5 security substations within the trench through which the attack team will fly. Each substation is uniquely colored—Yellow, Blue, Orange, Red, and Green—corresponding exactly to the Squardon colors in play. The ordering of the colored substation corresponds exactly to the order in which the 5 robots need to line up at the Death Star ventilation shaft. This information provide an error-checking algorithm for each squadron who also has intelligence about their rendezvous location based on the information seeded in their phase of the challenge. Use this redundancy of information to your advantage to avoid errors and defeat the evil Dark Side.

In addition, the Green substation will always be placed off-set from the other 4 substations thus giving your squadron information about its rendezvous location with both color and physical proximity. This number represents your code number in the final assault and must be prominently displayed on your robot. At the end of this phase, your next task is to await the arrival of your fellow Rebel squadrons in order to proceed down the Death star ventilation shaft in the proper order. Remember that your integer number must be kept on for the remainder of the mission including in the Death Star ventilation shaft when all team members are lined up. Only through proper Bot ordering will the Imperial code be broken and balance be restored to the Force.

The Rebel Alliance is very much counting on you, young Jedi!

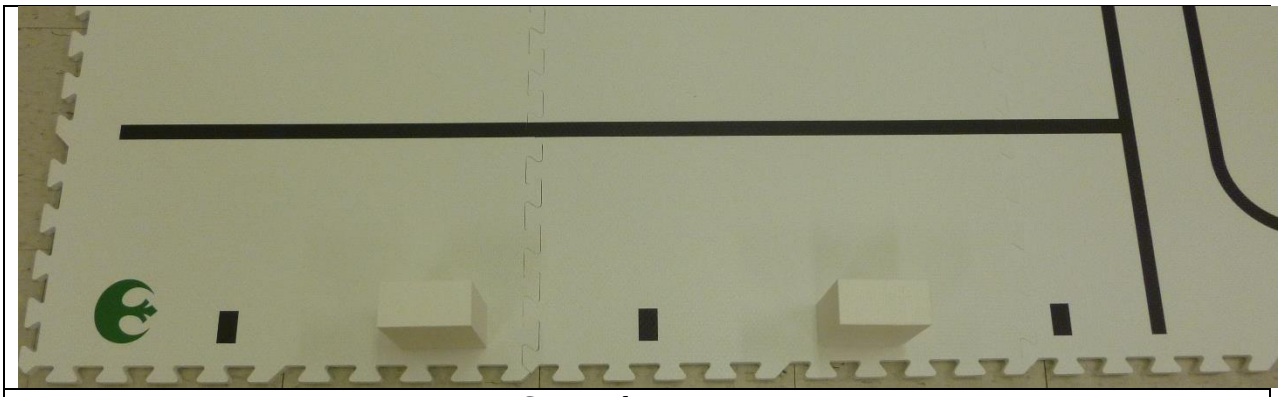

Figure 5. Star Fighter Reconnaissance

Rebel Alliance Intelligence Report Code All

Squadrons Security Clearance: A-1 Subject

Keywords: Death Star Assault

"Boom"

Your team's final mission is to destroy the Death Star. Surveillance has been able to scout out the location of the core. Your objective is to assault the core in the proper order to disable the core and escape to the final regrouping area (see figure below).

This will be the most difficult assault yet, and a victory here can be a turning point for the rebels and will restore balance to the force.

It is recommended that you all line up at the staging area before assaulting the core, although this is not required. The only requirement in this phase of the mission is that you pass the core in the order that you determined in your individual missions and line up properly in the regrouping area. The first BOE is expected to traverse to the farthest hash mark, with each following BOE behind it. Once all BOEs have reached their hash marks, the timer is **stopped on the overall assault. This will be your final tie-breaking time**

1 2 3 4 5

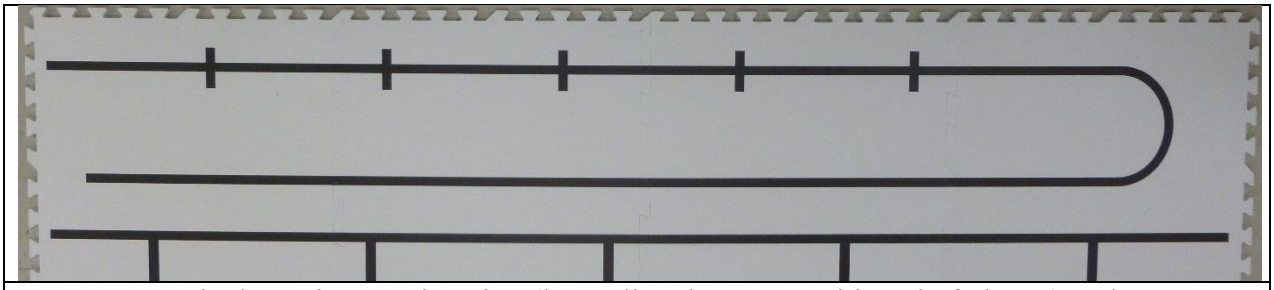

Figure 6. Final Rendezvous location (lower line that "T's" with end of phases) and Reactor Core Ventilation Shaft hemisphere

Design Project Grading Criteria

Deliverable	**Responsible**	**Percent**
Status Updates & Participation		***Total 10%***
Status Updates (due as 3 min. presentation in lab)	Initially Team and later Assigned Group	10% (2.5% each)
Documentation		***Total 30%***
Conceptual Design Report (due in lab)	Groups on Team	10%
Final Design Report (Sat., 12/9/17, 12:00pm, in lab)	Group	20%
Demonstrations		***Total 50%***
Communication (in lab)	Team	10%
Separate Line Following, Information Gathering, & Communication (in lab)	Groups on Team	10%
Integrated Sensing, Processing, Navigation, & Communication (in lab)	Assigned Group	10%
Team Sensing, Processing, Navigation, & Communication(in lab)	Assigned Group (Al Bots on board)	10%
Full System (in lab)	Team	10%
Oral Design Explanation and Defense		***Total 10%***
Oral Defense (in lab)	Assigned Group	10%
		Total 100%

Terms:

Groups in Team—The IDC requires a Team approach. Initially, no assigned groups are formed. Instead, the Team may choose to break into task groups to complete the Conceptual Design for specific phases of the Challenge. While breaking into groups is not required, it is recommended for efficiency.

Assigned Groups—Groups are assigned the week after Line Following, Information Gathering, and Communication. Assigned Groups are comprised of 2-3 students each (and 1 Arduino BOE-Bot!)

Teams—Teams are comprised of an entire lab section; there are as many Teams as there are lab sections in ECE 110L.

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Conceptual Design Report Grading Criteria
(Group Report)

Note: Groups MUST submit Components Request by Monday, October 30, 2017 at 8:00AM. (Components Request site: http://ecelab.pratt.duke.edu)
SAVE THE CONFIRMATON E-MAIL to submit with your report!

Team Members:_____

1. Introduction	**Possible**	**Earned**
Grand Overview of Team Challenge	5	
Group Robot Problem Statement or Task	5	
Group and Team Objectives and Deliverables	10	
Total	***20***	
2. Planning and Management		
Gantt Chart (Project Schedule, Milestones, Task Assignments)	15	
Written description of Gantt chart (incl. ind. group member contributions & recorded time spent in lab by each ind.)	15	
Cost estimate	10	
Total	***40***	
3. Technical		
Trade Study Results (at least 3 sensors compared)	40	
Total	***40***	
Components Request confirmation e-mail attached	✓/–	
Total Score	***100***	

*** Report should include a cover page with title, group name and membership, date, and Community Standard statement (signed by all).**

*** See additional handouts for a description of how to complete a Pros and Cons evaluation as part of a Trade Study and how to construct a Gantt Chart.**

Weekly Status Report Format
(Group Presentations in lab)

Weekly status reports are due 4 times during the IDC and are prepared by each robot group (groups are 2-3 robot designers assigned to 1 'Bot).

Weekly Status reports include the following and should be presented as a **3 min overhead presentation** to your Team. The INDIVIDUAL lab partner who presents each section must alternate EACH WEEK so that each lab partner presents each section at least once during the semester.

Presentation in Lab [60%]

1.) **Progress summary** [20%]
   a. Biggest Successes this week [10%]
   b. Biggest Challenges this week [10%]
2.) **Code** [20%]
   a. Annotated code with comments to share with Team [10%]
   b. Highlighted code snippets to emphasize additions or modifications since last week [10%]
3.) Was the **presentation effective** [10%]?
4.) Did **each member** of the team contribute to the presentation equally [10%]
   (0 pts. for little or no contribution by a single group member)

Documentation turned in to TA [40%]

5.) **Gantt chart** [30%]
   a. Up-to-date showing accomplishments, milestones, and what is left to be done [10%]
   b. Added sub-task planning bars (for planned work)
   c. Annotated progress bars showing how much time was actually spent by each individual in group (actual work) [10%]
6.) **Cost of Bot** [10%]
   a. To-date cost of all parts on Bot [10%]

Lab Section Time: _____TA:_____ Demo TA: _____
Group Members:_____

Presentation in Lab [60%]

	IDC Wk. 1 Conceptual Design. and Communication	**IDC Wk. 2** Line Following, Info. Gathering, and Communication	**IDC Wk. 3** Integrated Sensing, Processing, Navigation, and Communication	**IDC Wk. 5** Team Sensing, Processing, Navigation, and Communication
Progress summary [20]				
Biggest Success [10]				
Biggest Challenge [10]				
Code [20]				
Effectiveness of presentation [10]				
Ind. contr.[10 each]				

Documentation turned in [40%]

Gantt chart [30]				
Accomplishments, milestones, & what's left [10]				
Sub-task bars added [10]				
Actual work bars added [10]				
Cost of Bot [10]				

Total:				

Demonstration Grading Criteria
(Team and Group Demonstrations)
Each occurs at beginning of lab in the week listed below

Each robot group will be evaluated for each demonstration as follows:

IDC Wk. 1—Communication requires that all robots and can send and receive a signal from one another.

Week of Lab 7—Line Following spot check—squiggly line test requires that the robot can follow 4 pre-printed lines in lab plus the actual line on the IDC mat the group will use reliably and without significantly deviating from the line or getting off-track.

IDC Wk. 2—Line Following & Information Gathering requires that each robot be able to line follow its path and also separately demonstrate that it can detect the sensory objects and information required to successfully complete its individually assigned phase of the Challenge.

IDC Wk. 3—Integrated Sensing, Processing, & Navigation requires that each robot be able to successfully sense the information present in its individually assigned phase of the Challenge, use this information to complete the phase, and navigate it's line of the Challenge from start to finish on its own.

IDC Wk. 4—Team Sensing, Processing, & Navigation requires that with the entire team of robots on the board, each robot is able to simultaneously sense the information present in its phases of the Challenge, use this information to complete the phase, and navigate from start to finish. Scoring this week is still done on a per-bot (i.e. Group basis)

IDC Wk. 5—Full System repeats the Team Sensing, Processing, & Navigation demonstration. However, scoring this week is done on a team basis.

The performance criteria used to assess the above demonstrations is outlined on the next pages.

E.g.

Description	*5 correct demos*	*4 correct demos*	*3 correct demos*	*2 correct demos*	*1 correct demo*	*Functioning Bot(s), no correct demos*	*Non-functioning Bot(s)*	*No Bot*	**Score**
Grade	A+ (100)	A (95)	B (85)	C (75)	D (65)	F (50)	Z (30)	N (0)	
Example—Communication Demo				**Team score—all 6 Bots: (Sum of weighted scores, below)**					83.5
Tx (40%)		✓	✓	✓	✓		4 is 95 x 40%		38
Rx (40%)		0/4	3/4	4/4	2/4		9/4=2.25 is 77.5 x 40%		31
Display (20%)		0/4	2/4	3/4	2/4		7/4=1.75 is 72.5 x 20%		14.5

Demonstration Grading Criteria

Lab Section Time: _____TA: _____Demo TA:_____

Group Members:_____

Description	*5 correct demos*	*4 correct demos*	*3 correct demos*	*2 correct demos*	*1 correct demo*	*Functioning Bot(s), no correct demos*	*Non-functioning Bot(s)*	*No Bot*	**Score**
Grade	A+ (100)	A (95)	B (85)	C (75)	D (65)	F (50)	Z (30)	N (0)	
Communication Demo				**Team score—all 6 Bots: (Sum of weighted scores, below)**					
Tx (40%)									
Rx (40%)									
Display (20%)									

Line Following spot check—4 pre-printed + IDC				**Group score---1 Bot:**					
Line Follow (100%)									

Line Following & (Separate) Information Gathering				**Group score—Avg. of 1 Bot Line/Sense + 6 Bot Team Communication:**					
Line Follow (30%)									
(Separate) Sensed objects (60%)									
Comm.(Tx,Rx, Display) (10%)									

Integrated Sens., Proc., Nav., & Communication				**Group score—Avg. of 1 Bot Line/Sense + 6 Bot Team Communication:**					
Int. Line Follow (30%)									
Int. Sense object (60%)									
Comm.(Tx,Rx, Display) (10%)									

Team Integrated Sens., Proc., Nav. & Communication				**Group score—1 Bot (but all 6 Bots run at once):**					
Line followed path (10%)									
Sensed all objects (20%)									
Obtained correct no.(20%)									
Tx & Rx Comm. (10%)									
Team Sum (30%)									

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Grade	A+ (100)	A (95)	B (85)	C (75)	D (65)	F (50)	Z (30)	N (0)	**Score**
Full System Demonstration				**Team score—Avg. of 6 Bots Averages:**					
Yellow Squadron								Avg.:	
Line followed path (10%)									
Sensed all objects (20%)									
Obtained correct no.(20%)									
Tx & Rx Comm. (10%)									
Performed Team Sum (30%)									
Blue Squadron								Avg.:	
Line followed path (10%)									
Sensed all objects (20%)									
Obtained correct no.(20%)									
Tx & Rx Comm. (10%)									
Performed Team Sum (30%)									
Orange Squadron								Avg:	
Line followed path (10%)									
Sensed all objects (20%)									
Obtained correct no.(20%)									
Tx & Rx Comm. (10%)									
Performed Team Sum (30%)									
Red Squadron								Avg.:	
Line followed path (10%)									
Sensed all objects (20%)									
Obtained correct no.(20%)									
Tx & Rx Comm. (10%)									
Performed Team Sum (30%)									
Green Squadron								Avg:	
Line followed path (10%)									
Sensed all objects (20%)									
Obtained correct no.(20%)									
Tx & Rx Comm. (10%)									
Performed Team Sum (30%)									

Oral Defense
(Group Defense)

Lab Section Time:_____ TA: _____ Demo TA:_____

Group Members: _____ _____
Phase of Challenge: _____

Sensors & Purpose: _____***QTI***_____ _____***Line following***_____
(Sensor 1) *(Purpose)*

** Indicate which sensor queried for Technical Knowledge (show work on reverse)*

_____ _____
(Sensor 2) *(Purpose)*

_____ _____
(Sensor 3) *(Purpose)*

_____ _____
(Sensor 4) *(Purpose)*

Name:

1. Defense of Design	**Possible**	**Earned**	
Justification of Design Choices	10		
Alternatives considered and depth of testing	10		
What would be done differently next time?	10		
Sub Total	***30***		
2. Technical Knowledge of System			
Sensors implemented in design*	25		
How information is processed in code/design	25		
Arduino Code in design–efficient, easy to read, commented	20		
Sub Total	***60***		
Total Score	***100***		

ABET Question: Overall Effectiveness of Oral Communication (needs improvement (NI), meets minimum expectations (MM), meets expectations (ME), or exceeds expectations (EE).	*NI, MM, ME, EE*		

Comments:

Final Design Report Grading Criteria

Final reports should be written in the format of a formal laboratory report. Each group should submit one report. Pages must be numbered.

Recall that in formal, technical writing, third person is the preferred written perspective. It is common for students, upon learning to write an effective laboratory report including
all five sections, to experience a sense of redundancy across the report sections. The Abstract summarizes the important elements of the exercise including results and conclusions in a very concise manner. The Introduction provides background and motivation for the experimental procedure. The Experimental Procedure and Results section provides details of the experimental process that would allow another person to reproduce the results presented. The Analysis and Discussion section provides theoretical analyses and compares the theoretical results with the experimental results as well as a critical interpretation and evaluation of these results. The conclusion ties together the elements of the entire report and provides closure. All formal scientific papers provide information in this manner.

The report should include a discussion of the following topics (in the appropriate section of the report):

I. Abstract
An abstract is a concise summary of the entire report that highlights the most important findings and conclusions. Although abstracts should be limited to no more than 275 words, effectively written, they should enable the reader to know what was performed and why, along with the most important results and conclusions.

A well-written Abstract will achieve the four-fold criterion of:
- Clarity
- Conciseness
- Accuracy
- Completeness

II. Introduction
The Introduction is the second section of a formal laboratory report, following the Abstract. The Introduction provides a backdrop for the entire experiment and should provide enough information to adequately place the experiment into context with prior work. Describe the objective(s) of your experiment (you will refer to these again later in the Discussion and/or Conclusion section) and summarize what you did. A good Introduction also provides whatever background theory, formulas and equations, or previous research/experiments that the reader needs to know in order to understand the work presented in the laboratory report.

An effective Introduction will address the following questions:

1. What is the problem?
- ***Describe*** the overall Challenge as your team was faced with it

2. Why is it important?
- What do you hope to get out of this Challenge? What tools and resources will be used to solve this challenge?

3. What solution (or step toward a solution) do you propose?
- Briefly ***describe*** your individual robot's contribution to the successful completion of the overall Challenge. Where does your Bot fit in? What will your robot do and how will it do it?
- Consider real-world applications your robot might connect to. How could it be used in a practical challenge of a similar nature?

III. Experimental Procedures and Results
Experimental Procedure and Results is the third section of a formal laboratory report, following the Abstract and Introduction. In most laboratory exercises you will be required to make measurements. In the Experimental Procedure and Results section, you are to present your experimental set-up, experimental procedure, and measurements. Documenting your procedure is important so that you and others can replicate your experiment.
Generally, you should state what equipment, electronic components, and other hardware/software were used and provide all diagrams and schematics necessary to illustrate your experimental set-up. You should show, as a Figure, any sub-circuit you are referring to in the report. Full circuit diagrams can be included as an appendix. **Only discrete elements that you populate on your board need to have schematic diagrams. You do not need to provide**

schematics for sensory modules. State what was measured. Data should be presented in the form of either a table or a graph. Provide figures, tables, graphs, diagrams, and appendices as appropriate to present your experimental procedure and results. Procedural detail should be kept as concise as possible but must enable others to reproduce every experimental result that you present in your report.

The Experimental Procedures and Results section is best written in a chronological format. Note that it is perfectly acceptable to reference a single table, list of code, or diagram placed within the report (e.g. Appendices, Analysis and Discussion, etc…) It is not necessary to repeat the same or a similar table or diagram more than once. However, if parts of the referenced document merit a more thorough description (e.g. "In the second DO… LOOP of the robot code (below), …"). It is also perfectly acceptable to reference pre-existing work in your report. As always, cite all work that is not original to you. The Experimental Procedures and Results section should include the following information for ***each week*** of the Challenge:

1. How did you study the problem?
- Briefly ***explain*** **Design considerations**, including constraints and requirements and conceptual designs that were considered.

2. What did you use?
- ***Describe*** as part of a **Detailed design** - including detailed descriptions (and supporting documentation such as circuit diagrams and code) of hardware and software - what equipment, electronic components and other hardware/software you used.

3. How did you proceed?
- ***Explain*** the steps you took in implementing your design in the completion of your robot
- **Design justification**, including design choices and alternative designs that were considered but not selected (e.g., use your trade study to support choices), data collected/analyzed in making design decisions (e.g., how were thresholds set, frequency of operation chosen, etc.), challenges, and solutions

4. What did you observe?
- **Testing and design evaluation**, including sensor, integration, and reliability demonstration results, discussion of issues/challenges identified during testing/demo and solutions.
- Your complete raw data should be included in an Appendix.

IV. Analysis and Discussion

Analysis and Discussion is the fourth section of a formal laboratory report, following the Abstract, Introduction, and Experimental Procedure and Results. This section is arguably the most essential section of a laboratory report. The Analysis and Discussion section is where thoughtful consideration and critical refection on the experiments and simulations you have done is presented. This should go beyond simply answering the questions posed in the laboratory manual (although this is necessary). Comment on what you learned in performing the experiment, both through what went right and, perhaps more importantly, what went wrong. Often, you will need to make use of experimental data from the previous section to support the calculations presented here. **Full credit will only be given to Analysis and Discussion sections that demonstrate independent thought and evidence of a critical evaluation of the experiment and its results.**

An Analysis and Discussion section for this report should include:
- **Statement of cost**, including a discussion of ways costs might have been reduced or the design streamlined given more time and resources
- **Analysis of final design** as a whole. Any areas of improvement? Persistent issues? You need not repeat your Design Justifications for individual weeks in their entirety. You may find it useful to reference previously written Design Justifications for this purpose. There are certain considerations that it was necessary to make in the design of the overall robot. Those considerations should be dealt with here.
- **Proposed design changes and improvements** including the changes you would have made given more time and resources. If no changes, what made your robot perform perfectly?

V. Conclusion

The Conclusion is the fifth and final (regular) section of a formal laboratory report, following the Abstract, Introduction, Experimental Procedure and Results, and Analysis and Discussion. The conclusion must effectively tie together the objectives, experimental results, and analysis. You must state whether the objectives of the exercise were fulfilled and briefly state the reasons for your claim. You should address each objective separately.

Final Design Report Grading Criteria
Due: 12:00pm, Saturday, Dec. 9th, 2017 (Teer 210/216 Laboratory)

****** Staple this form to the FRONT of your Final Design Report******

	Possible	Earned
I. Abstract • Clarity • Conciseness • Accuracy • Completeness	**8**	
II. Introduction 1. What is the problem? 2. Why is it important? 3. What solution do you propose?	**15**	
III. Experimental Procedures and Results For ***each week*** of the Challenge: 1. How did you study the problem? 2. What did you use? 3. How did you proceed? 4. What did you observe?	**35**	
IV. Analysis and Discussion • Statement of cost • Analysis of final design • Proposed design changes and improvements	**20**	
V. Conclusion • Effectively ties together obj., exp. results, and analysis • States whether obj. met and why (address each separately)	**10**	
Supporting documentation – complete circuit diagrams, entire Arduino Code, pictures of Bot and sensors used on Bot	**5**	
Overall document quality – spelling correct, grammar, paragraph breaks, easy to follow order and format, Tables, Figures, Graphs, and Formulas properly labeled	**7**	
Total Score	***100***	

Supporting documentation (e.g., Arduino code, complete circuit schematics) can be included in an Appendix.

*** Report should include a cover page with title, group name and membership, date, pages numbered, and Community Standard statement (signed by all).**